Progress report of SKAO activity in Japan



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国立天文台SKA1サブプロジェクト
NAOJ SKA1 Promotion Group

Quick Summary

Japan has been an observer of the SKAO project.

Japan's participation plan is:

WHO?	**Nagoya U. and NAOJ jointly**
WHY?	**To accomplish 3 key science goals**
WHEN?	**Around late 2020's and 2030's**
WHERE?	**SKA phase 1 LOW and MID**
WHAT?	**Band 5/6 pack, VLBI, AIV/CSV, SRCNet**
HOW?	**Obtain 2% share of the construction**

Organization

1. The History

17 years activities of Japan SKA Consortium

International

2012-2014 long-stay of researchers in UK, AU, ZA (頭脳循環)

2016 ASKAP & MWA Int'l conferences

2019 3rd EASKA@CN

2021 4th EASKA@JP

2023 5th EASKA@KR

2026 6th EASKA → Asia-Pacific SKA

2022 **SRC member**

2025 **SRCNet v0.1 node**

2022 **AIV MoU**

2016 **MWA member**

2020 **SCJ Masterplan Priority candidate**

2023 **SCJ Long-term nominated MEXT Roadmap unsuccess**

2025 **SCJ Long-term submitted**

2013 2nd EASKA@JP

2011 1st EASKA workshop@KR

2014 **SCJ Masterplan Priority**

2017 Masterplan unsubmitted

2015 **SKAJP Science Book**

2017 Mizusawa Science Book

2020 **SKAJP Science Book (453 pages)**

2021 SKAJP webinar

2025 NAOJ Science Roadmap submitted

2010/2011 **SCJ Masterplan Priority MEXT Roadmap**

2015 ASJ session

2017 JPS session

2023 ASJ session

2008 **SKA-JP launch → #280 as of 2025.12**

2013 Udenkon SKA symposium

2015 SKA-JP workshop

2016 SKA-JP symposium

2019 SKA-JP symposium

2021 **SKA-JP Science strategy workshop**

2024 SKA-JP symposium

Domestic

17 years outcomes

Papers 554

Grant 834 MYen

Ph.D 33

Master 202

NAOJ from "observe" to "investigate"

2000's
An observer to SKA Board & Sci./Eng. Adv. Committee

2015-2017
Sent university staff members to UK & AU

2017.10~
Mizusawa launched the section of future project (SKA)

2019.4~
SKA1 Study Group

2023.4~
SKA1 Promotion Group

Fostering Young Researcher



Science book, webinar series, SWG/EWG activity



WG Leader, Oversea stay, Funding PI

Becomes core member of executives

Organization

2. The SKA1 Promotion Group in NAOJ



グループリーダー： 赤堀卓也 60%
Group Leader : Takuya Akahori



シニアアドバイザ：小林秀行
Senior Advisor: Hideyuki Kobayashi



事務：勝川まりえ 100%
Admin: Marie Katsukawa

広報：中西裕之 10%
Outreach: Hiroyuki Nakanishi





水沢VLBI観測所長：本間希樹 5%
MVO Director: Mareki Honma



科学部門長：町田真美 10%
Head of Science: Mami Machida (DoS)



SRC部門長：市來淨與 10%
Head of SRC Kiyotomo Ichiki



技術部門長：新沼浩太郎 10%
Head of Engineering: Kotaro Niinuma



科学検討：廣田朋也 10%
Use cases: Tomoya Hirota



国際連携：高橋慶太郎 10%
Oversea: Keitaro Takahashi



VLBI運用協定：寺家孝明 10%
VLBI Op./Alliance: Takaaki Jike



VLBI運用協定：今井裕 10%
VLBI Op./Alliance Hiroshi Imai



講習会：藏原昂平 5%
VLBI Test: Kohei Kurahara



講習会：酒見はる香 5%
Tutorial: Haruka Sakemi



部門長補佐：赤堀卓也 20%
Support: Takuya Akahori



クラウド：山下一芳 60%
Cloud: Kazuyoshi Yamashita (ADC)



クラウド：吉浦伸太郎 40%
Cloud: Shintaro Yoshiura



クラウド：加藤亮 40%
Workflow: Ryo Kato



クラウド：出口真輔 10%
Cloud: Shinsuke Ideguchi (CfCA)



