https://linktr.ee/cosmicpudding

The quest for an autonomous ASKAP Automating the next-generation of survey telescopes

IMAGE CREDIT: A. CHERNEY

CSIR

Vanessa Moss Head of ASKAP Science Operations



#TFOM





Acknowledgement of country

Wajarri

5.A

Dharug

Ngambri

Wallumedegal

Noongar





Overview of this talk

- Introduction: ASKAP and its location at MRO
- **ASKAP Surveys:** From EMU to FLASH to RACS
- Context of ASKAP: History and future of ATNF
- Automating ASKAP: Towards autonomy in ASKAP operations
 - **Coordination:** working cross-country to run ASKAP
 - **Specification:** designing ASKAP to be autonomous
 - Initialisation: the role of automation in setting up ASKAP
 - **Diagnosis:** identifying issues in a complex system
 - Monitoring: from data mining to collaborative intelligence
 - **Processing:** turning terabytes of visibilities into science
- **Summary:** The path to the future of ASKAP

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n at MRO H to RACS

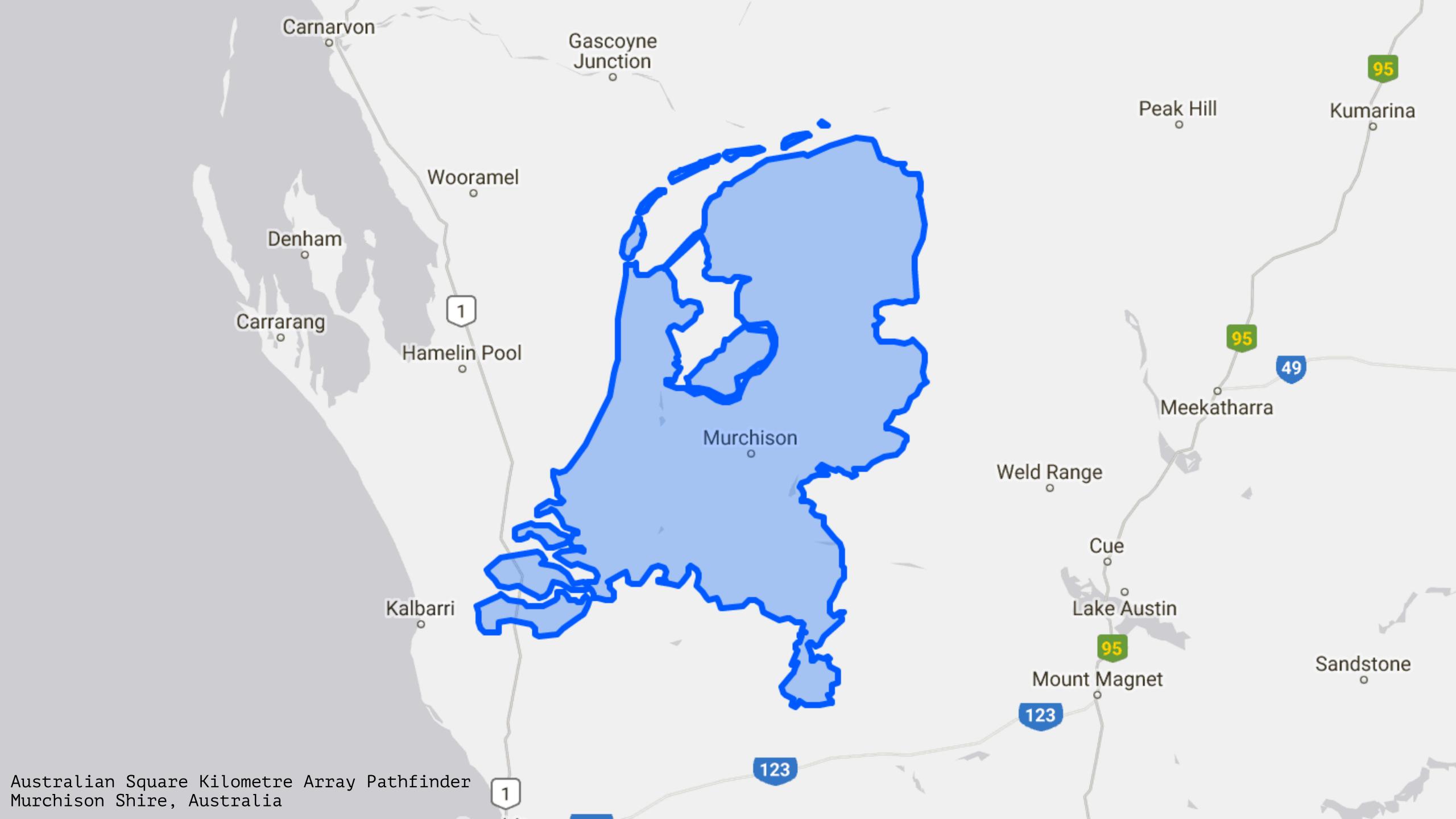
ASKAP omous ing up ASKA vstem

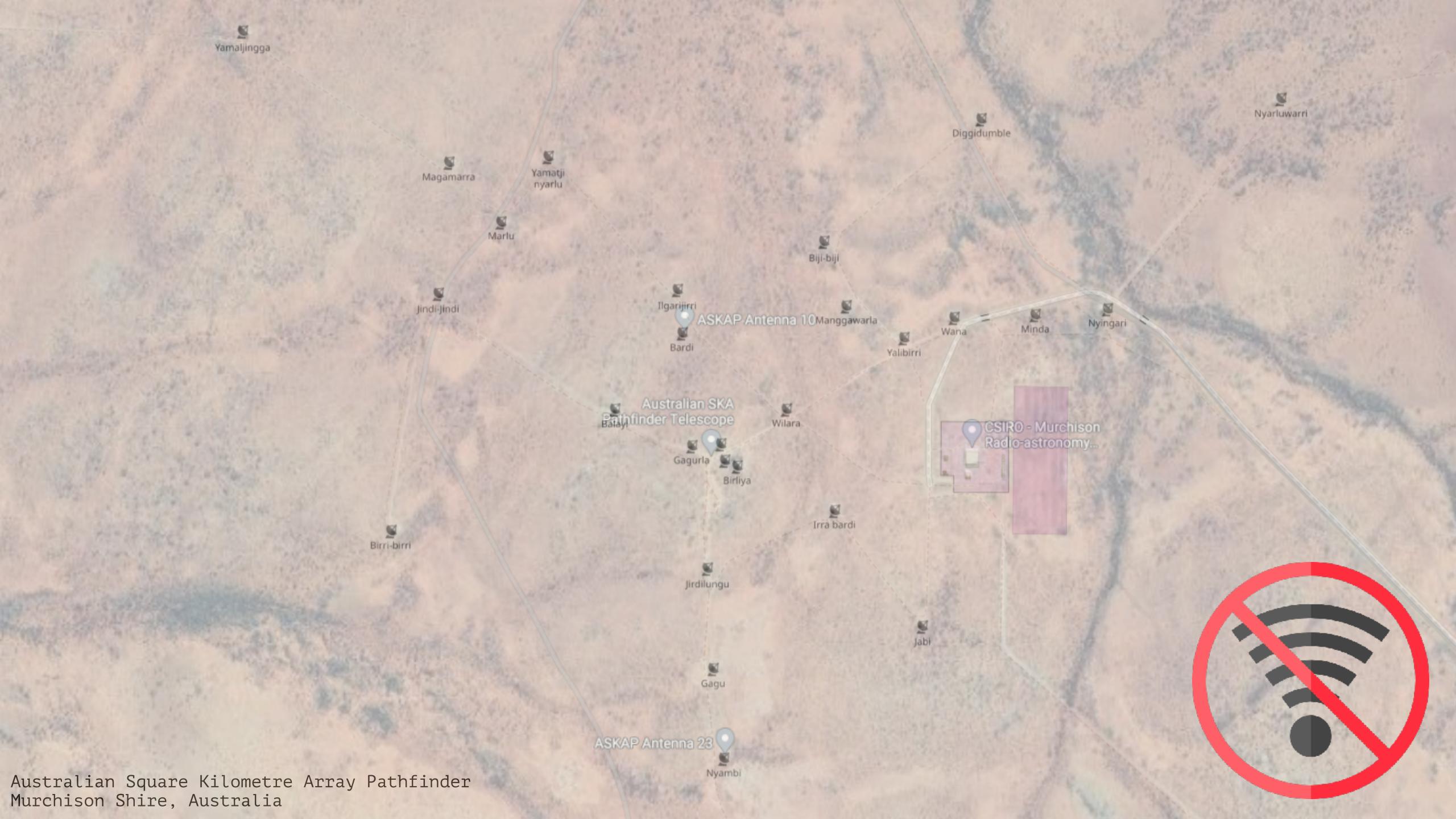


Part I: Introduction ASKAP and its location at MRO

IMAGE CREDIT: B. HISCOCK







Australian Square Kilometre Array Pathfinder ASKAP

HOTAN+ 2021, ARXIV 2102.01870



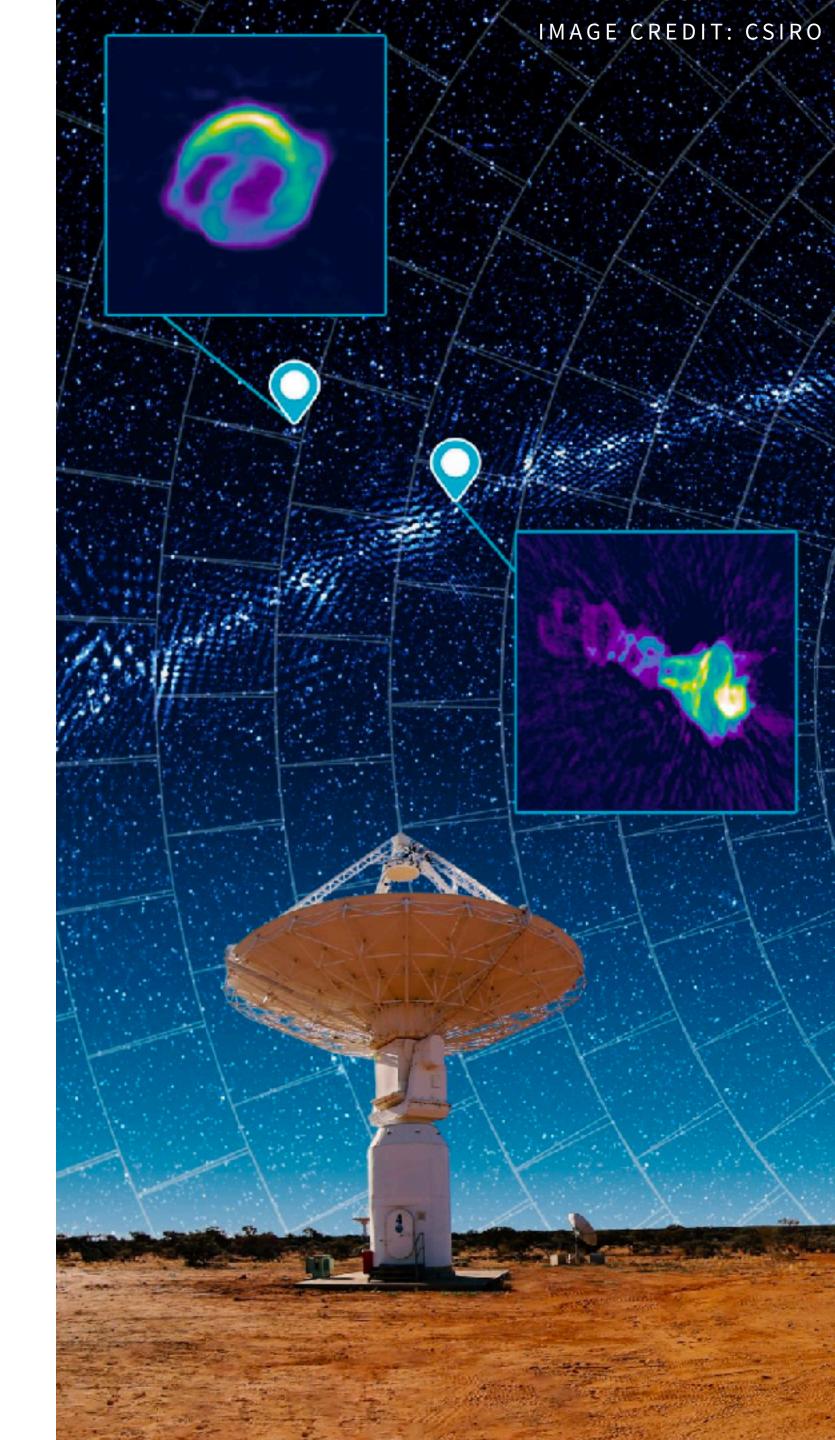
 Table 1 Key parameters of the ASKAP telescope.

