# SKA1 commitment plan of Japan

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NAOJ SKA1 Promotion Group

SKAJ

# Treatment of SKA1 in this symposium

- SKA1 was proposed to the MEXT Roadmap 2023
- To avoid any interference to the roadmap selection process, SKA1 was not asked to submit the LoI and the document (申請書)
- We appreciate SOC’s special concerns to SKA1

# Contents

1. Introduction

# Square Kilometre Array Phase 1

The world 16 countries commit ~2B Euro in total and construct/operate the world-largest radio interferometer in 2020’s

SKA Convention (2021.1.15~)

**Inter-governmental organization**

## SKA Observatory

**Decision Making**

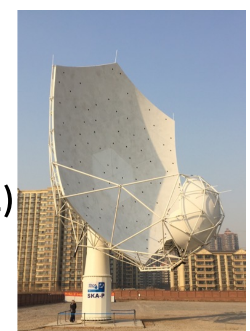
**SKAO Council**

- **Science and Engineering Advisory Committee**
- **Finance Committee**
- **Time Allocation Committee**
- **Other Committees**

**UK Headquarter**
**At Jodrell Bank Observatory**

**Australia LOW Observatory**
**(50-350 MHz)**
**131k units (512 stations)**
**Max 65km baseline (SKA1)**
**↓**
**1.25M units (4880 stations)**
**Max 300km (SKA2)**

**South Africa MID Observatory**
**(0.35-15.4 GHz)**
**197 (15m & 13.5m) dishes**
**Max 150km baseline (SKA1)**
**↓**
**2000 (15m) dishes**
**Max 3000km (SKA2)**



- SKA1: 10x better sensitivity, 10x better resolution, wider field-of-view & multi-mode → 100x better survey capability than before
- Only-one world-largest telescope covering the long-wavelength radio (<1GHz) in 2020’s
- Diverse Science (Epoch of Reionization, Gravity Theory with Pulsars, Magnetism, Cosmology, Galaxy Evolution, Astrobiology, Transients, …)
- General-purpose, international common-use telescope
- SKA1 construction started in July 2021
- Full operation in ~2028

# The History

## World ~ 30 years preparation toward construction

| 1993 | 1997 | 2000 | 2007 | 2012-2013 | 2015 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|
| URSI mtg | R&D start 6 countries | Sci./Eng. committee | SKA office | Site decision Baseline design | PDR White Book | CDR Conv. Sign | SKA Obs. Con. Prop. | SKA1 Con. start |

## Japan ~ 15.5 years activities made a mature community

**International**

2008 **SKA-JP launch → #270 as of 2023.4**

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

2011 1st EASKA workshop

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

2013 2nd EASKA workshop

2013 Udenkon SKA symposium

2014 **SCJ Masterplan Priority**

2015 **SKAJP Science Book**

2015 ASJ session

2015 SKA-JP workshop

2016 ASKAP & MWA Int'l conferences

2016 **MWA member**

2016 SKA-JP symposium

2017 Masterplan unsubmitted

2017 Mizusawa Science Book

2017 JPS session

2019 3rd EASKA workshop

2019 SKA-JP symposium

2020 **SCJ Masterplan Priority candidate**

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

2021 4th EASKA workshop

2021 SKAJP webinar

2021 **SKA-JP Science strategy workshop**

2022 **SRC member**

2023 **SCJ Long-term nominated**

2023 5th EASKA workshop

2023 **MEXT Roadmap application (supported by ASJ & Udenkon)**

2023 ASJ session

**Domestic**

**15 years outcomes**

Papers 508

Grant 561 MYen

Ph.D 36

Master 177

## NAOJ ~from "observe" to "investigate"

| 2000's | 2015-2017 | 2017.10~ | 2019.4~ | 2023.4~ |
|---|---|---|---|---|
| An observer to SKA Board & Sci./Eng. Adv. Committee | Sent university staff members to UK & AU | Mizusawa launched the section of future project (SKA) | SKA1 Study Group | SKA1 Promotion Group |

# Scope of SKA1 Project


- **SKA Phase 1 (SKA1)**
  - SKA1 construction and operation were endorsed at the first Council in February 2021
  - SKA1 construction was started in July 2021
- **Cost for SKA1 to 2030**
  - Construction：1297 M€
  - Operation: 725 M€

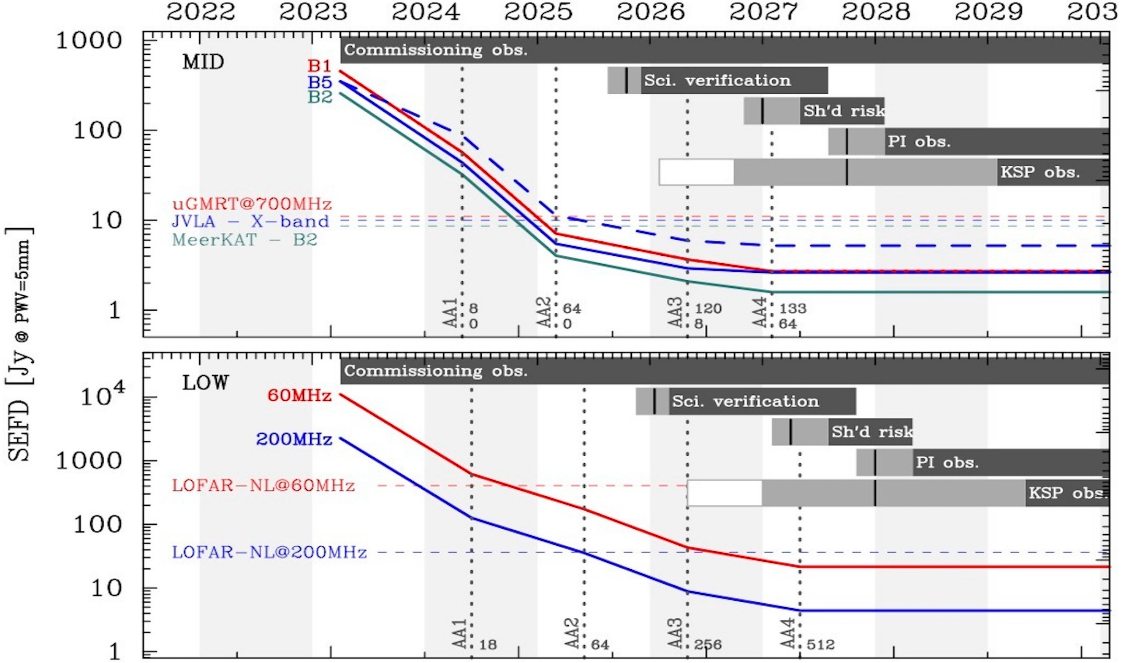
**(Including the development program? Yes)** SKA Observatory Development Program (SODP) is out of the scope of the SKA1 design and construction. However, the SODP is within the budget of the SKA phase 1. Therefore, our proposal includes the participation to the SODP.

**(Including SKA2? No)** Although the SKA Council has ambition to the SKA phase 2, the Council has concentrated on the implementation of the SKA phase 1. There is less discussion about the phase 2, so that the budget and schedule for the phase 2 are totally unclear. Therefore, our proposal scopes only the phase 1 and does not include the phase 2 of the SKA.

