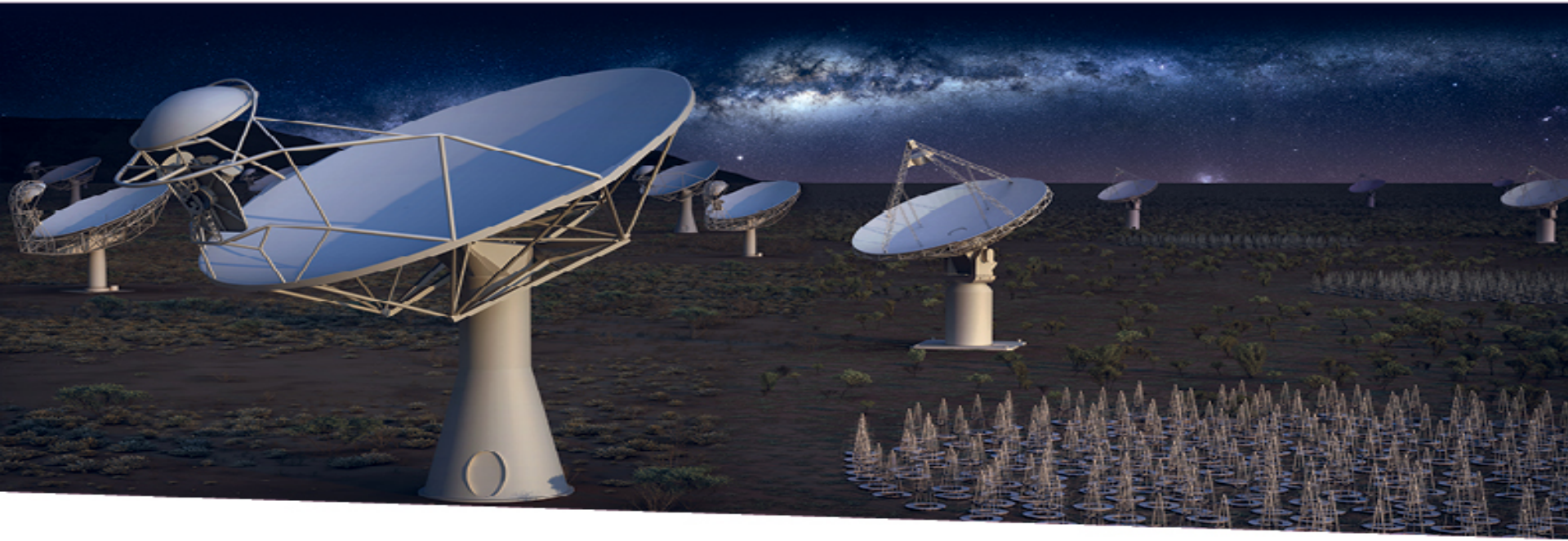
Planning the Verification of the SKA1 Telescopes

