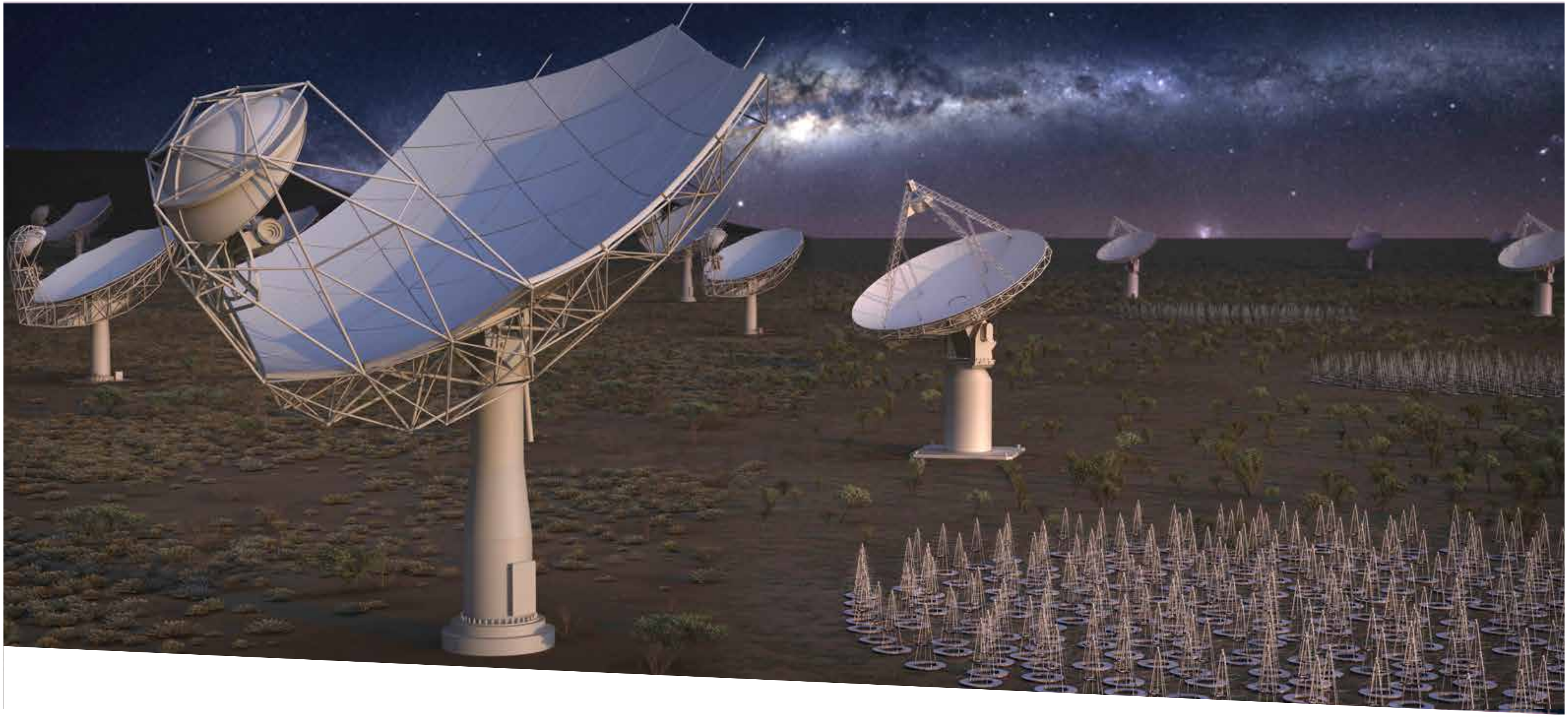
SKA SWG Update



SQUARE KILOMETRE ARRAY

Exploring the Universe with the world's largest radio telescope

Robert Braun, Science Director

13 March 2018

SKA Dish Prototype 06/02/2018

SKA HQ:

€20M project.

Progress: as of March 2018

CDR Activity – Updates

Element	RRN Submission	CDR Submission	CDR Meeting
SaDT & SAT	17 January 2018	28 February 2018	15-18 May 2018
TM	29 January 2018	28 February 2018	17-20 Apr
CSP	05 March 2018 - PSS Sub-Element CDR - PST Sub-Element CDR - CBF-Low Sub-El CDR - CBF-Mid Sub-El CDR	16 April 2018	29 May – 01 June 2018
INAU	19 March 2018	30 April 2018	27-29 June 2018
INSA	19 March 2018	30 April 2018	2-4 July 2018
LFAA	30 March 2018	11 May 2018	16-17 July 2018
System CDR (incl. AIV) close	See Roadmap	See Roadmap	30 March 2019
SDP	17 September 2018	31 October 2018	TBD
DSH	17 September 2018	30 November 2018 (Not confirmed)	07 January 2018 (Not confirmed)

Green: Successful phase
Red: Potential schedule change
Blue: Updated from last report

SKA Observatory Convention

Convention & Tier 1 documents now finalised; released to delegations.

