Long Baseline Interferometry with the Square Kilometre Array

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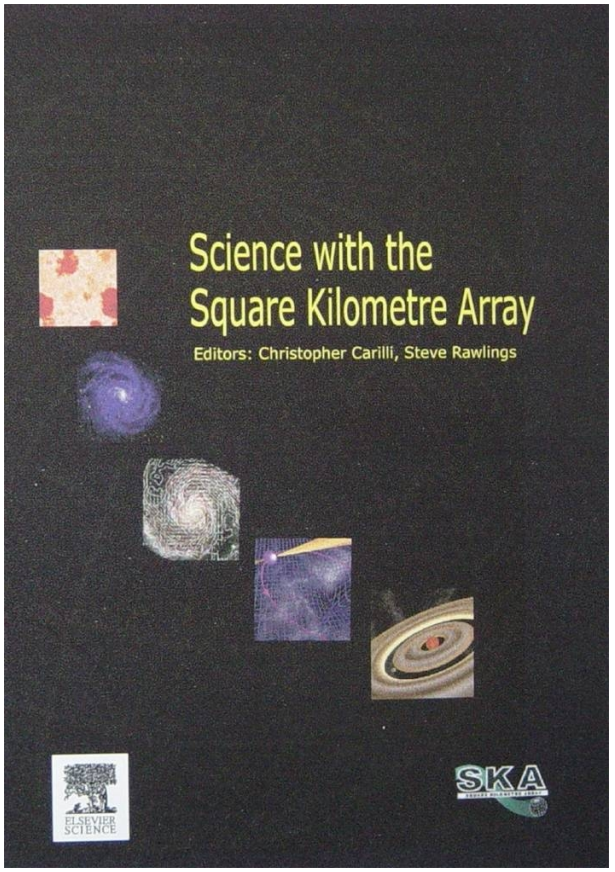
Presentation Outline

- SKA – A description
  - Outline Specifications
- Long Baselines in the SKA
  - Science drivers
  - Delivery of signal transport networks
- SKA Programme development office
  - Organisation
  - Turning science requirements into instrument specifications

What is the SKA for?

Five Key Science Projects (KSPs)

2. **Probing the Dark Ages**
3. **Galaxy Evolution, Cosmology, & Dark Energy**
4. **The Origin & Evolution of Cosmic Magnetism**
5. **Strong Field Tests of Gravity Using Pulsars and Black Holes**
6. **The Cradle of Life/Astrobiology**



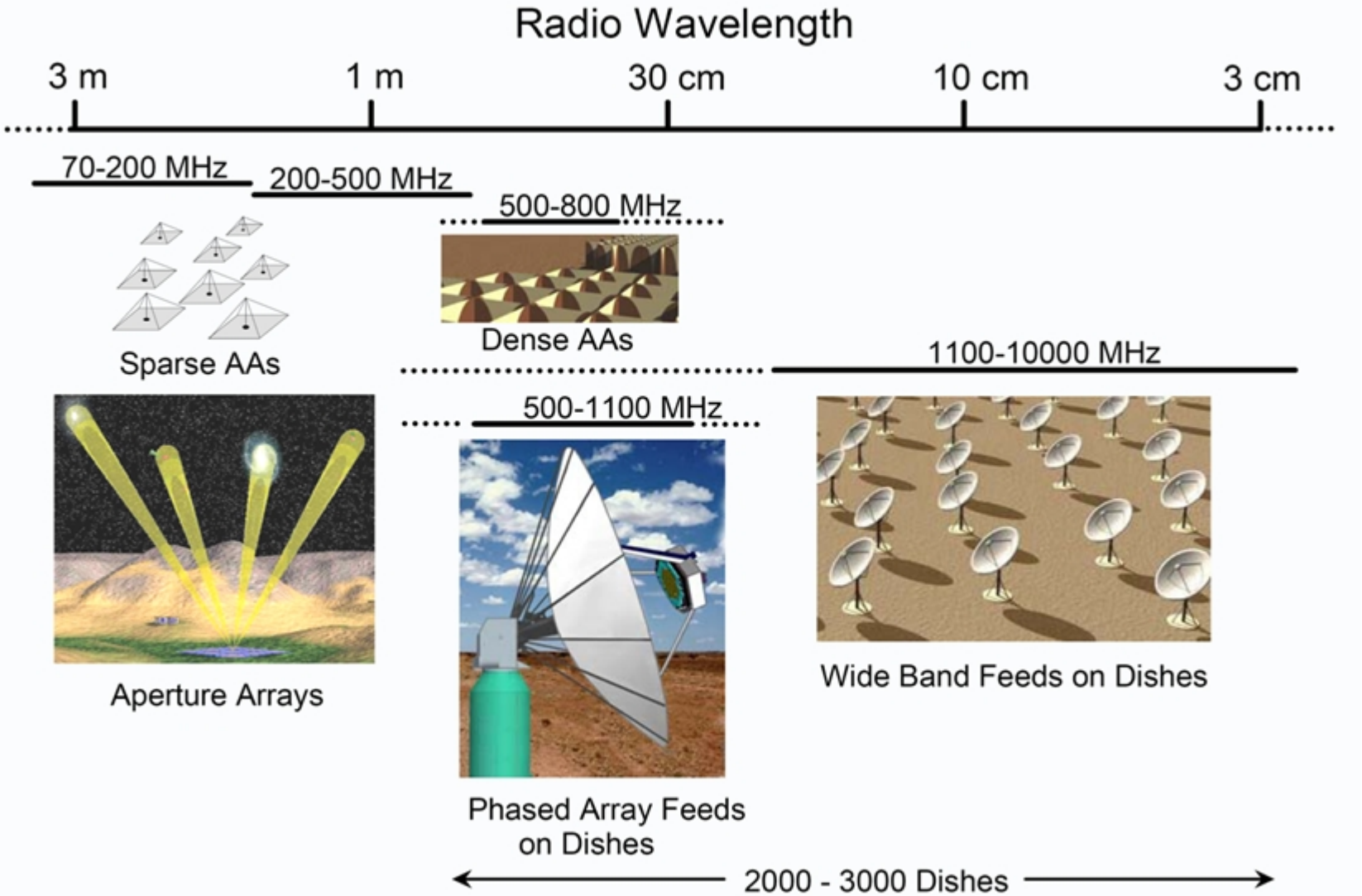
… plus **The Exploration of the Unknown** as an underlying philosophy for design of the instrument

