The African VLBI Network (AVN)

- progress @ Astro-JEDI

September 2015, Monkey Valley

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SKA South Africa

Overview of presentation

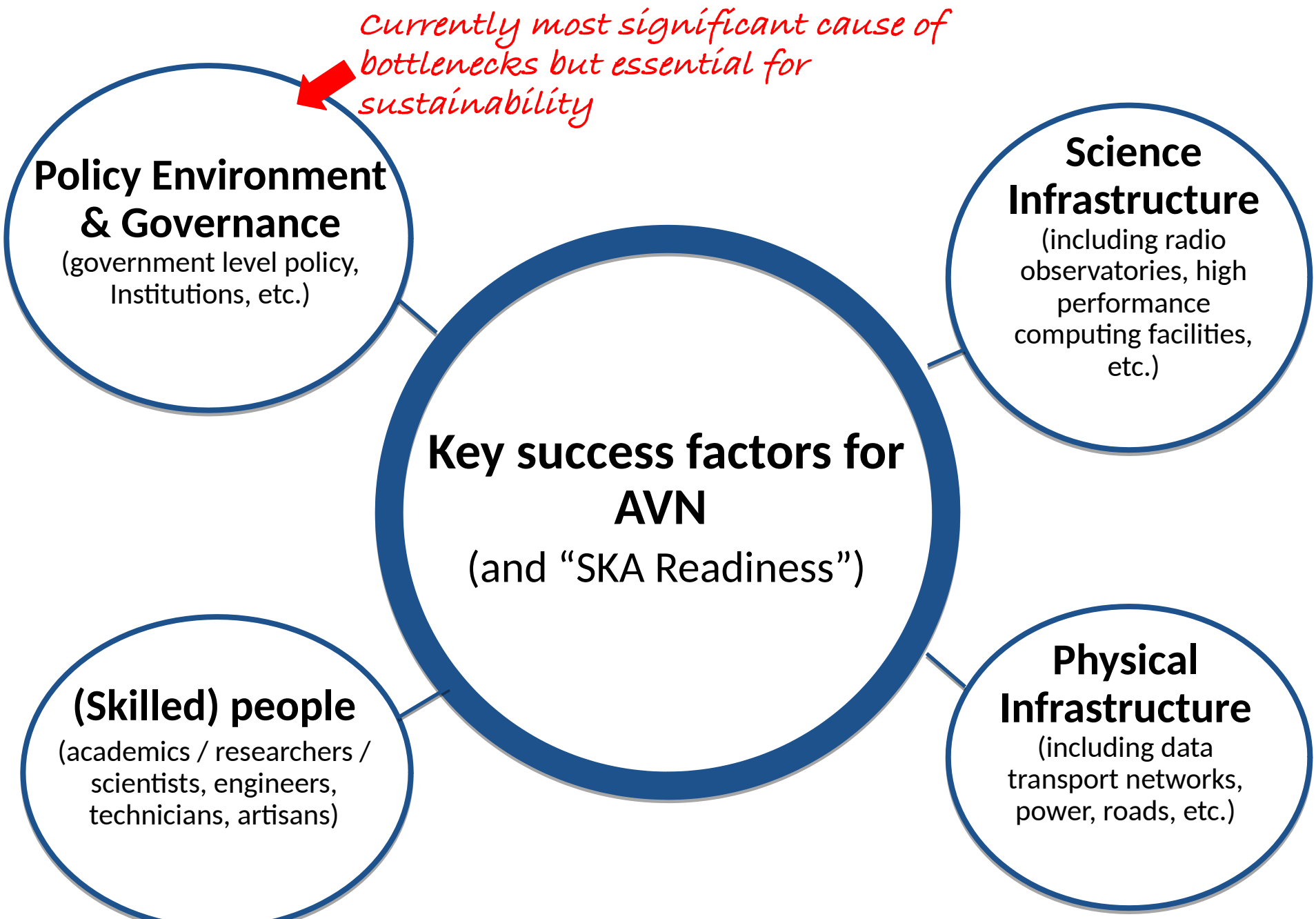
- Progress update;
- Pictures;
- Questions / Discussion.

What is the AVN & why are we doing it?

- Develop a network of VLBI-capable radio telescopes on the African continent;
- Africa (led by South Africa) will co-host the Square Kilometre Array telescope with Australia, 9 African countries to host stations in SKA2 (including SA):
  - Develop the skills, regulations and institutional capacity needed in SKA partner countries to optimise African participation in SKA2 and enable participation in SKA pathfinder technology development and science;
  - Skills and knowledge transfer in African partner countries to build, maintain and operate radio telescopes independently;
  - Bring new science opportunities and develop strong RA science communities.

AVN Engineering options

- Conversions of redundant large telecommunications antenna systems:
  - Ghana, Kenya, Zambia, Madagascar;
  - Agreement to use for science, transfer of telecomms facility;
  - Establish “home” for the observatory, with funds for engineering, operations and maintenance phases;
  - Resource adequately and train extensively (people, telescope equipment and tools, institutional support, funds etc.)
- New-builds: **Unfunded at present**, site requirements and selection and associated science case work initiated (also require infrastructure on a site suitable for radio astronomy (SKA2 site??));
- Correlator: Software correlator, initial investigations ongoing;


Currently most significant cause of bottlenecks but essential for sustainability
Policy Environment & Governance
(government level policy, Institutions, etc.)
Science Infrastructure
(including radio observatories, high performance computing facilities, etc.)
Key success factors for AVN
(and "SKA Readiness")
(Skilled) people
(academics / researchers / scientists, engineers, technicians, artisans)
Physical Infrastructure
(including data transport networks, power, roads, etc.)

Ghana Conversion @ Kutunse

- Antenna ready for use with Royal Society trainees in September:
  - Antenna painting completed (excluding reflector surface), AZ and El encoders fitted and tested;
  - Electrical cabling and wiring (80%) completed, lights fitted to structure;
  - Receiver chain & dehumidifier fitted and receiver being tested;
  - RFI measurement campaign & report completed, action plan under development (incl. meetings with National Communications Authority (Ghanaian regulator));
  - Camera fitted for optical pointing, sun drift scan tests successful;
  - All procedural and installation documentation completed with engineering data packs as part of the process;
  - First use of telescope for engineering / instrumentation training - drift scans as part of Royal Society project and training wrt astronomy instrumentation in September 2015.
  - Major structural repairs immediately thereafter.
  - Full motion antenna available in February / March, VLBI fringes in June 2016.

Zambia – Mwembeshi

- Contract to EMSS to understand impact of mast on VLBI telescope on Mwembeshi site (completed);
- Science impact and spectrum management / allocation discussions under way;
- Will engage with Zambian Regulator (ZICTA) and Zambian officials to agree next steps.

