AERAP Framework Programme for Cooperation

DRAFT

04 March 2013

To be discussed at the AERAP workshop on 6 and 7 March in Brussels

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I. Introduction

The African-European Radio Astronomy Platform (AERAP) is a response to the calls of the European Parliament, through the adoption of the Written Declaration 45/2011, and of the Heads of State of the African Union, through their decision "Assembly/AU/Dec.407 CXVIII", for radio astronomy to be a priority focus area for Africa—EU cooperation. AERAP is a stakeholder forum of industry, academia and the public sector established to define and implement priorities for radio astronomy cooperation between Africa and Europe. This framework will enable major research and technological advances that will drive socioeconomic development and competitiveness in both Africa and Europe.

Since the initiation of AERAP in May 2012, the platform organised several workshops in Brussels and South Africa. The events focused on human capital development, renewable energies, infrastructure investment and technology development for radio astronomy and explored the opportunities for African-European collaboration in these fields. On the 15th of November 2012, the European Parliament's AERAP Group has been established to secure on-going political support for AERAP's activities.

The present AERAP Framework Programme for Cooperation is AERAP's next step towards the implementation of the Written Declaration 45/2011. It builds on the outcomes of the successful events held in 2012 and describes AERAP's vision for the future of African-European radio astronomy cooperation. This vision is shaped around seven thematic priorities: ICT and big data, renewable energy, research infrastructure investment, scientific instrumentation, education and public awareness, human capital development and the support for global actions. The background and importance of each topic for the advancement of radio astronomy, AERAP's objectives as well as key actions for the implementation of the objectives will be outlined in the centrepiece of this document. Even though each thematic priority will be explored in a separate chapter, various links between the topics exist and will be pointed out. The last chapter describes the different supporting actions that will be necessary to achieve the goals of this Framework Programme; this includes political, financial and practical assistance.

II. Thematic Priorities for African-European Radio Astronomy Cooperation

1. ICT and Big Data

1.1. Background and Objectives

ICT is the backbone of modern radio astronomy and will enable radio astronomers to reveal some of the most extreme events in the universe. Due to improving observation capacities (advances in technology and larger instruments), the amount of data that radio telescopes collect is increasing dramatically and will soon reach the Exabyte/year level. This requires new infrastructures, technologies and software for the capturing, processing, transporting and storing of data.

Undoubtedly, future communication networks will marry the mobility offered by wireless connectivity to the high bandwidth provided by an optical distribution network. SKA with its broadband needs, its distributed antenna or radio cells, can also help to provide a vision for how this cross-fertilization will work: how an optical digital network infrastructure can benefit the future mobile wireless networks and how the requirements of the mobile wireless network may define the choice of particular solutions in the optical infrastructure.

Of particular importance is that radio astronomical projects promote the adoption of technologies relevant for the 5th generation of Long Term Evolution (LTE) or 4G services that will accelerate convergence of mobile/fixed network services and therefore improve broadband access to new communities. Projects like SKA will definitely boost demand for high-end network transponders, reducing time to market introduction of roadmap standards like 100 Giga-bit Ethernet. The huge volumes involved mean these radio astronomy projects will help to reduce price of commodities and facilitate the adoption of internationally agreed/developed standards.

Furthermore, advanced network architectures combined with distributed and collaborative smart antenna technologies, common to radio astronomy and to telecommunications, will provide a road map of commercial enhancements and likely constitute a field of continuous upgrade and deployment of cutting-edge transmission technologies. The data production and transmission up to the Exaflop regime will boost distributed storage and processing services that will likely benefit and cross-fertilise cloud computing initiatives in Africa. This will enable citizen science projects to use databases constituted by radio astronomy projects and open market opportunities for information processing. This last aspect will provide a backbone for other concurring areas of science related applications like space navigation with Galileo, Global Monitoring and Earth Surveillance (GMES) for climate studies and crop control) and new businesses.