# Expected status during 5$^{th}$ mid-term plan period

## ■ End of construction and start of stable operation including key science projects (KSPs)

Early (AA2) operation 2025~
Full (AA4orAA*) operation 2029~


**SODP (SKA Observatory Development Program) will start soon. Some candidates:**

- Extend $B_{max}$ to 300 km
- Band 3/4 (2-5 GHz)
- **Band 6/7 (15-50 GHz)**
- Band 1 phased array feed
- **VLBI**
- # of beamform to 1500
- Data processor to 100 PFlops

# Phased integration of arrays

**End of Construction 2029 July**

Table 34: Characteristics of each Array Assembly (AA) milestone and the functionality delivered.

| **Telescope** | | **AA0.5** | **AA1** | **AA2** | **AA3** | **AA4** |
|---|---|---|---|---|---|---|
| LOW | Stations | 8 | 18 | 64 | 256 | 512 |
| | Observing Modes* | Basic imaging | | Pulsar Timing, Dynamic Spectrum | Pulsar Search, Transient Capture | VLBI |
| | | | | | | |
| MID | Dishes | 4 | 8 | 64 | 121 | 197 |
| | Integrated MeerKAT dishes | 0 | 0 | 1 | 8 | 84 |
| | Receiver bands | 1, 2 | 1, 2 | 1, 2 5 (on 32 dishes) | 1, 2 5 (on 64 dishes | 1, 2, 5 |
| | Observing Modes* | Basic imaging | Basic Pulsar Timing | Pulsar Search | Scaled up capability of existing functions | Dynamic Spectrum, Transient Capture, VLBI |

Decision of delivery system

AA*

AA* = AA3 and AA4 will be combined to reduce the risk in the case of budget shortage in future

AA* decision will be made at the end of AA1 (2025)

# Updated construction schedule

| Milestone Event (earliest) | | SKA-Mid (end date) | SKA-Low (end date) |
|---|---|---|---|
| Construction Approval | | 2021 Jul | 2021 Jul |
| AA0.5 | 4 dishes<br>6 stations | 2025 May | 2024 Nov |
| AA1 | 8 dishes<br>18 stations | 2026 Apr | 2025 Nov |
| AA2 | 64 dishes<br>64 stations | 2027 Mar | 2026 Oct |
| AA* | 144 dishes<br>307 stations | 2027 Dec | 2028 Jan |
| Operations Readiness Review | | 2028 Apr | 2028 Apr |
| End of Staged Delivery programme | | 2028 Jul<br>2029 Mar | 2028 Jul<br>2029 Mar |
| AA4 | 197 dishes<br>512 stations | TBD | TBD |

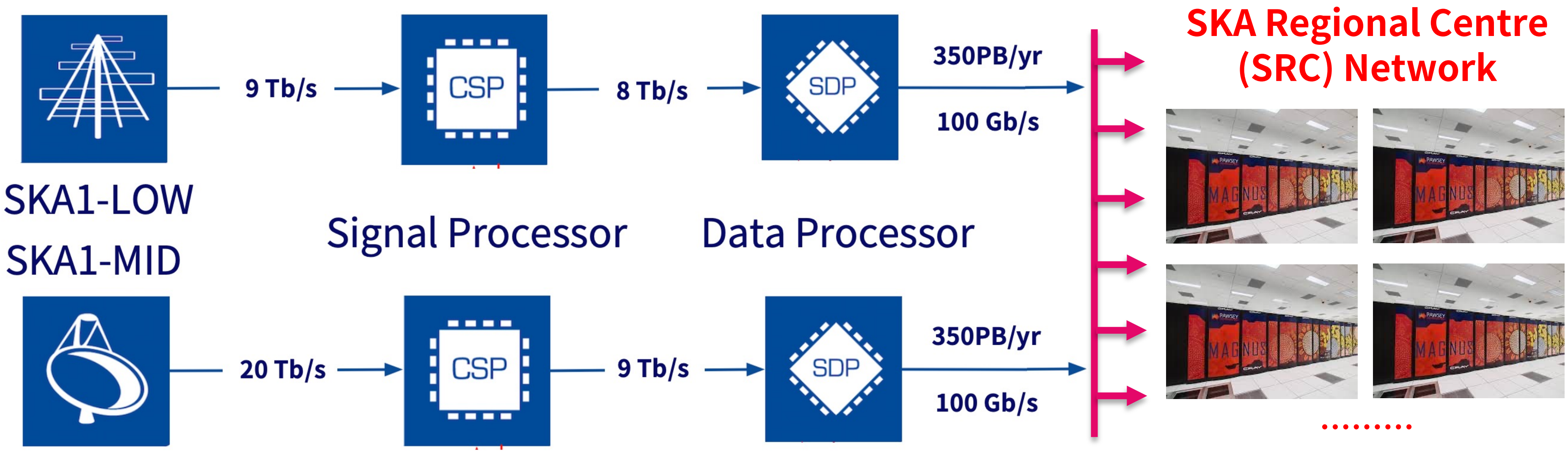
Dates from Integrated Project Schedule Version July 2023; schedule modelling projects ~2 months per year shift in schedule for the project execution

First data release to the community expected in 2026/27 (for science verification)

- **2025~ Japan can commit construction and early science including key science start-up**
- **2028~ Japan can only commit steady operation including key science, AA4, and SODP**

# Data Flow and SKA Regional Centre

■ **Delivery of SKA's big data in collaboration with world-wide nodes**




In a lifetime of science, SKAO is responsible for

SRC is responsible for

- Proposal system
- Time allocation

→

- Scheduling
- Observation

→

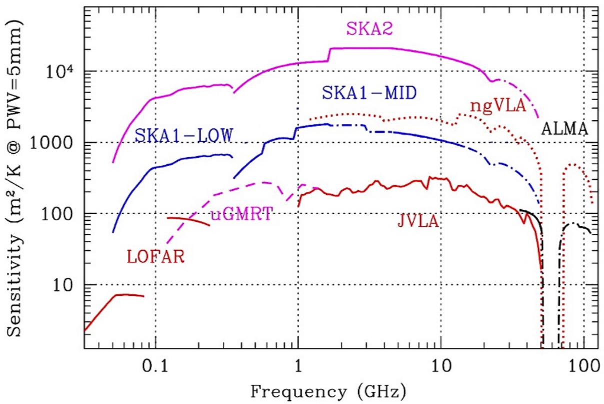
- Data reduction
- Archiving observatory data product (ODP)

→

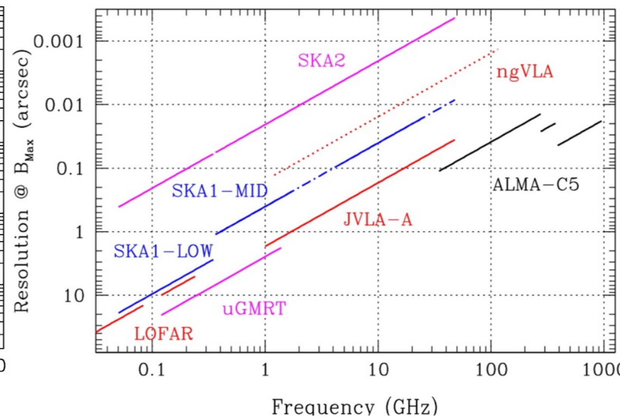
- Access to ODP
- Data analysis
- Storing advanced data product (ADP)

