AFRICAN VLBI NETWORK

The African VLBI Network

A Project by SKA Partner Countries towards SKA in Africa

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Rev 1

Agenda

- **Motivation for AVN**
- **Approach**
  - Conversion of redundant telecom antennas in partner countries into VLBI Capable radio telescopes
  - New-build VLBI stations with a strategic long term plan towards SKA Phase 2
  - Human Capital Development in the partner countries
- **Tangible Benefits in Ghana**
- **The Future…**

Motivation for AVN

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Having won a good share of SKA Deployment in the Continent during the decision on SKA bid in 2012:

To demonstrate that the Partner Countries for SKA in Africa (Botswana, Ghana, Kenya, Madagascar, Mauritius, Mozambique, Namibia, South Africa and Zambia) have a positive approach and clear focus to specify, build, operate, look after, upgrade and use radio astronomy infrastructure

To develop the required Human Resources and indigenous skill base towards the above in those Countries

And thus to counter the Afro-pessimism and PROVE to the World that AFRICA CAN DO IT and IS FULLY CAPABLE OF HOSTING SKA!!

SKA Partner Countries in Africa

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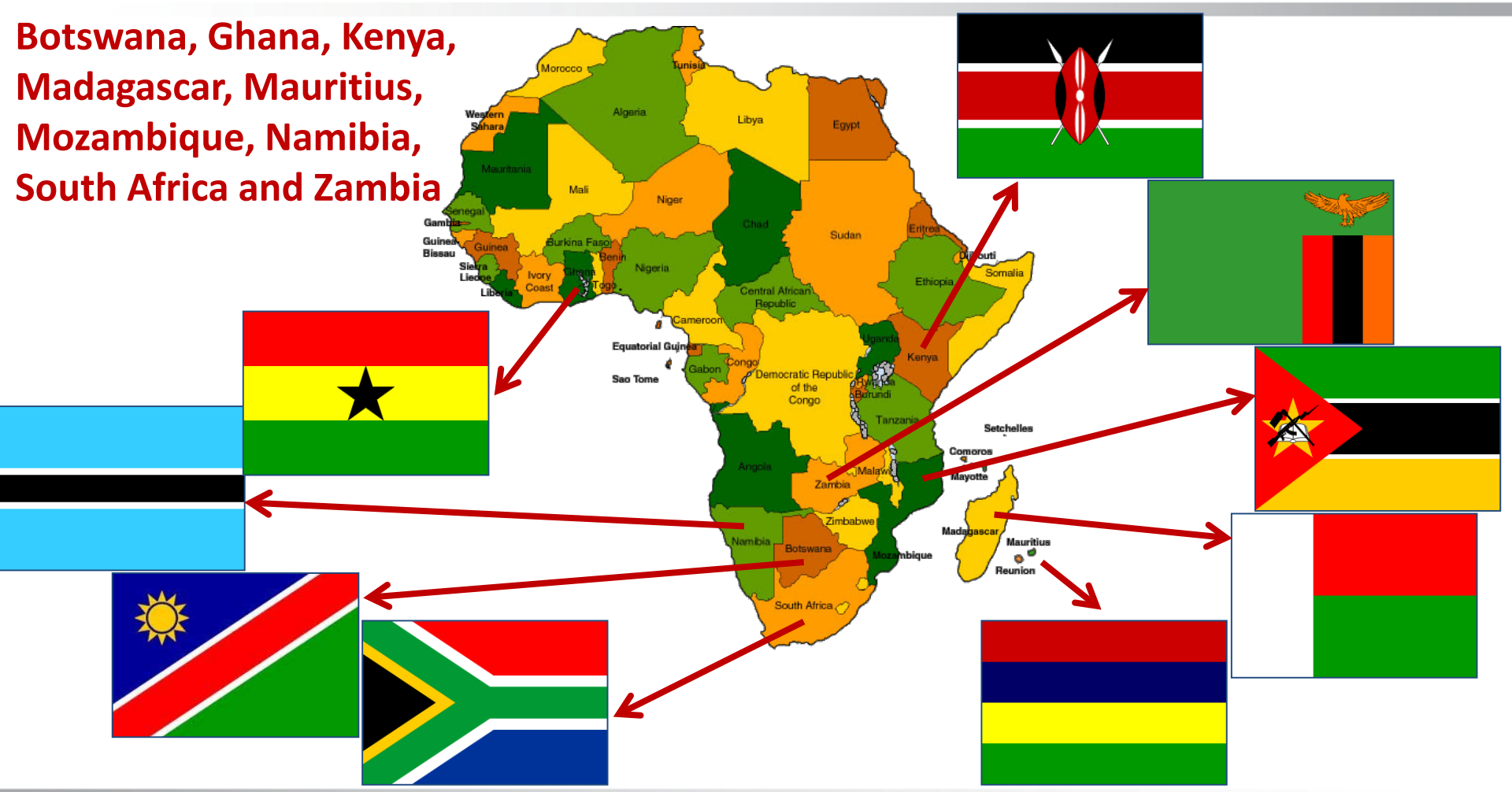
Botswana, Ghana, Kenya, Madagascar, Mauritius, Mozambique, Namibia, South Africa and Zambia