2019 SKA Shanghai Meeting



SQUARE KILOMETRE ARRAY

Exploring the Universe with the world's largest radio telescope

Richard T. Lord

26 November 2019

Introduction

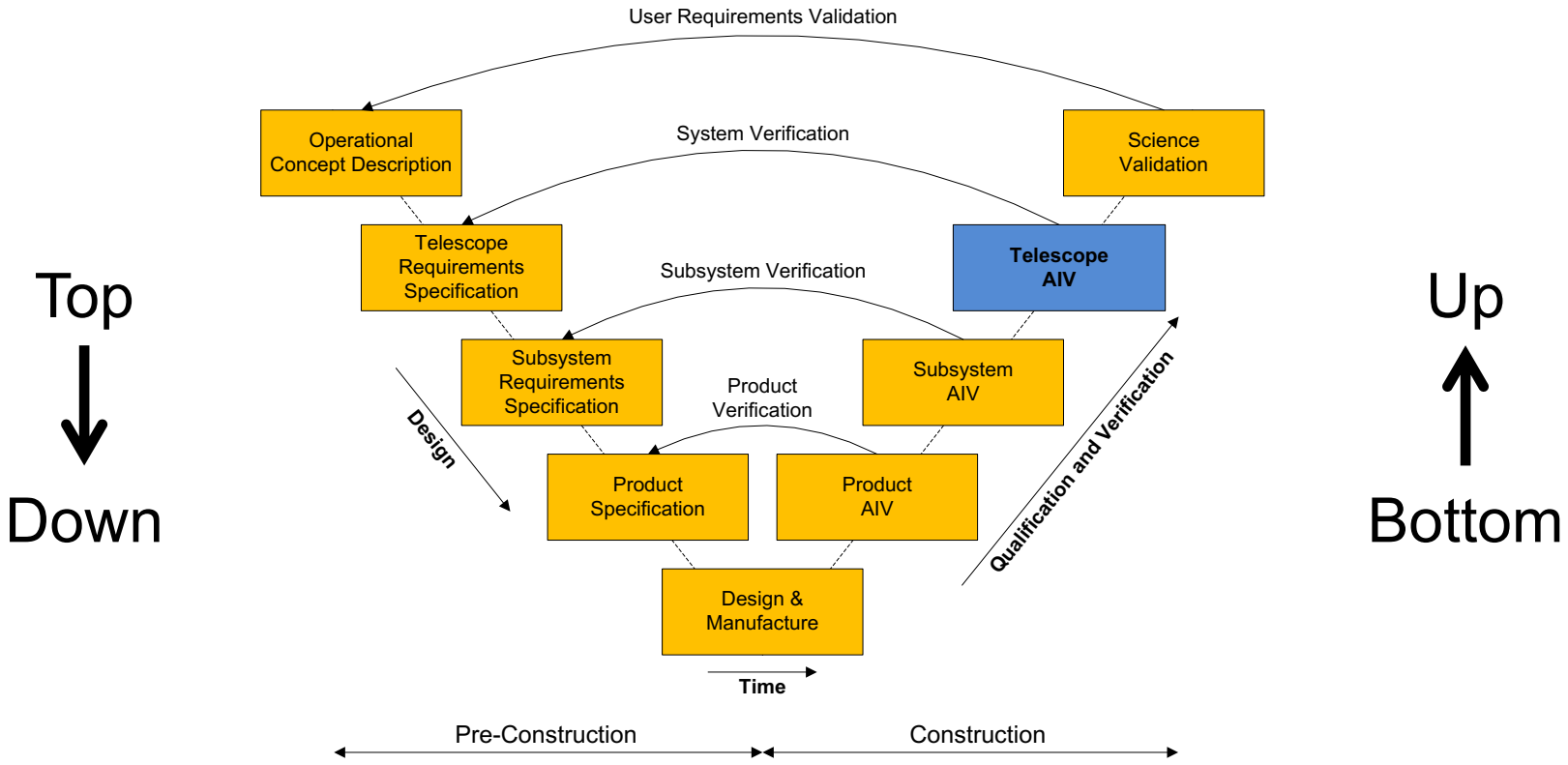
- Risk-based approach to verification planning
- Illustration and clarification of some of the key concepts regarding verification planning
- Lessons Learned

