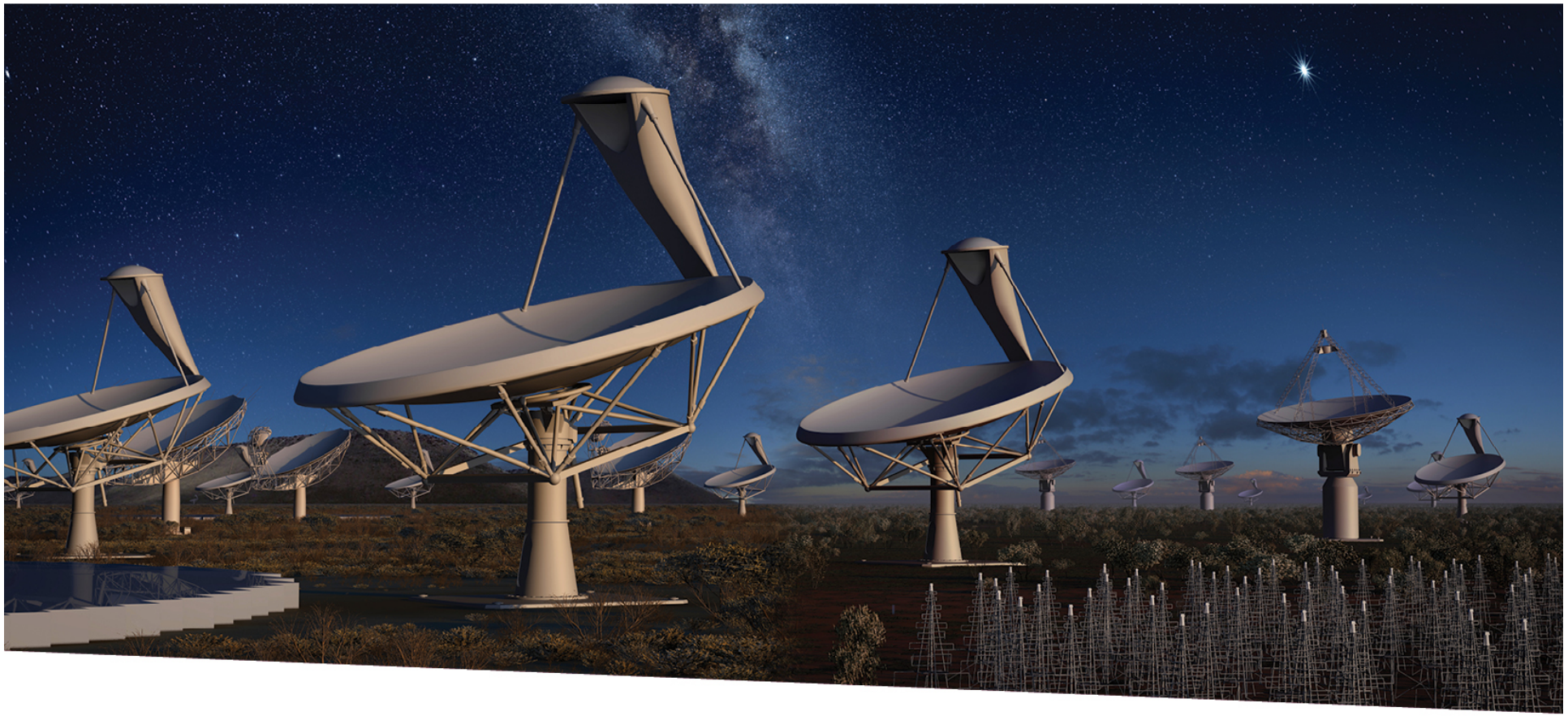
SKA KSP Update



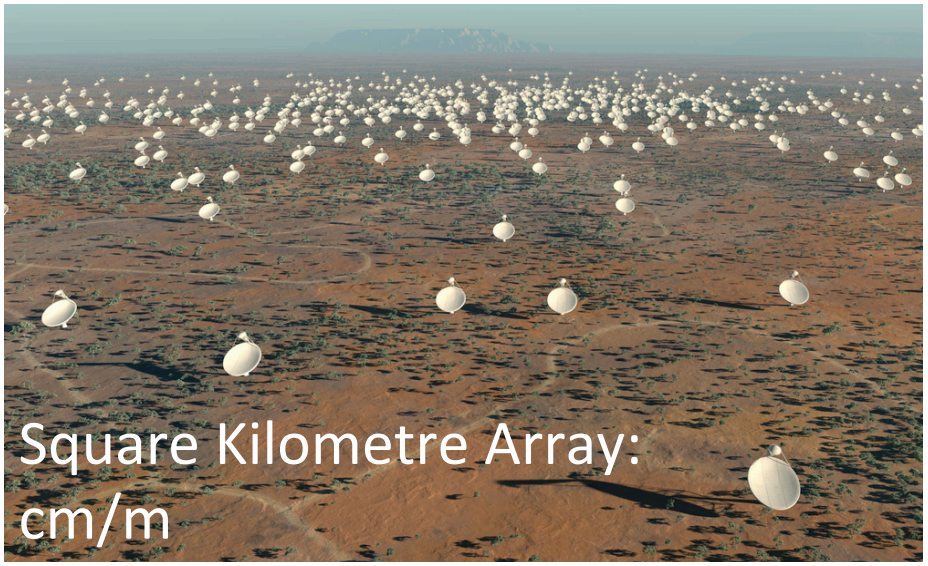
SQUARE KILOMETRE ARRAY

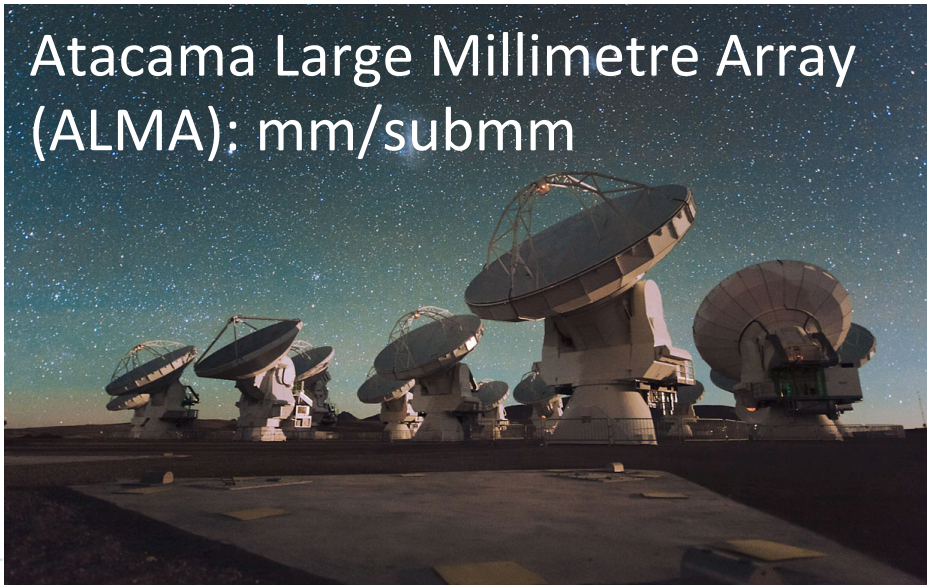
Exploring the Universe with the world's largest radio telescope

Robert Braun, Science Director

24 August 2015

Great Observatories for the coming decades





SKA Science

- SKA: will be one of the great physics machines of 21st Century and, when complete, one of the world's engineering marvels.
- Science goals:
  - Fundamental physics: Gravity, Dark Energy, Cosmic Magnetism
  - Astrophysics: Cosmic Dawn, First galaxies, galaxy assembly and evolution; proto-planetary discs, biomolecules, SETI + much more
  - The unknown: transients; +…????

Advancing Astrophysics

with the Square Kilometre Array

9-13 June 2014, Giardini Naxos, Italy

#skascicon14

2014 marks 10 years since the publication of the comprehensive **'Science with the Square Kilometre Array'** book and 15 years since the first such volume appeared in 1999. In that time numerous and unexpected advances have been made in the fields of astronomy and physics relevant to the capabilities of the Square Kilometre Array (SKA). This meeting will facilitate the publication of a new, updated science book, which will be relevant to the current astrophysical context.