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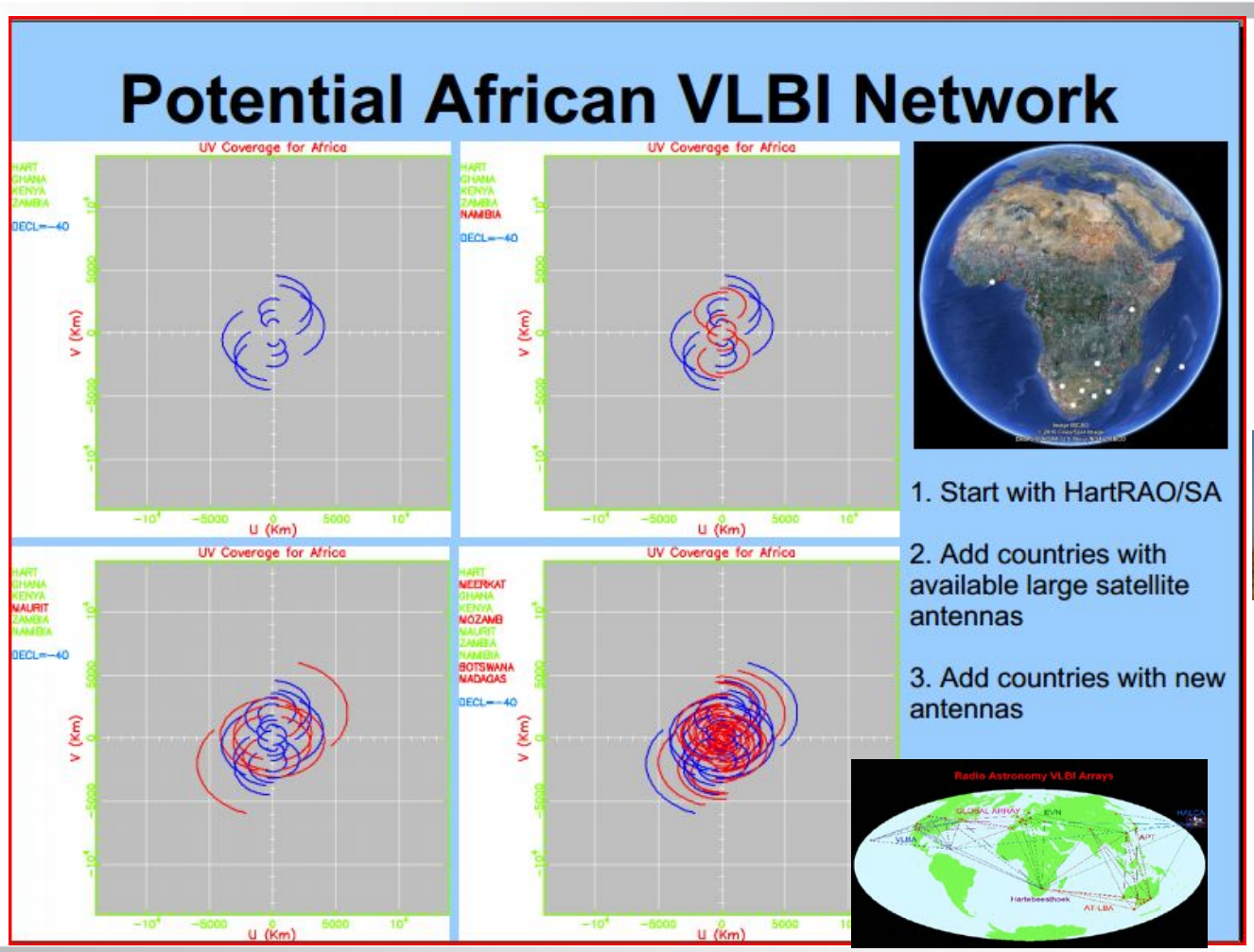
SKA AFRICA
SQUARE KILOMETRE ARRAY

Scientific Motivation for AVN



Vision of (late) Dr. Mike Gaylard, who was a driving force behind AVN….

Fill the Big Gap In Africa!

Approach - Conversion

GHANA

KENYA

ZAMBIA

MADAGASCAR

Would-be VLBI Stations of AVN at Kuntunse, Accra, Ghana, Longonot, Kenya, Mwembeshi, Zambia and Arivanimamo, Madagascar using redundant large 30m. class telecommunication antennas built in the 80s

Tsirinana, Madagascar

Conversion – What it entails?

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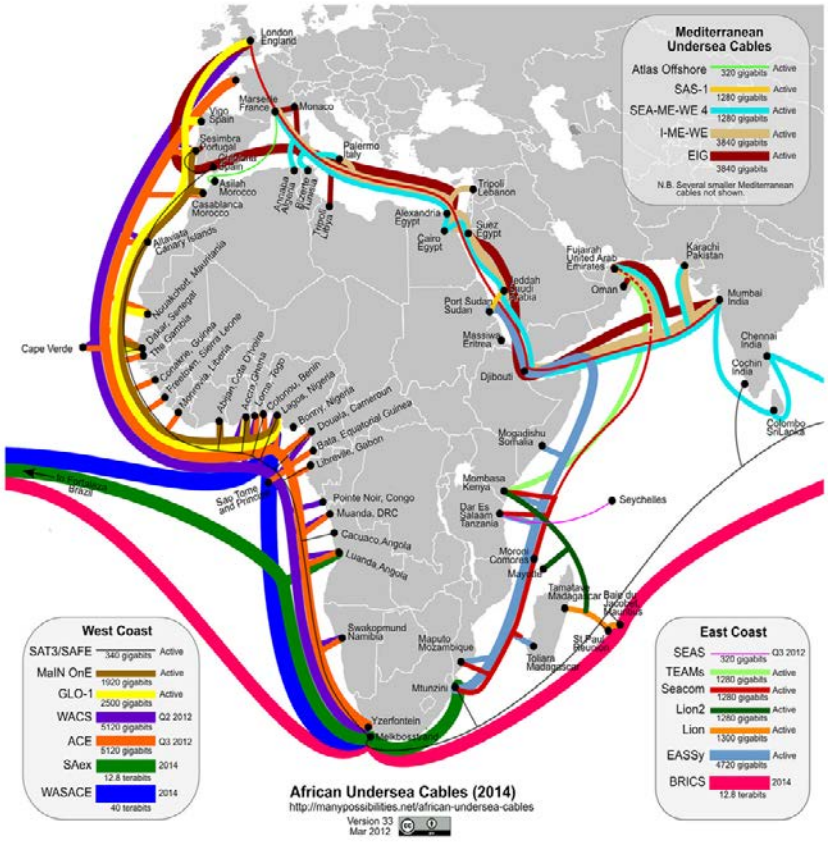
- **Mitigating risks due to (possible) poor OR no maintenance after retirement of the original mission (due to advent of submarine long-haul optical fibre networks) about a decade ago**
- ***Taking care of change in mission requirements***
  - **from a Satellite Earth Station which LOOKS at a defined geo-synchronous satellite; but with a capability to slew from one satellite to another (if and when needed)**
  - ***to a radio telescope which slews between astronomical sources and tracks a source-under-study over the full azimuth and elevation ranges of the antenna***
- **Blind tracking instead of Beacon tracking**
- **Mitigating risks due to obsolescence of parts and unsupported components during life time**

Approach made feasible due to growth in optical fibre connectivity in the Continent



What could the radio telescope stations of AVN do?