It's all about Managing Risk

- Are we building the right thing?
  - Qualification of Design

- Are we building it correctly?
  - Verification of Requirements

The Famous V-Diagram



Element CDRs

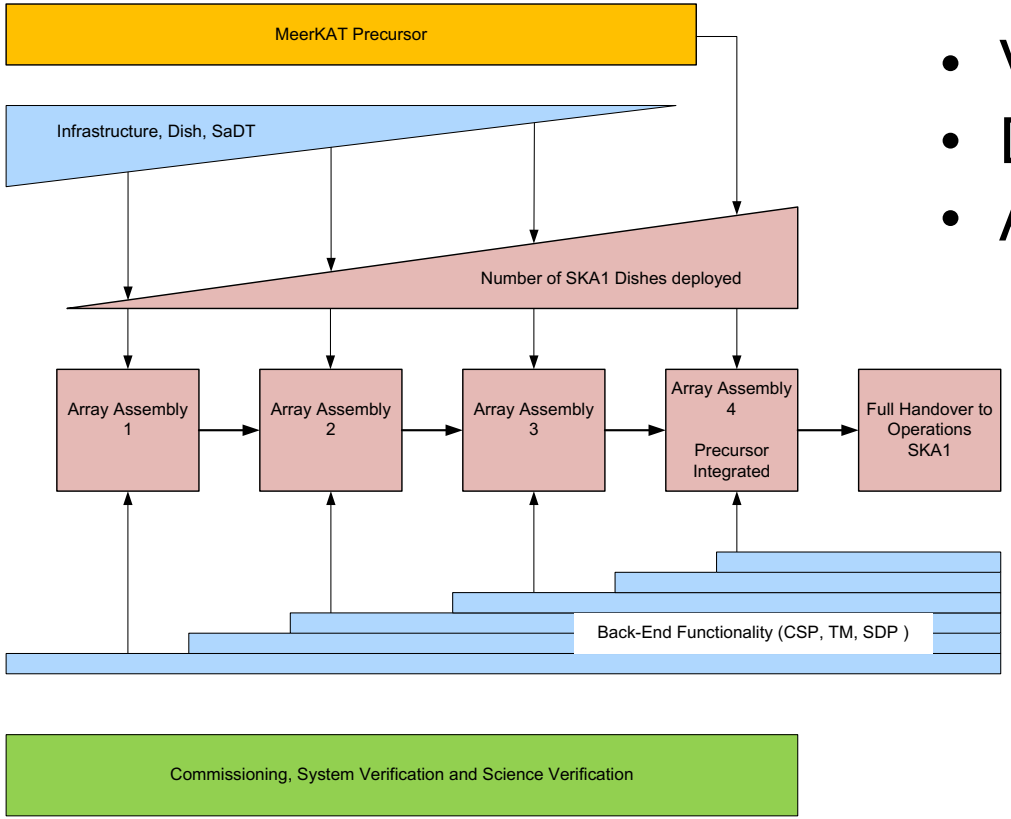
- Should provide evidence that design requirements have been met
- Heavy reliance on analysis
- Interfacing products do not exist
- Simulators/Emulators might mask problems
- Prototype hardware used
- Different levels of rigor applied

$\Rightarrow$ System-level risks remain after product-level designs have been qualified

Product Hand-Over Process

- Important quality gate
- Well-tested products -> less system I&V issues
- Factory Acceptance Testing
- On-Site Acceptance Testing
- Product can be supported and maintained after hand-over

Sequential Roll-Out



- Verify the system in stages
- Detect problems early
- Apply design changes early

Array Assemblies (AAs)

- Fixed number of Dishes / Stations
  - Determined by Correlator size
  - But: Flexibility regarding *which* Dishes / Stations
- Defined Capability / Functionality
  - Basis for the delivery of products and planning of I&V activities
- Start Date
  - When all AA components are available
  - But: Maintain I&V flexibility regarding exact product delivery date