Scientific Organising Committee

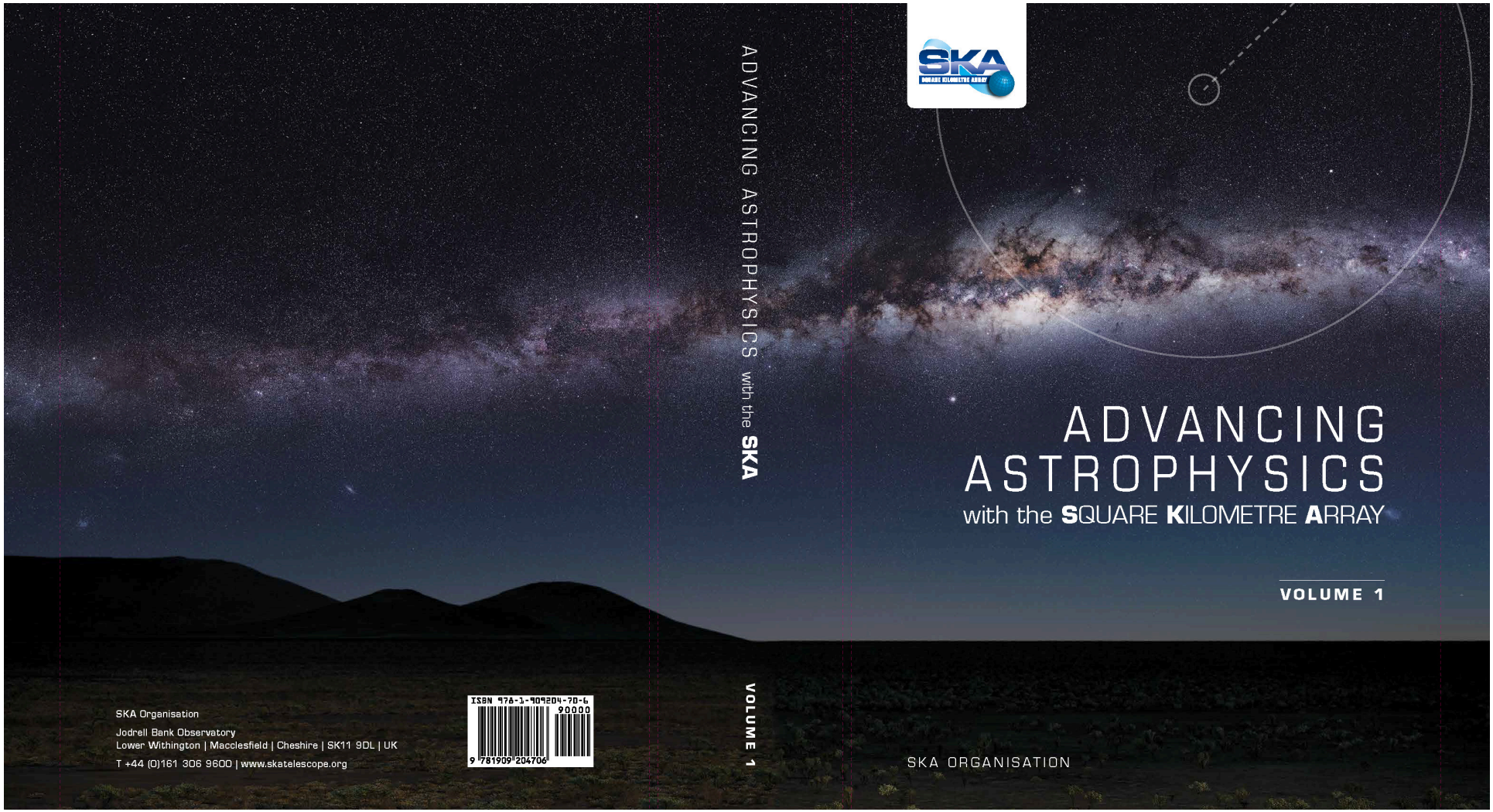
Robert Braun (SKAO) – co-Chair
Grazia Umana (INAF-OACt) – co-Chair
Tyler Bourke (SKAO)
Rob Fender (Oxford)
Federica Govoni (INAF–OA Cagliari)
Jimi Green (SKAO)
Melvin Hoare (Leeds)
Melanie Johnston-Hollitt (Victoria Univ. Wellington)
Leon Koopmans (Kapteyn Astronomical Institute)
Michael Kramer (MPIfR)
Roy Maartens (Univ. Western Cape)
Tom Oosterloo (ASTRON)
Isabella Prandoni (INAF–IRA)
Nicholas Seymour (CASS)
Ben Stappers (Manchester)
Lister Staveley-Smith (ICRAR)
Wen Wu Tian (NAOC)
Jeff Wagg (SKAO)

Enquiries: ska-june14@skatelescope.org
or visit: indico.skatelescope.org/event/AdvancingAstrophysics2014

SKA Science Book:

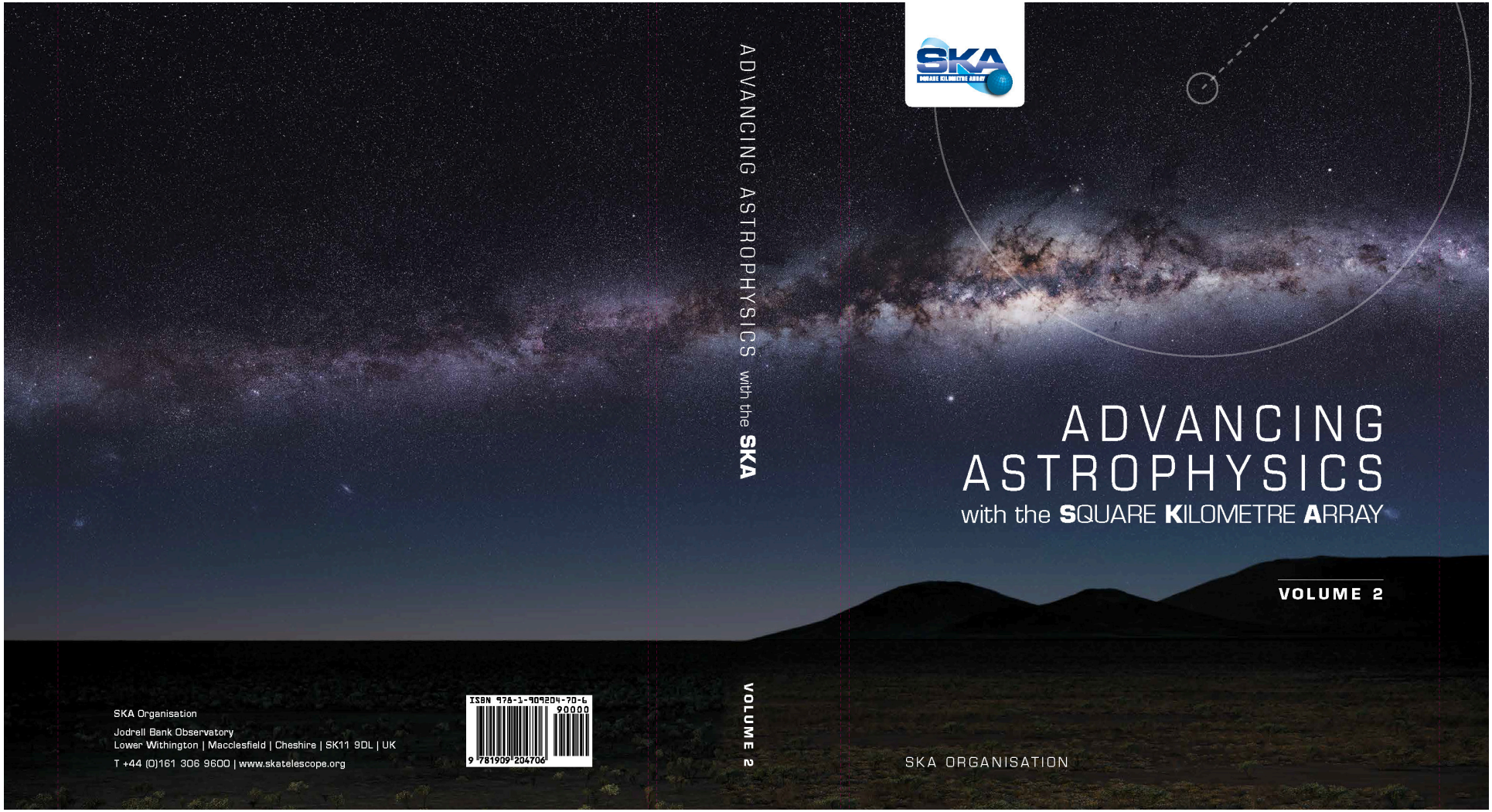
- Meeting Program based on advanced Chapter drafts
- 135 self-contained chapters
- Published electronically in PoS May 2015
- Printed Book ~2000 pages, in 2 volumes now with printer

SKA Science Book (Volume 1)



Exploring the Universe with the world's largest radio telescope

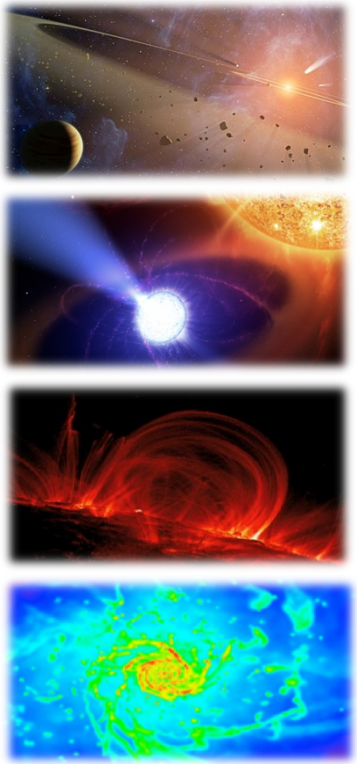
SKA Science Book (Volume 2)



Exploring the Universe with the world's largest radio telescope

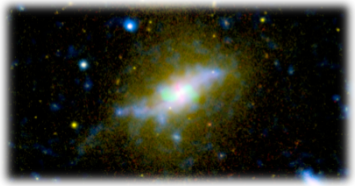
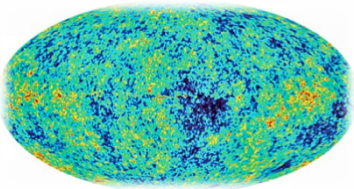
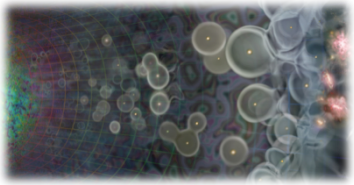
Headline Science with SKA1 and SKA2

	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.