- **Our First focus in AVN is to look at the Universe in 5 and 6.7 GHz bands with VLBI, Spectrometer, Radiometer and Pulsar Timer capabilities.**
- **Looking in other frequency bands with an "Improved Eye" will be an Upgrade Activity**
- **AVN Data Centre in Africa when Four stations become operational**
- ***The deliverables from SKA Phase 2 stations in the Partner Countries will follow the Phase 1 effort in Karoo, South Africa.***

Structural activities – Pintle Bearing

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Structural activities– Bump Stop

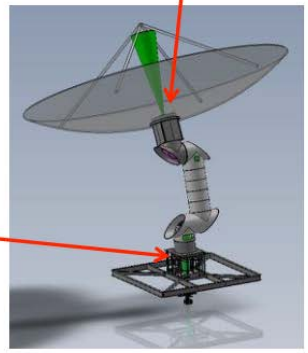
Structural activities – Quad Legs

Manufacturing of quad legs for replacement in Ghana

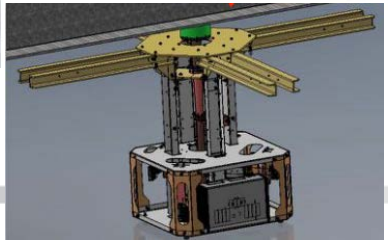
Signal Chain activities







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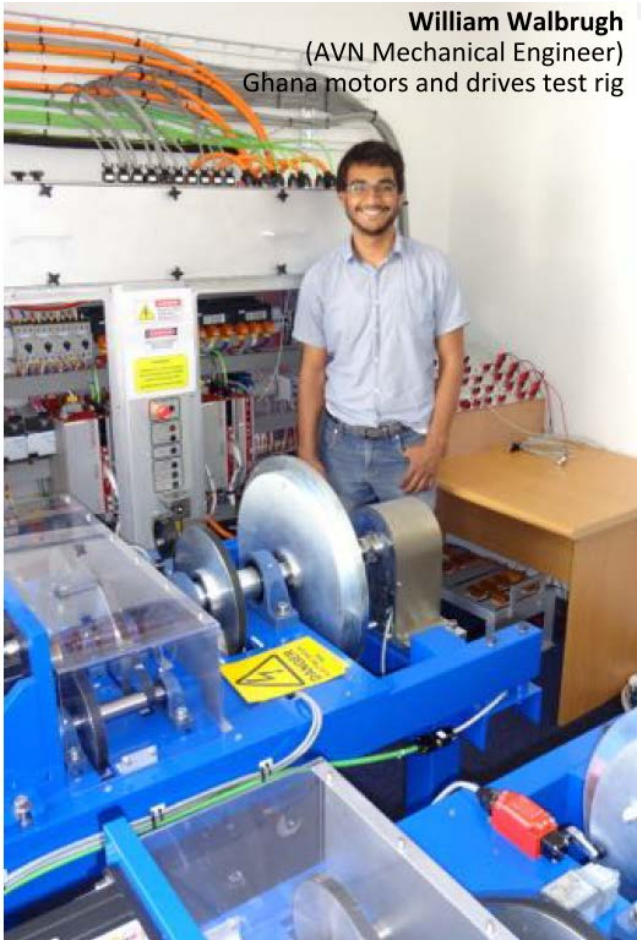
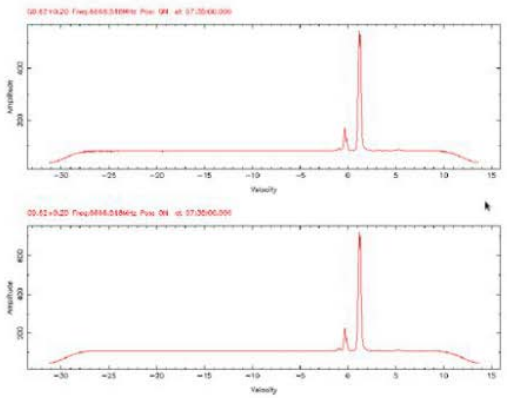
Technical activities in South Africa for Ghana

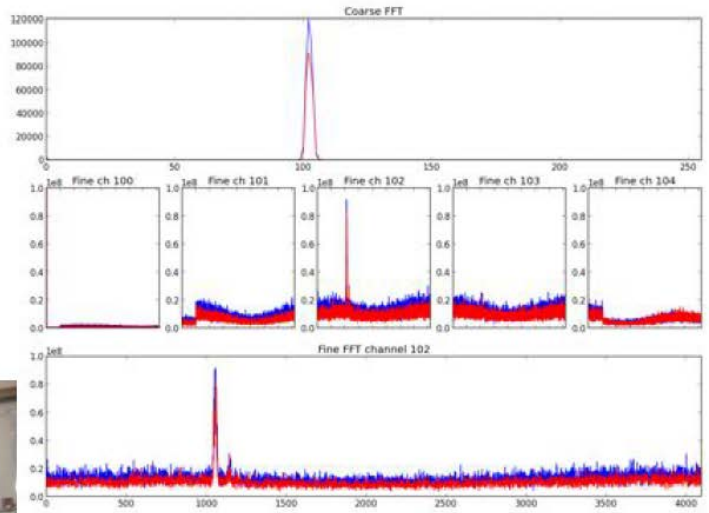


William Walbrugh
(AVN Mechanical Engineer)
Ghana motors and drives test rig

Methanol Maser G 9.62
HartRAO ATNF correlator, 2 minute integration

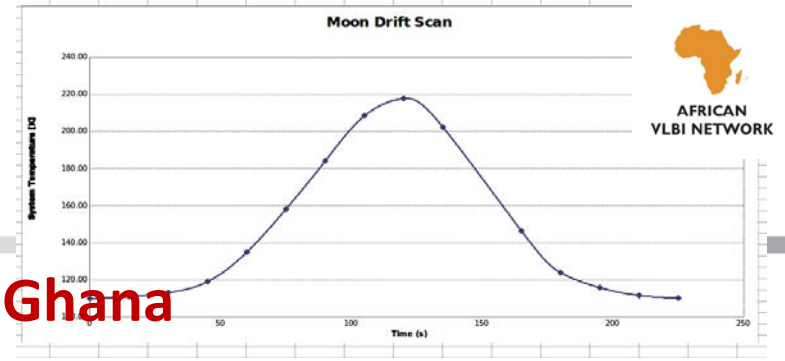


Methanol Maser G 9.62
AVN High-resolution spectrometer, 130 ms integration



15 April 2015 - Early results from Hartrao digital backend deployment successfully resolved a methanol maser using ROACH-based spectrometer, and confirmed it with measurements from HartRAO instruments.

