# PEARL-ISL Inter-Satellite Communication Experiment

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Center for Astronautical Physics and Engineering,

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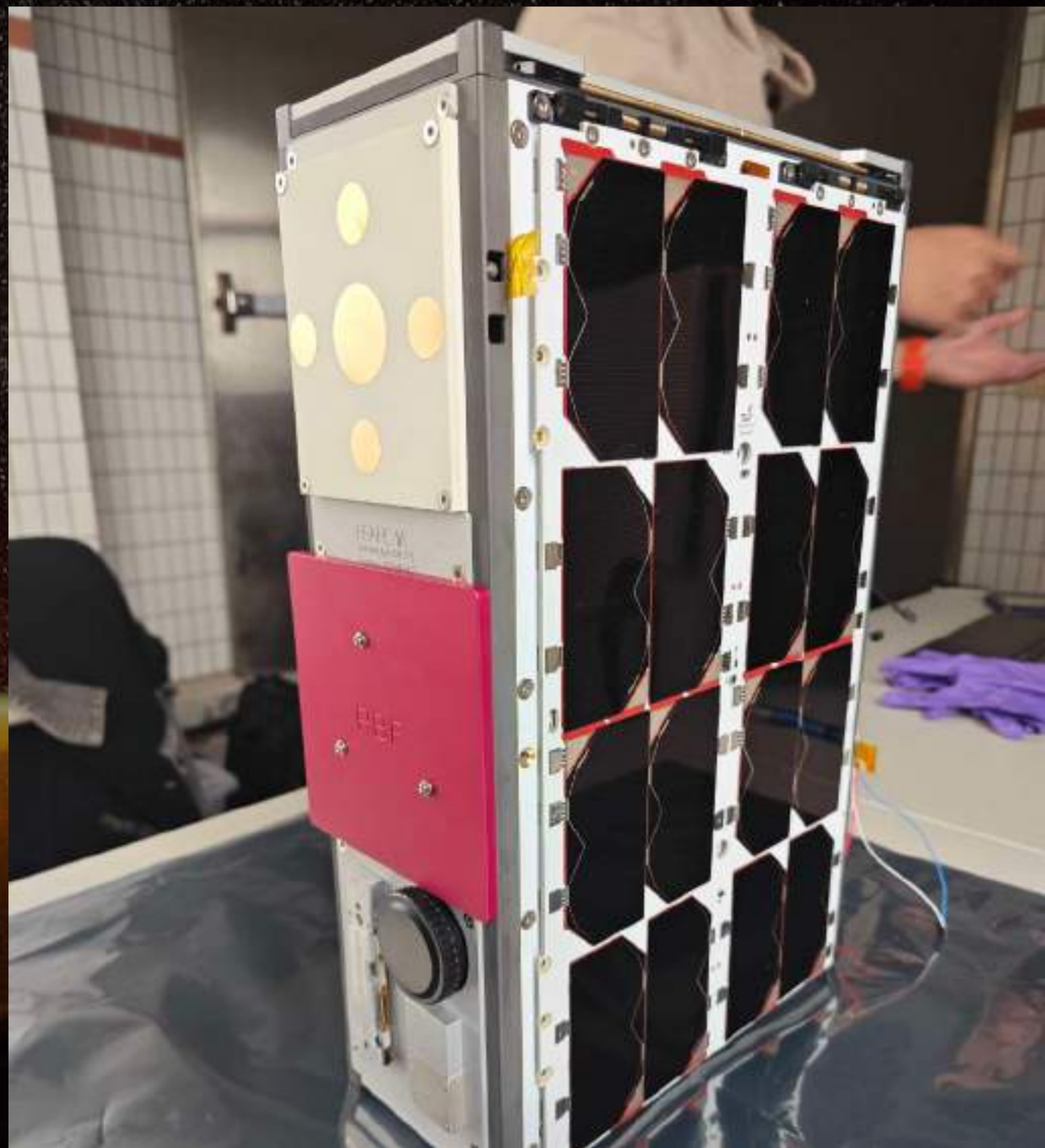
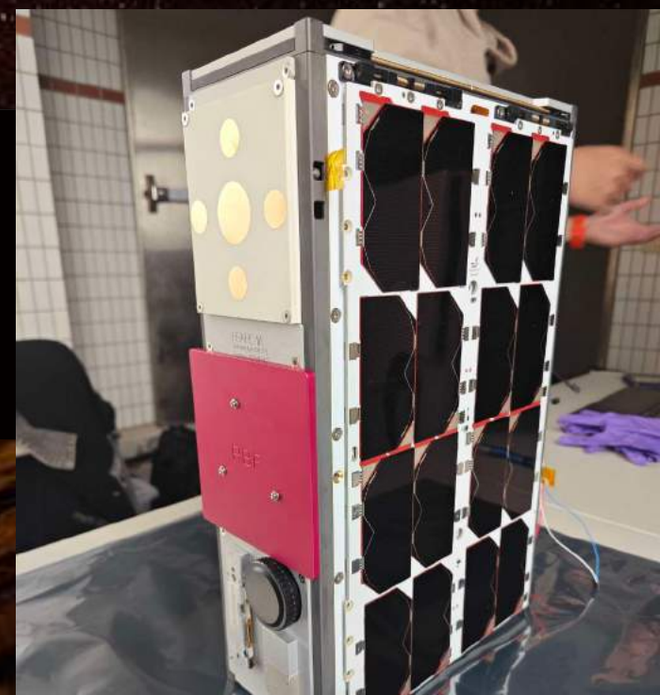
# Outline

- Mission
- S/C
- P/L:  ISL, CIP, and PSC
- Ground facilities
  - UT, TT&C, and SpaceOps
- Launch service
- Summary



# PEARL-ISL

- **PEARL-ISL** (**P**ropagation **E**xperiment using kurz-**A**bove-band **R**adio in **L**ow earth orbit for **I**nter-**S**atellite **L**ink) are 2 x 6U XL CubeSats for technical demo and education training on broadband communication (Inter-Satellite Link, **ISL**), space communication disruption & navigation outage (Compact Ionospheric Probe, **CIP**), and technical demo (Payload for Solar Cells, **PSC**).
- Number: 2 (**1A**/**1B**).
- Mission lifetime: > 5 years.
- Mass: ~10 kg.
- Orbit: ~590 km and MLTAN 11:00, SSO.

