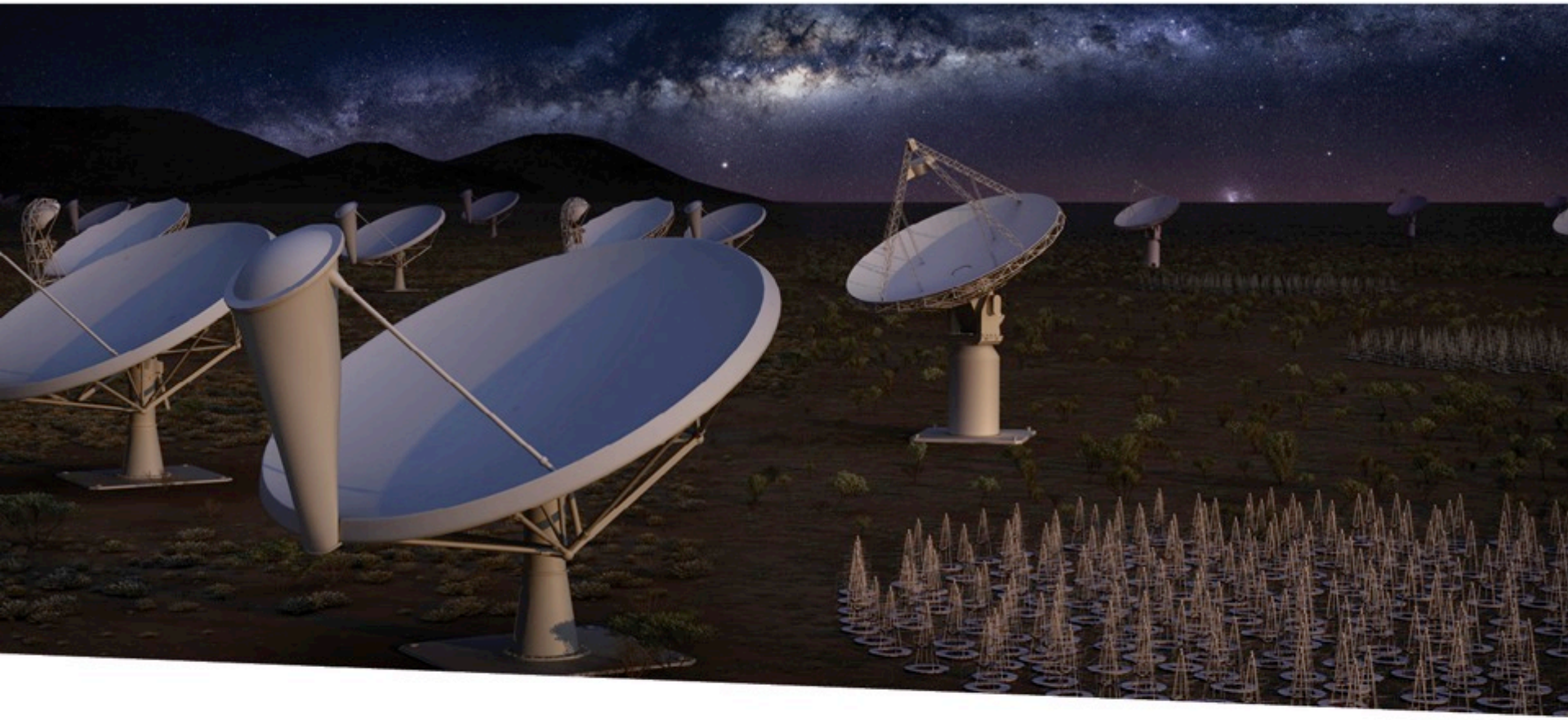
From JIVE to SKA:

