1.3.3. WT3 Work package descriptions

Work package number [9]	WP1	**Lead beneficiary** [10]	1 - JIV-ERIC
Work package title	Management		
Start month	1	**End month**	48

Objectives

The management of JUMPING JIVE will be located at JIVE. The objective is to transparently facilitate the range of activities and monitor the progress. JIVE will distribute the funds associated with 3rd party travel. This management WP will coordinate all reporting of the project to the EC.

Description of work and role of partners

WP1 - Management [Months: 1-48]
JIV-ERIC
For this programme JIVE proposes to work with a limited number of partners, mostly institutes already closely involved in the JIVE and EVN governance. This reflects the distributed nature of the VLBI research infrastructure and makes sure that an optimal use is made of existing expertise. As a result, it will be necessary to agree on a consortium agreement that institutes a project board, but in many practical cases this can be aligned with the JIV-ERIC council. The consortium agreement will be
based on the DESCA template augmented through our experiences in RadioNet, ASTERICS and (N)EXPReS.

The main objective of the management is to make sure that the project stays on track by providing the coordinator and the work package leaders regular metrics for monitoring progress. This involves tracking time sheets, spending and deliverables. The choice of JIVE as the location of the management team follows naturally from the fact that JIVE is the main and coordinating partner of the consortium. The management will facilitate communication by maintaining distribution lists and calling meetings. An internal website (wiki) will give all partners access to the project information. Because most partners are JIVE partners, we know we can accomplish these tasks with a modest team effort.

In past projects JIVE has acquired extensive experience with administering travel funds for 3rd party travel. It is proposed that JIVE will hold all the resources for travel associated with events organised by the other Work Packages, when it involves non-partner participation. This includes funds for workshops and training activities.

Finally the management will take responsibility for delivering the reports for the programme, where we anticipate that there will be 2 reports over the 4 year period.

WP leader: JIVE (Huib van Langevelde).

Participation per Partner

Partner number and short name	WP1 effort
1 - JIV-ERIC	19.00
Total	19.00

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D1.1	First Periodic Report	1 - JIV-ERIC	Report	Public	18
D1.2	Second Periodic Report	1 - JIV-ERIC	Report	Public	36

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D1.3	Final Periodic Report	1 - JIV-ERIC	Report	Public	48

Description of deliverables

D1.1 : First Periodic Report [18]
First Periodic Report

D1.2 : Second Periodic Report [36]
Second Periodic Report

D1.3 : Final Periodic Report [48]
Final Periodic Report

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS1	First periodic report	1 - JIV-ERIC	18	First periodic report, approved by board
MS2	Second periodic report	1 - JIV-ERIC	36	Second periodic report, approved by board
MS3	Final periodic report	1 - JIV-ERIC	48	Final periodic report, approved by board

Work package number [9]	WP2	**Lead beneficiary** [10]	1 - JIV-ERIC
Work package title	Outreach and Advocacy		
Start month	1	**End month**	48

Objectives

Support the sustainability of JIV-ERIC and the EVN in the coming decade through profiling the scientific impact of high-resolution radio astronomy amongst the general public, policy makers and peers in the scientific community.

Description of work and role of partners

WP2 - Outreach and Advocacy [Months: 1-48]
JIV-ERIC
Background. JIVE has been in existence for over 20 years, serving the EVN and its users. As the mission of JIVE has focused on an operational role to facilitate EVN usage, any outreach targeting the general public, the European policy makers and prospective users was limited to activities by JIVE management and individual scientists. The only exception occurred during the EC-funded (N)EXPReS projects, where a dedicated outreach effort created far more visibility in the general European
scientific and industrial arena.

One can argue that without such a small (5%) but dedicated outreach effort, organisations like JIVE/EVN are not making effective use of the output they are generating. Nevertheless, the JIVE partners have always given priority to operational aspects and user interfaces, as they consider outreach to be a national matter. With JIVE now being a European entity it is crucial that the excitement of VLBI is communicated at a super-national level, notably so as the strategy is to involve more countries and advocate global VLBI.

It is of key importance that JIVE communicates with potential users across Europe. We have learned in past RadioNet (FP7) efforts that this is a delicate process; it requires the authority of a scientist to attract new users to the facility. The EVN and JIVE have been making slow but steady progress in this area, helped by the efforts of the support scientists at JIVE, who have consistently forged close collaborations with new users.

Task 1. Outreach for non-experts.
We propose to employ a half-time communication expert who will help us to profile JIVE among nonexperts. This will involve shaping a number of communication tools, such as a web page and annual reports. Most importantly, we require new communication materials now that JIVE has become a new legal entity. The outreach person will also become point of contact for EVN-wide press releases. The EVN recently adopted a guideline on how to relay press material in all partner countries, after it was realised that some exciting results had not reached all communities that contribute to European VLBI.
This plan calls for central resources at JIVE. With the press officer in place the EVN will also be more visible at conferences and events. This effort will make use of the existing expertise amongst the partners, notably at IGN Spain and the SKA Organisation.

Task 2. Advocacy of EVN capabilities to scientists.
It is equally important to communicate the exciting capabilities of EVN/JIVE to the scientific community. For this an active scientist (actively pursuing a scientific career) is required. This person will raise the visibility of EVN observing opportunities, targeting the communities that are not (yet involved in VLBI. Important goals will be to attend (regional) science meetings of astrophysicists and other potential VLBI users (space applications and geodesy). Considering the close links to WP6 (geodesy) and WP9 (Africa), one suitable person might combine the position of project scientist with that of policy officer in WP3 (new partnerships) and WP4 (ERIC scope).

WP leader: JIVE (Huib van Langevelde)

Participation per Partner

Partner number and short name	WP2 effort
1 - JIV-ERIC	42.00

Partner number and short name	WP2 effort
Total	42.00

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D2.1	Brochure	1 - JIV-ERIC	Websites, patents filling, etc.	Public	14
D2.2	Display	1 - JIV-ERIC	Websites, patents filling, etc.	Public	24
D2.3	Report on advocating the EVN	1 - JIV-ERIC	Report	Public	18
D2.4	Final report on attracting new users for EVN	1 - JIV-ERIC	Report	Public	47

Description of deliverables

D2.1 : Brochure [14]
Brochure explaining the principles and practices of VLBI

D2.2 : Display [24]
Project display to be used at conferences

D2.3 : Report on advocating the EVN [18]
Report on advocating the EVN outside regular circles

D2.4 : Final report on attracting new users for EVN [47]
Final report on attracting new users for the EVN

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS4	Brochure	1 - JIV-ERIC	14	Brochure explaining the principles and practices of VLBI, approved by exec.
MS5	Display	1 - JIV-ERIC	24	Display to be used at conferences, approved by exec
MS6	Report on advocating the EVN	1 - JIV-ERIC	18	Report on advocating the EVN outside regular circles, approved by board
MS7	Final report on attracting new users for the EVN	1 - JIV-ERIC	47	Final report on attracting new users for the EVN, shared with EVN-CBD

Work package number [9]	WP3	**Lead beneficiary** [10]	1 - JIV-ERIC
Work package title	Building new Partnerships		
Start month	1	**End month**	48

Objectives

In order for JIV-ERIC to be an efficient and sustainable European entity, it must attract more partners in its first 5-year cycle. A number of opportunities exist to target new countries, involved or interested in VLBI. This WP implements support for the JIVE director and management in this process.