Delegations seeking authority to initial. Aiming for initialing being open in mid-March.

Signing ceremony, Rome, mid-September 2018

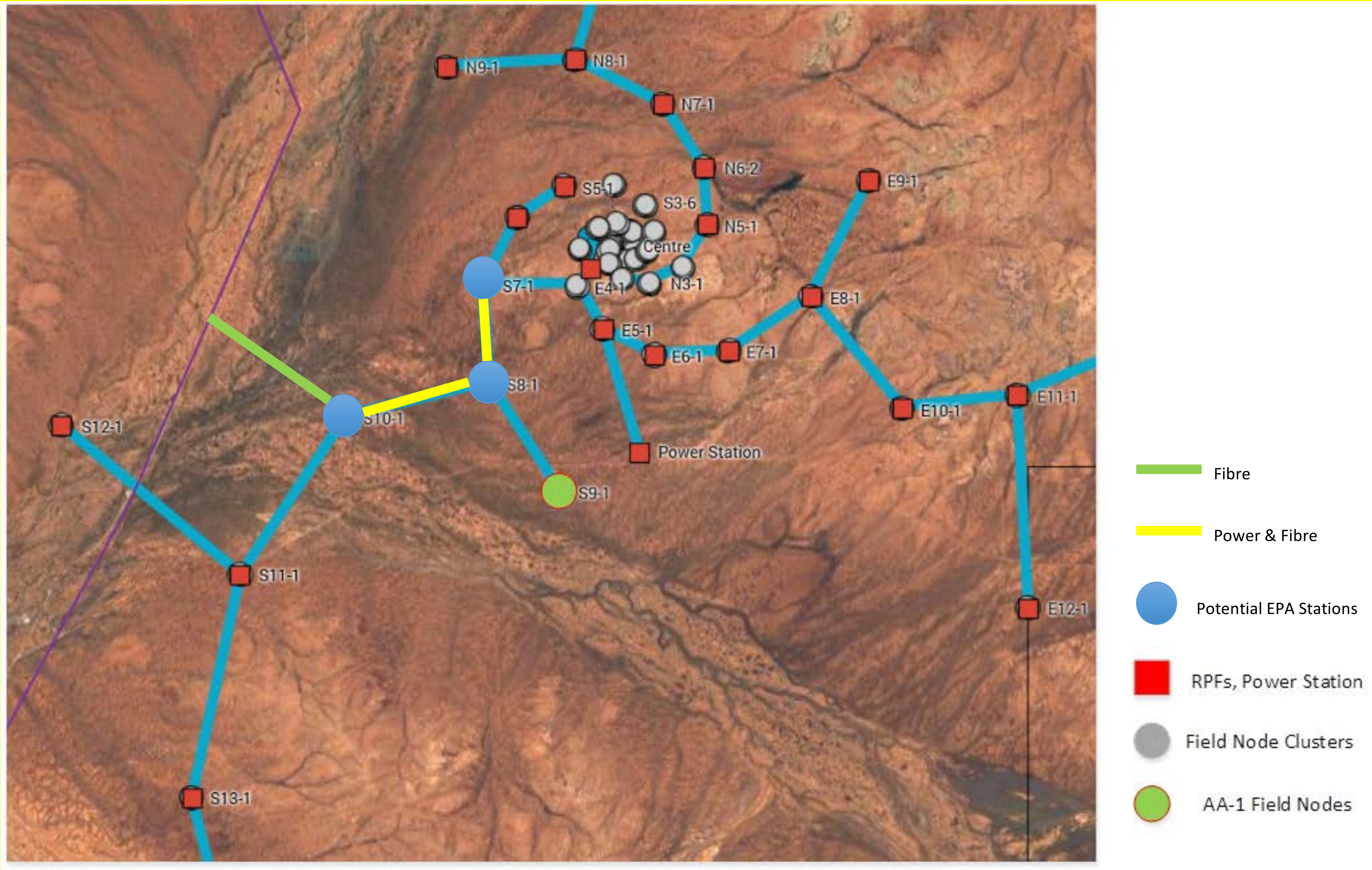
Early Production Arrays (EPAs)

The Early Production Array is intended to be a representative end-to-end system based on the SKA reference design, that is the result of system CDR. The EPA will be a prototype integrated system built on a realistic infrastructure and will be used to:

The objective of the EPA is to reduce the risks associated with the roll-out of the telescope in terms of cost, design and performance.

The impact of the EPA will increase when as many sub-systems as possible (hardware and software) are available for integration into the Early Production Array, even if in rudimentary or prototype form.