The music of the spheres



SQUARE KILOMETRE ARRAY

Exploring the Universe with the world's largest radio telescope

Philip Diamond, Director General

April 2015

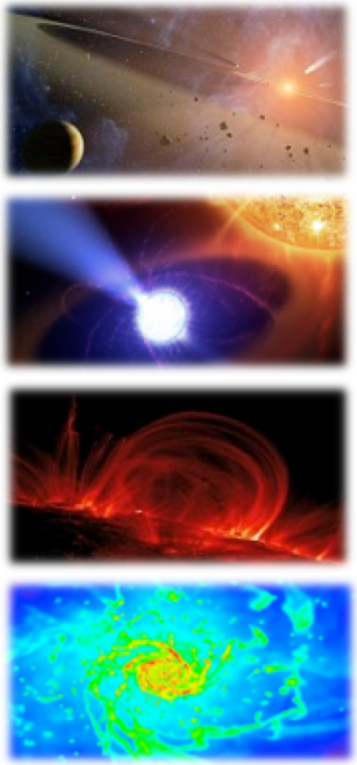
VLBI → SKA

- I see a direct connection from the development of VLBI to the establishment of SKA.
- Astronomy, and VLBI in particular, has been an excellent tool of scientific diplomacy. I am sure that scientific cooperation is part of calculation by governments in deciding to join projects like SKA.
- African dimension is a unique component of SKA.
- SKA will do VLBI.

SKA Headline Science

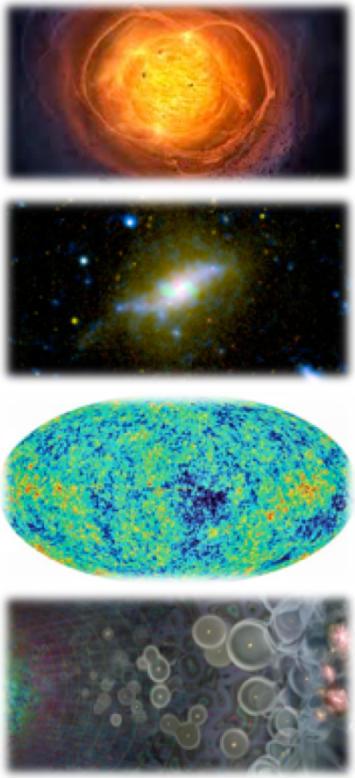
Headline Science with SKA1 and SKA2

	SKA1	SKA2
The Cradle of Life & Astrobiology	Proto-planetary disks; imaging inside the snow/ice line (@ < 100pc), Searches for amino acids.	Proto-planetary disks; sub-AU imaging (@ < 150 pc), Studies of amino acids.
	Targeted SETI: airport radar 10^4 nearby stars.	Ultra-sensitive SETI: airport radar 10^5 nearby star, TV ~10 stars.
Strong-field Tests of Gravity with Pulsars and Black Holes	1st detection of nHz-stochastic gravitational wave background.	Gravitational wave astronomy of discrete sources: constraining galaxy evolution, cosmological GWs and cosmic strings.
	Discover and use NS-NS and PSR-BH binaries to provide the best tests of gravity theories and General Relativity.	Find all ~40,000 visible pulsars in the Galaxy, use the most relativistic systems to test cosmic censorship and the no-hair theorem.
The Origin and Evolution of Cosmic Magnetism	The role of magnetism from sub-galactic to Cosmic Web scales, the RM-grid @ 300/deg2.	The origin and amplification of cosmic magnetic fields, the RM-grid @ 5000/deg2.
	Faraday tomography of extended sources, 100pc resolution at 14Mpc, 1 kpc @ z ≈ 0.04.	Faraday tomography of extended sources, 100pc resolution at 50Mpc, 1 kpc @ z ≈ 0.13.
Galaxy Evolution probed by Neutral Hydrogen	Gas properties of 10^7 galaxies, <z> ≈ 0.3, evolution to z ≈ 1, BAO complement to Euclid.	Gas properties of 10^9 galaxies, <z> ≈ 1, evolution to z ≈ 5, world-class precision cosmology.
	Detailed interstellar medium of nearby galaxies (3 Mpc) at 50pc resolution, diffuse IGM down to N_H < 10^17 at 1 kpc.	Detailed interstellar medium of nearby galaxies (10 Mpc) at 50pc resolution, diffuse IGM down to N_H < 10^17 at 1 kpc.