The Square Kilometre Array

4 prime characteristics

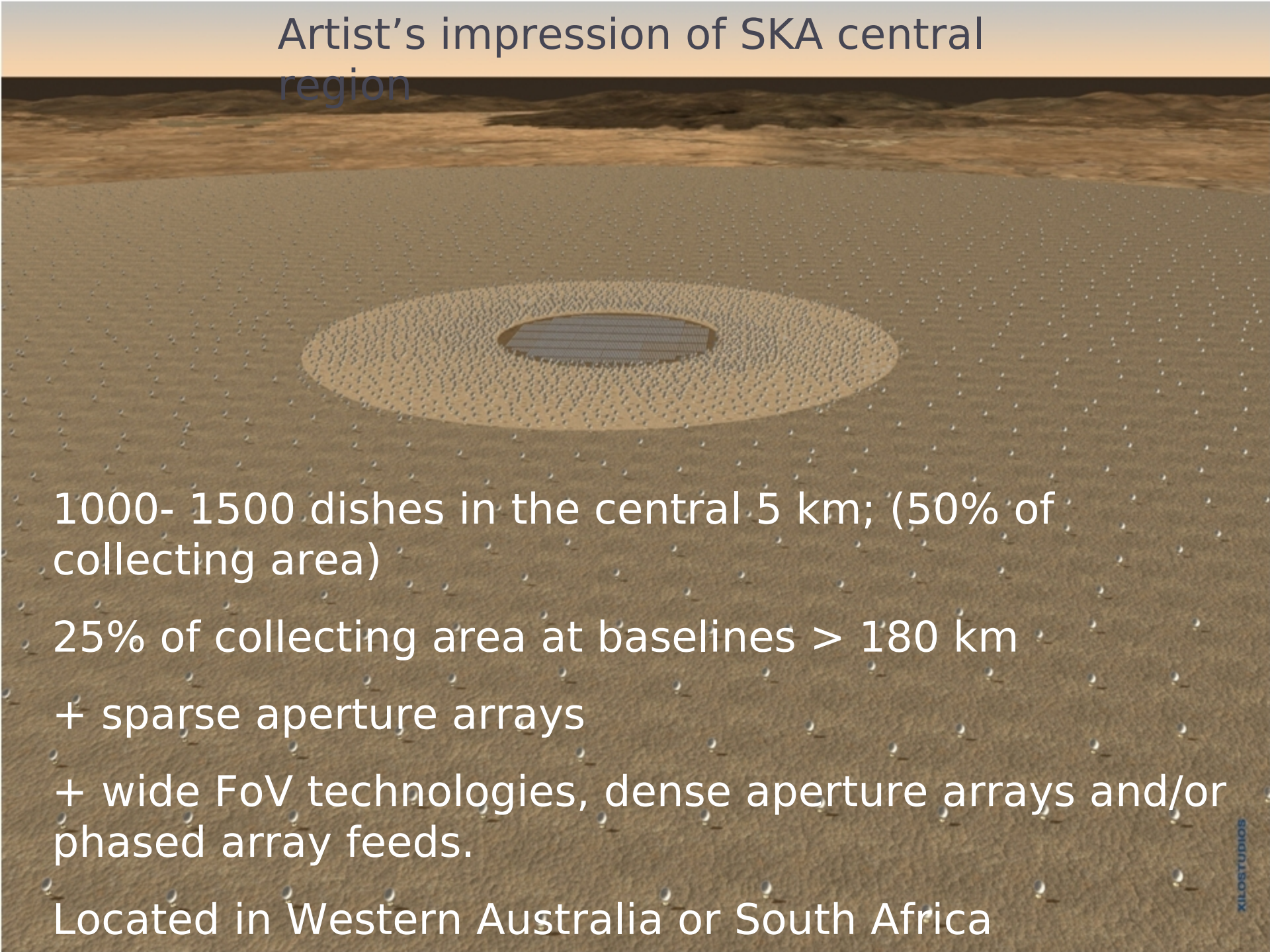
- **very large collecting area (km²)** → sensitivity to detect and image hydrogen in the early universe
  - *sensitivity 40 x EVLA, 50 x LOFAR*
- **very-large-angle field of view** → fast surveying capability over the whole sky
  - *survey speed ~10000 x EVLA with FoV=1 sq. deg.*
- **wide frequency range required for the Science Reference Mission**
  - **low : 70-300 MHz**
  - **mid: 300 MHz-10 GHz**
  - **high: 10-25+ GHz**
- **large physical extent (3000+ km)** → capability for detailed imaging of compact objects and astrometry with milli-arcsec resolution

More Concise Picture of s



Numbers of dishes (2000-3000) depends on whether Phased Array Feeds and/or Aperture Arrays are used in the SKA.

Artist’s impression of SKA central region



1000- 1500 dishes in the central 5 km; (50% of collecting area)

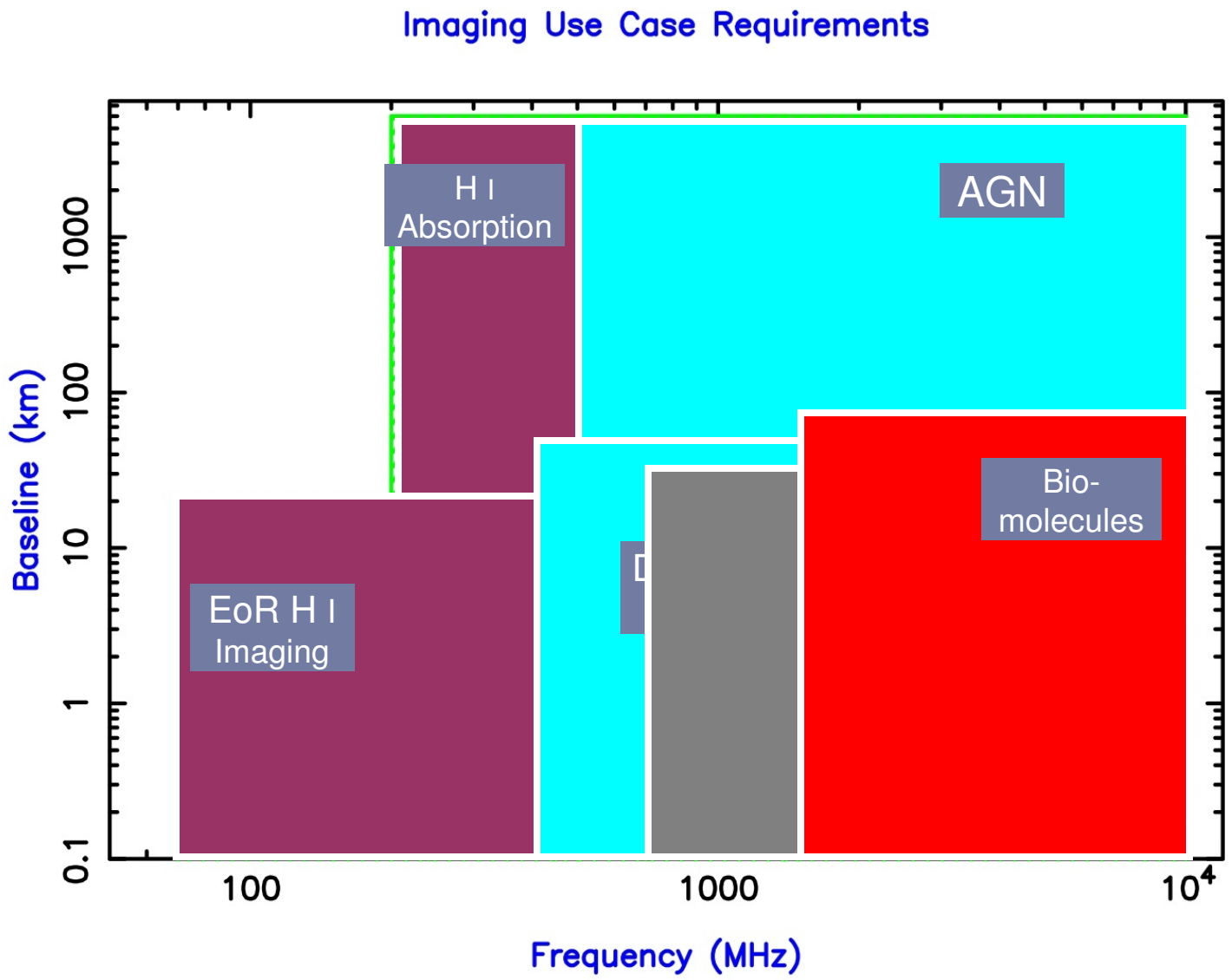
25% of collecting area at baselines > 180 km