Description of work and role of partners

WP3 - Building new Partnerships [Months: 1-48]
JIV-ERIC
Background. VLBI is collaborative and international by its very nature. The EVN was established by combining the efforts of European institutes and observatories, established primarily for activities other than VLBI. After exploring the scientific needs of astrophysical, astrometric and geodetic research for more than four decades, we think that the science case for VLBI necessitates true globalisation. On a European scale, it means involving new partners and connecting them to top-level science by integrating them with EVN and JIVE activities. As member of a VLBI network that one day will include the SKA, local, medium-size European facilities can participate in the on-going revolution in radio astronomy.

The aim will be to communicate the incentives to contribute to JIVE to national policy makers:
• Involvement in cutting-edge science research with links to global teams and organizations;
• Direct access to the intellectual property of the European VLBI collaboration and involvement in interdisciplinary innovation efforts;
• Joint exploitation of the science potential of VLBI for capacity building through exchanges, training events, schools and science meetings;
• Joint exploitation of the educational and public outreach potential of EVN and JIVE.

Task: Generate interest among potential new member countries to participate in JIVE. This WP has only a single task, but we adapt our strategy to the current level of involvement in the EVN and JIVE. We define three tiers:

Tier 1: countries and organisations already involved in one way or another in the EVN, JIVE, and/or JIVE-related FP7 or other joint activities. These are
a) Finland: Aalto University, Metsähovi Radio Astronomy Observatory;
b) Latvia: Ventspils International Radio Astronomy Center, Ventspils University College;
c) Poland: Torun University, Center for Astrophysics.
Tier 1 countries are fairly close to attaining the status of full members of JIV-ERIC; all three are either full members of the EVN or are in the process of establishing a full EVN membership.
The main activity will be preparatory work for admission of the Tier 1 countries into JIV-ERIC. This may involve consultation on local policy roadmaps and funding proposals, as well as drafting collaborative agreements. In specific cases it may entail the implementation of joint science, educational, R&D and PO activities in these countries in close collaboration with the EVN.

Tier 2: countries/organisations that deploy VLBI activities consistent with the JIVE mission but not yet involved in JIV-ERIC:
a) Hungary: FOMI Satellite Geodetic Observatory, with one of the leading VLBI users groups in Europe;
b) Ireland: Cork University College, another one of the leading VLBI users groups in Europe;
c) Russia: Institute of Applied Astronomy, a full member of the EVN, but with a disproportionally small users community.
d) Ukraine: Radio Astronomy Institute, a well-established school of low-frequency radio astronomy with experience in VLBI technology and geodesy, but also with a disproportionally small users community.
We will start with establishing mechanisms to involve scientists, engineers and students from Tier 2 countries in JIVE activities. Note that this is related to WP2 activities, but also WP7.

Tier 3: countries/organisations with declared interest in radio astronomy and VLBI, but without established facilities and/or sizable user groups:
a) Israel: Weizmann Institute and Tel-Aviv University – radio astronomy groups being established, strong tradition in theoretical astrophysics;

b) Jordan: National Meteorology and Geography Authority – a declared interest in pursuing radio astronomy research;
c) Norway: active involvement in geodetic VLBI (Ny Ålesund, Svalbard), but with a virtually nonexistent user community;
d) Portugal: Institute of Telecommunications, Santiago University (Aveiro) – strong tradition and interest in radio astronomy related technology (including SKA), VLBI antennas on Azores.
Specific activities in this category include assisting local contacts with creating a case to the respective national authorities for radio astronomy and VLBI activities. We also envision involvement in educational and nationally oriented PR actions, again in line with the activities in WP2.

The activities listed will start from collaborations along existing partnerships (Tier 1 and 2) and establishing new partnerships (Tier 3). These activities will range from preparing documents on science cases and legal frameworks (Tier 1) to preparing the initial input documents for initiating JIV-ERIC admission process (Tier 2) to assessing science potential of establishing national VLBI "seedgroups" (Tier 3).

The WP3 activity will be implemented by a policy officer, who will prepare engagement of national representatives with JIVE management and/or council members. Where applicable the work-package should be able to invoke legal expertise.

WP Leader: JIVE (Leonid Gurvits)

Participation per Partner

Partner number and short name	WP3 effort
1 - JIV-ERIC	11.80
Total	11.80

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D3.1	Inventory of state of VLBI involvement	1 - JIV-ERIC	Report	Public	8
D3.2	Progress report on working with national representatives	1 - JIV-ERIC	Report	Public	24
D3.3	Final report on JIV-ERIC memberships	1 - JIV-ERIC	Report	Public	46

Description of deliverables

As it is impossible to predict when and which country will make progress in this complex process, the deliverables will be limited to a number of evaluations:

D3.1 : Inventory of state of VLBI involvement [8]

Inventory of state of VLBI involvement

D3.2 : Progress report on working with national representatives [24]

Progress report on working with national representatives

D3.3 : Final report on JIV-ERIC memberships [46]

Final report on JIV-ERIC memberships

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS8	Inventory of state of VLBI involvement	1 - JIV-ERIC	8	Inventory of state of VLBI involvement, shared with JIV-ERIC council
MS9	Progress report on working with national representatives	1 - JIV-ERIC	24	Progress report on working with national representatives, shared with the JIV-ERIC council
MS10	Final report on JIV-ERIC memberships	1 - JIV-ERIC	46	Final report on JIV-ERIC memberships, shared with JIV-ERIC council

Work package number [9]	WP4	**Lead beneficiary** [10]	8 - ASTRON
Work package title	ERIC scope: The International LOFAR Telescope		
Start month	1	**End month**	36

Objectives

Carry out an assessment, to be presented in a discussion document for the JIVE and ILT governing bodies and stakeholders, of the possible merits and pitfalls of a closer operational alignment of these two facilities, and possibly their merging into one ERIC.

Description of work and role of partners

WP4 - ERIC scope: The International LOFAR Telescope [Months: 1-36]
ASTRON, JIV-ERIC
Background. Scientifically and organisationally there are a number of similarities between the European VLBI Network and the International LOFAR telescope. Both run a distributed international telescope network and both rely on a central facility for correlation, data curation, quality control and user interfaces. With the aim of optimising the governance for long-term sustainability, we propose to research if there are advantages in lining up the organisations more closely.

Task 1. Assessment studies. There will be a single task to carry out two assessment studies, with documents to be made public at the end of the project, to evaluate the overlaps/similarities as well as differences between JIVE and ILT. Each document will start from a description of the current status and then assess how changing internal and external circumstances (national, European, and international) may alter the respective positions of JIVE and ILT in the next decade; the associated opportunities, challenges, and risks will be discussed. Each document will conclude with a study of the possible advantages and risks that specific collaborations between JIVE and the ILT would entail, including a full merger of the two entities into a combined ERIC.

1. The first document will focus on the operational model and core technologies employed by the respective facilities. It will first describe the current modus operandi. The document will then proceed to explore the likely evolution and enhancement paths of the respective facilities. These will be required in order to stay abreast of expanding technological capabilities as well as growing scientific end-user needs, particularly within the European landscape. The document will conclude with an analysis of the advantages and risks in bringing the JIVE and ILT operational models and technological efforts more closely into alignment.