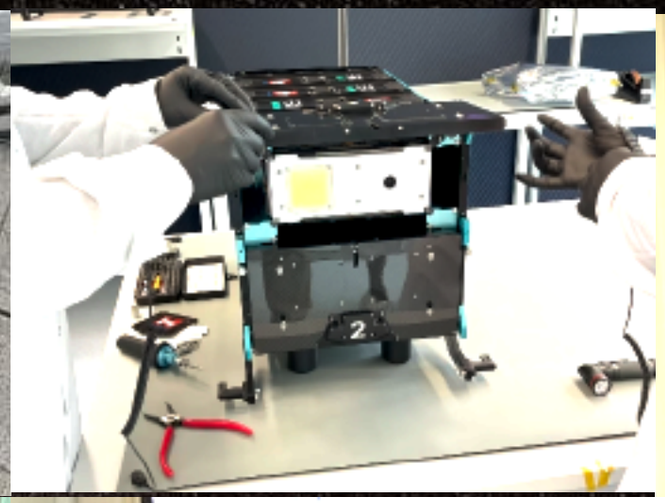


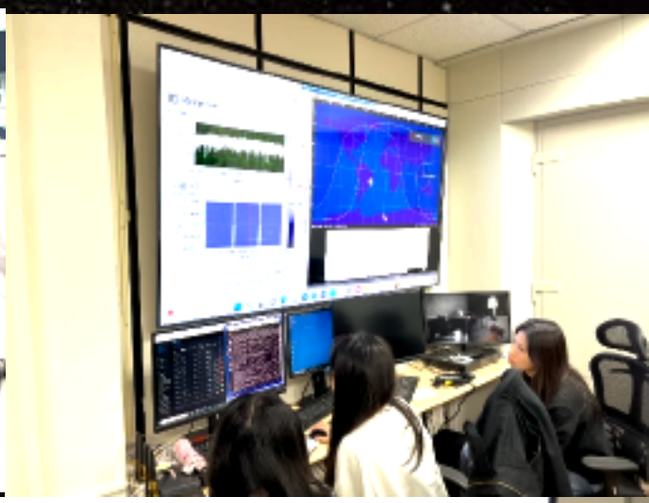
# PEARL-ISL missions

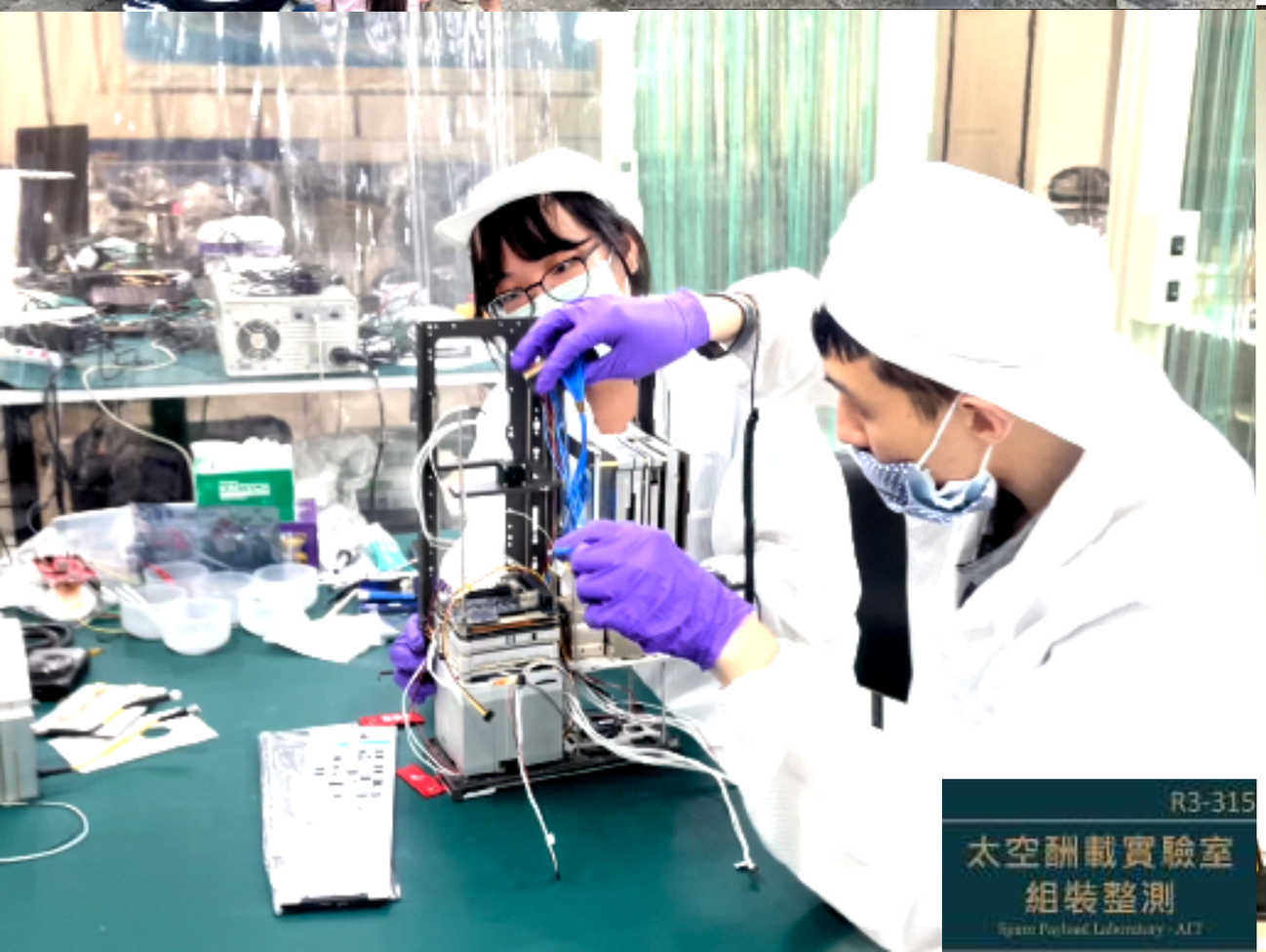
- To assemble/integrate/test two **6U XL CubeSats** (**PEARL-1A** and **PEARL-1B**) to perform ISL experiment within 5 years.
- To develop an **Inter-Satellite Link** (**ISL**) payload, in addition to continuing broadband Ka SATCOM experiment of PEARL-1C/1H, mainly focuses on broadband Ka-band ISL experiment.
- To install a **Compact Ionospheric Probe** (**CIP**) to in-situ monitor space communication environment, like ionospheric plasma density irregularities.
- To test performance of a **Payload for Solar Cells** (**PSC**) in space environment with in-house solar cells provided by domestic company and institution.
- To setup a S-band TT&C G/S, in addition to 3 x UHF TT&C G/S, to operate PEARL-1A/1B seamless and more efficiently.