Number of antennas	36
Antenna diameter	$12\mathrm{m}$
Focal ratio f/D	0.5
Total collecting area	$4071.5\mathrm{m^2}$
Maximum baseline	$6\mathrm{km}$
Angular resolution	$10^{\prime\prime}$ at $1{\rm GHz}$
Observing frequency	$0.7 ext{ to } 1.8 ext{ GHz}$
Processed bandwidth	$288\mathrm{MHz}$
Frequency channels	15552
Frequency resolution	$18.5 \mathrm{kHz}$ to 0.581
Effective system temperature	$75\mathrm{K}$
Sensitivity	$54\mathrm{m}^2/\mathrm{K}$
Dual-polarisation beams	36
Field of view ^a (800 MHz)	$31{ m deg^2}$
Field of view ^a (1700 MHz)	$15 \mathrm{deg^2}$
Survey speed ^b (800 MHz)	$91400{ m m}^4{ m deg}^2{ m K}$
Survey speed ^b (1700 MHz)	$44200{ m m}^4{ m deg}^2{ m K}^2$

See <u>www.atnf.csiro.au/projects/askap</u> for the latest updates!



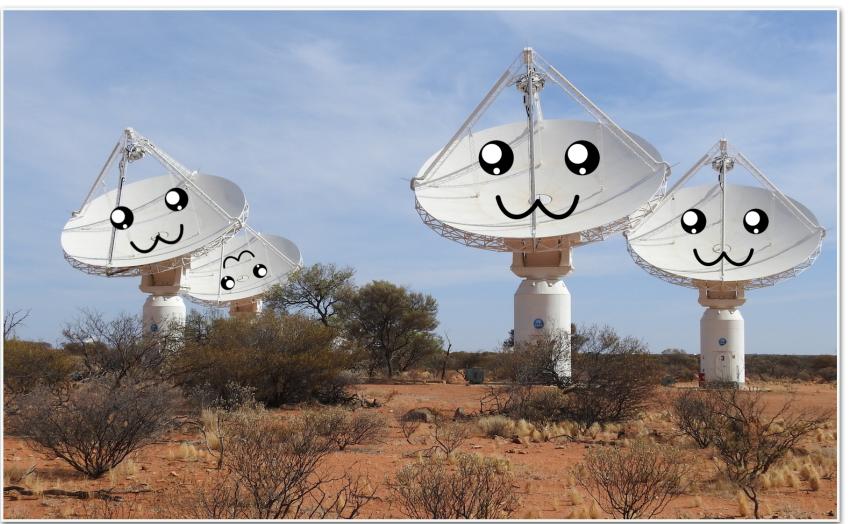
Part II: ASKAP Surveys From EMU to FLASH to RACS



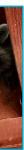
What are the ASKAP Surveys?

- ASKAP was conceived and designed to be a rapid survey instrument and will spend the majority of its time doing all-sky surveys
- Nine active **ASKAP Survey Science Projects**: EMU, WALLABY, POSSUM, DINGO, CRAFT, VAST, GASKAP-HI, GASKAP-OH and FLASH
- Two **Observatory Projects**: RACS and SWAG-X
- Guest science time will be capped to ~10% and become available over the next 1-2 years
- There is some limited capacity for **target-ofopportunity** observations, which are supported in collaboration with existing ASKAP SSTs









What are the ASKAP Surveys?



Evolutionary Map of the Universe



Widefield ASKAP L-Band Legacy All-Sky Blind Survey



Commensal Real-time ASKAP Fast Transients

10% guest science

SciOps 2022 (V. Moss)



An ASKAP Survey for Variables and Slow Transients

TOOs

FAINT HI

Deep Investigations of Neutral Gas Origins

(DINGO)

HIABSORPTION

First Large Absorption Survey in HI The First Large Absorption Survey in HI

POLARISATION SKY SURVEY OF THE UNIVERSE'S MAGNETISM

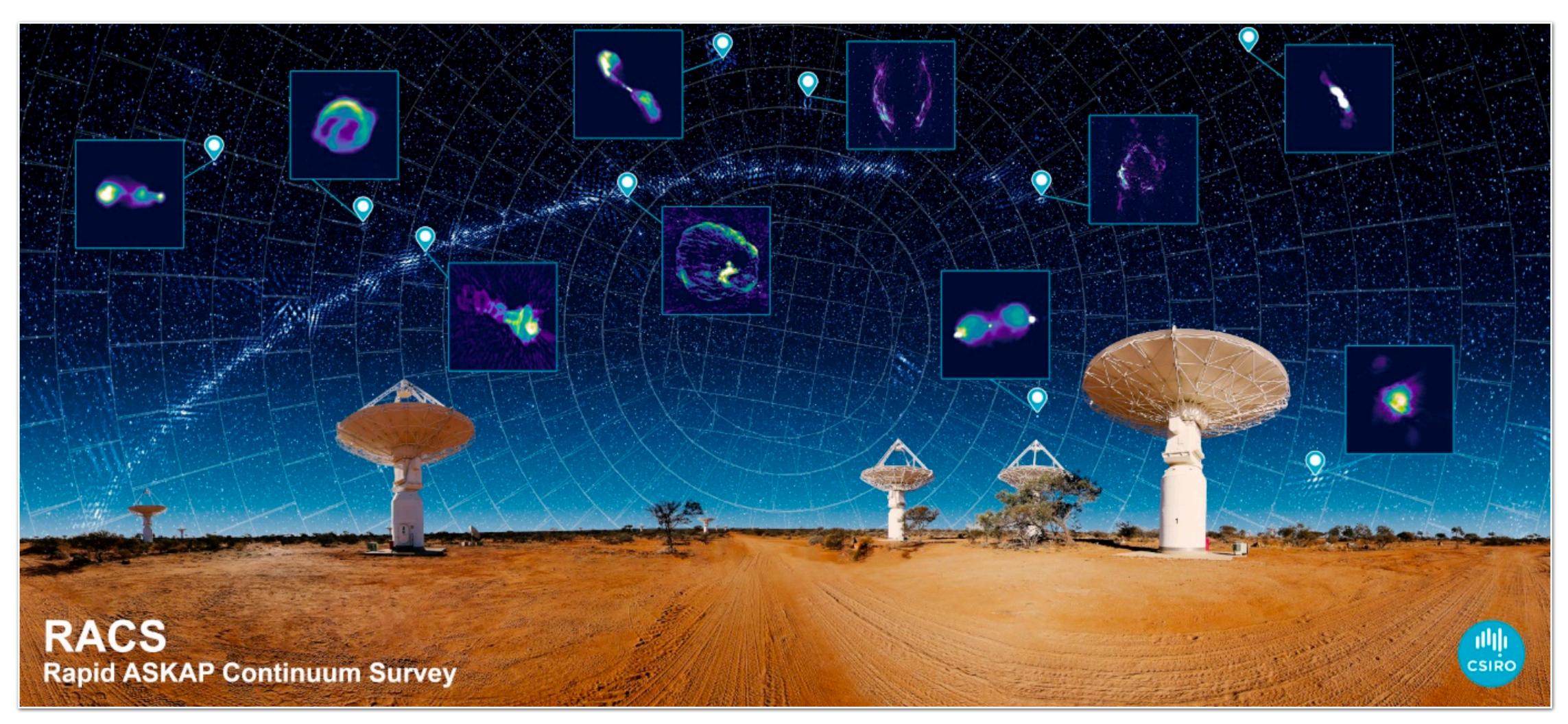
Polarization Sky Survey of the Universe's Magnetism



The Galactic ASKAP Spectral Line Survey



Rapid ASKAP Continuum Survey



SEE: <u>HTTPS://RESEARCH.CSIRO.AU/RACS</u>

09

ASKAP SURVEYS COMMENCE

Launch multi-year observing campaigns based on pilot surveys

08

COMPLETE PHASE II PILOT SURVEYS

Test a combined survey strategy that maximises efficiency

07

COMPLETE PHASE I PILOT SURVEYS

Release data that meets international science team standards

Counting down to the launch of ASKAP 36 full

csiro.au/ASKAP

CSIRO

06

COMPLETE A RAPID ALL-SKY SURVEY Release data from the Rapid ASKAP Continuum Survey project

