SKA1 High Level System Description

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System Delta CoDR

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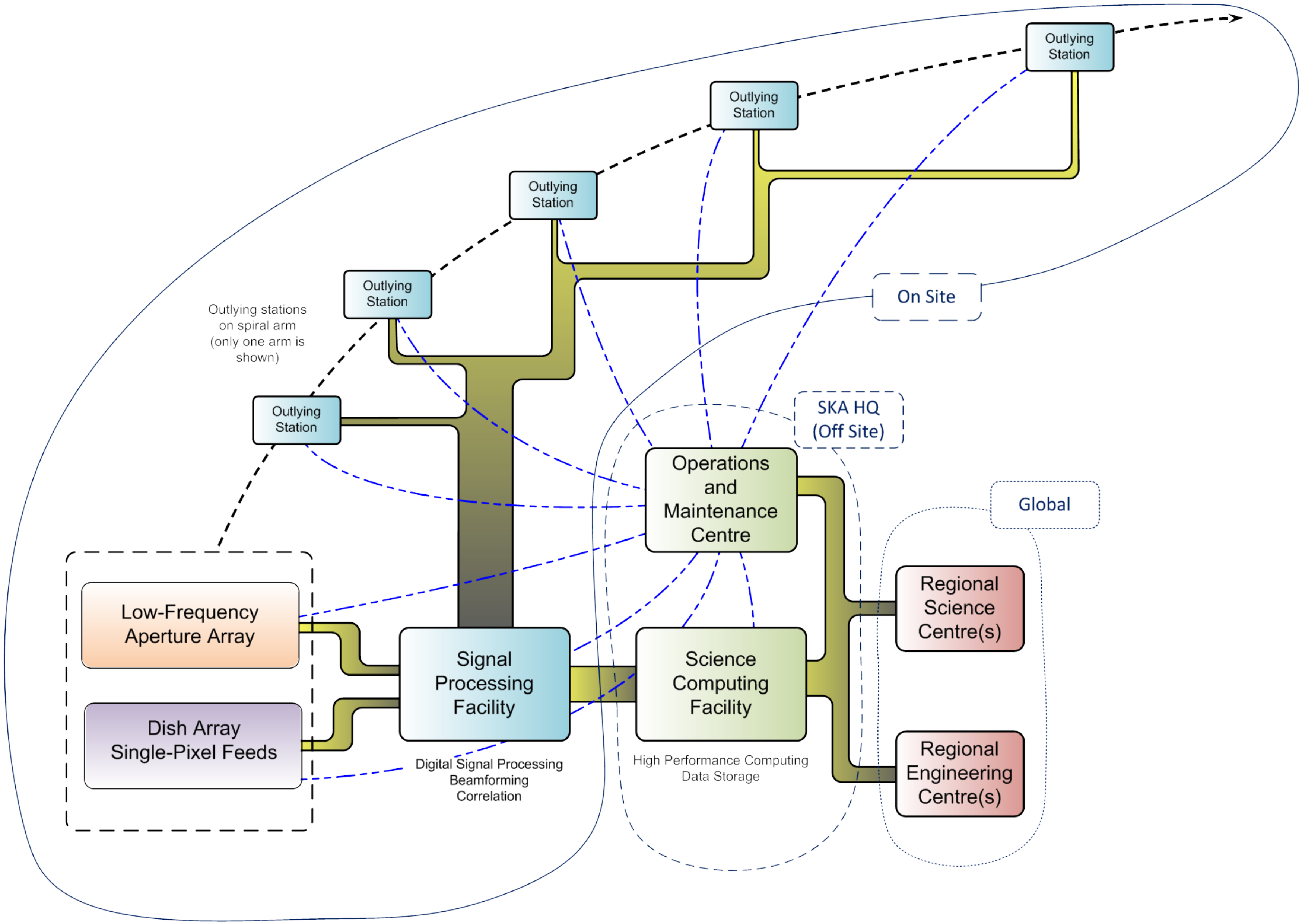
Purpose and Use of HLD

- Overview of the SKA1 system as a concept commensurate with the current view of system requirements,
- Provide a current system view consistent with the SKA1 DRM,
- Describe technical risks and cost implications for SKA1,
- Decisions on SKA1 science goals and receptor technology have been broadly made:
  - the starting point for this description is very different from the starting point for the original system CoDR.
- Retain the “representative implementation” approach
  - Not final designs but rather concrete examples
  - First-order manifestation of key aspects of the system and is subject to modification as the system design matures.
- Used to explore:
  - Technical flow-down into support services (data transport, correlation, time-domain processing, visibility and non-visibility processing, etc),
  - Potential science performance capability,
  - Scale.
- Describe the basic methodology and system implications that must be taken into account in SKA1 so that it can be extended to SKA2.

SKA1 High Level System Diagram

SPDO



Receptor Concepts

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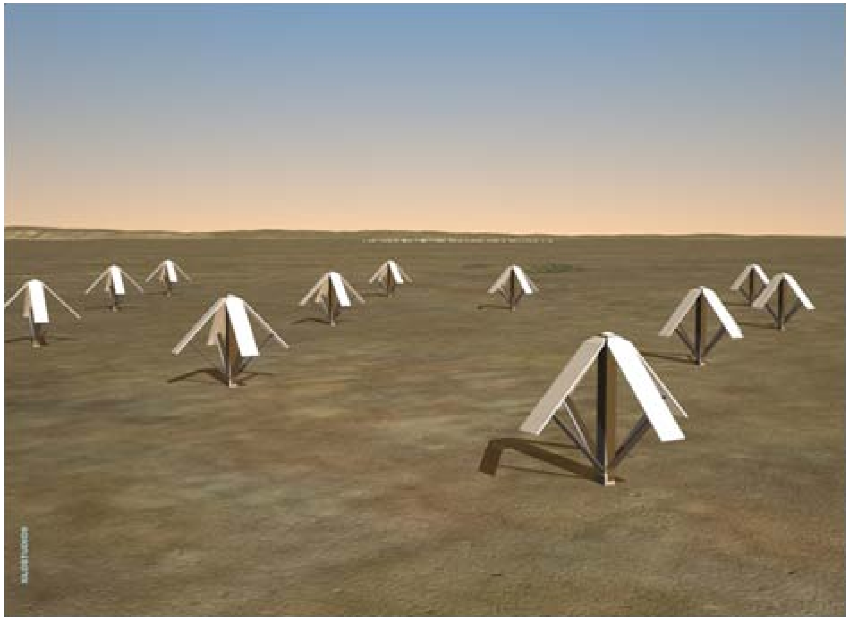


- Close-up of one station.
- Arrays of “droopy dipoles”, one for each polarisation.
- Each dipole connected to a Low Noise Amplifier,
    - sends signal via cable to a local electronics “hut”,
    - further amplification, digitisation and beamforming.

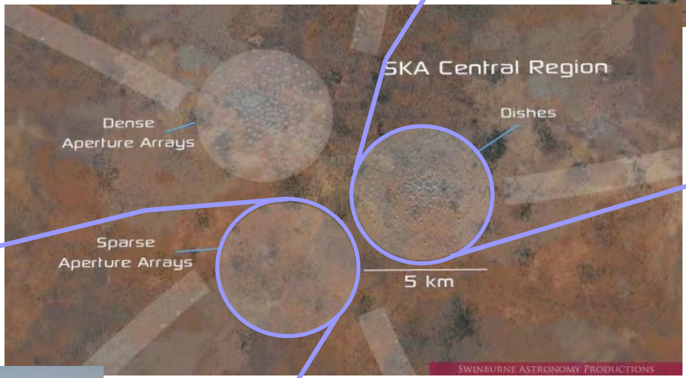
- Array of parabolic antennas (dishes).
    - Not arranged into stations.
- Equipped with standard feeds and receivers,
- Supplies digitised signal via optical fibre directly to the signal processing facility.
- Each dish ~15 m diameter.

SKA1 Array & Receptor Technologies

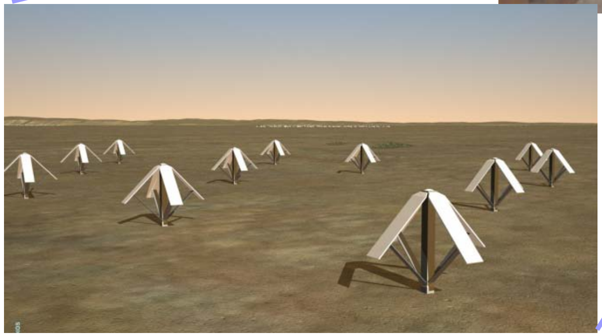
SPDO

Dishes

2-Core Central Region



One Core reserved
for later use.

