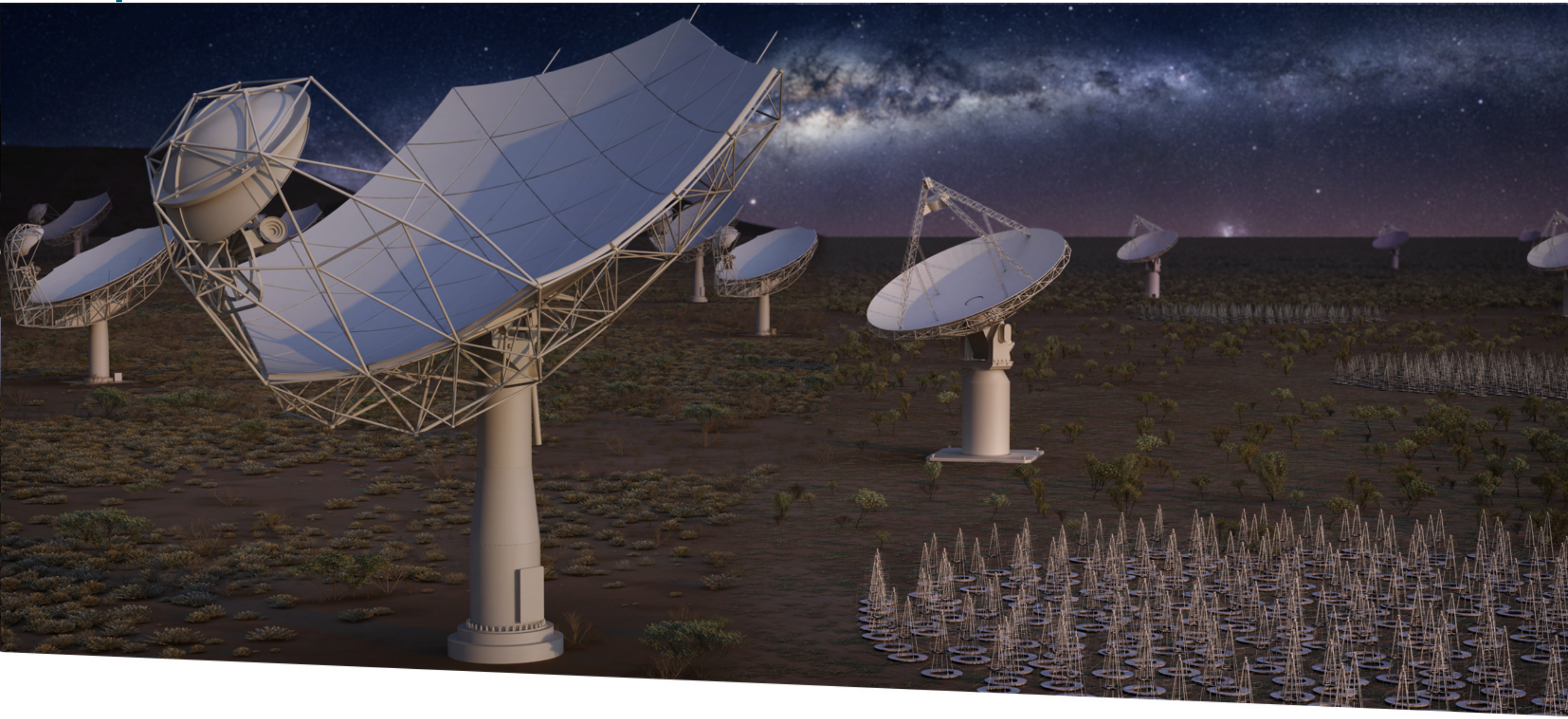
The SKA Project: technical requirements and challenges

Proposal



SQUARE KILOMETRE ARRAY

Exploring the Universe with the world's largest radio telescope

L. Stringhetti

Bologna, SKA_Italy 2018, 03/12/18

Hypothesis

- What are the technical challenges for the SKA engineering office?

  – The biggest challenge is the system

    - Why is that?
    - What is the plan to address that?
    - Who is working on this plan?
    - Translation in technical requirements

Technical Challenges

Pointing accuracy

Timing precision

Data Rate

Surface accuracy

Availability

Spectral Stability

Data processing

Bandwidth

Technical Challenges

- y
-
- Data Rate
- acy
- ity

7,99 £

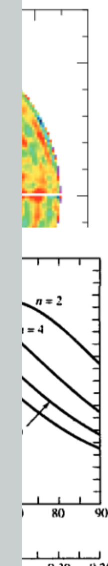
eBay

High-pre … **scope**

Sergio …

[a] INAF Osserv … I-09012

[b]INAF … na, Italy



1975 Experimental 2.94 Mbit

10 Mbit/s 10BASE5

ial cable)

10 Mbit/s 10BASE-T

ed pair)