+ sparse aperture arrays

+ wide FoV technologies, dense aperture arrays and/or phased array feeds.

Located in Western Australia or South Africa

Baseline Distribution



Long Baselines – Science Drivers

- Resolving Active Galactic Nuclei (AGN) and Star Formation in Galaxies
  - Specific goal of tracking and distinguishing the contribution of star formation and AGN to the evolution of galaxies.
  - Maximum baseline > 3,000 km

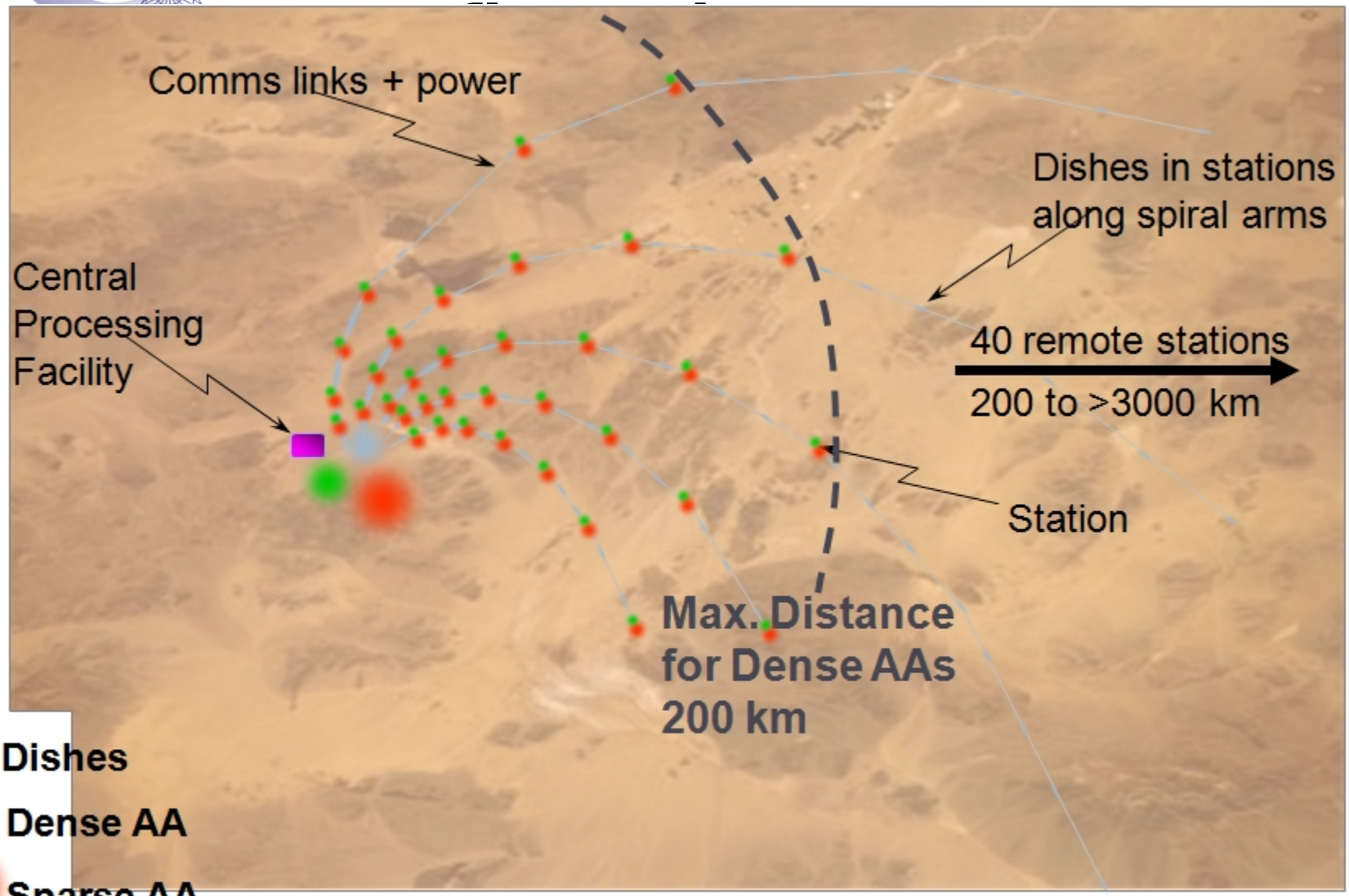
    for Flux densities of > 30μJ ; Brightness temperatures of 10^6 K ; Redshifts 2 to 7
  - Frequency 0.5-8 GHz

Long Baselines – Science Drivers

- H1 Absorption
  - Probe the circum-nuclear environment of Active Galactic Nuclei.
  - Maximum baseline > 3,000 km

    Resolutions of the order of sub kpc to probe the innermost regions of galactic nulclei at high red-shift