Companies involved in ICT development for radio astronomy will be optimally positioned to offer such services. Additionally, an increase in broadband connectivity may bring benefits in many areas which are critical for the future of Africa. It may support education with e-Learning that can bring schooling for everyone also in remote areas. A greater potential lies in the establishment of e-health services, contributing to greatly improve maternal care and reduce child mortality rate while improving mother's welfare.

The future radio astronomy will push ICT developers to pioneer new developments to enable high bandwidths at the Petabit/second rate through an interconnected network of multi-continental sizes. Among others things, innovation on optical fibres and the cost effective production of them will be necessary. Development of equipment for radio astronomy and related ICT infrastructure require careful attention to radio frequency interference (RFI) issues to ensure optimum efficiency of equipment and maximise the science output from the instruments.

The collected and partly processed data have to be delivered from the often remotely located telescopes in Africa to data processing centres and researchers all over the world. Between Africa and Europe this data transfer connection is ensured by submarine cables such as SEACOM and the West African Cable System (WACS). The telescopes and data processing facilities have to be connected to these major intercontinental links and significant high-speed high capacity terrestrial data transfer networks might be necessary.

The objectives of AERAP in this thematic priority are to support cooperation related to:

- Data processing, transport and storage solutions for radio astronomy projects
- Development of technologies and techniques to minimise radio frequency emissions from ICT equipment or shield telescope equipment from radio frequency interference generated by ICT equipment
- Exploitation of ICT developments for the benefit of the local population (collateral and direct economic benefit) and transfer these benefits to local markets
- Identify potential ICT partners in the EU and Africa with interest in radio astronomy projects
- Ensure local participation so that projects are not EU-projects in Africa, but African projects with EU cooperation

1.2. Key Actions

- Future internet for science applications:
  - Explore content-centric networks to create a global namespace for science data
  - Content delivery networks for global distribution system of science data and better data streaming;

- Cloud based distributed processing and science access, including citizen science: Explore cloud computing applications versus high Performance Computing. This allows development of new software/hardware assisted based correlation methods and couple the implication for education and research.
- Couple whenever possible hands-on activities to workshops or promote hands-on driven workshops (for example student friendly competition). This potentially engages industry in training and attracts business creation along science driven activities. (for example: chip testing (FPGAs/GPU/CPU) through algorithm creations for data correlation)

- Internet of connected sensors:
  - Address large scale management, sensors and the related information
  - Correlation of science data with monitoring data

- Develop European and African projects for extra ICT capability exploitation: e-Science, e-Learning, distributed remote sensing, remote medicine etc.

2. Renewable Energy for Radio Astronomy

2.1. Background and Objectives

Due to the increased use of the broadcast spectrum (that portion of the electromagnetic spectrum that is ideal for telecommunication), more and more modern radio telescopes have to be built in remote (and often rural areas) where there is limited broadcasting in the frequency domains relevant to radio astronomy science. This requirement for "radio quiet zones" and the African geography require innovative thinking from the designers of radio astronomy infrastructure to ensure effective and efficient technologies for future energy production, distribution and storage.

The radio telescopes envisaged in Africa will create a launch pad for reliable green power generation in remote areas without grid connection. This real need for autonomous modular power supply at remote observation sites is only one of several promising opportunities renewable energy presents for African-European radio astronomy. Furthermore, the high solar radiation of many African regions creates ideal conditions for solar power plants. Another positive factor are the dramatically falling material costs for solar power plants. This will help reducing the financing cost and thus the risk associated with the investment. The use of renewable energy sources will make radio astronomy facilities independent from fossil fuels and thus from the rising prices and the finite availability of these fuels.

Green power plants that supply radio astronomy infrastructure with electricity may set a pioneering example for self-sustainable mega-science production and infrastructure operation, with an expected direct economic and indirect societal impact in the developing nations. The spin-off triggered by radio astronomy projects can have a positive impact on the quality of life of more than 1.6 billion people by providing reliable power access. These people will benefit from the energy solutions and its early market introduction to be developed around the radio astronomy projects in Africa. The European Union has a direct interest in supporting a sustainable energy roadmap in Africa, for reasons that include environmental concerns (reducing global CO_2 emissions) as well as opening up new markets for its "green energy" industry.