IMAGE: CSIRO

01

FRINGES BETWEEN ALL ANTENNAS

Verify that all antennas function as an interferometer

02

SINGLE-BEAM IMAGE Test phase stability and array calibration

03

MULTI-BEAM IMAGE Test ASKAP's processing pipeline

survey science

04

IMAGE OF A

COMPLEX FIELD

Test ASKAP on a

challenging part

of the sky

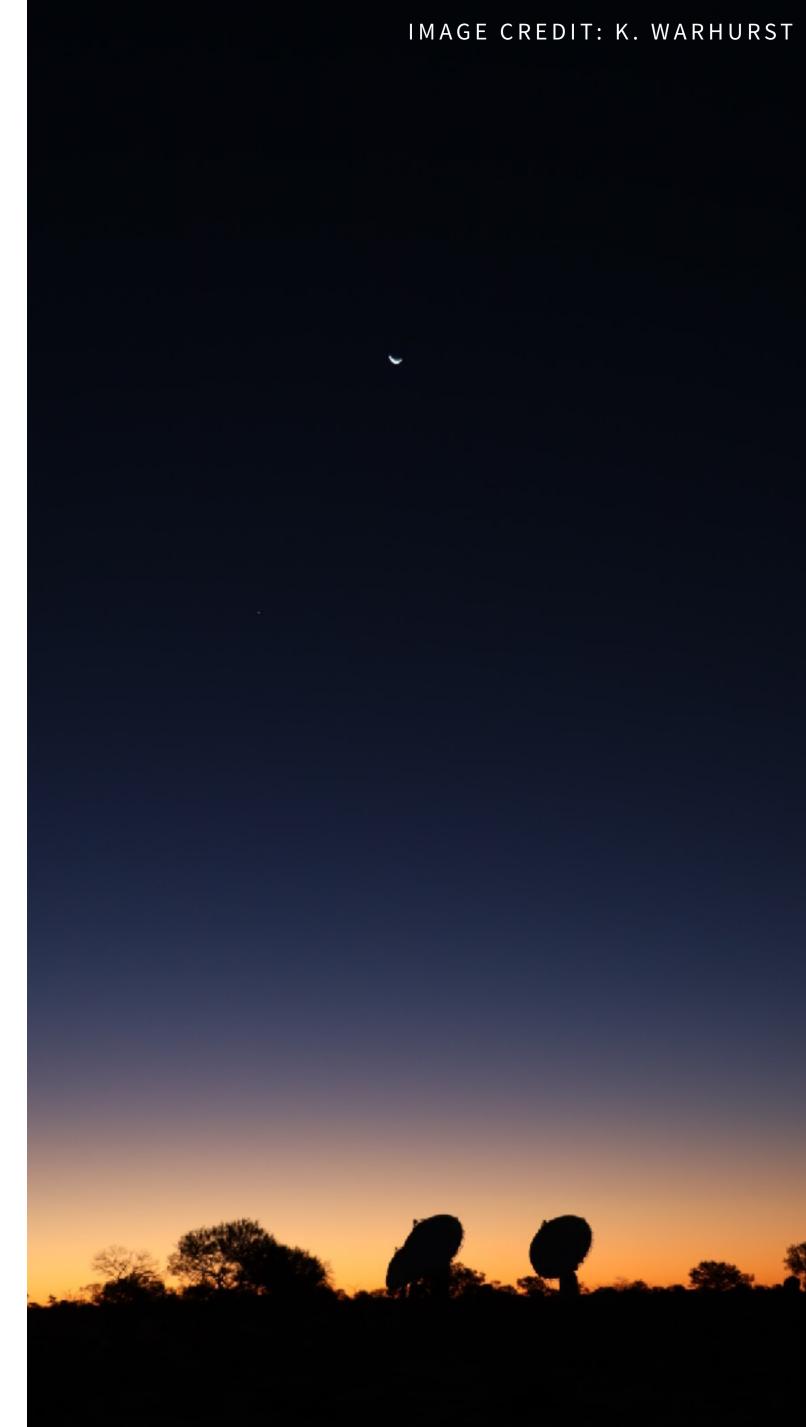
05 **OBSERVE SCIENCE** TEST FIELDS

Demonstrate performance using fields of scientific interest

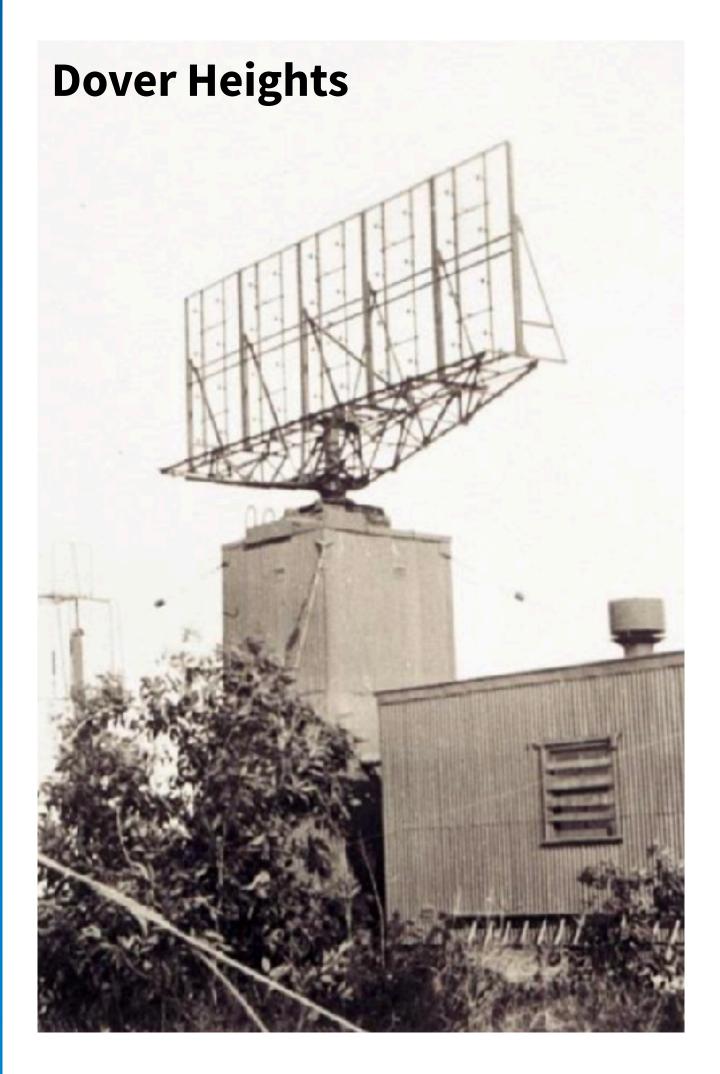


Part III: Context of ASKAP History and future of ATNF

IMAGE CREDIT: K. WARHURST



History and evolution of the ATNF







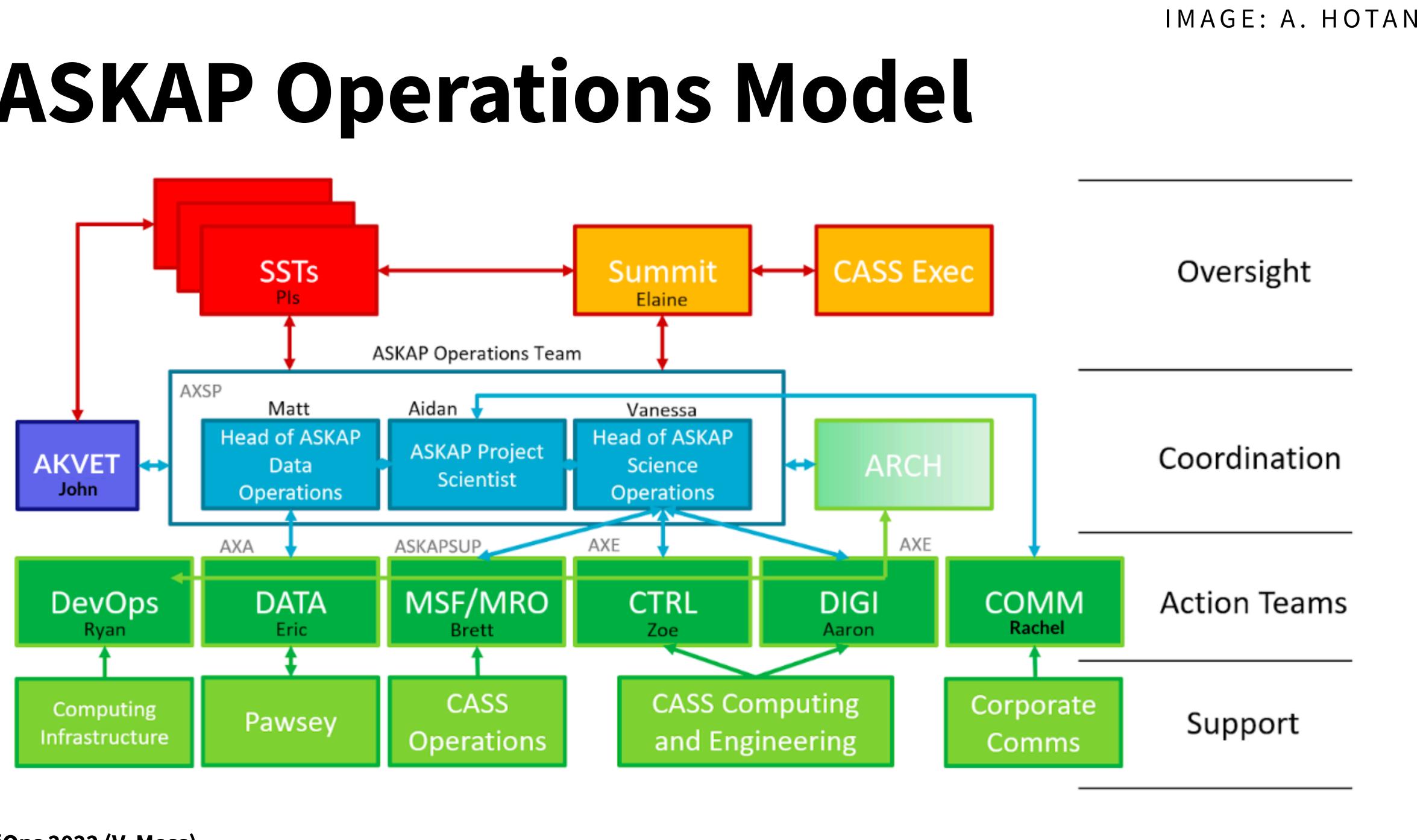
SciOps 2022 (V. Moss)