ワークフロー：岩田悠平 10%
workflow: Yuhei Iwata



ワークフロー：酒見はる香 5%
Workflow: Haruka Sakemi



部門長補佐：大前陸人 10%
Support: Rikuto Omae



MID性能検証：砂田和良 80%
MID AIV: Kazuyoshi Sunada



LOW性能検証：河野裕介 25%
LOW AIV: Yusuke Kono



LOW開発：河野裕介 25%
LOW R&D: Yusuke Kono



LOW開発：吉浦伸太郎 10%
LOW R&D: Shintaro Yoshiura



VLBI記録系：小山友明 10%
VLBI Dev.: Tomoaki Oyama



VLBI：藏原昂平 5%
VLBI Test: Kohei Kurahara



受信機：山崎康正
Receiver: Yasumasa Yamazaki (ALMA)



将来技術発掘：河野裕介 20%
Engineering Items: Yusuke Kono

MVO staff 14, 3.9FTE + admin
NAOJ others 3, 0.2FTE+α
Universities 7, 0.7FTE

3. Participation plan

Japan targets 2% share of the project, and invests mainly the AA4 construction in around late 2020's – 2030's

Note: we are updating our plan based on the latest forecast of the SKAO project in 2030's, with the currency exchange late of 170 ¥/€

€/¥	150	SKA1 Construction						SKA1 Operation	SKA1 SODP		SRC Construction		Domestic	
Unit	M€													
Con 6 yrs total		In-kind AIV/CSV	In-kind Soft	FWR Cryo-Compressor	FWR RX45 Digitizer	FWR Band5	Cash Non FWR	Cash Operation	Band6	VLBI	JPSRC DevOp	User Support	HR,Travel	Science Promotion
		3.49	0.30	6.07	4.07	8.84	9.31	25.62	0.31	0.32	10.60	1.15	1.88	1.60
		22.78					34.93		0.63		11.75		3.49	
Total		57.72							0.63		11.75		3.49	
Grand Total		73.58												

Project Asso.P
Project Assi.P
#6-8

- Long-term visit or remote op.
- Benefit to own science (30-50% efforts)

Project Asso.P #1

- Compressor #60, Digitizer #60, Band5 Feed #60
- System evaluation, industry liaison