Possible telescope



Adapted from A. Faulkner

SKA Signal Transport Infrastructure

The Tour de France is a 3,000 km race

SKA antenna will be spread along 3,000 km arms

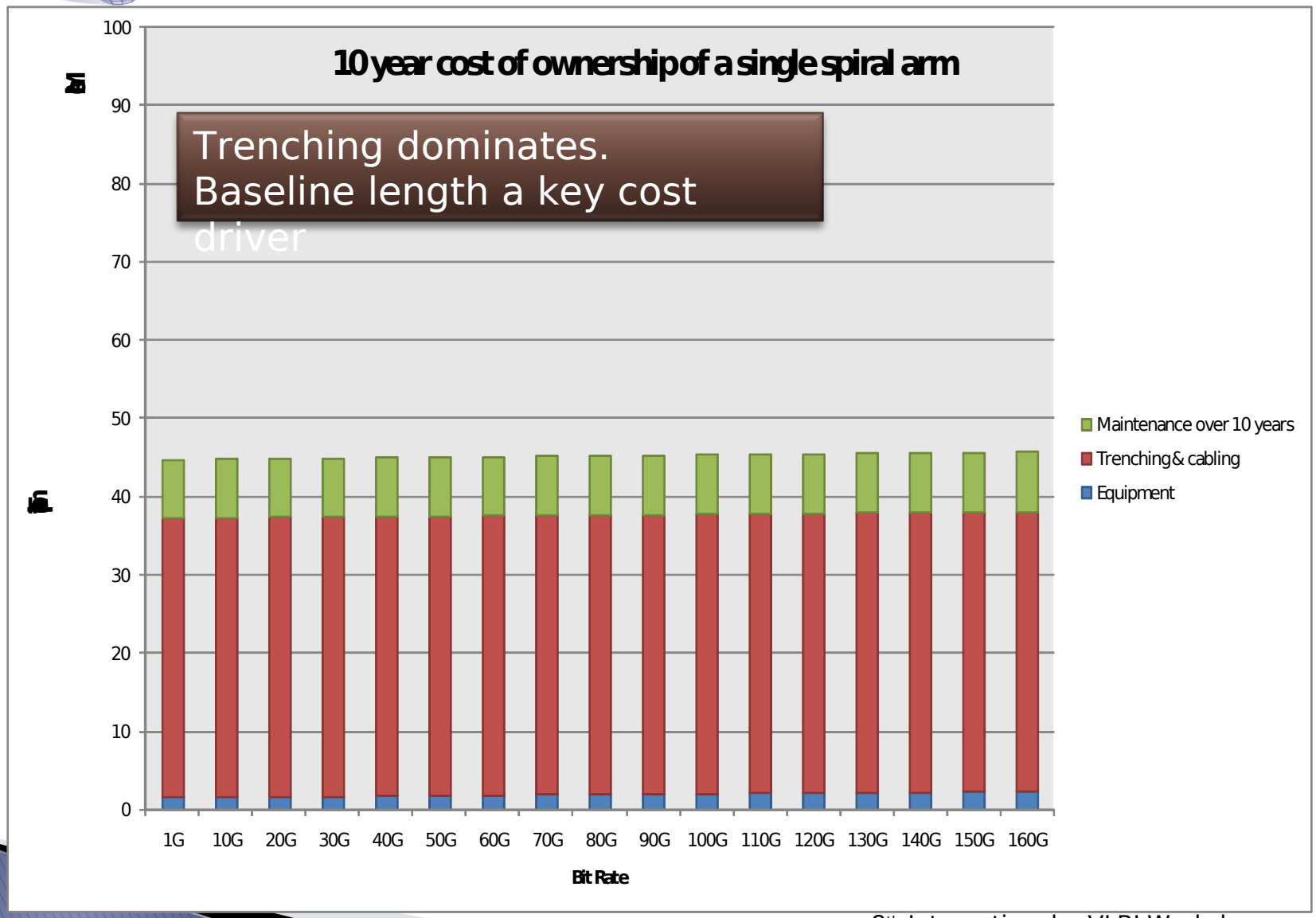
Signal Transport & Networks for the SKA

- Data Network
  - For transporting astronomical signals to a central processing facility (CPF)
- Timing Network
  - For the distribution of local oscillator signals for clocks and down converters.
- A Monitor & Control Network (M&C)
- Connections from the CPF to the outside world

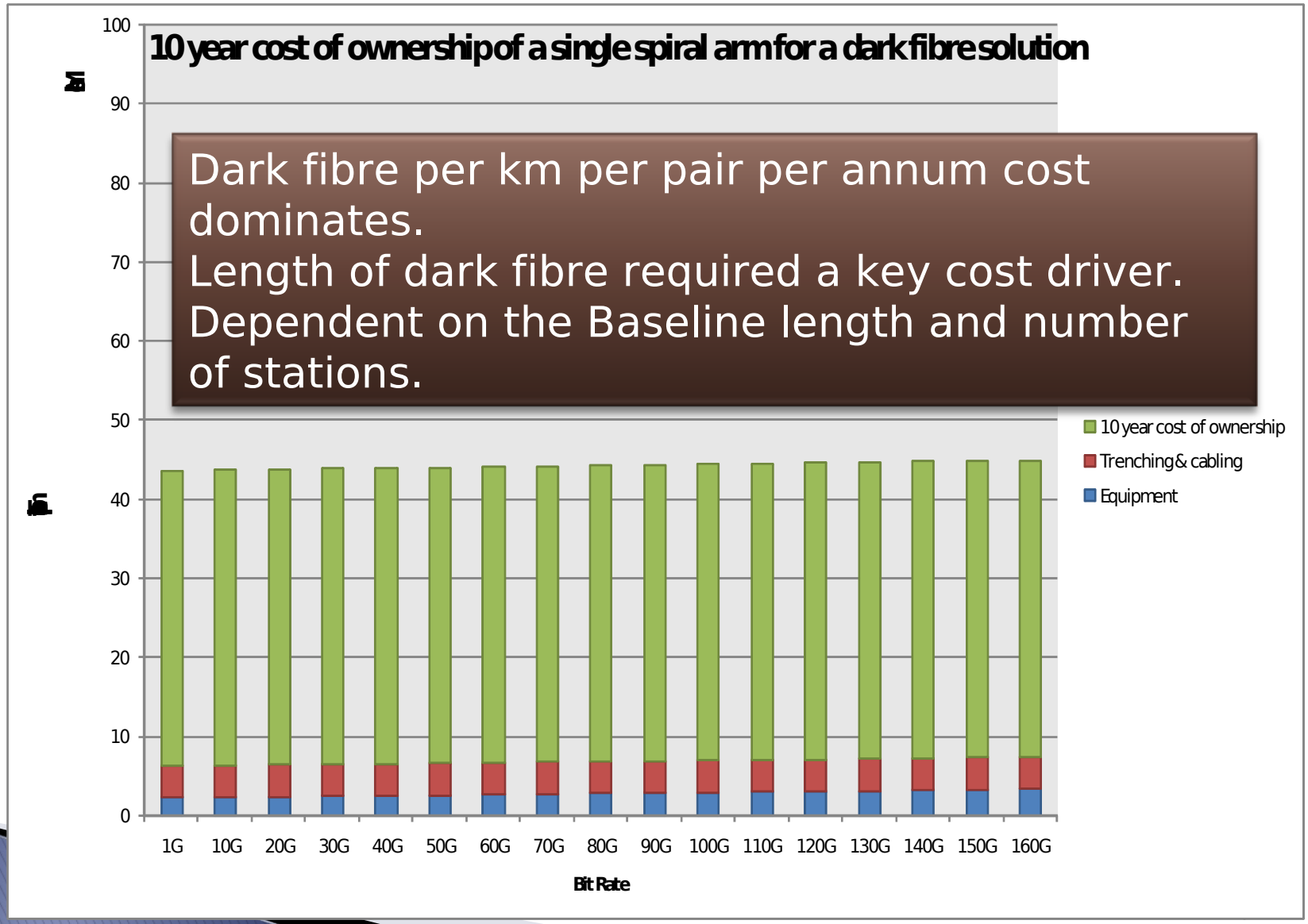
Implementation strategies for Signal Transport on long baselines