# Ultimate survey performance

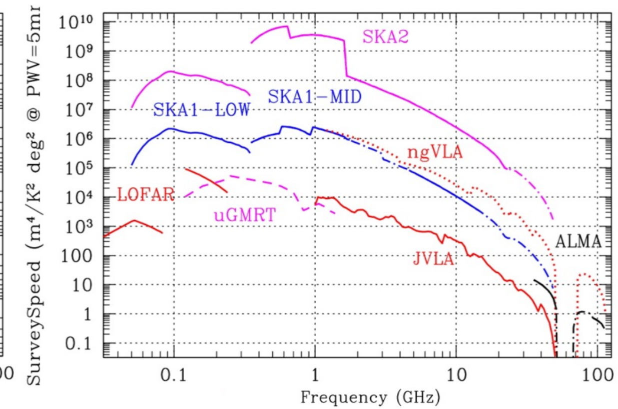
## ①Sensitivity




## ②Resolution




## ③Survey Merit




## ④Multi-mode

We can perform multiple observing modes simultaneously

| Subarray | Band | Continuum Imag BW (MHz) | # Zoom Windows | # PSS Beams | PST BW (MHz) | # PST Beams | VLBI BW (MHz) | # VLBI Beams |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 810.0 | 3 | 1500 | 810.0 | 16 | 810.0 | 2 |

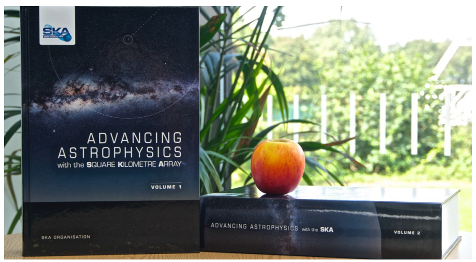
- **The sensitivity and resolution are 10 times better, the survey merit is 100 times better than the current largest facilities**
- **An effective annual operation time >> 1 year = 8760 hours**
  - There are two (LOW & MID) telescopes and there are multi-beam & multi-mode capabilities

# Key Science goals and surveys

HI 1420 MHz (21cm) =
z=6 → 202 MHz (1.5m)
z=27 → 51 MHz (5.9m)

The SKA community led by the int'l science working groups (SWGs) wrote **SKA Science Book (2015)**

https://pos.sissa.it/cgi-bin/reader/conf.cgi?confid=215




SWGs also have been developing **notional key science projects (KSPs)** during regular SKA science conferences.

| | 周波数 | 分解能 kHz | 感度 image rms | Dyn range dB | 時間分解 msec | 空間分解 arcsec | 視野 deg² | 天域 deg² | 積分時間 hr | 掃天時間 hr | 備考 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **EoR imaging** | 50-200 MHz | 1000 | 1.4 mK | 50/50 | 400 | 300 | 20 | 100 | 2000 | 5000 | Deep |
| **EoR power spectrum** | 50-200 MHz | 1000 | 4.6 mK | 50/40 | 400 | 300 | 20 | 1000 | 200 | 5000 | Drift scan |
| | 50-200 MHz | 1000 | 14 mK | 50/35 | 400 | 300 | 20 | 10000 | 200 | 5000 | Wide |
| **HI High-z** | 790-950 MHz | 50 | 16µJy | 50/35 | 150 | 2-10 | 1.1 | 5.4 | 1000 | 5000 | Line |
| **HI Low-z** | 1.3-1.4 GHz | 20 | 14µJy | 50/30 | 150 | 2-10 | 0.38 | 3.8 | 200 | 2000 | Line |
| **HI MW** | 1415-1425 MHz | 4 | 75µJy | 50/30 | 150 | 2-10 | 0.38 | 1080 | 4.4 | 12600 | Line |
| **Cosmology High-z IM** | 350-1050 MHz | 300 | 3.3mJy | 40/40 | 150 | 1.7deg | 1.4 | 30000 | 2.2 | 10000 | Drift scan, Line, Wide |
| **Cosmology ISW, Dipole** | 1-1.7 GHz | 1000 | 7µJy | 45/30 | 150 | 2 | 0.38 | 31000 | 0.12 | 10000 | Wide |
| **Continuum +Mag. Band 2** | 1-1.7 GHz | 1000 | 1.3µJy | 60/30 | 150 | 0.5 | 0.38 | 1000 | 3.8 | 10000 | Wide |
| | 1-1.7 GHz | 1000 | 250nJy | 60/30 | 150 | 0.5 | 0.38 | 7.8 | 95 | 2000 | Medium |
| | 1-1.7 GHz | 1000 | 65nJy | 60/30 | 150 | 0.5 | 0.38 | 0.38 | 2000 | 2000 | Deep |
| **Continuum +Mag. Band 5** | 7-11 GHz | 4000 | 400nJy | 45/30 | 150 | 0.05 | 30 min² | 0.5 | 16.4 | 1000 | Wide |
| | 7-11 GHz | 4000 | 50nJy | 45/30 | 150 | 0.05 | 30 min² | 30 min² | 1000 | 1000 | Deep |
| **Cradle of Life** | 8-12 GHz | 4000 | 80nJy | 40/25 | 150 | 0.04 | 18 min² | 0.05 | 600 | 6000 | 1視野に複数ターゲット |

# Highlights of SKA Key Science 1

| | SKA1 | SKA2 = 10*SKA1 |
|---|---|---|
| **Cosmic Dawn and the Epoch of Reionization** | Direct imaging of EoR structures ($z = 6 – 12$) | Direct imaging of Cosmic Dawn structures ($z = 12 – 30$) |
| | Power spectra of Cosmic Dawn down to arcmin scales, possible imaging at 10 arcmin. | First glimpse of the Dark Ages ($z > 30$). |
| **Cosmology & Dark Energy** | Constraints on DE, modified gravity, the distribution & evolution of matter on super-horizon scales: competitive to Euclid. | Constraints on DE, modified gravity, the distribution & evolution of matter on super-horizon scales: redefines state-of-art. |
| | Primordial non-Gaussianity and the matter dipole: 2x Euclid. | Primordial non-Gaussianity and the matter dipole: 10x Euclid. |
| **Galaxy Evolution probed by Neutral Hydrogen** | Gas properties of $10^7$ galaxies, $<z> \approx 0.3$, evolution to $z \approx 1$, BAO complement to Euclid. | Gas properties of $10^9$ galaxies, $<z> \approx 1$, evolution to $z \approx 5$, world-class precision cosmology. |
| | Detailed ISM of galaxies (50pc@3Mpc), diffuse IGM down to $N_H < 10^{17}$ at 1 kpc. | Detailed ISM of galaxies (50pc@10Mpc), diffuse IGM down to $N_H < 10^{17}$ at 1 kpc. |
| **Galaxy Evolution probed in the Radio Continuum** | Star formation rates (10 $M_\odot$/yr to $z \sim 4$). | Star formation rates (10 $M_\odot$/yr to $z \sim 10$). |
| | Resolved star formation astrophysics (sub-kpc active regions at $z \sim 1$). | Resolved star formation astrophysics (sub-kpc active regions at $z \sim 6$). |