Semior Exp. #1, Project Res. #1

- Optics
- EM simulations

Senior Exp. #2

- IT, IoT
- Cloud, big data

Assi.P #2
Project Res. #2

- Help desk

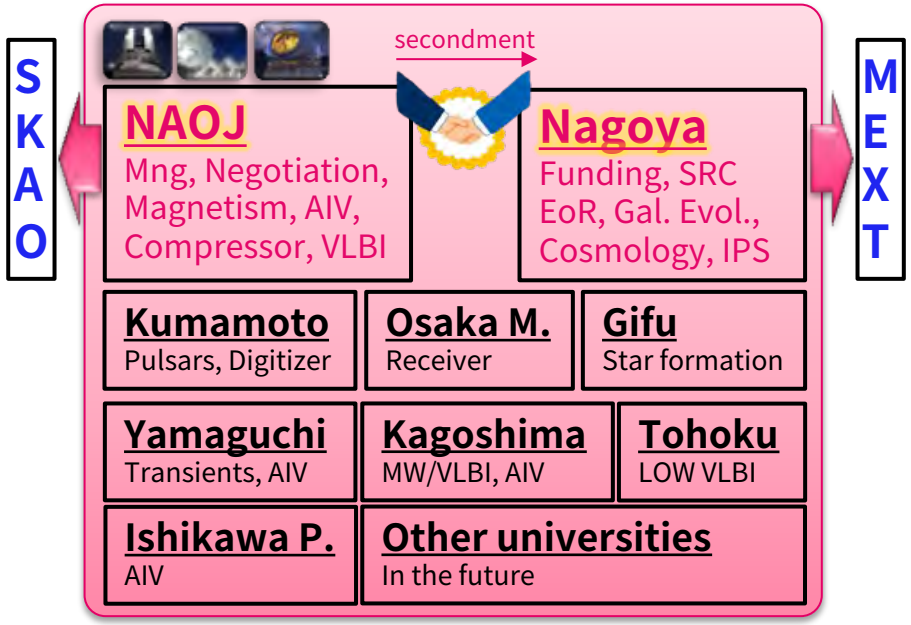
Prof/Asso.P #4

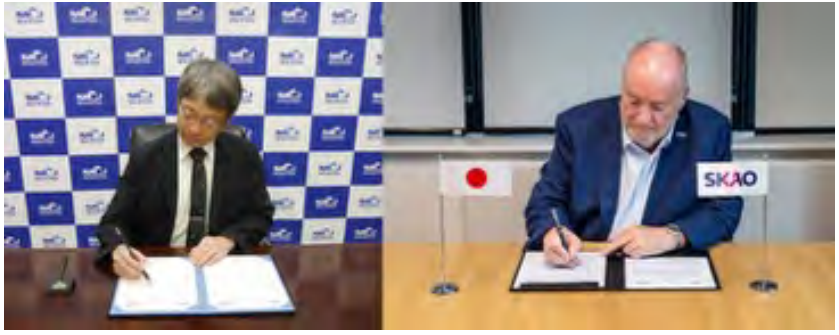
- Leadership
- Int'l committee

Project Assi.P #3
Project Res. #3

- Research position
- Future science leaders

4. Recent progress

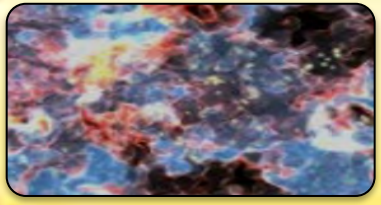




- Taking into account the current circumstances of NAOJ, the framework has been revised so that **Nagoya Univ. now serves as the central institute**, with **NAOJ providing supporting roles**.
- The project has been submitted to **ASJ's future academic promotion vision** and **NAOJ's science roadmap**. Review underway. We will apply for the **MEXT roadmap 2026**.
- NAOJ and SKAO have signed a new **memorandum of understanding** to expand Japan's contribution to AIV (assembly, integration, and verification)
  - FTE doubled to at least 3.0 FTE
  - Added University members and remote work
  - https://www.skao.int/en/news/656/skao-and-japan-strengthen-ties

5. Japan's Science Goals with SKA1

- Japan SKA Consortium has discussed key sciences in 2021 symposium and determined the following three key science goals.



Deciphering the cosmic reionization with cosmology and astrophysics



In-depth/Tomographic study of the magnetic field governing the cosmic hierarchy and activities



Pioneering long-wavelength gravitational-wave astronomy with pulsar observations.

6. Japan's Science Use Cases







2015: 8 chapters, 326 pages, cumulative 74 authors
(EoR, Cosmology, Galaxy Evolution, Pulsars, Magnetism, VLBI, ISM, Transients)

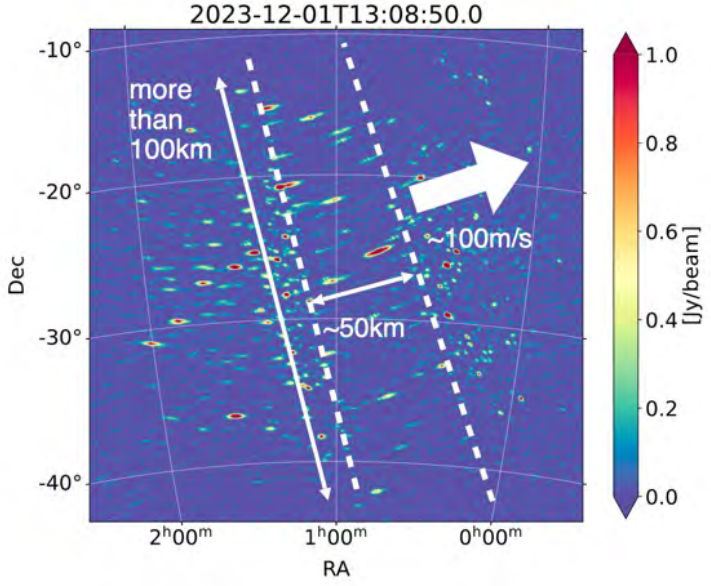
2020: 10 chapters, 463 pages, cumulative 135 authors
10 chapters (Star formation and Plants were added).