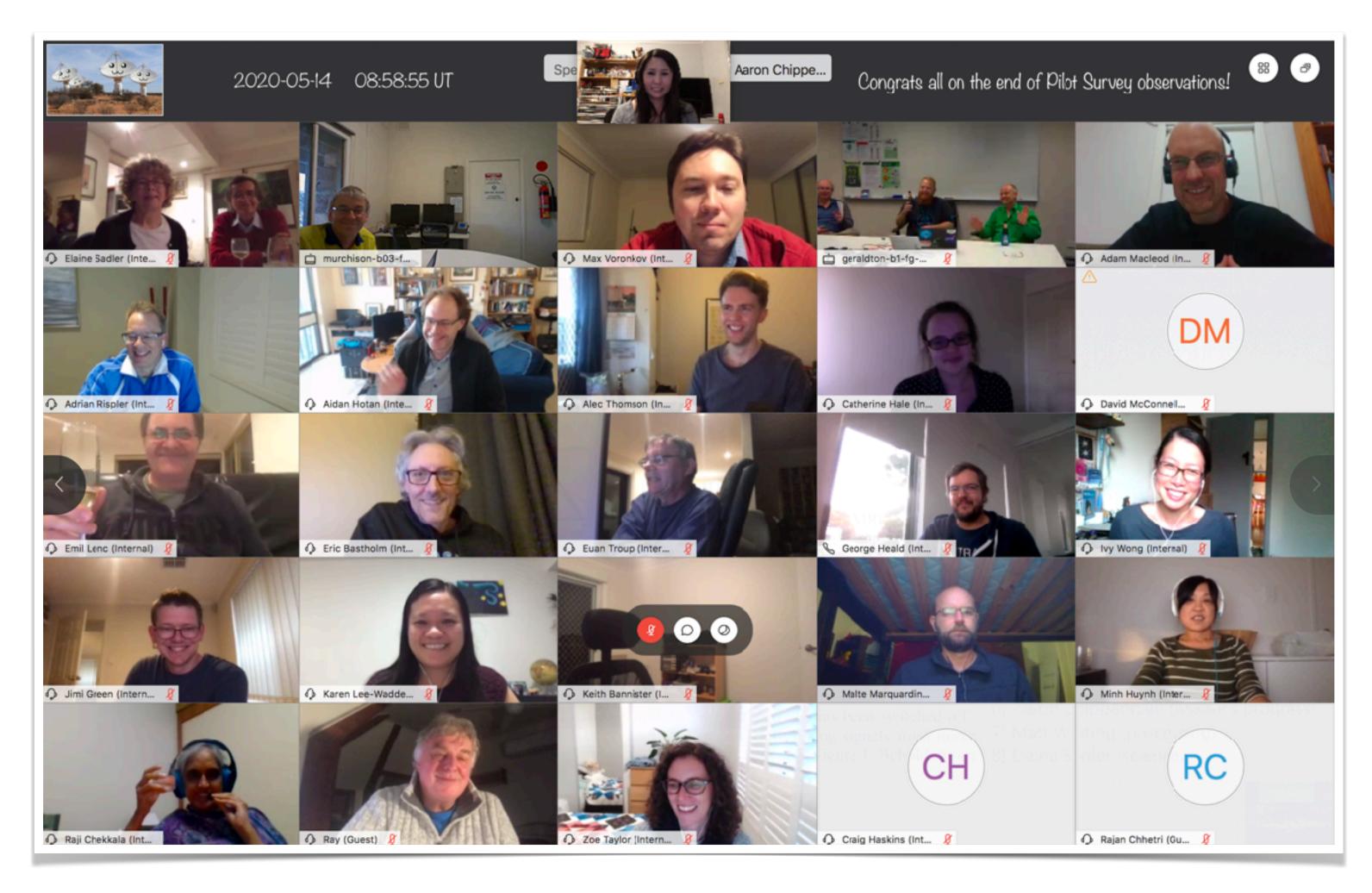
IMAGES: CSIRO, V. MOSS, S. AMY, SKAO

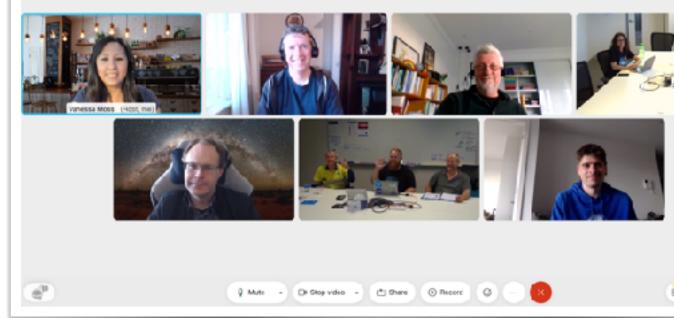


ASKAP Operations Model



Distributed nature of the team









Remoteness of the site

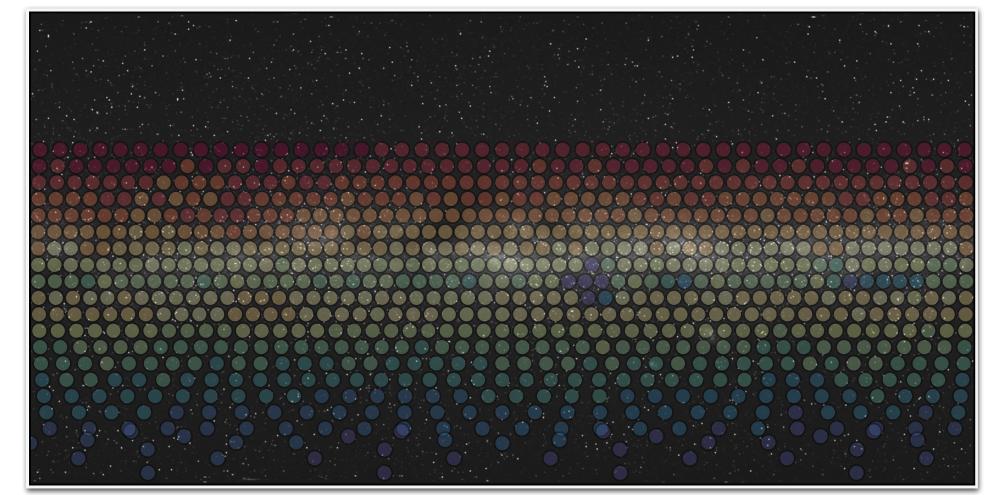


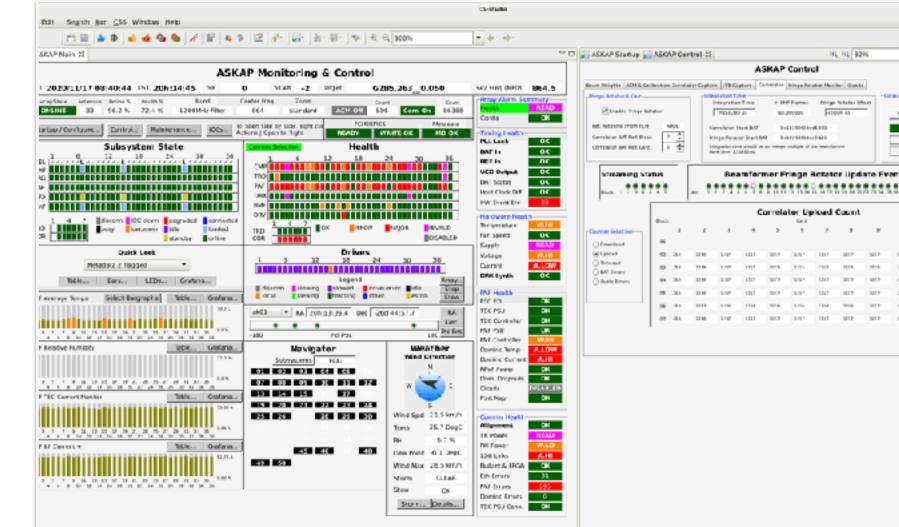
Part IV: Automating ASKAP Towards autonomy in ASKAP operations



ASKAP: the role of autonomy

- Australia is relatively **unique** with a long history of astronomers being in charge directly of ATNF telescopes (e.g. no operator model)
- ASKAP is designed to be a **high-efficiency** survey instrument, without direct supervision and without staff on site for significant periods
- As we transition from commissioning to survey operations, we are seeking to **minimise** the role of the human to where it is best invested
- This has **parallels** with the transition from remote operations to remote management, as well as remote-controlled **robotic telescopes**

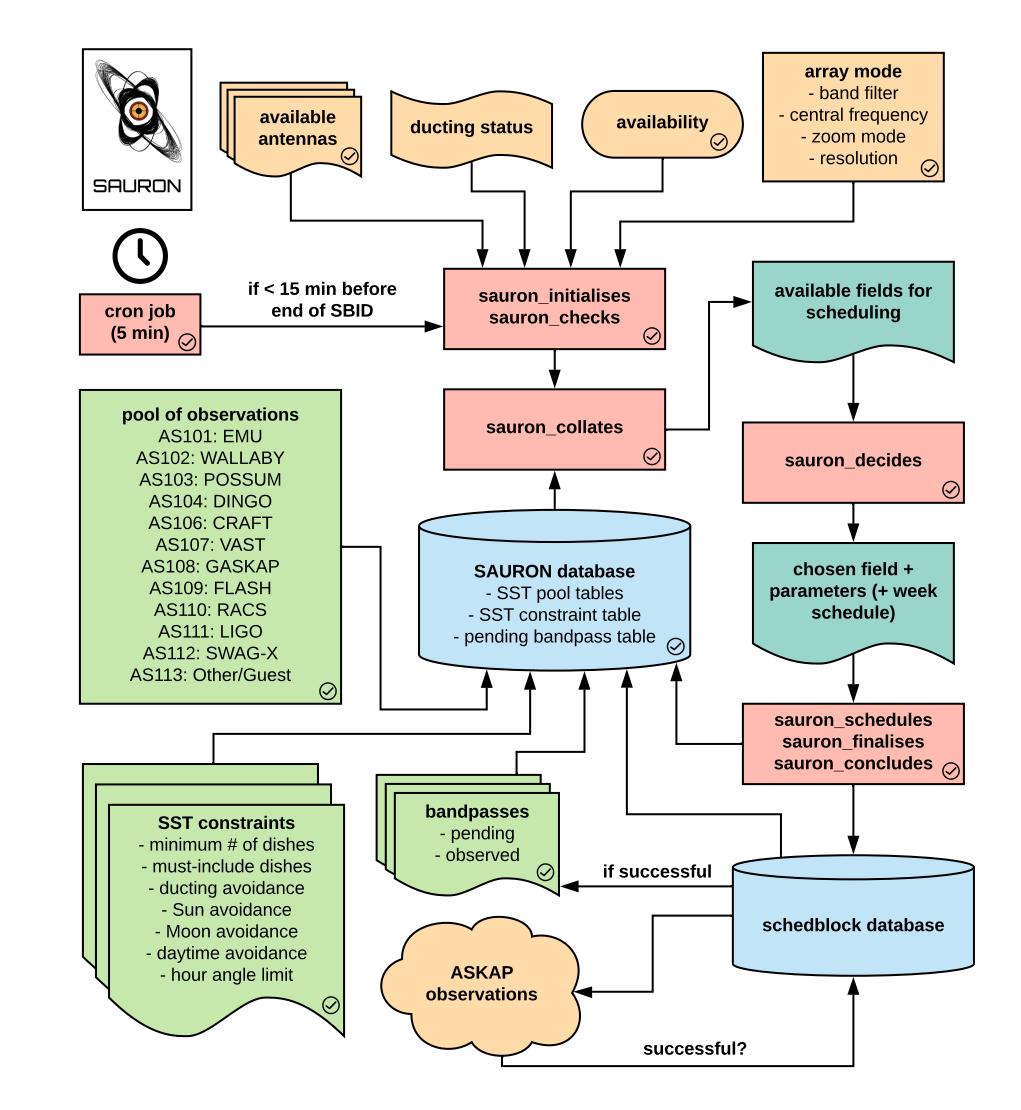




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J2 J3 J2 + 327 2.23 1314 919 2.3 1211 329 2.3 1211 919 2.3 1211 919 2.3 1211 919 2.3
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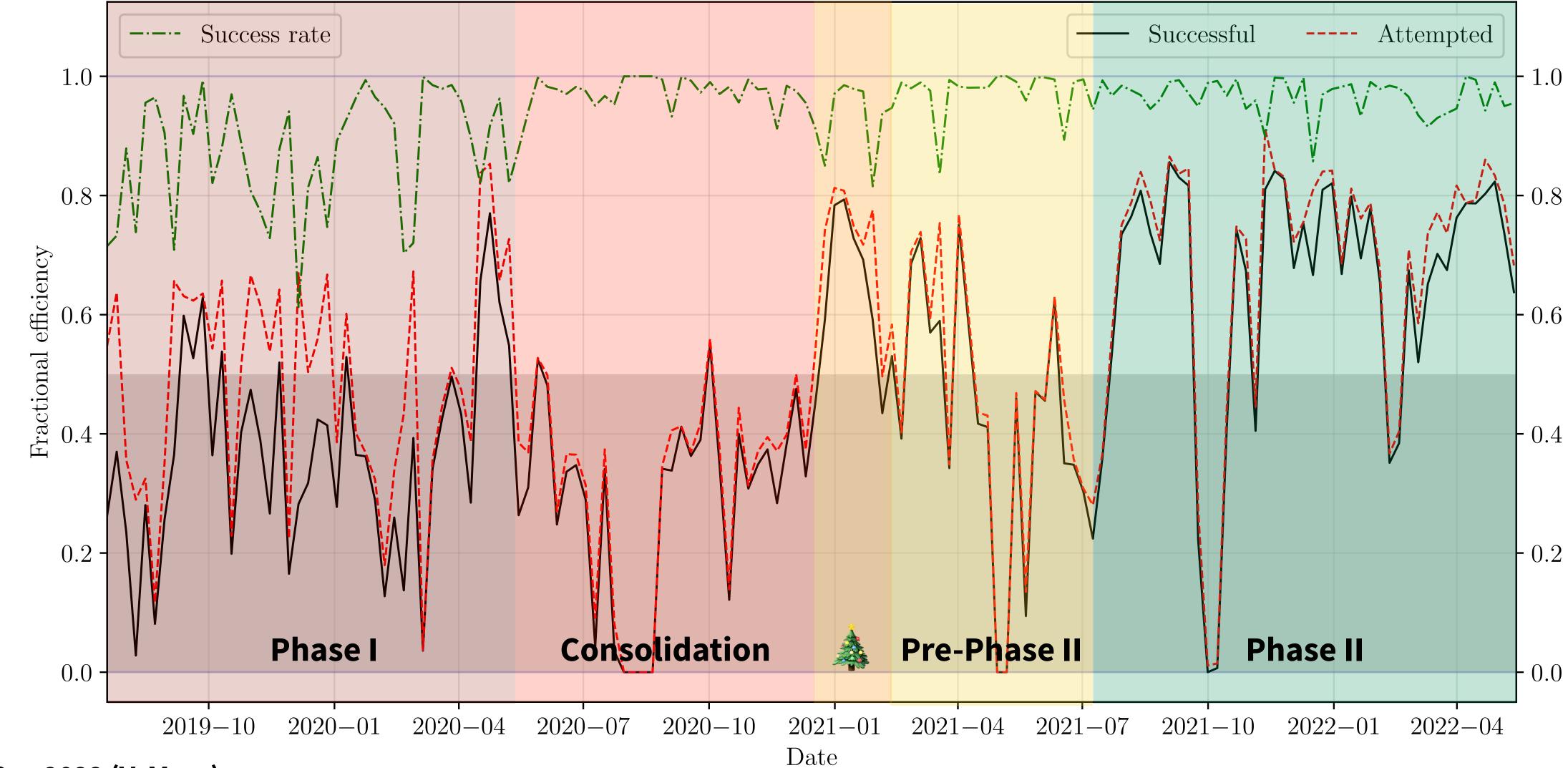
Development of SAURON