Headline Science with SKA1 and SKA2

	SKA1	SKA2
The Transient Radio Sky	Use fast radio bursts to uncover the missing "normal" matter in the universe.	Fast radio bursts as unique probes of fundamental cosmological parameters and intergalactic magnetic fields.
	Study feedback from the most energetic cosmic explosions and the disruption of stars by super-massive black holes.	Exploring the unknown: new exotic astrophysical phenomena in discovery phase space.
Galaxy Evolution probed in the Radio Continuum	Star formation rates (10 M_Sun/yr to z ~ 4).	Star formation rates (10 M_Sun/yr to z ~ 10).
	Resolved star formation astrophysics (sub-kpc active regions at z ~ 1).	Resolved star formation astrophysics (sub-kpc active regions at z ~ 6).
Cosmology & Dark Energy	Constraints on DE, modified gravity, the distribution & evolution of matter on super-horizon scales: competitive/superior to Euclid.	Constraints on DE, modified gravity, the distribution & evolution of matter on super-horizon scales: redefines state-of-art.
	Primordial non-Gaussianity and the matter dipole: 2x Euclid.	Primordial non-Gaussianity and the matter dipole: 10x Euclid.
Cosmic Dawn and the Epoch of Reionization	Direct imaging of EoR structures (z = 6 - 12).	Direct imaging of Cosmic Dawn structures (z = 12 - 30).
	Power spectra of Cosmic Dawn down to arcmin scales, possible imaging at 10 arcmin.	First glimpse of the Dark Ages (z > 30).



SKA Re-baselining outcome

July 2013 Board resolution on cost-cap

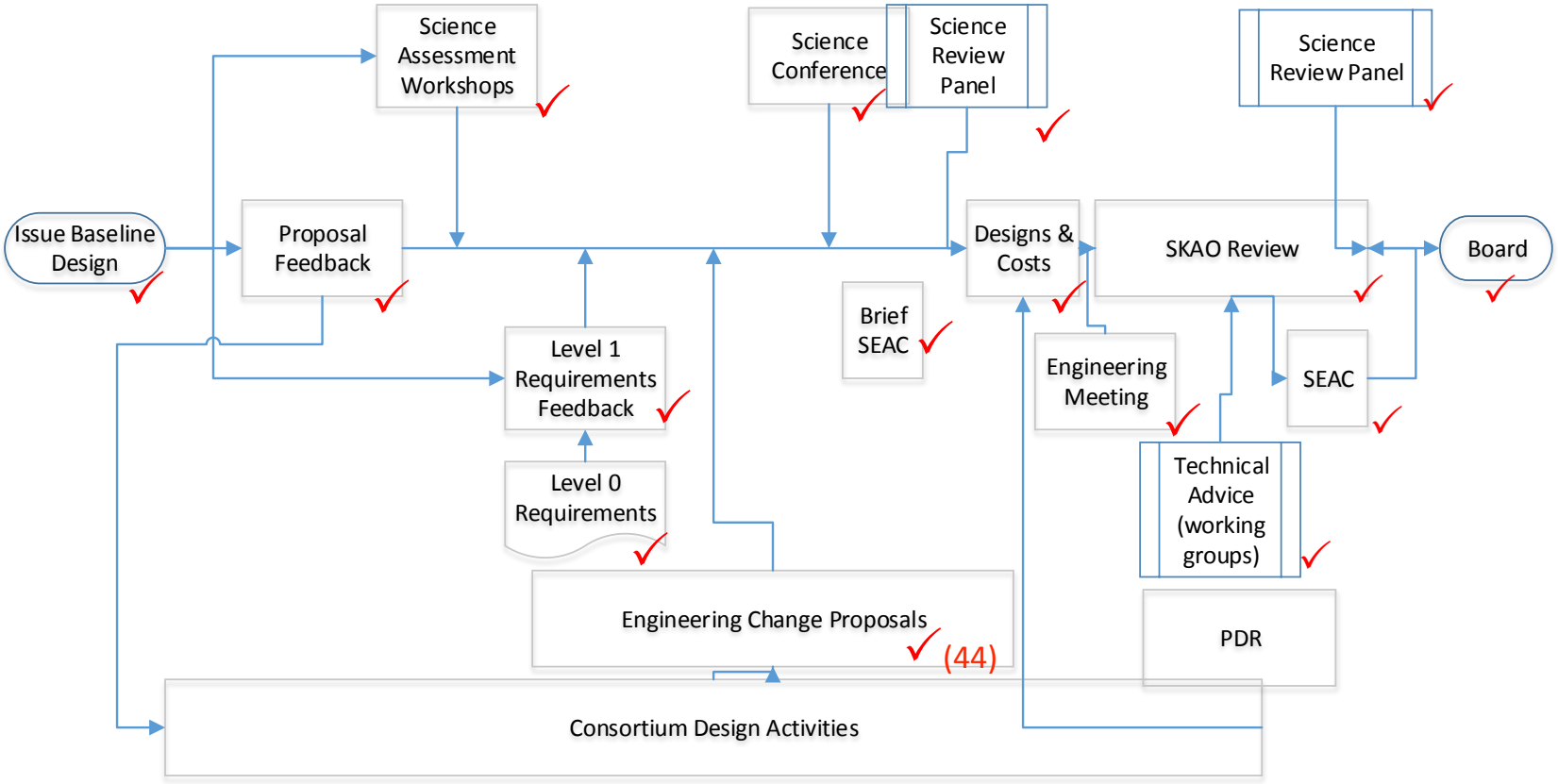
- *The SKA Board instructs the SKA Office to proceed with the design phase assuming a cost ceiling for SKA1 capital expenditures of 650 Million Euro [2013 value]. The evolution of the SKA phase 1 project to fit within this cost ceiling will be guided both during the design phase and construction by scientific and engineering assessments of the baseline design undertaken by the SKA Office in collaboration with the community and the advisory bodies.*