- Construction of a private fibre network along the baseline lengths
- Dark fibre network provision to long baseline stations
  - Assuming capacity in the locations required
- Bandwidth provision over commercial networks to long baseline stations
  - Assuming capacity in the locations required

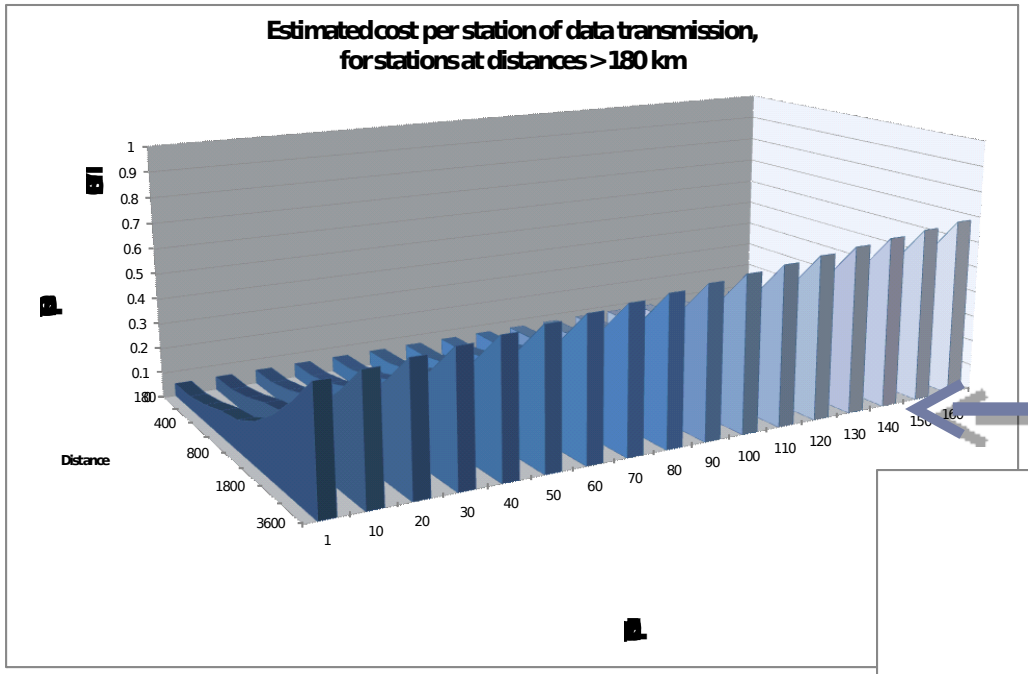
Network Construction



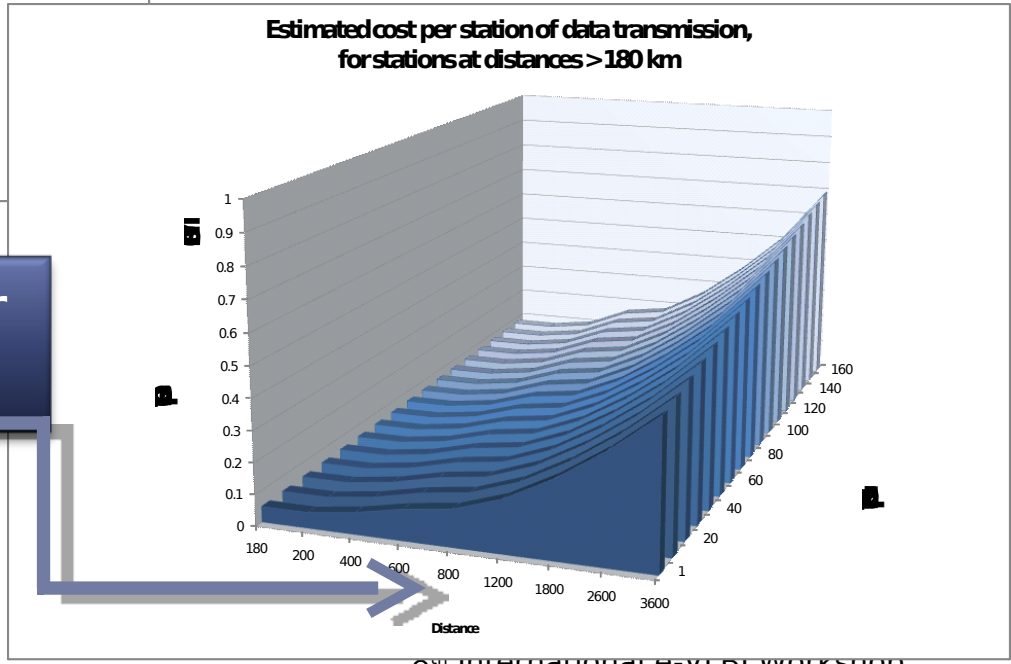
Dark fibre


10 year cost of ownership of a single spiral arm for a dark fibre solution
Dark fibre per km per pair per annum cost dominates.
Length of dark fibre required a key cost driver.
Dependent on the Baseline length and number of stations.
100
90
80
70
60
50
40
30
20
10
0
10 year cost of ownership
Trenching & cabling
Equipment
1G
10G
20G
30G
40G
50G
60G
70G
80G
90G
100G
110G
120G
130G
140G
150G
160G
Bit Rate

Increased bandwidth not a significant cost driver. Provide multiple beams at long baselines for a small incremental



Distance main cost driver for transmission.