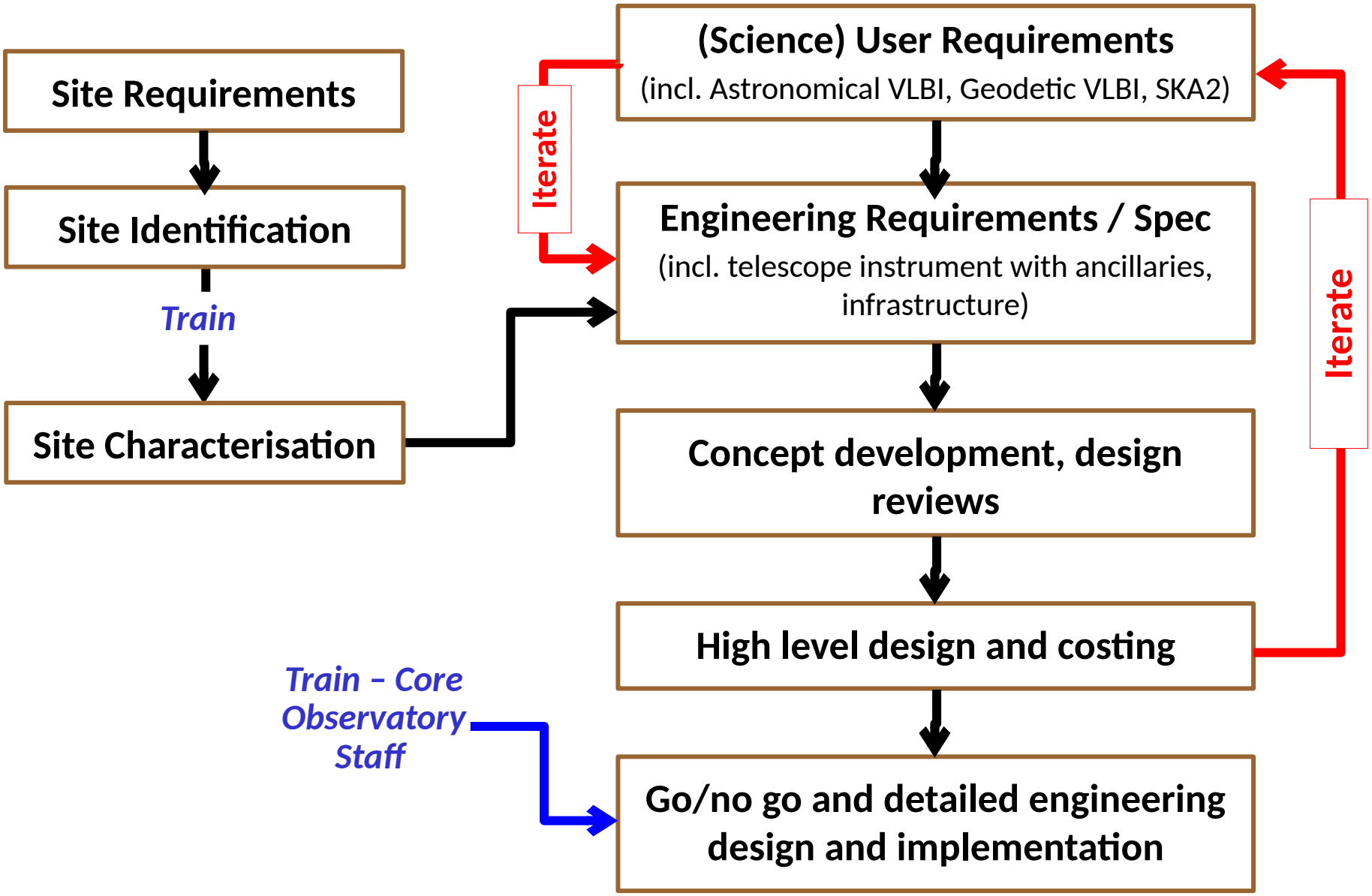
Kenya - Longonot

- Final steps by Kenyan Government to secure Longonot site for the conversion;
- Feasibility work started in 2014, project could be kicked off as soon as governance bottlenecks have been addressed.

Madagascar - Arivonimamo

- March 2015 - indicated that conversion is now ready for discussion – feasibility visit planned for later in 2015;
- Ongoing e-mail exchanges to discuss a feasibility visit, request technical information especially with regards to antenna design, site conditions etc.

Key steps towards an AVN new-build telescope & observatory



Holistic approach for training interventions

Observatory Essential Skills

(hands-on 6 month training of 6 member team from partner country in SA and thereafter during conversion)

Short courses not leading to degree / diploma

(eg short courses (soldering, CAD, FEKO etc.))

Training for the AVN and towards self-sufficiency in maintenance and operations of AVN stations and participation in SKA2

Tertiary qualification

(aimed at ensuring a robust user / research community, incl. scientists, engineers, technicians, etc.)

Artisans

(formal training towards a qualification as an artisan, etc.)

Newton Fund project – overview

- Newton Fund (UK) and DST (SA) matching Funds:
  - Principal SA Investigator Prof Ludwig Combrinck (Director: HartRAO), principal UK investigator Prof Melvin Hoare (University of Leeds);
  - Close collaboration with joint delivery and one Steering Committee from SA & UK;
  - UK/SA 5-year collaboration, ZAR1.5million per year (SA activities funded by DST) *plus* £500 000 (UK activities, funded by Newton Fund)
- Initial 3-year training programme with the aim to develop researchers in radio astronomy fields and related instrumentation, who can become part of the international science community and ensure optimum use of the new observatories deployed through the AVN;
  - "Official" participants Zambia, Kenya and Namibia;
  - Botswana receiving training PC laboratory and two-dish interferometer and tailored training programme (funded by SA);
- Visits to Zambia, Namibia, Kenya and Botswana completed to kick off project.
- It will train 130 researchers using the available telescopes in Ghana, Kenya, Zambia and at HartRAO for the observing periods.

