EUROPEAN COMMISSION
Communications Networks, Content and Technology

Digital Excellence & Science infrastructure
eInfrastructure Science Cloud

GRANT AGREEMENT

NUMBER — 731016 — AENEAS

This **Agreement** ('the Agreement') is **between** the following parties:

on the one part,

*the **European Union** ('the EU'), represented by the European Commission ('the Commission')*[1],

represented for the purposes of signature of this Agreement by Head of Unit, Authorised Representative of the Director General, Communications Networks, Content and Technology, Digital Industry, Administration and Finance, Ales FIALA,

and

on the other part,

1. 'the coordinator ':

STICHTING ASTRON, NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY (ASTRON) NL6, 41166026, established in Oude Hoogeveensedijk 4, DWINGELOO 7991PD, Netherlands, VAT number NL003447741B01, represented for the purposes of signing the Agreement by Managing Director / Deputy Director, Marco DE VOS

and the following other beneficiaries, if they sign their 'Accession Form' (see Annex 3 and Article 56):

2. **THE UNIVERSITY OF MANCHESTER (UMAN)** GB22, RC000797, established in OXFORD ROAD UNIVERSITY OF MANCHESTER OFFICE OF DIRECTOR OF FINANCE, MANCHESTER M13 9PL, United Kingdom, VAT number GB849738956,

3. **THE CHANCELLOR, MASTERS AND SCHOLARS OF THE UNIVERSITY OF CAMBRIDGE (UCAM)** GB12, Not applicable, established in TRINITY LANE THE OLD SCHOOLS, CAMBRIDGE CB2 1TN, United Kingdom, VAT number GB823847609,

4. **ISTITUTO NAZIONALE DI ASTROFISICA (INAF)**, 97220210583, established in Viale del Parco Mellini 84, ROMA 00136, Italy, VAT number IT06895721006,

5. **CHALMERS TEKNISKA HOEGSKOLA AB (CHALMERS)** AB, 5564795598, established in -, GOETEBORG 41296, Sweden, VAT number SE556479559801,

6. **GEANT LIMITED (GEANT LTD)** LTD, 2806796, established in 126-130 HILLS ROAD CITY HOUSE, CAMBRIDGE CB2 1PQ, United Kingdom, VAT number GB599731672,

7. **Stichting EGI (EGI.eu)** NL6, 34380182, established in SCIENCE PARK 140, AMSTERDAM 1098 XG, Netherlands,

8. **MAX-PLANCK-GESELLSCHAFT ZUR FORDERUNG DER WISSENSCHAFTEN EV (MPG)** EV, VR13378B, established in HOFGARTENSTRASSE 8, MUENCHEN 80539, Germany, VAT number DE129517720,

1 Text in *italics* shows the options of the Model Grant Agreement that are applicable to this Agreement.

9. **FORSCHUNGSZENTRUM JULICH GMBH (Juelich)** GEM GMBH, HRB3498, established in WILHELM JOHNEN STRASSE, JULICH 52428, Germany, VAT number DE122624631,

10. **SKA ORGANISATION (SKAO)** GB5, 07881918, established in JODRELL BANK OBSERVATORY LOWER WITHINGTON, MACCLESFIELD SK11 9DL, United Kingdom,

11. **SCIENCE AND TECHNOLOGY FACILITIES COUNCIL (STFC)**, RC000747, established in Polaris House North Star Avenue, SWINDON SN2 1SZ, United Kingdom, VAT number GB618367325,

12. **AGENCIA ESTATAL CONSEJO SUPERIOR DEINVESTIGACIONES CIENTIFICAS (CSIC)**, established in CALLE SERRANO 117, MADRID 28006, Spain, VAT number ESQ2818002D,

13. **INSTITUTO DE TELECOMUNICACOES (IT)** IPSS, 249/970502, established in AVENIDA DE ROVISCO PAIS 1, LISBOA 1049-001, Portugal, VAT number PT502854200,

14. **CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS (CNRS)**, 180089013, established in RUE MICHEL ANGE 3, PARIS 75794, France, VAT number FR40180089013,

15. **ETHNIKO DIKTYO EREVNAS TECHNOLOGIAS AE (GRNET)** AE, 003057201000, established in LEOFOROS KIFISIAS 7, ATHINA 11523, Greece, VAT number EL094536469,

16. **STICHTING VOOR FUNDAMENTEEL ONDERZOEK DER MATERIE - FOM (FOM)** NL6, 41150068, established in Van Vollenhovenlaan 659, UTRECHT 3527 JP, Netherlands, VAT number NL002882243B01,

17. **JOINT INSTITUTE FOR VERY LONG BASELINE INTERFEROMETRY AS A EUROPEAN RESEARCH INFRASTRUCTURE CONSORTIUM (JIV-ERIC) (JIV-ERIC)**, 62827278, established in OUDE HOOGEVEENSEDIJK 4, DWINGELOO 7991 PD, Netherlands, VAT number NL854973527B01,

18. **STICHTING INTERNATIONAL LOFAR TELESCOPE (ILT)** NL6, 51272059, established in OUDE HOOGEVEENSEDIJK 4, Dwingeloo 7991 PD, Netherlands, VAT number NL n/a,

*19. **UPPSALA UNIVERSITET (SNIC)**, 2021002932, established in SANKT OLOFSGATAN 10 B, UPPSALA 751 05, Sweden, VAT number SE202100293201, as 'beneficiary not receiving EU funding' (see Article 9),*

20. **ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE (EPFL)**, 414110, established in BATIMENT CE 3316 STATION 1, LAUSANNE 1015, Switzerland, VAT number CHE116075613TVA,

21. **UNIVERSITE DE GENEVE (UNIGE)**, CHE110644228, established in RUE DU GENERAL DUFOUR 24, GENEVE 1211, Switzerland, VAT number CHE114927636TVA,

*22. **COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION (CSIRO)**, 41687119230, established in CLUNIES ROSS STREET CSIRO BLACK MOUNTAIN SCIENCE AND INNOVATION PARK, ACTON ACT 2601, Australia, VAT number AU41687119230, as 'beneficiary not receiving EU funding' (see Article 9),*

*23. **AARNET PTY LTD (AARNet)** AU7, 084540518, established in 3 RICHARDSON PLACE BINGRY CENTRE LEVEL 2 BUILDING, NORTH RYDE 2113, Australia, VAT number AU54084540518, as 'beneficiary not receiving EU funding' (see Article 9),*

*24. **THE RESEARCH TRUST OF VICTORIA UNIVERSITY OF WELLINGTON (VUW)** NZ13, CC21718, established in KELBURN PARADE 18, WELLINGTON 6140, New Zealand, VAT number NZ10665485, as 'beneficiary not receiving EU funding' (see Article 9),*

25. **COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH (CSIR)**, 461988, established in Meiring Naude Road, Brummeria 46, PRETORIA 0001, South Africa, VAT number ZA4470114283,

26. **UNIVERSITY OF CAPE TOWN (UCT)**, established in PRIVATE BAG X3, RONDEBOSCH 7701, South Africa, VAT number 4540125707,

27. **NATIONAL RESEARCH FOUNDATION (NRF)**, established in Meiring Naude Road Brummeria, PRETORIA 0001, South Africa, VAT number ZA4960119727,

*28. **RESEARCH DATA ALLIANCE FOUNDATION (RDA)**, 09021881, established in RUTHERFORD APPLETON LABORATORY HARWELL OXFORD DIDC, OXFORDSHIRE OX11 0QX, United Kingdom, as 'beneficiary not receiving EU funding' (see Article 9),*

Unless otherwise specified, references to 'beneficiary' or 'beneficiaries' include the coordinator.

The parties referred to above have agreed to enter into the Agreement under the terms and conditions below.

By signing the Agreement or the Accession Form , the beneficiaries accept the grant and agree to implement it under their own responsibility and in accordance with the Agreement, with all the obligations and conditions it sets out.

The Agreement is composed of:

Terms and Conditions

Annex 1 Description of the action

Annex 2 Estimated budget for the action

Annex 3 Accession Forms

Annex 4 Model for the financial statements

Annex 5 Model for the certificate on the financial statements

Annex 6 Model for the certificate on the methodology

TERMS AND CONDITIONS

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CHAPTER 1 GENERAL

ARTICLE 1 — SUBJECT OF THE AGREEMENT

This Agreement sets out the rights and obligations and the terms and conditions applicable to the grant awarded to the beneficiaries for implementing the action set out in Chapter 2.

CHAPTER 2 ACTION

ARTICLE 2 — ACTION TO BE IMPLEMENTED

The grant is awarded for the action entitled '***Advanced European Network of E-infrastructures for Astronomy with the SKA — AENEAS***' **('action')**, as described in Annex 1.

ARTICLE 3 — DURATION AND STARTING DATE OF THE ACTION

The duration of the action will be ***36*** **months** as of *1 January 2017* ('**starting date of the action**').

ARTICLE 4 — ESTIMATED BUDGET AND BUDGET TRANSFERS

4.1 Estimated budget

The '**estimated budget**' for the action is set out in Annex 2.

It contains the estimated eligible costs and the forms of costs, broken down by beneficiary *(and linked third party)* and budget category (see Articles 5, 6*, and 14*). *It also contains the estimated costs of the beneficiaries not receiving EU funding (see Article 9).*

4.2 Budget transfers

The estimated budget breakdown indicated in Annex 2 may be adjusted by transfers of amounts between beneficiaries or between budget categories (or both). This does not require an amendment according to Article 55, if the action is implemented as described in Annex 1.

However, the beneficiaries may not add costs relating to subcontracts not provided for in Annex 1, unless such additional subcontracts are approved by an amendment or in accordance with Article 13.

CHAPTER 3 GRANT

ARTICLE 5 — GRANT AMOUNT, FORM OF GRANT, REIMBURSEMENT RATES AND FORMS OF COSTS

5.1 Maximum grant amount

The '**maximum grant amount**' is **EUR 2,999,995.00** (two million nine hundred and ninety nine thousand nine hundred and ninety five EURO).

5.2 Form of grant, reimbursement rates and forms of costs

The grant reimburses ***100% of the action's eligible costs*** (see Article 6) ('**reimbursement of eligible costs grant**') (see Annex 2).

The estimated eligible costs of the action are EUR **2,999,995.00** (two million nine hundred and ninety nine thousand nine hundred and ninety five EURO).

Eligible costs (see Article 6) must be declared under the following forms ('**forms of costs**'):

(a) for **direct personnel costs**:

- as actually incurred costs ('**actual costs**') or
- on the basis of an amount per unit calculated by the beneficiary in accordance with its usual cost accounting practices ('**unit costs**').

Personnel **costs for SME owners** or **beneficiaries that are natural persons** not receiving a salary (see Article 6.2, Points A.4 and A.5) must be declared on the basis of the amount per unit set out in Annex 2 (**unit costs**);

(b) for **direct costs for subcontracting**: as actually incurred costs (**actual costs**);

(c) for **direct costs of providing financial support to third parties**: *not applicable;*

(d) for **other direct costs**: as actually incurred costs (**actual costs**);

(e) for **indirect costs**: on the basis of a flat-rate applied as set out in Article 6.2, Point E ('**flat-rate costs**');

(f) ***specific cost category(ies):*** *not applicable.*

5.3 Final grant amount — Calculation

The '**final grant amount**' depends on the actual extent to which the action is implemented in accordance with the Agreement's terms and conditions.

This amount is calculated by the *Commission* — when the payment of the balance is made (see Article 21.4) — in the following steps:

Step 1 – Application of the reimbursement rates to the eligible costs

Step 2 – Limit to the maximum grant amount

Step 3 – Reduction due to the no-profit rule

Step 4 – Reduction due to improper implementation or breach of other obligations

5.3.1 Step 1 — Application of the reimbursement rates to the eligible costs

The reimbursement rate(s) (see Article 5.2) are applied to the eligible costs (actual costs, unit costs and flat-rate costs; see Article 6) declared by the beneficiaries *and linked third parties* (see Article 20) and approved by the *Commission* (see Article 21).

5.3.2 Step 2 — Limit to the maximum grant amount

If the amount obtained following Step 1 is higher than the maximum grant amount set out in Article 5.1, it will be limited to the latter.

5.3.3 Step 3 — Reduction due to the no-profit rule

The grant must not produce a profit.

'**Profit**' means the surplus of the amount obtained following Steps 1 and 2 plus the action's total receipts, over the action's total eligible costs.

The '**action's total eligible costs**' are the consolidated total eligible costs approved by the *Commission*.

The '**action's total receipts**' are the consolidated total receipts generated during its duration (see Article 3).

The following are considered **receipts**:

(a) income generated by the action; if the income is generated from selling equipment or other assets purchased under the Agreement, the receipt is up to the amount declared as eligible under the Agreement;

(b) financial contributions given by third parties to the beneficiary *or to a linked third party* specifically to be used for the action, and

(c) in-kind contributions provided by third parties free of charge and specifically to be used for the action, if they have been declared as eligible costs.

The following are however not considered receipts:

(a) income generated by exploiting the action's results (see Article 28);

(b) financial contributions by third parties, if they may be used to cover costs other than the eligible costs (see Article 6);

(c) financial contributions by third parties with no obligation to repay any amount unused at the end of the period set out in Article 3.

If there is a profit, it will be deducted from the amount obtained following Steps 1 and 2.

5.3.4 Step 4 — Reduction due to improper implementation or breach of other obligations — Reduced grant amount — Calculation

If the grant is reduced (see Article 43), the *Commission* will calculate the reduced grant amount by deducting the amount of the reduction (calculated in proportion to the improper implementation of the action or to the seriousness of the breach of obligations in accordance with Article 43.2) from the maximum grant amount set out in Article 5.1.

The final grant amount will be the lower of the following two:

- the amount obtained following Steps 1 to 3 or

- the reduced grant amount following Step 4.

5.4 Revised final grant amount — Calculation

If — after the payment of the balance (in particular, after checks, reviews, audits or investigations; see Article 22) — the *Commission* rejects costs (see Article 42) or reduces the grant (see Article 43), it will calculate the '**revised final grant amount**' for the beneficiary concerned by the findings.

This amount is calculated by the *Commission* on the basis of the findings, as follows:

- in case of **rejection of costs**: by applying the reimbursement rate to the revised eligible costs approved by the *Commission* for the beneficiary concerned;

- in case of **reduction of the grant**: by calculating the concerned beneficiary's share in the grant amount reduced in proportion to its improper implementation of the action or to the seriousness of its breach of obligations (see Article 43.2).

In case of **rejection of costs and reduction of the grant**, the revised final grant amount for the beneficiary concerned will be the lower of the two amounts above.

ARTICLE 6 — ELIGIBLE AND INELIGIBLE COSTS

6.1 General conditions for costs to be eligible

'**Eligible costs**' are costs that meet the following criteria:

(a) for **actual costs**:

(i) they must be actually incurred by the beneficiary;

(ii) they must be incurred in the period set out in Article 3, with the exception of costs relating to the submission of the periodic report for the last reporting period and the final report (see Article 20);

(iii) they must be indicated in the estimated budget set out in Annex 2;

(iv) they must be incurred in connection with the action as described in Annex 1 and necessary for its implementation;

(v) they must be identifiable and verifiable, in particular recorded in the beneficiary's accounts in accordance with the accounting standards applicable in the country where the beneficiary is established and with the beneficiary's usual cost accounting practices;

(vi) they must comply with the applicable national law on taxes, labour and social security, and

(vii) they must be reasonable, justified and must comply with the principle of sound financial management, in particular regarding economy and efficiency;

(b) for **unit costs**:

(i) they must be calculated as follows:

{amounts per unit set out in Annex 2 or calculated by the beneficiary in accordance with its usual cost accounting practices (see Article 6.2, Point A)

multiplied by

the number of actual units};

(ii) the number of actual units must comply with the following conditions:

- the units must be actually used or produced in the period set out in Article 3;
- the units must be necessary for implementing the action or produced by it, and
- the number of units must be identifiable and verifiable, in particular supported by records and documentation (see Article 18);

(c) for **flat-rate costs**:

(i) they must be calculated by applying the flat-rate set out in Annex 2, and

(ii) the costs (actual costs or unit costs) to which the flat-rate is applied must comply with the conditions for eligibility set out in this Article.

6.2 Specific conditions for costs to be eligible

Costs are eligible if they comply with the general conditions (see above) and the specific conditions set out below for each of the following budget categories:

A. direct personnel costs;
B. direct costs of subcontracting;
C. *not applicable;*
D. other direct costs;
E. indirect costs;
F. *not applicable.*

'Direct costs' are costs that are directly linked to the action implementation and can therefore be attributed to it directly. They must not include any indirect costs (see Point E below).

'Indirect costs' are costs that are not directly linked to the action implementation and therefore cannot be attributed directly to it.

A. Direct personnel costs

Types of eligible personnel costs

A.1 **Personnel costs** are eligible, if they are related to personnel working for the beneficiary under an employment contract (or equivalent appointing act) and assigned to the action ('**costs for employees (or equivalent)**'). They must be limited to salaries (including during parental leave), social security contributions, taxes and other costs included in the **remuneration**, if they arise from national law or the employment contract (or equivalent appointing act).

Beneficiaries that are non-profit legal entities[2] may also declare as personnel costs **additional remuneration** for personnel assigned to the action (including payments on the basis of supplementary contracts regardless of their nature), if:

(a) it is part of the beneficiary's usual remuneration practices and is paid in a consistent manner whenever the same kind of work or expertise is required;

(b) the criteria used to calculate the supplementary payments are objective and generally applied by the beneficiary, regardless of the source of funding used.

Additional remuneration for personnel assigned to the action is eligible up to the following amount:

(a) if the person works full time and exclusively on the action during the full year: up to EUR 8 000;

(b) if the person works exclusively on the action but not full-time or not for the full year: up to the corresponding pro-rata amount of EUR 8 000, or

(c) if the person does not work exclusively on the action: up to a pro-rata amount calculated as follows:

{{EUR 8 000

divided by

the number of annual productive hours (see below)},

multiplied by

the number of hours that the person has worked on the action during the year}.

A.2 The **costs for natural persons working under a direct contract** with the beneficiary other than an employment contract are eligible personnel costs, if:

(a) the person works under the beneficiary's instructions and, unless otherwise agreed with the beneficiary, on the beneficiary's premises;

(b) the result of the work carried out belongs to the beneficiary, and

(c) the costs are not significantly different from those for personnel performing similar tasks under an employment contract with the beneficiary.

A.3 The **costs of personnel seconded by a third party against payment** are eligible personnel costs, if the conditions in Article 11.1 are met.

[2] For the definition, see Article 2.1(14) of the Rules for Participation Regulation No 1290/2013: '**non-profit legal entity**' means a legal entity which by its legal form is non-profit-making or which has a legal or statutory obligation not to distribute profits to its shareholders or individual members.

A.4 **Costs of owners** of beneficiaries that are small and medium-sized enterprises ('**SME owners**') who are working on the action and who do not receive a salary are eligible personnel costs, if they correspond to the amount per unit set out in Annex 2 multiplied by the number of actual hours worked on the action.

A.5 **Costs of 'beneficiaries that are natural persons'** not receiving a salary are eligible personnel costs, if they correspond to the amount per unit set out in Annex 2 multiplied by the number of actual hours worked on the action.

Calculation

Personnel costs must be calculated by the beneficiaries as follows:

{{hourly rate

multiplied by

the number of actual hours worked on the action},

plus

for non-profit legal entities: additional remuneration to personnel assigned to the action under the conditions set out above (Point A.1)}.

The number of actual hours declared for a person must be identifiable and verifiable (see Article 18).

The total number of hours declared in EU or Euratom grants, for a person for a year, cannot be higher than the annual productive hours used for the calculations of the hourly rate. Therefore, the maximum number of hours that can be declared for the grant is:

{the number of annual productive hours for the year (see below)

minus

total number of hours declared by the beneficiary for that person in that year for other EU or Euratom grants}.

The '**hourly rate**' is one of the following:

(a) for personnel costs declared as **actual costs:** the hourly rate is the amount calculated as follows:

{actual annual personnel costs (excluding additional remuneration) for the person

divided by

number of annual productive hours}.

The beneficiaries must use the annual personnel costs and the number of annual productive hours for each financial year covered by the reporting period. If a financial year is not closed at the end of the reporting period, the beneficiaries must use the hourly rate of the last closed financial year available.

For the 'number of annual productive hours', the beneficiaries may choose one of the following:

(i) 'fixed number of hours': 1 720 hours for persons working full time (or corresponding pro-rata for persons not working full time);

(ii) 'individual annual productive hours': the total number of hours worked by the person in the year for the beneficiary, calculated as follows:

{annual workable hours of the person (according to the employment contract, applicable collective labour agreement or national law)

plus

overtime worked

minus

absences (such as sick leave and special leave)}.

'Annual workable hours' means the period during which the personnel must be working, at the employer's disposal and carrying out his/her activity or duties under the employment contract, applicable collective labour agreement or national working time legislation.

If the contract (or applicable collective labour agreement or national working time legislation) does not allow to determine the annual workable hours, this option cannot be used;

(iii) 'standard annual productive hours': the 'standard number of annual hours' generally applied by the beneficiary for its personnel in accordance with its usual cost accounting practices. This number must be at least 90% of the 'standard annual workable hours'.

If there is no applicable reference for the standard annual workable hours, this option cannot be used.

For all options, the actual time spent on **parental leave** by a person assigned to the action may be deducted from the number of annual productive hours;

(b) for personnel costs declared on the basis of **unit costs**: the hourly rate is one of the following:

(i) for SME owners or beneficiaries that are natural persons: the hourly rate set out in Annex 2 (see Points A.4 and A.5 above), or

(ii) for personnel costs declared on the basis of the beneficiary's usual cost accounting practices: the hourly rate calculated by the beneficiary in accordance with its usual cost accounting practices, if:

- the cost accounting practices used are applied in a consistent manner, based on objective criteria, regardless of the source of funding;

- the hourly rate is calculated using the actual personnel costs recorded in the beneficiary's accounts, excluding any ineligible cost or costs included in other budget categories.

The actual personnel costs may be adjusted by the beneficiary on the basis of budgeted or estimated elements. Those elements must be relevant for calculating

the personnel costs, reasonable and correspond to objective and verifiable information;

and

- the hourly rate is calculated using the number of annual productive hours (see above).

B. Direct costs of subcontracting (including related duties, taxes and charges such as non-deductible value added tax (VAT) paid by the beneficiary) are eligible if the conditions in Article 13.1.1 are met.

C. Direct costs of providing financial support to third parties *not applicable.*

D. Other direct costs

D.1 **Travel costs and related subsistence allowances** (including related duties, taxes and charges such as non-deductible value added tax (VAT) paid by the beneficiary) are eligible if they are in line with the beneficiary's usual practices on travel.

D.2 *The **depreciation costs of equipment, infrastructure or other assets** (new or second-hand) as recorded in the beneficiary's accounts are eligible, if they were purchased in accordance with Article 10.1.1 and written off in accordance with international accounting standards and the beneficiary's usual accounting practices.*

*The **costs of renting or leasing** equipment, infrastructure or other assets (including related duties, taxes and charges such as non-deductible value added tax (VAT) paid by the beneficiary) are also eligible, if they do not exceed the depreciation costs of similar equipment, infrastructure or assets and do not include any financing fees.*

*The costs of equipment, infrastructure or other assets **contributed in-kind against payment** are eligible, if they do not exceed the depreciation costs of similar equipment, infrastructure or assets, do not include any financing fees and if the conditions in Article 11.1 are met.*

The only portion of the costs that will be taken into account is that which corresponds to the duration of the action and rate of actual use for the purposes of the action.

D.3 **Costs of other goods and services** (including related duties, taxes and charges such as non-deductible value added tax (VAT) paid by the beneficiary) are eligible, if they are:

(a) purchased specifically for the action and in accordance with Article 10.1.1 or

(b) contributed in kind against payment and in accordance with Article 11.1.

Such goods and services include, for instance, consumables and supplies, dissemination (including open access), protection of results, certificates on the financial statements (if they are required by the Agreement), certificates on the methodology, translations and publications.

D.4 **Capitalised and operating costs of 'large research infrastructure'**[3]*: Not applicable*

E. Indirect costs

Indirect costs are eligible if they are declared on the basis of the flat-rate of 25% of the eligible direct costs (see Article 5.2 and Points A to D above), from which are excluded:

(a) costs of subcontracting and

(b) costs of in-kind contributions provided by third parties which are not used on the beneficiary's premises;

(c) *not applicable;*

(d) *not applicable.*

Beneficiaries receiving an operating grant[5] financed by the EU or Euratom budget cannot declare indirect costs for the period covered by the operating grant.

F. *Specific cost category(ies)*

Not applicable

6.3 Conditions for costs of linked third parties to be eligible

Costs incurred by linked third parties are eligible if they fulfil — mutatis mutandis — the general and specific conditions for eligibility set out in this Article (Article 6.1 and 6.2) and Article 14.1.1.

6.4 Conditions for in-kind contributions provided by third parties free of charge to be eligible

In-kind contributions provided free of charge are eligible direct costs (for the beneficiary *or linked third party*), if the costs incurred by the third party fulfil — *mutatis mutandis* — the general and specific conditions for eligibility set out in this Article (Article 6.1 and 6.2) and Article 12.1.

6.5 Ineligible costs

'**Ineligible costs**' are:

(a) costs that do not comply with the conditions set out above (Article 6.1 to 6.4), in particular:

(i) costs related to return on capital;

[3] '**Large research infrastructure**' means research infrastructure of a total value of at least EUR 20 million, for a beneficiary, calculated as the sum of historical asset values of each individual research infrastructure of that beneficiary, as they appear in its last closed balance sheet before the date of the signature of the Agreement or as determined on the basis of the rental and leasing costs of the research infrastructure.

[5] For the definition, see Article 121(1)(b) of Regulation (EU, Euratom) No 966/2012 of the European Parliament and of the Council of 25 October 2012 on the financial rules applicable to the general budget of the Union and repealing Council Regulation (EC, Euratom) No 1605/2002 (OJ L 218, 26.10.2012, p.1) ('**Financial Regulation No 966/2012**'): '**operating grant**' means direct financial contribution, by way of donation, from the budget in order to finance the functioning of a body which pursues an aim of general EU interest or has an objective forming part of and supporting an EU policy.

(ii) debt and debt service charges;

(iii) provisions for future losses or debts;

(iv) interest owed;

(v) doubtful debts;

(vi) currency exchange losses;

(vii) bank costs charged by the beneficiary's bank for transfers from the *Commission*;

(viii) excessive or reckless expenditure;

(ix) deductible VAT;

(x) costs incurred during suspension of the implementation of the action (see Article 49);

(b) costs declared under another EU or Euratom grant (including grants awarded by a Member State and financed by the EU or Euratom budget and grants awarded by bodies other than the *Commission* for the purpose of implementing the EU or Euratom budget); in particular, indirect costs if the beneficiary is already receiving an operating grant financed by the EU or Euratom budget in the same period.

6.6 Consequences of declaration of ineligible costs

Declared costs that are ineligible will be rejected (see Article 42).

This may also lead to any of the other measures described in Chapter 6.

CHAPTER 4 RIGHTS AND OBLIGATIONS OF THE PARTIES

SECTION 1 RIGHTS AND OBLIGATIONS RELATED TO IMPLEMENTING THE ACTION

ARTICLE 7 — GENERAL OBLIGATION TO PROPERLY IMPLEMENT THE ACTION

7.1 General obligation to properly implement the action

The beneficiaries must implement the action as described in Annex 1 and in compliance with the provisions of the Agreement and all legal obligations under applicable EU, international and national law.

7.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 43).

Such breaches may also lead to any of the other measures described in Chapter 6.

ARTICLE 8 — RESOURCES TO IMPLEMENT THE ACTION — THIRD PARTIES INVOLVED IN THE ACTION

The beneficiaries must have the appropriate resources to implement the action.

If it is necessary to implement the action, the beneficiaries may:

- purchase goods, works and services (see Article 10);
- use in-kind contributions provided by third parties against payment (see Article 11);
- use in-kind contributions provided by third parties free of charge (see Article 12);
- call upon subcontractors to implement action tasks described in Annex 1 (see Article 13);
- call upon linked third parties to implement action tasks described in Annex 1 (see Article 14).

In these cases, the beneficiaries retain sole responsibility towards the *Commission* and the other beneficiaries for implementing the action.

ARTICLE 9 — IMPLEMENTATION OF ACTION TASKS BY BENEFICIARIES NOT RECEIVING EU FUNDING

9.1 Rules for the implementation of action tasks by beneficiaries not receiving EU funding

Beneficiaries not receiving EU funding must implement the action tasks attributed to them in Annex 1 according to Article 7.1.

Their costs are estimated in Annex 2 but:

- *will not be reimbursed and*
- *will not be taken into account for the calculation of the grant (see Articles 5.2, 5.3 and 5.4, and 21).*

Chapter 3, Articles 10 to 15, 18.1.2, 20.3(b), 20.4(b), 20.6, 21, 23a, 26.4, 27.2, 28.1, 28.2, 30.3, 31.5, 40, 42, 43, 44, 47 and 48 do not apply to these beneficiaries.

They will not be subject to financial checks, reviews and audits under Article 22.

Beneficiaries not receiving EU funding may provide in-kind contributions to another beneficiary. In this case, they will be considered as a third party for the purpose of Articles 11 and 12.

9.2 Consequences of non-compliance

If a beneficiary not receiving EU funding breaches any of its obligations under this Article, its participation of the Agreement may be terminated (see Article 50).

Such breaches may also lead to any of the other measures described in Chapter 6 that are applicable to it.

ARTICLE 10 — PURCHASE OF GOODS, WORKS OR SERVICES

10.1 Rules for purchasing goods, works or services

10.1.1 If necessary to implement the action, the beneficiaries may purchase goods, works or services.

The beneficiaries must make such purchases ensuring the best value for money or, if appropriate, the lowest price. In doing so, they must avoid any conflict of interests (see Article 35).

The beneficiaries must ensure that the Commission, the European Court of Auditors (ECA) and the European Anti-Fraud Office (OLAF) can exercise their rights under Articles 22 and 23 also towards their contractors.

10.1.2 Beneficiaries that are 'contracting authorities' within the meaning of Directive 2004/18/EC[6] or 'contracting entities' within the meaning of Directive 2004/17/EC[7] must comply with the applicable national law on public procurement.

10.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under Article 10.1.1, the costs related to the contract concerned will be ineligible (see Article 6) and will be rejected (see Article 42).

If a beneficiary breaches any of its obligations under Article 10.1.2, the grant may be reduced (see Article 43).

Such breaches may also lead to any of the other measures described in Chapter 6.

ARTICLE 11 — USE OF IN-KIND CONTRIBUTIONS PROVIDED BY THIRD PARTIES AGAINST PAYMENT

11.1 Rules for the use of in-kind contributions against payment

If necessary to implement the action, the beneficiaries may use in-kind contributions provided by third parties against payment.

The beneficiaries may declare costs related to the payment of in-kind contributions as eligible (see Article 6.1 and 6.2), up to the third parties' costs for the seconded persons, contributed equipment, infrastructure or other assets or other contributed goods and services.

The third parties and their contributions must be set out in Annex 1. The *Commission* may however approve in-kind contributions not set out in Annex 1 without amendment (see Article 55), if:

- they are specifically justified in the periodic technical report and
- their use does not entail changes to the Agreement which would call into question the decision awarding the grant or breach the principle of equal treatment of applicants.

[6] Directive 2004/18/EC of the European Parliament and of the Council of 31 March 2004 on the coordination of procedures for the award of public work contracts, public supply contracts and public service contracts (OJ L 134, 30.04.2004, p. 114).

[7] Directive 2004/17/EC of the European Parliament and of the Council of 31 March 2004 coordinating the procurement procedures of entities operating in the water, energy, transport and postal services sectors (OJ L 134, 30.04.2004, p. 1).

The beneficiaries must ensure that the Commission, the European Court of Auditors (ECA) and the European Anti-Fraud Office (OLAF) can exercise their rights under Articles 22 and 23 also towards the third parties.

11.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the costs related to the payment of the in-kind contribution will be ineligible (see Article 6) and will be rejected (see Article 42).

Such breaches may also lead to any of the other measures described in Chapter 6.

ARTICLE 12 — USE OF IN-KIND CONTRIBUTIONS PROVIDED BY THIRD PARTIES FREE OF CHARGE

12.1 Rules for the use of in-kind contributions free of charge

If necessary to implement the action, the beneficiaries may use in-kind contributions provided by third parties free of charge.

The beneficiaries may declare costs incurred by the third parties for the seconded persons, contributed equipment, infrastructure or other assets or other contributed goods and services as eligible in accordance with Article 6.4.

The third parties and their contributions must be set out in Annex 1. The *Commission* may however approve in-kind contributions not set out in Annex 1 without amendment (see Article 55), if:

- they are specifically justified in the periodic technical report and
- their use does not entail changes to the Agreement which would call into question the decision awarding the grant or breach the principle of equal treatment of applicants.

The beneficiaries must ensure that the Commission, the European Court of Auditors (ECA) and the European Anti-Fraud Office (OLAF) can exercise their rights under Articles 22 and 23 also towards the third parties.

12.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the costs incurred by the third parties related to the in-kind contribution will be ineligible (see Article 6) and will be rejected (see Article 42).

Such breaches may also lead to any of the other measures described in Chapter 6.

ARTICLE 13 — IMPLEMENTATION OF ACTION TASKS BY SUBCONTRACTORS

13.1 Rules for subcontracting action tasks

13.1.1 If necessary to implement the action, the beneficiaries may award subcontracts covering the implementation of certain action tasks described in Annex 1.

Subcontracting may cover only a limited part of the action.

The beneficiaries must award the subcontracts ensuring the best value for money or, if appropriate, the lowest price. In doing so, they must avoid any conflict of interests (see Article 35).

The tasks to be implemented and the estimated cost for each subcontract must be set out in Annex 1 and the total estimated costs of subcontracting per beneficiary must be set out in Annex 2. The *Commission* may however approve subcontracts not set out in Annex 1 and 2 without amendment (see Article 55), if:

- they are specifically justified in the periodic technical report and

- they do not entail changes to the Agreement which would call into question the decision awarding the grant or breach the principle of equal treatment of applicants.

The beneficiaries must ensure that the Commission, the European Court of Auditors (ECA) and the European Anti-Fraud Office (OLAF) can exercise their rights under Articles 22 and 23 also towards their subcontractors.

13.1.2 The beneficiaries must ensure that their obligations under Articles 35, 36, 38 and 46 also apply to the subcontractors.

Beneficiaries that are ‘contracting authorities’ within the meaning of Directive 2004/18/EC or ‘contracting entities’ within the meaning of Directive 2004/17/EC must comply with the applicable national law on public procurement.

13.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under Article 13.1.1, the costs related to the subcontract concerned will be ineligible (see Article 6) and will be rejected (see Article 42).

If a beneficiary breaches any of its obligations under Article 13.1.2, the grant may be reduced (see Article 43).

Such breaches may also lead to any of the other measures described in Chapter 6.

ARTICLE 14 — IMPLEMENTATION OF ACTION TASKS BY LINKED THIRD PARTIES

14.1 Rules for calling upon linked third parties to implement part of the action

*14.1.1 The following **affiliated entities**[9] and **third parties with a legal link to a beneficiary**[10] (‘**linked third parties**’) may implement the action tasks attributed to them in Annex 1:*

- *GEANT VERENIGING (GÉANT Assn), affiliated or linked to GEANT LTD*
- *OBSERVATOIRE DE LA COTE D'AZUR (OCA) (OCA), affiliated or linked to CNRS*

The linked third parties may declare as eligible the costs they incur for implementing the action tasks in accordance with Article 6.3.

The beneficiaries must ensure that the Commission, the European Court of Auditors (ECA) and the European Anti-Fraud Office (OLAF) can exercise their rights under Articles 22 and 23 also towards their linked third parties.

14.1.2 The beneficiaries must ensure that their obligations under Articles 18, 20, 35, 36 and 38 also apply to their linked third parties.

14.2 Consequences of non-compliance

If any obligation under Article 14.1.1 is breached, the costs of the linked third party will be ineligible (see Article 6) and will be rejected (see Article 42).

If any obligation under Article 14.1.2 is breached, the grant may be reduced (see Article 43).

Such breaches may also lead to any of the other measures described in Chapter 6.

ARTICLE 15 — FINANCIAL SUPPORT TO THIRD PARTIES

15.1 Rules for providing financial support to third parties

Not applicable

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[9] For the definition, see Article 2.1(2) of the Rules for Participation Regulation No 1290/2013: '**affiliated entity**' means any legal entity that is:
- under the direct or indirect control of a participant, or
- under the same direct or indirect control as the participant, or
- directly or indirectly controlling a participant.

‘Control’ may take any of the following forms:
(a) the direct or indirect holding of more than 50% of the nominal value of the issued share capital in the legal entity concerned, or of a majority of the voting rights of the shareholders or associates of that entity;
(b) the direct or indirect holding, in fact or in law, of decision-making powers in the legal entity concerned.

However the following relationships between legal entities shall not in themselves be deemed to constitute controlling relationships:
(a) the same public investment corporation, institutional investor or venture-capital company has a direct or indirect holding of more than 50% of the nominal value of the issued share capital or a majority of voting rights of the shareholders or associates;
(b) the legal entities concerned are owned or supervised by the same public body.

[10] ‘**Third party with a legal link to a beneficiary**’ is any legal entity which has a legal link to the beneficiary implying collaboration that is not limited to the action.

15.2 Financial support in the form of prizes

Not applicable

15.3 Consequences of non-compliance

Not applicable

ARTICLE 16 — PROVISION OF TRANS-NATIONAL OR VIRTUAL ACCESS TO RESEARCH INFRASTRUCTURE

16.1 Rules for providing trans-national access to research infrastructure

Not applicable

16.2 Rules for providing virtual access to research infrastructure

Not applicable

16.3 Consequences of non-compliance

Not applicable

SECTION 2 RIGHTS AND OBLIGATIONS RELATED TO THE GRANT ADMINISTRATION

ARTICLE 17 — GENERAL OBLIGATION TO INFORM

17.1 General obligation to provide information upon request

The beneficiaries must provide — during implementation of the action or afterwards and in accordance with Article 41.2 — any information requested in order to verify eligibility of the costs, proper implementation of the action and compliance with any other obligation under the Agreement.

17.2 Obligation to keep information up to date and to inform about events and circumstances likely to affect the Agreement

Each beneficiary must keep information stored in the 'Beneficiary Register' (via the electronic exchange system; see Article 52) up to date, in particular, its name, address, legal representatives, legal form and organisation type.

Each beneficiary must immediately inform the coordinator — which must immediately inform the *Commission* and the other beneficiaries — of any of the following:

(a) **events** which are likely to affect significantly or delay the implementation of the action or the EU's financial interests, in particular:

(i) changes in its legal, financial, technical, organisational or ownership situation *or those of its linked third parties and*

(ii) changes in the name, address, legal form, organisation type of its linked third parties;

(b) **circumstances** affecting:

(i) the decision to award the grant or

(ii) compliance with requirements under the Agreement.

17.3 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 43).

Such breaches may also lead to any of the other measures described in Chapter 6.

ARTICLE 18 — KEEPING RECORDS — SUPPORTING DOCUMENTATION

18.1 Obligation to keep records and other supporting documentation

The beneficiaries must — for a period of *five* years after the payment of the balance — keep records and other supporting documentation in order to prove the proper implementation of the action and the costs they declare as eligible.

They must make them available upon request (see Article 17) or in the context of checks, reviews, audits or investigations (see Article 22).

If there are on-going checks, reviews, audits, investigations, litigation or other pursuits of claims under the Agreement (including the extension of findings; see Articles 22), the beneficiaries must keep the records and other supporting documentation until the end of these procedures.

The beneficiaries must keep the original documents. Digital and digitalised documents are considered originals if they are authorised by the applicable national law. The *Commission* may accept non-original documents if it considers that they offer a comparable level of assurance.

18.1.1 Records and other supporting documentation on the scientific and technical implementation

The beneficiaries must keep records and other supporting documentation on scientific and technical implementation of the action in line with the accepted standards in the respective field.

18.1.2 Records and other documentation to support the costs declared

The beneficiaries must keep the records and documentation supporting the costs declared, in particular the following:

(a) for **actual costs**: adequate records and other supporting documentation to prove the costs declared, such as contracts, subcontracts, invoices and accounting records. In addition, the beneficiaries' usual cost accounting practices and internal control procedures must enable direct reconciliation between the amounts declared, the amounts recorded in their accounts and the amounts stated in the supporting documentation;

(b) for **unit costs**: adequate records and other supporting documentation to prove the number of units declared. Beneficiaries do not need to identify the actual eligible costs covered or to keep or provide supporting documentation (such as accounting statements) to prove the amount per unit.

In addition, **for direct personnel costs declared as unit costs calculated in accordance with the beneficiary's usual cost accounting practices**, the beneficiaries must keep adequate records and documentation to prove that the cost accounting practices used comply with the conditions set out in Article 6.2, Point A.

The beneficiaries *and linked third parties* may submit to the Commission, for approval, a certificate (drawn up in accordance with Annex 6) stating that their usual cost accounting practices comply with these conditions ('**certificate on the methodology**'). If the certificate is approved, costs declared in line with this methodology will not be challenged subsequently, unless the beneficiaries have concealed information for the purpose of the approval.

(c) for **flat-rate costs**: adequate records and other supporting documentation to prove the eligibility of the costs to which the flat-rate is applied. The beneficiaries do not need to identify the costs covered or provide supporting documentation (such as accounting statements) to prove the amount declared at a flat-rate.

In addition, for **personnel costs** (declared as actual costs or on the basis of unit costs), the beneficiaries must keep **time records** for the number of hours declared. The time records must be in writing and approved by the persons working on the action and their supervisors, at least monthly. In the absence of reliable time records of the hours worked on the action, the *Commission* may accept alternative evidence supporting the number of hours declared, if it considers that it offers an adequate level of assurance.

As an exception, for **persons working exclusively on the action**, there is no need to keep time records, if the beneficiary signs a **declaration** confirming that the persons concerned have worked exclusively on the action.

For costs declared by linked third parties (see Article 14), it is the beneficiary that must keep the originals of the financial statements and the certificates on the financial statements of the linked third parties.

18.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, costs insufficiently substantiated will be ineligible (see Article 6) and will be rejected (see Article 42), and the grant may be reduced (see Article 43).

Such breaches may also lead to any of the other measures described in Chapter 6.

ARTICLE 19 — SUBMISSION OF DELIVERABLES

19.1 Obligation to submit deliverables

The coordinator must submit the '**deliverables**' identified in Annex 1, in accordance with the timing and conditions set out in it.

19.2 Consequences of non-compliance

If the coordinator breaches any of its obligations under this Article, the *Commission* may apply any of the measures described in Chapter 6.

ARTICLE 20 — REPORTING — PAYMENT REQUESTS

20.1 Obligation to submit reports

The coordinator must submit to the *Commission* (see Article 52) the technical and financial reports set out in this Article. These reports include requests for payment and must be drawn up using the forms and templates provided in the electronic exchange system (see Article 52).

20.2 Reporting periods

The action is divided into the following '**reporting periods**':

- RP1: from month 1 to month 18
- *RP2: from month 19 to month 36*

20.3 Periodic reports — Requests for interim payments

The coordinator must submit a periodic report within 60 days following the end of each reporting period.

The **periodic report** must include the following:

(a) a '**periodic technical report**' containing:

(i) an **explanation of the work carried out** by the beneficiaries;

(ii) an **overview of the progress** towards the objectives of the action, including milestones and deliverables identified in Annex 1.

This report must include explanations justifying the differences between work expected to be carried out in accordance with Annex 1 and that actually carried out.

The report must also detail the exploitation and dissemination of the results and — if required in Annex 1 — an updated '**plan for the exploitation and dissemination of the results**';

(iii) a **summary** for publication by the *Commission*;

(iv) the answers to the '**questionnaire**', covering issues related to the action implementation and the economic and societal impact, notably in the context of the Horizon 2020 key performance indicators and the Horizon 2020 monitoring requirements;

(b) a '**periodic financial report**' containing:

(i) an '**individual financial statement**' (see Annex 4) from each beneficiary *and from each linked third party*, for the reporting period concerned.

The individual financial statement must detail the eligible costs (actual costs, unit costs and flat-rate costs; see Article 6) for each budget category (see Annex 2).

The beneficiaries *and linked third parties* must declare all eligible costs, even if — for actual costs, unit costs and flat-rate costs — they exceed the amounts indicated in the estimated budget (see Annex 2). Amounts which are not declared in the individual financial statement will not be taken into account by the *Commission*.

If an individual financial statement is not submitted for a reporting period, it may be included in the periodic financial report for the next reporting period.

The individual financial statements of the last reporting period must also detail the **receipts of the action** (see Article 5.3.3).

Each beneficiary *and each linked third party* must **certify** that:

- the information provided is full, reliable and true;
- the costs declared are eligible (see Article 6);
- the costs can be substantiated by adequate records and supporting documentation (see Article 18) that will be produced upon request (see Article 17) or in the context of checks, reviews, audits and investigations (see Article 22), and
- for the last reporting period: that all the receipts have been declared (see Article 5.3.3);

(ii) an **explanation of the use of resources** and the information on subcontracting (see Article 13) and in-kind contributions provided by third parties (see Articles 11 and 12) from each beneficiary *and from each linked third party*, for the reporting period concerned;

(iii) *not applicable;*

(iv) a '**periodic summary financial statement**' (see Annex 4), created automatically by the electronic exchange system, consolidating the individual financial statements for the reporting period concerned and including — except for the last reporting period — the **request for interim payment**.

20.4 Final report — Request for payment of the balance

In addition to the periodic report for the last reporting period, the coordinator must submit the final report within 60 days following the end of the last reporting period.

The **final report** must include the following:

(a) a '**final technical report**' with a **summary** for publication containing:

(i) an overview of the results and their exploitation and dissemination;

(ii) the conclusions on the action, and

(iii) the socio-economic impact of the action;

(b) a '**final financial report**' containing:

(i) a '**final summary financial statement**' (see Annex 4), created automatically by the electronic exchange system, consolidating the individual financial statements for all reporting periods and including the **request for payment of the balance** and

(ii) a '**certificate on the financial statements**' (drawn up in accordance with Annex 5) for each beneficiary *and for each linked third party*, if it requests a total contribution of EUR 325 000 or more, as reimbursement of actual costs and unit costs calculated on the basis of its usual cost accounting practices (see Article 5.2 and Article 6.2, Point A).

20.5 Information on cumulative expenditure incurred

Not applicable

20.6 Currency for financial statements and conversion into euro

Financial statements must be drafted in euro.

Beneficiaries *and linked third parties* with accounting established in a currency other than the euro must convert the costs recorded in their accounts into euro, at the average of the daily exchange rates published in the C series of the *Official Journal of the European Union*, calculated over the corresponding reporting period.

If no daily euro exchange rate is published in the *Official Journal of the European Union* for the currency in question, they must be converted at the average of the monthly accounting rates published on the Commission's website, calculated over the corresponding reporting period.

Beneficiaries *and linked third parties* with accounting established in euro must convert costs incurred in another currency into euro according to their usual accounting practices.

20.7 Language of reports

All reports (technical and financial reports, including financial statements) must be submitted in the language of the Agreement.

20.8 Consequences of non-compliance — Suspension of the payment deadline — Termination

If the reports submitted do not comply with this Article, the *Commission* may suspend the payment deadline (see Article 47) and apply any of the other measures described in Chapter 6.

If the coordinator breaches its obligation to submit the reports and if it fails to comply with this obligation within 30 days following a written reminder sent by the *Commission*, the Agreement may be terminated (see Article 50).

ARTICLE 21 — PAYMENTS AND PAYMENT ARRANGEMENTS

21.1 Payments to be made

The following payments will be made to the coordinator:

- one **pre-financing payment**;
- one or more **interim payments**, on the basis of the request(s) for interim payment (see Article 20), and
- one **payment of the balance**, on the basis of the request for payment of the balance (see Article 20).

21.2 Pre-financing payment — Amount — Amount retained for the Guarantee Fund

The aim of the pre-financing is to provide the beneficiaries with a float.

It remains the property of the *EU* until the payment of the balance.

The amount of the pre-financing payment will be EUR **2,399,996.00** (two million three hundred and ninety nine thousand nine hundred and ninety six EURO).

The *Commission* will — except if Article 48 applies — make the pre-financing payment to the coordinator within 30 days either from the entry into force of the Agreement (see Article 58) or from 10 days before the starting date of the action (see Article 3), whichever is the latest.

An amount of EUR **149,999.75** (one hundred and forty nine thousand nine hundred and ninety nine EURO and seventy five eurocents), corresponding to 5% of the maximum grant amount (see Article 5.1), is retained by the *Commission* from the pre-financing payment and transferred into the '**Guarantee Fund**'.

21.3 Interim payments — Amount — Calculation

Interim payments reimburse the eligible costs incurred for the implementation of the action during the corresponding reporting periods.

The *Commission* will pay to the coordinator the amount due as interim payment within 90 days from receiving the periodic report (see Article 20.3), except if Articles 47 or 48 apply.

Payment is subject to the approval of the periodic report. Its approval does not imply recognition of the compliance, authenticity, completeness or correctness of its content.

The **amount due as interim payment** is calculated by the *Commission* in the following steps:

Step 1 – Application of the reimbursement rates

Step 2 – Limit to 90% of the maximum grant amount

21.3.1 Step 1 — Application of the reimbursement rates

The reimbursement rate(s) (see Article 5.2) are applied to the eligible costs (actual costs, unit costs and flat-rate costs ; see Article 6) declared by the beneficiaries *and the linked third parties* (see Article 20) and approved by the *Commission* (see above) for the concerned reporting period.

21.3.2 Step 2 — Limit to 90% of the maximum grant amount

The total amount of pre-financing and interim payments must not exceed 90% of the maximum grant amount set out in Article 5.1. The maximum amount for the interim payment will be calculated as follows:

{90% of the maximum grant amount (see Article 5.1)

minus

{pre-financing and previous interim payments}}.

21.4 Payment of the balance — Amount — Calculation — Release of the amount retained for the Guarantee Fund

The payment of the balance reimburses the remaining part of the eligible costs incurred by the beneficiaries for the implementation of the action.

If the total amount of earlier payments is greater than the final grant amount (see Article 5.3), the payment of the balance takes the form of a recovery (see Article 44).

If the total amount of earlier payments is lower than the final grant amount, the *Commission* will pay the balance within 90 days from receiving the final report (see Article 20.4), except if Articles 47 or 48 apply.

Payment is subject to the approval of the final report. Its approval does not imply recognition of the compliance, authenticity, completeness or correctness of its content.

The **amount due as the balance** is calculated by the *Commission* by deducting the total amount of pre-financing and interim payments (if any) already made, from the final grant amount determined in accordance with Article 5.3:

{final grant amount (see Article 5.3)

minus

{pre-financing and interim payments (if any) made}}.

At the payment of the balance, the amount retained for the Guarantee Fund (see above) will be released and:

- if the balance is positive: the amount released will be paid in full to the coordinator together with the amount due as the balance;

- if the balance is negative (payment of the balance taking the form of recovery): it will be deducted from the amount released (see Article 44.1.2). If the resulting amount:

    - is positive, it will be paid to the coordinator

- is negative, it will be recovered.

The amount to be paid may however be offset — without the beneficiary's consent — against any other amount owed by the beneficiary to the Commission or an executive agency (under the EU or Euratom budget), up to the maximum EU contribution indicated, for that beneficiary, in the estimated budget (see Annex 2).

21.5 Notification of amounts due

When making payments, the *Commission* will formally notify to the coordinator the amount due, specifying whether it concerns an interim payment or the payment of the balance.

For the payment of the balance, the notification will also specify the final grant amount.

In the case of reduction of the grant or recovery of undue amounts, the notification will be preceded by the contradictory procedure set out in Articles 43 and 44.

21.6 Currency for payments

The *Commission* will make all payments in euro.

21.7 Payments to the coordinator — Distribution to the beneficiaries

Payments will be made to the coordinator.

Payments to the coordinator will discharge the *Commission* from its payment obligation.

The coordinator must distribute the payments between the beneficiaries without unjustified delay.

Pre-financing may however be distributed only:

(a) if the minimum number of beneficiaries set out in the call for proposals has acceded to the Agreement (see Article 56) and

(b) to beneficiaries that have acceded to the Agreement (see Article 56).

21.8 Bank account for payments

All payments will be made to the following bank account:

Name of bank: ABN AMRO BANK N.V.
Address of branch: 10, GUSTAV MAHLERLAAN AMSTERDAM, Netherlands
Full name of the account holder: ASTRON
Full account number (including bank codes):
IBAN code: NL82ABNA0642388180

21.9 Costs of payment transfers

The cost of the payment transfers is borne as follows:

- the *Commission* bears the cost of transfers charged by its bank;

- the beneficiary bears the cost of transfers charged by its bank;

- the party causing a repetition of a transfer bears all costs of the repeated transfer.

21.10 Date of payment

Payments by the *Commission* are considered to have been carried out on the date when they are debited to its account.

21.11 Consequences of non-compliance

21.11.1 If the *Commission* does not pay within the payment deadlines (see above), the beneficiaries are entitled to **late-payment interest** at the rate applied by the European Central Bank (ECB) for its main refinancing operations in euros ('reference rate'), plus three and a half points. The reference rate is the rate in force on the first day of the month in which the payment deadline expires, as published in the C series of the *Official Journal of the European Union*.

If the late-payment interest is lower than or equal to EUR 200, it will be paid to the coordinator only upon request submitted within two months of receiving the late payment.

Late-payment interest is not due if all beneficiaries are EU Member States (including regional and local government authorities or other public bodies acting on behalf of a Member State for the purpose of this Agreement).

Suspension of the payment deadline or payments (see Articles 47 and 48) will not be considered as late payment.

Late-payment interest covers the period running from the day following the due date for payment (see above), up to and including the date of payment.

Late-payment interest is not considered for the purposes of calculating the final grant amount.

21.11.2 If the coordinator breaches any of its obligations under this Article, the grant may be reduced (see Article 43) and the Agreement or the participation of the coordinator may be terminated (see Article 50).

Such breaches may also lead to any of the other measures described in Chapter 6.

ARTICLE 22 — CHECKS, REVIEWS, AUDITS AND INVESTIGATIONS — EXTENSION OF FINDINGS

22.1 Checks, reviews and audits by the Commission

22.1.1 Right to carry out checks

The Commission will — during the implementation of the action or afterwards — check the proper implementation of the action and compliance with the obligations under the Agreement, including assessing deliverables and reports.

For this purpose the Commission may be assisted by external persons or bodies.

The Commission may also request additional information in accordance with Article 17. The Commission may request beneficiaries to provide such information to it directly.

Information provided must be accurate, precise and complete and in the format requested, including electronic format.

22.1.2 Right to carry out reviews

The Commission may — during the implementation of the action or afterwards — carry out reviews on the proper implementation of the action (including assessment of deliverables and reports), compliance with the obligations under the Agreement and continued scientific or technological relevance of the action.

Reviews may be started **up to two years after the payment of the balance**. They will be formally notified to the coordinator or beneficiary concerned and will be considered to have started on the date of the formal notification.

If the review is carried out on a third party (see Articles 10 to 16), the beneficiary concerned must inform the third party.

The Commission may carry out reviews directly (using its own staff) or indirectly (using external persons or bodies appointed to do so). It will inform the coordinator or beneficiary concerned of the identity of the external persons or bodies. They have the right to object to the appointment on grounds of commercial confidentiality.

The coordinator or beneficiary concerned must provide — within the deadline requested — any information and data in addition to deliverables and reports already submitted (including information on the use of resources). The Commission may request beneficiaries to provide such information to it directly.

The coordinator or beneficiary concerned may be requested to participate in meetings, including with external experts.

For **on-the-spot** reviews, the beneficiaries must allow access to their sites and premises, including to external persons or bodies, and must ensure that information requested is readily available.

Information provided must be accurate, precise and complete and in the format requested, including electronic format.

On the basis of the review findings, a '**review report**' will be drawn up.

The Commission will formally notify the review report to the coordinator or beneficiary concerned, which has 30 days to formally notify observations ('**contradictory review procedure**').

Reviews (including review reports) are in the language of the Agreement.

22.1.3 Right to carry out audits

The Commission may — during the implementation of the action or afterwards — carry out audits on the proper implementation of the action and compliance with the obligations under the Agreement.

Audits may be started **up to two years after the payment of the balance**. They will be formally notified to the coordinator or beneficiary concerned and will be considered to have started on the date of the formal notification.

If the audit is carried out on a third party (see Articles 10 to 16), the beneficiary concerned must inform the third party.

The Commission may carry out audits directly (using its own staff) or indirectly (using external persons or bodies appointed to do so). It will inform the coordinator or beneficiary concerned of the identity of the external persons or bodies. They have the right to object to the appointment on grounds of commercial confidentiality.

The coordinator or beneficiary concerned must provide — within the deadline requested — any information (including complete accounts, individual salary statements or other personal data) to verify compliance with the Agreement. The Commission may request beneficiaries to provide such information to it directly.

For **on-the-spot** audits, the beneficiaries must allow access to their sites and premises, including to external persons or bodies, and must ensure that information requested is readily available.

Information provided must be accurate, precise and complete and in the format requested, including electronic format.

On the basis of the audit findings, a '**draft audit report**' will be drawn up.

The Commission will formally notify the draft audit report to the coordinator or beneficiary concerned, which has 30 days to formally notify observations ('**contradictory audit procedure**'). This period may be extended by the Commission in justified cases.

The '**final audit report**' will take into account observations by the coordinator or beneficiary concerned. The report will be formally notified to it.

Audits (including audit reports) are in the language of the Agreement.

The Commission may also access the beneficiaries' statutory records for the periodical assessment of unit costs or flat-rate amounts.

22.2 Investigations by the European Anti-Fraud Office (OLAF)

Under Regulations No 883/2013[15] and No 2185/96[16] (and in accordance with their provisions and procedures), the European Anti-Fraud Office (OLAF) may — at any moment during implementation of the action or afterwards — carry out investigations, including on-the-spot checks and inspections, to establish whether there has been fraud, corruption or any other illegal activity affecting the financial interests of the EU.

[15] Regulation (EU, Euratom) No 883/2013 of the European Parliament and of the Council of 11 September 2013 concerning investigations conducted by the European Anti-Fraud Office (OLAF) and repealing Regulation (EC) No 1073/1999 of the European Parliament and of the Council and Council Regulation (Euratom) No 1074/1999 (OJ L 248, 18.09.2013, p. 1).

[16] Council Regulation (Euratom, EC) No 2185/1996 of 11 November 1996 concerning on-the-spot checks and inspections carried out by the Commission in order to protect the European Communities' financial interests against fraud and other irregularities (OJ L 292, 15.11.1996, p. 2).

22.3 Checks and audits by the European Court of Auditors (ECA)

Under Article 287 of the Treaty on the Functioning of the European Union (TFEU) and Article 161 of the Financial Regulation No 966/2012[17], the European Court of Auditors (ECA) may — at any moment during implementation of the action or afterwards — carry out audits.

The ECA has the right of access for the purpose of checks and audits.

22.4 Checks, reviews, audits and investigations for international organisations

Not applicable

22.5 Consequences of findings in checks, reviews, audits and investigations — Extension of findings

22.5.1 Findings in this grant

Findings in checks, reviews, audits or investigations carried out in the context of this grant may lead to the rejection of ineligible costs (see Article 42), reduction of the grant (see Article 43), recovery of undue amounts (see Article 44) or to any of the other measures described in Chapter 6.

Rejection of costs or reduction of the grant after the payment of the balance will lead to a revised final grant amount (see Article 5.4).

Findings in checks, reviews, audits or investigations may lead to a request for amendment for the modification of Annex 1 (see Article 55).

Checks, reviews, audits or investigations that find systemic or recurrent errors, irregularities, fraud or breach of obligations may also lead to consequences in other EU or Euratom grants awarded under similar conditions (‘**extension of findings from this grant to other grants**’).

Moreover, findings arising from an OLAF investigation may lead to criminal prosecution under national law.

22.5.2 Findings in other grants

The Commission may extend findings from other grants to this grant (‘**extension of findings from other grants to this grant**’), if:

(a) the beneficiary concerned is found, in other EU or Euratom grants awarded under similar conditions, to have committed systemic or recurrent errors, irregularities, fraud or breach of obligations that have a material impact on this grant and

(b) those findings are formally notified to the beneficiary concerned — together with the list of grants affected by the findings — no later than two years after the payment of the balance of this grant.

[17] Regulation (EU, Euratom) No 966/2012 of the European Parliament and of the Council of 25 October 2012 on the financial rules applicable to the general budget of the Union and repealing Council Regulation (EC, Euratom) No 1605/2002 (OJ L 298, 26.10.2012, p. 1).

The extension of findings may lead to the rejection of costs (see Article 42), reduction of the grant (see Article 43), recovery of undue amounts (see Article 44), suspension of payments (see Article 48), suspension of the action implementation (see Article 49) or termination (see Article 50).

22.5.3 Procedure

The Commission will formally notify the beneficiary concerned the systemic or recurrent errors and its intention to extend these audit findings, together with the list of grants affected.

22.5.3.1 If the findings concern **eligibility of costs**: the formal notification will include:

(a) an invitation to submit observations on the list of grants affected by the findings;

(b) the request to submit **revised financial statements** for all grants affected;

(c) the **correction rate for extrapolation** established by the Commission on the basis of the systemic or recurrent errors, to calculate the amounts to be rejected if the beneficiary concerned:

(i) considers that the submission of revised financial statements is not possible or practicable or

(ii) does not submit revised financial statements.

The beneficiary concerned has 90 days from receiving notification to submit observations, revised financial statements or to propose a duly substantiated **alternative correction method**. This period may be extended by the Commission in justified cases.

The amounts to be rejected will be determined on the basis of the revised financial statements, subject to their approval.

If the Commission does not receive any observations or revised financial statements, does not accept the observations or the proposed alternative correction method or does not approve the revised financial statements, it will formally notify the beneficiary concerned the application of the initially notified correction rate for extrapolation.

If the Commission accepts the alternative correction method proposed by the beneficiary concerned, it will formally notify the application of the accepted alternative correction method.

22.5.3.2 If the findings concern **improper implementation** or a **breach of another obligation**: the formal notification will include:

(a) an invitation to submit observations on the list of grants affected by the findings and

(b) the flat-rate the Commission intends to apply according to the principle of proportionality.

The beneficiary concerned has 90 days from receiving notification to submit observations or to propose a duly substantiated alternative flat-rate.

If the Commission does not receive any observations or does not accept the observations or the proposed alternative flat-rate, it will formally notify the beneficiary concerned the application of the initially notified flat-rate.

If the Commission accepts the alternative flat-rate proposed by the beneficiary concerned, it will formally notify the application of the accepted alternative flat-rate.

22.6 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, any insufficiently substantiated costs will be ineligible (see Article 6) and will be rejected (see Article 42).

Such breaches may also lead to any of the other measures described in Chapter 6.

ARTICLE 23 — EVALUATION OF THE IMPACT OF THE ACTION

23.1 Right to evaluate the impact of the action

The Commission may carry out interim and final evaluations of the impact of the action measured against the objective of the *EU* programme.

Evaluations may be started during implementation of the action and up to *five* years after the payment of the balance. The evaluation is considered to start on the date of the formal notification to the coordinator or beneficiaries.

The Commission may make these evaluations directly (using its own staff) or indirectly (using external bodies or persons it has authorised to do so).

The coordinator or beneficiaries must provide any information relevant to evaluate the impact of the action, including information in electronic format.

23.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the *Commission* may apply the measures described in Chapter 6.

SECTION 3 RIGHTS AND OBLIGATIONS RELATED TO BACKGROUND AND RESULTS

SUBSECTION 1 GENERAL

ARTICLE 23a — MANAGEMENT OF INTELLECTUAL PROPERTY

23a.1 Obligation to take measures to implement the Commission Recommendation on the management of intellectual property in knowledge transfer activities

Beneficiaries that are universities or other public research organisations must take measures to implement the principles set out in Points 1 and 2 of the Code of Practice annexed to the Commission Recommendation on the management of intellectual property in knowledge transfer activities[18].

This does not change the obligations set out in Subsections 2 and 3 of this Section.

[18] Commission Recommendation C (2008) 1329 of 10.4.2008 on the management of intellectual property in knowledge transfer activities and the Code of Practice for universities and other public research institutions attached to this recommendation.

The beneficiaries must ensure that researchers and third parties involved in the action are aware of them.

23a.2 Consequences of non-compliance

If a beneficiary breaches its obligations under this Article, the *Commission* may apply any of the measures described in Chapter 6.

SUBSECTION 2 RIGHTS AND OBLIGATIONS RELATED TO BACKGROUND

ARTICLE 24 — AGREEMENT ON BACKGROUND

24.1 Agreement on background

The beneficiaries must identify and agree (in writing) on the background for the action ('**agreement on background**').

'**Background**' means any data, know-how or information — whatever its form or nature (tangible or intangible), including any rights such as intellectual property rights — that:

(a) is held by the beneficiaries before they acceded to the Agreement, and

(b) is needed to implement the action or exploit the results.

24.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 43).

Such breaches may also lead to any of the other measures described in Chapter 6.

ARTICLE 25 — ACCESS RIGHTS TO BACKGROUND

25.1 Exercise of access rights — Waiving of access rights — No sub-licensing

To exercise access rights, this must first be requested in writing ('**request for access**').

'**Access rights**' means rights to use results or background under the terms and conditions laid down in this Agreement.

Waivers of access rights are not valid unless in writing.

Unless agreed otherwise, access rights do not include the right to sub-license.

25.2 Access rights for other beneficiaries, for implementing their own tasks under the action

The beneficiaries must give each other access — on a royalty-free basis — to background needed to implement their own tasks under the action, unless the beneficiary that holds the background has — before acceding to the Agreement —:

(a) informed the other beneficiaries that access to its background is subject to legal restrictions or limits, including those imposed by the rights of third parties (including personnel), or

(b) agreed with the other beneficiaries that access would not be on a royalty-free basis.

25.3 Access rights for other beneficiaries, for exploiting their own results

The beneficiaries must give each other access — under fair and reasonable conditions — to background needed for exploiting their own results, unless the beneficiary that holds the background has — before acceding to the Agreement — informed the other beneficiaries that access to its background is subject to legal restrictions or limits, including those imposed by the rights of third parties (including personnel).

'**Fair and reasonable conditions**' means appropriate conditions, including possible financial terms or royalty-free conditions, taking into account the specific circumstances of the request for access, for example the actual or potential value of the results or background to which access is requested and/or the scope, duration or other characteristics of the exploitation envisaged.

Requests for access may be made — unless agreed otherwise — up to one year after the period set out in Article 3.

25.4 Access rights for affiliated entities

Unless otherwise agreed in the consortium agreement, access to background must also be given — under fair and reasonable conditions (see above; Article 25.3) and unless it is subject to legal restrictions or limits, including those imposed by the rights of third parties (including personnel) — to affiliated entities[19] established in an EU Member State or '**associated country**'[20], if this is needed to exploit the results generated by the beneficiaries to which they are affiliated.

Unless agreed otherwise (see above; Article 25.1), the affiliated entity concerned must make the request directly to the beneficiary that holds the background.

Requests for access may be made — unless agreed otherwise — up to one year after the period set out in Article 3.

25.5 Access rights for third parties

Not applicable

25.6 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 43).

Such breaches may also lead to any of the other measures described in Chapter 6.

[19] For the definition, see 'affiliated entity' footnote (Article 14.1).

[20] For the definition, see Article 2.1(3) of the Rules for Participation Regulation No 1290/2013: '**associated country**' means a third country which is party to an international agreement with the Union, as identified in *Article 7 of Horizon 2020 Framework Programme Regulation No 1291/2013. Article 7 sets out the conditions for association of non-EU countries to Horizon 2020.*

SUBSECTION 3 RIGHTS AND OBLIGATIONS RELATED TO RESULTS

ARTICLE 26 — OWNERSHIP OF RESULTS

26.1 Ownership by the beneficiary that generates the results

Results are owned by the beneficiary that generates them.

'**Results**' means any (tangible or intangible) output of the action such as data, knowledge or information — whatever its form or nature, whether it can be protected or not — that is generated in the action, as well as any rights attached to it, including intellectual property rights.

26.2 Joint ownership by several beneficiaries

Two or more beneficiaries own results jointly if:

(a) they have jointly generated them and

(b) it is not possible to:

(i) establish the respective contribution of each beneficiary, or

(ii) separate them for the purpose of applying for, obtaining or maintaining their protection (see Article 27).

The joint owners must agree (in writing) on the allocation and terms of exercise of their joint ownership ('**joint ownership agreement**'), to ensure compliance with their obligations under this Agreement.

Unless otherwise agreed in the joint ownership agreement, each joint owner may grant non-exclusive licences to third parties to exploit jointly-owned results (without any right to sub-license), if the other joint owners are given:

(a) at least 45 days advance notice and

(b) fair and reasonable compensation.

Once the results have been generated, joint owners may agree (in writing) to apply another regime than joint ownership (such as, for instance, transfer to a single owner (see Article 30) with access rights for the others).

26.3 Rights of third parties (including personnel)

If third parties (including personnel) may claim rights to the results, the beneficiary concerned must ensure that it complies with its obligations under the Agreement.

If a third party generates results, the beneficiary concerned must obtain all necessary rights (transfer, licences or other) from the third party, in order to be able to respect its obligations as if those results were generated by the beneficiary itself.

If obtaining the rights is impossible, the beneficiary must refrain from using the third party to generate the results.

26.4 *EU* ownership, to protect results

26.4.1 *The EU* may — with the consent of the beneficiary concerned — assume ownership of results to protect them, if a beneficiary intends — up to four years after the period set out in Article 3 — to disseminate its results without protecting them, except in any of the following cases:

(a) the lack of protection is because protecting the results is not possible, reasonable or justified (given the circumstances);

(b) the lack of protection is because there is a lack of potential for commercial or industrial exploitation, or

(c) the beneficiary intends to transfer the results to another beneficiary or third party established in an EU Member State or associated country, which will protect them.

Before the results are disseminated and unless any of the cases above under Points (a), (b) or (c) applies, the beneficiary must formally notify the *Commission* and at the same time inform it of any reasons for refusing consent. The beneficiary may refuse consent only if it can show that its legitimate interests would suffer significant harm.

If the *Commission* decides to assume ownership, it will formally notify the beneficiary concerned within 45 days of receiving notification.

No dissemination relating to these results may before the end of this period or, if the *Commission* takes a positive decision, until it has taken the necessary steps to protect the results.

26.4.2 *The EU* may — with the consent of the beneficiary concerned — assume ownership of results to protect them, if a beneficiary intends — up to four years after the period set out in Article 3 — to stop protecting them or not to seek an extension of protection, except in any of the following cases:

(a) the protection is stopped because of a lack of potential for commercial or industrial exploitation;

(b) an extension would not be justified given the circumstances.

A beneficiary that intends to stop protecting results or not seek an extension must — unless any of the cases above under Points (a) or (b) applies — formally notify the *Commission* at least 60 days before the protection lapses or its extension is no longer possible and at the same time inform it of any reasons for refusing consent. The beneficiary may refuse consent only if it can show that its legitimate interests would suffer significant harm.

If the *Commission* decides to assume ownership, it will formally notify the beneficiary concerned within 45 days of receiving notification.

26.5 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 43).

Such breaches may also lead to the any of the other measures described in Chapter 6.

ARTICLE 27 — PROTECTION OF RESULTS — VISIBILITY OF EU FUNDING

27.1 Obligation to protect the results

Each beneficiary must examine the possibility of protecting its results and must adequately protect them — for an appropriate period and with appropriate territorial coverage — if:

(a) the results can reasonably be expected to be commercially or industrially exploited and

(b) protecting them is possible, reasonable and justified (given the circumstances).

When deciding on protection, the beneficiary must consider its own legitimate interests and the legitimate interests (especially commercial) of the other beneficiaries.

27.2 *EU* ownership, to protect the results

If a beneficiary intends not to protect its results, to stop protecting them or not seek an extension of protection, *the EU* may — under certain conditions (see Article 26.4) — assume ownership to ensure their (continued) protection.

27.3 Information on EU funding

Applications for protection of results (including patent applications) filed by or on behalf of a beneficiary must — unless the *Commission* requests or agrees otherwise or unless it is impossible — include the following:

> *"The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731016" .*

27.4 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 43).

Such a breach may also lead to any of the other measures described in Chapter 6.

ARTICLE 28 — EXPLOITATION OF RESULTS

28.1 Obligation to exploit the results

Each beneficiary must — up to four years after the period set out in Article 3 — take measures aiming to ensure '**exploitation**' of its results (either directly or indirectly, in particular through transfer or licensing; see Article 30) by:

(a) using them in further research activities (outside the action);

(b) developing, creating or marketing a product or process;

(c) creating and providing a service, or

(d) using them in standardisation activities.

This does not change the security obligations in Article 37, which still apply.

28.2 Results that could contribute to European or international standards — Information on EU funding

If results are incorporated in a standard, the beneficiary concerned must — unless the *Commission* requests or agrees otherwise or unless it is impossible — ask the standardisation body to include the following statement in (information related to) the standard:

> *"Results incorporated in this standard received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731016" .*

28.3 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced in accordance with Article 43.

Such a breach may also lead to any of the other measures described in Chapter 6.

ARTICLE 29 — DISSEMINATION OF RESULTS — OPEN ACCESS — VISIBILITY OF EU FUNDING

29.1 Obligation to disseminate results

Unless it goes against their legitimate interests, each beneficiary must — as soon as possible — '**disseminate**' its results by disclosing them to the public by appropriate means (other than those resulting from protecting or exploiting the results), including in scientific publications (in any medium).

This does not change the obligation to protect results in Article 27, the confidentiality obligations in Article 36, the security obligations in Article 37 or the obligations to protect personal data in Article 39, all of which still apply.

A beneficiary that intends to disseminate its results must give advance notice to the other beneficiaries of — unless agreed otherwise — at least 45 days, together with sufficient information on the results it will disseminate.

Any other beneficiary may object within — unless agreed otherwise — 30 days of receiving notification, if it can show that its legitimate interests in relation to the results or background would be significantly harmed. In such cases, the dissemination may not take place unless appropriate steps are taken to safeguard these legitimate interests.

If a beneficiary intends not to protect its results, it may — under certain conditions (see Article 26.4.1) — need to formally notify the *Commission* before dissemination takes place.

29.2 Open access to scientific publications

Each beneficiary must ensure open access (free of charge online access for any user) to all peer-reviewed scientific publications relating to its results.

In particular, it must:

(a) as soon as possible and at the latest on publication, deposit a machine-readable electronic copy of the published version or final peer-reviewed manuscript accepted for publication in a repository for scientific publications;

Moreover, the beneficiary must aim to deposit at the same time the research data needed to validate the results presented in the deposited scientific publications.

(b) ensure open access to the deposited publication — via the repository — at the latest:

(i) on publication, if an electronic version is available for free via the publisher, or

(ii) within six months of publication (twelve months for publications in the social sciences and humanities) in any other case.

(c) ensure open access — via the repository — to the bibliographic metadata that identify the deposited publication.

The bibliographic metadata must be in a standard format and must include all of the following:

- the terms *"European Union (EU)" and "Horizon 2020"*;
- the name of the action, acronym and grant number;
- the publication date, and length of embargo period if applicable, and
- a persistent identifier.

29.3 Open access to research data

*Regarding the digital research data generated in the action ('**data**'), the beneficiaries must:*

(a) deposit in a research data repository and take measures to make it possible for third parties to access, mine, exploit, reproduce and disseminate — free of charge for any user — the following:

(i) the data, including associated metadata, needed to validate the results presented in scientific publications as soon as possible;

*(ii) other data, including associated metadata, as specified and within the deadlines laid down in the **'data management plan'** (see Annex 1);*

(b) provide information — via the repository — about tools and instruments at the disposal of the beneficiaries and necessary for validating the results (and — where possible — provide the tools and instruments themselves).

This does not change the obligation to protect results in Article 27, the confidentiality obligations in Article 36, the security obligations in Article 37 or the obligations to protect personal data in Article 39, all of which still apply.

As an exception, the beneficiaries do not have to ensure open access to specific parts of their research data if the achievement of the action's main objective, as described in Annex 1, would be jeopardised by

making those specific parts of the research data openly accessible. In this case, the data management plan must contain the reasons for not giving access.

29.4 Information on EU funding — Obligation and right to use the EU emblem

Unless the *Commission* requests or agrees otherwise or unless it is impossible, any dissemination of results (in any form, including electronic) must:

(a) display the EU emblem and

(b) include the following text:

> *"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731016" .*

When displayed together with another logo, the EU emblem must have appropriate prominence.

For the purposes of their obligations under this Article, the beneficiaries may use the EU emblem without first obtaining approval from the *Commission*.

This does not however give them the right to exclusive use.

Moreover, they may not appropriate the EU emblem or any similar trademark or logo, either by registration or by any other means.

29.5 Disclaimer excluding *Commission* responsibility

Any dissemination of results must indicate that it reflects only the author's view and that the *Commission* is not responsible for any use that may be made of the information it contains.

29.6 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 43).

Such a breach may also lead to any of the other measures described in Chapter 6.

ARTICLE 30 — TRANSFER AND LICENSING OF RESULTS

30.1 Transfer of ownership

Each beneficiary may transfer ownership of its results.

It must however ensure that its obligations under Articles 26.2, 26.4, 27, 28, 29, 30 and 31 also apply to the new owner and that this owner has the obligation to pass them on in any subsequent transfer.

This does not change the security obligations in Article 37, which still apply.

Unless agreed otherwise (in writing) for specifically-identified third parties or unless impossible under applicable EU and national laws on mergers and acquisitions, a beneficiary that intends to transfer ownership of results must give at least 45 days advance notice (or less if agreed in writing) to the other beneficiaries that still have (or still may request) access rights to the results. This notification

must include sufficient information on the new owner to enable any beneficiary concerned to assess the effects on its access rights.

Unless agreed otherwise (in writing) for specifically-identified third parties, any other beneficiary may object within 30 days of receiving notification (or less if agreed in writing), if it can show that the transfer would adversely affect its access rights. In this case, the transfer may not take place until agreement has been reached between the beneficiaries concerned.

30.2 Granting licenses

Each beneficiary may grant licences to its results (or otherwise give the right to exploit them), if:

(a) this does not impede the rights under Article 31 and

(b) *not applicable.*

In addition to Points (a) and (b), exclusive licences for results may be granted only if all the other beneficiaries concerned have waived their access rights (see Article 31.1).

This does not change the dissemination obligations in Article 29 or security obligations in Article 37, which still apply.

30.3 *Commission* right to object to transfers or licensing

Not applicable

30.4 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 43).

Such a breach may also lead to any of the other measures described in Chapter 6.

ARTICLE 31 — ACCESS RIGHTS TO RESULTS

31.1 Exercise of access rights — Waiving of access rights — No sub-licensing

The conditions set out in Article 25.1 apply.

The obligations set out in this Article do not change the security obligations in Article 37, which still apply.

31.2 Access rights for other beneficiaries, for implementing their own tasks under the action

The beneficiaries must give each other access — on a royalty-free basis — to results needed for implementing their own tasks under the action.

31.3 Access rights for other beneficiaries, for exploiting their own results

The beneficiaries must give each other — under fair and reasonable conditions (see Article 25.3) — access to results needed for exploiting their own results.

Requests for access may be made — unless agreed otherwise — up to one year after the period set out in Article 3.

31.4 Access rights of affiliated entities

Unless agreed otherwise in the consortium agreement, access to results must also be given — under fair and reasonable conditions (Article 25.3) — to affiliated entities established in an EU Member State or associated country, if this is needed for those entities to exploit the results generated by the beneficiaries to which they are affiliated.

Unless agreed otherwise (see above; Article 31.1), the affiliated entity concerned must make any such request directly to the beneficiary that owns the results.

Requests for access may be made — unless agreed otherwise — up to one year after the period set out in Article 3.

31.5 Access rights for the EU institutions, bodies, offices or agencies and EU Member States

The beneficiaries must give access to their results — on a royalty-free basis — to EU institutions, bodies, offices or agencies, for developing, implementing or monitoring EU policies or programmes.

Such access rights are limited to non-commercial and non-competitive use.

This does not change the right to use any material, document or information received from the beneficiaries for communication and publicising activities (see Article 38.2).

31.6 Access rights for third parties

Not applicable

31.7 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 43).

Such breaches may also lead to any of the other measures described in Chapter 6.

SECTION 4 OTHER RIGHTS AND OBLIGATIONS

ARTICLE 32 — RECRUITMENT AND WORKING CONDITIONS FOR RESEARCHERS

32.1 Obligation to take measures to implement the European Charter for Researchers and Code of Conduct for the Recruitment of Researchers

The beneficiaries must take all measures to implement the principles set out in the Commission Recommendation on the European Charter for Researchers and the Code of Conduct for the Recruitment of Researchers[22], in particular regarding:

[22] Commission Recommendation 2005/251/EC of 11 March 2005 on the European Charter for Researchers and on a Code of Conduct for the Recruitment of Researchers (OJ L 75, 22.3.2005, p. 67).

- working conditions;
- transparent recruitment processes based on merit, and
- career development.

The beneficiaries must ensure that researchers and third parties involved in the action are aware of them.

32.2 Consequences of non-compliance

If a beneficiary breaches its obligations under this Article, the *Commission* may apply any of the measures described in Chapter 6.

ARTICLE 33 — GENDER EQUALITY

33.1 Obligation to aim for gender equality

The beneficiaries must take all measures to promote equal opportunities between men and women in the implementation of the action. They must aim, to the extent possible, for a gender balance at all levels of personnel assigned to the action, including at supervisory and managerial level.

33.2 Consequences of non-compliance

If a beneficiary breaches its obligations under this Article, the *Commission* may apply any of the measures described in Chapter 6.

