Outline

1. Overview of PrepSKA.
2. WP2 Methodology
3. Specific Issues
4. Dish Verification Programme
5. Role of EVLA.
• Numbers of dishes (2000-3000) depends on whether Phased Array Feeds and/or Aperture Arrays are used in the SKA.
• Each technology is characterized by a frequency range and field of view.
Approximate Site Schematic

Note: Full extent of the array is ~3000 km.
Potential Maximum System Size

15m Dishes with Single Pixel Feeds: 3000
Sparse AAs: ~$10^6$ m$^2$
Dense AAs: 700,000 m$^2$ (250 x 60m dia. stations)
15m Dishes with Phased Array Feeds: 2000
SKA timeline

- **Pathfinder implementation**
  - 06 | 08 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26

- **Concept Design**
- **System Design**
  - **Detailed Design**
  - **Prod. Eng. & Tool g**
- **Phase 1 Construction**
- **Full SKA mid + low construction and commissioning**

- **Pathfinder operations**
- **External Engineering Review of design**

- **Phase 1 funding request**
- **Phase 2 funding request**
- **Prod. Readiness Review**

- **SSEC Site funding request**
- **SKA Site Characterisation**

- **EC-FP7: PrepSKA**
  - System design
  - Funding
  - Governance
  - Site Characterisation

- **US TDP**

- **SKADS**

26 February 2009
WP2 Project Deliverables*

1. SKA Technology Selection.
2. Reference Science Plan (RSP).
4. Risk Assessment.
5. Cost.
7. Operational – Construction Trade-offs.
10. Upgrade Guide.

*See Dewdney, “Guiding Principles, Activities & Targets for WP2”
Top Down
WP2 Overall Time Plan (Finish Times)

VSS = Verification Sub-System
Role of RSP* in Design Cycle

- Not another science case.
- Does not include all science.
  - Includes all key science as a minimum.
- Assembly of science case studies that can be used to define the technical requirements of the telescope.
- May contain priorities.
- Coverage is critical.
- Must be seen to be well justified, decisions traceable to a primary science case.
- See subsequent talks on RSP and Technology Selection

*Reference Science Plan
Flow from RSP to Technical & Ops Requirements*

Reference Science Plan

Feedback

For each RSP component

Technical Requirements (cost)

Operational Requirements (costs)
WP2 Methodology

- Bundle and re-organize original WP2 tasks to focus on large, verifiable sub-systems.
  - Various methods of verification
    - Depends on the nature of the subsystem.
      - Dishes, RF equipment, digital equipment, software, etc.
    - Build if necessary,
  - In the case of dishes, building prototypes is necessary.
  - Obtain cost information.

- Result is verified building blocks.
  - Well understood performance, cost.
  - Not too many types.
    - Easier to visualize the system if it does not seem too complex.
    - Funding agencies need to be convinced.
The Name (Verification Programme)

- Emphasizes the transition of SKA programme:
  - This is the only route to a costed system design.
  - Emphasizes the need for verification (testing).
- Standard engineering term
  - One of a pair of terms (validation & verification).
Key Instrumental Issues

- Stability
- Linearity
- “Calibratibility”
- System Temperature
- Cost
  - Capital
  - Operations

All Contribute to Dynamic Range
Specific Issues

- **Calibration and Imaging**
  - New technology implies new calibration techniques.
  - **Cannot model and calibrate systematic effects (errors) that are not fully understood.**
    - Sounds obvious … but years of work on specific telescopes have typically been required to understand the subtle systematic effects needed to achieve high DR imaging.
    - Lessons learned from this work must be applied to the SKA from the beginning.
  - Unprecedented level of collaboration needed for the SKA between design engineers and astronomers (also cross-training).

- **Large Loop System Interactions**
  - e.g. Calibration techniques affected by antenna design, which is in turn affected by calibration techniques.
  - **Must break this loop (intuition, experience, conservative design for system components that cannot be changed).**
Specific Issues

- Software Development
  - Hardware production and scaling relationships do not apply to software.
  - Survey speed, time-variable astronomy implies very high data flows and possibly number crunching.
  - Scale of SKA implies the use of supercomputer architectures (1000’s of cores) for which there is no current body of code.
  - Downloading design/cost issues to S/W
    - The cost of developing S/W to solve for (or calibrate) additional parameters to make the H/W less expensive could be false economy (e.g. 3rd axis on ASKAP antennas could be well worth the cost).
Intellectual Property (IP) Issues

- Intellectual Property (IP) and Copyright resulting from PrepSKA work:
  - Unless exceptional circumstances, IP must be made available to the SKA project;
  - Unfettered right to use the IP, free of further charge, for the further development of SKA technology/telescope,
  - Including the right to combine designs from different sources with each other.
  - Relevant IP includes design documentation, calculations, and fabrication methods.
  - Provides flexibility and surety in procurement.
- SKA project must become a legal entity to make progress here.
- IP concerns have already started to affect engineering work.
- Part of the solution: an agreement on IP sharing.
  - Industry Participation Mgr will be working on this issue.
Pre-Design Considerations for Dishes

- **Scalability of design** – Can proposed technology be scaled to SKA?
  - Can the design be produced in large quantities?
  - Can prototypes be tested adequately before production?
- **Scalability of production methods.**
  - Production rate compatible with required rollout rate?
  - Can the production rate be adjusted easily?
  - Rapid installation with small team on site, minimum RFI.
  - Can they be built “anywhere”?
- **Scalability of cost?**
  - Do unit costs fall rapidly with number up to the 2000-3000 range?
    - Transportation, material, labour costs as function of quantity.
  - Operations costs?
    - Parts count, maintenance.
New Technology Hurdles

- **Ultra-wide band feeds**
  - Need to prove they result in better $A_e/T_{sys}$ per dollar/euro than multiple narrower band feeds
    - Accounting for mechanical complexities of multiple feeds.