Moreover, the development and construction of renewable power plants can create new local jobs and businesses, while new skills and knowledge can be transferred to the local population. Many of these opportunities will require higher levels of skills that might currently be available in the affected areas, stimulating interest in education into technical domains.

Nevertheless, some challenges need to be overcome before renewable energy projects for radio astronomy can be realised. These challenges concern mainly technical and financial issues. For example, the storage of energy (especially for solar energy) to assure around-the-clock power supply is a technological challenge that receives global attention. Adequate backup solutions for renewable energy systems will be necessary as well to prevent the loss of data and interruptions during astronomical surveys. This is a particularly challenging issue because several remote telescope stations will not have grid power connectivity.

The development of small-scale smart-grids, which can assess and match local power needs and power generation capabilities, at a small cost, could also help overcoming this challenge. Smaller, but real-scale demonstration projects will provide hints on the best day observing regimes, what best observation strategies can be recommended under this extreme circumstances and how to reconcile peak energy production with peak use and thus peak science production.

The objectives of AERAP in this thematic priority are to support cooperation related to:

- Demonstration of the viability of solar power (voltaic, thermal or combinations) for radio astronomy
- Exploration of the possibility to use biomass, wind energy and geothermal energy for radio astronomy
- Identification of candidate renewable energy technologies according to requirements of the installations and local renewable energy resources
- Development of technologies and techniques to avoid or shield radio frequency interference of power plants and equipment
- Uplifting the skills levels in local communities to participate in the operations and maintenance of any infrastructure deployed in their immediate vicinities
- Design power plants and grids in a way that it benefits local communities
- Increasing the number of energy-related studies in Africa, with applicability to radio astronomy research infrastructures

2.2. Key Actions

- Characterise the power and energy requirements of radio astronomy installations
- Develop impact analysis of renewable power scenarios on radio telescopes sites
    - This includes aspects of radio interference and potential for excess power
    - Identify R&D aspects for large scale implementation and use
- Promote joint bursary programs with industry engaging on teaching of sustainable energy, energy efficiency and resource conservation. Energy has a long term investment cycle. Hence, it presents a unique opportunity to promote market and company fidelities via education.
- Developing a training programme for the construction and maintenance of renewable energy plants that can be used to train local engineers and technicians

Various SKA member countries (Netherlands, Germany) and others i.e. Portugal and Spain in Europe are presently engaged in “sustainable energy for science” initiatives. The planned telescopes in Africa together with partners form these countries, offer excellent opportunities for collaborative projects for furthering the Key Actions pointed out above.

3. Research Infrastructure Investment

3.1. Background and Objectives

The main radio astronomy research infrastructure project that could benefit greatly from African-European partnerships is the establishment of an African VLBI (very-long-baseline interferometry) network and the second phase of the global Square Kilometre Array (SKA) radio telescope.

The African VLBI Network (AVN) will be established through a combination of new-built antenna systems (25m or larger in diameter) as well as converted systems composed of satellite communication antenna systems that have fallen into dis-use (30m diameter or larger) due to advances in satellite communications technologies. These antennas will be converted so that they can be used for radio astronomical observations. The AVN will serve to fill a major gap in the European VLBI Network (EVN). The EVN includes telescopes in Europe and non-European regions like China and the Hartebeesthoek telescope in South Africa. Nevertheless, the number of radio telescopes in Africa is very limited which derogates the observation capacities of the EVN. The AVN project has a strong focus on capacity building and will ensure self-sustainability of all observatories established on the continent by training technical teams to maintain and operate observatories in their countries. Scientific staff will be trained to develop bespoke science programmes for these observatories for the periods not engaged in the global EVN activities. This initiative can be expanded to ensure that African participants in the SKA can maintain and operate SKA remote stations to the required international standard once deployed

Antenna conversions already started in Ghana and are under investigation in Kenya; similar projects are foreseen in Zambia and eventually Madagascar. Not all countries that would like to participate in the AVN have large redundant telecommunication systems at their disposal. In some countries, like Botswana, Mauritius, Namibia and Mozambique, the construction of radio telescopes is envisaged to complete the network. Additionally, the MeerKAT array, currently under construction at the proposed African SKA core site, will be a very sensitive element in the VLBI Networks.