Tailor-made programme for Botswana

- What are the critical components of a 10-year plan for Botswana to ensure SKA readiness? How can our partnership help deliver SKA Readiness?
- PC training lab and two-dish training interferometer;
- 5 JEDI workshops specifically “catering” for HCD needs of Botswana (2 x science and science data processing, RFI measurements and campaigns, 2 x engineering / instrumentation);
- Botswana to provide venue, participants, 2 JEDI co-presenters and local arrangements.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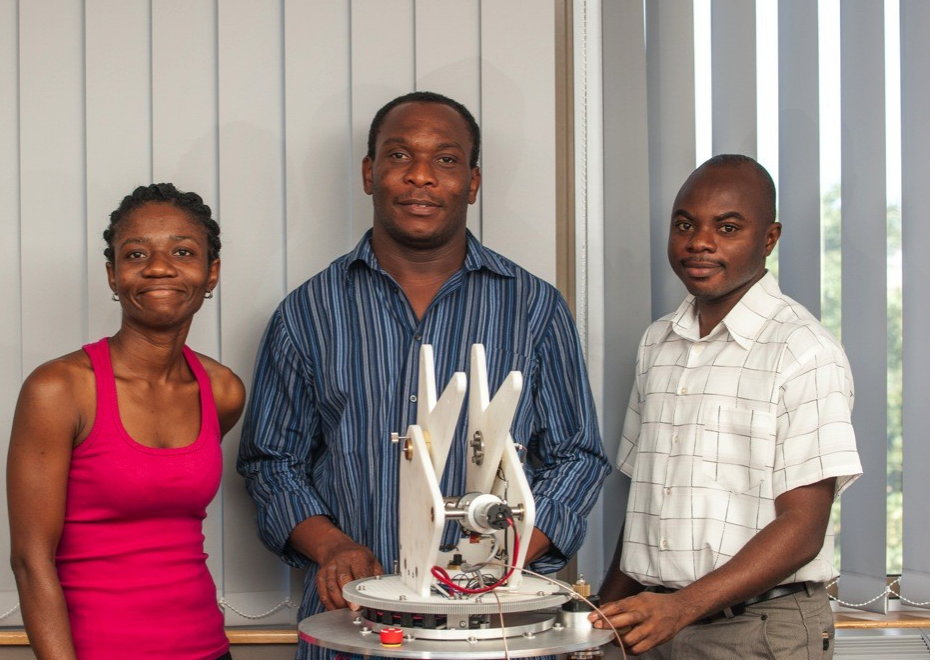
A WINDOW TO



“Baby telescope” key training tool as part of knowledge transfer and hands-on immersive learning

Laboratory, handskills and IPC soldering course and certificate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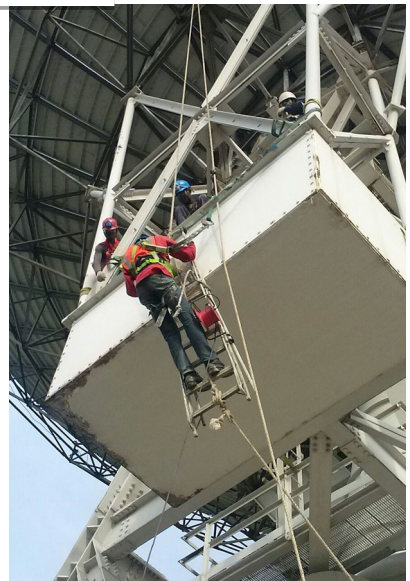
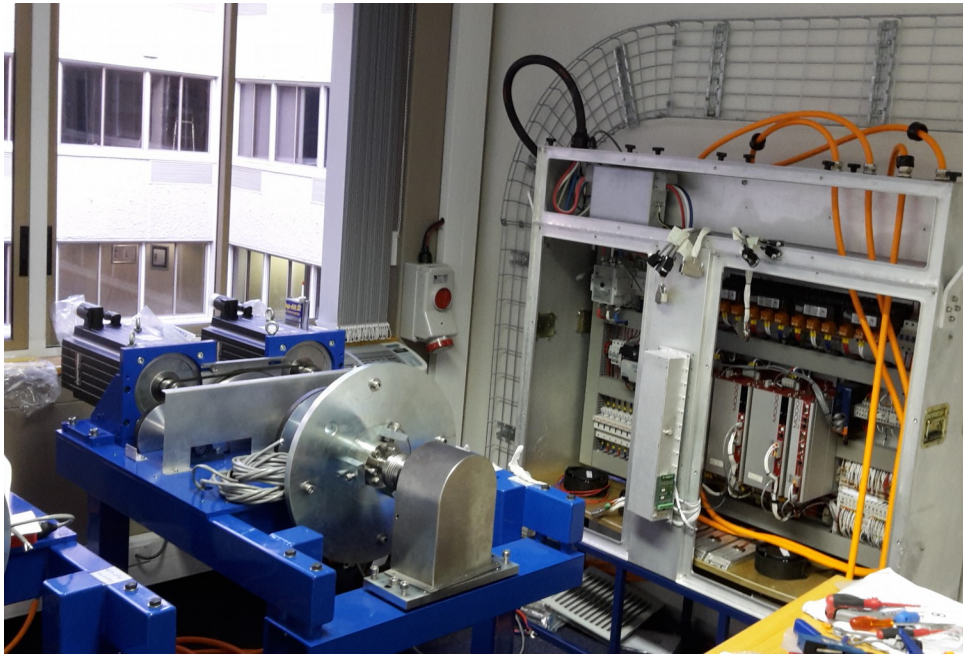
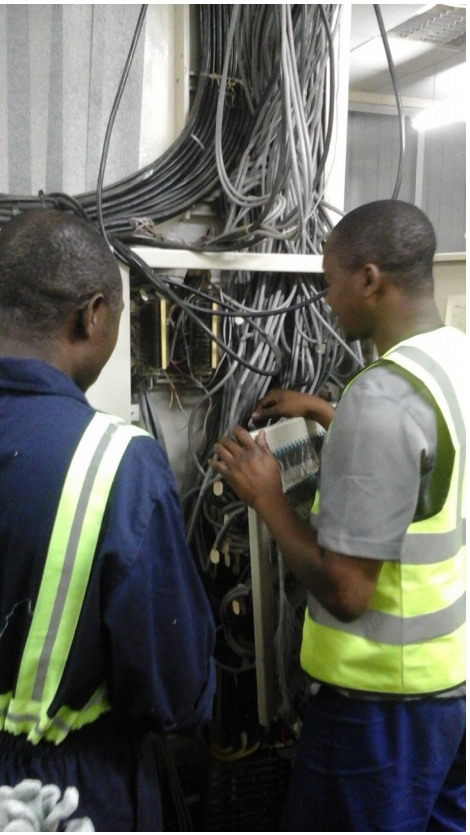
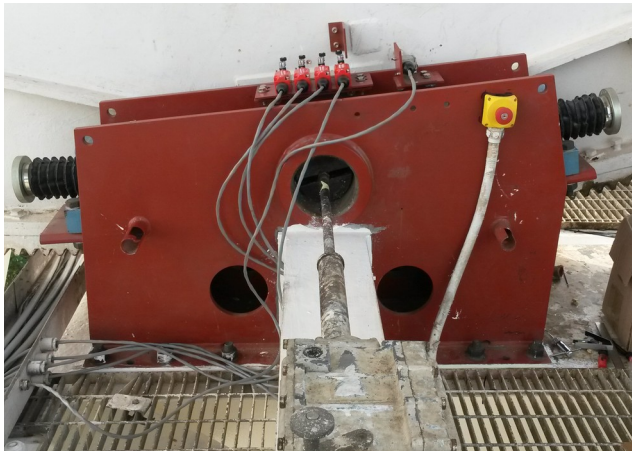