Observing Modes for each AA

	# Dishes	Frequency Bands	Imaging	Pulsar Timing	Dynamic Spectrum	Pulsar Search	Transient Capture	VLBI
AA1	8	Band: 1 + 2	✓ • Basic Continuum and Spectral Line imaging • Using CASA • 16k channels • 400 MHz bandwidth	✓ • Basic • 1 boresight non-steerable beam • 400 MHz bandwidth				
AA2	64	Band: 1 + 2 Band: 5 (on 32 Dishes, but may not be supported by correlator)	✓ • Basic Continuum and Spectral Line imaging • Using CASA • 16k channels • 800 MHz bandwidth	✓ • 6 steerable beams • With de-dispersion • 800 MHz bandwidth		✓ • 16 steerable beams • Not fully pipelined • Non-real time operation • Full bandwidth		
AA3	128	Band: 1 + 2 Band: 5 (on 64 Dishes)	✓ • Continuum and Spectral Line imaging pipelines • 64k channels • Zoom mode • 5200 MHz bandwidth	✓ • 16 steerable beams • With de-dispersion • Full bandwidth	? • Maybe	✓ • 128 steerable beams • Not fully pipelined • Non-real time operation • Full bandwidth	? • Maybe	
AA4	197	Band: 1 + 2 Band: 5	✓ • Full Continuum and Spectral Line imaging pipelines • 64k channels • Zoom mode • Full bandwidth	✓ • 16 steerable beams • With de-dispersion • Full bandwidth	✓ • Supported by PST	✓ • 1500 steerable beams • Fully pipelined • Real time operation • Full bandwidth	✓	✓ • 4 beams

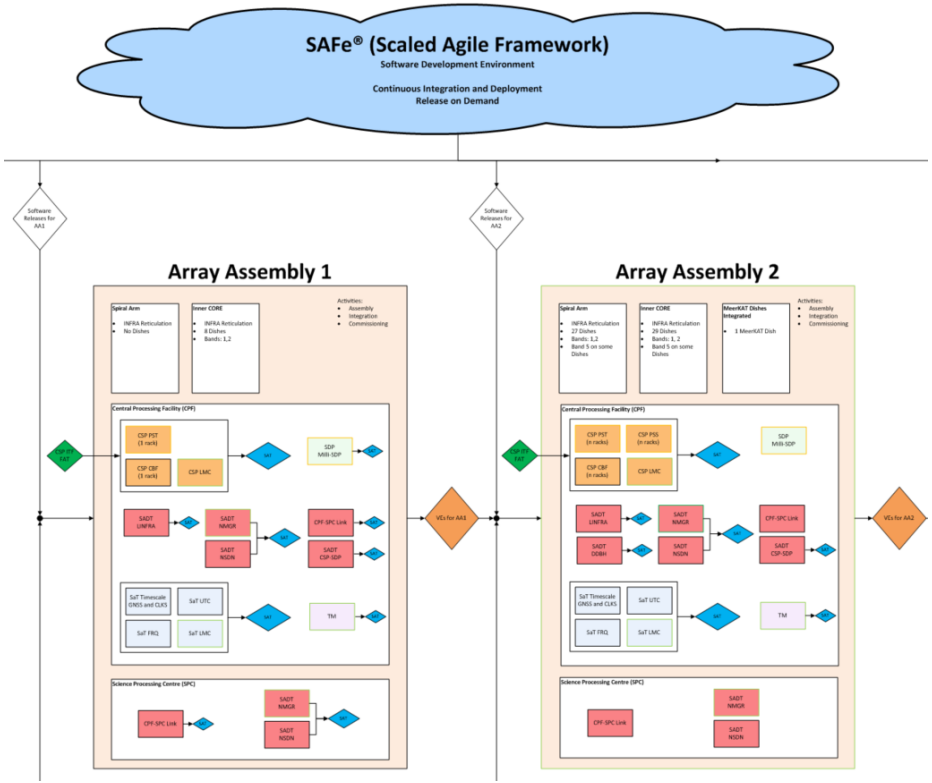
Integration Test Facility (ITF)

- Convenient environment to
  - install products
  - integrate with other products
  - test product-to-product interfaces
  - troubleshoot issues, etc
- Line-up of products to (partially) qualify the system-level design
- Verify new releases of software/firmware (and hardware), before installing on-site
- Knowledge transfer between contractors, engineers, AIV Team, Science Commissioning Team, etc

Rolling-Out Software

- Scaled Agile Framework (SAFe ®)
- An agile process that allows scalability of overall team size by having “teams of teams”
- 3-month “cadence” called Program Increment
- Release on demand, develop on cadence
- Continuously builds value and reduces risk
- Has an evolving architectural runway
- Working product demonstrated frequently
- Regular stakeholder engagement