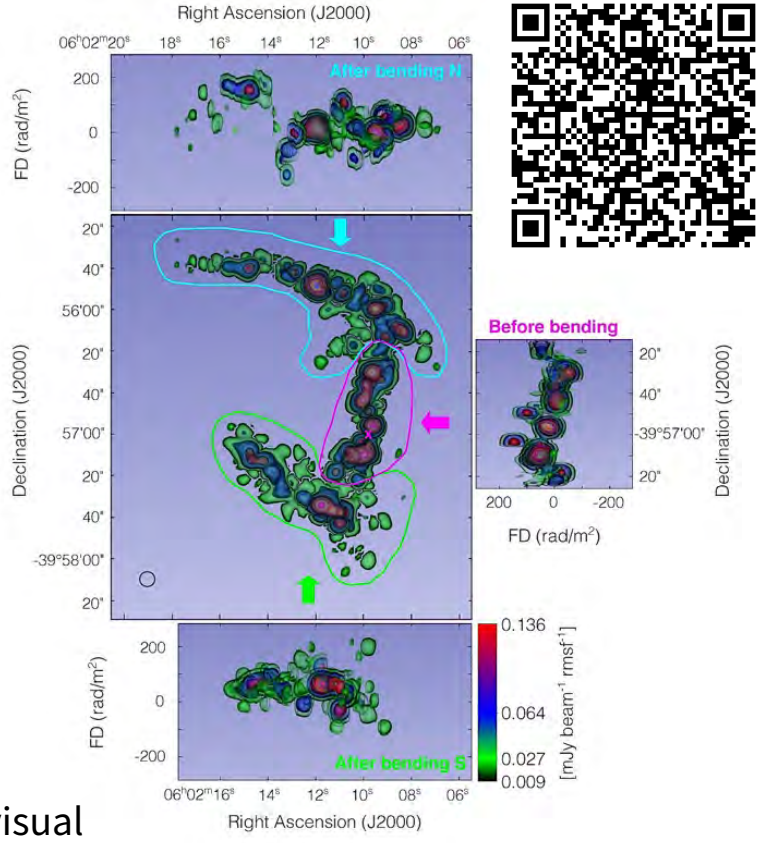
2023: PASJ Special Issue
Metre and Centimetre Radio Astronomy in the Next Decade
13 papers



Japanese recent scientific presence
SKA General Science Meeting 2025: **5 Oral and 6 poster** presentations
SKA Science Book 2025: **7 PI and 20 Co-I** chapters

7. Selected science highlights

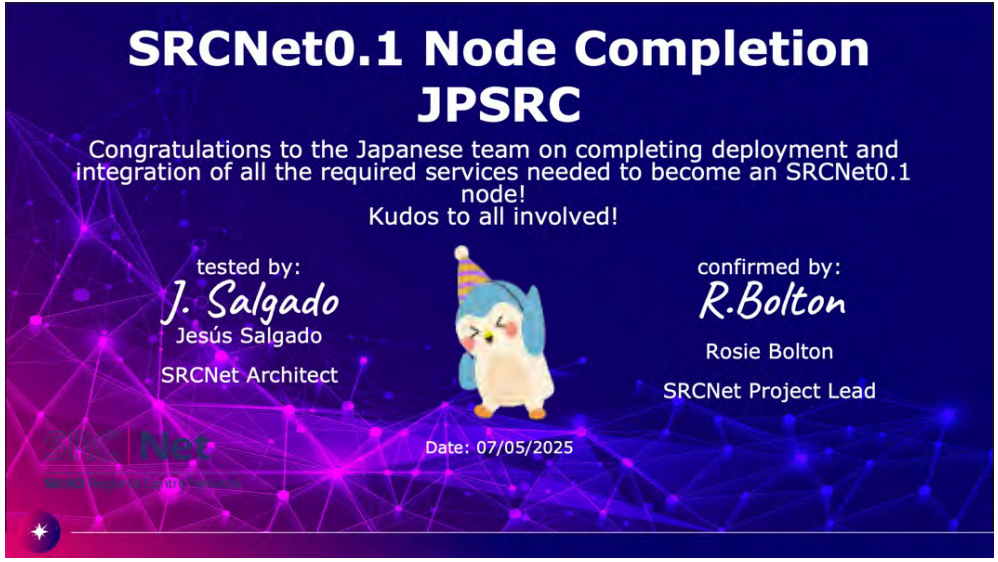




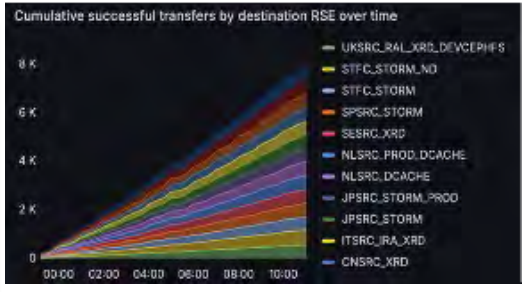
Yoshiura et al. (2024) used the MWA to capture ionospheric structures moving at a speed of approximately 100 km s^{-1} during the geomagnetic storm on 1 December 2023.