2. The second document will focus on institutional partnerships, financing, and governance models. It will first clearly describe the current governance and partnerships of the respective facilities. The document will then explore plausible national, European, and international developments in the next decade with regard to funding and collaboration on operating large-scale research facilities in radio astronomy, keeping the ESFRI priorities in mind. The document will assess the possible places and roles of our facilities against the evolution of research infrastructures. Taking into account in particular the substantially overlapping membership of JIVE and the ILT and the ambitions of both organisations to grow (in part) by acquiring new partners in Europe, the document will conclude with an analysis of possible advantages, risks, and challenges, of aligning the JIVE and ILT governance and financing models, including the discussion of a full merger scenario.

Several intensive meeting sessions or workshops will be required to carry out the studies and the development of the documents described above. The workshops will initially involve relevant operational and general management staff from the respective organisations, followed by a meeting with representation from governing bodies; experts from similar European or international (prospective) partner facilities will also be invited. It is to be expected that external technical and legal/financial experts will be called upon as needed to ensure thorough assessments. One or more of the meetings will probably be held in Brussels, where relevant experts from the EC will be invited to share their insight based on specific prior communication with them.

Finally, the documents will be presented and discussed in the JIVE Council, and in the ILT Board and the national LOFAR consortia. This will be the culmination and conclusion of this work package. It will be up to these governing entities to decide whether to take any further actions, and if so, what, when, and how. A possible follow-up is outside the scope of this work package

WP Leader: ILT/ASTRON (René Vermeulen)

Participation per Partner

Partner number and short name	WP4 effort
1 - JIV-ERIC	4.60
8 - ASTRON	6.00
Total	10.60

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D4.1	Workshops boards discussing position papers	9 - ILT	Report	Confidential, only for members of the consortium (including the Commission Services)	16
D4.2	Workshops with external experts	9 - ILT	Report	Confidential, only for members of the consortium (including the Commission Services)	30
D4.3	Final documents	9 - ILT	Report	Public	35

Description of deliverables

D4.1 : Workshops boards discussing position papers [16]
Workshops with board representatives discussing position papers

D4.2 : Workshops with external experts [30]
Broader-scoped workshops with external experts

D4.3 : Final documents [35]
Final documents presented and discussed in JIVE council and ILT board

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS11	Workshop board discussing position papers	9 - ILT	16	Workshop board discussing position papers, noted by JIV-ERIC council and ILT board
MS12	Workshop with external experts	9 - ILT	30	Workshop with external experts, noted by JIV-ERIC council and ILT board
MS13	Final documents	9 - ILT	35	Final documents, approved by JIV-ERIC council and ILT board

Work package number [9]	WP5	**Lead beneficiary** [10]	6 - MFOM-E
Work package title	Integrating new elements		
Start month	1	**End month**	48

Objectives

This work package will test and verify the performance of new telescopes in the EVN. This is important both for the new consortium members, as well as the EVN user community. A special focus will be on quality control and calibration

Description of work and role of partners

WP5 - Integrating new elements [Months: 1-48]
MFOM-E, JIV-ERIC
Background. From its birth as a consortium of five European radio astronomy observatories, the growth of the EVN has been a principal factor in being able to offer astronomers an ever more capable instrument. Additional telescopes provide improved imaging fidelity and sensitivity to fainter sources. Developments in digital back-end technology over the past few years, and, more recently, in the distribution of clock and frequency standards, are lowering the barrier for aspiring telescopes to participate in the EVN. Examples of such network enlargements in the new millennium are the - element KVAZAR network in Russia and the 3-element KVN in Korea, the latter operating at the higher frequencies covered by the EVN. In addition, new telescopes with significantly enhanced capabilities at existing EVN institutes have come on line (the 40m telescope at Yebes, Spain; the 65m telescope at Tianma, near Shanghai, China), as well as new or refurbished telescopes at institutes not previously associated with the EVN (the new 65m telescope in Sardinia; the 32m telescope in Irbene, Latvia). Characterising and monitoring the performance of these telescopes is a considerable effort.

Task 1. Significant enhancements at existing EVN and affiliated stations. Some of the new EVN telescopes are upgrading their receivers to better match the EVN observing frequencies. For example, the Kunming 40m telescope in south-west China has participated in very few EVN observations, as currently only one frequency band overlaps with the frequency coverage of the EVN. Recently, multifrequency front-end equipment has been purchased, but has yet to be tested with the EVN. The inclusion of this telescope at more frequency bands will provide an enhanced coverage in the eastern reaches of the EVN, improved image fidelity and the capability to track sources for longer periods of time, especially when conducting joint observations with the Australian LBA. JIVE's support team will need to verify the data quality and work with the station staff to determine a reliable calibration of
such observations. We also point out the exciting possibility of using the enormous FAST telescope in China for VLBI.

We will also work towards incorporating the short baselines formed by the individual eMERLIN telescopes in the UK. It is obvious that this will significantly improve the EVN's sensitivity to extended structure. As the signals from these telescopes go through the eMERLIN correlator before they can be processed for EVN correlation we can expect some subtle problems. With the implementation of this eMerlin mode recently completed, we will focus on verifying the data quality and calibration effects in detail. Similar work is anticipated for the Westerbork array as a VLBI element, after the deployment of the phased-array feed APERTIF system. APERTIF provides a multi-beam, wide-field capability for 18-21cm observations. The EVN could benefit from the full Westerbork array sensitivity at these frequencies with the new wider-field feature for projects conducting deep surveys. Similar workwould be needed for the SKA precursor telescope MeerKAT in South Africa.

In this task a dedicated support scientist at JIVE will serve as a contact person for the stations that use new receivers or data interfaces. He/she will make a plan for testing new capabilities and discuss the requirements for delivering calibration. When progress is deemed satisfactory, the new modes can be incorporated in the standard Network Monitoring Experiments. The support scientist's findings will be discussed with the stations in the EVN Technical and Operations Group (TOG). We note that the support scientist will also be an active scientist, pursuing a career in astrophysics.

Task 2. Supporting new telescopes. Several 30-m class telescopes are found throughout Europe that could greatly improve the EVN's image fidelity by providing baselines currently not available. The first step would be to conduct a census of such telescopes, their institutional situation and technical needs for a conversion to an EVN-ready radio telescope. We have had expressions of interest from the UK, Portugal, Finland, and Ireland. In addition there are a number of geodetic stations in European countries that have not participated (for a long time) in EVN observations. Besides dedicated support at the correlator, we propose to make provisions to support tiger teams comprising technical experts from EVN stations, that could accelerate the progress towards EVN participation. Note that the same expertise will be used in WP9 to facilitate African VLBI telescopes. This however we view as a special category, as an exchange programme on all levels is required.

The support scientist dedicated to this task will make an inventory of the telescopes that could benefit from this programme. For these a technical assessment will be made of potential bottlenecks that stand in the way of EVN participation. Where needed, special tiger team visits will be arranged to facilitate test observations. These efforts will be coordinated and reported at the EVN TOG (the Technical Operations Group). The support scientist will also be responsible for scheduling and data inspection.