ARTICLE 34 — ETHICS

34.1 Obligation to comply with ethical principles

The beneficiaries must carry out the action in compliance with:

(a) ethical principles (including the highest standards of research integrity — as set out, for instance, in the European Code of Conduct for Research Integrity[23] — and including, in particular, avoiding fabrication, falsification, plagiarism or other research misconduct) and

(b) applicable international, EU and national law.

Funding will not be granted for activities carried out outside the EU if they are prohibited in all Member States.

The beneficiaries must ensure that the activities under the action have an exclusive focus on civil applications.

The beneficiaries must ensure that the activities under the action do not:

[23] The European Code of Conduct for Research Integrity of ALLEA (All European Academies) and ESF (European Science Foundation) of March 2011.
http://www.esf.org/fileadmin/Public_documents/Publications/Code_Conduct_ResearchIntegrity.pdf

(a) aim at human cloning for reproductive purposes;

(b) intend to modify the genetic heritage of human beings which could make such changes heritable (with the exception of research relating to cancer treatment of the gonads, which may be financed), or

(c) intend to create human embryos solely for the purpose of research or for the purpose of stem cell procurement, including by means of somatic cell nuclear transfer.

34.2 Activities raising ethical issues

Activities raising ethical issues must comply with the '**ethics requirements**' set out in Annex 1.

Before the beginning of an activity raising an ethical issue, the coordinator must submit (see Article 52) to the *Commission* copy of:

(a) any ethics committee opinion required under national law and

(b) any notification or authorisation for activities raising ethical issues required under national law.

If these documents are not in English, the coordinator must also submit an English summary of the submitted opinions, notifications and authorisations (containing, if available, the conclusions of the committee or authority concerned).

If these documents are specifically requested for the action, the request must contain an explicit reference to the action title. The coordinator must submit a declaration by each beneficiary concerned that all the submitted documents cover the action tasks.

34.3 Activities involving human embryos or human embryonic stem cells

Activities involving research on human embryos or human embryonic stem cells may be carried out only if:

- they are set out in Annex 1 or
- the coordinator has obtained explicit approval (in writing) from the *Commission* (see Article 52).

34.4 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 43) and the Agreement or participation of the beneficiary may be terminated (see Article 50).

Such breaches may also lead to any of the other measures described in Chapter 6.

ARTICLE 35 — CONFLICT OF INTERESTS

35.1 Obligation to avoid a conflict of interests

The beneficiaries must take all measures to prevent any situation where the impartial and objective implementation of the action is compromised for reasons involving economic interest, political or national affinity, family or emotional ties or any other shared interest ('**conflict of interests**').

They must formally notify to the *Commission* without delay any situation constituting or likely to lead to a conflict of interests and immediately take all the necessary steps to rectify this situation.

The *Commission* may verify that the measures taken are appropriate and may require additional measures to be taken by a specified deadline.

35.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 43) and the Agreement or participation of the beneficiary may be terminated (see Article 50).

Such breaches may also lead to any of the other measures described in Chapter 6.

ARTICLE 36 — CONFIDENTIALITY

36.1 General obligation to maintain confidentiality

During implementation of the action and for four years after the period set out in Article 3, the parties must keep confidential any data, documents or other material (in any form) that is identified as confidential at the time it is disclosed ('**confidential information**').

If a beneficiary requests, the *Commission* may agree to keep such information confidential for an additional period beyond the initial four years.

If information has been identified as confidential only orally, it will be considered to be confidential only if this is confirmed in writing within 15 days of the oral disclosure.

Unless otherwise agreed between the parties, they may use confidential information only to implement the Agreement.

The beneficiaries may disclose confidential information to their personnel or third parties involved in the action only if they:

(a) need to know to implement the Agreement and

(b) are bound by an obligation of confidentiality.

This does not change the security obligations in Article 37, which still apply.

The *Commission* may disclose confidential information to its staff, other EU institutions and bodies or third parties, if:

(a) this is necessary to implement the Agreement or safeguard the EU's financial interests and

(b) the recipients of the information are bound by an obligation of confidentiality.

Under the conditions set out in Article 4 of the Rules for Participation Regulation No 1290/2013[24], the Commission must moreover make available information on the results to other EU institutions, bodies, offices or agencies as well as Member States or associated countries.

The confidentiality obligations no longer apply if:

(a) the disclosing party agrees to release the other party;

(b) the information was already known by the recipient or is given to him without obligation of confidentiality by a third party that was not bound by any obligation of confidentiality;

(c) the recipient proves that the information was developed without the use of confidential information;

(d) the information becomes generally and publicly available, without breaching any confidentiality obligation, or

(e) the disclosure of the information is required by EU or national law.

36.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 43).

Such breaches may also lead to any of the other measures described in Chapter 6.

ARTICLE 37 — SECURITY-RELATED OBLIGATIONS

37.1 Results with a security recommendation

Not applicable

37.2 Classified results

Not applicable

37.3 Activities involving dual-use goods or dangerous materials and substances

Not applicable

37.4 Consequences of non-compliance

Not applicable

ARTICLE 38 — PROMOTING THE ACTION — VISIBILITY OF EU FUNDING

38.1 Communication activities by beneficiaries

38.1.1 Obligation to promote the action and its results

[24] Regulation (EU) No 1290/2013 of the European Parliament and of the Council of 11 December 2013 laying down the rules for participation and dissemination in "Horizon 2020 - the Framework Programme for Research and Innovation (2014-2020)" (OJ L 347, 20.12.2013 p.81).

The beneficiaries must promote the action and its results, by providing targeted information to multiple audiences (including the media and the public) in a strategic and effective manner.

This does not change the dissemination obligations in Article 29, the confidentiality obligations in Article 36 or the security obligations in Article 37, all of which still apply.

Before engaging in a communication activity expected to have a major media impact, the beneficiaries must inform the *Commission* (see Article 52).

38.1.2 Information on EU funding — Obligation and right to use the EU emblem

Unless the *Commission* requests or agrees otherwise or unless it is impossible, any communication activity related to the action (including in electronic form, via social media, etc.) and any infrastructure, equipment and major results funded by the grant must:

(a) display the EU emblem and

(b) include the following text:

> For communication activities: *"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731016"* .
>
> For infrastructure, equipment and major results: *"This [infrastructure][equipment][insert type of result] is part of a project that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731016"* .

When displayed together with another logo, the EU emblem must have appropriate prominence.

For the purposes of their obligations under this Article, the beneficiaries may use the EU emblem without first obtaining approval from the *Commission*.

This does not, however, give them the right to exclusive use.

Moreover, they may not appropriate the EU emblem or any similar trademark or logo, either by registration or by any other means.

38.1.3 Disclaimer excluding *Commission* responsibility

Any communication activity related to the action must indicate that it reflects only the author's view and that the *Commission* is not responsible for any use that may be made of the information it contains.

38.2 Communication activities by the *Commission*

38.2.1 Right to use beneficiaries' materials, documents or information

The *Commission* may use, for its communication and publicising activities, information relating to the action, documents notably summaries for publication and public deliverables as well as any other material, such as pictures or audio-visual material that it receives from any beneficiary (including in electronic form).

This does not change the confidentiality obligations in Article 36 and the security obligations in Article 37, all of which still apply.

However, if the *Commission's* use of these materials, documents or information would risk compromising legitimate interests, the beneficiary concerned may request the *Commission* not to use it (see Article 52).

The right to use a beneficiary's materials, documents and information includes:

(a) **use for its own purposes** (in particular, making them available to persons working for the *Commission* or any other EU institution, body, office or agency or body or institutions in EU Member States; and copying or reproducing them in whole or in part, in unlimited numbers);

(b) **distribution to the public** (in particular, publication as hard copies and in electronic or digital format, publication on the internet, as a downloadable or non-downloadable file, broadcasting by any channel, public display or presentation, communicating through press information services, or inclusion in widely accessible databases or indexes);

(c) **editing or redrafting** for communication and publicising activities (including shortening, summarising, inserting other elements (such as meta-data, legends, other graphic, visual, audio or text elements), extracting parts (e.g. audio or video files), dividing into parts, use in a compilation);

(d) **translation**;

(e) giving **access in response to individual requests** under Regulation No 1049/2001[25], without the right to reproduce or exploit;

(f) **storage** in paper, electronic or other form;

(g) **archiving**, in line with applicable document-management rules, and

(h) the right to authorise **third parties** to act on its behalf or sub-license the modes of use set out in Points (b),(c),(d) and (f) to third parties if needed for the communication and publicising activities of the *Commission*.

If the right of use is subject to rights of a third party (including personnel of the beneficiary), the beneficiary must ensure that it complies with its obligations under this Agreement (in particular, by obtaining the necessary approval from the third parties concerned).

Where applicable (and if provided by the beneficiaries), the *Commission* will insert the following information:

> "© – [year] – [name of the copyright owner]. All rights reserved. Licensed to the *European Union (EU)* under conditions."

38.3 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 43).

Such breaches may also lead to any of the other measures described in Chapter 6.

[25] Regulation (EC) No 1049/2001 of the European Parliament and of the Council of 30 May 2001 regarding public access to European Parliament, Council and Commission documents, OJ L 145, 31.5.2001, p. 43.

ARTICLE 39 — PROCESSING OF PERSONAL DATA

39.1 Processing of personal data by the Commission

Any personal data under the Agreement will be processed by the Commission under Regulation No 45/2001[26] and according to the 'notifications of the processing operations' to the Data Protection Officer (DPO) of the Commission (publicly accessible in the DPO register).

Such data will be processed by the '**data controller**' of the Commission for the purposes of implementing, managing and monitoring the Agreement or protecting the financial interests of the EU or Euratom (including checks, reviews, audits and investigations; see Article 22).

The persons whose personal data are processed have the right to access and correct their own personal data. For this purpose, they must send any queries about the processing of their personal data to the data controller, via the contact point indicated in the 'service specific privacy statement(s) (SSPS)' that are published on the Commission websites.

They also have the right to have recourse at any time to the European Data Protection Supervisor (EDPS).

39.2 Processing of personal data by the beneficiaries

The beneficiaries must process personal data under the Agreement in compliance with applicable EU and national law on data protection (including authorisations or notification requirements).

The beneficiaries may grant their personnel access only to data that is strictly necessary for implementing, managing and monitoring the Agreement.

The beneficiaries must inform the personnel whose personal data are collected and processed by the Commission. For this purpose, they must provide them with the service specific privacy statement (SSPS) (see above), before transmitting their data to the Commission.

39.3 Consequences of non-compliance

If a beneficiary breaches any of its obligations under Article 39.2, the *Commission* may apply any of the measures described in Chapter 6.

ARTICLE 40 — ASSIGNMENTS OF CLAIMS FOR PAYMENT AGAINST THE *COMMISSION*

The beneficiaries may not assign any of their claims for payment against the *Commission* to any third party, except if approved by the *Commission* on the basis of a reasoned, written request by the coordinator (on behalf of the beneficiary concerned).

If the *Commission* has not accepted the assignment or the terms of it are not observed, the assignment will have no effect on it.

[26] Regulation (EC) No 45/2001 of the European Parliament and of the Council of 18 December 2000 on the protection of individuals with regard to the processing of personal data by the Community institutions and bodies and on the free movement of such data (OJ L 8, 12.01.2001, p. 1).

In no circumstances will an assignment release the beneficiaries from their obligations towards the *Commission*.

CHAPTER 5 DIVISION OF BENEFICIARIES' ROLES AND RESPONSIBILITIES

ARTICLE 41 — DIVISION OF BENEFICIARIES' ROLES AND RESPONSIBILITIES — RELATIONSHIP WITH COMPLEMENTARY BENEFICIARIES — RELATIONSHIP WITH PARTNERS OF A JOINT ACTION

41.1 Roles and responsibilities towards the *Commission*

The beneficiaries have full responsibility for implementing the action and complying with the Agreement.

The beneficiaries are jointly and severally liable for the **technical implementation** of the action as described in Annex 1. If a beneficiary fails to implement its part of the action, the other beneficiaries become responsible for implementing this part (without being entitled to any additional EU funding for doing so), unless the *Commission* expressly relieves them of this obligation.

The **financial responsibility** of each beneficiary is governed by Articles 44, 45 and 46.

41.2 Internal division of roles and responsibilities

The internal roles and responsibilities of the beneficiaries are divided as follows:

(a) Each **beneficiary** must:

(i) keep information stored in the 'Beneficiary Register' (via the electronic exchange system) up to date (see Article 17);

(ii) inform the coordinator immediately of any events or circumstances likely to affect significantly or delay the implementation of the action (see Article 17);

(iii) submit to the coordinator in good time:

- individual financial statements for itself *and its linked third parties* and, if required, certificates on the financial statements (see Article 20);
- the data needed to draw up the technical reports (see Article 20);
- ethics committee opinions and notifications or authorisations for activities raising ethical issues (see Article 34);
- any other documents or information required by the Commission under the Agreement, unless the Agreement requires the beneficiary to submit this information directly to the Commission.

(b) The **coordinator** must:

(i) monitor that the action is implemented properly (see Article 7);

(ii) act as the intermediary for all communications between the beneficiaries and the *Commission* (in particular, providing the *Commission* with the information described in Article 17), unless the Agreement specifies otherwise;

(iii) request and review any documents or information required by the *Commission* and verify their completeness and correctness before passing them on to the *Commission*;

(iv) submit the deliverables and reports to the *Commission* (see Articles 19 and 20);

(v) ensure that all payments are made to the other beneficiaries without unjustified delay (see Article 21);

(vi) inform the *Commission* of the amounts paid to each beneficiary, when required under the Agreement (see Articles 44 and 50) or requested by the *Commission*.

The coordinator may not delegate the above-mentioned tasks to any other beneficiary or subcontract them to any third party.

41.3 Internal arrangements between beneficiaries — Consortium agreement

*The beneficiaries must have internal arrangements regarding their operation and co-ordination to ensure that the action is implemented properly. These internal arrangements must be set out in a written '**consortium agreement**' between the beneficiaries, which may cover:*

- *internal organisation of the consortium;*
- *management of access to the electronic exchange system;*
- *distribution of EU funding;*
- *additional rules on rights and obligations related to background and results (including whether access rights remain or not, if a beneficiary is in breach of its obligations) (see Section 3 of Chapter 4);*
- *settlement of internal disputes;*
- *liability, indemnification and confidentiality arrangements between the beneficiaries.*

The consortium agreement must not contain any provision contrary to the Agreement.

41.4 Relationship with complementary beneficiaries — Collaboration agreement

Not applicable

41.5 Relationship with partners of a joint action — Coordination agreement

Not applicable

CHAPTER 6 REJECTION OF COSTS — REDUCTION OF THE GRANT — RECOVERY — PENALTIES — DAMAGES — SUSPENSION — TERMINATION — FORCE MAJEURE

SECTION 1 REJECTION OF COSTS — REDUCTION OF THE GRANT — RECOVERY — PENALTIES

ARTICLE 42 — REJECTION OF INELIGIBLE COSTS

42.1 Conditions

42.1.1 The *Commission* will — at the time of an **interim payment**, **at the payment of the balance** or **afterwards** — reject any costs which are ineligible (see Article 6), in particular following checks, reviews, audits or investigations (see Article 22).

42.1.2 The rejection may also be based on the **extension of findings from other grants to this grant**, under the conditions set out in Article 22.5.2.

42.2 Ineligible costs to be rejected — Calculation — Procedure

Ineligible costs will be rejected in full.

If the *Commission* rejects costs **without reduction of the grant** (see Article 43) or **recovery of undue amounts** (see Article 44), it will formally notify the coordinator or beneficiary concerned the rejection of costs, the amounts and the reasons why (if applicable, together with the notification of amounts due; see Article 21.5). The coordinator or beneficiary concerned may — within 30 days of receiving notification — formally notify the *Commission* of its disagreement and the reasons why.

If the *Commission* rejects costs **with reduction of the grant** or **recovery of undue amounts**, it will formally notify the rejection in the '**pre-information letter**' on reduction or recovery set out in Articles 43 and 44.

42.3 Effects

If the *Commission* rejects costs at the time of an **interim payment** or **the payment of the balance**, it will deduct them from the total eligible costs declared, for the action, in the periodic or final summary financial statement (see Articles 20.3 and 20.4). It will then calculate the interim payment or payment of the balance as set out in Articles 21.3 or 21.4.

If the *Commission* — **after an interim payment but before the payment of the balance** — rejects costs declared in a periodic summary financial statement, it will deduct them from the total eligible costs declared, for the action, in the next periodic summary financial statement or in the final summary financial statement. It will then calculate the interim payment or payment of the balance as set out in Articles 21.3 or 21.4.

If the *Commission* rejects costs **after the payment of the balance**, it will deduct the amount rejected from the total eligible costs declared, by the beneficiary, in the final summary financial statement. It will then calculate the revised final grant amount as set out in Article 5.4.

ARTICLE 43 — REDUCTION OF THE GRANT

43.1 Conditions

43.1.1 The *Commission* may — **at the payment of the balance** or **afterwards** — reduce the maximum grant amount (see Article 5.1), if the action has not been implemented properly as described in Annex 1 or another obligation under the Agreement has been breached.

43.1.2 The *Commission* may also reduce the maximum grant amount on the basis of the **extension of findings from other grants to this grant**, under the conditions set out in Article 22.5.2.

43.2 Amount to be reduced — Calculation — Procedure

The amount of the reduction will be proportionate to the improper implementation of the action or to the seriousness of the breach.

Before reduction of the grant, the *Commission* will formally notify a '**pre-information letter**' to the coordinator or beneficiary concerned:

- informing it of its intention to reduce the grant, the amount it intends to reduce and the reasons why and

- inviting it to submit observations within 30 days of receiving notification

If the *Commission* does not receive any observations or decides to pursue reduction despite the observations it has received, it will formally notify **confirmation** of the reduction (if applicable, together with the notification of amounts due; see Article 21).

43.3 Effects

If the *Commission* reduces the grant at the time of **the payment of the balance**, it will calculate the reduced grant amount for the action and then determine the amount due as payment of the balance (see Articles 5.3.4 and 21.4).

If the *Commission* reduces the grant **after the payment of the balance**, it will calculate the revised final grant amount for the beneficiary concerned (see Article 5.4). If the revised final grant amount for the beneficiary concerned is lower than its share of the final grant amount, the *Commission* will recover the difference (see Article 44).

ARTICLE 44 — RECOVERY OF UNDUE AMOUNTS

44.1 Amount to be recovered — Calculation — Procedure

The *Commission* will — after **termination of the participation of a beneficiary, at the payment of the balance** or **afterwards** — claim back any amount that was paid but is not due under the Agreement.

Each beneficiary's financial responsibility in case of recovery is limited to its own debt *(including undue amounts paid by the Commission for costs declared by its linked third parties)*, except for the amount retained for the Guarantee Fund (see Article 21.4).

44.1.1 Recovery after termination of a beneficiary's participation

If recovery takes place after termination of a beneficiary's participation (including the coordinator), the *Commission* will claim back the undue amount from the beneficiary concerned, by formally notifying it a debit note (see Article 50.2 and 50.3). This note will specify the amount to be recovered, the terms and the date for payment.

If payment is not made by the date specified in the debit note, the Commission will **recover** the amount:

(a) by '**offsetting**' it — without the beneficiary's consent — against any amounts owed to the beneficiary concerned by the Commission or an executive agency (from the EU or Euratom budget).

In exceptional circumstances, to safeguard the EU's financial interests, the *Commission* may offset before the payment date specified in the debit note;

(b) *not applicable;*

(c) by **taking legal action** (see Article 57) or by **adopting an enforceable decision** under Article 299 of the Treaty on the Functioning of the EU (TFEU) and Article 79(2) of the Financial regulation No 966/2012.

If payment is not made by the date specified in the debit note, the amount to be recovered (see above) will be increased by **late-payment interest** at the rate set out in Article 21.11, from the day following the payment date in the debit note, up to and including the date the Commission receives full payment of the amount.

Partial payments will be first credited against expenses, charges and late-payment interest and then against the principal.

Bank charges incurred in the recovery process will be borne by the beneficiary, unless Directive 2007/64/EC[27] applies.

44.1.2 Recovery at payment of the balance

If the payment of the balance takes the form of a recovery (see Article 21.4), the *Commission* will formally notify a '**pre-information letter**' to the coordinator:

- informing it of its intention to recover, the amount due as the balance and the reasons why;
- specifying that it intends to deduct the amount to be recovered from the amount retained for the Guarantee Fund;
- requesting the coordinator to submit a report on the distribution of payments to the beneficiaries within 30 days of receiving notification, and
- inviting the coordinator to submit observations within 30 days of receiving notification.

[27] Directive 2007/64/EC of the European Parliament and of the Council of 13 November 2007 on payment services in the internal market amending Directives 97/7/EC, 2002/65/EC, 2005/60/EC and 2006/48/EC and repealing Directive 97/5/EC (OJ L 319, 05.12.2007, p. 1).

If no observations are submitted or the *Commission* decides to pursue recovery despite the observations it has received, it will **confirm recovery** (together with the notification of amounts due; see Article 21.5) and:

- pay the difference between the amount to be recovered and the amount retained for the Guarantee Fund, **if the difference is positive** or

- formally notify to the coordinator a **debit note** for the difference between the amount to be recovered and the amount retained for the Guarantee Fund, **if the difference is negative**. This note will also specify the terms and the date for payment.

If the coordinator does not repay the *Commission* by the date in the debit note and has not submitted the report on the distribution of payments: the Commission will **recover** the amount set out in the debit note from the coordinator (see below).

If the coordinator does not repay the *Commission* by the date in the debit note, but has submitted the report on the distribution of payments: the *Commission* will:

(a) identify the beneficiaries for which the amount calculated as follows is negative:

{{{{beneficiary's costs declared in the final summary financial statement and approved by the *Commission* multiplied by the reimbursement rate set out in Article 5.2 for the beneficiary concerned

plus

its linked third parties' costs declared in the final summary financial statement and approved by the Commission multiplied by the reimbursement rate set out in Article 5.2 for each linked third party concerned}

divided by

the EU contribution for the action calculated according to Article 5.3.1}

multiplied by

the final grant amount (see Article 5.3)}},

minus

{pre-financing and interim payments received by the beneficiary}}.

(b) formally notify to each beneficiary identified according to point (a) a **debit note** specifying the terms and date for payment. The amount of the debit note is calculated as follows:

{{amount calculated according to point (a) for the beneficiary concerned

divided by

the sum of the amounts calculated according to point (a) for all the beneficiaries identified according to point (a)}

multiplied by

the amount set out in the debit note formally notified to the coordinator}.

If payment is not made by the date specified in the debit note, the *Commission* will **recover** the amount:

(a) by '**offsetting**' it — without the beneficiary's consent — against any amounts owed to the beneficiary concerned by the Commission or an executive agency (from the EU or Euratom budget).

In exceptional circumstances, to safeguard the EU's financial interests, the *Commission* may offset before the payment date specified in the debit note;

(b) by **drawing on the Guarantee Fund**. The Commission will formally notify the beneficiary concerned the debit note on behalf of the Guarantee Fund and recover the amount:

(i) *not applicable;*

(ii) by **taking legal action** (see Article 57) or by **adopting an enforceable decision** under Article 299 of the Treaty on the Functioning of the EU (TFEU) and Article 79(2) of the Financial Regulation No 966/2012.

If payment is not made by the date in the debit note, the amount to be recovered (see above) will be increased by **late-payment interest** at the rate set out in Article 21.11, from the day following the payment date in the debit note, up to and including the date the Commission receives full payment of the amount.

Partial payments will be first credited against expenses, charges and late-payment interest and then against the principal.

Bank charges incurred in the recovery process will be borne by the beneficiary, unless Directive 2007/64/EC applies.

44.1.3 Recovery of amounts after payment of the balance

If, for a beneficiary, the revised final grant amount (see Article 5.4) is lower than its share of the final grant amount, it must repay the difference to the *Commission*.

The beneficiary's share of the final grant amount is calculated as follows:

{{{beneficiary's costs declared in the final summary financial statement and approved by the *Commission* multiplied by the reimbursement rate set out in Article 5.2 for the beneficiary concerned

plus

its linked third parties' costs declared in the final summary financial statement and approved by the Commission multiplied by the reimbursement rate set out in Article 5.2 for each linked third party concerned}

divided by

the EU contribution for the action calculated according to Article 5.3.1}

multiplied by

the final grant amount (see Article 5.3)}.

If the coordinator has not distributed amounts received (see Article 21.7), the *Commission* will also recover these amounts.

The *Commission* will formally notify a **pre-information letter** to the beneficiary concerned:

- informing it of its intention to recover, the due amount and the reasons why and
- inviting it to submit observations within 30 days of receiving notification.

If no observations are submitted or the *Commission* decides to pursue recovery despite the observations it has received, it will **confirm** the amount to be recovered and formally notify to the beneficiary concerned a **debit note**. This note will also specify the terms and the date for payment.

If payment is not made by the date specified in the debit note, the *Commission* will **recover** the amount:

(a) by '**offsetting**' it — without the beneficiary's consent — against any amounts owed to the beneficiary concerned by the Commission or an executive agency (from the EU or Euratom budget).

In exceptional circumstances, to safeguard the EU's financial interests, the *Commission* may offset before the payment date specified in the debit note;

(b) by **drawing on the Guarantee Fund**. The Commission will formally notify the beneficiary concerned the debit note on behalf of the Guarantee Fund and recover the amount:

(i) *not applicable;*

(ii) by **taking legal action** (see Article 57) or by **adopting an enforceable decision** under Article 299 of the Treaty on the Functioning of the EU (TFEU) and Article 79(2) of the Financial Regulation No 966/2012.

If payment is not made by the date in the debit note, the amount to be recovered (see above) will be increased by **late-payment interest** at the rate set out in Article 21.11, from the day following the date for payment in the debit note, up to and including the date the Commission receives full payment of the amount.

Partial payments will be first credited against expenses, charges and late-payment interest and then against the principal.

Bank charges incurred in the recovery process will be borne by the beneficiary, unless Directive 2007/64/EC applies.

ARTICLE 45 — ADMINISTRATIVE AND FINANCIAL PENALTIES

45.1 Conditions

Under Articles 109 and 131(4) of the Financial Regulation No 966/2012, the *Commission* may impose **administrative** and **financial penalties** if a beneficiary:

(a) has committed substantial errors, irregularities or fraud or is in serious breach of its obligations under the Agreement or

(b) has made false declarations about information required under the Agreement or for the submission of the proposal (or has not supplied such information).

Each beneficiary is responsible for paying the financial penalties imposed on it.

Under Article 109(3) of the Financial Regulation No 966/2012, the Commission may — under certain conditions and limits — publish decisions imposing administrative or financial penalties.

45.2 Duration — Amount of penalty — Calculation

Administrative penalties exclude the beneficiary from all contracts and grants financed from the EU or Euratom budget for a maximum of five years from the date the infringement is established by the *Commission*.

If the beneficiary commits another infringement within five years of the date the first infringement is established, the *Commission* may extend the exclusion period up to 10 years.

Financial penalties will be between 2% and 10% of the maximum EU contribution indicated, for the beneficiary concerned, in the estimated budget (see Annex 2).

If the beneficiary commits another infringement within five years of the date the first infringement is established, the *Commission* may increase the rate of financial penalties to between 4% and 20%.

45.3 Procedure

Before applying a penalty, the *Commission* will formally notify the beneficiary concerned:

- informing it of its intention to impose a penalty, its duration or amount and the reasons why and

- inviting it to submit observations within 30 days.

If the *Commission* does not receive any observations or decides to impose the penalty despite of observations it has received, it will formally notify **confirmation** of the penalty to the beneficiary concerned and — in case of financial penalties — deduct the penalty from the payment of the balance or formally notify a **debit note**, specifying the amount to be recovered, the terms and the date for payment.

If payment is not made by the date specified in the debit note, the Commission may **recover** the amount:

(a) by '**offsetting**' it — without the beneficiary's consent — against any amounts owed to the beneficiary concerned by the Commission or an executive agency (from the EU or Euratom budget).

In exceptional circumstances, to safeguard the EU's financial interests, the *Commission* may offset before the payment date specified in the debit note;

(b) by **taking legal action** (see Article 57) or by **adopting an enforceable decision** under Article 299 of the Treaty on the Functioning of the EU (TFEU) and Article 79(2) of the Financial Regulation No 966/2012.

If payment is not made by the date in the debit note, the amount to be recovered (see above) will be increased by **late-payment interest** at the rate set out in Article 21.11, from the day following the payment date in the debit note, up to and including the date the Commission receives full payment of the amount.

Partial payments will be first credited against expenses, charges and late-payment interest and then against the principal.

Bank charges incurred in the recovery process will be borne by the beneficiary, unless Directive 2007/64/EC applies.

SECTION 2 LIABILITY FOR DAMAGES

ARTICLE 46 — LIABILITY FOR DAMAGES

46.1 Liability of the *Commission*

The *Commission* cannot be held liable for any damage caused to the beneficiaries or to third parties as a consequence of implementing the Agreement, including for gross negligence.

The *Commission* cannot be held liable for any damage caused by any of the beneficiaries or third parties involved in the action, as a consequence of implementing the Agreement.

46.2 Liability of the beneficiaries

46.2.1 Conditions

Except in case of force majeure (see Article 51), the beneficiaries must compensate the *Commission* for any damage it sustains as a result of the implementation of the action or because the action was not implemented in full compliance with the Agreement.

Each beneficiary is responsible for paying the damages claimed from it.

46.2.2 Amount of damages - Calculation

The amount the *Commission* can claim from a beneficiary will correspond to the damage caused by that beneficiary.

46.2.3 Procedure

Before claiming damages, the *Commission* will formally notify the beneficiary concerned:

- informing it of its intention to claim damages, the amount and the reasons why and

- inviting it to submit observations within 30 days.

If the *Commission* does not receive any observations or decides to claim damages despite the observations it has received, it will formally notify **confirmation** of the claim for damages and a **debit note**, specifying the amount to be recovered, the terms and the date for payment.

If payment is not made by the date specified in the debit note, the Commission may **recover** the amount:

(a) by '**offsetting**' it — without the beneficiary's consent — against any amounts owed to the beneficiary concerned by the Commission or an executive agency (from the EU or Euratom budget).

In exceptional circumstances, to safeguard the EU's financial interests, the *Commission* may offset before the payment date specified in the debit note;

(b) by **taking legal action** (see Article 57) or by **adopting an enforceable decision** under Article 299 of the Treaty on the Functioning of the EU (TFEU) and Article 79(2) of the Financial Regulation No 966/2012.

If payment is not made by the date in the debit note, the amount to be recovered (see above) will be increased by **late-payment interest** at the rate set out in Article 21.11, from the day following the payment date in the debit note, up to and including the date the Commission receives full payment of the amount.

Partial payments will be first credited against expenses, charges and late-payment interest and then against the principal.

Bank charges incurred in the recovery process will be borne by the beneficiary, unless Directive 2007/64/EC applies.

SECTION 3 SUSPENSION AND TERMINATION

ARTICLE 47 — SUSPENSION OF PAYMENT DEADLINE

47.1 Conditions

The *Commission* may — at any moment — suspend the payment deadline (see Article 21.2 to 21.4) if a request for payment (see Article 20) cannot be approved because:

(a) it does not comply with the provisions of the Agreement (see Article 20);

(b) the technical reports or financial reports have not been submitted or are not complete or additional information is needed, or

(c) there is doubt about the eligibility of the costs declared in the financial statements and additional checks, reviews, audits or investigations are necessary.

47.2 Procedure

The *Commission* will formally notify the coordinator of the suspension and the reasons why.

The suspension will **take effect** the day notification is sent by the *Commission* (see Article 52).

If the conditions for suspending the payment deadline are no longer met, the suspension will be **lifted** — and the remaining period will resume.

If the suspension exceeds two months, the coordinator may request the *Commission* if the suspension will continue.

If the payment deadline has been suspended due to the non-compliance of the technical or financial reports (see Article 20) and the revised report or statement is not submitted or was submitted but is also rejected, the *Commission* may also terminate the Agreement or the participation of the beneficiary (see Article 50.3.1(l)).

ARTICLE 48 — SUSPENSION OF PAYMENTS

48.1 Conditions

The *Commission* may — at any moment — suspend, in whole or in part, the pre-financing payment and interim payments for one or more beneficiaries or the payment of the balance for all beneficiaries, if a beneficiary:

(a) has committed or is suspected of having committed substantial errors, irregularities, fraud or serious breach of obligations in the award procedure or under this Agreement or

(b) has committed — in other EU or Euratom grants awarded to it under similar conditions — systemic or recurrent errors, irregularities, fraud or serious breach of obligations that have a material impact on this grant (**extension of findings from other grants to this grant**; see Article 22.5.2).

48.2 Procedure

Before suspending payments, the *Commission* will formally notify the coordinator:

- informing it of its intention to suspend payments and the reasons why and

- inviting it to submit observations within 30 days of receiving notification.

If the *Commission* does not receive observations or decides to pursue the procedure despite the observations it has received, it will formally notify **confirmation** of the suspension. Otherwise, it will formally notify that the suspension procedure is not continued.

The suspension will **take effect** the day the confirmation notification is sent by the *Commission*.

If the conditions for resuming payments are met, the suspension will be **lifted**. The *Commission* will formally notify the coordinator.

During the suspension, the periodic report(s) (see Article 20.3) must not contain any individual financial statements from the beneficiary concerned *and its linked third parties*. When the *Commission* resumes payments, the coordinator may include them in the next periodic report.

The beneficiaries may suspend implementation of the action (see Article 49.1) or terminate the Agreement or the participation of the beneficiary concerned (see Article 50.1 and 50.2).

ARTICLE 49 — SUSPENSION OF THE ACTION IMPLEMENTATION

49.1 Suspension of the action implementation, by the beneficiaries

49.1.1 Conditions

The beneficiaries may suspend implementation of the action or any part of it, if exceptional circumstances — in particular *force majeure* (see Article 51) — make implementation impossible or excessively difficult.

49.1.2 Procedure

The coordinator must immediately formally notify to the *Commission* the suspension (see Article 52), stating:

- the reasons why and
- the expected date of resumption.

The suspension will **take effect** the day this notification is received by the *Commission*.

Once circumstances allow for implementation to resume, the coordinator must immediately formally notify the *Commission* and request an **amendment** of the Agreement to set the date on which the action will be resumed, extend the duration of the action and make other changes necessary to adapt the action to the new situation (see Article 55) — unless the Agreement or the participation of a beneficiary has been terminated (see Article 50).

The suspension will be **lifted** with effect from the resumption date set out in the amendment. This date may be before the date on which the amendment enters into force.

Costs incurred during suspension of the action implementation are not eligible (see Article 6).

49.2 Suspension of the action implementation, by the *Commission*

49.2.1 Conditions

The *Commission* may suspend implementation of the action or any part of it:

(a) if a beneficiary has committed or is suspected of having committed substantial errors, irregularities, fraud or serious breach of obligations in the award procedure or under this Agreement;

(b) if a beneficiary has committed — in other EU or Euratom grants awarded to it under similar conditions — systemic or recurrent errors, irregularities, fraud or serious breach of obligations that have a material impact on this grant (**extension of findings from other grants to this grant**; see Article 22.5.2), or

(c) if the action is suspected of having lost its scientific or technological relevance.

49.2.2 Procedure

Before suspending implementation of the action, the *Commission* will formally notify the coordinator:

- informing it of its intention to suspend the implementation and the reasons why and
- inviting it to submit observations within 30 days of receiving notification.

If the *Commission* does not receive observations or decides to pursue the procedure despite the observations it has received, it will formally notify **confirmation** of the suspension. Otherwise, it will formally notify that the procedure is not continued.

The suspension will **take effect** five days after confirmation notification is received by the coordinator (or on a later date specified in the notification).

It will be **lifted** if the conditions for resuming implementation of the action are met.

The coordinator will be formally notified of the lifting and the Agreement will be **amended** to set the date on which the action will be resumed, extend the duration of the action and make other changes necessary to adapt the action to the new situation (see Article 55) — unless the Agreement has already been terminated (see Article 50).

The suspension will be lifted with effect from the resumption date set out in the amendment. This date may be before the date on which the amendment enters into force.

Costs incurred during suspension are not eligible (see Article 6).

The beneficiaries may not claim damages due to suspension by the *Commission* (see Article 46).

Suspension of the action implementation does not affect the *Commission's* right to terminate the Agreement or participation of a beneficiary (see Article 50), reduce the grant or recover amounts unduly paid (see Articles 43 and 44).

ARTICLE 50 — TERMINATION OF THE AGREEMENT OR OF THE PARTICIPATION OF ONE OR MORE BENEFICIARIES

50.1 Termination of the Agreement by the beneficiaries

50.1.1 Conditions and procedure

The beneficiaries may terminate the Agreement.

The coordinator must formally notify termination to the *Commission* (see Article 52), stating:

- the reasons why and
- the date the termination will take effect. This date must be after the notification.

If no reasons are given or if the *Commission* considers the reasons do not justify termination, the Agreement will be considered to have been '**terminated improperly**'.

The termination will **take effect** on the day specified in the notification.

50.1.2 Effects

The coordinator must — within 60 days from when termination takes effect — submit:

(i) a periodic report (for the open reporting period until termination; see Article 20.3) and

(ii) the final report (see Article 20.4).

If the *Commission* does not receive the reports within the deadline (see above), only costs which are included in an approved periodic report will be taken into account.

The *Commission* will **calculate** the final grant amount (see Article 5.3) and the balance (see Article 21.4) on the basis of the reports submitted. Only costs incurred until termination are eligible (see Article 6). Costs relating to contracts due for execution only after termination are not eligible.

Improper termination may lead to a reduction of the grant (see Article 43).

After termination, the beneficiaries' obligations (in particular Articles 20, 22, 23, Section 3 of Chapter 4, 36, 37, 38 and 40) continue to apply.

50.2 Termination of the participation of one or more beneficiaries, by the beneficiaries

50.2.1 Conditions and procedure

The participation of one or more beneficiaries may be terminated by the coordinator, on request of the beneficiary concerned or on behalf of the other beneficiaries.

The coordinator must formally notify termination to the *Commission* (see Article 52) and inform the beneficiary concerned.

If the coordinator's participation is terminated without its agreement, the formal notification must be done by another beneficiary (acting on behalf of the other beneficiaries).

The notification must include:

- the reasons why;
- the opinion of the beneficiary concerned (or proof that this opinion has been requested in writing);
- the date the termination takes effect. This date must be after the notification, and
- a request for amendment (see Article 55), with a proposal for reallocation of the tasks and the estimated budget of the beneficiary concerned (see Annexes 1 and 2) and, if necessary, the addition of one or more new beneficiaries (see Article 56). If termination takes effect after the period set out in Article 3, no request for amendment must be included unless the beneficiary concerned is the coordinator. In this case, the request for amendment must propose a new coordinator.

If this information is not given or if the *Commission* considers that the reasons do not justify termination, the participation will be considered to have been **terminated improperly**.

The termination will **take effect** on the day specified in the notification.

50.2.2 Effects

The coordinator must — within 30 days from when termination takes effect — submit:

(i) a report on the distribution of payments to the beneficiary concerned and

(ii) if termination takes effect during the period set out in Article 3, a '**termination report**' from the beneficiary concerned, for the open reporting period until termination, containing an overview of the progress of the work, an overview of the use of resources, the individual financial statement and, if applicable, the certificate on the financial statement (see Articles 20.3 and 20.4).

The information in the termination report must also be included in the periodic report for the next reporting period (see Article 20.3).

If the request for amendment is rejected by the *Commission*, (because it calls into question the decision awarding the grant or breaches the principle of equal treatment of applicants), the Agreement may be terminated according to Article 50.3.1(c).

If the request for amendment is accepted by the *Commission*, the Agreement is **amended** to introduce the necessary changes (see Article 55).

The *Commission* will **calculate** — on the basis of the periodic reports, the termination report and the report on the distribution of payments — if the (pre-financing and interim) payments received by the beneficiary concerned exceed the beneficiary's EU contribution (calculated by applying the reimbursement rate(s) to the eligible costs declared by the beneficiary *and its linked third parties* and approved by the *Commission*). Only costs incurred by the beneficiary concerned until termination takes effect are eligible (see Article 6). Costs relating to contracts due for execution only after termination are not eligible.

- If the payments received **exceed the amounts due**:

  - if termination takes effect during the period set out in Article 3 and the request for amendment is accepted, the beneficiary concerned must repay to the coordinator the amount unduly received. The *Commission* will formally notify the amount unduly received and request the beneficiary concerned to repay it to the coordinator within 30 days of receiving notification. If it does not repay the coordinator, the *Commission* will draw upon the Guarantee Fund to pay the coordinator and then notify a **debit note** on behalf of the Guarantee Fund to the beneficiary concerned (see Article 44);

  - in all other cases (in particular if termination takes effect after the period set out in Article 3), the *Commission* will formally notify a **debit note** to the beneficiary concerned. If payment is not made by the date in the debit note, the Guarantee Fund will pay to the *Commission* the amount due and the *Commission* will notify a debit note on behalf of the Guarantee Fund to the beneficiary concerned (see Article 44);

  - if the beneficiary concerned is the former coordinator, it must repay the new coordinator according to the procedure above, unless:

    - termination is after an interim payment and

    - the former coordinator has not distributed amounts received as pre-financing or interim payments (see Article 21.7).

In this case, the *Commission* will formally notify a **debit note** to the former coordinator. If payment is not made by the date in the debit note, the Guarantee Fund will pay to the *Commission* the amount due. The *Commission* will then pay the new coordinator and notify a debit note on behalf of the Guarantee Fund to the former coordinator (see Article 44).

- If the payments received **do not exceed the amounts due**: amounts owed to the beneficiary concerned will be included in the next interim or final payment.

If the *Commission* does not receive the termination report within the deadline (see above), only costs included in an approved periodic report will be taken into account.

If the *Commission* does not receive the report on the distribution of payments within the deadline (see above), it will consider that:

- the coordinator did not distribute any payment to the beneficiary concerned and that

- the beneficiary concerned must not repay any amount to the coordinator.

Improper termination may lead to a reduction of the grant (see Article 43) or termination of the Agreement (see Article 50).

After termination, the concerned beneficiary's obligations (in particular Articles 20, 22, 23, Section 3 of Chapter 4, 36, 37, 38 and 40) continue to apply.

50.3 Termination of the Agreement or the participation of one or more beneficiaries, by the *Commission*

50.3.1 Conditions

The *Commission* may terminate the Agreement or the participation of one or more beneficiaries, if:

(a) one or more beneficiaries do not accede to the Agreement (see Article 56);

(b) a change to their legal, financial, technical, organisational or ownership situation *(or those of its linked third parties)* is likely to substantially affect or delay the implementation of the action or calls into question the decision to award the grant;

(c) following termination of participation for one or more beneficiaries (see above), the necessary changes to the Agreement would call into question the decision awarding the grant or breach the principle of equal treatment of applicants (see Article 55);

(d) implementation of the action is prevented by force majeure (see Article 51) or suspended by the coordinator (see Article 49.1) and either:

(i) resumption is impossible, or

(ii) the necessary changes to the Agreement would call into question the decision awarding the grant or breach the principle of equal treatment of applicants;

(e) a beneficiary is declared bankrupt, being wound up, having its affairs administered by the courts, has entered into an arrangement with creditors, has suspended business activities, or is subject to any other similar proceedings or procedures under national law;

(f) a beneficiary (or a natural person who has the power to represent or take decisions on its behalf) has been found guilty of professional misconduct, proven by any means;

(g) a beneficiary does not comply with the applicable national law on taxes and social security;

(h) the action has lost scientific or technological relevance;

(i) *not applicable;*

(j) *not applicable;*

(k) a beneficiary (or a natural person who has the power to represent or take decisions on its behalf) has committed fraud, corruption, or is involved in a criminal organisation, money laundering or any other illegal activity affecting the EU's financial interests;

(l) a beneficiary (or a natural person who has the power to represent or take decisions on its behalf) has — in the award procedure or under the Agreement — committed:

(i) substantial errors, irregularities, fraud or

(ii) serious breach of obligations, including improper implementation of the action, submission of false information, failure to provide required information, breach of ethical principles;

(m) a beneficiary has committed — in other EU or Euratom grants awarded to it under similar conditions — systemic or recurrent errors, irregularities, fraud or serious breach of obligations that have a material impact on this grant ('**extension of findings from other grants to this grant**').

50.3.2 Procedure

Before terminating the Agreement or participation of one or more beneficiaries, the *Commission* will formally notify the coordinator:

- informing it of its intention to terminate and the reasons why and

- inviting it, within 30 days of receiving notification, to submit observations and — in case of Point (l.ii) above — to inform the *Commission* of the measures to ensure compliance with the obligations under the Agreement.

If the *Commission* does not receive observations or decides to pursue the procedure despite the observations it has received, it will formally notify to the coordinator **confirmation** of the termination and the date it will take effect. Otherwise, it will formally notify that the procedure is not continued.

The termination will **take effect**:

- for terminations under Points (b), (c), (e), (g), (h), (j), and (l.ii) above: on the day specified in the notification of the confirmation (see above);

- for terminations under Points (a), (d), (f), (i), (k), (l.i) and (m) above: on the day after the notification of the confirmation is received by the coordinator.

50.3.3 Effects

(a) for **termination of the Agreement**:

The coordinator must — within 60 days from when termination takes effect — submit:

(i) a periodic report (for the last open reporting period until termination; see Article 20.3) and

(ii) a final report (see Article 20.4).

If the Agreement is terminated for breach of the obligation to submit the reports (see Articles 20.8 and 50.3.1(l)), the coordinator may not submit any reports after termination.

If the *Commission* does not receive the reports within the deadline (see above), only costs which are included in an approved periodic report will be taken into account.

The *Commission* will **calculate** the final grant amount (see Article 5.3) and the balance (see Article 21.4) on the basis of the reports submitted. Only costs incurred until termination takes effect are eligible (see Article 6). Costs relating to contracts due for execution only after termination are not eligible.

This does not affect the *Commission's* right to reduce the grant (see Article 43) or to impose administrative and financial penalties (Article 45).

The beneficiaries may not claim damages due to termination by the *Commission* (see Article 46).

After termination, the beneficiaries' obligations (in particular Articles 20, 22, 23, Section 3 of Chapter 4, 36, 37, 38 and 40) continue to apply.

(b) for **termination of the participation of one or more beneficiaries**:

The coordinator must — within 60 days from when termination takes effect — submit:

(i) a report on the distribution of payments to the beneficiary concerned;

(ii) a request for amendment (see Article 55), with a proposal for reallocation of the tasks and estimated budget of the beneficiary concerned (see Annexes 1 and 2) and, if necessary, the addition of one or more new beneficiaries (see Article 56). If termination is notified after the period set out in Article 3, no request for amendment must be submitted unless the beneficiary concerned is the coordinator. In this case the request for amendment must propose a new coordinator, and

(iii) if termination takes effect during the period set out in Article 3, a **termination report** from the beneficiary concerned, for the open reporting period until termination, containing an overview of the progress of the work, an overview of the use of resources, the

individual financial statement and, if applicable, the certificate on the financial statement (see Article 20).

The information in the termination report must also be included in the periodic report for the next reporting period (see Article 20.3).

If the request for amendment is rejected by the *Commission* (because it calls into question the decision awarding the grant or breaches the principle of equal treatment of applicants), the Agreement may be terminated according to Article 50.3.1(c).

If the request for amendment is accepted by the *Commission*, the Agreement is **amended** to introduce the necessary changes (see Article 55).

The *Commission* will **calculate** — on the basis of the periodic reports, the termination report and the report on the distribution of payments — if the (pre-financing and interim) payments received by the beneficiary concerned exceed the beneficiary's EU contribution (calculated by applying the reimbursement rate(s) to the eligible costs declared by the beneficiary *and its linked third parties* and approved by the *Commission*). Only costs incurred by the beneficiary concerned until termination takes effect are eligible (see Article 6). Costs relating to contracts due for execution only after termination are not eligible.

- If the payments received **exceed the amounts due**:

  - if termination takes effect during the period set out in Article 3 and the request for amendment is accepted, the beneficiary concerned must repay to the coordinator the amount unduly received. The *Commission* will formally notify the amount unduly received and request the beneficiary concerned to repay it to the coordinator within 30 days of receiving notification. If it does not repay the coordinator, the *Commission* will draw upon the Guarantee Fund to pay the coordinator and then notify a debit note on behalf of the Guarantee Fund to the beneficiary concerned (see Article 44);

  - in all other cases, in particular if termination takes effect after the period set out in Article 3, the *Commission* will formally notify a **debit note** to the beneficiary concerned. If payment is not made by the date in the debit note, the Guarantee Fund will pay to the *Commission* the amount due and the *Commission* will notify a debit note on behalf of the Guarantee Fund to the beneficiary concerned (see Article 44);

  - if the beneficiary concerned is the former coordinator, it must repay the new coordinator the amount unduly received, unless:

    - termination takes effect after an interim payment and

    - the former coordinator has not distributed amounts received as pre-financing or interim payments (see Article 21.7)

    In this case, the *Commission* will formally notify a **debit note** to the former coordinator. If payment is not made by the date in the debit note, the Guarantee Fund will pay to the *Commission* the amount due. The *Commission* will then pay the new

coordinator and notify a debit note on behalf of the Guarantee Fund to the former coordinator (see Article 44).

- If the payments received **do not exceed the amounts due**: amounts owed to the beneficiary concerned will be included in the next interim or final payment.

If the *Commission* does not receive the termination report within the deadline (see above), only costs included in an approved periodic report will be taken into account.

If the *Commission* does not receive the report on the distribution of payments within the deadline (see above), it will consider that:

- the coordinator did not distribute any payment to the beneficiary concerned, and that
- the beneficiary concerned must not repay any amount to the coordinator.

After termination, the concerned beneficiary's obligations (in particular Articles 20, 22, 23, Section 3 of Chapter 4, 36, 37, 38 and 40) continue to apply.

SECTION 4 FORCE MAJEURE

ARTICLE 51 — FORCE MAJEURE

'Force majeure' means any situation or event that:

- prevents either party from fulfilling their obligations under the Agreement,
- was unforeseeable, exceptional situation and beyond the parties' control,
- was not due to error or negligence on their part (or on the part of third parties involved in the action), and
- proves to be inevitable in spite of exercising all due diligence.

The following cannot be invoked as force majeure:

- any default of a service, defect in equipment or material or delays in making them available, unless they stem directly from a relevant case of force majeure,
- labour disputes or strikes, or
- financial difficulties.

Any situation constituting force majeure must be formally notified to the other party without delay, stating the nature, likely duration and foreseeable effects.

The parties must immediately take all the necessary steps to limit any damage due to force majeure and do their best to resume implementation of the action as soon as possible.

The party prevented by force majeure from fulfilling its obligations under the Agreement cannot be considered in breach of them.

CHAPTER 7 FINAL PROVISIONS

ARTICLE 52 — COMMUNICATION BETWEEN THE PARTIES

52.1 Form and means of communication

Communication under the Agreement (information, requests, submissions, 'formal notifications', etc.) must:

- be made in writing and
- bear the number of the Agreement.

Until the payment of the balance: all communication must be made through the electronic exchange system and using the forms and templates provided there.

After the payment of the balance: formal notifications must be made by registered post with proof of delivery ('formal notification on paper').

Communications in the electronic exchange system must be made by persons authorised according to the 'Terms and Conditions of Use of the electronic exchange system'. For naming the authorised persons, each beneficiary must have designated — before the signature of this Agreement — a 'Legal Entity Appointed Representative (LEAR)'. The role and tasks of the LEAR are stipulated in his/her appointment letter (see Terms and Conditions of Use of the electronic exchange system).

If the electronic exchange system is temporarily unavailable, instructions will be given on the Commission websites.

52.2 Date of communication

Communications are considered to have been made when they are sent by the sending party (i.e. on the date and time they are sent through the electronic exchange system).

Formal notifications through the **electronic** exchange system are considered to have been made when they are received by the receiving party (i.e. on the date and time of acceptance by the receiving party, as indicated by the time stamp). A formal notification that has not been accepted within 10 days after sending is considered to have been accepted.

Formal notifications **on paper** sent by **registered post** with proof of delivery (only after the payment of the balance) are considered to have been made on either:

- the delivery date registered by the postal service or
- the deadline for collection at the post office.

If the electronic exchange system is temporarily unavailable, the sending party cannot be considered in breach of its obligation to send a communication within a specified deadline.

52.3 Addresses for communication

The **electronic** exchange system must be accessed via the following URL:

https://ec.europa.eu/research/participants/portal/desktop/en/projects/

The *Commission* will formally notify the coordinator and beneficiaries in advance any changes to this URL.

Formal notifications on paper (only after the payment of the balance) addressed **to the *Commission*** must be sent to the following address:

European Commission
Communications Networks, Content and Technology
eInfrastructure Science Cloud
B-1049 Brussels Belgium

Formal notifications on paper (only after the payment of the balance) addressed **to the beneficiaries** must be sent to their legal address as specified in the 'Beneficiary Register'.

ARTICLE 53 — INTERPRETATION OF THE AGREEMENT

53.1 Precedence of the Terms and Conditions over the Annexes

The provisions in the Terms and Conditions of the Agreement take precedence over its Annexes.

Annex 2 takes precedence over Annex 1.

53.2 Privileges and immunities

Not applicable

ARTICLE 54 — CALCULATION OF PERIODS, DATES AND DEADLINES

In accordance with Regulation No 1182/71[28], periods expressed in days, months or years are calculated from the moment the triggering event occurs.

The day during which that event occurs is not considered as falling within the period.

ARTICLE 55 — AMENDMENTS TO THE AGREEMENT

55.1 Conditions

The Agreement may be amended, unless the amendment entails changes to the Agreement which would call into question the decision awarding the grant or breach the principle of equal treatment of applicants.

Amendments may be requested by any of the parties.

55.2 Procedure

The party requesting an amendment must submit a request for amendment signed in the electronic exchange system (see Article 52).

[28] Regulation (EEC, Euratom) No 1182/71 of the Council of 3 June 1971 determining the rules applicable to periods, dates and time-limits (OJ L 124, 8.6.1971, p. 1).

The coordinator submits and receives requests for amendment on behalf of the beneficiaries (see Annex 3).

If a change of coordinator is requested without its agreement, the submission must be done by another beneficiary (acting on behalf of the other beneficiaries).

The request for amendment must include:

- the reasons why;
- the appropriate supporting documents;
- for a change of coordinator without its agreement: the opinion of the coordinator (or proof that this opinion has been requested in writing).

The *Commission* may request additional information.

If the party receiving the request agrees, it must sign the amendment in the electronic exchange system within 45 days of receiving notification (or any additional information the *Commission* has requested). If it does not agree, it must formally notify its disagreement within the same deadline. The deadline may be extended, if necessary for the assessment of the request. If no notification is received within the deadline, the request is considered to have been rejected

An amendment **enters into force** on the day of the signature of the receiving party.

An amendment **takes effect** on the date agreed by the parties or, in the absence of such an agreement, on the date on which the amendment enters into force.

ARTICLE 56 — ACCESSION TO THE AGREEMENT

56.1 Accession of the beneficiaries mentioned in the Preamble

The other beneficiaries must accede to the Agreement by signing the Accession Form (see Annex 3) in the electronic exchange system (see Article 52) within 30 days after its entry into force (see Article 58).

They will assume the rights and obligations under the Agreement with effect from the date of its entry into force (see Article 58).

If a beneficiary does not accede to the Agreement within the above deadline, the coordinator must — within 30 days — request an amendment to make any changes necessary to ensure proper implementation of the action. This does not affect the *Commission's* right to terminate the Agreement (see Article 50).

56.2 Addition of new beneficiaries

In justified cases, the beneficiaries may request the addition of a new beneficiary.

For this purpose, the coordinator must submit a request for amendment in accordance with Article 55. It must include an Accession Form (see Annex 3) signed by the new beneficiary in the electronic exchange system (see Article 52).

New beneficiaries must assume the rights and obligations under the Agreement with effect from the date of their accession specified in the Accession Form (see Annex 3).

ARTICLE 57 — APPLICABLE LAW AND SETTLEMENT OF DISPUTES

57.1 Applicable law

The Agreement is governed by the applicable EU law, supplemented if necessary by the law of Belgium.

57.2 Dispute settlement

If a dispute concerning the interpretation, application or validity of the Agreement cannot be settled amicably, the General Court — or, on appeal, the Court of Justice of the European Union — has sole jurisdiction. Such actions must be brought under Article 272 of the Treaty on the Functioning of the EU (TFEU).

As an exception, if such a dispute is between the Commission and ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE, UNIVERSITE DE GENEVE, COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION, COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH, UNIVERSITY OF CAPE TOWN, NATIONAL RESEARCH FOUNDATION, the competent Belgian courts have sole jurisdiction.

As an exception, for the following beneficiaries:

- *AARNET PTY LTD*

- *THE RESEARCH TRUST OF VICTORIA UNIVERSITY OF WELLINGTON*

such disputes must — if they cannot be settled amicably — be referred to arbitration.

The Permanent Court of Arbitration Optional Rules for Arbitration Involving International Organisations and States in force at the date of entry into force of the Agreement will apply.

The appointing authority will be the Secretary-General of the Permanent Court of Arbitration following a written request submitted by either party.

The arbitration proceedings must take place in Brussels and the language used in the arbitral proceedings will be English.

The arbitral award will be binding on all parties and will not be subject to appeal.

If a dispute concerns administrative or financial penalties, offsetting or an enforceable decision under Article 299 TFEU (see Articles 44, 45 and 46), the beneficiaries must bring action before the General Court — or, on appeal, the Court of Justice of the European Union — under Article 263 TFEU.

ARTICLE 58 — ENTRY INTO FORCE OF THE AGREEMENT

The Agreement will enter into force on the day of signature by the *Commission* or the coordinator, depending on which is later.

SIGNATURES

For the coordinator

Marco DE VOS with ECAS id nvosaaaj signed in the Participant Portal on 11/10/2016 at 12:26:23 (transaction id SigId-326188-1HVQZqdzpqKSgn2wzWDe56mVedppdtFN57BPK10JDCQc7jZzUZRNHtTLmuuAP1vDFqag4Wlzhg88wycOYUvgvrC-Jj71zxYb8yrYiyGUQlxsv0-XP66asxRQHW7TGfoIEbqcEs5bUCFegv38BenDufQwDy). Timestamp by third party at
Tue Oct 11 13:26:48 CEST 2016

For the *Commission*

Signed by Paolo GARELLO with ECAS id garelpa as an authorised representative on 17-11-2016 10:05:29 (transaction id SigId-3299-bdjuAdxOdLm5DBPPwhNtK42qE1I8NfZmbbwByLQjGi2njoagLuDtUYkzY7Jq3ae6XD1cJszgAE0lsKPWlQcS9B-PHslUMVSXYC3y9Y47r6OLW-HxqJqWsPXIA0NACeBbmeiGtUllQeaoP5116PPrJ5f4S)
Thu Nov 17 10:05:57 CET 2016

EUROPEAN COMMISSION
Communications Networks, Content and Technology
eInfrastructure Science Cloud

ANNEX 1 (part A)

Research and Innovation action

NUMBER — 731016 — AENEAS

Table of Contents

1.1. The project summary

Project Number [1]	731016	Project Acronym [2]	AENEAS

One form per project

General information	
Project title [3]	Advanced European Network of E-infrastructures for Astronomy with the SKA
Starting date [4]	01/01/2017
Duration in months [5]	36
Call (part) identifier [6]	H2020-INFRASUPP-2016-1
Topic	INFRASUPP-03-2016 Support to policies and international cooperation for e-infrastructures
Fixed EC Keywords	
Free keywords	Advanced, European, Network, E-infrastructures, Astronomy, SKA, Data

Abstract [7]

The objective of the AENEAS project is to develop a concept and design for a distributed, federated European Science Data Centre (ESDC) to support the astronomical community in achieving the scientific goals of the Square Kilometre Array (SKA). The scientific potential of the SKA radio telescope is unprecedented and represents one of the highest priorities for the international scientific community. By the same token, the large scale, rate, and complexity of data the SKA will generate, present challenges in data management, computing, and networking that are similarly world-leading. SKA Regional Centres (SRC) like the ESDC will be a vital resource to enable the community to take advantage of the scientific potential of the SKA. Within the tiered SKA operational model, the SRCs will provide essential functionality which is not currently provisioned within the directly operated SKA facilities. AENEAS brings together all the European member states currently part of the SKA project as well as potential future EU SKA national partners, the SKA Organisation itself, and a larger group of international partners including the two host countries Australia and South Africa.

1.2. List of Beneficiaries

Project Number [1]	731016	Project Acronym [2]	AENEAS

List of Beneficiaries

No	Name	Short name	Country	Project entry month[8]	Project exit month
1	STICHTING ASTRON, NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY	ASTRON	Netherlands	1	36
2	THE UNIVERSITY OF MANCHESTER	UMAN	United Kingdom	1	36
3	THE CHANCELLOR, MASTERS AND SCHOLARS OF THE UNIVERSITY OF CAMBRIDGE	UCAM	United Kingdom	1	36
4	ISTITUTO NAZIONALE DI ASTROFISICA	INAF	Italy	1	36
5	CHALMERS TEKNISKA HOEGSKOLA AB	CHALMERS	Sweden	1	36
6	GEANT LIMITED	GEANT LTD	United Kingdom	1	36
7	Stichting EGI	EGI.eu	Netherlands	1	36
8	MAX-PLANCK-GESELLSCHAFT ZUR FORDERUNG DER WISSENSCHAFTEN EV	MPG	Germany	1	36
9	FORSCHUNGSZENTRUM JULICH GMBH	Juelich	Germany	1	36
10	SKA ORGANISATION	SKAO	United Kingdom	1	36
11	SCIENCE AND TECHNOLOGY FACILITIES COUNCIL	STFC	United Kingdom	1	36
12	AGENCIA ESTATAL CONSEJO SUPERIOR DEINVESTIGACIONES CIENTIFICAS	CSIC	Spain	1	36
13	INSTITUTO DE TELECOMUNICACOES	IT	Portugal	1	36
14	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	CNRS	France	1	36
15	ETHNIKO DIKTYO EREVNAS TECHNOLOGIAS AE	GRNET	Greece	1	36
16	STICHTING VOOR FUNDAMENTEEL ONDERZOEK DER MATERIE - FOM	FOM	Netherlands	1	36
17	JOINT INSTITUTE FOR VERY LONG BASELINE INTERFEROMETRY AS A EUROPEAN RESEARCH INFRASTRUCTURE CONSORTIUM (JIV-ERIC)	JIV-ERIC	Netherlands	1	36
18	STICHTING INTERNATIONAL LOFAR TELESCOPE	ILT	Netherlands	1	36
19	UPPSALA UNIVERSITET	SNIC	Sweden	1	36
20	ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE	EPFL	Switzerland	1	36
21	UNIVERSITE DE GENEVE	UNIGE	Switzerland	1	36

1.2. List of Beneficiaries

No	Name	Short name	Country	Project entry month[8]	Project exit month
22	COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION	CSIRO	Australia	1	36
23	AARNET PTY LTD	AARNet	Australia	1	36
24	THE RESEARCH TRUST OF VICTORIA UNIVERSITY OF WELLINGTON	VUW	New Zealand	1	36
25	COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH	CSIR	South Africa	1	36
26	UNIVERSITY OF CAPE TOWN	UCT	South Africa	1	36
27	NATIONAL RESEARCH FOUNDATION	NRF	South Africa	1	36
28	RESEARCH DATA ALLIANCE FOUNDATION	RDA	United Kingdom	1	36

1.3. Workplan Tables - Detailed implementation

1.3.1. WT1 List of work packages

WP Number[9]	WP Title	Lead beneficiary[10]	Person-months[11]	Start month[12]	End month[13]
WP1	AENEAS Management Support Team (AMST)	1 - ASTRON	24.00	1	36
WP2	Development of ESDC Governance Structure and Business Models	1 - ASTRON	22.00	1	36
WP3	Computing Requirements	2 - UMAN	91.00	1	36
WP4	Analysis of Global SKA Data Transport and Optimal European Storage Topologies	6 - GEANT LTD	58.00	1	36
WP5	Access and Knowledge Creation	4 - INAF	59.00	1	36
WP6	Services	7 - EGI.eu	35.00	1	36
		Total	289.00		

1.3.2. WT2 list of deliverables

Deliverable Number[14]	Deliverable Title	WP number[9]	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D1.1	AENEAS Website online	WP1	1 - ASTRON	Websites, patents filling, etc.	Public	3
D1.2	Set of defined AENEAS KPIs	WP1	1 - ASTRON	Report	Public	3
D1.3	Data Management Plan	WP1	1 - ASTRON	ORDP: Open Research Data Pilot	Public	6
D1.4	Brochures and outreach	WP1	1 - ASTRON	Websites, patents filling, etc.	Public	9
D2.1	Inventory of potential ESDC resources	WP2	1 - ASTRON	Report	Public	12
D2.2	ESDC User Requirements	WP2	1 - ASTRON	Report	Public	18
D2.3	ESDC Design Study	WP2	1 - ASTRON	Report	Public	33
D2.4	ESDC (preliminary) implementation plan	WP2	1 - ASTRON	Report	Public	36
D3.1	Analysis of compute load, data transfer and data storage anticipated as required for SKA Key science	WP3	2 - UMAN	Report	Public	21
D3.2	Report on suggested solutions to address each of the key software areas associated with running a distributed ESDC	WP3	2 - UMAN	Report	Public	24
D3.3	Preliminary System sizing report	WP3	2 - UMAN	Report	Public	24
D3.4	Report on design & costing for ESDC	WP3	2 - UMAN	Report	Public	36
D3.5	Report on suggested solutions to interface requirements for a distributed ESDC	WP3	2 - UMAN	Report	Public	36
D4.1	Best practice Data transport and storage	WP4	6 - GEANT LTD	Report	Public	14
D4.2	Site Catalogue storage and networking	WP4	6 - GEANT LTD	Websites, patents filling, etc.	Public	18

Deliverable Number[14]	Deliverable Title	WP number[9]	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D4.3	ESDN network architecture and costing	WP4	6 - GEANT LTD	Report	Public	27
D4.4	Global network architecture and costing	WP4	6 - GEANT LTD	Report	Public	32
D4.5	Data Transport Tests and Recommendations	WP4	6 - GEANT LTD	Report	Public	34
D5.1	Survey report	WP5	4 - INAF	Report	Public	18
D5.2	Gap analysis	WP5	4 - INAF	Report	Public	18
D5.3	Design recommendations #1	WP5	4 - INAF	Report	Public	24
D5.4	Design recommendations #2	WP5	4 - INAF	Report	Public	24
D5.5	Applicability of VO framework	WP5	4 - INAF	Report	Public	28
D5.6	User interaction model resourcing	WP5	4 - INAF	Report	Public	28
D5.7	Growing the ESDC community	WP5	4 - INAF	Report	Public	28
D5.8	Final integration of WP5 materials	WP5	4 - INAF	Report	Public	34
D6.1	AAI requirements and AAI architecture design	WP6	7 - EGI.eu	Report	Public	24
D6.2	AENEAS Service Portfolio	WP6	7 - EGI.eu	Report	Public	24
D6.3	Federated AAI pilot results	WP6	7 - EGI.eu	Report	Public	36
D6.4	SRC federated service management recommendations	WP6	7 - EGI.eu	Report	Public	36

1.3.3. WT3 Work package descriptions

Work package number [9]	WP1	**Lead beneficiary** [10]	1 - ASTRON
Work package title	AENEAS Management Support Team (AMST)		
Start month	1	**End month**	36

Objectives

This work package will establish the AENEAS Management Support Team (MST) to manage the project and ensure the smooth execution of all financial, administrative and reporting elements of the project. The MST will exercise central control and oversight of the scientific and technical progress of AENEAS 27 INFRASUPP-03-2016 the project, as measured by the successful delivery of agreed outputs and the passage of agreed milestones (see also section 3.2). To design a European Science Data Centre on a suitable scale for the SKA data, AENEAS will need to bring people and ideas together, and keep the effort well-focussed throughout the project. To this end, annual workshops will be organised during the project with, in the final year, an expanded workshop to show-case the design of the SKA European Science Data Centre and its relevance to other fields and other relevant stakeholders.

The MST will also be responsible for all internal dissemination of AENEAS results and the promotion and engagement of the project within the community and beyond.

Description of work and role of partners

WP1 - AENEAS Management Support Team (AMST) [Months: 1-36]
ASTRON
Partner: ASTRON
The work is conducted by the AMST which includes the AENEAS Coordinator, the Project Manager, Project Scientist, Financial Controller and Administrator.

Task 1.1: Project Governance
- Establish the appropriate governance structure for the project, as laid down in the Consortium Agreement, including (but not limited to) the appointment of the AENEAS General Assembly (GA), AENEAS Management Team (AMT), AENEAS Management Support Team (AMST) and AENEAS External Advisory Board (AEAB).
- Organise, prepare and minute meetings of the AGA, AMT, AMST and AEAB.
- Oversee the implementation of the decisions of the AGA, AMT, and advice of the AEAB.
- Update and maintain the Consortium Agreement.

Task 1.2: Project Coordination
- Develop a close-knit network of intra-project communication channels between all WPs, the AMST and the AMT.
- Ensure close cooperation with the various astronomical projects, and direct engagement with senior figures in their central organisations.
- Foster cooperation with all relevant organisations, including other EC projects (such as RADIONET, ASTERICS, CIRAS, GEANT LTD, EGI, RDA, etc.), and industrial stakeholders, other research infrastructures, national funding agencies, etc.
- Visibly promote AENEAS to the global, European and national communities by attending relevant meetings (e.g. IAU General Assembly, EWASS, Big Data gatherings with industry and SMEs) and making high quality presentations.
- Organise yearly consortium meeting to align progress of the project.
- A grand Integrating Event will be held to show-case the final results of the AENEAS project and engage with all relevant stakeholders.

Task 1.3: Project Management
- Distribute EC funding to the partners based on the Horizon 2020 rules and the Consortium Agreement.
- Maintain a broad overview of the AENEAS project in terms of overall staff effort, including subcontractors.
- Implement appropriate and transparent reporting structures within and between the various WPs.
- Monitor milestones and deliverables, chasing any outstanding actions/deadlines.
- Define and monitor a variety of Key Performance Indicators (KPIs). A full set of defined AENEAS KPIs will be an early deliverable of the project in WP1 (D1.2).
- Prepare, compile and generate all relevant project reports (including financial data) for all major external and internal stakeholders (e.g. the EC, AGA, AMT etc.).

- Generate a Data Management Plan (D1.3) that addresses all aspects of AENEAS dissemination activities.
- Establish, maintain and update the:
o central risk register, incl. entries for contingency and risk mitigation,
o Intellectual Property (IP) register,
o list of all publications, open source software contributions and other AENEAS products,
o global registry of AENEAS partners, third parties, subcontractors, industry contacts and SMEs

Task 1.4 Internal dissemination and project outreach
- Generate standard branding and outreach materials for the AENEAS project (including a booth to be used for events and exhibitions)
- Create a project website and portal for internal coordination, and internal and external dissemination of AENEAS results (D1.1).
- Create brochures for informed communities and public-facing websites for AENEAS activities (D1.4).
- Attend high-level events and meetings where AENEAS results can be show-cased to external stakeholders, including industrial and commercial concerns.
- Overall data dissemination, communication and exposure of the results to the target communities

Participation per Partner

Partner number and short name	WP1 effort
1 - ASTRON	24.00
Total	24.00

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D1.1	AENEAS Website online	1 - ASTRON	Websites, patents filling, etc.	Public	3
D1.2	Set of defined AENEAS KPIs	1 - ASTRON	Report	Public	3
D1.3	Data Management Plan	1 - ASTRON	ORDP: Open Research Data Pilot	Public	6
D1.4	Brochures and outreach	1 - ASTRON	Websites, patents filling, etc.	Public	9

Description of deliverables

D1.1 : AENEAS Website online [3]
AENEAS Website online

D1.2 : Set of defined AENEAS KPIs [3]
Set of defined AENEAS KPIs

D1.3 : Data Management Plan [6]
Data Management Plan

D1.4 : Brochures and outreach [9]

Brochures for informed communities and public-facing websites for AENEAS activities

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification

Work package number [9]	WP2	Lead beneficiary [10]	1 - ASTRON
Work package title	Development of ESDC Governance Structure and Business Models		
Start month	1	End month	36

Objectives

The objective of the AENEAS project is to develop a plan for the implementation of a European Science Data Centre for the Square Kilometre Array. While work packages 3-6 address the largely technical challenges involved in processing, transporting and storing data, WP2 will cover the non-technical aspects. Topics include a number of surveys and an analysis of the landscape into which the distributed centre must fit. The initial outcome of the surveys will feed into a governance model of the ESDC, which will be refined over the course of the project. A business model for the ESDC will also be developed as part of WP2.

The final deliverable of WP2, and also of the entire AENEAS project, is a design study of a European Science Data Centre. The Design Study will bring together the work on computing requirements and technologies developed in WP3, the networking and data transport topologies investigated in WP4 and the data access and knowledge creation with SKA data that is part of WP5. It will build on the federation architecture and services that are part of WP6.

Description of work and role of partners

WP2 - Development of ESDC Governance Structure and Business Models [Months: 1-36]
ASTRON, UMAN, UCAM, INAF, CHALMERS, GEANT LTD, EGI.eu
T2.1 Inventory of national and European facilities + commercial providers of computing, data storage and networking services; partnerships beyond radio astronomy
Partners: ASTRON (lead), Chalmers, INAF, UMAN, UCAM, EGI.eu, GÉANT LTD, RDA
Stakeholders: STFC, MPIfR, Jülich, CNRS, UNIGE, IT, CSIC
The landscape of research infrastructures, e-infrastructures, academic and commercial service providers is extensive and advancing rapidly. Developments such as cloud computing are bringing about fundamental changes in the approach to computing, data storage and their interaction. Until recently, the combined computing and data storage needs associated with the SKA would have required setting up a dedicated joint co-located storage & computing infrastructure, but for certain applications cloud based solutions are becoming an attractive proposition.
In Task 2.1 we will perform a survey of available and planned facilities in order to compile an inventory of relevant infrastructures that could become part of the ESDC. The forward look is particularly important, because SKA construction will only start in 2018-2019, and the first data will not be available until 2020-2021. Information will be collected by the AENEAS partners and stakeholders (e.g. through European entities such as ILT, JIV-ERIC, EVN & RadioNet) in their own country/network based on available information plus additional interviews and correspondence. EGI will provide information through its network of 54 countries involved in the EGI federation. GEANT will base its input on the GEANT service catalogue. We will approach commercial providers of computing, data storage and networking services with a view towards assessing whether they can form part of an ESDC. The Research Data Alliance (RDA) is an international member organisation that is working to develop and implement a global infrastructure to facilitate data sharing and re-use. Through its working groups and at twice-yearly plenary meetings, AENEAS will have access to a growing global community engaged in facilitating cross-disciplinary coordination of data infrastructure that bridges across countries, disciplines, scales and technologies.
AENEAS partners will send experts to relevant RDA working groups, or, in collaboration with RDA, set up new working groups. Due to the iterative nature of this research, it is at proposal stage not clear what working groups will be optimal to contact, or create. Therefore, it is not possible to identify the experts necessary for the work. A budget to support these experts is reserved in the ASTRON budget.
The search will also reach out to other data-intensive application areas beyond (radio) astronomy and related fields. AENEAS partners have good links to EU-T0 and various national initiatives (UK-T0 and LSDMA in DE); EUDAT/ European Open Science Cloud; ETP4HPC, PRACE; CERN, ESS, MAX IV.
There is a risk that the information gathered is too varied and not uniform and therefore difficult to integrate and compare. This will be countered by setting an early internal milestone to ensure consistent input. It is possible that the forward look to 2021 and beyond will be patchy and incomplete. If this is the case, we will extrapolate the short term plans using scenarios informed by technology roadmaps. T2.1 will be successful if a homogeneous inventory can be completed in the first year of the project.

T2.2 User community requirements of a European SKA Science Data Centre
Partners: ASTRON (lead), Chalmers
Task 2.2 will engage with SKA Science Working Groups and general users to establish a set of user requirements for the ESDC. Special attention will be paid to look beyond the established community and reach out to non-experts and users from (in particular European) non SKA-member countries. Coordination with the SKAO to engage communities that have expressed an interest in joining the SKA project will take place, but we will also endeavour to look beyond and attract the interest from users (as yet) unlikely to join. There will be a Users Committee to provide guidance to the ESDC, and the survey described here is intended to scope out the ESDC ambitions. The plan is for the users to have a strong sense of ownership and the requirements document will be kept alive and evolve as understanding within the user community develops, improves and changes. A widely advertised survey in the form of an on-line questionnaire will be carried out by ASTRON and Chalmers (in the first 9 months). Community input will be sought through announcements at large conferences such as the European Week of Astronomy and Space Science, national equivalents and other meetings, as well as through European and national and institutional distribution channels. Input for the survey will consist of a draft user requirements document and a number of example use cases. The questionnaire will be followed by a workshop where a selection of respondents will be asked to help develop and discuss the user requirements document in more detail (in month 15) – we will use the opportunity to complete initial membership of an AENEAS Users Committee with a broad base in European astronomy. The first official release of the ESDC user requirements document will be complete in month 18. Updates will be initiated as and when the need arises.
The involvement of the national radio astronomy centres (ASTRON, Onsala Observatory/Chalmers, University of Manchester, INAF, etc.) as well as through European level entities such as ILT, JIV-ERIC, EVN and RadioNet will give us access to an active community of users that will help identify the long term strategic objectives. Linking up with WP3.1 will be important. Early input from WP5.1 will be gathered. Depending on the outcome WP5.1 and other work in WP3 and WP5 may trigger a later update of the user requirements.

T2.3 Governance and Business models for a European SKA Data Centre
Partners: ASTRON (lead), Chalmers, INAF, UMAN, UCAM,
Stakeholders: SKAO, STFC, MPIfR, JIV-ERIC, ILT, Jülich, CNRS, UNIGE, IT, CSIC
Based on the ESDC design developed in T2.4, T2.3 will produce a suitable organisational and governance model for a distributed European SKA Science Data Centre. The partners and stakeholders will also seek to identify realistic sources of sustainable funding for the ESDC. In close collaboration with the SKA Organisation and its successor the SKA Observatory (an international treaty organisation for which negotiations between SKA Member governments are currently underway), aspects of data access and possible legal implications will also be addressed.
The resources that will be incorporated into the ESDC will most likely be many and varied, ranging from (academic) computer/data centres to commercial cloud providers. Service level agreements – or similar arrangements – will be needed to guarantee the availability of the infrastructure. It seems likely that these agreements will be concluded by one (or more) contracting parties in each of the ESDC/SKA member countries.
As part of T2.3, we will draw up rules that can be incorporated into the various agreements and define a suitable structure for the management of the resources, make plans for further expansion of the ESDC over time and possibly develop new techniques and tools to enhance the services provided to the users. The governance structure will reflect the financial commitments (whether in-cash or in-kind) provided by the parties and will also retain the strong sense of ownership by the user community.
Starting point for T2.3 will be the ESDC design developed in T2.4. Organisations from each of the participating countries will investigate the feasibility of options that meet an achievable combination of specifications and cost. Regular meetings between national representatives will be scheduled to discuss progress, find a suitable compromise between cost and capability and seek to align ESDC development and resources with the SKA construction and operations schedule.

T2.4 Design Study of a European SKA Science Data Centre
Partners: ASTRON (lead), Chalmers, INAF, UMAN, UCAM, EGI.eu, GÉANT LTD, RDA
Stakeholders: SKAO, STFC, MPIfR, JIV-ERIC, ILT, Jülich, CNRS, UNIGE, IT, CSIC
The final deliverable of the AENEAS project will be a design study for a European SKA Science Data Centre. The study will be produced in Task 2.4 and will be based on information gathered in T2.1, T2.2 and WP 3-6. In order to provide structure and guidance to the work in the AENEAS project and also in discussions with the SKA Organisation and other SKA members, regular releases are planned, gradually incorporating more results. Together with the operational requirements that may be derived it will be a starting point for the discussions on Governance and Financial support that will be explored in T2.3.

Participation per Partner

Partner number and short name	WP2 effort
1 - ASTRON	12.00
2 - UMAN	1.00
3 - UCAM	1.00
4 - INAF	2.00
5 - CHALMERS	2.00
6 - GEANT LTD	2.00
7 - EGI.eu	2.00
Total	22.00

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D2.1	Inventory of potential ESDC resources	1 - ASTRON	Report	Public	12
D2.2	ESDC User Requirements	1 - ASTRON	Report	Public	18
D2.3	ESDC Design Study	1 - ASTRON	Report	Public	33
D2.4	ESDC (preliminary) implementation plan	1 - ASTRON	Report	Public	36

Description of deliverables

D2.1 : Inventory of potential ESDC resources [12]
Final Inventory - after review & selection of the most suitable options.

D2.2 : ESDC User Requirements [18]
ESDC user requirements document

D2.3 : ESDC Design Study [33]
ESDC Design Study - Final Version

D2.4 : ESDC (preliminary) implementation plan [36]
ESDC (preliminary) implementation plan

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS3	Preliminary input of inventory survey due, to provide guidance in order to align level of detail.	1 - ASTRON	6	Preliminary input of inventory survey due, to provide guidance in order to align level of detail.

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS11	List of possible regional site locations	6 - GEANT LTD	9	List of possible regional site locations
MS28	Feedback to WP2 on policy options	1 - ASTRON	20	Feedback to WP2 on policy options

Work package number [9]	WP3	Lead beneficiary [10]	2 - UMAN
Work package title	Computing Requirements		
Start month	1	End month	36

Objectives

WP3 will identify and assess the components necessary to bring about a European Science Data Centre, both in hardware and software, from a total science delivery perspective (it is therefore complementary to WP5 which addresses the needs from the perspective of the individual user). The focal questions are "What does the ESDC need to do to maximise European science delivery from the SKA?" and "how can we build such a science data centre, and at what cost?" This WP will develop a set of recommendations for the design of the ESDC pertinent to its data handling strategy, scientific functionality and software environment. We will also produce a high level architectural design for the ESDC and a sizing and costing estimate. In order to show that the resulting ESDC vision is credible, these recommendations will be supported by verification work, including both theoretical analyses and direct prototyping of critical elements using SKA pre-cursor data and a range of representative scaleable systems, with gaps or risks highlighted and recommendations made with respect to mitigation.