Sakemi et al. (2025) successfully provided a more visual characterization of the polarization structure of the radio jet MRC 0600–399 through Faraday tomography analysis of MeerKAT data.

8. jpSRC: Japan's SRCNet node



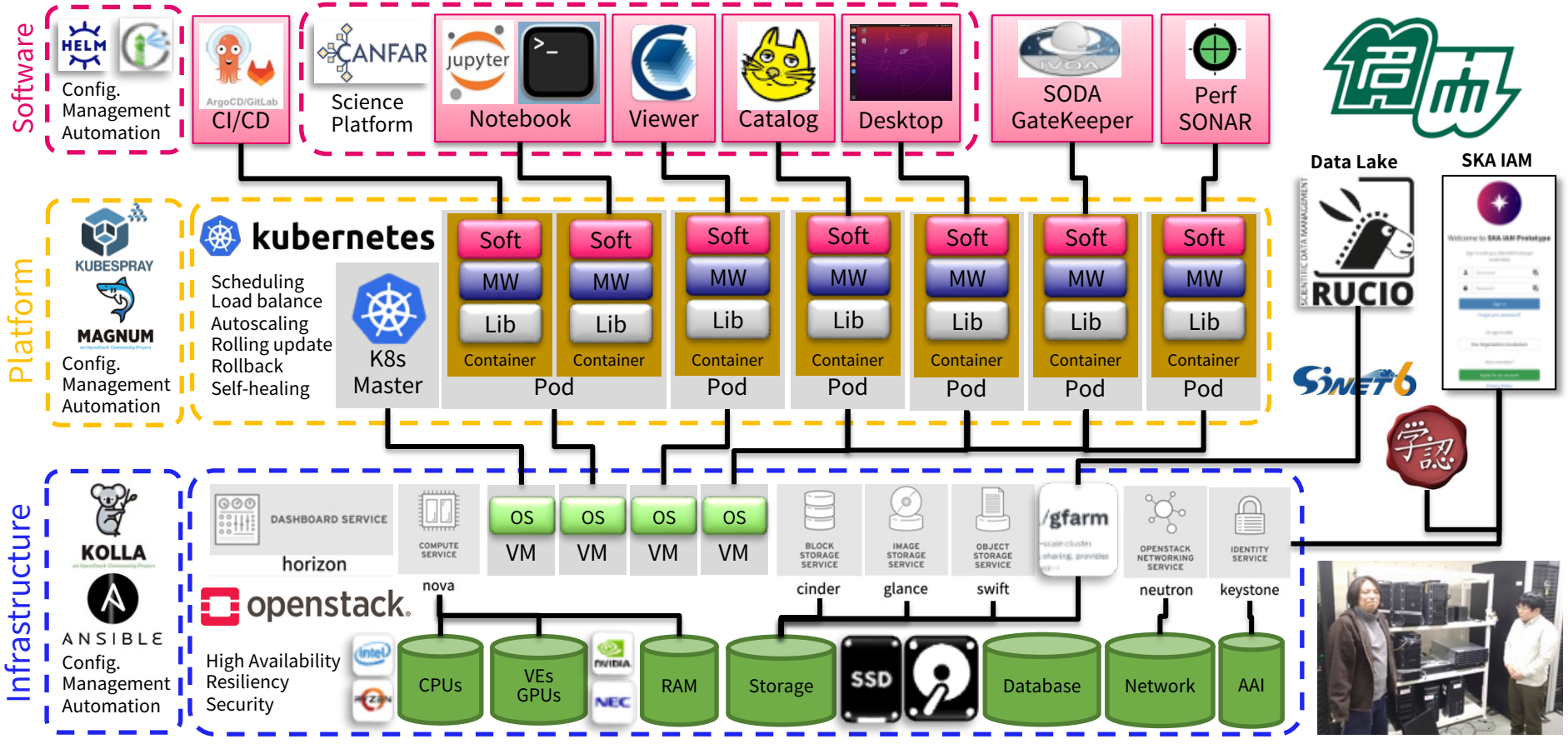




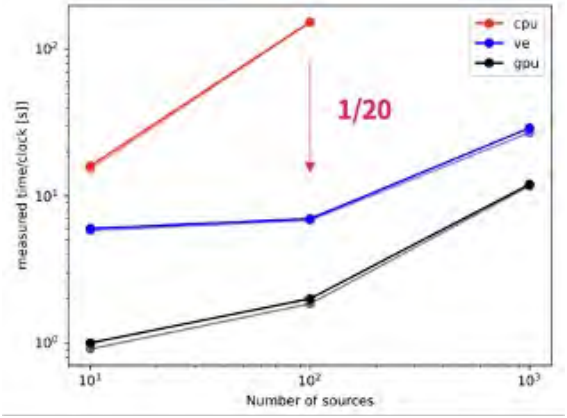
- **7th formal node of SRCNet v0.1**
- In SRCNet, the distributed data management system **Rucio** is used. Each node functions as a **Rucio Storage Element (RSE)**. JPSRC provides a RSE with a capacity of **450 TB**, built on the **Gfarm file system** as its backend. Data transfer tests are being conducted in coordination with RSEs worldwide.
- SRCNet employs container orchestration using **Kubernetes (k8s)**. On k8s, JPSRC implements **CANFAR** science platform, data processing and delivery services (**SODA, PrepareData, GateKeeper**), and continuous deployment management services (**GitOps/ArgoCD**).

9. jpSRC system SHION(紫苑)

SRC Heterogeneous Inter-university OpenStack Network



10. Japan's Technology Developments





① Accelerated Computing

We are evaluating the performance of the NEC vector processor. So far, we have confirmed a speed-up of a factor of 20–30 compared with conventional CPUs for a magnetic-field analysis code (Faraday tomography) and an EoR analysis code (foreground removal). We are currently working on accelerating CASA. In parallel, we are also accelerating the Faraday tomography code using GPUs.

② Distributed File System

We are evaluating the performance of the Gfarm file system, which is used in HPCI for data sharing on Fugaku. One of the notable advantages of Gfarm over other file systems is that it is extremely easy to implement and highly cost-effective.

③ High Speed Data Transfer

We are planning to introduce NEC's High-speed Data Transfer System (HDTS) and conduct a proof of concept in collaboration with the German SRC.

④ User Support Tools