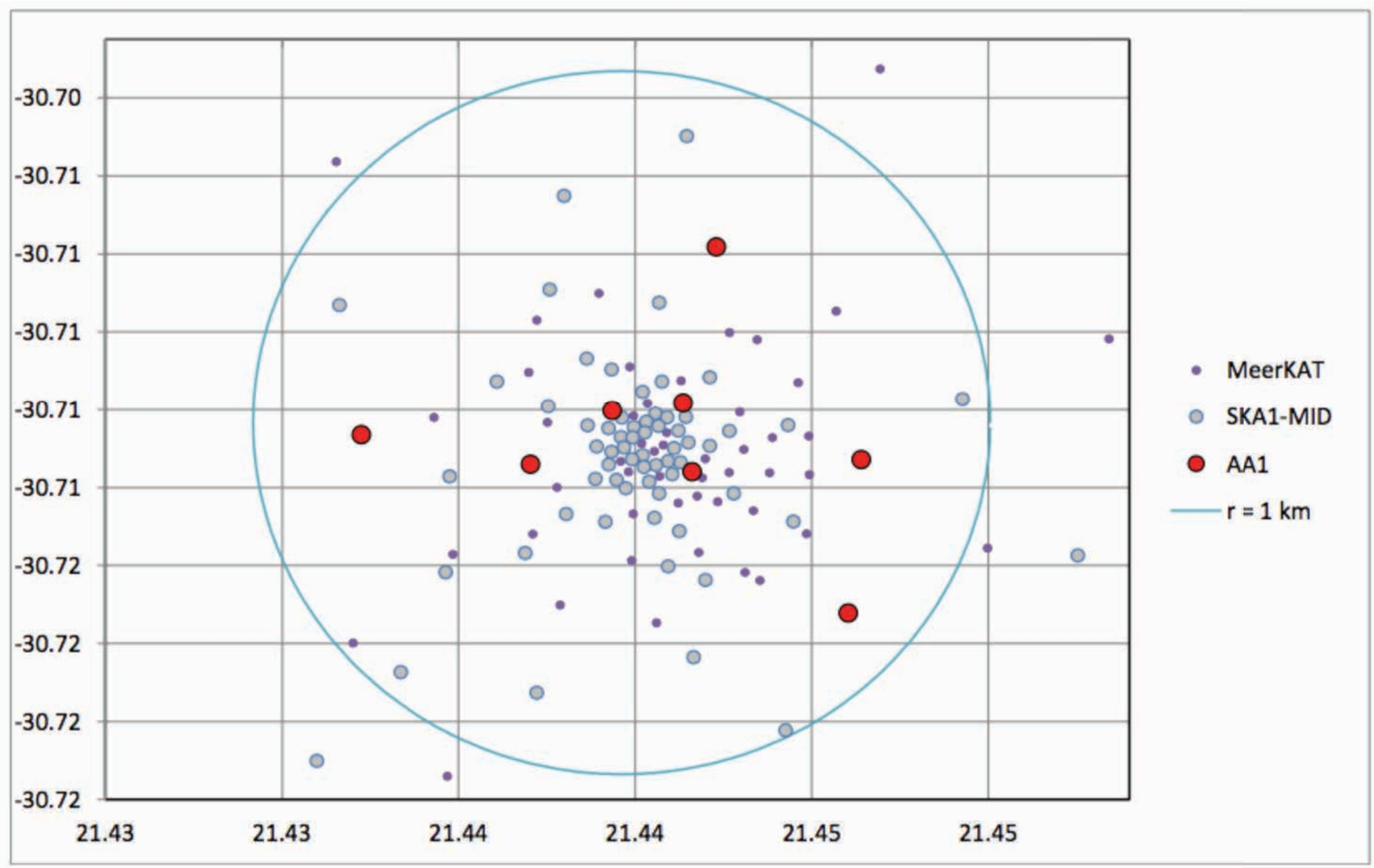
SKA1-Low EPA: Four stations on 3 clump sites



Low EPA Qualification + Verification (subset of AA1)

- Qualification of Antenna design
- Qualification of TPM design
- Qualification of RPF
- Qualification of Frequency Distribution
- Correct operation of POST (Power On Start-up Test), BIT (Built In Test) and alarm handling
- Fine tuning beam steering on the sky
- Manual calibration and beam steering (requires a basic correlator)
- Basic test of beam shape and beam stability (Raster or drift scan)
- Phase closure
- Amplitude closure
- Fringes
- Absolute & relative timing models (SaDT: 1PPS and synchronisation tone)
- Band pass characterisation and calibration (gain flatness over frequency and spurious signals)
- Early performance comparisons against simulations
- Development of methods for managing beam shapes, pointing models, beam rotation
- Basic operational Interface (TM)
- Ability to reliably conduct long observing runs (beam shape, beam stability over seconds, minutes and hours including operational interface stability)
- Interferometric pointing
- Fringe rotation and delay compensation models.
- Basic continuum image
- Basic spectral line Image
- Frequency agility
- Do comparison observations with MWA.