Sequencing of Milestones and Dependencies



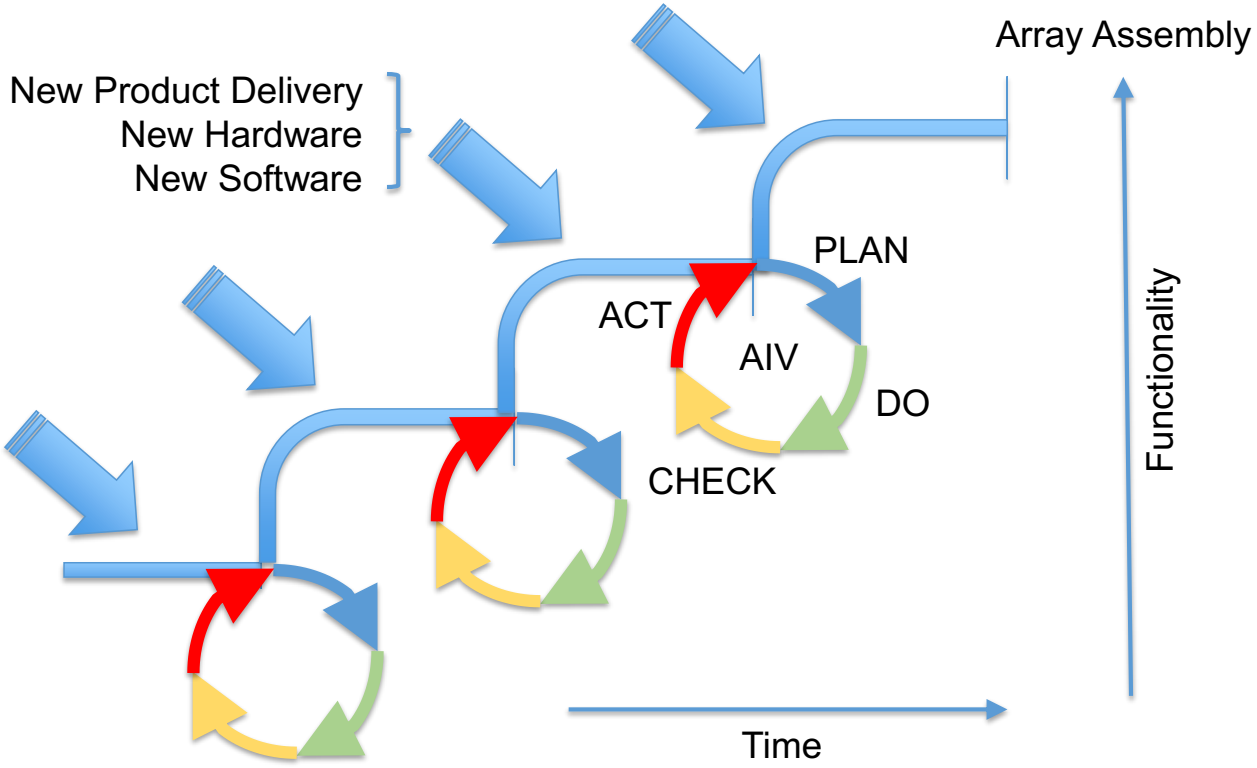
Verification Flow Diagram (*)

- Factory Acceptance Tests
- Delivery of hardware or software to site
- Site Acceptance Tests
- Major Verification Events
- Hand-over of responsibility from product contractor to SKAO

Useful to ensure that there are no gaps in the verification planning

(*) Initiated by L. Stringhetti

Iterative and Continuous Process



(Slide taken from P. Hekman)