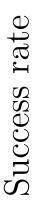
- Scheduling as a starting point for a broader exploration of automation possibilities for the entire ASKAP operational workflow
- **SAURON:** Scheduling Autonomously Under **Reactive Observational Needs**
- Operating ASKAP in this way is possible thanks to improvements in stability, robustness and automation as part of consolidation efforts
- Christmas 2020 was the first road test of the initial version of SAURON, incorporating the system improvements from consolidation
- Development and improvement is **ongoing**



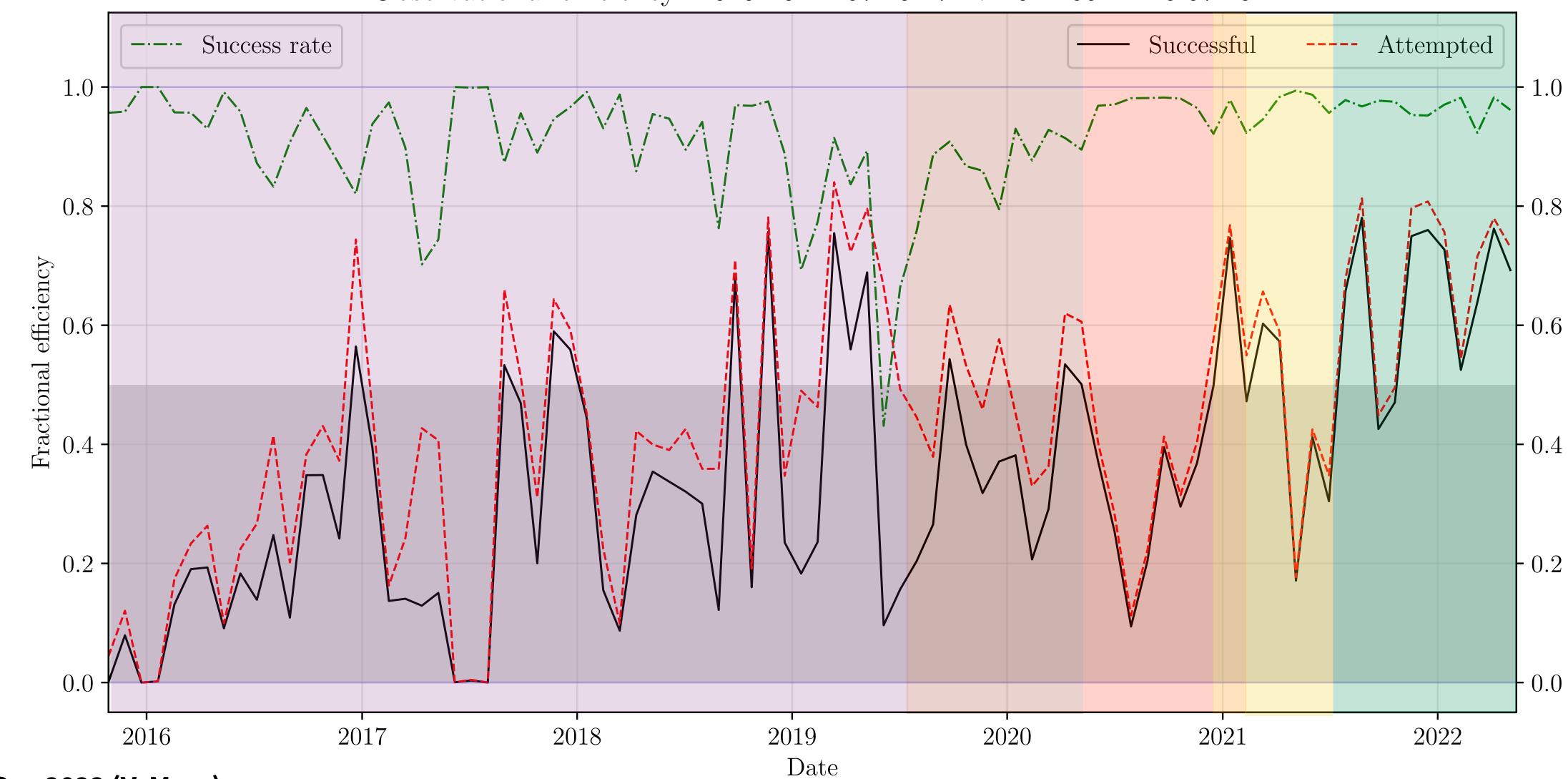
Increasing operational efficiency

Observational efficiency: 2019-07-15 05:25:56 \rightarrow 2022-05-14 10:07:45



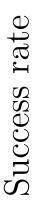


Towards full survey efficiency



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Observational efficiency: 2015-10-14 07:25:17 \rightarrow 2022-05-14 10:07:45



Data complexity

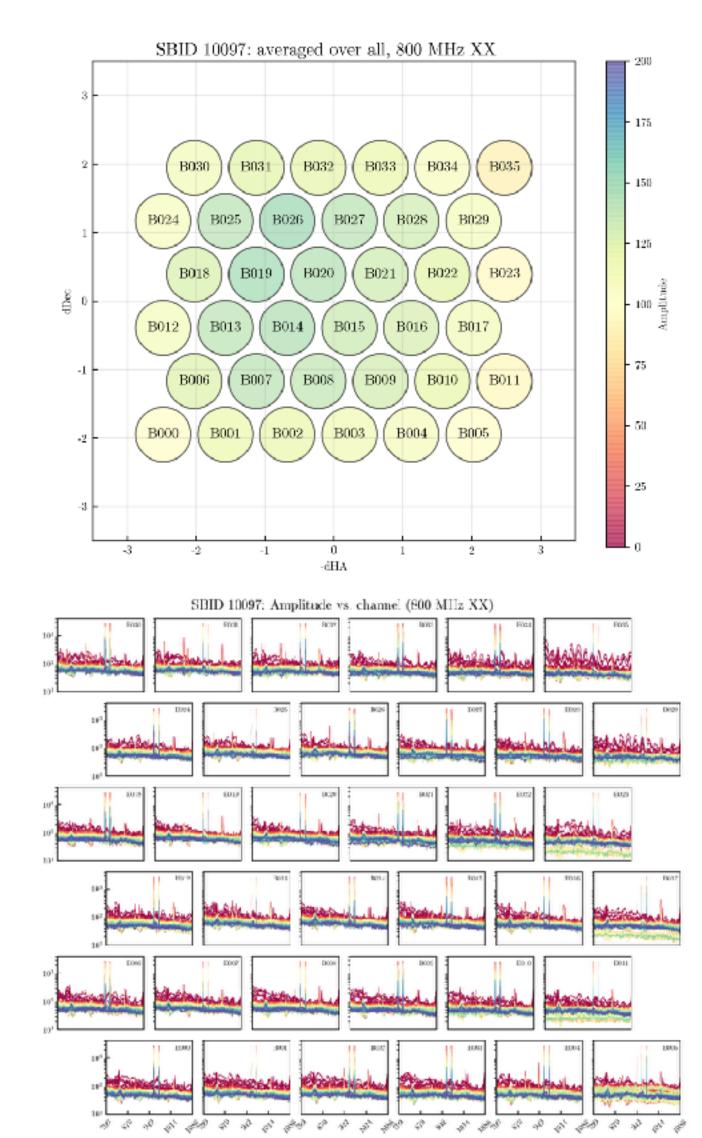
- ASKAP datasets have many **complexities** compared to **traditional** astronomical datasets
 - 36 antennas
 - **36** beams
 - **100s** of timestamps, **1000s** of channels
- Data sizes are also **immense**
 - continuum bandpass: 170 GB
 - continuum target: 729 GB
 - spectral bandpass: 8.7 TB
 - spectral target: 32 TB
- Need a **quick way** to see data quality!