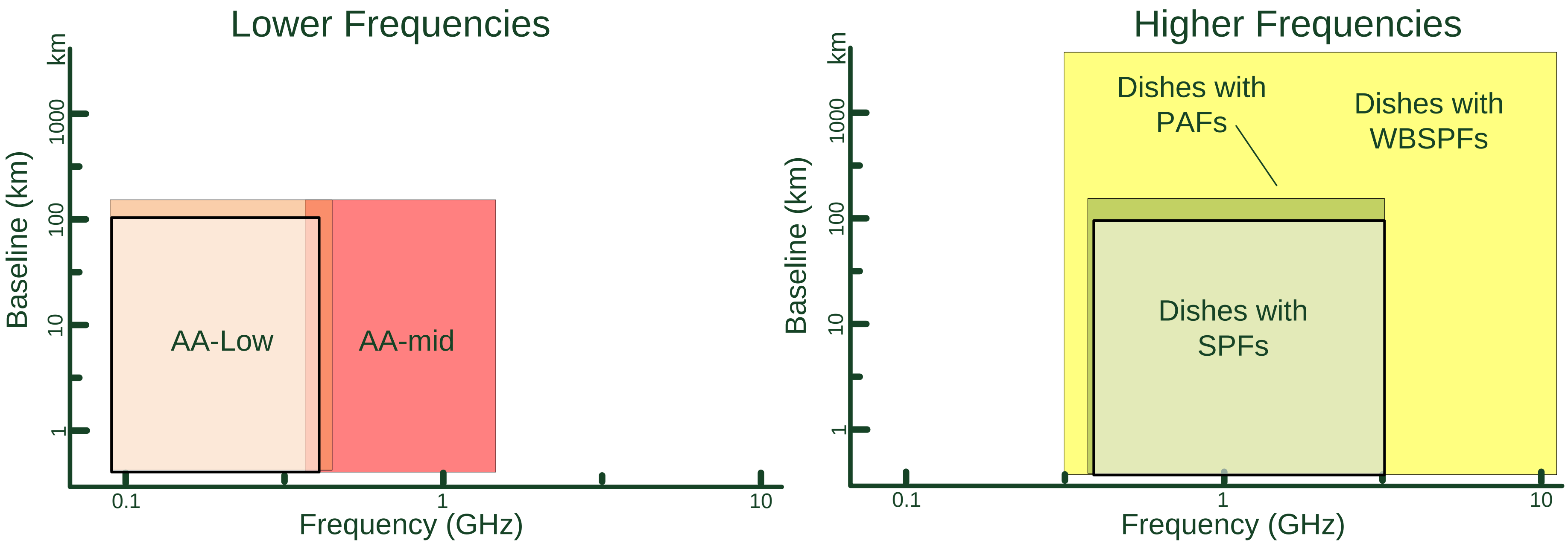


AA-low

Artists' Renditions from Swinburne Astronomy Productions

SKA1 Receptor Concepts

Receptor Concepts



System Signal Flow and Control Slice

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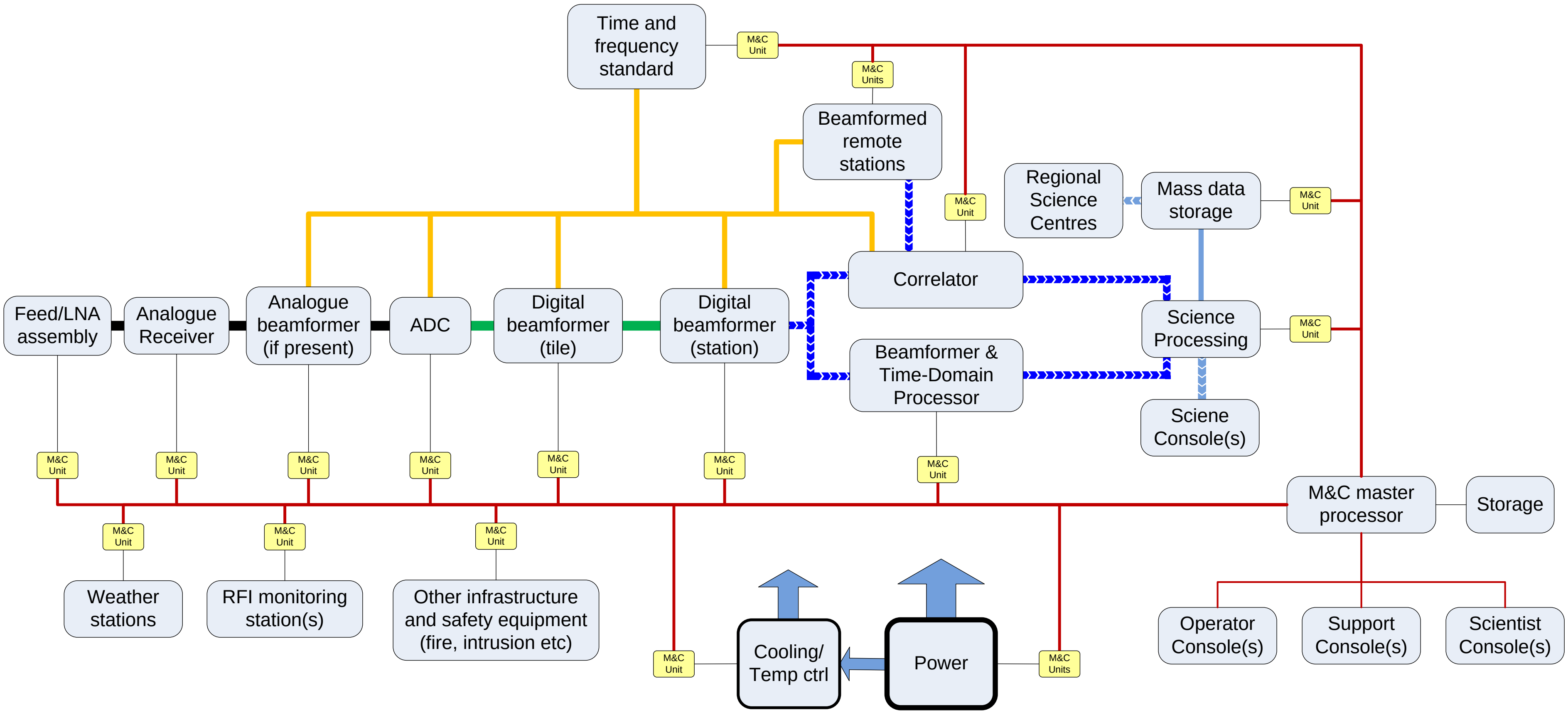
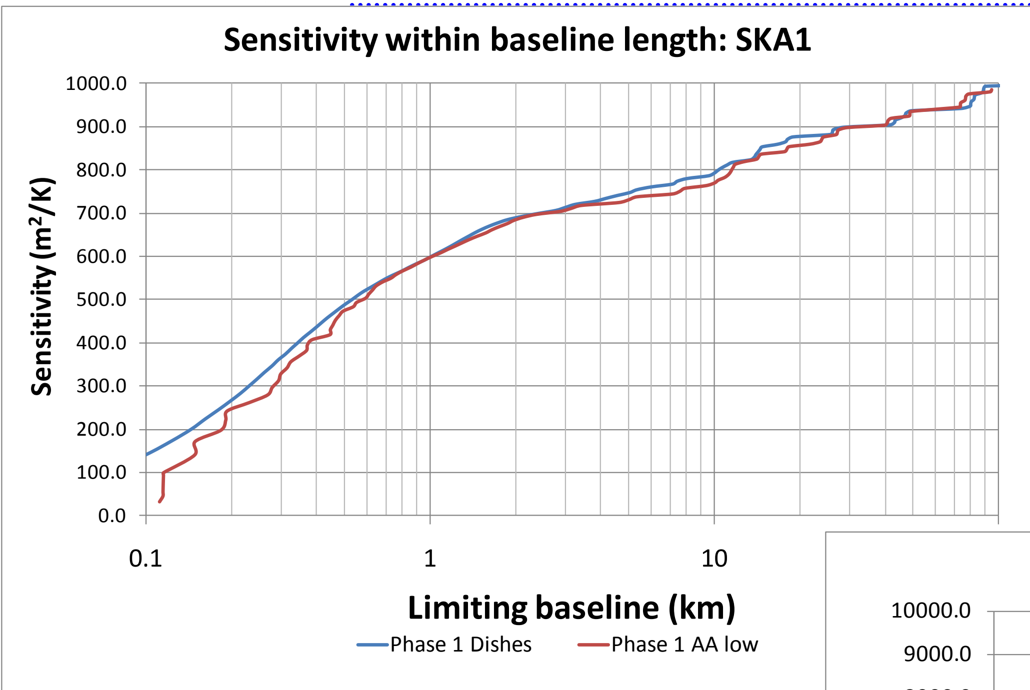
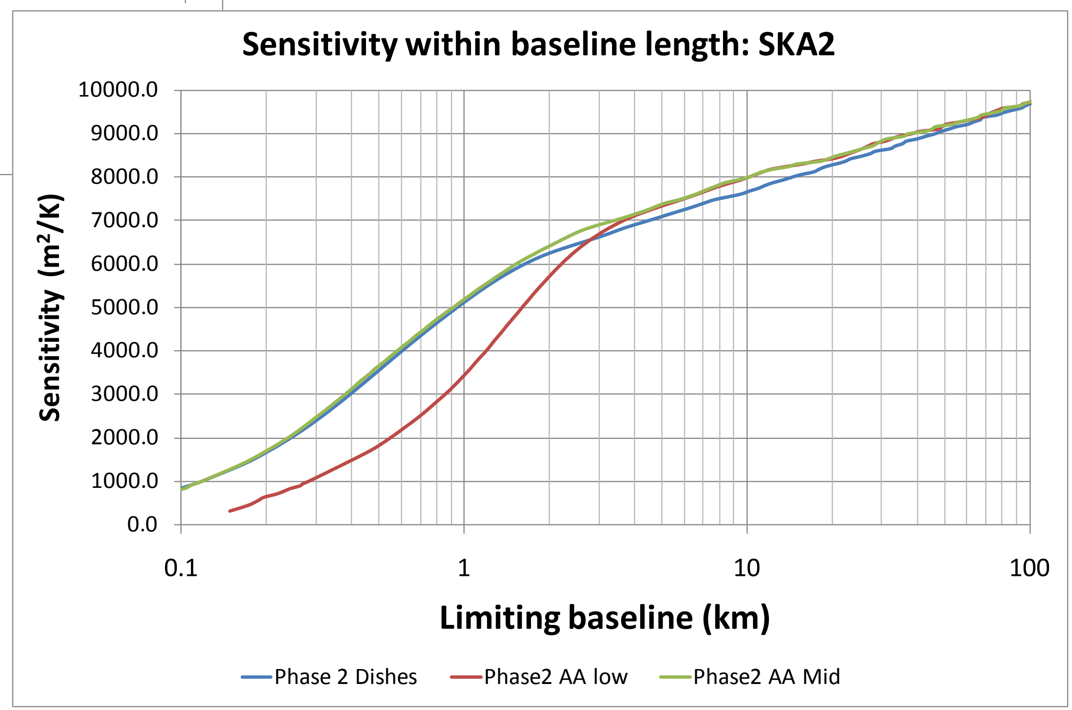