We developed web-based tools that automatically generate .DRG files for the JVN Ibaraki and Yamaguchi stations and .vex files for VERA. Our current focus is on building an integrated software package for pulsar data analysis.

11. Use heritages of Japan's VLBI

AA*(2025-2027)
- ✓ AIV (4-5 FTE/year)

AA4 (2028-2030)
- ✓ Band5 Receiver
- ✓ Helium Compressor
- ✓ Band4/5 Digitizer
- ✓ AIV/CSV (4-7 FTE/year)

SODP (2031-)
- ✓ Band6
- ✓ VLBI Recorder

It's time. Show the flag!

- NAOJ has been providing 1.5 FTE since 2021 under the MoU. Univ. members will give further 1.0 FTE in total from FY2025.
- **Develop young researchers who know the telescope system** → it is benefit for science too

We do not make copies. We develop the systems that improve the performance.

- These developments and know-how of system engineering will also **benefit** Japanese telescopes such as **EAVN, JVN, Nobeyama** as well as future projects such as **ngVLA**

	Improvement	Mass production	Test facility
Band 5	better/wider bandwidth	#60 by industry	Yamaguchi or OMU
Compressor	smaller size, higher power	#60 by industry	TBD
Digitizer	direct sampling	#60 by industry	Kumamoto

12. AIV: key to make the system real

Key Technologies

- **AIV-JP in verification team**. Plan & do the test procedure to evaluate that the system satisfies the system requirements → Need skills of RF/IF/Digital + **new skill sets, e.g., SAFe, TANGO**
- **CSV**. Evaluate that the telescope satisfies the science requirements → Obtaining experiences useful for science too

Heritages, dev. status and plan

- SKAO has high expectations for JP's skills of AIV (Nobeyama, ALMA, and VERA)
- **AIV MoU** bet. NAOJ and SKAO since 2021. **LOW - S. Yoshiura, S. Kumari:** verification tests. **MID - K. Sunada:** RFI monitoring system, dish pointing, etc
- Mitaka: Test and evaluation of phase center of the log-periodic antenna, and test signal generator