Description of work and role of partners

WP3 - Computing Requirements [Months: 1-36]
UMAN, ASTRON, UCAM, INAF, CHALMERS, EGI.eu, Juelich, STFC, CSIC, IT, EPFL, UNIGE
T3.1 ESDC Processing: Inventory of SKA science cases and post-SDP computing requirements
Partners: UCAM (lead), INAF, CSIC
Stakeholders: VUW
The SKA has developed a list of 13 High-Priority Science Objectives (HPSOs) which are being used to generate survey strategies for the SKA in its first several years of observations. These are large projects with many thousands of observing hours each. Since these will be made up of tens to hundreds of separate data sets substantial processing and manipulation of the SKA data products will be required in the regional data centres to deliver the survey science at anticipated fidelity. This task will focus specifically on the delivery of these key experiments and their compute processing requirements, and provide a basis on which to proceed with the sizing and costing efforts.
Once these large surveys are complete, enormous benefits will be available if we can combine data from other observatories (e.g. LSST, Euclid). Using results and insights from the Asterics programme we will make estimates for ESDC resources needed to support these efforts and maximise scientific return on the ESFRI astronomy projects.
Further work will investigate whether specific Science Use Cases (more representative of open time programmes) could have significantly different ESDC compute requirements. We will also consider the options for “Discovery Products” which would be generic products not covered by specific experiments, but piggy-backing on observing time.
Cambridge will bring significant expertise in SKA processing and use expectations whilst the input from INAF and VUW will be from precursor astronomy experiments and SKA Science Working Groups – giving good access into the radio astronomy community.
The output of this task will be a series of system-sizing and functional requirements to appear in deliverable 3.1.
Within the AENEAS project there will be a need to coordinate with T2.2 – to prevent duplication and make use of the already available information on the 13 High Priority Science Objectives.

T3.2 ESDC Data storage: Inventory and sizing of SKA science data products and ESDC user-derived products
Partners: UCAM (lead), ASTRON, INAF, CSIC
Stakeholder: VUW
SKA will provide a well-defined set of data products but the total volume of these data products arriving into the ESDC will depend greatly on the details of the key science programmes and open time programmes undertaken. This task will assess the data storage requirements from a European perspective, considering the type, size and volume of SKA- and ESDC user-derived data products.
This task will also analyse the data access patterns that might be expected for the ESDC. Additionally, we will assess storage requirements from other observatories as well.
In addition to the expertise in task T3.1, ASTRON bring relevant expertise in LOFAR data processing and long term preservation.
The output of this task will be a series of data storage and functional requirements to appear in deliverable 3.1. There are again cross-links with T2.2 and the User Requirements produced by WP 2.2..

T3.3 Evaluation of existing HPC, cloud and distributed computing technologies
Partners: UCAM (lead), STFC, EGI, EPFL, ASTRON, Chalmers, CSIC, IT
Stakeholders: SNIC
This task will enumerate the key elements needed for the software infrastructure required for the ESDC, and evaluate options for fulfilling them, these include:
1) Middleware – i.e. infrastructure to support distributed compute models within, for example a cloud-like environment although also including HPC facilities. Different software products and middleware solutions for allowing access to distributed computing facilities and capabilities will be analysed and compared to the data analysis requirements collected in Tasks T3.1 and T3.2. This will include products and solutions for compute (cloud compute, HTC (High Throughput Computing), HPC (High Performance Computing) and container-based cloud compute).
This will include an evaluation of OpenStack, and other cloud middleware stacks with the aim of ensuring portability of data and applications in the distributed environment to be implemented in the ESDC. It will also include an analysis of available replica management and data transport organisation tools such as PHEDEX & PANDA.
2) Elements required for a federated ESDC, including services. The ESDC must provide resources to users in a way which combines many different computing resources but presents these in a harmonized way to each user, and which can validate users' requests for data access and keep accounts of computing and storage resources for each user or use group, while avoiding un-necessary data movement between sites. Some of this federation functionality may be present in a selected middleware layer, but other aspects may not and these must be considered: for example Authentication and Authorization Infrastructure (AAI), efficient movement of data based on policies; integration with HPC software stacks so that (as needed) the ESDC is able to utilise HPC resources for processing; accounting elements and ensuring proper and fair use of resources.
3) The top-level software stack providing an environment for efficient distributed analysis of data – the task should certainly look at the possibility of building on top of industry-standard Big Data / data-science stacks such as Spark (now beginning to take over from Hadoop).
The deliverable of this task will be D3.2: "Report on suggested solutions to address each of the key software areas associated with running a distributed ESDC", which will include a list of options, each assessed for suitability.
There are a number of different contributors to this task, which ensures good coverage of the technical areas. UCAM's contribution will include Coles (production manager for GridPP, the UK particle physics compute network); STFC likewise have expertise in distributed HPC, EGI (leaders of WP6) have knowledge of current and forthcoming federation methodologies. CSIC bring experience porting different astronomical software packages onto a range of HPC systems.

T3.4 Design and costing for distributed ESDC computing architecture
Partners: UCAM (lead), STFC, EGI.eu, EPFL, ASTRON, CSIC, IT
Stakeholders: SNIC
Based on input from the evaluations in D3.1 and D3.2 this task will provide a top-level architecture and functional design for the ESDC.
To proceed we will make use of the inventory of national roadmaps from WP2 (D 2.1) and determine the potential for incorporation / co-use of existing or planned facilities to achieve economies of scale.
We will develop a costing of additional resources needed (over and above existing facilities) to bring about a functioning ESDC, considering the full SKA observatory lifecycle from commissioning as the SKA is built and well into full operations as the SKA observatory develops and undergoes upgrade cycles.
The outputs of this task will be a 1) A preliminary system sizing estimate (D3.3) and 2) a documented design for a ESDC model, to appear in (D3.4).

T3.5 Requirements for interfaces to SKA Science Archives & Other Repositories
Partners: UMAN (lead), INAF, STFC, CSIC
Stakeholders: VUW
This task performs technical evaluation of interface requirements that impact ESDC compute.
The work in this task includes the assessment of existing policies for interactions between science facilities and data centres, incorporating an evaluation of policy items with respect to their technical applicability in the SKA case, as well as a gap analysis for SKA-specific needs. This technical assessment will feed into more general policy recommendations via a joint milestone with WP2 (M3.5.2.1).
The ESDC will incorporate multiple interfaces, both functional and digital (data IO). This task will assess the requirements both for ensuring controlled and managed ingest of data across these interfaces, and of the subsequent storage strategy. This requires an assessment of existing data-moving tools and protocols (commercial and academic – for example WLCG (Worldwide LHC Computing Grid), their compatibility with an ESDC architecture, as well as verified assessments of data ingest from global sources including the SKA Science Data Processors, other nodes within the ESDC, and external archives (e.g. LSST, EUCLID, JWST etc). It will also ensure the compatibility of recommended

ESDC standards with the widely used VO standards. In doing this it will also form recommendations on minimum meta-data requirements for ESDC-held data, in line with analyses from the ASTERICS project.
A major functional interface within an ESDC will be the mapping of user specifications onto data processing work flows, from ingest to delivery. This mapping should incorporate both a translation between user-defined parameters (data product specific) and processing parameters (function specific) as well as the impact of different parameter choices mapped onto different types of compute system (data access patterns, distribution of processing etc). This task will also inform policy decisions governing the persistence of user work-flows to enable reproducibility of results or regeneration of data.
The output of this task will be deliverable D3.5.
The work in this task builds on domain specific experience at UMAN in data networks for existing international facilities and involves input from INAF, who lead WP5 and have extensive experience in user interfaces and VO compatibility. STFC and VUW bring in wide-ranging expertise in data ingest to distributed systems from scientific facilities and external archives.

T3.6 Validation, Verification & Proof of concept activities utilizing SKA pathfinder and pre-cursor facilities
Partners: UMAN (lead), UCAM, Chalmers, STFC
Stakeholders: VUW
This task contains the technical work required to verifying the design recommendations developed for the ESDC in T3.1 - T3.5 using, where appropriate, data from precursor and pathfinder instruments.
The work in this task includes the provision of a standardised set of appropriate test data, incorporating output from existing facilities and pathfinder instruments. The task also includes the provision of prototype software blocks to verify and validate the functional requirements derived in T3.3, as well as the incorporation of these software blocks into pilot workflows to verify recommendations in T3.3 on applicability of different middleware environments. This work will specifically address the potential distribution of functionality, given a particular processing need, as well as the required data access patterns and the evaluation of appropriate replica managers. This work will contribute to deliverable D3.3.
This task will provide technical effort to address a number of technical interface requirements between WP3 and WPs 4&5. This task will verify that user interface requirements from WP5 can be mapped effectively to workflow models for ESDC processing needs (see Table 3.22), as well as evaluating the ingest requirements are met for data transfers utilising data moving tools assessed jointly between WP3 and WP4 (joint milestone). These joint milestones will contribute to deliverable D3.4 as well as deliverables in WP4 & WP5.
Furthermore, this task will provide technical work to verify the scaling of critical elements for the system sizing in T3.4. This will involve prototyping system elements identified as critical by T3.4 and verifying the sizing of these elements. This work will contribute to deliverable D3.4.
This task is built upon extensive expertise at UMAN, UCAM & VUW in prototyping of SKA processing as part of the SKA SDP project, as well as in software development for existing instruments (such as LOFAR) at Chalmers. It also draws upon expertise in distributed and HPC processing at STFC.

Participation per Partner

Partner number and short name	WP3 effort
1 - ASTRON	11.00
2 - UMAN	12.00
3 - UCAM	11.00
4 - INAF	15.00
5 - CHALMERS	8.00
7 - EGI.eu	4.00
9 - Juelich	9.00
11 - STFC	6.00
12 - CSIC	3.00
13 - IT	6.00
20 - EPFL	3.00

Partner number and short name	WP3 effort
21 - UNIGE	3.00
Total	91.00

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D3.1	Analysis of compute load, data transfer and data storage anticipated as required for SKA Key science	2 - UMAN	Report	Public	21
D3.2	Report on suggested solutions to address each of the key software areas associated with running a distributed ESDC	2 - UMAN	Report	Public	24
D3.3	Preliminary System sizing report	2 - UMAN	Report	Public	24
D3.4	Report on design & costing for ESDC	2 - UMAN	Report	Public	36
D3.5	Report on suggested solutions to interface requirements for a distributed ESDC	2 - UMAN	Report	Public	36

Description of deliverables

D3.1 : Analysis of compute load, data transfer and data storage anticipated as required for SKA Key science [21]

Analysis of compute load, data transfer and data storage anticipated as required for SKA Key science

D3.2 : Report on suggested solutions to address each of the key software areas associated with running a distributed ESDC [24]

Report on suggested solutions to address each of the key software areas associated with running a distributed ESDC

D3.3 : Preliminary System sizing report [24]

Preliminary System sizing report

D3.4 : Report on design & costing for ESDC [36]

Report on design & costing for ESDC

D3.5 : Report on suggested solutions to interface requirements for a distributed ESDC [36]

Report on suggested solutions to interface requirements for a distributed ESDC

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS2	Preliminary functionality assessment	2 - UMAN	4	Preliminary functionality assessment
MS10	Joint Milestone (WP4) on data moving applications & tools	2 - UMAN	9	Joint Milestone (WP4) on data moving applications & tools
MS12	Analysis of compute load, data transfer and data storage anticipated as required for SKA Key science	2 - UMAN	10	Analysis of compute load, data transfer and data storage anticipated as required for SKA Key science
MS13	Detailed schedule of anticipated SKA-related data products and their storage requirements	2 - UMAN	10	Detailed schedule of anticipated SKA-related data products and their storage requirements
MS14	Middleware FoM review	2 - UMAN	12	Middleware FoM review
MS15	Top-level software FoM review	2 - UMAN	12	Top-level software FoM review
MS16	Full functionality assessment	2 - UMAN	12	Full functionality assessment
MS17	Test data sets available	2 - UMAN	12	Test data sets available
MS20	Joint Milestone (WP4) on SKA Sci DMZ recommendations	2 - UMAN	14	Joint Milestone (WP4) on SKA Sci DMZ recommendations
MS21	Best practice recommendations Data moving applications, protocols and storage	6 - GEANT LTD	14	Best practice recommendations Data moving applications, protocols and storage
MS22	Specification for SKA Science DMZ	6 - GEANT LTD	14	Specification for SKA Science DMZ
MS23	Performance required to enable synergistic science incorporating multi-wavelength surveys	2 - UMAN	15	Performance required to enable synergistic science incorporating multi-wavelength surveys
MS25	radio astronomy data over global routes from South Africa to Europe	6 - GEANT LTD	18	radio astronomy data over global routes from South Africa to Europe
MS26	Initial System Sizing	2 - UMAN	19	Initial System Sizing
MS27	Joint Milestone (WP4) on demonstration of moving data from observatory sites (SA) to ESDC	2 - UMAN	19	Joint Milestone (WP4) on demonstration of moving data from observatory sites (SA) to ESDC
MS28	Feedback to WP2 on policy options	1 - ASTRON	20	Feedback to WP2 on policy options
MS30	Joint Milestone (WP4) on data replica manager	2 - UMAN	21	Joint Milestone (WP4) on data replica manager

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS31	Specifications for SKA Replica Manager	6 - GEANT LTD	21	Specifications for SKA Replica Manager
MS32	Joint Milestone (WP5) demonstration of compatibility of user interface specification with example work flow models	2 - UMAN	24	Joint Milestone (WP5) demonstration of compatibility of user interface specification with example work flow models
MS33	Joint Milestone (WP4) on demonstration of moving data from observatory sites (AUS) to ESDC	2 - UMAN	24	Joint Milestone (WP4) on demonstration of moving data from observatory sites (AUS) to ESDC
MS36	Report on Data Transport ESDC within Europe	6 - GEANT LTD	28	Report on Data Transport ESDC within Europe
MS37	radio astronomy data over global routes from Australia to Europe	6 - GEANT LTD	30	radio astronomy data over global routes from Australia to Europe
MS38	Joint Milestone (WP5) on consolidation of outputs from WP5.3 with WP3.5.6.1	2 - UMAN	31	Joint Milestone (WP5) on consolidation of outputs from WP5.3 with WP3.5.6.1
MS39	Joint Milestone (WP5) demonstration of interface data specification compatibility with VO standards	2 - UMAN	31	Joint Milestone (WP5) demonstration of interface data specification compatibility with VO standards
MS40	Joint Milestone (WP4) on demonstration of moving data within ESDC	2 - UMAN	31	Joint Milestone (WP4) on demonstration of moving data within ESDC

Work package number [9]	WP4	Lead beneficiary [10]	6 - GEANT LTD
Work package title	Analysis of Global SKA Data Transport and Optimal European Storage Topologies		
Start month	1	End month	36

Objectives

WP4 will investigate and demonstrate the data transfer and storage techniques required for the network design of the SKA Regional Centres, and hence confirm the viability of a distributed computing and network architecture for a European Science Data Centre (ESDC). It will seek to build on existing work in use in other areas of science, such as the Particle Physics community, and the services available from the European e-Infrastructures.

The work will also collaborate with the SKA host countries South Africa and Australia, where the telescopes will be located, to address the challenges of moving large volumes of data produced at the Telescopes over global distances to the Regional Centres. This will take the form of Proof of Concept tests between the National Research Networks SANReN in South Africa, AARnet in Australia, and GEANT in Europe as well as moving data between Radio Astronomy end sites to demonstrate science global interoperability and support the work of WP3.

The network tasks will reach up the stack to include study of data access protocols, data transfer protocols, replica and transfer management, and data moving applications as well as some network level investigations. This would support other areas in the project like the retrieval/access of archive data, and storage facilities for data products or collections, on which the processing and physics analysis rely.

The output of WP4 will be design and best practice recommendations for the construction of the networking, data transfer and storage required to construct an ESDC together with cost model for European and Global connectivity.

Description of work and role of partners

WP4 - Analysis of Global SKA Data Transport and Optimal European Storage Topologies [Months: 1-36]
GEANT LTD, UMAN, INAF, CHALMERS, Juelich
Within this Work Package AARNet, CSIRO and SANReN will contribute their expertise and make hardware available for the investigations of data transfer protocols, applications and the interactions between network and storage sub-systems. MPIfR and IT will provide access and help with file systems and data replica managers and the required inter-play between applications and the networks.

T4.1 Evaluation of existing data transfer protocols, storage sub-systems and applications
Partners: Chalmers (lead), GÉANT LTD, Jülich, INAF, UMAN
Stakeholders: CSIRO, IT, SANReN
The aim of this task is to investigate and evaluate the existing data transfer protocols and applications over both European and global distances, in order to select those suitable to support the high performance long distance data transfers required by the SKA computing models.
It will also build on the work of the ESFRI and other science projects, such as Bio Informatics and LHC to survey and evaluate data replica and data transfer managers, file systems and storage sub-systems. This work will be at the detailed technical level complementing and supporting the work of WP3.3 which is examining this middleware from the computing requirements aspects.
It will examine the ability of modern end hosts with server quality motherboards to utilise 10, 40, and 100 Gigabit Ethernet network and storage sub-systems with modern disk technologies and file systems to provide understanding of how to overcome any limitations of these network and disk I/O sub-systems. It will produce guidelines and techniques to cover performance aspects such as ensuring that the NIC driver interrupts and the application threads are handled by the correct CPU cores.
It will evaluate the performance of various protocols such as UDP, TCP and Remote Direct Memory Access (RDMA) together with the possible data applications required by SKA for the access and transfer of data. The technical work at this level will feed into the transfer tool assessments, being performed by WP3, of existing data-moving tools and protocols to meet the data access patterns that might be expected for the SKA data processing.
The task will explore the new capabilities available from Software Defined Networking for allowing the applications to access the data via fine-grained traffic handling and data flow management.
The outputs of this task will include technical notes that will form the milestones M6, M7 covering evaluation of existing data transfer protocols, data moving applications, storage sub-systems, and data replica managers. Some of this information will provide support for other work packages in the form of joint milestones M21 with WP3.

The deliverable D4.1 will give a set of best practice recommendations to optimise network and storage performance that will feed into the overall design of the ESDC in WP2.

Planned liaison and discussions with WP3 on the distributed computing required will enable definition of the network requirements such as Data rates, Traffic profiles, bandwidth and time for delivery together with the acceptable tolerances or ranges of these characteristics. This input will facilitate the definition of the tests of the protocols to verify that they will support the ESDC requirements. Tests at the network transport level will include measurements of network characteristics including packet loss, achievable bandwidth and round trip time variations over representative network paths e.g. across GÉANT and NRENs to existing data centres and between South Africa and Australia and Europe.
The evaluation of the application and data replication protocols will first analyse the experience of existing user communities (LHC, Bio-Informatics) and, in collaboration with WP3, perform tests to measure consistency of the required data throughput and replications times using representative data sets and file sizes. These evaluations link together the work of WP3, WP4.1 and WP4.4; the evaluation process will be documented to provide a methodology for any future testing that may be required should the networks or requirements change.

T4.2 Inventory of the storage and network capabilities of existing and planned European Facilities for SKA
Partners: INAF (lead), GÉANT LTD
Stakeholders: ASTRON, IT
In agreement with sites in Europe, this task will collect technical information on the network topology, the connectivity of the site, and details of the storage technology in use at each site to form an inventory of capabilities.
This task will use the work of WP2.1 to provide an initial list of the possible locations across Europe that could act as sites for the SKA ESDC. It is expected that these sites would include existing and proposed radio astronomy centres as well as e-infrastructure locations. These sites would contain suitable equipment to facilitate network connectivity, data storage, and computations as well as acting as focal points for the astronomy community.
The output of this task will be D4.2 an online catalogue of the technical capabilities of each site which will facilitate the selection and incorporation of the sites into the ESDC to provide the capabilities required by European researchers to extract science from the SKA data products.

T4.3 Optimized design and cost model for a distributed ESDC data topology with world connectivity
Partners: GÉANT LTD (lead), INAF, Chalmers, UMAN
Stakeholders: AARNet, CSIRO, SANReN, IT
This task will have close links with work packages WP3 and WP5 to establish the network requirements of the ESDC. The outputs of this task will feed into the overall design of the ESDC led by WP2.
The task will work with the European and global National Research and Education Networks (NRENs) as well as international submarine cable operators and ISPs to:
- Design and produce specifications for a suitable network infrastructure to support both internal and remote access to the storage and Data Transfer Nodes at the sites making up the ESDC, milestone M20. It is expected this will take the form of a De-Militarised Zone (DMZ) at the sites, thus maintaining site security but enabling reliable high performance data access.
- Assess the capability and use of Software Defined Networking to provide operational flexibility for virtual networks in the distributed data centre environment.
- Design and evaluate a network topology for interconnecting the sites of a European, distributed Regional Centre. This work is expected to include appropriate use of technologies such as VRF, Point-to-Point links, SDN as well as the normal IP network.
- The work will also include liaising with the academic e-infrastructures to agree the operational procedures for the deployment of the network services with the NRENs and academic network providers involved.
- Design and produce specifications for an SKA Replica Manager, milestone M31.
- Develop a world-wide network architecture for moving SKA data from the telescopes to archives at the Regional Centres and hence to the European and international end-user community.
- Provide indicative cost models and estimates of the European and global inter-continental links with the appropriate bandwidth.

The main outputs will be deliverable D4.3, Architecture and cost model for European ESDN network, and deliverable D4.4 an Architecture and cost model for World-wide network for SKA.

T4.4 Proof of Concept Activities supporting the design of data access and transport within Europe and from the Host countries to Europe
Partners: GEANT LTD (lead), Chalmers, UCAM, UMAN
Stakeholders: AARNet, CSIRO, JIV-ERIC, SANReN, IT

Working with the partner sites, the NRENs, and e-Infrastructures and using existing infrastructure wherever possible, this task would set up suitable long distance paths both across Europe and globally utilizing SKA pathfinder and precursor facilities to enable the required PoC tests.
The preliminary specifications for a Science DMZ from WP4.3 will be tested by implementing them as a pilot at an AENEAS partner site. This work will facilitate discussion of the suggested security policies for Science DMZ as well as demonstrating the performance benefits to the Radio Astronomy community. Together with input from established e-science computer centres, output of this PoC will be used by WP4.3 to complete the specifications for an SKA Science DMZ.
The PoC testing of Data Transfer capability and performance within Europe will start by evaluating the data transfer performance with the tuning recommendations of WP4.1 between Data Transfer Nodes located in the GÉANT backbone and those in likely ESDC sites. This will be followed by comprehensive tests between storage located at the possible ESDC sites. This supports a joint milestone M4.4.1 with WP3.6 for the verification of science Data Transported between ESDC within Europe, and reinforces the design recommendations of WP4.3.
Two further PoC will reinforce the objective of enhancing the collaboration with the SKA host countries South Africa and Australia and Europe by addressing the challenges of moving large volumes of SKA data produced at the Telescopes over global distances to the Regional Centres. Tests will be made between Data Transfer Nodes located in the GÉANT backbone and those in AARNet and SANReN and then between storage located at remote radio astronomy sites and possible ESDC sites. This demonstration of moving or accessing (emulated) radio astronomy data over global routes from the telescopes to Europe will form joint milestones M4.4.3 and M4.4.5 with WP3 to support the work of WP3.6.

Participation per Partner

Partner number and short name	WP4 effort
2 - UMAN	6.00
4 - INAF	1.00
5 - CHALMERS	20.00
6 - GEANT LTD	22.00
9 - Juelich	9.00
Total	58.00

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D4.1	Best practice Data transport and storage	6 - GEANT LTD	Report	Public	14
D4.2	Site Catalogue storage and networking	6 - GEANT LTD	Websites, patents filling, etc.	Public	18
D4.3	ESDN network architecture and costing	6 - GEANT LTD	Report	Public	27
D4.4	Global network architecture and costing	6 - GEANT LTD	Report	Public	32
D4.5	Data Transport Tests and Recommendations	6 - GEANT LTD	Report	Public	34

Description of deliverables

D4.1 : Best practice Data transport and storage [14]
Best practice recommendations Data moving applications, protocols and storage
D4.2 : Site Catalogue storage and networking [18]
Site Catalogue of the storage and network capabilities
D4.3 : ESDN network architecture and costing [27]
Architecture and cost model for European ESDN network
D4.4 : Global network architecture and costing [32]
Architecture and cost model for World-wide network for SKA
D4.5 : Data Transport Tests and Recommendations [34]
Report on Data Transport Tests and Recommendations

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS6	Protocols and end hosts evaluation	6 - GEANT LTD	7	Protocols and end hosts evaluation
MS7	Storage sub-systems evaluation	6 - GEANT LTD	8	Storage sub-systems evaluation
MS10	Joint Milestone (WP4) on data moving applications & tools	2 - UMAN	9	Joint Milestone (WP4) on data moving applications & tools
MS11	List of possible regional site locations	6 - GEANT LTD	9	List of possible regional site locations
MS19	Data transfer test South African site to European site	6 - GEANT LTD	13	Data transfer test South African site to European site
MS20	Joint Milestone (WP4) on SKA Sci DMZ recommendations	2 - UMAN	14	Joint Milestone (WP4) on SKA Sci DMZ recommendations
MS21	Best practice recommendations Data moving applications, protocols and storage	6 - GEANT LTD	14	Best practice recommendations Data moving applications, protocols and storage
MS22	Specification for SKA Science DMZ	6 - GEANT LTD	14	Specification for SKA Science DMZ
MS25	radio astronomy data over global routes from South Africa to Europe	6 - GEANT LTD	18	radio astronomy data over global routes from South Africa to Europe
MS27	Joint Milestone (WP4) on demonstration of moving data from observatory sites (SA) to ESDC	2 - UMAN	19	Joint Milestone (WP4) on demonstration of moving data from observatory sites (SA) to ESDC
MS30	Joint Milestone (WP4) on data replica manager	2 - UMAN	21	Joint Milestone (WP4) on data replica manager
MS31	Specifications for SKA Replica Manager	6 - GEANT LTD	21	Specifications for SKA Replica Manager

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS33	Joint Milestone (WP4) on demonstration of moving data from observatory sites (AUS) to ESDC	2 - UMAN	24	Joint Milestone (WP4) on demonstration of moving data from observatory sites (AUS) to ESDC
MS35	Data transfer test Australian site to European site	6 - GEANT LTD	27	Data transfer test Australian site to European site
MS36	Report on Data Transport ESDC within Europe	6 - GEANT LTD	28	Report on Data Transport ESDC within Europe
MS37	radio astronomy data over global routes from Australia to Europe	6 - GEANT LTD	30	radio astronomy data over global routes from Australia to Europe
MS40	Joint Milestone (WP4) on demonstration of moving data within ESDC	2 - UMAN	31	Joint Milestone (WP4) on demonstration of moving data within ESDC

Work package number [9]	WP5	Lead beneficiary [10]	4 - INAF
Work package title	Access and Knowledge Creation		
Start month	1	End month	36

Objectives

This work package (WP5) is focused on the interface between a distributed European SKA Data Centre (ESDC) and a distributed body of end users whose goal is the exploitation of SKA data for knowledge creation. WP5 will therefore study the design of "user interaction models" that could be implemented for the ESDC.

All astronomical facilities have a system for user interactions and these models vary, depending on a very wide range of factors, including: the physical nature of the facility (maturity, location, distributed or single site); volumes/types of data produced; level of compute processing/storage required; range of science missions supported; size and nature of the user community; facility access policies (Open Skies, consortium, single institution); levels of available resources; and many other considerations.
These factors may both influence the physical design of the ESDC (via user-driven requirements based on science missions) and be constrained by technical realities of the physical infrastructure. Clearly the design of an ESDC requires a system view that encompasses consideration of data transfer, data storage, data processing, and user interaction requirements/limitations, in order to be optimized.

Thus, the objectives for WP5 are:
- to closely connect with the other two primary technical work packages, WP3 and WP4, in order to ensure that the design of an ESDC is self-consistent across technical, scientific, and user-driven requirements and limitations;
- to survey the range of user interaction models currently in operation (task WP5.1), to determine the elements of existing user interaction models that work best and can be adopted (or plausibly scaled up) to a facility of the scale of the SKA;
- to identify the gaps in current experience required for an ESDC to deliver maximal knowledge creation from the SKA;
- to feed the user interaction model survey and gap analysis into WP3 and WP4 and be likewise guided by the outputs of WP3 and WP4 supporting an iterative design process to obtain a self-consistent system description for an ESDC;
- to examine the specific applicability of the Virtual Observatory Interoperability Framework in terms of an ESDC user interaction model;
- to estimate the resourcing requirements of an ESDC user interaction model and to examine aspects of training and education required within the ESDC user community, including the need to grow the ESDC user community beyond the current European SKA membership over time.

These objectives are encapsulated in a series of six work package tasks, described below. Each task has associated milestones and deliverables.

Description of work and role of partners

WP5 - Access and Knowledge Creation [Months: 1-36]
INAF, ASTRON, UMAN, UCAM, CSIC, CNRS
Task 5.1 Survey of existing user interaction models for large-scale radio astronomy facilities and integration of WP5 outputs into consolidated ESDC design study
Partners: INAF (lead), UMAN, UCAM, Chalmers, ASTRON, CNRS
Stakeholders: CSIRO, JIV-ERIC
A primary task for WP5 will be a survey of existing user interaction models for large-scale radio astronomy facilities. The emphasis will be on models currently operating in Europe (e.g. ALMA, EVN/JIVE) and/or SKA-relevant models (e.g. LOFAR, MWA, ASKAP, MeerKAT). A lesser but important component will be the analysis of well-known traditional user interaction models (e.g. ATCA, JVLA).
Deep expertise exists within the WP5 team to undertake this task: representatives of the UK, Swedish, and Italian nodes of the European ALMA Regional Centre; the Director of JIVE; the former Director of the MWA; the Head of Astrophysics at ASTRON; and long-standing expert users of all the major radio astronomy facilities in the world.
Liason with the SKA Organisation and consideration of their views in terms of the interfaces between the SKA and the ESDC will be important, including consideration of relevant SKA pre-construction activity. The WP5 team includes: high level members of SKA Science Working Groups; members of the SKA Data Centre Task Force; members of the SKA Board; and members of several of the SKA pre-construction consortia. Therefore, a high level and diverse range of information channels exist to the SKAO.

The survey (Deliverable D5.1) will seek to identify the important requirements of an ESDC from a user perspective (connecting with WP2.2 and D2.2). These elements may be adopted directly from existing user interaction models or may be scaled up from existing models to suit the SKA regime. An important gap analysis will result (Deliverable D5.2). The final deliverable from this task will be to collate all outputs from WP5 and integrate them into the overall AENEAS study report (D5.8).

Task 5.2 Recommendations for the design of user interfaces for data discovery, access, and retrieval
Partners: INAF (lead), UMAN, GÉANT LTD
Stakeholders: VUW
Based on the results of the survey and the gap analysis performed in WP5.1, recommendations will be made for the design of user interfaces for the discovery of data, data access, and data retrieval within an ESDC.
Data discovery, access, and retrieval by users will be key steps toward knowledge creation from SKA datasets. Identifying the appropriate datasets, understanding methods of access, and retrieving data to appropriate locations for processing/re-processing is likely to be a significant challenge to users on the scale of SKA data volumes across a distributed ESDC.
This process, which is generally linear in nature in traditional user interaction models, will need to be hierarchical, iterative, or both for the SKA, with very large datasets requiring different levels of processing and re-processing (perhaps in different locations) in order to abstract the data to the appropriate density of information for meaningful/efficient knowledge creation.
A close connection between these considerations and the technical approach to the physical and soft infrastructure of an ESDC exists, for example depending on how widely SKA data are distributed across Europe, along which dimensions data are distributed. (e.g. by science goal, observing mode, instrument, time), and where key processing pipelines are installed.
Thus, a close connection exists between these considerations and WP3/WP4. WP5.2 participants will also participate in WP3/WP4 tasks to ensure these connections are established and exercised.
The deliverable from this task will be a set of design recommendations for user interfaces for data discovery, access, and retrieval (Deliverable D5.3).

Task 5.3 Recommendations for the design of user interfaces for data processing, reprocessing, analysis, and visualization
Partners: INAF (lead)
Stakeholders: VUW, JIV-ERIC
Based on the results of the survey and the gap analysis performed in WP5.1, recommendations will be made for the design of user interfaces for data processing, reprocessing, analysis, and visualization for an ESDC.
Once users have discovered, accessed, and retrieved data of interest, and have conceptualized data processing plans, the plans will need to be implemented using data processing tools available to the user via the ESDC. These tools may be in the form of automated and/or configurable pipelines running on large-scale computing facilities (perhaps distributed facilities).
The tools themselves and their computing requirements are the subject of WP3. WP5.3 is concerned with the presentation of these tools to users via convenient interfaces. The design of user interfaces for data processing are highly coupled with the related interaction models, ranging from pipeline models, that require low levels of user interaction, to desktop models that require high levels of interaction. The interfaces should also support workflow management systems, sequenced pipeline processing and detailed monitoring, and diagnostics of workflows. In this case a survey on existing Scientific Gateways (SG) that are playing this role for DCI and HPC/HTC resources will be investigated.
Thus, a close connection exists between these considerations and WP3. WP5.3 participants will also participate in WP3 tasks to ensure these connections are established and exercised.
The deliverable from this task will be a set of design recommendations for user interfaces for data processing, reprocessing, analysis, and visualization (Deliverable D5.4).

Task 5.4 Integration with VO Interoperability Framework
Partners: INAF (lead), Cambridge, GÉANT LTD., CSIC, CNRS
This task is designed as an effort to explore one possible framework for implementing user interfaces relevant for WP5.2 and WP5.3, the Virtual Observatory (VO) architecture, within the ESDC. VO is starting to be established across astronomy and in some areas is defining “industry standards” for user interactions with astronomical data.
This exploration is not intended to pre-empt the design requirements under study in WP5.2 or WP5.3, but is intended to be receptive to the recommendations of WP5.2 and WP5.3 as they develop over the course of the project. WP5.4 will focus on determining if the current and future capabilities of VO can fulfil the needs of an ESDC in the areas of concern for WP5.2 and WP5.3 i.e. fill the gaps.
The use of VO tools may reach across experts internal to an ESDC (ESDC staff scientists, ESDC data quality analysts etc.) and ESDC users, spanning a wide range of required interaction modes with data, processing tools (and processing

resources), and visualization. As such, WP5.4 has an important link to WP3 and WP4, in terms of the overall physical and soft architectures for the ESDC.
Fundamental questions to pose in this exploration include: is VO the environmental approach radio astronomers would like to use? Is VO fit for purpose for the SKA? If not, could it be adapted/scaled? Would ESDC integration into a VO framework entail compliance with existing VO standards or require the definition of radio astronomical oriented standards in the scope of VO initiatives?
The deliverable from this task will be a report on the likely applicability of the VO framework for an ESDC at a range of levels in the system, but focused primarily at the user interface level (Deliverable D5.5).

Task 5.5 Recommendations for the resourcing of an ESDC user interaction model
Partners: INAF (lead), UMAN, Chalmers
Based on the results of the survey in WP5.1 and the recommendations/outputs from WP5.2, WP5.3, and WP5.4, we will estimate the resourcing required to realize the user interaction aspects of an ESDC. This will include consideration of the training required to produce a pipeline of suitably qualified individuals across Europe to staff an ESDC.
The range of skilled individuals required for an ESDC is likely to be very broad, reflected by the range of work packages and tasks described in this proposal. An important cohort of ESDC staff will be those on the frontline of interacting with users. These ESDC staff will likely have to be expertly familiar with the hardware and software environments of the ESDC, the capabilities of the SKA itself and the ESDC facilities, the science missions of the SKA, and the requirements of users as they pursue knowledge creation via the ESDC.
Thus, these ESDC staff will be the human interface between the technical and intellectual assets of the ESDC and the technical and intellectual assets of the SKA user community in Europe.
Experience shows that suitably qualified individuals in this area are relatively rare. A thumbnail calculation shows that an ESDC could quickly employ every such skilled individual in the world. This is clearly unrealistic, so this task will consider a calculation of the level of resourcing required in this cohort for an ESDC and, importantly, will develop recommendations for the ongoing training of individuals to fill the demand of an ESDC.
In order to guide users through SKA data processing and knowledge creation, such user support staff will require specific training in Big Data management, training in the use of large-scale computing facilities, astroinformatics, and high level software development.
The deliverable from this task will be a set of recommendations for the level of resourcing required in an ESDC to implement a user interaction model consistent with the findings of the overall AENEAS study (Deliverable D5.6).

Task 5.6 Recommendations for a plan of user community formation and knowledge distribution
Partners: INAF (lead), Chalmers
Based on the results of the survey, we will draft a plan that recommends user outreach methodologies required to allow the European SKA science community to grow.
The ESDC should aspire to grow beyond the current set of SKA member countries in Europe, allowing the maximum scientific return from European investments in the SKA across the continent.
Thus, a training program to educate and inform non-expert users should be implemented by the ESDC, which is a different concept to that dealt with in WP5.5 (although clearly related). Non-expert users may be from countries with little existing expertise in astrophysics in general or, most likely, may be expert astronomers from outside radio astronomy (from optical astronomy or high energy astrophysics, for example). Thus, an ESDC could play a major role in bringing SKA science together with other areas of multi-wavelength astrophysics in Europe.
The deliverable from this task will be a recommended strategy for the ESDC to grow the SKA science community in Europe well beyond the current SKA partners, delivering enhanced opportunities in a pan-European context (Deliverable D5.7).

Participation per Partner

Partner number and short name	WP5 effort
1 - ASTRON	12.00
2 - UMAN	6.00
3 - UCAM	6.00
4 - INAF	27.00
12 - CSIC	6.00

Partner number and short name	WP5 effort
14 - CNRS	0.00
OCA	2.00
Total	59.00

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D5.1	Survey report	4 - INAF	Report	Public	18
D5.2	Gap analysis	4 - INAF	Report	Public	18
D5.3	Design recommendations #1	4 - INAF	Report	Public	24
D5.4	Design recommendations #2	4 - INAF	Report	Public	24
D5.5	Applicability of VO framework	4 - INAF	Report	Public	28
D5.6	User interaction model resourcing	4 - INAF	Report	Public	28
D5.7	Growing the ESDC community	4 - INAF	Report	Public	28
D5.8	Final integration of WP5 materials	4 - INAF	Report	Public	34

Description of deliverables

D5.1 : Survey report [18]

Survey of existing user interaction models for traditional and next generation radio telescope facilities, with an emphasis on distributed service delivery models in a European context.

D5.2 : Gap analysis [18]

The gap analysis will be limited to an identification of gaps. Detailed analysis of the gaps will take place in the other tasks (WP5.2 to WP5.6) and will lead to recommendations in key areas.

D5.3 : Design recommendations #1 [24]

Recommendations for the design of user interfaces for data discovery, access, and retrieval for an ESDC

D5.4 : Design recommendations #2 [24]

Recommendations on the design of user interfaces for data processing, re-processing, analysis, and visualization for the ESDC

D5.5 : Applicability of VO framework [28]

Report on the potential for VO to be a central part of the ESDC software stack. Answering questions such as those above and addressing the recommendations from WP5.2 and WP5.3

D5.6 : User interaction model resourcing [28]

Report recommending the level of resourcing required for a user interaction model consistent with the findings of WP5.1, WP5.2, WP5.3, WP5.4, and WP5.6.

D5.7 : Growing the ESDC community [28]

Report recommending the elements of a user interaction model for the ESDC that will be required to grow the SKA science community in Europe beyond the current SKA membership.

D5.8 : Final integration of WP5 materials [34]

Final integration of WP5 materials into the ESDC design.

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS1	Definition of WP5.1 survey scope	4 - INAF	3	Definition of WP5.1 survey scope
MS4	WP5.1 survey data collected	4 - INAF	6	WP5.1 survey data collected
MS5	Define scope of WP5.4 VO report	4 - INAF	6	Define scope of WP5.4 VO report
MS8	WP5.1 survey discussion paper	4 - INAF	8	WP5.1 survey discussion paper
MS9	Consideration of WP5.1 survey discussion paper in WP5.2-6	4 - INAF	8	Consideration of WP5.1 survey discussion paper in WP5.2-6
MS18	Draft WP5.1 survey and gap analysis	4 - INAF	12	Draft WP5.1 survey and gap analysis
MS24	Initial elaboration of WP5.1 gap analysis in WP5.2-6	4 - INAF	15	Initial elaboration of WP5.1 gap analysis in WP5.2-6
MS29	Consideration of WP5.1 survey in WP5.2,3,5,6	4 - INAF	20	Consideration of WP5.1 survey in WP5.2,3,5,6
MS32	Joint Milestone (WP5) demonstration of compatibility of user interface specification with example work flow models	2 - UMAN	24	Joint Milestone (WP5) demonstration of compatibility of user interface specification with example work flow models
MS34	Address WP5.2 and WP5.3 considerations in WP5.4	4 - INAF	26	Address WP5.2 and WP5.3 considerations in WP5.4
MS38	Joint Milestone (WP5) on consolidation of outputs from WP5.3 with WP3.5.6.1	2 - UMAN	31	Joint Milestone (WP5) on consolidation of outputs from WP5.3 with WP3.5.6.1
MS39	Joint Milestone (WP5) demonstration of interface data specification compatibility with VO standards	2 - UMAN	31	Joint Milestone (WP5) demonstration of interface data specification compatibility with VO standards

Work package number [9]	WP6	Lead beneficiary [10]	7 - EGI.eu
Work package title	Services		
Start month	1	End month	36

Objectives

SKA data (re)processing, analysis and visualization will be delivered by the implementation of a worldwide network of SKA Regional Centres, which will require seamless access to a distributed web of research objects (datasets, applications, publications, computing resources etc.) provided via federated service management processes and tools for seamless delivery of end-to-end services.
The SKA community-specific services offered by the SRCs, will have to integrate with generic capabilities offered by external providers, like identity provisioning offered by the end-user home organizations and generic computing and data management capabilities operated by the national e-Infrastructures supporting the SKA users. These are already federated at national, European and international level as shown in Figure 6 below.

By adopting standards for service portfolio management, Task 6.2 “Interoperable Federated IT Service Management System” will define the AENEAS service portfolio, which is meant to provide capabilities delivered by the combination of relevant services from existing e-Infrastructure service catalogues, and Community Services delivering ad-hoc applications, pipelines and data products necessary to extract knowledge from SKA data. This will allow the leverage state of the art capabilities for compute, storage, data management, security and advanced network connectivity from e-Infrastructures, and complement these with new services specific to SKA.

Figure 6: Business relationships between SKA community services and generic e-Infrastructure services.

Purpose of this work package is to provide recommendations and define best practices on how to:
- organize federated service management within the ESDC and across multiple SRCs to address the management of the SKA community-specific services.
- federate the ESDC services with existing e-Infrastructure federated services (Identity Provisioning, Authentication and Authorization, tools for federated service management) to ensure interoperability between community and generic e-Infrastructure services.
- collect SKA and e-Infrastructures requirements to federate and eventually enhance existing federation services.

This WP will help establishing interoperability between existing e-Infrastructure AAI services, and between management processes and tools adopted by the SKA-relevant e-Infrastructures (see figure above). This activity will be carried out in collaboration with other regions of the world to ensure the federated operations model, and the supporting processes and tools can interoperate with e-Infrastructures outside Europe. The Canadian Astronomy Data Centre (CADC) and the Canadian Advanced Network for Astronomical Research (CANFAR, Canada) will collaborate with the WP6 partners.

In South Africa activities will leverage the on the ongoing collaboration between EGI and CSIR Meraka Institute , aiming at federating e-Infrastructures in the Africa-Arabia region. A component of this initiative, the South African National Grid (SAGrid), is responsible for promoting international collaboration of grid computing infrastructures in South Africa and has coordinated similar activities in the Sub-Saharan region since 2009. SAGrid is a core component of AAROC, and the Meraka Institute (https://documents.egi.eu/document/495) is responsible for the core SAGrid services which enable interoperability with EGI. In addition, the South African NREN operates within the Meraka Institute, which is responsible for several operational tools and services which the grid community relies on, such as monitors, Certificate Authority, and low-level network optimisation. Through the Ubuntunet Alliance, these services are available to the wider community in the region. Similar collaborative activities will be established with Australia.

As shown in the diagram below, the SKA requirements will be taken into account to co-develop and advance the current Authentication and Authorization services, the federated operations model and the supporting tools.

Figure 7: Innovation cycle involving regional SDCs and e-Infrastructure in WP6.

This overall goal can be broken down into the following objectives:
- (Task 6.1) Provide guidelines to establish interoperability between different international e-Infrastructure AAI systems and trust models and SKA AAI services for seamless identification, authorization and authentication in the SRC network of services and resources in SKA leveraging federated Identity provisioning (IdP).
- (Task 6.2) Recommend a ESDC operations architecture and reference standards and best practices for federated IT service management.

- (Task 6.3) Identify a core set of interoperable tools for federated ITSM.

Description of work and role of partners

WP6 - Services [Months: 1-36]
EGI.eu, INAF, GEANT LTD, GRNET, FOM
Task 6.1 Federated Authentication, Authorization and Identity Provisioning (AAI)
Partners: INAF (lead), EGI.eu, GRNET, FOM
The execution of data processing, access and analysis involving the services and resources offered by the distributed network of SRCs, will require the capability of performing authentication and authorization operations across services and resources hosted by different operational domains, of users affiliated to different research organizations worldwide. Because of the diversity of service providers and user credentials involved in the process, the AAI infrastructure will need to harmonize different policies and protocols to ensure transparency to the end-user. The final goal is to allow SKA users to access federated services and resources offered by different e-infrastructure providers and different organizations in Europe and other regions of the world. In order to address this challenge the task will include the following activities:
- Collect the requirements generated by SKA end-users, RSDAs (the service providers) and e-Infrastructure providers. These requirements will be produced after analysis of: (a) the types of identity provisioning systems in use at the SKA end-user home organizations, (b) the federated AAI infrastructures operated by the e-Infrastructures, (c) the local RSDA AAI infrastructures and (d) the authorization policies and required levels of assurance for both SKA, service providers and e-Infrastructures.
- Recommend approaches and solutions for a federated AAI infrastructure combining community-specific AAI services and existing e-Infrastructure AAI services, by identifying the components that are needed to support a cross-domain authentication and authorization for the SKA users, according to the collected requirements. The task will involve experts in authentication and authorization from SKA and RSDA providers and e-Infrastructures. Products and solutions for a user friendly, trusted and reliable cross-domain international AAI infrastructure will be identified and tested. Solutions will include services to ensure interoperability like credential translation services. Coordination with the H2020-funded ASTERICS project is envisaged.
- Propose a SKA trust model for handling of data protection, the operations and the access to ESDC services and resources, and of the research outputs generated by data analysis according to the policies and requirements gathered in WP2, to be shared between the SRCs and the external e-infrastructures involved.

This work will leverage the finding of other initiatives aiming at promoting the adoption of federated identity provisioning, including the following projects: AARC (https://aarc-project.eu/) , EGI-Engage (http://go.egi.eu/EngageWeb) and ASTERICS (http://cordis.europa.eu/project/rcn/196641_en.html).

Task 6.2 Interoperable Federated IT Service Management System
Partners: EGI.eu (lead)
This task includes the following activities:
- The assessment of the existing structures and tools operating at a national level and the relationship with the SKA SRCs, and the adopted best practices and standards for service management, including IT service management and security incident management.
- The analysis of applicable standards and best practices for federated service management. These will at facilitating service management in IT service provision, including federated scenarios to adopt a pragmatic, lightweight and achievable standard that allows for effective IT service management (ITSM) in SKA which offers a version of ITSM that can cope with federated environments, which often lack the hierarchy and level of control seen in other situations. This task will support the definition of the AENEAS service catalogue, a collaborative activity that will involve experts from all work packages. The catalogue will be published online on the project web site, and on the EGI marketplace being prototyped in the context of the EC funded project EGI-Engage (The EGI Marketplace will be available as online platform by December 2016 (http://www.egi.eu/about/egi-engage/)) for a wide promotion of the project outputs. In addition, AENEAS will rely on other EC-lead initiatives and projects aiming at increasing the visibility of services and products resulting from EC-funded projects.
- The recommendation of an operational architecture and core set of FitSM processes necessary for running service management in the e-Infrastructures network. This includes the definition of the activities and roles needed in the IT Service Management (ITSM) in the SRC operating environment.

This task will be carried out in collaboration with WP2 to make sure that the operations architecture complies to the governance model defined there, and internationally with the contribution of CADC (Canada), CSIR (South Africa) and nectar (Australia). Purpose of their contribution is to make sure the distributed ESDC operational architecture relies

on existing federated management processes that are already in place involving Europe, Canada, South Africa and Australia, to support other large-scale international research collaborations.

Task 6.3 Federated ITSM support tools
Partners: EGI.eu (lead), GRNET
In order to run federated service management across different service providers tools are needed to support the processes of the ITSM defined in task 6.2, for example for monitoring, security monitoring, accounting and incident management. This task will be responsible for:
- The recommendation of a set of e-Infrastructure tools necessary to support federated ITSM in the ESDC network.
- The piloting of an integrated system of ITSM support tools instantiated in different e-Infrastructures supporting the ESDC network.

Participation per Partner

Partner number and short name	WP6 effort
4 - INAF	3.00
6 - GEANT LTD	0.00
GÉANT Assn	4.00
7 - EGI.eu	16.00
15 - GRNET	6.00
16 - FOM	6.00
Total	35.00

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D6.1	AAI requirements and AAI architecture design	7 - EGI.eu	Report	Public	24
D6.2	AENEAS Service Portfolio	7 - EGI.eu	Report	Public	24
D6.3	Federated AAI pilot results	7 - EGI.eu	Report	Public	36
D6.4	SRC federated service management recommendations	7 - EGI.eu	Report	Public	36

Description of deliverables

D6.1 : AAI requirements and AAI architecture design [24]

The deliverable will present the SKA requirements and trust model, the proposed AAI architecture with the respective functional components needed to meet these requirements.

D6.2 : AENEAS Service Portfolio [24]

Leveraging the project findings and the services of existing e-Infrastructure catalogues, the deliverable will describe the services of the AENEAS Service Portfolio, the portfolio structure and the service portfolio management procedures adopted in the project.

D6.3 : Federated AAI pilot results [36]

The document will describe the outcomes of piloting activities conducted to test the realization of the AAI infrastructure defined in D6.1.

D6.4 : SRC federated service management recommendations [36]

The document will analyse different approaches, standards, best practices and processes necessary to manage the services in a geographically distributed network of SRCs while ensuring interoperability and seamless delivery of services to the end-users.

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification

1.3.4. WT4 List of milestones

Milestone number[18]	Milestone title	WP number[9]	Lead beneficiary	Due Date (in months)[17]	Means of verification
MS1	Definition of WP5.1 survey scope	WP5	4 - INAF	3	Definition of WP5.1 survey scope
MS2	Preliminary functionality assessment	WP3	2 - UMAN	4	Preliminary functionality assessment
MS3	Preliminary input of inventory survey due, to provide guidance in order to align level of detail.	WP2	1 - ASTRON	6	Preliminary input of inventory survey due, to provide guidance in order to align level of detail.
MS4	WP5.1 survey data collected	WP5	4 - INAF	6	WP5.1 survey data collected
MS5	Define scope of WP5.4 VO report	WP5	4 - INAF	6	Define scope of WP5.4 VO report
MS6	Protocols and end hosts evaluation	WP4	6 - GEANT LTD	7	Protocols and end hosts evaluation
MS7	Storage sub-systems evaluation	WP4	6 - GEANT LTD	8	Storage sub-systems evaluation
MS8	WP5.1 survey discussion paper	WP5	4 - INAF	8	WP5.1 survey discussion paper
MS9	Consideration of WP5.1 survey discussion paper in WP5.2-6	WP5	4 - INAF	8	Consideration of WP5.1 survey discussion paper in WP5.2-6
MS10	Joint Milestone (WP4) on data moving applications & tools	WP3, WP4	2 - UMAN	9	Joint Milestone (WP4) on data moving applications & tools
MS11	List of possible regional site locations	WP2, WP4	6 - GEANT LTD	9	List of possible regional site locations
MS12	Analysis of compute load, data transfer and data storage anticipated as required for SKA Key science	WP3	2 - UMAN	10	Analysis of compute load, data transfer and data storage anticipated as required for SKA Key science
MS13	Detailed schedule of anticipated SKA-related data products and their storage requirements	WP3	2 - UMAN	10	Detailed schedule of anticipated SKA-related data products and their storage requirements
MS14	Middleware FoM review	WP3	2 - UMAN	12	Middleware FoM review
MS15	Top-level software FoM review	WP3	2 - UMAN	12	Top-level software FoM review

Milestone number[18]	Milestone title	WP number[9]	Lead beneficiary	Due Date (in months)[17]	Means of verification
MS16	Full functionality assessment	WP3	2 - UMAN	12	Full functionality assessment
MS17	Test data sets available	WP3	2 - UMAN	12	Test data sets available
MS18	Draft WP5.1 survey and gap analysis	WP5	4 - INAF	12	Draft WP5.1 survey and gap analysis
MS19	Data transfer test South African site to European site	WP4	6 - GEANT LTD	13	Data transfer test South African site to European site
MS20	Joint Milestone (WP4) on SKA Sci DMZ recommendations	WP3, WP4	2 - UMAN	14	Joint Milestone (WP4) on SKA Sci DMZ recommendations
MS21	Best practice recommendations Data moving applications, protocols and storage	WP3, WP4	6 - GEANT LTD	14	Best practice recommendations Data moving applications, protocols and storage
MS22	Specification for SKA Science DMZ	WP3, WP4	6 - GEANT LTD	14	Specification for SKA Science DMZ
MS23	Performance required to enable synergistic science incorporating multi-wavelength surveys	WP3	2 - UMAN	15	Performance required to enable synergistic science incorporating multi-wavelength surveys
MS24	Initial elaboration of WP5.1 gap analysis in WP5.2-6	WP5	4 - INAF	15	Initial elaboration of WP5.1 gap analysis in WP5.2-6
MS25	radio astronomy data over global routes from South Africa to Europe	WP3, WP4	6 - GEANT LTD	18	radio astronomy data over global routes from South Africa to Europe
MS26	Initial System Sizing	WP3	2 - UMAN	19	Initial System Sizing
MS27	Joint Milestone (WP4) on demonstration of moving data from observatory sites (SA) to ESDC	WP3, WP4	2 - UMAN	19	Joint Milestone (WP4) on demonstration of moving data from observatory sites (SA) to ESDC
MS28	Feedback to WP2 on policy options	WP2, WP3	1 - ASTRON	20	Feedback to WP2 on policy options
MS29	Consideration of WP5.1 survey in WP5.2,3,5,6	WP5	4 - INAF	20	Consideration of WP5.1 survey in WP5.2,3,5,6
MS30	Joint Milestone (WP4) on data replica manager	WP3, WP4	2 - UMAN	21	Joint Milestone (WP4) on data replica manager
MS31	Specifications for SKA Replica Manager	WP3, WP4	6 - GEANT LTD	21	Specifications for SKA Replica Manager
MS32	Joint Milestone (WP5) demonstration of	WP3, WP5	2 - UMAN	24	Joint Milestone (WP5) demonstration of

Milestone number[18]	Milestone title	WP number[9]	Lead beneficiary	Due Date (in months)[17]	Means of verification
	compatibility of user interface specification with example work flow models				compatibility of user interface specification with example work flow models
MS33	Joint Milestone (WP4) on demonstration of moving data from observatory sites (AUS) to ESDC	WP3, WP4	2 - UMAN	24	Joint Milestone (WP4) on demonstration of moving data from observatory sites (AUS) to ESDC
MS34	Address WP5.2 and WP5.3 considerations in WP5.4	WP5	4 - INAF	26	Address WP5.2 and WP5.3 considerations in WP5.4
MS35	Data transfer test Australian site to European site	WP4	6 - GEANT LTD	27	Data transfer test Australian site to European site
MS36	Report on Data Transport ESDC within Europe	WP3, WP4	6 - GEANT LTD	28	Report on Data Transport ESDC within Europe
MS37	radio astronomy data over global routes from Australia to Europe	WP3, WP4	6 - GEANT LTD	30	radio astronomy data over global routes from Australia to Europe
MS38	Joint Milestone (WP5) on consolidation of outputs from WP5.3 with WP3.5.6.1	WP3, WP5	2 - UMAN	31	Joint Milestone (WP5) on consolidation of outputs from WP5.3 with WP3.5.6.1
MS39	Joint Milestone (WP5) demonstration of interface data specification compatibility with VO standards	WP3, WP5	2 - UMAN	31	Joint Milestone (WP5) demonstration of interface data specification compatibility with VO standards
MS40	Joint Milestone (WP4) on demonstration of moving data within ESDC	WP3, WP4	2 - UMAN	31	Joint Milestone (WP4) on demonstration of moving data within ESDC

1.3.5. WT5 Critical Implementation risks and mitigation actions

Risk number	Description of risk	WP Number	Proposed risk-mitigation measures
1	Project governance does not work	WP1	The partners forming the consortium (see section 3.3) have extensive experience in working on EC funded projects and understand the requirements they demand, also with respect to reporting and financial administration.
2	Project coordinator does not work	WP1	Governance structure in place to monitor and act.
3	Project management does not work	WP1	Project coordinator and Governanc structure in place to monitor and act.
4	Dissemination and outreach does not reach far enough	WP1	ASTRON (lead) has a good record on outreach and dissemination and has an interest in making the project well known to everyone.
5	Results in various WP's do not link to overall progress	WP1	Governance structure in place to monitor and act. Bi-monthly meetings of Management Team.
6	Overall project result not supported by policy makers and funding agencies	WP1, WP2	Ensure close cooperation with the important stakeholders.
7	Science community itself does not have the technical knowledge of SKA to accurately predict what its own needs will be w.r.t re-processing of SKA data in the future.	WP3	The task leader for the WP3 task assessing required processing for the ESDC is the current SDP project scientist and she is already engaging with the science communities (through presentations at national and international meetings and small group videoconferences) to educate them about the scope and limitations of SDP processing. Our strong links with the SKA Organisation will also ensure that we understand the operational models for the SKA instruments as they evolve. Thus, the AENEAS project is extremely well connected to the needs of SKA experiments, with a network in place for information exchange to develop a shared understanding between AENEAS, the SKAO and the science community. In addition, several members of the AENEAS project also sit on SKA Science Working Groups.
8	Inter-work package dependencies (Joint Milestones) cause delays	WP3, WP4	Internal reports and check-points monitor progress; members of both WP are involved in the work.
9	Network or hardware failures	WP4	The production academic network will be used. NRENs and GÉANT operate to SLAs; the backbones support alternate paths. Several end-host Data Transfer Nodes will be available for the PoC tests.
10	Host country partners do not deliver	WP3, WP4	All partners in the host countries are very keen to support SKA. They are in SaDT consortium and asked to join AENEAS. Positive encouragement from senior members of AENEAS.

Risk number	Description of risk	WP Number	Proposed risk-mitigation measures
11	Key personnel unavailable	WP4	Ensure close cooperation with WP2 for the identification of the relevant user communities, and prioritize use cases
12	The available technologies and services for AAI, distributed data management and computing are not suitable for the SKA needs	WP2, WP3, WP6	SKA requirements will be provided to technology and service providers to request innovation
13	Effective linkages between WP3, WP4, WP5, and WP6 not established or maintained	WP3, WP4, WP5, WP6	Joint WP3, WP4, WP5, WP6 meetings, attached to “all hands” meetings, plus regular cross-WP teleconferences and videoconference. Joint monitoring of deliverables by WP3, WP4, and WP5 work package leaders.
14	Early deliverables not completed in a timely manner, causing slippage to downstream tasks	WP3, WP4, WP5, WP6	Front-loading effort on early dependencies and enhanced monitoring of early deliverables by work package leaders.
15	Not all in-kind effort of minor project partners eventuates	WP1, WP2, WP3, WP4, WP5, WP6	Allocated of sufficient dedicated effort within major funded partners to complete all deliverables as a core team.
16	International SKA Board and SKA Project Office alter policy directions regarding regional science and engineering centres	WP1, WP2, WP3, WP4, WP5, WP6	Retain sufficient flexibility in allocation of resources to react to changes in the policy environment. Maintain close strategic connections to SKA Board and Project Office to monitor and inform policy environment.
17	The requirements gathered for authentication, authorization and the European Science Data Centre trust model are conflicting or difficult to harmonize	WP6	Ensure close cooperation with WP2 for the identification of the relevant user communities, and prioritize use cases

1.3.6. WT6 Summary of project effort in person-months

	WP1	WP2	WP3	WP4	WP5	WP6	Total Person/Months per Participant
1 - ASTRON	24	12	11	0	12	0	59
2 - UMAN	0	1	12	6	6	0	25
3 - UCAM	0	1	11	0	6	0	18
4 - INAF	0	2	15	1	27	3	48
5 - CHALMERS	0	2	8	20	0	0	30
6 - GEANT LTD	0	2	0	22	0	0	24
· GÉANT Assn	0	0	0	0	0	4	4
7 - EGI.eu	0	2	4	0	0	16	22
8 - MPG	0	0	0	0	0	0	0
9 - Juelich	0	0	9	9	0	0	18
10 - SKAO	0	0	0	0	0	0	0
11 - STFC	0	0	6	0	0	0	6
12 - CSIC	0	0	3	0	6	0	9
13 - IT	0	0	6	0	0	0	6
14 - CNRS	0	0	0	0	0	0	0
· OCA	0	0	0	0	2	0	2
15 - GRNET	0	0	0	0	0	6	6
16 - FOM	0	0	0	0	0	6	6
17 - JIV-ERIC	0	0	0	0	0	0	0
18 - ILT	0	0	0	0	0	0	0
19 - SNIC	0	0	0	0	0	0	0
20 - EPFL	0	0	3	0	0	0	3
21 - UNIGE	0	0	3	0	0	0	3

	WP1	WP2	WP3	WP4	WP5	WP6	Total Person/Months per Participant
22 - CSIRO	0	0	0	0	0	0	0
23 - AARNet	0	0	0	0	0	0	0
24 - VUW	0	0	0	0	0	0	0
25 - CSIR	0	0	0	0	0	0	0
26 - UCT	0	0	0	0	0	0	0
27 - NRF	0	0	0	0	0	0	0
28 - RDA	0	0	0	0	0	0	0
Total Person/Months	24	22	91	58	59	35	289

1.3.7. WT7 Tentative schedule of project reviews

Review number [19]	Tentative timing	Planned venue of review	Comments, if any
RV1	18	Brussels	
RV2	36	Luxembourg	

1. Project number

The project number has been assigned by the Commission as the unique identifier for your project. It cannot be changed. The project number **should appear on each page of the grant agreement preparation documents (part A and part B)** to prevent errors during its handling.

2. Project acronym

Use the project acronym as given in the submitted proposal. It can generally not be changed. The same acronym **should appear on each page of the grant agreement preparation documents (part A and part B)** to prevent errors during its handling.

3. Project title

Use the title (preferably no longer than 200 characters) as indicated in the submitted proposal. Minor corrections are possible if agreed during the preparation of the grant agreement.

4. Starting date

Unless a specific (fixed) starting date is duly justified and agreed upon during the preparation of the Grant Agreement, the project will start on the first day of the month following the entry into force of the Grant Agreement (NB : entry into force = signature by the Commission). Please note that if a fixed starting date is used, you will be required to provide a written justification.

5. Duration

Insert the duration of the project in full months.

6. Call (part) identifier

The Call (part) identifier is the reference number given in the call or part of the call you were addressing, as indicated in the publication of the call in the Official Journal of the European Union. You have to use the identifier given by the Commission in the letter inviting to prepare the grant agreement.

7. Abstract

8. Project Entry Month

The month at which the participant joined the consortium, month 1 marking the start date of the project, and all other start dates being relative to this start date.

9. Work Package number

Work package number: WP1, WP2, WP3, ..., WPn

10. Lead beneficiary

This must be one of the beneficiaries in the grant (not a third party) - Number of the beneficiary leading the work in this work package

11. Person-months per work package

The total number of person-months allocated to each work package.

12. Start month

Relative start date for the work in the specific work packages, month 1 marking the start date of the project, and all other start dates being relative to this start date.

13. End month

Relative end date, month 1 marking the start date of the project, and all end dates being relative to this start date.

14. Deliverable number

Deliverable numbers: D1 - Dn

15. Type

Please indicate the type of the deliverable using one of the following codes:

R	Document, report
DEM	Demonstrator, pilot, prototype
DEC	Websites, patent fillings, videos, etc.
OTHER	
ETHICS	Ethics requirement

16. Dissemination level

Please indicate the dissemination level using one of the following codes:

PU	Public
CO	Confidential, only for members of the consortium (including the Commission Services)
EU-RES	Classified Information: RESTREINT UE (Commission Decision 2005/444/EC)
EU-CON	Classified Information: CONFIDENTIEL UE (Commission Decision 2005/444/EC)
EU-SEC	Classified Information: SECRET UE (Commission Decision 2005/444/EC)

17. Delivery date for Deliverable

Month in which the deliverables will be available, month 1 marking the start date of the project, and all delivery dates being relative to this start date.

18. Milestone number

Milestone number:MS1, MS2, ..., MSn

19. Review number

Review number: RV1, RV2, ..., RVn

20. Installation Number

Number progressively the installations of a same infrastructure. An installation is a part of an infrastructure that could be used independently from the rest.

21. Installation country

Code of the country where the installation is located or IO if the access provider (the beneficiary or linked third party) is an international organization, an ERIC or a similar legal entity.

22. Type of access

VA	if virtual access,
TA-uc	if trans-national access with access costs declared on the basis of unit cost,
TA-ac	if trans-national access with access costs declared as actual costs, and
TA-cb	if trans-national access with access costs declared as a combination of actual costs and costs on the basis of unit cost.

23. Access costs

Cost of the access provided under the project. For virtual access fill only the second column. For trans-national access fill one of the two columns or both according to the way access costs are declared. Trans-national access costs on the basis of unit cost will result from the unit cost by the quantity of access to be provided.

History of Changes after proposal submission on 30 March 2016

Date	Location of change	Change
31/03/2016	All sections	Minor formatting and layout changes.
21/08/2016	Section 2.1	Expanded text to address reviewer concerns about concrete exploitation plans on the business models for e-Infrastructures.
25/08/2016	Table 3.16	Text added to work description for WP6 to add detail on how new services will build on existing services. + added Deliverable D6.2 and adjusted numbering of others.
26/08/2016	Section 3.1	Added additional text in the description of the overall AENEAS work plan and work packages to address the relative balance in resource allocations for WP3 and WP5.
27/08/2016	Section 3.2	Added additional text to provide more detail on innovation potential and management.
28/08/2106	Section 2.1	Added section describing anticipated project KPIs.
29/08/2016	Section 2.2	Text added to end of section to clarify IPR management.
30/08/2016	Table 3.14	Additional text added to the work description for WP4, Task 4.1 to provide additional detail on how evaluation of networking requirements and technologies will be carried out. + Adjusted Milestone numbering in text
31/08/2016	Section 3.1	Detailed timelines have been added for the various work packages to describe the schedule for the project in more detail.
02/09/2016	Table 3.11	Added deliverable on KPIs (D1.2) and copied deliverables from the text into the Deliverable list (D1.3, D1.4)
02/09/2016	Table 3.12	Adjusted Deliverable order.
02/09/2016	Table 3.15	Added CNRS third party OCA to list Adjusted effort CNRS-OCA from 6 to 2 PM Adjusted two Deliverable numbers
02/09/2016	Table 3.17	Adjusted effort CNRS-OCA from 6 to 2 PM in WP5 Adjusted discrepancy between PartB and portal WP5-->WP6 (4PM)
02/09/2016	Table 3.18	Made Deliverable table up to date with text for discrepancies in proposal and after additions described above.
02/09/2016	Table 3.4a	Added CNRS-OCA and adjusted 4 PM + removed typo on RDA total and WP totals
02/09/2016	Table 3.4b	Changed justification for CNRS as they requested to move PM to travel budget.
02/09/2016	Table 4.1.14	Added that the parties linked to CNRS through joint research units will not claim any costs in the project.

12/09/2016	Table 3.4b	Changed justification for ASTRON: added cost for audit certificate to other goods and services.
12/09/2016	Part A budget table	Moved subcontracting budget for ASTRON to other costs, as this was for the audit certificate and should not be listed here.
12/09/2016	Part A	Added GÉANT Association as linked third party and moved 4PM in WP6 from GÉANT ltd to GÉANT Assn. together with the corresponding budget.
12/09/2016	Section 4.2.6	removed incorrect reference to WP5
12/09/2016	Section 4.2.14	Added COA as linked third party to CNRS
19/09/2016	Section 4.2.28	Removed Rensselaer Polytechnic Institute as subcontracting party to RDA. Added justification why Rensselaer Polytechnic Institute is linked third party to RDA and why a USA organisation is needed in the consortium.
20/09/2016	Part A	Added RPI as linked third party to RDA and moved effort and budget from RDA to RPI.
29/09/2016	Section 2.2	Text adjusted to clarify the role of the RDA as a non-funded external partner and how the AENEAS project will engage with the RDA initiative.
29/09/2016	Section 4.1.28	Changed the description of RDA participation in the project.
29/09/2016	Part A	WP2 added description of action around RDA Working Groups.
29/09/2016	Section 4.2.28	Removed Rensselaer Polytechnic Institute as linked third party to RDA.
29/09/2016	Part A	Removed RPI as linked third party to RDA and moved effort and budget from RPI to ASTRON as reservation for Working Group effort.
29/09/2016	Table 3.4b	Changed justification for ASTRON: added cost for reservation for yet Working Group effort for yet unidentified experts to other goods and services.

Table of Contents

1. EXCELLENCE

The AENEAS[1] (A*dvanced* E*uropean* N*etwork of* E-*infrastructures for* A*stronomy with the* S*KA*) proposal has been designed to address the Horizon 2020 Work Programme and Part A of the INFRASUPP-03-2016-2017 call "Research and Innovation Actions for International Co-operation on high-end e-infrastructure requirements" specifically supporting the Square Kilometre Array (SKA), an ESFRI Landmark Project. The scientific potential of the forthcoming SKA radio telescope is simply unprecedented and represents one of the highest priorities for the international scientific community in the coming decade. By the same token, the large scale, rate, and complexity of data the SKA will generate present challenges in data management, computing, and networking that are similarly world-leading. Like the SKA itself, a coordinated, global effort will be required to solve these challenges and fully realize the ground-breaking scientific potential of the project.

AENEAS brings together all of the European member states currently formally part of the SKA collaboration as well as potential future EU SKA national partners, the SKA Organisation itself, and a larger group of international partners including the SKA site host countries. Letters of support from many of these SKA partners are included in the Appendices. The AENEAS project directly engages with several key, EC e-infrastructures such as GÉANT, the European GRID Initiative (EGI), the European Virtual Observatory (EURO-VO), and the Research Data Alliance (RDA). AENEAS also draws on experience and expertise from several world-class, European research infrastructures including the Joint Institute for VLBI ERIC (JIV-ERIC) and the International LOFAR Telescope (ILT). These partners are further supported by an impressive array of National Research and Education Networks (NRENs) at the various national levels.

The SKA is an ambitious project to construct the world's largest radio telescope and enable transformational science and discoveries impossible with current facilities. Built over two sites in Australia and Africa, it will, when complete, provide over a million square metres of collecting area through many thousands of connected radio antennas. The SKA is currently foreseen to be constructed in two phases. By adopting a phased rollout, more developed technologies will be utilized early on in the project to secure the first wave of scientific discoveries at the earliest opportunity and then upgraded with new technology currently under development during the second phase. The first phase of the project, SKA1, represents a €650M investment and, together with other countries in the world, European member states are leading partners in the construction. SKA1 is currently in the pre-construction phase where the design and specifications are being finalized with construction slated to start toward the end of 2018 and first science operations in the early 2020's.

With this timeline, the next few years will be crucial in preparing to support this first SKA science. Based on current projections, the SKA Observatory, once its first phase is operational, is expected to produce an archive of standard data products with a growth rate on the order of 50—300 petabytes per year. Although the challenges associated with populating and maintaining the SKA science archive are already impressive, these data products actually represent only the first part of the full science extraction chain. Further processing and subsequent science extraction by the community will require a significant research infrastructure providing capacity in networking, storage, computing, and expertise. The AENEAS project represents an opportunity to pursue the design, deployment, and operation of the necessary research infrastructure for SKA science at a European level and in close coordination with the SKA project, the host countries, and other international partners. Ultimately, our ambition is to ensure the astronomy community has the resources it will need to achieve the truly transformational science potential of the SKA.

[1] A glossary of acronyms is provided at the end of the proposal.

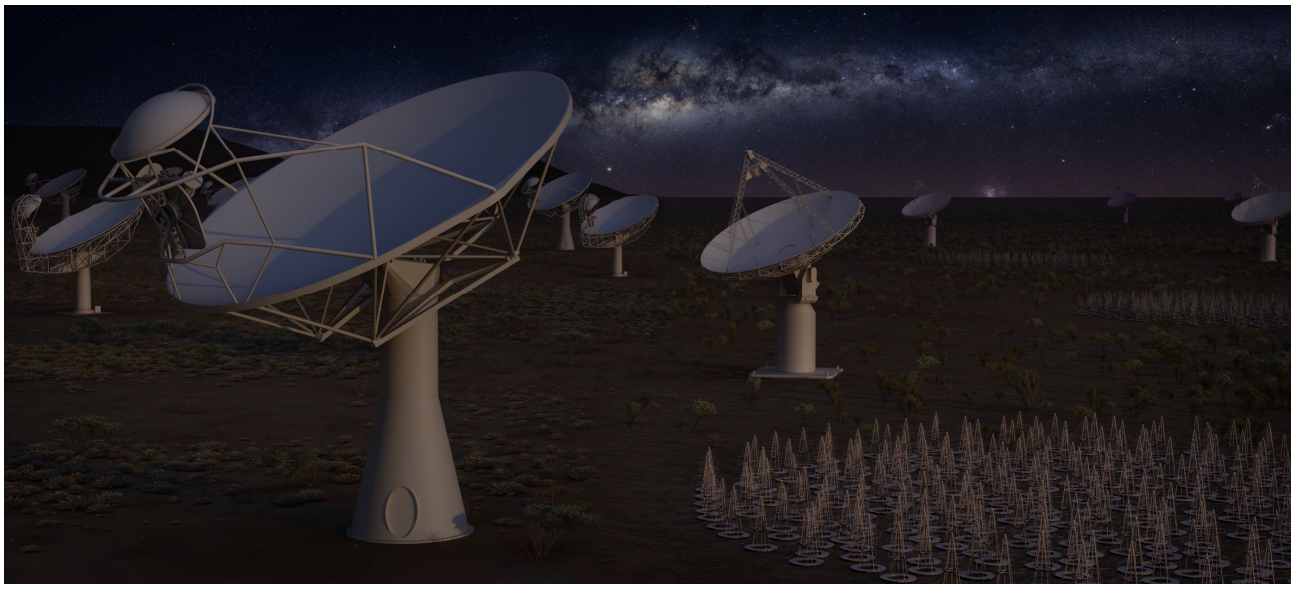


Figure 1: An artist's conception of the two types of radio telescope arrays to be constructed during Phase 1 of the SKA. During this first phase, thousands of radio dishes and stations of phased-array dipoles will be deployed across the deserts of South Africa and Australia, respectively.

1.1 Context

SKA Science Drivers

The SKA will be a radio observatory of unparalleled sensitivity across a wide range of angular scales and radio wavelengths. Its scientific impact will spread from studies of star formation within our own Milky Way, to probing distant galaxies in the furthest reaches of the Universe. It will unveil the hidden structures of cosmic magnetic fields stretching over vast distances, and examine the organic chemistry of Earth-like terrestrial planets. It will perhaps even detect signs of extra-terrestrial life as the SKA will be sensitive enough to detect signals, comparable to terrestrial television transmitters, from planets in nearby solar systems.

From contributions to the last SKA science conference, a two volume book was recently produced describing this broad science case[2]. It contains 135 chapters written by 1,213 contributors from 31 countries. Of those chapters 62% were first-authored by scientists from European institutions. The Observatory itself is being built in South Africa and Australia, but the SKA clearly lies at the heart of the European science agenda. The headquarters for the Observatory is located in Europe in the UK, and European scientific interest spans the complete range of research areas proposed for the SKA. In particular, key European participation is currently foreseen in both of the most transformational science topics driving the SKA design. These are summarized here.

Our understanding of cosmology has grown more complete in recent years, but one of the remaining knowledge frontiers in this area is the cosmological dawn – the era when the first stars and galaxies formed. Phase 1 of the SKA will provide the first direct imaging of this Epoch of Re-ionization. This epoch happened around 380,000 years after the Big Bang when proto-galaxies and quasars began to form in a sea of neutral hydrogen. These objects are intrinsically faint and their emission suffers significant absorption by the surrounding medium, which has made it extremely difficult to detect them

[2] Advancing Astrophysics with the Square Kilometre Array, https://www.skatelescope.org/books/

to date. However, an alternative way to measure growth in the early Universe is instead to observe the effect these objects have on their surroundings. These energetic objects ionize pockets of the neutral gas around them, creating voids. Astronomers have labeled this as the epoch of re-ionization and it can be observed by mapping the distribution of neutral hydrogen. The SKA will be able to image the patterns in the neutral gas during the Epoch of Re-ionization, providing the first pictures of Universe in this formative era (see Figure 2).

In terms of fundamental physics, the SKA will also allow us to perform strong field tests of gravity itself. Using pulsars, the collapsed spinning cores of dead stars, we will be able to measure ripples in the fabric of space-time caused by gravitational waves. A pulsar is a highly magnetised, rotating neutron star with a mass 1.4 times larger than the Sun, but only a few kilometres in diameter. As a pulsar spins it acts like a cosmic lighthouse, emitting a beam of radiation from its pole that periodically sweeps past the observer's line of sight. These pulses are extremely regular and hence pulsars act as natural clocks, as precise as the best atomic clocks on Earth. This precise timing can be used to detect ripples caused by gravitational waves as well as to test general relativity in extreme gravitational conditions such as those produced in the vicinity of black holes. The SKA will be able to investigate the strong-field realm of gravitational physics by finding and timing pulsars. About 50 years after the discovery of pulsars marked the beginning of a new era in fundamental physics, pulsars observed with the SKA have the potential to transform our understanding of gravitational physics.

In addition to these flagship experiments, the SKA will enable a wide range of science. Neutral hydrogen emission surveys out to a redshift of 0.5 will allow the study of the evolution of gas in galaxies across five billion years of cosmic time, as well as placing further important constraints on the dark energy equation of state and its evolution with redshift. New classes of transient and variable sources will be detected and identified, including the recently-discovered "fast radio bursts", at a ground-breaking rate of several detections per day. Imaging of planet-forming disks around young stars will also result in key breakthroughs related to the physics of planet formation, and in turn the origin of life itself.

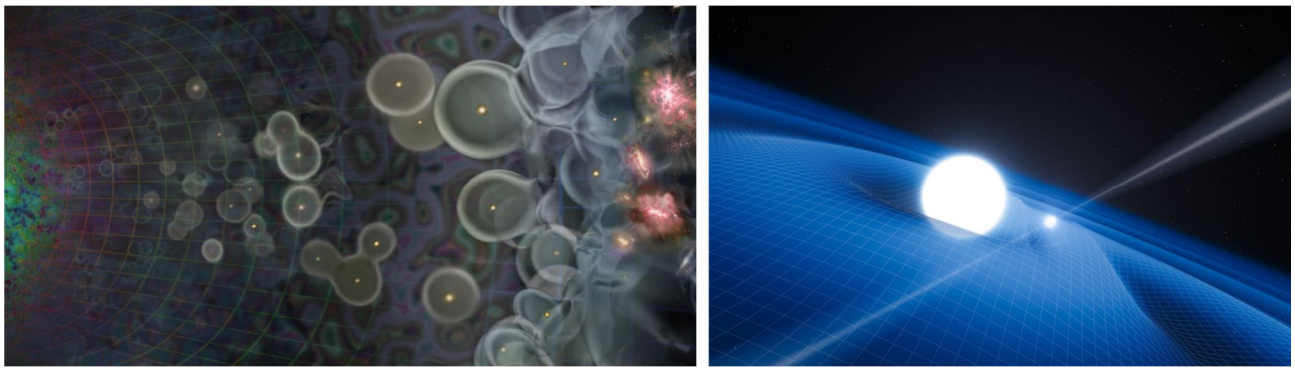


Figure 2: (Left panel) The earliest phases in the Universe, from left to right: the Cosmic Microwave Background (green), the time when hydrogen in the Universe became neutral and the Universe entered the "Dark Ages". During the Cosmic Dawn, the first stars (yellow dots with bubbles) started to emit radiation heating the intergalactic medium. During re-ionisation, stars ionised hydrogen again (big, overlapping bubbles) and the Universe became transparent to radiation. It is after and during this period that we see the first galaxies (right) with present-day telescopes (e.g. HST). (Right panel) Artist's conception of a pulsar orbiting a much larger white dwarf star. The extreme gravitational field of the pulsar warps space time, and its lighthouse-like radio beam allows us to precisely map its motion such that we can test the predictions of gravitational theories in a way that would be otherwise impossible.