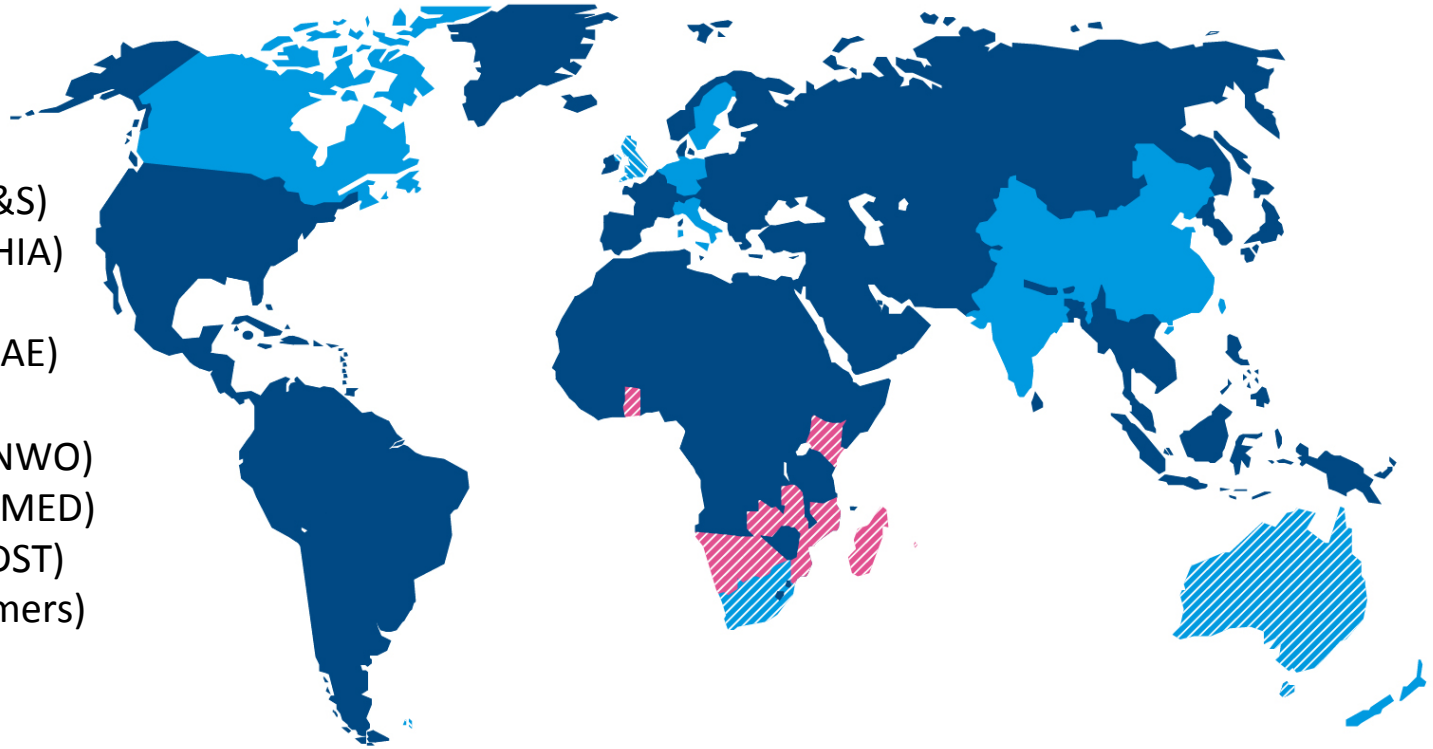
Headline Science with SKA1 and SKA2

	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 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 Organisation: 10 countries, more to join

Australia (DoI&S)
Canada (NRC-HIA)
China (MOST)
India (NCRA/DAE)
Italy (INAF)
Netherlands (NWO)
New Zealand (MED)
South Africa (DST)
Sweden (Chalmers)
UK (STFC)



Full members

SKA Headquarters host country

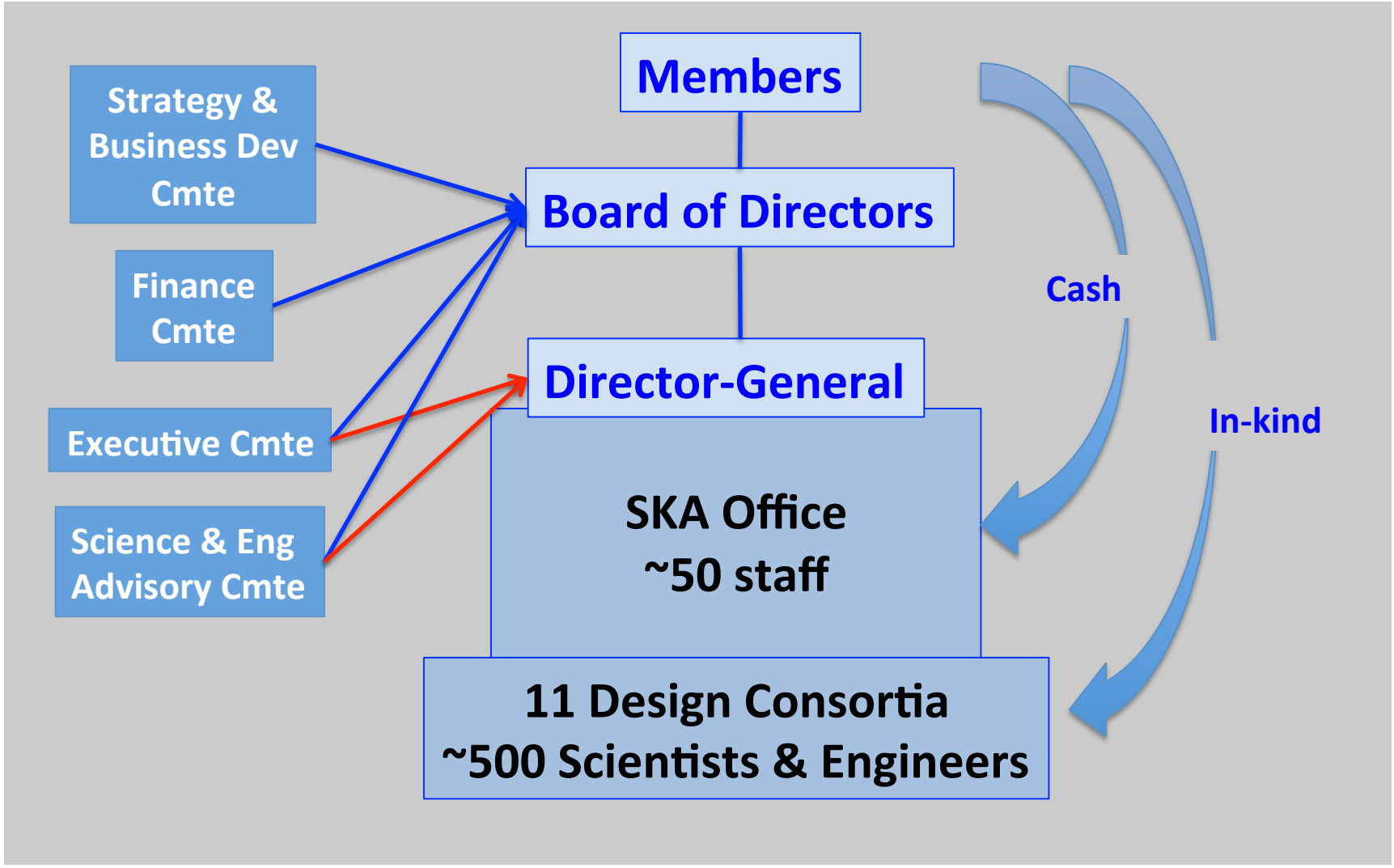
SKA Phase 1 and Phase 2 host countries

Exploring

African partner countries
(non-member SKA Phase 2 host countries)

This map is intended for reference only and is not meant to represent legal borders

SKA Governance + current funding

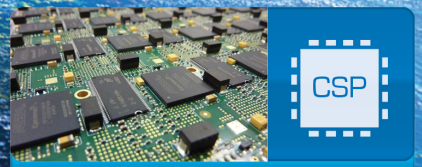


International Design Teams

- Project Management and System Engineering based at Jodrell Bank, Manchester, UK
- ~500 scientists & engineers in institutes and industry in 11 Member countries of the SKA


WIDE BAND SINGLE PIXEL FEEDS


TELESCOPE MANAGER



CENTRAL SIGNAL PROCESSOR


SIGNAL AND DATA TRANSPORT

SCIENCE DATA PROCESSOR


DISH


MID-FREQUENCY APERTURE ARRAY


LOW-FREQUENCY APERTURE ARRAY


ASSEMBLY, INTEGRATION & VERIFICATION


INFRASTRUCTURE AUSTRALIA


INFRASTRUCTURE SOUTH AFRICA

€150M design effort – fully funded

SKA: driving innovation

Element	SKA1 scale	SKA2 scale
Dishes, feeds, receivers	~200	~2500
Aperture arrays	~130,000	~1,000,000
Signal transport	~1 Pb/s	~10 Pb/s
Signal processing	~exa-MACs	~exa-MACs
High performance computing	~100s tera-flops	~exa-flops
Data storage	Exa-byte capacity	Exa-byte
Power requirements	~10MW	~50MW

Key innovation: Software engineering and algorithm development

Exa = 10^{18}, or 1 followed by 18 zeroes;
increase in compute capability by factor 1000

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.*

SKA1 Scope: Members decision 05/03/2015

- SKA1-MID
  - 70% of planned SKA1 dishes, ie. 133x15m
  - Integration of MeerKAT, ie. 64x13.5m
  - Deployment of SPF2, SPF5 and SPF1
  - B_{max} ~ 150km (with 120km fall-back)
  - 50% savings on non-image-processing
- SKA1-LOW
  - 50% of planned LPDs, ie. 131,000 x Antennas
  - B_{max} ~ 65km
  - Pulsar search and timing capability
- Advanced Instrumentation Program
  - Highlighting PAF development
- Negotiate ASKAP integration into SKAO