LOW AIV team



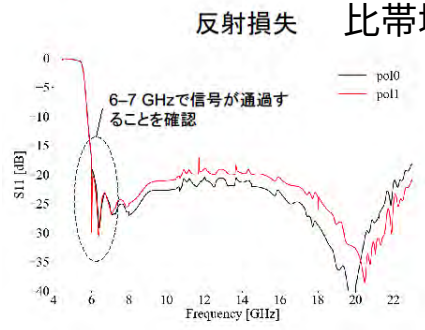
Visit to MID AIV team

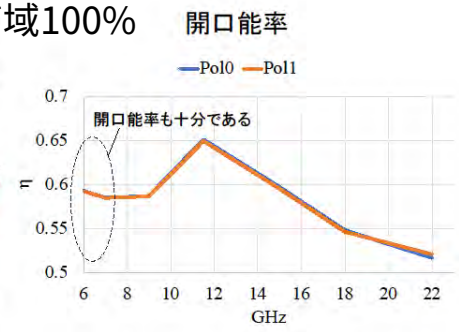


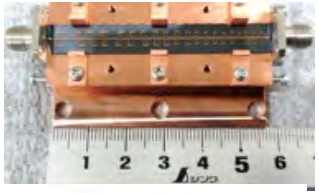
Experiments at Mitaka HQ with young researchers

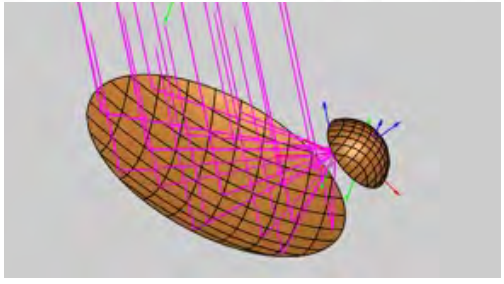
13. Band 5/6 Receivers

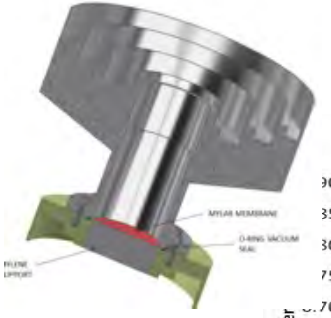
- **Key Technology**
  - Single pixel feed: very wideband antenna
  - Polarizer: good cross-pol. specification
- **Heritages, dev. status and plan**
  - Toward 100% fractional bandwidth (**Kimura/JAXA, Hasegawa/NICT, Yamazaki/NAOJ, Dakie/OMU**)
  - **Niinuma+** (6-18 GHz), **Sekiya+** → 6-18 GHz ultra-wide receiver and 13 band rejection filter by HTSF
  - Continue researches about the possibility to expand the frequency up to 26 GHz

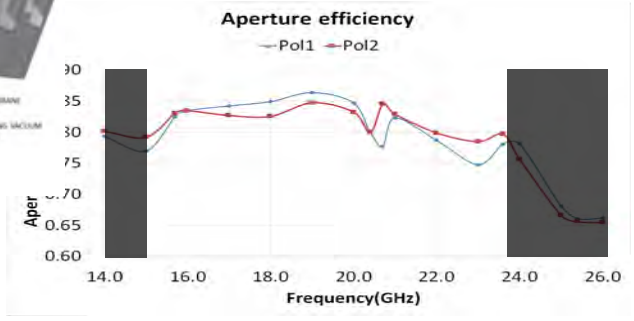












14. Helium Compressor

- **Key Technology**
  - Limited space and electricity
  - Matching with cold-heads procured by other countries
  - Outdoor use
- **Heritages, development status and plan**
  - **Sumitomo Heavy Industry (SHI)**
  - We visited South Africa with SHI team in 2020 and learn about the demand and requirements of SKAO
  - Sumitomo FA40 cooling test was made.









https://www.shi.co.jp/

15. Digitizer

- **Key Technology**
  - Band4/5 (2.8-15.4GHz) digitization; down convert vs. direct sample
  - Electromagnetic interference (EMI)
  - Thermal design, Outdoor use
- **Heritages, development status and plan**
  - OCTAD, KJCC, …
  - **Nakanishi** → Digital signal processing circuit (ROACH)
  - **Elecs Industry Co. Ltd.**
    - ➢ We are keeping discussions about developing our “improved” digitizer for Band 4/5 including direct sampling
    - ➢ Good response from the industry

Direct RF sampler
（エレックス工業）
https://www.elecs.co.jp/en/





New Direct-to-Digital COTS Boards Are Powered by 64 Gsps Agilex™ 9 SoC FPGA Direct RF-Series

Posted on May 6, 2024 by Barnaby Wickham

Annapolis Micro Systems, a leading COTS board and systems supplier, is now offering two powerful direct-to-digital COTS products based on Altera's Agilex™ 9 SoC FPGA Direct RF-Series.