SKA as a Big Data Project

The first phase of the SKA Observatory will include telescopes located in both South Africa and Australia and will feature both a high-frequency interferometric array of 15-meter reflecting dishes (SKA1-MID) and a large collection of individual, dipole antennas (SKA1-LOW) inspired by the LOFAR approach (see Figure 1). SKA1-LOW in Australia will consist of nearly 130,000 antennas, distributed over roughly 500 stations and have an operating frequency between 50 MHz and 350 MHz. SKA1-MID will be located in South Africa and will consist of 200 dishes equipped with a suite of receivers to cover the 350 MHz – 14 GHz range of the radio spectrum. Signals from the individual telescopes and antenna stations will be transported to a central processing facility on-site in each hosting country, with a dedicated high-bandwidth connection to initial science processing and archiving centres in Perth (AU) and Cape Town (SA).

The SKA will transmit high volumes of data through its dedicated network and intelligently reduce these data to a manageable size in near real time. With data rates from the dishes of over 1 petabits per second and 10 petabits per second from the low-frequency phased-arrays, the total data rates when the SKA1 is complete and starting operations (between about 2020 and 2023) are expected to exceed the total global internet traffic at present day rates.

Correspondingly, the magnitude of processing power that the SKA will need to handle this volume of data will be comparable to that of the largest computers in the world in the early 2020s – systems that are at least ten times the size of today's biggest machines. The computational processing requirements for the full SKA phase 1 system are predicted to be of order 300 petaflops – about 10 times the performance of the world's current fastest supercomputer. This level of performance will require development of innovative management for the ICT infrastructure to ensure sustained, optimal performance throughout the expected SKA lifetime, simultaneously driving and benefiting from the growth in capability provided by the ICT industry.

A range of innovative software will also be required both before and after construction, with much of the pre-construction development being re-usable after construction for monitoring system performance and the impact of component upgrades. With reduced science data products that will still run to 100's of petabytes per year in size, enabling access to the data for the science community will present a further major challenge. It is currently envisioned that these products will be distributed to the international community via intercontinental networks to scientists using SKA Regional Centres (SRCs) distributed across the globe (see Figure 3).

The SKA has been widely identified as one of the major "Big Data" challenges for the next decade. The technical challenges in computing, storage, networking, and analytics required to deploy a research infrastructure capable of supporting European SKA science are also attractive to the IT community, and have much wider applicability both within an academic but also commercial context. A distributed and federated European SRC, therefore, can provide a platform for a European and nationally focused partnership with industry for the continued development of these core technologies and hence a clear route to delivering impact and return.

Figure 3: Illustration of the proposed federated network of SKA Regional Centres (SRCs) distributed around the world. These SRCs will provide access to the accumulated SKA science data for communities in different regions and globally. The proposed European Science Data Centre (ESDC) would serve as the European hub in such a network and support the European SKA community.

A European Science Data Centre for the SKA

The SKA Organisation (SKAO) is expected to adopt a tiered model for data and science support similar to that employed for other successful large infrastructures in particular CERN. Storage and computing resources associated with the operational SKA Observatory itself are expected to be highly constrained in order to keep up with SKA operations. Any further processing and subsequent science extraction by users will require significant, outside computing and storage resources in the form of SKA Regional Centres. In this model, SKA Regional Centres will play a role analogous to CERN's Tier 1 sites and provide sufficient resources to store subsets of the SKA archive, support significant processing and post-processing capability, and further distribute data to users and smaller Tier 2 sites. The specific capabilities required by the SKAO of affiliated SRCs are still being defined; however, based on the science drivers of the SKA project, we can anticipate a well-informed model for the functions that a regional centre must support.

In this context, SKA Regional Centres will be a vital resource to enable the community to take maximal advantage of the scientific potential of the SKA. Moreover, within the tiered SKA operational model currently being considered, the SRCs will provide essential functionality which is not currently provisioned within the directly operated SKAO facilities. Therefore, SRCs will form an intrinsic part of SKA operations and be the working interface for most scientists using the SKA (see Figure 4). As such, national investments in a distributed SRC across Europe could represent a significant contribution to SKA operations.

As the primary interfaces for extracting science, the ultimate success of the SKA will be directly coupled to the capabilities of these SRCs. Establishing a large-scale, distributed European Science Data Centre (ESDC) for SKA research represents an important opportunity to provide the astronomy community with the scale of computational infrastructure necessary to maximally exploit the scientific potential of the SKA. Within Europe, a joint effort provides the opportunity to utilize existing infrastructure in a uniform way, coordinate engagement with both European and national ICT

communities and industry, and facilitate shared development and expertise. On a practical level, a European initiative to deploy an SKA research infrastructure opens the possibility to leverage national and European investments to support SKA science (see Figure 5). Finally, a coordinated approach also offers the opportunity to increase support and engagement from the wider European scientific community.

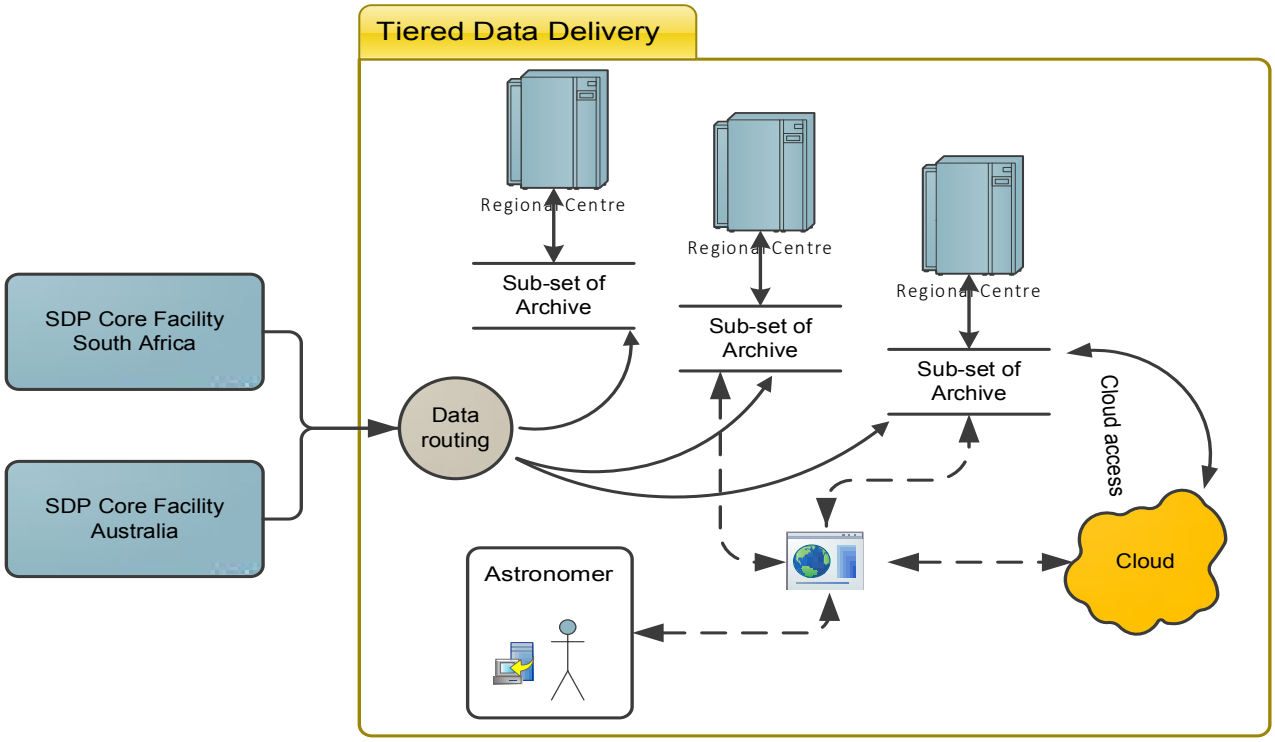


Figure 4: Schematic illustrating the connections between the proposed SKA Regional Centres (SRCs) and the SKA primary archive sites. Note the SRCs are assumed to host subsets of the full SKA science archive.

1.2 Objectives

The ultimate objective of the AENEAS project is to develop a concept and design for a distributed, federated European Science Data Centre (ESDC) to support the astronomical community in achieving the scientific goals of the SKA. This design must include the functionality required by the scientific community to enable the extraction of SKA science and integrate the necessary underlying infrastructure not currently provided as part of the SKA Observatory to support that extraction. Taken all together, the European contribution to the SKA design and construction phase represents a large fraction of the total project, and the European radio astronomy community is both large and actively involved in the full breadth of the SKA science case. Actively engaging with that community to define the required capabilities of the envisioned ESDC network will be one of the central activities of the 3 year AENEAS project.

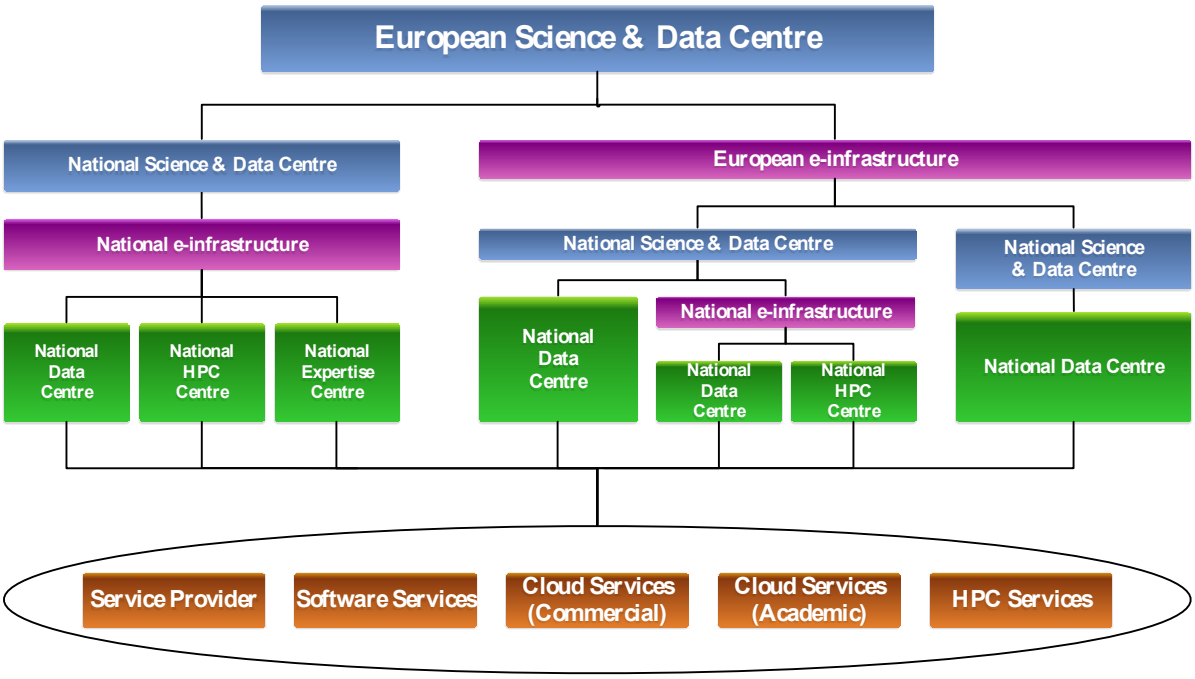


Figure 5: Diagram illustrating the variety of ways in which the proposed European Science & Data Centre (ESDC) for the SKA will integrate existing European resources. Core functionalities (shown in brown at the bottom) are resourced through various national infrastructure providers (show in green). These local infrastructures can be federated through existing national e-infrastructures to form integrated, virtual national science and data centres. At the European level, the proposed ESDC can federate these national centres directly, or through European-wide e-infrastructures. Individual national nodes will be heterogeneous and operate local facilities as well as interface with national infrastructures or commercial providers.

The AENEAS activity will leverage existing products, technologies, services, best practices and standards offered by European e-Infrastructures and integrated e-Infrastructures worldwide. The SKA requirements gathered in the project will further advance the state of the art through co-design and accelerate the current level of e-Infrastructure interoperability. This interoperability will be achieved in Europe by involving some of the major European e-Infrastructures, and in the world by collaborating with other e-Infrastructure operators in Canada, South Africa and Australia. In these regions, e-Infrastructures are already cooperating to provide an interoperable service environment for international research collaborations in various research disciplines like environmental science, genomics, structural biology, astronomy, and high energy physics. AENEAS will allow advancing the current state of the art of networking, distributed computing and data management through co-design and with SKA user-driven innovation.

Given the physically distributed nature of the SKA Observatory itself and the large data volumes and processing scales expected, technical issues related to networking, storage, computing, data management, access, and analysis are all key components of this ESDC design. As a Research and Innovation Action, much of the activity in the AENEAS project has been purposefully constructed to address these topics. Issues related to data movement from the SKA host countries and distribution of that data collection over large-scale storage and computing sites in Europe will be examined with an eye towards deriving an optimal topology for use by the science community. Similarly, the computing and storage requirements for the foreseen post-processing and analysis needs of the European SKA community will be used to weigh different architectures and technologies. A similar analysis will be conducted to produce requirements and designs for the access interfaces and tools the community will need to analyse SKA data. These studies will be combined into a science-driven, functional design for

the capabilities of the ESDC that does not reinvent existing solutions, but rather utilizes and extends the state of the art.

As an integral part of the full science extraction chain, how these SRCs, including a European version, will function in a coordinated way with an operational SKA Observatory is an issue of crucial importance. The operational model for the SKA Observatory is currently under development by the SKA Organization and an important aspect of the AENEAS project will be to engage with the SKAO during this definition process to ensure a smooth interface between the science archives managed and populated by the SKA itself and the network of SRCs that will connect the scientists to that data. Similarly, many of the technical challenges related to networking, computing, and data management addressed by AENEAS are also the subject of active investigation by the international SKA design consortia. One clear objective of AENEAS is to establish and maintain an active communication channel between technical developments in the wider community and the SKA design consortia coordinated by the SKAO to facilitate sharing of results, ensure compatibility across the Observatory maintained data boundaries, and avoid duplication of effort.

AENEAS also aims to extend this engagement beyond the immediate SKA collaboration to the wider community. By partnering with existing EC e-infrastructures such as GÉANT, EGI, the EURO-VO, and participating in initiatives like the RDA, AENEAS can take advantage of expertise beyond radio astronomy from the wider astronomical community and even other research domains, and reuse relevant open source technology, existing services, processes, tools and knowledge. As we discuss below in the section on impact, these same partners represent an effective means to disseminate results from the project back to that broader community which AENEAS fully intends to exploit.

Of course the SKA project itself is a global endeavour involving member nations from around the world. The challenges of enabling science extraction by the SKA researchers is one common to other international communities. By addressing these challenges on a European level, AENEAS intends to act as a counterpart for engagement with other similar efforts internationally during the design and integration stage just as the ESDC itself is foreseen to interact with other SKA Regional Centres around the world in the operational phase. The AENEAS collaboration was designed to incorporate this global cooperation as reflected in its partnerships with many of the international SKA member countries and institutions pursuing similar efforts. Letters of support from several of these international partners are presented in Appendix 1. At the e-Infrastructure layer, AENEAS will leverage existing international e-Infrastructure federation initiatives, like the EGI cooperation with Compute Canada and the Canadian Astronomy Data Centre[3], SAGrid in South Africa[4] and the Africa-Arabia international e-Infrastructure federation, and the e-Infrastructure collaborations in the Asia-Pacific region[5].

Beyond tackling the technical design challenges, AENEAS aims to develop a model for how this distributed, federated European Science Data Centre network will operate and be governed in a sustainable way. These models will include mechanisms for service-level agreements (SLAs) between both academic and commercial infrastructure providers. As it is likely additional EU member states will join the SKA project, this governance model must allow for the validation and incorporation of additional nodes in the ESDC network over time. To ensure the capabilities provided by the envisioned ESDC are available to the science community for the duration of SKA operations, possible funding strategies, and synergies with existing e-Infrastructure service providers will also be explored. Finally, as any network of Regional Centres delivering analysis capabilities based on SKA data must operate within the policy boundaries of the SKA Organization, the AENEAS project will actively engage with the SKAO and SKA governing bodies to define the ESDC governance.

[3] https://documents.egi.eu/document/2629
[4] https://documents.egi.eu/document/495
[5] https://documents.egi.eu/document/1754

Specific primary objectives of the AENEAS project are to:

- Develop a concept and design for a distributed, federated European Science Data Centre (ESDC) to support the astronomical community in achieving the scientific goals of the SKA.
- Engage with the science community to define requirements on the analysis capabilities of the ESDC to achieve the science goals of the SKA.
- Produce design and best practice recommendations for the networking, data transfer, storage, and the authentication and authorization infrastructure required to construct an ESDC together with cost models for European and Global connectivity.
- Address the challenges of moving the large volumes of data produced at the Telescopes over global distances to the Regional Centres, making this available to European researchers.
- Establish the optimal technical solution for a highly distributed SKA Science Data Centre in Europe, that learns from previous experience in federating infrastructures and leverages existing investments of the European scientific and computing communities.
- Estimate the level of resources required to establish an optimal European SKA Data Centre, from technical and human resource points of view.
- Establish the policy and governance framework that allows maximal scientific exploitation of a European SKA Data Centre by the European scientific communities.
- Establish a plan for pan-European participation in the SKA science program, well beyond the current European SKA partner counties, in order to grow the astrophysics community in Europe and offer opportunities to countries without a strong history in astrophysics.

1.3 Relation to the Work Programme

AENEAS is a response to the Horizon 2020 work programme INFRASUPP-03-2016-2017 designed to support the SKA radio telescope. The proposal outlines a range of activities to facilitate the definition of both a technical design and operational model for a distributed, federated European Science Data Centre to enable the astronomy community to extract ground-breaking SKA science. As specified in the requirements of the Call, AENEAS brings together key international partners from the SKA collaboration within Europe and globally, the SKA Organisation itself, and relevant e-infrastructures. Working as integrated teams, these partners will pursue a range of tasks to define and test the necessary technologies required for data dissemination, computational processing, and analysis capabilities to support SKA science. The focus in AENEAS is on a total science delivery perspective for the SKA community as a whole. To achieve this goal, however, will require fundamental changes in perspective both on how the community engages in the scientific analysis of SKA data and how we provision the resources for that analysis.

For many astronomers, the standard analysis scenario involves a moderately sized dataset, obtained from a given facility, and analyzed personally on their individual workstation or other local facilities. This “single desktop” analysis paradigm allows astronomers to improve their results by additional processing or reprocessing, to correlate and compare with other existing data, and to explore interesting features, all in an adaptive way that combines both pre-defined and interactive elements. At SKA scales, the complexity and magnitude of the underlying infrastructure required to deal with the data can break this paradigm and make it difficult for researchers to engage with their data in familiar ways, thereby slowing or complicating the discovery process. This analysis bottleneck is already evident in SKA pathfinders like LOFAR, and will also be an issue for the SKA site precursor instruments MeerKAT and ASKAP.

One of the main goals of AENEAS is to explore the core technologies necessary to provide researchers with a flexible and familiar analysis environment that can handle the extremes of SKA data. To do so, as

indicated in the Call, AENEAS will exploit expertise from existing e-infrastructures such as GÉANT, the Virtual Observatory (VO), the EGI federation, and the Research Data Alliance (RDA) to integrate the underlying, distributed network of research infrastructures into a single, virtual analysis facility from the user perspective.

Integrating the level of infrastructure and resources necessary to enable SKA community science presents an additional challenge in that, for perhaps the first time, the required scale exceeds what can reasonably be dedicated to a single instrument or even a single research domain. It therefore follows that the scientific success of the SKA will depend critically on the ability of the community to leverage existing networks and computational resources and adapt them to the analysis needs of SKA science, or alternatively to layer these analysis needs effectively on top of that existing infrastructure. Here again, the AENEAS partners bring a wealth of experience and expertise with supporting exactly these types of porting and integration activities.

In addition, AENEAS is engineered by design to work in conjunction with the ongoing SKA design consortia and the SKAO to ensure smooth integration with the ultimate, operational SKA telescope. The AENEAS work programme and the broad international teams represented in the work packages are intended to deliver the objectives outlined in the project, but also to foster working relationships between these partners and e-infrastructures that will persist into the operational phase of the SKA and to support its continued development as well as its scientific success.

The INFRASUPP-03-2016-2017 Call clearly outlines a number of key challenges required to support the astronomy community in the full range of SKA science, and we believe the total work package and activities contained in the AENEAS project are well aligned with these challenges.

1.4 Concept and Approach

Guiding Principles

In constructing the AENEAS work programme, we have adopted several guiding principles to shape the overall structure of the project and define priorities amongst the many possible tasks:

- The project assumes that the distributed European Science Data Centre in question will function as the European hub in an interoperable, global network of SKA Regional Centres.
- The functionality considered must bridge the gap between what the SKA Observatory provides and what the user needs, such that the integral sum covers the full science extraction chain.
- The resulting design must interface smoothly with an operational SKA Observatory at the technical, policy, and governance levels.
- The foundations of this design will be built upon and take maximal advantage of existing infrastructures and e-infrastructures, and promote their development and innovation with novel requirements drawn from the SKA community.
- All data, code, tests, documentation, and reports produced under the auspices of the AENEAS project will be made freely available under an Open Access and open source policies.

Taken together, these principles summarize a consensus vision amongst the AENEAS partners for how to approach the challenge of empowering the astronomical community to fully realize the scientific potential of the SKA. This consensus represents the end result of a series of meetings between representatives of all the European SKA member states including scientific leaders and national funding agencies. Discussion during these meetings covered a gamut of topics from technical concerns to issues of governance and sustainability. The agreement to pursue solutions to this challenge jointly at the

European level and in coordination with other international partners arose out of these initial meetings, and the AENEAS proposal is one result of that decision.

The need to resource the scientific exploitation of the SKA has also been clearly identified as essential to the success of the Observatory by the SKA Organisation. A Data Flow Advisory Panel (DFAP) was initiated by the SKA Board in July 2015 to advise the board on how to optimise the data flow system for the SKA. The SKAO has noted that, within the current construction costs, no provision is made for the distribution of data to users, nor for computational facilities to enable users to undertake further data analysis, both of which are mission-critical if the SKA is to deliver on its scientific promise. As part of its advice to the SKA Board, the DFAP has noted that full scientific exploitation of the SKA will require "…a research ecosystem be in place for efficiently translating the large data volume into science results". In addition, the DFAP has identified three components that are not provisioned within the current scope of the SKA Observatory:

- Computational capacity for re-processing and science analysis
- Long-term storage capacity for archiving of standard SKA and derived data products
- Local user support for post-processing and science analysis

Although the DFAP has considered a number of top-level options, including a centralized solution whereby the missing elements would be added to the project scope albeit at substantial increase in the cost of the project, it has also identified several advantages to a regionally distributed solution. This option, in the form of a network of SKA Regional Centres, recognises the understandable preference of any country to invest in infrastructure within its own borders. It also allows resources to be tailored to the local needs of the regions, which are diverse across the SKA partnership. Finally, it offers the opportunity to leverage existing computational infrastructure across the SKA partnership. Following the report of the DFAP, the SKA Board has yet to officially endorse a specific course of action to address this community need. Pending that decision, however, the DFAP has recommended that "…regions commence work immediately to identify the appropriate resources, and that the SKA Organization provide support as required". The AENEAS proposal represents the intention of the European SKA community to act on this advice in partnership with the SKAO.

Composition of the AENEAS Consortium

The AENEAS consortium consists of the following organisations:

Full Member Partners: these are institutes or university departments from current SKA member countries. They have the radio astronomy and/or technical experience to lead the AENEAS workpackages and are ultimately responsible for their delivery. ASTRON (NL), UMAN, UCAM (UK), INAF (IT), Chalmers (SE).

Non-Member Partners: institutes or organisations from countries that are currently not a member of the SKA Organisation, but who do have an aspiration to join. They are keen to develop their technological experience and may host a node of the ESDC. These partners are funded at a lower level than the Full Member Partners. MPIfR (DE), CSIC (ES), IT (PT), CNRS (FR), UNIGE(CH)

Technical Experts: Organisations that have relevant expertise to help the AENEAS project reach its goals. These organisations receive moderate amounts of AENEAS funding. Alternatively, they receive only travel support from AENEAS but are committed to (self-funded) activities that are directly relevant for the AENEAS project. Jülich (DE), SNIC (SE), EPFL (CH), FOM (NL), GRNET (GR), SANReN (ZA), AARNET (AU), (NZ).

non-EU SKA Members: (inc. Host Countries): organisations from current SKA Member countries, deeply involved in the SKA project and likely to commit to setting up a Science Data Centres to support

their local community. CSIRO (AU) and NRF and IDIA (ZA), VUW (NZ). There are three SKA Members missing from this list: India, China and Canada. More informal contacts with suitable organisations from these countries have been established and they will be consulted in the WP2 activities.

SKA Organisation: The SKA Organisation is a UK Limited Liability Company that is responsible for the overall management of the SKA Project. Negotiations are underway between the SKA Member countries to set up a Convention or Treaty, similar to other large international facilities (e.g. ITER, CERN, ESO). This new organisation will be the SKA Observatory and is expected to take over all responsibilities from the current SKA Organisation. SKAO (Int.)

e-Infrastructure Partners: Specialist organisations responsible for a particular aspect of e-infrastructure that is essential for the design of the ESDC. EGI and GÉANT are Full Partners in the AENEAS Project and are, in fact, leading two of the work packages. The Research Data Alliance (RDA) is an international member organisation, supported by the European Commission and other research agencies and foundations that is working to develop and implement a global infrastructure to facilitate data sharing and re-use. GÉANT, EGI (both EU), RDA (Int.).

In the summary of the work packages in Section 3, the parties listed above can be either Partners or Stakeholders. Partners are funded for their contribution to the tasks whereas Stakeholders are not. Stakeholders may provide technical expertise and have an interested in the work being conducted, but are not on the critical path.

National and international innovation activities linked with AENEAS

Radio Astronomy facilities have evolved over the past two decades into large, international, data intensive instruments such as LOFAR, ALMA and e-VLBI. The Square Kilometre Array is a natural step in this evolution towards global radio astronomy facilities. AENEAS builds on a long standing history of SKA precursors, associated research projects, and international collaborations to support this evolution and the science community driving it.

The SKA precursor, LOFAR, has produced a considerable data archive of over 20 petabytes in its almost five years of full science operations. The data are stored and accessed via a distributed science data archive which is in itself a precursor for the ESDC targeted by AENEAS. The expertise built up on the LOFAR science data archive will be used as important input and reference for the ESDC design. The evolution from LOFAR towards the low-frequency part of the SKA has led to the NL-IBM-NWO-ZA collaboration, A collaborative project on “Precursor Regional Science Data Centres for the SKA” between NRF/SKA-SA, UCT/IDIA, NWO, ASTRON and IBM.

This evolution of these facilities has been supported by a multitude of international research projects and studies that have addressed the challenges and complexity. Many of these studies have been funded by the member states of the European Union and the EU itself. We note several here.

RADIONET: The RADIONET projects funded by FP6 and FP7 have played a catalyzing role in the evolution of the national Radio Astronomy institutes into a truly collaborative European community. RADIONET has set the stage for the establishing of new governance models for the community, the institutes and their facilities. The ambition of AENEAS to design a federated European Science Data Centre is a natural step in the evolution of European Radio Astronomy and AENEAS will build on the governance models derived by RADIONET. The software related Joint Research Activities HILADO of the RADIONET projects have delivered and will deliver software packages that are required for SKA data reduction. They will form an essential part of the ESDC.

SKADS, PrepSKA, GO-SKA: Earlier phases of the SKA project were also supported by the European Commission under the 6th and 7th Framework Programmes. The FP6 SKADS[6] (Square Kilometre Array Design Studies) project (2005-2009) investigated technologies that would allow the SKA to be built. Under FP7 the PrepSKA[7] project (2008-2012) looked at the SKA design, its legal framework and governance structure as well as mechanisms for the procurement of the various parts of the telescope. GO-SKA[8] (2011-2015) provided guidance at policy-level to ensure it will be optimally prepared for the construction and operation of the SKA.

NEXPReS: The FP6 Novel EXplorations Pushing Robust e-VLBI Services (NEXPReS) project focused on technical activities in the data handling part of large distributed radio astronomy telescopes including Cloud Computing, Network Infrastructure and High-Bandwidth, High-Capacity Networked Storage. Led by the AENEAS partner, JIV-ERIC, these results will feed directly into the concepts and designs of the AENEAS project in particular in the networking WP4.

DOME: The DOME project (www.dome-exascale.nl) is a research collaboration between ASTRON and IBM on Exascale technology. Its ambition is to provide solutions for the computing challenges of the SKA by delivering new algorithms, photonics, signal processing and new hardware architectures for green computing. DOME has provided many analyses and reports for the Science Data Processor of the SKA and equally relevant for the ESDC. One of the breakthroughs of DOME is a radically new microserver architecture that could allow the ESDC of AENEAS to operate as a next generation green data centre.

ASTERICS: The ASTERICS project is a large Research Infrastructure funded by the European Commission's Horizon 2020 framework. ASTERICS aims to address the cross-cutting synergies and common challenges shared by the various Astronomy ESFRI facilities (SKA, CTA, KM3NeT & E-ELT). It brings together for the first time, the astronomy, astrophysics and particle astrophysics communities, in addition to other related research infrastructures. The ASTERICS results on software re-use, robust, scalable and flexible handling and exploitation of the huge data streams and distributed, petascale database systems will be valuable input for the design of AENEAS.

CIRAS: The CIRAS (Cloud Infrastructure for Radio Astronomy Software) proposal is an initiative to develop an e-science cloud HPC service to support and help develop the European radio astronomy community and has been designed to address the Horizon 2020 Work Programme EINFRA-22-2016 call ``User-driven e-infrastructure innovation''. CIRAS builds upon the RadioNET advanced community and incorporates cloud-ready processing for data from RadioNET facilities. The objective of this project is to widen participation in RadioNET science, lowering the expertise threshold, by providing a user-friendly web interface for running cloud-based workflows for RadioET processing that allow the user to select a suitable cloud, control their own finances and initiate their processing, whilst (optionally) hiding them from the technical detail of the cloud access, data archive access and the algorithmic complexity of the processing.

Along with the astronomy focused and radio-specific developments, AENEAS will align with and take advantage of several international collaborations and communities including:

IVOA: AENEAS will take into account the recommendations from ASTRONET, the European consortium for establishing a roadmap for all of European astronomy, on how to achieve a successful exploitation of the astronomic data. This consortium tasked the European Radio Telescope Review Committee (ERTRC) to take a broader look at the present situation of radio astronomy in Europe. These recommendations highlight the role of the Virtual Observatory (VO) as well as of the web environments

[6] http://www.skads-eu.org
[7] http://www.jb.man.ac.uk/prepska/
[8] http://goska.skatelescope.org

known as Science Gateways (SGs), as powerful tools that ease the access to data distributed among different computing resources, promoting the sharing of methods and data among the user community. From 2002 the International Virtual Observatory Alliance (IVOA) has been developing standards for exchanging astronomical data, and maintaining registries of data repositories and services, thus forming the VO, a network of interoperable services and data that provides a unique and homogeneous access to a wide range of astronomical data. AENEAS will integrate the VO in the ESDC design (WP5). The high demanding requirements of SKA data will force to seek for new solutions to exploit vast volumes of data, make an efficient use of the existing computational resources, enabling data and methods sharing and ensuring reproducibility.

SAGrid: AENEAS will leverage the activities of the Council for Scientific and Industrial Research which is promoting the Africa-Arabia Regional Operations Centre (AAROC, or ROC Africa-Arabia), an initiative coordinated by a collaboration of regional institutes from African and Arabian states. The collaboration is represented by the Meraka Institute in South Africa — itself an operating unit of the Council for Scientific and Industrial Research (CSIR) – which hosts the South African Initiative for Cyberinfrastructure (NICI). A component of this initiative, the South African National Grid (hereafter referred to as SAGrid), is responsible for promoting international collaboration of grid computing infrastructures in South Africa and has coordinated similar activities in the Sub-Saharan region since 2009. SAGrid is a core component of AAROC, and The Meraka Institute is responsible for the core SAGrid services which enable interoperability with EGI. In addition, SANReN, the South African NREN, operates within the Meraka Institute, which is responsible for several operational tools and services on which the grid community relies.

CANFAR: AENEAS will directly benefit from the EGI collaboration with The Canadian Advanced Network for Astronomical Research (CANFAR), a computing infrastructure for astronomers in Canada and the Canadian Astronomy Data Centre (CADC). CANFAR and EGI are working together in the context of the EC funded project EGI-Engage to integrate both e-Infrastructures towards a seamless platform for international astronomy research collaboration. Community services will be provided on top of the federated cloud of EGI using open source solutions and re-using the CANFAR experience. The outputs of this collaboration will be made available to AENEAS as pathfinder activity for the definition of its interoperability and federation model.

EOSC: The governance, policies and access modes defined in WP2, will be compliant to the principles of openness of the European Open Science Cloud initiative of the EC[9] and the Commons governing rules[10] , in particular, the ESDC will be:

- Open in design, participation and use
- Publicly funded & governed with the “commons approach”
- Research-centric with an agile co-design with researchers and research communities
- Interoperable with common standards for resources and services

As the ESDC will be part of an international network, it will help promoting the adoption of EOSC beyond Europe. Also, AENEAS will adopt the FAIR principles[11], by helping making SKA data findable, accessible, interoperable and reusable.

[9] https://ec.europa.eu/research/openscience/index.cfm?pg=open-science-cloud
[10] https://documents.egi.eu/public/RetrieveFile?docid=2637&version=1&filename=OSC_Position_Paper.pdf
[11] https://www.force11.org/group/fairgroup/fairprinciples

1.5 Ambition

AENEAS is addressing the needs of the European research community by providing a detailed design for the scientific processing of SKA data. At SKA scales, the complexity and magnitude of the underlying infrastructure necessary to deal with these data goes far beyond the existing paradigm of radio astronomy data processing, requiring innovative solutions not only in order to process and distribute data around Europe, but also to ensure the usability of this compute for the astronomers who will be leveraging it to create science outputs. Our ambitions for this project are:

- European leadership in SKA data processing
- European leadership in SKA science
- Unification of the European SKA science community

Here we describe the main challenges, the current situation and the innovation potential of AENEAS for achieving each of these ambitions.

European leadership in SKA data processing

The challenge: Data processing for the SKA is often described as a problem that ends at the output of the Science Data Processor (SDP); however, those data products produced by SDP are only the tip of the processing iceberg required to extract scientific information from the telescope. Scientific excellence from SKA data depends heavily on the quality of processing that is available for post-SDP analysis. This is the processing that identifies objects in images, extracts source information, and determines structural quantities such as power spectra and frequency variations. Such analysis has much more in common with data mining and standard "big data" tools than the processing performed on the raw data by SDP. Nevertheless, an SKA Data Centre should accommodate both types of processing in order to maximise scientific return.

Currently: The existing model of data processing for radio astronomy is in a state of flux. Historically, astronomers would receive and process data sets individually on desktop machines. However, in recent years the arrival of next generation "software telescopes" has made this processing model unfeasible for modern radio astronomers. Demand for processing and storage in radio astronomy has increased significantly, with many astronomers finding that they do not have sufficient resource to extract science products from their data in a timely matter, if at all. This situation will be aggravated in the extreme for the SKA and a fragmented approach of institute level compute across Europe will not be sufficient for processing these new data. Without a federated approach to SKA processing and storage, European radio science will suffer compared to that from regions with federated SKA compute such as South Africa, Australia and China.

Innovation potential: The AENEAS project will produce a design for a federated European SKA data centre that will enable scientists from European research institutes to fully extract scientific potential from their data. It will also allow the re-use of archival data and enable reproducibility of SKA scientific results. These qualities are essential components of an Open Science environment for SKA in Europe. In doing so, AENEAS will provide innovative processing solutions for SKA post-SDP analysis as well as integrating many of the processing steps of the SDP itself into a highly distributed European network. Not only will this integration bring software innovation, but it will also require innovative approaches to usage models in order to overcome the existing "single desktop" analysis paradigm.

European leadership in SKA science

The challenge: The scientific ambitions of the European research community with respect to the SKA have been made very clear. The high level of European participation in the SKA science working groups and publications demonstrates a keen ambition for European scientists to extract maximal scientific return from the SKA. In order for this scientific leadership to continue past the design stages of the telescope and into the operational phase, Europe requires an SKA data centre capable of producing the science that is being talked about at the moment.

Currently: As a continent, Europe dominates the SKA scientific literature and plays a leading role in guiding the scientific direction of the instrument. The situation of the SKA headquarters in Europe reflects the leading role that Europe maintains in the project, in spite of the fact that the hardware itself will be deployed in South Africa and Australia. Eight of the ten[12] SKA Science Working Groups are currently chaired or co-chaired by European-based scientists. With one of the two remaining SWGs having recently rotated away from a European chair. Europe currently maintains a strong position in SKA science, that it should seek to maintain into operations.

Innovation potential: AENEAS will provide a detailed design for a European data centre that will fulfill the scientific requirements of the European research community. This design will take into account the science use cases for the instrument and ensure that the processing functionality and environment, as well as the associated data storage and transport needs, will be met for the needs of the European SKA community. This design will enable maximal scientific return, which is essential for continued European leadership in SKA science.

Unification of the European SKA science community

The challenge: A successful distributed, federated European Science Data Centre (ESDC) to support the astronomical community in achieving the scientific goals of the SKA requires the cooperation and support of the European community. However, although the research community is already dreaming of SKA science, they have not yet woken up to the reality of what will be necessary to achieve it. The work of the AENEAS project – focusing on a *European* data centre - is essential to demonstrate the scale of the processing and storage that will be necessary locally, within Europe, to the wider scientific community. Realizing the universal comprehension of this reality is a challenge that AENEAS faces.

Currently: AENEAS is a project built on the core SKA member countries, but also involves extensive additional participation from other European countries with a vested interest in SKA. The broad partnership of the AENEAS project shows that, at a certain level, Europe recognizes that SKA processing will require a progressive design and federated approach. However, on another level within the academic community, the "single desktop" analysis paradigm still dominates the mindset. This is perhaps unsurprising, as the sheer level of SKA computing and the associated data volumes – especially to those astrophysicists who have not yet had to deal with the new software telescopes – is simply incomprehensible.

Innovation potential: The AENEAS project has the opportunity to cause a paradigm shift in radio astronomy research. By making the design process for an ESDC open, via the website and regular interaction with the wider astronomy and technical community, the radio research community will gain a better understanding of the scale of SKA processing and post-processing.

[12] The Solar & Heliospheric Physics SWG is not yet included in this number as its membership is not available via SKAO.

2. IMPACT

2.1 Expected Impact

Community Impact

The objective of the AENEAS project is to design a structure for the SKA Regional Centres - and those in Europe in particular - that will allow the user community to take maximum advantage of the scientific potential of the SKA. Through consultation and ongoing engagement of the user community (via the Users Committee) a solid understanding of the user requirements will be reached, not just at the level of (large) Key Science Projects which currently dominate the discussions within the project, but also of individual users and outside the sphere of current SKA Member countries. This will be essential in creating a European Science Data Centre that serves the needs of the users. A further aim is to provide support for the growth of astrophysics across Europe in a coordinated manner specifically related to the science goals of the SKA, encouraging countries that are not traditionally strong in radio astronomy to become participants in the SKA program.

On the part of the users, it will be important to realise that a paradigm shift is taking place from the familiar "single desktop" approach based on what can be achieved on individual workstations or local resources to the data intensive regime heralded by SKA pathfinders like LOFAR and the precursors, ASKAP and MeerKAT.

Technical Impact

The ability of a European Science Data Centre to deliver the required performance depends critically on availability and suitability of technology. Investigation of the chain of infrastructure hardware, middleware, software and other tools needed to achieve the performance targets will be vital to the design of the ESDC. WP3 will assess the suitability of HPC, cloud and distributed computing technologies and will test different concepts using SKA pathfinder and pre-cursor facilities. WP4 will assess the feasibility of transporting data from the SKA host countries to Europe - and between the nodes of the distributed ESDC. WP5 will address the integration of the ESDC into the well-established distributed Virtual Observatory framework - a vital element in lowering the threshold for users, especially those outside the traditional radio astronomy community. In order to operate efficiently the ESDC will require seamless access to a distributed web of datasets, applications, publications, computing resources, etc., provided via federated service management processes and tools. WP6 will produce recommendations on how this can be achieved across multiple service providers (both from the community and generic/shared e-Infrastructure services).

In the course of the AENEAS project we will explore and demonstrate the feasibility of key technologies required to meet the requirements, as described above. Where possible and feasible, this will be done using SKA pathfinder and pre-cursor data and facilities. The end result will be a design of an ESDC that is technically achievable.

Performing the Proof of Concept tests to address the challenges of moving large volumes of data between the National Research Networks SANReN in South Africa, AARnet in Australia, and GÉANT in Europe and the Radio Astronomy end sites will enhance global collaboration and demonstrate global science interoperability. It will also provide useful insight into the operational requirements needed for networks and compute centres for the continuous streaming of high volume science data over long distances at very high speeds. These experiences will be valuable for both academic and commercial infrastructures.

Political Impact

An aim of the AENEAS project is to harness and leverage existing investments in European network and computing infrastructure, plus future European investments in the SKA, to provide to the European community the tools, platform, and expert support required to deliver the scientific discovery potential that the SKA has.

Around the end of the three year AENEAS project (2019) will be the time to begin making investment decisions for the implementation of the European SKA Science Data Centre. The AENEAS Design Study will be the starting point for a discussion among national radio astronomy centres, similar entities in countries aspiring to join the SKA project, national laboratories, (super)computing centres, funding agencies etc. to agree on a governance and associated funding model that can support a European SKA Science Data Centre.

Societal impact

The SKA will be the biggest and most visible project in astrophysics over the next 20 years. A distributed European SKA Science Data Centre will be the natural conduit for education and outreach for the SKA across Europe, to both professional and lay audiences. The social impact of local dissemination of SKA science, in terms of education and training will be large.

Radio astronomy is currently one of the most challenging applications in terms of management and exploitation of massive data sets, development of complex algorithms, and utilization of distributed computing resources. The SKA will continue down this path, providing unprecedented opportunities for high level technical training in data science. The ESDC will need to lead this drive in Europe, in order to satisfy its own requirements for highly trained data scientists. Naturally, many data scientists will diffuse into and out from the ESDC over its lifetime, forming a significant part of the European future data science ecosystem.

Key Performance Indicators

As the areas described above demonstrate, the AENEAS is expected to have significant scientific, technical, and societal impact. In order to monitor that impact, the consortium will define and monitor a variety of Key Performance Indicators (KPIs) over the course of the project specific to each of these foreseen impact areas. The currently identified KPIs for the AENEAS project include:

- Evolving census of user requirements obtained through community engagement
- Database of institutes, research groups, and individual users polled for requirements
- Size and rate of growth of the AENEAS community email distribution list
- List and archive all publications produced solely or in part through the AENEAS project
- List and materials for all AENEAS-related presentations at meetings, workshops, and forums
- Evolving census of technologies examined for compliance with requirements
- List, materials, and results for all proof-of-concept technology tests
- Evolving census of existing facilities and national resources related to the AENEAS project
- Database of institutes, research groups, and individuals involved in the governance definition
- List of skilled personnel trained solely or in part through the AENEAS project
- List of student projects supported solely or in part through the AENEAS project
- Database of institutes, research groups, and individuals involved in AENEAS-related training

These KPIs will be reported periodically to the European Commission over the three-year span of the AENEAS program. We note that this set is not intended to be definitive and may be amended or adjusted as the project proceeds and as we gain experience with which KPIs are effective in tracking project impact. A full set of defined AENEAS KPIs will be an early deliverable of the project in WP1.

Innovation capacity and integration of new knowledge

Design work for an ESDC is necessarily innovative in its approach, with best practice recommendations for all aspects of a system being considered including networking, data transport, software, and storage. Furthermore, this design will be combined with the development of cost models and governance structures. These different aspects of system design bring together stakeholders from a wide range of communities and create an opportunity for both technical innovation and valuable knowledge transfer. This opportunity is highlighted by the fact that it will be created in such a high impact technology area.

Based on past experience with other radio telescopes, and given the challenges that the SKA poses, it is certain that development and innovation of the processing, storage, user-driven analysis of SKA data will continue throughout the operational period. The breadth of these developments lend themselves to creating an environment where knowledge institutions and private companies work together closely. The AENEAS project, and the ESDC centres themselves, therefore have the potential to act as incubators for technical innovation. The inclusive nature of the AENEAS project maximizes the impact potential of such incubation, both geographically and in terms of the wide range of communities that can be reached.

Where possible, the ESDC nodes will have the potential to work closely with, or share, the infrastructure with other data intensive applications. For example, a data centre that provides (part of) the storage of the ESDC may also have commercial clients that can benefit from the innovations that are developed for the SKA. The ESDC network can therefore act as a catalyst for scientific excellence in Big Data and HPC, with ESDC centres having the potential to enhance the business models of SMEs that provide their services. We do not, however, anticipate creating SMEs as part of the AENEAS proposal itself.

Barriers and obstacles

The SKA is currently still in a definition phase and shifts of SKA project scope and policy over the next 3 years may affect the direction of ESDC planning. The AENEAS project will be actively engaged with the SKA policy-making bodies, in order to inform the future directions of SKA policy and ensure alignment with the SKA project scope.

It may be difficult to extract clear requirements from users that go well beyond today's perceived needs, but also look to the future and identify requirements that are relevant 5-10 years from now. Ambitions and expectations are high. It may not be possible (initially at least) to deliver what the users expect – though it seems likely that this will improve over time. What may not yet be achievable in 2023, may well become possible 3-5 years later as technology develops.

We expect that the inventory of available compute and storage resources (provided as part of WP2.1) will be significant, heterogeneous and more than likely considerably greater (in number) than required. This means choices will have to be made and parties will be disappointed. Striking a balance between political (who pays), performance, operability and maintainability considerations will no doubt be complicated. The long term impact of a scientific instrument depends on the availability and accessibility of the data products. Considerations such as long term sustainability of the (archival) functions of the ESDC will therefore be of great importance.

2.2 Measures to Maximise Impact

The most powerful tool AENEAS will utilize to achieve maximum impact in the areas described above is an active engagement with our target audience. This engagement will go beyond more passive types of dissemination and primarily take the form of active, ongoing collaborations where possible. The target audience for the AENEAS project is broad and ranges from potential scientific users of the SKA, to the SKA Organisation and design consortia, various technical partners and service providers, national and international e-infrastructures, and national and EU policy makers. The AENEAS consortium has been constructed to include direct partnerships with representatives from as many of these stakeholder communities as possible. Although such a large collaboration carries with it a certain amount of management overhead, we believe the opportunity to form direct working relationships with these diverse communities is essential to the success of AENEAS and outweighs those costs. In this section, we summarize the specific mechanisms the AENEAS project will employ to build these working relationships.

SKA community engagement

Engaging with the SKA scientific community is naturally one of the highest priorities for AENEAS. Meeting the scientific needs of this community drive the AENEAS project and are the ultimate metric by which the success of the resulting European Science Data Centre design will be judged. Ongoing engagement of the user community will be crucial to ensure that the ESDC design continues to meet the developing requirements, which are to be expected at the cutting edge of scientific discovery. To ensure this regular interaction, AENEAS will identify a committed group of users, recruited as part of the survey of the astronomical user community (in WP2.2), to form a Users Committee. These users will be drawn from the current SKA science teams, thereby ensuring a base knowledge of the SKA capabilities and post-Observatory science extraction requirements. It will also include members from the wider astronomical community to ensure the ESDC design does not neglect issues related to broader multi-wavelength analyses outside the SKA bands or even beyond radio frequencies. Regular interactions with the Users Committee will be scheduled twice a year over the course of the project to track progress and adjust the ESDC design accordingly.

If this resulting ESDC design is to be viable, it must interface smoothly at a technical, operational, and policy level with the SKA Observatory itself. At the working level in AENEAS, this smooth interface is achieved in two ways. First, the majority of the partner organisations in the AENEAS project are already part of the SKA design consortia and actively involved in developing the detailed design for the SKA Observatory including computing, data transport, and operations among other components. Some of the relevant SKA consortia where AENEAS partners play key roles include the Science Data Processor (SDP, analogous to WP3), Signal and Data Transport (SADT, analogous to WP4), and SDP-DELIV and Observatory Support Tools (DELIV and OST, analogous to WP5). This dual identity ensures the AENEAS project has an accurate and up to date picture on exactly where the boundaries of the SKA Observatory end and where this project begins. Secondly, the SKAO which coordinates and oversees the work of the design consortia is also a partner in the AENEAS program. By actively taking part in the day to day execution of the work programme, this partnership with the SKAO will guarantee that results from the SKA design process and the complementary work in AENEAS are regularly transmitted and synchronized. Representatives of the SKAO will take part in the biannual AENEAS all-hands meetings as well all relevant meetings of the various WP teams.

Community engagement beyond astronomy

One of the unique challenges facing the AENEAS team and the ultimate ambition to construct an ESDC of sufficient scale and capability to support the full range of SKA science, is how to effectively integrate existing research infrastructures across Europe and globally. While these challenges are relatively novel

for the astronomy community to date, there is fortunately a wealth of experience in this area available in the wider community of e-infrastructure organizations. Consistent with the terms of the INFRASUPP-03-2016 call, AENEAS directly integrates this expertise into the work programme through partnerships with GÉANT (WP4, WP5, WP2), the EGI federation (WP6, WP3, WP2), and the RDA (WP2). In addition to leading several of the major technical WPs directly, these e-infrastructure partners provide a conduit to the larger global e-infrastructure community. Similar to the role of the SKAO in AENEAS, these partners provide a natural two-way communication channel to both leverage this larger, global pool of expertise and also communicate results from the AENEAS project back to that larger community. As with all partners, the e-infrastructure member organisations will attend the full AENEAS team meetings and WP-specific team meetings. Where appropriate, they may also host special outreach forums to disseminate relevant SKA community requirements and AENEAS results to the large e-infrastructure community.

In addition to existing e-infrastructures, a new initiative is underway to establish a European Open Science Cloud (EOSC) to support the wider European research community. This EOSC would offer European researchers "…a virtual environment with free at the point of use, open and seamless services for storage, management, analysis and re-use of the data that are linked to their research activities, across borders and scientific disciplines"[13]. Such an environment is clearly consistent with the vision behind the AENEAS project and of direct potential benefit to the SKA science community. Recently the EC has appointed a High Level Expert Group (HLEG) on the EOSC to advise on the scientific services to be provided on the cloud and on its governance structure. Several of the partners in the AENEAS project, including the SKAO, are already actively engaged with this HLEG. The AENEAS team will seek to continue and strengthen this working relationship with the EOSC effort in order to ensure the needs and requirements of the SKA community are considered. In particular, the governance, policies and access modes developed for the ESDC will be compliant with the principles of openness set out by the EOSC.

Although radio astronomy, and the SKA in particular, is leading the field in terms of the sheer volume of data combined with the utilization of distributed computing resources, many (research) communities are facing similar challenges. The Research Data Alliance (RDA) is an international member organisation, supported by the European Commission and other research agencies and foundations that is working to develop and implement a global infrastructure to facilitate data sharing and re-use. Through focused Working Groups and more exploratory Interest Groups, the RDA develops and implements concrete Recommendations and Supporting Outputs that provide the social and technical connections necessary for a functional data infrastructure that bridges across countries, disciplines, scales, and technologies.

RDA provides the tools, mechanisms, and lightweight governance for engaging with a wide community and facilitating cross-disciplinary coordination. RDA provides:

- An online collaborative workspace.
- Administrative support from a global Secretariat
- Formal expert review and advice on proposed infrastructure development and Recommendations through a community-led Technical Advisory Board and Organisational Advisory Board.
- Twice-yearly Plenary meetings that convene the community to develop and report on current data infrastructure.
- Formal dissemination of Recommendations and other outputs through government and community networks and diverse communication channels.
- Promotion and support of infrastructure Recommendations developed within RDA.

[13] https://ec.europa.eu/research/openscience/index.cfm?pg=open-science-cloud

Within the context of RDA, we will seek to coordinate federated SKA data systems and science data centre development. The goal is to gain efficiency in meeting the objectives above while ensuring SKA systems are appropriately and globally interoperable.

The AENEAS project will directly join appropriate RDA Working and Interest Groups in developing relevant components of the SKA analysis infrastructure. Current groups of interest might include, Big Data, Persistent Identifiers, Data Typing, Array Databases, Bibliometrics, Workflows, and others. The RDA's Technical Advisory Board will also advise on the development of new Working and Interest Groups coming from the SKA and how they can engage with other RDA Groups. The RDA Secretary General and Secretariat will advise and assist the AENEAS project on the development of and participation in relevant RDA Working and Interest Groups. The RDA Secretariat and other parts of RDA will help disseminate and facilitate the adoption of AENEAS-led Recommendations and other outputs to a broad constituency of researchers, government officials, private vendors, and others.

Finally, as discussed below in Section 3, all of these stakeholder communities mentioned above, astronomical and otherwise, will be directly represented in the management structure of the project through the AENEAS External Advisory Board (AEAB). The AEAB will provide independent advice to the AENEAS coordinator and to conduct independent assessments of the progress being made by the project. The Board will specifically include members from all of these stakeholders as well as national and EU policy makers.

Communication Plan

Some aspects of the AENEAS communication and engagement plan are well codified at this point such as the central role of the biannual, all-hands project meeting. Other aspects such as possible design reviews conducted jointly with the SKAO, policy discussions with the SKA Organisation, or special-purpose forums organized to target specific non-astronomical communities remain to be defined in detail. For now, we foresee the following activities:

- Biannual meetings of the full AENEAS consortium including international partners
- Monthly work package-specific team meetings as necessary (via video or telecon)
- Coordination meetings with SKAO and relevant SKA design consortia personnel as necessary
- Biannual reviews of the design requirements and progress with the AENEAS Users Committee
- Regular attendance at biannual RDA plenary meetings by AENEAS team members
- Special purpose forums to communicate AENEAS results with e-infrastructure community
- Special purpose design reviews with SKAO to ensure AENEAS compatibility with SKA design
- Special purpose reviews with SKA Organisation to ensure compatibility with SKA policies
- Presentations at relevant astronomical and technical meetings

We note that this list is not intended to be definitive at this stage. A full plan for the communication, dissemination, and exploitation of AENEAS will be an early deliverable of the project in WP1.

Dissemination and publication of results

At the end of the AENEAS project we will deliver a design study for a European SKA Science Data Centre as well as initial plans for the governance, business model, and implementation. At this stage, it is hard to judge the likely scope and cost of what can be implemented and therefore the extent to which the user requirements can be achieved. We will adopt an iterative approach to creating an outline of the ESDC early on and filling in the details as requirements, technical design implications and cost become clearer. It will be important throughout to make sure the plans meet the governance requirements set by the global SKA project, anticipated funding agencies as well as any external partners. These parties are all engaged as part of WP2.

All documentary deliverables from the project will be made publicly available on the AENEAS web portal. Publications in peer reviewed journals will be made Open Access using either the green or gold route. Gold route Open Access will be sought for all cases in the first instance, with additional green route access being made available via the dual routes of an online document repository linked directly to the project web portal and use of relevant archives (e.g. astrophysics arXiv service). No publications will be submitted to journals that deny use of the green route. To ensure this an appropriate restriction will be included in the Consortium Agreement.

In order to maximise the exploitation of project software as well as fostering community engagement, all software produced by the project will be Open Source and made available via the github service under the Apache license. As well as maximising access to the project for external users, this policy also encourages re-use and development of the software beyond the scope of the pilot processing workflows targeted by the AENEAS project.

Knowledge management and protection

Although all results will be open source, the consortium needs to ensure that new knowledge and the rights of innovation be appropriately shared, protected and secured across the project. Given the academic nature of most of the partners, information exchange will happen in an open atmosphere, but there may be areas in which management of knowledge capital will be important. We will secure the sharing and protection in the AENEAS Consortium and IP agreement. For this a flexible implementation of Intellectual Property Rights (IPR) will be necessary. This formal process of ownership and for use and sharing of intellectual property will be defined in the AENEAS Consortium Agreement. In general, developments within the project will be viewed as shared products, equally available to all project partners. Nonetheless, the agreement will provide adequate and effective protection of knowledge that is likely to be of industrial or commercial application. This is clearly required for the developments of technological processes but also for special design and characterisation procedures developed in the partners' laboratories. IPR will be a standing agenda item at the team meetings and followed by the Management Team throughout the projects duration.

3. IMPLEMENTATION

3.1 Work Plan — Work Packages, Deliverables and Milestones

Overall structure of the Work plan

The AENEAS work programme is divided over 6 main work packages (WPs). The first WP deals with the oversight and management of the AENEAS project itself and its structure, along with those of the other WPs, is discussed in more detail in Section 3.2 below. The AENEAS Management Support Team (AMST) will be responsible for maintaining oversight of the project and the various WPs and consist, at a minimum, of the project coordinator, the program manager, and the WP leaders. WP1 will also oversee the collection and dissemination of all project materials and be the central point of communication within the project and with the larger community. The remaining WPs represent the main technical content of the project.

The ultimate objective of the AENEAS project is to develop a plan for the implementation of a European Science Data Centre for the Square Kilometre Array. WP2 will focus on the non-technical aspect of assembling such a plan including an assessment of the overall European landscape into which the envisioned ESDC must integrate. In addition, WP2 will consider issues of policy, funding, overall governance, and industrial engagement. WP2 will also oversee the integrating activity whereby the results from WPs 3-6 are assembled into the final design study.

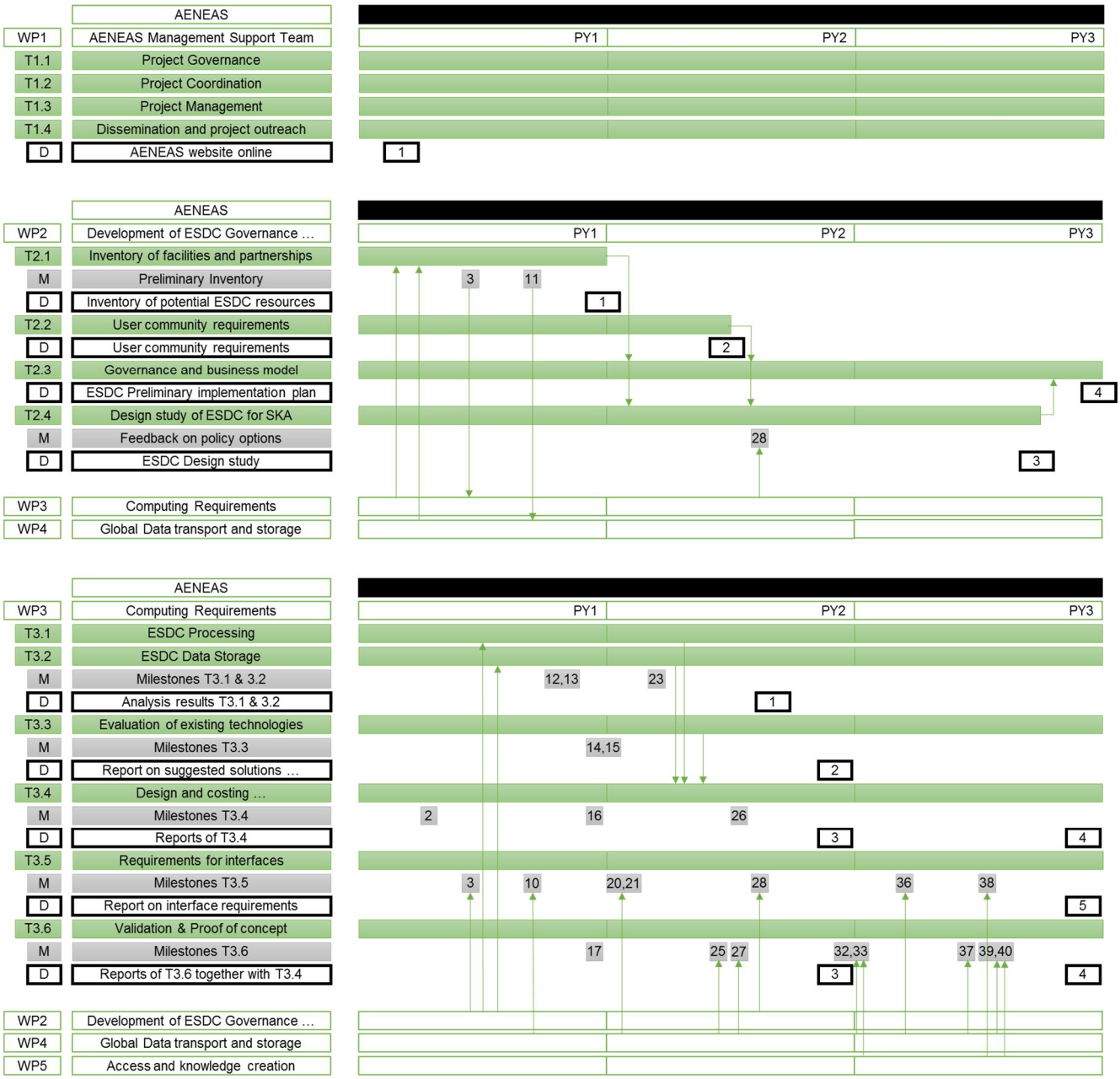
Work packages 3 and 4 encompass various aspects of the computing and networking components for the ESDC design. WP3 will focus on the computing requirements and in particular identify and assess the components, both in hardware and software, necessary to deploy the functionality required by the SKA science community. Based on the full SKA science case, WP3 takes a perspective of total science delivery and will consider requirements, computing and storage scales, and assess relevant technologies. WP4 will investigate and demonstrate the data transfer and storage techniques required for the network design of a distributed computing and network architecture for an ESDC. It will cover a range of activities including data access and transfer protocols, replica and transfer management, data movement, and network level testing.

The remaining work packages 5 and 6 are intended to address aspects of data access and knowledge creation as well as other cross-cutting services to ensure interoperability across the integrated infrastructure and e-infrastructure upon which the ESDC will be deployed. WP5 will emphasize data access and interfaces to the SKA data in the ESDC from the perspective of an individual user. It will build upon existing VO experience and frameworks to provide interoperable access to scientists across all SKA member states. In this sense, it is complementary to the total science delivery approach of WP3. The primary driver for WP5 will be enabling the extraction of scientific results by a distributed body of SKA end users.

We have consciously struck a careful balance in the resources dedicated to the development of computing requirements (WP3) and access and knowledge creation (WP5). Although computing is arguably one of the most challenging aspects of the SKA project, the balance between WP3 and WP5 reflects two key boundary conditions for the AENEAS project. First, the bulk of the design effort for the SKA computing challenge will be done under the auspices of the SKA project itself and the effort in WP3 is intended to both extend and connect to that larger effort, both technically and organizationally. WP3 will specifically focus on the computing elements necessary to support additional user processing and science extraction and take full advantage of the larger design effort underway in the SKA SDP design consortium. By contrast, WP5 focuses on the user interaction and accessibility aspects of working with SKA data scientifically, and as such covers areas that are either largely outside the current

envisioned scope of the SKA design effort or present at a minimal level. In this sense, the relative weighting of resources for the AENEAS work packages, when combined with the relative priorities of the SKA project design effort itself, is designed to achieve the integral sum of functionality required to support community science extraction.

Finally, WP6 will concentrate on processes, protocols, tools, and services required to ensure interoperability between existing SKA-relevant e-Infrastructures. By addressing topics such as a seamless Authentication and Authorization Infrastructure (AAI) across the underlying network of service providers, WP6 is relevant to all of the preceding technical WPs 3-5 and essential to lower the barriers for potential users of the final SKA ESDC. By enabling SKA users to access federated services and resources offered by different e-infrastructure providers in Europe and around the world, WP6 is also crucial to connecting AENEAS with other similar efforts worldwide.



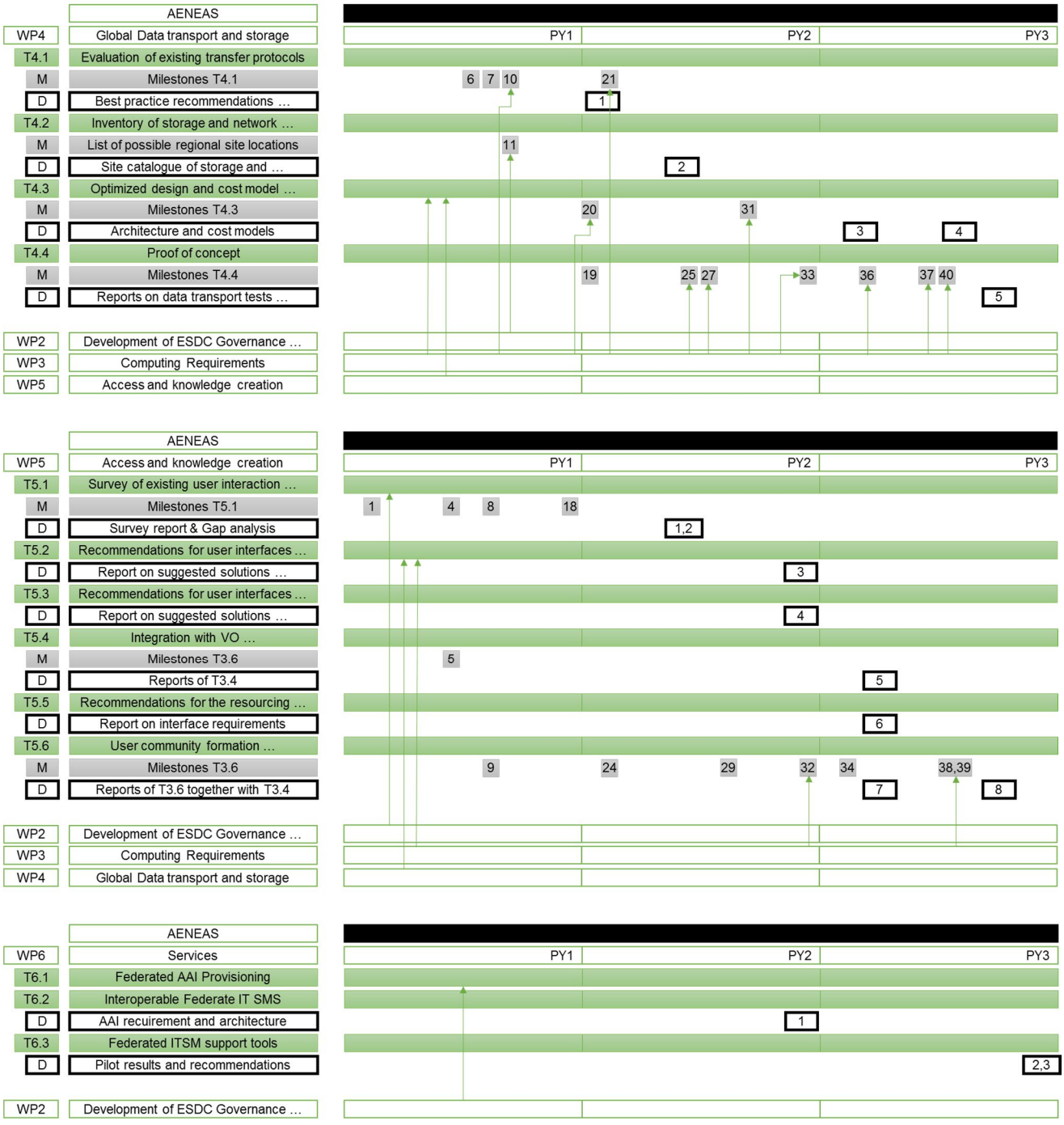


Figure 6: Timeline of project and dependencies of WPs, Tasks, Deliverables and Milestones.

Detailed Work Package Descriptions

AENEAS WP6: Services

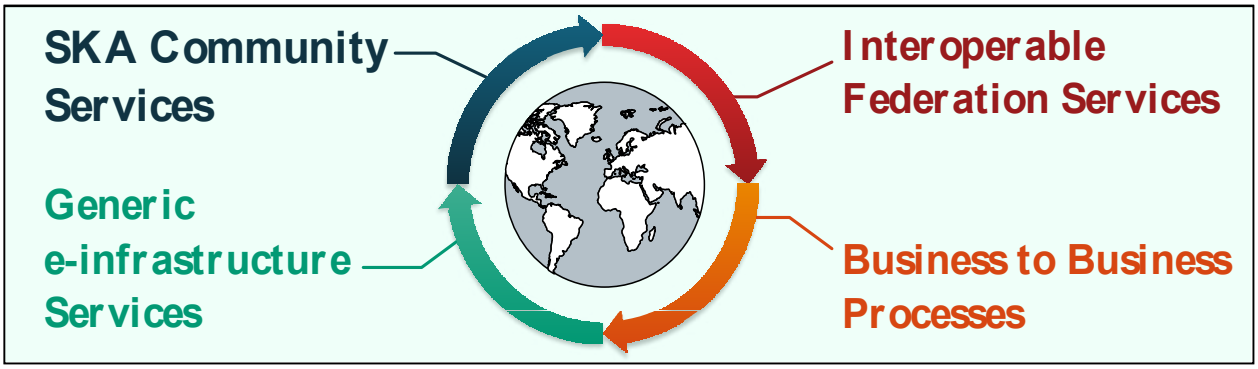


Figure 7: Business relationships between SKA community services and generic e-Infrastructure services.

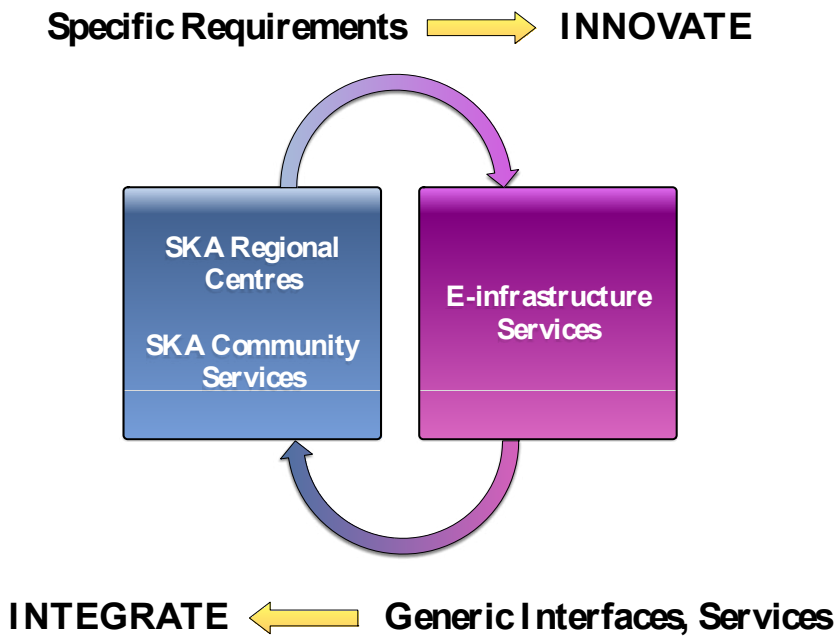


Figure 8: Innovation cycle involving regional SDCs and e-Infrastructure in WP6.

Graphical representation of the WP components

Figure 8 shows the AENEAS work packages and the manner in which they interact. Although the WPs have been designed to be largely independent, there are direct interactions between several of the work packages. In particular, WP3 on the Computing Requirements has clear interfaces with both WP4 on Data Transport and WP5 on Data Access and Knowledge Creation. Similarly, WP6 on Services has obvious connections with WP5. These interfaces between the work packages are reflected in the Milestones list in Table 3.22**.** In addition to focusing on governance issues, WP2 also provides an

integrating activity for collecting the inputs from WP3-6 to assemble into the final deliverable design. This integrating activity will occur iteratively on an annual basis over the 3-year term of the project culminating in the final design for the ESDC. Throughout the project, WP1 provides oversight for the whole work programme and support for each of the WPs individually.

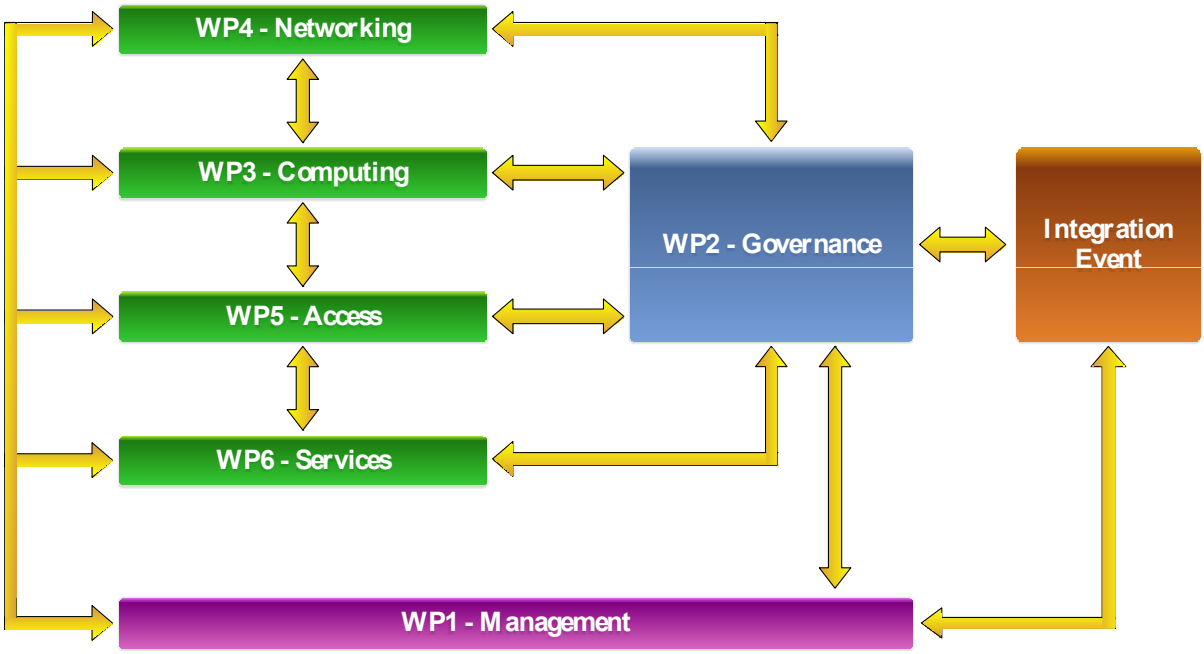


Figure 9: Graphical representation of the ASTERICS work package components and their interconnections.

3.2 Management Structure and Procedures

Innovation management

Although the AENEAS project has a relatively short timeline, many of the core areas involved in the project are undergoing rapid development both technologically and in terms of community adoption. The recent initiatives in terms of cloud technologies for computing and data access such as the European Open Science Cloud (EOSC) are perfect examples where significant evolution is expected even over the three-year timeframe of the AENEAS project. Consequently, the project must be prepared to both recognize and potentially adapt to external innovations as well as communicate innovations that arise internally over the course of the project back to the wider community.

Fortunately, this situation is a familiar one for many of the AENEAS partners who have been involved with the development and operation of cutting-edge astronomical facilities. In fact, the institutes involved in the AENEAS project are leading the development and operation of most of the SKA pathfinder and precursor instruments including LOFAR, MeerKAT, and ASKAP among others. As such, they have an established track record for both recognizing new innovations and incorporating them into ongoing efforts rapidly as well as optimally exploiting and communicating internal innovations. Most of the AENEAS member institutes have extensive networks of contacts with other disciplines, small and large businesses, and other industry partners who keep them connected to the latest round of innovations and help them contribute back to that cycle. Within Europe, the development of the LOFAR telescope led by ASTRON in collaboration with other European member countries is a

perfect example of how crucial this constellation of external, non-astronomical partners can be for effectively managing innovation. The collaboration with IBM on both LOFAR, and now the SKA itself with the DOME project, is a prime example in this respect.

Proactively staying abreast of new innovations will be especially important for the AENEAS project. The ultimate deliverable for AENEAS is a detailed design study for a distributed, federated European Science Data Centre that can be rolled out in the 2020 timeframe. Consequently, where possible, we must incorporate expected innovations into our planning so as to not deliver a design that is already obsolete by the time we are ready to begin implementation. At the same time, we recognize that, despite the considerable experience of the AENEAS partners, we cannot rely solely on that internal experience.

To augment that experience, AENEAS will follow several approaches. First the AENEAS project will adopt an open access, open innovation policy for publications, code and associated data, and research results consistent with the principles of Science 2.0[14]. As part of that policy, the AENEAS project will pursue open research collaborations with other partners (universities, industry, business, SMEs, general public etc.) that extend beyond the AENEAS consortium. Finally, AENEAS will take advantage of its partnership with the RDA effort to broaden that community of potential innovation partners beyond the established network of the consortium members. Innovation management and open innovation will therefore be at the core of the AENEAS project.

Risk management

The AENEAS work programme, like the SKA project itself, is embedded in areas of science and technology that are evolving rapidly. The SKA is of course a long-term, global effort and a strong driver of technical innovation as witnessed by the enthusiastic engagement with industry the project has sparked. Similarly, given the technical challenges in computing, storage, networking, and analytics required to deploy a research infrastructure capable of supporting European SKA science, AENEAS is quite likely to have significant technical innovation potential in its own right. With these considerations in mind, it is virtually certain that the AENEAS project will encounter new concepts and technologies over its lifetime and must be prepared to adapt. Completely mitigating the risks that come with unforeseen change is perhaps impossible; however, the Open Access approach the AENEAS project has adopted is perhaps its best defense against these risks.

AENEAS is a project involving state-of-the-art research, and the level of risk across the various WPs is not insignificant. By design, the WPs have been developed so that any inter-dependencies are limited, and especially limited in terms of overall risk to the project. So far as possible, the same approach has been applied to the various tasks within a WP, but here the cross-dependence is naturally much higher. To proactively mitigate the risks associated with AENEAS, and to make them fully visible on a central platform, the AENEAS Management Support Team (AMST) will establish a project-based risk register (risk database). The risk register will be "owned" by the AENEAS Project Manager, and be updated on a regular basis. Input to the risk management register will be established at all levels within the project, with WP leaders naturally playing a major role. The risk register will appear as a standing agenda item on the monthly meetings of the AMT. The register will identify the nature of the risk, and evaluate its likelihood, and impact. The latter will be differentiated between impact at task, WP and total project level. Contingency planning and risk mitigation will also be included as essential components of the register. Regular reviews of the risk register, including any outstanding concerns will be presented to the AENEAS General Assembly (GA) for discussion and resolution during its biannual meetings.

The main critical risks identified at this stage of the project, together with the anticipated mitigating actions are described in PartA.

[14] See https://ec.europa.eu/research/consultations/science-2.0/background.pdf.

AENEAS Organisational structure

The organisational structure and decision-making process of AENEAS will largely follow the main principles of the DESCA (Development of a Simplified Consortium Agreement) initiative (see www.desca-2020.eu for details) but with some minor modification. Specifically, AENEAS will recognise five main governance entities: (1) a General Assembly, (2) a Management Team, (3) a Coordinator, (4) a Management Support Team, and (5) an External Advisory Board. Figure 9 shows the basic AENEAS governance structure, and how these entities interact with each other and various other external stakeholders.

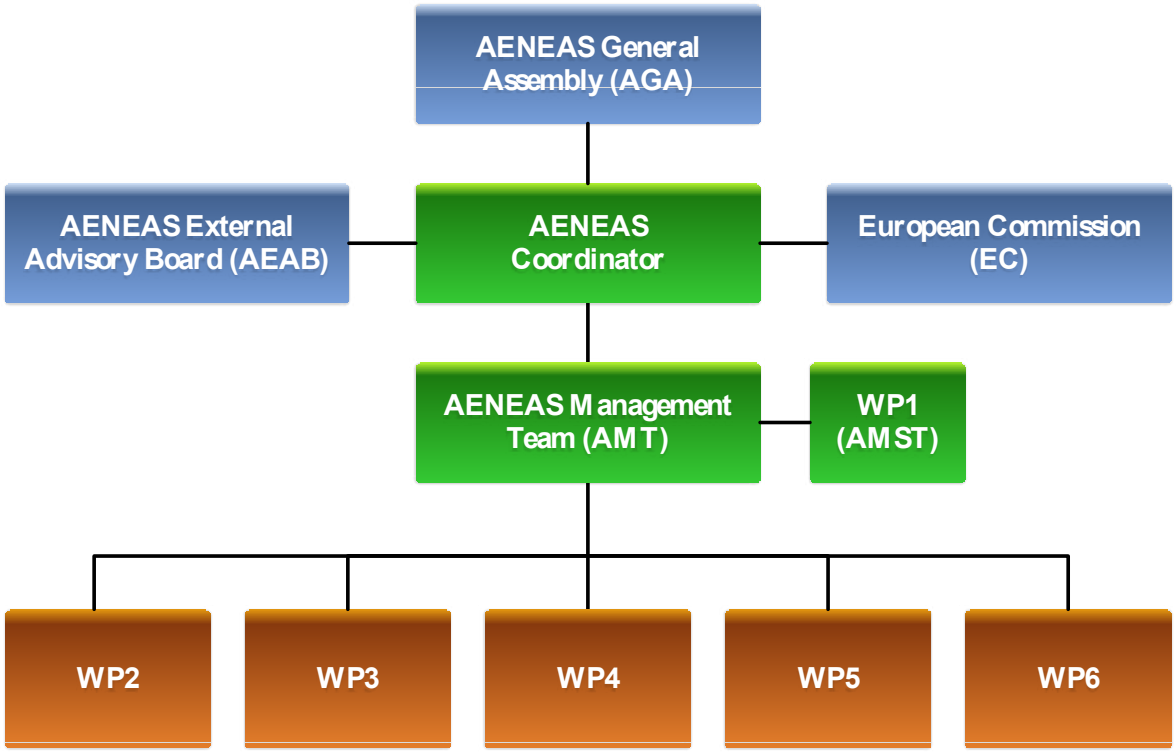


Figure 10: The overall governance and organisation of the AENEAS project.