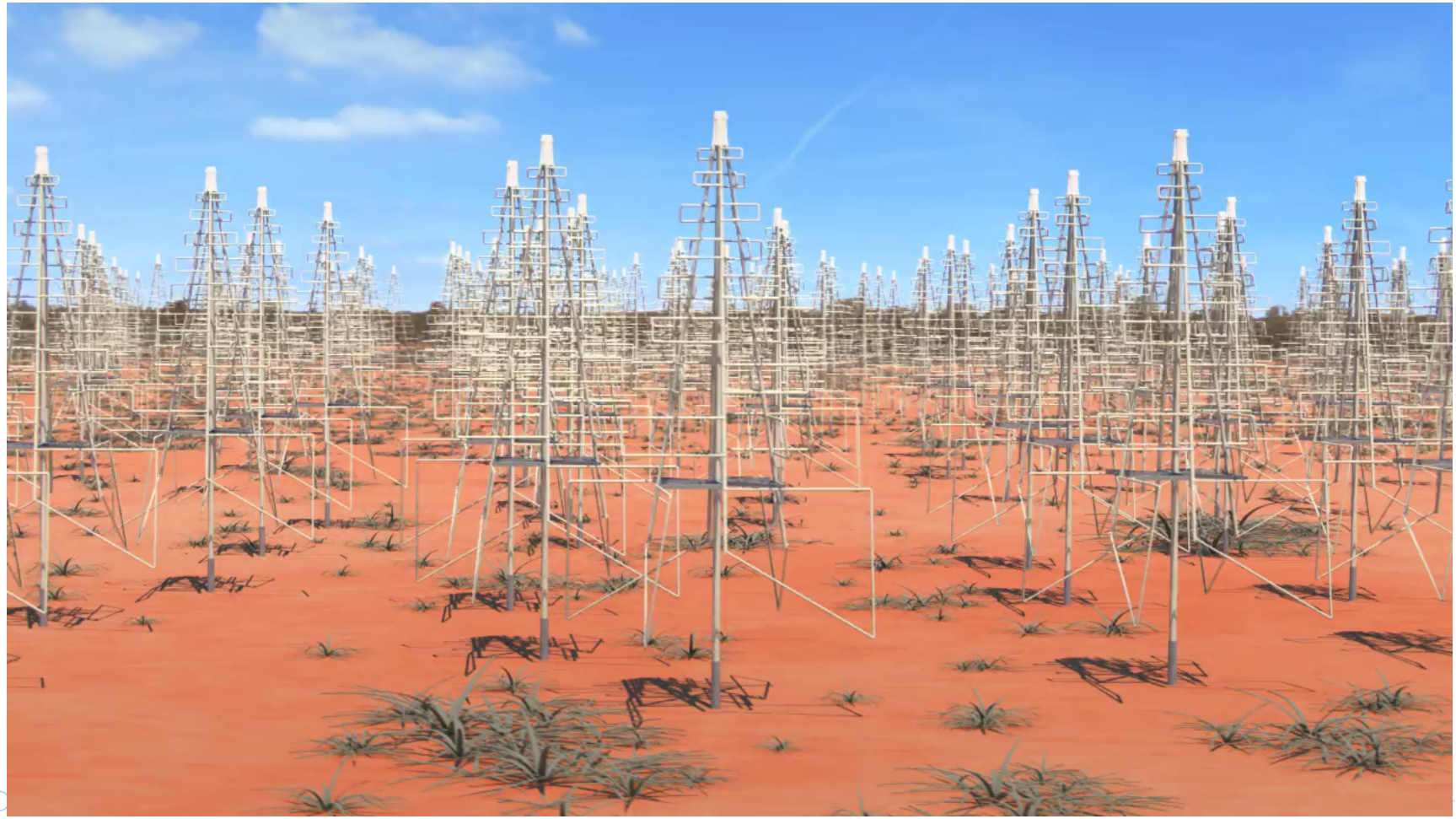
SKA1-MID, Karoo, South Africa:

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

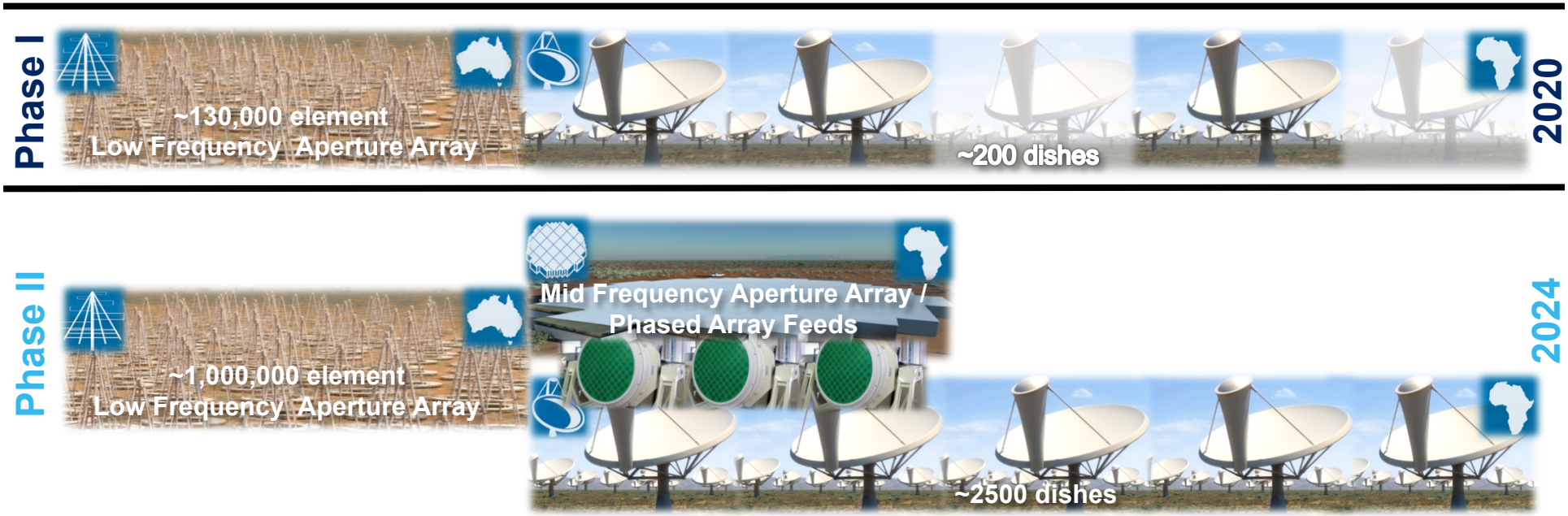
Bands: 2 (0.95–1.76 GHz), 5 (4.6–14(24) GHz), 1 (0.35–1.1 GHz)

SKA1-LOW, Murchison, Australia:

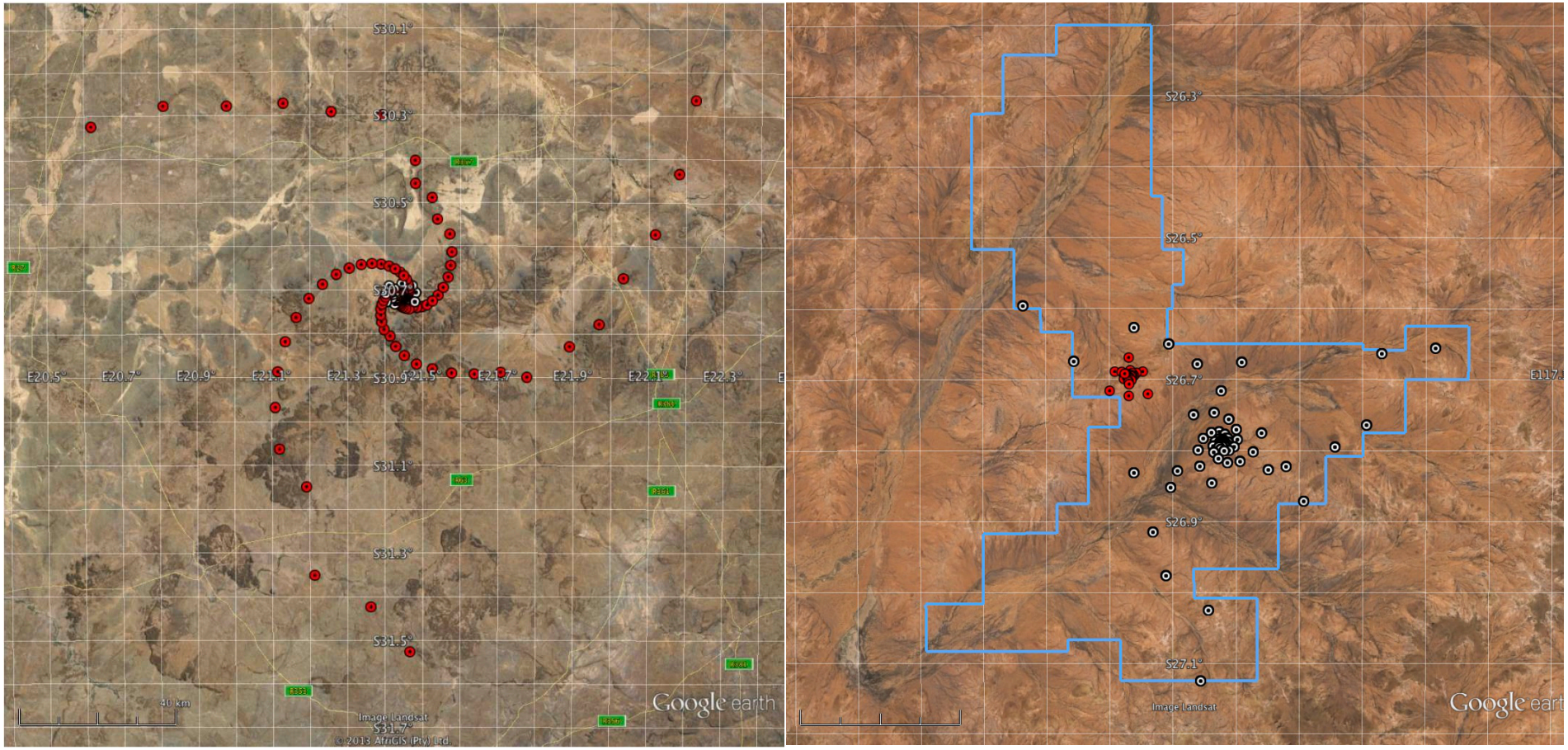
130,000 dipoles (512 stations x 256 antennas); 50–350 MHz
~80km baselines; large areal concentration in core



What is the SKA?