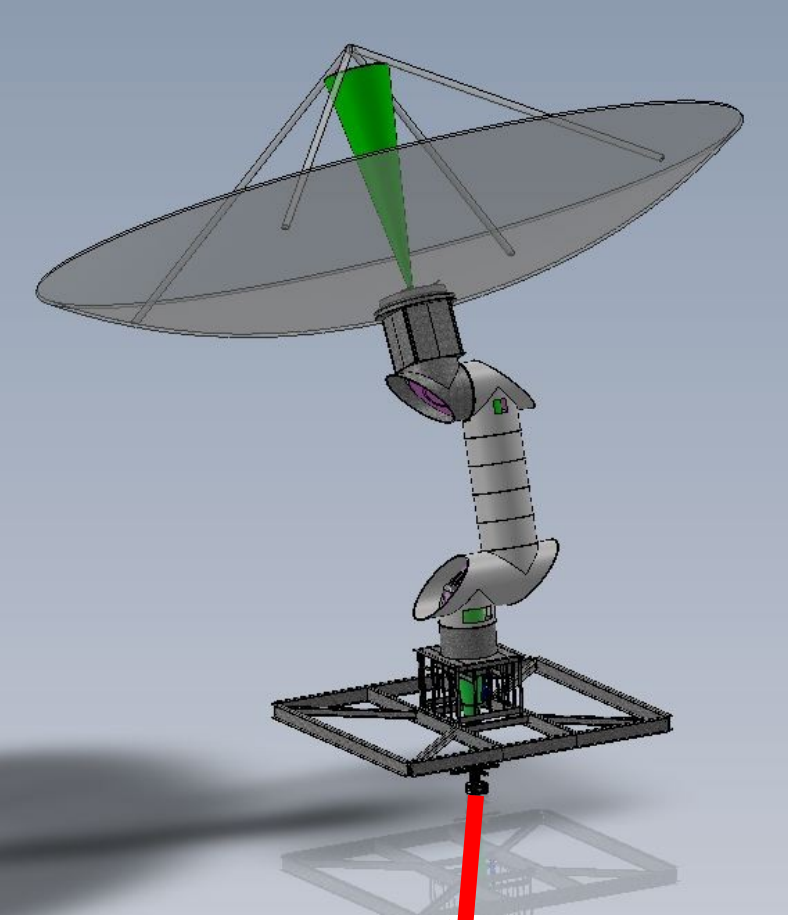
(August 2015) Wiring of MOOG controller and motor test jig in Cape Town

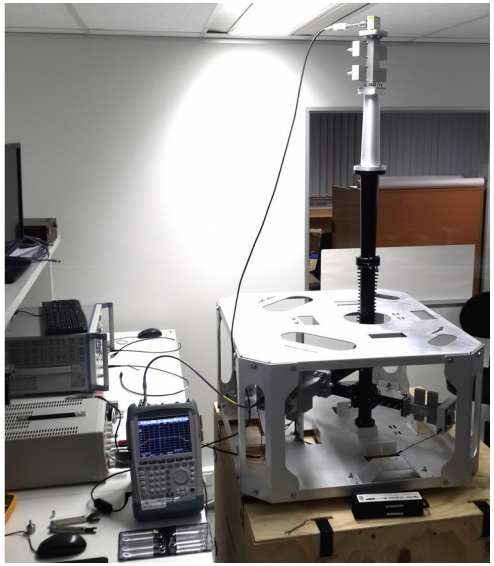


Ghana (April 2015) re-wiring of the entire system, emergency stops, lights, limit switches connected and tested, etc.







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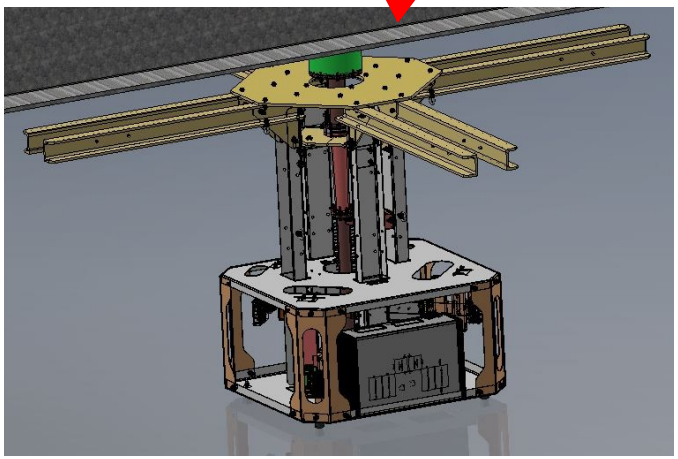
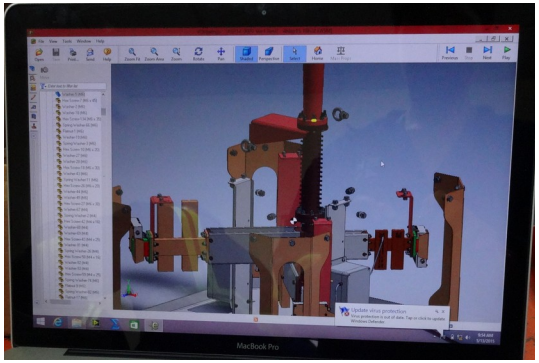
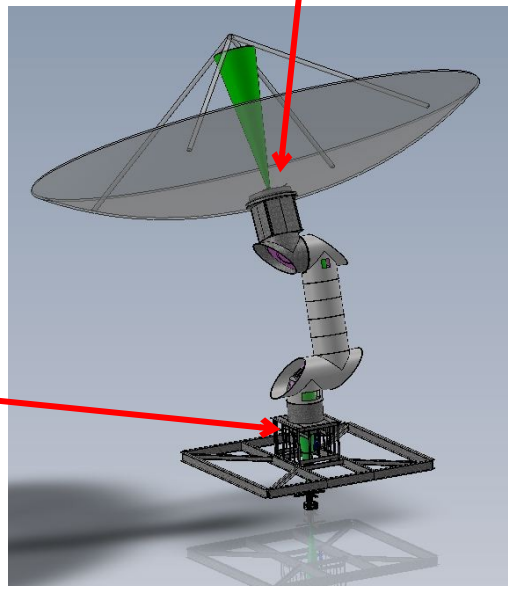
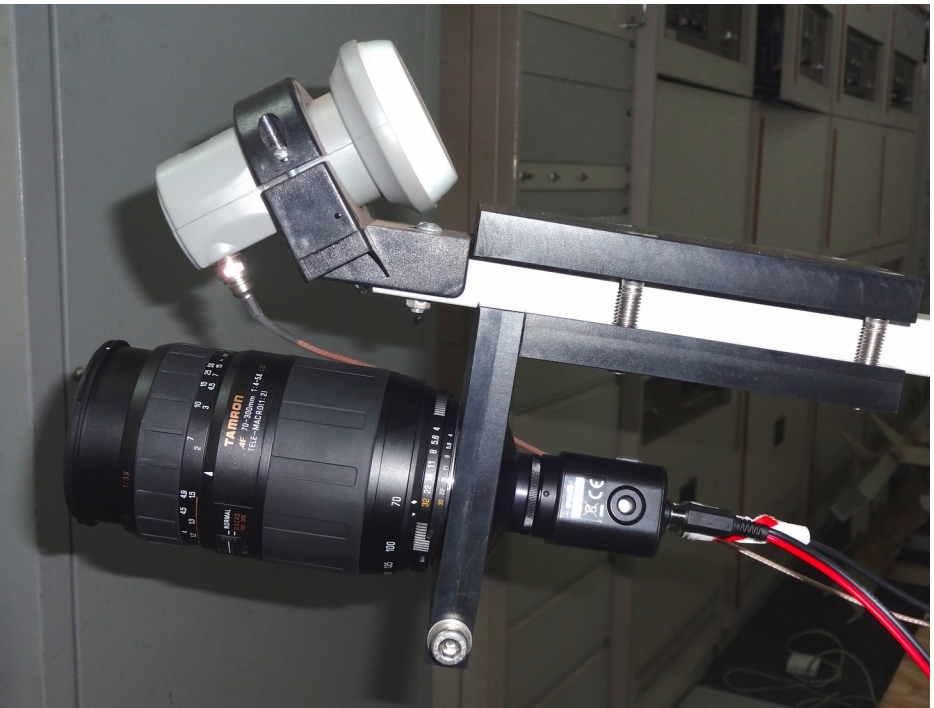