- *The SKA Board instructs the SKA Office to promptly provide clear scientific and programmatic deliverables that fit within the cost ceiling of 650 Million Euro.*

Re-baselining

- Re-baselining: 'the act of generating a new baseline design, evolving from the existing baseline design'
  - ALMA: significant re-baselining
  - E-ELT: (100m) → 42m → 39m → phased deployment
  - LOFAR: reduced collecting area by 75%, reduced number of stations by 50%

Re-baselining Process



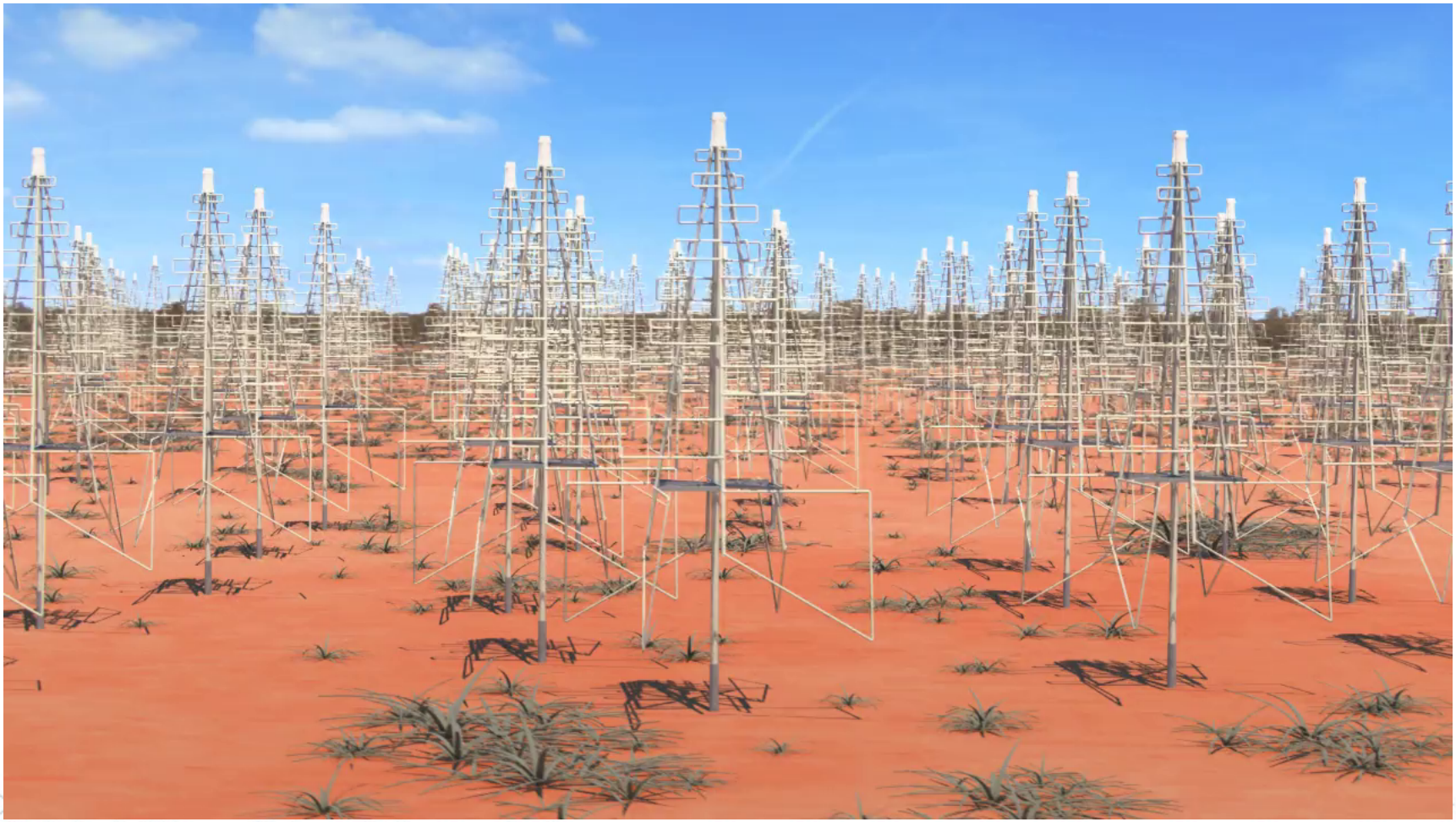
SKA1-MID, Karoo, South Africa:

133 SKA1 + 64 MeerKAT dishes. Max baseline ~150km.

Bands: 2 (0.95–1.76 GHz), 5 (4.6–13.8 GHz), 1 (0.35–1.05 GHz)

SKA1-LOW, Murchison, Australia:

130,000 dipoles (512 stations x 256 antennas); 50–350 MHz
~80km baselines; large areal concentration in core

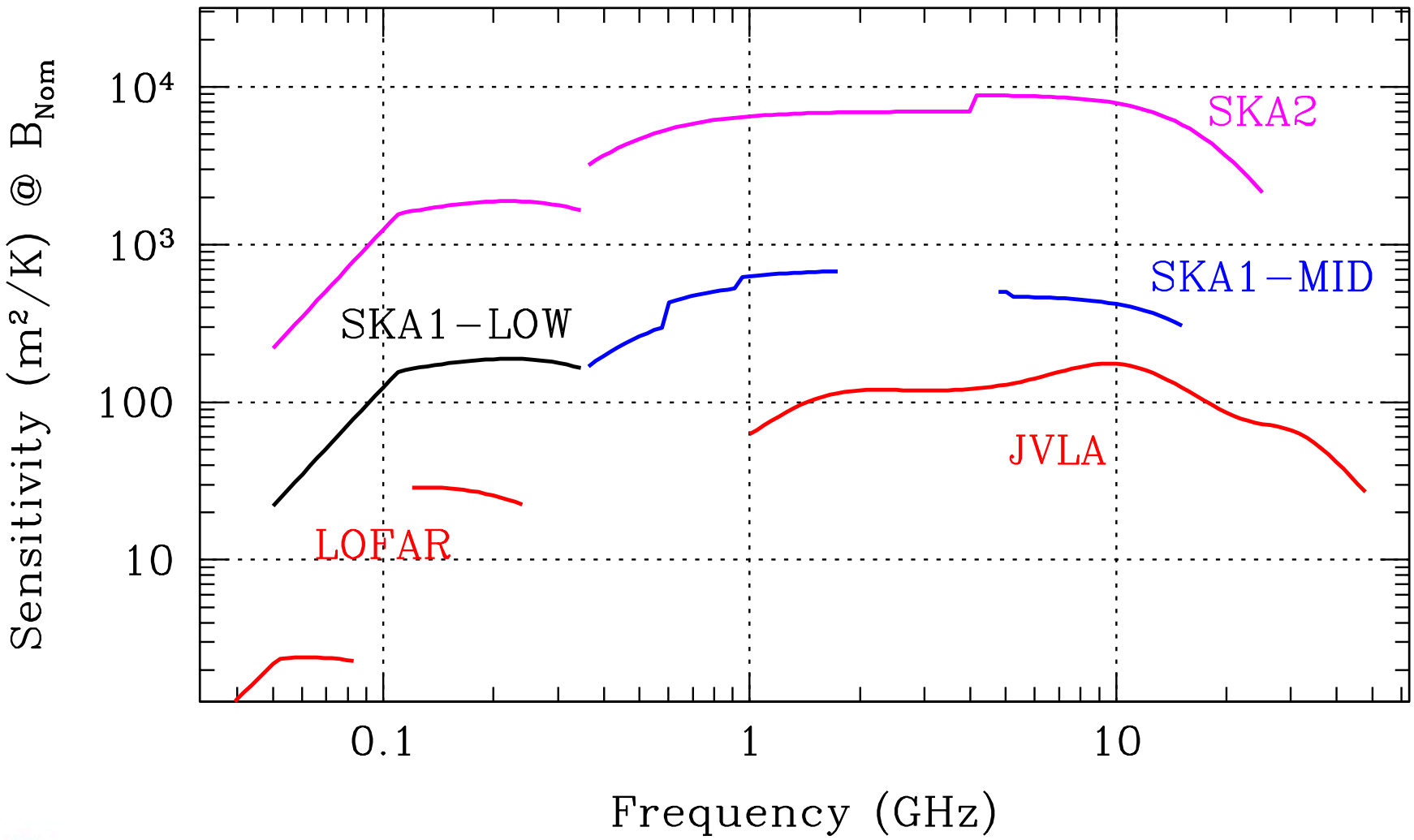


Other outcomes of re-baselining

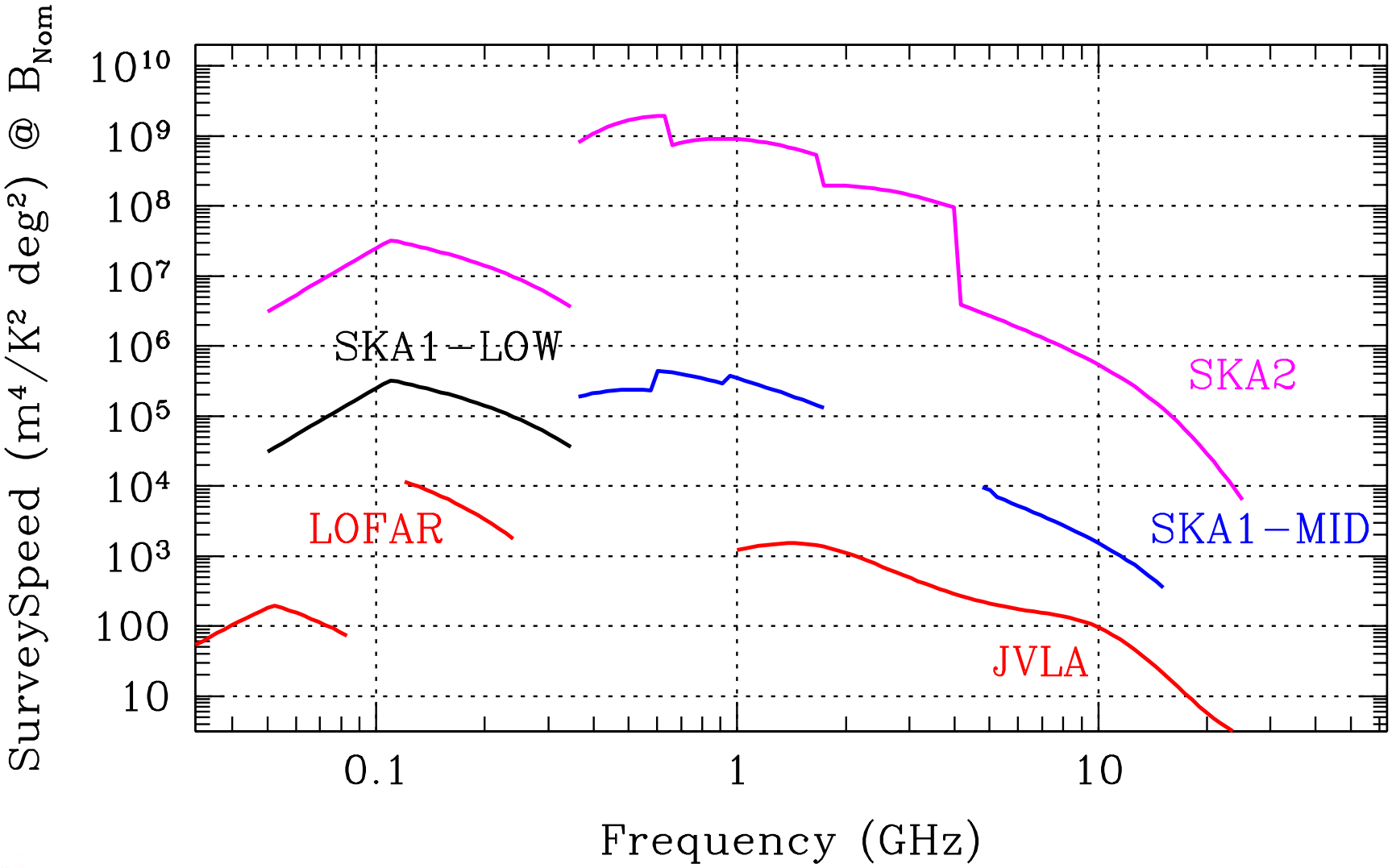
An SKA Phased Array Feed (PAF) development programme will be initiated as part of a broader Advanced Instrumentation Programme.