# PEARL-ISL team

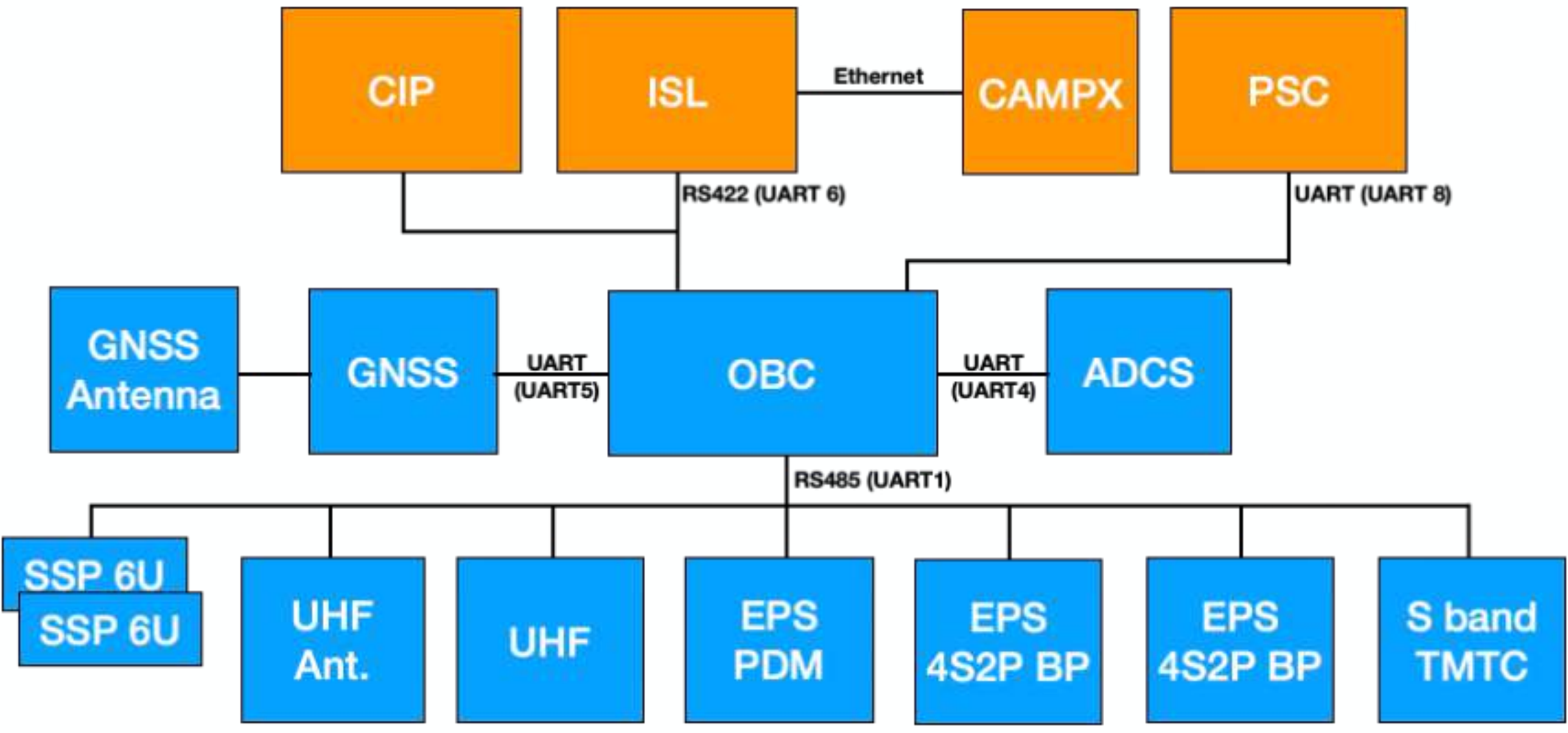

# All AIT works done by NCU students

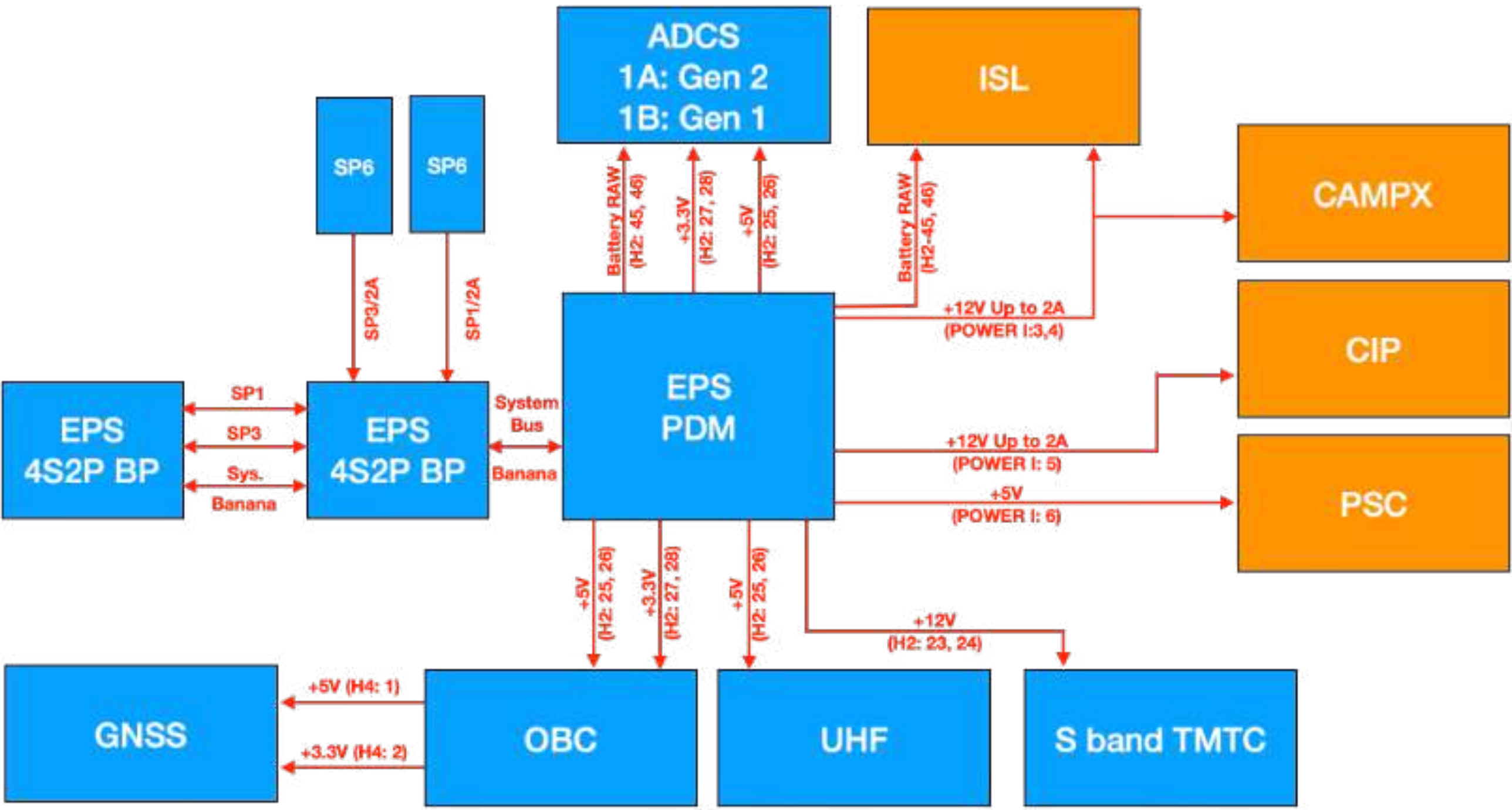





# 1A/1B comm. interface

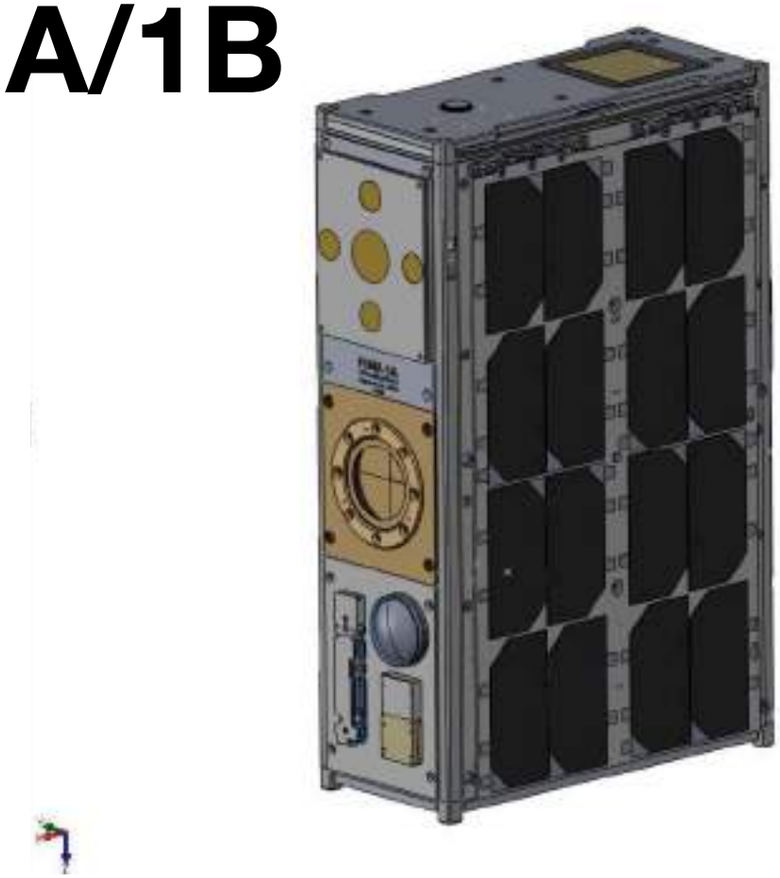


# 1A/1B power interface



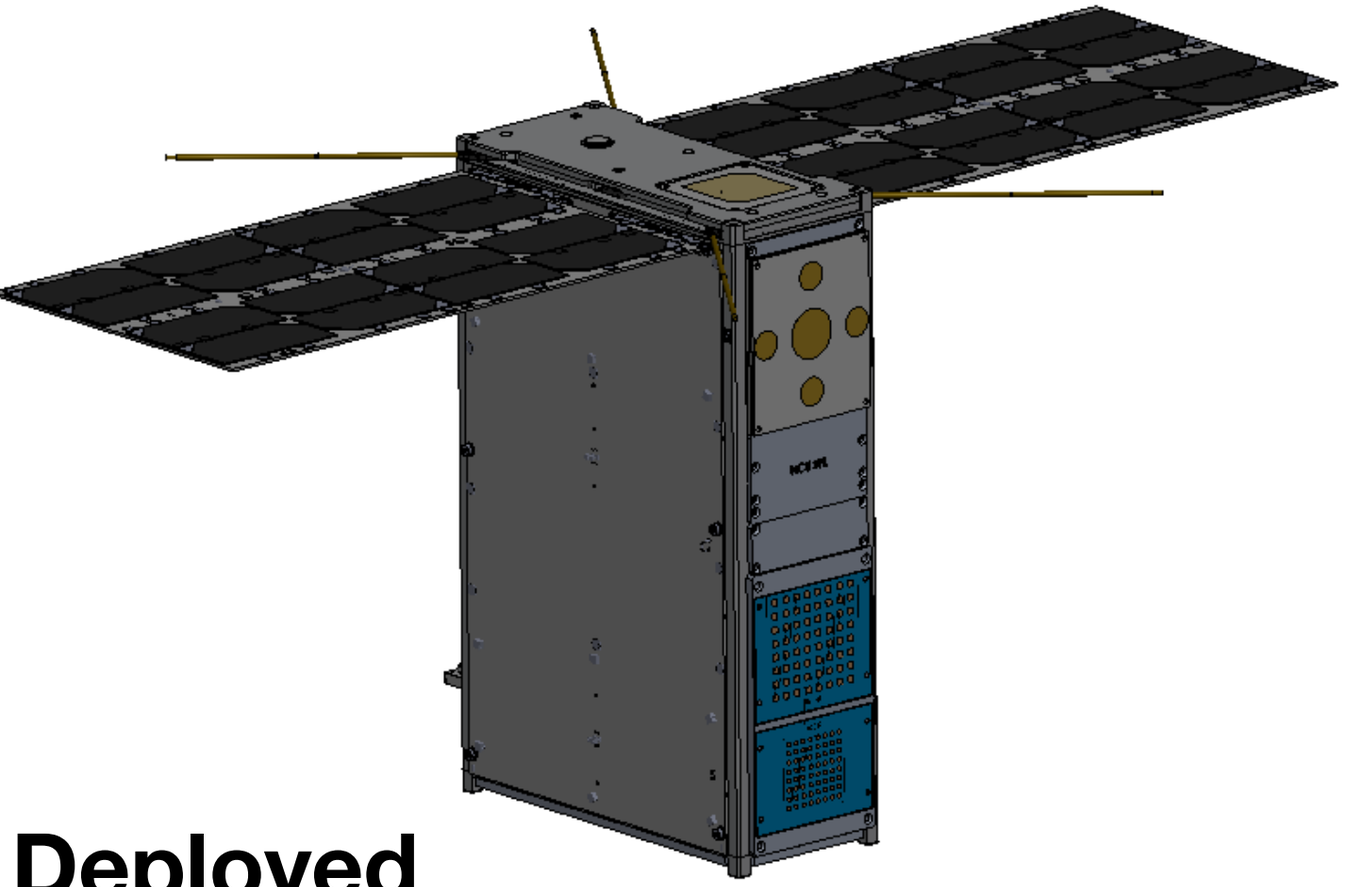
# PEARL-1A/1B

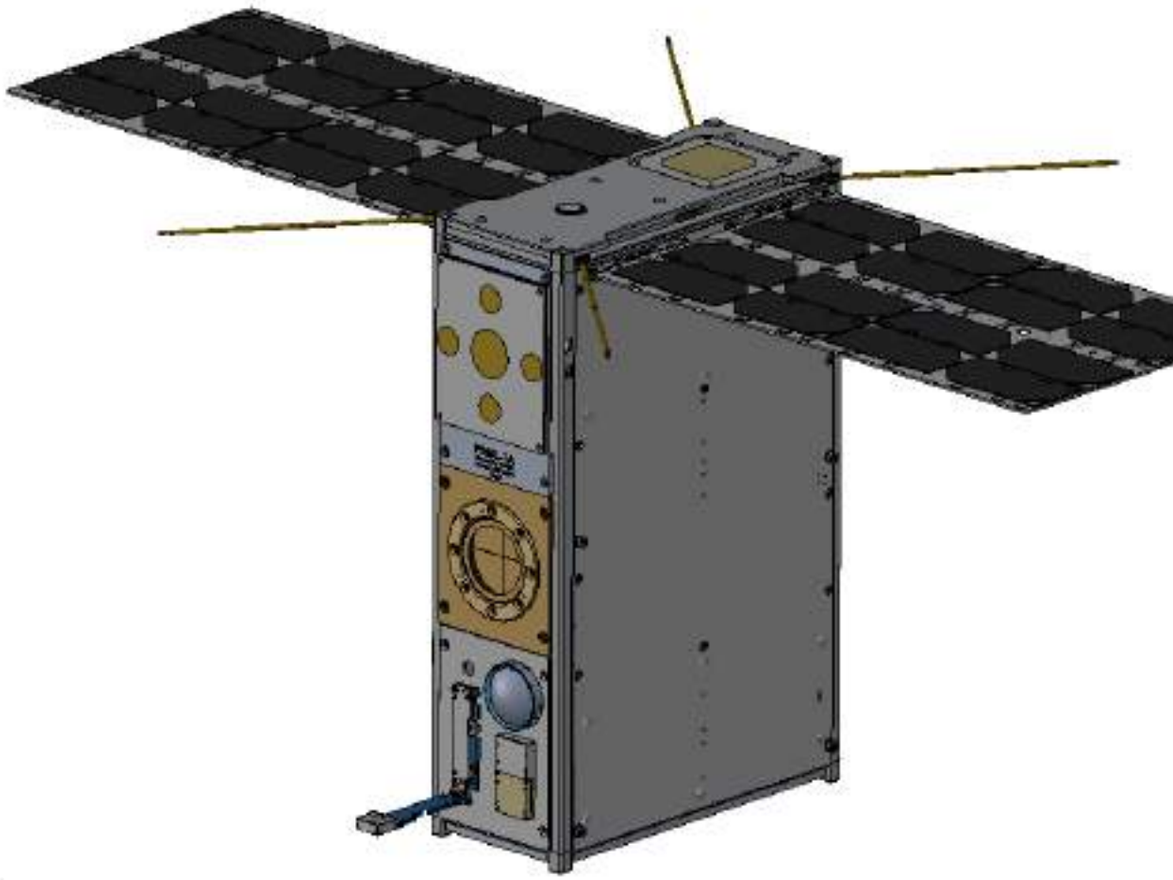