100 Mbit/s Fast Ethern

Gigabit Ethernet

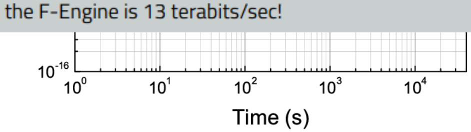
10 Gigabit Ethernet

100 Gigabit Ethernet

200/400 Gigabit Ethernet

F-ENGINE

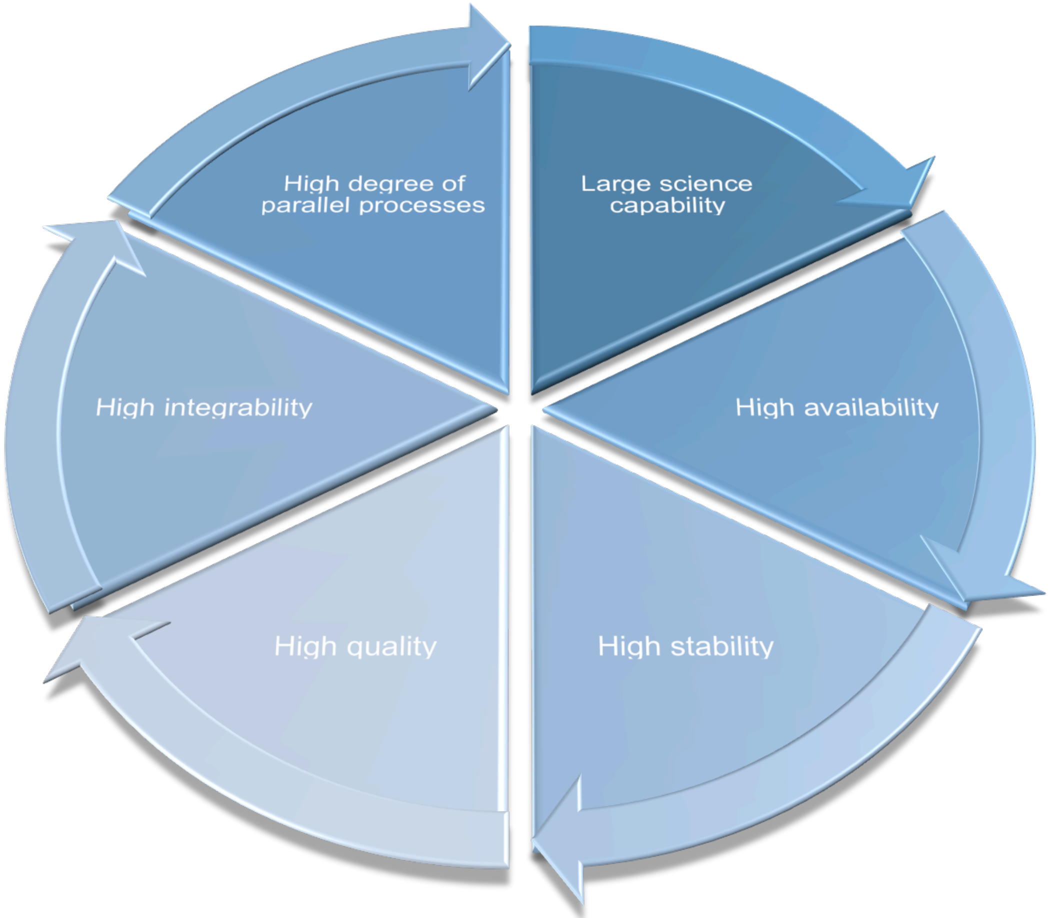
The FPGA-based F-Engine is housed in two specially shielded 20-foot shipping containers located between the cylinders. The system digitizes each analog signal input 800 million times per second and converts each microsecond of data (2048 samples) into a 1024-element frequency spectrum between 400 and 800 MHz, with a frequency resolution of 0.39 MHz. It then organizes the data by frequency bin and sends it over optical fibre to the X-Engine for spatial correlation. The input data rate processed by the F-Engine is 13 terabits/sec!



So what's the point?