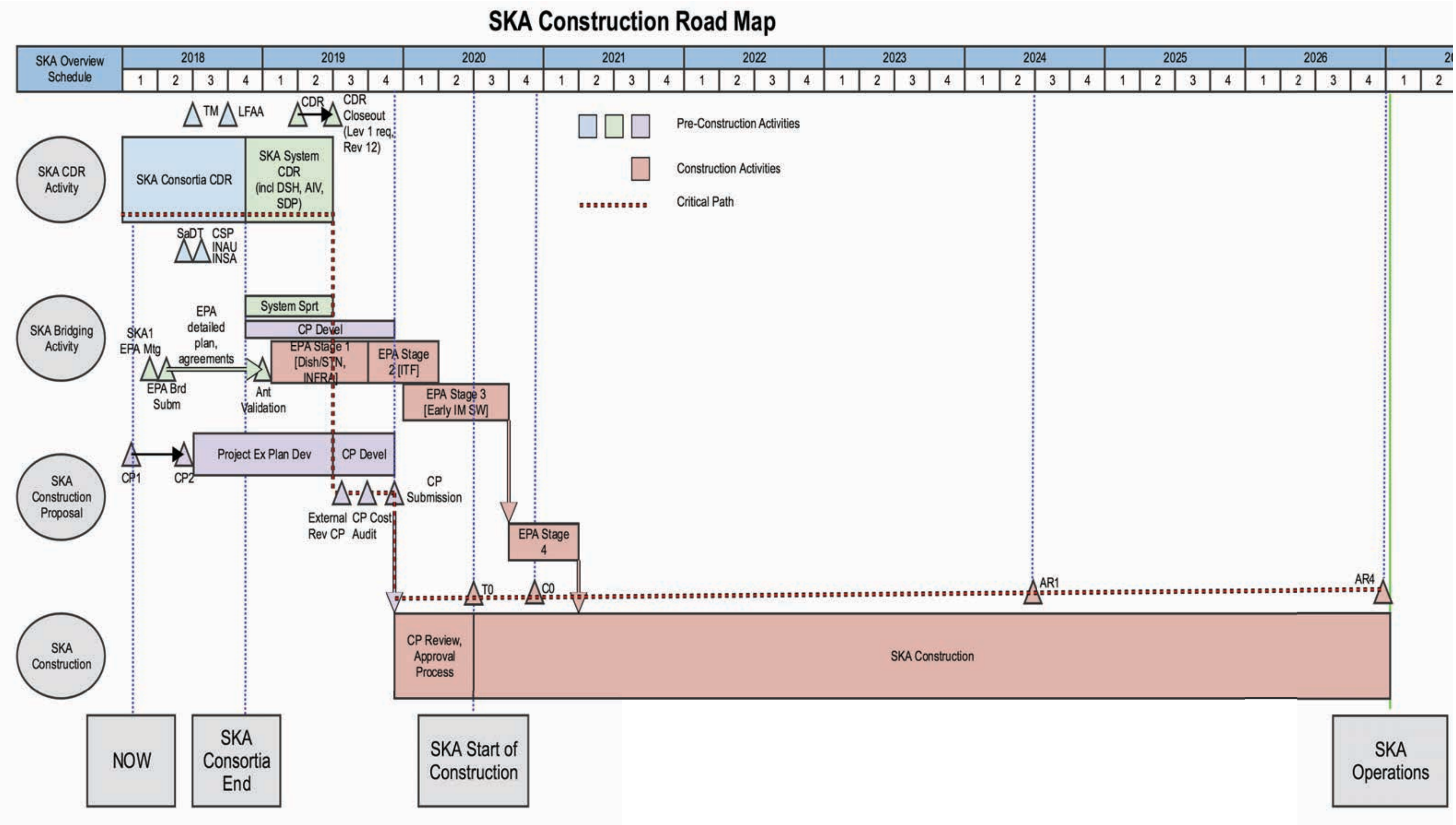
SKA1-Mid EPA: Subset of 4/8 AA1 Dish locations



Mid EPA Qualification + Verification (subset of AA1)