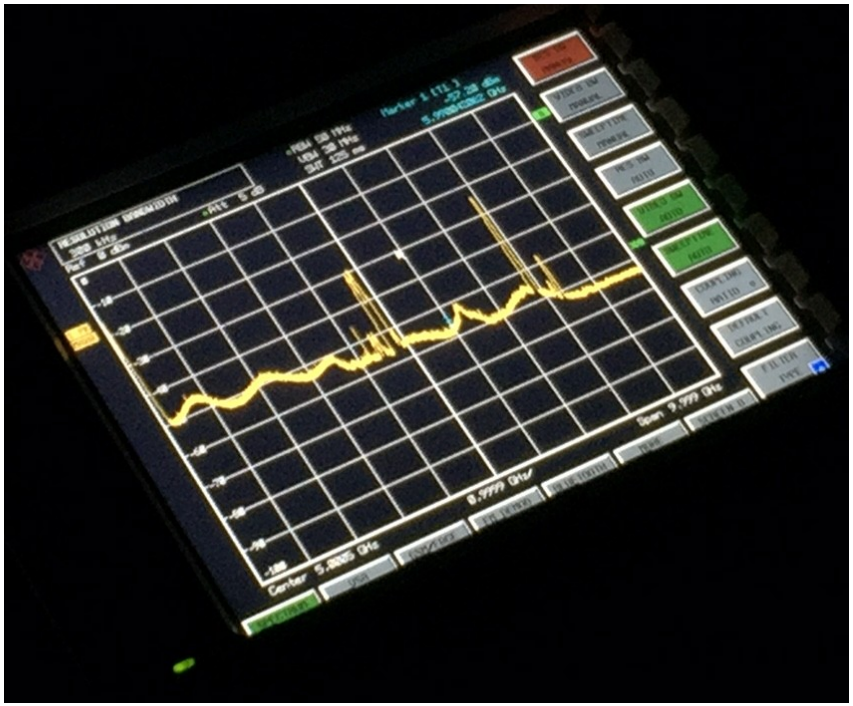




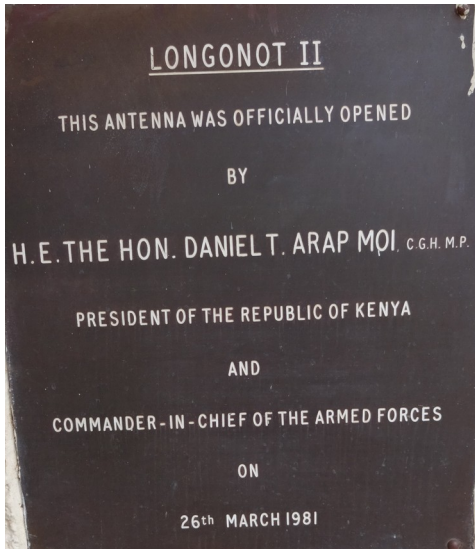
“Baby telescope” in use for outreach, software development, development of the pointing model for the big telescope etc.

Figure 1. NCA Officials in the Middle

Zambia feasibility



RFI report issued, Electromagnetic analysis completed, science implications being assessed.


LONGONOT II
THIS ANTENNA WAS OFFICIALLY OPENED
BY
H.E. THE HON. DANIEL T. ARAP MOI C.G.H. M.P.
PRESIDENT OF THE REPUBLIC OF KENYA
AND
COMMANDER-IN-CHIEF OF THE ARMED FORCES
ON
26th MARCH 1981

Equipment at each AVN VLBI radio telescope

- **Receiver** covering at least one standard VLBI band;
- **Hydrogen maser frequency standard** providing frequency standard and reference frequencies for the receiver / signal chain;
- **GPS receiver** providing time standard for recording systems;
- **Internet connection** (10 Mbps min bandwidth) for: receiving VLBI test and science schedules, liaising with operators at other telescopes in the schedule and at the correlator that is processing the data, sending VLBI test data samples to the correlator to check for fringes;
- **Wideband internet connection** for: sending science data by e-shipment after the VLBI to the correlator – 128 Mbps min bandwidth, real-time e-VLBI transmission of narrowband spectroscopy data to the correlator – 128 Mbps min bandwidth, real-time e-VLBI transmission of wideband continuum and pulsar data to the correlator – 1 Gbps – 1024 Mbps min bandwidth;
- **Reliable continuous power and other infrastructure.**

Technical skills needed for a single dish observatory

- Structural and mechanical engineering;
- Control and Monitor engineering;
- Radio Frequency / Signal chain engineering;
- Software and data processing engineering;
- Scientists with data processing skills;
- Civil engineers and related disciplines for new-builds;
- Systems engineers, project managers, variety of technicians, electricians, CAD specialists etc.