Courtesy of Camilla

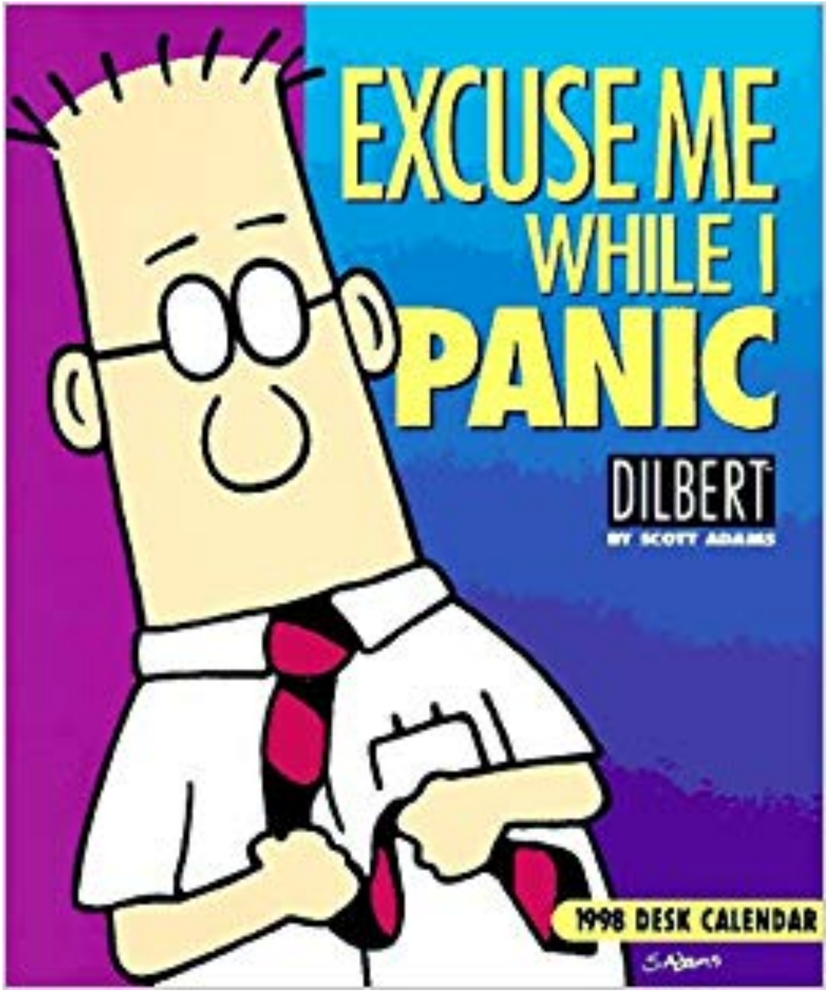
The full system is the challenge



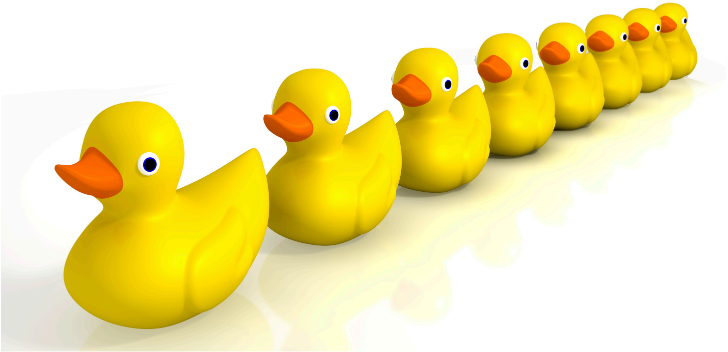
Hypothesis

- What are the technical challenges for the SKA engineering office?
  - The biggest challenge is the system
    - Why is that? => the scale of the system imposes very stringent requirements
    - What is the plan to address that?
    - Who is working on this plan?
    - Translation in technical requirements

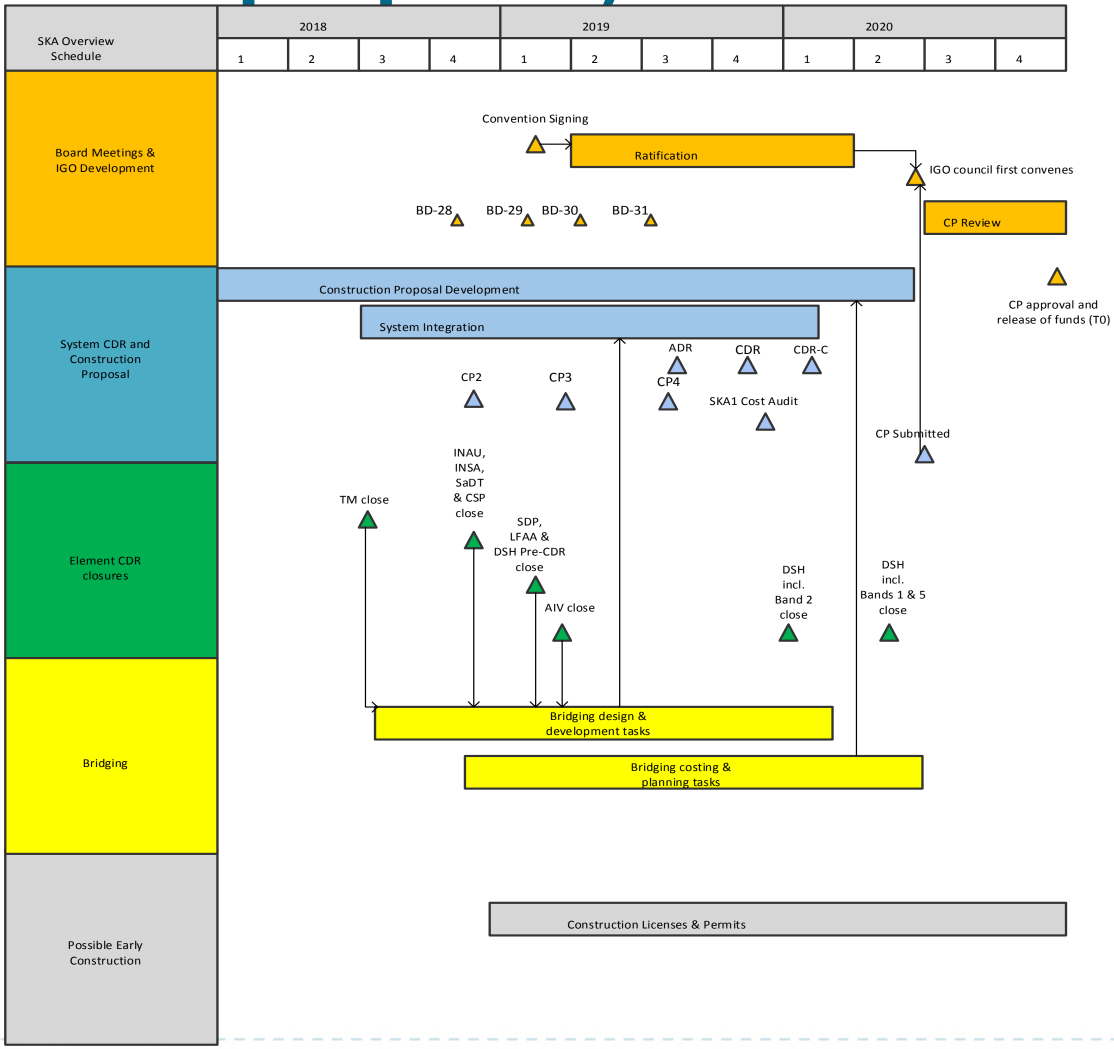
So what is the plan?