The WILDSTAR™ SAF1 Small Form Factor Module (WSSAF1) integrates the Agilex™ 9 AGRW014 FPGA in a palm-size unit, for edge applications close to the sensor and in other tight envelope man-portable environments. It delivers high-performance processing and four channels each of 64 Gsps A/D and D/A converting at 10-bit resolution.

The WILDSTAR™ 3AE1 3U OpenVPX FPGA Processor (WB3AE1) integrates the Agilex™ 9 AGRW027 FPGA in a standard 3U VPX SOSA™-aligned Plug-In Card (PIC) form factor. The AGRW027 FPGA delivers similar performance as the AGRW014 FPGA but with double the channels: 8x transmit and 8x receive.

"By supporting much higher conversion and processing rates, these boards make it possible for customers to acquire and process adversary emissions from a wider portion of the electromagnetic spectrum, with a lower SWaP RF front end," said Noah Donaldson, Chief Technical Officer, Annapolis Micro Systems. "Now larger swaths of the RF spectrum can be efficiently digitized, processed, and recorded at the edge."

"Altera's Agilex™ 9 SoC FPGAs have

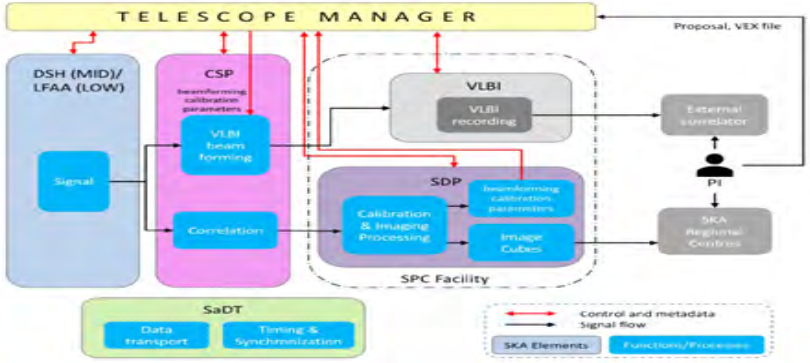
16. VLBI Recorder

Key Technology

- SKA-VLBI is recognized as a major SODP candidate. Goal: astrometric accuracy of 1 micro-arcsec. Requirements: minimize systematic errors → develop the multi-beam VLBI system and its calibration method
- Development and implementation of high-speed VLBI recording for more than 4 beams → data recording (800Gbps) is more than 100 times

Heritages, development status and plan

- SKAJP VLBI WG is discussing development plans (from 2027). SKAJ already started a test of 200 Gbps recording
- **Imai** → improvement of low-frequency astrometry (multi-view)
- **Kobayashi, Yoshiura** → Relevant activities.
- **Oyama** → 200 Gbps recording tests
- Fringes detected between **Iidata/Tohoku U.** and **GMRT/Ooty!** Test with **MWA** is underway



SKA1-MID						
#sub-array	#VLBI beam	Bandwidth (per pol, MHz)	Digiti-zation	Sampling	Data rate (Gbps)	Buffer size (1h, TB)
1	4	256	2	Nyquist	8	3.5
1	4	512	2	Nyquist	16	7
2	4	512	2	Nyquist	32	14
1	4	2500	2	Nyquist	78.12	34
1	16	512	2	Nyquist	64	28
1	52	200	2	Nyquist	81.25	35.7
10	52	200	2	Nyquist	812.5	357
SKA1-LOW						
#sub-array	#VLBI beam	Bandwidth (per pol, MHz)	Digiti-zation	Sampling	Data rate (Gbps)	Buffer size (1h, TB)
1	4	256	2	Nyquist	8	3.5
1	16	256	2	Nyquist	32	14
1	16	256	8	Nyquist	128	56.3