**Stowed**



**Rear**

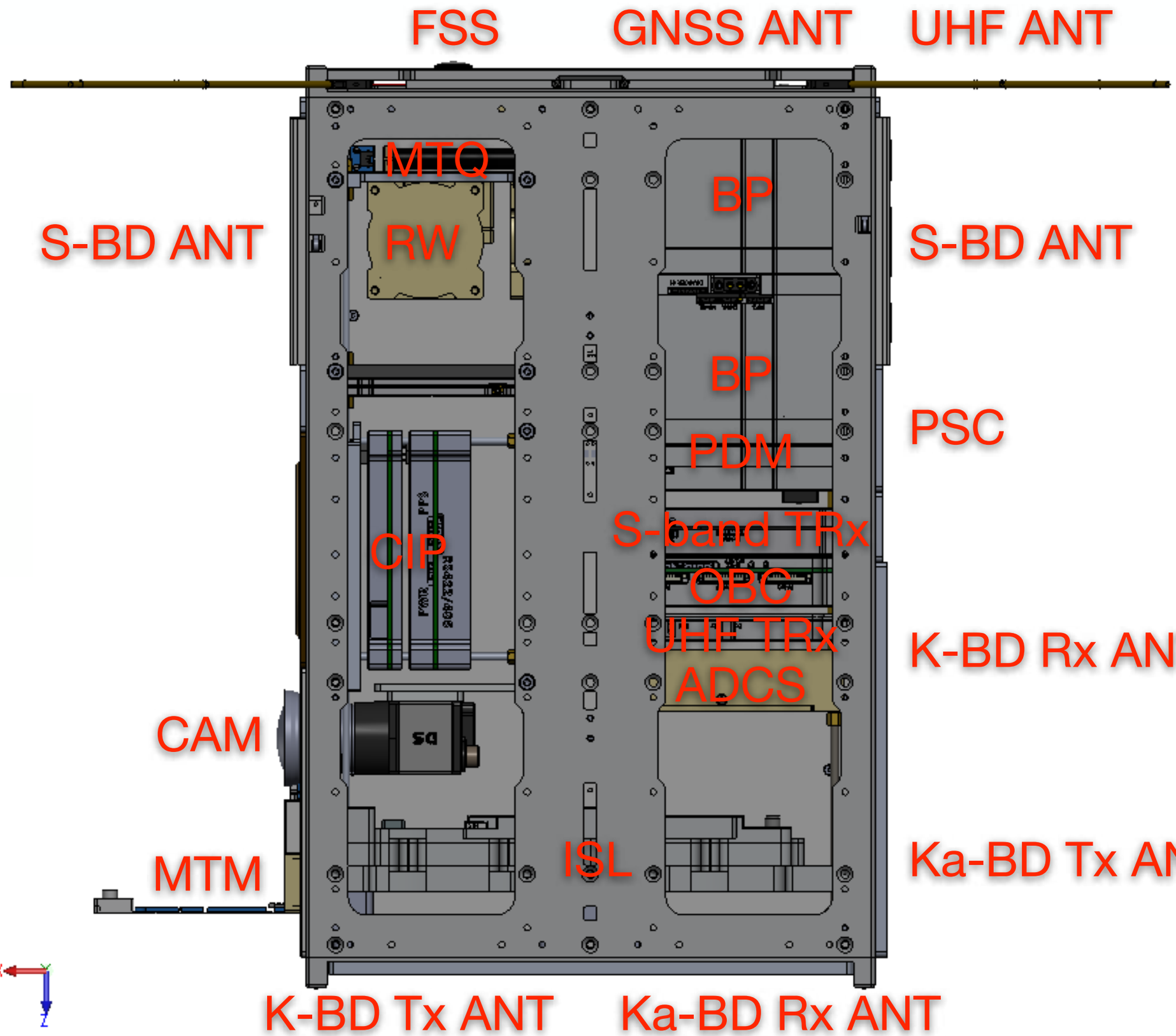
**Front**



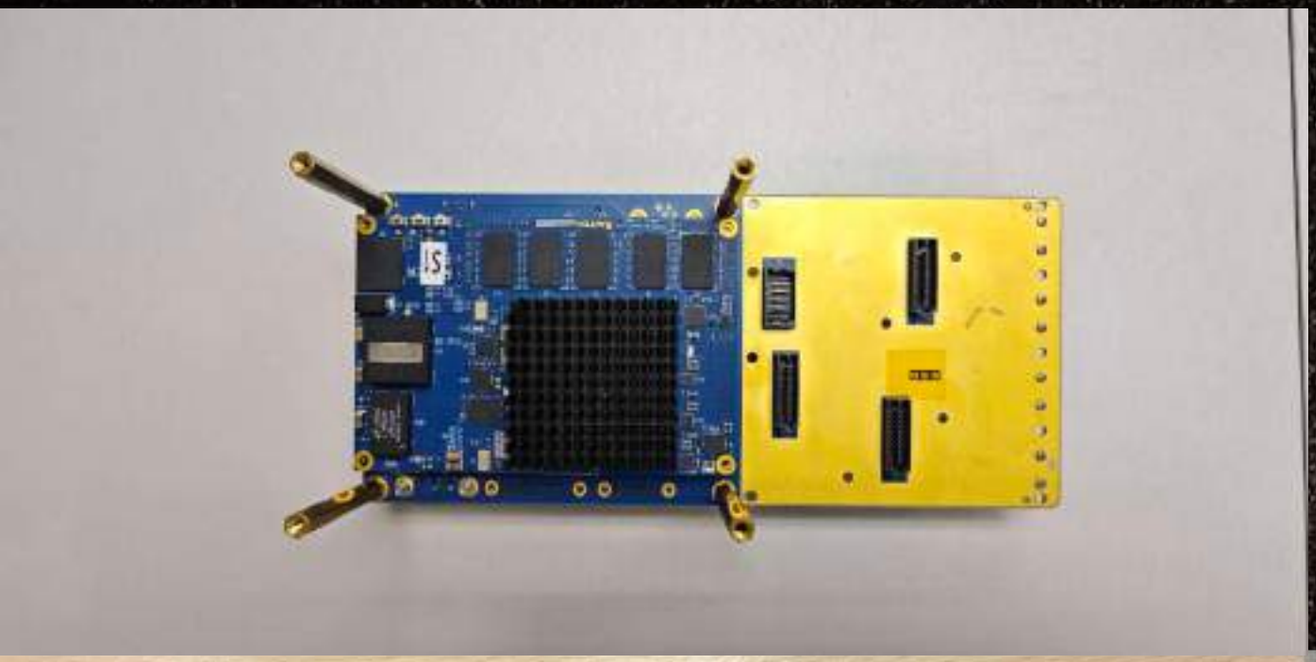


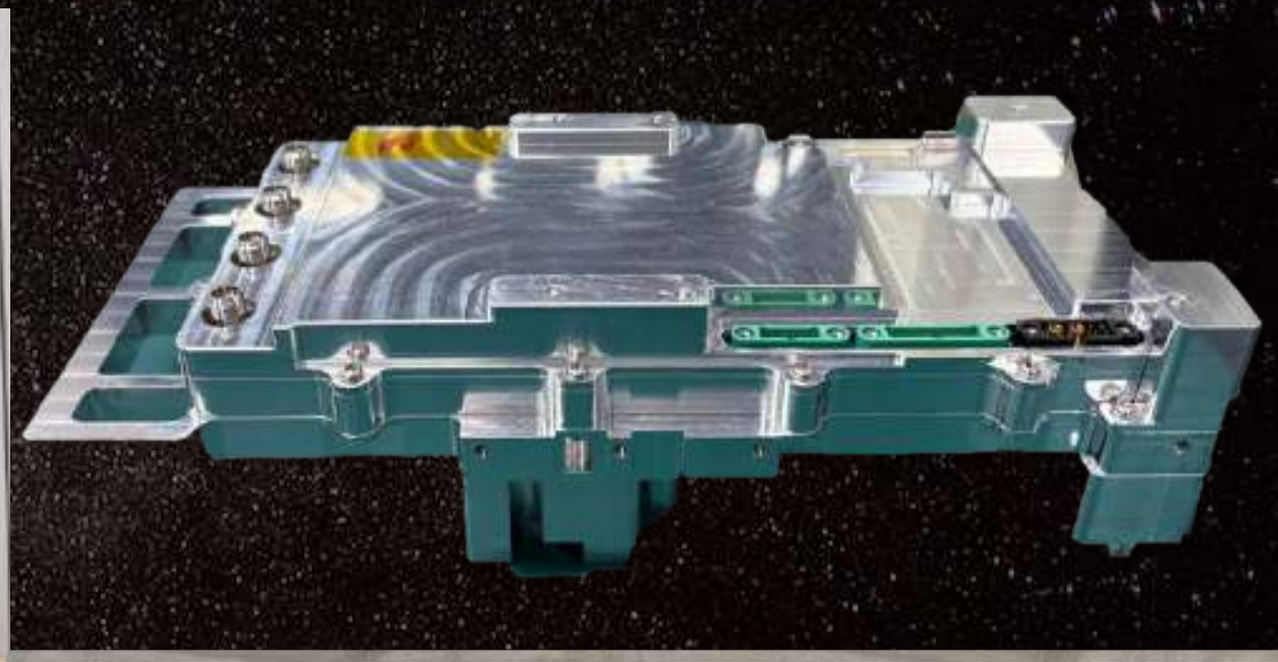
**Deployed**

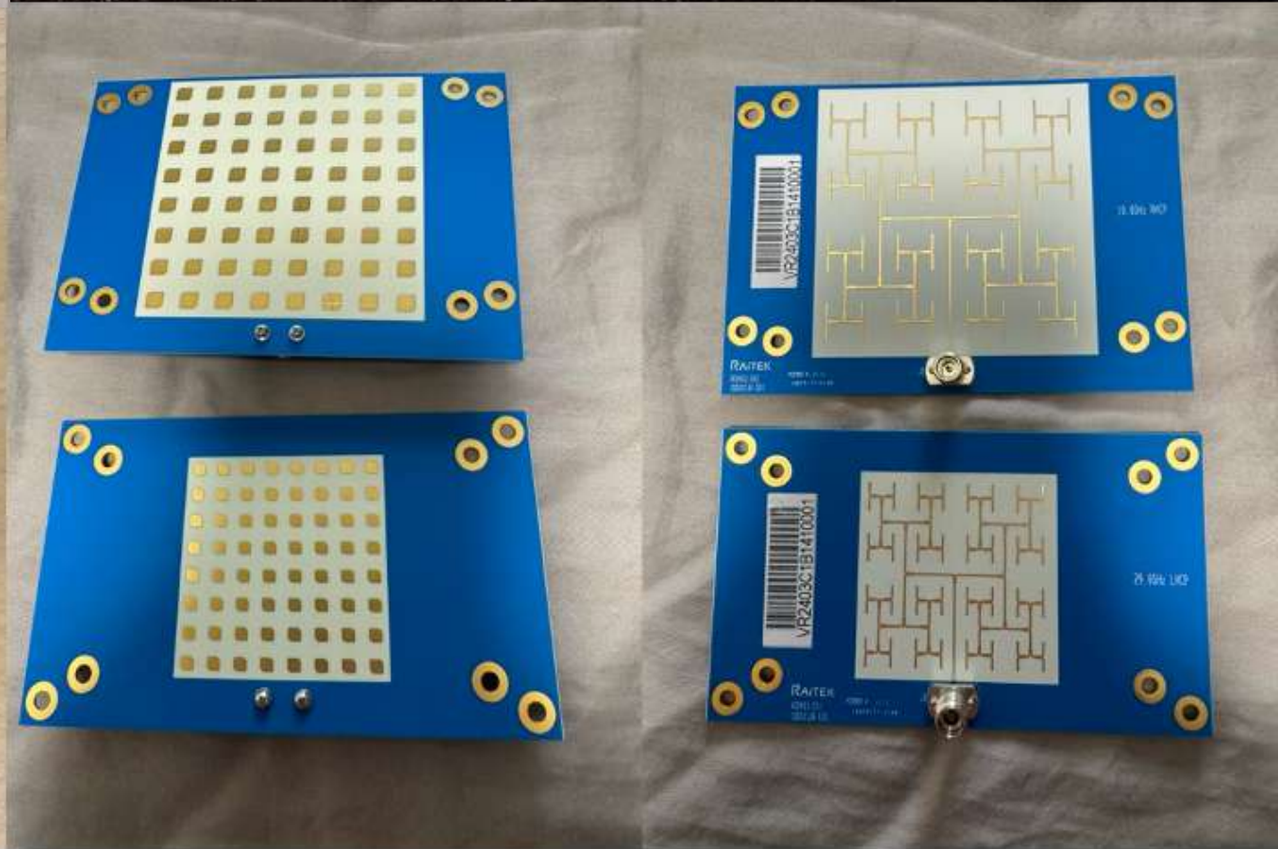
# PEARL-1A/1B


FSS
GNSS ANT
UHF ANT
MTQ
BP
S-BD ANT
RW
S-BD ANT
BP
PSC
PDM
S-band TRx
CIP
OBC
UHF TRx
K-BD Rx ANT
ADCS
CAM
ISL
Ka-BD Tx ANT
MTM