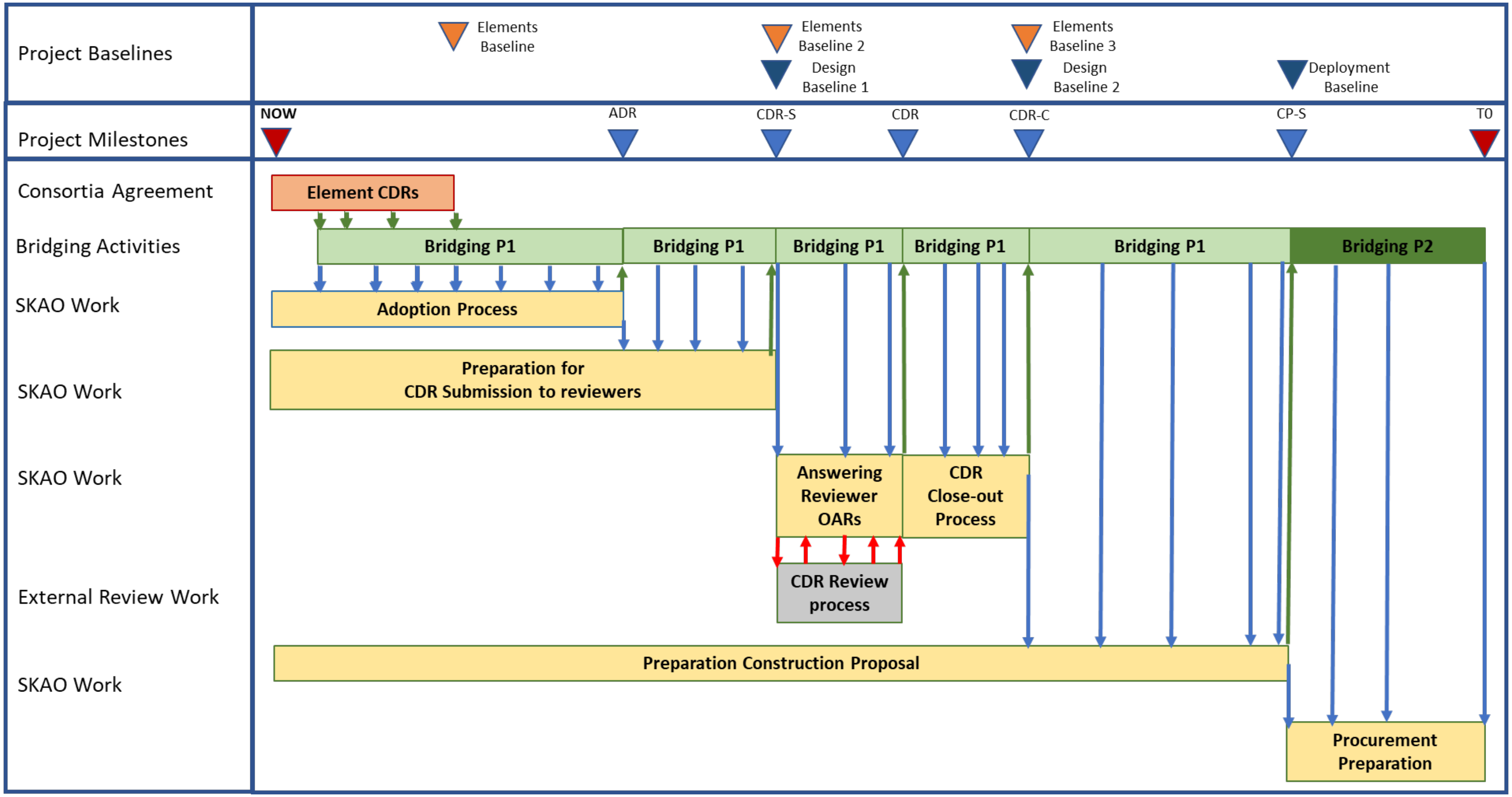
OR



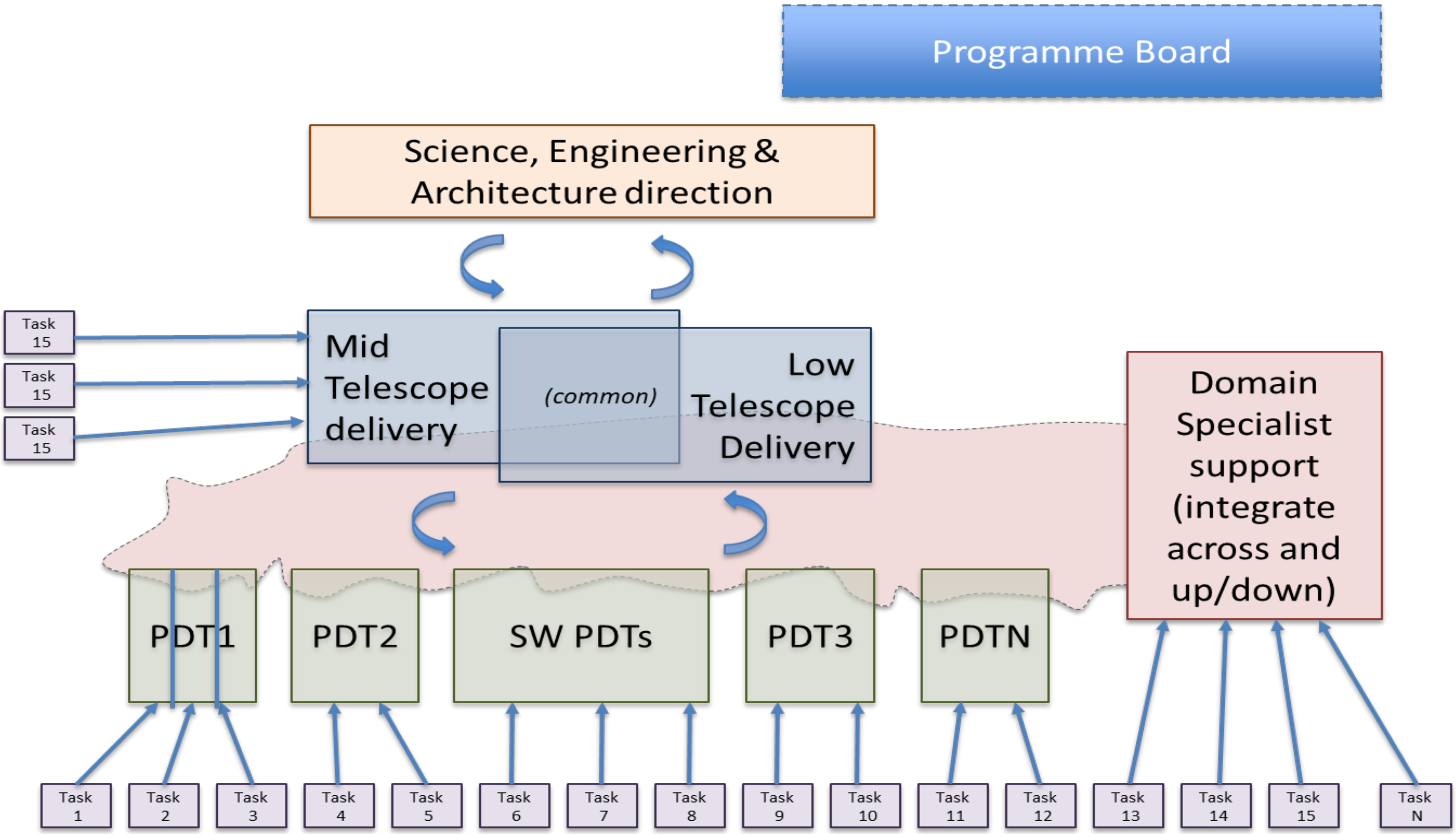
HOW – Next Project stages (up to construction proposal)