SKA1 and SKA2 Sensitivity vs Baseline

SPDO





SKA1 and SKA2 Array Configurations

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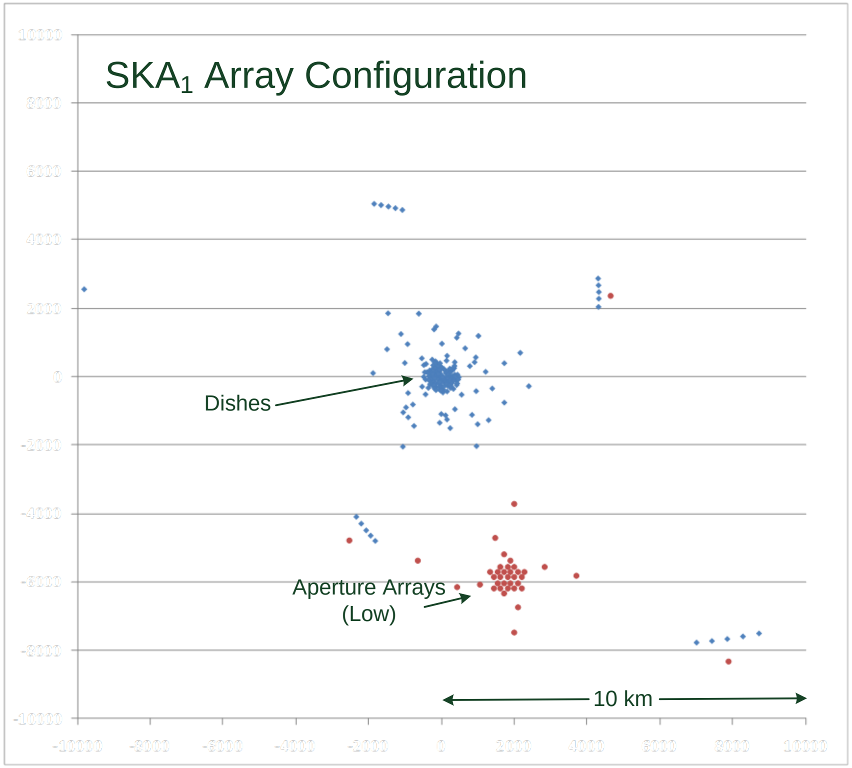

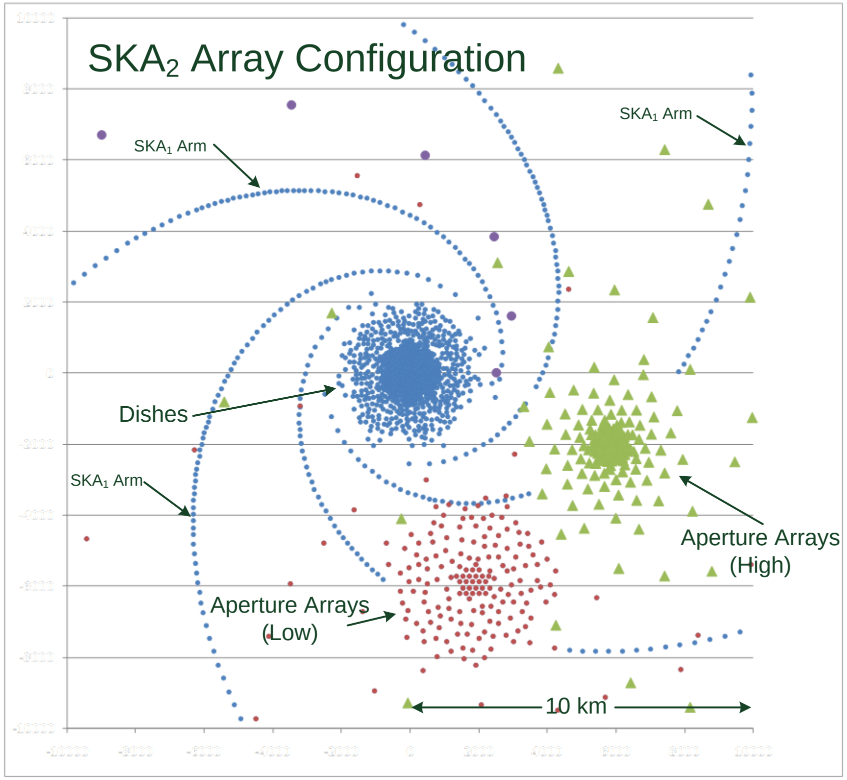

Central SKA Site

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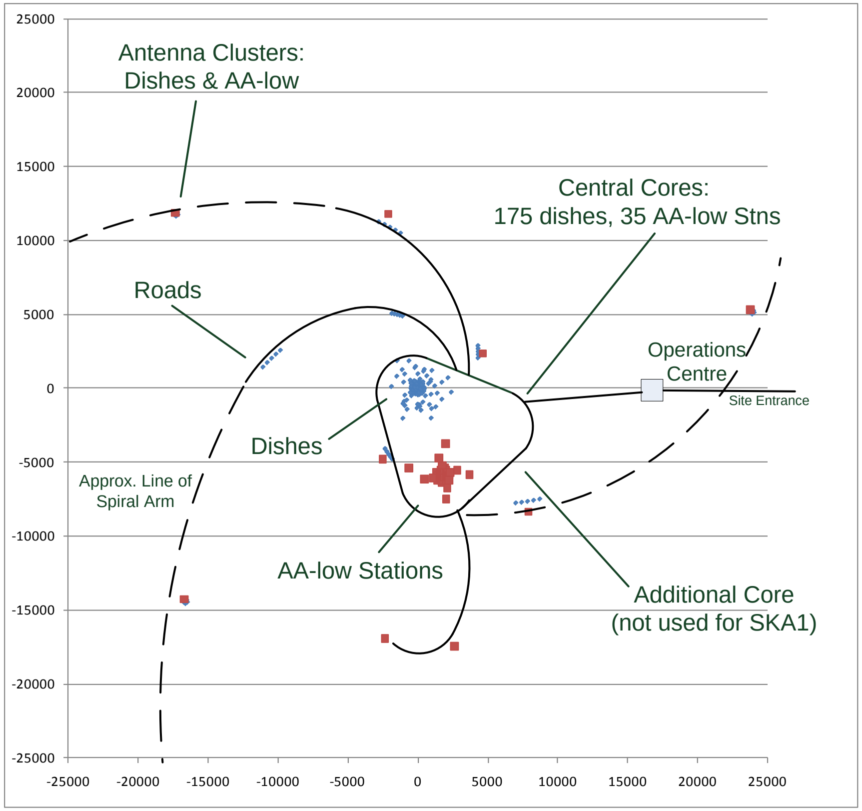
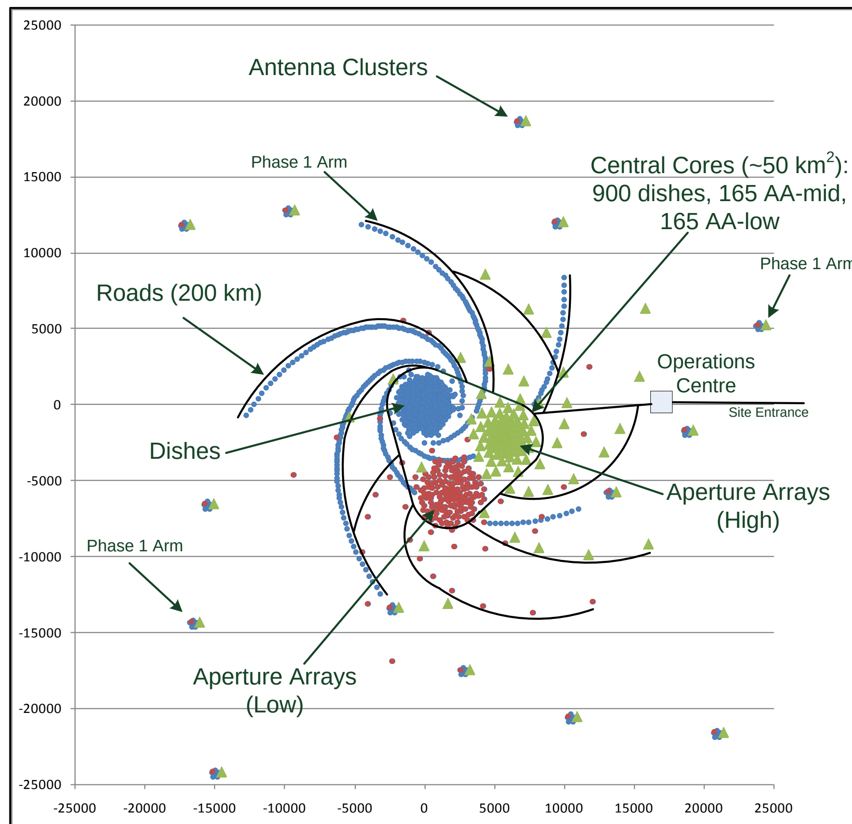
Central SKA1 Site