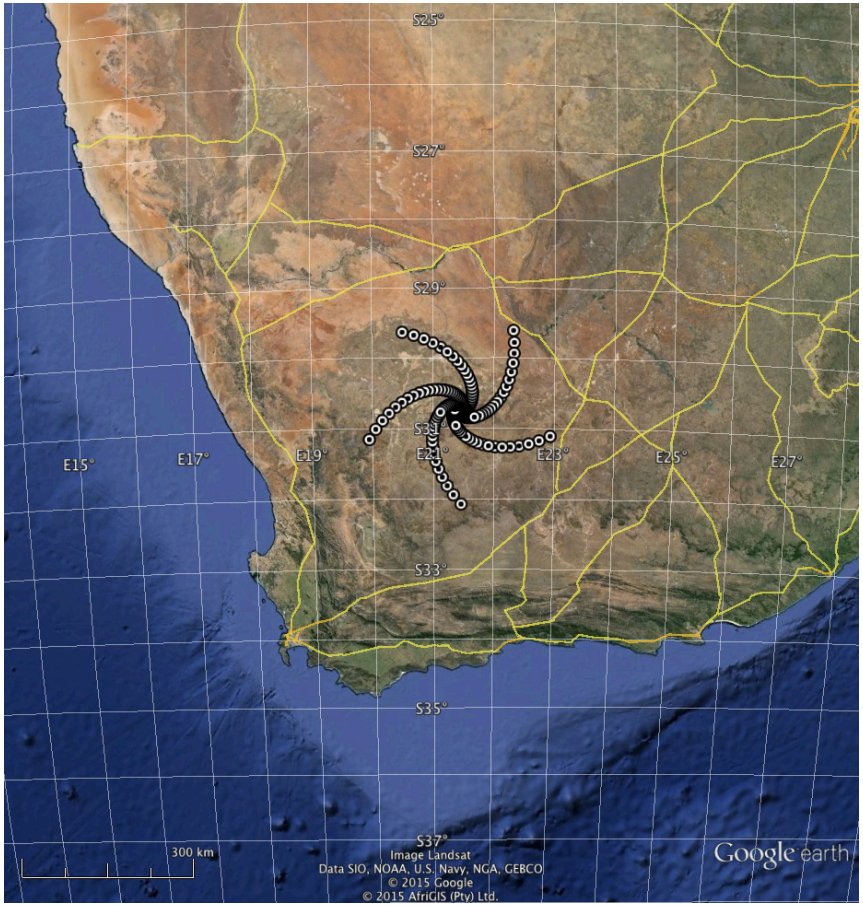


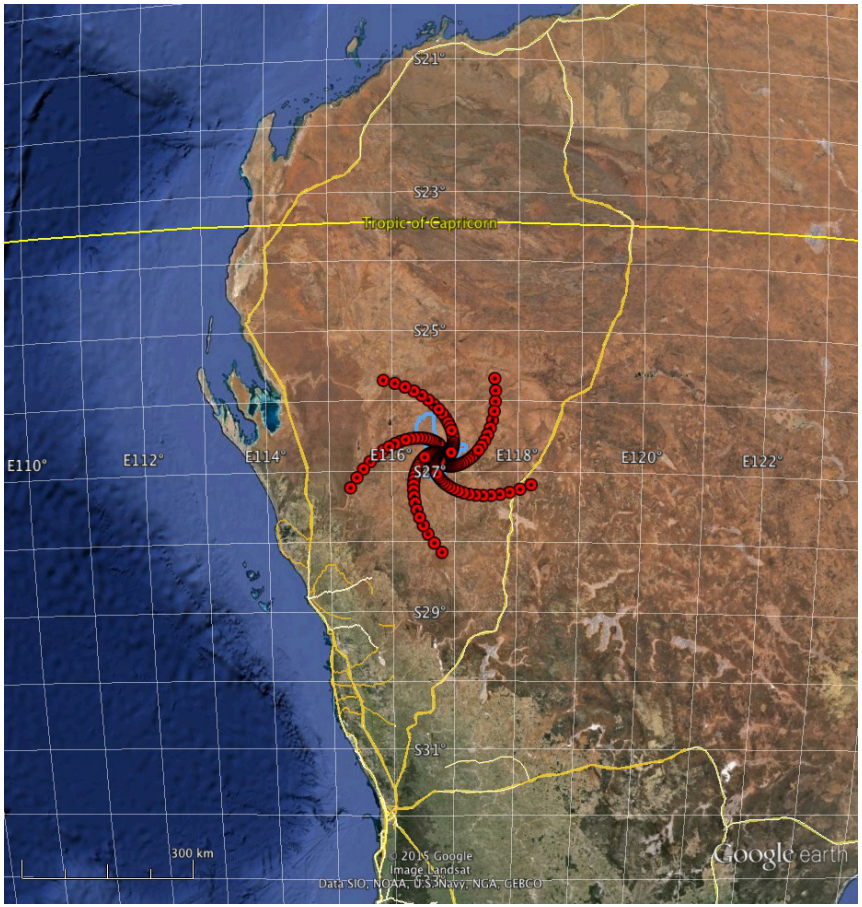
SKA1 Configurations



- SKA1–MID, –LOW: B_{Max} = 156, 65 km

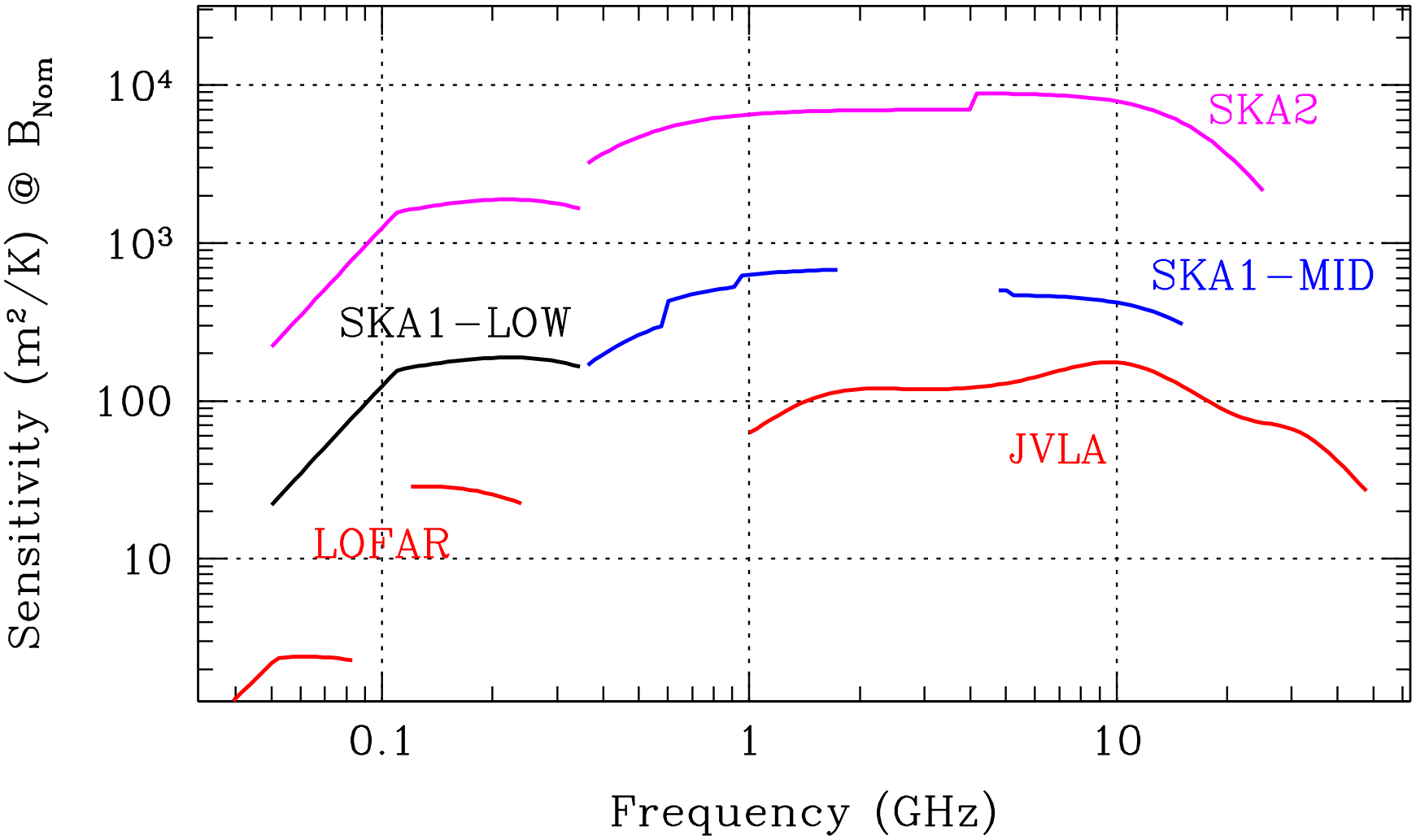
SKA2 Configurations



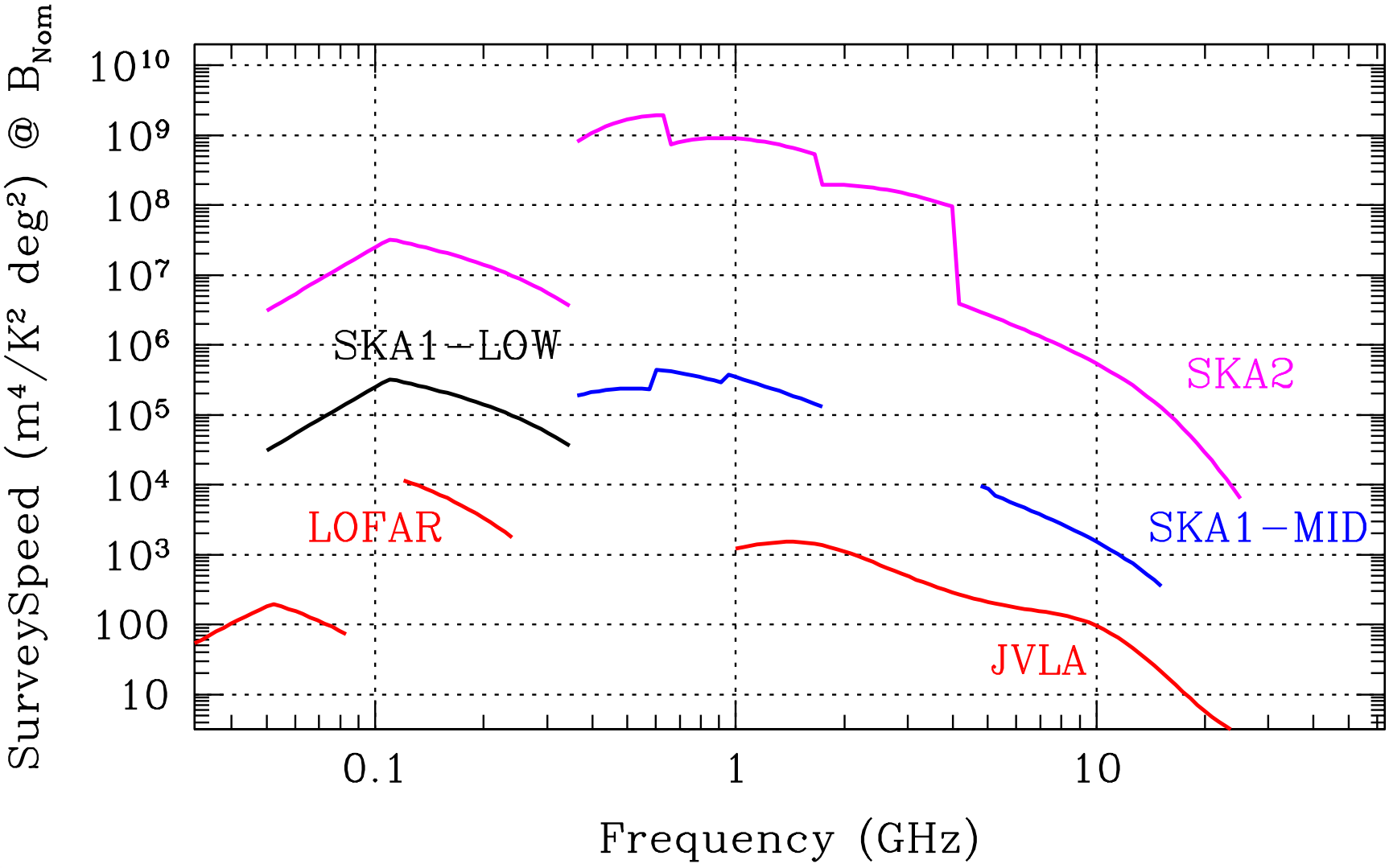