# Highlights of SKA Key Science 2

| | SKA1 | SKA2 = 10*SKA1 |
|---|---|---|
| **Strong-field Tests of Gravity with Pulsars and BHs** | 1st detection of nHz-stochastic gravitational wave background. | GW astronomy of discrete sources: constraining galaxy evolution, cosmological GWs and cosmic strings. |
| | Discover and use NS-NS and PSR-BH binaries to provide the best tests of gravity theories and General Relativity. | Find all ~40,000 visible pulsars in MW, use the most relativistic systems to test cosmic censorship and the no-hair theorem. |
| **The Origin and Evolution of Cosmic Magnetism** | The role of magnetism from sub-galactic to Cosmic Web scales, the RM-grid @ 300/deg$^2$. | The origin and amplification of cosmic magnetism, the RM-grid @ 5000/deg$^2$. |
| | Faraday tomography of extended sources (100pc@14Mpc, 1kpc@z≈0.04) | Faraday tomography of extended sources (100pc@50Mpc, 1kpc@z≈0.13) |
| **The Transient Radio Sky** | Use fast radio bursts to uncover the missing "normal" matter in the universe. | Fast radio bursts as unique probes of fundamental cosmological parameters and intergalactic magnetic fields. |
| | Study feedback from the most energetic cosmic explosions and the disruption of stars by super-massive black holes. | Exploring the unknown: new exotic astrophysical phenomena in discovery phase space. |
| **The Cradle of Life & Astrobiology** | Proto-planetary disks; imaging inside the snow/ice line (@ < 100pc), Searches for amino acids. | Proto-planetary disks; sub-AU imaging (@ < 150 pc), Studies of amino acids. |
| | Targeted SETI: find airport radars for $10^4$ nearby stars. | Ultra-sensitive SETI: find airport radars for $10^5$ nearby stars, TV ~10 stars. |

# SKA science book of Japan




**2015: First science book**

8 chapters (EoR, Cosmology, Gal. Evolution, Pulsars, Magnetism, VLBI, ISM, Transients)

**2020: Second science book**

2 chapters (Star formation and Plants) added.

**10 Science Working Groups in SKA-JP as of 2023**

**2023: PASJ Special Issue**

Metre and Centimetre Radio Astronomy in the Next Decade

13 papers

https://academic.oup.com/pasj/pages/special-issue-metre-and-centimetre-radio-astronomy-in-the-next-decade

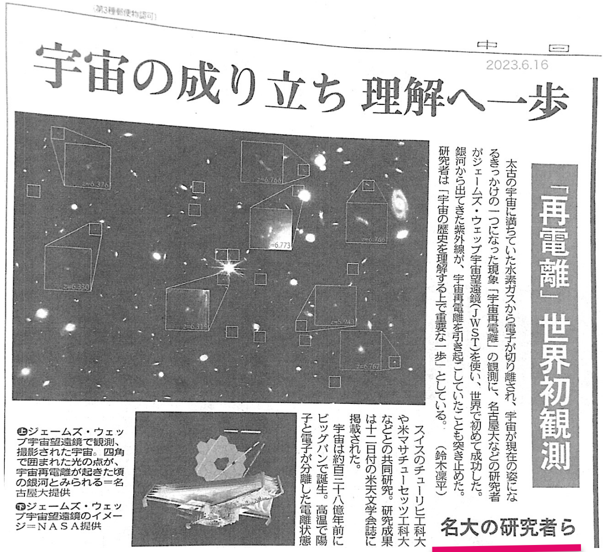
3. Science goals

# Key Science Goals of Japan


How the first stars & galaxies formed?


How Universe's structure and activity made?


Do we understand the gravity theory?



中日 2023.6.16

宇宙の成り立ち 理解へ一歩

「再電離」世界初観測

名大の研究者ら

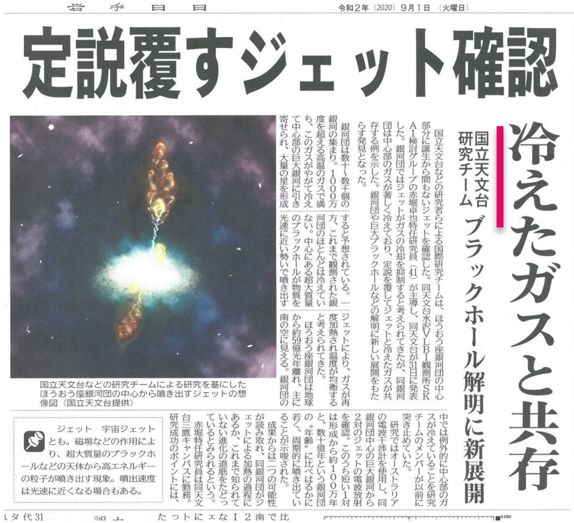
太古の宇宙に満ちていた水素ガスから電子が切り離され、宇宙が現在の姿になるきっかけの一つになった現象「宇宙再電離」の観測に、名古屋大などの研究者がジェームズ・ウェッブ宇宙望遠鏡（JWST）を使い、世界で初めて成功した。銀河から出てきた紫外線が、宇宙再電離を引き起こしていたことも突き止めた。研究者は「宇宙の歴史を理解する上で重要な一歩」としている。（鈴木涼平）

スイスのチューリヒ工科大や米マサチューセッツ工科大などとの共同研究。研究成果は十三日付の米天文学会誌に掲載された。

宇宙は約百三十八億年前にビッグバンで誕生。高温で陽子と電子が分離した電離状態

㊤ジェームズ・ウェッブ宇宙望遠鏡で観測、撮影された宇宙。四角で囲まれた光の点が、宇宙再電離が起きた頃の銀河とみられる＝名古屋大提供
㊦ジェームズ・ウェッブ宇宙望遠鏡のイメージ＝NASA提供

(© 中日新聞 2023年6月16日 朝刊)



岩手日日 令和2年（2020）9月1日（火曜日）

定説覆すジェット確認

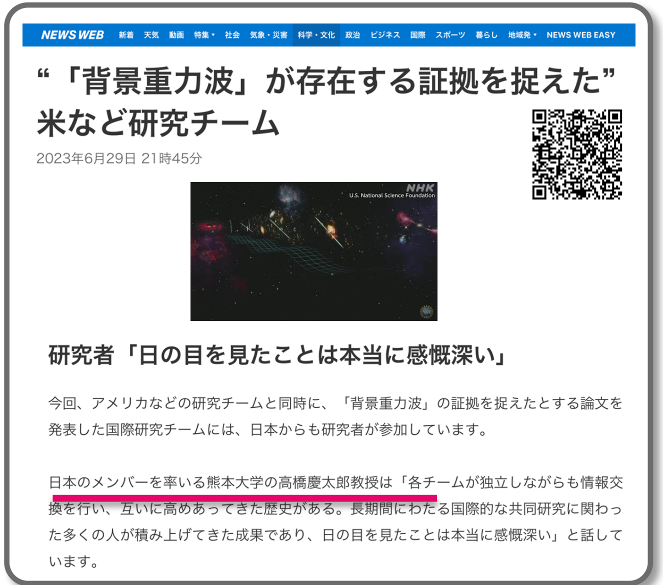
冷えたガスと共存

国立天文台研究チーム ブラックホール解明に新展開

国立天文台などの研究チームによる研究を基にしたほうおう座銀河団の中心から噴き出すジェットの想像図（国立天文台提供）

ジェット 宇宙ジェットとも。磁場などの作用により、超大質量のブラックホールなどの天体から高エネルギーの粒子が噴き出す現象。噴出速度は光速に近くなる場合もある。

(© 岩手日日 2020年9月1日)



