

RMS and SKA:

AN EVOLUTIONARY PATH FOR THE DECADE?

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***Building on New Worlds, New Horizons:
New Science from Sub-millimeter to Meter Wavelengths***

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Introduction

- The current world of RMS science is very rich
 - **New facilities have/are coming on line (ALMA, EVLA, GBT, LMT, LOFAR, SMA, SPT/ACT, VLBA enhancements,...)**
 - **New astrophysics is emerging**
 - **New experiments and new facilities in planning and/or development (FASR, CCAT, MWA, PAPER, ASKAP, MeerKAT, FAST...)**
- Concurrently, but perhaps not synchronously, the major next generation facility--SKA--is prominent in international planning; Asynchronicity leads to questions:

How do we prioritize between experiments & facilities, and between current science and future facilities?

What is the relation between (US) RMS science and (international) SKA planning?

Context

- In the RMS context, the science enabled by SKA represents an important goal for the *NEXT* decade, as reiterated by ASTRO2010
- Large effort (many countries) to define, design, implement SKA (or pieces thereof) ongoing
 - international project office doing preparatory work, funded/overseen by an international collaboration
 - substantial, SKA-specific resources invested by South Africa (MeerKAT) and Australia (ASKAP)
 - investments in many pathfinders/precursors (PAPER, MWA, LOFAR, EVLA, ATA, etc)
- US Decadal Survey endorsed SKA science goals, but only technology development for this decade
 - SKA is still a concept more than a facility
 - HERA, NanoGrav backed as SKA precursors/roadmaps
- US Decadal Survey also strongly endorsed *non*-SKA RMS science (e.g. CCAT, FASR)

Context-2

- In international SKA community, however, there is strong sentiment to move forward rapidly to maintain momentum
 - Create legal entity (non-profit corporation)
 - Select site
 - Initiate ~3-4 year pre-construction detailed design phase (~90ME)
 - Implement SKA Phase 1 in last half of this decade (~500ME)
- Little doubt that a qualitatively new RMS facility is necessary in the future, but to many, the current international process is premature, unrealistic
 - *Based on overly optimistic funding scenario*
 - *Doesn't incorporate current scientific investments*
 - *Designing facility before getting results from current pathfinders could result in less-than-optimal design (scientifically)*
 - *Risk that detailed design will be obsolete by the time funding is available*

Current international process funding assumptions

- 90M Euros in 2012-2015 to design SKA Phase 1
- close to half-billion Euros in last half of decade to design and construct SKA Phase 1
- several billion more Euros at end of decade for full SKA Phase 2, ten to twenty times more sensitive than Phase 1

Funding assumptions do not appear credible, given

- current and near term global fiscal climate
- international priorities for large astronomy facilities: one or more EELTs *and* an LSST *before* SKA

Questions

- Question 1: *Is there a better path forward?*
 - one that maintains the **overall science vision and international momentum** (one of big issues in some quarters)
 - one that builds on current efforts and is potentially fundable
- Question 2: *Does the underlying SKA assumption of a single facility addressing common scientific goals & too large for any single country to build, need to be revisited?*
 - 2a: Is the proposed large international superstructure appropriate to reality, cost effective?
- Question 3: *What is the future of the current process?*
 - **Will it proceed as currently planned?**
- Question 4: *How should the US participate in SKA?*
 - *A somewhat nuanced question!*

A strawman roadmap alternative

- start with current precursors/pathfinders and "build out" where possible
- define/continue necessary technology developments
- define science investigations needed to specify the eventual full SKA
 - *Essential that roadmap is driven by science*
- identify appropriate partners and/or collaborations to carry these out (some of this is starting)
- allow different components to develop on parallel paths as funding allows
 - eliminate need for large centralized infrastructure

provide an overall science-driven path to eventual SKA, likely with multiple sites/facilities