- SKA2–Dish, –LOW: B_{max} ≈ 300 km “core”, ≈3000+ km remote

Sensitivity Comparison



Survey Speed Comparison



Resolution Comparison

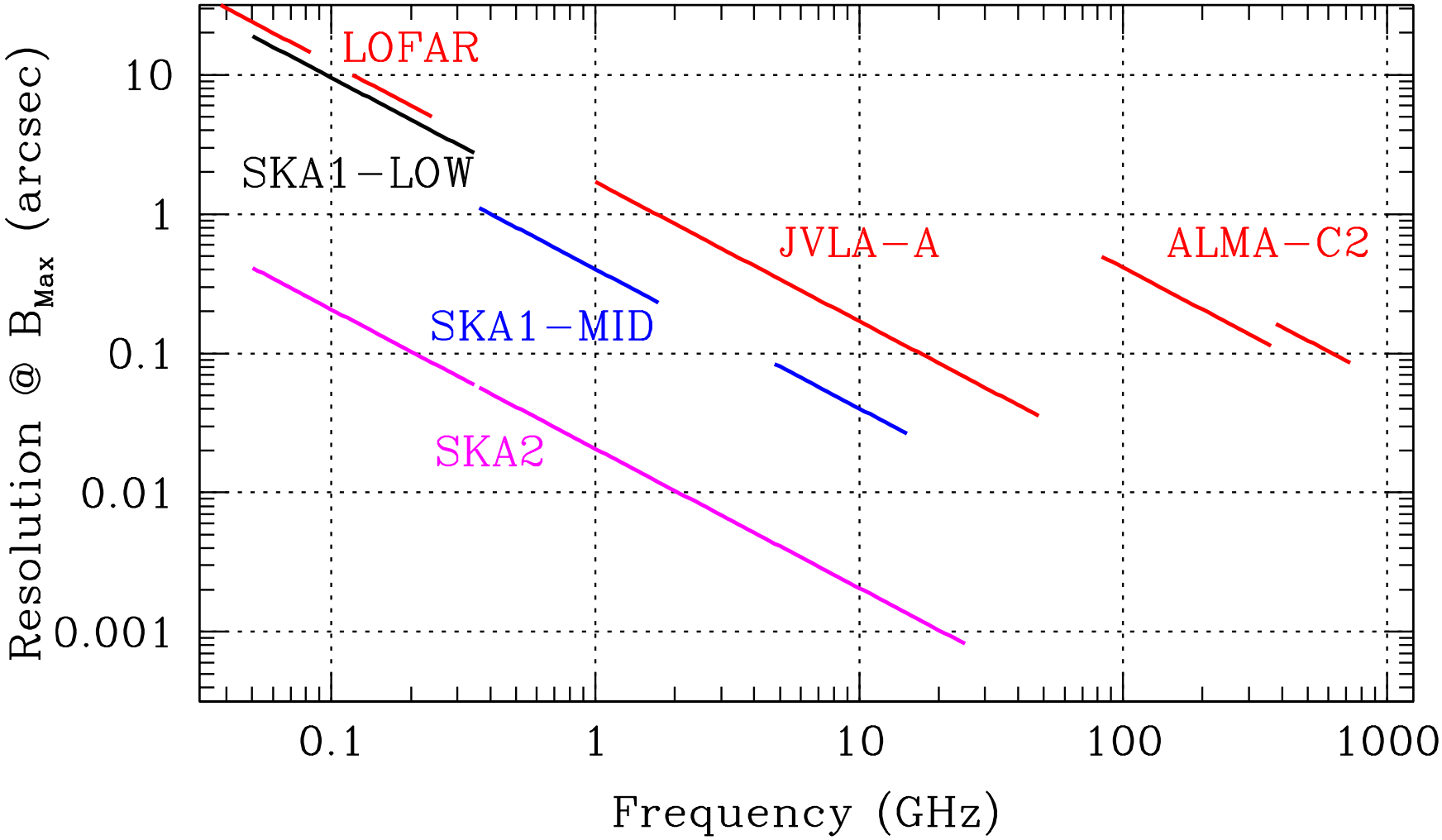
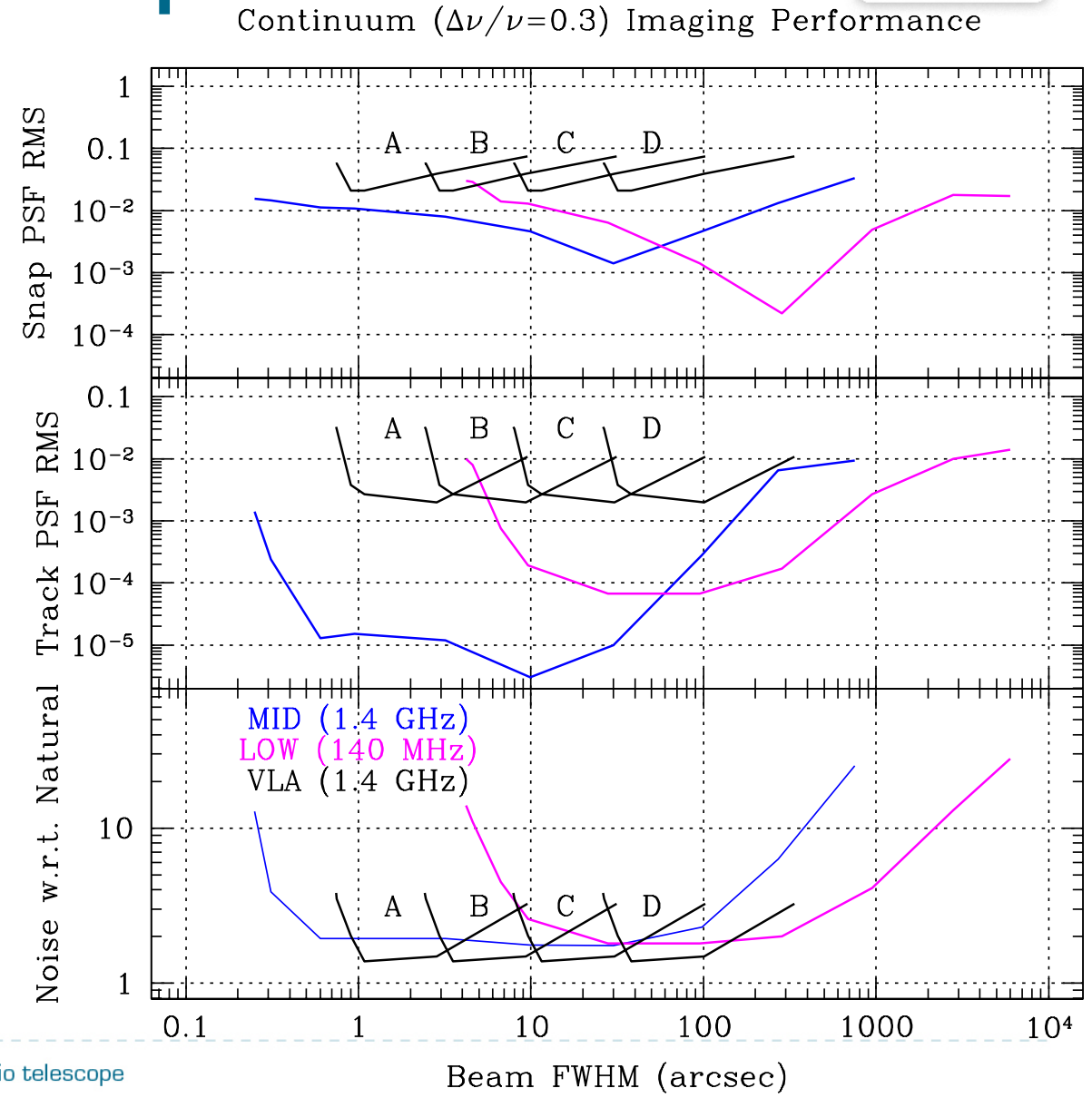