Central SKA2 Site



System Context Diagram

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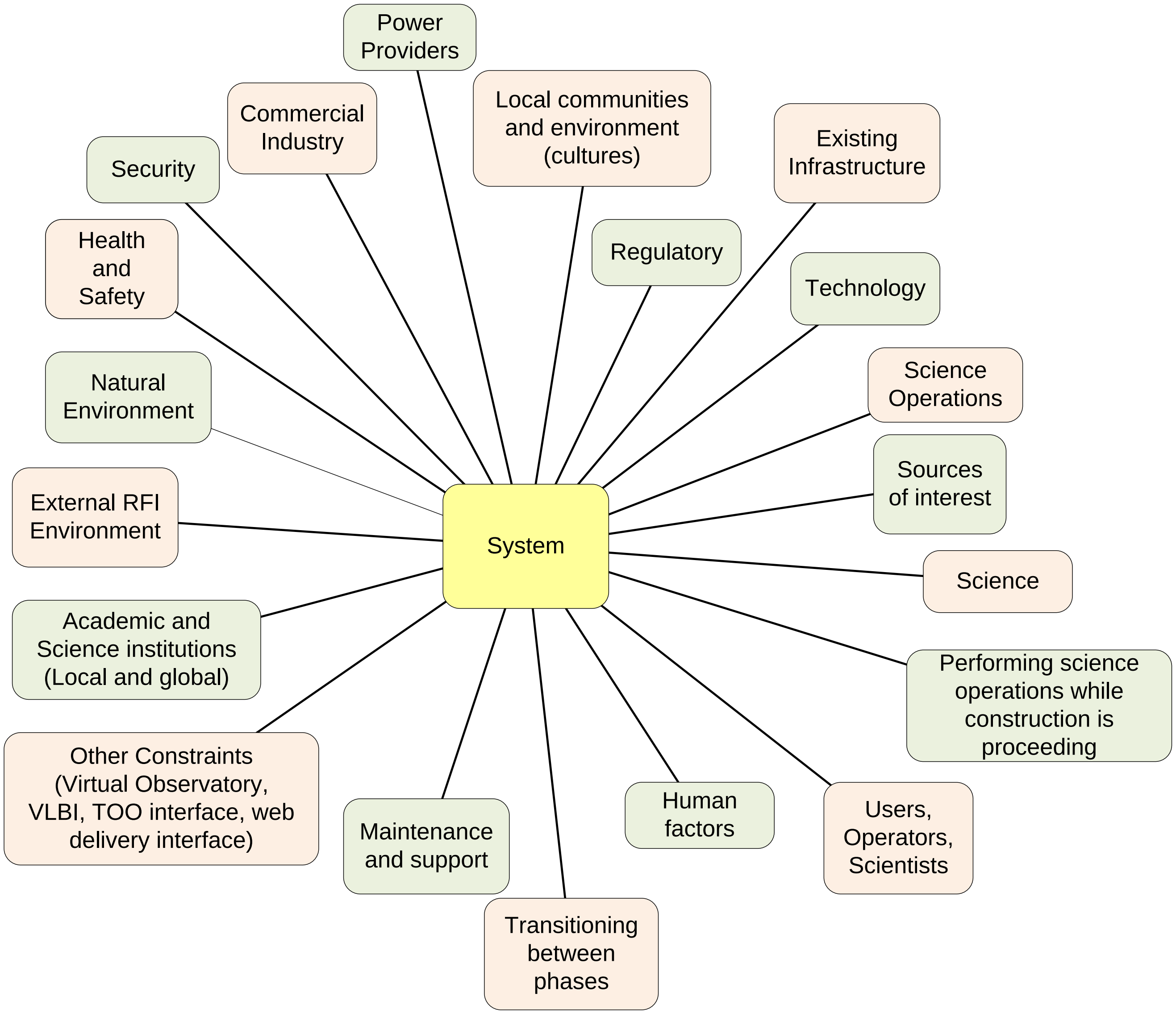
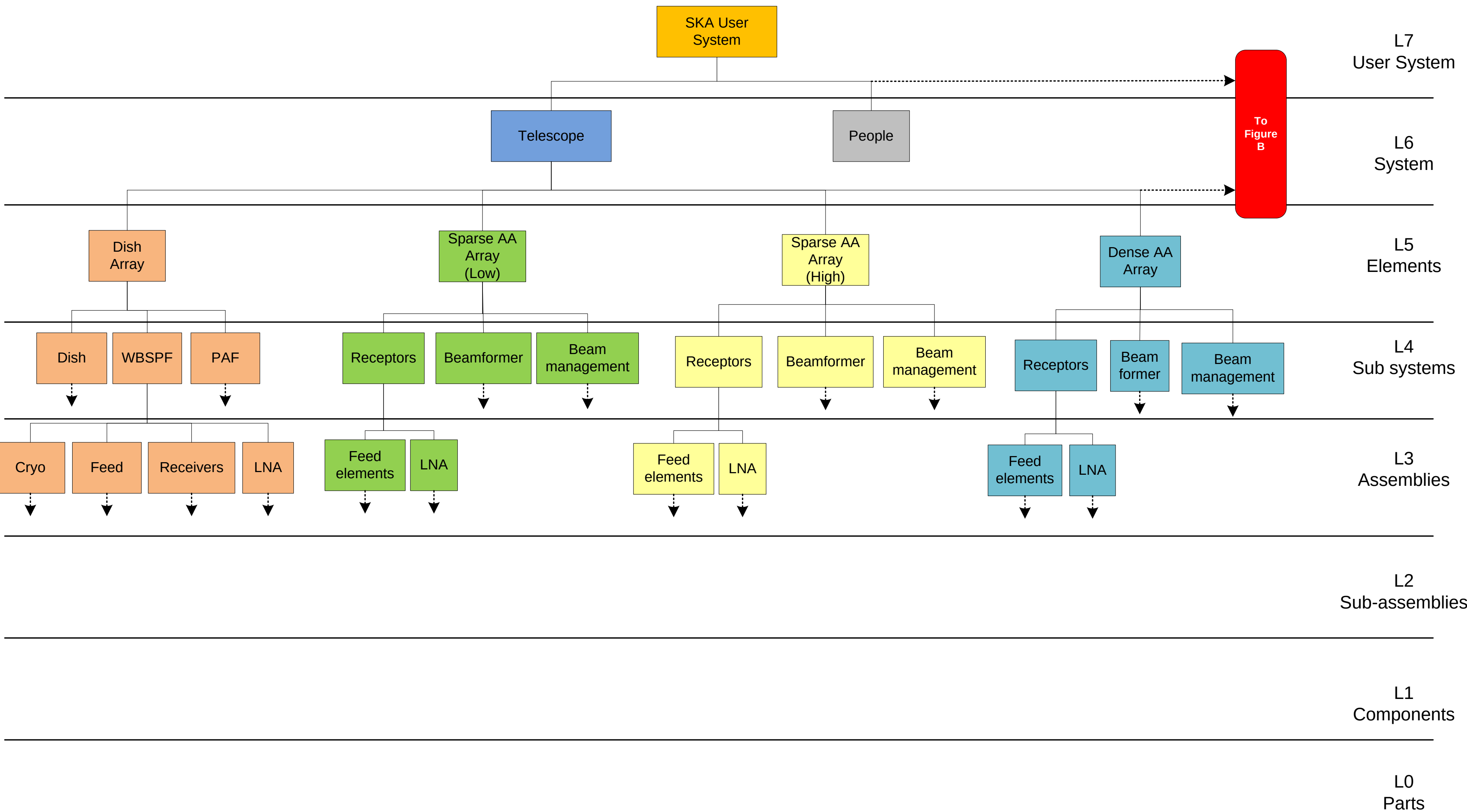