As much local participants as possible will be involved in the conversion of existing telecommunication systems into radio telescopes. This is typically challenging in countries, where few radio astronomy practitioners and relevant engineering skills are available. Suitably skilled scientists, engineers and technicians need to be trained to support this project and its objective of human capital development. A pilot training programme is planned for engineers and technicians to maintain and operate the telescope systems established in Africa to be cared for by their own people who can build bigger teams and transfer their skills and knowledge.

The objectives of AERAP in this thematic priority are to support cooperation related to:

- Development of cost effective solutions for the conversion of redundant dishes
- Securing funding to ensure the roll-out of the entire envisaged AVN and its related infrastructure (power, data transfer, etc.)
- Developing a global network of collaborators who can assist with provision of equipment needed for science surveys and experiments of global interest

- Enabling local engineers and technicians to convert and maintain the AVN dishes through extensive and holistic human capital development programmes

3.2. Key Actions

- **Compatibility with global VLBI equipment**
  The refurbishing of the existing communication antennas is the starting point of building a joint research infrastructure. If the AVN antennas are to co-observe with the EVN and other VLBI networks, then some backend equipment needs to be in place that ensures compatibility in the data formatting of all the other telescopes. The EVN has a standing Technical Operations Group that concerns the development of such equipment. The electronic connection in real-time of modern VLBI telescopes by fibre is formally in this category as well, and it should be considered for African telescopes. This action involves updating data backends and participating in the international process to develop data standards.

- **Integration in science observation**
  Through collaboration with the EVN there is a clear path for integrating these new African antennas rapidly into a world-class instrument. The EVN partner telescopes can offer help with deploying the refurbished dishes for VLBI operations. After getting the telescopes and receivers to work, provisions need to be made that make turn the African elements into full-functional VLBI telescopes. For example, one will need to start measuring various calibration data (position, pointing, frequency and time, sensitivity) and make these available during science observations. The expertise for this is available in the EVN countries, as is the know-how on the operational logistics that are required for participating in science runs. An action could be formulated that helps the African telescopes to set-up the necessary calibration methods.

- **Joint correlation**
  The VLBI instrument is complete only when all the telescope data are combined in a so-called correlator. Currently the Hartebeesthoek dish subscribes to the EVN correlator at JIVE. This could be implemented for all the AVN elements, but at the same time the idea should be entertained to develop some African correlation capacity for stand-alone observations as well. Besides some hardware purchases (on both continents), this requires the exchange of expertise in specific computational methods and sharing the complex software for this process.

- **Scientific services**
  The VLBI network needs to be open to scientists, notably to African astronomers that will have to become familiar with VLBI science processing. In this action some work will need to go in setting up tools for science proposals and telescope scheduling. Most importantly user support facilities will be required that introduce (new) users to the data and the scientific processing. Some specific training actions will need to be implemented to harvest the science from the new instrument.

4. Scientific Instrumentation

4.1. Background and Objectives

Good instrumentation is one of the key elements of successful telescopes. It is essential to have state-of-the-art receivers that are compatible with other VLBI Networks such as the European VLBI Network (EVN), the Australian Long Baseline Array (LBA), or the Very Long Baseline Array in the US (VLBA). The most commonly used bands at these networks are L-band (1--2 GHz) and C-band (4--8 GHz). Receivers at higher frequencies, e.g. the important K-band between 18 and 26 GHz, require new dishes at suitable sites for high frequency observations (preferably dry and at high altitude).

Training of engineers and technicians throughout Africa in state-of-the-art receiver technology is also an important aspect, in particular in light of the upcoming SKA. Hands-on training and maintenance is required to reach this goal. The transfer of knowledge can be achieved by close cooperation between African and European Institutions.