Bridging and Adoption



WHO: telescope delivery teams



Bridging agreements

- Because Consortia Agreements are no longer in force, SKAO needs agreements directly with each organisation (**Consultant**) involved in Bridging: these will be Memoranda of Understanding (MOUs)
  - The MOUs are managed between SKAO's nominated **Service Managers** and each Consultant's nominated contact
  - There are currently 6 Service Managers (all SKAO EPMs) looking after 19 MOUs
  - The MOUs have annexes based on NEC4 Professional Service Contracts
  - This is to introduce NEC4 terminology and ways of working to all involved in preparation for how we will work in construction
- Because several Consultants are involved in each task, **Task Managers** pull together the teams and lead the work
  - There are currently 65 P1 tasks owned by 22 Task Managers requiring an estimated 112 people-years of effort
  - A further 36 P2 tasks remain to be further defined and initiated
  - Task Managers include SKAO project managers, engineers and scientists and also ex-consortia staff

Bridging

Consultant	SKAO Service Manager	Consultant Contact	Status
ASTRON	Maurizio Miccolis	Michiel van Haarlem	Draft contract & tasks discussed
ATC	Maurizio Miccolis	Alan Bridger	Draft contract & tasks discussed; work started
CSIRO	Martin Austin	Ant Schinckel	Draft contract & tasks discussed; fortnightly progress calls ongoing
ICRAR/Curtin	Peter Hekman	Tom Booler	Draft contract & tasks discussed
ICRAR/UWA	Jill Hammond	Peter Quinn	Draft contract & tasks discussed
INAF	**Maurizio Miccolis**	**Isabella Prandoni**	**Draft contract & tasks discussed**
IT-Aveiro Portugal	Maurizio Miccolis	Domingos Barbosa	Draft contract & tasks discussed; work started
JIVE	Jill Hammond	Arpad Szomoru	Draft contract & tasks discussed; currently over-allocated
JLRAT	Mark Harman	Wang Feng	Draft tasks discussed; closing Dish Structure CDR first
NCRA	Maurizio Miccolis	Yashwant Gupta	Draft contract & tasks discussed; work started
NRC	Mark Harman	Luc Simard	Draft contract & tasks discussed; over-allocated
NZA	Maurizio Miccolis	Andrew Ensor	Draft contract & tasks discussed
SARAO	Martin Austin	Thomas Kusel	MOU signed October 2018; fortnightly progress calls ongoing
Swinburne University of Technology	Philip Gibbs	Adam Deller	Potential need highlighted at CSP CDR meeting
Tsinghua University	Jill Hammond	Wang Bo	Draft contract & tasks sent
University of Bordeaux	Mark Harman	Stephane Gauffre	Draft tasks defined; closing Receiver CDR first; may be included in SKA France level MOU instead
University of Cambridge	Maurizio Miccolis	Paul Alexander	Draft contract discussed; closing SDP first
University of Manchester	Jill Hammond	Keith Grainge	Draft contract & tasks discussed; closing SaDT first
University of Oxford (incl. Malta)	Mark Harman	Mike Jones	Draft tasks defined and discussed

WHY: Need for Design Adoption

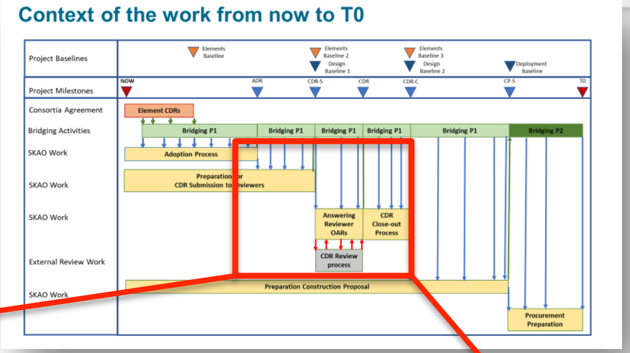
- The pre-Construction work of the SKA is delivering the Element Design Baselines through their Element CDRs, or in some cases, Pre-CDR. Although this development work was guided by a set of Level 1 Requirements (Rev. 11) this does not guarantee that the Element products, when integrated together, will perform as envisaged.
- In heading to System CDR, it is thus necessary for the SKAO to integrate the Element designs to establish their alignment with each other and with the overall system design and requirements. During this process further issues, gaps and risks will be exposed, and decisions will have to be made on how to address these.
- Without a systemic preparation the System CDR for such a complex environment will be “complicated”