AENEAS General Assembly (AGA)

The AENEAS General Assembly (hereafter AGA) will be the ultimate decision making body of the consortium, with each of the full partners (see the list of participants on page 1) able to appoint one assembly member. The AGA will typically meet face-to-face at least once per year – additional meetings (should they be required) will be held via video conference. Quorum will be achieved when 2/3 of the AGA members are present or represented by a proxy.

The AGA will elect from its membership a chairperson who will serve for the duration of the project. We note that on this specific point, the Governance of AENEAS differs from the DESCA model in which the coordinator is suggested to be the chair. Our experience in previous large EC projects suggests that having an independent chair of the AGA empowers that body to act as a proper sparring partner with the coordinator and Management Team.

In keeping with the fundamental spirit of good collaboration, decisions will be made wherever possible, on the basis of consensus. In the event that consensus cannot be achieved, motions will be approved with a majority of 2/3 of the votes cast. Other non-voting guests (e.g. the Management Team) will be invited to AGA meetings by the chair.

AENEAS Management team (AMT)

The AENEAS Management Team (hereafter AMT) is a supervisory body for the execution of the Project. The AMT shall report to and be accountable to the AGA. In particular, the AMT will be responsible for the proper execution and implementation of the decisions of the AGA. It will also assess and monitor the progress of the project in terms of compliance with the original (or modified) planning, and advise the AGA on actions required to remedy potential deviations from the schedule of deliverables and milestones. AMT meetings will occur regularly (roughly once per month) and will be chaired by the coordinator. The Management Team will be invited to open sessions of the AGA meeting. The AMT membership will be proposed by the project coordinator, and approved by the AGA. The AMT is expected to consist of the coordinator and the Work Package (WP) leaders.

The role of the WP leaders is to:

- ensure that the agreed work programme is followed and that the dates of milestones and deliverables are adhered to,
- monitor, manage and report on all relevant WP resources and performance indicators,
- provide quarterly financial reports, half-yearly progress reports and a comprehensive annual report to the AMST, including financial statements, all in a timely fashion.

AENEAS Coordinator

The AENEAS Coordinator will be a member of the AGA and chair the AMT. The coordinator will act as an intermediary between the AENEAS partners and the EC, and shall perform all tasks assigned to it as described in the Grant Agreement and Consortium Agreement.

The partners have selected Dr. Michael W. Wise of ASTRON (the Netherlands Institute for Radio Astronomy), as the AENEAS coordinator. The coordinator will dedicate approximately 20% of his working time to the project. This effort will be financed by ASTRON.

The tasks of the coordinator (see also the DESCA documentation) will include:

- Monitoring the compliance of the partners with respect to the obligations they have assumed as AENEAS partners,
- Maintaining and making available the address list of the AENEAS project partners and other relevant contact persons,
- Collecting, verifying and reviewing the various submitted reports, other AENEAS deliverables (including financial statements, related certifications and other relevant documents) to the EC,
- Transmitting AENEAS documents and information to all relevant parties, including internal participants (e.g. WP leaders) and external stakeholders,
- Administering the financial contribution of the EC and fulfilling the financial tasks described in the Grant Agreement and the Consortium Agreement.
- Providing, upon request, the AENEAS partners with official copies or originals of documents that are in the sole possession of the Coordinator when such copies or originals are necessary for the partners to present claims.

AENEAS Management Support Team (AMST)

The Management Support Team (AMST) will be proposed by the Coordinator and formally appointed by the Management Team. The AENEAS AMST will assist and facilitate the work of the Coordinator and the Management Team. In particular, it will execute the decisions made by the AGA, and support the day-to-day and overall management of the AENEAS project. On behalf of the coordinator, the AMST will collect and provide all necessary information from and to the partners (i.e. minutes of meetings, scientific and financial reports etc.). However, the responsibility for providing these scientific and financial reports on the envisaged time schedule lies with the project partners. The AMST will be composed of a Project Manager (0.25 FTE/yr), Project Scientist (0.25 FTE/yr) a Financial Assistant (0.15 FTE/yr). The AENEAS coordinator and the AMST will be in regular contact and formal meetings (with minutes) will be scheduled on a monthly basis.

Collectively, the responsibilities of the AMST will include:

- supporting the coordinator in all aspects of the projects management and execution,
- implementing strategic decisions and recommendations made by the AGA and AMT,
- monitoring progress of the various AENEAS WPs against the milestones and deliverables agreed by the Board,
- commissioning and receiving progress and financial reports from all AENEAS activities.
- reporting to the AGA and AMT on a regular basis on all relevant developments,
- commissioning and receiving plans for next stage (annual implementation plan) of the AENEAS programme,
- submitting approved reports to the AENEAS coordinator for submission to the EC.
- managing the AENEAS budget, including reconciliation of annually audited accounts.
- maintaining all financial, administrative and statistical records for review by the Board.
- supporting the promotion of AENEAS at international fora.
- provision of secretarial support for the AGA and AMT.

AENEAS External Advisory Board (AEAB)

An AENEAS External Advisory Board (AEAB) will be established in order to provide independent advice to the AENEAS coordinator, and to conduct an independent assessment of the progress being made by the project. The AEAB will be composed of independent experts. Members will be proposed by the coordinator, but formally approved by the AGA. The AEAB will appoint a chairperson from within its membership. The AEAB will meet face-to-face at least once per year and will provide a written report on their findings. The report will be received by the coordinator, who will also distribute it to the AGA. The coordinator will send a written response to the AEAB chair with a copy to the AGA. The chair of the AEAB (and potentially other members) will be invited to participate in AGA meetings. Reports of the AEAB (and the response of the coordinator) can be useful input to the mid-term and final evaluation of the project.

A list of the AENEAS project milestones is shown in PartA.

Appropriate organization for the scale of the project

Our experience in managing and executing previous large multi-partner (EC) projects is that the governance model described above is appropriate for a project with the complexity and scale of AENEAS. The AGA is the ultimate decision making body of the consortium, and has total oversight of the project as a whole. The AMT runs the Work Packages, ensuring that they deliver on schedule and within budget, and reports to the AGA on an annual basis. The Work package leaders report to the coordinator via the AMT on a monthly basis. The AMST supports the coordinator and the AMT on all day-to-day matters, enabling them to focus on the technical content, managing and monitoring the WP

effort on the basis of a result oriented approach. The Coordinator will be fully immersed in all aspects of the project, and operate within and between the different governance entities – he is independently advised by the AEAB and reports to the AGA and EC.

We are confident we understand the governance structure well, and how to properly implement and execute it. The AENEAS partners are familiar with this type of construct, and have previously demonstrated their ability to deliver and to make it work. The partners forming the consortium (see section 3.3) have extensive experience in working on EC funded projects and understand the requirements they demand, also with respect to the reporting and financial administration aspects. Our conclusion is that by adopting the standard DESCA model, we are well prepared to tackle the type of problems that always arise in projects that are distributed across many partners. The coordinator of AENEAS, his management team and the WP leaders have significant experience in working in this kind of environment, and making it successful. We're confident that while AENEAS is a large and complicated project, the organisational structure can cope with these pressures and deliver on its promises.

Transnational access

No pilot trans-national access programme is foreseen at this stage of the AENEAS project.

3.3 Consortium as a Whole

Consortium partners

AENEAS brings together partners representing the majority of the international community involved in the design and construction of the SKA project. It includes all of the European member states currently, formally part of the SKA as well as the SKA Organization and the SKA host countries. Although initiated by the EU SKA partners, AENEAS was from its inception intended to allow broader participation within Europe and that is reflected in the wider group of EU member states that are involved. By bringing in participants from the SKA international partners, AENEAS provides an opportunity to incorporate this European initiative into the global effort to support the SKA science community.

The AENEAS consortium represents more than an interest group however. The consortium partners include virtually all of the leading European radio astronomy institutes. These partners, along with the international collaborators, have unparalleled expertise in radio astronomy techniques, data process, and networking. They also bring extensive experience in large, European projects and are familiar with the expectations of consortium membership having fulfilled management roles, PI roles, project scientist roles and system engineering roles. In many cases, the partners in AENEAS already operate state-of-the-art facilities, both observational infrastructures and astronomical data centres. In addition to traditional radio astronomy expertise, the consortium also includes partners with a broader multi-wavelength perspective and crucial EU e-infrastructure partners (e.g., GÉANT, EGI, the EURO-VO, and RDA) who bring extensive experience integrating distributed infrastructures over a range of research disciplines.

In summary, the AENEAS consortium consists of internationally leading organisations with complementary and overlapping expertise, spread both within Europe and around the world. We note that the consortium includes partners with a track record of working together previously, but also represents new collaborations or increased engagement between partners. Building this wider collaboration and deepening the pool of expertise and experience it can wield is one of the true strengths of the AENAS proposal. We are confident that the consortium we have assembled brings together all the

necessary skills, experience, and more importantly motivation to successfully execute the work programme described in the AENEAS proposal.

Industrial and commercial involvement

Industrial and commercial involvement in the AENEAS project is currently foreseen to be relatively minor as least in the initial stages. We note that this status could easily change as the project evolves and new industrial and commercial partnerships may be established. In such cases, to ensure that industrial and commercial partners have sufficient input to the AENEAS project, several industrial representatives will be asked to serve on the AEAB (AENEAS External Advisory Board).

Other countries

Most of the AENEAS partners are entities based in the Member States of the EU, and are therefore eligible for EC funding. Since the SKA observatory will be located in South Africa and Australia and the data will be collected there, it is imminent that these countries are involved in the design of the networking and data transport and therefore will be part of the consortium. The European solution could in principle be different from the solution elsewhere in the world, but since all SKA partners are looking for the best and most economical solution, close collaboration is expected with SKA partners and data centre experts around the world.

3.4 Resources to be Committed

Tables 3.4a (in PartA) and 3.4b summarise the staff resources committed to the project and other direct costs.

Table 3.4b: Other direct costs (travel, equipment, other goods and services, access costs)

1 ASTRON	Cost (€)	Justification
Travel	**128.800**	In detail below
	25.200	42 European trips of € 600 for project management and project actions
	15.600	26 European trips of € 600 to support experts
	24.000	12 international trips of € 2.000 to RDA and other world wired network meetings
	48.000	24 international trips of € 2.000 to support international experts for all hands meetings
	16.000	8 international trips of € 2.000 to support international experts to WP2 Governance meetings
Other goods and services	**75.500**	organization of all hands meetings and WP2 meetings in detail below. Also support for RDA Working Groups actions.
	18.000	6 all hands meetings of €3.000
	4.400	4 WP2 governance meetings of €1.100
	7.500	Tasks 2.2 meetings
	8.000	Audit certificate.
	37.600	Support for RDA Working group experts at partners, not subcontracting.
Total	**204.300**	

12 CSIC	Cost (€)	Justification
Travel	7.800	13 European trips of €600
Total	7.800	

13 IT	Cost (€)	Justification
Travel	6.000	10 European trips of €600
Total	6.000	

14 CNRS	Cost (€)	Justification
Travel	18.000	4 persons to 3 WP5 meetings 4 * 3 * 600 euros = 7200 euros 3 participants to 6 all hands meetings = 3 * 6 * 600 euros = 10800 euros
Total	18.000	

20 EPFL	Cost (€)	Justification
Travel	3.000	5 European trips of €600
Total	3.000	

Partners with only travel funding, no man months, therefore over 15%	Cost (€)	Justification
8 MPIfR	2.400	4 European trips of €600, no person months
10 SKAO	2.400	4 European trips of €600, no person months
17 JIV-ERIC	3.600	6 European trips of €600, no person months
18 ILT	3.600	6 European trips of €600, no person months
25 CSIR	8.000	4 international trips of €2.000, no person months
26 UCT	8.000	4 international trips of €2.000, no person months
27 NRF	8.000	4 international trips of €2.000, no person months
Total	36.000	

4. MEMBERS OF THE CONSORTIUM

4.1 Participants (applicants)

4.1.1 ASTRON

ASTRON is the Netherlands Institute for Radio Astronomy. Its mission is to make discoveries in radio astronomy happen, via the development of novel and innovative technologies, the operation of world class radio astronomy facilities, and the pursuit of fundamental astronomical research. ASTRON hosts both JIVE (Joint Institute for VLBI ERIC), the NOVA Optical/IR Group and DOME (the ASTRON & IBM Center for Exascale Technology). ASTRON designed, built and now operates the International LOFAR Telescope (a recognized Pathfinder for the SKA). ASTRON plays a major role in the various consortia contributing to the current SKA Design Phase. It leads both the SKA Low Frequency Aperture Array and the SKA Mid Frequency Aperture Array work packages. In addition, ASTRON plays a prominent role in the Science Data Processor (SDP) work package and also several others.

ASTRON hosts the NOVA Optical Infrared group. The group develops optical instrumentation for the European Southern Observatory in Chile and the Isaac Newton Group of telescopes on La Palma. In the course of 25 years a wide range of instruments has been built, but in general the emphasis has been on spectrographs, on the infrared wavelength range and consequently on cryogenic instruments. The group plays an important role in the development of the Extreme Large Telescope (E-ELT), with a substantial participation in 4 of the 7 E-ELT instruments.

ASTRON Staff

Michael Wise (m) is Head of the Astronomy Group at ASTRON and an adjunct professor in Radio Astronomy at the University of Amsterdam. He is an active astrophysicist whose research interests include cluster of galaxies, AGN feedback, and the formation and evolution of large-scale structure. He has worked extensively at a variety of wavelengths including X-ray, optical, infra-red, and radio. He has over 20 years of experience supporting the construction and operation of large-scale astronomical facilities first as a staff member of the Chandra X-ray Science Center, and later with the design and construction of the LOFAR telescope. As part of the LOFAR collaboration, he has led the development and commissioning effort for the telescope and served as LOFAR Project Scientist. Along with basic astronomy research, his interests include a variety of topics in data-intensive astronomy. He is currently President of IAU Commission B2 on Data and Documentation, chair of the European Working Group on SKA Regional Centres, a member of the ASTERICS project, and a member of the Steering Group for the SKA Data Flow Advisory Panel.

Michiel van Haarlem (m) is Head of the NL SKA Office at ASTRON. He leads the Netherlands participation in the SKA project and is PI on the National Roadmap proposal which is funding the NL participation in the current pre-construction phase (2013-2017). As executive officer and later director general he was responsible for setting up the SKA Organisation in Manchester (UK) which is leading the project. From 1998 to 2011 he was involved in all phases of the design and construction of LOFAR radio telescope, as programme manager, project scientist and in the latter stages as managing director of the LOFAR Foundation which built the telescope which has pioneered the use of modern aperture array technology in low frequency radio astronomy.

Rob van der Meer (m) is Program Officer European Collaboration at ASTRON. He is a (astro)physicist from origin and in the last nine years worked on EC projects in astronomy and astroparticle physics. He is currently project manager for ASTERICS at ASTRON, finding synergies, similarities and common challenges between four ESFRI infrastructures in astronomy and astroparticle physics. He worked on the projects ASPERA I and II for APPEC, finding synergies, similarities and common challenges between funding bodies of astroparticle physics research in Europe and on distributed e-infrastructures in EGI-InSPIRE for EGI, working on stakeholder management, project administration and organization and contact person for the EC Project officer during negotiation and start-up of the project.

Gert Kruithof (m) is head of Research and Development at Astron. He is responsible for all research and development projects related to LOFAR, Westerbork and Square Kilometre Array including the joint research programme DOME with IBM on Exascale technology. In SKA, he is chairman of the Board of one of the consortia, the Low Frequency Aperture Array. He is a physicist from origin and obtained a PhD in Applied Physics from the University of Groningen. He has conducted industrial research at KPN on Network Technology and Software Mass Customization at the University of Groningen. As a senior business consultant for TNO, he advised multi-national organisations on board level on IT management.

ASTRON Publications

1. Haarlem M. van, Wise M., Gunst A.W. et al. (2013). *LOFAR: The LOw-Frequency Array*. Astronomy & Astrophysics, Vol. 556, id.A2, EDP Sciences, DOI: 10.1051/0004-6361/201220873

2. Vos M. de, Gunst A.W., Nijboer R. (2009). *The LOFAR Telescope: System Architecture and Signal Processing.* Proceedings of the IEEE, Vol. 97, Issue: 8, pp 1431-1437

3. Broekema P.C., Boonstra A.J., Engbersen T. et al. (2012). *Dome: Towards the ASTRON & IBM Center for ExaScale Technology.* Proceedings AstroHPC'12, Delft, The Netherlands

4. Wise M.W., Alexov A., Folk M., Pierfederici F., Anderson K., Bähren L. (2011). *Towards HDF5: Encapsulation of Large and/or Complex Astronomical Data*. Astronomical Data Analysis Software and Systems XX, ASP Conference Proceedings Vol. 442, p 663

5. Anderson K., Alexov A., Bähren L., Grießmeier J.-M., Wise M.W., and Renting G.A. (2011). *LOFAR and HDF5: Toward a New Radio Data Standard*. Astronomical Data Analysis Software and Systems XX, ASP Conference Proceedings Vol. 442, p 53

ASTRON Projects

ASTRON is leading the pre-construction phase of two SKA Element consortia.: the Low Frequency Array Element construction expected to start in 2018 in Australia and the Mid Frequency Array Element that is planned in South Africa. Next to leading these consortia ASTRON is participating in other SKA element consortia.

ASTRON is leading the ASTERICS project, which brings together for the first time the astronomy, astrophysics and particle astrophysics communities to find imaginative new solutions to the common data avalanche problems. ASTERICS help Europe's world-leading observatories work together to find common solutions to their Big Data challenges, their interoperability and scheduling, and their data access. ASTERICS will also open up these facilities to the full international community, from professionals to the public, through the International Virtual Observatory Alliance and by funding citizen science mass participation experiments for the current and next generation of world-leading European observatories.

LOFAR (http://www.astron.nl/radio-observatory/radio-observatory) is the Low Frequency Array in the low frequency range for radio astronomy (10-240 MHz). LOFAR is an interferometric array using dipole antennas stations distributed throughout the Netherlands, the UK, France, Sweden and Poland. LOFAR was designed and built by ASTRON and is one of the SKA pathfinders.

The DOME (http://www.dome-exascale.nl/) project is a collaboration between ASTRON and IBM that carries out fundamental research in technologies needed to develop the Square Kilometre Array. The main research areas are green computing, data & streaming and nano-photonics.

ASTRON has a leading role in the development of the mid infrared instrument METIS for E-ELT. The prime management (principal investigator, project management, system engineering, project scientist) is shared between Leiden and the ASTRON group. The core technical development team will be the NOVA team at ASTRON. The full integration and final test phase will be in the Netherlands and most likely at ASTRON, needing several technical disciplines like optics, mechanics, electronics, systems and software and project management. Besides METIS other technical development for 3 other E-ELT instruments will be done by the NOVA-ASTRON group within different time frames of each other, covering a period from now (METIS is running) up to 2030.

ASTRON infrastructure/technical equipment

The International LOFAR telescope consists of around 50 stations and is operated by ASTRON. It has recently been enlarged with 3 stations in Poland. In 2016, a station will be built in Ireland. The LOFAR Long Term Archive is accessible via datacentres in Groningen, Amsterdam and Jülich.

The Westerbork Synthesis Radio Telescope (WSRT) is currently being equipped with the focal plane array system APERTIF. Several dishes remain in operation for VLBI. The survey data will be made available via the APERTIF Long Term Archive (ALTA).

The Research and Development at ASTRON exploits a state of the art

laboratory for the development of radio astronomy instruments in all its aspects from antennas, signal transport and processing to software pipelines.

ASTRON main tasks in project

Profile: representing SKA, LOFAR
Main tasks:

- Consortium lead,
- Lead of: WP1, WP2
- Participation: Several Tasks in other WPs

4.1.2 UMAN

Jodrell Bank Centre for Astrophysics comprises research activities in astronomy and astrophysics in the School of Physics and Astronomy at The University of Manchester, the world leading facilities of the Jodrell Bank Observatory, the e-MERLIN/VLBI National Facility and hosts the Square Kilometre Array Organisation. The Jodrell Bank Observatory site also welcomes visitors to the Jodrell Bank Discovery Centre. The Centre occupies three main locations: the world-famous Jodrell Bank Observatory in Cheshire, and the Alan Turing and Sackville St Buildings in central Manchester.

Jodrell Bank is a world leader in radio astronomy-related research and technology development but also carries out research across the electromagnetic spectrum and in theoretical topics. Our research covers a wide range of modern astrophysics. We have particular expertise in radio-mm observational astronomy but we also make observations at a wide range of other wavelengths and combine these with theory and modelling.

Technical development at JBCA covers a wide range of technologies and science areas. As well as developing systems for locally supported telescopes such as e-MERLIN and ALMA, JBCA developed the 30 and 44 GHz LNAs for the Planck satellite, has lead the construction of the receivers and LNAs for the C-Band All-Sky Survey (C-BASS) instrument, has contributed to the design of the Five hundred Aperture Spherical Telescope (FAST) 19 beam receiver, as well as many other projects.

UMAN Staff

Dr. Anna Scaife (f) is a Reader in Radio Astronomy and Head of the Interferometry Centre of Excellence at Jodrell Bank Centre for Astrophysics. She leads the design of the Imaging Pipelines for the SKA Science Data Processor (SDP) consortium and is a key member of the SKA Science Working Group on Cosmic Magnetism. She is PI of the LOFAR Magnetism KSP and vice-chair of the BALTICS ("Building on Advanced Lofar Technology for Innovation, Collaboration, and Sustainability") EU training network. She teaches the graduate Radio Astronomy course at the University of Manchester. Anna holds a European Research Council Fellowship, which funds her research group's work investigating the origin and evolution of large-scale cosmic magnetic fields. She is also active in science and data science communication and has given talks all over the world to a wide range of audiences. She is a regular speaker for New Scientist magazine, and will be speaking on Big Data at the EuroScience Open Forum (ESOF) as well as the BlueDot festival this year. In 2014, Anna was honoured by the World Economic Forum as one of thirty scientists under the age of 40 selected for their contributions to advancing the frontiers of science, engineering or technology in areas of high societal impact.

Prof. Richard Schilizzi (m) is Professor of Astrophysics at the University of Manchester in the UK. He obtained his Ph.D. in Radio Astronomy from the University of Sydney in 1973. After a post-doctoral fellowship at Caltech, he joined the Netherlands Foundation for Research in Astronomy in 1976 and played a leading role in building the European VLBI Network (EVN) over the next decade. From 1991 to 2008, he held a concurrent position as Professor in Radio Astronomy at Leiden University. In 1993 he was appointed foundation Director of

the Joint Institute for Very Long Baseline Interferometry in Europe (JIVE) and established JIVE as the central data processing and support institute for the EVN. In 2003 he became the first Director of the International Square Kilometre Array (SKA) Project. He led the SKA project for nine years from its early days as a research concept to the point where it had become a well-supported global project and a legal entity. At the end of 2011, he joined the University of Manchester to establish the SKA Group in the University and lead design work in signal transport for the SKA, a position he held for two years.

Dr Chris Skipper (m) is a software engineer turned astronomer, with a particular interest in developing fast algorithms for radio astronomy. Between undergraduate degrees in Computer Science (Swansea, 1999, 1st class) and Physics (Southampton, 2009, 1st class) he worked in a variety of permanent and contract software engineering roles developing applications for various manufacturing and engineering companies. In 2013 he received his astrophysics PhD from Southampton for his research on the fast spectral variability of X-ray binary systems and AGN. He has since worked on software proto-tying and requirements testing for the imaging pipeline of the SKA, combining his interests in fast, low-level programming and astronomy in order to develop CPU/GPU prototypes of various SKA pipeline components.

Dr Robert Beswick (m) is e-MERLIN project scientist and heads the science and user-support for e-MERLIN. He is an active research scientist with over 150 papers on a wide range of topics from Supernovae and star-formation through to high redshift galaxies and weak lensing.

Dr. Anita M. S. Richards (f), formerly MERLIN archivist and now working for the UK ALMA Regional Centre. Her research includes star and planet formation, astrophysical masers and radio interferometry techniques and she has published 160 research papers. Anita leads the

Prof. Simon Garrington (m) is Director of the e-MERLIN/VLBI National Facility and the Head of Operations at JBO. His research interests are in fields as diverse as VLBI studies of stars in Orion to deep-field observations of the most distant parts of the Universe. He is a member of the RadioNET board and co-ordinates

UMAN Publications

1. Garrington, S. T., (2014). E-MERLIN, Proceedings of the 10th European VLBI Network Symposium and EVN Users Meeting: VLBI and the new generation of radio arrays. September 20-24, 2010. Manchester, UK

2. Argo, M. (2014). e-MERLIN data reduction pipeline, Journal of Open Research Software 3(1):e2, published 29 January 2015; doi:10.5334/jors.bp

3. Radcliffe, J. F.; Garrett, M. A.; Beswick, R. J.; et al. (2016). Multi-source self-calibration: Unveiling the microJy population of compact radio sources, Astronomy & Astrophysics, Volume 587, id.A85, 7

4. Scaife, Anna M. M.; Heald, George H., *A broad-band flux scale for low-frequency radio telescopes*, MNRAS Letters, 423, L30, 2012

5. Packet Loss in High Data Rate Internet Data Transfer for eVLBI, Spencer, R.; Hughes-Jones, R.; Mathews, A.; O'Toole, S., Proceedings of the 7th European VLBI Network Symposium held

in Toledo, Spain on October 12-15, 2004. (arXiv:astro-ph/0501018)

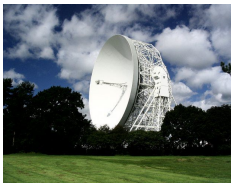
UMAN Projects

UMAN operates the e-MERLIN/VLBI National Facility, the UK's facility for high resolution radio astronomy observations. E-MERLIN is an array of seven radio telescopes, spanning 217km, connected by an optical fibre network to Jodrell Bank Observatory. Operated by Jodrell Bank as a UK National Facility, e-MERLIN observes at L- and C-band and provides sub-arcsecond resolution at micro-Jy sensitivity. The European VLBI Network (EVN) is an interferometric array of radio telescopes spread throughout Europe (and beyond) that conducts unique, high resolution, radio astronomical observations of cosmic radio sources. It is the most sensitive VLBI array in the world, thanks to the collection of extremely large telescopes that contribute to the network. The UK, via the e-MERLIN/VLBI national facility has been a major participant in VLBI since its outset and Jodrell Bank Observatory was one of the five founding European institutes of the EVN in 1980. The e-MERLIN/VLBI National Facility at UMAN provides the UK contribution to the European VLBI Network (EVN), which links telescopes across Europe and China for observations at milli-arcsecond resolution.

UMAN is leading the pre-construction phase of the SKA Signal and Data Transport (SaDT) consortium with additional significant involvement in the Central Signal Processing (CSP) consortium and the Science Data Processor (SDP) consortium. UMAN also hosts the Office for the SKA Organisation, which is responsible for coordinating the global activities of the SKA project. This includes engineering, science, site evaluation, operations and public outreach. It is located at the Jodrell Bank Observatory, hosted by the University of Manchester. The history runs from the first discussions in 1993, to the establishment of the project Office at the Jodrell Bank Centre for Astrophysics in 2008, and the SKA organisation in 2011.

UMAN hosts the UK ALMA Regional centre, providing support to UK scientists using the Atacama Large Millimeter/submillimeter Array. ALMA is the largest observatory ever built operating at millimetre and submillimetre wavelengths in the world. UMAN is also involved in digital fibre optic transmission for ALMA as well as various aspects of the data transport system.

UMAN runs the Lovell Telescope. At 76 metres in diameter this is the world's 3rd-largest fully steerable telescope. Since the summer of 1957 it has been quietly probing the depths of space, a symbol of our wish to understand the universe in which we live. It remains one of the biggest and most powerful radio telescopes in the world following a recent substantial upgrade of its digital system and refurbishment of the dish.



UMAN main tasks in project

Profile: representing SKA, LOFAR, VLBI
Main tasks:

- Lead of: WP3
- Participation: WP2, WP4, WP5

4.1.3 UCAM

The University of Cambridge hosts one of the most important centres of physics research in Europe, especially in the field of astronomy. Astronomy research is carried out in the Battcock Centre for Astrophysics in the Cavendish Laboratory (Department of Physics), in the Institute of Astronomy and theoretical research in astronomy is also done at the Department of Applied Mathematics and Theoretical Physics. There is also a cross-departmental venture, the Kavli Institute for Cosmology in Cambridge, in which all three groups participate and which provides an environment for close collaboration between the three groups in areas of common interest. The Astrophysics Group at the Battcock Centre has about 40 research staff, 25 research students and 10 support staff. Cambridge has a wide ranging astrophysical research programme and a long-established excellence in radio astronomy.
The University of Cambridge also has a High Performance Computing Service, which is an internationally leading university-based HPC group. It specializes in development and deployment of commodity based HPC solutions with excellent power/performance characteristics, e.g. the recently deployed Wilkes cluster (http://www.hpc.cam.ac.uk/services/wilkes). Cambridge has strong interactions with a large number of computing industry partners, including NVidia (Cambridge is a CUDA centre of Excellence) DELL and Intel.

The Battcock centre is home to a number of the SKA Science Data Processor Consortium's management team, including the Consortium Lead (Paul Alexander), the Project Manager (Jeremy Coles), the Project Scientist (Rosie Bolton) and the Project Engineer.

UCAM Staff

Paul Alexander (m) is Professor of Radio Astronomy, the head of Astrophysics and Director of the Battcock Centre for Experimental Astrophysics in the Cavendish Laboratory. He has over 150 publications and currently holds grants directly supporting 17 postdoctoral staff. He is the lead of the SKA Science Data Processor consortium. He has a long record of contribution to the SKA and in addition to his role in the SKA SDP work he is also the UK SKA Science Director of the SKA Organization. His astrophysical research is in the areas of galaxy evolution, design of radio interferometers and the analysis of interferometric observations.

Rosie Bolton (f) is a Senior Research Associate at the University of Cambridge in the Astrophysics Group. She is Project Scientist of the SKA Science Data Processor consortium. In this role she liaises with SDP engineers, the science community and the SKA organisation to ensure that the scientific goals of the community are correctly translated into engineering requirements for the SDP, and that the SDP design is capable of delivering data products from the SKA instruments that are of sufficient fidelity that they can be reprocessed off-line to generate science results. Rosie has worked on the SKA project for a decade, and has a great deal of experience in modelling the system sizing for SKA, from initial cost models during the SKADS project to the current parametric modelling of SDP compute requirements.

Jeremy Coles (m) For the last ten years Coles has been the Deployment and Operations manager within GridPP (see below) and continues to sit on the WLCG Grid Deployment Board and is an active member of the WLCG Operations Coordination Team. As such Coles, together with colleagues at institutes such as RAL STFC (Sansum), bring with them a wealth of project experience, lessons-learned and best practice needed for the development of a regional science centre. In addition, for the last year, Jeremy has been the Project Manager of the SKA SDP Consortium and has developed a good knowledge of the computing and support needs for SKA science, as such he is perfectly placed to contribute to the AENEAS work.

Peter Braam (m) has a strong track record in distributed storage systems (he invented the Lustre file system, used by more than half of the world's Top500 supercomputers). He has expertise in parallel computing and in the development and use of programming languages to address parallel computing challenges. He has been working as part of the SKA SDP consortium, as an expert reviewer of the high level architecture and on testing and improving compute efficiency for some of the most challenging problems in interferometric radio telescope data analysis.

John Taylor (m) has over 30 years' experience in development, management and technical marketing primarily in the field of High Performance Computing. He possess a thorough technical knowledge of the software stack, compute server, storage and networking technologies together with the ability to articulate business propositions with particular reference to the HPC and Big Data markets: systems and applications. John is currently working for the SKA SDP consortium at Cambridge, with a focus on computational design and logistics support. He is also working on a separate design study for an OpenStack research computing platform and has an advisory role to the UK High Performance Technical Computing and E-infrastructure arena.

UCAM Publications

1. **Alexander**, Bregman and Faulkner (2010). *SKA Data Flow and Processing*. *Wide-Field Astronomy and Technology for the SKA*. http://www.skads-eu.org/PDF/limelette2_v1.1.pdf, p 119
2. **Bolton**, et al. (2008) *SKADS Benchmark Scenario Design and Costing 2* (2008)
3. Colling et al, including **Coles**, (2012) *Processing LHC data in the UK*
4. **Coles** (2015) *Grid-PP – Preparing for LHC Run 2 and the Wider Context*, Journal of Physics: Conference Series 664 (2015) 052006

UCAM Projects

UCAM is active with projects related to almost every major astronomy instrument today and actively involved in the HPC and Big Data aspects of these instruments. Here are some examples:

University of Cambridge is leading the consortium for the design of the SKA Science Data Processor (SDP): the SKA SDP-Consortium will deliver the design of the software and computing element of the SKA. This involvement with

the SDP Consortium is one of the key areas of relevant expertise that UCAM will bring to the AENEAS project: the work of the SDP consortium has required us to develop a thorough understanding of the near-real-time data processing required at each SKA site and of the SKA's data products; this will flow directly into the AENEAS work where we are required to develop an understanding of the off-line requirements for science delivery.

Cambridge has a strong track record in delivery to the SKA project including leading the first costed system design as part of SKADS, development of the "Design and Costing tool", significant contributions to the site selection process, the SKA Low Frequency antenna design and co-leadership of the Software and Computing CoDR and is also a major contributor to the design of the SKA low-frequency aperture array (work which is led by ASTRON).

Cambridge also has a strong track record in astronomical software: the delivery of end-to-end software for all telescopes at our observatory; it hosts the level-3 Planck data analysis centre as well as the Cambridge Astronomical Survey unit which is currently developing pipelines for VISTA and other wide area sky-survey projects.

Cambridge hosts the (DPCI) photometric processing centre for the ESA Gaia Cornerstone mission, processing all data from Gaia's camera, the largest flown in space. DPCI also has sole responsibility for real-time discoveries from Gaia photometry, to be published through http://gaia.ac.uk. In addition, dynamical modelling of the Petabyte-scale Gaia data are a core specification and test data set for next-generation HPC developments in the UK, to be hosted in Cambridge.

UCAM is part of the H2020 **ASTERICS** project (led by ASTRON), with a contribution in data analysis challenges common to data from multiple observatories. This involvement strengthens cross-linkage between the SKA project work and the data processing, storage and delivery aspects from observatories working at other wavelengths

CERN uses distributed High Throughput Computing (HTC) in the Worldwide LHC Computing Grid (WLCG) in a Tiered structure similar to that needed for AENEAS. The UK input to this effort comes from the **GridPP Project** in which Cambridge has been a long-term contributor.

UCAM main tasks in project

Main tasks:

- Joint WP lead for WP3 – leading the sub-tasks associated with SKA Science delivery in terms of the overall size, technical scope, and use cases for a European Science Data Centre for SKA.
- Engagement in WP2 via strong connections with SKA project, at the Board level and at the pre-construction design consortium level (SDP).
- Participation in WP5,via tasks 5.1 and 5.4 (which have strong cross-linkages with WP3).

4.1.4 INAF

INAF is a governmental research organization with 19 research centers geographically distributed over the national territory, plus the “Galileo” observing facility located in La Palma, Canary Islands. INAF promotes, realizes and coordinates, also within programs of the European Union and international organisms, research activities in many astronomical fields, such as optical/infrared astronomy, radio astronomy, X-ray and gamma-ray astronomy, particle astrophysics and cosmic physics, both in collaboration with Universities and with other public and private, national and international agencies. INAF is a major partner of the astrophysics related ESFRI projects (CTA, SKA and E-ELT), having actively participated in their definition since the initial phases; it has furthermore important participations in several other world class projects, both ground-based (e.g. ALMA, LBT, MAGIC) and space-borne (e.g. Planck, Gaia, Euclid). INAF is also active in the field of infrastructures for research, and in particular distributed computing technologies (deployment of infrastructure and integration of domain specific applications, leadership of the A&A Heavy Users Community in the FP7 EGI-Inspire project), distributed archives of astronomical data (both from ground-based and space-borne facilities) and the astronomical Virtual Observatory (Euro-VO and IVOA). Participation in the ESFRI projects allows INAF to focus on their real needs in terms of infrastructure, and the experience from previous and current projects increases the feasibility of the planned facilities.

INAF Staff

Steven Tingay (m) is Direttore dell’Osservatorio di Radio Astronomia (ORA) at INAF, the combination of INAF Structures in Bologna (Instituto di Radioastronomia: IRA) and in Cagliari (Osservatorio Astronomico Cagliari). ORA maintains a scientific and technical staff of approximately 200 people over four sites in Italy. Tingay is an internationally renowed astronomer, across astrophysics, instrumentation, and project management. He is Professor of Radio Astronomy at Curtin University in Australia, where he was previously founding Director of the Curtin Institute of Radio Astronomy (CIRA) from 2007 to 2015, now the equal first ranked astronomy group in the Australian university system. He has published over 180 refereed publications, gaining over 4,900 citations. He has been the recipient (as PI or CI) of over $A80m in research funding over the last decade. Tingay was Director of the first (and still only) SKA Precursor to become fully operational for science, the $A50m Murchison Widefield Array (MWA), during its design, prototype, construction, commissioning, and operations phases. He also obtained funding to double the size of the MWA and improve its science capacity by a factor of ten in 2016.

Riccardo Smareglia (m) is a senior INAF Research Astronomer, author/co-author of over 250 papers and technical reports. Since 1988 at the Astronomical Observatory of Trieste, and permanent staff since 1991. He designs and implements the archive at TNG located at the La Palma, Canary Island. He participates to the design and development of several astronomical archives making them fully compatible with VO standards, like the LBT telescope. Had participation in several EU FP7 funded projects such as Euro-VO-DCA, Euro-VO-AIDA, Euro-VI-ICE. Since 2004 he is responsible of the creation and management of the Italian Centre for Astronomical Archives (IA2) which manage and save data from the main ground base INAF telescopes. In 2009 and 2012 he promotes and chairs the “Vo-Day … inTout” and "VO publish" initiative

funded through the EU FP7 Euro-VO-AIDA project. He is active in IVOA and RDA initiative. Since 2013 he is team leader of INAF community in SKA Telescope Manager (SKA.TM) Consortium. He is also Head of ICT of INAF (Scientific Directorate – Office VI).

Marcella Massardi (f) Marcella Massardi is a INAF researcher, author/co-author of over 100 papers. Member of the collaboration that produced the AT20G survey. Since 2004 member of the ESA's Planck satellite consortium, of the Planck Core Team (2007-2013) and Planck Scientist (2011-2013). Since 2008 member of the Herschel-ATLAS satellite consortium. Since 2010 member of the EMU-ASKAP collaboration.
Since 2011, in addition to her research activities in the field of galaxy evolution and radio source population characterization and modeling, she is manager the Italian Node of the European ALMA Regional Centre. She supervises and coordinate the support activities for the Italian ALMA users. She works for Quality assessment of ALMA data, as ALMA contact scientist and to the development of the ALMA science archive. She contributes to the organization of outreach activities and events useful to join the Italian scientific community that observes in the millimetric and submillimetric bands. She is responsible of working packages and PI for a few national projects financed by Italian MIUR and INAF since 2012. She operates as referee for international journals (MNRAS, A&A, ApJ). She has been involved as PI or observer in more than 30 observing programs that got time at Medicina radiotelescope, SRT, ATCA, JVLA, Chandra and ALMA. Since 2014, she collaborates with PhD courses in SISSA (Trieste) and master courses at University of Bologna, supervising master and PhD thesis.

Cristina Knapic (f) has a grant contract with OATs for the development and maintenance of distributed archives of several ground base telescopes. She is also involved in several European H2020 projects like ASTERICS, INDIGO, STARNET and national and international projects. She is involved in IA2 (Italian Astronomical Archives) about ground based telescope Virtual Observatory (VO) compliant archives (TNG , Asiago), educational VO compliant Archives (VAPE), Radio Astronomical Archive (MEDICINA and NOTO), and international collaborations like Large Binocular Telescopes, Square Kilometre Array , TANGO collaboration and European southern Observatory survey like Pessto, and Global Architecture of Planetary Systems international collaboration. She collaborated in data modeling for the Radio Raw data. She is also involved in the activities related to the Authentication and Authorization mechanisms for SKA and for IA2 and is strongly involved in the Observation Preparation tools foreseen for SKA. Recently she was asked to participate to a new proposal for a H2020 call called CIRAS for what concern the Radio archives domain.

Grazia Umana (f) is a senior staff researcher (Primo ricercatore) at INAF-Osservatorio Astrofisico di Catania. Current position is Director of INAF-Osservatorio Astrofisico di Catania. Main scientific interests include: SKA and its pathfinders; Galactic Foregrounds studies for CMB; Final phases of stellar evolution via radio, millimetric and infrared observations (JVLA, IRAM, PLANCK, Spitzer/IRAC/IRS) and in the far-IR (HERSCHEL /PACS/SPIRE); Mass-loss from massive stars via high frequency and angular resolution radio observations (JVLA/EVLA/ATCA) and mid-IR and far-IR observations (VLT/VISIR, SPITZER, HERSCHEL); Modelling and radio observations of chemically peculiar and active stars (JVLA, ATCA, MERLIN, VLBA); Multi-wavelengths campaigns. She is authors of 168 publications in peer-reviewed journals, H-index 52, more than 11000 citations . Professional activities

include:Co-Chair of the SKA Science Working Group: Our Galaxy; Chair of the SKA-DC Board ;Member of the SKA Science Working Group: Continuum; Member of the EMU, The Evolutionary Map of the Universe, ASKAP survey-Chair of the Radio stars WG; Member of the PLANCK Core-Team CTA09; PLANCK Scientist.

Mauro Nanni (m) Physics Master Degree at the Bologna University in year 1980. Permanent position at the Institute of Radioastronomy in Bologna (CNR) starting from 1982; Technologist Director starting from 2010. He has worked to the development of software for data reduction and image analysis of the data of the "Norther Cross" radiotelescope on Vax minicomputer. In the national Astronet project he has coordinated the Astronomical Database WG for the realization of DIRA package. Moreover he works in the field of the astronomical archives of images (AVO and Skyeye projects) and collaborate in the realization and management of the EVN VLBI-GPS technical data archive. He has projected the network of the CNR Campus of Bologna where he coordinates the campus computer science commission. He has worked in the national commission of the CNR and today of the INAF for the development and the management of infrastructures and the services of net. Starting from 2001 he is participating to the realization of the Italian network for the E-VIbi. He take care the relationships with the Region Emilia Romagna the INAF and the GARR for the fiber connection between the Medicine radiotelescope and the Garr Pop network. Starting from 2005 he is a member of the scientific board of the CyberSar project. The target of this project is to set up and connect, by a optical switched network, the "grid clusters" of the scientific sites of the region Sardegna. From 2009 is a member of the scientific board of the Italian NREN: the GARR.

Ugo Becciani (m) is a senior INAF Research Astronomer, author/co- author of about 180 papers, proceeding of conferences, circulars and technical reports. He holds a permanent position as Astronomer Researcher (computing science field) at INAF - Astrophysical Observatory of Catania. He is a member of the board on the Scientific Unit ICT - INAF. In the period 1999 - 2015 he has been PI and CoPI of several research projects on different computational astrophysical topics, advanced studies in supercomputing and parallel computing (HPC), visual analytic, data exploration, grid computing, virtual observatory. He is responsible of ESA-GAIA mission for HPC on AVU-GSR, involved on SKA-1 project for the design of the DISH-LMC and on CTA Data management. The main EU projects where he was involved in the last few years are: FP7 SCI-BUS (INAF responsible, for A&A visualization Science Gateway and Mobile app.), FP7 VIA-LACTEA (FP7 project WP leader), EGI-InSPIRE (for A&A visualization tools and HPC tools).

Alessandro Costa (m) is a senior INAF Technologist and Researcher. He has got his Master's degree in Telecommunications Engineering in 2000 and he works at INAF since 2001. He works as computer scientist in Authentication & Authorization Infrastructures (AAI), Scientific Visualization, High Performance Computing and Virtual Observatory. He has been taking part to the CTA Project and in particular to the Data Management activity (2013-present). In CTA he works as software engineer and is the main contact point for the INAF involvement in the development and production of a scientific gateway (http://cta-sg.oact.inaf.it/) and authorization infrastructure (http://grouper.oact.inaf.it/grouper). Both products are documented in the current CTA Data Management CDR/TDR. He has been representing INAF in the FIM4R (Federated Identity Management for Research Collaborations) group

https://cdsweb.cern.ch/record/1442597 (2015-present). He has been representing INAF in the Scientific Technical Committee of IDEM-GARR: the Italian identity federation of universities and research institutes for authentication and authorization (2013-present). He works as computer scientist in Scientific Visualization where he developed VisIVO (https://sourceforge.net/projects/visivoserver/), an integrated suite of visualization tools and services. In the VIALACTEA FP7 project he is contributing in the development of instruments integrated in the Virtual Observatory for data mining, visual analytics and visual-collaborative environments (Science Gateways). The list of most recent European Projects (last five years) where Alessandro Costa took part is: EDGI, EGI-InSPIRE, SCI-BUS, ER-flow, VIALACTEA.

Jan Brand (m) obtained his Ph.D. in 1986 at Leiden University (NL) with a thesis on “The Velocity Field of the Outer Galaxy”. He held post-doctoral positions at the Max-Planck-Institut für Radioastronomie (Bonn) and the Arcetri Astrophysical Observatory (Florence), before being employed at the Istituto di Radioastronomia (Bologna) in 1992; since Dec. 2001 he is ‘primo ricercatore’. He has been the coordinator of the Italian ALMA Regional Centre (ARC) since its foundation in 2005. Since then he has contributed to the development of the ARC to its present form, where it has its own offices at the IRA, with powerful computing facilities and data storage capacities, and employs 5 postdoctoral fellows, and a full-time tenured ARC staff member. His scientific interests are in the fields of the physics and chemistry of the galactic ISM; properties of star-forming regions across the Galaxy; the earliest evolutionary phases of massive star formation; circumstellar envelopes; and masers. These interests are pursued with collaborators both in Italy and abroad, making use of telescopes (both single dish and interferometers) to carry out observations across the electromagnetic spectrum from optical to infrared to (sub)mm to radio. He has guided several students with thesis projects (both for Master and PhD degrees). He is part of an international collaboration that studies the mass loss process of late-type stars, and is a member of a large (mostly Italian) collaboration to survey the “forgotten” 3rd Galactic Quadrant with the Arizona Radio Observatory ALMA antenna. He has published 86 papers in peer-reviewed journals, and contributed 67 papers to non-refereed publications (conference proceedings, reports, popular press). He is a regular referee for scientific journals (ApJ, A&A, MNRAS, New Astronomy) since 1985, and has served on the time allocation committees for the Italian TNG for several years and on the ESO OPC for 4 periods.

Giuliano Taffoni (m) PhD in Astrophysics and author of over 70 refereed papers, invited reviews, conference and technical papers. He is a development scientist at the Astronomical Observatory of Trieste. He has a coordination role in international working groups on HPC and Cloud projects and owns a valuable experience in HPC, Distributed Computing, Cloud Computing distributed/federated systems. Since 2003 he is involved in distributed computing projects (EGEE-I-II-III, EGI-Inspire, EGI-Engage, OGF) and he is the coordinator of the Astronomy and Astrophysics community. Since 2006, he actively contributes to the International Virtual Observatory Alliance where he is the deputy coordinator of the Grid and WebServices working group. Since 2013 he joined the coordination team of the Information Technology Office at INAF and he is the INAF representative at SISSA supercomputing center. He is the Infrastructure Manager for Euclid Italian SDC. Since 2015 se coordinates the scientific applications WP activity of ExaNest Project for the design and development of the first European exascale computing infrastructure.

INAF Publications

5. Hatziminaoglou, E. et al. 2015, “The European ALMA Regional Centre Network: A Geographically Distributed User Support Model”, The Messenger (ESO), #162, 24 – 29.

6. Tingay, S. J. et al. 2013, “The Murchison Widefield Array: The Square Kilometre Array Precursor at Low Radio Frequencies”, PASA, 30, 7

7. De Marco, M., Knapic, C. & Smareglia, R. 2015, “New Archiving Distributed InfrastructuRe (NADIR): Status and Evolution”, Astronomical Data Analysis Software an Systems XXIV (ADASS XXIV), Proceedings of a conference held 5-9 October 2014 at Calgary, Alberta Canada. Edited by A. R. Taylor and E. Rosolowsky. San Francisco: Astronomical Society of the Pacific, 2015. p.461

8. Taffioni, G., Sciacca, E., Pietrinferni, A., Becciani, U., Costa, A., Cassisi, S., Pasian, F., Pelusi, D. & Vuerli, C. 2015, “Feeding an astrophysical database via distributed computing resources: The case of BaSTI”, Astronomy and Computing, 11, 109

9. Bolli, P. et al. 2016, “Sardinia Radio Telescope”, Journal of Astronomical Instrumentation, 4, 3n04

INAF Projects

INAF is making leading contributions to pre-construction tasks for the SKA, including in the Low Frequency Aperture Array (LFAA), Telescope Manager (TM), and Dish (DSH) consortia. In addition, INAF staff represent Italy on the SKA Board as Government and Science Members. INAF led Italian contributions to the current version of the SKA science case. Italy is the largest contributor to the SKA science case.

Cherenkov Telescope Array: INAF has started the participation in the CTA project since the very beginning in 2006. The INAF contribution to this project spans on a wide number of activities from the realization of a prototype of the small size telescope to the participation to the data analysis and archiving chain. As a path-finder for CTA, the ASTRI Project is in charge of the implementation of an end-to-end prototype of a Small Size Telescope (SST) for the CTA in a dual-mirror configuration (SST-2M) and, subsequently, of a mini-array comprising seven SST-2M telescopes.

Virtual Observatory (VObs) initiatives: INAF participates in initiatives aimed at giving access to the open, highly diverse, highly distributed data holdings of astronomy as a founding member of the world-wide International Virtual Observatory Alliance (IVOA) and of the European Virtual Observatory initiative (Euro-VO). INAF has played an active role in a number of related projects funded by the EU Framework Programmes: VO-TECH, EuroVO-DCA, EuroVO-AIDA, EuroVO-ICE and CoSADIE. INAF staff has also specific responsibilities within IVOA: Massimo Ramella chairs the Interest Group on Education, Marco Molinaro is the Vice-Chair of the Data Access Layer Working Group and Giulia Iafrate is about to become the IVOA Documentation Coordinator.

Grid and Distributed Computing projects: INAF has played an active role in a number of projects dedicated to distributed computing infrastructures, both in Italy (Grid.it, DRACO) and at European level (all funded by EU/FP7): EGEE-II (unfunded partner), EGEE-III, EGI-Inspire. In particular, EGI-Inspire is a collaborative effort involving more than 50 institutions in over 40 countries to establish a sustainable European Grid Infrastructure (EGI) and to join together the new Distributed Computing Infrastructures (DCIs) such as clouds, supercomputing networks and desktop grids, for the benefit of user communities within the European Research Area. INAF represents and supports the astronomical community, providing some operational Grid nodes as well.

INAF main tasks in project

Profile: representing SKA, IVOA
Main tasks:

- Lead of: WP5, Tasks 5.1, 5.2, 5.3, 5.4, 5.5
- Participation: WP1, WP2, WP3, WP4, WP6

4.1.5 Chalmers

Onsala Space Observatory (OSO) is the Swedish National Facility for Radio Astronomy. OSO is hosted by Department of Earth and Space Sciences at Chalmers University of Technology in Göteborg, and is operated on behalf of the Swedish Research Council (VR). VR's present contract with OSO defines its mission as providing equipment and expertise in radio astronomy and associated geoscience to the Swedish scientific community to ensure that Swedish research in these areas is world leading. OSO operates three telescopes at Onsala, a 25 m diameter cm-wave telescope, a 20 m diameter mm-wave telescope, and a LOFAR station. OSO hosts the Nordic ALMA regional centre (ARC) node, which is part of the European ARC. It provides support services to astronomers in the Nordic region and develops tools for advanced data reduction and analysis. OSO is one of three partners in the Atacama Pathfinder EXperiment (APEX) project. It is a 12 m diameter single dish sub-millimetre wavelength telescope located in the Atacama desert in Chile at an altitude of 5100 m. OSO has a strong receiver development programme for mm and sub-mm wavelengths, as well as pursues developments of other radio astronomical instruments (radiometers, feeds, etc.). In addition, OSO provides the channel through which Sweden is involved in large international radio astronomy projects, such as the EVN, JIVE, LOFAR, ALMA and SKA. OSO is involved in both cm-wavelength VLBI, through our participation in the EVN and in mm-wavelength VLBI, via the Global Millimetre VLBI Array (GMVA). OSO was among the pioneers in developing the VLBI technique and was one of the founding members of the EVN as well as of the GMVA and has for a long time contributed not just with its antennae but also with scientific and technical expertise. Since June 2012 OSO represents Sweden in the SKA Organisation Ltd, a British company that will lead the SKA project during its pre-construction/final design phase through to the end of 2016.

Chalmers Staff

Prof John Conway (m) is Director of Onsala Space Observatory (OSO). He serves as a board member of the SKA Organisation Company, as one of the two representatives from Sweden. He is also leader of the SKA Wide Bandwidth Single Pixel (WBSPF) design consortium. He is a board member of the International LOFAR Telescope (ILT). He has a long interest and experience in radio interferometry being involved during his career in algorithm development and the design of the antenna layout for the Atacama Large Millimetre Array (ALMA). He will participate in WP2

Prof Wouter Vlemmings (m) is the Head of the Nordic ARC (ALMA Regional Centre) node at Onsala since 2011 and between 2007 and 2011 he was manager of the German ARC node in Bonn. The ARC nodes provide user support in Europé for the ALMA submillimetre wavelength array in Chile. He was a member of the SKA Science Review Panel and a member at large of the EVN PC. He is a member of the Swedish LOFAR Executive and has also served on the NRAO and ESO referee panels. He currently has an ERC Consolidator grant and a distinguished young researcher grant from the Swedish Research Council. He will participate in WP5.

Michael Lindqvist (m) is the Head of Telescope Operation at Onsala and has been the Chairman of EVN Technical Operation Group (TOG) between 2012-2014 and is since 2015 he is the Chairman of the EVN Programme Committee (PC) and will participate in WP2 and WP5. He was the vice-Chairman of the EVN TOG between 2007-2011 and has been an observatory member of the EVN PC since 2005. Using his knowledge from the VLBI community. He will be part of WP2 and WP5.

Dr Simon Bourke (m) Dr. S. Bourke is a LOFAR support scientist at Onsala and will participate in WP3. He has over ten years of experience in the area of radio interferometry software. He is an experienced parallel and distributed programmer and Linux/UNIX systems administrator. Recently, he led the Software and Computing team at Caltech, USA, responsible for the data processing system for the Owens Valley Long Wavelength Array, a 22 Terabyte/day instrument. During his time at Caltech he also wrote the data processing pipeline for the Jansky VLA Stripe 82 survey.

Dr. S. Casey (m) is a network specialist and part of the computer group at Onsala and will participate in WP4. His thesis work involved investigating the properties of different network protocols for transferring VLBI data, as well as looking at the effects which end-hosts had on the attainable transfer rates, helping to pave the way to e-VLBI at 1 Gbps. As part of the FABRIC JRA in the EXPReS project, he assisted with data transfer and remote-recording tests at 4 and 8 Gbps over both routed IP networks and switched lightpaths, using both PCs and the FPGA based iBOB as end hosts. More recently he has been involved in the RadioNet3 DIVA JRA, working on creating a VLBI data recorder for rates of up to 32 Gbps.

Chalmers Publications

1. Kocz J., Bourke S., et al., Digital Signal Processing Using Stream High Performance Computing, 2015, JAI, 4, id. 1550003

2. Lindqvist M., Szomoru A., Present status and technical directions of the EVN, 2014, Proceedings of the 12th European VLBI Network Symposium and Users Meeting (EVN 2014). Online at: http://pos.sissa.it/archive/conferences/230/031/EVN%202014_031.pdf

3. Lindroos L., Knudsen K.K., Vlemmings W., Conway J., Martí-Vidal I., 2015, Stacking of large interferometric data sets in the image- and uv-domain - a comparative study, MNRAS, 446, 3502

4. Szomoru A., Lindqvist M., From tape reel to intercontinental lightpaths: Technical developments in the EVN, 2013, IEEE AFRICON Conference. Online at: http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6757823

5. Tuccari G., Alef W., Bertarini A., Buttaccio S., Casey S., Felke A., Lindqvist M., Platania P.R., Wunderlich M., DBBC3 Development, 2014, Proceedings of the 12th European VLBI Network Symposium and Users Meeting (EVN 2014). Online at: http://pos.sissa.it/archive/conferences/230/032/EVN 2014_032.pdf

Chalmers Projects

Onsala has a strong involvement in the Square Kilometre Array (SKA), OSO represents Sweden in the SKA Organisation as one of the 10 full members.
In addition OSO is part of two SKA design consortia, developing receivers within the Dish consortium and leading the Wide Band Single Pixel Feed consortium.

LOFAR (http://www.astron.nl/radio-observatory/radio-observatory) is the Low Frequency Array in the low frequency range for radio astronomy (10-240 MHz). LOFAR is a pathfinder telescope for SKA-low. Onsala runs a LOFAR station and is a member of the International LOFAR telescope. Data handling from LOFAR provides experience with large radio astronomy survey type data which will be the norm for SKA.

Onsala was a partner in the EVN-wide EC-funded R&D projects, EXPReS in the FP6 programme, followed by NEXPReS in FP7. The main aim of the projects was to introduce e-VLBI (electronic Very Long Baseline Interferometry (VLBI) using real time transmission of data from radio telescopes around Europe to every VLBI experiment and thus improving the robustness and flexibility of the array. From these projects experience was gained in large scale data transfer across; experience which will be used in the AENEAS project.

Under contract to ESO the Onsala receiver development lab is delivering 70 ALMA Full Production receivers aimed at equipping all ALMA (Atacama Large Millimetre Array in Chile) antennas with a Band 5. The ALMA Band 5 receiver covers the frequency range 163–211 GHz and is centred on the para-H_2O (3_{13}–2_{20}) line at 183 GHz; one of the few H_2O lines that can be observed from the Earth's surface.

Chalmers main tasks in project

Profile: representing SKA,
Main tasks:

- Participation: WP2, WP3, WP4

4.1.6 GÉANT

GÉANT develops, delivers and promotes advanced network and associated e-infrastructure services for research and education, supporting open collaboration and knowledge-sharing amongst its members and the wider research and education community. GÉANT has offices in Cambridge (GEANT Limited) and Amsterdam (GÉANT Association) and their activities are closely interrelated.
GEANT Limited is a limited liability company and a not-for-profit organisation, wholly owned by the GÉANT Association BV. The GÉANT Association BV is owned by its core membership of the European National Research and Education Network (NREN) organisations.
The organisation coordinates pan-European research and education (R&E) networking, planning, procurement, build and operation of the backbone network, as well as coordination of research programmes and development of innovative services.

GÉANT Staff

Steve Cotter (m), CEO GÉANT. Steve is responsible for developing and fulfilling the organisation's strategic vision, through management of GÉANT's day-to-day operations, strengthening relationships with NRENs and developing major international collaborations. Prior to this position, Steve was CEO of REANNZ, New Zealand's NREN, and Head of ESnet. He has also worked for technology companies in Europe and the US including Google, Internet2 and Cisco. Steve brings a track record of working with government funders and research and academic users.

Matthew Scott (m), General Manager since January 2010. Matthew joined DANTE in June 1996 as Commercial Manager responsible for the financial operation of DANTE, and in February 2003, became Chief Financial Officer. He has considerable experience in procurement and commercial negotiations, having been involved in the procurements for the last four pan-European networks that GEANT Limited has implemented, and has extensive knowledge of the international telecoms carrier market. He is qualified as a Chartered Accountant and has an Engineering degree from the University of Newcastle upon Tyne.

Richard Hughes-Jones (m) joined the organisation in 2008. He is the Senior Network Advisor in the Office of the CTO and is also standards coordinator for the GN4 project. As well as working in the office of the CTO on strategic directions, his role includes assisting NRENs and user groups in getting the best out of the network. Richard is also a network architect in the SKA Signal and Data Transport consortium with responsibility for the long-haul data transmission within the telescopes and the connectivity of the telescopes to the world-wide academic networks. Richard has a first-class honours BSc in Physics and a PhD in Particle Physics from the University of Manchester. He worked on the real-time data acquisition and networking aspects of several international experiments including the ATLAS LHC experiment at the particle physics laboratory CERN in Geneva. He also led the e-science grid network research and development at the University of Manchester, focusing on the high-performance, high-throughput data transfers and real-time requirements of European Union and UK e-science projects. This included the needs of the radio astronomy Very Long Baseline Interferometry (VLBI), and high-energy particle physics communities, as well as other e-science users. He was responsible for

the Proof of Concept demonstrations of moving VLBI data at gigabit and multi-gigabit speeds over the National Research Networks and the GEANT backbone. Richard is the area director for infrastructure in the Open Grid Forum (OGF) standards organisation and a co-chair of the Network Measurements Working Group.

Vicenzo Capone (m) is in charge of the user support for network solutions of pan-European and international scientific groups and collaborations, with a background in computer science and networking. His main involvements are with the Life Science (EMBL-EBI, Elixir), Radio astronomy (JIVE, SKA) and the physics area (LHC, Belle II, Pierre Auger Observatory, etc.) for which he provides solution support for different aspects of the networking: end-to-end connectivity and performance, services selection, monitoring, intra- and extra-European connectivity.
Previous positions were with the Department of Physics of the University of Naples, where he was the network architect and manager in charge of the computing resources for physics experiments, and Technical Associate to the ATLAS experiment collaboration at CERN.

GÉANT Projects

GÉANT is participating in the pre-construction phase of the Signal and Data Transport SKA Element consortium with responsibility for the long-haul data transmission within the telescopes and the connectivity of the telescopes to the world-wide academic networks, and involvement with the Non-Science Data Network inftastructure. The work supports both SKA1-Low to be built in Australia and SKA1-Mid to be built in South Africa.

GÉANT4 is only the latest in a succession of highly advanced Europe-wide data networks GEANT Limited has managed, following in the footsteps of GÉANT (1, 2 and 3), EuropaNET, TEN-34 and TEN-155. GEANT Limited has an enviable record of success in delivering and operating these networks. As a result of this experience, during its almost twenty years of operation GEANT Limited has developed considerable knowledge and expertise in the technical and commercial disciplines required to provide high-speed international networks ahead of the market.
It should also be emphasised that while the GÉANT network provides mainly pan-European coverage, the project and its members currently also fund GÉANT´s international capacity to the R&E networking partners in North America (Internet2, ESNet and CANARIE) as well as to China and Latin America. Other world regions are connected to GÉANT, thanks to support received over the past 15 years from DG-DEVCO, and now also from DG-NEAR. These projects are managed by GEANT Limited and are supported by the members of the GÉANT community. Through these projects, GÉANT today connects to 65 countries beyond its European footprint. The projects include: AfricaConnect2 (DEVCO), supporting pan-African connectivity and interconnections to Europe; EAPConnect (NEAR), for the Eastern Partnership countries; as well as CAREN (DEVCO), in Central Asia, and EUMEDCONNECT (NEAR), in the Eastern Mediterranean. GÉANT also supports TEIN (DEVCO), which interconnects the Asia–Pacific region and South Asia.
In addition to these connectivity projects coordinated by GEANT Limited, the organisation participates in the DG CONNECT-funded MAGIC project, which supports the sharing of knowledge and roll-out of GÉANT services around the world, as well as TANDEM, a network connectivity project in West and Central Africa.

GÉANT main tasks in project

Profile: representing European National Research Networks, Global Connectivity, SKA SaDT
Main tasks:

- Lead of: WP4, Tasks 4.3, 4.4
- Participation: Tasks 2.1, 2.4, 4.1, 4.2, 5.4

4.1.7 EGI.eu

Stichting EGI (abbreviated EGI.eu) is a not-for-profit foundation established under the Dutch law to coordinate EGI. EGI is an international collaboration that federates the digital capabilities, resources and expertise of national and international research communities in Europe and worldwide. The main goal is to empower researchers from all disciplines to collaborate and to carry out data- and compute-intensive science and innovation.

EGI offering includes a federated IaaS cloud to run compute- or data-intensive tasks and host online services in virtual machines or docker containers on IT resources accessible via a uniform interface; high-throughput data analysis to run compute-intensive tasks for producing and analysing large datasets and store/retrieve research data efficiently across multiple service providers; federated operations to manage service access and operations from heterogeneous distributed infrastructures and integrate resources from multiple independent providers with technologies, processes and expertise offered by EGI; consultancy for user-driven innovation to assess research computing needs and provide tailored solutions for advanced computing.
EGI is also responsible for the support, software distribution validation and verification of middleware for distributed access to cluster computing, storage and data, and for the running of Authentication and Authorization services that enable access by more than 50,000 registered users.

Over the last decade, EGI has built a federation of long-term distributed compute and storage infrastructures that has delivered unprecedented data analysis capabilities to many research disciplines (e.g., Medical and Health Sciences, Natural Sciences, Engineering and Technology, Agricultural Sciences, and Art and Humanities). Examples of the supported research include the search for the Higgs boson at the Large Hadron Collider particle accelerator at CERN; finding new tools to diagnose and monitor diseases such as Alzheimer's, or the development of complex simulations to model climate change. To date, the EGI federated infrastructure actively supports astronomy, astrophysics and astro-particle physics with 28, 10, and 32 active research projects, including LOFAR and CTA.

EGI.eu has participants and associated participants drawn from representatives of national e-infrastructure consortiums (NGIs), EIROs, ERICs, and other legal entities. These entities provide the physical resources and shared services that enable EGI to deliver, improve and innovate services for communities. EGI.eu coordinates areas such as overseeing infrastructure operations, user community support, contact with technology providers, strategy and policy development, flagship events and dissemination of news and achievements.

EGI has collaborations agreements in place with e-Infrastructures operating in Canada, North America, Latin America, Africa-Arabia, and the Asia-Pacific region, and is technically integrated with these. The technical infrastructure and its operations are fully distributed with central coordination.

The EGI Cloud Federation aggregates resources by defining a set of standard open-source interfaces and protocols to access the different cloud functions - such as resource discovery, user authentication, compute and data access services - in a uniform way at all the sites, enabling workloads to span and seamlessly migrate across resource centers. Through the EGI Virtual Machine

image library – the Application Database – EGI offers the possibility to share and reuse virtual appliances and to dynamically deploy them in a federated cloud infrastructure. Besides cloud compute and storage services, the cloud will offer the capability of accessing open datasets of public and commercial relevance for scalable access to big research data, fostering a culture and environment for sharing and reuse of open research data. EGI supports the implementation and adoption of cloud open standards.

The EGI technical platforms are co-developed with research communities and technology providers. In order to do so, EGI has established processes and technical infrastructures for requirements gathering, software validation, verification and distribution through the Unified Middleware Distribution.

Through its solutions for High Throughput Computing, Cloud, Federated Operations and Community-driven innovation and support, EGI is contributing to the Open Science Commons vision (http://go.egi.eu/osc) according to which Researchers from all disciplines have easy, integrated and open access to the advanced digital services, scientific instruments, data, knowledge and expertise they need to collaborate to achieve excellence in science, research and innovation.

EGI.eu Staff

Dr. Tiziana Ferrari (f) is Technical Director of EGI.eu, and the project director of the EGI-InSPIRE FP7 project. She has been involved in Grid operations since 2007 contributing to the coordination of operations for the Italian Grid infrastructure and holds a PhD in Electronics and Data Communications Engineering from the Universita' degli Studi in Bologna.

Małgorzata Krakowian (f) has worked in operations since 2006, collaborating with the EGEE2, EGEE3, EGI-InSPIRE, ENVRI, FedSM and PL-Grid projects. She holds a Master degree in Applied Computer Science and finished post-diploma studies in Project Management (IT project management, International project management). Currently she holds Senior Operations Officer position in EGI.eu and coordinates EGI Production Infrastructure by supervising the operational status and advancement of global and national operational services, collecting operational requirements, contributing to the definition of the operations integration technical roadmap and supervising its progress.

Peter Solagna (m) works as Senior Operations Manager at EGI.eu. He has particular expertise in the field of distributed and federated infrastructures, and has been successfully coordinating two activities in the EGI- InSPIRE project, among which Technology provisioning (which includes the activities for the deployment of a Federated Cloud infrastructure) and the Operations of the production infrastructure. Before EGI.eu and EGI-InSPIRE, Peter worked for INFN in the context of EGEE-III projects, and for other big international collaborations involving distributed operations. Peter holds a MSc in Computer Engineering from the University of Padova.

EGI.eu Publications

1. *Validation of Grid Middleware for the European Grid Infrastructure*; David, M.; Borges, G.; Pina, J. et al.; Journal of Grid Computing, DOI: 10.1007/s10723-014-9301-z, May 2014

2. EGI: Implementing service management in a large scale e-Infrastructure, Sy Holsinger, Sergio Andreozzi, Proceedings of the IEEE Network Operations and Management Symposium (NOMS) Conference, 2014, Krakow, Poland, DOI: 10.1109/NOMS.2014.6838371

3. *EGI: an Open e-Infrastructure Ecosystem for the Digital European Research Area*, Sergio Andreozzi, Sy Holsinger, Damir Marinovic, Steven Newhouse, Proceedings of eChallenges e-2012 Conference, Lisbon, Portugal, ISBN: 978-1-905824-35-91

4. *Federating Infrastructure as a Service Cloud Computing Systems to Creates a Uniform E-Infrastructure for Research*, Wallom, D.C.H.; Turilli, M., Drescher, M.; Scardaci, D. & Newhouse, S., IEEE 11th International Conference on e-Science 2015, DOI: 10.1109/eScience.2015.51

5. *The user support programme and the training infrastructure of the EGI Federated Cloud*, Fernandez, E.; Sipos, G.; Scardaci, D.; Wallom, D.C.H.& Chen, Y., International Conference on High Performance Computing & Simulation (HPCS) 2015, DOI: 10.1109/HPCSim.2015.7237016

EGI.eu Projects

EGI-Engage (Engaging the Research Community towards an Open Science Commons) https://www.egi.eu/about/egi-engage/,
EGI-Engage is a 8 M Euro H2020 project that started in March 2015, co-funded by the European Commission for 30 months, as a collaborative effort involving more than 70 institutions in over 30 countries. EGI-Engage aims to accelerate the implementation of the Open Science Commons by expanding the capabilities of a European backbone of federated services for compute, storage, data, communication, knowledge and expertise, complementing community-specific capabilities. In the context of EGI-Engage EGI collaborates with INAF and CADC/CANFAR in Canada for the realization of a distributed data cloud that facilitates the downstream access and analysis of astronomical distributed datasets.

AARC (Authentical and Authorization for Research and Collaboration)
https://aarc-project.eu/
AARC is an European Commission funded project that brings together 20 different partners among National Research and Education Networks (NRENs), e-Infrastructures Service Providers and libraries, to develop an integrated cross-discipline AAI framework, built on production and existing federated access services.
The AARC project vision is to avoid a future in which different e-Infrastructures and (new) research collaborations develop and operated independent (and not inter-operable) AAIs.
The AARC project will achieve its vision by improving the interoperability of existing AAIs, defining a common policy framework that is accepted and implemented by all e-Infrastructures and by offering a diversified training package for different communities.
Via user-communities driven pilots, AARC will test critical technical and policy components developed within the AARC project and will pilot the integration of

policy frameworks into production services and the adoption of ready to use solutions for institutions to deploy federated.

Indigo DataCloud is a H2020 project aims at developing a data/computing platform targeted at scientific communities, deployable on multiple hardware, and provisioned over hybrid (private or public) e-Infrastructures. This platform will be built by leading European developers, resource providers, e-Infrastructures and scientific communities in order to ensure its successful exploitation. The project will allow application development and execution on Cloud- and Grid--based e-Infrastructures, as well as on HPC clusters. An essential part of DataCloud will be to extend existing PaaS solutions, allowing public and private e-Infrastructures, including those provided by EGI, EUDAT, PRACE and HelixNebula, to integrate their existing services, make them available through GEANT -compliant federated authentication and distributed authorization policies, guaranteeing transparency and trust in the provisioning of such services.

FedSM (Implementing Service Management in federated e-Infrastructures) is an FP7 EU project (Contract no. 312851) that develops and implements a lightweight approach to IT Service Management (ITSM) suitable for e-Infrastructure services. It developed the FitSM standard (www.fitsm.eu), which is compatible with international standard ISO/IEC 20000 and leading framework ITIL. FitSM is being implemented by EGI.eu as well as national infrastructures in several countries, and has been used by Helix Nebula and other European initiatives and organisations. EGI.eu acted as a pilot client and gave input to the creation and design of the standard and certification scheme, and promotes the adoption of FitSM within the EGI community to support improved value delivery to researchers.

HNSciCloud - Bridging Cloud Computing Innovation & Open Science (http://www.helix-nebula.eu/about-hnscicloud)
The HNSciCloud is a European pre-commercial procurement (PCP) project co-funded by the European Commission Horizon 2020 Work Programme, which kicked-off in January 2016. Driven by the Pre-Commercial Procurement (PCP) commitment of leading research organisations from across Europe, HNSciCloud creates a competitive marketplace of innovative cloud services serving scientific users from a wide range of domains. The marketplace builds on a hybrid cloud platform including commercial cloud service providers, publicly funded e-infrastructures and procurers' in-house resources.

EGI.eu main tasks in project

Profile: representing EGI
Main tasks: lead WP6

- Tasks: WP6

4.1.8 MPIfR

The Max-Planck-Institut für Radioastronomie (MPIfR) is one of 83 independent research institutes of the Max Planck Society (MPG) that perform basic research in the natural sciences, life sciences, social sciences, and the humanities. The MPIfR is the leading radio astronomical institute in Germany and operates the 100-m radio telescope in Effelsberg at centimetre and millimetre wavelengths, one of the world's most important facilities in radio astronomy. With a long expertise in technological developments, the MPIfR led the construction of the 12-m HHT on Mt.Graham, USA, the 12-m submillimetre telescope APEX at Llano de Chajnantor, Chile (2005), and the 30-m radio telescope on Pico Veleta, Spain. The institute completed in 2007 the first international LOFAR station DE-1 in Effelsberg. It also participates in the European Pulsar Timing Array (EPTA) and Effelsberg is the reference telescope for the Large European Array for Pulsars (LEAP). MPIfR staff has been involved in very-long-baseline interferometry (VLBI) since the mid-1970s and has been operating five generations of VLBI correlators. Currently, MPIfR operates a new-generation correlator – a software correlator based on an international cooperation with the USA, Australia and Finland. It operates several technical labs that develop technical equipment for mm-cm, mm-submm, infrared, and optical telescopes. MPIfR is engaged in national, European and international scientific cooperation. The institute is involved in a number of emerging facilities: SOFIA, ALMA, MeerKAT, SKA, optical interferometry facilities (VLTI and LBT), and mm-VLBI.

Max-Planck-Institut
für Radioastronomie

MPIfR Staff

Prof. Dr. Michael Kramer (m), Executive Director and head of the Department of "Fundamental Physics in Radio Astronomy" and supervises the Effelsberg department operating the 100-m telescope and the LOFAR DE-1 station. He is a world-leading expert in pulsar astronomy. He is member of several committees, e.g. LIGO Oversight Committee or the Scientific Council of the ERC. He will He will be overall responsible for the MPIfR participation in.

Dr. Hans-Rainer Klöckner (m), Expert in calibrating radio measurements of interferometers and data pipelining. He organised the science simulation for the SKA in the SKA Design Study programme of the EC (SKADS) and is member of the SKA science-working group in cosmology and the SKA focus group of VLBI. He will be involved in WP2.

The MPIfR team will be closely collaborating with the FZJ team in WP2.

MPIfR Publications

1. Mauch, Klöckner, Rawlings, Jarvis et al. "A 325-MHz GMRT survey of the Herschel-ATLAS/GAMA fields" 2013 MNRAS, 435, 650

2. Obreschkow, Klöckner, Heywood, Levrier, Rawlings "A Virtual Sky with Extragalactic H I and CO Lines for the Square Kilometre Array and the Atacama Large Millimeter/Submillimeter Array", 2009, ApJ, 703, 1890

3. Ng, Champion, et al., Kramer, "The High Time Resolution Universe Pulsar Survey - XII. Galactic plane acceleration search and the discovery of 60 pulsars", 2015, MNRAS, 450, 2992

4. Eatough, Kramer, Lyne, Keith, “A coherent acceleration search of the Parkes multibeam pulsar survey - techniques and the discovery and timing of 16 pulsars”, 2013, MNRAS, 431, 292

MPIfR Projects

The MPIfR has been coordinating RadioNet3, is coordinating the ERC StG Beacon, has been and is participating actively in a number of EU-funded projects: ERC-SyG BlackHoleCam, ERC-AdG GLOSTAR, ERC-AdG LEAP, COST Action MP0905, RadioNet-FP7, NEXPReS, PrepSKA, E-SQUID (all FP7), e.g. RadioNet, SKADS and EXPReS (all FP6) and several Marie Curie Projects.

MPIfR infrastructure/technical equipment

Effelsberg 100m Telescope, APEX telescope, LOFAR station, DiFX Correlator, Cryogenic Waver, Prober, Mechanical and Electronics Workshops

MPIfR main tasks in project

Participation: WP2

4.1.9 Jülich

Forschungszentrum Jülich GmbH – a member of the Helmholtz Association – is one of the largest research centres in Europe. It pursues cutting-edge interdisciplinary research addressing the challenges facing society in the fields of health, energy and the environment, and information technologies. Within the Forschungszentrum Jülich GmbH, the Jülich Supercomputing Centre (JSC) is one of the three national supercomputing centres in Germany as part of the Gauss Centre for Supercomputing (GCS).

Presently, JSC operates a 6 Petaflop/s BlueGene/Q system, one of the largest European HPC systems and a 1.8 Petaflop/s General Purpose Supercomputer system. The current data infrastructure of JSC includes 16 Petabyte disk storage and 100 Petabyte tape storage. JSC has more than 30 years expertise in providing computational and data services to national and international user communities. It undertakes research and development in HPC architectures, performance analysis, HPC software and tools, data management and analysis, Grid computing, and networking. JSC successfully managed numerous national and European projects including the PRACE Preparatory Phase and Implementation Phase 1-4 projects where it contributes to the evolution of the research infrastructure, dissemination, technical operations, petascaling, and future technologies. JSC is data provider for the communities LOFAR and ILDG and a core partner of the European Data Infrastructure (EUDAT).

Jülich Staff

Ralph Niederberger (m), Jülich Supercomputing Centre of the Forschungszentrum Jülich GmbH, is the deputy leader of the communication systems department and leader of the operational security group. He is an expert in high-speed communication, Internet Security, Network Management and Network Administration. Currently he is the leader of the network operations group of the EU FP7 PRACE project. Within the EU FP7 project EUDAT he is working as the deputy-IT-Security-officer. Within the EU Flagship project Human Brain he is leading the task low-level infrastructure dealing with operation and maintenance of network, AAI, accounting, and monitoring. As representative for the HBP project he joined the International User Advisory Committee of GEANT in 2013.
He will contribute to WP4.

Oleg Tsigenov (m) studied Physics at the State University of SAMARKAND, Uzbekistan and got his diploma degree in 1997. Since 2007, as member of the German data storage support group, he maintained one of the biggest German T2 dCache based storage clusters in the CMS Experiment at the Large Hadron Collier(LHC) as data transfer and site administrator. Currently he is responsible of the T1 Long Term Archive(LTA) site for the LOFAR Experiment at the Jülich Supercomputing Centre of the Forschungszentrum Jülich GmbH, in the areas of optimization of the data transfers, load balancing and the distribution of replicas.
He will be involved in WP3 and WP4, and will contribute to WP2 in tight collaboration with the MPIfR.

Jülich Publications

1. Mallmann, D. ; von St. Vieth, B. ; Riedel, M. ; Rybicki, J. ; Koski, K. ; Lecarpentier, D. ; Wittenburg, P., EUDAT - Towards a pan-European Collaborative Data Infrastructure, Innovatives Supercomputing in Deutschland: inSiDE 10(1), 84 - 85 (2012)

2. Riedel, M. ; Wittenburg, P. ; Reetz, J. ; van de Sanden, M. ; Rybicki, J. ; von St. Vieth, B. ; Fiameni, G. ; Mariani, G. ; Michelini, A. ; Cacciari, C. ; Elbers, W. ; Broeder, D. ; Verkerk, R. ; Erastova, E. ; Lautenschlaeger, M. ; Budig, R. ; Thielmann, H. ; Coveney, P. ; Zasada, S. ; Haidar, A. ; Büchner, O. ; Manzano, C. ; Memon, A. ; Memon, M. S. ; Helin, H. ; Suhonen, J. ; Lecarpentier, D. ; Koski, K. ; Lippert, T., A data infrastructure reference model with applications: towards realization of a ScienceTube vision with a data replication service, Journal of internet services and applications 4(1), 1 - (2013) [10.1186/1869-0238-4-1]

3. Lippert, T. ; Eickermann, T. ; Erwin, D., PRACE: Europe's Supercomputing Research Infrastructure, Applications, Tools and Techniques on the Road to Exascale Computing / ed.: K. De Bosschere, E.H. D'Hollander, G.R. Joubert, David Padua, Frans Peters, Mark Sawyer, IOS Press, 2012, Advances in Parallel Computing, Vol. 22. - 978-1-61499-040-6. - S. 7 - 18 (2012) [10.3233/978-1-61499-041-3-7]

4. Hoeft, B. ; Stoy, R. ; Schröder, F. ; Reymund, A. ; Niederberger, R. ; Mextorf, O. ; Werner, S., 100G Ethernet in the wild - first experiences, Journal of physics / Conference Series 331, 052007 (2011) [10.1088/1742-6596/331/5/052007]

Jülich Projects

The JSC has been coordinating the European supercomputing infrastructure projects DEISA, the PRACE Preparatory Phase project PHASE-PP, the Implementation Phase projects PREACE-1IP, PRACE-2IP, PRACE-3IP and is coordinating the Implementation Phase project PREACE-4IP. JSC coordinated the European Exascale Project DEEP and is coordinating DEEP-ER. Furthermore, JSC participates in numerous projects HPC and data projects like Mont-Blanc 2, EUDAT2020, and the Human Brain Project.