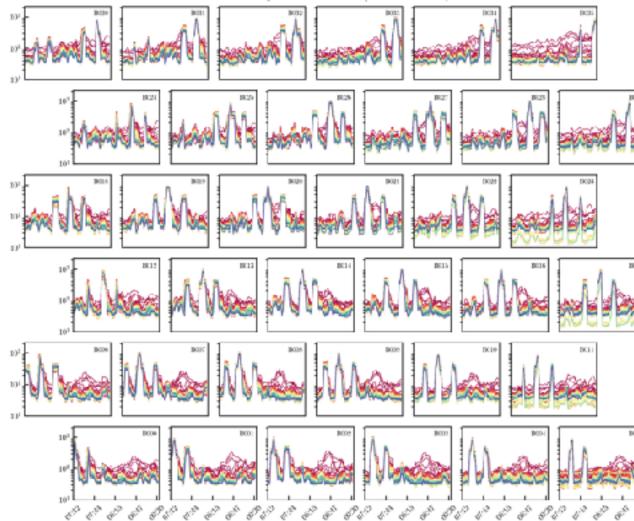


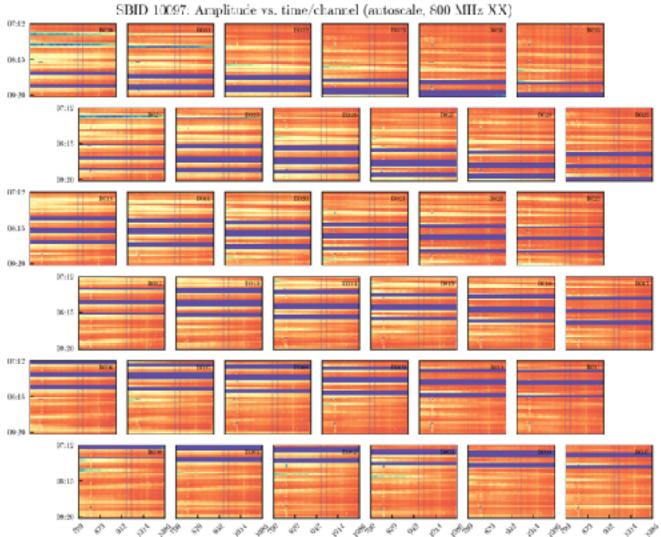
	00 rows Refresh				
ID	17 Alias Name	↓1 State ↓†	Template Name 41	Run/Scheduled Time 41	Duration
10668	AS113_FLASHiast_v1.0_191150_100000	ERRORED	Standard	2019-11-50 12:06:23	07:10:29
10665	genorio_system_test	OBSERVED	Standard	2019-11-80 09:20:08	00:06:18
10664	B1934-638_boresight	OBSERVED	Standard	2019-11-30 09:13:47	00:05:04
10663	AS113_FLASHlest_v1.0_191130_100000	OBSERVED	Standard	2019-11-30 09:59:59	02:00:20
10662	generic_system_test	OBSERVED	Standard	2019-11-30 09:01:46	00:05:57
10661	B1904-600_boresight	OBSERVED	Standard	2019-11-30 08:53:15	00:05:42
10660	B1934-638_boresight	OBSERVED	Standard	2019-11-50 08:46:33	00:05:45
10668	ODC_NoDrive	OBSERVED	FakeOba	2019-11-80 08:40:22	00:01:13
10658	ODC_NoDrive	OBSERVED	FakeObs	2019-11-30 09:36:13	00:01:15
10657	bandpess square_6x6 1664.5 MHz	OBSERVED	Bandpass	2019-11-30 08:05:12	02:12:01
10656	GASKAP_OHTest	OBSERVED	Standard	2019-11-29 18:01:42	12:00:29
10665	test square_6x8 1664.5 MHz	OBSERVED	Standard	2019-11-29 11:42:33	00:08:37
10664	tost square_6x8 1664.5 MHz	OBSERVED	Standard	2019-11-29 11:35:49	00:06:48
10658	fest square_6x6 1684.5 MHz	OBSERVED	Standard	2010-11-29 11:28:28	00:09:09
10652	B1934 838_borosight	OBSERVED	Standard	2019-11-29 11:16:44	00:05:41
10651	B1904-600 boresight	ERBORED	Standard	2019-11-29 11:11:12	00:00:56
10650	B1904-600 boresight	OBSERVED	Standard	2018-11-29 10:50:49	00:05:46
10949	ODC_NoDrive	OBSERVED	FakeObs	2019-11-29 10:55:06	00:01:14
10648	H1934 638_bonsight	ERRORED	Standard	2019-11-29 10:41:81	00:05:45
10647	B1934 639_boresicht	ERROBED	Standard	2019-11-29 10:38:17	00:03:12
10646	B1934-639_boresight	OBSERVED	Standard	2019-11-29 10:30:50	00:05:20
10645	ODC_NoDrive	OBSERVED	FakeOts	2018-11-29 10:21:54	00:01:14
10844	genatio_system_tast	OBSERVED	Standard	2019-11-29 10:18:41	00:03:12
10845	ODC_NoDrive	OBSERVED	FakeObs	2019-11-29 10:14:42	00:01:15
10642	generic_system_less	OBSERVED	Standard	2019-11-29 10:10:28	00:03:58
10641	ODC_NoDrive	OBSERVED	FakeObs	2019-11-29 10:04:21	00:01:14
10640	B1934-639_boresight	OBSERVED	Standard	2019-11-29 09:56:02	00:07:17
10639	ODC_NoDrive	OBSERVED	FakeObs	2019-11-29 09:40:44	00:01:14
10638	ODC_NoDriva	OBSERVED	FakeObs	2019-11-29 09:37:52	00:01:15
10687	ODC_NoDrive	OBSERVED	FakeObs	2019-11-29 09:16:00	00:01:16
10638	Apel_2266	OBSERVED	Standard	2019-11-24 16:10:45	06:46:14
10635	EMU_2205-51	PROCESSING	Standard	2019-11-24 06:09:52	10:00:52
10604	bandpase dosepack36 820.5 MHz	OBSERVED	Bandpass	2018-11-24 03:53:53	02:12:00
10633	test closepack36 920.5 MHz	OBSERVED	Standard	2019-11-24 03:36:48	00:05:47
10682	test closepack56 820.5 MHz	OBSERVED	Standard	2018-11-24 03:30:50	00:05:57
10681	H1934-638_borcsight	OBSERVED	Standard	2019-11-24 03:24:85	00:06:18
10630	B1934-638_boresight	OBSERVED	Standard	2019-11-24 03:16:08	00:08:09
10629	ODC_NoDrive	OBSERVED	FakeObs	2019-11-24 03:10:29	00:01:44
10626	bandpasa square_5x6 1272.5 MHz	OBSERVED	Gandpass	2018-11-23 10:36:54	02:11:19
10626	Hydra_28	OBSERVED	Standard	2019-11-23 18:45:21	08:02:50
10625	tost square_Extil 1272.5 MHz	OBSERVED	Standard	2019-11-23 10:30:49	00:06:01
10624	test square_6x6 1272.5 MHz	OBSERVED	Standard	2019-11-23 10:24:84	00:09:14
10623	B1934 838_boresight	OBSERVED	Standard	2019-11-23 10:18:24	00:05:09
10622	B1934-639_boresight	OBSERVED	Standard	2019-11-23 10:11:53	00:05:49
10621	B1904-630 boresight	OBSERVED	Standard	2018-11-20 10:04:04	00:05:51
10620	B1934-638_boresight	OBSERVED	Standard	2019-11-23 09:50:23	00:05:46
10619	H1934 639_bomsioht	OBSERVED	Standard	2019-11-23 09:48:84	00:05:46
10618	B1934-638_boresight	OBSERVED	Standard	2019-11-23-09:19:24	00:07:35



Raw data diagnostics







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SBID 10097: Amplitude vs. time (800 MHz XX)

ASKAP Inspection Plots

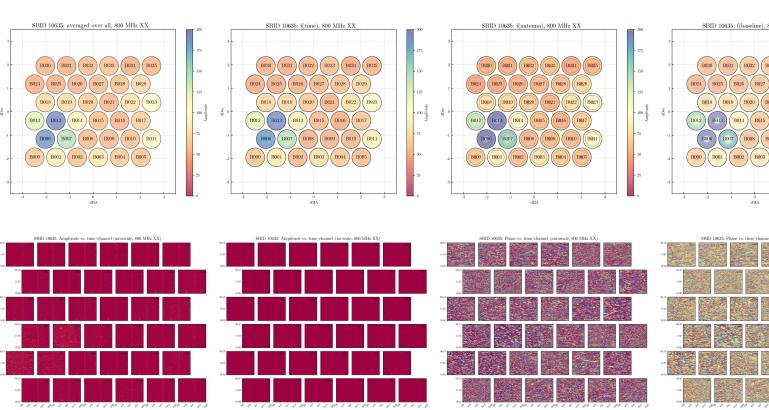
2019-11-24_061040_EMU_2205-51

METADATA FOR 2019-11-24_061040_EMU_2205-51 (SBID 10635)

Source:	EMU_2205-51	Bandwidth:	288.000 MHz				
RA:	22:15:21.432	Channels:	288				
Dec:	-53:04:08.811	Frequency resolution:	1000.000 kHz				
Start (UT):	$2019\text{-}11\text{-}24 \ 06\text{:}10\text{:}19.297$	Start frequency:	799.991 MHz				
End (UT):	$2019 \textbf{-} 11 \textbf{-} 24 \ 16 \textbf{:} 10 \textbf{:} 30 \textbf{.} 264$	Central frequency:	943.491 MHz				
Duration: 10:00:00 End frequency: 1086.991 MH							
Array: ak01, ak02, ak03, ak04, ak05, ak06, ak07, ak08, ak09,							
ak10, ak11, ak12, ak13, ak14, ak15, ak16, ak17, ak18, ak19, ak20,							
ak21, ak22, ak23, ak24, ak25, ak26, ak27, ak28, ak29, ak30,							
ak31, ak32, ak33, ak34, ak35, ak36							

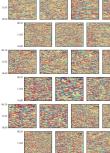
PREDICTIONS FOR 2019-11-24_061040_EMU_2205-51 Data assessment: BAD (LOW) Bad telescopes: ak09, ak32

XX polarisation:



<u>______</u>

SBID 10635: Amplitude vs. channel (800 MHz XX)

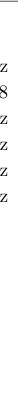


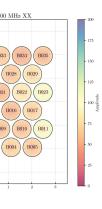
¹¹⁰ Section and Section Section and Section and Section Section (Section Section Section

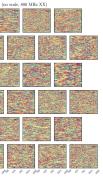
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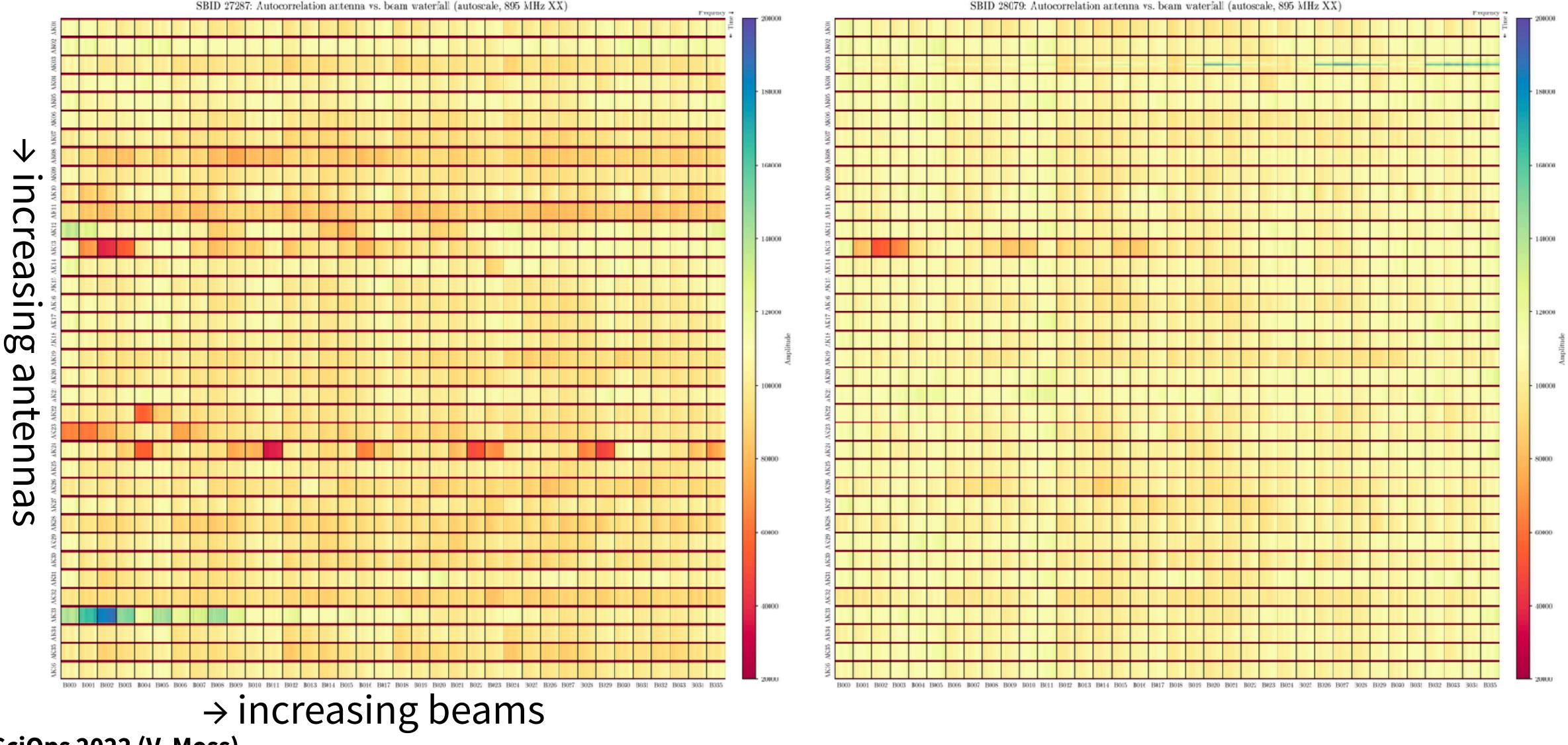