Image Quality Comparison

- Single SKA1 track equivalent to VLA A+B+C+D + **E+A$^+$**
- "Structural" dynamic range of ~1000:1 rather than ~3:1 per track
- Beam quality ~100 times better than VLA



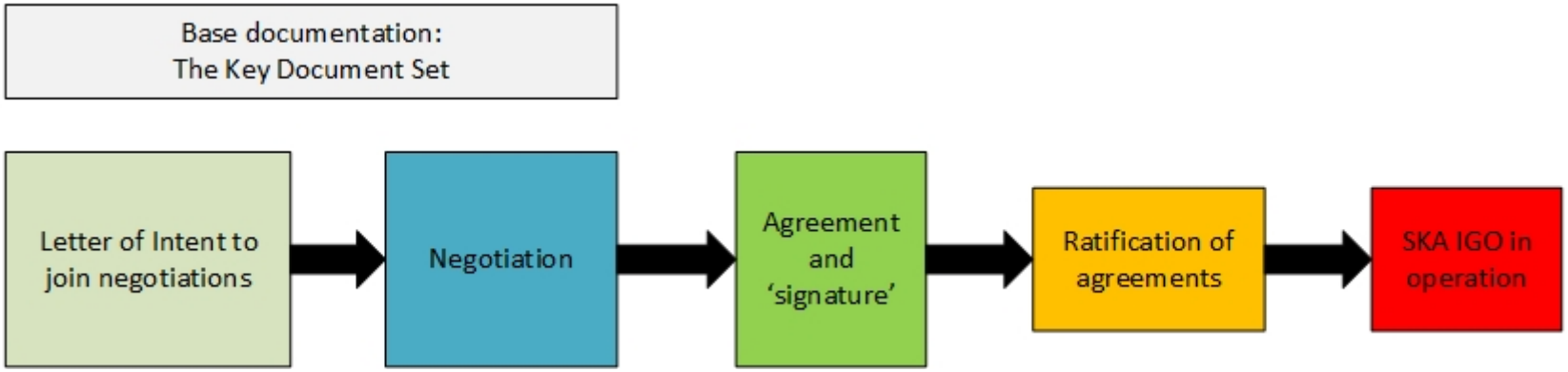
Key events in last 12 months

- August 2014: India becomes Full Member of SKAO
- Sept 2014: SKA rated as top priority new project in French 5-year astronomy infrastructure planning.
- Dec 2014: Portugal releases its national research infrastructure roadmap: SKA included
- Dec 2014: Italian government passes legislation, includes €30M for industrial astronomy – SKA/CTA
- Dec 2014: UK releases its 10-year Science and Technology strategy – SKA prominent (UK construction funding £100M (€130M) for SKA1 construction already committed in March 2014)
- March 2015: SKA1 re-baselining
- April 2015: SKA HQ decision