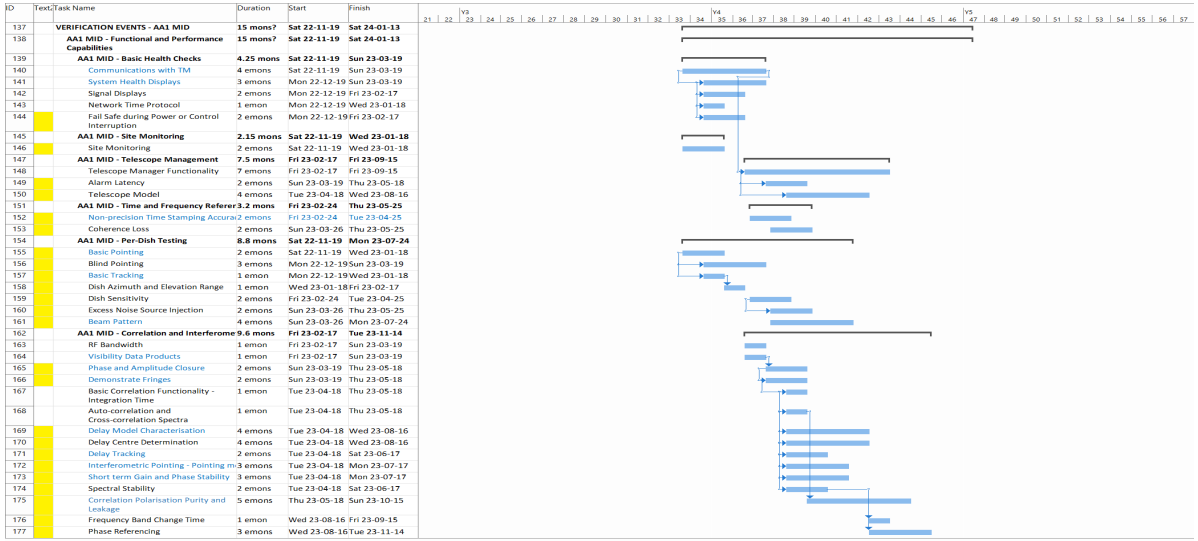
MeerKAT Precursor Integration

- Significant activity which carries schedule, technical and budgetary risks
- Requires careful roll-out planning
- Ensure that interfaces between MeerKAT components and SKA1-MID components are fully described

MeerKAT Precursor Telescope Dishes

Integration & Verification Plan

- Structured framework, in which all integration and verification activities will be carried out in a coordinated manner