NEWS WEB

“「背景重力波」が存在する証拠を捉えた” 米など研究チーム

2023年6月29日 21時45分

研究者「日の目を見たことは本当に感慨深い」

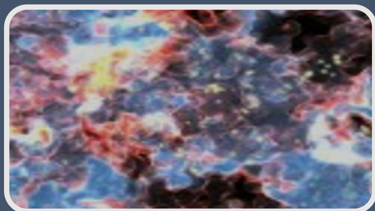
今回、アメリカなどの研究チームと同時に、「背景重力波」の証拠を捉えたとする論文を発表した国際研究チームには、日本からも研究者が参加しています。

日本のメンバーを率いる熊本大学の高橋慶太郎教授は「各チームが独立しながらも情報交換を行い、互いに高めあってきた歴史がある。長期間にわたる国際的な共同研究に関わった多くの人が積み上げてきた成果であり、日の目を見たことは本当に感慨深い」と話しています。

(© NHK NEWS WEB 2023年6月29日)

**Goals** Achieve the proposal & paper share of 2% comparable to European countries (FR, DE, SP, GE)

# Key Science and Others

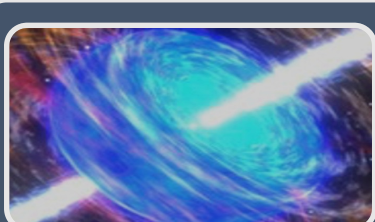


## Deciphering the cosmic reionization with cosmology and astrophysics

- Our strengths: theory and distant galaxy surveys, Our technique: foreground removal, calibration, Link: **Cosmology, galaxy evolution**


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

- Our strengths: high-energy astrophysics, Our technique: Faraday Tomography, Link: **ISM, star and planet**



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

- Our strengths: multi-messenger astronomy, VLBI, Our technique: time-domain analysis and pulsar timing array, Link: **Transients, VLBI**

- **Also promote individual science goals including "unknown"**
- **Encourage software developments for KSP areas**

# SKA engineering reports of Japan


SKAエンジニアリングレポート



日本 Square Kilometre Array コンソーシアム

技術検討班

2016


SKAエンジニアリングレポート２０２１



日本 Square Kilometre Array コンソーシアム

技術検討班

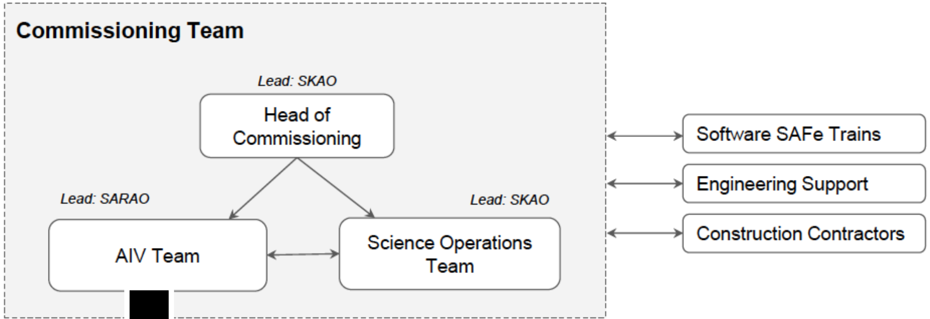
**<u>2016: First report</u>**
Overview of SKA system and developments

**<u>2021: Second report</u>**
Japanese strategy of SKA engineering contribution

- AIC/CSV
- Faraday Tomography
- EoR pipeline
- UHF receivers
- Band 6/7
- VLBI
- On-the-fly Interferometer

**7 Engineering Working Groups in SKA-JP as of 2023**

# AIV and our engineering target




- AIV (assembly, integration, verification) is a vital part of huge systems like SKA
- Japan joins (leads) the Verification Team

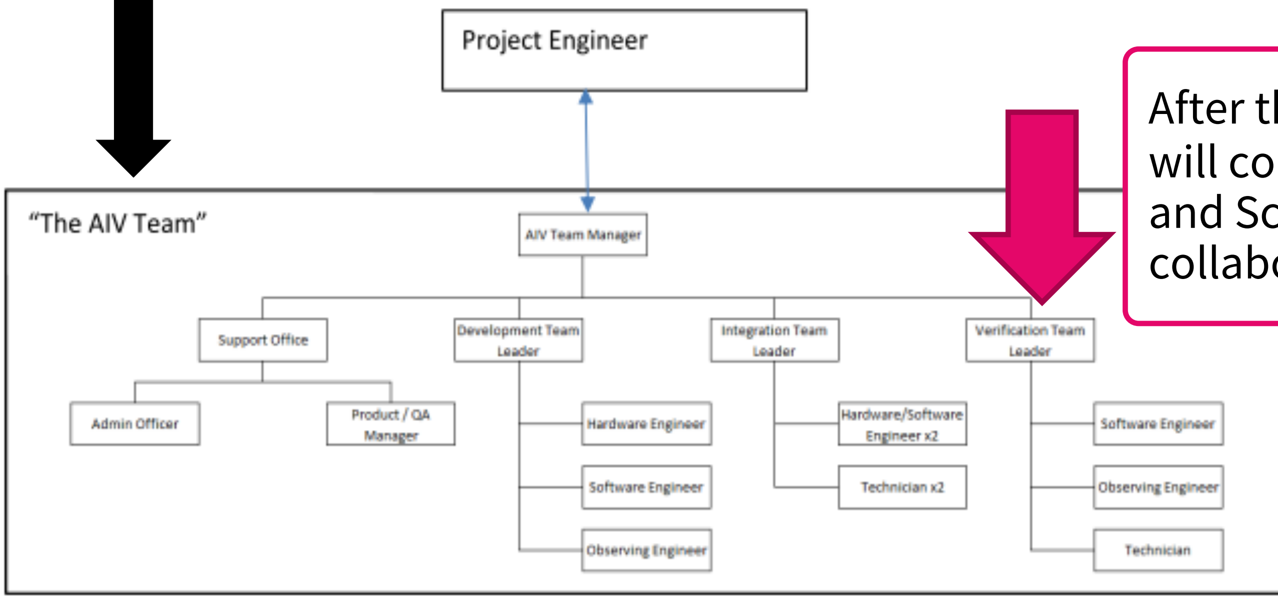



Figure 4: The AIV Team has Clear Reporting Lines.

After the construction, the team will contribute Commissioning and Science Verification (CSV) in collaboration with science team

4. Engineering Contribution

# Participating to LOW/MID AIV

## ■ Join AIV teams since 2021

- **Y. Kono (NAOJ - MoU)**
  - ➢ Test procedures of AA0.5
- **K. Sunada (NAOJ – MoU)**
  - ➢ RFI monitoring system, DISH pointing and others
- After AIV, we plan to move forward to commissioning and science verification (CSV)

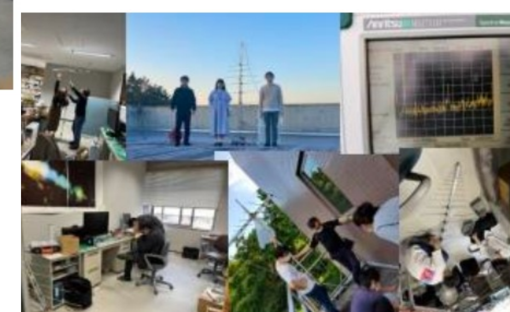
## ■ Tests in Japan

- Test and evaluation of phase center of the log-periodic antenna
- Test signal generator