Task 3. Station feedback from pipeline and archive. An asset of the central JIVE organisation at the heart of the EVN is a very complete, interactive and public archive. Through a pipeline, which runs after correlation, the archive is populated not only with the correlated raw data, but also with calibration data and preliminary images. We propose to make changes to this system that will allow telescope operators to query the archive for information on telescope performance. The focus will be on calibrator observations, which will allow a direct assessment of a specific telescope's performance.

Offering this capability will require re-engineering of the existing data flows and a careful evaluation by the experts in the JIVE telescope support team.

WP Leaders: IGN/MFOM-E (Pablo de Vicente), JIVE (Bob Campbell)

Participation per Partner

Partner number and short name	WP5 effort
1 - JIV-ERIC	50.40
Total	50.40

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D5.1	reports to TOG	1 - JIV-ERIC	Report	Public	18
D5.2	Changes in pipeline & EVN archive interface	1 - JIV-ERIC	Other	Public	42
D5.3	Final report on integrating new elements	6 - MFOM-E	Report	Public	46

Description of deliverables

D5.1 : reports to TOG [18]

Bundle of reports to the TOG on Task 1 and 2 activities

D5.2 : Changes in pipeline & EVN archive interface [42]

Pipeline and the EVN archive interfaces for monitoring station performance

D5.3 : Final report on integrating new elements [46]

Final report on integrating new elements

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS14	Reports to TOG	1 - JIV-ERIC	18	Reports to the TOG, minuted by EVN TOG
MS15	Changes in pipeline & EVN archive interface	1 - JIV-ERIC	42	Changes in pipeline & EVN archive interface, published to community
MS16	Final report on integrating new elements	6 - MFOM-E	46	Final report on integrating new elements, minuted by EVN TOG

Work package number [9]	WP6	Lead beneficiary [10]	2 - CNRS
Work package title	Geodetic capabilities		
Start month	1	End month	42

Objectives

This work package will enable geodetic use of the JIVE data processor. When validated, this mode will allow the use of the JIV-ERIC infrastructure for high accuracy (global) astrometric and geodetic applications. In addition it will provide means to verify the data quality on a more fundamental level and improve the accuracy with which EVN station positions are known.

Astronomers typically use the EVN for self-calibration or phase-referencing imaging, or for phase-referencing relative astrometry in which the positions of a target are determined relative to a nearby reference source. The data produced by the EVN software correlator at JIVE (SFXC) contains visibility phases calculated on the basis of an a-priori correlator model that accounts for the earth/sky geometry, relativistic effects and propagation effects at the time of the observations. This correlator model, although it can be linked to the output data, is not yet included in the files that the astronomer receives.

If the data files contained this correlator model, scientists could use this for:
• Absolute astrometry to determine source positions directly in the ICRF, which would provide the means to find new reference sources in targeted areas of the sky, which in turn could improve the astrometry derived from the current phase-referencing practice.
• Geodesy, which can determine the position of the participating telescopes by observing sources of known positions spread over the whole sky. This would be especially useful to the EVN for new telescopes or those that do not have the specific receivers necessary to participate in IVS observations.
• Accounting for changes in the correlator model that may arise between epochs of multi-epoch programmes, or from the use of different correlators. This will give the users more flexibility and will allow the JIVE staff to do detailed quality checks.

A preliminary assessment of the astrometric quality of the SFXC was done at JIVE in 2015, with a re-correlation of four stations from an IVS 24-hour geodetic observation. A member of the geodetic VLBI community compared the standard output files from this re-correlation, plus the correlator model used for the original IVS geodetic correlation. The preliminary conclusion was that a fairly straightforward engineering effort would be sufficient to make SFXC ready for precise absolute astrometry. In fact, the exercise illustrated that in some cases a sensitivity improvement could result from the use of the SFXC correlation algorithm.

This demonstration of the astrometric quality and favourable sensitivity of the SFXC was a first step towards being able to deploy geodetic capabilities. Using standard data-analysis methods these will be directly accessible to both astronomy and geodesy.

Description of work and role of partners

WP6 - Geodetic capabilities [Months: 1-42]
CNRS, JIV-ERIC
Task1. Data interface. The first task is to attach the correlator model to the data product following international standards. This is a straightforward task for the experts at JIVE who understand the time series description of the correlator model. However, careful comparison of the model delay computed at arbitrary times using the correlator algorithm with the resulting data correction files will be needed to validate this transformation.

Task 2. Experiment definition. Because they cannot rely on tracking a nearby calibrator, the scheduling strategies for geodetic and absolute astrometry observations differ from those used in more typical EVN observations. In particular, the need to obtain atmospheric calibration over the whole sky often requires forming sub-arrays within the overall set of participating telescopes ("sub-netting"). Because of these different strategies, these observations often use a different scheduling program, that makes schedule files in a format which is different from the usual EVN schedules. The ability to handle sub-netting (different sets of telescopes/sources at the same time) and to read in the different schedule format needs to be developed for the local SFXC environment.

One or more test observations would be conducted and analysed to validate the newly implemented SFXC features and correlator-model information in the AIPS tables.

Task 3. Application: Station Positions. We propose to carry out (at least) one full-scale geodetic-style observation to determine the positions of EVN telescopes that do not participate in standard IVS observations. A similar observation at 6cm wavelength was done in 2000 by Bordeaux experts to determine the positions of the telescopes at Jodrell Bank (UK), Westerbork (NL), and Torun (PL). These positions, along with a plate-motion model, have formed the basis of the location used for these telescopes in subsequent EVN observations. A separate 1.3cm geodetic-style observation in 2006 determined the position of the Jodrell Bank Mark2 telescope, consistent with the earlier determination when accounting for the modelled tectonic plate motion. A new 1.3cm observation would thus enable a new determination of the position (and the motion) of the Mark2 telescope, as well as of the Torun telescope which has obtained a 1.3cm receiver since the previous observations, with a long enough time-baseline to measure the site velocity empirically rather than through a plate-motion model. A new 6cm observation would extend these advantages to Westerbork, which cannot observe at 1.3cm. The advantage of shorter-wavelength observations is that they reduce ionospheric effects and thereby yield better precision.

Such observations will also provide improved accuracy for several new telescopes, notably Irbene (LV) and the Sardina Radio Telescope (IT). As such the proposed programme is connected to the work on integrating new antennas (WP5) and future observing with antennas in Africa (WP9). It is worth noting that many of the telescopes we are serving have a keen interest to participate in large scale geodetic programmes, for which this work will be a starting point.