SKA HQ selection: decision 29 April

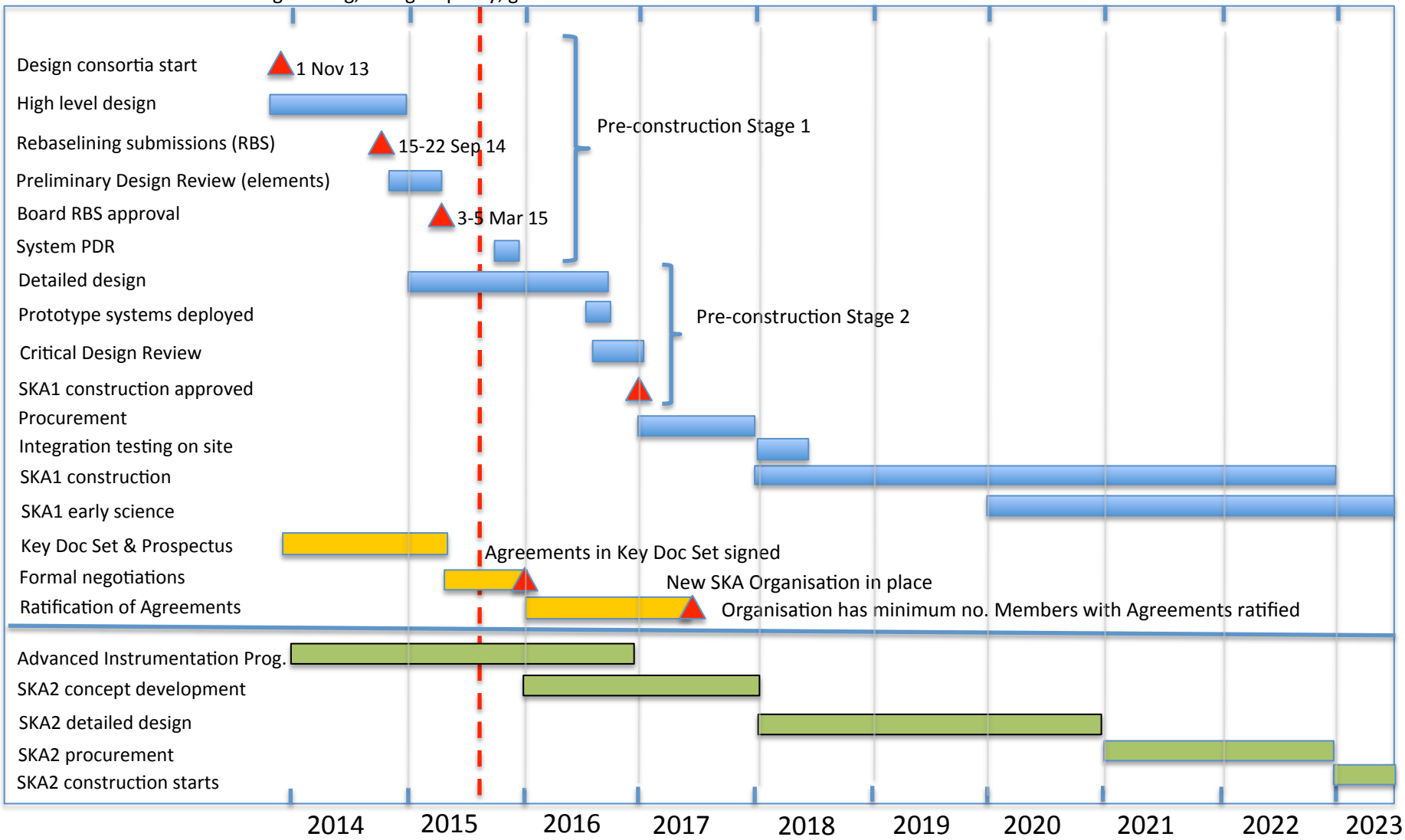
Governance/organisational structure

- 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

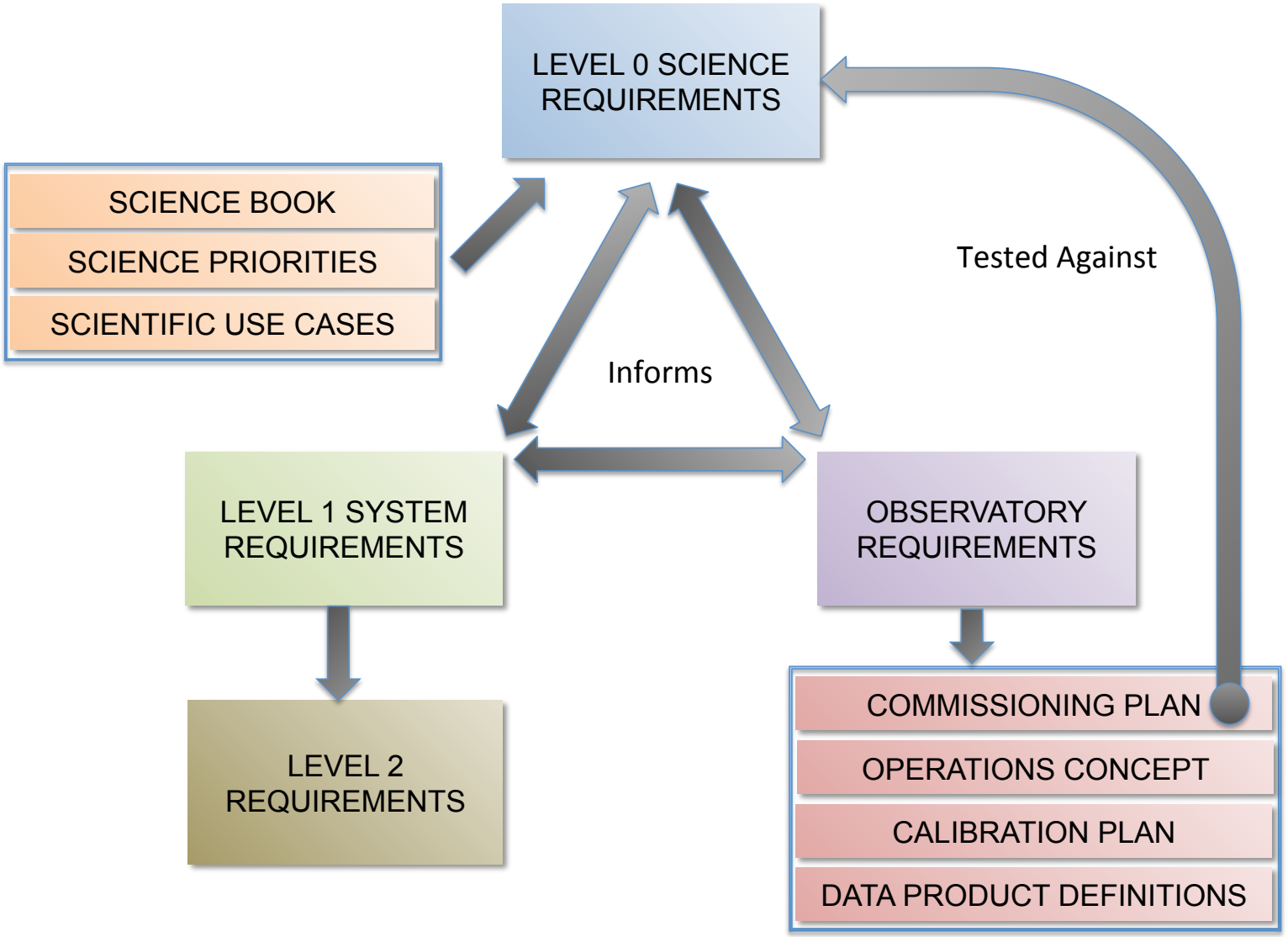


High-level SKA Schedule

KEY: Blue = SKA1 science & engineering; orange = policy; green = SKA2



SKA1 Science Requirements



Key Science Projects:

- **Notional** package of Key Science Projects in Q1 2015 based on the highest priority science objectives that have been recommended by our science community that will be:
  - Consistent with capabilities of the SKA1 design
  - Consistent with a realistic observing schedule filled at approximately 50% for the first 5 years of scientific operations
- Adopt KSP policy
  - Only scientists from SKA member countries may lead a KSP
  - KSP Leadership is guaranteed to be distributed amongst SKA members in proportion to their financial contribution
  - KSP participation (at the non-Leader level) is guaranteed to be distributed amongst SKA members in proportion to their financial contribution
  - KSP participation (at the non-Leader level) of SKA non-members is capped at the value defined in the Access Policy

Key Science Projects:

- Issue Call for KSP Letters of Intent (circa 2018)
  - Provides opportunity to coordinate appropriate balance of prospective SKA member teams and science topic coverage
- Issue Call for full KSP proposals
- Proposal assessment criteria:
  - Scientific merit
  - Technical feasibility
  - Plans and capabilities for data analysis
  - Publication and derived data product release arrangements
  - Collaboration policies and management arrangements
  - Consistency with science aims expressed in the set of notional KSPs

Key Science Projects:

- Resourcing
  - KSP teams can propose and receive dedicated SKA resources
  - General expectation that teams bring significant additional resourcing
- Data rights
  - Primary data rights remain with the SKA Observatory
  - Data rights are granted to KSP teams for specific objectives
  - Commensal programs can be granted data rights for complementary objectives
- Ongoing review
  - Satisfactory progress against project plan, including timely public release of agreed data products is condition for further allocations

A Package of Notional SKA1 Key Science Projects

SWG	Objective
CD/EoR	Physics of the early universe IGM - I. Imaging
CD/EoR	Physics of the early universe IGM - II. Power spectrum
Pulsars	Reveal pulsar population and MSPs for gravity tests and Gravitational Wave detection
Pulsars	High precision timing for testing gravity and GW detection
HI	Resolved HI kinematics and morphology of ~10^10 M_sol mass galaxies out to z~0.8
HI	High spatial resolution studies of the ISM in the nearby Universe.
HI	Multi-resolution mapping studies of the ISM in our Galaxy
Transients	Solve missing baryon problem at z~2 and determine the Dark Energy Equation of State
Cradle of Life	Map dust grain growth in the terrestrial planet forming zones at a distance of 100 pc
Magnetism	The resolved all-Sky characterisation of the interstellar and intergalactic magnetic fields
Cosmology	Constraints on primordial non-Gaussianity and tests of gravity on super-horizon scales.
Cosmology	Angular correlation functions to probe non-Gaussianity and the matter dipole
Continuum	Star formation history of the Universe (SFHU) – I+II. Non-thermal + Thermal processes

- Outcome of well-documented SKA1 science prioritisation process
  - All objectives originate with the science community
  - Review and strong endorsement by advisory bodies (SRP, SEAC)
- Should be viewed as ***representative*** package of high-impact science deliverables for the first five years of science operations

KSPs: Community consultation outcomes

- Broad support for KSP concept
- Some areas of feed-back/concern and their clarification:
  - ***Notional*** KSPs versus ***actual*** KSPs
    - Need to stress that the current list is representative and not final
    - KSP process must allow for best new ideas and not be frozen too early
  - KSP ***programs*** versus KSP ***proposals***
    - Need to clarify that KSPs are large but otherwise normal observing proposals
    - KSPs are not blanket allocations of science areas to specific groups
  - ***General*** versus ***limited*** data rights
    - KSPs only granted limited data rights for specific science objectives and well-motivated proprietary period
    - Same data stream may well serve multiple KSPs, each with limited objectives
  - ***Global*** versus ***project*** member balance
    - Member balance would only be imposed globally on entire KSP package
    - Letter of Intent phase to gauge national aspirations and membership projections

KSPs: Next step, 2015 Stockholm Workshop

- Further develop KSP concepts
  - A notional KSP list has emerged from the SKA1 Science prioritization process, but this is only a representative placeholder, and will be continually reviewed.
    - This workshop aims to provide a forum for open discussion of KSP concepts, reviewing the notional list and identifying missing concepts.
- Support development of potential KSP collaborations
  - There will ultimately be a competitive process of KSP proposal submission, evaluation and allocation, implying that all discussions at this stage are informal and come with no guarantees.
    - This workshop aims to provide a forum for the key areas of interest of particular communities to be presented, leadership aspirations to begin to be identified and resourcing strategies to begin development.
- Maximizing commensality
  - It is likely that the same data stream will serve multiple KSP or PI-led groups, each with limited data rights to address specific scientific objectives.
    - This workshop aims to provide a forum for early discussion of support for such commensal programs, including the development of efficient survey strategies intending to maximise the scientific return of the KSP package.

KSW2015 Program

Day1

09:00	Introductory talk from office [Robert Braun]
10:00	Question & Answer
10:30	Coffee Break
11:00	Continuum [Isabella Prandoni]
11:25	Cosmology [Mario Santos]
11:50	Cradle of life [Melvin Hoare]
12:15	Epoch of reionization/cosmic dawn [Jonathan Pritchard]
12:40	Lunch
13:40	Extragalactic molecular spectroscopy [Mark Sargent]
14:05	HI galaxy science [Martin Meyer]
14:30	High Energy Cosmic Particles [Stijn Buitink]
14:55	Magnetism [Russ Taylor]
15:20	Our Galaxy [Mark Thompson]
15:45	Coffee Break
16:15	Pulsars [Gemma Janssen]
16:40	Solar/Heliospheric physics [Divya Oberoi]
17:05	Transients [J-P. Macquart]
17:30	VLBI [Ivan Agudo & Hiroshi Imai]
17:55	End of Day

18:30	Welcome reception at Albanova Building (10 minutes walk from the Wenner-Gren Centre) - Sponsored by Onsala Space Observatory.

Day2

Topical Breakouts

18:00 - 20:00	City Hall Tour and Reception, including drink and buffet (hosted by the City of Stockholm) - The reception starts 18:00 prompt, followed by a guided tour of the building.

Day3

Day4

09:00	VLBI [Zsolt Paragi + TBD]
09:25	Transients [Michael Rupen]
09:50	Solar/Heliospheric physics [Divya Oberoi]
10:15	Pulsars [Andrea Possenti]
10:40	Coffee Break
11:10	Our Galaxy [Grazia Umana]
11:35	Magnetism [Sui Ann Mao]
12:00	High Energy Cosmic Particles [Justin Bray]
12:25	HI galaxy science [Erwin de Blok]
12:50	Lunch
13:50	Extragalactic molecular spectroscopy [John Conway]
14:15	Epoch of reionization/cosmic dawn [Cath Trott]
14:40	Cradle of life [Andrew Siemion]
15:05	Coffee Break
15:30	Cosmology [Xuelei Chen]
15:55	Continuum [Minh Huynh & Rosella Cassano]
16:20	Talk describing the next steps from office [Robert Braun]
17:00	End of Workshop

Welcome to KSW2015 …

… and have a productive week !

SQUARE KILOMETRE ARRAY

Exploring the Universe with the world's largest radio telescope

www.skatelescope.org