Conversion: Status



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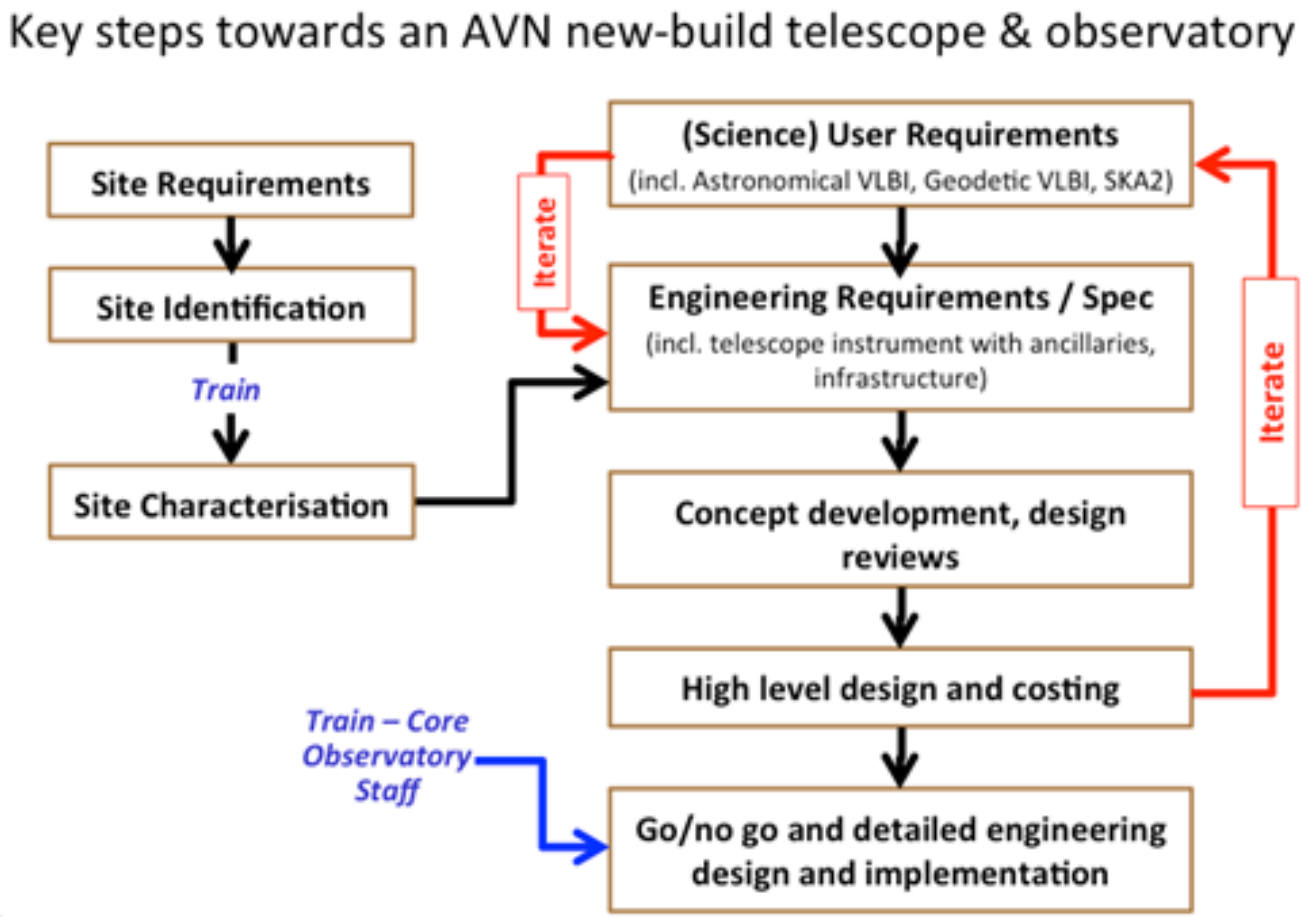
- **Activity in progress with full focus in Ghana**
  - **Process and procedure for the AVN Engineering activities being fine-tuned in the "Pilot Project" with Ghana.**
    - **Goal is to demonstrate VLBI capability by the middle of 2016 as a joint programme of SKA-SA in South Africa and GSSTI, GAEC, Ghana**
    - **Funding for conversion phase by South Africa.**
    - **Transfer the facility to GSSTI for operation, maintenance and upgrades with a life time expectation of 15 years**
  - **Stakeholders' interest is HIGH**
    - **Royal Society, UK has approved a programme to train 60 PhD students in Ghana in 3 years**
    - **Keen interest by International VLBI community to use the facility**
- **Activity under different stages of discussions in Kenya, Madagascar and Zambia**

Approach – New Build

- This is currently an unfunded activity but picking up momentum….
- *Aim would be to strategically choose the site (access road, power, water, connectivity, weather and RFI) and locate new VLBI capable stations in some of the partner countries to gain critical knowledge essential during SKA Phase 2 deployment*
- The User Requirement Specifications are in the process of getting finalised
- An effective diameter of at least 25m. with slew rate capabilities meeting astrometric and geodesic VLBI apart from astrophysical VLBI would be a good goal.
- Receivers could be cryogenically cooled to operate initially in 5 and 6.7 GHz bands (to match capability of conversion stations)
- eVLBI capability will be a goal while supporting conventional disk-based VLBI.
- Radiometry, Spectroscopy and Pulsar Timer capbilities will be available when used in “Stand Alone”mode

New Build Process



Approach – Human Capital Development

In all the efforts of AVN, Human Capital Development in the continent has been a prime driver so as to meet *(and exceed)* the motivation

From concept to reality: The AVN Scaled Training Telescope (ASTT) or The "Baby Telescope" as a Basic Training Tool together with a 6-months training programme for the Core Partner Country Team in South Africa