WP leaders: CNRS (Patrick Charlot, Bordeaux) and JIVE (Bob Campbell)

Participation per Partner

Partner number and short name	WP6 effort
1 - JIV-ERIC	12.00
2 - CNRS	24.00
Total	36.00

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D6.1	New correlator data products	1 - JIV-ERIC	Other	Public	12
D6.2	Software to deal with geodetic observing schedules	1 - JIV-ERIC	Other	Public	18
D6.3	Analysis of EVN station positions	2 - CNRS	Report	Public	40

Description of deliverables

D6.1 : New correlator data products [12]

New correlator data products, verified for use with geodatic software

D6.2 : Software to deal with geodetic observing schedules [18]

Software to deal with geodetic observing schedules, verified by tests observations

D6.3 : Analysis of EVN station positions [40]

Document with analysis of EVN station position determination

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS17	New correlator data products	1 - JIV-ERIC	12	New correlator data products, available to user community
MS18	Software to deal with geodetic observing schedules	1 - JIV-ERIC	18	Software to deal with geodetic observing schedules, available to user community
MS19	Analysis of EVN station positions	2 - CNRS	40	Analysis of EVN station positions, presentation to EVN TOG

Work package number [9]	WP7	**Lead beneficiary** [10]	5 - INAF
Work package title	The VLBI future		
Start month	6	**End month**	48

Objectives

Because of the progress in the field of astrophysics and the changes in the radio astronomy landscape it is timely to revisit the EVN science case. In consultation with the user community and global partners we will define the most important science areas for future VLBI arrays.

Description of work and role of partners

WP7 - The VLBI future [Months: 6-48]
INAF, JIV-ERIC, CHALMERS
Background. Very Long Baseline Interferometry (VLBI) arrays are the only instruments that reach angular resolutions of the order of a milli-arcsecond and less, allowing unique studies of the central black holes of active galactic nuclei and their evolution, star formation and stellar evolution, gamma-ray bursts, searches for extra-solar planets, and ultra precision astrometry, to name just some of the many research areas and applications. The European VLBI Network is one of the world's most sensitive VLBI arrays over a broad range of frequencies. This has been achieved by the close collaboration and communication between the scientific and technological/engineering staff, and by long-term coordinated investment and development programme among all partners. Science and technology need to progress hand in hand to ensure the most outstanding scientific output. Moreover, the continued effort of JIVE, particularly in providing user support at many stages, has ensured a considerable growth of the VLBI scientific community, making the intrinsic complex observational technique and data analysis broadly accessible to all.

Radio-astronomical facilities are currently undergoing a rapid evolution, which in many cases involves VLBI as a key ingredient. Beyond the ALMA-VLBI connection, most relevant to the current proposal are the potential developments in Africa (African VLBI Network, AVN, addressed in WP9) and the construction phase of the SKA (addressed in WP10). In particular, the establishment of a 30m class of radio telescopes throughout Africa would ensure an almost continuous distribution of radio telescopes from Northern Europe to South Africa, with a resulting substantial increase in that portion of the sky accessible for high-fidelity milli-arcsecond resolution imaging. In addition, the possibility of a phased SKA for VLBI observations would provide a step change in sensitivity, and hence in the scientific potential of VLBI.

Many (European) partners realise the potential of radio astronomy and are joining up with the VLBI community (WP3, 5) or are joining complementary SKA pathfinders (WP4). In this rapidly evolving framework it is essential that the tight synergy between science and development is continued, and that a scientific roadmap is defined, to fully exploit the forthcoming generation of VLBI arrays. The prospect of this project is timely as the SKA is being designed and the establishment of an AVN has started. Defining a new roadmap for VLBI is urgent.

Task 1. VLBI science case. The main deliverable will be a document, in the form of a White Paper, that will address and explore several relevant points in setting the future priorities of VLBI science capabilities. Besides the global developments it is also important to take technical capabilities into consideration. One example is the question how to implement a "large-survey mode" for VLBI in order to address the wishes of the scientific community and thus ensure the best scientific returns. Another is the feasibility of transient surveys. Deep surveys of individual targets, or somewhat shallower surveys with a large field of view, are scientifically profitable, but the question is in which case the EVN resources are best used. The first would benefit from the large telescopes in the EVN and the traditional observing mode (limited to the EVN sessions), while the latter would be better implemented by adding smaller dishes to the array. Those would provide large field of view, would be available most of the year and would better complement the SKA. Other technical aspects that need to be considered are the frequency coverage and bandwidth available, but also the capabilities of the central data processor, the correlator, which forms the final science products. Maybe in the future it will become possible to do VLBI observations with array feeds, providing multiple beams per station.

The synergy with the new astrophysical frontiers which will become accessible with future space missions and ground facilities (some remarkable examples include LSST, GAIA, XIPE) will play a major role in shaping the White Paper. Beyond the challenges raised above, we should keep in mind that astronomy is undergoing a major revolution at another level: namely the massive increase in the data volumes which are becoming prevalent in the new state-of-the-art facilities. This is the case in many wave bands, but particularly in radio astronomy, requiring the development of data archiving and data mining tools. In this rapidly evolving framework it is important to propose future directions for the development of the EVN data archive at JIVE.

We expect the VLBI community to be aware of the future challenges. So it is our task to engage the user base in an efficient feedback process and involve them actively in the discussion. However, it is essential that the needs of the next generation of radio astronomers are also identified, in terms of the development of software tools, user-support, and data analysis. How this should be implemented at JIVE to enhance and improve its invaluable role in supporting user access to the EVN to maximize the scientific return will be part of the process and discussion.

To achieve the goal of the White Paper, and ensure that at least all the above points are properly addressed we propose to set up a team which includes both members from the partners in the project, and external experts in other fields of astronomy as well as from the technology and engineering community. To keep the feedback process with the VLBI community alive, some members of the WP may attend key science meetings and workshops, such as for instance the EVN Symposia, whose scientific discussions and results will be relevant for our purpose. This WP will work in synergy with WP6 - to include astrometry and geodesy in the VLBI revised science case - WP9 (to link up with the science developments in Africa) and will provide input to WP10 (that aims to define an operational SKA-VLBI and to develop global VLBI science for it).

WP leader: INAF (Tiziana Venturi) with support from JIVE and in coordination with the EVN PC chair (Michael Lindqvist, CHALMERS-OSO)

Participation per Partner

Partner number and short name	WP7 effort
1 - JIV-ERIC	3.60
3 - CHALMERS	3.00
5 - INAF	9.00
Total	15.60

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D7.1	Minutes of Kick-off meeting	1 - JIV-ERIC	Report	Public	7
D7.2	Minutes of meeting 2	5 - INAF	Report	Public	15
D7.3	Minutes of meeting 3	5 - INAF	Report	Public	30
D7.4	White paper	5 - INAF	Report	Public	45

Description of deliverables

D7.1 : Minutes of Kick-off meeting [7]

Meeting 1, kick-off meeting among the WP members

D7.2 : Minutes of meeting 2 [15]

Meeting 2, here we will invite external experts to take part in the discussion

D7.3 : Minutes of meeting 3 [30]

Meeting 3, the available draft of the white paper will be discussed and improved

D7.4 : White paper [45]

White paper delivered

Schedule of relevant Milestones

Milestone number[18]	**Milestone title**	**Lead beneficiary**	**Due Date (in months)**	**Means of verification**
MS20	Minutes of Kick-off meeting	1 - JIV-ERIC	7	Minutes of Kick-off meeting, noted by EVN CBD
MS21	Minutes of meeting 2	5 - INAF	15	Minutes of meeting 2, noted by EVN CBD
MS22	Minutes of meeting 3	5 - INAF	30	Minutes of meeting 3, noted by EVN CBD
MS23	White paper	5 - INAF	45	White paper, approved by EVN CBD

Work package number [9]	WP8	Lead beneficiary [10]	1 - JIV-ERIC
Work package title	Global VLBI interfaces		
Start month	3	End month	45

Objectives

In order to support the globalisation of VLBI it will be necessary to update tools and methods that allow the telescopes to be addressed in a uniform way. This work package will take charge of scheduling and monitoring tools, adapting and modernising them as needed, while taking care to continue to adhere to international standards and requirements.