Jülich infrastructure/technical equipment

6 Petaflop/s BlueGene/Q Supercomputer, 1.8 Petaflop/s General Purpose Supercomputer, 16 Petabyte disk storage and 100 Petabyte tape storage, Network center for German LOFAR stations, LOFAR Long Term Archive

Jülich main tasks in project

Participation: WP3, WP4

4.1.10 SKAO

The Square Kilometre Array (SKA) Organisation is a private UK company limited by guarantee. The company does not have a share capital, but has Members who are guarantors (with limited liability) instead of shareholders. It was formed in December 2011 to formalise relationships between the international partners and to centralise the leadership of the SKA project; formally its mission is to complete the detailed design of the SKA and prepare for construction; a subsequent evolution of the Organisation to another form is planned to enact the construction phase. Formal negotiations on this new legal structure began in 2015, with the ambition of creating an SKA International Organisation. Implementation of the new organisation is anticipated to begin in 2018.

The current Members of the SKA Organisation are funding bodies and government departments with an interest in realising the construction and operation of the SKA, and delivering science for their respective communities. Presently, there are ten member countries – Australia, Canada, China, India, Italy, New Zealand, South Africa, Sweden, The Netherlands, United Kingdom.

The Office of the SKA Organisation is responsible for coordinating the global activities of the SKA project, including in the design and development phase, engineering, science, policy, outreach and planning for the future operation of the telescope. SKA Organisation staff have been involved in previous EC-funded instruments in the past; the FP6-funded SKA Design Study (SKADS) project, the Preparatory Phase programme PrepSKA in the technical/policy domain, and more recently in supporting the FP7 policy instrument GO-SKA. In Horizon 2020, SKAO acts as Coordinator for the IN-SKA project, an initiative to complete the detailed design of the SKA's core telescope infrastructure in Australia and South Africa.

SKAO Staff

Simon Berry (m) is Director of Policy Development at the SKAO where he is responsible for developing the policy regime (governance, funding, procurement etc) needed to design, construct and ultimately operate the SKA. His role in AENEAS will be to provide policy oversight and input where required on alignment of activity with the development of the future SKA overall governance and observatory structure model. Simon has significant experience of working in European projects having been involved in the earlier PrepSKA project (leading a workpackage and supporting the role of the Science and Technology Facilities Council as Coordinator in that project) and as Deputy-Coordinator in the FP7-funded instrument GO-SKA. He is now Coordinator or the H2020 IN-SKA programme.

Miles Deegan (m) is Engineering Project Manager at the SKAO where he is responsible for overseeing the work of two of the SKA's design consortia: the Science Data Processor (SDP) and Telescope Manager (TM). The TM consoritum are designing the software required to monitor and control the two SKA telescopes and manage the observation programmes. The SDP is concerned with the design of th hardware platforms, algorithms and software required to process SKA data into science products for distribution to a network of SKA Regional Centres. Miles's role in AENEAS will be to liaise with the work packages in areas such as governance, business models and technical matters to ensure a smooth interface between the SKAO and ESDC.

Antonio Chrysostomou (m) is the Head of Scientific Operations Planning at the Square Kilometre Array Organisation. He was previously Associate Director of the James Clerk Maxwell Telescope, (while on leave of absence from the University of Hertfordshire) from 2007-2012 where he was responsible for the operations, staffing and budget of the James Clerk Maxwell Telescope, as well as managing the JCMT Legacy Survey. He has served on several review panels and committees for the UK's Science and Technology Facilities Council and for other observatories, facilities and research councils. Antonio's research interests are in star formation and the roles that magnetic fields and outflows play in governing that process.

Nicholas Rees (m) has been Head of Computing and Software at the Square Kilometre Array Organisation since February 2016. He was previously at Diamond Light Source where he led both the Beamline Controls Team and the Scientific Computing Team. He joined Diamond in 2004 from the Joint Astronomy in Hawaii, where he led the software and computing teams in a number of projects to automate the Observation Management of the observatory including scheduled, service and remote observing, automated target of opportunity observing, and the automated data analysis of large astronomical data sets for input into the Virtual Observatory infrastructure. His interest in the processing of large scientific data sets goes back to his PhD in the 1980's, when he was responsible for 8C survey - the 8th Cambridge survey of Radio Sources.

SKAO Projects

PrepSKA: SKA Organisation and particularly its predecessor, the SKA Programme Development Office (SPDO) were centrally involved in the PrepSKA project (2007-2012). PrepSKA, funded under FP7, was an initiative associated with the SKA's Preparatory Phase, to develop both high-level technical and policy aspects of the project. SPDO undertook a range of system design tasks and acted as a coordinating body for the global SKA design effort. In the policy domain, the workpackage programme marked the transformation of SKA into a project with significant backing from funding agencies and governments. More significantly, it provide direct support for the transition to and establishment of the current legal entity and governance structure for the project.

GO-SKA: SKA Organisation was centrally involved in the FP7 GO-SKA project, which supported workpackages aimed at developing the 'globalisation' of the SKA. Building on the work of PrepSKA, SKA Organisation supported work towards an appropriate globally-appropriate legal structure and financial model for the construction and operation phase. The programme also considered the development of a procurement policy for SKA construction activities, and how to formulate and construct an overall 'business case' for the project. This fundamental work formed many of the basic principles used for the establishment of intergovernmental negotiations towards an SKA Convention in 2015.

IN-SKA: Following the recommendation by ESFRI that SKA would benefit from specific enabling funding to assist with transition to the implementation phase, SKA Organisation developed and now coordinates the IN-SKA project in response to the Horizon 2020 INFRADEV-3 Call. In IN-SKA, valued at €4.9M, SKA Organisation leads teams in Australia and South Africa to finalise the detailed design of the most critical infrastructure components for the telescopes, necessary to move to the construction of the facility on schedule in late 2018.

SKAO main tasks in project

Profile:
Main tasks: Participating in WP2

4.1.11 STFC

The Science and Technology Facilities Council (STFC) is one of the UK's seven publicly funded Research Councils responsible for supporting, co-ordinating and promoting research, innovation and skills development in the areas of particle physics and astronomy. STFC's funded science program includes not only SKA but many other major astronomy and particle physics projects likely to generate large distributed datasets in the coming decade.

STFC's Scientific Computing Department (SCD) operates several high capacity HPC and HTC platforms likely to evolve to have capabilities matching the needs of SKA in the next decade:

- The UK LHC Tier-centre1 (14000 cores, 70 Petabytes storage) is one of the main backbone nodes in the Worldwide LHC Computing Grid (WLCG). The Tier-1 team has 10 years' experience handling and optimising large scale data flows across a global optical private network.
- The JASMIN super-data-cluster for environmental science, a 14 petabyte international exemplar in Data Intensive Computing.
- The STFC Hartree centre provides industry and business access to HPC and Big Data services and expertise. Hartree is a collaborator on the SKA Science Data Processor (SDP).

SCD has internationally recognised expertise in the management and operation of globally distributed e-Infrastructures, high capacity computing platforms as well as the rapidly evolving field of hybridised private/public cloud computing.

STFC Staff

David Corney (m) is Director of SCD at STFC. David is a member of the EU-T0 Executive board, and has significant experience in FP7 and H2020 governance agreements. SCD is a member of EGI and EUDAT, and David was involved in developing the initial EUDAT bid, and is involved in frequent discussion with Kimmo Koski and Damien Le Carpentier from EUDAT.

Dr. Andrew Sansum (m) is Head of Systems Division at STFC and is responsible for delivery of computing services to a wide range of disciplines. Andrew has been involved in the deployment of Grid services for the LHC since 2001 and until 2015 was the Service Manager for the UK Tier-1 Andrew has expertise in long range planning and modelling of UK computing infrastructure for the LHC.

Brian Davies (m) is responsible for optimisation of data transfer rates between the LHC Computing Grid and the GridPP's fifteen national computing centres within the UK. He assists WLCG sites with their storage configuration so as to improve the transfer rates between sites. He has previous experience evaluating new storage technologies for use as a replacement of those currently used by the WLCG.

STFC Publications

1. Processing LHC data in the UK. D. Colling et al. Phil Trans R Soc A 2012 371:20120094; doi:10.1098/rsta.2012.0094

2. EUDAT D7.1.2 (13 May 2015): Towards a Globally Scalable Archive Federation Technology (Shaun de Witt (STFC), Maciej Brezniak (PSNC)) https://b2share.eudat.eu/record/222/

3. Storing and manipulating environmental big data with JASMIN. Lawrence et al. Proceedings of IEEE Big Data 2013, p68-75 doi:10.1109/BigData.2013.6691556 (pdf)

4. The Hartree Centre: http://www.hartree.stfc.ac.uk/hartree/

STFC Projects

STFC is a member of the H2020 EUDAT, leading the EUDAT Technology Exploration work package. STFC also contributes to the EUDAT WP6 operations work package, delivering EUDAT services and resources to data projects.

STFC is an active member of EGI and lead the EGI Security Response Team, having responsibility for policy coordination, software vulnerability handling and risk assessment. STFC operates several core services for EGI (accounting, site registry and the distributed filesystem)

STFC has very strong links with the Research Data Alliance (RDA) and is an Organisational Member of the RDA. Tony Hey, Chief Data Scientist at STFC, is a member of the RDA Council, and Juan Bicarregui, head of the Data Services Division in SCD is co-chair of the RDA Organisational Advisory Board. STFC is a partner in the RDA Europe project, concentrating particularly on policy level engagement and practitioner engagement.

STFC is a member of HNSciCloud funded by the European Commission Horizon 2020 Work Programme. The HNSciCloud consortium is a European pre-commercial procurement (PCP) project for Cloud services.

STFC is a member of the Indigo-Datacloud, funded by the European Commission Horizon 2020 Work Programme. Indigo-Datacloud is targeted at scientific communities, provisioned over hybrid, private or public, e-infrastructures.

STFC infrastructure/technical equipment

To support the WP3 prototyping work STFC will provide access to the UK LHC Tier-1 at STFC's Rutherford Appleton Laboratory

STFC main tasks in project

Contribute to tasks 2.1, 3.3, 3.4, 3.5 and 3.6

4.1.12 CSIC

The Spanish National Research Council (CSIC) is the largest public institution dedicated to research in Spain and the third largest in Europe. Belonging to the Spanish Ministry of Economy and Competitiveness through the Secretary of State for Research, Development and Innovation, its main objective is to develop and promote research that will help bring about scientific and technological progress, and it is prepared to collaborate with Spanish and foreign entities in order to achieve this aim. According to its Statute (article 4), its mission is to foster, coordinate, develop and promote scientific and technological research, of a multidisciplinary nature, in order to contribute to advancing knowledge and economic, social and cultural development, as well as to train staff and advise public and private entities on this matter.
It has a staff of more than 13,000 employees, among these about 3,300 are permanent researchers and about 4,300 are pre- and post-doctoral researchers.
The CSIC has 70 fully own institutes or centres distributed throughout Spain. In addition, it has 53 Joint Research Units with universities or other research institutions. There is also a delegation in Brussels and Rome.
CSIC has considerable experience in both participating and managing R&D projects and training of research personnel.
CSIC provides services to the entire scientific community through management of the Singular Scientific and Technological Infrastructures (ICTS) such as Calar Alto Astronomical Observatory, Doñana Biological Station, European Synchrotron Radiation Facility, Hesperides Ocean Research Vessel, Integrated Micro and Nanoelectronics Clean Room, Juan Carlos I Antarctic Base, Max Von Laue-Paul Langevin Institute and Sarmiento de Gamboa Ocean Research Vessel.
Under the 7th Framework Programme CSIC has signed approximately 700 actions (including 97 coordinated by CSIC and 47 ERC projects). Funding wise, CSIC is listed the 1st organisation in Spain and the 5th in Europe in the 7th Framework Programme, with a total FP7 contribution of over 260 million euros.
As to the funding obtained by CSIC within each programme, the distribution is People 19 %, Cooperation 45%, Capacities 10 % and Ideas 26 %. Taking into account the research areas, the most relevant ones in terms of funding have been Physical Science and Technology and Biology and Biomedicine.
During the first calls of H2020, CSIC has had an intense participation in all programmes. It has been remarkable the participation in certain calls, such as ERC and Marie Curie, as well as in ICT, NMBP, and Societal Challenges. In December 2015 CSIC has obtained 149 projects with a total financial contribution of 63 million euros.
In addition, CSIC presents a large participation in other European programmes as LIFE, INTERREG, EMRP, RFCS, ERANET, etc.

CSIC Staff

Dr. Lourdes Verdes-Montenegro (f) is staff Scientist at IAA-CSIC, expert on the study of the effect of the environment in galaxy evolution using multiwavelength and especially radioastronomical techniques. She is PI of the international collaboration AMIGA, involving more than 15 research groups abroad, currently funded by the Spanish Ministry for Science and Innovation under project “AMIGA4GAS: AMIGA for GTC, ALMA and SKA pathfinders” and “AMIGA5: gas in and around galaxies. Scientific and technological preparation for the SKA”. She has more than 60 refereed papers and ~1500 citations, and has been advisor for 6 PhD Thesis, plus one in progress. She also coordinated

the “Astronomy” work package of the Wf4Ever, EC FP7 funded project. She has trained four instrumentalist scientists who have developed their work in three ALMA nodes and the Square Kilometre Array Organization office, and built a pioneer group for scientific and technical developments in e-Science. She coordinates the participation of Spain in the SKA, VIA-SKA, with the participation of 14 Spanish centres and universities, including her participation of her group in the SKA Science Data Processor design. She is member of the Ministry advisory committee on “Radioastronomical infrastructures”, of the SKA HI Science Working Group, and of the Science Data Processor consortium of the SKA. She has been as well Chair of the PE9 Panel on Sciences of the Universe for the Starting Grants of the.

Susana Sánchez (f) has a degree in computer engineering from the Granada University (UGR) and since 2007 belongs to IAA-CSIC. She was the technical leader of the e-CA project that aimed to promote the e-Science tools in Andalusia. She collaborated with the GRID-CSIC project on the installation and configuration of the IAA-CSIC Ibergrid node and migrated several astrophysics applications to the Grid. She has been collaborating with the Kapteyn Institute to improve the Groningen Image Processing System (GIPSY) for data cubes analysis, building a Graphical User Interface and connecting it with the Virtual Observatory. She has participated in the EU FP7 funded project Wf4Ever as a developer of astrophysics workflows. She also was the technical leader of the AMIGA4GAS, aiming to facilitate the deployment of astrophysics workflows on heterogeneous distributed computing infrastructures. Currently, she participates in the Science Data Processor consortium as a member of the DELIV team, which is designing the system for delivering the SKA science ready data to the end users.

Dr. Julián Garrido (m) holds a PhD in Informatics from the University of Granada since 2011. He received his M.Sc. in Soft Computing and Intelligent Systems in 2008. He has been awarded with several research grants from University of Granada and Andalucía Government. He is currently member of the AMIGA group at IAA-CSIC, and as part of it, he participated in the FP7 project Wf4Ever, where he developed the AstroTaverna plugin to adapt Taverna to Astronomy users and supply access to VO services. He also participated in the AMIGA4GAS project, in which he contributed to the elaboration of standards in the VO and the development of workflows. He works with LVM as Project Manager of the Spanish technological participation in the SKA. He also participates in the Science Data Processor as member of the DATA team, which is defining the data model for the Long Term Archive and identifying the data flow and data life-cycle requirements.

CSIC Publications

1. J.E. Ruiz, J. Garrido, J.D. Santander-Vela, S. Sánchez-Expósito, L. Verdes-Montenegro. AstroTaverna - Building workflows with Virtual Observatory services. 2014 Astronomy and Computing 7-8 Special Issue on The Virtual Observatory: I, 3-11, doi:10.1016/j.ascom.2014.09.002

2. S. Sanchez-Exposito, P. Martin, J.E. Ruiz, L. Verdes-Montenegro,J. Garrido, R. Sirvent, A. Ruiz-Falcó, R. Badia. 2015 Web services as building blocks for Science Gateways in Astrophysics. Proceedings of the International Workshop on Science Gateways. DOI:10.1109/IWSG.2015.7

3. J.D. Santander Vela, L. Verdes-Montenegro et al.. A VO Compliant Radio Astronomical Data Model for Single dish radio telescopes (RADAMS). Experimental Astronomy (2012).

4. Miguel A. Perez-Torres (Editor-in-chief), L. Verdes-Montenegro, J. C. Guirado, A. Alberdi, J. Martin-Pintado, R. Bachiller, D. Herranz, J. M. Girart, J. Gorgas, C. Hernandez-Monteagudo, S. Migliari and J. M. Rodriguez Espinosa. The Spanish Square Kilometre Array White Book. ISBN: 978-84-606-8955-3

5. S. Leon, V. Espigares, J.E. Ruiz, L. Verdes-Montenegro, R. Mauersberger, W. Brunswig, C. Kramer, J.D. Santander-Vela, H. Ungerechts, and H. Wiesemeyer. APAS, a VO radio archive at the IRAM-30 meter telescope. Experimental Astronomy, 2012, Volume 34, Number 1, Pages 65-88.

CSIC Projects

CSIC is leading **VIA-SKA**, a project for the feasibility study of SKA-related technological capabilities of Spanish research centres and industries. Funding was awarded on December 2011, under MICINN grant AIC-A-2011-0658. Since then, VIA-SKA has been interacting with the Spanish technology and research centres interested in participating in the SKA, and has also been fostering industry participation in the project. As a result, more than 20 Spanish research centers and companies contribute to the design of the SKA since its beginning in 2013.

BIOSTIRLING-4SKA is a FP7 project (Project Number 309028) to design and develop solar power generation systems, composed by dishes with Stirling engines, bio-hybrid energy collector, and efficient storage at the industrial scale. The system will be designed so that it can be scaled to support part of SKA power needs, guaranteeing 24/7 energy supply independently of weather conditions, and support for different power loads, through modularity. CSIC researchers are involved in the establishment of the requirements and specifications of all the components of the Power Plant, in terms of the project objectives, taking also into account requirements that would be imposed by the SKA as a final user

AMIGA (Analysis of the Interstellar Medium of Isolated Galaxies, http://amiga.iaa.es) is an international collaboration lead by CSIC and funded by the Spanish Ministery of Science and Innovation since 2002 through several projects (AYA2002-03338, AYA2005-07516-C02-01, AYA 2008-06181-C02-01, AYA2011-30491-C02-01, AYA2014-52013-C2-1-R, AYA2015-65973-C3-1-R). This group focuses on the multi-wavelength study of extreme galaxy environments and its technological developments aims at lowering the barriers associated to the complexities of dealing with distributed, heterogeneous and large data volumes as a preparation for the coming data deluge from the Square Kilometre Array (SKA). Currently AMIGA6 project gathers four Spanish groups involved in the data flow of the SKA (SaDT, CSP, SDP).

Advanced Workflow Preservation Technologies for Enhanced Science - WF4EVER. CSIC coordinated the Astrophysics WP of this EU FP7 funded project. It played the role of users in the Astrophysics field, providing requirements from this community that drove the developments of standards and models for the preservation of scientific workflows.

CSIC main tasks in project

Profile: representing SKA SDP consortium
Main tasks:

- Consortium participant,

Participation: Tasks WP2.1, WP2.3, WP2.4, WP3.1, WP3.2,WP3.3, WP3.4, WP3.5 and WP5.4

4.1.13 IT

Instituto de Telecomunicações (IT), is a private, not-for-profit organization, of public interest, a partnership of nine institutions with research and development in the field of Telecommunications and related areas. Currently, IT Coordinates ENGAGE SKA, a National Research Infrastructure Consortium enabling Green E-science for the SKA and part of the National Roadmap on RIs. Advanced laboratory facilities are available in most Scientific Areas of IT to support fundamental and applied research, which is carried out in the framework of national and international projects in cooperation with similar research institutions worldwide. Each year IT is involved in more than 170 projects, of which about 30 have European funding. Example projects were Openlab2 – FP7 (An Open Federated Laboratory Supporting Network Research for the Future Internet), SooS – FP7 (Service-oriented Operating Systems) for Resource-independent execution support on exa-scale systems. IT is also known for world record on signal transmission bandwidth over Optical Networks. IT is an official supporter of Openstack, contributing to several aspects, mostly related to the support of Network Function Virtualization through the Service/Port Chaining blueprints, and the extension of the Ceilometer component to support heterogeneous cloud services. Radio astronomy activities are also run on behalf of ENGAGE SKA.

Currently, ENGAGE SKA offers a wide variety of activities, such as advanced training in radio astronomy, radio frequency and core optical technologies for radioastronomy, training in computational astrophysics, characterization and testing facilities with inclusion of Green (Solar) technologies, Aperture Array technologies optimization, solar observations (radio and optical), astronomy software development and E-Science, Cloud Computing and Data Storage. ENGAGE SKA aggregates several institutions like : U. Porto, U. Aveiro, U.Evora and IP Beja. U. Porto and U. Aveiro are widely known for their competences on ICT, in particular Cloud, SDN, CDN technologies applied to Science, SmartCities and the 5G-PPP. IT is an official developer of OpenStack with expertise on Virtualization in cloud environments, Network Function Virtualization, Internet-of-Things ecologies. U. Evora is a PT node of PRACE and chairs the HPC Astrophysics Simulation Group at PRACE (4IP). FCUP has been a member of solar infrastructures related to ESA and NASA. Members of ENGAGE SKA have actively participants to PrepSKA (FP7) and SKA Pre-Construction Design Consortia like Software Data processor, Telescope Manager and Signal and Digital Transport, and were consultants to NEXpress, GEANT, etc. IT also possesses its own 9-meter radiotelescope.

IT Staff

Domingos Barbosa (m) is the Coordinator of ENGAGE SKA, and Senior Researcher at IT. He participated in PrepSKA and served as a member of the previous SKA Science & Engineering Committee (SSEC). Barbosa has more than 50 publications and was responsible for the installation of a 9-meter radiotelescope for the GEM project. He has experience in EU projects : he was a member of FP7 PrepSKA project, the FP7 Biostirling 4 SKA (sustainable energy systems for the SKA Aperture arrays). He was a member of the MAXIMA CMB collaboration and Planck Surveyor. He is an active astronomer with an interest in the application of Big Data, in particular Cloud computing and smart Visualization techniques.

Dalmiro Maia (m) is the Managing Director of Geo-Space Sciences Research Centre at the School of Sciences of Porto University, a member of ENGAGE SKA Research Infrastructure, coordinated by IT. Maia is a solar radioastronomer, member of the Heliophysics SKA Science WG. Maia was one of the radioastronomers that made the first ever radio cartography of a solar coronal mass ejection (CME) using the radio-heliograph of Nançay of the Observatory of Paris. He was a member of Soho, Ulysses solar missions. Maia ia also a a Portuguese representative to the COPUOS United Nations Committee for the Peaceful Use of Space. CICGE was a lead of GEONET, a GNSS Continuously Operating Reference Stations (CORS) network, intended to be a science-driven Permanent Network, with precisely known coordinates in the ITRS and, also, in the ETRS89 systems.

João Paulo Barraca (m) is a Researcher at IT, a professor at University of Aveiro and a member of ENGAGE SKA. Currently, he is the group Coordinator of ATNOG, a research group previously centered around HNG(heterogeneous networking group), with a broader scope and increased cooperation with industry. He is an expert in Machine to Machine and Internet of Things Technologies, Virtualization in cloud environments, Network Function Virtualization. Among its projects he developed a multi-resolution visualization tool based on the Healpix visualization scheme for astronomical all-sky data. Barraca is also the Technical Lead for the Local Infrastructure WP of the SKA Telescope Manager Element Consortium.

Diogo Gomes (m) is Researcher at IT, a professor at University of Aveiro and a member of ENGAGE SKA . He is an expert on 3GPP/IMS Wireless Networks, IP Mobility, IP Broadcast/Multicast, Service Architectures, Context Management. He was a mebre of several major project like C-CASt (FP7), on Context Casting, a Cloud Service Broker for Portugal telecom, Daidalos I and II.

Miguel Avillez (m) is a Professor at University of Évora and a member of ENGAGE SKA He is a (astro)physicist from origin, was President of the Portuguese Astronomical Society and is a lead expert on HPC. He served as PI of the Astrophysics WG for PRACE-2IP. Avillez is an expert on the Local Bubble, Interstellar medium, Disk-halo interaction in star-forming galaxies, and a top expert on Adaptive Mesh Refinement, Computational Astrophysics, Computational Atomic Physics. He was also a member of the German White Paper on the SKA. Avillez was co-responsible for some of the state-of-art HPC Software Development like EAF-PAMR code, EA+MPEC, CPIPES, and OpenCL astrophysical software to run in GPUs.

IT Publications

1. D. Barbosa , S. Anton , L. Gurvits , D. Maia , The Square Kilometer Array: paving the way for the new 21st century radio astronomy paradigm , Springer , Dordrecht , 2012

2. Marica Amadeo, Claudia Campolo, José Quevedo, Daniel Corujo, Antonella Molinaro, Antonio Iera, Rui L. Aguiar, Athanasios V. Vasilakos, "Information-Centric Networking for the Internet of Things: Challenges and Opportunities", IEEE Network Magazine, Mar 2016

3. Domingos Barbosa, João Paulo Barraca, Albert-Jan Boonstra, Rui L. Aguiar, Arnold Van Ardenne, Juande De Santader-Vela, Lourdes Verdes-Montenegro, "A Sustainable approach to large ICT Science based infrastructures; the case for Radio Astronomy", Proc. 2014 IEEE

EnergyCon , Croatia, Feb 2014

4. Javad Zarrin, Rui L. Aguiar, João Paulo Barraca, "Dynamic, scalable and flexible resource discovery for large-dimension many-core systems", Journal of Future Generation Computer Systems, Elsevier, Jan 2015

5. Aharonian, F.; Arshakian, T. G.; Allen, B.; Banerjee, R.; Beck, R.; Becker, W.; Bomans, D. J.; Breitschwerdt, D.; Brüggen, M.; Brunthaler, A.; and 63 coauthors, Pathway to the Square Kilometre Array - The German White Paper , Editors: H. R. Kl\"ockner, M. Kramer, H. Falcke, D.J. Schwarz, A. Eckart, G. Kauffmann, A. Zensus, 2013arXiv1301.4124A

IT Projects

IT participates in several pre-construction phase SKA Element consortia. Among its tasks, IT/ENGAGE SKA leads the cyberinfrastructure for the Telescope Manager Consortium that will control and monitor the SKA.

S(o)OS- Service-oriented Operating Systems (S(o)OS) (http://www.soos-project.eu/)address the needs of future distributed systems by drawing from service-oriented architectures (SOA) and the strengths of Grids. S(o) operating systems are modular and minimal, optimised to fit into the cache of distributed compute units and enable process-centric management of resources and distributed execution, thus maximising the resource usage whilst minimising overhead

ENGAGE SKA – Enabling Green E-Science for the SKA. ENGAGE SKA is a Research Infrastructure from the National Roadmap on RIs of Strategic Relevance. This RI sets up a capacitation and sustainability plan for a Green e-Science Infrastructure fostering Portugal participation in the ESFRI SKA project along the Big Data and Green Power lines.

CNPG – Cloud Networking for Next generation - The concepts of Software Defined Networking (SDN) and Network Function Virtualization (NFV) are two of the hottest Telco topics of the moment. SDN brings new capabilities in terms of network automation, programmability and agility that facilitate the integration with the cloud. NFV envisions accelerating the innovation of networks and services allowing new operational approaches, faster service deployment (shorter time to market), service assurance and security. The overall platform will consist on the development of three layers (Service Plane, Service Function Orchestration Plane and Infrastructure Management Plane), following close the ETSI NFV reference architectural framework. Open-source platforms OpenStack and OpenDaylight will be used for a reference implementation framework.

IT main tasks in project

Profile: representing SKA, ENGAGE SKA
Main tasks:

- Participation: Tasks 3.2, 3.3, 3.4, 3.5, 4.1,4.3, 4.4

4.1.14 CNRS

The Centre National de la Recherche Scientifique (National Centre for Scientific Research) is a government-funded research organization, under the administrative authority of France's Ministry of Research. CNRS's annual budget represents a quarter of French public spending on civilian research. As the largest fundamental research organization in Europe, CNRS carried out research in almost all fields of knowledge, through its eight research institutes: Mathematics (INSMI), Physics (INP), Chemistry (INC); Biological Sciences (INSB); Humanities and Social Sciences (INSHS); Ecology and Environment (INEE); Engineering and Systems (INSIS); Information Sciences (INS2I); and its two national institutes: the National Institute of Earth Sciences and Astronomy (INSU); and the National Institute of Nuclear and Particle Physics (IN2P3).
Its own laboratories as well as those it maintains jointly with universities, other research organizations, or industry are located throughout France, but also overseas with international joint laboratories located in several countries. Measured by the amount of human and material resources it commits to scientific research or by the great range of disciplines in which its scientists carry on their work, the CNRS is clearly the hub of research activity in France. It is also an important breeding ground for scientific and technological innovation.
The institute of the CNRS concerned with the AENEAS project is INSU (National Institute of Science of the Universe and the three Joint Research Units involved in the project are the Laboratoire J.-L. Lagrange, the Observatoire Astronomique de Strasbourg and the Laboratoire d'Etudes du Rayonnement et de la Matière en astrophysique (LERMA) as well as the Nancay radioastronomy Observatory.

4.1.14.a Lagrange

The UMR 7293 Laboratoire J.-L. Lagrange will participate to WP2 and WP5 of the AENEAS project. Lagrange laboratory is a joint research unit of the National Centre for Scientific Research (CNRS), Observatoire de la Côte d'Azur (OCA) and the Université Nice-Sophia Antipolis. The Université Nice-Sophia Antipolis will not claim any costs in the AENEAS project.
Lagrange aims to develop multidisciplinary research and teaching activities in the field of astrophysics, cosmology, optical instrumentation and imaging, fluid mechanics and applied mathematics. This research is supported and enabled by unique skills, organized transverse group in physical methods of observation and high performance numerical computing (HPC performance, massive parallelism, 3D visualization). Lagrange has leading roles in several major international projects (e.g. MATISSE at ESO; GAIA and Euclid ESA satellites) and is the European centre to access the interferometric facility CHARA at the Mount Wilson Observatory (California) in remote mode. Lagrange also participated in the French Virtual Observatory project by co-coordinating national working groups on workflows and on 3D images analysis.
Since 2008, Lagrange has been more and more actively involved in the scientific and technical preparation of SKA and precursor/pathfinder instruments, with the participation to LOFAR, ASKAP and MeerKAT continuum survey projects, as well as the affiliation to the core team of the SKA Science Working Group “Extragalactic Continuum” and to the SKA Work Package LFAA of the “Aperture Array Design and Construction”¬¬¬¬ (AADC) consortium..

Lagrange Staff

Chiara FERRARI (f) is senior staff astronomer. She is an expert of combined multi-wavelength and numerical analysis of galaxy clusters to study their dynamical state, the star formation history of their galaxies and its connections with the environment, the presence and origin of diffuse and extended radio emission. She is (co-)author of 83 refereed papers, with more than 1700 refereed citations. Chiara Ferrari is member of the radio survey projects of most of the new and upcoming SKA pathfinders and precursors (LOFAR in Europe, ASKAP in Australia, MeerKAT in South Africa). She co-leads the “Galaxy Clusters” working group of the EMU survey (ASKAP, with M. Johnston-Hollitt from Wellington University, NZ). Since 2013, she is in the core team of the SKA Science Working Group “Extragalactic Continuum” to perform feasibility studies of galaxy cluster observations with the SKA. Together with signal processing colleagues of Lagrange, she has recently joined the SKA “Aperture Array Design and Construction”¬¬¬¬ (AADC) technical consortium and she is an invited observer of the “Science Data Processor” SKA Work Package.

Eric SLEZAK (m) is a senior staff astronomer. He is working on the structure, dynamics and evolution of clusters of galaxies from multi-wavelength observations since more than 20 years and has expertise in astronomical image and data processing. He was among the first to introduce multiscale techniques in observational cosmology, developing wavelet-based approaches to analyze images, compute density probability functions, perform spectro-imagery from low S/N X-ray data. He has published about 60 refereed papers (with ~ 1 500 citations) with the detection of faint line emitters in hyperspectral data and the restoration of faint features with complex diffuse morphologies in radio interferometric images as recent results using sparse-based representations. He led a few years ago a 5-years IT national research project aiming to develop the signal processing methods required to analyze the massive hyperspectral datasets provided by the new generation of integral field spectrographs in astronomy. He also participated in the French Virtual Observatory project by (co-)coordinating national working groups on workflows and on 3D images analysis. He currently chairs the French group of experts which reviews the activities of the CNRS-INSU astronomical data centers.

Lagrange Publications

1. Dabbech, A., Ferrari, C., Mary, D., Slezak, E., Smirnov, O. and Kenyon, J. S., MORESANE: MOdel REconstruction by Synthesis-ANalysis Estimators. A sparse deconvolution algorithm for radio interferometric imaging, In : Astronomy and Astrophysics, vol. 576, p. 7 (2015)

2. Ferrari, A., Deguignet, J., Ferrari, C. et al., Multi-frequency image reconstruction for radio interferometry. A regularized inverse problem approach, In : SPARCS 2015 (2015)

3. Robin, A. C., Luri, X., Reylé, C., et al. (including Slezak, E.) Gaia Universe model snapshot. A statistical analysis of the expected contents of the Gaia catalogue, Astronomy and Astrophysics, vol. 543, p. 100 (2012)

4. Schaaff, A., Bonnarel, F., Louys, M., Slezak, E., Gassmann, B., Pestel, C., Benjelloun, O. and Mantelet, G. Workflow systems and VO standards, Memorie della Societa Astronomica Italiana, vol. 80, p. 559 (2009)

5. C. Ferrari is the main author of one chapter of the new SKA Science book « Advancing

Astrophysics with the Square Kilometre Array » (published in 2015) and co-author of 7 other chapters

Lagrange Projects

Two projects, lead by Lagrange researchers and related to the subject of this proposal, have been financed by the French National Research Agency (ANR): OPALES (P.I. C. Ferrari) and MAGELLAN (P.I. A. Ferrari).

OPALES (2009-2014) is a project aiming at exploiting the capabilities of modern low frequency radio telescopes for the physical characterization of the diffuse radio emission from galaxy clusters. A consistent part of the project has also been devoted to the development of tools for an optimized reconstruction of diffuse radio sources from interferometric radio data (web page: https://opales.oca.eu/foswiki).
This project has boosted the interest on radio interferometry of the signal-processing experts at Lagrange. In 2013, they answered to a call of the interdisciplinary mission of CNRS, which has launched since March 2012 the challenge “MASTODONS”, targeting the management, analysis and exploitation of massive scientific data sets. A Lagrange project focused on the study of distributed processing for very large arrays in radioastronomy (DISPLAY) was financed for two years. Importantly, DISPLAY has paved the way to MAGELLAN (2015-2018), a multi-laboratory fully signal-processing oriented project, devoted to machine learning research for very large arrays in radioastronomy. MAGELLAN aims at the theoretical development of new calibration and imaging algorithms for big-data processing, in view of the SKA (web page: https://magellan.oca.eu).

4.1.14.b OAS (Observatoire Astronomique de Strasbourg)

The Observatoire Astronomique de Strasbourg (Strasbourg Astronomical Observatory) is a Joint Research Unit (UMR7550) of the CNRS and of the Université de Strasbourg (UNISTRA). It hosts the Centre de Données astronomiques de Strasbourg (Strasbourg astronomical Data Centre CDS, http://cds.unistra.fr). Since its creation in 1972, the CDS has been providing reference services which are widely used by the world-wide astronomical community with more than 1 million queries/day in average in 2015. The CDS is labelled as a Research Infrastructure in the French national Research Infrastructure Roadmap. The CDS has lead, since 2006, the European commission funded projects for the development of the European Virtual Observatory.
The Université de Strasbourg will not claim any costs in the AENEAS project.

In AENEAS the CDS will contribute high level expertise on the development of interoperable systems for astronomical data services and on the use of the Virtual Observatory framework.

OAS Staff

Mark ALLEN (m) is a CNRS research scientist at the Observatoire Astronomique de Strasbourg, and is the director of the CDS since 2015. He has 14 years experience implementing e-Science projects in Astronomy within the

CDS and EC funded European Virtual Observatory (Euro- VO) projects. He is the chair of the IVOA Committee for Science Priorities and has served as the IVOA Applications Working Group chair and IVOA Executive Secretary. As Euro-VO project scientist he has engaged and coordinated astronomical data centers, software developers and scientists in the development and use of the Virtual Observatory framework including support to the astronomy community via leading schools and workshops at the national and European levels. He also served as a member of the Astronet Infrastructure Roadmap (Panel D - Theory, computing facilities and networks, Virtual Observatory). His astronomical interests include active galactic nuclei and comparison of theoretical plasma models to multi-wavelength observations.

Francoise GENOVA (f) has been the director of the CDS between 1995 and 2015. She led the data center transition to the internet era, and has been one of the key persons in the International Virtual Observatory Alliance from the start of the VO project around 2000. Since 2006, she has been leading the four projects supported by the European Commission in support to the development of the European Virtual Observatory on behalf of the CNRS, and she leads ASTERICS Work Package 4. She has been leading the national project which supports the development of the VO in France, Action Spécifique Observatoires Virtuels France, since its creation in 2004. She is a member of the IVOA Executive Board, representing the French VO and Euro-VO, and she chaired the Board in 2006-2007. She is a member of the RDA – Europe projects and co-chair of the RDA Technical Advisory Board.

OAS Publications

1. CDS develops services that are widely used by the international astronomical community: SIMBAD, the reference database for the nomenclature and bibliography of astronomical objects, VizieR, the reference service for astronomical catalogues and tables published in academic journals, and the Aladin interactive sky atlas, the VO portal for images.

2. Euro-VO - Coordination of Virtual Observatory activities in Europe, F. Genova, M. G. Allen, C. Arviset, A. Lawrence, F. Pasian, E. Solano, J. Wambsganss, Astronomy and Computing, 2015, Volume 11, p. 181-189

3. Technical Sustainability Report of European Virtual Observatory, M. Allen, K. Noddle, F. Genova. Deliverable (D3.5) of the Euro-VO CoSADIE project (Call INFRA-2012-3.3 Research Infrastructures, project 312559)

4. Françoise Genova was a member of the High Level Expert Group on Scientific Data set up by the European Commission in 2010, which produced the influential report “Riding the Wave - How Europe can gain from the rising tide of scientific data” (2010).

5. Hierarchical Progressive Surveys - Multi-resolution HEALPix data structures for astronomical images, catalogues and 3-dimensional data cubes. P. Fernique, M. G Allen, T. Boch, A. Oberto, F-X. Pineau, D. Durand, C. Bot, L. Cambresy, S. Derriere, F. Bonnarel, F. Genova, 2015, A&A, 578, A114

OAS Projects

CDS participates in the ASTERICS project (Research and Innovation action under grant agreement n. 653477) as the leader of Work Package 4, ‘Data

Access, Discoverability and Interoperability'.

Since 2006 CDS has been the coordinator, on behalf of the CNRS, of all the projects funded by the European Commission to support the implementation of European Virtual Observatory (one FP6 and 3 FP7 projects): the Euro-VO Data Centre Alliance Collaboration Action (EuroVO-DCA - Project RI031675, Communication Network Development framework, 2006-2008), the Euro-VO Astronomical Infrastructure for Data Access FP7 Integrated Infrastructure Initiative (EuroVO-AIDA - Project 212104, Call INFRA-2007-1.2.1 Scientific Digital Repositories, 2008-2010), and two Coordination and Support Actions, Euro-VO International Cooperation Empowerment (EuroVO-ICE, Project 261541, Call INFRA-2010-3.3, http://www.eurovo-ice.eu, 2010-2012) and Collaborative and Sustainable Data Infrastructure for Europe (CoSADIE, Call INFRA-2012-3.3 Research Infrastructures, project 312559, http://www.cosadie.eu, 2012-2015).

Several CDS staff members lead IVOA Working Groups: Pierre Fernique (chair of the Application Working Group), François Bonnarel (chair of the Data Access Layer WG), André Schaaff (chair of the Grid & Web Services WG). Mireille Louys (associated researcher to CDS, ICUBE laboratory, UNISTRA) is the co-chair of the Semantics Working Group. Thomas Boch and Sébastien Derriere are also key participants in the development of Applications and Semantics IVOA Recommendations.
CDS is a partner, on behalf of CNRS, of the Research Data Alliance Europe project (Formerly iCORDI International Collaboration on Research Data Infrastructure, Coordination and Support Action, Project 312424, Call FP7-INFRASTRUCTURES-2012-1, 2012-2015) and of RDA Europe 2 (Coordination and Support Action, Project 632756, Call FP7-INFRASTRUCTURES-2013-2).

4.1.14.c LERMA (Laboratoire d'Etudes du Rayonnement et de la Matière en Astrophysique et Atmosphères)

LERMA is one of the departments of the Observatoire de Paris. It comprises about 130 people, which carry out research in 4 different groups. One of the groups is dedicated to instrumentation, mainly heterodyne instrumentation at millimetre to THz wavelengths. The group - of about 20 staff including Ph.D. students - focuses on astronomical receivers for ground based and space borne astronomical telescopes. The instrumentation group has delivered a mixer to the Herschel satellite and is involved in the Submillimeter Wave Instrument (SWI) on JUICE (Jupiter Icy Moon Explorer) mission. The instrumentation group has, and currently is, carrying out several R&D projects and is well represented at international conferences. The instrumentation group will use its expertise to contribute to the AETHRA JRA in order to exploit new technologies to significantly improve the next generation of mm and submm receivers.
The Observatoire de Paris will not claim any costs in the AENEAS project.

LERMA Staff

Françoise COMBES (f) is an astronomer specialised in galaxy formation and evolution, both in multi-wavelength observations and numerical simulations. She is in particular an expert of radio frequencies, both cm and millimeter. She is professor at College de France, and member of the French Academy of Sciences. Her research activity at Paris Observatory covers a large range of

topics, from bar and spiral dynamics, galaxy interactions, gas hydrodynamics, star formation efficiency, high-z objects absorption lines, dark matter and AGN fueling and feedback. She has served in IAU for 12 years, and was president of the Division "Galaxy and Cosmology" from 2012 to 2015. She received an ERC Advanced grant from 2011 to 2015, and several awards, in particular the EAS (European Astronomical Society) Tycho Brahe prize in 2009. She worked on the European SKA-Design study from 2005 to 2009, and is now member of the SKA science working group "Extragalactic Spectroscopy".

Benoît SEMELIN (m) is a professor specialised in the study of the Epoch of Reionization and he makes predictions of the 21 cm signal from the neutral IGM using full numerical simulations. He focuses especially on providing realistic predictions for the signal during the early absorption phase. He's also interested in the possibility of observing the 21 cm forest. Professor at Université Pierre et Marie Curie, he's a member of the SKA SWG and Science Team on Cosmic Dawm / Epoch of Reionization and co-coordinator of the "Theory/Physics for understanding model space/subgrid physics" focus group. He's the PI of two ANR projects focused on the EoR funded for a total of > 700 keuros.

Philippe SALOMÉ (m) is an associate-astronomer at Observatoire de Paris. He's specialized on galaxy formation and evolution. He's particularly interested in Brightest Cluster Galaxies (BCGs) and the mechanisms of star formation and AGN feedback. He developped an expertise in Radio-Astronomy in the millimeter and sub-millimeter domain, in order to probe the cold interstellar medium via molecules and dust observations. He worked at IRAM (International research institute for radio astronomy) between 2004 and 2010 where he developed a scientific software for ALMA. Since 2010, he's also involved in the ALMA Astronomer Support and the ALMA data mining project at the ANO3 ALMA Regional Center.

François LEVRIER (m) is an associate-professor at Ecole Normale Supérieure. His research activity within the ENS team of LERMA revolves around the structure and dynamics of interstellar gas and dust, from the most diffuse regions of the interstellar medium (ISM) to the initial stages of star formation, with an emphasis on methods related to observational simulations. Since 2011, he's a Member of the Planck-HFI Core Team. In this framework, he participated to the analysis of Planck polarization data at 353 GHz. Since February 2016, he's a member of the Time Allocation Committtee of IRAM.

LERMA Publications

1. Combes, F. "The Square Kilometer Array: cosmology, pulsars and other physics with the SKA" in Journal of Instrumentation, Volume 10, Issue 09, article id. C09001 (2015). September 2015.

2. Semelin, B.; Iliev, I. " The physics of Reionization: processes relevant for SKA observations" in Proceedings of Advancing Astrophysics with the Square Kilometre Array (AASKA14). 9 -13 June, 2014.

3. Levrier, F.; Wilman, R. J.; Obreschkow, D.; Kloeckner, H. R.; Heywood, I. H.; Rawlings, S. "Mapping the SKA Simulated Skies with the S3-Tools" in "Proceedings of Wide Field Astronomy & Technology for the Square Kilometre Array (SKADS 2009). 4-6 November 2009.

4. Obreschkow, D.; Klöckner, H.-R.; Heywood, I.; Levrier, F.; Rawlings, S. "A Virtual Sky with Extragalactic H I and CO Lines for the Square Kilometre Array and the Atacama Large

Millimeter/Submillimeter Array" in The Astrophysical Journal, Volume 703, Issue 2, pp. 1890-1903 (2009).

5. Salomé, P., Combes, F., Revaz, Y. et al. : 2008, «Cold gas in the Perseus cluster core: excitation of molecular gas in filaments", A&A 484, 317

LERMA Projects

OBSPARIS participated in the JRA AMSTAR (RadioNet FP6), AMSTAR+ (RadioNet-FP7) and AETHER (RadioNet3). The LERMA participated in particular to the SKA-Design Study (FP6) from 2005 to 2009. The team developed numerical simulations to predict the Epoch of Reionisation (EoR) 21cm signal, and orient the SKA design (Semelin et al 2007, Baek et al 2009, 2010). We are also developing theory data bases for the EoR (Semelin et al 2016), on the same manner as we developed numerical simulations data-bases, on the Theoretical Virtual Observatory (TVO, Chilingarian et al 2010, galmer.obspm.fr).
Paris Observatory hosts the Paris Astronomical Data Centre (PADC, http://padc.obspm.fr/about/vopdc), which is a regional data centre recognized by CNRS and devoted to the diffusion and archiving of astronomical data. It aims in particular at providing VO access to its databases resources, at participating to international standards developments, at implementing VO compliant simulation codes, data visualization and analysis softwares. PADC hosts high level permanent activities for tools and data distribution under the format of reference services. These sustainable services are recognized at the national level as CNRS labeled services. They are accessible through their own portals (see http://padc.obspm.fr/services/). Paris Astronomical Data Centre offers to laboratories a central support for various activities through central storage and web servers computing facilities.

4.1.14.d USN (Nançay Radio Observatory)

The Nançay Radio Observatory (USN - Unité Scientifique de Nançay) is jointly operated by the Observatoire de Paris, by the National Research Council for Scientific Research (Centre national de recherche scientifique - CNRS), and by the University of Orléans. It comprises about 50 persons, with ~3 % being engineers. USN hosts a number of world class radio astronomy instruments operating in various frequency bands between 10kHz and 10GHz: e.g. the Nançay Radio Telescope (the second in diameter in Europe), a world-wide and unique suite of instruments dedicated to the continuous observations of the Sun in radio and a new instrument in construction at low frequency (NenuFAR, a SKA pathfinder) that will nicely complement the International LOFAR Telescope, including the LOFAR station operating at Nançay. USN also has a vibrant research group related to electronics, microelectronics, receiving systems. The microelectronics team works mainly on developments related to the Square Kilometre Array (SKA). USN developments include the design of integrated circuits for receivers including Low Noise Amplifiers, filters, mixers, phase shifters, switches, and others.
The Université d'Orléans and Observatoire de Paris will not claim any costs in the AENEAS project.

USN Staff

Stéphane CORBEL (m) is a professor at Université Paris Diderot and, since 2014, the Director of the Nançay Radio Observatory. He's involved in several international collaboration such as Fermi/LAT, Lofar (TKP, FLOW, LSS), MeerKAT (ThunderKAT), ASKAP (VAST) + NuStar, E-Merlin. He is a core member of the SKA transients working group. He was the scientific contact for the CEA of the FP7 ITN Project « Black hole universe» (2008-2013) and of the French National Research Agency Project « CHAOS » (2013-2017). For the period 2011-2019, he is the leader of workpackage F3 "The transient catastrophic Universe" of the UnivEarthS' LabEx (http://www.univearths.fr/en/overview).

USN Publications

1. Corbel, S.; Miller-Jones, J. C. A.; Fender, R.; Gallo, E.; Maccarone, T.; O'Brien, T.; Paragi, Z.; Rupen, M.; Rushton, A.; Sabatini, S. and 3 coauthors "Incoherent transient radio emission from stellar-mass compact objects in the SKA era" in Proceedings of Advancing Astrophysics with the Square Kilometre Array (AASKA14). 9 -13 June, 2014.

2. Garsden, H., Girard, J. N., Starck, J. L., Corbel, S., Tasse, C. et al: "LOFAR sparse image reconstruction", A&A 575, A90

3. Paragi, Z., Godfrey, L., Reynolds, C. et al: "Very Long Baseline Interferometry with the SKA", 2015aska.confE.143

USN Projects

EMBRACE is the Electronic MultiBeam Radio Astronomy Concept. Developed in collaboration with ASTRON in the Netherlands, EMBRACE is a prototype instrument using an array of 4608 densely-packed antenna elements creating a fully sampled, unblocked aperture. This technology is proposed for the Square Kilometre Array and has the potential to provide an extremely large field of view making it the ideal survey instrument.

Radio telescopes of the Nançay Radio Astronomy Station of the Observatoire de Paris. The list of the instruments is available on http://www.obs-nancay.fr/-Instruments-.html

The NenuFAR instrument (New extension in Nançay upgrading LOFAR), is in construction at Nançay and has been officially labellised "Pathfinder" for the Square Kilometre Array (SKA) in 2014. NenuFAR is not only an extension of the LOFAR network, the European radio telescope which a station is installed in Nançay, but also a great stand-alone instrument. The experience gained from the design, construction, and operation of NenuFAR instrument will be a valuable asset to useful benefits for the development and operation of the SKA.

CNRS main tasks in project

Main tasks:

- Participation WP2 (T2.1, T2.3, T2.4)
- Participation WP5 (T5.1, 5.4)

4.1.15 GRNET

The Greek Research and Technology Network (GRNET S.A. www.grnet.gr) is a state-owned company, operating under the auspices of the Greek Ministry of Education - General Secretariat for Research and Technology. Its mission is to provide high-quality Infrastructure and services to the academic, research and educational community of Greece, and to disseminate ICT to the general public. GRNET is the National Research and Education Network (NREN) provider, operating the Greek Academic network, that connects local universities and research institutions via dark fibre at speeds up to 10Gbps, and offering to the Greek R&E community access to the pan-European GEANT network through 4x10Gbps links. GRNET also plays a key role at national level in the field of distributed and large-scale research infrastructures including Grid, Cloud and HPC. The company coordinates the Greek National Grid Initiative – HellasGrid, with more than 1,400 CPUs and 200 Terabytes of storage and is member of EGI pan-European Grid infrastructure. GRNET has developed and operates its own public IaaS cloud solution named Okeanos, offering cloud resources to the Greek Universities. GRNET coordinates and operates the GRNET CERT and GRNET Federation for the Greek Authentication and Authorization Infrastructure. GRNET is leading the AAI implementation in the EGI-Engage project and is coordinating the development and operation of the ARGO monitoring service in EGI and EUDAT. Furthermore, GRNET is leading the “Architectures for an integrated and interoperable AAI” Work Package in the AARC (Authentication and Authorization for Research Collaboration) project and the eduGAIN – STORK/eIDAS technical Interoperability pilot activity between the GEANT project (GN3Plus/GN4P1) and eIDAS (previously STORK2).

GRNET Staff

Christos Kanellopoulos (m) has been involved in European and National research and infrastructure projects since 2000, serving in various technical and management positions. In the period 2000 - 2002 he was a team leader in the project CAMPUS of Lufthansa coordinating the infrastructure rollouts at the airports of Athens, Beirut, Paris, Venice, Vienna and Zurich. In the period 2002 - 2012 he was the technical coordinator of the Scientific Computing Centre at the University of Thessaloniki leading the activities of the centre in more than 15 FP6 & FP7 projects in the areas of Grids, Distributed Systems and High Performance Computing. During that period, he served as a Work Package Leader, Activity Leader and Working Group chair in various projects and fora. Since 2012 he works at GRNET S.A. in the fields of Distributed Systems, Cloud Computing & Security. Currently, he is leading the Architecture Work Package in the AARC (Authentication and Authorization for Research Collaboration) project, the AAI (Authentication and Authorization Infrastructure) activity in the EGI-Engage project, the “Cross-sector interoperability” task in GN4 phase 1 focusing in the interoperability aspects between the Academic Identity Federations and eIDAS and he is the Product Manager of the ARGO Monitoring Service.

GRNET Publications

1. Darriba, D., Kanellopoulos, C., Mayo-Garcia, R., Posada, D., Prnjat, O. (2014). A new workflow for seamlessly executing portable applications for a reproducible research. IEEE Cluster 2014.

2. Chadwick, K., Gaines, I., Groep, D. L., Kaila, U., Kanellopoulos, C., Kelsey, D., Marsteller, J., Niederberger, R., Ribaillier, V., Wartel, R., Weisz, W., Wolfrat, J. (2013). A Trust Framework for Security Collaboration among Infrastructures. WLCG Security - PoS (ISGC 2013) 011.

3. Kanellopoulos, C., Kouril, Korosoglou, P., D., L'Orphelin, C., Lequeux, O., Ma, M., Prochazka, M., Triantafyllidis, C., Veyre, P. (2012). EGI Security Monitoring. PoS (ISGC 2012) 026.

4. Kanellopoulos, C., Kouril, D., Procházka, M., Triantafyllidis, C., Wartel, R. (2011). A Race for Security: Identifying Vulnerabilities on 50 000 Hosts Faster than Attackers. PoS (ISGC 2011 & OGF 31) 031.

5. e-IRG White Paper 2009 (Reviewer of the Security section)

GRNET Projects

Coordinator of the GRNET AAI Federation and the GRNET CERT;

Partner in the GEANT series of project. In GN3Plus and GN4 Phase 1 GRNET is involvement included the coordination of the eduGAIN – STORK/eIDAS technical interoperation pilot;

Partner in the EGEE series of projects. In EGI-Engage it led the implementation of the EGI AAI, it was responsible for the operation of the EGI Catch All CA and coordinator of the development and operation of the ARGO monitoring service;

Partner in the AARC project in which it led the “Architectures for an integrated and interoperable AAI” work package.

GRNET infrastructure/technical equipment

GRNET operates Infrastructure as a Service ~okeanos via large datacenters (22 racks, 400+ servers, more than 9000 Virtual Machines active, 4 Petabytes of storage), and is/was involved in a number of core pan-European cloud projects such as StratusLab, CELAR, etc. GRNET is also developing Synnefo, the cloud software for ~okeanos.

GRNET main tasks in project

Participating in WP6

4.1.16 FOM-Nikhef

FOM-Nikhef, the Dutch National Institute for Subatomic Physics, is a partnership between the Foundation for Fundamental Research on Matter (FOM, part of the Netherlands Organisation for Scientific Research) and the Dutch universities in its field. A founding partner of the Dutch national e-Infrastructure, ICT has been a core activity since its beginning as the research at Nikhef relies on the development of innovative technologies. Together with SURFsara it hosts an LHC Tier-1 facility and is a colocation for the Amsterdam Internet Exchange (AMS-IX) that started here. The Nikhef collaboration consists of about 200 physicists (60 tenured staff, 40 postdocs, 100 PhD students), 75 technical and engineering staff and 25 support staff.

The FOM-institute Nikhef is located in the Amsterdam Science Park. FOM-Nikhef strongly promotes the outreach of existing and emerging federated AAI to the research communities, and actively engages with these communities by providing consulting advice and support. The knowledge and technology transfer to third parties, i.e., industry, civil society and general public, is an integral part of Nikhef mission.

Nikhef, the national institute for subatomic physics in the Netherlands and a partner of the Dutch National e-Infrastructure, is an institute whose entire mission is centred around collaboration. It is part of the major global experiments with particle accelerators on the structure of matter, like at the LHC at CERN, and has a wide astro-particle physics programme which is likewise international - including VIRGO/LIGO looking for gravitational waves, the "Xenon-1T" experiment in dark matter, and the submarine KM3NET neutrino telescope. All these require a collaborative ICT infrastructure and advanced access control to data and compute resources.
As part of the Dutch National e-Infrastructure DNI coordinated by SURF, Nikhef supports a wide range of over 40 of data-intensive high-throughput applications, and has specific responsibility for AAI and site access control mechanisms in its 'scalable multi-domain security' programme line.

Both for its own research use cases as well as for the other domains that use the DNI-SURF infrastructure in the Netherlands, Nikhef needs a ubiquitous AAI to be available, and to integrate that closely with community formation and service provisioning in a production environment.

Nikhef has been involved in the development and operation of advanced distributed AAI infrastructures for distributed computing since its early beginnings in Europe, specializing in scalable multi-domain security. These activities at Nikhef cover the entire spectrum from the development of site access control middleware and federated security protocols, to defining policies and handling operational incident response and risk assessment. It has extensive experience in security policy liaison with the Interoperable Global Trust Federation IGTF and in developing scalable policy mechanisms in numerous European e-Infrastructure projects where it has been developing and supporting the security middleware and policy. In addition FOM-Nikhef has executed several national and international projects that integrated various federated AAI technologies such as SAML, the interoperability of XACML policies, and exploiting and developing mechanisms based on OAuth2, but also certificate-based services, for delegation with access to e-Infrastructure services. In AARC Nikhef coordinates the policy and best practice harmonisation work, and

developed pilots on integrating federated AAI with data and compute e-Infrastructures using a diversified protocol set. We want to extend that work, specifically the integration in production infrastructure and the take-up of collaborative federated AAI that is able to extend the user base beyond its current base - that would not only broaden the user base, but also alleviate many of the concerns the current uses of technology-specific users have with usability, permitting more end-users to benefit from the collaborative e-Infrastructure. It is also deeply involved in operational security in EGI and Nikhef hosts the EGI Security Officer function.
Knowledge and technology transfer to third parties, beyond other research domains, and including industry, civil society and general public, is an integral part of Nikhef mission.

FOM Staff

Dr. David Groep (m) is a senior researcher at Nikhef and has worked on a wide range of IT and IT security activities since 2000. Started in EU DataGrid and EGEE, he coordinated the site access security architecture and has been a leading member of the security coordination groups in EGEE and EGI. He also established the e-infrastructure identity management authority in the Netherlands, and ensured European acceptance. Since the founding in 2004 of the EUGridPMA he has been its Chair, and he was the founding chair of the Interoperable Global Trust Federation IGTF in October 2005. From 2007 onwards, he served a three-year term as Area Director for security in the Open Grid Forum and is currently a co-chair of the CAOPS and VOMS-PROC working groups. In EGI he serves as the co-chair of the security policy coordination group and is the liaison officer for the IGTF. In AARC-1 he leads the policy and best practice harmonisation activities. Outside the security area, Dr. Groep is a member of the Dutch e-Infrastructure Executive Team and responsible for resource acquisition and operations of the e-Infrastructure and 'LCG Tier-1' facilities at Nikhef – together with SURFsara the core data centre of the LHC Computing Grid Project in the Netherlands. He also was the project lead for the scaling and validation programme of the Dutch Virtual Laboratory for e-Science. Dr. David Groep holds a PhD in physics.

Dr. Mischa Salle (m) is senior technical researcher specializing in distributed security architectures. He has extensive experience in the design of access control and provisioning mechanisms and their integration with existing IT systems. He is the main responsible person for the provisioning software for computation in use across all of EGI, and a member of the EGI Risk Assessment Team addressing security vulnerabilities and their impact on the operational infrastructure for in many software more packages. He is active in OGF on attribute interoperability and works globally with the US Open Science Grid on coordination of security middleware. Dr. Misha Salle holds a PhD in physics.

Dr. Sven Gabriel (m) is senior technical staff specializing in operational security, incident response, and monitoring in distributed infrastructures. He has extensive experience dealing with high-profile security incidents and their mitigation, and is responsible for accreditation and certification of the EGI security operations with European and international standards bodies.
He coordinates globally the security drills training programme for e-Infrastructures including the LHC Computing Grid and the US Open Science Grid for development op site operational security capabilities. Dr. Sven Gabriel holds a PhD in chemistry.

FOM main tasks in project

- Participation in WP6

4.1.17 JIV-ERIC

The Joint Institute for VLBI ERIC (JIVE) is the central node of the European VLBI Network (EVN, http://www.evlbi.org/), a distributed array of radio telescopes, in and outside of Europe, offering astronomers the highest resolution view of radio sources. JIVE provides the scientific data product as well as support for the astrophysicists using the instrument, including training. In close collaboration with the EVN telescope staff, JIVE monitors the quality and calibration of the EVN.
Besides user and telescope services, JIVE excels in research and development to innovate VLBI and related radio astronomy techniques. The institute pioneered e-VLBI by connecting the telescopes through optical fibre networks and enabling real-time science, leading to the development of a unique correlation platform as well. With RadioNet partners, JIVE has developed the UniBoard platform, which is a low-power solution for future beam forming and correlation applications. Through past programmes and the current ERC BlackHoleCam project, the JIVE experts are addressing the data processing needs of current and future VLBI users. In particular, JIVE has been advocating the science case for involving the SKA elements and precursor telescopes in VLBI. JIVE is contributing to the development of the SKA in the Signal and Data Transport (SADT) consortium.
After 21 years as a foundation based on international funding, JIVE became an ERIC in the last month of 2014. As the only truly European legal entity in centimetre astronomy, JIVE remains actively engaged in discussions on the governance of European radio astronomy.

JIV-ERIC Staff

Prof. dr. Huib van Langevelde (m) is the director of JIVE and a professor in Galactic Radio Astronomy at Leiden University. He is an active astrophysicist, studying the formation, distribution and life cycle of stars, mostly through observations of molecular emission, often using the special properties of astrophysical masers. He is involved in several international consortia that carry out astrometric VLBI studies, measuring stellar motions and distances. In addition, he has contributed to various data processing tools and has been the lead on various past work packages that address user software and correlation platforms. As the director of JIVE he was the coordinator of (N)EXPReS and more recently he has completed the transition of JIVE from an internationally funded foundation into an ERIC. He is a member of the ASTERICS board, chair of the SADT consortium and member of the SKA Working Groups on Cradle of Life and VLBI.

Dr. Arpad Szomoru (m) is the head of technical operations and R&D at JIVE. He has considerable experience as work package leader in several EC and NWO-funded projects. Notably, he was instrumental in the development of global real-time electronic VLBI. He also led the development of an FPGA-based computing platform as the basis of a next generation VLBI correlator. His group is currently working on expanding the capabilities of the SFXC software correlator, which was developed at JIVE, the upgrade to higher observing bandwidths throughout the EVN, and the research into high precision time and frequency transfer over public networks. Arpad Szomoru is the leader of the connectivity efforts in ASTERICS: “Connecting Locations of ESFRI Observatories and Partners in Astronomy for Timing and Real-time Alerts” (CLEOPATRA).

JIV-ERIC Publications

1. Keimpema, A.; Kettenis, M. M.; Pogrebenko, S. V.; Campbell, R. M.; Cimó, G.; Duev, D. A.; Eldering, B.; Kruithof, N.; van Langevelde, H. J.; Marchal, D.; Molera Calvés, G.; Ozdemir, H.; Paragi, Z.; Pidopryhora, Y.; Szomoru, A.; Yang, J., “The SFXC software correlator for very long baseline interferometry: algorithms and implementation”, 2015 Experimental Astronomy, Volume 39, Issue 2, pp.259-279

2. Paragi, Z.; Godfrey, L.; Reynolds, C. et al., including Szomoru, A.; Garrett, M. A.; van Langevelde, H. J.; “Very Long Baseline Interferometry with the SKA”, 2015, Proceedings of Advancing Astrophysics with the Square Kilometre Array (AASKA14). 9 -13 June, 2014. Giardini Naxos, Italy.

3. Kettenis, M.; van Langevelde, H. J.; Reynolds, C.; Cotton, B. "ParselTongue: AIPS Talking Python" 2005, ADASS XV, ASP Conf series, eds C. Gabriel, Arviset C., Ponz D., Solano E., p497

4. Garrett, M. A.; Charlot, P.; Garrington, S. T.; Klöckner, H-R; van Langevelde, H.; Mantovani, F.; Russel, A.; Schuster, K.; Vermeulen, R. C.; Zensus, A.; -the QSG Study Group "RadioNet3 Study Group White Paper on: The Future Organisation and Coordination of Radio Astronomy in Europe" 2016, ArXiv e-prints None, arXiv:1602.04216

5. Giroletti, M.; Paragi, Z.; Bignall, H.; Doi, A.; Foschini, L.; Gabányi, K. É.; Reynolds, C.; Blanchard, J.; Campbell, R. M.; Colomer, F.; Hong, X.; Kadler, M.; Kino, M.; van Langevelde, H. J.; Nagai, H.; Phillips, C.; Sekido, M.; Szomoru, A.; Tzioumis, A. K. "Global e-VLBI observations of the gamma-ray narrow line Seyfert 1 PMN J0948+0022" 2011, A&A 528, 11

JIV-ERIC Projects

NEXPReS (http://www.nexpres.eu/) was the project to enhance the operational practices and scientific capabilities after EXPReS (http://www.expres-eu.org/) in which e-VLBI was introduced as an operational facility. Both were close collaborations between radio astronomical research institutes and research network providers.

Within the RadioNet collaboration (http://www.radionet-eu.org/) JIVE took on management responsibilities for the overall network programme, the EVN Trans National Access, the UniBoard2 project, as well as some of the communication programmes with peers, the public and policy makers.

JIVE is also a member of EuroPlaNet (http://www.europlanet-eu.org/) and related initiatives. The technique of measuring the accurate position of spacecraft is planned to be used in current and future space missions.

The ASTERICS (https://www.asterics2020.eu/) project aims to establish common methods for the (ESFRI-listed,) European astronomy facilities. JIVE leads projects that build on the data transport expertise, for example to coordinate rapid response science.

JIV-ERIC main tasks in project

JIVE is committed to provide input to the work in WP2 on the governance of a future European SKA data centre. The proof of concept activities on long-haul data connectivity (WP4, Task 4) will benefit from JIVE's expertise with data streaming applications for radio astronomy, such as pioneered in (N)EXPReS and under development in ASTERICS. JIVE also offers expert input on the work on user models and user interaction methods in WP5.

4.1.18 ILT

The International LOFAR Telescope (ILT) is the foundation, established under Netherlands law in November 2010 and seated in Dwingeloo, The Netherlands, in which ASTRON and national LOFAR astronomy consortia in France, Germany, The Netherlands, Sweden, the United Kingdom and Poland collaborate on the exploitation of all LOFAR facilities for astronomy in their countries. The ILT offers these facilities in a common-user environment to all interested parties. The ILT employs no personnel. ASTRON, seated in Dwingeloo, the Netherlands, is the coordinating operational entity within the ILT; it employs the ILT Director, and commits the bulk of the annual operational resources. The ILT formally started its full functions on 1 January 2011.

ILT Staff

René C. Vermeulen (m) is the director of both the International LOFAR Telescope (ILT) and of the ASTRON Radio Observatory. He is responsible for the operation of both the ILT and the WSRT/APERTIF telescopes and the science production on the archives for LOFAR, WSRT and APERTIF.

ILT Publications

1. Van Haarlem, M. P., Wise, M. W., Gunst, A. W., Heald, G., McKean, J. P., Hessels, J. W. T., et al. “LOFAR: The low-frequency array”. Astronomy & Astrophysics, 556, A2, 2013.

2. Buitink S, Corstanje A., Falcke H. et al, 2016, Nature, 531, 70, A large light-mass component of cosmic rays at 10E17-1017.5 electronvolts from radio observations.

3. Falcke H. Apel W.D. et al, 2015, Nature, 435, 313-316, Detection and imaging of atmospheric radio flashes from cosmic ray air showers

4. Hermsen W., Hessels J. W. T., Kuiper L. et al, 2013, Science, 339, 436, Synchronous X-ray and Radio Mode Switches: A Rapid Global Transformation of the Pulsar Magnetosphere

5. Heald G. H., Pizzo R. F., Orru E., et al., 2015, A&A, 582, A123, The LOFAR Multifrequency Snapshot Sky Survey (MSSS). I. Survey description and first results.

ILT infrastructure/technical equipment

The ILT currently consists of 50 stations (the most recent addition being three stations in Poland) and is operated by ASTRON.
In 2016, a station will be built in Ireland. The LOFAR Long Term Archive is accessible via datacentres in Groningen, Amsterdam and Juelich.

ILT main tasks in project

Profile: representing LOFAR
Main tasks: WP2

4.1.19 UPPSALA UNIVERSITY (SNIC)

The Swedish National Infrastructure for Computing (SNIC), hosted by Uppsala University, is a national research infrastructure with a 3-fold mission: (i) provide a balanced and cost-efficient set of resources and user support for large scale computation and data storage, (ii) meet the needs of researchers from all scientific disciplines and from all institutes for higher education and research institutes and (iii) make the resources available through open application procedures such that the best Swedish research is supported and new research is facilitated. SNIC is funded in part by the Swedish Research Council (Vetenskapsrådet) and in part by the university partners (CTH, KTH, LiU, LU, UmU and UU).
SNIC is the Swedish research infrastructure that is responsible to ensure that the Swedish HPC infrastructure is adequately integrated into the European HPC ecosystem.
Presently, SNIC has six university partners. Each of these partners has an HPC/data centre. These centres are responsible for delivering HPC and data services to the Swedish academic community. The SNIC centres have many years of experience in collaborating with each other related to HPC, computational grids and clouds. SNIC has expertise in adopting and maturing software systems for leading edge technologies, systems management tools development, including accounting systems for distributed environments, user training and support, performance tools and application development in both classical areas for HPC such as weather and climate applications, computational fluid dynamics, computational electromagnetics, astronomy, molecular systems simulations and material science, as well as new areas, such as bioinformatics, biomedicine and neuro-informatics.
The SNIC partners form a Joint Research Unit (JRU).

SNIC Staff

Dr. Jacko Koster (m). Director of SNIC (2012-2016). Jacko Koster is member of several national and international supervisory boards, advisory boards and governing boards, among them the Council for the PRACE AISBL, the Council for the European Grid Infrastructure (EGI) and the Board for the Nordic e-Infrastructure Collaboration (NeIC). Koster holds a PhD in Computer Science from Institut National Polytechnique de Toulouse (INPT), France. He has worked as postdoctoral researcher at Rutherford Appleton Laboratory, has been leader for the HPC group Parallab at the University of Bergen (Norway) and has been director for UNINETT Sigma, the limited company responsible for the Norwegian HPC infrastructure (Trondheim, Norway).
Until 2004, Koster was an active researcher in algorithms and software for the parallel solution of large sparse linear systems of equations. He contributed to some of the core parts of the MUltifrontal Massively Parallel Sparse solver MUMPS that is used by many scientists from a variety of scientific domains.

SNIC Publications

1. Survey of e-infrastructure needs for eight large infrastructures. Report from SNIC to the Swedish Research Council. 2015

SNIC Projects

SNIC operates a national HPC infrastructure with more than 100 000 cores and a national storage infrastructure that includes more than 8 PetaByte storage. SNIC participates in the European infrastructures PRACE, EGI and EUDAT, and participated/participates in the corresponding EC-funded projects PRACE-1IP, PRACE-2IP, PRACE-3IP, PRACE-4IP, EGI-InSPIRE, EGI-Engage, and EUDAT, EUDAT2020. SNIC also participated in the FP7-funded EISCAT-3D Preparatory Phase project and contributed to the design of the Data Handling System that builds on the national infrastructures of the Nordic countries.

SNIC main tasks in project

SNIC is engaged in WP 3 (tasks T3.3 and T3.4). SNIC will contribute to the evaluation of existing HPC, cloud and distributed computing technologies and to the design for the distributed ESDC computing architecture.

4.1.20 EPFL

The “École Polytechnique Fédérale de Lausanne” (EPFL) is one of the two Swiss Federal Polytechnical Schools. A multi-cultural institution at the cutting edge of science and technology, EPFL fosters innovation and excellence. (http://www.epfl.ch).
EPFL has a unique organisation that stimulates interdisciplinary research and fosters partnerships with other institutions and companies, with both theoretical and applied research being carried out. Ecole Polytechnique Fédérale de Lausanne (EPFL) is a higher education and research organisation with about 4’500 employees, 10’000 students, and a total annual budget of approximately 800 million Euros. EPFL has participated and is currently taking part in a very large number of EU projects and initiatives, in a wide variety of scientific and technological field. With more than 330 laboratories and research groups on campus, EPFL is one of the Europe's most innovative and productive technology institutes and is also renowned for the quality of its teaching and training programs.
The Embedded Systems Laboratory (ESL) of EPFL will be the main research unit working in this project. ESL, consists of 20 members, and focuses its research on thermal and reliability exploration frameworks and management approaches for many-cores and high-performance computing systems, both at micro-architectural and system level. In the aforementioned research areas related to AENEAS, the ESL personnel has a long and deep experience in low-power and high-performance multi-core computing system design and multi-objective optimization methodologies for high-performance computing, and has been interacting with companies such as Sun Microsystems, IBM, Oracle, and ST on these topics for more than 10 years. Indeed ESL has been one of the EPFL representative in the FP7-Network on Excellence HIPEAC-2, and is partner in the recent or ongoing FP7 projects “PRO3D”, “GreenDataNet”, ”PHIDIAS” (leading partner) and the recent H2020 “MANGO” project related to the research areas of AENEAS on HPC and computing infrastructure design. It is also participating in the Swiss confederation's Nano-Tera RTD projects “YINS” (as leading partner) and “CMOSAIC”, where energy-efficient large-scaled datacenter architectures are being developed.

EPFL Staff

Prof. David Atienza (m) is an Associate Professor of Electrical and Computer Engineering at EPFL, and Director of ESL at EPFL, Switzerland. He received his M.Sc. and Ph.D. degrees in Computer Science from Complutense University, Madrid, Spain, and Inter-University Micro-Electronics Center (IMEC), Leuven, Belgium, in 2001 and 2005, respectively. His research interests focus on system-level energy- and thermal- aware design methodologies for multi-core computing systems and high-performance embedded systems, including new modelling and control frameworks to develop dynamic thermal management techniques for Multi-Processor System-on-Chip (MPSoCs), servers and datacenters. In these fields, he has co-authored more than 200 publications in prestigious journals and conferences. He has received the IEEE Early Career Award in 2013, the ACM SIGDA Outstanding New Faculty Award (ONFA) in 2012,two Best Paper Award at VLSI-SoC 2009 and CST-HPCS 2012, and five Best Paper Award Nominations at the DAC 2013, DATE 2013, WEHA-HPCS 2010, ICCAD 2006 and DAC 2004. He is or has been associate editor of IEEE T-Comp., IEEE T-CAD, Elsevier Integration and DAES, and Distinguished

Lecturer for IEEE CASS (period 2014-2015). He is a IEEE Fellow and Senior Member of the ACM. Since 2005, Prof. David Atienza has participated as PI or co-PI in 12 European projects (42 multi-partner projects overall), including 3 directly related to the objectives of AENEAS, assisting in the development of new methodologies for system-level optimization of MPSoC architectures, and server and datacenter cooling optimization.

EPFL Publications

2. Arvind Sridhar, Mohamed Sabry, David Atienza, "A Semi-Analytical Thermal Modeling Framework for Liquid-Cooled ICs", IEEE T-CAD, Vol. 33, Issue/Nr: 8, pp. 1145-1158, August 2014.

3. Jungsoo Kim, Mohamed M. Sabry, David Atienza, Kalyan Vaidyanathan, Kenny Gross, “Global Fan Speed Control Considering Non-Ideal Temperature Measurements in Enterprise Servers”, Proc. of DATE, 2014.

4. Jungsoo Kim, Martino Ruggiero, David Atienza, Marcel Ledergerber, “Correlation-Aware Virtual Machine Allocation for Energy-Efficient Datacenters”, Proc. of DATE, 2013.

5. Arvind Sridhar, Alessandro Vincenzi, Martino Ruggiero, David Atienza, “Neural Network-Based Thermal Simulation of Integrated Circuits on GPUs”, IEEE T-CAD, Vol. 31, pp.23-36, January 2012.

6. Ayse K. Coskun, Jie Meng, David Atienza, Mohamed Sabry. “Attaining Single-Chip High-Performance Computing Through 3D Systems with Active Cooling”. IEEE Micro, Special Issue on Big Chips, in July/Aug 2011.

EPFL Projects

PRO3D: www.pro3d.eu. This project targeted the design of a holistic optimization methodology (targeting both hardware and software) to enable the development of 3D-stacked many-cores architectures.

GreenDataNet: www.greendatanet.eu. This project aims at designing and validating a new, system-level optimisation solution allowing urban data centres to radically reduce their energy consumption and environmental impact.

EPFL main tasks in project

Participation in WP2, WP3

4.1.21 UNIGE

UNIGE is member of League of European Research Universities (LERU, www.leru.org), an association of twelve research-intensive universities sharing the values of high-quality teaching within an environment of internationally competitive research. Highly ranked in various international University Rankings.

The « Geneva Observatory », the Astronomy Department of the Geneva University, has a worldwide reputation in astrophysics. Together with the Astrophysics Lab of the Swiss Federal Institute of Technology (EPFL) it forms a unique joint center of astrophysics in the french-speaking part of Switzerland. It has also close links to the Department of Theoretical Physics, with world-leading experts in cosmology. The Department staff includes 3 full professors, 4 adjunct professors, 2 associate professors, for a total of approx. 45 perrmanent staff researchers. Overall the Geneva Observatory employs approximately 140 researchers, engineers, and other staff. Members of UNIGE are active in several Science Working Groups of the SKA.

The Astronomy Department hosts the Data Center for Astrophysics, a well renowned center, which has been and is involved in various space mission, such as ESA's INTEGRAL, Planck, Gaia, Euclid, and CHEOPS missions, in Japanase-led missions such as Hitomi (Astro-H), and in future space projects such as ATHENA, LOFT, SPICA, XIPE, JEM-EUSO and others. The Data Center for Astrophysics is also bound to play an important role for Swiss participation in CTA and in the SKA.

UNIGE Staff

Prof Daniel Schaerer (m) is an adjunct Professor for astrophysics at the University of Geneva, Coordinator of Swiss participation in the SKA project. He is an active astrophysicist working on galaxy formation and evolution, the sources of cosmic reionization, the first stars and related topics, developing both state-of-the-art modeling tools and using ample multi-wavelength observations from numerous ground-based facilities and ESA and NASA satellites. Leader of a research group using millimetre interferometric observations (PdBI, ALMA). PI of a Swiss Research Network (SINERGIA) to develop and promote the use of millimetre and radio observations for studies of star-formation in the nearby Universe and a high redshift. PI and CoI numerous international research projects and networks.

UNIGE Publications

Numerous publications in astrophysics.

UNIGE Projects

DataCenter for Astrophysics: www.isdc.unige.ch. Formerly the ISDC, hosted by the Astronomy Department of the University of Geneva, which plays a role in several European space missions.

EUCLID: www.isdc.unige.ch/euclid. ESA medium class mission for observational cosmology, dark matter and dark energy studies. Hardware contribution and

significant contributions to software development, ground data analysis, and data processing.

CHEOPS: cheops.unige.ch. CHaracterizing ExOPlanet Satellite – will be the first mission dedicated to searching for exoplanetary transits by performing ultrahigh precision photometry on bright stars already known to host planets. First Swiss-led ESA mission with important contributions from UNIGE.

For other projects with contributions from the DataCenter for Astrophysics see www.isdc.unige.ch.

UNIGE main tasks in project

Participation in WP3

4.1.22 CSIRO

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) employs ~5,000 people. It is Australia's premier science and research organization across a wide range of scientific fields, and also builds and operates a number of critical national facilities. CSIRO Astronomy and Space Science (CASS) is the business unit which has designed, constructed and operates major national radio-astronomy, as well as deep space communications facilities. It also has extensive experience in developing novel instruments and data archive systems to support front-line astronomy. CASS works in partnership with other CSIRO divisions with key expertise in antenna design, 3D electromagnetic modelling, data archives and digital systems.

The Australia Telescope National Facility (ATNF), managed by CASS, comprises receiving antennas, associated instrumentation, control systems and computing capability and data archive services for four observatories, supported by staff and facilities at headquarters in Marsfield, Sydney. Three observatories are near the New South Wales towns of Parkes, Narrabri and Coonabarabran. Most recently, CASS has designed and built the new Australian SKA Pathfinder, based at the Murchison Radio-astronomy Observatory (MRO) located in the remote Mid West region of Western Australia. This is a novel radio array with each of its 36 dish antennas equipped with a planar PAF operating from 0.7 GHz – 1.8 GHz. The MRO site is also where the Square Kilometre Array telescope infrastructure in Australia will be located

CSIRO Staff

Dr Jessica Chapman (f) is a senior research scientist and Data Management Leader at CSIRO Astronomy and Space Science. She gained her PhD in 1986 in radio astronomy and carries out research in radio maser emission from evolved stars with around 70 refereed publications. She has held several research management roles, including as Research Progam Leader, with responsibilities for ATNF Observatory Operations and as Data Management Leader, with responsibility for the ATNF Data Archives.