The objectives of AERAP in this thematic priority are to support cooperation related to:

- Investigate the procurement if the best set of receivers for the AVN
- Training local engineers and technicians to maintain state-of-the-art receivers

4.2. Key Actions

To be discussed

5. Education and Public Awareness

5.1. Background and Objectives

Modern astronomy plays a key role as a tool for inspiring and educating young people. As one of the most approachable and fascinating sciences to children, especially the very young, astronomy is an excellent vehicle for introducing them to science and technology. Due to its unique combination of science with inspiration and excitement, it has distinct potential in facilitating education and capacity building throughout the world. Astronomy is also a powerful tool for raising the awareness of adult citizens, companies and policy makers for the potential of science and innovation for socio-economic development.

Such an impact on the Mathematics and Science education system as well as influencing the public perception of science and technology will also feed directly into the Human Capital Development programme, supplying young enthusiastic school leavers into the tertiary education system.

The objectives of AERAP in this thematic priority are to support cooperation related to:

- Increasing the number of schools using astronomy for science education
- Developing astronomy-based educational materials for young children and teenagers to excite them about science in non-school based contexts
- Training of teachers on astronomy content and teaching methodology in order for them to use astronomy to enhance the teaching of mathematics and science
- Raising the awareness of European and African citizens, companies and policy makers for the potential of radio astronomy
- Using the cultural links through indigenous knowledge of astronomy both in Europe and Africa to promote ownership of the science of astronomy and stimulate a culture of scientific thinking
- Improve the uptake of science and mathematics at schools and undergraduate levels at universities

5.2. Key Actions

- Curriculum design: Work closely with the curriculum specialists within partner countries to identify ways in which the teaching of the existing local school curriculum could be enhanced through strategic topics relating to the fascination of astronomy, e.g. calculate the distance to the moon using trigonometry. This project should be sensitive to the local curriculum needs and objectives and how astronomy can help to achieve that. The long term goal would be to incorporate astronomical topics strategically within the mathematics and science curricula in order to enhance the learning of these subjects.
- Teacher training: Identify and work with facilitators in European and African countries who will be able to inject astronomy-related training into the teacher training systems within that country. The principle will be to try to link the excitement of astronomy to the existing mathematics and science curricula. By developing a community of teachers associated with the project, both in Europe and in Africa, there will be an exchange of ideas, materials and methodology to enhance teaching in both continents.

- Inspiring the very young: Develop training programmes and materials for facilitators in each partner country who deal with young children. These facilitators could be based at science centres, observatories, museums, schools, child care facilities, etc. The training and the materials would focus on conveying the beauty and scale of the universe to young children in order to inspire them to follow an education path that includes mathematics and science. It should also convey a sense of tolerance and global citizenship through the knowledge of the vastness of the universe.

6. Human Capital Development

6.1. Background and Objectives

Radio astronomy investment has raised both the supply of and demand for a skilled, scientifically literate as well as engineering workforce. Because of this increase of capital in African economies, it has contributed to the creation and growth of a high-knowledge skills base on the African continent.

The International Astronomical Union has highlighted the effective role of astronomy in human and economic development in its Strategic Plan 2010-2020 "Astronomy for the Development World". Astronomy has been an important driver behind the development of advanced technology, such as the most sensitive detectors of light and radio waves and the fastest computers. Radio astronomy is also embedded in one of the committees of the International Radio Science Union (URSI) showing the relevance of synergies between (radio) science fields e.g. between radio astronomy imaging and medical imaging techniques. Moreover, unlike most sciences, astronomers can participate in frontier astronomical research regardless of their geographic location. Many of the cutting-edge facilities, both on the ground and in space, developed for astronomy are available for use at no cost by scientists throughout the world.