It is also recommended that the Board approve funding, with Australia's agreement, for the operations of ASKAP as an integral component of SKA1; the start date to be negotiated with Australia. This would enable ASKAP to provide SKA1 with an early survey capability and also serve as a platform for the development of next-generation PAFs.

Sensitivity Comparison



Survey Speed Comparison



VLBI with the SKA

SKA1 VLBI capabilities

Capability:

- 1 - 4 VLBI beams on SKA1-MID
- VLBI terminal at either correlator facility or science data processor facility
- VLBI correlation, processing, data archive outside scope of SKA
- Sub-arraying
- Selectable frequency resolutions of 1 – 512 MHz for beam data
- Selectable channelisation
- Appropriate data formatting (VLBI standards)

Science goals for SKA1-VLBI laid out by Paragi et al (2015)

VLBI with the SKA: SKA-VLBI

Combining the SKA telescopes:

- SKA1-MID (LOW?)
- SKA2

with planned & existing VLBI arrays:

- European VLBI Network (EVN)
- Long Baseline Array (LBA)
- African VLBI Network (AVN)

aiming for baselines >3000km

Approaches with SKA-VLBI

- Traditional phase referencing (likely approach for early-SKA1/ SKA1)
  - utilises phase referencing of a nearby (<10 arcsec) background quasar as a calibrator, measuring phase delay between two to determine relative position
  - requires significant portion of time for calibration, and availability of calibrators, but less sensitivity for calibrator

- In-beam calibrators, 'Multiview' VLBI (likely approach for SKA2)
  - utilises multiple phased up beams of tied array to observe target source and calibrators (within few arcmin) simultaneously
  - requires much greater sensitivity to detect sufficient calibrators, but enables greater accuracy