Summary

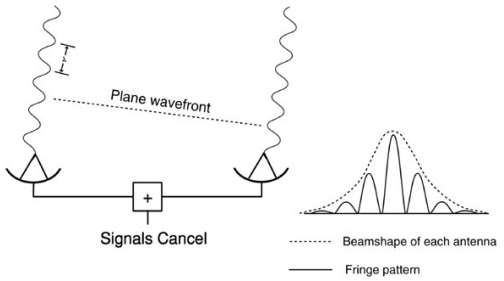
- Progress slowed down by governance issues (bi-lateral and multi-lateral agreements, re-prioritisation of national funds, institution establishment and building, resourcing) - crucial to ensure sustainability and effortless SKA2 delivery;
- Engineering done at “component” level to ensure maintainability - independence from specialist suppliers (eg control systems, antenna drives etc).
  - Conversion projects be executed in series, new-builds could fast-track deployment if team is augmented.
- Initial site selection and science case(s) for new-builds to increase in priority with a view to fast-track AVN deployment through parallel new-build programme ;

- Dankie
- Enkosi
- Ha khensa
- Re a leboga
- Ro livhuwa
- Siyabonga
- Siyathokoza
- Thank you

Extra

Newton Fund Project gets under way in Zambia, Kenya, Namibia (Botswana added with AVN funds)

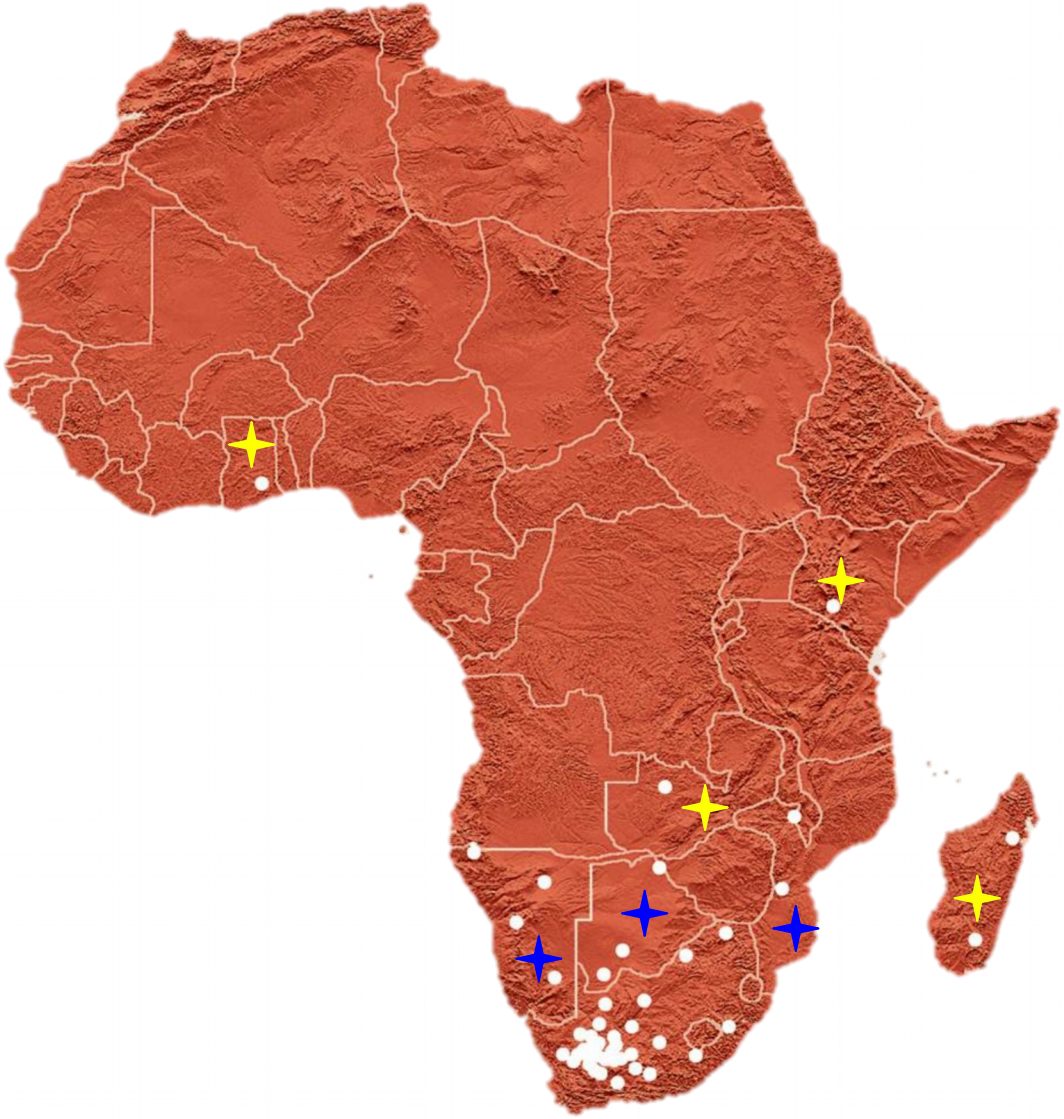
- Two element radio astronomy interferometer (UCT) (21 cm wavelength)
- Existing network of similar equipment (The project EUHOU Connecting classrooms to the Milky Way" (EUHOUMW))
- Dish diameter 2.3 m; operating frequency up to 12 GHz
- Data processing software online
- Online system; involve universities and high schools by creating an online community of users.
- The UCT team leaders (Claude Carignan, Yannick Libert) will be the local administrators in charge of managing the schedule of the instruments.



Africa & the SKA

Conversions

New-builds (unfunded)

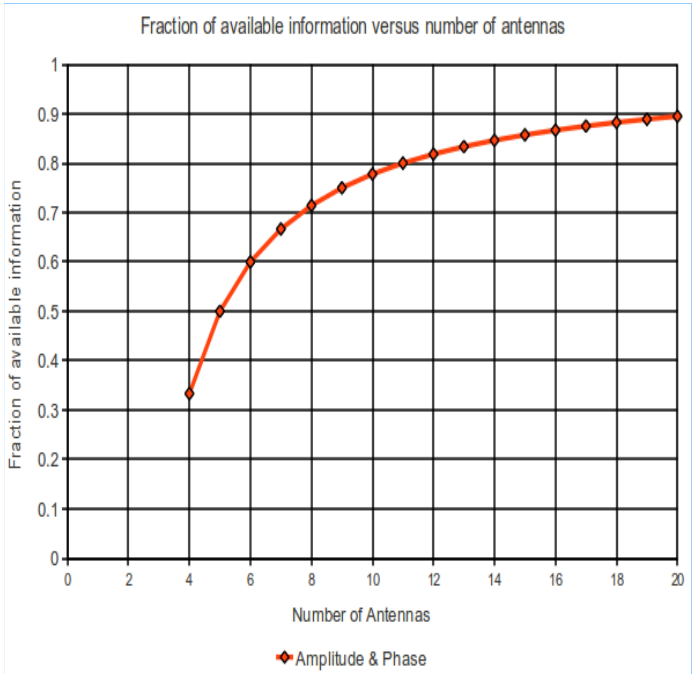


- South Africa,
- Botswana,
- Ghana,
- Kenya,
- Madagascar,
- Mauritius,
- Mozambique,
- Namibia, and
- Zambia

AVN telescope main considerations

- What science case? How many telescopes? Where (which countries, on which site?);
- Compatibility with other VLBI networks;
- Telescope sensitivity target / System Equivalent Flux Density (SEFD) target;
- Antenna optical design;
- Required antenna diameter to achieve targeted sensitivity;
- Number and type of receivers and feeds.