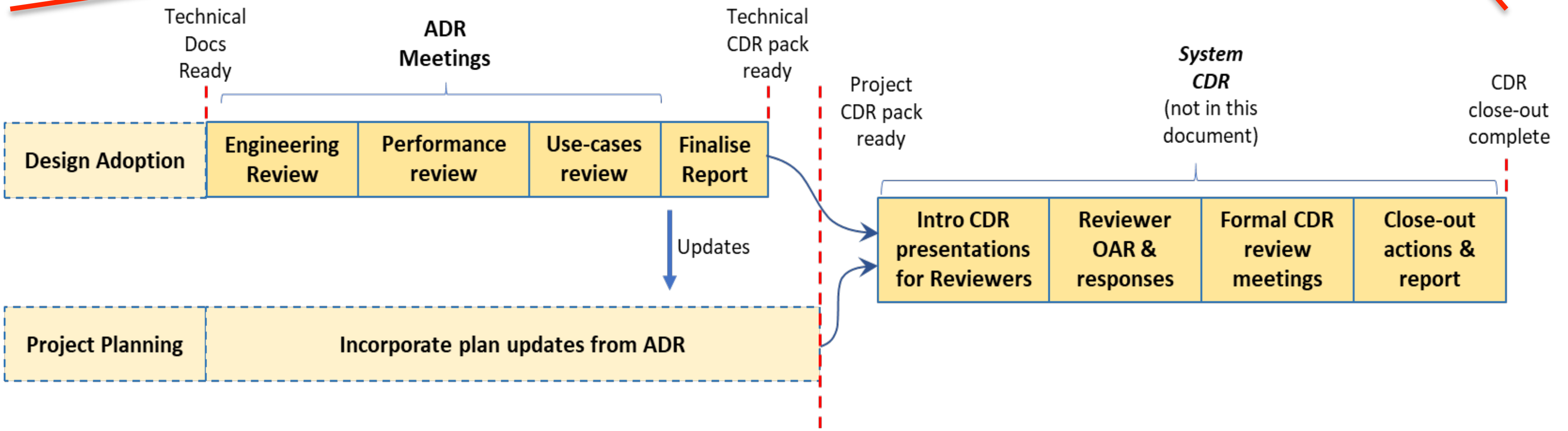
WHY: Objectives of the Design Adoption

- to **assess the completeness** of the design and plan to support the SKA software and hardware implementation in Construction,
- to **demonstrate the remaining risks are acceptable** for the SKA Organisation, to move forward to the SKA System CDR, based on the information presented.
- To **establish the Element Design Baseline**, a set of approved documents representing our best understanding of the requirements, design, internal interfaces, lower level requirements, plans going forward and justification thereof.

Adoption Design Review Meeting

(and a few words on system CDR)





And after that?

Early Construction Opportunity:

- **AA0.5 (Array Assembly 0.5) MID+ MeerKAT Extension (1)**
- **AA0.5 LOW**

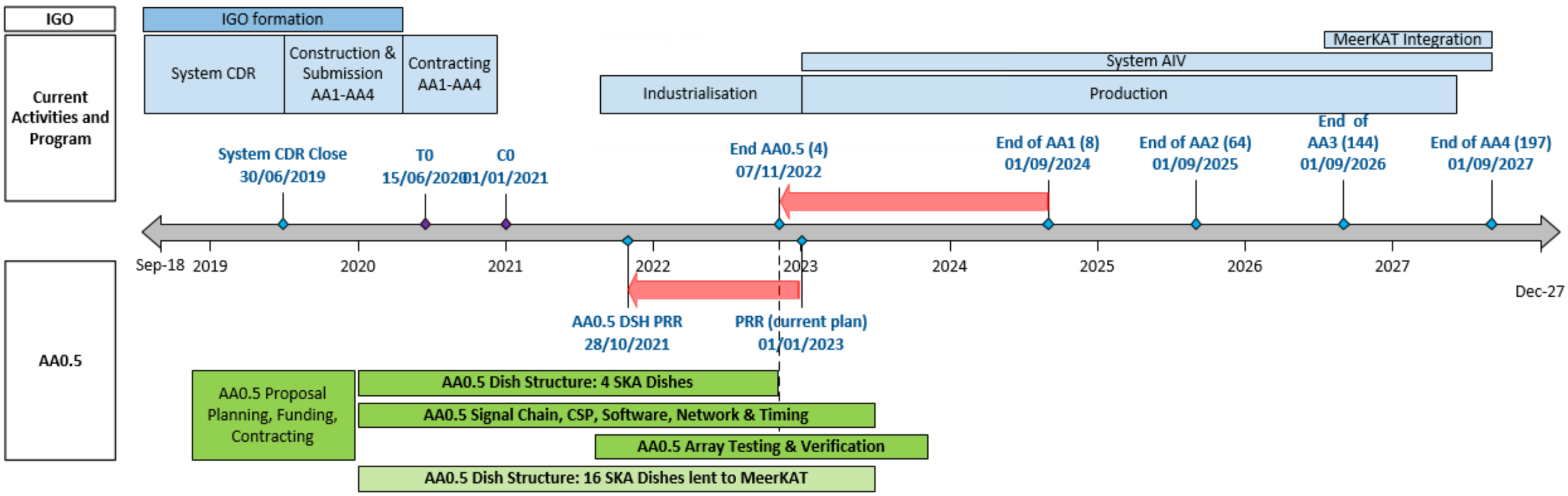
Objectives for AA0.5

- AA0.5 is a means of verifying the SKA1 system design and reducing the risk on the construction phase through the deployment of a minimal array capable of demonstrating both compliance and production capabilities

- Carry out astronomical tests to:
  - Commission the Low and Mid EPAs
  - Verify system performance to the extent that this is feasible with the available hardware and software
  - Identify components which do not meet requirements/need rework/are unreliable
  - Work with hardware and software engineers to debug, optimize and improve the system.