Approach – Human Capital Development

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- **The non-conversion partner country HCD efforts will be taking different shapes:**
  - Train the Trainers
  - Short (1 week) Joint Exchange Development Initiative (JEDI) Intervention on a focused topic in SA or in the partner country
    - RFI monitoring, Big Data, Archival data mining….
  - Build interferometer systems with small antennas as a part of training in Universities of partner countries
  - Assist in developing the curriculum in Astrophysics in Universities of partner countries
  - Training activities for partner country teams at HartRAO as a part of Newton Fund deliverable
- **Training for partner country with a converted antenna will have an additional component of skills and knowledge transfer of the actual system delivered at a nut-and-bolt (or R, L and C) level. This will be a continuing exercise with the Core Team for training identified very early in the conversion process.**

Ghana – Tangible Benefits

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- Ghana Radio Astronomy Club launched with funding provided by AVN – now has over 100 members and meets weekly, chaired by Head of School of Science (SNAS);
  - 3 outreach events per term, the 1st is a presentation on astronomy (students introduced to the science of astronomy) & observations they can do on their phone, 2nd involves a Kutunse visit, 3rd involves building of simple optical telescopes.
- Team of 10 riggers /painters complete antenna refurbishment & paint contract at a fraction of the cost of any competing bid;
- GAEC workshop contracted for manufacture and supply of major structural repair (quadropod replacement) in 2016;
- Several other contracts awarded to suppliers in Ghana.

Ghana – Tangible Benefits

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- In 2012, no university in Ghana offered Astrophysics. In 2015, all participate in the Royal Society Astrophysics training because of AVN.
- PhD bursaries awarded to Ghanaians since the start of AVN in Ghana:
  - 1 PhD to complete in 2016, now Chief Scientist of Kutunse Observatory;
  - 3 PhD bursaries to members of AVN Core Essential Observatory Staff trained in SA;
- MEng bursary to Severin Azankpo (mechanical engineering) and one other member of AVN Core Essential Observatory Staff trained in SA;
- Royal Society programme – 12 trainees completed one year training, second group of 14 selected by Prof Melvin Hoare (UK) in October 2015;
- Unprecedented interest from Ghanaians in post-graduate SKA SA bursaries for studies from 2016 onwards in fields previously unknown or inaccessible to them:
  - 7 Ghanaian applicants for M-level SKA SA bursaries, AVN to award bursaries to 3;
  - 5 Ghanaian applicants for PhD-level SKA SA bursaries, none successful but 1 selected for Young Professionals Development (YPD) programme and to be based in AVN team for 2016.

The Future…

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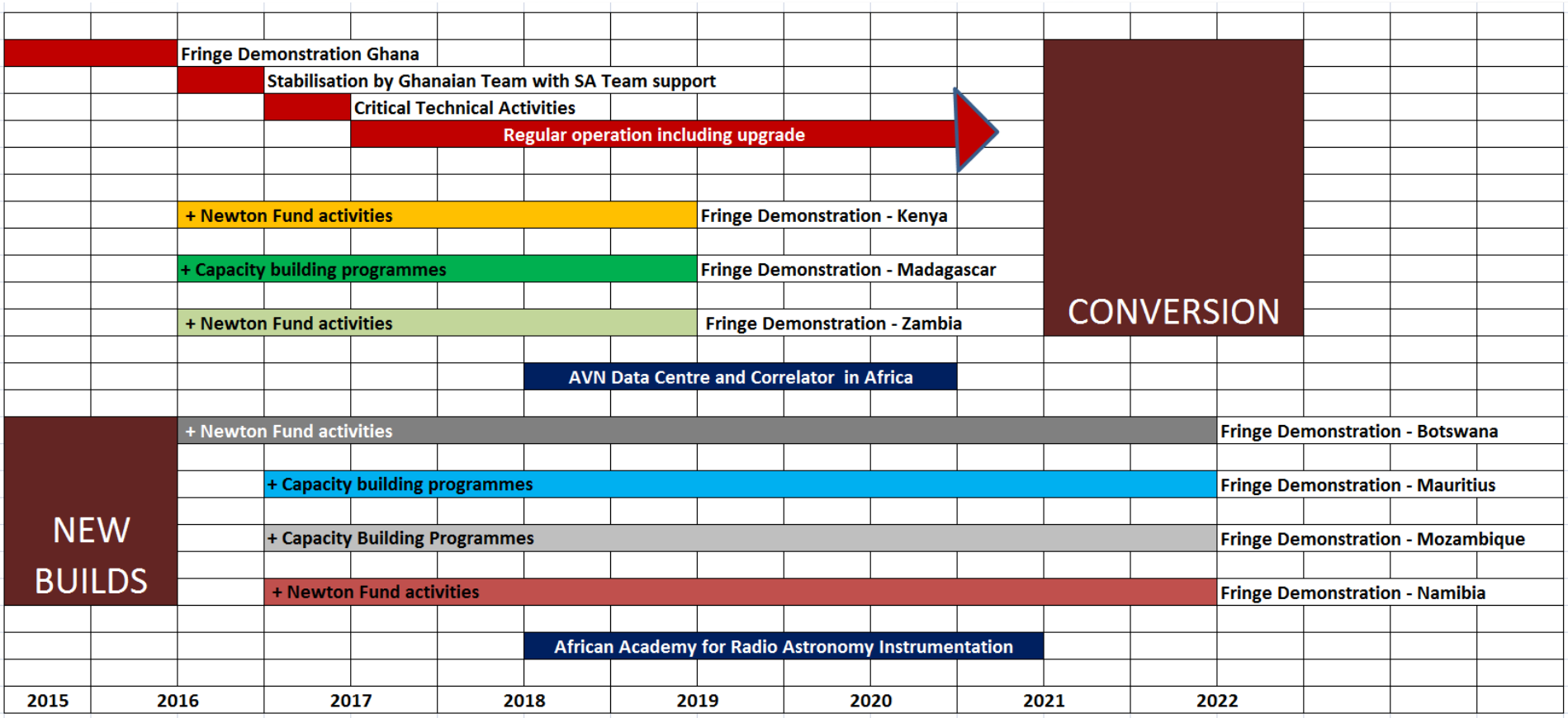

THANX FOR YOUR PATIENT LISTENING….. ANY QUESTIONS?