- **Noise, efficiency & FoV expansion technologies**
  - $[A_e/T_{sys}]$ & $[(A_e/T_{sys})^2 * \Omega]$ both have strong dependence on $T_{sys}$.
  - Critically important that gains in $\Omega$ are not cancelled by sacrifices in $T_{sys}$.
  - Cost/performance measures could still favour traditional systems if this happens.
Why we need to plan ahead for DR

• Don’t want to build a supersensitive (high $A/T_{sys}$) telescope:
  – then find that it hits a limit after 50-hrs integration, which is then irreducible because of systematic errors.
  – i.e. not fully understood, or rapidly time variable.

• High DR is a system issue.
  – need to consider the whole signal chain, signal processing and imaging as a system.

• The fraction of the error budget generated by antenna imperfections
  – Could be substantial if not considered ab initio.
  – Difficult to measure except in a real system.
  – Difficult to remedy after many have been fabricated.
Dish Verification Programme

- Initial guidance from Reference Science Plan
  - System A/T, Survey Speed (>10,000, ~10^9)
  - Frequency range (0.3 – 10 GHz)
  - System imaging dynamic range (>70 dB)
- Use experience, reasonable assumptions to derive
  - Approx dish diameter, Tsys & efficiency goals.
- Select candidate designs to examine more carefully.
- Carry out first order designs
  - Iterate
  - Review these designs
  - Eliminate down to one or two possibilities.
- Carry out more detailed designs
  - Re-review against system requirements.
- Develop test plans.
  - Verify performance
Scattering in Reflector Design

- All antennas have sidelobes (diffraction).
  - Sidelobes can be reduced to arbitrarily low levels by under-feeding the reflector(s), at the cost of aperture efficiency, which costs money.

- Reflector antennas have scattering surfaces:
  - Worst case is structures directly in optical path
  - Scattering cannot be reduced to zero.

- “Sky-mount” reflectors stabilize the sidelobes and scattering patterns on the sky (e.g. ASKAP antennas)
  - Time-variable to time-invariant errors.
  - May be very important for high DR imaging.

- Choice between clear-aperture designs whose pattern rotates on the sky vs blocked aperture designs with sky-mounts.

- Either way, we cannot “afford” poor quality antennas for the SKA.
  - The cost of mitigating the effects of uncorrected errors induced by antenna imperfections could be larger than the cost of making the antennas better.
Why Do We Need the EVLA?

• **2-D array**
  – Good snapshot capability.
  – Field sources can be mapped quickly and accurately.
  – Rapid self-calibration.
  – Well understood system by 2011/2012.

• **EVLA system should be very stable.**
  – Digital data transmission system so far indicates considerable improvement over VLA.

• **High sensitivity**
  – Deep images in short time.
  – Needed to examine time-dependent effects.
Why Do We Need the EVLA? (cont’d)

• Frequency range covers most of the mid-SKA range relevant to dishes.
  – Field source spectra can be determined, if not already known.

• Correlator has capacity.
  – Additional antennas can be plugged in.
  – Lots of frequency channels.
    ▪ Frequency effects can be exposed.
  – Unusual modes not needed (I hope).

• Skilled people to assist with analysis.
  – Understanding antenna behaviour is “bread and butter”.

• Measurements possibly combined with some algorithm development and/or simulation.
What Sort of Tests with EVLA?

- Observing time must be used very judiciously.
  - Considerable advance work as single dish
    - Debugging.
    - Photogrammetry, laser tracker, holography, initial pointing model, temperature sensor array, etc

- Stability
  - Thermal and wind effects on pointing & beam shape.
  - Repeatability over day/week/month intervals.

- Beam Parameters
  - e.g. circular symmetry (if not sky-mount).

- Linearity
  - Spectral dynamic range of system.
    - Linearity of RF system in the presence of RFI.
Potential Test Setup for SKA antenna in the EVLA array

- Mosaic map pre-observed.
- Calibrator:
  - On-axis for EVLA array.
  - Half-power point for SKA antenna.
• **System Temperature**
  - On the sky as function of frequency, time.
  - Behaviour over long integrations.

• **Dish Efficiency**
  - Function of frequency.

• **Recovered parameters**
  - Carry out some data processing experiments to recover beam parameters from data.
  - May be tricky with dissimilar dish sizes, but probably not impossible.
    - Some pre-observations of regions around calibrators may be needed.

• **Bandshape stability**
  - Over long observations.
What Sort of Tests with EVLA? (cont’d)

- Sidelobe stability measurements (sky-mount).
  - Put strong source on a sidelobe of the test antenna.
  - e.g. Cyg A could be used here.

- Polarization properties.
  - Stability of instrumental components of pol’n.
  - Algorithm for removing rotating pol’n artifacts needed?

- Crosstalk
  - Possible only if two SKA dishes available.
What Sort of Tests with EVLA? (cont’d)

• Array Configuration
  – ‘C’ or ‘D’ may be best.
  – Larger configurations may also be OK.
  – Group of tests would have to be done in the same configuration.
    • Field sources will be resolved in/out, depending on the configuration.
End