- Develop methods and working practices for full production
  - Commissioning team organization
  - Training
  - Test scripts and analysis software

Example of plan



Plan is still in progress. Senior PM of the two TDT are working to finalise them and march 2019 (TBC) there will be a second workshop for the AA0.5 (a.k.a. EPA).

Requirements

- Infrastructure
- Antenna (Dish/LFAA)
  - Band 2, Band 5 for Mid (high frequency to enable antenna tests)
- Time and frequency reference
  - reduced requirements
- CSP
  - Limited number of stations
  - Limited bandwidth and fixed channelisation
- Telescope management
  - Basic monitor and control
  - Interfaces (partial functionality)
  - Pointing and delay models
  - Control low beam weights
  - Simple scripting layer
- Data written to measurement set for analysis in CASA
  - Pointing measurement requires a work-round if SDP real-time pipeline is not available
  - Pointing and delay calibration analysis off-line

- Mid observations
  - Pointed observations of bright, unresolved calibrators
  - "Blank" sky
  - Raster scan for holography
  - 5-point for pointing
- Low observations
  - Drift scans (Galactic centre, Sun, Orbcom satellites) and drone observations to monitor station beams
  - Interferometric observations of "A-team" sources
  - Raster scans

Hypothesis

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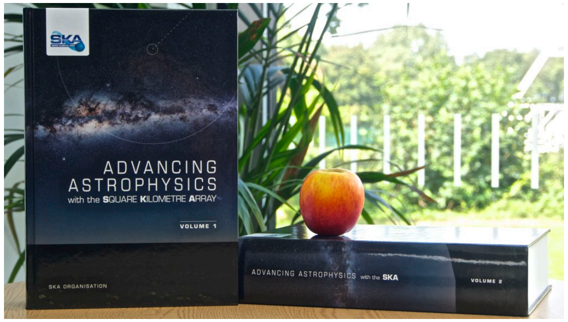
    - What is the plan to address that? => adoption plan to prepare system CDR with the support of bridging tasks
    - Who is working on this plan?=> The TDT through the PDT supported by the bridging tasks experts.
    - Translation in technical requirements

Technical Challenges

- Pointing accuracy
- Timing precision
- Data Rate
- Surface accuracy
- (Spectral) Stability
- Bandwidth
- Availability
- Data processing

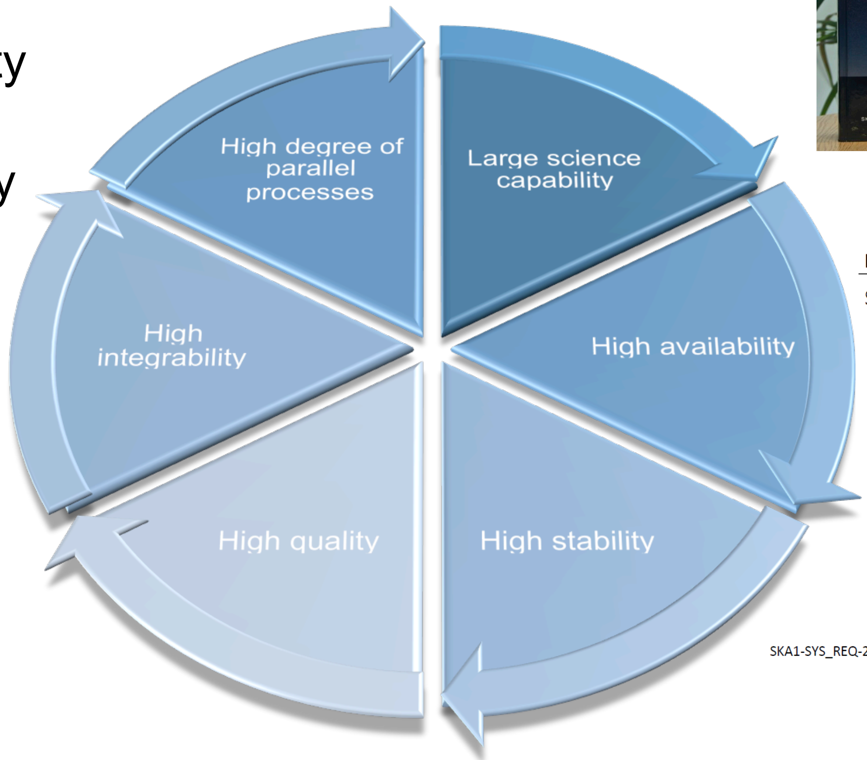
SKA1-SYS_REQ-2621	Station beam bandpass stability On a maximum time scale of 600 seconds, and within the envelope of the listed spline points with TBD frequency smoothness, SKA1_Low shall have a station beam bandpass stability, post calibration and RFI mitigation, of: • 0.05 % at 50 MHz • 0.02 % at 110 MHz • 0.03 % at 160 MHz • 0.03 % at 220 MHz • 0.05 % at 280 MHz • 0.08 % at 350 MHz compared to the full polarization parameterized beam model.

The full system is the challenge



First preliminary list

- Availability
  - Maintainability
- Stability
  - Band Stability
  - RFI flagging policy
  - Calibration
- Quality
- Integrability
  - SW/HW integration
- Parallel processes



ID	Requirement description
SKA1-SYS_REQ-2716	Operational availability The SKA1_Mid and SKA1_Low shall each have an operational availability of at least 95%.