Description of work and role of partners

WP8 - Global VLBI interfaces [Months: 3-45]
JIV-ERIC, CHALMERS, TUM
Background. VLBI, by its very nature, depends on the seamless interaction of many elements spread around the globe. Over many years, various mechanisms and tools have been put in place to make this possible. Some of these tools, although still functional, have now become very hard to maintain, let alone upgrade to new functionality. With new telescopes coming online and being added to VLBI networks, and observing modes and standards rapidly evolving, it has become essential to address these issues. Moreover, the VLBI user experience is seriously affected by the scheduling experience; new tools to involve scientists at various stages with a modern interface can currently not be implemented.

This work package will deal with two most outstanding problems. The first is scheduling of observations, which today is (mostly) handled through a programme called SCHED, dating from the early eighties and entirely written in FORTRAN. The second is the continuous monitoring of the status of stations participating in VLBI sessions. This is not only important for the early detection of technical problems, thus preventing the waste of valuable observing time, but also could prove very useful during the commissioning phase of new VLBI telescopes, for example in Africa. Resolving these issues will help to enable truly global operations, and prepare VLBI for the inclusion of the large instruments of the future, notably the phased up MeerKat and SKA arrays.

Task 8.1: Re-factoring of legacy scheduling software. The program SCHED was written in the early eighties in order to provide a common, generalised user interface for scheduling VLBI observations. It does so by combining observing parameters, source catalogues and frequency setup catalogues, which describe the detailed settings at all different stations. This is by no means trivial, considering that all telescopes are different, in terms of location, architecture, hardware limitations, equipment and frequency coverage. The resulting schedule comes in the form of a so-called VEX file, for which an international standard was defined, a plain-text human-readable equivalent of a database. This file is sent to the stations, where the control computer parses the schedule and translates it into a series of commands to the telescope control system and the recording/transmitting equipment. The decades-old code base makes the program extremely hard to modify in order to adapt it to the modern-day demands of VLBI networks. And in spite of the fact that several VLBI networks around the world depend on it, there is no formal support for SCHED in place.

The aim of this task will be to re-factor the existing code, rather than re-writing all from scratch. This will be done by separating out well-defined bits of functionality and re-writing these as individual modules in a modern language, most likely Python. In this way a “gold standard” will remain available throughout the process, enabling an incremental replacement of the original code base. Static parts of the code that do not need frequent modifications will be kept as they are. The end product will be a modernised version of SCHED that will be far easier to adapt, written in a widely used and well-known programming language. It will be usable for all aspects of the proposal-observational cycle, which means during the proposal phase, the programming by the PI and finally the actual generation of an observing schedule by the JIVE staff. This functionality will be essential for VLBI users in the SKA era. As an aside, we will set up a forum of SCHED experts and users, to ensure that the engineering effort will keep the different needs of different VLBI networks in mind.

Task 8.2: Remote access and monitoring In the past, monitoring of the elements of a VLBI array during observations used to be virtually impossible. Equipment failures, human mistakes or other mishaps would often only be noted during or even after correlation by inspecting the data, which might take place months after the actual observations. The advent of e-VLBI, transferring data in real time to the correlator, brought with it a considerable improvement in the communications between stations and correlator. However, VLBI observations are still mostly done using recorders, during sessions that hardly have any central overview of the network as a whole. This will be unavoidably the case for the proposed global VLBI, involving remote stations all over the world.

During the EC-funded NEXPReS project, a remote control and monitoring system was developed and deployed at a number of geodetic stations. This task will evaluate this product and other existing monitoring systems to find a common ground in order to ensure interoperability. It will adapt existing software for integration into a central infrastructure and set up web-based access techniques. The final product will be a central, web-based monitoring system, usable for both astronomical and geodetic VLBI. This system will be accessible to all involved, correlator and stations, and will serve to continuously monitor and assess the status of the VLBI network, enabling automated warnings in case of failures and providing the information needed to continuously improve the performance of the network. Such a system will also be of great value when helping with the commissioning of new VLBI telescopes, in particular in areas of the world where radio astronomy is not well-established yet.

Work on these tasks will be carried out at JIVE and TUM, while CHALMERS-OSO will provide hardware and personnel for testing the results in the field.

WP leader: JIVE (Arpad Szomoru)

Participation per Partner

Partner number and short name	WP8 effort
1 - JIV-ERIC	36.00
3 - CHALMERS	4.00
10 - TUM	24.00
Total	64.00

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D8.1	Setting up of SCHED re-factoring forum	1 - JIV-ERIC	Other	Public	3
D8.2	Document of SCHED	1 - JIV-ERIC	Report	Public	8
D8.3	Re-factored SCHED	1 - JIV-ERIC	Other	Public	36
D8.4	Evaluation software packages	10 - TUM	Report	Public	4
D8.5	Integration existing software into central infrastructure	10 - TUM	Other	Public	12
D8.6	Completed monitoring schedule	10 - TUM	Other	Public	24

Description of deliverables

D8.1 : Setting up of SCHED re-factoring forum [3]

Setting up of SCHED re-factoring forum

D8.2 : Document of SCHED [8]

document detailing what functionality of SCHED will be re-written, and method to be followed, based partly on input from SRFF

D8.3 : Re-factored SCHED [36]

re-factored SCHED

D8.4 : Evaluation software packages [4]
Evaluation of different monitoring software packages

D8.5 : Integration existing software into central infrastructure [12]
Integration of existing software into central infrastructure

D8.6 : Completed monitoring schedule [24]
Completed monitoring system, deployed at JIVE and Geodetic obs. Wettzell

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS24	Setting up of SCHED re-factoring forum	1 - JIV-ERIC	3	Setting up of SCHED re-factoring forum, noted by exec.
MS25	Document on SCHED	1 - JIV-ERIC	8	Document on SCHED, published to global community
MS26	Re-factored SCHED	1 - JIV-ERIC	36	Re-factored SCHED, available to user community
MS27	Evaluation software packages	10 - TUM	4	Evaluation software packages, noted by exec.
MS28	Integration existing software into central infrastructure	10 - TUM	12	Integration existing software into central infrastructure, noted by exec.
MS29	Completed monitoring schedule	10 - TUM	24	Completed monitoring schedule, available to telescope operators

Work package number [9]	WP9	**Lead beneficiary** [10]	12 - UMAN
Work package title	Capacity for VLBI in Africa		
Start month	1	**End month**	48

Objectives

The SKA is a transformational project with the aim to build up to 3000 dishes to extend current capabilities in radio astronomy by orders of magnitude. It is being constructed in a phased way with the 64 dish MeerKAT SKA-precursor following on from the KAT-7 prototype in the Karoo desert in the Northern Cape district. These will be integrated in the Phase 1 of the SKA mid-frequency array with the addition of 250 dishes in South Africa to be built over the 2018-2023 period with maximum 150km baselines. To provide the high angular resolution on the sky of the full SKA some of the remaining dishes will be spread over 1000s of kilometres, as well as work in tandem with existing VLBI arrays, in a 'VLBI-mode' (see WP10). So, although the core of the telescope will be in South Africa, the outlying stations will be located in 8 partner countries across Africa, namely: Botswana, Ghana, Kenya, Madagascar, Mauritius, Mozambique, Namibia and Zambia. Given that the stations in these countries will not be built until Phase 2 of the SKA project during 2023-30, and that there is virtually no research astronomy activity in the partner countries at present, the South African SKA project (SKA-SA) initiated the African VLBI Network project or AVN.