ID	Text1	Task Name	Duration	Start	Finish
137		**VERIFICATION EVENTS - AA1 MID**	**15 mons?**	**Sat 22-11-19**	**Sat 24-01-13**
138		**AA1 MID - Functional and Performance Capabilities**	**15 mons?**	**Sat 22-11-19**	**Sat 24-01-13**
139		**AA1 MID - Basic Health Checks**	**4.25 mons**	**Sat 22-11-19**	**Sun 23-03-19**
140		Communications with TM	4 emons	Sat 22-11-19	Sun 23-03-19
141		System Health Displays	3 emons	Mon 22-12-19	Sun 23-03-19
142		Signal Displays	2 emons	Mon 22-12-19	Fri 23-02-17
143		Network Time Protocol	1 emon	Mon 22-12-19	Wed 23-01-18
144		Fail Safe during Power or Control Interruption	2 emons	Mon 22-12-19	Fri 23-02-17
145		**AA1 MID - Site Monitoring**	**2.15 mons**	**Sat 22-11-19**	**Wed 23-01-18**
146		Site Monitoring	2 emons	Sat 22-11-19	Wed 23-01-18
147		**AA1 MID - Telescope Management**	**7.5 mons**	**Fri 23-02-17**	**Fri 23-09-15**
148		Telescope Manager Functionality	7 emons	Fri 23-02-17	Fri 23-09-15
149		Alarm Latency	2 emons	Sun 23-03-19	Thu 23-05-18
150		Telescope Model	4 emons	Tue 23-04-18	Wed 23-08-16
151		**AA1 MID - Time and Frequency Referer**	**3.2 mons**	**Fri 23-02-24**	**Thu 23-05-25**
152		Non-precision Time Stamping Accurac	2 emons	Fri 23-02-24	Tue 23-04-25
153		Coherence Loss	2 emons	Sun 23-03-26	Thu 23-05-25
154		**AA1 MID - Per-Dish Testing**	**8.8 mons**	**Sat 22-11-19**	**Mon 23-07-24**
155		Basic Pointing	2 emons	Sat 22-11-19	Wed 23-01-18
156		Blind Pointing	3 emons	Mon 22-12-19	Sun 23-03-19
157		Basic Tracking	1 emon	Mon 22-12-19	Wed 23-01-18
158		Dish Azimuth and Elevation Range	1 emon	Wed 23-01-18	Fri 23-02-17
159		Dish Sensitivity	2 emons	Fri 23-02-24	Tue 23-04-25
160		Excess Noise Source Injection	2 emons	Sun 23-03-26	Thu 23-05-25
161		Beam Pattern	4 emons	Sun 23-03-26	Mon 23-07-24
162		**AA1 MID - Correlation and Interferome**	**9.6 mons**	**Fri 23-02-17**	**Tue 23-11-14**
163		RF Bandwidth	1 emon	Fri 23-02-17	Sun 23-03-19
164		Visibility Data Products	1 emon	Fri 23-02-17	Sun 23-03-19
165		Phase and Amplitude Closure	2 emons	Sun 23-03-19	Thu 23-05-18
166		Demonstrate Fringes	2 emons	Sun 23-03-19	Thu 23-05-18
167		Basic Correlation Functionality - Integration Time	1 emon	Tue 23-04-18	Thu 23-05-18
168		Auto-correlation and Cross-correlation Spectra	1 emon	Tue 23-04-18	Thu 23-05-18
169		Delay Model Characterisation	4 emons	Tue 23-04-18	Wed 23-08-16
170		Delay Centre Determination	4 emons	Tue 23-04-18	Wed 23-08-16
171		Delay Tracking	2 emons	Tue 23-04-18	Sat 23-06-17
172		Interferometric Pointing - Pointing m	3 emons	Tue 23-04-18	Mon 23-07-17
173		Short term Gain and Phase Stability	3 emons	Tue 23-04-18	Mon 23-07-17
174		Spectral Stability	2 emons	Tue 23-04-18	Sat 23-06-17
175		Correlation Polarisation Purity and Leakage	5 emons	Thu 23-05-18	Sun 23-10-15
176		Frequency Band Change Time	1 emon	Wed 23-08-16	Fri 23-09-15
177		Phase Referencing	3 emons	Wed 23-08-16	Tue 23-11-14

Gantt Chart showing Verification Events

I&V Planning Level of Effort

Number of Engineering (Level-1) Requirements is about 650

		Integration Events	Verification Events	Test Procedures
SKA1-MID	ITF	20	13	25
	AA1	30	21	68
	AA2	35	27	86
	AA3		24	55
	AA4		22	28
SKA1-LOW	ITF	20	13	32
	AA1	20	21	70
	AA2	20	28	95
	AA3		27	105
	AA4		29	102

Configuration Management

- Critical to the I&V effort
- Hardware / Firmware / Software configuration status of the Telescope shall be recorded with test results documentation

Lessons Learned

- Roll-out activities and AIV work scope is often under-estimated, even at product level
- Separate R&D from construction
- The value of a qualified solution is immense (much more valuable than another unproven solution that looks good)
- Learn from prototypes
- Accurate and complete requirements (that are traceable to science goals) are very important, especially when placing contracts
- Properly qualify subsystems
- Integrate early!
- Get timely and effective support and maintenance

Conclusions

- The SKA project is one of the largest scientific endeavours in history
  - Unprecedented scale
  - Remote sites
  - Global effort, etc
- It needs mature processes and thorough planning in order to succeed
  - Stakeholder management
  - Project management
  - Standardisation of tools
  - Issue tracking
  - Requirements management
  - Configuration management
  - Change management, etc
- Important to have a common Telescope roll-out vision across the project
- Keep looking at Lessons Learned


Thank You
谢谢