LOW AIV team

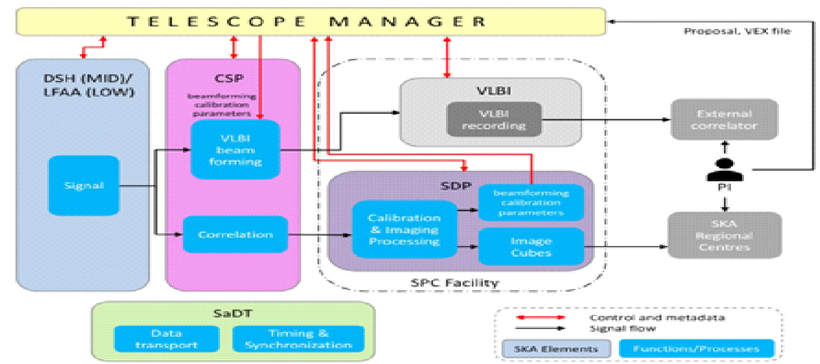
MID ITF inspection

Experiments at Mitaka HQ with young researchers



# SODP: Challenge of VLBI recording

- **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
- **Functionality tests planned at AA***
  - Test of integration between CSP and the VLBI system (both HW and SW) using voltage output mode (common with pulsar data) from CSP
  - Development and implementation of high-speed VLBI recording for more than 4 beams → **data recording (800Gbps) is more than 100 times**
  - Upgrade of partner VLBI stations + development of a new correlator
- **SKAJP VLBI WG is discussing development plans (from 2027)**
  - SKAJ already started a test of 200 Gbps recording

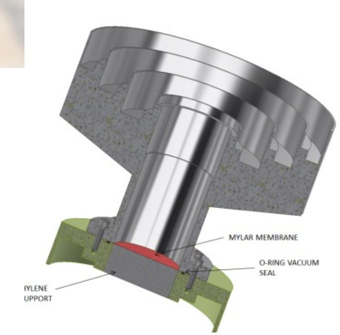


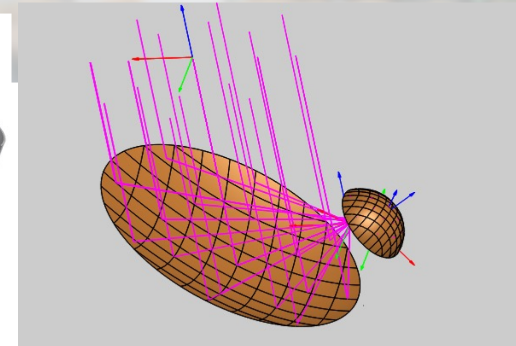

| SKA1-MID | | | | | | |
|---|---|---|---|---|---|---|
| #sub-array | #VLBI beam | Bandwidth (per pol, MHz) | Digiti-zation | Sampling | Data rate (Gbps) | Buffer size (1h, TB) |
| 1 | 4 | 256 | 2 | Nyquist | 8 | 3.5 |
| 1 | 4 | 512 | 2 | Nyquist | 16 | 7 |
| 2 | 4 | 512 | 2 | Nyquist | 32 | 14 |
| 1 | 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 |

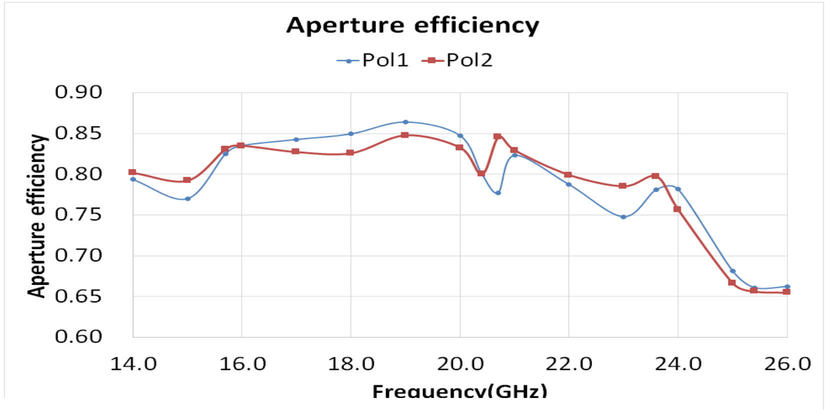
| SKA1-LOW | | | | | | |
|---|---|---|---|---|---|---|
| #sub-array | #VLBI beam | Bandwidth (per pol, MHz) | Digiti-zation | Sampling | Data rate (Gbps) | Buffer size (1h, TB) |
| 1 | 4 | 256 | 2 | Nyquist | 8 | 3.5 |
| 1 | 16 | 256 | 2 | Nyquist | 32 | 14 |
| 1 | 16 | 256 | 8 | Nyquist | 128 | 56.3 |

# SODP: Receivers

- **SKA1 study & promotion group activities**
  - **Kimura (JAXA)+ 2019**
    - Axially corrugated horn
    - Design using Champ
    - SKAO's GRASP model was already integrated
  - **Yamazaki (OMU) 2022,2023**
    - Optics design of Band 6 (15-29 GHz)
  - **Sumitomo Heavy Industry (SHI)**
    - Visited South Africa with SHI
    - Sumitomo FA40 cooling test
- **In the SKA project, we**
  - Continue scientific and engineering researches about the possibility to expand the observing frequency up to 26 GHz
  - Watch the on-going study of antenna specification (antenna pointing accuracy)