- Verify hardware and software product interfaces
- Verify basic operator interface to control the system and to monitor system health
- Verify the available functionality provided by SaDT NMGR, NSDN and SAT.LMC
- Verify science data link performance between DSH and CSP over direct connection between DSH and CSP
- Verify non-science data link performance between pedestal-located NSDN and MID-CPF-located NSDN
- Verify non-science data connectivity between NSDN and all NSDN-connected equipment at all locations including pedestal, MID-CPF and the Operations Control Centre
- Verify correlator products
- Obtain and verify the Dish pointing model for each Dish, using interferometry
- Obtain the position for each Dish
- Perform delay calibration
- Perform delay tracking
- Perform baseline delay and phase calibration
- Obtaining fringes, phase closure and amplitude closure
- Verify time and frequency reference accuracy and stability using interim CLOCKS solution
- Verify gain and phase stability
- Verify channelisation performance
- Verify frequency agility
- Perform bandpass calibration
- Verify correlator efficiency
- Start measurements of polarization performance
- Start to verify tied-array beamforming functionality
- Verify overall system sensitivity
- Measure antenna voltage patterns and surface accuracy on the sky
- Measure polarization leakage (at least on-axis)
- Verify calibration
- Verify reference pointing
- Verify EMI requirements

High Level Road Map



EPA Scope

- EPA costs are constrained by the value provided to the construction phase (Scenario 3)
- Value assessed through risk mitigation and resultant asset value

Value = [Δ Risk Exposure – Additional Incurred Costs – Additional Risks] + Asset Value

Δ Risk Exposure =
$\sum$ (Risk Exposure)$_{\text{Construction (Monte Carlo 80\% probability)}}$ –
$\sum$ (Risk Exposure with EPA) $_{\text{Construction (Monte Carlo 80\% probability)}}$
= Risk Reduction due to EPA activity

Note:

Additional Incurred Costs of EPA: e.g., limited production increased costs, additional mobilization/demobilization, earlier staff ramp up); note assumes construction value handles the tax implications of pre-IGO activity.

Additional Risks incurred due to EPA: e.g., higher costs due to assigned rather than competed contracts, incomplete understanding of system design (if initiated before system CDR completion).

EPA Scope

Value = [Δ Risk Exposure – Additional Incurred Costs/Risks] + Assets

Δ Risk Exposure = 115M€ – 84M€ = 31M€ (from M.C. analysis)

Additional Incurred Costs/Risks = ~ 10 M€ (needs review)

Asset Value: Construction WBS Costing = ~20M€

Value = ~ 41 M€ for total EPA Activity

- Amounts to "early" expenditure of contingency budget of ~20M€ if undertaken at this scope

SKA1 HPC Requirements

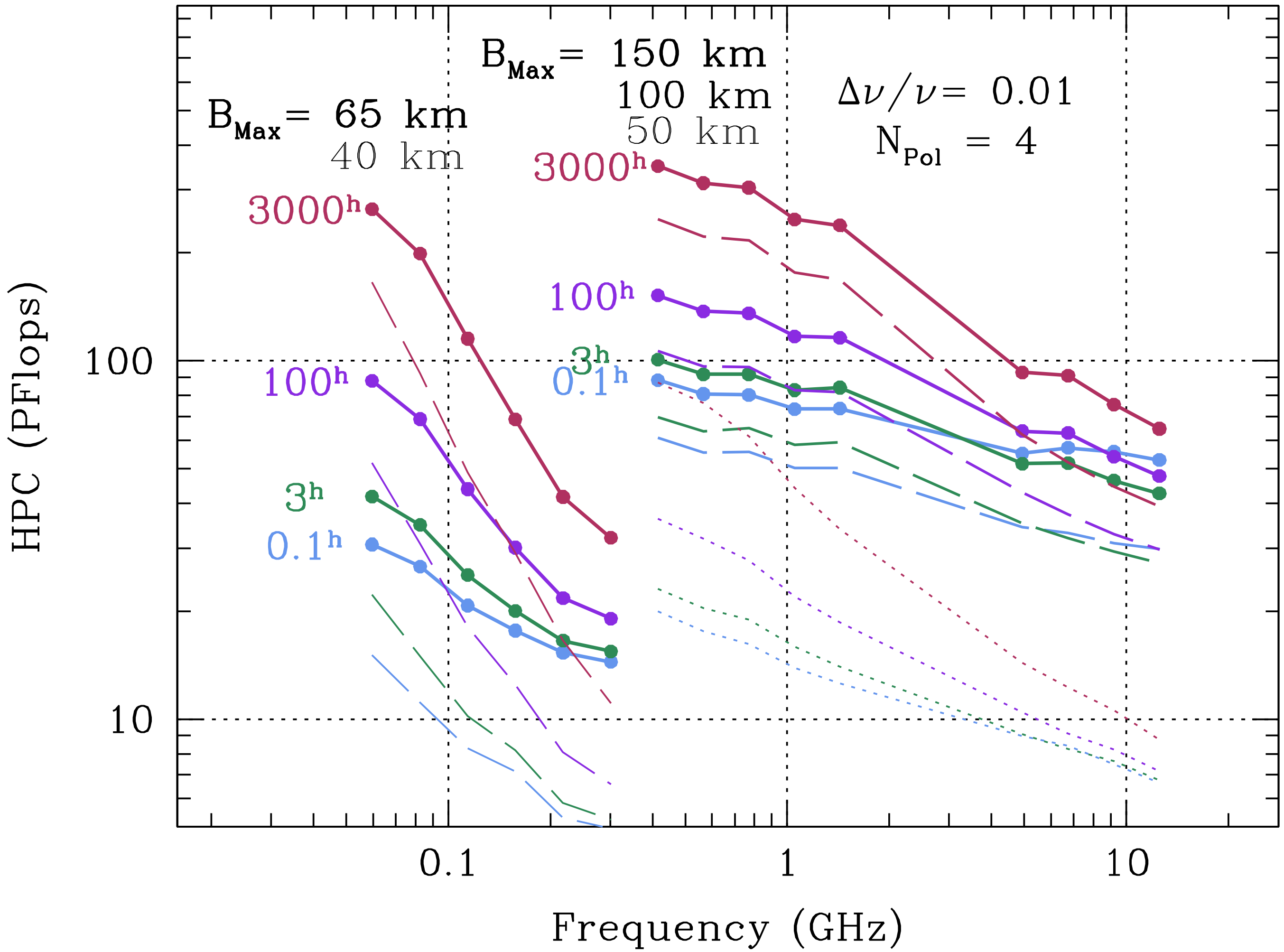
- SDP Parametric Model key parameters:
  - Use-Case Parameters: B_{Max}, ν_{Min} and ν_{Max}, T_{Point} (**total** depth for pointing)
  - Calibration Parameters: N_{Ateam}, N_{Source}, $N_{SelfCal}$, N_{Major}, $N_{Ipatches}$ all are strong functions of (B_{Max}, ν and T_{Point})
  - Model presented in draft document for functional dependence of the Calibration parameters on the Use-case parameters