AVN - how many telescopes and what frequencies?

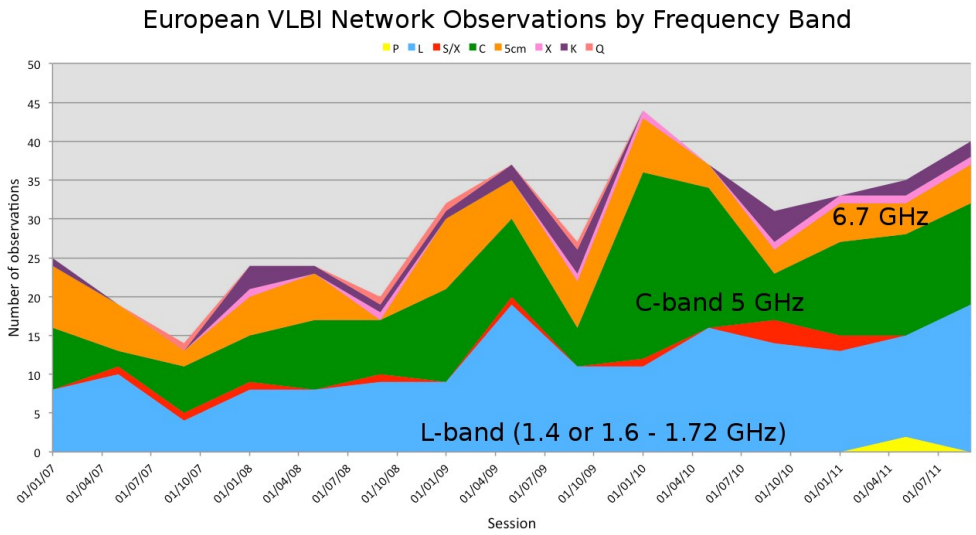


N. Tels.	Rel. Recov.
4	1.0
5	1.5
6	1.8
7	2.0
8	2.13
9	2.25

No of tele-scopes	Relative Recovery
4	1.0
5	1.5
6	1.8
7	2.0
8	2.13
9	2.25

- Four telescopes - minimum VLBI network size able to do imaging;
- Currently have funds for 3 conversions;
- 8 telescopes recover just over 2x more data than 4.

(Reference: Thompson, Moran & Swenson 1986 P360 Fig 11.4 eqn 11.22)



Training PCs

- 10 PCs allocated to each country participating in Newton Fund project, SA AVN making it available for Botswana as well;
- Access via internet – all Universities can utilise but all 10 PCs to be hosted in one location;
- Funded throguh Newton Fund, to be purchased by HartRAO, configured with operating system (Linux) and loaded with appropriate radio astronomy data processing packages;
- PCs to be managed by host institutions in partner countries;
- Training on Linux skills, data processing will be given at HartRAO and the host countries;
- Participating countries will provide facilities to host these PCs.

Newton Fund Work Package Focus Areas

WP	Title	Leader	UK/SA
WP1	Basic Training in Zambia	Melvin	UK
WP2	Basic Training in Kenya	Peter	UK
WP3	Basic Training in Namibia & Botswana	Alet/Ludwig	SA
WP4	Annual Network Training Meetings	Melvin/Ludwig/Alet	SA/UK
WP5	Advanced Training Programme	Melvin Hoare	UK
WP6	Pulsar Backend	Ben Stappers	UK
WP7	CARA Website	Tim O'Brien	UK
WP8	Computers	Roelf	SA
WP9	Teaching Interferometer	Claude/Yannick	SA
WP10	Training Dish and Receiver	Alet/Pieter	SA
WP11	Management	Melvin/Ludwig	UK/SA

Newton Fund project – Governance

- A formal agreement signed between the Univ. of Leeds and HartRAO to allow administrative and financial procedures to be met within the framework of the project.
- One Steering Committee with UK and SA members;
  - SA Committee members:
    - Prof Ludwig Combrinck (Co-chair),
    - T.L. Venkatasubramani (SKA SA / AVN),
    - Dr Eugene Avenant (SANSA),
    - Prof Claude Carignan (UCT),
    - Dr Kevin Govender (OAD).
  - SA Committee members:
    - Prof Melvin Hoare (Leeds, Co-chair)
    - Prof Peter Wilkinson (Manchester)
    - Prof Angela Taylor (Oxford),
    - Prof Mark Thompson (Herts),
    - Ian Jones (Goonhilly).

Newton Fund project – partners

- **UK partners:** Universities of Leeds, Manchester, Oxford and Hertfordshire as well as Goonhilly Earth Station Ltd.;
- **SA partners:** HartRAO, SKA-SA / AVN, the Office of Astronomy for Development, Universities of Cape Town, Rhodes, Western Cape, North West and South Africa, as well as the South African National Space Agency;
- First training session (theory) will take place in Kenya during September 28 to the 9th of October (Technical University of Kenya) provided principally by:
  - Prof Peter Wilkinson (University of Manchester, UK)
  - Prof Ludwig Combrinck (HartRAO, SA)
  - Dr Alet de Witt (HartRAO, SA)
  - Dr Jonathan Quick (HartRAO, SA)
  - Dr Aris Karastergiou (University of Oxford, UK and Visiting Professor at the University of the Western Cape and Rhodes University, SA)
  - Mr Ian Jones (CEO of Goonhilly Earth Station Ltd) - entrepreneur in the satellite communications business.
  - Mr Eugene Avenant (Chief Engineer at SANSA Space Operations).