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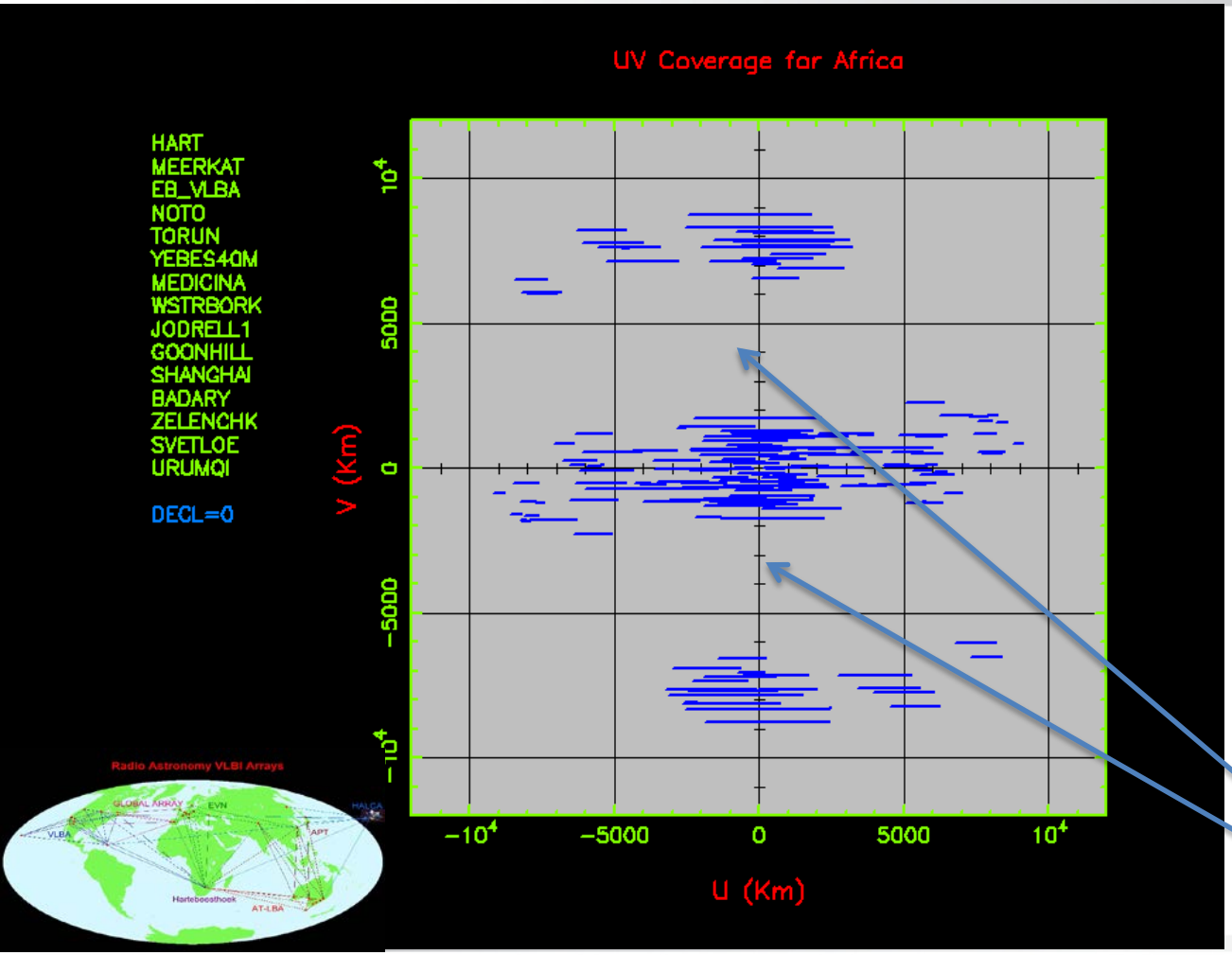
EXTRA SLIDES