SKA1 HPC Requirements

ν_{min} (GHz)	ν_c (GHz)	ν_{max} (GHz)	Sub-band	Band	σ_c (μJy/Bm)	θ'_{min} (")	θ_{min} (")	θ_{max} (")	θ'_{max} (")
0.050	**0.060**	**0.069**	Low sb1		163	16.4	23.5	1175	3290
0.069	**0.082**	**0.096**	Low sb2		47	11.9	17.0	850	2379
0.096	**0.114**	**0.132**	Low sb3		26	8.6	12.3	614	1719
0.132	**0.158**	**0.183**	Low sb4		18	6.2	8.9	444	1244
0.183	**0.218**	**0.253**	Low sb5		14	4.5	6.4	321	899
0.253	**0.302**	**0.350**	Low sb6		11	3.3	4.6	232	650
0.35	**0.41**	**0.48**	Mid sb1	B1	16.8	1.015	2.031	270.8	541.6
0.48	**0.56**	**0.65**	Mid sb2	B1	8.1	0.745	1.489	198.6	397.2
0.65	**0.77**	**0.89**	Mid sb3	B1	4.4	0.546	1.092	145.6	291.2
0.89	**1.05**	**1.21**	Mid sb4	B2	2.7	0.400	0.801	106.8	213.5
1.21	**1.43**	**1.65**	Mid sb5	B2	2.0	0.294	0.587	78.3	156.6
1.65	**1.95**	**2.25**	Mid sb6		1.6	0.215	0.431	57.4	114.9
2.25	**2.66**	**3.07**	Mid sb7		1.4	0.158	0.316	42.1	84.2
3.07	**3.63**	**4.18**	Mid sb8		1.6	0.116	0.232	30.9	61.8
4.18	**4.94**	**5.70**	Mid sb9	B5a	1.4	0.085	0.170	22.7	45.3
5.70	**6.74**	**7.78**	Mid sb10	B5a	1.3	0.062	0.125	16.6	33.2
7.78	**9.19**	**10.61**	Mid sb11	B5b	1.2	0.046	0.091	12.2	24.4
10.61	**12.53**	**14.46**	Mid sb12	B5b	1.2	0.034	0.067	8.9	17.9