With its potential to advance our fundamental understanding of the universe, radio astronomy has captured the imagination of young people and increased the number of students studying astronomy and space-related sciences at universities. Current radio astronomy projects, like MeerKAT, are already contributing to the development of astronomical and engineering skills across Africa. Since technologies being developed for these telescopes will be commercialised in the next 10-20 years, young African people currently working on the project will find themselves in high demand around the world. Embedded in the wider international perspective of the SKA, the building, commissioning and operation will significantly enhance science and engineering experience in working with multidisciplinary science infrastructure together with international colleagues.

The objectives of AERAP in this thematic priority are to support cooperation related to:

- Increasing the number of Africans studying astronomy, physics, engineering and other astronomy related subjects
- Increasing the number of post-graduate astronomy programmes
- Facilitating the mobility of students and young researchers between Africa and Europe

6.2. Key Actions

- Establish regular radio science and engineering schools and workshop in relevant areas for early researchers interacting with experienced researchers
    - A particular example is the recent Calibration Workshop but could in general relate to system integration and commissioning
    - Other examples are follow programs from FP7 Marie Curie SKADS and Radionet
- Establish low threshold exchange programs e.g. like FP7 IRSES

- Programs like these are essential to enable exchange of persons at all experience levels between Europe and Africa

- Seek hosting of events related to the scientific unions (IAU, URSI etc.) and other (e.g. IEEE)
    - Developing an African base /house for these activities ensures improved interaction potential with these Unions such as is advancing with IAU
    - An ambition could be to host a general assembly of a scientific union within a decade. Prior to that smaller events could be organised, as is done with IEEE related events. Prior to that, dedicated smaller event could be planned such as now done for the upcoming Africon-IEEE event hosting a specific Europe-Africa URSI meeting emphasizing Radio Astronomy and Instrumentation.
- Establish educational and outreach platforms with primary and secondary schools and schools for higher (technical and other) education
    - Platforms could mean project related activities as part of the (local and/or regional) education for both pupils and teachers
- Design and implement training and Masters programmes, in collaboration with industry and the European scientific community, with traineeship opportunities both in Africa and abroad.
- Develop post-graduate curricula and related teaching facilities and resources (lecturers) to grow the fields of radio astronomy and all its related disciplines in engineering on the continent
- Establish academies and relevant other educational facilities to enable Africa to enter into the global knowledge economies of the world as equals and take leadership in niche domains

7. Support for Global Projects

7.1. Background and Objectives

The most important radio astronomy project of the coming years is certainly the Square Kilometre Array (SKA). The first phase of the project, SKA_1, is already well planned and prepared by pathfinder projects like PAPER, MeerKAT and ASKAP. On the other hand, the second phase SKA_2, especially the African part, is still undefined and it is not clear how this part of the project can be financed. African-European partnerships can contribute to provide the necessary knowledge, workforce and funding for filing this gap.

The objectives of AERAP in this thematic priority are to support cooperation related to:

- Extending aperture arrays to higher frequencies ~ 1420 MHz
- Reducing manufacturing and operating costs while maintaining performance and reliability
- Establishing a quick data connection between Africa and Europe

7.2. Key Actions

To be discussed

III. Support for the Implementation of the Framework Programme

The implementation of the described actions requires primarily the engagement of European and African scientists, engineers and industry. They need to match their ideas, establish consortia with appropriate partners and prepare proposals for suitable funding opportunities. Political, financial and practical support would facilitate and accelerate this process significantly and multiply thus the potential of African-European radio astronomy cooperation.

Political support

- Raising awareness of policy makers
- Establish a sound policy basis for the development/promotion of African-European radio astronomy cooperation (research and development policy) in EU and Africa
- Ensure that funding instruments are adapted to African-European RA partnerships (eligibility of African countries; radio astronomy, science capacity and human capital building as eligible topics; adequate financial resources for the funding instruments)
- Raising public and media awareness

Financial support

- Help to open up new/alternative financial sources (industry, foundations...)
- Guide the way to public funding

Technical/practical support

- Support to find partners and match ideas (seminars, workshops, consortium building meetings, AERAP matching expressions of interest)
- Support to prepare proposals (AERAP Helpdesk, proposal writing meetings)