SKA1-SYS_REQ-2621 Station beam bandpass stability

On a maximum time scale of 600 seconds, and within the envelope of the listed spline points with TBD frequency smoothness, SKA1_Low shall have a station beam bandpass stability, post calibration and RFI mitigation, of:

- 0.05 % at 50 MHz
- 0.02 % at 110 MHz
- 0.03 % at 160 MHz
- 0.03 % at 220 MHz
- 0.05 % at 280 MHz
- 0.08 % at 350 MHz

compared to the full polarization parameterized beam model.

SKA1-SYS_REQ-3458 SKA1_Mid spectral stability

The bandpass of SKA1_Mid, on timescales of 600 seconds or less and for all processed bandwidths, post-calibration and RFI mitigation, shall be stable to better than 0.03%.

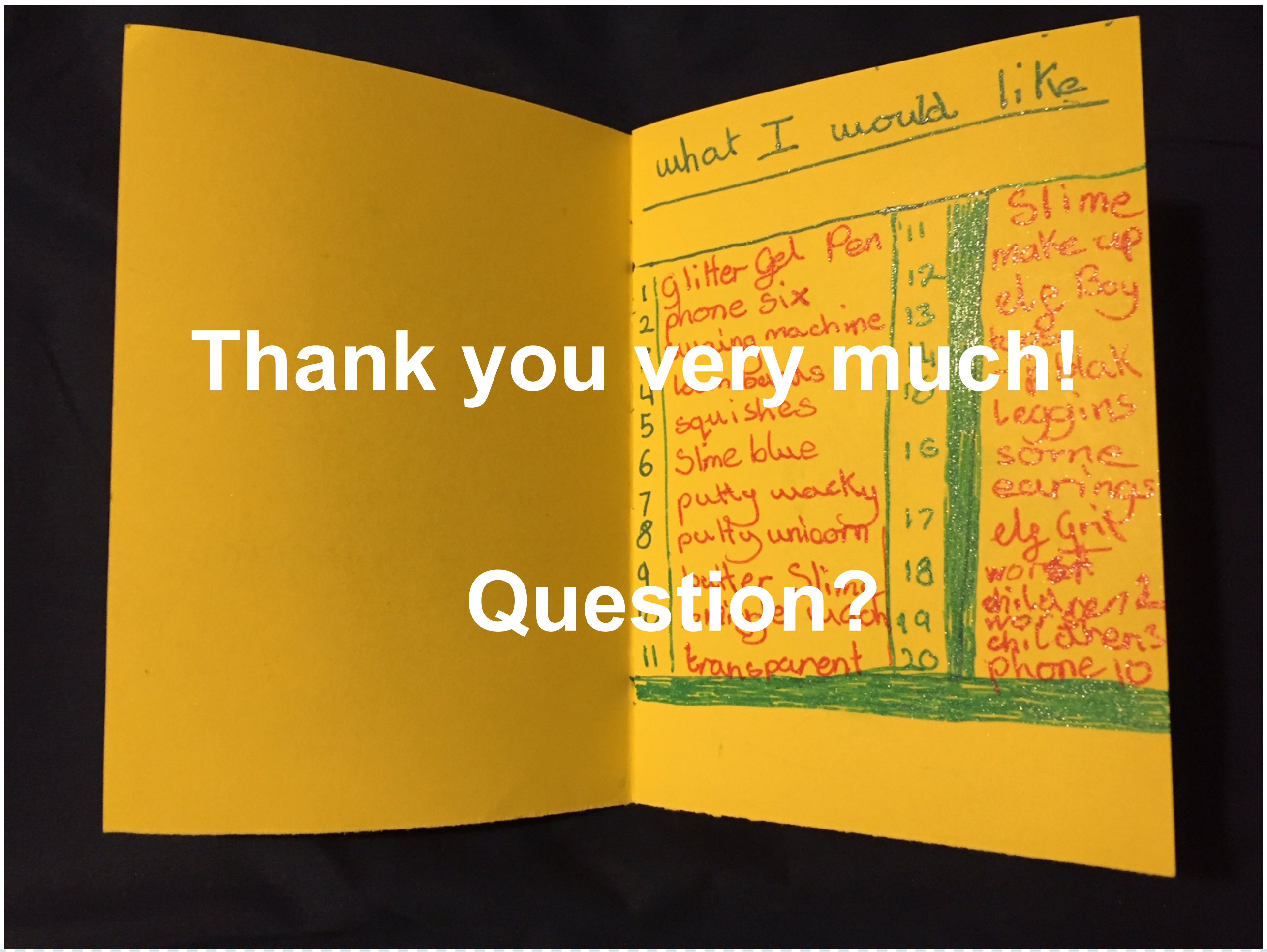
Conclusion

- What are the technical challenges for the SKA engineering office?
  - The biggest challenge is the system
    - Why is that? the scale of the system imposes very stringent requirements
    - What is the plan to address that? => adoption plan to prepare system CDR with the support of bridging tasks
    - Who is working on this plan?=> The TDT through the PDT supported by the bridging tasks experts.
    - Translation in technical requirements => System Budgets needs to be completed (still) and they will be addressed during the Adoption phase.

Adoption process already kicked off in SKAO.
System CDR plan is still in a very draft version.
The adoption process will achieve success only with the large collaboration of different experts that contributed to the elements designs (Bridging).
The TDTs, will replace the TTs, and will own the process form Jan 2019.
Adoption Review Q3 2019
System CDR Q4 2019

Bridging Task 1

Any idea how to support this?



Thank you very much!

Question?

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