K-BD Tx ANT
Ka-BD Rx ANT

# ISL P/L





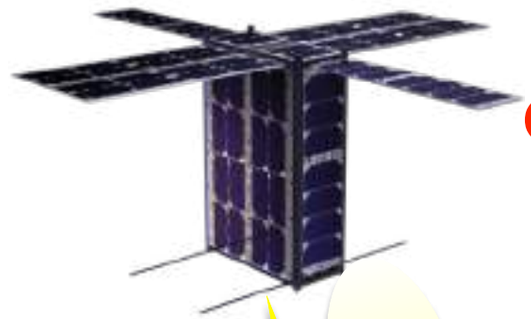



# NCU→1A (TT)→1B→CWA

PEARL-1B

PEARL-1A

**CubeADCS Gen 1**



**CubeADCS Gen 2**

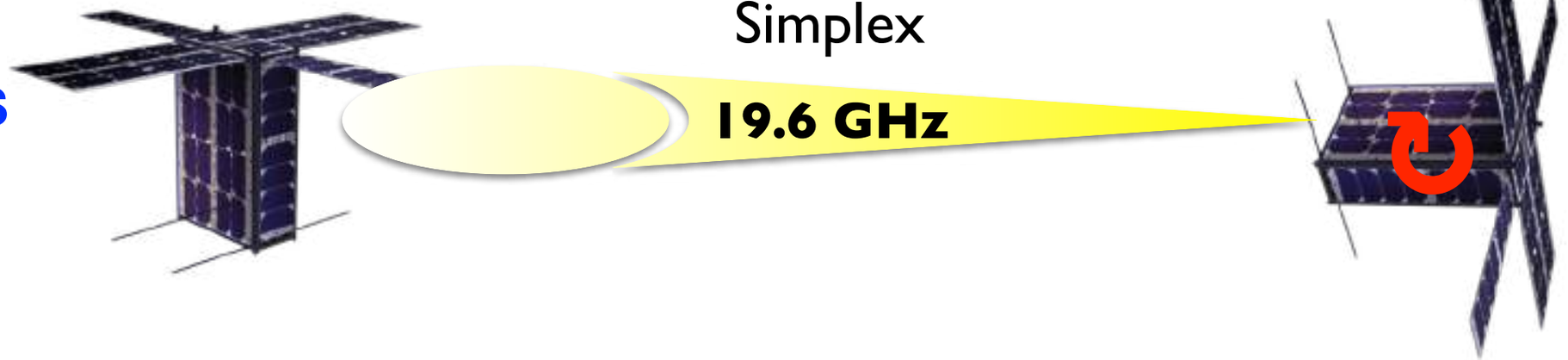

Ka-band UT (CWA)

Ka-band UT (NCU)

# NCU→1A (ST)→1B (LVLH)→CWA

PEARL-1B

PEARL-1A




CubeADCS Gen 1

CubeADCS Gen 2

Ka-band UT (CWA)