8th International e-VLBI Workshop, 2009

Data Transport

Very Large Bit Rates:

R = Total Bit Rate

B = Bandwidth;

A_{tot} = Total Collecting Area

Ω = Field of View

λ = wavelength

$$R \propto \frac{B A_{tot} \Omega}{\lambda^2}$$

In summary this leads to bit rates of

- 160 Gbps per WBSPF dish
- 20 Tbps per Aperture Array Station
- 420 Gbps per Phased Array Feed

Commercial Bandwidth

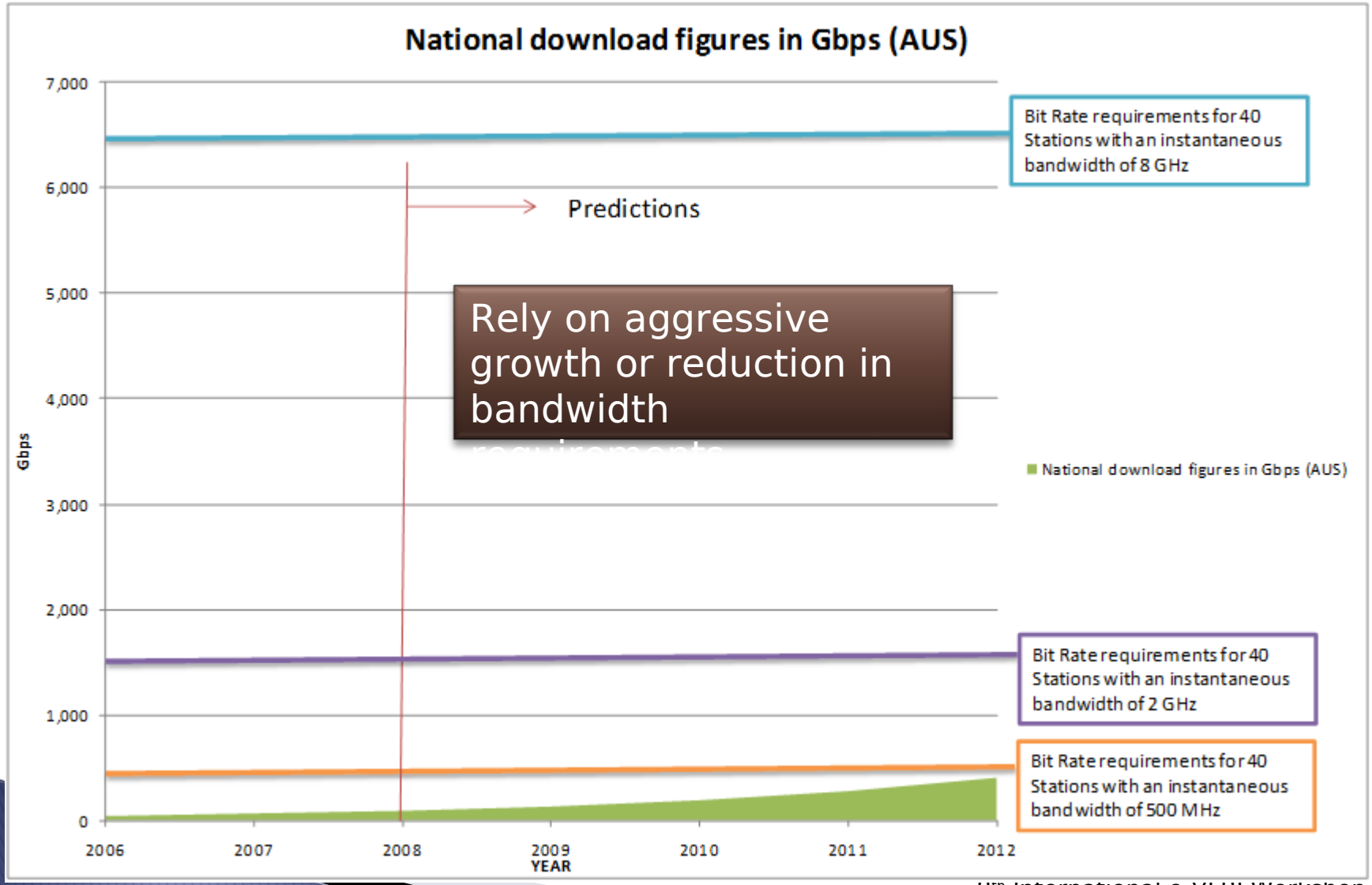
- For 40 stations on long baselines, the total bandwidth requirements are:
  - 6.4 Tbps for an 8GHz bandwidth
  - 1.6 Tbps for a 2 GHz bandwidth
  - 0.4 Tbps for a 500 MHz bandwidth
- SKA Bandwidth requirements are static, whilst IP traffic and networks are growing.

Putting SKA Bandwidths into perspective....

- Cisco* estimated that in 2007 the total, global IP traffic was the equivalent of 22 Tbps.
- Cisco predict a 46% CAGR of IP traffic upto 2012
- John Stankey** of AT&T showed AT&T's IP traffic at 1 Tbps in 2007 (or 5% of the global total).
- Australian Bureau of statistics show national download figures for 2007 are the equivalent of 65 Gbps (or < 1% of the global total)
- No equivalent statistics are published for South

*Cisco White Paper, Visual Networking Index – Forecast and Methodology, 2007–2012
**Presentation by John Stankey, Group President-Telecom Operations, AT&T Inc., delivered to 2007 Analyst Conference, December 11, 2007

SKA Bandwidths compared to AUS download traffic



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Cost Drivers

Design Solution	Dominant Cost drivers	Key Cost assumptions used
Station solution	• Trenching cost/km • Length of trenching o Baseline	€ 10,000 per km
Dark Fibre solution	• Cost of the dark fibre/annum • Length of dark fibre required which depends upon: o Baseline	€ 500 per fibre pair per annum
Bandwidth solution	• Cost per lambda or Gbps /annum o Number of Stations • Bandwidth Requirements o Number of Stations	unknown

SPDO Team

Project Director	Richard Schilizzi
Project Engineer	Peter Dewdney
Executive Officer	Colin Greenwood
Project Scientist	Joe Lazio
System Engineer	Kobus Cloete
Domain Specialist Receptors	Neil Roddis
Domain Specialist Signal Transport	Roshene McCool
Domain Specialist Computing & Software	Duncan Hall
Domain Specialist Signal Processing	Wallace Turner
Site Engineer	Rob Millenaar
Project Management Officer	Billy Adams
Industry Relations Manager	Phil Crosby
Office Manager	Lisa Bell