System Hierarchy (Part 1)

SPDO



System Hierarchy (Part 2)

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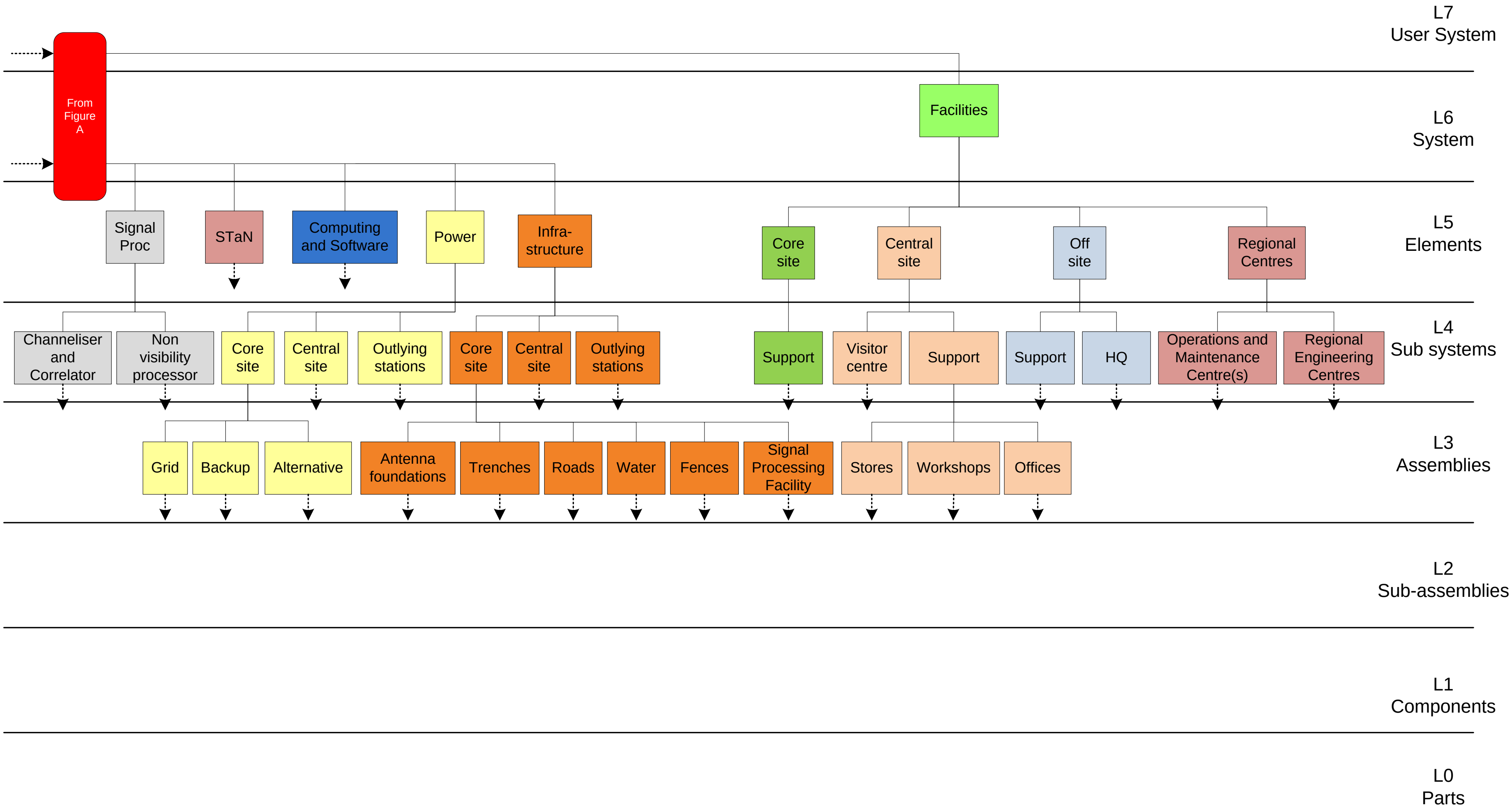
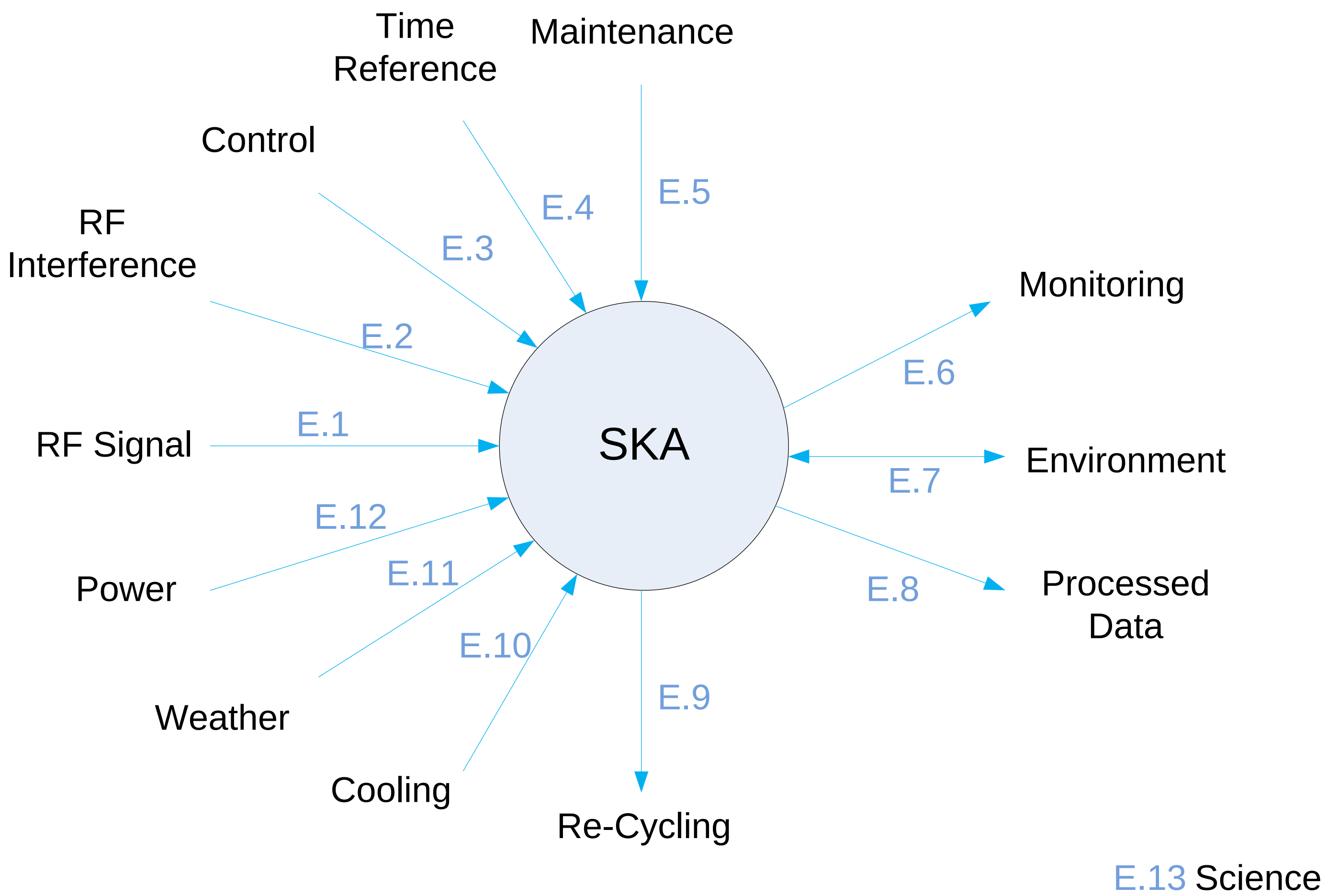
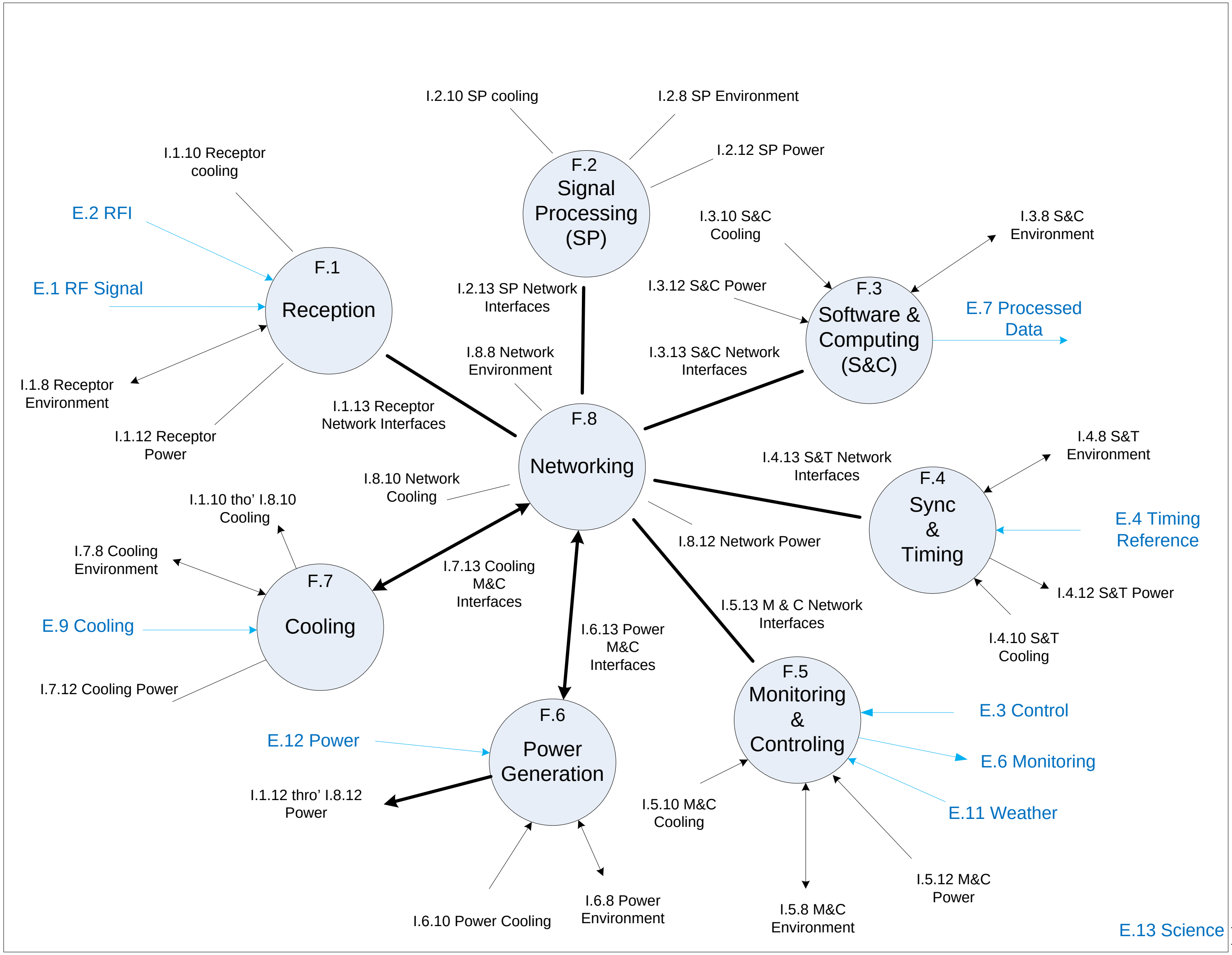