VLBI Focus Group

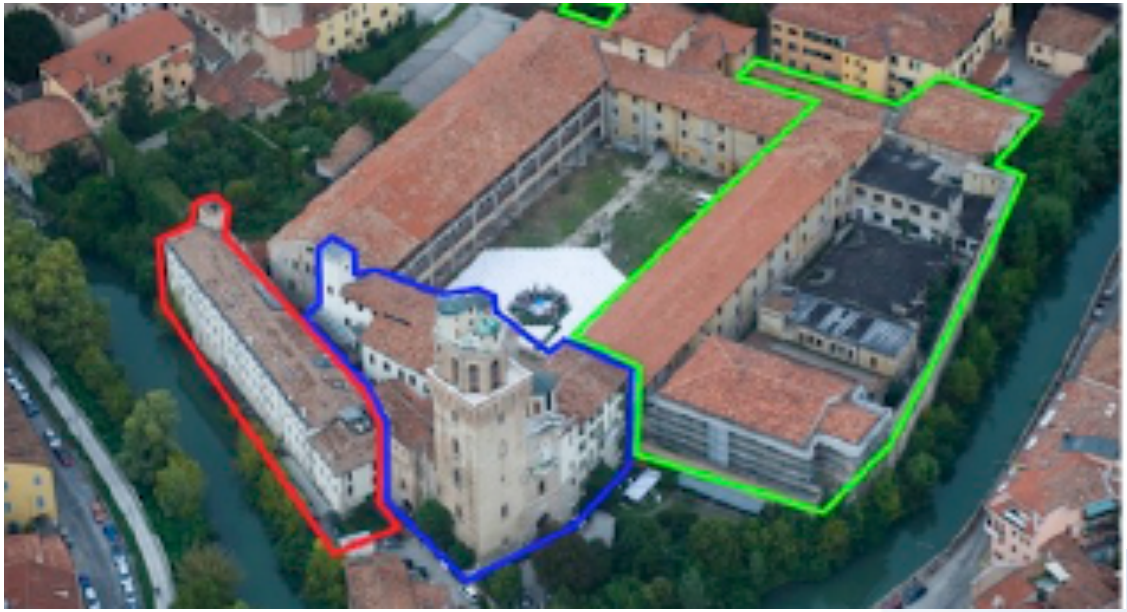
- Science Focus group established to provide input on VLBI related matters to the organisation
- http://astronomers.skatelescope.org/home/focus-groups/vlbi/
- Open membership, please let us (Jimi Green) know if you would like to join
- To date provided input on ECP for clarification of VLBI capability

Next steps for SKA

Next steps

- Implement Board-approved re-baselining outcome
- Carry out detailed costings on that solution
- Review Level 1 Requirements
- Review Architecture
- Review element Statements of Work
- Produce Revised Baseline
- Carry out Systems Review for BDV02

SKA HQ selection: decision 29 April

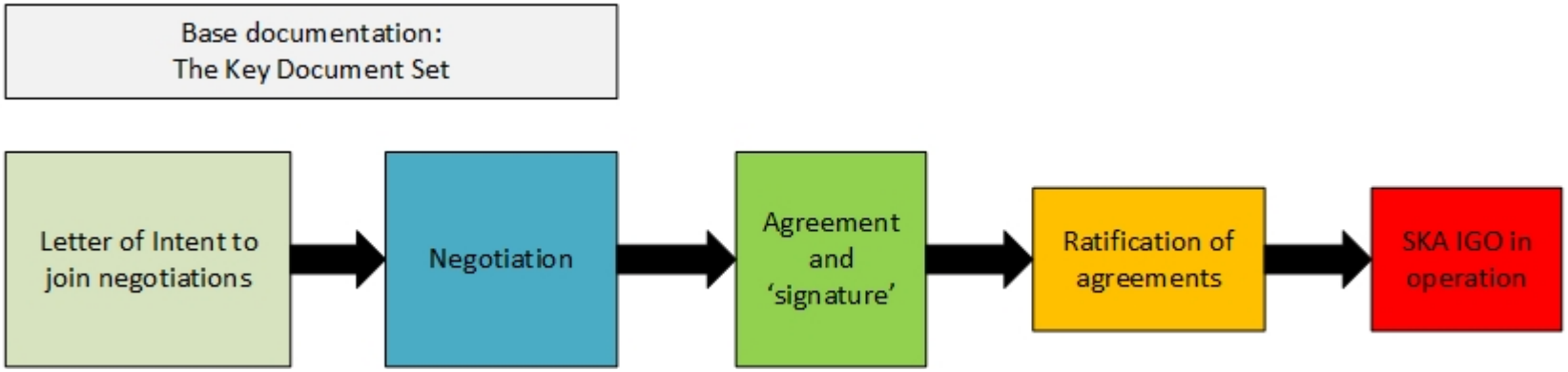


Padua, Italy

Jodrell Bank, UK

Governance/organisational structure

- Evolution planned to an SKA Inter-Governmental Organisation: a structure like ESO/ESA/ITER/EMBL/CERN
- Rationale:
  - Government commitment: Long-term political stability, funding stability
  - Availability of 'concessions' through Privileges and Immunities from members
  - 'Freedom to operate', specifically through procurement process



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Thank-you

www.skatelescope.org