The "everything" plot

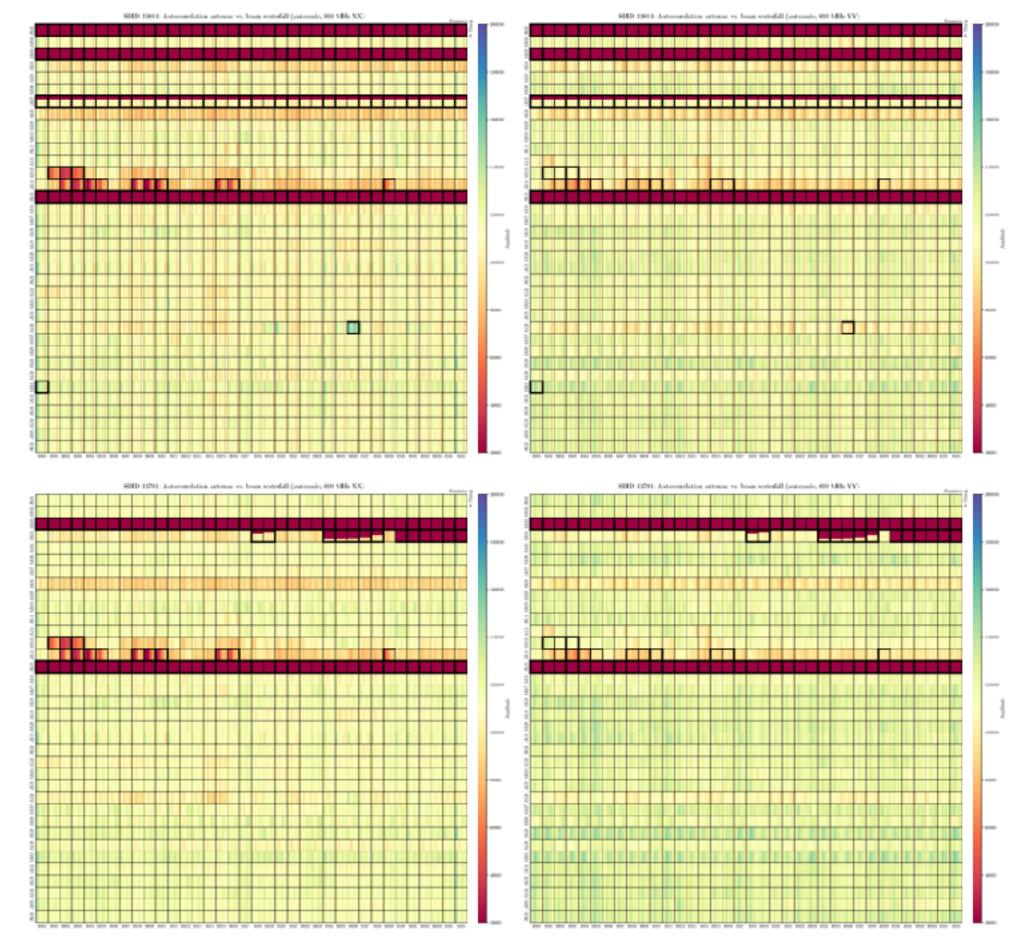
SBID 27287: Autocorrelation antenna vs. beam waterfall (autoscale, 895 MHz XX)



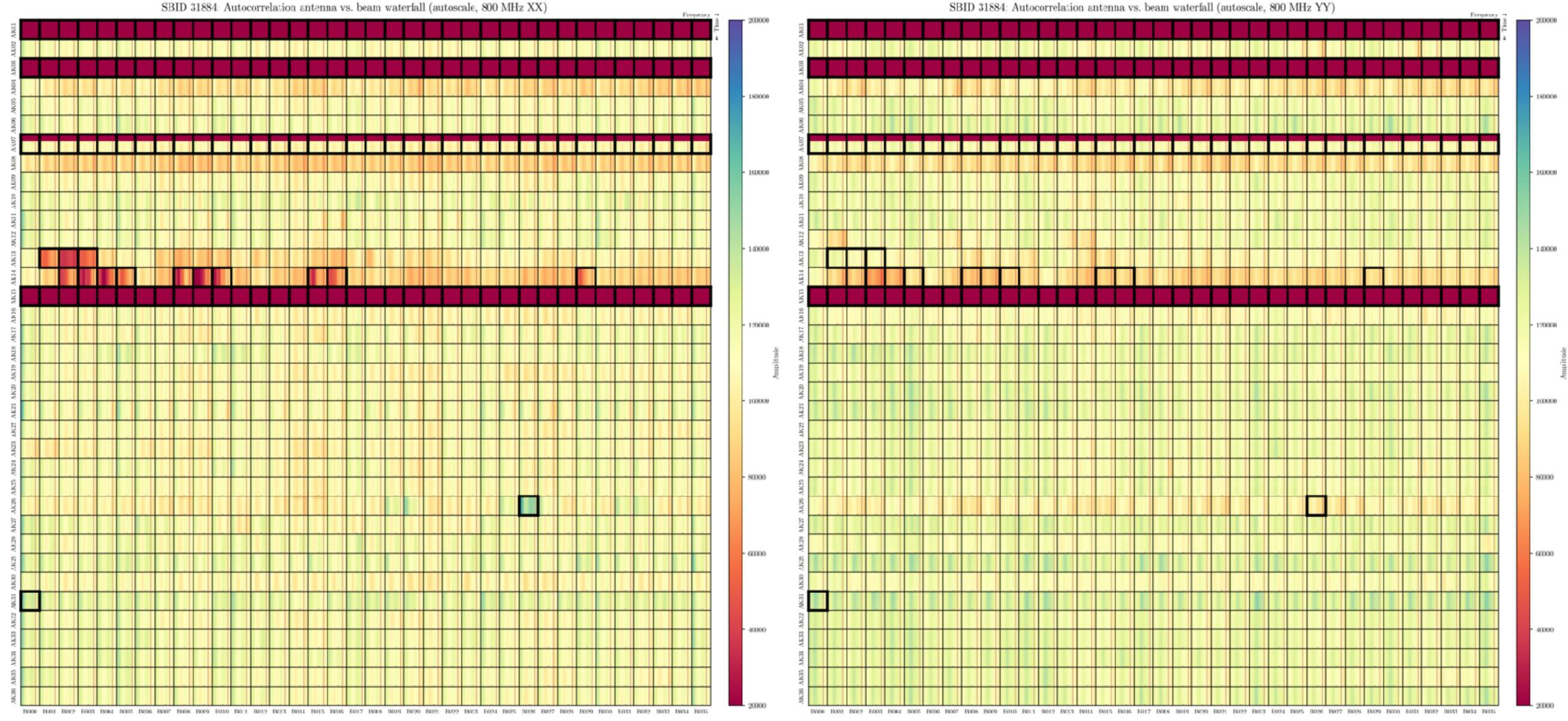
SAMWISE for outlier detection

- Currently prototyping options for identifying bad data based on raw data diagnostics
- **SAMWISE:** Selecting Anomalous Matter With Intelligent Semi-unsupervised Encoders
- **Outlier detection** on autocorrelation waterfalls does relatively well at identifying correctly which data to flag, based on early tests
- We also are looking into ML classification of data (as opposed to images used above)
- Goal: determine feasibility in producing **flagging directives** that can be fed to pipeline





SAMWISE example



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SBID 31884: Autocorrelation antenna vs. beam waterfall (autoscale, 800 MHz YY)