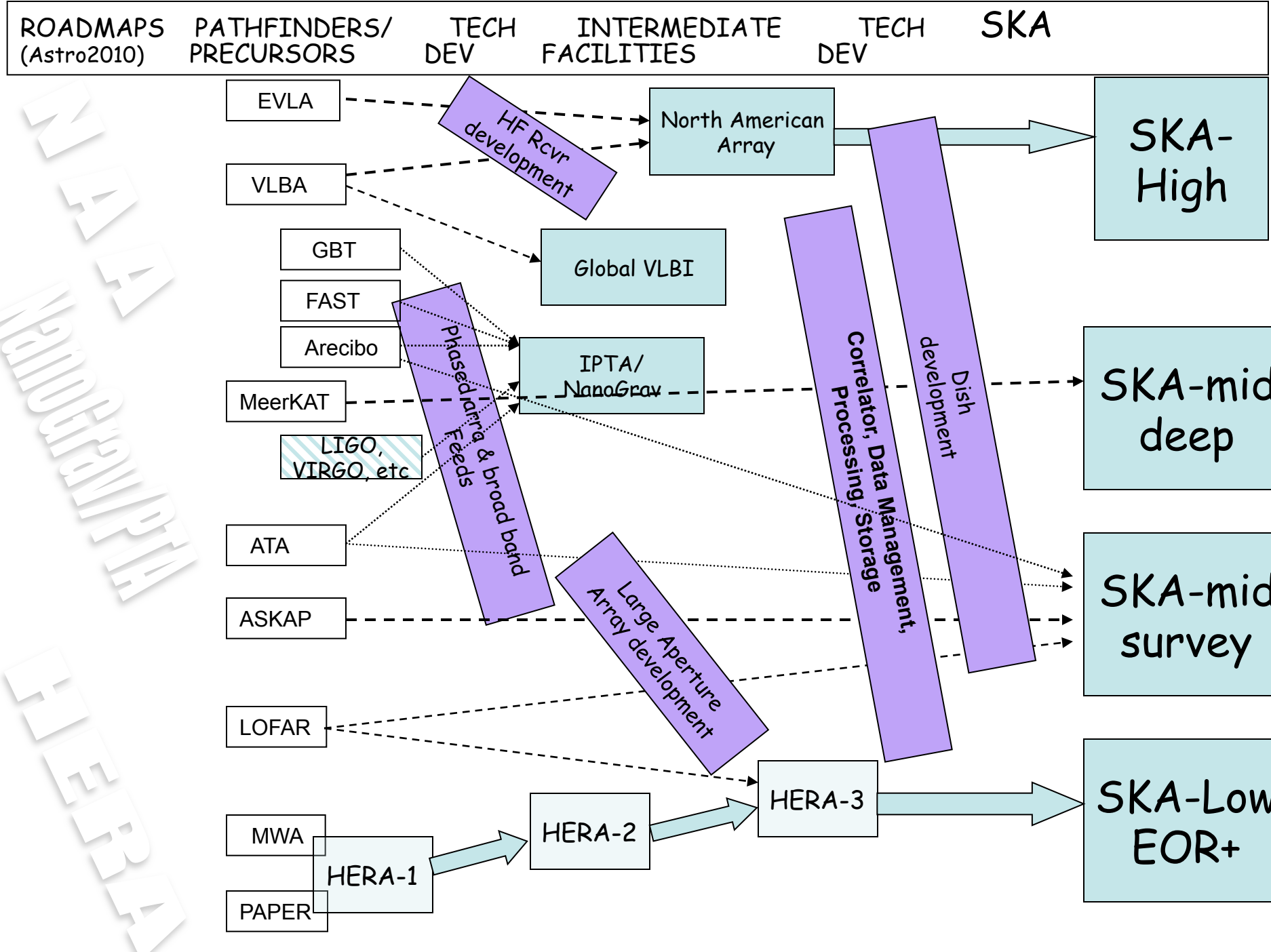
Some Foundational Results

needed to inform SKA roadmap

- Constraints on amplitude and redshifts of HI signals from EOR, Cosmic Dawn, Dark Ages (MWA, PAPER, LOFAR, LWA, GMRT...)
- Improved determination of HI mass function, particularly as function of redshift (Arecibo, WSRT/APERTIF, ASKAP, GMRT...)
- Improved nHz gravitational wave constraints from, & improved techniques for, pulsar timing (GBT, Arecibo, Parkes, MeerKAT, EVLA...)
- Deeper continuum images and improved wide-field imaging techniques (EVLA, MeerKAT, ASKAP/APERTIF...) total intensity *and* polarization
- Additional experience with, and understanding of limitations on, cosmological observations at radio wavelengths, notably weak lensing and intensity mapping (GBT, ASKAP, ...)
- Constraints on centimeter-wavelength SEDs of proto-planetary disk and efforts to image (EVLA, eMERLIN, ALMA)
- Additional experience in classifying radio sources, obtaining multi-wavelength data on objects, and understanding of what it means
- Additional experience in managing and processing large data sets; SKA-class correlators
- ***Serendipity with new facilities***