External Interfaces

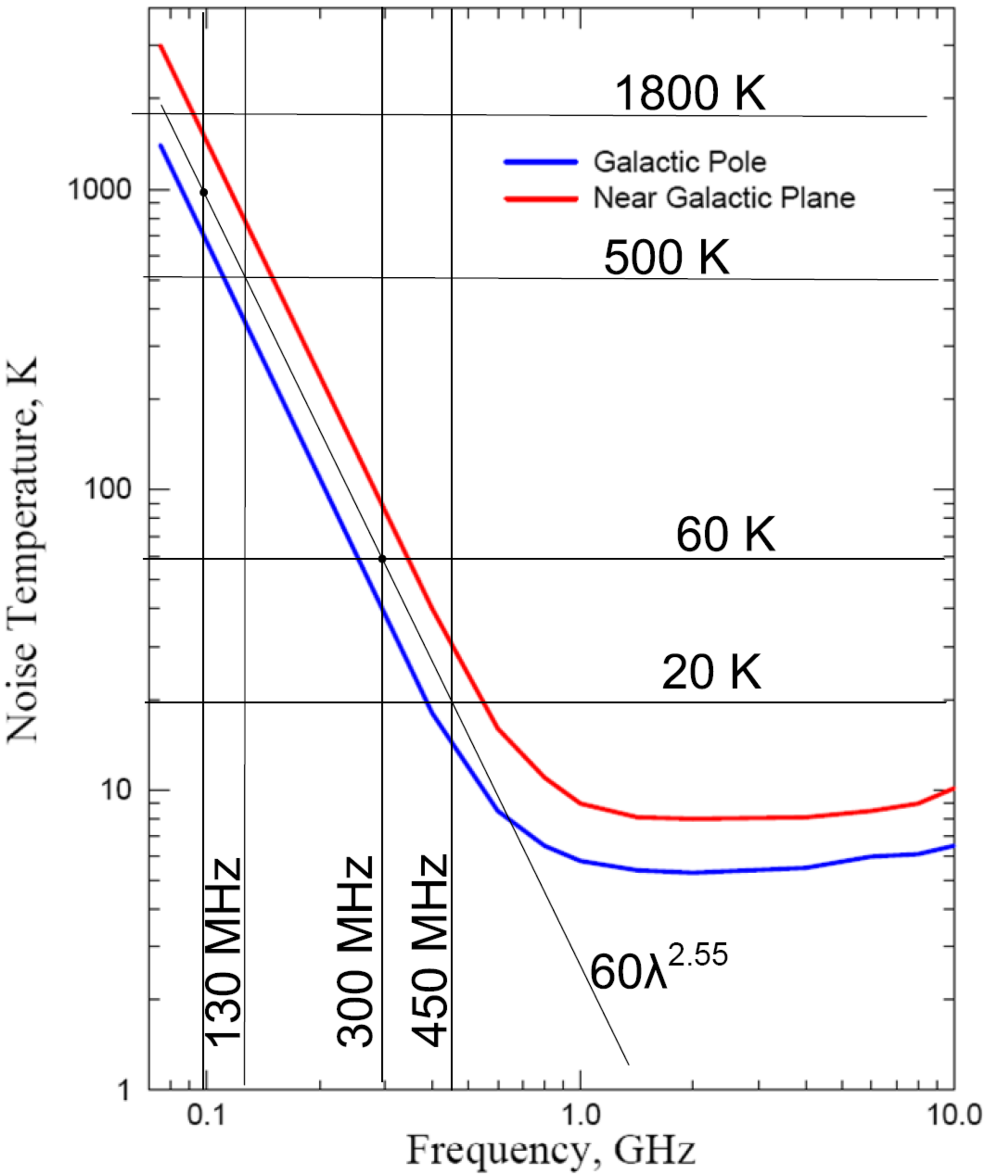


External interfaces (E)