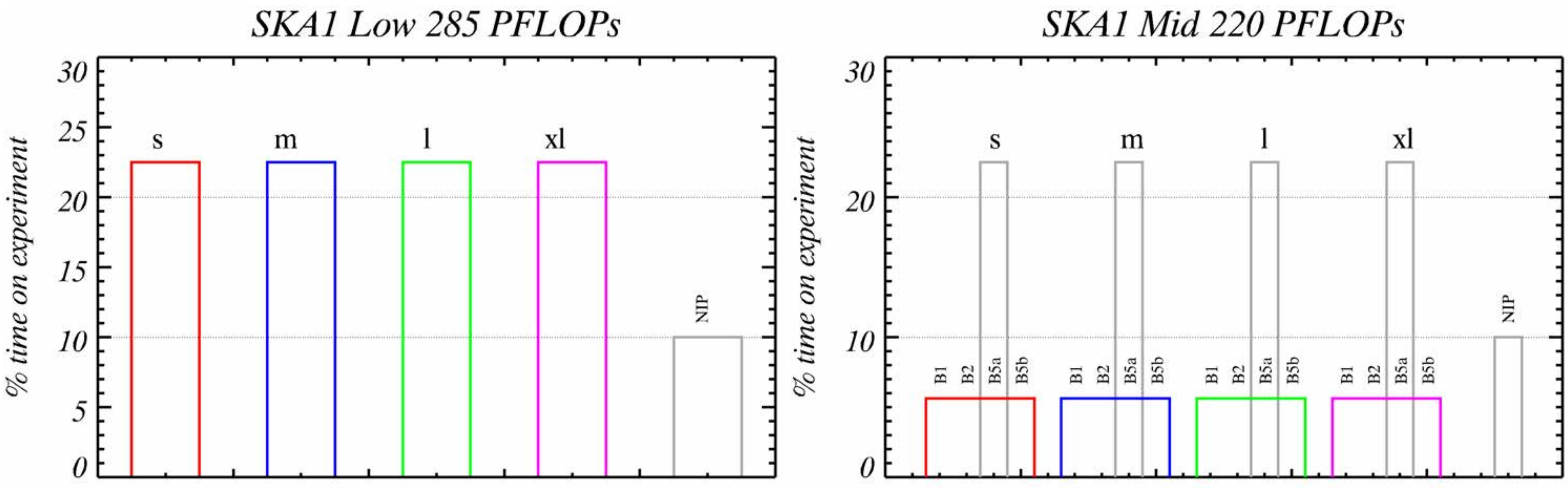
- Frequency sub-band definitions for use-case study

SKA1 HPC Requirements



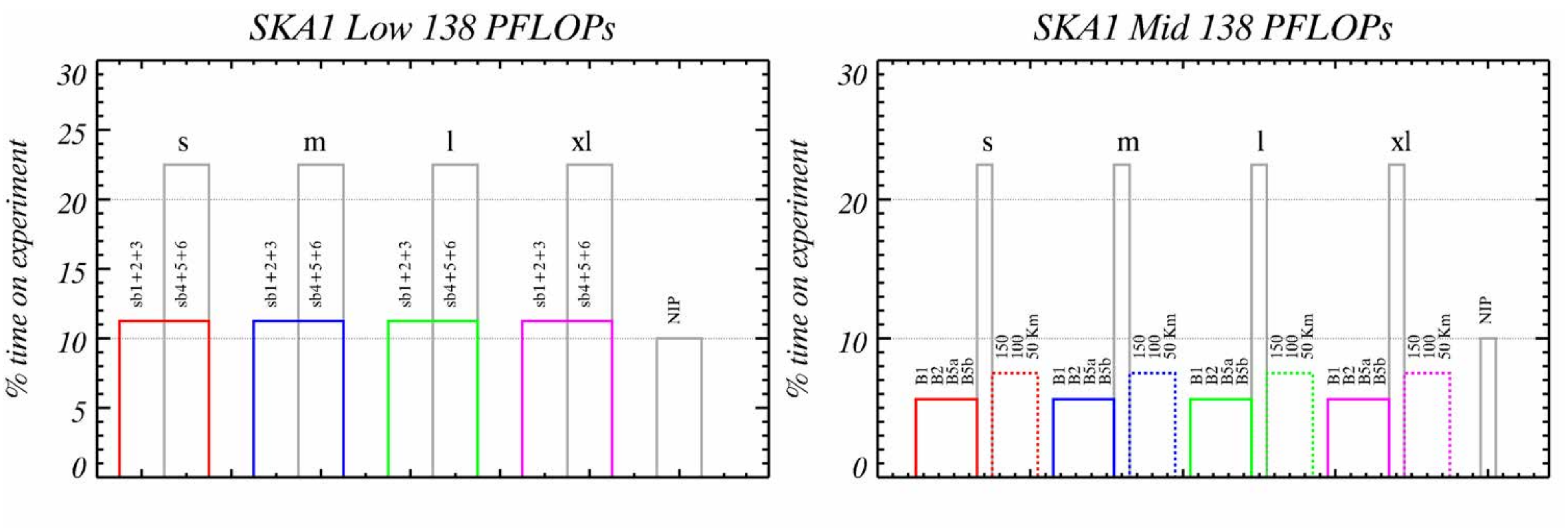
- Derived HPC load as function of (B_{Max}, ν, T_{Point})