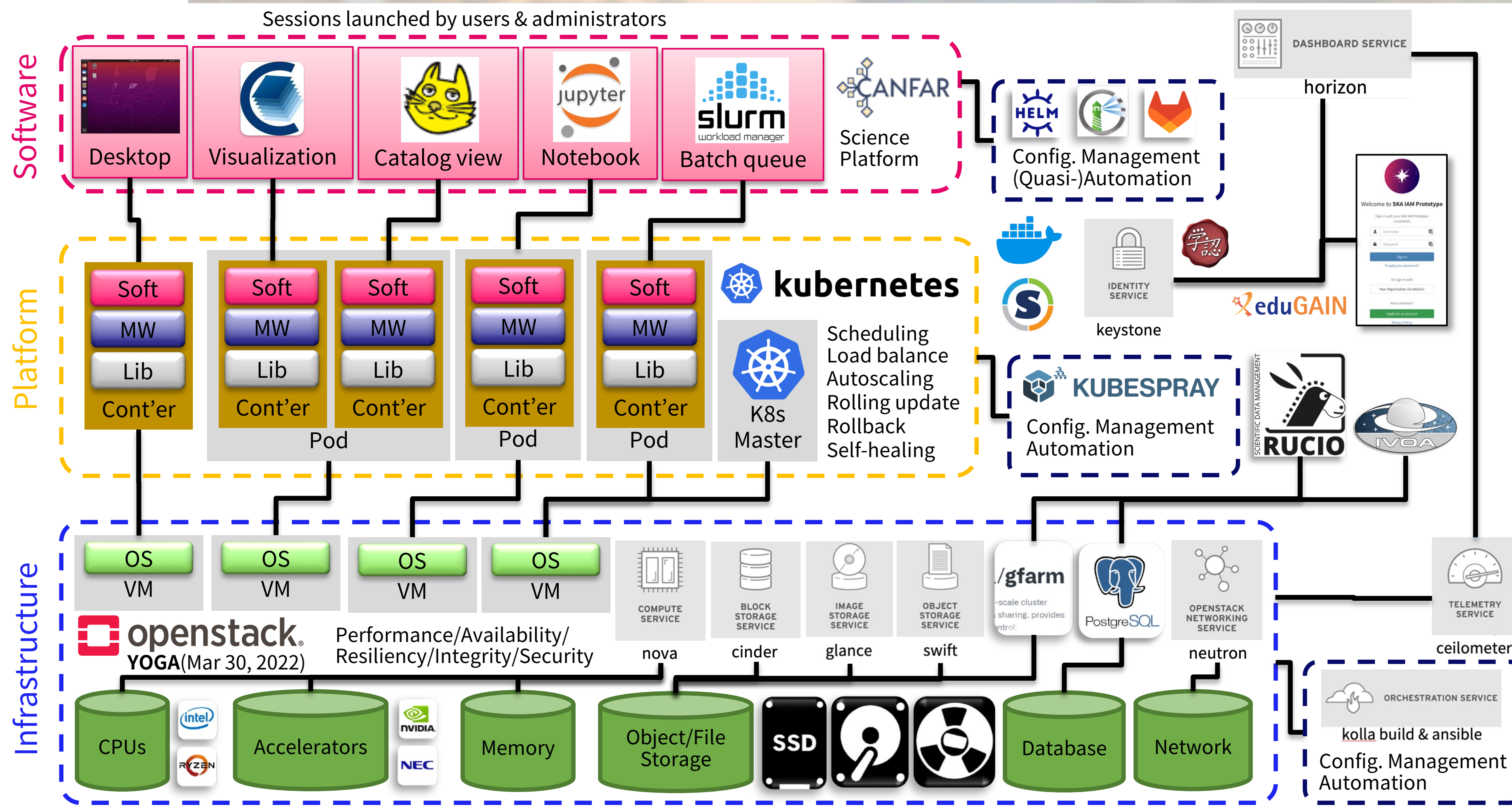




https://www.shi.co.jp/

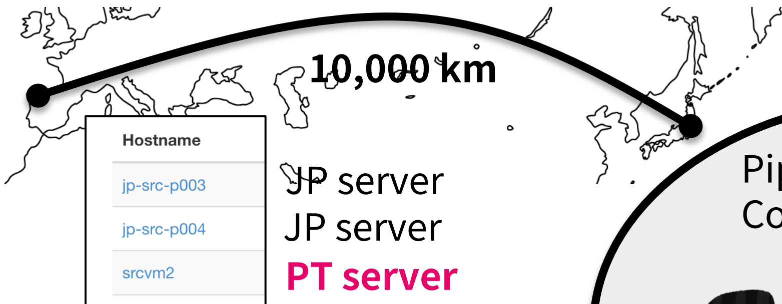
# JPSRC Architecture

Utilize **Cloud**, **Container**, and **Web** technologies
→ Looking at the same direction as ADC!



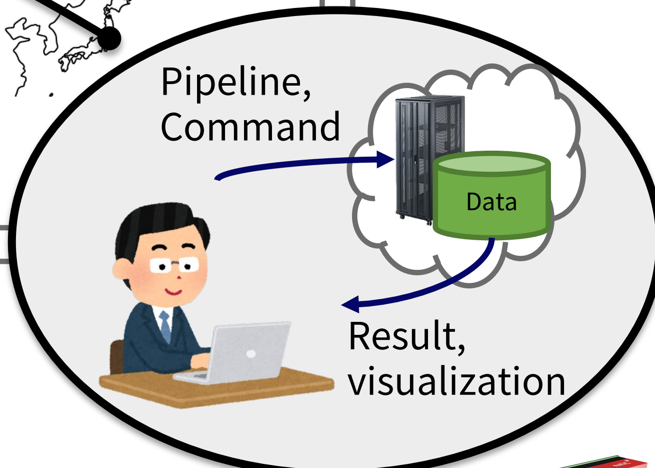
# SRC Prototyping

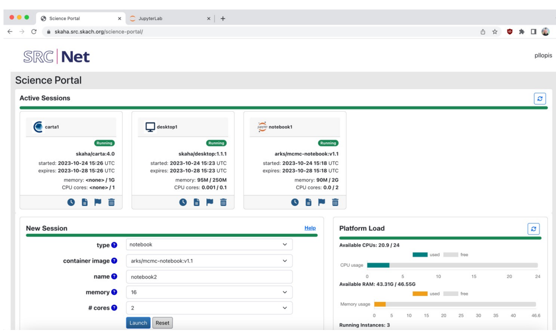
## The intercontinental cloud testbed
(Lead: **JP**, collaboration: PT, NE)




## An East Asia Rucio Storage Element
(Lead: ESP, collaboration: **JP**+7 countries)

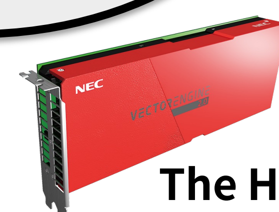
| Src\Dst | SPSRC_STORM | SESRC_XRD_RBD | KRSRC_STORM | JPSRC_STORM |
|---|---|---|---|---|
| STFC_STORM | 0% | 0% | 100% | 0% |
| SPSRC_STORM | - | 0% | 100% | 0% |
| SESRC_XRD_RBD | 0% | - | 100% | 0% |
| JPSRC_STORM | 0% | 0% | 100% | - |
| IMPERIAL | 0% | 0% | 100% | 0% |
| CNAF | 0% | 0% | 100% | 0% |
| CHSRC_XRD | 0% | 0% | 100% | 0% |
| CASRC_XRD | 0% | 0% | 100% | 0% |
| AUSSRC_STORM | 0% | 0% | 100% | 0% |




## The science platform testbed
(Lead: CA, collaboration: **JP**, ESP, SE, CH)

| acceleration | CPU | VE |
|---|---|---|
| Magnetism Faraday tomography | 1 | 30↑ |
| EoR foreground subtraction | 1 | 20↑ |




## The HPC technology testbed
(Lead: **JP**)

# Japanese Target Share of Science

- **We target to obtain the share of science outputs larger than 2%, which is Japanese share of the telescope time.**
  - Although there are huge uncertainties, the 2% corresponds to

| Common-use category | # of proposals | # of approvals | # of papers |
|---|---|---|---|
| Key Science Projects<br>(KSPs, large & long-term proposals) | 15-30 | 3 | 6 |
| PI Proposals<br>(PIPs, small & short-term proposals) | 33-66 | 6 | 6 |
| Total (per year) | 48-96 | 9 | 12* † ‡ |

* This number per cost is comparable to those of Subaru, Suzaku, and ALMA.
† This number is comparable to the current SKAJP's output using SKA pathfinders.
‡ This number is also the target for SKA precursors before SKA1 is in operation.

| Common-use category | CPU Power | Storage | FTE |
|---|---|---|---|
| SKA Regional Centre<br>(SRCs, data center and user support) | 0.7 PFlops | > 50 PB | 4# |

# This number is for the international SRC network only. Further 8 FTEs are requested for domestic tasks.

# Engineering Motivated by Science

- The development plan has been made with long discussion with the community and SKAO. The plan links to Japan's key science objectives and engineering know-how.