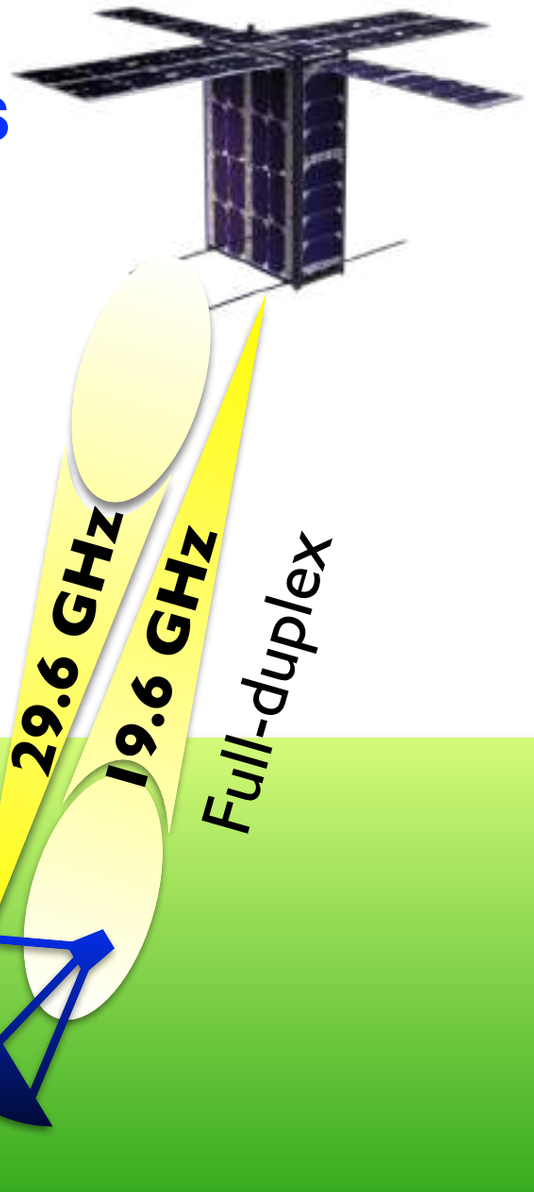
Ka-band UT (NCU)

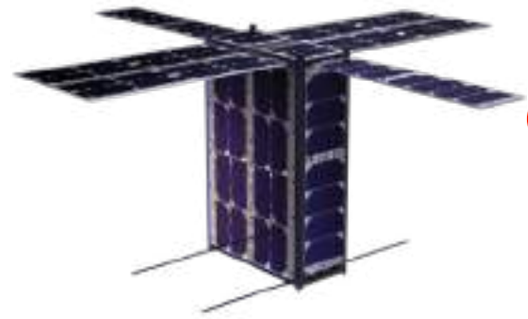
# NCU→1A→1B (TT)→CWA

PEARL-1B

PEARL-1A

**CubeADCS Gen 1**



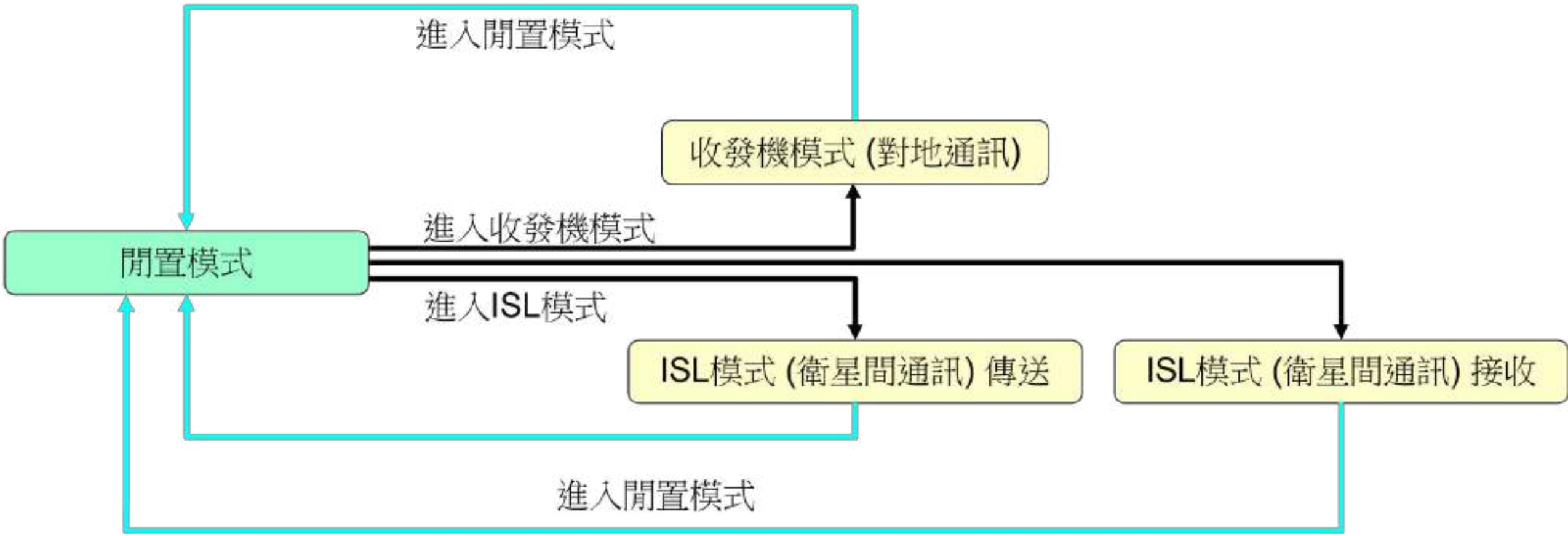



**CubeADCS Gen 2**

Ka-band UT (CWA)

Ka-band UT (NCU)

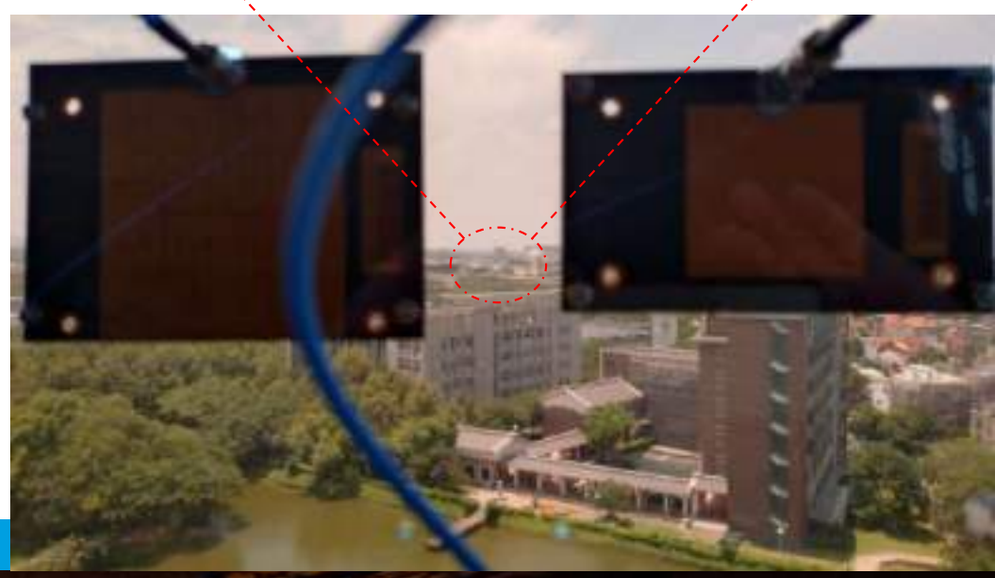
# ISL P/L state machine



# ISL OTA (2025/8/4-6)

太遙對科四


科四對太遙



# ISL OTA (2025/8/4-6)

測試對應的BER, PHY Data Rate 如下表

| | DL | | | | UL |
|---|---|---|---|---|---|
| MCS | 5 (QPSK 3/5) | 13 (8PSK 2/3) | 21 (16APSK 5/6) | 24 (32APSK 3/4) | 4 (QPSK 1/2) |
| BER | 0 | 0 | $3*10^{-7}$ | $1*10^{-5}$ | 0 |
| Data Rate (Mbps) | 62 | 104 | 174 | 195 | 43 |