CSIRO Publications

1. Chapman, J., CASDA: The CSIRO ASKAP Science Data Archive (abstract), IAU General Assembly, meeting 29, id.223458

2. Hobbs, G.; Miller, D.; Manchester, R. N.; Dempsey, J.; Chapman, J. M.; Khoo, J.; Applegate, J.; Bailes, M.; Bhat, N. D. R.; Bridle, R.; and 32 coauthors, The Parkes Observatory Pulsar Data Archive, 2011, PASA, 28, 202

CSIRO Projects

Dr Chapman is responsible for several CSIRO data archives and has played a key role in their development. These include:

The Australia Telescope Online Archive provide access to data taken with the Australia Telescope Compact Array, Parkes radio telescope, Mopra radio

telescope and Very Long Baseline Interferometry observations. First released in 2006, the archive holds around 200 Terabytes including all observations taken with the Compact Array since 1989. Dr Chapman led the construction of the ATOA for National facility use.

The CSIRO Parkes pulsar data archive provides access to approximately 400 TB of data taken with the Parkes radio telescope for observations of pulsars. This archive has been established using the CSIRO Data Access Portal and was first released in 2011. This project won a CSIRO Service for Science award.

The CSIRO ASKAP Science Data Archive (CASDA) was first released in late 2015. This will hold up to five PB of data products per year and is now ready for the start of ASKAP Early Science.' Data Products will be produced in science data processing pipelines. CASDA provides long term data storage and user access through both web and Virtual Observatory services. The archive has been developed by CSIRO in partnership with the Pawsey Supercomputing Centre in Perth.

CASDA makes use of physical infrastructure provided at the Pawsey Supercomputing Centre (Pawsey) and the Canberra Data Centre in Canberra. Pawsey was constructed at a total cost of around $AUD 80 million, with 25 per cent of its resources available for radio astronomy operations. The CASDA project has access to four environments in Pawsey and a current storage allocation of 2 x 10 PB (including data backup). Dr Chapman is the CSIRO Project Leader for the CASDA project and has closely led it through requirements gathering, design and construction to the recent release.

CSIRO main tasks in project

Main tasks: WP2

4.1.23 AARNET

Australia's Academic and Research Network (AARNet) is the not-for-profit company that operates Australia's National Research and Education Network (NREN). Our shareholders are 38 Australian universities and the Commonwealth Scientific and Industrial Research Organisation (CSIRO). We provide high-capacity, leading-edge Internet and other advanced communications services to Australia's universities, health and other research organisations, as well as schools, vocational training providers and cultural institutions. AARNet serves over one million end users who access the network and services through shareholder and other customer institutions.
AARNet is among the Australian participants in the global Square Kilometre Array project. To enable Australia's participation in the SKA project, AARNet expanded its network across the Nullabor, from Adelaide to Perth and on to the Murchison Radio Observatory (MRO), the future home of the SKA in remote outback Western Australia. The newly deployed terrestrial network is capable of transmission speeds of up to 8 Terabits per second (Tbps). CSIRO and AARNet worked together to connect the ASKAP antennas to the AARNet network. New optical fibres were laid between Geraldton and ASKAP, connecting to the new Geraldton-Perth link constructed by Nextgen Networks for the federal government-funded Regional Backbone Blackspots Program. This enables ASKAP to connect directly via a high-capacity link to the Pawsey supercomputing facilities in Perth. The network is scalable to support the needs of ASKAP and MWA now and into future early phases of the SKA.

AARNET Staff

Guido Aben (m) is AARNet's eResearch liaison in Europe. AARNet's eResearch department is conversant in the ways of big science —e.g, grids, SDN, scalable compute— but its staff share a boutique interest in scoping and developing relatively simple tooling to address "common problems" in a typical researcher's eResearch workflow. Some eScience luminaries regard these problems as too pedestrian; yet at AARNet, we think they often constitute precisely that threshold that prevents people from serious eScience adoption.
Guido previously worked in technical development roles in AARNet as well as in SURFnet. He holds an MSc in Physics from Utrecht University.

AARNET Publications

1. Reid, A, AARNet's Cloudstor+ Cloud storage initiative, Australian Journal of Telecommunications and the Digital Economy; http://telsoc.org/ajtde/2014-06-v2-n2/a35

2. Wilde, D, "Order-of-magnitude improvements for research data throughput", TERENA TNC2015 conference, https://tnc15.terena.org/core/presentation/159

3. Aben, G, "Distributed sync&share operations at AARNet", Cloud Services for Synchronisation and Sharing (CS3) workshop, http://cs3.ethz.ch/CS3-ETHZ-BookOfAbstracts.pdf

AARNET Projects

Petabyte-scale distributed sync&share using the EOS storage system; a joint project with CERN and ownCloud to deliver a truly worldwide replicating science data store that can be collaborated on, and written to, by very widely distributed groups simultaneously while retaining data integrity and state; a recent writeup is here -- https://opensource.com/business/16/3/cern-and-owncloud

OpenCloudMesh, a joint international initiative under the umbrella of the GÉANT Association, is built on ownCloud's open server-to-server sharing application programming interface (API). It delivers universal file access through a globally interconnected mesh of research clouds, without sacrificing any of the advantages in privacy, control and security an on-premises cloud provides. AARNet takes care of field testing the interoperability performance of the new protocol. http://news.aarnet.edu.au/globally-interconnected-secure-private-clouds-for-universities-and-researchers/

Australia Wide-area SDN testbed: A consortium of researchers from, nine Universities and the CSIRO, led by UNSW and including AARNet, has been awarded a LIEF grant by the Australian Research Council to deploy SDN equipment within each of their labs. These sites are being interconnected by AARNet to create a national wide-area SDN testbed environment, with the potential to peer internationally with testbeds in the USA, Europe and elsewhere.

This testbed is helping us better understand the SDN ecosystem - Openflow-enabled hardware (Noviflow, Pica8, Corsa), controller software (Floodlight, Ryu, ONOS), application development APIs, and SDN applications themselves. Building this wide-area testbed is helping us learn the complexity, maturity, performance, and scalability aspects of carrier SDN deployment, as well as identify current gaps. The intended result is a growing store of knowledge and experience, to be shared with network operators who are potentially interested in exploring SDN solutions. http://news.aarnet.edu.au/aarnet-launches-sdn-innovation-platform-for-researchers/

AARNET main tasks in project

Main tasks: WP4

4.1.24 VUW

Victoria University of Wellington (VUW) is a research-focused New Zealand university established in 1897. The institution was initially established with a humanities focus but has expanded to cover research across science and engineering and is currently ranked number one nationally in the government-assessed research performance exercise. Radio astronomy became a research strength at VUW in 2009 and New Zealand joined the SKA project shortly thereafter. Radio Astronomy research at VUW spans a range of activities split across the Science and Engineering Faculties. Current SKA-related research includes development of science analysis pipelines, source detection algorithms, visualization software, low frequency surveys and project management. VUW has been an institutional member of the Murchison Widefield Array (MWA) collaboration and the SKA Science Data Processor (SDP) consortium since 2012 and hosts one of the three MWA data processing nodes.

VUW Staff

A/Prof. Melanie Johnston (f) is Director of Astrophysics at Victoria University of Wellington where she leads a team of 18 research and engineering staff involved in end-to-end scientific exploitation of radio telescopes including pipeline design, algorithm development, data processing and visualization. In her 15 year career in radio astronomy, Melanie has worked on the design, management and scientific exploitation of several telescopes including LOFAR, the MWA and the SKA. She holds substantial roles across the SKA project spanning technical, scientific and management aspects. She is a member of the Board of Directors of the SKA Organisation and chairs the international Board of the Murchison Widefield Array telescope, the only fully operational SKA precursor. She leads the design of the Science Analysis Pipelines for the SKA Science Data Processor (SDP) consortium and has recently completed a 3.5 year term as co-chair of the SKA Science Working Group on Cosmic Magnetism where she maintains a role as a core member. She has chaired the cluster science working group for the ASKAP EMU survey since 2009 (co-chaired with Ferrari since 2015) and is PI for cluster science with the MWA. Her primary research focus is cosmic magnetism and multiwavelength observations of galaxy clusters. She has 140 publications with over 2000 citations.

Kevin Buckley (m) is the eScience Consultant at Victoria University of Wellington, based in the School of Engineering and Computer Science, and a member of the Murchison Widefield Array (MWA) Consortium. Kevin's remit involves both the administration and the maintenance of computational resources for researchers across a range of subject domains: UNIX servers; grid-computing infrastructure; GPU nodes and NGAS data infrastructure, as well as the consultation and liaison with researchers, on how to get the best out of such resources. Kevin was responsible for the establishment of the MWA data processing node in NZ which acts in a similar way to the proposed SKA regional science centers. Kevin was also the initial deployer of pilots for federated identity, grid-computing nodes and gateways, and iRODs data storage node in NZ, interfacing into the then pan-Australasian infrastructures, as well as its current MWA NGAS node. Kevin has a BSc and ARCS from taking a Physics degree at Imperial College, London, and did postgraduate work involving computational hydrology/hydrogeology on parallel processing platforms at the University of Lancaster, UK, where, prior to moving to New Zealand, he had become its central IT facilitator's High Performance Systems Consultant.

VUW Publications

1. Hollitt, C., Johnston-Hollitt, M., Dehghan, S., Frean, M., Butlter-Yeoman, T., 2016, “An Overview of the SKA Science Analysis Pipeline”, in ADASS XXV, edited by N.P.F. Lorente and K. Shortridge (San Francisco: ASP), ASP Conf. Series.

2. Mohan, P., Hawkins, C., Klapaukh, R., Johnston-Hollitt, M., 2016, “Three tools to aid visualization of FITS files for astronomy”, in ADASS XXV, edited by N.P.F. Lorente and K. Shortridge (San Francisco: ASP), ASP Conf. Series.

3. Johnston-Hollitt, M., Govoni, F., Becket, R., et al. 2015, “Using SKA Rotation Measures to Reveal the Mysteries of the Magnetised Universe”, in Advancing Astrophysics with a Square Kilometre Array, Eds T. L. Bourke, R. Braun, R. Fender, F. Govoni, J. Green, M. Hoare, M. Jarvis, M. Johnston-Hollitt, E. Keane, L. Koopmans, M. Kramer, R. Maartens, J.-P. Macquart, G. Mellema, T. Oosterloo, I. Prandoni, J. Pritchard, M. Santos, N. Seymour, B. Stappers, L. Staveley-Smith, W.W. Tian, G. Umana, J. Wagg, Dolman Scott Ltd for SKA Organisation, ISBN: 978-1-909204-70-6, Volume 1, pp 371-388.

4. Tingay, S. J. et al. 2013, “The Murchison Widefield Array: The Square Kilometre Array Precursor at Low Radio Frequencies”, PASA, 30, 7

5. Hollitt, C. & Johnston-Hollitt, M., 2012, “Feature Detection in Radio Astronomy using the Circle Hough Transform”, PASA, 29, 309.

VUW Projects

VUW is a full member of the SKA Science Data Processor (SDP) consortium responsible for leading the pre-construction design of the Science Analysis Pipelines, required for best scientific exploitation of the SKA.

Murchison Widefield Array (MWA) (http://www.mwatelescope.org) is the low frequency (70-300 MHz) precursor telescope to the SKA. The MWA is located at the SKA site in Western Australia and operated by a consortium of Australian, NZ, US, Canadian and Indian Universities, of which VUW is the lead NZ institution in the project. In an arrangement similar to that proposed for the SKA, primary MWA data processing is undertaken in Perth before being pushed out to 3 regional internationally based ‘nodes’, the second of which was established at VUW in 2012.

Astronomical Algorithm and Visualisation Development: In a project related to the SDP work, staff at VUW are involved in development of source detection algorithms for next generation radio telescopes. Such algorithms significantly advance the current state of the art, particularly for diffuse, low surface brightness sources and are ideal for deployment in SKA regional centres to enhance automatic science analysis. Additionally, VUW’s human-computer interaction group carries out research on information visualisation techniques and systems. Most recently this work has been focused on developemnet of visulatisation interfaces needed for SKA-scale datasets.

VUW main tasks in project

Profile: representing SKA, MWA
Main tasks:

- Participation: WP3: 3.1, 3.2, 3.5, 3.6 and, WP5: 5.2, 5.3.

4.1.25 CSIR

The CSIR is a scientific and technology research, development and implementation organisations in Africa. Constituted by an Act of Parliament in 1945 as a science council, the CSIR in South Africa performs multidisciplinary research and technological innovation with the aim of contributing to industrial development and improving the quality of life of people in South Africa — and increasingly on the wider continent.

The South African National Research Network's (SANReN) initiative, together with the Centre for High Performance Computing (CHPC) and the Data Intensive Research Initiative of South Africa (DIRISA) forms part of the Department of Science and Technology's (DST) National Integrated Cyberinfrastrucutre System (NICIS), which is under the custodianship of the Meraka Institute at the CSIR.

The SANReN Competency Area is focussed at designing and implementing the broadband network and advanced services required to support the efforts of the South African higher education and science communities. The SANReN network is operated and maintained by the Tertiary Education and Research Network of South Africa (TENET), through a collaboration agreement with the SANReN.

CSIR Staff

Simeon Miteff (m) heads up the Network and Services Engineering team at SANReN. He has experience in network operations, design and architecture, and has been involved with software development and high performance computing. Currently he represents Africa on the global eduroam governance committee and South Africa on the SKA SADT design consortium and the Global Network Architecture working group. Simeon is currently studying toward his MSc in Engineering at WITS University with a research topic in the field of Software Defined Networks, and holds an Honours Degree in Computer Science from the University of South Africa.

Uli Horn (m) is currently focused on the SKA SADT design consortium, collaborating in the Signal and Timing work package. In addition, he is involved with cloud computing infrastructure and applications. He has wide experience in simulation and modelling from diverse disciplines and various industries such as defence, electrical supply companies, mining, chemical process control to bioprocess and bioinformatics, as well as microprocessor and analog electronic design. He has a BSc Eng (Elec) degree in electronics from the Univeristy of Cape Town (UCT) and a Diploma in Datametrics in Computing from the Univeristy of South Africa (UNISA).

CSIR main tasks in project

Main tasks: WP4

4.1.26 IDIA (UCT)

IDIA is the Inter-University Institute for Data Intensive Astronomy. IDIA was established in September 2015 as partnership among research-intensive South African universities. The current partners are The University of Cape Town, North-West University, the University of Pretoria and the University of the Western Cape. IDIA is represented legally by its lead institution, the University of Cape Town. IDIA is engaged in research and development programs to develop solutions to enable data intensive astronomy in South Africa on the pathway to the SKA. Programs include platform development for collaborative research on big data, distributed data systems, federated cloud infrastructures, computing architectures for processing of large astronomical data sets, visual analytics of big data, and data science research form mining and scientific analysis of astronomy data sets. IDIA researchers play a leading role in several MeerKAT large survey project and major programs on other SKA pathfinder. IDIA also plays a leading role in the SKA Science Data Processor work package consortium, leading the SKA DELIV work package to design systems and tools for scientific access by end users to the SKA data.
South Africa is developing the MeerKAT radio telescope as a precursor the SKA. MeerKAT will be incorporated into the SKA1-mid array. IDIA works closely with the SKA South Africa project on developing scientific data delivery solutions for MeerKAT as scalable prototypes for SKA. IDIA is also a partner with the South African Astronomical Observatory, the SKA-SA project and the Hartebeesthoek Radio Observatory on the South African Astroinformatics Alliance, a collaboration to oversee implementation of IVOA services in South Africa and integration into the big data infrastructure.

IDIA Staff

Russ Taylor (m) is the Director of IDIA, and a Professor and SKA Research Chair at the University of Cape Town and the Western Cape. . He has played a leading role on Square Kilometre Array Project since its inception, serving as founding Executive Secretary of the International Square Kilometre, Array Steering Committee, founding chair of the International SKA Science Advisory Committee, vice-chair of the International SKA Science and Engineering Committee, and as a member of the International Board of the Preparatory Phase Program for the SKA and of the International Board of the SKA Organization. Taylor has published over 200 professional scientific articles, and has edited five books. He is an active astronomer an is currently engaged in research in the SKA key science area of cosmic magnetic fields, and in the development of techniques and data science solutions for major SKA programs in this area. He currently serves as the co-chair of the SKA Cosmic Magnetism Science Working Group. Over the course of his career had mentored over 50 young scientists in radio astrophysics and the techniques of radio imaging of the sky.

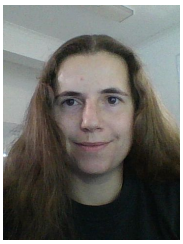
Rob Simmonds (m) is IDIA Associate Director Technology Initiatives, and a Professor in Computer Science at the University of Cape Town. He is the task lead for the data delivery work package and a member of the core architecture design team for the SKA Science Data Processor Work Package Consortium. He is technical lead for the development for a proposed South African regional data intensive research facility for scientific processing of MeerKAT data and data from other SKA pathfinder projects. Simmonds was the Chief Technology Officer for Westgrid, the western Canadian high performance computing grid that

provides computing solutions for the Canadian academic research community, for ten years before moving to South Africa. He was the PI of the Grid Research Centre, that developed distributed systems to support big science projects during that same period.

Bradley Frank (m) is a lecture at the University of Cape Town and the South African Project Scientist for the SA-NL collaboration to develop precursor regional science and data centres as scalable solutions for the data intensive MeerKAT and LOFAR large science programs. Brad has worked at ASTRON on the science data processing pipeline for the APERTIF upgrade to the WSRT telescope; including automation of the self-calibration process and developing a novel, lightweight interface to the pipeline. He is now consolidating the processing requirements of the Large MeerKAT Imaging Survey Projects to develop a flexible, scalable and comprehensive calibration pipeline architecture for deployment on high performance systems. Brad is a scientific and technical contributor to all of the major imaging surveys that are planned with MeerKAT. He has an active scientific interest in the evolution of galaxies.

Patrick Woudt (m) is Head of Department and Professor of Astronomy at the University of Cape Town. He is the president-elect of the South African Institute of Physics. Woudt is the co-PI of the MeerKAT Large Survey Project on radio transients (ThunderKAT) THUNDERKAT project, a time-domain astronomy program for commensal detection of radio transients in the full MeerKAT data stream. He is also the co-PI of MeerLICHT, a dedicated optical telescope that is permanently (and robotically) tied to the MeerKAT observing schedule, creating a real-time simultaneous optical and radio view of the transient Universe. His research is focused on high-time domain astrophysics, in particular the study of accretion onto white dwarfs. He has published over 90 peer-reviewed journal articles and co-edited three books.

David Aikema (m) is a Senior Data Scientist at IDIA. He's part of the team working on the data delivery work package for the SKA Science Data Processor. Data management and distribution tools for the CyberSKA portal, a platform for astronomers to collaborate, share data, and perform remote visualisations, is another key component of his work. David completed his PhD in Computer Science in 2013 at the University of Calgary.



Adrianna Pińska (f) is a software developer at IDIA. She is focusing on incorporating support for large data into existing astronomical viewing and analysis tools, to prepare them for use with the data output produced by the SKA. She has previously worked on the monitoring and control software component of the MeerKAT project, and is pursuing a masters degree in computer science at the University of Cape Town.

IDIA Publications

6. Taylor, A.R., 2015, Data *Intensive Radio Astronomy en route to the SKA: The rise of big radio data*, in Highlights of Astronomy, 16, pp. 677-678.

7. Rosolowsky, E., Kern, J., Federl, P., Jacobs, J., Loveland, S., Taylor, J., Sivakoff, G., and Taylor, A.R. 2015, *The Cube Analysis and Rendering Tool for Astronomy*, in Astronomical Data Analysis and Software Systems XXIV, PASP, 495, pp. 121-124.

8. Jagannathan, P., Bhatnagar, S., Urvashi, R and Taylor, A.R. 2014, *Direction Dependent Effects in Wide-field, Wide-band Full Stokes Radio Imaging*, in Astronomical Data Analysis and Software Systems XXIV, PASP, 495, pp. 379 – 382.

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IDIA Projects

IDIA is leading the SKA data delivery architecture work package (DELIV) within the SKA Science Data Processor Work Package Consortium. This work is being performed In collaboration with teams from the Canadian Astronomy Data Centre, the Oxford eResearch Centre, ASTRON, Instituto de Astrofísica de Andalucía (IAA) and Space Advisory Company. They have also recently become leads in the design of the Observatory Support Tools, the toolset that will support scientists working at the SDP sites. Prof. Simmonds is also a member of the SDP core architecture team (ARCH) and has also led the creation of documents describing possible roles for SKA regional centres and on the use of existing big data processing systems for use in SKA processing and analysis.

IDIA together with SKA-SA are the South African participants in a collaboration with ASTRON, NWO and IBM-NL to develop precursor SKA Regional Science and Data Centres. This project will build scalable hardware and software platforms, tools and cyber infrastructure for end-to-end science for MeerKAT large survey projects and LOFAR data sets.

IDIA is the lead organization in a proposed Western Cape Data Intensive Research Facility (WCDIRF). The WCDIRF will be a data-centric high performance computing facility focussed on providing data intensive research capacity for astronomy and bioinformatics as part of a national tiered distributed infrastructure within the Data Intensive Research Initiative for South Africa (DIRISA). IDIA will lead the development and implementation of the astronomy focussed data intensive research solutions, with primary goal to provide the infrastructure and software systems for execution of MeerKAT large survey projects.

IDIA and the US National Radio Astronomy Observatory a collaborating on the development of next generation data processing systems for radio astronomy survey programs with MeerKAT, the JVLA and the GMRT. The work focuses on user interface, execution environment, and pipeline implementation in high performance parallel computing environments.

IDIA main tasks in project

Profile: representing: SKA SDP DELIV, SA University Partnership, MeerKAT Projects
Main tasks:

- Participation: Tasks 2.1, 2.6, 3.3, 3.5, 3.6, 4.1, 4.4, 5.2, 5.3, 5.4, 6.5

4.1.27 NRF

SKA South Africa (SKA SA) is a business unit of the National Research Foundation of South Africa, is funded by the Department of Science and Technology, and is the organisation responsible for leading South Africa's (and Africa's) SKA activities. SKA SA owns and operates the SKA site in the Karoo region in South Africa and has offices in Cape Town and Johannesburg. SKA SA is also designing, building and operating the MeerKAT radio telescope array, a SKA precursor telescope to be merged into SKA Phase 1, the African VLBI Network, and runs the substantial SKA Human Capital Development programme in South Africa.

NRF Staff

Dr Jasper Horrell (m) is the General Manager: Science Computing and Innovation at SKA SA and is manager responsible for the scientific data processing for MeerKAT and associated computing research projects. He is also participates in activities of the SKA Science Data Processor Consortium and in the management of SKA SA.

Mr Simon Ratcliffe (m) is the Technical Lead for Scientific Computing for SKA SA, responsible for the technical delivery of the Science Data Processor for MeerKAT. He is also leading a number of associated computing platform development research projects and participates in the activities of the SKA Science Data Processor Consortium.

Mr Jeremy Main (m) is Senior Science Processing Developer in the MeerKAT Science Processing Team and is responsible for computing hardware and networking activities supporting MeerKAT archiving and science data processing.

Mr Thomas Bennett (m) is Senior Science Processing Developer in the MeerKAT Science Processing Team and is responsible for the MeerKAT archive development.

NRF Projects

SKA SA Projects (not the NRF as a whole):

- MeerKAT Radio Telescope (design, build, operate)
- African VLBI Network (design, build, operate)
- SKA Human Capital Development Programme (establish and operate)
- Karoo Radio Astronomy Reserve (establish and operate)

NRF main tasks in project

Provide the South African host country link to AENEAS and participate in some of the management related areas of the proposal and how these relate to host countries as well as various precursor and prototyping technical activities linking MeerKAT with the EU scientists.

4.1.28 RDA

The Research Data Alliance Foundation is the legal entity supporting the Research Data Alliance (RDA). RDA is an international member organisation, supported by the European Commission and other research agencies and foundations that is working to develop and implement a global infrastructure to facilitate data sharing and re-use. Through focused Working Groups and more exploratory Interest Groups, the RDA develops and implements concrete Recommendations and Supporting Outputs that provide the social and technical connections necessary for a functional data infrastructure that bridges across countries, disciplines, scales, and technologies.
RDA, as a global organisation, receives support from multiple government agencies and non-profit, charitable foundations. Support for the Secretary General, in particular, comes through the RDA Foundation. Currently, the RDA/Europe project provides partial (~3 months/year) support for the SG for 2016 and 2017. Other support comes from the US National Science Foundation, the Australian government, and Jisc in the UK. The funding portfolio for the SG will continue to evolve based on the needs of the funders and RDA.
The RDA Foundation has no direct employees. Staff are required to be part of an institution that can contract with the Foundation.

RDA Staff

Mark Parsons (m) is the Secretary General of the Research Data Alliance (RDA) and an Associate Director of the Rensselaer Institute for Data Exploration and Applications. Before being appointed Secretary General, Mark was the Managing Director of RDA/United States and the Rensselaer Center for the Digital Society. He focusses on stewarding research data and making them more accessible and useful across different ways of knowing. He has been leading major data stewardship efforts for more than 20 years, and received the American Geophysical Union Charles S. Falkenberg Award as an advocate of robust data stewardship as a vital component of Earth system science and as an important profession in its own right.
Prior to joining Rensselaer, Mark was a Senior Associate Scientist and the Lead Project Manager at the National Snow and Ice Data Center (NSIDC). While at NSIDC, he defined and implemented their overall data management process and led the data management effort for the ICSU/WMO International Polar Year 2007-2008. He is currently active in several international committees while helping lead the Research Data Alliance in its goal of accelerating innovation through data exchange. As a geographer, his research interests include the role of social interaction in the success, development, and extension of data sharing networks.

RDA Publications

1. Lannom, L., D. Broeder, et al. 2015. *Data Type Registry Working Group Recommendation.* Research Data Alliance. http://dx.doi.org/10.15497/A5BCD108-ECC4-41BE-91A7-20112FF77458.

2. Moore, R., R. Stotzka, et al. *Machine Actionable Policy Templates*. Research Data Alliance. http://dx.doi.org/10.15497/83E1B3F9-7E17-484A-A466-B3E5775121CC.

3. Parsons, M. A. 2015. “Creating the culture and technology for a global data infrastructure.” *ERCIM News, no. 100*. http://ercim-news.ercim.eu/images/stories/EN100/EN100-web.pdf.

4. Weigel, T., T. DiLauro, T. Zastrow, et al. 2015. *Persistent Type Identifier Registry*. Research Data Alliance. http://dx. doi.org/10.15497/FDAA09D5-5ED0-403D-B97A-2675E1EBE786.

5. Parsons, M. A. and P. A. Fox. 2013. “Is data publication the right metaphor?”. *Data Science Journal. 12*(WDS32-WDS46). http://dx.doi.org/10.2481/dsj.WDS-042

RDA Projects

Basic operations of RDA are supported by grants from the European Commission, the US National Science Foundation, and the Australian government.

RDA main tasks in project

Participation in tasks in WP2.
This is important, high-profile work for RDA, so a senior executive officer needs to be closely involved. Therefore, the work is to be done by the Secretary General of RDA. The SG is selected by the RDA Council, which is also the Board of Trustees for the Foundation.
The AENEAS project and the SKA infrastructure in general will require special attention from RDA because of the overwhelming complexities and volumes of the data involved. This is a project that will require extra attention and engagement by the SG to ensure that RDA is well connected to the developing SKA infrastructure and to help ensure the SKA is well informed on the appropriate recommendations developed by RDA. The SG will also ensure that SKA-related developments get considered in the broader global context of RDA and myriad other data.
The work of the SG in this project is well outside the normal range of support that the SG provides to collaborative projects. There will be no funding from AENEAS, so the work needs to be balanced with the other taskswithin the more general support provided by the current RDA/Europe project and others.

4.2. Third parties involved in the project (including use of third party resources)

4.2.1 ASTRON

No third parties involved

4.2.2 UMAN

No third parties involved

4.2.3 UCAM

No third parties involved

4.2.4 INAF

No third parties involved

4.2.5 Chalmers

No third parties involved

4.2.6 GÉANT

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)?	N
Does the participant envisage that part of its work is performed by linked third parties?	Y

GÉANT Association

The GÉANT Association is an association under Dutch law. It is owned by its core membership, including 36 National Members – European national research and education networks (NRENs) – and one Representative Member – NORDUnet – which participates on behalf of five Nordic NRENs.

The organisation promotes innovation amongst its members in the development and exploitation of new technologies and other opportunities. It also coordinates collaborative projects and community initiatives, such as task forces and special interest groups, and supports the development of knowledge, skills and competencies via workshops, learning and development activities, and the flagship networking conference TNC.

GÉANT develops, delivers and promotes advanced network and associated e-infrastructure services for research and education, supporting open collaboration and knowledge-sharing amongst its members and the wider research and education community. GÉANT has offices in Cambridge (GEANT Limited) and Amsterdam (GÉANT Association) and their activities are closely interrelated.

GÉANT Association will contribute expertise on Federated AAI infrastructures and trust models to allow SKA users to access federated services and resources offered by different e-infrastructure providers and different organizations in Europe and other regions of the world. They will participate in WP6.

Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)?	N

4.2.7 EGI.eu

No third parties involved

4.2.8 MPIfR

No third parties involved

4.2.9 Jülich

No third parties involved

4.2.10 SKAO

No third parties involved

4.2.11 STFC

No third parties involved

4.2.12 CSIC

No third parties involved

4.2.13 IT

No third parties involved

4.2.14 CNRS

Does the participant plan to subcontract certain tasks (please note that core tasks of the project should not be sub-contracted)?	N
Does the participant envisage that part of its work is performed by linked third parties?	Y
The Observatoire of Côte d'Azur will appear as CNRS third party through their Joint Research Unit UMR 7293 Laboratoire J.-L. Lagrange, which will participate to WP2 and WP5. The Observatoire de la Côte d'Azur (OCA) is a world-leading institute in the field of the Science of Universe. OCA is organized around three poles: Astrophysics, Geophysics and an instrumental/theoretical pole focused on Gravitational waves. The Astrophysics part is now concentrated within one institute: the Lagrange laboratory, a joint research unit depending on three agencies: the National Centre for Scientific Research (CNRS), Observatoire de la Côte d'Azur (OCA) and the Université Nice-Sophia Antipolis.	

Lagrange aims to develop multidisciplinary research and teaching activities in the field of astrophysics, cosmology, optical instrumentation and imaging, fluid mechanics and applied mathematics. This research is supported and enabled by unique skills, organized transverse group in physical methods of observation and high performance numerical computing (HPC performance, massive parallelism, 3D visualization). Lagrange has leading roles in several major international projects (e.g. MATISSE at ESO; GAIA and Euclid ESA satellites) and is the European centre to access the interferometric facility CHARA at the Mount Wilson Observatory (California) in remote mode. Lagrange also participated in the French Virtual Observatory project by co-coordinating national working groups on workflows and on 3D images analysis. Since 2008, OCA has been more and more actively involved in the scientific and technical preparation of SKA and precursor/pathfinder instruments, with the participation to LOFAR, ASKAP and MeerKAT continuum survey projects, as well as the affiliation to the core team of the SKA Science Working Group “Extragalactic Continuum” and to the SKA Work Package LFAA of the “Aperture Array Design and Construction”¬¬¬¬ (AADC) consortium.	
Does the participant envisage the use of contributions in kind provided by third parties (Articles 11 and 12 of the General Model Grant Agreement)?	N

4.2.15 GRNET

No third parties involved

4.2.16 FOM

No third parties involved

4.2.17 JIV-ERIC

No third parties involved

4.2.18 ILT

No third parties involved

4.2.19 SNIC

No third parties involved

4.2.20 EPFL

No third parties involved

4.2.21.UNIGE

No third parties involved

4.2.22 CSIRO

No third parties involved

4.2.23 AARNET

No third parties involved

4.2.24 VUW

No third parties involved

4.2.25 CSIR

No third parties involved

4.2.26 UCT

No third parties involved

4.2.27 NRF

No third parties involved

4.2.28 RDA

No third parties involved

5. ETHICS AND SECURITY

5.1 Ethics

There are no ethical issues associated with the ASTERICS project or its programme of activities.

5.2 Security[15]

There are no security issues associated with the ASTERICS project or its programme of activities. More specifically:

- activities or results raising security issues: NO
- 'EU-classified information' as background or results: NO

APPENDIX 1: LETTERS OF SUPPORT

In this appendix, we present letters of support from the SKA Organization and several SKA international partners, including the two host countries South Africa and Australia, associated with the AENEAS proposal. They are presented in the following order:

- Letter of Support from Prof. Philip Diamond, Director General of the Square Kilometre Array (SKA) Organization.
- Letter of Support from Dr. Sarah Pearce, Deputy Director of CSIRO Astronomy and Space Science and Australian SKA Science Director.
- Letter of Support from Dr. Rob Adams, Project Director for SKA South Africa.
- Letter of Support from Prof. Bryan M. Gaensler, Director of the Dunlap Institute for Astronomy and Astrophysics and Canadian SKA Science Director.
- Letter of Support from Dr. Mark A. Parsons, Secretary General of the Research Data Alliance Foundation (RDA).

[15] Article 37.1 of the Model Grant Agreement: *Before disclosing results of activities raising security issues to a third party (including affiliated entities), a beneficiary must inform the coordinator — which must request written approval from the Commission/Agency.* Article 37.2: *Activities related to 'classified deliverables' must comply with the 'security requirements' until they are declassified. Action tasks related to classified deliverables may not be subcontracted without prior explicit written approval from the Commission/Agency. The beneficiaries must inform the coordinator — which must immediately inform the Commission/Agency — of any changes in the security context and — if necessary —request for Annex 1 to be amended (see Article 55*

SKA Organisation
Jodrell Bank Observatory
Lower Withington
Macclesfield
Cheshire, SK11 9DL
United Kingdom

29th March 2016

Letter of support for AENEAS proposal in response to H2020 Call INFRASUPP-03-2016

I am writing in my capacity of Director-General of the SKA Organisation to offer my strong support for the AENEAS proposal.

The proposal provides an excellent description of the SKA project, its promise and potential. Being designed and organised as a global endeavour, the project features a potentially unique combination of scientific capability across many domains and broader societal impact. Scientists and governments in Europe and around the world have recognised its importance; demonstrated recently in the award of Landmark status in the ESFRI Roadmap 2016.

Managing and exploiting the massive data volumes through the observatory infrastructure, processing those data and then delivering them to the end user community forms perhaps the greatest challenge for the global SKA community.

AENEAS is designed to respond to this challenge. Through its proposed workpackages, it will prepare the way for a European Science Data Centre; establishing the requirements from future users, performing highly relevant testing programmes using the developing SKA Precursor facilities in Australia and South Africa, and then designing the core European infrastructure needed for the future centre.

The team is highly experienced, featuring all of the relevant and interested actors in the European radio science community. The project leaders have established links with networking infrastructure and data experts in Europe and beyond who will inform and ultimately participate in delivering the future Data Centre networks for SKA. For our part I am pleased to provide resources and effort in several workpackages. SKA Organisation has a key role in providing technical input and policy oversight in the programme to ensure alignment of this important European element in the overall global design of the project. I will ensure that appropriate senior staff are available to support the work over the project, if successful.

In summary: I wish to commend the proposal for its ambition, relevance to the SKA project and potential for significant impact for the European science community. I look forward to a successful outcome for the proposal in its review and hope that we may be able to start formal support of activities at the soonest possible opportunity.

Sincerely,

Prof Philip Diamond
SKA Director-General

SKA Organisation
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28 March 2016

LETTER OF SUPPORT FOR AENEAS PROPOSAL

To whom it may concern,

In my role as Australian SKA Science Director, I am writing with my strong support for the AENEAS proposal (Advanced European Network of E-infrastructures for Astronomy with the SKA), in response to the call H2020 INFRASUPP-3-2016-2017 (Part A).

The SKA will be one of the world's greatest mega-science projects, breaking new ground in radio astronomy and addressing fundamental questions about the Universe. The project will produce unprecedented data rates, requiring cutting-edge solutions in processing, data storage, analytics and networking. As with the Large Hadron Collider, the SKA will need a worldwide network of distributed Regional Centres, enabling access to data, processing, software and user support for the international community. Only through meeting this enormous data challenge will the SKA be able to deliver its scientific potential.

The AENEAS project will lead the way in establishing the concept and design for the European Science Data Centre. We envisage similar structures being established in other SKA regions, and as an SKA Host Country Australia will be closely engaged in these developments. Both Australia's Academic and Research Network (AARNet) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) will be partners in AENEAS, and we look forward to working with the other partners to establish a comprehensive and robust design for SKA e-infrastructure.

Yours sincerely,

Dr Sarah Pearce
Deputy Director, CSIRO Astronomy and Space Science
Australian SKA Science Director

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First Floor, 17 Baker Street,
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29 March 2016

To Whom It May Concern,

Support for the AENEAS H2020 Proposal from SKA South Africa

This letter is to express support from South Africa as a host country of the Square Kilometre Array (SKA) telescope for the AENEAS Proposal in response to the H2020 INFRASUPP-3-2016-2017 call. It is clear that, in order for the SKA to reach its scientific potential, major attention will be needed from all significant partners in the areas of data transport, storage, data delivery/access, reprocessing and science extraction. This is in line with the recent trend of all major astronomical and physics instrumentation where massive datasets prevail and the international efforts of large teams are required to extract the science. SKA will set new benchmarks in this area with its unprecedented data volumes.

SKA South Africa is the organization in South Africa charged with responsibility for the hosting of the SKA in Africa including the leading of the SKA Phase 1 design efforts in South Africa and as such has a responsibility and strong interest in ensuring that the SKA delivers on its promise i.e. is very scientifically productive. The AENEAS proposal, coordinated by ASTRON and comprising a strong team of experienced collaborators with a significant work programme, is a major initiative to develop the required SKA data processing readiness from the scientifically strong European partners of the SKA by developing the regional centre concept for the SKA. We see this as a major part of the global effort needed in this area.

At the SKA precursor level, through the MeerKAT and LOFAR telescopes, SKA SA is already exploring mechanisms for effective science delivery with our EU partners and would see the AENEAS proposal as a significant extension of that work which we would support in ways appropriate to the role of SKA host countries.

Yours faithfully,

Dr Rob Adam
Project Director SKA South Africa

Dunlap Institute for
Astronomy & Astrophysics
UNIVERSITY OF TORONTO

Dunlap Institute for Astronomy and Astrophysics
The University of Toronto
50 St. George Street, Toronto
ON M5S 3H4, CANADA

Prof. Bryan M. Gaensler PhD FAA
Director, Dunlap Institute for Astronomy and Astrophysics
Canadian SKA Science Director

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E bgaensler@dunlap.utoronto.ca
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23 March 2016

Letter of support for AENEAS proposal in response to H2020 Call INFRASUPP-03-2016

To whom it may concern,

I am writing in my capacity as Canadian Science Director for the Square Kilometre Array (SKA) to express my strong support for the AENEAS proposal. The scientific potential of the SKA will be truly transformational; this billion-dollar facility will address questions ranging from fundamental physics to the origins of the Universe and even life itself. However, the incredible volume and complexity of data that the SKA will produce present technical challenges that are almost as formidable as the questions themselves. To achieve the full science potential of the SKA, the scientific community will need a research infrastructure of unprecedented scale and capability. Assembling that infrastructure will require a coordinated global effort.

The AENEAS project represents an important initiative to begin the process of assembling that infrastructure within Europe. An international network of SKA Regional Centres as described in the AENEAS proposal is currently seen by the SKA project as a critical complement to the Observatory itself to support the scientific community. The work program described in the AENEAS proposal mirrors our own similar efforts here in Canada to provide the necessary infrastructure for SKA science, and will serve as an important international connection point for those national efforts.

I believe that the AENEAS proposers have assembled an experienced and competent team for the project, and have defined an excellent program of work. Should the AENEAS proposal be funded, I am confident that it will yield valuable results that will move us substantially closer to a scientifically successful SKA, and I am excited for the Canadian SKA community to be able to contribute to the work program. I am pleased to endorse the proposal and look forward both to our future cooperation as part of the AENEAS project and to the exciting science it will ultimately enable.

yours sincerely,

Professor Bryan Gaensler
Director, Dunlap Institute for Astronomy and Astrophysics
Canadian SKA Science Director

rd-alliance.org

Secretary General

c/o Rensselaer Polytechnic Institute
1550 Linden Ave
Boulder, CO 80304
USA

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27 March 2016

AENEAS Project Letter of Support

To whom it may concern,

I am writing to express my interest in participating in AENEAS proposal (Advanced European Network of E-infrastructures for Astronomy with the SKA), in response to the call H2020 INFRASUPP-3-2016-2017 (Part A). Many of the AENEAS project objectives are consistent with and will complement the work of the RDA. Moreover, I believe that the activities of the RDA can make significant contributions to your efforts.

RDA is an international member organisation, supported by the European Commission and other research agencies and foundations that is working to develop and implement a global infrastructure to facilitate data sharing and re-use. Through focused Working Groups and more exploratory Interest Groups, the RDA develops and implements concrete Recommendations and Supporting Outputs that provide the social and technical connections necessary for a functional data infrastructure that bridges across countries, disciplines, scales, and technologies.

RDA provides a neutral place for researchers, computer scientists, engineers, data practitioners, librarians, and others from around the world to collaborate and learn in the creation of e-infrastructure. RDA provides the tools, mechanisms, and lightweight governance for engaging with a wide community and facilitating cross-disciplinary coordination. RDA will work with AENEAS to help coordinate a network of distributed Regional Centres, enabling access to data, processing, software and user support for the international community.

I, as the RDA Secretary General, or my designee will work actively in the AENEAS project to advise and assist the SKA community on the development of and participation in relevant RDA Working and Interest Groups and assist in working within the RDA philosophy and processes. In turn, I will help bring astronomy-related concerns and use cases back to relevant groups within RDA.

If successful, The AENEAS project will lead the way in establishing the concept and design for the European Science Data Centre. RDA will help the center be interconnected within a global data infrastructure.

Sincerely,

Mark A. Parsons
Secretary General

research data sharing without barriers

APPENDIX 2: LIST OF ACRONYMS

AAI	Authentication and Authorization Infrastructure
AARC	Authentication and Authorization for Research and Collaboration
AAROC	Africa-Arabia Regional Operations Centre
AEAB	AENEAS External Advisory Board
AENEAS	Advanced European Network of E-infrastructures for Astronomy with the SKA
AGA	AENEAS General Assembly
ALMA	Atacama Large Millimeter/submillimeter Array
AMST	AENEAS Management Support Team
AMT	AENEAS Management Team
APPEC	AstroParticle Physics European Consortium
ASKAP	Australian Square Kilometre Array Pathfinder
ASTERICS	Astronomy ESFRI & Research Infrastructure Cluster
ASTRONET	An ERA-NET of European funding agencies for long-term planning in astronomy
CADC	Canadian Astronomy Data Centre
CANFAR	Canadian Advanced Network for Astronomical Research
CERN	European Organization for Nuclear Research
CSIR	Council for Scientific and Industrial Research
CTA	Cherenkov Telescope Array
DCI	Distributed Computing Instrastructure
DESCA	Development of a Simplified Consortium Agreement
DFAP	Data Flow Advisory Panel
DMZ	De-Militarised Zone
DOME	ASTRON IBM Center for Exascale Computing
E-ELT	European Extremely Large Telescope
EGI	European Grid Infastructure
EOSC	European Open Science Cloud
ERA-NET	European Research Area Network
ERIC	European Research Infrastructure Consortium
ERTRC	European Radio Telescope Review Committee
ESA	European Space Agency
ESDC	European Science and Data Centre
ESFRI	European Strategy Forum on Research Infrastructures
ESO	European Space Agency
Euclid	ESA medium class astronomy and astrophysics space Mission
EUDAT	Collaborative Pan-European infrastructure providing research data services
EU-T0	Data Research and Innovation Hub (European Tier 0)
EURO-VO	European Virtual Observatory
e-VLBI	Electronic VLBI (see VLBI)
EVN	European VLBI Network
EWASS	European Week of Astronomy and Space Science
GRID	Global Resource Information Database
HLEG	High Level Expert Group (HLEG) on the EOSC
HPSO	High-Priority Science Objective
HPC	High Perfomance Computing
HST	Hubble Space Telescope
HTC	High Throughput Computing
IAU	International Astronomical Union
IdP	Identity provisioning
ITSM	IT service management
IVOA	International Virtual Observatory Alliance

JWST	James Webb Space Telescope
KPI	Key Performance Indicator
KM3-NeT	KM^3 Neutrino Telescope
LHC	Large Hadron Collider
LOFAR	Low Frequency Array
LSST	Large Synoptic Survey Telescope
MeerkKAT	Karoo Array Telescope (under construction)
MWA	Murchison Widefield Array
NEXPReS	Novel Explorations Pushing Robust e-VLBI Services
NICI	South African Initiative for Cyberinfrastructure
NREN	National Research and Education Network
OST	Observatory Support Tools
PoC	Point of Contact
PRACE	Partnership for Advanced Computing in Europe
PM	Person Month
RI	Research Infrastructure
RSDA	Reliability and Security Data Analysis
SADT	Signal and Data Transport
SAGrid	South African National Grid
SDP	Science Data Processor
SG	Science Gateways
SKA	Square Kilometre Array
SKA1	Square Kilometre Array Phase 1, (representing 10% of the full array)
SLA	Service Level Agreement
SRC	SKA Regional Centre
SWG	Science Working Group
UK-T0	UK national equivalent to EU-T0
VLBI	Very Long Baseline Interferometry
VO	Virtual Observatory
WLCG	Worldwide LHC Computing Grid
WP	Work Package

ESTIMATED BUDGET FOR THE ACTION (page 1 of 3)

	Estimated eligible[1] costs (per budget category)									EU contribution			Additional information		
	A. Direct personnel costs				B. Direct costs of subcontracting	C. Direct costs of fin. support	D. Other direct costs	E. Indirect costs[2]	Total costs	Reimbursement rate %	Maximum EU contribution[3]	Maximum grant amount[4]	Information for indirect costs	Information for auditors	Other information:
	A.1 Employees (or equivalent) A.2 Natural persons under direct contract A.3 Seconded persons [A.6 Personnel for providing access to research infrastructure]		A.4 SME owners without salary A.5 Beneficiaries that are natural persons without salary				D.1 Travel D.2 Equipment D.3 Other goods and services D.4 Costs of large research infrastructure						Estimated costs of in-kind contributions not used on premises	Declaration of costs under Point D.4	Estimated costs of beneficiaries/ linked third parties not receiving EU funding
Form of costs[6]	Actual	Unit[7]	Unit[8]		Actual	Actual	Actual	Flat-rate[9] 25%							
	(a)	Total (b)	No hours	Total (c)	(d)	(e)	(f)	(g)=0,25x ((a)+(b)+ (c)+(f) +[(h1)+(h2)]- (m))	(i)= (a)+(b)+(c)+ (d)+(e)+(f)+ (g)+(h1)+(h2)+(h3)	(j)	(k)	(l)	(m)	Yes/No	
1. ASTRON	489700.00	0.00	0	0.00	0.00	0.00	204300.00	173500.00	867500.00	100.00	867500.00	867500.00	0.00	No	
2. UMAN	146600.00	0.00	0	0.00	0.00	0.00	9000.00	38900.00	194500.00	100.00	194500.00	194500.00	0.00	No	
3. UCAM	149996.00	0.00	0	0.00	0.00	0.00	7200.00	39299.00	196495.00	100.00	196495.00	196495.00	0.00	No	
4. INAF	275856.00	0.00	0	0.00	0.00	0.00	23400.00	74814.00	374070.00	100.00	374070.00	374070.00	0.00	No	
5. CHALMERS	210000.00	0.00	0	0.00	0.00	0.00	14400.00	56100.00	280500.00	100.00	280500.00	280500.00	0.00	No	
6. GEANT LTD	180000.00	0.00	0	0.00	0.00	0.00	8400.00	47100.00	235500.00	100.00	235500.00	235500.00	0.00	No	
- GÉANT Assn[14]	30000.00	0.00	0	0.00	0.00	0.00	1200.00	7800.00	39000.00	100.00	39000.00	39000.00	0.00	No	
Total beneficiary 6	210000.00	0.00			0.00	0.00	9600.00	54900.00	274500.00		274500.00	274500.00	0.00		
7. EGI.eu	167200.00	0.00	0	0.00	0.00	0.00	5400.00	43150.00	215750.00	100.00	215750.00	215750.00	0.00	No	
8. MPG	0.00	0.00	0	0.00	0.00	0.00	2400.00	600.00	3000.00	100.00	3000.00	3000.00	0.00	No	
9. Juelich	144000.00	0.00	0	0.00	0.00	0.00	7200.00	37800.00	189000.00	100.00	189000.00	189000.00	0.00	No	
10. SKAO	0.00	0.00	0	0.00	0.00	0.00	3600.00	900.00	4500.00	100.00	4500.00	4500.00	0.00	No	
11. STFC	40872.00	0.00	0	0.00	0.00	0.00	3600.00	11118.00	55590.00	100.00	55590.00	55590.00	0.00	No	
12. CSIC	33752.00	0.00	0	0.00	0.00	0.00	7800.00	10388.00	51940.00	100.00	51940.00	51940.00	0.00	No	
13. IT	29400.00	0.00	0	0.00	0.00	0.00	6000.00	8850.00	44250.00	100.00	44250.00	44250.00	0.00	No	
14. CNRS	0.00	0.00	0	0.00	0.00	0.00	18000.00	4500.00	22500.00	100.00	22500.00	22500.00	0.00	No	
- OCA[14]	13200.00	0.00	0	0.00	0.00	0.00	0.00	3300.00	16500.00	100.00	16500.00	16500.00	0.00	No	
Total beneficiary 14	13200.00	0.00			0.00	0.00	18000.00	7800.00	39000.00		39000.00	39000.00	0.00		
15. GRNET	34320.00	0.00	0	0.00	0.00	0.00	3600.00	9480.00	47400.00	100.00	47400.00	47400.00	0.00	No	
16. FOM	49800.00	0.00	0	0.00	0.00	0.00	3600.00	13350.00	66750.00	100.00	66750.00	66750.00	0.00	No	
17. JIV-ERIC	0.00	0.00	0	0.00	0.00	0.00	3600.00	900.00	4500.00	100.00	4500.00	4500.00	0.00	No	
18. ILT	0.00	0.00	0	0.00	0.00	0.00	3600.00	900.00	4500.00	100.00	4500.00	4500.00	0.00	No	
19. SNIC[13]															0.00
20. EPFL	18000.00	0.00	0	0.00	0.00	0.00	3000.00	5250.00	26250.00	100.00	26250.00	26250.00	0.00	No	
21. UNIGE	21000.00	0.00	0	0.00	0.00	0.00	3000.00	6000.00	30000.00	100.00	30000.00	30000.00	0.00	No	
22. CSIRO[13]															0.00

ESTIMATED BUDGET FOR THE ACTION (page 2 of 3)

	Estimated eligible[1] costs (per budget category)									EU contribution			Additional information		
	A. Direct personnel costs				B. Direct costs of subcontracting	C. Direct costs of fin. support	D. Other direct costs	E. Indirect costs[2]	Total costs	Reimbursement rate %	Maximum EU contribution[3]	Maximum grant amount[4]	Information for indirect costs	Information for auditors	Other information:
	A.1 Employees (or equivalent) A.2 Natural persons under direct contract A.3 Seconded persons [A.6 Personnel for providing access to research infrastructure]		A.4 SME owners without salary A.5 Beneficiaries that are natural persons without salary				D.1 Travel D.2 Equipment D.3 Other goods and services D.4 Costs of large research infrastructure						Estimated costs of in-kind contributions not used on premises	Declaration of costs under Point D.4	Estimated costs of beneficiaries/ linked third parties not receiving EU funding
Form of costs[6]	Actual	Unit[7]	Unit[8]		Actual	Actual	Actual	Flat-rate[9] 25%							
	(a)	Total (b)	No hours	Total (c)	(d)	(e)	(f)	(g)=0,25x ((a)+(b)+ (c)+(f) +[(h1)+(h2)]- (m))	(i)= (a)+(b)+(c)+ (d)+(e)+(f)+ (g)+(h1)+(h2)+(h3)	(j)	(k)	(l)	(m)	Yes/No	
23. AARNet[13]															0.00
24. VUW[13]															0.00
25. CSIR	0.00	0.00	0	0.00	0.00	0.00	8000.00	2000.00	10000.00	100.00	10000.00	10000.00	0.00	No	
26. UCT	0.00	0.00	0	0.00	0.00	0.00	8000.00	2000.00	10000.00	100.00	10000.00	10000.00	0.00	No	
27. NRF	0.00	0.00	0	0.00	0.00	0.00	8000.00	2000.00	10000.00	100.00	10000.00	10000.00	0.00	No	
28. RDA[13]															0.00
Total consortium	2033696.00	0.00		0.00	0.00	0.00	366300.00	599999.00	2999995.00		2999995.00	2999995.00	0.00		0.00

ESTIMATED BUDGET FOR THE ACTION (page 3 of 3)

(1) See Article 6 for the eligibility conditions
(2) The indirect costs covered by the operating grant (received under any EU or Euratom funding programme; see Article 6.5.(b)) are ineligible under the GA. Therefore, a beneficiary that receives an operating grant during the action's duration cannot declare indirect costs for the year(s)/reporting period(s) covered by the operating grant (see Article 6.2.E).
(3) This is the theoretical amount of EU contribution that the system calculates automatically (by multiplying all the budgeted costs by the reimbursement rate). This theoretical amount is capped by the 'maximum grant amount' (that the Commission/Agency decided to grant for the action) (see Article 5.1).
(4) The 'maximum grant amount' is the maximum grant amount decided by the Commission/Agency. It normally corresponds to the requested grant, but may be lower.
(5) Depending on its type, this specific cost category will or will not cover indirect costs. Specific unit costs that include indirect costs are: costs for energy efficiency measures in buildings, access costs for providing trans-national access to research infrastructure and costs for clinical studies.
(6) See Article 5 for the forms of costs
(7) Unit : hours worked on the action; costs per unit (hourly rate) : calculated according to beneficiary's usual accounting practice
(8) See Annex 2a 'Additional information on the estimated budget' for the details (costs per hour (hourly rate)).
(9) Flat rate : 25% of eligible direct costs, from which are excluded: direct costs of subcontracting, costs of in-kind contributions not used on premises, direct costs of financial support, and unit costs declared under budget category F if they include indirect costs
(10) See Annex 2a 'Additional information on the estimated budget' for the details (units, costs per unit).
(11) See Annex 2a 'Additional information on the estimated budget' for the details (units, costs per unit, estimated number of units, etc)
(12) Only specific unit costs that do not include indirect costs
(13) See Article 9 for beneficiaries not receiving EU funding
(14) Only for linked third parties that receive EU funding

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

THE UNIVERSITY OF MANCHESTER (UMAN) GB22, RC000797, established in OXFORD ROAD UNIVERSITY OF MANCHESTER OFFICE OF DIRECTOR OF FINANCE, MANCHESTER M13 9PL, United Kingdom, VAT number GB849738956, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('2')

in Grant Agreement No 731016 ('the Agreement')

between STICHTING ASTRON, NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY **and** the European Union ('the EU'), represented by the European Commission ('the Commission'),

for the action entitled 'Advanced European Network of E-infrastructures for Astronomy with the SKA (AENEAS)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

Andrew WALSH with ECAS id nwlshadr signed in the Participant Portal on 20/11/2016 at 09:45:33 (transaction id SigId-30394-JPuEBQuT6oh2uaRhF1Hv60HPiOBp4zi1TYWOzli1NyPWoLqBSn1J0IpC3ud8ZfZwRs1s0Xu5cCnyVj8onuorDi-PHslUMVSXYC3y9Y47r6OLW-hapc0m8Eipa0HhRRKIroHpoWikjrbuMt6EAmRDeLTpa). Timestamp by third party at
Sun Nov 20 09:46:36 CET 2016

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

THE CHANCELLOR, MASTERS AND SCHOLARS OF THE UNIVERSITY OF CAMBRIDGE (UCAM) GB12, Not applicable, established in TRINITY LANE THE OLD SCHOOLS, CAMBRIDGE CB2 1TN, United Kingdom, VAT number GB823847609, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('3')

in Grant Agreement No 731016 ('the Agreement')

between STICHTING ASTRON, NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY **and** the European Union ('the EU'), represented by the European Commission ('the Commission'),

for the action entitled 'Advanced European Network of E-infrastructures for Astronomy with the SKA (AENEAS)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

Renata P. SCHAEFFER with ECAS id nschaert signed in the Participant Portal on 08/12/2016 at 14:01:50 (transaction id SigId-13032-yjnMrcmsIlCzazGODjOzj8GdYcH9qh8gflr84LeZy5Lk1tCnqYO5kS2y4YzQE2XLpMr82VkdW36W3Rix4wY3xEC-Jj71zxYb8yryEnwGPo6Oly-BbNK1YzJrpzhRxvkeQlgheH2h1ozJVjadx4XZhqJrnQW). Timestamp by third party at
Thu Dec 08 14:02:36 CET 2016

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

ISTITUTO NAZIONALE DI ASTROFISICA (INAF), 97220210583, established in Viale del Parco Mellini 84, ROMA 00136, Italy, VAT number IT06895721006, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('4')

in Grant Agreement No 731016 ('the Agreement')

between STICHTING ASTRON, NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY **and** the European Union ('the EU'), represented by the European Commission ('the Commission'),

for the action entitled 'Advanced European Network of E-infrastructures for Astronomy with the SKA (AENEAS)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

Steven TINGAY with ECAS id ntingast signed in the Participant Portal on 19/11/2016 at 08:43:29 (transaction id SigId-29961-yQOozZzWHOiCC9sfvNaH9bUHubuUqgfv3zV9TamMhhn1FtvgkE0gPF1EQrMTe9gsekMC0Szucx5USrCMOgAKfHm-PHslUMVSXYC3y9Y47r6OLW-zTmHuCw4A25jyJnUzbUJnwfbTy6DtuOJhYQkZCQnOIlG). Timestamp by third party at
Sat Nov 19 08:43:53 CET 2016

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

CHALMERS TEKNISKA HOEGSKOLA AB (CHALMERS) AB, 5564795598, established in -, GOETEBORG 41296, Sweden, VAT number SE556479559801, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('5')

in Grant Agreement No 731016 ('the Agreement')

between STICHTING ASTRON, NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY **and** the European Union ('the EU'), represented by the European Commission ('the Commission'),

for the action entitled 'Advanced European Network of E-infrastructures for Astronomy with the SKA (AENEAS)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

Gunnar ELGERED with ECAS id nelgegun signed in the Participant Portal on 20/11/2016 at 17:07:05 (transaction id SigId-69-OgZ2HoKd2ahx05rGNgK1OGzr8fKrG3hK7l7RSjsujsQKlKMPoTk8CS77hAdIgQeWrtmQqEzfKaybb5BOH2tSYu-PHslUMVSXYCvpQJoajo5jG-xL2dGHsA0rwjNajtPLKo6OWc8zoTeqp04CEL27pzTAJm). Timestamp by third party at Sun Nov 20 17:07:32 CET 2016

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

GEANT LIMITED (GEANT LTD) LTD, 2806796, established in 126-130 HILLS ROAD CITY HOUSE, CAMBRIDGE CB2 1PQ, United Kingdom, VAT number GB599731672, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('6')

in Grant Agreement No 731016 ('the Agreement')

between STICHTING ASTRON, NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY **and** the European Union ('the EU'), represented by the European Commission ('the Commission'),

for the action entitled 'Advanced European Network of E-infrastructures for Astronomy with the SKA (AENEAS)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

Steve COTTER with ECAS id ncotters signed in the Participant Portal on 18/11/2016 at 19:17:18 (transaction id SigId-29662-zOXBC5uBkKtZyFd9CUK8lXpL74Ipw3FE9GKzzxRnVNdfzhxtgszklf8Mtzg2QZA0lgv8Wve6YqMxrHLoI5lpbuUW-PHslUMVSXYC3y9Y47r6OLW-iMtOArx6DBzSTgk4y4Kqvt1zmwzbSIK0eNOyDzIXREMG). Timestamp by third party at Fri Nov 18 19:17:42 CET 2016

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

Stichting EGI (EGI.eu) NL6, 34380182, established in SCIENCE PARK 140, AMSTERDAM 1098 XG, Netherlands, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('7')

in Grant Agreement No 731016 ('the Agreement')

between STICHTING ASTRON, NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY **and** the European Union ('the EU'), represented by the European Commission ('the Commission'),

for the action entitled 'Advanced European Network of E-infrastructures for Astronomy with the SKA (AENEAS)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

Yannick LEGRE with ECAS id nlegyann signed in the Participant Portal on 29/11/2016 at 23:10:59 (transaction id SigId-52365-HIIgw1jXp2lW3VuHqyqtMZ5vXBX69NTsfzKFZtBpI48ujh67uzzNbdgaeY8nx2RK38l8YlPDle8hawZxVf3ROUm-PHslUMVSXYCl4G08U3ZwBS-wd5FFQsH7lZzSPGLhq54Jf9qf0HJBd51zr8nT2rslnqG). Timestamp by third party at
Tue Nov 29 23:11:41 CET 2016

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

MAX-PLANCK-GESELLSCHAFT ZUR FORDERUNG DER WISSENSCHAFTEN EV (MPG) EV, VR13378B, established in HOFGARTENSTRASSE 8, MUENCHEN 80539, Germany, VAT number DE129517720, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('8')

in Grant Agreement No 731016 ('the Agreement')

between STICHTING ASTRON, NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY **and** the European Union ('the EU'), represented by the European Commission ('the Commission'),

for the action entitled 'Advanced European Network of E-infrastructures for Astronomy with the SKA (AENEAS)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

Michael KRAMER with ECAS id nkrameme signed in the Participant Portal on 21/11/2016 at 17:20:32 (transaction id SigId-14423-GzbAQ00De0zpfJzhmIOzozfu3gyUkUCIjZUk67tYwC22KYgaEXEjD1MIBMmwEoA3sO1eqKEq197lSkwFLG0qDdg-PHslUMVSXYCvpQJoajo5jG-zvNNB58QyOJU9UW5e2Odflu686kOmjiSrf7LwzRRImPG). Timestamp by third party at
Mon Nov 21 17:21:08 CET 2016

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

FORSCHUNGSZENTRUM JULICH GMBH (Juelich) GEM GMBH, HRB3498, established in WILHELM JOHNEN STRASSE, JULICH 52428, Germany, VAT number DE122624631, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('9')

in Grant Agreement No 731016 ('the Agreement')

between STICHTING ASTRON, NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY **and** the European Union ('the EU'), represented by the European Commission ('the Commission'),

for the action entitled 'Advanced European Network of E-infrastructures for Astronomy with the SKA (AENEAS)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

Volker MARX with ECAS id nmarxmvo signed in the Participant Portal on 22/11/2016 at 13:01:37 (transaction id SigId-24338-1tVjZTFh5ztX33pzuJn29VNN4vgoSOONdxoIIWsQuzkLU4BCDcmBwVUbzytVUcvPe9AmL85eaD7f4qYq16BfFga-PHslUMVSXYCvpQJoajo5jG-49VB9rbPabpHzzTTsaXWbZWPSK4HRk4bd1hzwj593l5u). Timestamp by third party at Tue Nov 22 13:02:12 CET 2016

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

SKA ORGANISATION (SKAO) GB5, 07881918, established in JODRELL BANK OBSERVATORY LOWER WITHINGTON, MACCLESFIELD SK11 9DL, United Kingdom, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('10')

in Grant Agreement No 731016 ('the Agreement')

between STICHTING ASTRON, NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY **and** the European Union ('the EU'), represented by the European Commission ('the Commission'),

for the action entitled 'Advanced European Network of E-infrastructures for Astronomy with the SKA (AENEAS)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

Colin GREENWOOD with ECAS id ngreecli signed in the Participant Portal on 19/11/2016 at 12:50:57 (transaction id SigId-30071-3A9116e0K3BBzGhuGzLusjXqLSFmxOljad8BZ9qy4zWvFYxXe7lowceA5OaXwEzIPTSmP7fSk7I6BBPfXJtZ1Du-PHslUMVSXYC3y9Y47r6OLW-baYdLPGIuPTfvSSzxSd6h1i9zVeoykqXzZMyijmy7Uae). Timestamp by third party at Sat Nov 19 12:51:21 CET 2016

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

SCIENCE AND TECHNOLOGY FACILITIES COUNCIL (STFC), RC000747, established in Polaris House North Star Avenue, SWINDON SN2 1SZ, United Kingdom, VAT number GB618367325, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('11')

in Grant Agreement No 731016 ('the Agreement')

between STICHTING ASTRON, NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY **and** the European Union ('the EU'), represented by the European Commission ('the Commission'),

for the action entitled 'Advanced European Network of E-infrastructures for Astronomy with the SKA (AENEAS)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

Nicola GOTHARD with ECAS id ngothnic signed in the Participant Portal on 21/11/2016 at 11:48:17 (transaction id SigId-5646-zNkmHMrtGAZDQzzezGFMBAu6RIbAZGK3tBAGduq4GpKznwjmnzzzXVOB7vCBVXougA8A7zwM1m6dC2DBC4YiXRGS0-PHslUMVSXYCvpQJoajo5jG-mGzr3zUmwQ2jzaRvAuW8tbIaxwM42N2dwio8pCDdwlXa). Timestamp by third party at
Mon Nov 21 11:48:46 CET 2016

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

AGENCIA ESTATAL CONSEJO SUPERIOR DEINVESTIGACIONES CIENTIFICAS (CSIC), established in CALLE SERRANO 117, MADRID 28006, Spain, VAT number ESQ2818002D, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('12')

in Grant Agreement No 731016 ('the Agreement')

between STICHTING ASTRON, NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY **and** the European Union ('the EU'), represented by the European Commission ('the Commission'),

for the action entitled 'Advanced European Network of E-infrastructures for Astronomy with the SKA (AENEAS)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

Cristina DE LA PUENTE with ECAS id nfianton signed in the Participant Portal on 25/11/2016 at 11:53:40 (transaction id SigId-6466-7YUMbo4YW7qhH3jSg2Qnl33FCJHHzOTALzNpZvFOMWCgcgZzZm6N0loMBmzxT8gv63OiORXXrBZvqgDjNGRg7ku-PHslUMVSXYCI4G08U3ZwBS-kUdzzaEQYE5RCjxYL2UwzWM9O8QCEZMXXYizgwlYzGtGm). Timestamp by third party at Fri Nov 25 11:54:15 CET 2016

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

INSTITUTO DE TELECOMUNICACOES (IT) IPSS, 249/970502, established in AVENIDA DE ROVISCO PAIS 1, LISBOA 1049-001, Portugal, VAT number PT502854200, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('13')

in Grant Agreement No 731016 ('the Agreement')

between STICHTING ASTRON, NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY **and** the European Union ('the EU'), represented by the European Commission ('the Commission'),

for the action entitled 'Advanced European Network of E-infrastructures for Astronomy with the SKA (AENEAS)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

Jose Carlos da SILVA NEVES with ECAS id nsilvaja signed in the Participant Portal on 07/12/2016 at 19:31:51 (transaction id SigId-64-DLd5zWHXiBa6vAPzzKAhudZYcEhzgXszy2MKmtzft1oKznWZHjBdbRTCpcRKtDOwKzfMfVdFs0bZ46Urxd96ejUW-Jj71zxYb8yryEnwGPo6Oly-eKkWLvuXoGTWcqBxGlbsVZgczMDttKvhxsBoJ8YgTpu). Timestamp by third party at Wed Dec 07 19:32:56 CET 2016

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS (CNRS), 180089013, established in RUE MICHEL ANGE 3, PARIS 75794, France, VAT number FR40180089013, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('14')

in Grant Agreement No 731016 ('the Agreement')

between STICHTING ASTRON, NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY **and** the European Union ('the EU'), represented by the European Commission ('the Commission'),

for the action entitled 'Advanced European Network of E-infrastructures for Astronomy with the SKA (AENEAS)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

Brigitte PAPIN with ECAS id npapinbr signed in the Participant Portal on 29/11/2016 at 10:00:26 (transaction id SigId-36865-ksUvSpsLnRdyd1YKEUD1ioSHzn8uH4TcJHuIFMXv4MG1ZjN8HzyLGZQP2U8TxoAFWBYczvSVOZZWaQLTXOjlN0G-PHslUMVSXYCI4G08U3ZwBS-FggWbqlHF6CcDvgzfI8kZzLmqArxVNaRCF6JASCVZgwm). Timestamp by third party at Tue Nov 29 10:01:06 CET 2016

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

ETHNIKO DIKTYO EREVNAS TECHNOLOGIAS AE (GRNET) AE, 003057201000, established in LEOFOROS KIFISIAS 7, ATHINA 11523, Greece, VAT number EL094536469, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('15')

in Grant Agreement No 731016 ('the Agreement')

between STICHTING ASTRON, NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY **and** the European Union ('the EU'), represented by the European Commission ('the Commission'),

for the action entitled 'Advanced European Network of E-infrastructures for Astronomy with the SKA (AENEAS)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

Panayiotis TSANAKAS with ECAS id ntpanayi signed in the Participant Portal on 18/11/2016 at 18:07:09 (transaction id SigId-29216-S2BR73TvQ9izzvpM5pMTC6qOjvgWpr44zsyxdkPzTlOzNymyC6SzR8dbfTJiPVm719xr6BJJUeUSkA1KAT3Fs270-PHslUMVSXYC3y9Y47r6OLW-gHZY957BODJmVKnWDkOolpVlOokecM0miOfbZmnzzhdG). Timestamp by third party at Fri Nov 18 18:07:30 CET 2016

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

STICHTING VOOR FUNDAMENTEEL ONDERZOEK DER MATERIE - FOM (FOM) NL6, 41150068, established in Van Vollenhovenlaan 659, UTRECHT 3527 JP, Netherlands, VAT number NL002882243B01, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('16')

in Grant Agreement No 731016 ('the Agreement')

between STICHTING ASTRON, NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY **and** the European Union ('the EU'), represented by the European Commission ('the Commission'),

for the action entitled 'Advanced European Network of E-infrastructures for Astronomy with the SKA (AENEAS)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

Arjen VAN RIJN with ECAS id nvanriar signed in the Participant Portal on 07/12/2016 at 12:25:55 (transaction id SigId-31829-i1gzZ7lVv1X9N1BhOiu9h9qukEWzY1V6FGw45s38JkNhcPvmzyCNaEkuEosJJBNuBwIO6dHkPU9JHPUuyazNyFG-PHslUMVSXYCuynWSMXbHJK-8lKK6REOp1m3WHwNAfculGu8ryzc1b7r4CYfSGciuvE). Timestamp by third party at Wed Dec 07 12:26:40 CET 2016

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

JOINT INSTITUTE FOR VERY LONG BASELINE INTERFEROMETRY AS A EUROPEAN RESEARCH INFRASTRUCTURE CONSORTIUM (JIV-ERIC) (JIV-ERIC), 62827278, established in OUDE HOOGEVEENSEDIJK 4, DWINGELOO 7991 PD, Netherlands, VAT number NL854973527B01, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('17')

in Grant Agreement No 731016 ('the Agreement')

between STICHTING ASTRON, NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY **and** the European Union ('the EU'), represented by the European Commission ('the Commission'),

for the action entitled 'Advanced European Network of E-infrastructures for Astronomy with the SKA (AENEAS)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

Huib VAN LANGEVELDE with ECAS id nlanhuib signed in the Participant Portal on 22/11/2016 at 09:09:10 (transaction id SigId-18095-Nm5cRAYAAo2zzsrStrig3XGI95ZvfoSPeMSYZqBzJVOgyLDRG6iagCMgBybnRoBwMvZaGNGIaS94yQmLjWm7QoG-PHslUMVSXYCvpQJoajo5jG-1J2po9IlssJgynXDrIlYFk1RVlvTzs4eh1EuYzhS13zW). Timestamp by third party at Tue Nov 22 09:09:44 CET 2016

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

STICHTING INTERNATIONAL LOFAR TELESCOPE (ILT) NL6, 51272059, established in OUDE HOOGEVEENSEDIJK 4, Dwingeloo 7991 PD, Netherlands, VAT number NL n/a, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('18')

in Grant Agreement No 731016 ('the Agreement')

between STICHTING ASTRON, NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY **and** the European Union ('the EU'), represented by the European Commission ('the Commission'),

for the action entitled 'Advanced European Network of E-infrastructures for Astronomy with the SKA (AENEAS)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

Rene VERMEULEN with ECAS id nvermere signed in the Participant Portal on 01/12/2016 at 11:03:32 (transaction id SigId-76388-1xOHMU7VRytBN2IMp7NibnepjBndAXx5IvzmOa8S09rfzkbi9wzmoV7lvzPBOU9zZrzqigf6Tn26vLnHoZVXROSW-PHslUMVSXYCI4G08U3ZwBS-N5JKxott5BczlX7oYLcMY2NGnveu9HsB1B2hKqn16BQ). Timestamp by third party at Thu Dec 01 11:04:40 CET 2016

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

UPPSALA UNIVERSITET (SNIC), 2021002932, established in SANKT OLOFSGATAN 10 B, UPPSALA 751 05, Sweden, VAT number SE202100293201, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('19')

in Grant Agreement No 731016 ('the Agreement')

between STICHTING ASTRON, NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY **and** the European Union ('the EU'), represented by the European Commission ('the Commission'),

for the action entitled 'Advanced European Network of E-infrastructures for Astronomy with the SKA (AENEAS)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

Katarina BJELKE with ECAS id nfustaaa signed in the Participant Portal on 22/11/2016 at 09:56:58 (transaction id SigId-19138-HSzuHu8TxNGQmJJ5FJOhf7xUk596rmlwJg76ZngWzQQrSkjtzPjoSzihEkYCYRZtLv6xVoMXiaJY1PtGa5wSsbe-PHslUMVSXYCvpQJoajo5jG-PuldnzgFoInqbKVVnzw9QFf2rDNxEAxuCg4JwihipSzy). Timestamp by third party at
Tue Nov 22 09:57:32 CET 2016

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE (EPFL), 414110, established in BATIMENT CE 3316 STATION 1, LAUSANNE 1015, Switzerland, VAT number CHE116075613TVA, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('20')

in Grant Agreement No 731016 ('the Agreement')

between STICHTING ASTRON, NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY **and** the European Union ('the EU'), represented by the European Commission ('the Commission'),

for the action entitled 'Advanced European Network of E-infrastructures for Astronomy with the SKA (AENEAS)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

Andreas MORTENSEN with ECAS id nmortena signed in the Participant Portal on 23/11/2016 at 09:39:02 (transaction id SigId-2851-zelzNzl7SaONrQokKC8am64HhS1RI2U7PYAXFWkl5RRqjFqeiFFgFsdQFN1sIt9hMWtVOeXwvD2hqzw2Aj2KibG-Jj71zxYb8yrgsOBSBvcQLO-LLzoBB5qm6zjlsqzzMAojIqXvMQodAQVl9jJZkZVzIE5G). Timestamp by third party at Wed Nov 23 09:39:46 CET 2016

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

UNIVERSITE DE GENEVE (UNIGE), CHE110644228, established in RUE DU GENERAL DUFOUR 24, GENEVE 1211, Switzerland, VAT number CHE114927636TVA, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('21')

in Grant Agreement No 731016 ('the Agreement')

between STICHTING ASTRON, NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY **and** the European Union ('the EU'), represented by the European Commission ('the Commission'),

for the action entitled 'Advanced European Network of E-infrastructures for Astronomy with the SKA (AENEAS)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

Alex WAEHRY with ECAS id nwaehrax signed in the Participant Portal on 07/12/2016 at 12:26:04 (transaction id SigId-31830-JgkMSd1zhPzJAHFExDcZ4RmauQVYaZBEfsjJvQMlJmSrMU3HX1795rIv2wRUxW2UgCTuzxB6FtPmyEUM4JUla6m-PHslUMVSXYCuynWSMXbHJK-1179zQ2hgndkzkY9zNplbyVa3VkbIQU6zUoGDG564KzVW). Timestamp by third party at
Wed Dec 07 13:26:51 CET 2016

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION (CSIRO), 41687119230, established in CLUNIES ROSS STREET CSIRO BLACK MOUNTAIN SCIENCE AND INNOVATION PARK, ACTON ACT 2601, Australia, VAT number AU41687119230, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('22')

in Grant Agreement No 731016 ('the Agreement')

between STICHTING ASTRON, NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY **and** the European Union ('the EU'), represented by the European Commission ('the Commission'),

for the action entitled 'Advanced European Network of E-infrastructures for Astronomy with the SKA (AENEAS)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

Sarah PEARCE with ECAS id nparcsar signed in the Participant Portal on 08/12/2016 at 23:55:39 (transaction id SigId-23787-i9RXzzWeN5xL1xlH1giQQrBqzoBi9LonXsxTHU5x0wfFupwfh4SoeDbvdtC1C4wJTrGXfCPDD2BcxVdAkMPfzJa-Jj71zxYb8yryEnwGPo6Oly-iNG5d6rtNsncUxlnioa6vi9WupoX0rUasOZp3Zba6mu). Timestamp by third party at
Thu Dec 08 23:56:21 CET 2016

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

AARNET PTY LTD (AARNet) AU7, 084540518, established in 3 RICHARDSON PLACE BINGRY CENTRE LEVEL 2 BUILDING, NORTH RYDE 2113, Australia, VAT number AU54084540518, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('23')

in Grant Agreement No 731016 ('the Agreement')

between STICHTING ASTRON, NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY **and** the European Union ('the EU'), represented by the European Commission ('the Commission'),

for the action entitled 'Advanced European Network of E-infrastructures for Astronomy with the SKA (AENEAS)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

Phillip EDWARDS with ECAS id nedphill signed in the Participant Portal on 20/11/2016 at 23:21:10 (transaction id SigId-194-QaPeVzsDsJzpTWibsmlwhtWYULMXIszMgQ4QK6tJQI3XoC2s8smCEkqh26KLF1izZ1iDGJCTVPnzYAcQTNEEjaS-PHslUMVSXYCvpQJoajo5jG-ArlLSvoZ0exrInym8GV19STPC6v3p1l9lB8ZqaCKlL0). Timestamp by third party at
Sun Nov 20 23:21:40 CET 2016

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

THE RESEARCH TRUST OF VICTORIA UNIVERSITY OF WELLINGTON (VUW) NZ13, CC21718, established in KELBURN PARADE 18, WELLINGTON 6140, New Zealand, VAT number NZ10665485, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('24')

in Grant Agreement No 731016 ('the Agreement')

between STICHTING ASTRON, NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY **and** the European Union ('the EU'), represented by the European Commission ('the Commission'),

for the action entitled 'Advanced European Network of E-infrastructures for Astronomy with the SKA (AENEAS)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

Ian MCINTOSH with ECAS id nintosia signed in the Participant Portal on 02/12/2016 at 04:03:53 (transaction id SigId-91219-wP99hwsFgbrHauYhzhsqXL7pxtpj3Asj90YKfms9VEZagIruik07KPhgzqRDAfauL5bw3kifSLuav3khFtMj37-PHslUMVSXYCI4G08U3ZwBS-6ZzkDmE16BFA4JkYmvUSGfesFW9zrGWuva3sTakeqLZ0). Timestamp by third party at Fri Dec 02 04:04:33 CET 2016

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH (CSIR), 461988, established in Meiring Naude Road, Brummeria 46, PRETORIA 0001, South Africa, VAT number ZA4470114283, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('25')

in Grant Agreement No 731016 ('the Agreement')

between STICHTING ASTRON, NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY **and** the European Union ('the EU'), represented by the European Commission ('the Commission'),

for the action entitled 'Advanced European Network of E-infrastructures for Astronomy with the SKA (AENEAS)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

Leon STAPHORST with ECAS id nstaphle signed in the Participant Portal on 15/12/2016 at 15:09:33 (transaction id SigId-123784-ZU2detUjJ2V4y64wG9OSyLMoP6P3dnRRdeQbF5ipZ4uyXNXrFQhDIrJdj2mKxXp3mrpnBxmmDxxPivPyfBfHCm-Jj71zxYb8yryEnwGPo6Oly-Q6gzjoeZB29f5trLSPCSabfBFB89SACOcfMdA47gFGS). Timestamp by third party at
Thu Dec 15 15:10:15 CET 2016

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

UNIVERSITY OF CAPE TOWN (UCT), established in PRIVATE BAG X3, RONDEBOSCH 7701, South Africa, VAT number 4540125707, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('26')

in Grant Agreement No 731016 ('the Agreement')

between STICHTING ASTRON, NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY **and** the European Union ('the EU'), represented by the European Commission ('the Commission'),

for the action entitled 'Advanced European Network of E-infrastructures for Astronomy with the SKA (AENEAS)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

Piet Barnard with ECAS id nbarnapi signed in the Participant Portal on 21/11/2016 at 08:01:00 (transaction id SigId-908-tyQtA0k81CVkTuytwGULtt0XdJtI2fRyl44xbNgSWXieEkNM4PsR3aWZIzHw1UqG5a7RbEy3YjIMotvfbE6Nh8-PHslUMVSXYCvpQJoajo5jG-KDGPO9og9FCky93PN6WY0al6RYNChpgQqjF3Eze9bay). Timestamp by third party at Mon Nov 21 08:01:30 CET 2016

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

NATIONAL RESEARCH FOUNDATION (NRF), established in Meiring Naude Road Brummeria, PRETORIA 0001, South Africa, VAT number ZA4960119727, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('27')

in Grant Agreement No 731016 ('the Agreement')

between STICHTING ASTRON, NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY **and** the European Union ('the EU'), represented by the European Commission ('the Commission'),

for the action entitled 'Advanced European Network of E-infrastructures for Astronomy with the SKA (AENEAS)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

Jacob MAHLANGU with ECAS id nmahljac signed in the Participant Portal on 21/11/2016 at 07:48:09 (transaction id SigId-842-9R6G3AMejDR7FAhKBgZnq7120zxATLb49seZm5lFn6hl75fia28ZL2a STRGmHwfnhlrjXltvOAHMoH28rmfM64-PHslUMVSXYCvpQJoajo5jG-9q8eTwOUYnwew6FAl7nYYSrcGHPzhZcniYwuXdl1niv). Timestamp by third party at Mon Nov 21 07:48:39 CET 2016

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

RESEARCH DATA ALLIANCE FOUNDATION (RDA), 09021881, established in RUTHERFORD APPLETON LABORATORY HARWELL OXFORD DIDC, OXFORDSHIRE OX11 0QX, United Kingdom, ('the beneficiary'), represented for the purpose of signing this Accession Form by the undersigned,

hereby agrees

to become beneficiary No ('28')

in Grant Agreement No 731016 ('the Agreement')

between STICHTING ASTRON, NETHERLANDS INSTITUTE FOR RADIO ASTRONOMY **and** the European Union ('the EU'), represented by the European Commission ('the Commission'),

for the action entitled 'Advanced European Network of E-infrastructures for Astronomy with the SKA (AENEAS)'.