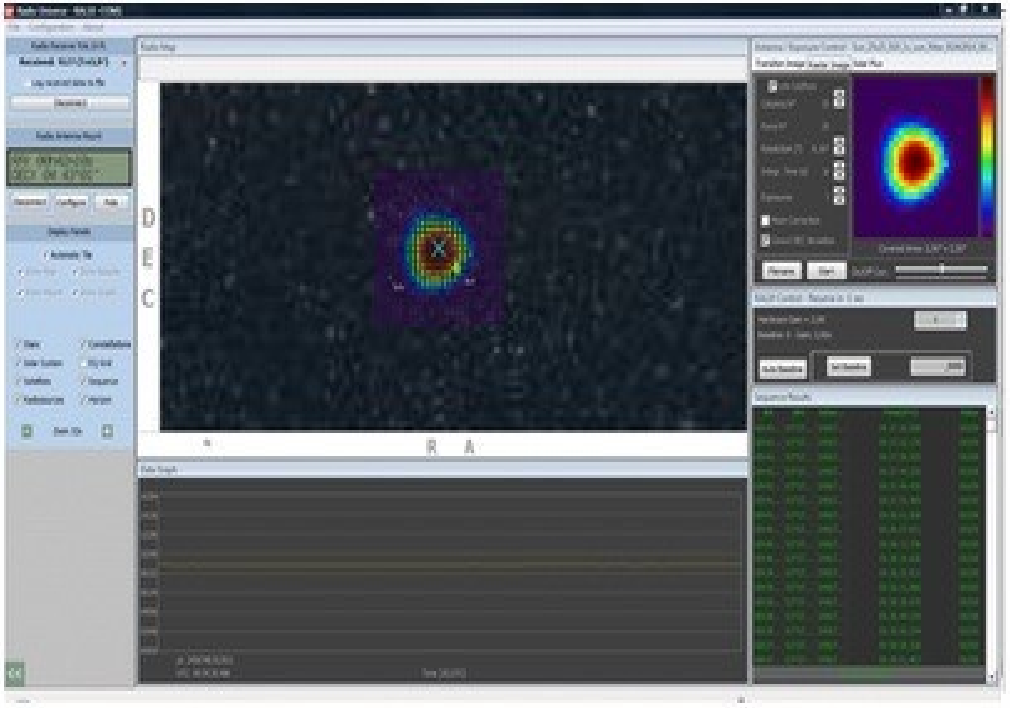
Newton Fund project – overview

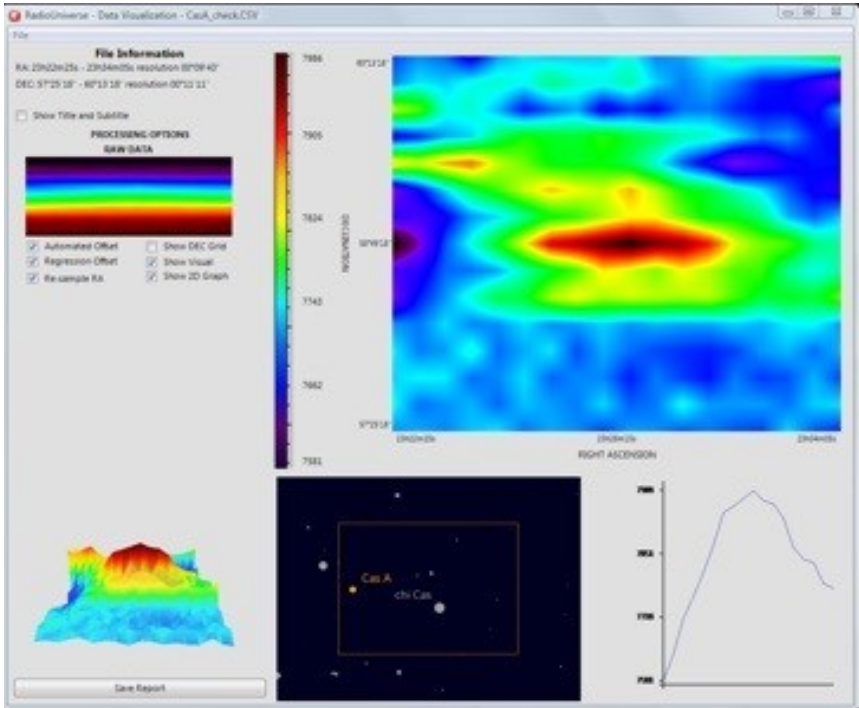
- End of year 1 (2015):
  - Basic resources for start of training in place including computers, books, subscriptions, training equipment, 1st (one week) training sessions in Zambia and Kenya (Melvin Hoare, Peter Wilkinson, Alet de Witt);
- End of year 2 (2016):
  - 20 participants completed basic training (10 Zambia + 10 Kenya);
  - PhD and MSc advanced training students and interns started;
  - Network training meeting taken place in South Africa;
  - Outreach events taken place across the partner countries.
- End of year 3 (2017):
  - 30 participants completed basic training (Namibia, Zambia and Kenya);
  - MSc advanced training students continue and new interns started;
  - Network training meeting taken place in AVN partner country;
  - Outreach events taken place across the partner countries.
- Two more additional years could be funded (2018/2019).

Newton Fund project – annually

- 8 weeks training per year for the selected trainees;
  - Unit 1: Astrophysics, Radio Astronomy Theory and Multi-Wavelength Astronomy;
  - Unit 2: Observational Training;
  - Unit 3: Technical (Instrumentation and Engineering) Training;
  - Unit 4: Radio Astronomy Data Reduction and Analysis.
- Annual Network Training Meeting (~ 1 week)

- Software included - Software Defined Radio for flexible and adaptable receivers (easy to upgrade to other frequencies);
- Data freely accessible;
- Easy interfaces;
- Training material;
- Commitment to implement this interferometer in Botswana as a training instrument;
- Could be expanded to AVN countries (Mauritius preparing a proposal to fund their own);
- Fast, useful precursor for AVN activities, i.e. have something on the ground at relatively small cost.





Two complementary Newton Fund projects

Radio Astronomy for Development in Africa (Ludwig)	SKA Africa Astronomy Training Platform (ATP) (Bonita)
Training Programmes:	**Training Workshops:**
1. 20 Students from SKA Africa partner countries to undertake basic training programme with practical component at HartRAO	1. JEDI in Machine Learning in Mauritius (15 – 26 July 2015)
2. Advanced training – 3 MSc and 2 PhD awards to be made in 2015 and 2016	2. JEDI facilitator's training workshop in South Africa (6 – 11 Sep 2015)
Training Equipment:	**Training Equipment:**
1. Computer training laboratory installed at HartRAO	1. Mobile computer lab for carrying out JEDIs (20 laptops and server)
2. Equipment purchased for computer laboratories to be setup in South Africa, Kenya, Zambia and Namibia (Botswana to be included but funded separately)	2. Equipment for training programmes at MeerKAT/SKA site in South Africa
3. Two-dish training interferometer(s) in SA and selected partner countries	

Newton Fund Training leaders / coordinators

Title	Leader	UK/SA
Basic Training in Zambia	Prof Melvin Hoare	UK
Basic Training in Kenya	Prof Peter Wilkinson	UK
Basic Training in Namibia	Dr Alet de Witt/ Prof Ludwig Combrinck	SA
Annual Network Training Meetings	Prof Melvin Hoare / Prof Ludwig Combrinck / Dr Alet de Witt	SA/UK
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Management	Prof Melvin Hoare / Prof Ludwig Combrinck	UK/SA