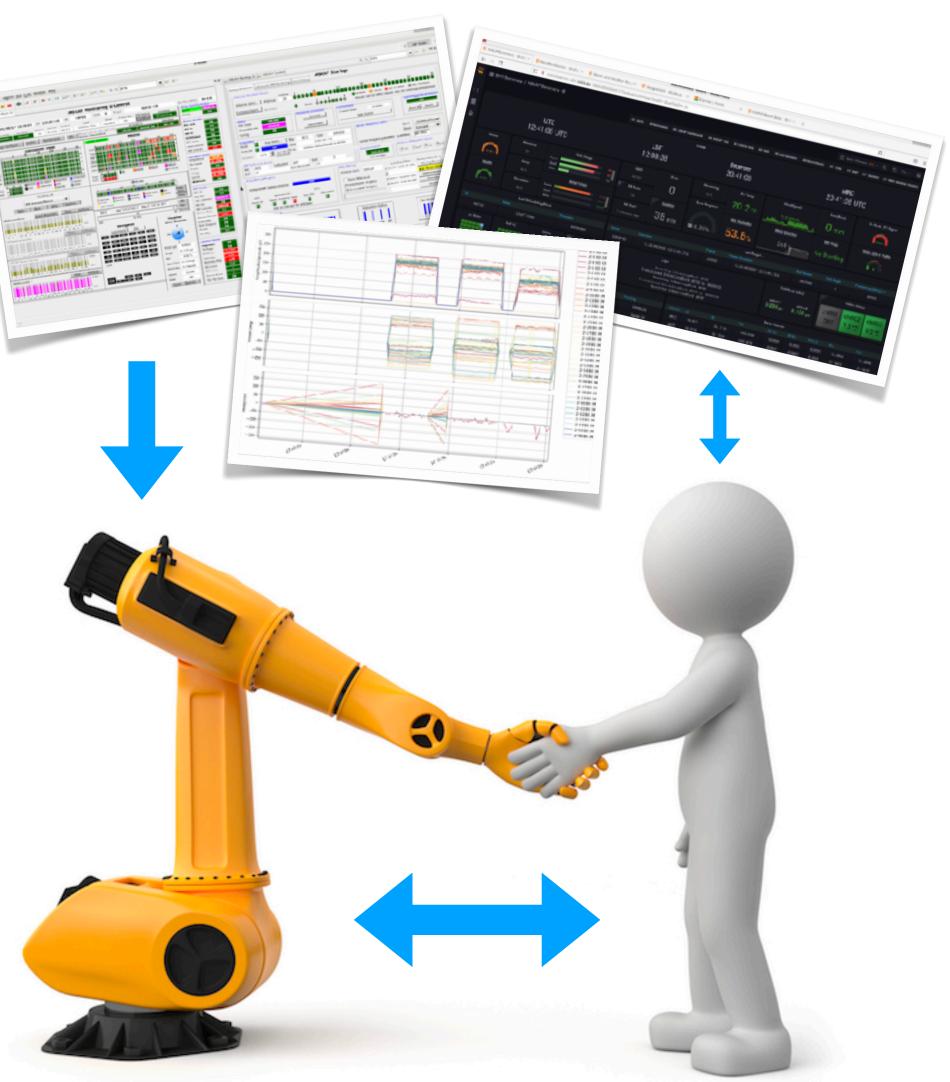
IMAGE: SAMWISE

ASKAP Operations and CINTEL

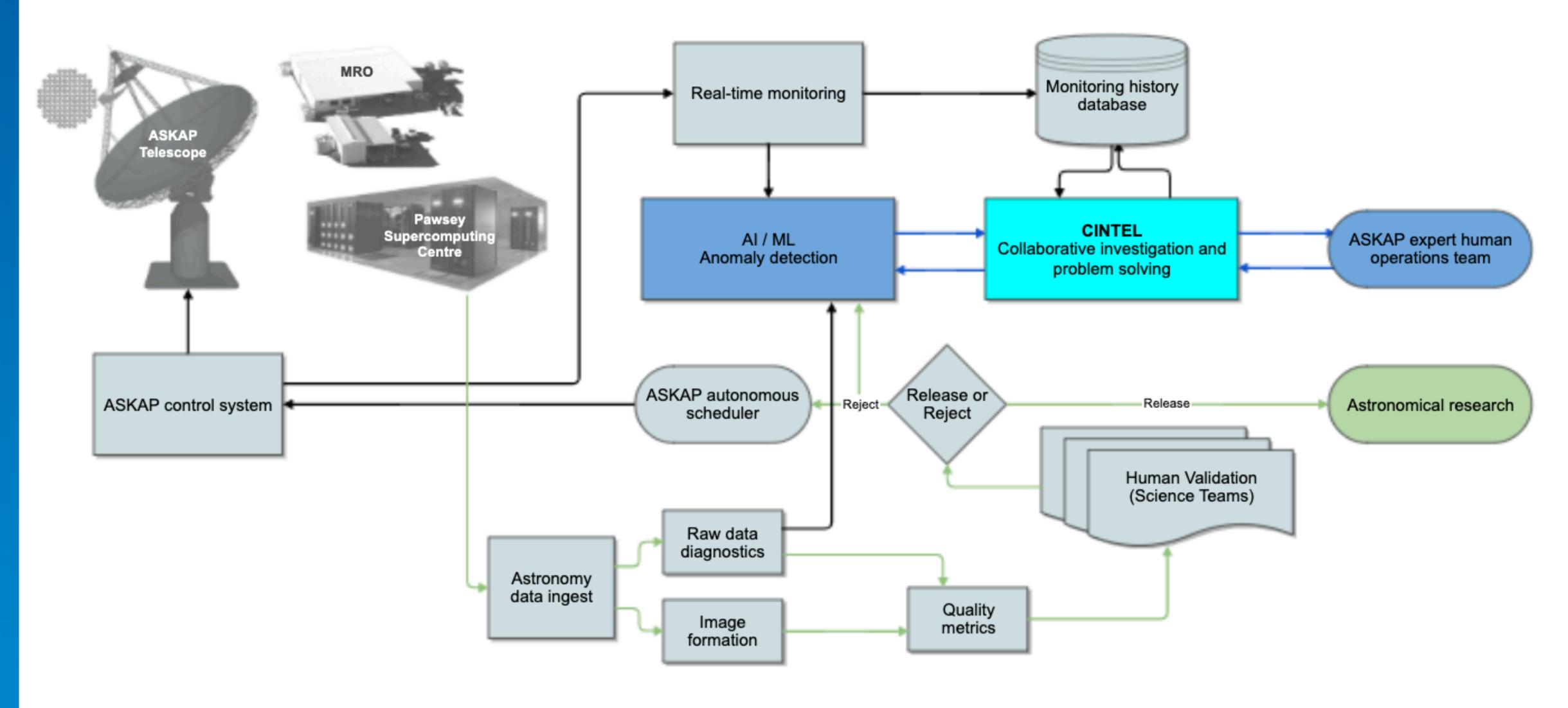
- **CINTEL:** Collaborative Intelligence, referring to the collaboration between AI and humans
- Cross-CSIRO Future Science Platform (FSP) bringing together researchers facing CINTEL challenges in **many disciplines**
- Within the CINTEL context, our ASKAP project will look at **merging** human analytical skill and expertise with the power and speed of machine-driven data cleaning to improve monitoring and surveillance
- Advertising for a **postdoc** to join our team will take place during 2022 stay tuned!

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SEE ALSO: <u>HTTPS://WWW.CSIRO.AU/EN/ABOUT/STRATEGY/FUTURE-SCIENCE-PLATFORMS</u>



ASKAP Operations and CINTEL

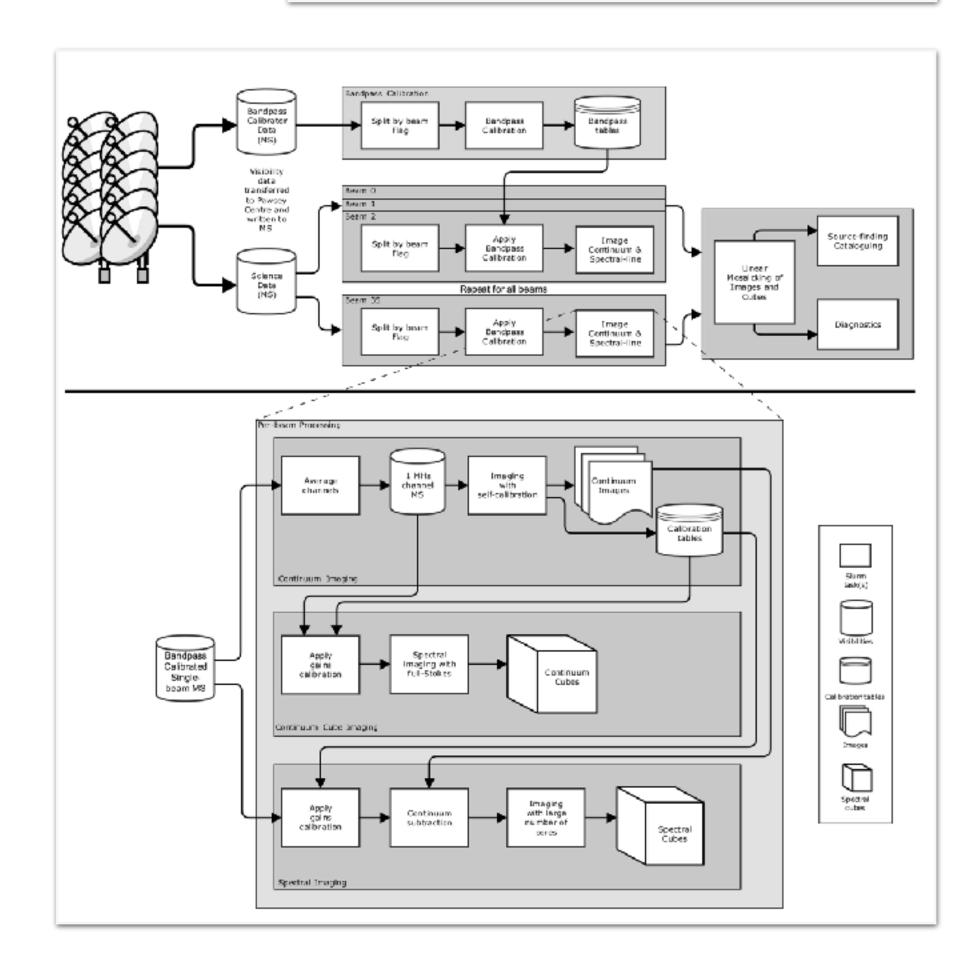


Processing all the data

- **ASKAPsoft** is a custom pipeline designed for calibration, imaging and analysis of ASKAP data
- For **operational processing**, it is run on the Pawsey supercomputing infrastructure, specifically on Galaxy while accessing the data that is available on Payne or Scott
- Once processing is completed, data is sent to **CASDA**, the online archive for ASKAP
- Processing is currently **semi-automatic**, via scripts and slurm processes, but is intended to be automatically triggered in future
- Better **linking** of observations and processing

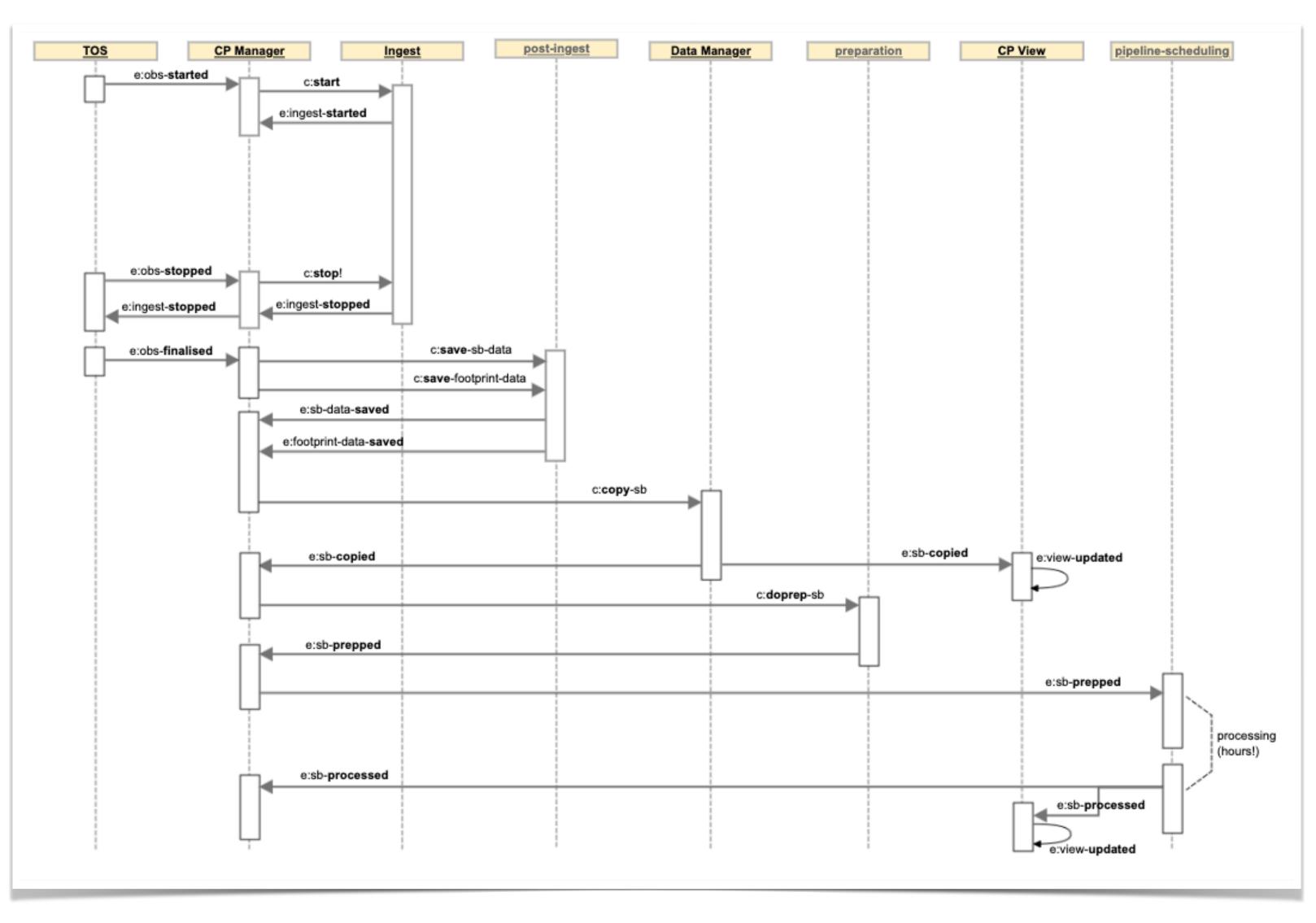
SciOps 2022 (V. Moss)

IMAGE: PAWSEY, ASKAPSOFT TEAM



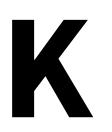


The rise of CLINK



SciOps 2022 (V. Moss)

IMAGE: M. AUSTIN, E. BASTHOLM



The path to the future of ASKAP

- ASKAP as a **remote survey instrument** is a unique context for the ATNF, encouraging us to explore a new operational regime
- The system has come a **long way** over the last few years, with big leaps in operability, stability, automation and autonomy
- So far, increasing the autonomy of ASKAP has not needed **AI in the classic sense** in order to replicate human roles - systematic logic has been sufficient for effective automation
- Our work in **CINTEL** will help us to establish collaborative human/machine workflows