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 55.

By signing this Accession Form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and conditions it sets out.

SIGNATURE

For the beneficiary

Mark PARSONS with ECAS id npsonsma signed in the Participant Portal on 29/11/2016 at 23:47:41 (transaction id SigId-52413-hCdthIia72WDNv5Ea5rTnV1ZpLgSwe69UCPdx0YTLsJ5LqXGAr3VTEY0F3CdzTEwZQJtrNRzsMnvgC4mUui7Bn-PHslUMVSXYCI4G08U3ZwBS-zJzIUvqWzuATzZsNAAmL6sTlOFkWrtTinxFFmiNSWeWs). Timestamp by third party at
Tue Nov 29 23:48:15 CET 2016

ⓘ print format A4 landscape

MODEL ANNEX 4 FOR H2020 GENERAL MGA — MULTI

FINANCIAL STATEMENT FOR *[BENEFICIARY [name]/ LINKED THIRD PARTY [name]]* FOR REPORTING PERIOD [reporting period]

	Eligible[1] costs (per budget category)											Receipts	EU contribution			Additional information
	A. Direct personnel costs				B. Direct costs of subcontracting	*[C. Direct costs of fin. support]*	D. Other direct costs		E. Indirect costs[2]	*[F. Costs of …]*		Total costs	Receipts	Reimbursement rate %	Maximum EU contribution[3]	Requested EU contribution	Information for indirect costs :
	A.1 Employees (or equivalent) A.2 Natural persons under direct contract A.3 Seconded persons *[A.6 Personnel for providing access to research infrastructure]*		A.4 SME owners without salary A.5 Beneficiaries that are natural persons without salary				D.1 Travel D.2 Equipment D.3 Other goods and services	*[D.4 Costs of large research infrastructure]*		*[F.1 Costs of …]*			Receipts of the action, to be reported in the last reporting period, according to Article 5.3.3				Costs of in-kind contributions not used on premises
Form of costs[4]	Actual	Unit	Unit		Actual	Actual	Actual	Actual	Flat-rate[5] 25%	Unit	Unit						
	a	Total b	No hours	Total c	d	*[e]*	f	*[g]*	h=0,25 x (a+b+ c+f+*[g]* + *[i1]*[6] +*[i2]*[6] - o)	No units	Total *[i1]*	Total *[i2]*	j = a+b+c+d+*[e]* +f +*[g]* +h+*[i1]* +*[i2]*	k	l	m	n	o
[short name beneficiary/linked third party]																	

The beneficiary/linked third party hereby confirms that:
The information provided is complete, reliable and true.
The costs declared are eligible (see Article 6).
The costs can be substantiated by adequate records and supporting documentation that will be produced upon request or in the context of checks, reviews, audits and investigations (see Articles 17, 18 and 22).
For the last reporting period: that all the receipts have been declared (see Article 5.3.3).

ⓘ Please declare all eligible costs, even if they exceed the amounts indicated in the estimated budget (see Annex 2). Only amounts that were declared in your individual financial statements can be taken into account lateron, in order to replace other costs that are found to be ineligible.

[1] See Article 6 for the eligibility conditions

[2] The indirect costs claimed must be free of any amounts covered by an operating grant (received under any EU or Euratom funding programme; see Article 6.2.E). If you have received an operating grant during this reporting period, you cannot claim any indirect costs.

[3] This is the *theoretical* amount of EU contribution that the system calculates automatically (by multiplying the reimbursement rate by the total costs declared). The amount you request (in the column 'requested EU contribution') may have to be less (e.g. if you and the other beneficiaries are above budget, if the 90% limit (see Article 21) is reached, etc).

[4] See Article 5 for the form of costs

[5] Flat rate : 25% of eligible direct costs, from which are excluded: direct costs of subcontracting, costs of in-kind contributions not used on premises, direct costs of financial support, and unit costs declared under budget category F if they include indirect costs (see Article 6.2.E)

[6] Only specific unit costs that do not include indirect costs

ANNEX 5

MODEL FOR THE CERTIFICATE ON THE FINANCIAL STATEMENTS

- **For options [*in italics in square brackets*]: choose the applicable option. Options not chosen should be deleted.**
- **For fields in [grey in square brackets]: enter the appropriate data**

TABLE OF CONTENTS

Terms of Reference for an Independent Report of Factual Findings on costs declared under a Grant Agreement financed under the Horizon 2020 Research and Innovation Framework Programme

This document sets out the '**Terms of Reference (ToR)**' under which

[OPTION 1: [insert name of the beneficiary] ('the Beneficiary')] [OPTION 2: [insert name of the linked third party] ('the Linked Third Party'), third party linked to the Beneficiary [insert name of the beneficiary] ('the Beneficiary')]

agrees to engage

[**insert legal name of the auditor**] ('the Auditor')

to produce an independent report of factual findings ('the Report') concerning the Financial Statement(s)[1] drawn up by the *[Beneficiary] [Linked Third Party]* for the Horizon 2020 grant agreement [insert number of the grant agreement, title of the action, acronym and duration from/to] ('the Agreement'), and

to issue a Certificate on the Financial Statements' ('CFS') referred to in Article 20.4 of the Agreement based on the compulsory reporting template stipulated by the Commission.

The Agreement has been concluded under the Horizon 2020 Research and Innovation Framework Programme (H2020) between the Beneficiary and *[OPTION 1: the European Union, represented by the European Commission ('the Commission')][OPTION 2: the European Atomic Energy Community (Euratom,) represented by the European Commission ('the Commission')][OPTION 3: the [Research Executive Agency (REA)] [European Research Council Executive Agency (ERCEA)] [Innovation and Networks Executive Agency (INEA)] [Executive Agency for Small and Medium-sized Enterprises (EASME)] ('the Agency'), under the powers delegated by the European Commission ('the Commission').]*

[1] By which costs under the Agreement are declared (see template 'Model Financial Statements' in Annex 4 to the Grant Agreement).

The *[Commission] [Agency]* is mentioned as a signatory of the Agreement with the Beneficiary only. The *[European Union][Euratom][Agency]* is not a party to this engagement.

1.1 Subject of the engagement

The coordinator must submit to the *[Commission][Agency]* the final report within 60 days following the end of the last reporting period which should include, amongst other documents, a CFS for each beneficiary and for each linked third party that requests a total contribution of EUR 325 000 or more, as reimbursement of actual costs and unit costs calculated on the basis of its usual cost accounting practices (see Article 20.4 of the Agreement). The CFS must cover all reporting periods of the beneficiary or linked third party indicated above.

The Beneficiary must submit to the coordinator the CFS for itself and for its linked third party(ies), if the CFS must be included in the final report according to Article 20.4 of the Agreement..

The CFS is composed of two separate documents:

- The Terms of Reference ('the ToR') to be signed by the *[Beneficiary] [Linked Third Party]* and the Auditor;
- The Auditor's Independent Report of Factual Findings ('the Report') to be issued on the Auditor's letterhead, dated, stamped and signed by the Auditor (or the competent public officer) which includes the agreed-upon procedures ('the Procedures') to be performed by the Auditor, and the standard factual findings ('the Findings') to be confirmed by the Auditor.

If the CFS must be included in the final report according to Article 20.4 of the Agreement, the request for payment of the balance relating to the Agreement cannot be made without the CFS. However, the payment for reimbursement of costs covered by the CFS does not preclude the *[Commission,][Agency,]* the European Anti-Fraud Office and the European Court of Auditors from carrying out checks, reviews, audits and investigations in accordance with Article 22 of the Agreement.

1.2 Responsibilities

The *[Beneficiary] [Linked Third Party]:*

- must draw up the Financial Statement(s) for the action financed by the Agreement in compliance with the obligations under the Agreement. The Financial Statement(s) must be drawn up according to the *[Beneficiary's] [Linked Third Party's]* accounting and book-keeping system and the underlying accounts and records;
- must send the Financial Statement(s) to the Auditor;
- is responsible and liable for the accuracy of the Financial Statement(s);
- is responsible for the completeness and accuracy of the information provided to enable the Auditor to carry out the Procedures. It must provide the Auditor with a written representation letter supporting these statements. The written representation letter must state the period covered by the statements and must be dated;
- accepts that the Auditor cannot carry out the Procedures unless it is given full access to the *[Beneficiary's] [Linked Third Party's]* staff and accounting as well as any other relevant records and documentation.

The Auditor:

- *[Option 1 by default:* is qualified to carry out statutory audits of accounting documents in accordance with Directive 2006/43/EC of the European Parliament and of the Council of 17 May 2006 on statutory audits of annual accounts and consolidated accounts, amending Council Directives 78/660/EEC and 83/349/EEC and repealing Council Directive 84/253/EEC or similar national regulations*]*.
- *[Option 2 if the Beneficiary or Linked Third Party has an independent Public Officer:* is a competent and independent Public Officer for which the relevant national authorities have established the legal capacity to audit the Beneficiary*].*
- *[Option 3 if the Beneficiary or Linked Third Party is an international organisation:* is an [internal] [external] auditor in accordance with the internal financial regulations and procedures of the international organisation*].*

The Auditor:

- must be independent from the Beneficiary *[and the Linked Third Party]*, in particular, it must not have been involved in preparing the *[Beneficiary's] [Linked Third Party's]* Financial Statement(s);
- must plan work so that the Procedures may be carried out and the Findings may be assessed;
- must adhere to the Procedures laid down and the compulsory report format;
- must carry out the engagement in accordance with this ToR;
- must document matters which are important to support the Report;
- must base its Report on the evidence gathered;
- must submit the Report to the *[Beneficiary] [Linked Third Party]*.

The Commission sets out the Procedures to be carried out by the Auditor. The Auditor is not responsible for their suitability or pertinence. As this engagement is not an assurance engagement, the Auditor does not provide an audit opinion or a statement of assurance.

1.3 Applicable Standards

The Auditor must comply with these Terms of Reference and with[2]:

- the International Standard on Related Services ('ISRS') 4400 *Engagements to perform Agreed-upon Procedures regarding Financial Information* as issued by the International Auditing and Assurance Standards Board (IAASB);
- the *Code of Ethics for Professional Accountants* issued by the International Ethics Standards Board for Accountants (IESBA). Although ISRS 4400 states that independence is not a requirement for engagements to carry out agreed-upon procedures, the *[Commission][Agency]* requires that the Auditor also complies with the Code's independence requirements.

The Auditor's Report must state that there is no conflict of interests in establishing this Report between the Auditor and the Beneficiary *[and the Linked Third Party]*, and must specify - if the service is invoiced - the total fee paid to the Auditor for providing the Report.

1.4 Reporting

The Report must be written in the language of the Agreement (see Article 20.7).

Under Article 22 of the Agreement, the [*Commission*] [*Agency*], the European Anti-Fraud Office and the Court of Auditors have the right to audit any work that is carried out under the action and for which costs are declared from [*the European Union*] [*Euratom*] budget. This includes work related to this engagement. The Auditor must provide access to all working papers (e.g. recalculation of hourly rates, verification of the time declared for the action) related to this assignment if the *[Commission] [Agency]*, the European Anti-Fraud Office or the European Court of Auditors requests them.

1.5 Timing

The Report must be provided by *[*dd Month yyyy*]*.

[2] Supreme Audit Institutions applying INTOSAI-standards may carry out the Procedures according to the corresponding International Standards of Supreme Audit Institutions and code of ethics issued by INTOSAI instead of the International Standard on Related Services ('ISRS') 4400 and the Code of Ethics for Professional Accountants issued by the IAASB and the IESBA.

1.6 Other terms

[*The [Beneficiary] [Linked Third Party] and the Auditor can use this section to agree other specific terms, such as the Auditor's fees, liability, applicable law, etc. Those specific terms must not contradict the terms specified above.*]

[legal name of the Auditor]	[legal name of the *[Beneficiary][Linked Third Party]*]
[name & function of authorised representative]	[name & function of authorised representative]
[dd Month yyyy]	[dd Month yyyy]
Signature of the Auditor	Signature of the *[Beneficiary][Linked Third Party]*

Independent Report of Factual Findings on costs declared under Horizon 2020 Research and Innovation Framework Programme

(To be printed on the Auditor's letterhead)

To

[name of contact person(s)], [Position]

[[*Beneficiary's*] [*Linked Third Party's*] name]

[Address]

[dd Month yyyy]

Dear [Name of contact person(s)],

As agreed under the terms of reference dated [dd Month yyyy]

with *[OPTION 1: [insert name of the beneficiary] ('the Beneficiary')] [OPTION 2: [insert name of the linked third party] ('the Linked Third Party'), third party linked to the Beneficiary [insert name of the beneficiary] ('the Beneficiary')],*

we

[name of the auditor] ('the Auditor'),

established at

[full address/city/state/province/country],

represented by

[name and function of an authorised representative],

have carried out the procedures agreed with you regarding the costs declared in the Financial Statement(s)[3] of the *[Beneficiary] [Linked Third Party]* concerning the grant agreement

[insert grant agreement reference: number, title of the action and acronym] ('the Agreement'),

with a total cost declared of

[total amount] EUR,

and a total of actual costs and 'direct personnel costs declared as unit costs calculated in accordance with the [*Beneficiary's*] [*Linked Third Party's*] usual cost accounting practices' declared of

[sum of total actual costs and total direct personnel costs declared as unit costs calculated in accordance with the *[Beneficiary's] [Linked Third Party's]* usual cost accounting practices] EUR

and **hereby provide our Independent Report of Factual Findings ('the Report')** using the compulsory report format agreed with you.

The Report

Our engagement was carried out in accordance with the terms of reference ('the ToR') appended to this Report. The Report includes the agreed-upon procedures ('the Procedures') carried out and the standard factual findings ('the Findings') examined.

The Procedures were carried out solely to assist the [*Commission*] [*Agency*] in evaluating whether the [*Beneficiary's*] [*Linked Third Party's*] costs in the accompanying Financial Statement(s) were declared in accordance with the Agreement. The *[Commission] [Agency]* draws its own conclusions from the Report and any additional information it may require.

[3] By which the Beneficiary declares costs under the Agreement (see template 'Model Financial Statement' in Annex 4 to the Agreement).

The scope of the Procedures was defined by the Commission. Therefore, the Auditor is not responsible for their suitability or pertinence. Since the Procedures carried out constitute neither an audit nor a review made in accordance with International Standards on Auditing or International Standards on Review Engagements, the Auditor does not give a statement of assurance on the Financial Statements.

Had the Auditor carried out additional procedures or an audit of the *[Beneficiary's] [Linked Third Party's]* Financial Statements in accordance with International Standards on Auditing or International Standards on Review Engagements, other matters might have come to its attention and would have been included in the Report.

Not applicable Findings

We examined the Financial Statement(s) stated above and considered the following Findings not applicable:

Explanation (to be removed from the Report):

*If a Finding was not applicable, it must be marked as '**N.A.**' ('Not applicable') in the corresponding row on the right-hand column of the table and means that the Finding did not have to be corroborated by the Auditor and the related Procedure(s) did not have to be carried out.*

The reasons of the non-application of a certain Finding must be obvious i.e.

i) if no cost was declared under a certain category then the related Finding(s) and Procedure(s) are not applicable;

ii) if the condition set to apply certain Procedure(s) are not met the related Finding(s) and those Procedure(s) are not applicable. For instance, for 'beneficiaries with accounts established in a currency other than euro' the Procedure and Finding related to 'beneficiaries with accounts established in euro' are not applicable. Similarly, if no additional remuneration is paid, the related Finding(s) and Procedure(s) for additional remuneration are not applicable.

List here all Findings considered not applicable for the present engagement and explain the reasons of the non-applicability.

….

Exceptions

Apart from the exceptions listed below, the *[Beneficiary] [Linked Third Party]* provided the Auditor all the documentation and accounting information needed by the Auditor to carry out the requested Procedures and evaluate the Findings.

Explanation (to be removed from the Report):

- *If the Auditor was not able to successfully complete a procedure requested, it must be marked as '**E**' ('Exception') in the corresponding row on the right-hand column of the table. The reason such as the inability to reconcile key information or the unavailability of data that prevents the Auditor from carrying out the Procedure must be indicated below.*
- *If the Auditor cannot corroborate a standard finding after having carried out the corresponding procedure, it must also be marked as '**E**' ('Exception') and, where possible, the reasons why the Finding was not fulfilled and its possible impact must be explained here below.*

List here any exceptions and add any information on the cause and possible consequences of each exception, if known. If the exception is quantifiable, include the corresponding amount.

….

Example (to be removed from the Report):

1. *The Beneficiary was unable to substantiate the Finding number 1 on … because ….*
2. *Finding number 30 was not fulfilled because the methodology used by the Beneficiary to calculate unit costs was different from the one approved by the Commission. The differences were as follows: …*
3. *After carrying out the agreed procedures to confirm the Finding number 31, the Auditor found a difference of _____ EUR. The difference can be explained by …*

Further Remarks

In addition to reporting on the results of the specific procedures carried out, the Auditor would like to make the following general remarks:

Example (to be removed from the Report):

1. *Regarding Finding number 8 the conditions for additional remuneration were considered as fulfilled because …*
2. *In order to be able to confirm the Finding number 15 we carried out the following additional procedures: ….*

Use of this Report

This Report may be used only for the purpose described in the above objective. It was prepared solely for the confidential use of the *[Beneficiary] [Linked Third Party]* and the [*Commission*] [*Agency*], and only to be submitted to the [*Commission*] [*Agency*] in connection with the requirements set out in Article 20.4 of the Agreement. The Report may not be used by the *[Beneficiary] [Linked Third Party]* or by the [*Commission*] [*Agency*] for any other purpose, nor may it

be distributed to any other parties. The [*Commission*] [*Agency*] may only disclose the Report to authorised parties, in particular to the European Anti-Fraud Office (OLAF) and the European Court of Auditors.

This Report relates only to the Financial Statement(s) submitted to the *[Commission] [Agency]* by the *[Beneficiary] [Linked Third Party]* for the Agreement. Therefore, it does not extend to any other of the [*Beneficiary's*] [*Linked Third Party's*] Financial Statement(s).

There was no conflict of interest[4] between the Auditor and the Beneficiary *[and Linked Third Party]* in establishing this Report. The total fee paid to the Auditor for providing the Report was EUR _____ (including EUR_____ of deductible VAT).

We look forward to discussing our Report with you and would be pleased to provide any further information or assistance.

[legal name of the Auditor]

[name and function of an authorised representative]

[dd Month yyyy]

Signature of the Auditor

[4] A conflict of interest arises when the Auditor's objectivity to establish the certificate is compromised in fact or in appearance when the Auditor for instance:
- was involved in the preparation of the Financial Statements;
- stands to benefit directly should the certificate be accepted;
- has a close relationship with any person representing the beneficiary;
- is a director, trustee or partner of the beneficiary; or
- is in any other situation that compromises his or her independence or ability to establish the certificate impartially.

Agreed-upon procedures to be performed and standard factual findings to be confirmed by the Auditor

The European Commission reserves the right to i) provide the auditor with additional guidance regarding the procedures to be followed or the facts to be ascertained and the way in which to present them (this may include sample coverage and findings) or to ii) change the procedures, by notifying the Beneficiary in writing. The procedures carried out by the auditor to confirm the standard factual finding are listed in the table below.

If this certificate relates to a Linked Third Party, any reference here below to 'the Beneficiary' is to be considered as a reference to 'the Linked Third Party'.

The 'result' column has three different options: 'C', 'E' and 'N.A.':

- 'C' stands for 'confirmed' and means that the auditor can confirm the 'standard factual finding' and, therefore, there is no exception to be reported.
- 'E' stands for 'exception' and means that the Auditor carried out the procedures but cannot confirm the 'standard factual finding', or that the Auditor was not able to carry out a specific procedure (e.g. because it was impossible to reconcile key information or data were unavailable),
- 'N.A.' stands for 'not applicable' and means that the Finding did not have to be examined by the Auditor and the related Procedure(s) did not have to be carried out. The reasons of the non-application of a certain Finding must be obvious i.e. i) if no cost was declared under a certain category then the related Finding(s) and Procedure(s) are not applicable; ii) if the condition set to apply certain Procedure(s) are not met then the related Finding(s) and Procedure(s) are not applicable. For instance, for 'beneficiaries with accounts established in a currency other than the euro' the Procedure related to 'beneficiaries with accounts established in euro' is not applicable. Similarly, if no additional remuneration is paid, the related Finding(s) and Procedure(s) for additional remuneration are not applicable.

Ref	Procedures	Standard factual finding	Result (C / E / N.A.)
A	**ACTUAL PERSONNEL COSTS AND UNIT COSTS CALCULATED BY THE BENEFICIARY IN ACCORDANCE WITH ITS USUAL COST ACCOUNTING PRACTICE**		

Ref	Procedures	Standard factual finding	Result (C / E / N.A.)
	The Auditor draws a sample of persons whose costs were declared in the Financial Statement(s) to carry out the procedures indicated in the consecutive points of this section A. (*The sample should be selected randomly so that it is representative. Full coverage is required if there are fewer than 10 people (including employees, natural persons working under a direct contract and personnel seconded by a third party), otherwise the sample should have a minimum of 10 people, or 10% of the total, whichever number is the highest)* The Auditor sampled _____ people out of the total of _____ people.		
A.1	**PERSONNEL COSTS** <u>For the persons included in the sample and working under an employment contract or equivalent act (general procedures for individual actual personnel costs and personnel costs declared as unit costs)</u> To confirm standard factual findings 1-5 listed in the next column, the Auditor reviewed following information/documents provided by the Beneficiary: ○ a list of the persons included in the sample indicating the period(s) during which they worked for the action, their position (classification or category) and type of contract; ○ the payslips of the employees included in the sample; ○ reconciliation of the personnel costs declared in the Financial Statement(s) with the accounting system (project accounting and general ledger) and payroll system; ○ information concerning the employment status and employment conditions of personnel included in the sample, in particular their employment contracts or equivalent;	1) The employees were i) directly hired by the Beneficiary in accordance with its national legislation, ii) under the Beneficiary's sole technical supervision and responsibility and iii) remunerated in accordance with the Beneficiary's usual practices.	
		2) Personnel costs were recorded in the Beneficiary's accounts/payroll system.	
		3) Costs were adequately supported and reconciled with the accounts and payroll	

Ref	Procedures	Standard factual finding	Result (C / E / N.A.)
	○ the Beneficiary's usual policy regarding payroll matters (e.g. salary policy, overtime policy, variable pay); ○ applicable national law on taxes, labour and social security and ○ any other document that supports the personnel costs declared. The Auditor also verified the eligibility of all components of the retribution (see Article 6 GA) and recalculated the personnel costs for employees included in the sample.	records.	
		4) Personnel costs did not contain any ineligible elements.	
		5) There were no discrepancies between the personnel costs charged to the action and the costs recalculated by the Auditor.	
	Further procedures if 'additional remuneration' is paid To confirm standard factual findings 6-9 listed in the next column, the Auditor: ○ reviewed relevant documents provided by the Beneficiary (legal form, legal/statutory obligations, the Beneficiary's usual policy on additional remuneration, criteria used for its calculation…); ○ recalculated the amount of additional remuneration eligible for the action based on the supporting documents received (full-time or part-time work, exclusive or non-exclusive dedication to the action, etc.) to arrive at the applicable FTE/year and pro-rata rate (see data collected in the course of carrying out the procedures under A.2 'Productive hours' and A.4 'Time recording system').	6) The Beneficiary paying "additional remuneration" was a non-profit legal entity.	
		7) The amount of additional remuneration paid corresponded to the Beneficiary's usual remuneration practices and was consistently paid whenever the same kind of work or expertise was required.	

Ref	Procedures	Standard factual finding	Result (C / E / N.A.)
	IF ANY PART OF THE REMUNERATION PAID TO THE EMPLOYEE IS NOT MANDATORY ACCORDING TO THE NATIONAL LAW OR THE EMPLOYMENT CONTRACT ("ADDITIONAL REMUNERATION") AND IS ELIGIBLE UNDER THE PROVISIONS OF ARTICLE 6.2.A.1, THIS CAN BE CHARGED AS ELIGIBLE COST TO THE ACTION UP TO THE FOLLOWING AMOUNT: *(A) IF THE PERSON WORKS FULL TIME AND EXCLUSIVELY ON THE ACTION DURING THE FULL YEAR: UP TO EUR 8 000/YEAR;* *(B) IF THE PERSON WORKS EXCLUSIVELY ON THE ACTION BUT NOT FULL-TIME OR NOT FOR THE FULL YEAR: UP TO THE CORRESPONDING PRO-RATA AMOUNT OF EUR 8 000, OR* *(C) IF THE PERSON DOES NOT WORK EXCLUSIVELY ON THE ACTION: UP TO A PRO-RATA AMOUNT CALCULATED IN ACCORDANCE TO ARTICLE 6.2.A.1.*	8) The criteria used to calculate the additional remuneration were objective and generally applied by the Beneficiary regardless of the source of funding used.	
		9) The amount of additional remuneration included in the personnel costs charged to the action was capped at EUR 8,000 per FTE/year (up to the equivalent pro-rata amount if the person did not work on the action full-time during the year or did not work exclusively on the action).	
	Additional procedures in case "unit costs calculated by the Beneficiary in accordance with its usual cost accounting practices" is applied: Apart from carrying out the procedures indicated above to confirm standard factual findings 1-5 and, if applicable, also 6-9, the Auditor carried out following procedures to confirm standard factual findings 10-13 listed in the next column:	10) The personnel costs included in the Financial Statement were calculated in accordance with the Beneficiary's usual cost accounting practice. This methodology was consistently used in all H2020 actions.	

Ref	Procedures	Standard factual finding	Result (C / E / N.A.)
	○ obtained a description of the Beneficiary's usual cost accounting practice to calculate unit costs;. ○ reviewed whether the Beneficiary's usual cost accounting practice was applied for the Financial Statements subject of the present CFS; ○ verified the employees included in the sample were charged under the correct category (in accordance with the criteria used by the Beneficiary to establish personnel categories) by reviewing the contract/HR-record or analytical accounting records; ○ verified that there is no difference between the total amount of personnel costs used in calculating the cost per unit and the total amount of personnel costs recorded in the statutory accounts; ○ verified whether actual personnel costs were adjusted on the basis of budgeted or estimated elements and, if so, verified whether those elements used are actually relevant for the calculation, objective and supported by documents.	11) The employees were charged under the correct category.	
		12) Total personnel costs used in calculating the unit costs were consistent with the expenses recorded in the statutory accounts.	
		13) Any estimated or budgeted element used by the Beneficiary in its unit-cost calculation were relevant for calculating personnel costs and corresponded to objective and verifiable information.	
	<u>For natural persons included in the sample and working with the Beneficiary under a direct contract other than an employment contract, such as consultants (no subcontractors).</u> To confirm standard factual findings 14-18 listed in the next column the Auditor reviewed following information/documents provided by the Beneficiary: ○ the contracts, especially the cost, contract duration, work description, place of work, ownership of the results and reporting obligations to the Beneficiary;	14) The natural persons reported to the Beneficiary (worked under the Beneficiary's instructions).	
		15) They worked on the Beneficiary's premises (unless otherwise agreed with the Beneficiary).	

Ref	Procedures	Standard factual finding	Result (C / E / N.A.)
	○ the employment conditions of staff in the same category to compare costs and; ○ any other document that supports the costs declared and its registration (e.g. invoices, accounting records, etc.).	16) The results of work carried out belong to the Beneficiary.	
		17) Their costs were not significantly different from those for staff who performed similar tasks under an employment contract with the Beneficiary.	
		18) The costs were supported by audit evidence and registered in the accounts.	
	<u>For personnel seconded by a third party and included in the sample (not subcontractors)</u> To confirm standard factual findings 19-22 listed in the next column, the Auditor reviewed following information/documents provided by the Beneficiary: ○ their secondment contract(s) notably regarding costs, duration, work description, place of work and ownership of the results; ○ if there is reimbursement by the Beneficiary to the third party for the resource made available (in-kind contribution against payment): any documentation that supports the costs declared (e.g. contract, invoice, bank payment, and proof of registration in its accounting/payroll, etc.) and reconciliation of the Financial Statement(s) with the accounting system (project accounting and general ledger) as well as any proof that the amount invoiced by the third party did not include any profit;	19) Seconded personnel reported to the Beneficiary and worked on the Beneficiary's premises (unless otherwise agreed with the Beneficiary).	
		20) The results of work carried out belong to the Beneficiary.	
		If personnel is seconded against payment: 21) The costs declared were supported with documentation and recorded in the	

Ref	Procedures	Standard factual finding	Result (C / E / N.A.)
	○ if there is no reimbursement by the Beneficiary to the third party for the resource made available (in-kind contribution free of charge): a proof of the actual cost borne by the Third Party for the resource made available free of charge to the Beneficiary such as a statement of costs incurred by the Third Party and proof of the registration in the Third Party's accounting/payroll; ○ any other document that supports the costs declared (e.g. invoices, etc.).	Beneficiary's accounts. The third party did not include any profit.	
		If personnel is seconded free of charge: 22) The costs declared did not exceed the third party's cost as recorded in the accounts of the third party and were supported with documentation.	
A.2	**PRODUCTIVE HOURS** To confirm standard factual findings 23-28 listed in the next column, the Auditor reviewed relevant documents, especially national legislation, labour agreements and contracts and time records of the persons included in the sample, to verify that: ○ the annual productive hours applied were calculated in accordance with one of the methods described below, ○ the full-time equivalent (FTEs) ratios for employees not working full-time were correctly calculated.	23) The Beneficiary applied method [*choose one option and delete the others*] [**A**: 1720 hours] [**B**: the 'total number of hours worked'] [**C**: 'annual productive hours' used correspond to usual accounting practices]	

Ref	Procedures	Standard factual finding	Result (C / E / N.A.)
	If the Beneficiary applied method B, the auditor verified that the correctness in which the total number of hours worked was calculated and that the contracts specified the annual workable hours. If the Beneficiary applied method C, the auditor verified that the 'annual productive hours' applied when calculating the hourly rate were equivalent to at least 90 % of the 'standard annual workable hours'. The Auditor can only do this if the calculation of the standard annual workable hours can be supported by records, such as national legislation, labour agreements, and contracts. *BENEFICIARY'S PRODUCTIVE HOURS' FOR PERSONS WORKING FULL TIME SHALL BE ONE OF THE FOLLOWING METHODS:* ***A.*** *1720 ANNUAL PRODUCTIVE HOURS (PRO-RATA FOR PERSONS NOT WORKING FULL-TIME)* ***B.*** *THE TOTAL NUMBER OF HOURS WORKED BY THE PERSON FOR THE BENEFICIARY IN THE YEAR (THIS METHOD IS ALSO REFERRED TO AS 'TOTAL NUMBER OF HOURS WORKED' IN THE NEXT COLUMN). THE CALCULATION OF THE TOTAL NUMBER OF HOURS WORKED WAS DONE AS FOLLOWS: ANNUAL WORKABLE HOURS OF THE PERSON ACCORDING TO THE EMPLOYMENT CONTRACT, APPLICABLE LABOUR AGREEMENT OR NATIONAL LAW PLUS OVERTIME WORKED MINUS ABSENCES (SUCH AS SICK LEAVE OR SPECIAL LEAVE).*	24) Productive hours were calculated annually.	
		25) For employees not working full-time the full-time equivalent (FTE) ratio was correctly applied.	
		If the Beneficiary applied method B. 26) The calculation of the number of 'annual workable hours', overtime and absences was verifiable based on the documents provided by the Beneficiary.	
		If the Beneficiary applied method C. 27) The calculation of the number of 'standard annual workable hours' was verifiable based on the documents provided by the Beneficiary.	

Ref	Procedures	Standard factual finding	Result (C / E / N.A.)
	C. THE STANDARD NUMBER OF ANNUAL HOURS GENERALLY APPLIED BY THE BENEFICIARY FOR ITS PERSONNEL IN ACCORDANCE WITH ITS USUAL COST ACCOUNTING PRACTICES (THIS METHOD IS ALSO REFERRED TO AS 'TOTAL ANNUAL PRODUCTIVE HOURS' IN THE NEXT COLUMN). THIS NUMBER MUST BE AT LEAST 90% OF THE STANDARD ANNUAL WORKABLE HOURS. *'ANNUAL WORKABLE HOURS' MEANS THE PERIOD DURING WHICH THE PERSONNEL MUST BE WORKING, AT THE EMPLOYER'S DISPOSAL AND CARRYING OUT HIS/HER ACTIVITY OR DUTIES UNDER THE EMPLOYMENT CONTRACT, APPLICABLE COLLECTIVE LABOUR AGREEMENT OR NATIONAL WORKING TIME LEGISLATION.*	28) The 'annual productive hours' used for calculating the hourly rate were consistent with the usual cost accounting practices of the Beneficiary and were equivalent to at least 90 % of the 'annual workable hours'.	
A.3	**HOURLY PERSONNEL RATES** <u>I) For unit costs calculated in accordance to the Beneficiary's usual cost accounting practice (unit costs):</u> If the Beneficiary has a "Certificate on Methodology to calculate unit costs " (CoMUC) approved by the Commission, the Beneficiary provides the Auditor with a description of the approved methodology and the Commission's letter of acceptance. The Auditor verified that the Beneficiary has indeed used the methodology approved. If so, no further verification is necessary. If the Beneficiary does not have a "Certificate on Methodology" (CoMUC) approved by the	29) The Beneficiary applied [*choose one option and delete the other*]: [Option I: "Unit costs (hourly rates) were calculated in accordance with the Beneficiary's usual cost accounting practices"] [Option II: Individual hourly rates were applied]	

Ref	Procedures	Standard factual finding	Result (C / E / N.A.)
	Commission, or if the methodology approved was not applied, then the Auditor: o reviewed the documentation provided by the Beneficiary, including manuals and internal guidelines that explain how to calculate hourly rates; o recalculated the unit costs (hourly rates) of staff included in the sample following the results of the procedures carried out in A.1 and A.2. II) For individual hourly rates: The Auditor: o reviewed the documentation provided by the Beneficiary, including manuals and internal guidelines that explain how to calculate hourly rates; o recalculated the hourly rates of staff included in the sample following the results of the procedures carried out in A.1 and A.2. *"UNIT COSTS CALCULATED BY THE BENEFICIARY IN ACCORDANCE WITH ITS USUAL COST ACCOUNTING PRACTICES":* *IT IS CALCULATED BY DIVIDING THE TOTAL AMOUNT OF PERSONNEL COSTS OF THE CATEGORY TO WHICH THE EMPLOYEE BELONGS VERIFIED IN LINE WITH PROCEDURE A.1 BY THE NUMBER OF FTE AND THE ANNUAL TOTAL PRODUCTIVE HOURS OF THE SAME CATEGORY CALCULATED BY THE BENEFICIARY IN ACCORDANCE WITH PROCEDURE A.2.* *HOURLY RATE FOR INDIVIDUAL ACTUAL PERSONAL COSTS:* *IT IS CALCULATED BY DIVIDING THE TOTAL AMOUNT OF PERSONNEL COSTS OF AN EMPLOYEE VERIFIED IN LINE WITH*	*For option I concerning unit costs and if the Beneficiary applies the methodology approved by the Commission (CoMUC):* 30) The Beneficiary used the Commission-approved methodology to calculate hourly rates. It corresponded to the organisation's usual cost accounting practices and was applied consistently for all activities irrespective of the source of funding.	
		For option I concerning unit costs and if the Beneficiary applies a methodology not approved by the Commission: 31) The unit costs re-calculated by the Auditor were the same as the rates applied by the Beneficiary.	
		For option II concerning individual hourly rates:	

Ref	Procedures	Standard factual finding	Result (C / E / N.A.)
	PROCEDURE A.1 BY THE NUMBER OF ANNUAL PRODUCTIVE HOURS VERIFIED IN LINE WITH PROCEDURE A.2.	32) The individual rates re-calculated by the Auditor were the same as the rates applied by the Beneficiary.	
A.4	**TIME RECORDING SYSTEM** To verify that the time recording system ensures the fulfilment of all minimum requirements and that the hours declared for the action were correct, accurate and properly authorised and supported by documentation, the Auditor made the following checks for the persons included in the sample that declare time as worked for the action on the basis of time records: o description of the time recording system provided by the Beneficiary (registration, authorisation, processing in the HR-system); o its actual implementation; o time records were signed at least monthly by the employees (on paper or electronically) and authorised by the project manager or another manager; o the hours declared were worked within the project period; o there were no hours declared as worked for the action if HR-records showed absence due to holidays or sickness (further cross-checks with travels are carried out in B.1 below) ;	33) All persons recorded their time dedicated to the action on a **daily/ weekly/ monthly** basis using a **paper/computer-based** system. (*delete the answers that are not applicable)*	
		34) Their time-records were authorised at least monthly by the project manager or other superior.	
		35) Hours declared were worked within the project period and were consistent with the presences/absences recorded in HR-records.	

Ref	Procedures	Standard factual finding	Result (C / E / N.A.)
	○ the hours charged to the action matched those in the time recording system. *ONLY THE HOURS WORKED ON THE ACTION CAN BE CHARGED. ALL WORKING TIME TO BE CHARGED SHOULD BE RECORDED THROUGHOUT THE DURATION OF THE PROJECT, ADEQUATELY SUPPORTED BY EVIDENCE OF THEIR REALITY AND RELIABILITY (SEE SPECIFIC PROVISIONS BELOW FOR PERSONS WORKING EXCLUSIVELY FOR THE ACTION WITHOUT TIME RECORDS).*	36) There were no discrepancies between the number of hours charged to the action and the number of hours recorded.	
	<u>If the persons are working exclusively for the action and without time records</u> For the persons selected that worked exclusively for the action without time records, the Auditor verified evidence available demonstrating that they were in reality exclusively dedicated to the action and that the Beneficiary signed a declaration confirming that they have worked exclusively for the action.	37) The exclusive dedication is supported by a declaration signed by the Beneficiary's and by any other evidence gathered.	
B	**COSTS OF SUBCONTRACTING**		
B.1	**The Auditor obtained the detail/breakdown of subcontracting costs and sampled _____ cost items selected randomly** (*full coverage is required if there are fewer than 10 items, otherwise the sample should have a minimum of 10 item, or 10% of the total, whichever number is highest*). To confirm standard factual findings 38-42 listed in the next column, the Auditor reviewed the	38) The use of claimed subcontracting costs was foreseen in Annex 1 and costs were declared in the Financial Statements under the subcontracting category.	

Ref	Procedures	Standard factual finding	Result (C / E / N.A.)
	following for the items included in the sample: o the use of subcontractors was foreseen in Annex 1; o subcontracting costs were declared in the subcontracting category of the Financial Statement; o supporting documents on the selection and award procedure were followed; o the Beneficiary ensured best value for money (key elements to appreciate the respect of this principle are the award of the subcontract to the bid offering best price-quality ratio, under conditions of transparency and equal treatment. In case an existing framework contract was used the Beneficiary ensured it was established on the basis of the principle of best value for money under conditions of transparency and equal treatment). In particular, i. if the Beneficiary acted as a contracting authority within the meaning of Directive 2004/18/EC or of Directive 2004/17/EC, the Auditor verified that the applicable national law on public procurement was followed and that the subcontracting complied with the Terms and Conditions of the Agreement. ii. if the Beneficiary did not fall under the above-mentioned category the Auditor verified that the Beneficiary followed their usual procurement rules and respected the Terms and Conditions of the Agreement..	39) There were documents of requests to different providers, different offers and assessment of the offers before selection of the provider in line with internal procedures and procurement rules. Subcontracts were awarded in accordance with the principle of best value for money. *(When different offers were not collected the Auditor explains the reasons provided by the Beneficiary under the caption "Exceptions" of the Report. The Commission will analyse this information to evaluate whether these costs might be accepted as eligible)*	
	For the items included in the sample the Auditor also verified that: o the subcontracts were not awarded to other Beneficiaries in the consortium;	40) The subcontracts were not awarded to other Beneficiaries of the consortium.	

Ref	Procedures	Standard factual finding	Result (C / E / N.A.)
	○ there were signed agreements between the Beneficiary and the subcontractor; ○ there was evidence that the services were provided by subcontractor;	41) All subcontracts were supported by signed agreements between the Beneficiary and the subcontractor.	
		42) There was evidence that the services were provided by the subcontractors.	
C	**COSTS OF PROVIDING FINANCIAL SUPPORT TO THIRD PARTIES**		
C.1	**The Auditor obtained the detail/breakdown of the costs of providing financial support to third parties and sampled _____ cost items selected randomly** (*full coverage is required if there are fewer than 10 items, otherwise the sample should have a minimum of 10 item, or 10% of the total, whichever number is highest*). The Auditor verified that the following minimum conditions were met: a) the maximum amount of financial support for each third party did not exceed EUR 60 000, unless explicitly mentioned in Annex 1; b) the financial support to third parties was agreed in Annex 1 of the Agreement and the other provisions on financial support to third parties included in Annex 1 were	43) All minimum conditions were met	

Ref	Procedures	Standard factual finding	Result (C / E / N.A.)
	respected.		

D	OTHER ACTUAL DIRECT COSTS		
D.1	**COSTS OF TRAVEL AND RELATED SUBSISTENCE ALLOWANCES** **The Auditor sampled _____ cost items selected randomly** (*full coverage is required if there are fewer than 10 items, otherwise the sample should have a minimum of 10 item, or 10% of the total, whichever number is the highest*). The Auditor inspected the sample and verified that: ○ travel and subsistence costs were consistent with the Beneficiary's usual policy for travel. In this context, the Beneficiary provided evidence of its normal policy for travel costs (e.g. use of first class tickets, reimbursement by the Beneficiary on the basis of actual costs, a lump sum or per diem) to enable the Auditor to compare the travel costs charged with this policy; ○ travel costs are correctly identified and allocated to the action (e.g. trips are directly linked to the action) by reviewing relevant supporting documents such as minutes of meetings, workshops or conferences, their registration in the correct project account, their consistency with time records or with the dates/duration of the workshop/conference; ○ no ineligible costs or excessive or reckless expenditure was declared.	44) Costs were incurred, approved and reimbursed in line with the Beneficiary's usual policy for travels.	
		45) There was a link between the trip and the action.	
		46) The supporting documents were consistent with each other regarding subject of the trip, dates, duration and reconciled with time records and accounting.	
		47) No ineligible costs or excessive or reckless expenditure was declared.	
D.2	**DEPRECIATION COSTS FOR EQUIPMENT, INFRASTRUCTURE OR OTHER ASSETS** **The Auditor sampled _____ cost items selected randomly** (*full coverage is required if there are fewer than 10 items, otherwise the sample should have a minimum of 10 item, or 10% of the total, whichever number is the highest*). For "equipment, infrastructure or other assets" [from now on called "asset(s)"] selected in the	48) Procurement rules, principles and guides were followed.	
		49) There was a link between the grant agreement and the asset charged to the action.	

	sample the Auditor verified that: ○ the assets were acquired in conformity with the Beneficiary's internal guidelines and procedures; ○ they were correctly allocated to the action (with supporting documents such as delivery note invoice or any other proof demonstrating the link to the action) ○ they were entered in the accounting system; ○ the extent to which the assets were used for the action (as a percentage) was supported by reliable documentation (e.g. usage overview table); The Auditor recalculated the depreciation costs and verified that they were in line with the applicable rules in the Beneficiary's country and with the Beneficiary's usual accounting policy (e.g. depreciation calculated on the acquisition value). The Auditor verified that no ineligible costs such as deductible VAT, exchange rate losses, excessive or reckless expenditure were declared (see Article 6.5 GA).	50) The asset charged to the action was traceable to the accounting records and the underlying documents. 51) The depreciation method used to charge the asset to the action was in line with the applicable rules of the Beneficiary's country and the Beneficiary's usual accounting policy. 52) The amount charged corresponded to the actual usage for the action. 53) No ineligible costs or excessive or reckless expenditure were declared.	
D.3	**COSTS OF OTHER GOODS AND SERVICES** **The Auditor sampled _____ cost items selected randomly** (*full coverage is required if there are fewer than 10 items, otherwise the sample should have a minimum of 10 item, or 10% of the total, whichever number is highest*). For the purchase of goods, works or services included in the sample the Auditor verified that: ○ the contracts did not cover tasks described in Annex 1;	54) Contracts for works or services did not cover tasks described in Annex 1. 55) Costs were allocated to the correct action and the goods were not placed in the inventory of durable equipment.	

	○ they were correctly identified, allocated to the proper action, entered in the accounting system (traceable to underlying documents such as purchase orders, invoices and accounting); ○ the goods were not placed in the inventory of durable equipment; ○ the costs charged to the action were accounted in line with the Beneficiary's usual accounting practices; ○ no ineligible costs or excessive or reckless expenditure were declared (see Article 6 GA). In addition, the Auditor verified that these goods and services were acquired in conformity with the Beneficiary's internal guidelines and procedures, in particular: ○ if Beneficiary acted as a contracting authority within the meaning of Directive 2004/18/EC or of Directive 2004/17/EC, the Auditor verified that the applicable national law on public procurement was followed and that the procurement contract complied with the Terms and Conditions of the Agreement. ○ if the Beneficiary did not fall into the category above, the Auditor verified that the Beneficiary followed their usual procurement rules and respected the Terms and Conditions of the Agreement. For the items included in the sample the Auditor also verified that: ○ the Beneficiary ensured best value for money (key elements to appreciate the respect of this principle are the award of the contract to the bid offering best price-quality ratio, under conditions of transparency and equal treatment. In case an existing framework contract was used the Auditor also verified that the Beneficiary ensured it was established on the basis of the principle of best value for money under conditions of transparency and equal treatment); *SUCH GOODS AND SERVICES INCLUDE, FOR INSTANCE, CONSUMABLES AND SUPPLIES, DISSEMINATION (INCLUDING OPEN ACCESS), PROTECTION OF RESULTS, SPECIFIC EVALUATION OF THE ACTION IF IT IS REQUIRED BY THE*	56) The costs were charged in line with the Beneficiary's accounting policy and were adequately supported. 57) No ineligible costs or excessive or reckless expenditure were declared. For internal invoices/charges only the cost element was charged, without any mark-ups. 58) Procurement rules, principles and guides were followed. There were documents of requests to different providers, different offers and assessment of the offers before selection of the provider in line with internal procedures and procurement rules. The purchases were made in accordance with the principle of best value for money. *(When different offers were not collected the Auditor explains the reasons provided by the Beneficiary under the*	

	AGREEMENT, CERTIFICATES ON THE FINANCIAL STATEMENTS IF THEY ARE REQUIRED BY THE AGREEMENT AND CERTIFICATES ON THE METHODOLOGY, TRANSLATIONS, REPRODUCTION.	*caption "Exceptions" of the Report. The Commission will analyse this information to evaluate whether these costs might be accepted as eligible)*	
D.4	**AGGREGATED CAPITALISED AND OPERATING COSTS OF RESEARCH INFRASTRUCTURE** The Auditor ensured the existence of a positive ex-ante assessment (issued by the EC Services) of the cost accounting methodology of the Beneficiary allowing it to apply the guidelines on direct costing for large research infrastructures in Horizon 2020. ***In the cases that a positive ex-ante assessment has been issued*** *(see the standard factual findings 59-60 on the next column)****,*** The Auditor ensured that the beneficiary has applied consistently the methodology that is explained and approved in the positive ex ante assessment; ***In the cases that a positive ex-ante assessment has NOT been issued*** *(see the standard factual findings 61 on the next column),* The Auditor verified that no costs of Large Research Infrastructure have been charged as direct costs in any costs category;	59) The costs declared as direct costs for Large Research Infrastructures (in the appropriate line of the Financial Statement) comply with the methodology described in the positive ex-ante assessment report. 60) Any difference between the methodology applied and the one positively assessed was extensively described and adjusted accordingly. 61) The direct costs declared were free from any indirect costs items related to the Large Research Infrastructure.	

	In the cases that a draft ex-ante assessment report has been issued with recommendation for further changes *(see the standard factual findings 61 on the next column),* • The Auditor followed the same procedure as above (when a positive ex-ante assessment has NOT yet been issued) and paid particular attention (testing reinforced) to the cost items for which the draft ex-ante assessment either rejected the inclusion as direct costs for Large Research Infrastructures or issued recommendations.		
E	**USE OF EXCHANGE RATES**		
E.1	a) For Beneficiaries with accounts established in a currency other than euros **The Auditor sampled _____ cost items selected randomly and verified that the exchange rates used for converting other currencies into euros were in accordance with the following rules established in the Agreement** (*full coverage is required if there are fewer than 10 items, otherwise the sample should have a minimum of 10 item, or 10% of the total, whichever number is highest)*: *COSTS INCURRED IN ANOTHER CURRENCY SHALL BE CONVERTED INTO EURO AT THE AVERAGE OF THE DAILY EXCHANGE RATES PUBLISHED IN THE C SERIES OF OFFICIAL JOURNAL OF THE EUROPEAN UNION (https://www.ecb.int/stats/exchange/eurofxref/html/index.en.html), DETERMINED OVER THE CORRESPONDING REPORTING PERIOD.* *IF NO DAILY EURO EXCHANGE RATE IS PUBLISHED IN THE OFFICIAL JOURNAL OF THE EUROPEAN UNION FOR THE CURRENCY IN QUESTION, CONVERSION SHALL BE MADE AT THE AVERAGE OF THE MONTHLY ACCOUNTING RATES ESTABLISHED BY THE COMMISSION AND PUBLISHED ON ITS WEBSITE (http://ec.europa.eu/budget/contracts_grants/info_contracts/inforeuro/inforeuro_en.cfm),*	62) The exchange rates used to convert other currencies into Euros were in accordance with the rules established of the Grant Agreement and there was no difference in the final figures.	

	DETERMINED OVER THE CORRESPONDING REPORTING PERIOD.		
	b) For Beneficiaries with accounts established in euros **The Auditor sampled _____ cost items selected randomly and verified that the exchange rates used for converting other currencies into euros were in accordance with the following rules established in the Agreement** (*full coverage is required if there are fewer than 10 items, otherwise the sample should have a minimum of 10 item, or 10% of the total, whichever number is highest)*: *COSTS INCURRED IN ANOTHER CURRENCY SHALL BE CONVERTED INTO EURO BY APPLYING THE BENEFICIARY'S USUAL ACCOUNTING PRACTICES.*	63) The Beneficiary applied its usual accounting practices.	

[legal name of the audit firm]

[name and function of an authorised representative]

[dd Month yyyy]

<Signature of the Auditor>

ANNEX 6

MODEL FOR THE CERTIFICATE ON THE METHODOLOGY

- **For options [*in italics in square brackets*]: choose the applicable option. Options not chosen should be deleted.**
- **For fields in [grey in square brackets]: enter the appropriate data.**

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Terms of reference for an audit engagement for a methodology certificate in connection with one or more grant agreements financed under the Horizon 2020 Research and Innovation Framework Programme

This document sets out the '**Terms of Reference (ToR)**' under which

[OPTION 1: [insert name of the beneficiary] ('the Beneficiary')] [OPTION 2: [insert name of the linked third party] ('the Linked Third Party'), third party linked to the Beneficiary [insert name of the beneficiary] ('the Beneficiary')]

agrees to engage

[**insert legal name of the auditor**] ('the Auditor')

to produce an independent report of factual findings ('the Report') concerning the *[Beneficiary's] [Linked Third Party's]* usual accounting practices for calculating and claiming direct personnel costs declared as unit costs ('the Methodology') in connection with grant agreements financed under the Horizon 2020 Research and Innovation Framework Programme.

The procedures to be carried out for the assessment of the methodology will be based on the grant agreement(s) detailed below:

[title and number of the grant agreement(s)] ('the Agreement(s)')

The Agreement(s) has(have) been concluded between the Beneficiary and *[OPTION 1: the European Union, represented by the European Commission ('the Commission')][OPTION 2: the European Atomic Energy Community (Euratom,) represented by the European Commission ('the Commission')][OPTION 3: the [Research Executive Agency (REA)] [European Research Council Executive Agency (ERCEA)] [Innovation and Networks Executive Agency (INEA)] [Executive Agency for Small and Medium-sized Enterprises (EASME)] ('the Agency'), under the powers delegated by the European Commission ('the Commission').]*.

The *[Commission] [Agency]* is mentioned as a signatory of the Agreement with the Beneficiary only. The *[European Union] [Euratom] [Agency]* is not a party to this engagement.

1.1 Subject of the engagement

According to Article 18.1.2 of the Agreement, beneficiaries *[and linked third parties]* that declare direct personnel costs as unit costs calculated in accordance with their usual cost accounting practices may submit to the *[Commission] [Agency]*, for approval, a certificate on the methodology ('CoMUC') stating that there are adequate records and documentation to prove that their cost accounting practices used comply with the conditions set out in Point A of Article 6.2.

The subject of this engagement is the CoMUC which is composed of two separate documents:

- the Terms of Reference ('the ToR') to be signed by the *[Beneficiary] [Linked Third Party]* and the Auditor;

- the Auditor's Independent Report of Factual Findings ('the Report') issued on the Auditor's letterhead, dated, stamped and signed by the Auditor which includes; the standard statements ('the Statements') evaluated and signed by the *[Beneficiary] [Linked Third Party]*, the agreed-upon procedures ('the Procedures') performed by the Auditor and the standard factual findings ('the Findings') assessed by the Auditor. The Statements, Procedures and Findings are summarised in the table that forms part of the Report.

The information provided through the Statements, the Procedures and the Findings will enable the Commission to draw conclusions regarding the existence of the *[Beneficiary's] [Linked Third Party's]* usual cost accounting practice and its suitability to ensure that direct personnel costs claimed on that basis comply with the provisions of the Agreement. The Commission draws its own conclusions from the Report and any additional information it may require.

1.2 Responsibilities

The parties to this agreement are the *[Beneficiary] [Linked Third Party]* and the Auditor.

The *[Beneficiary] [Linked Third Party]:*

- is responsible for preparing financial statements for the Agreement(s) ('the Financial Statements') in compliance with those Agreements;
- is responsible for providing the Financial Statement(s) to the Auditor and enabling the Auditor to reconcile them with the *[Beneficiary's] [Linked Third Party's]* accounting and bookkeeping system and the underlying accounts and records. The Financial Statement(s) will be used as a basis for the procedures which the Auditor will carry out under this ToR;
- is responsible for its Methodology and liable for the accuracy of the Financial Statement(s);
- is responsible for endorsing or refuting the Statements indicated under the heading 'Statements to be made by the Beneficiary/ Linked Third Party' in the first column of the table that forms part of the Report;
- must provide the Auditor with a signed and dated representation letter;
- accepts that the ability of the Auditor to carry out the Procedures effectively depends upon the *[Beneficiary] [Linked Third Party]* providing full and free access to the *[Beneficiary's] [Linked Third Party's]* staff and to its accounting and other relevant records.

The Auditor:

- *[Option 1 by default: is qualified to carry out statutory audits of accounting documents in accordance with Directive 2006/43/EC of the European Parliament and of the Council of 17 May 2006 on statutory audits of annual accounts and consolidated accounts, amending Council Directives 78/660/EEC and 83/349/EEC and repealing Council Directive 84/253/EEC or similar national regulations]*.
- *[Option 2 if the Beneficiary or Linked Third Party has an independent Public Officer: is a competent and independent Public Officer for which the relevant national authorities have established the legal capacity to audit the Beneficiary]*.
- *[Option 3 if the Beneficiary or Linked Third Party is an international organisation: is an [internal] [external] auditor in accordance with the internal financial regulations and procedures of the international organisation]*.

The Auditor:

- must be independent from the Beneficiary *[and the Linked Third Party]*, in particular, it must not have been involved in preparing the Beneficiary's *[and Linked Third Party's]* Financial Statement(s);
- must plan work so that the Procedures may be carried out and the Findings may be assessed;
- must adhere to the Procedures laid down and the compulsory report format;
- must carry out the engagement in accordance with these ToR;
- must document matters which are important to support the Report;
- must base its Report on the evidence gathered;
- must submit the Report to the *[Beneficiary] [Linked Third Party]*.

The Commission sets out the Procedures to be carried out and the Findings to be endorsed by the Auditor. The Auditor is not responsible for their suitability or pertinence. As this engagement is not an assurance engagement the Auditor does not provide an audit opinion or a statement of assurance.

1.3 Applicable Standards

The Auditor must comply with these Terms of Reference and with[1]:

- the International Standard on Related Services ('ISRS') 4400 *Engagements to perform Agreed-upon Procedures regarding Financial Information* as issued by the International Auditing and Assurance Standards Board (IAASB);
- the *Code of Ethics for Professional Accountants* issued by the International Ethics Standards Board for Accountants (IESBA). Although ISRS 4400 states that independence is not a requirement for engagements to carry out agreed-upon procedures, the Commission requires that the Auditor also complies with the Code's independence requirements.

The Auditor's Report must state that there was no conflict of interests in establishing this Report between the Auditor and the Beneficiary *[and the Linked Third Party]* that could have a bearing on the Report, and must specify – if the service is invoiced - the total fee paid to the Auditor for providing the Report.

1.4 Reporting

The Report must be written in the language of the Agreement (see Article 20.7 of the Agreement).

Under Article 22 of the Agreement, the Commission, *[the Agency]*, the European Anti-Fraud Office and the Court of Auditors have the right to audit any work that is carried out under the action and for which costs are claimed from [*the European Union*] [*Euratom*] budget. This includes work related to this engagement. The Auditor must provide access to all working papers related to this assignment if the Commission*, [the Agency]*, the European Anti-Fraud Office or the European Court of Auditors requests them.

1.5 Timing

The Report must be provided by [dd Month yyyy].

[1] Supreme Audit Institutions applying INTOSAI-standards may carry out the Procedures according to the corresponding International Standards of Supreme Audit Institutions and code of ethics issued by INTOSAI instead of the International Standard on Related Services ('ISRS') 4400 and the Code of Ethics for Professional Accountants issued by the IAASB and the IESBA.

1.6 Other Terms

[The [Beneficiary] [Linked Third Party] and the Auditor can use this section to agree other specific terms, such as the Auditor's fees, liability, applicable law, etc. Those specific terms must not contradict the terms specified above.]

[legal name of the Auditor]	[legal name of the [Beneficiary] [Linked Third Party]]
[name & title of authorised representative]	[name & title of authorised representative]
[dd Month yyyy]	[dd Month yyyy]
Signature of the Auditor Signature	Signature of the *[Beneficiary] [Linked Third Party]*

Independent report of factual findings on the methodology concerning grant agreements financed under the Horizon 2020 Research and Innovation Framework Programme

(To be printed on letterhead paper of the auditor)

To

[name of contact person(s)], [Position]

[[Beneficiary's] [Linked Third Party's] name]

[Address]

[dd Month yyyy]

Dear [Name of contact person(s)],

As agreed under the terms of reference dated [dd Month yyyy]

with *[OPTION 1: [insert name of the beneficiary] ('the Beneficiary')] [OPTION 2: [insert name of the linked third party] ('the Linked Third Party'), third party linked to the Beneficiary [insert name of the beneficiary] ('the Beneficiary')]*,

we

[name of the auditor] ('the Auditor'),

established at

[full address/city/state/province/country],

represented by

[name and function of an authorised representative],

have carried out the agreed-upon procedures ('the Procedures') and provide hereby our Independent Report of Factual Findings ('the Report'), concerning the *[Beneficiary's] [Linked Third Party's]* usual accounting practices for calculating and declaring direct personnel costs declared as unit costs ('the Methodology').

You requested certain procedures to be carried out in connection with the grant(s)

[title and number of the grant agreement(s)] ('the Agreement(s)').

The Report

Our engagement was carried out in accordance with the terms of reference ('the ToR') appended to this Report. The Report includes: the standard statements ('the Statements') made by the *[Beneficiary] [Linked Third Party]*, the agreed-upon procedures ('the Procedures') carried out and the standard factual findings ('the Findings') confirmed by us.

The engagement involved carrying out the Procedures and assessing the Findings and the documentation requested appended to this Report, the results of which the Commission uses to draw conclusions regarding the acceptability of the Methodology applied by the *[Beneficiary] [Linked Third Party]*.

The Report covers the methodology used from [dd Month yyyy]. In the event that the *[Beneficiary] [Linked Third Party]* changes this methodology, the Report will not be applicable to any Financial Statement[2] submitted thereafter.

The scope of the Procedures and the definition of the standard statements and findings were determined solely by the Commission. Therefore, the Auditor is not responsible for their suitability or pertinence.

Since the Procedures carried out constitute neither an audit nor a review made in accordance with International Standards on Auditing or International Standards on Review Engagements, we do not

[2] Financial Statement in this context refers solely to Annex 4 of the Agreement by which the Beneficiary declares costs under the Agreement.

give a statement of assurance on the costs declared on the basis of the *[Beneficiary's] [Linked Third Party's]* Methodology. Had we carried out additional procedures or had we performed an audit or review in accordance with these standards, other matters might have come to its attention and would have been included in the Report.

Exceptions

Apart from the exceptions listed below, the *[Beneficiary] [Linked Third Party]* agreed with the standard Statements and provided the Auditor all the documentation and accounting information needed by the Auditor to carry out the requested Procedures and corroborate the standard Findings.

List here any exception and add any information on the cause and possible consequences of each exception, if known. If the exception is quantifiable, also indicate the corresponding amount.

…..

Explanation of possible exceptions in the form of examples (to be removed from the Report):

i. the [Beneficiary] [Linked Third Party] did not agree with the standard Statement number … because…;

ii. the Auditor could not carry out the procedure … established because …. (e.g. due to the inability to reconcile key information or the unavailability or inconsistency of data);

iii. the Auditor could not confirm or corroborate the standard Finding number … because ….

Remarks

We would like to add the following remarks relevant for the proper understanding of the Methodology applied by the [Beneficiary] [Linked Third Party] or the results reported:

Example (to be removed from the Report):

Regarding the methodology applied to calculate hourly rates …

Regarding standard Finding 15 it has to be noted that …

The [Beneficiary] [Linked Third Party] explained the deviation from the benchmark statement XXIV concerning time recording for personnel with no exclusive dedication to the action in the following manner: …

Annexes

Please provide the following documents to the auditor and annex them to the report when submitting this CoMUC to the Commission:

1. Brief description of the methodology for calculating personnel costs, productive hours and hourly rates;
2. Brief description of the time recording system in place;
3. An example of the time records used by the [*Beneficiary] [Linked Third Party*];
4. Description of any budgeted or estimated elements applied, together with an explanation as to why they are relevant for calculating the personnel costs and how they are based on objective and verifiable information;
5. A summary sheet with the hourly rate for direct personnel declared by the [*Beneficiary*] [*Linked Third Party*] and recalculated by the Auditor for each staff member included in the sample (the names do not need to be reported);
6. A comparative table summarising for each person selected in the sample a) the time claimed by the [*Beneficiary*] [*Linked Third Party*] in the Financial Statement(s) and b) the time according to the time record verified by the Auditor;
7. A copy of the letter of representation provided to the Auditor.

Use of this Report

This Report has been drawn up solely for the purpose given under Point 1.1 Reasons for the engagement.

The Report:

- is confidential and is intended to be submitted to the Commission by the [*Beneficiary*] [*Linked Third Party*] in connection with Article 18.1.2 of the Agreement;
- may not be used by the [*Beneficiary*] [*Linked Third Party*] or by the Commission for any other purpose, nor distributed to any other parties;
- may be disclosed by the Commission only to authorised parties, in particular the European Anti-Fraud Office (OLAF) and the European Court of Auditors.
- relates only to the usual cost accounting practices specified above and does not constitute a report on the Financial Statements of the [*Beneficiary*] [*Linked Third Party*].

No conflict of interest[3] exists between the Auditor and the Beneficiary *[and the Linked Third Party*] that could have a bearing on the Report. The total fee paid to the Auditor for producing the Report was EUR _____ (including EUR _____ of deductible VAT).

[3] A conflict of interest arises when the Auditor's objectivity to establish the certificate is compromised in fact or in appearance when the Auditor for instance:

- was involved in the preparation of the Financial Statements;

We look forward to discussing our Report with you and would be pleased to provide any further information or assistance which may be required.

Yours sincerely

[legal name of the Auditor]

[name and title of the authorised representative]

[dd Month yyyy]

Signature of the Auditor

- stands to benefit directly should the certificate be accepted;

- has a close relationship with any person representing the beneficiary;

- is a director, trustee or partner of the beneficiary; or

- is in any other situation that compromises his or her independence or ability to establish the certificate impartially.

Statements to be made by the Beneficiary/Linked Third Party ('the Statements') and Procedures to be carried out by the Auditor ('the Procedures') and standard factual findings ('the Findings') to be confirmed by the Auditor

The Commission reserves the right to provide the auditor with guidance regarding the Statements to be made, the Procedures to be carried out or the Findings to be ascertained and the way in which to present them. The Commission reserves the right to vary the Statements, Procedures or Findings by written notification to the Beneficiary/Linked Third Party to adapt the procedures to changes in the grant agreement(s) or to any other circumstances.

If this methodology certificate relates to the Linked Third Party's usual accounting practices for calculating and claiming direct personnel costs declared as unit costs any reference here below to 'the Beneficiary' is to be considered as a reference to 'the Linked Third Party'.

Please explain any discrepancies in the body of the Report.	
Statements to be made by Beneficiary	**Procedures to be carried out and Findings to be confirmed by the Auditor**
A. Use of the Methodology I. The cost accounting practice described below has been in use since *[*dd Month yyyy*]*. II. The next planned alteration to the methodology used by the Beneficiary will be from [dd Month yyyy*]*.	**Procedure:** ✓ The Auditor checked these dates against the documentation the Beneficiary has provided. **Factual finding:** 1. The dates provided by the Beneficiary were consistent with the documentation.
B. Description of the Methodology III. The methodology to calculate unit costs is being used in a consistent manner and is reflected in the relevant procedures. *[Please describe the methodology your entity uses to calculate personnel costs, productive hours and hourly rates, present your description to the Auditor and annex it to this certificate]* *[If the statement of section "B. Description of the methodology" cannot be endorsed by the Beneficiary or there is no written methodology to calculate unit costs it should be listed here below and reported as exception by the Auditor in the main Report of*	**Procedure:** ✓ The Auditor reviewed the description, the relevant manuals and/or internal guidance documents describing the methodology. **Factual finding:** 2. The brief description was consistent with the relevant manuals, internal guidance and/or other documentary evidence the Auditor has reviewed. 3. The methodology was generally applied by the Beneficiary as part of its usual costs accounting practices.

Please explain any discrepancies in the body of the Report.	
Statements to be made by Beneficiary	**Procedures to be carried out and Findings to be confirmed by the Auditor**
Factual Findings: - *…]*	
C. **Personnel costs** <u>General</u> IV. The unit costs (hourly rates) are limited to salaries including during parental leave, social security contributions, taxes and other costs included in the remuneration required under national law and the employment contract or equivalent appointing act; V. Employees are hired directly by the Beneficiary in accordance with national law, and work under its sole supervision and responsibility; VI. The Beneficiary remunerates its employees in accordance with its usual practices. This means that personnel costs are charged in line with the Beneficiary's usual payroll policy (e.g. salary policy, overtime policy, variable pay) and no special conditions exist for employees assigned to tasks relating to the European Union or Euratom, unless explicitly provided for in the grant agreement(s); VII. The Beneficiary allocates its employees to the relevant group/category/cost centre for the purpose of the unit cost calculation in line with the usual cost accounting practice; VIII. Personnel costs are based on the payroll system and accounting system. IX. Any exceptional adjustments of actual personnel costs resulted from relevant budgeted or estimated elements and were based on objective and verifiable information. *[Please describe the 'budgeted or estimated elements' and their relevance to personnel costs, and explain how they were reasonable and based on objective and verifiable information, present your explanation to the Auditor and annex it to this certificate].* X. Personnel costs claimed do not contain any of the following ineligible costs: costs related to return on capital; debt and debt service charges; provisions for future losses	**Procedure:** *The Auditor draws a sample of employees to carry out the procedures indicated in this section C and the following sections D to F.* *[The Auditor has drawn a random sample of 10 full-time equivalents made up of employees assigned to the action(s). If fewer than 10 full-time equivalents are assigned to the action(s), the Auditor has selected a sample of 10 full-time equivalents consisting of all employees assigned to the action(s), complemented by other employees irrespective of their assignments.].* For this sample: ✓ the Auditor reviewed all documents relating to personnel costs such as employment contracts, payslips, payroll policy (e.g. salary policy, overtime policy, variable pay policy), accounting and payroll records, applicable national tax , labour and social security law and any other documents corroborating the personnel costs claimed; ✓ in particular, the Auditor reviewed the employment contracts of the employees in the sample to verify that: i. they were employed directly by the Beneficiary in accordance with applicable national legislation; ii. they were working under the sole technical supervision and responsibility of the latter; iii. they were remunerated in accordance with the Beneficiary's usual practices; iv. they were allocated to the correct group/category/cost centre for the purposes of calculating the unit cost in line with the Beneficiary's usual cost accounting practices; ✓ the Auditor verified that any ineligible items or any costs claimed under other costs categories or costs covered by other types of grant or by other grants financed from the European Union budget have not been taken

Please explain any discrepancies in the body of the Report.	
Statements to be made by Beneficiary	**Procedures to be carried out and Findings to be confirmed by the Auditor**
or debts; interest owed; doubtful debts; currency exchange losses; bank costs charged by the Beneficiary's bank for transfers from the Commission/Agency; excessive or reckless expenditure; deductible VAT or costs incurred during suspension of the implementation of the action. XI. Personnel costs were not declared under another EU or Euratom grant (including grants awarded by a Member State and financed by the EU budget and grants awarded by bodies other than the Commission/Agency for the purpose of implementing the EU budget). <u>If additional remuneration as referred to in the grant agreement(s) is paid</u> XII. The Beneficiary is a non-profit legal entity; XIII. The additional remuneration is part of the beneficiary's usual remuneration practices and paid consistently whenever the relevant work or expertise is required; XIV. The criteria used to calculate the additional remuneration are objective and generally applied regardless of the source of funding; XV. The additional remuneration included in the personnel costs used to calculate the hourly rates for the grant agreement(s) is capped at EUR 8 000 per full-time equivalent (reduced proportionately if the employee is not assigned exclusively to the action). *[If certain statement(s) of section "C. Personnel costs" cannot be endorsed by the Beneficiary they should be listed here below and reported as exception by the Auditor in the main Report of*	into account when calculating the personnel costs; ✓ the Auditor numerically reconciled the total amount of personnel costs used to calculate the unit cost with the total amount of personnel costs recorded in the statutory accounts and the payroll system. ✓ to the extent that actual personnel costs were adjusted on the basis of budgeted or estimated elements, the Auditor carefully examined those elements and checked the information source to confirm that they correspond to objective and verifiable information; ✓ if additional remuneration has been claimed, the Auditor verified that the Beneficiary was a non-profit legal entity, that the amount was capped at EUR 8 000 per full-time equivalent and that it was reduced proportionately for employees not assigned exclusively to the action(s). ✓ the Auditor recalculated the personnel costs for the employees in the sample. **Factual finding:** 4. All the components of the remuneration that have been claimed as personnel costs are supported by underlying documentation. 5. The employees in the sample were employed directly by the Beneficiary in accordance with applicable national law and were working under its sole supervision and responsibility. 6. Their employment contracts were in line with the Beneficiary's usual policy; 7. Personnel costs were duly documented and consisted solely of salaries, social security contributions (pension contributions, health insurance, unemployment fund contributions, etc.), taxes and other statutory costs included in the remuneration (holiday pay, thirteenth month's pay, etc.); 8. The totals used to calculate the personnel unit costs are consistent with those registered in the payroll and accounting records; 9. To the extent that actual personnel costs were adjusted on the basis of budgeted or estimated elements, those elements were

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Statements to be made by Beneficiary	**Procedures to be carried out and Findings to be confirmed by the Auditor**
Factual Findings: - *…]*	relevant for calculating the personnel costs and correspond to objective and verifiable information. The budgeted or estimated elements used are: — (indicate the elements and their values). 10. Personnel costs contained no ineligible elements; 11. Specific conditions for eligibility were fulfilled when additional remuneration was paid: a) the Beneficiary is registered in the grant agreements as a non-profit legal entity; b) it was paid according to objective criteria generally applied regardless of the source of funding used and c) remuneration was capped at EUR 8000 per full-time equivalent (or up to up to the equivalent pro-rata amount if the person did not work on the action full-time during the year or did not work exclusively on the action).
D. Productive hours XVI. The number of productive hours per full-time employee applied is *[delete as appropriate]*: A. 1720 productive hours per year for a person working full-time (corresponding pro-rata for persons not working full time). B. the total number of hours worked in the year by a person for the Beneficiary C. the standard number of annual hours generally applied by the beneficiary for its personnel in accordance with its usual cost accounting practices. This number must be at least 90% of the standard annual workable hours. <u>If method B is applied</u> XVII. The calculation of the total number of hours worked was done as follows: annual workable hours of the person according to the employment contract, applicable labour agreement or national law plus overtime worked minus absences (such as sick leave and special leave). XVIII. 'Annual workable hours' are hours	**Procedure (same sample basis as for Section C: Personnel costs):** ✓ The Auditor verified that the number of productive hours applied is in accordance with method A, B or C. ✓ The Auditor checked that the number of productive hours per full-time employee is correct and that it is reduced proportionately for employees not exclusively assigned to the action(s). ✓ If method B is applied the Auditor verified i) the manner in which the total number of hours worked was done and ii) that the contract specified the annual workable hours by inspecting all the relevant documents, national legislation, labour agreements and contracts. ✓ If method C is applied the Auditor reviewed the manner in which the standard number of working hours per year has been calculated by inspecting all the relevant documents, national legislation, labour agreements and contracts and verified that the number of productive hours per year used for these calculations was at least 90% of the standard number of working hours per year.

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Statements to be made by Beneficiary	**Procedures to be carried out and Findings to be confirmed by the Auditor**
during which the personnel must be working, at the employer's disposal and carrying out his/her activity or duties under the employment contract, applicable collective labour agreement or national working time legislation. XIX. The contract (applicable collective labour agreement or national working time legislation) do specify the working time enabling to calculate the annual workable hours. <u>If method C is applied</u> XX. The standard number of productive hours per year is that of a full-time equivalent; for employees not assigned exclusively to the action(s) this number is reduced proportionately. XXI. The number of productive hours per year on which the hourly rate is based i) corresponds to the Beneficiary's usual accounting practices; ii) is at least 90% of the standard number of workable (working) hours per year. XXII. Standard workable (working) hours are hours during which personnel are at the Beneficiary's disposal preforming the duties described in the relevant employment contract, collective labour agreement or national labour legislation. The number of standard annual workable (working) hours that the Beneficiary claims is supported by labour contracts, national legislation and other documentary evidence. *[If certain statement(s) of section "D. Productive hours" cannot be endorsed by the Beneficiary they should be listed here below and reported as exception by the Auditor:* - *…]*	**Factual finding:** <u>General</u> 12. The Beneficiary applied a number of productive hours consistent with method A, B or C detailed in the left-hand column. 13. The number of productive hours per year per full-time employee was accurate and was proportionately reduced for employees not working full-time or exclusively for the action. <u>If method B is applied</u> 14. The number of 'annual workable hours', overtime and absences was verifiable based on the documents provided by the Beneficiary and the calculation of the total number of hours worked was accurate. 15. The contract specified the working time enabling to calculate the annual workable hours. <u>If method C is applied</u> 16. The calculation of the number of productive hours per year corresponded to the usual costs accounting practice of the Beneficiary. 17. The calculation of the standard number of workable (working) hours per year was corroborated by the documents presented by the Beneficiary. 18. The number of productive hours per year used for the calculation of the hourly rate was at least 90% of the number of workable (working) hours per year.
E. Hourly rates The hourly rates are correct because: XXIII. Hourly rates are correctly calculated since they result from dividing annual personnel	**Procedure** ✓ The Auditor has obtained a list of all personnel rates calculated by the Beneficiary in accordance with the methodology used. ✓ The Auditor has obtained a list of all the relevant employees, based on which the

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Statements to be made by Beneficiary	**Procedures to be carried out and Findings to be confirmed by the Auditor**
costs by the productive hours of a given year and group (e.g. staff category or department or cost centre depending on the methodology applied) and they are in line with the statements made in section C. and D. above. *[If the statement of section 'E. Hourly rates' cannot be endorsed by the Beneficiary they should be listed here below and reported as exception by the Auditor:* - *…]*	personnel rate(s) are calculated. For 10 full-time equivalent employees selected at random (same sample basis as Section C: Personnel costs): ✓ The Auditor recalculated the hourly rates. ✓ The Auditor verified that the methodology applied corresponds to the usual accounting practices of the organisation and is applied consistently for all activities of the organisation on the basis of objective criteria irrespective of the source of funding. **Factual finding:** 19. No differences arose from the recalculation of the hourly rate for the employees included in the sample.
F. Time recording XXIV. Time recording is in place for all persons with no exclusive dedication to one Horizon 2020 action. At least all hours worked in connection with the grant agreement(s) are registered on a **daily/weekly/monthly** basis *[delete as appropriate]* using a **paper/computer-based system** *[delete as appropriate]*; XXV. For persons exclusively assigned to one Horizon 2020 activity the Beneficiary has either signed a declaration to that effect or has put arrangements in place to record their working time; XXVI. Records of time worked have been signed by the person concerned (on paper or electronically) and approved by the action manager or line manager at least monthly; XXVII. Measures are in place to prevent staff from: i. recording the same hours twice, ii. recording working hours during absence periods (e.g. holidays, sick leave), iii. recording more than the number of productive hours per year used to calculate the hourly rates, and	**Procedure** ✓ The Auditor reviewed the brief description, all relevant manuals and/or internal guidance describing the methodology used to record time. The Auditor reviewed the time records of the random sample of 10 full-time equivalents referred to under Section C: Personnel costs, and verified in particular: ✓ that time records were available for all persons with not exclusive assignment to the action; ✓ that time records were available for persons working exclusively for a Horizon 2020 action, or, alternatively, that a declaration signed by the Beneficiary was available for them certifying that they were working exclusively for a Horizon 2020 action; ✓ that time records were signed and approved in due time and that all minimum requirements were fulfilled; ✓ that the persons worked for the action in the periods claimed; ✓ that no more hours were claimed than the productive hours used to calculate the hourly

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Statements to be made by Beneficiary	**Procedures to be carried out and Findings to be confirmed by the Auditor**
iv. recording hours worked outside the action period. XXVIII. No working time was recorded outside the action period; XXIX. No more hours were claimed than the productive hours used to calculate the hourly personnel rates. *[Please provide a brief description of the time recording system in place together with the measures applied to ensure its reliability to the Auditor and annex it to the present certificate[4]].* *[If certain statement(s) of section "F. Time recording" cannot be endorsed by the Beneficiary they should be listed here below and reported as exception by the Auditor:* *- …]*	personnel rates; ✓ that internal controls were in place to prevent that time is recorded twice, during absences for holidays or sick leave; that more hours are claimed per person per year for Horizon 2020 actions than the number of productive hours per year used to calculate the hourly rates; that working time is recorded outside the action period; ✓ the Auditor cross-checked the information with human-resources records to verify consistency and to ensure that the internal controls have been effective. In addition, the Auditor has verified that no more hours were charged to Horizon 2020 actions per person per year than the number of productive hours per year used to calculate the hourly rates, and verified that no time worked outside the action period was charged to the action. **Factual finding:** 20. The brief description, manuals and/or internal guidance on time recording provided by the Beneficiary were consistent with management reports/records and other documents reviewed and were generally applied by the Beneficiary to produce the financial statements. 21. For the random sample time was recorded or, in the case of employees working exclusively for the action, either a signed declaration or time records were available; 22. For the random sample the time records were signed by the employee and the action manager/line manager, at least monthly. 23. Working time claimed for the action occurred in the periods claimed; 24. No more hours were claimed than the number productive hours used to calculate the hourly

[4] The description of the time recording system must state among others information on the content of the time records, its coverage (full or action time-recording, for all personnel or only for personnel involved in H2020 actions), its degree of detail (whether there is a reference to the particular tasks accomplished), its form, periodicity of the time registration and authorisation (paper or a computer-based system; on a daily, weekly or monthly basis; signed and countersigned by whom), controls applied to prevent double-charging of time or ensure consistency with HR-records such as absences and travels as well as it information flow up to its use for the preparation of the Financial Statements.

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Statements to be made by Beneficiary	**Procedures to be carried out and Findings to be confirmed by the Auditor**
	personnel rates; 25. There is proof that the Beneficiary has checked that working time has not been claimed twice, that it is consistent with absence records and the number of productive hours per year, and that no working time has been claimed outside the action period. 26. Working time claimed is consistent with that on record at the human-resources department.

[official name of the** [Beneficiary] [Linked Third Party]**]	***[official name of the Auditor]***
[name and title of authorised representative]	***[name and title of authorised representative]***
[dd Month yyyy]	***[dd Month yyyy]***
<Signature of the** [Beneficiary] [Linked Third Party]**>	***<Signature** of the Auditor**>***

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