The AVN aims to establish a 30 m class radio telescope in each of the partner countries and link these together in a Very Long Baseline Interferometry (VLBI) network. This will operate in tandem with the European VLBI Network (EVN). This will be achieved through a combination of converting ex-telecommunications dishes, a programme that is mainly funded and driven by SKA-SA, and newly built antennas. These dishes will provide a focus for the development of radio astronomy in each partner country so that a skilled local team is ready to install, maintain and operate the SKA outstations when they arrive. Moreover, the aim is to establish astrophysics education and research communities in these countries as a springboard for wider technical and economic development.

This is a very ambitious objective since in most partner countries astrophysics and associated technologies are starting from scratch and so a significant amount of training is required. To this end a number of initiatives investing in the development of the AVN and training of scientists and engineers in partner countries are underway. Notably these include investments, initially through the period 2015-2017, via the Newton fund from South Africa and the UK's Royal Society to provide basic training and experience. These initiatives, along with the efforts of SKA-SA, have already established a network of contacts within a number of African countries. Available resources have limited these efforts to only a few countries (Kenya, Zambia, Namibia & Ghana) so far. This WP will provide an expansion of these existing initiatives to include other AVN partner countries (initially Botswana, Madagascar, Mauritius and Mozambique). Working in tandem and building upon these existing activities, this WP will bring the wealth of technical, operational and scientific expertise residing in Europe into this effort. It will provide a tangible platform for the future success of the AVN and provide an early link with the EVN, paving the path for early AVN and eventually SKA science delivery. This will be done in a sustainable manner by providing skills and training for communities in AVN countries to enable their future success.

Description of work and role of partners

WP9 - Capacity for VLBI in Africa [Months: 1-48]
UMAN, JIV-ERIC, UNIVLEEDS
To succeed in this goal this WP will provide the resources to expand and support on-going scientific and technical training initiatives. This will be broken down into 4 key objectives each of which will increase the links between European based VLBI expertise by providing a network of bi-directional training visits, and setting up a sustainable framework for future developments. The WP will target a number of AVN countries which are not currently supported by other initiatives (such as Newton) as well as provide added value and expertise to on-going activities, thus providing cost effective training delivery outcomes.

This WP will enable:
• European radio astronomers to participate as expert trainers in existing funded training activities in Africa thus broadening the base of European involvement in EU-Africa collaboration. This will build upon the existing UK's Newton project by mobilizing additional VLBI expertise from partner institutes to extend and enhance this effort. These VLBI partners will provide enhanced training opportunities, via technical and scientific expertise which will organise and contribute to annual network training meetings. Currently these Newton training initiatives are underway in Kenya,

Zambia, Namibia & Ghana and are capacity limited. This WP will aid and expand the capacity of these schemes, including extending them to a number of new participating countries, such as Botswana, Madagascar and Mozambique.
• European radio astronomers to travel to AVN and prospective AVN institutions to give seminars or short lecture series to major physics departments in countries with an interest in developing radio astronomy. This will provide a flexible resource to broaden the base of African radio astronomy. Initial self-funded activities by this group have provided seminars (>2000 attendees, Jan 2016) in major Universities in Nigeria highlighting the scope of potential expansion and the significant interest in prospective AVN countries.
• The funding of a limited number of short term placements of African personnel with an interest in developing their radio astronomy expertise, in both scientific and technical/operational areas, with European institutes. The scientific, technical and operational experience of the partners in this proposal will provide an invaluable training opportunity for the burgeoning AVN community. Trips will provide critical operational training in how a VLBI station is run, hands-on training at European telescopes, exposure to radio astronomy research and attendance at meetings and training schools within Europe. This will also help to initiate and facilitate communication between AVN technical staff and the pool of expertise in Europe, opening up future collaborative opportunities.
• The setting up of an AVN technical & support personnel forum network to remotely connect technical and operational staff within AVN countries allowing the dissemination of knowledge throughout the continent and channel communication of technical issues with EU partners. This forum would provide an AVN equivalent to the highly successful EVN Technical and Operations Group and a self-coordinating technical body for future AVN activities, helping to provide longterm technical sustainability of the AVN.

Implementation and Deliverables:
Staff effort from UMAN, UNIVLEEDS and JIVE will be utilised, along with significant in-kind contributions from all partners, to deliver these training opportunities, host exchanges and manage this WP (UMAN). Relevant partners are assigned against individual objectives above. All partners will provide in-kind contributions to training trips in Africa and host exchanges within Europe. EVN institute (JIVE, UMAN, INAF, CHALMERS-OSO) partners will provide exposure to hands-on VLBI observing during EVN sessions. In conjunction with UMAN and SKA-SA, UNIVLEEDS who lead the existing Newton programme will dedicate 5 months of effort over the project duration to manage the interface between
these initiatives. This will be vital to maximise the impact and return of both programmes. The budget request for this WP is 120 kEuro for travel and subsistence expenditure to cover objectives 1-3. This will comprise of 10-15 trips per year over the 4yr duration of the WP at an average cost of ~2-3 kEuro per trip (note that cost of exchange trips, which will be of longer duration and based in Europe, will have a higher average cost). Travel will comprise of a mixture of EU experts travelling to Africa to deliver training and lectures, and AVN trainees undertaking short (~1-3 week) placements in Europe, or within Africa, for example to SKA-SA to utilize their expertise.

WP Lead UMAN (Rob Beswick) liaising with the existing NEWTON project at University of Leeds (Melvin Hoare) and DST South Africa (Antia Loots).

Participation per Partner

Partner number and short name	WP9 effort
1 - JIV-ERIC	9.60
11 - UNIVLEEDS	4.00
12 - UMAN	9.00
Total	22.60

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D9.1	Minutes of telecom 1	12 - UMAN	Report	Public	2

List of deliverables

Deliverable Number[14]	Deliverable Title	Lead beneficiary	Type[15]	Dissemination level[16]	Due Date (in months)[17]
D9.2	Mid-term report on training visits to African countries	12 - UMAN	Report	Public	23
D9.3	Final report on exchange visits to be hosted in Europe	12 - UMAN	Report	Public	47

Description of deliverables

D9.1 : Minutes of telecom 1 [2]

Minutes of Telecom 1, kick-off meeting amongst WP partners

D9.2 : Mid-term report on training visits to African countries [23]

Mid-term report on training visits to African countries

D9.3 : Final report on exchange visits to be hosted in Europe [47]

Final report on exchange visits to be hosted in Europe

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS30	Minutes of telecom 1	12 - UMAN	2	Minutes of telecom 1, noted by exec
MS31	Mid-term report on training visits to African countries	12 - UMAN	23	Mid-term report on training visits to African countries, noted by exec.
MS32	Final report on exchange visits hosted in Europe	12 - UMAN	47	Final report on exchange visits hosted in Europe, approved by board

Work package number [9]	WP10	**Lead beneficiary** [10]	1 - JIV-ERIC
Work package title	VLBI with the SKA		
Start month	1	**End month**	48

Objectives

The driver for this Work Package is to pursue the globalisation of VLBI in the advent of SKA, to dramatically enhance VLBI observations by providing significantly increased sensitivity and access to a broad range of spatial resolutions. With this Work Package, we will support this unique opportunity to explore the synergies between VLBI and the SKA.