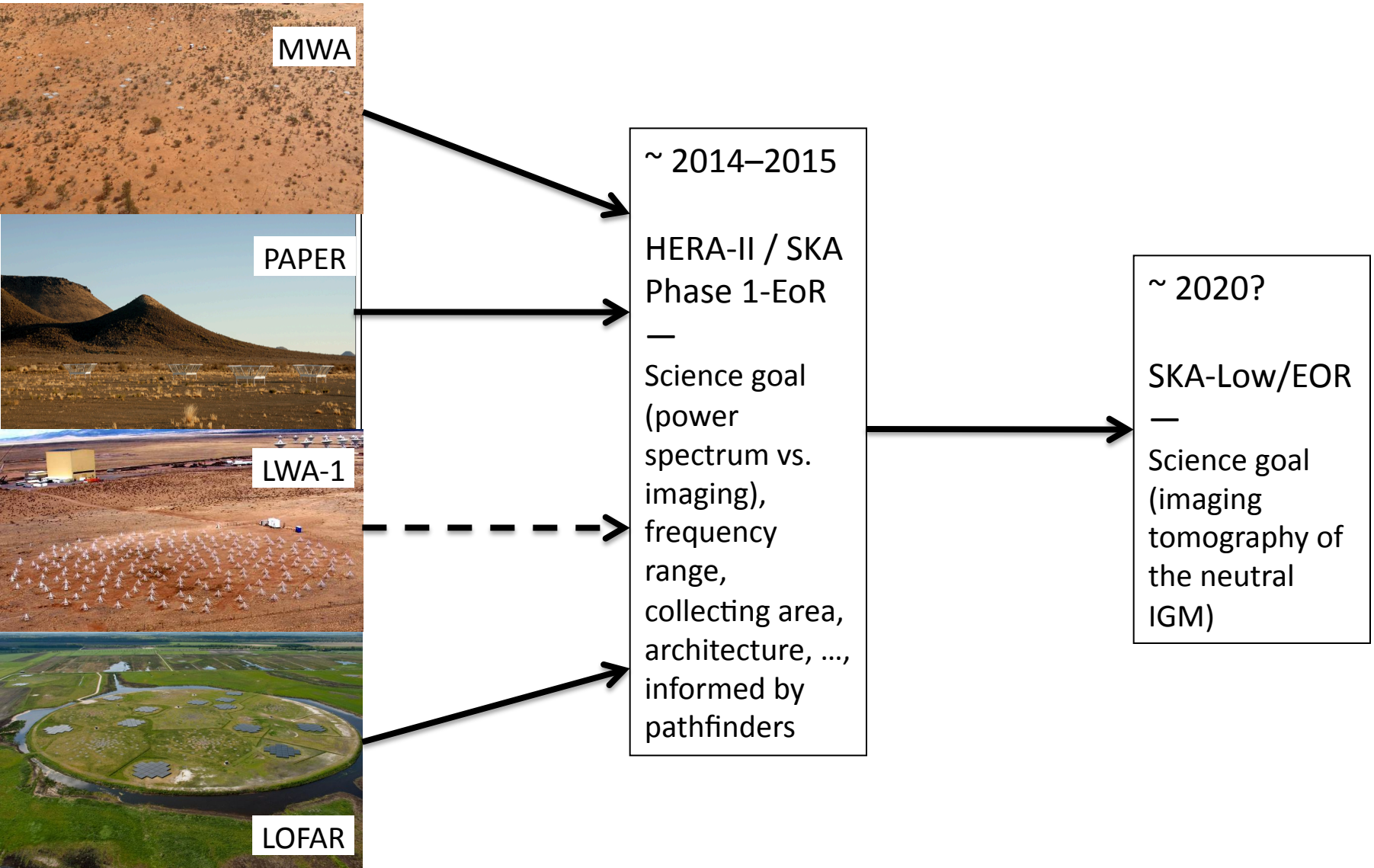
Roadmap Cartoon

- A very rough picture of an organizing principle
- Will need to be refined with required science inputs, technology developments, decision points