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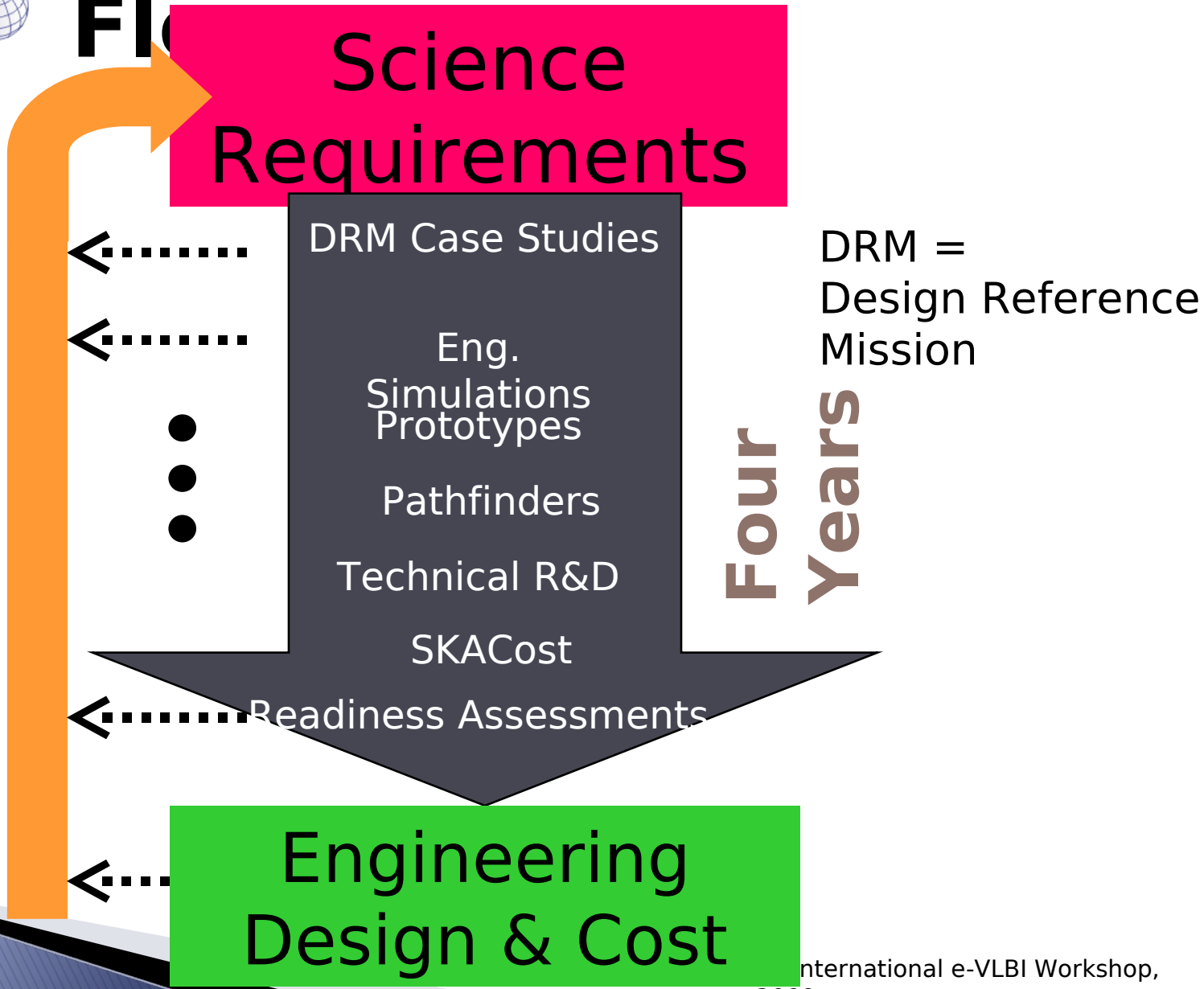
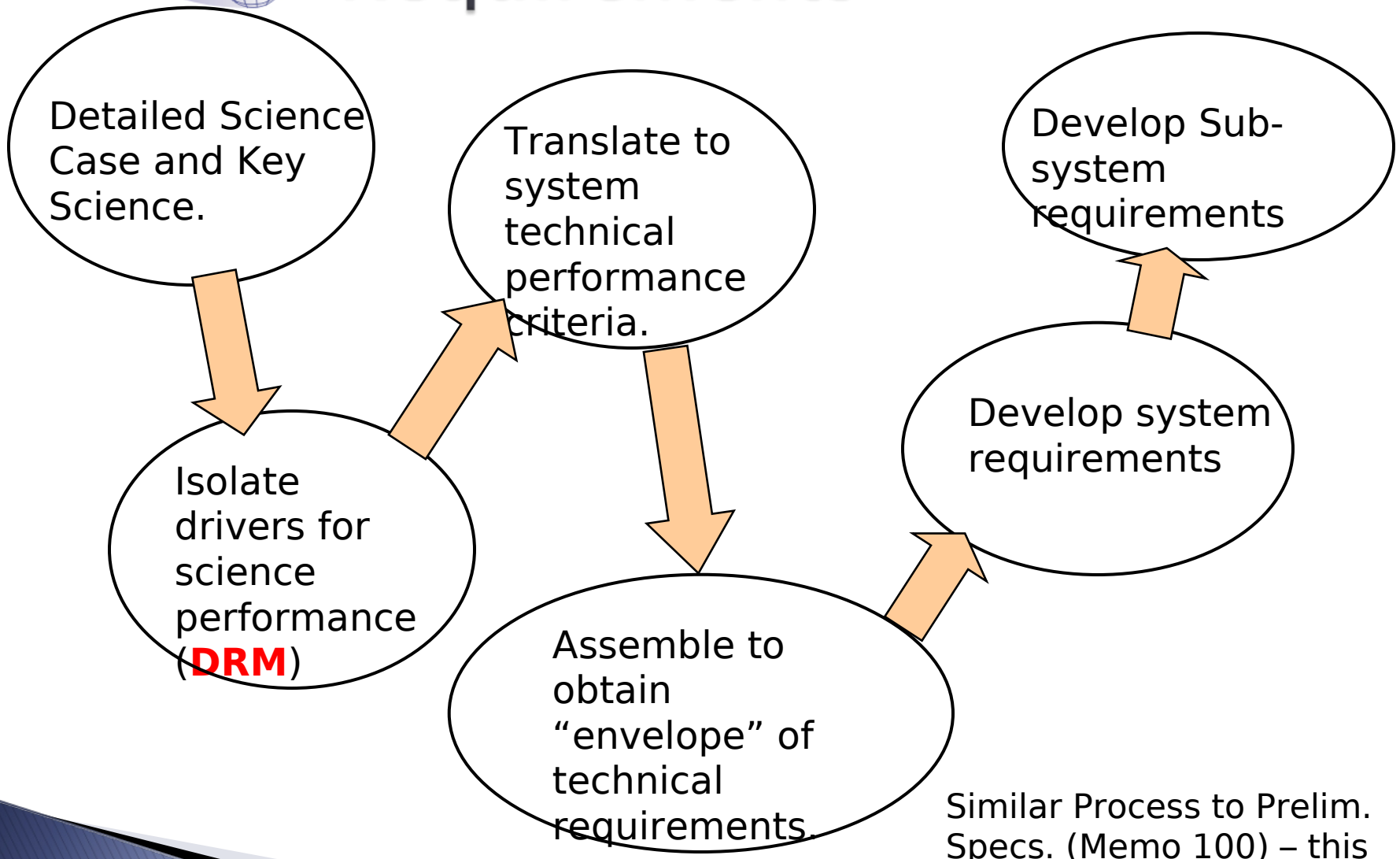
Goals

"A costed system design and deployment plan for the SKA"