Level 5 Functional Analysis



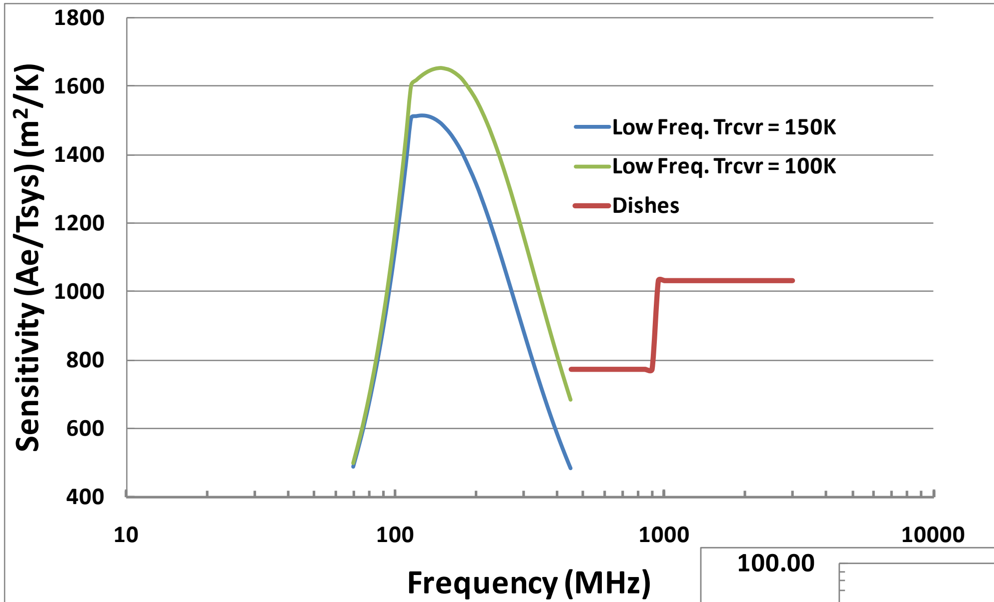
Sky Noise



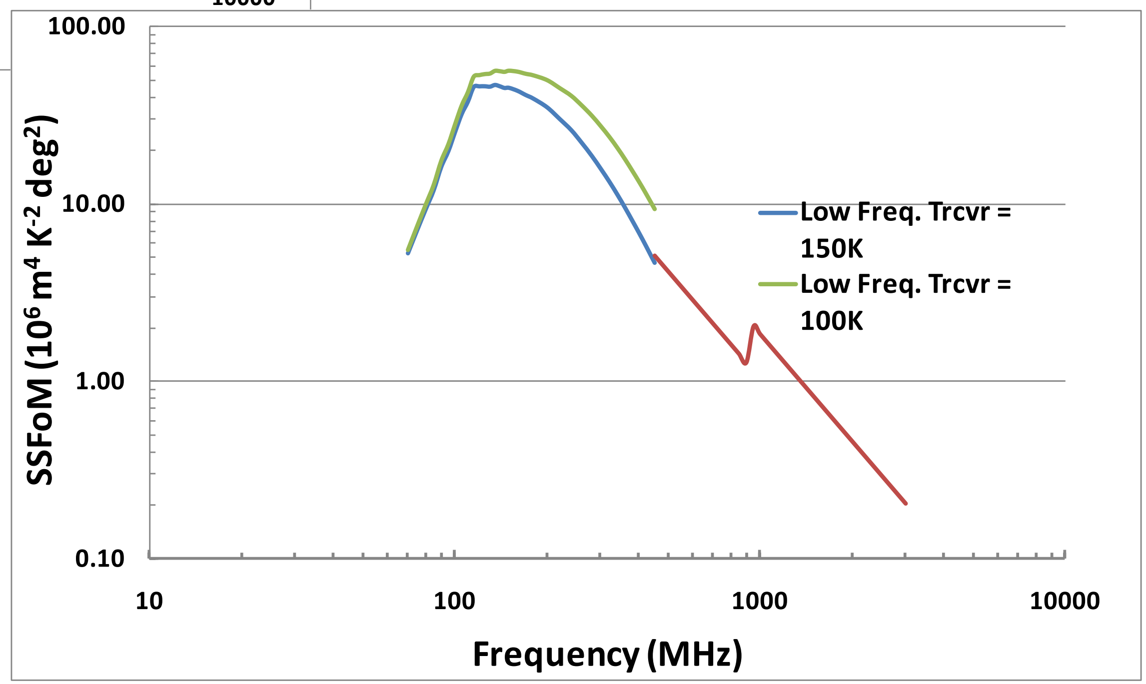
1800 K
Galactic Pole
Near Galactic Plane
500 K
60 K
20 K
130 MHz
300 MHz
450 MHz
60λ^2.55
1000
100
10
1
0.1
1.0
10.0
Noise Temperature, K
Frequency, GHz

SKA1 Sensitivity

SPDO

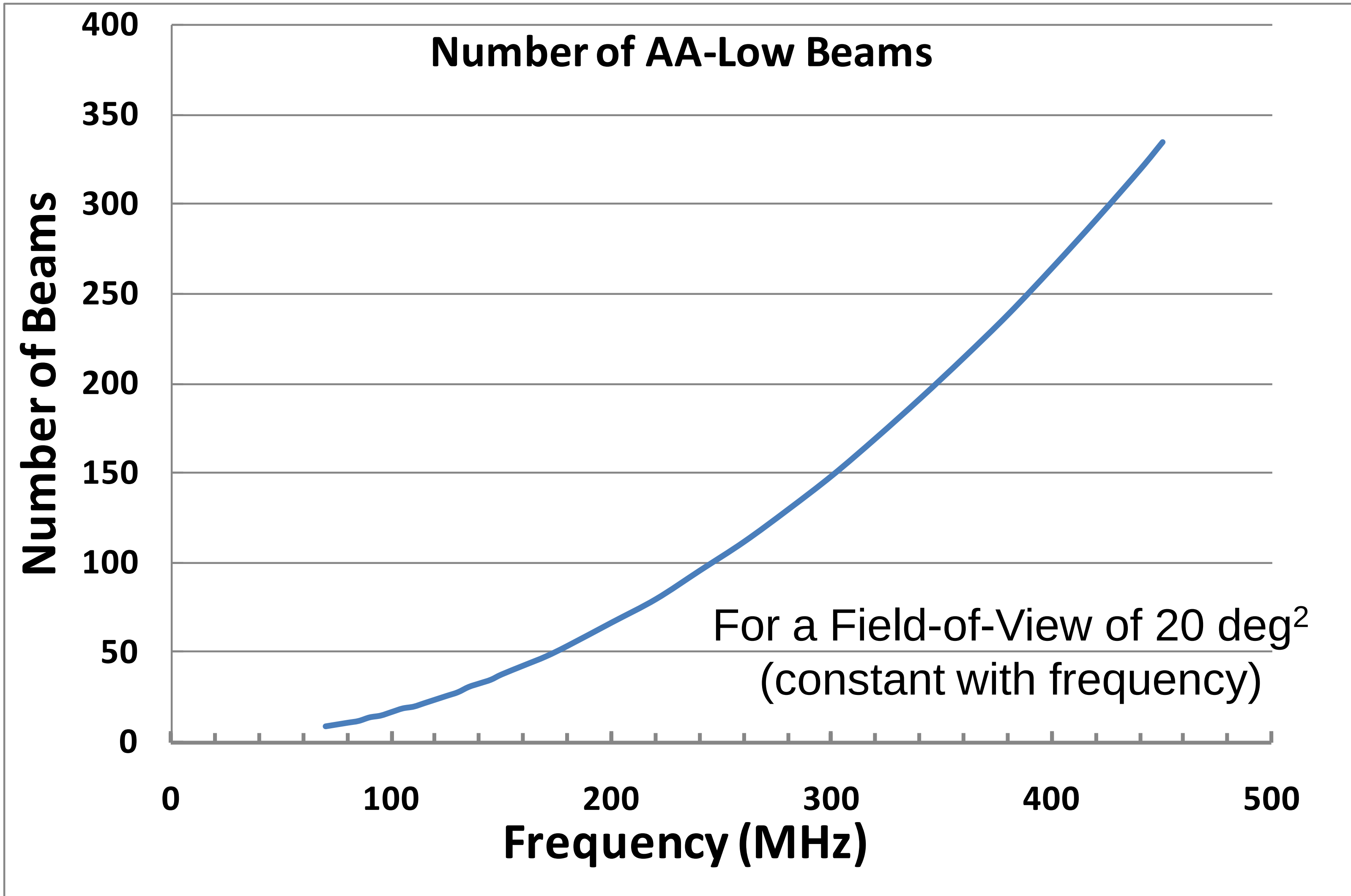


Better Tsys at 300<f<450 MHz would tend to flatten response for AA-low.



AA-low Beams with Frequency

SPDO



SKA1 Data Transport

Table 1: Working Assumptions for SKA1 Bit Rate Requirements			
Requirement	Dish Array	Sparse AA	Notes
Bandwidth	1 GHz	380 MHz	
Number of Beams	1	160	
Number of Polarisations	2	2	
Number of Bits	4	4	
Encoding factor	1.25	1.25	
Sampling factor	2.4	2	Assumes that channelization and beamforming take place at the AA station, but oversampling to accommodate filters would be required at dishes
Calculated number of bits/s	24 Gbps	1.22 Tbps	

Network Extensibility

- Complex aspect – could be a major cost risk.
- Multiple scenarios to look at:
  - SKA1 Baseline design
  - SKA1 design accommodating PAFs under the AIP
  - SKA1 Baseline extensible to SKA2 Baseline
  - SKA1 Baseline extensible to SKA2 dishes with WBSPF
  - SKA1 Baseline extensible to SKA2 dishes with PAFs
  - SKA1 Baseline extensible to SKA2 baseline and AA-mid stations
- Difficult to plan for them all.
- Some represent very large increase in cost to build for expansion to SKA2.
- Major on-going area of study.

- A similar issue is likely to occur for power distribution.