Importance of filling the Big Gap: uv coverage: Hart+meerKAT & EVN

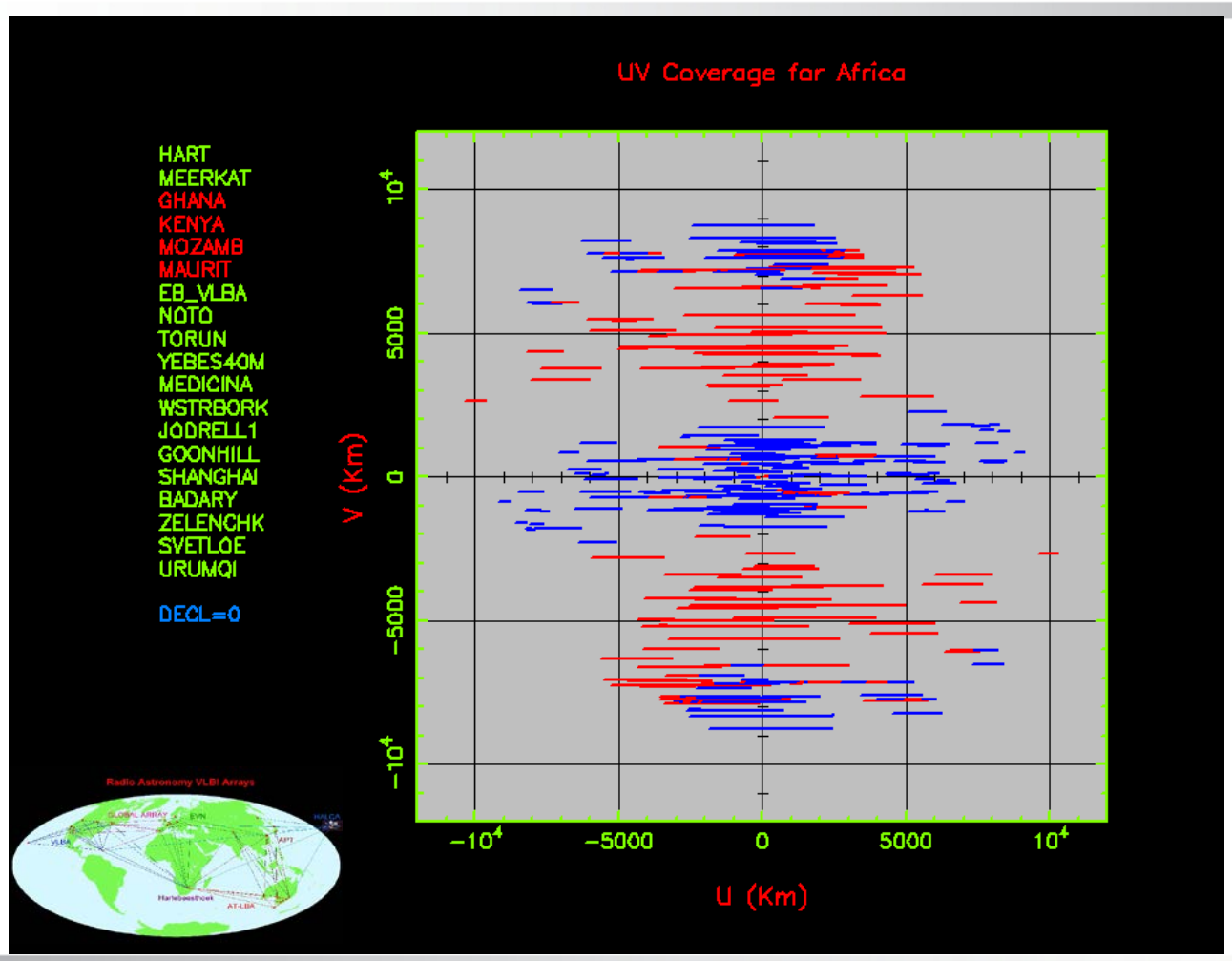


The UV coverage tells one about the response of an interferometer array

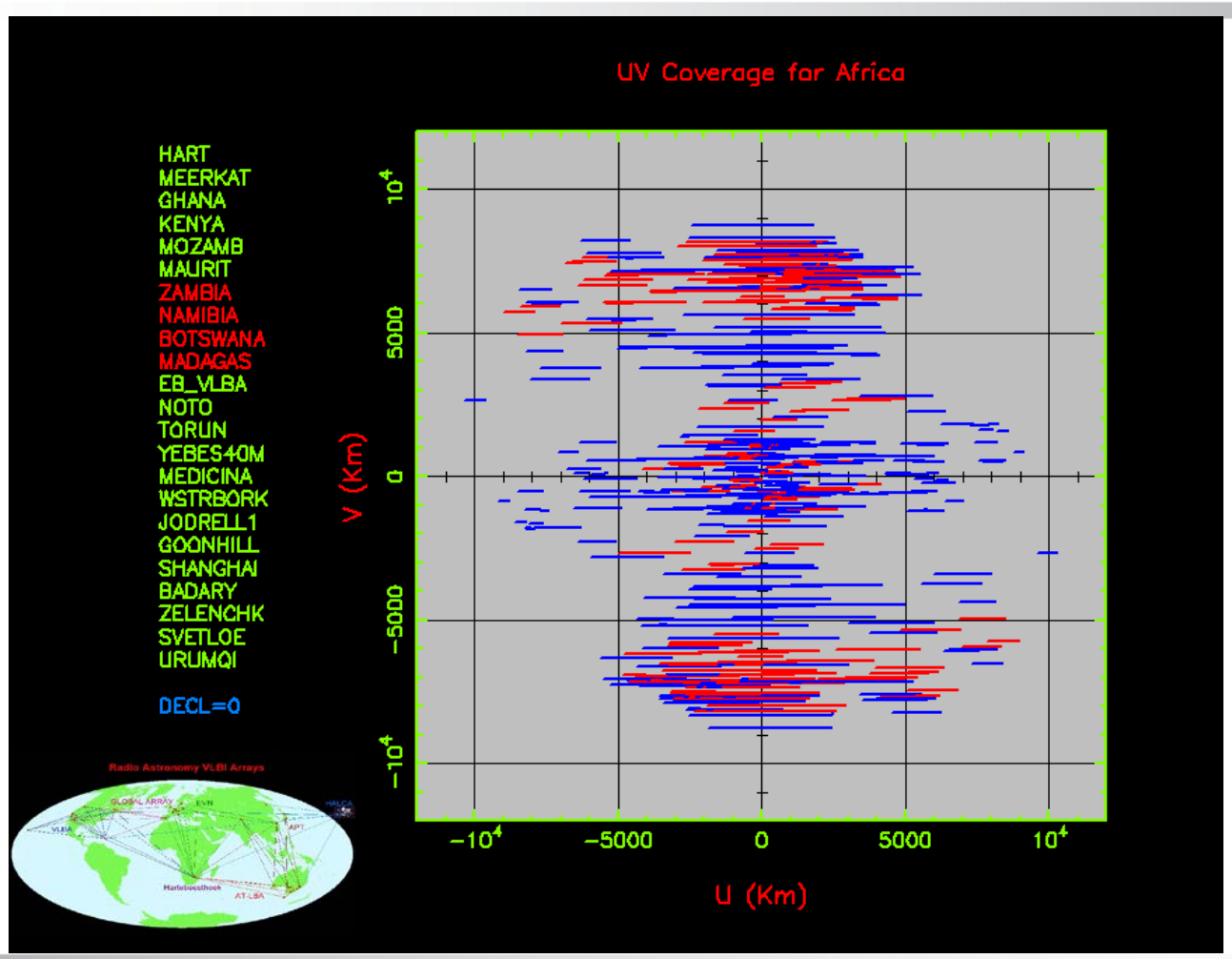
A better filled UV plane means a better array