- EoR, Cosmology, Galaxy Evolution
- Magnetism, Pulsars, Transients, ISM
- Milky Way, Cradle of Life, AGN

Band B

| 0.05 | 0.3 | 1.0 | 1.7 | 3 | 5 | 8 | 15 | 25~50 |
|---|---|---|---|---|---|---|---|---|
| LOW | Band 1 | Band 2 | Band 3 | Band 4 | Band 5a | Band 5b | Band 6/7 | Frequency (GHz) |

**1. Assembly, Integration, and Verification (AIV) and Commissioning and Science Verification (CSV)**

- One of the most important tasks to realize the designed performance of SKA
- SKAO has high expectations for Japanese technological capabilities

**2. VLBI system (both LOW and MID)**

- VERA's experiences of MID, a new frontier of LOW, toward global VLBI

**3. Software**
- EoR calibration and imaging pipeline
- Magnetism Faraday Tomography pipeline

**4. Band6/7/B receiver**

- Scientific needs
- VLBI experiences
- Continue research, test, and design

# Organization and staffing

NAOJ Mizusawa VLBI
NAOJ Others (volunteer)
External (volunteer)

## Organization (proposal to Roadmap)

- **THERS 東海大学機構**
  - **Nagoya University** — Management of project, EoR, Gal. Evol., Cosmology, IPS, SRC
  - **Gifu U.** — 星惑星形成
- **Kumamoto U.** — Pulsars
- **NAOJ (partly secondment to Nagoya U.)** — Negotiation, Magnetism, AIV, Cryostat, Digitizer, VLBI
- **Kagoshima U.** — Magnetism, AIV
- **Yamaguchi U.** — Transients, AIV
- **Osaka M. U.** — Receiver

- Director H. Kobayashi
  - Head of Science M. Machida
    - Use cases T. Hirota
    - Oversea K. Takahashi
    - CSV T. Jike
  - Head of SRC T. Akahori
    - Cloud K. Yamashita
    - Container S. Ideguchi
    - Container S. Yoshiura
    - Support Y. Iwata
    - Support H. Sakemi
  - Head of Engineering K. Niinuma
    - AIV Y. Kono
    - AIV K. Sunada
    - VLBI T. Oyama
    - Receiver Y. Yamazaki
  - Outreach H. Nakanishi

## Young Researcher



Science book (as a text), webinar, SWG/EWG → WG Leader, Oversea stay, Funding PI → Becomes core member

# SKA1 project proposal process

- **The Mizusawa VLBI Observatory, MVO, started considering the SKA as a future plan in October 2017 and organized a planning division for it.**
- **The SKA sub-project was proposed by MVO in March 2018.**
  - Discussions on what should be future projects of NAOJ need to be held first, and the SKA is not approved as a subproject of MVO at this point in time.
- **SKA1 Study Group from April 2018 to March 2022**
  - Clarification and concretization of Japan's science goals
  - Proposal of participation plan consistent with the SKA headquarters
  - Start of in-kind participation in the SKA project
- **SKA1 was nominated as a priority project of Master Plan of Science Council and proposed to Roadmap of MEXT from Nagoya Univ. in 2020.**
- **SKA1 was proposed a A-project from 2022 and approved as a sub-project of MVO.**
  - Needs of consideration of feasible budget plan with reductions of influence to NAOJ budget, 運営費交付金.
- **SKA1 was nominated in Future Initiative and Long-term Plan「未来の学術振興構想」of Science Council in 2023 and proposed to Science Roadmap of MEXT from Nagoya Univ. in 2023**

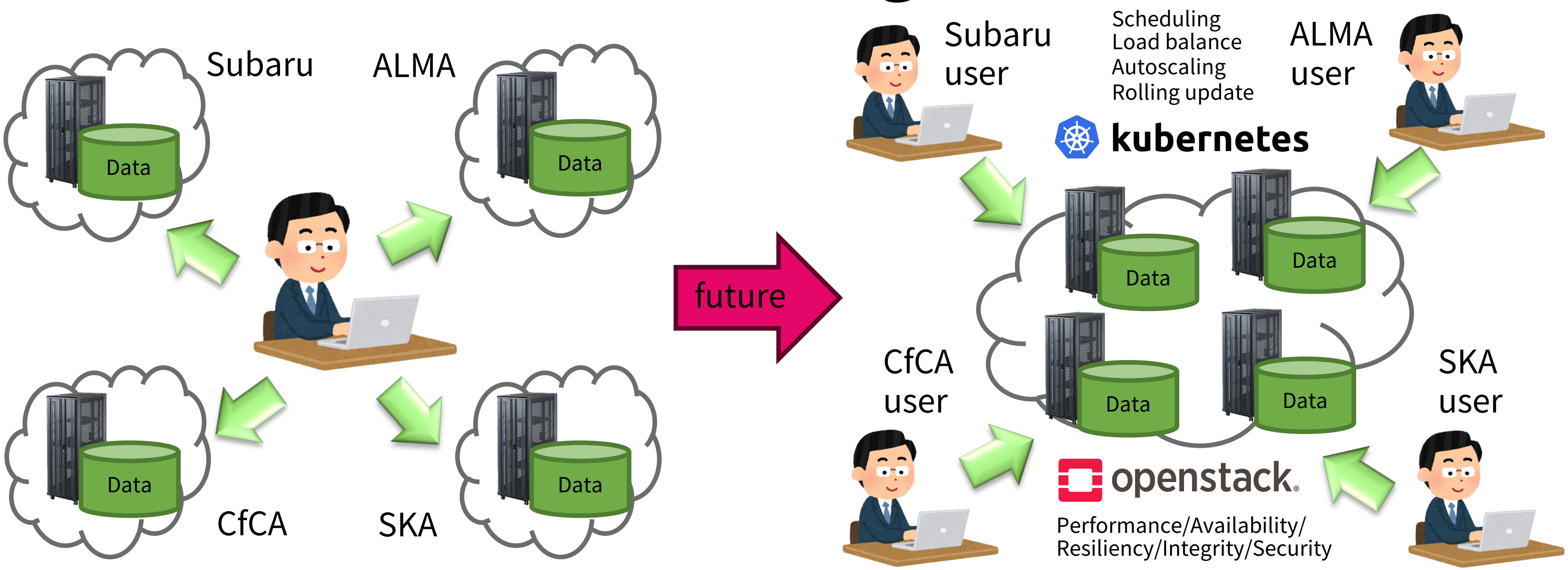
# Lessons learned from SKA1 proposal

- **Discussion and formulation of medium- and long-term future plans are necessary, and these activities of the science strategy committee are very important.**

- **What is a process of new science field development?**
  - The scientific objectives of the SKA are not entirely consistent with those of VLBI and any other NAOJ radio projects.

- **Many new projects derive from existing projects**
  - Is the current system suitable with fostering them?
  - What is sub-project and A-project?  Are they matching it?

# What does SRC brings to NAOJ?




- **SRC tech. allows us to consolidate NAOJ's resources of computing and storage, increasing the efficiency and reducing the cost**
  - E.g., Canadian Astronomy Data Centre (CADC)
  - NAOJ ADC would lead this federation. JPSRC is happy to join it.

# Summary

- **SKA1 is an innovative telescopes system and will open new fields of Astronomy**
- **SKA1 commitment plan**
  - Bottom-up plan with >2% contribution/observation time
  - 3 Japanese Key Science (EoR, Magnetism, Pulsar)
  - Engineering contribution (AIV/CSV, VLBI, Band6, SRC)
- **There is a strong need to clarify the process for developing future plans clearly**