雙向測試PHY Data Rate結果如下表

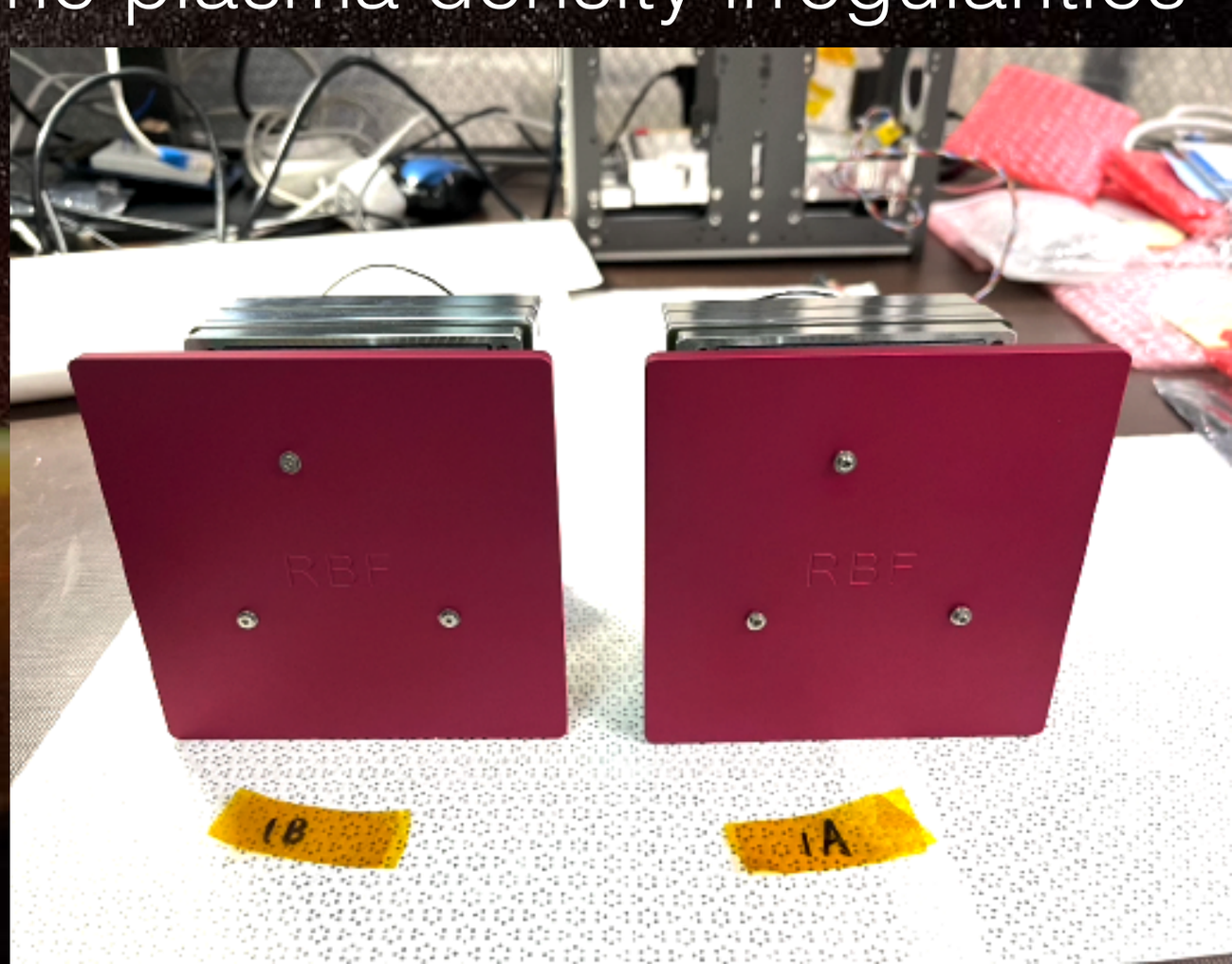
Symbol rate: 54 MHz

| | DL | UL |
|---|---|---|
| MCS | 5 (QPSK 3/5) | 4 (QPSK 1/2) |
| BER | 0 | 0 |
| Data Rate (Mbps) | 62 | 43 |

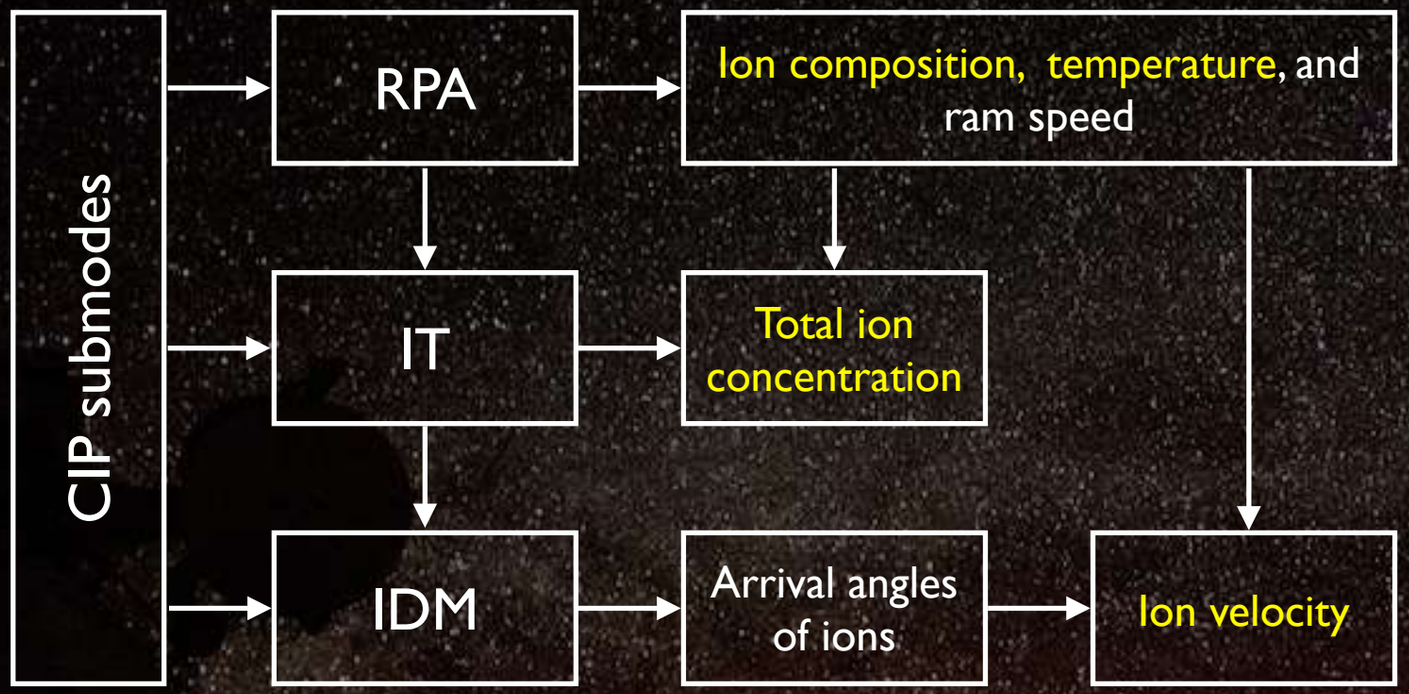
The Federal Communications Commission (FCC) defines broadband as a minimum of 25 Mbps download and 3 Mbps upload.

# CIP - 2nd generation

**Compact Ionospheric Probe** (**CIP**) is a miniature model (0.7U) of AIP for CubeSat missions and is also an all-in-one software-defined thermal plasma sensor to measure $N_i$, $\boldsymbol{V}_i$, and $T_i$. It is capable of measuring ionospheric plasma density irregularities at a sampling rate up to 1 kHz. The CIP-G2 had a maiden flight on PEARL-1C and will be delivered for ELITE (2026), PEARL-1A/1B (2026Q2) & 2T/2X/2Y/2Z (2028Q1), and FS-9A (2028Q1) to explore 3D structures of equatorial plasma density irregularities.