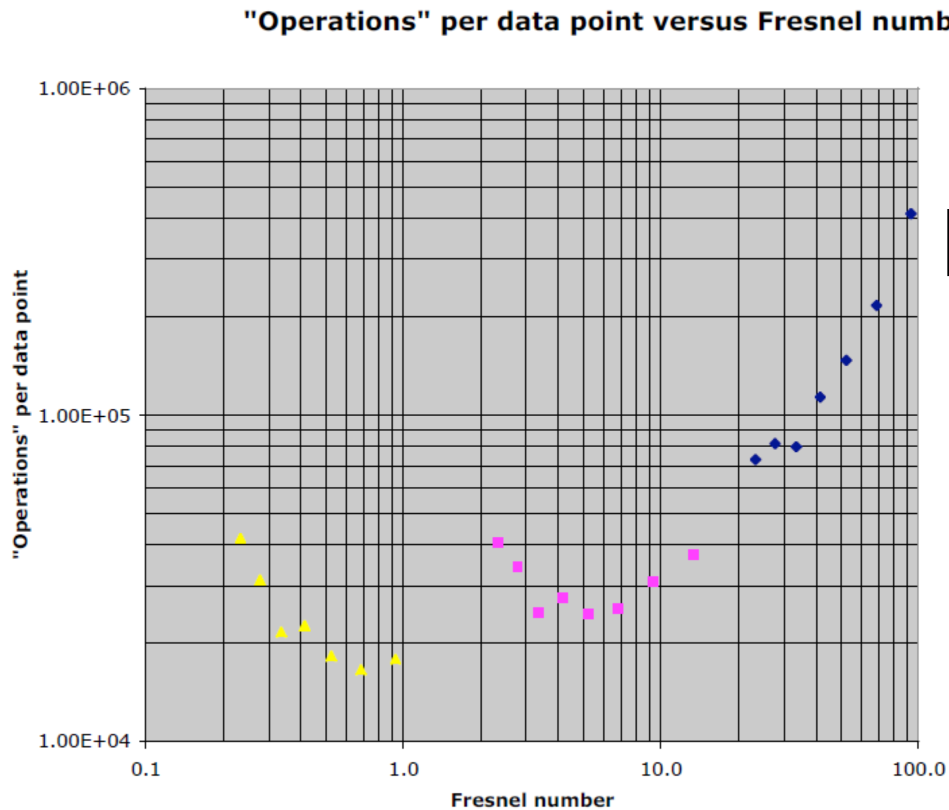
Signal Processing

- AA beam-forming part of AA element – separately considered.
- Channelization of dish signals and correlation (dish + AA-low):
  - SKA1 channelization and correlation are manageable and well understood.
  - Easily feasible system size.
- Central Beam-forming and Non-Imaging Computing:
- Processing effort dominated by pulsar searching.
  - Very large numbers of array beams required (for array radius of 5 km).
  - Each must be searched in real time.
  - Well beyond present practice.
  - Possibly an exaMAC needed – not impossible but expensive.
  - “holy grail” discoveries require acceleration searches.
  - Even processing candidates from real-time output is not a proven process.
  - Continuing discussion of actual requirements in the science community and elsewhere.

Software & Computing

- Both SKA1 and SKA2 “stick out” as major cost and performance drivers for imaging.
- Current thinking based on traditional architecture:
  - Correlator output data processed in general purpose computer.
- Wide fields, long baselines, multiple beams, large numbers of channels => all increase processing load, in some cases by power-law factors.
- Critical factor is number of operations per *u-v* point.
- Pushing past 10^5 for SKA regime (see next slide) – higher at low freq.
  - Implies ~100 Petaflops for SKA1.
  - Supercomputer class – typically power hungry.
- Non-imaging computing still not well understood.
- Software no longer independent of hardware.
  - Potential for periodic re-writes.
- Solutions:
  - cost capped approaches
  - Continuous development (see operations)
  - Possibly semi-hard architectures.

Where does the ~10^5 operations / float come from?



The Fresnel number is $\lambda B / D^2$.

B = baseline

D = aperture diameter

Figure 4 Operations per data point versus Fresnel number, calculated by scaling time by clock frequency, dividing by number of data points. The left end of each curve is biased upwards by constant cost terms.

Source: Tim Cornwell; EVLA Memo 77

Technical Risks

- Introduction of SKA1 and the AIP has reduced the technical risk enormously.
- Dishes and AA-low type receptors have a track record.
  - System size is ~10% in most areas.
- Considerable technical risk remains:
  - Computing and software.
  - Power consumption – cost issue.
  - Calibration of AAs at low frequencies.
  - Ultra-wide band AA arrays (6.5:1).
  - Extensibility issues to SKA2.
    - Fibre and power network.
  - Performance issues
    - Imaging dynamic range
    - Understanding ionospheric limitations at low frequencies.
  - Pulsar search processing
    - Feasibility at the required search rate and general scale.

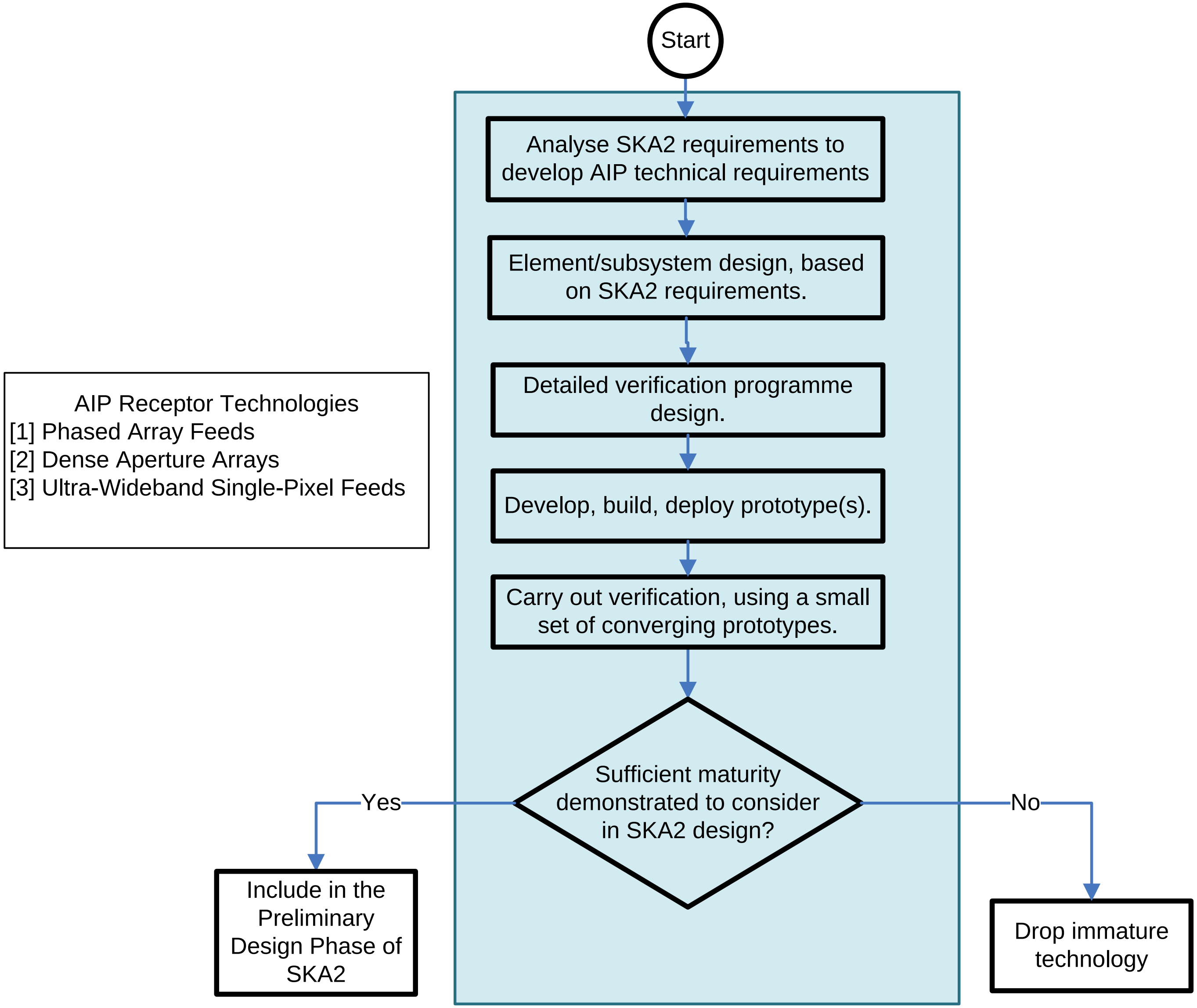
Technical Risks (cont'd)

- Construction of AA-low
  - ~3 x 10^6 elements
- Processing assumptions
  - Appropriate technology may not be available or widespread in time.
  - Costs of FPGAs may remain high for small feature sizes.
  - 1-2 MW / exaMAC without counting cooling.
- Cooling
  - Power, cost, reliability.
- Self-generated RFI
  - Sufficient sheilding for very sensitive telescope at low frequencies could "break the bank".
- Reliability, Availability and Maintainability
  - Balancing on-going operations for maintenance against super-robust (expensive) equipment.
  - Optical connections tend to fail in dusty environments.

Technical Risks (cont'd)

- Site risks
  - Unknown or undocumented geotechnical information
    - e.g. Historic flood information.
  - Environmental hazards not documented.
  - Power delivery
    - Power delivery method unknown.
    - Potential RFI issues.
- More computing:
  - Computing efficiencies (unrealistic expectations)
  - Availability of supercomputers on expect time frames
  - Ingest data rates – special measures may be required.
  - Raw data buffering at supercomputer.

Raising AIP Maturity Levels



Advanced Instrumentation Programme

- Phased Array Feeds & Dense Aperture Arrays
  - directed towards increasing survey speed through multi-beam imaging,
  - competing in similar frequency ranges.
- Dense Aperture Array technology
  - potentially capable of extremely high survey speeds,
  - at the cost of an additional array of receptors.
- Phased Array Feeds are an enhancement of dish technology,
  - much less expensive to add to the baseline system,
  - but cannot deliver the same survey speed as Dense Aperture Arrays.
- Wide-band-Single-Pixel-Feeds
  - main attraction is cost reduction.
  - WBSPFs with bandwidth ratios of 5-10:1 could replace several standard feeds.
  - the continuum sensitivity and the spectral line-search capability would be enhanced.
- All will have large system impact
  - Data transport, power, signal processing, computing
  - Reliability, maintenance, etc.
  - Science impact must justify.

End