PrepSKA WP2 Work Fl

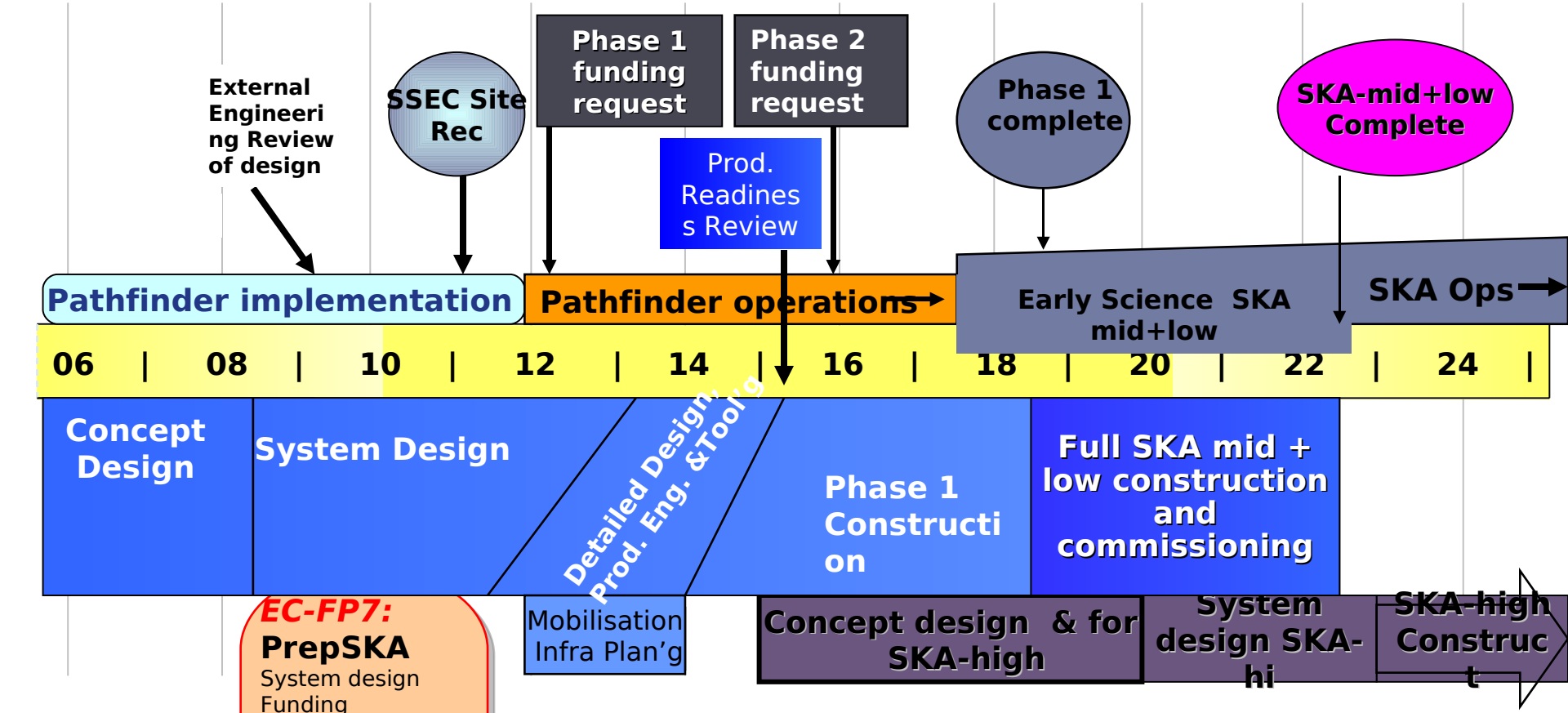
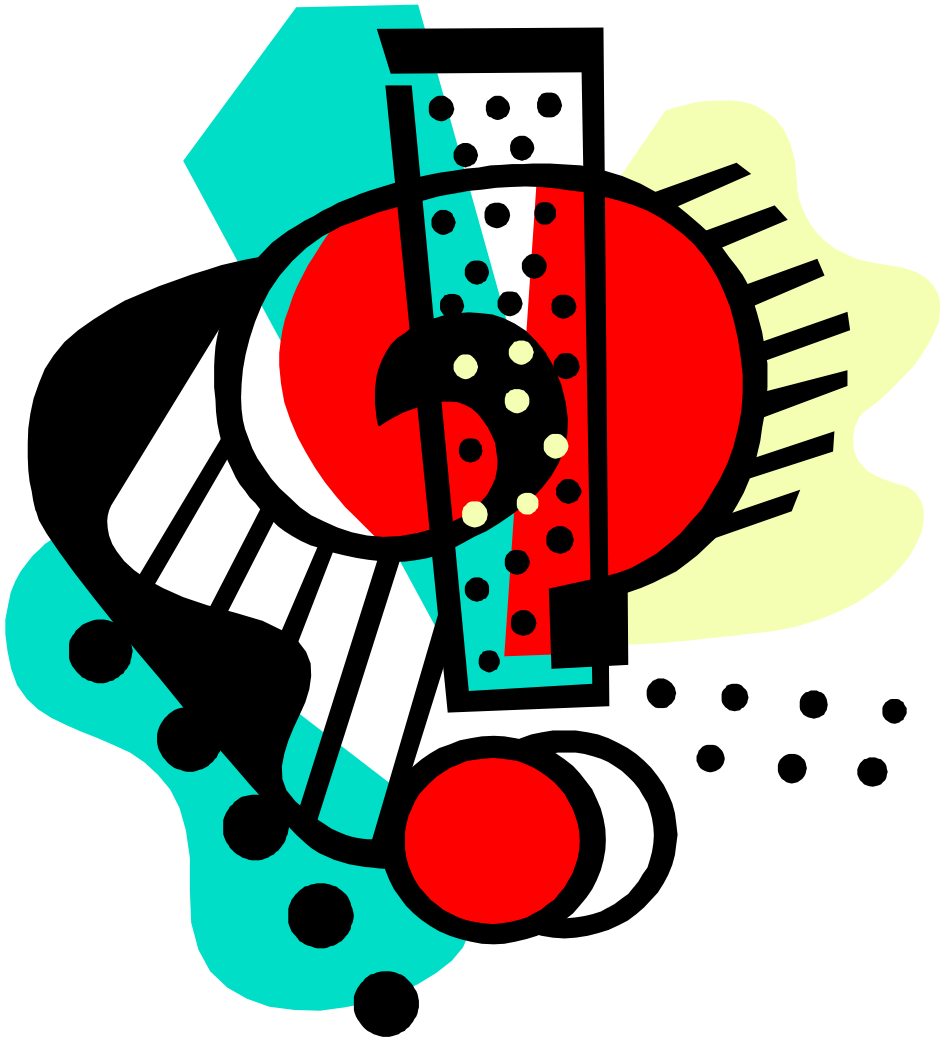


Developing System Requirements



Similar Process to Prelim. Specs. (Memo 100) – this time leading to "design action".

SKA timeline



Questions