Effect of Big Gap

Result of “filling the gap” with FOUR Partner Countries added

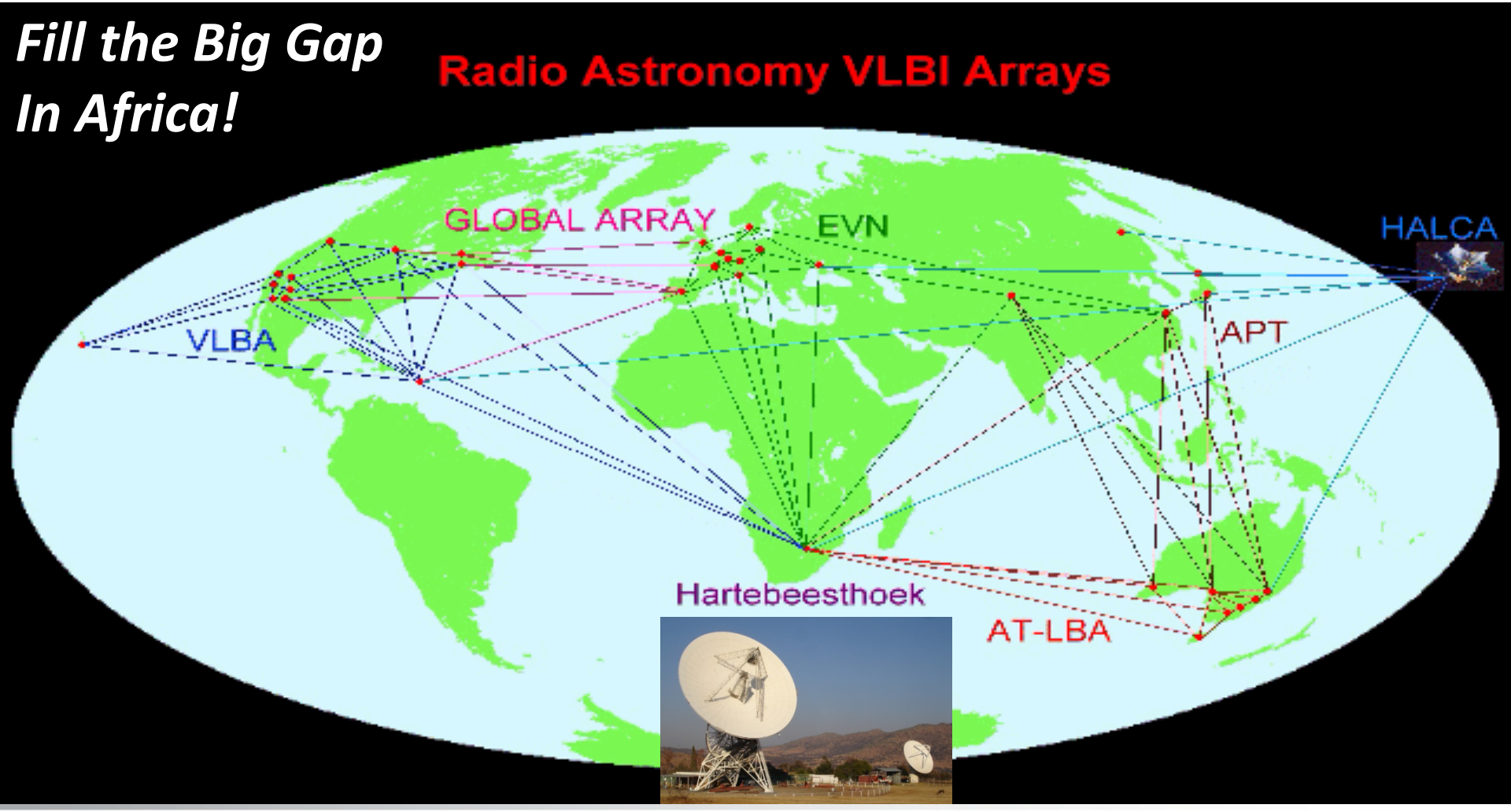


Result of “filling the gap” with four more Partner Countries added



Scientific Motivation for AVN

Fill the Big Gap In Africa!



Science Objectives – VLBI Astronomy

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Imaging with high angular resolution of compact, bright radio sources:

- Quasars – changes in jet structure, calibrators, astrometry, celestial reference frame;
- Gamma-ray flare source follow-up (HESS II in Namibia, FERMI-LAT, CTA);
- Masers – interstellar (e.g. methanol) – investigate variability / periodicity; measure maser spot movements; measure annual parallax to determine the distances to star-forming regions in the Milky and map the spiral arms;
- Pulsars – proper motions and distance determination through annual parallax, interstellar magnetic fields, interstellar scattering, emission region size;
- Transient radio source behaviour;
- Supernovae – behaviour of remnants of core-collapse supernovae;
- Interacting binary star behaviour e.g. Circinus X-1;
- E-VLBI and ToO VLBI through internet – rapid response to new events;
- Improve the Celestial Reference Frame for parallax determination and multi-wavelength astronomy.

Science with AVN – Global and Regional VLBI Observations

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- AVN stations will be important participants in International and Regional VLBI research
- An African Data Centre with a VLBI Correlator is planned on lines similar to European VLBI Network.
- Scientific and Technical Advisory Committees are being planned to advise on the operation of African network
- An academic optical fibre network to link all the African stations with the African data centre will assist in e-VLBI operation.
- It is expected that the VLBI mode will form 50% of the usage of an AVN station

Science with AVN – Stand-Alone

- **Instrument being equipped with back-ends to carry out research in continuum, spectroscopy and pulsar timing modes.**
- **Such usage is expected to be led by local Universities and resident astronomers for about 30% of the operational time**
- **Possible areas of research (not limited to):**
  - **Spectroscopy with narrowband multi-channel receiver:**
    - **Monitor masers in star-forming regions eg for periodic variations (methanol at 6668MHz);**
    - **Survey formaldehyde absorption in Milky Way dark clouds (4829 MHz).**
  - **Pulsar observing with wideband multi-channel timer:**
    - **Monitor pulsars for glitches, long term behaviour, proper motion;**
    - **Search / monitor for intermittent pulsars and transients (RRATs).**
  - **Radio continuum flux measurement with wideband multi-channel radiometer:**
    - **Monitoring of Gamma-ray flare sources.**

Strategic Objectives of AVN

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The strategic objectives of the AVN project are to:

Objective 1: **Establish and maintain political, practical and material commitment for the AVN in SKA partner countries;**

Objective 2: **Develop institutional capacity and memory, management & control skills as well as engineering and technology skills to realise SKA Phase 2 in an efficient and cost effective way;**

Objective 3: **Establish internationally recognised operational radio astronomy facilities in Africa as well as the requisite skills within the partner countries to counter Afro-pessimism and the international perception of risk**

Upgrade Feasibilities

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Upgrade feasibility exist in multi-dimension:

- Operation in additional RF Frequency bands
- Cryogenically cooled receivers
- Pulsar search mode
- Collocation of other scientific instruments and facilities
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