SKA1 HPC Examples



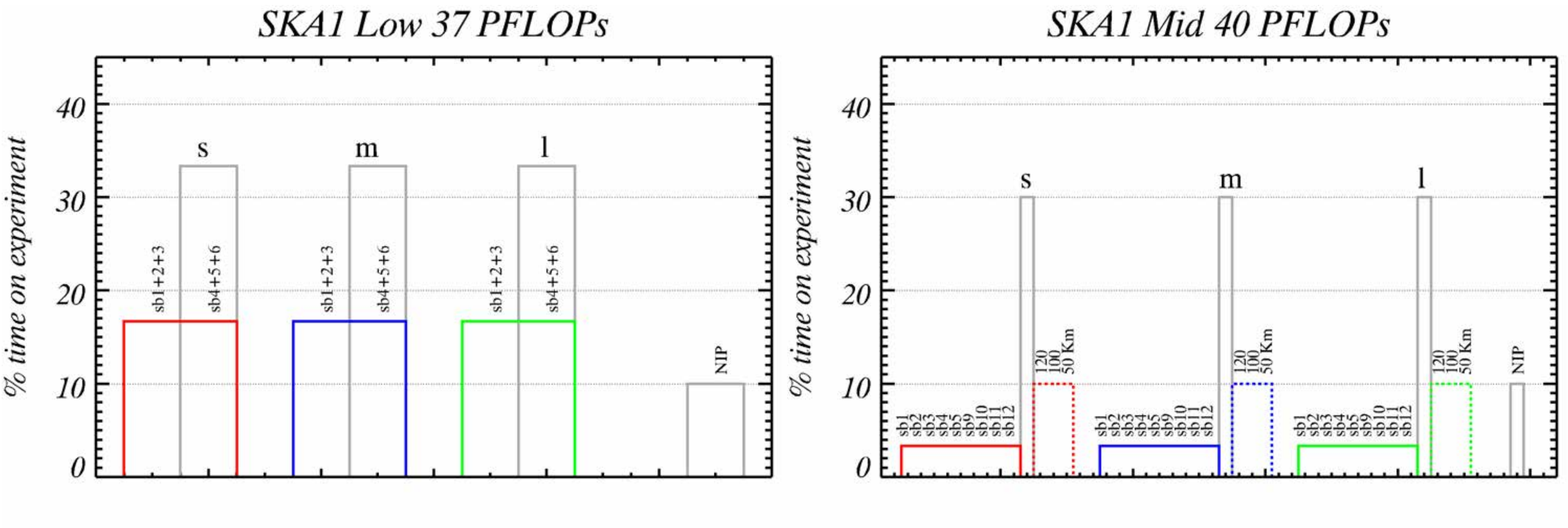
- Uniform mix of T_{Point} and Freq Bands with maximum B_{Max}
- Interesting target for combined HPC of steady-state SKAO plus SRC network – permits full commensality

SKA1 HPC Examples



- Uniform mix of T_{Point} and Freq (sub-)Bands with variable B_{Max} for Mid
- Good target for general use-case mix in steady-state SKAO operations = HPC deployment in current Design Baseline

SKA1 HPC Examples



- Uniform mix of T_{Point} (excluding “xl”) and Freq. sub-Bands with variable B_{Max} for Mid
- Possibly adequate to support interesting mix of use-cases in an SKAO early operations phase

SKA1 HPC Caveats

- Computational efficiency assumed to be 10%; could be better, might be worse
- Better representation of Direction Dependent Calibration methods needed in Parametric model
- HPC costs completely dominated by DFT; could be reduced with partial FFT usage; could be implemented with much higher than 10% efficiency
- Still need calibration against real-life HPC needs for large VLA and LOFAR use-cases

SKA Science for 15 – 50 GHz ?

- Current indications are that interesting dish and site performance are likely to extend up to about 50 GHz
- Existing cryo-stat design offers capacity for additional feed systems
- How might one go about exploring realisation of such possibilities?

SKA Science for 15 – 50 GHz ?

- Natural place for study of SKA upgrades within context of the “Observatory Development Programme”
  - Anticipated budget of 20 M€/year to co-fund R&D of new instrumentation option proposals
  - Anticipate R&D for 15 – 50 GHz, 2 – 5 GHz, PAFs, etc.
- Once various R&D efforts have led to mature designs a science trade-off amongst such options could be undertaken
- Upgrade proposal could then be made to SKAO Council

Upcoming Meetings

- SKA Key Science Project Workshop, SKA HQ, ~~3 – 7 September 2018~~
  - "New Science enabled by New Techniques in the SKA Era"
  - Readiness of new SKA Meeting Room and catering area for these dates viewed as too unlikely
  - Would need to charge £300+ conference fee to (partially) cover additional venue rental costs
- New provisional meeting dates 8 – 12 April 2019
  - Conference fee cap $\lesssim$ £200

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