Description of work and role of partners

WP10 - VLBI with the SKA [Months: 1-48]
JIV-ERIC, SKAO
Background. SKA1-MID, phase 1 of the mid-frequency telescope of the Square Kilometre Array (SKA), will be built in South Africa (with the low-frequency counterpart to be constructed in Australia). SKA1-MID is capable of providing very long and ultra-sensitive North-South baselines to the European VLBI Network (EVN), enabling exciting VLBI science to be achieved with this unique, global array. The SKA Organisation has initiated a number of international science working groups in order to inform and constrain the detailed design with high profile science cases. The SKA-VLBI Working Group was initiated in the summer of 2015 and has strong representation from JIVE/EVN, with the goal of identifying key science areas where SKA-VLBI will deliver breakthrough astrophysics.

Through the cooperation and coordination of work with the SKA, new and exciting opportunities will arise for global VLBI and JIVE. This Work Package is designed to achieve this through two well-defined tasks: to develop the operational model and the global science cases for SKA-VLBI.

Task 1. SKA-VLBI Operational Model. It is recognised that the development of SKA-VLBI requires a person with VLBI expertise to work closely with the SKA. This person will need to be located in the SKA office to ensure smooth communication channels between all stakeholders, namely, the SKA Office, the construction consortia, and JIVE. We identify a number of key outcomes to emerge from this task.
• Operational model for SKA-VLBI: Given that SKA construction is due to commence in 2018, it is important to ensure that science case developments are in line with existing SKA-VLBI requirements. Investigating this through a series of use cases and operational scenarios would ensure conformity with the SKA design. Commensal observing will be a common operational mode for the SKA. However, it is not clear whether this is also true for SKA-VLBI, and so it will be important to identify whether any technical or operational limitations exist to implementing this operational mode for SKA-VLBI and to increasing the observing efficiency and scientific throughput of VLBI.
• Interfaces: The interfaces between the VLBI and SKA require that there is someone identified to act as a liaison, or point-of-contact, between the SKA office, the construction teams and the global VLBI centres. This will occur at different levels of interaction, for example with the consortia responsible for the correlator or telescope managers. It will deal with data transport, and ensuring that the beam-formed data is in the correct format before being sent for correlation at the VLBI correlation centres. In addition, this work includes laying the foundations for establishing agreements between the SKA and the VLBI networks on issues such as proposal handling, time allocation, data rights and observation management. For instance, the SKA will expect to receive schedule blocks that conform with their telescope and observation management systems.
• Commissioning, test procedures and calibration strategy: Recognising that there is limited scope for SKA support of VLBI during the telescopes construction phase, there is a need to develop a commissioning and test plan for integrating the SKA into the VLBI network. This necessarily includes developing a calibration strategy.

In addition, in the course of much of this work it will be important to consider an upgrade path for SKA-VLBI commensurate with the development path of the SKA. The justification for this, and the requirements that would flow from there, will need to be documented and reviewed.

Task 2. Developing global VLBI science cases. The SKA1-MID will be a phased array with the capability of providing multiple beams over the field of view of individual dishes to observe multiple sources, and at the same time aid precision astrometry. The local interferometer data will complement the high-resolution VLBI results, providing simultaneous images of the sky at a broad range of angular resolutions. The unique combination of high-sensitivity and high-resolution capabilities have not been possible with traditional VLBI arrays. As such VLBI with the SKA is a fundamental tool providing for a wide range of SKA key science including maser astrometry, proto-planetary disks, Galactic and extragalactic structure, mapping stellar magnetic fields, pulsar astrometry and the localisation of transients on all timescales. SKA1-MID will also be capable of providing triggers to the EVN for following-up transient phenomena.

Our aim is to bring together VLBI experts to work on new research projects in the field of precision astrometry, large field-of-view VLBI, VLBI surveys and transients, in order to prepare for scientific exploration of SKA-VLBI. This will result in custom-designed use cases and possible science projects, as well as surveys with traditional VLBI, or other (pathfinder) facilities in preparation for possible SKA-VLBI Key Science Programmes. Involvement of experts as well as promising young scientists is important at this stage.

The aim of this task is to bring together VLBI experts to work on new science cases under the umbrella of the high precision astrometry provided by SKA-VLBI. This will allow the optimal preparation for the full scientific exploration of the science that will be enabled by SKA-VLBI, resulting in custom-designed use cases and science projects in the many VLBI-related science areas identified in the SKA Science Book (2015), as well as surveys with traditional VLBI, SKA pathfinder facilities in preparation for possible SKA-VLBI Key Science Programmes. Involvement of established experts, as well as talented young scientists, is vital at this stage. This task will support the SKA Science and Operations Teams, the SKA VLBI Working Group (core and associated members), as well as other VLBI experts. Besides workshops, we propose to support a number of working visits.

WP Lead: JIVE (Zsolt Paragi) and SKAO (Antonio Chrysostomou)

Participation per Partner

Partner number and short name	**WP10 effort**
7 - SKAO	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]
D10.1	Details on VLBI interfaces to SKA consortia	7 - SKAO	Report	Public	24
D10.2	Operational plan for inclusion of SKA in Global VLBI	7 - SKAO	Report	Public	36
D10.3	Portfolio of SKA-VLBI Science cases	1 - JIV-ERIC	Report	Public	30
D10.4	Report on SKA-VLBI Key Science Projects	1 - JIV-ERIC	Report	Public	42

Description of deliverables

D10.1 : Details on VLBI interfaces to SKA consortia [24]
Details on VLBI interfaces to SKA consortia

D10.2 : Operational plan for inclusion of SKA in Global VLBI [36]
Detailed operational plan for inclusion of SKA in Global VLBI

D10.3 : Portfolio of SKA-VLBI Science cases [30]
Portfolio of SKA-VLBI Science cases with details on science requirements

D10.4 : Report on SKA-VLBI Key Science Projects [42]

Report on SKA-VLBI Key Science Projects

Schedule of relevant Milestones

Milestone number[18]	Milestone title	Lead beneficiary	Due Date (in months)	Means of verification
MS33	Details on VLBI interfaces to SKA consortia	7 - SKAO	24	Details on VLBI interfaces to SKA consortia, noted by SKA VLBI working group
MS34	Operational plan for inclusion of SKA in Global VLBI	7 - SKAO	36	Operational plan for inclusion of SKA in Global VLBI, noted by SKA VLBI working group
MS35	Portfolio of SKA-VLBI Science cases	1 - JIV-ERIC	30	Portfolio of SKA-VLBI Science cases, approved by SKA VLBI working group
MS36	Report on SKA-VLBI key science projects	1 - JIV-ERIC	42	Report on SKA-VLBI key science projects, noted by SKA VLBI working group