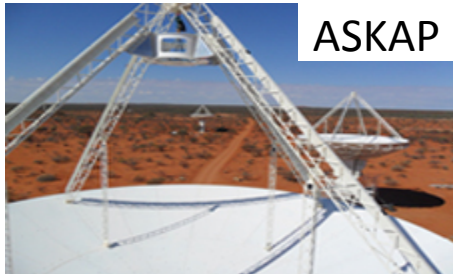


ROADMAPS
 PATHFINDERS/PRECURSORS
 TECH DEV
 INTERMEDIATE FACILITIES
 TECH DEV
 SKA

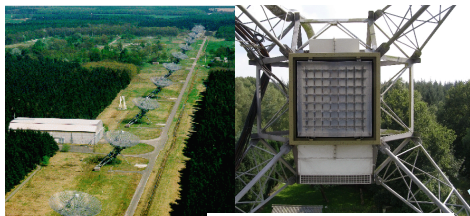
SKA-Low/EOR



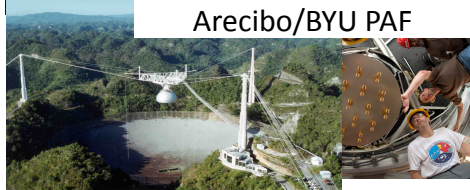
SKA-Survey



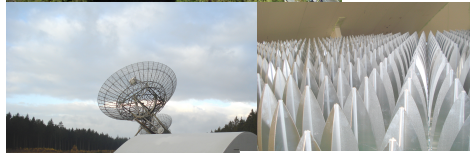
ASKAP



WSRT/APERTIF



Arecibo/BYU PAF



Dense Aperture Array



ATA

~ 2016--2018
Major surveys underway on PAF-enabled instruments (e.g., WALLABY, WODAN, ...) ---
Assessment of PAF capability

~ 2015—2016?
Aperture Array Verification Programme (AAVP)

Assessment of dAA

SKA-Survey
(Phase 1?)

SKA-Deep

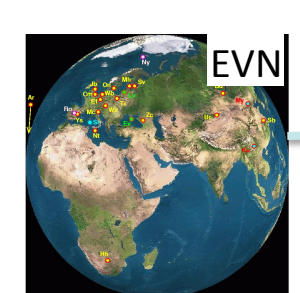
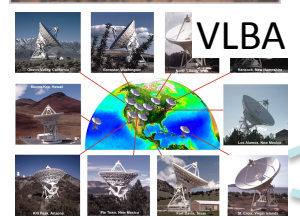
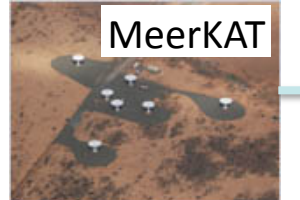
(deep H I fields, deep continuum fields, pulsar timing, ...)



~2017
Science case,
techniques,
instrument
parameters
(e.g., baseline
lengths)
informed by
other
telescopes



SKA-High (high-z, astrometry, life)



~ 2018
Science case
refined/expanded
+
specific technology
development (e.g.,
antenna cost
reduction)



Global VLBI

LBA, VERA, KVN, ...

Topics for Discussion

Question 1: *Is there a better path forward?*

Question 2: *Should we (US?, international? All?) revisit the underlying SKA assumption of a single facility?*

=> almost certainly yes! (but how may be regionally dependent)

- *A science-driven evolutionary path to SKA, building on current investments, consistent with flexible funding profiles*
- *recognize ultimate science vision for SKA, as well as science that can and will be achieved during SKA development*
- *recognize both technical and political realities in terms of siting the components of SKA*
- *allow different components to develop in parallel*
- *incorporate new elements in SKA as science discoveries and technology advances are made*

Topics for Discussion-2

Question 2a: Is the proposed large international superstructure appropriate to reality? Is it cost effective?

⇒ **Probably not**: a simpler coordination/oversight model could be developed, appropriate to refining the roadmap, coordinating technology/component development, coordinating operations and observing access...

Question 3: *What is the future of the current process?*

⇒ Hard to predict in detail, but we can be skeptical: depends in near term on how many countries commit serious funding this year

⇒ If current process does continue, it could evolve into a more realistic approach.

Topics for Discussion-3

Question 4: *How should the US participate in SKA?*

4A: In common international process?

- **Can we participate at all?** (there is no NSF “SKA money”)
- **Under what conditions?** (do we want to back the current approach if it continues as is?)
- **Will US be “shut out” in future if we don’t?** (reciprocal open skies?)

4B: In a US-centric approach?

- Via technology developments, as per ASTRO2010
- Via collaborations with international partners, as are naturally evolving e.g. putting detectors on arrays, developing s/w, etc.

CONCLUSION

- NSF will not fund “SKA” at this time
 - The sooner the entire SKA collaboration faces funding reality, the better
- Our international partners are hearing this and know that eventually US will be a part of SKA
- We will be discussing this “formally” in the next month

No matter what happens with SKA currently, RMS faces a bright future