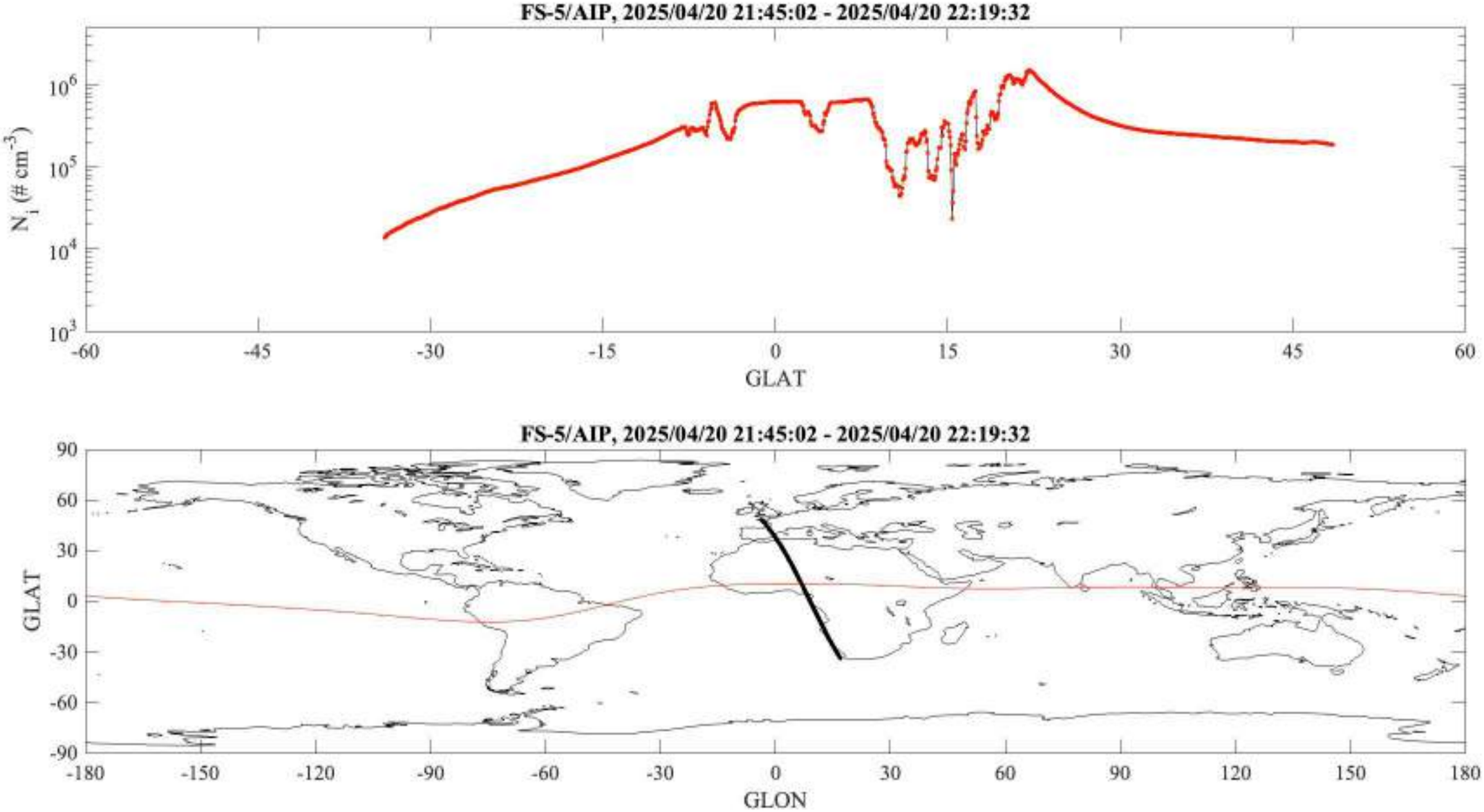
# Science data




| Sampling rates | Total ion concentration | Arrival angles of ions | Others |
|---|---|---|---|
| NORMAL | 128 Hz | 32 Hz | 1 Hz |
| FAST | 1,024 Hz | 256 Hz | 1 Hz |

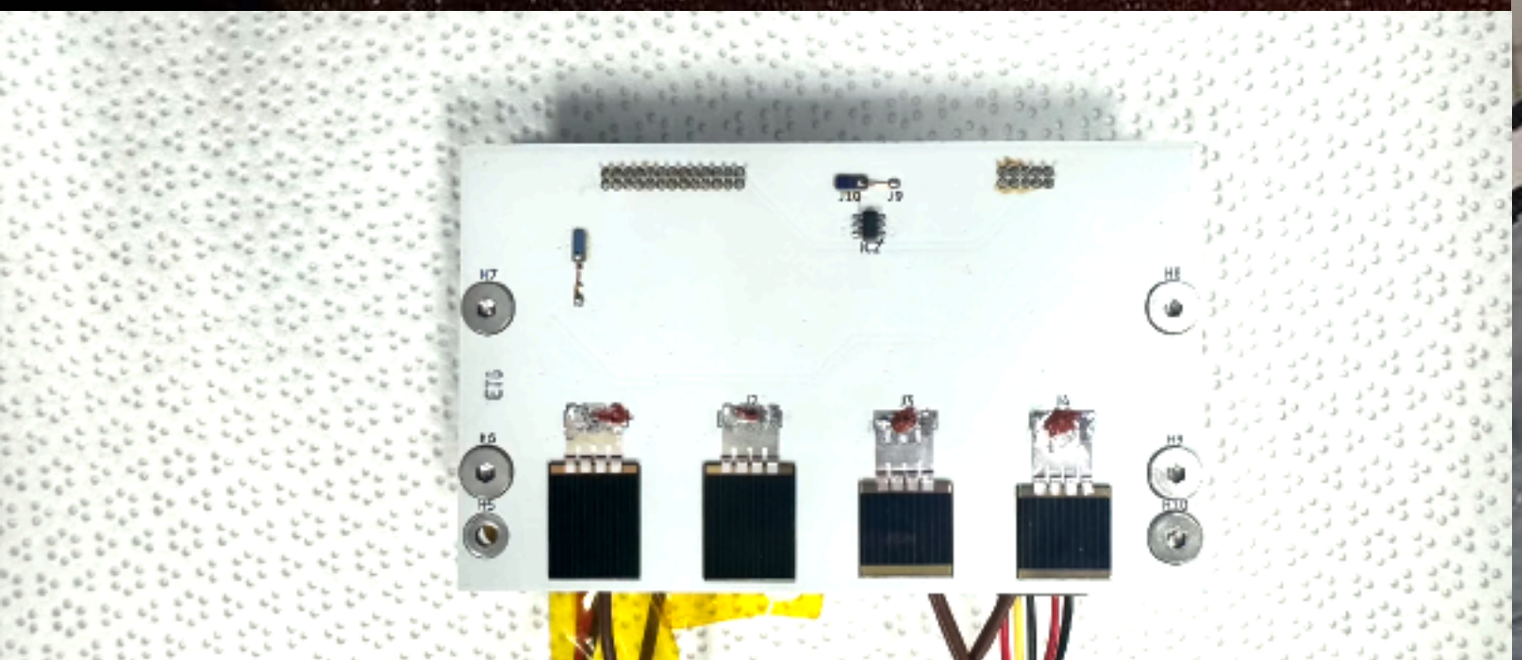
| Parameters | Range | Sensitivity | Accuracy |
|---|---|---|---|
| Composition $C_i$ | 3% to 100% | 1% | 10% |
| Total ion concentration $N_i$ | $10^3$ to $10^6$ $cm^{-3}$ | 1% | 10% |
| Ion velocity $\boldsymbol{V}_i$ | ±2.5 km $s^{-1}$ (cross-track)<br>7.5±1 km $s^{-1}$ (ram) | ± 10 m $s^{-1}$<br>± 100 m $s^{-1}$ | ± 50 m $s^{-1}$<br>± 200 m $s^{-1}$ |
| Ion temperature $T_i$ | 500 to 5,000 K | ±50 K | ±200 K |

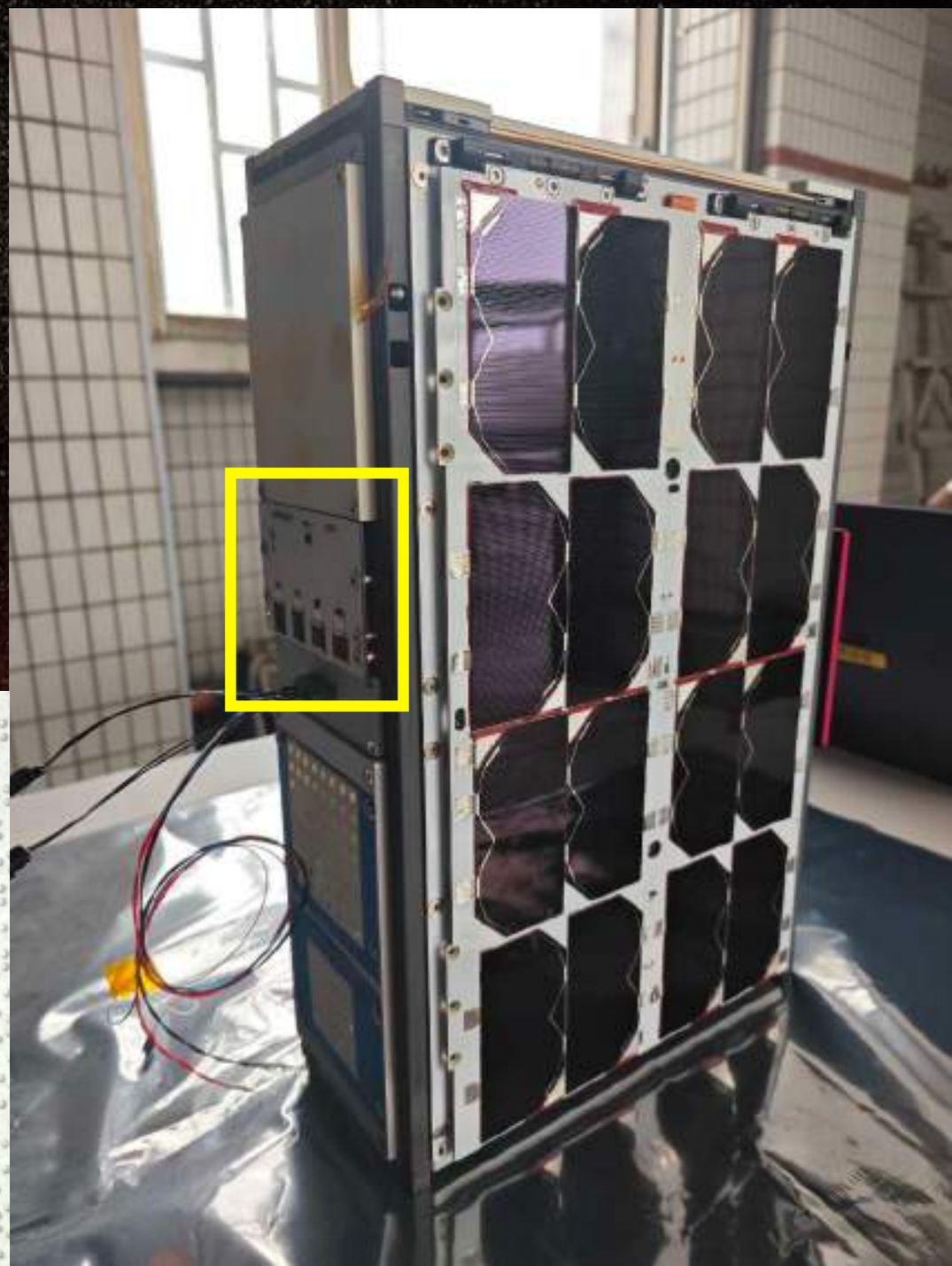
# Ion density profile per orbit

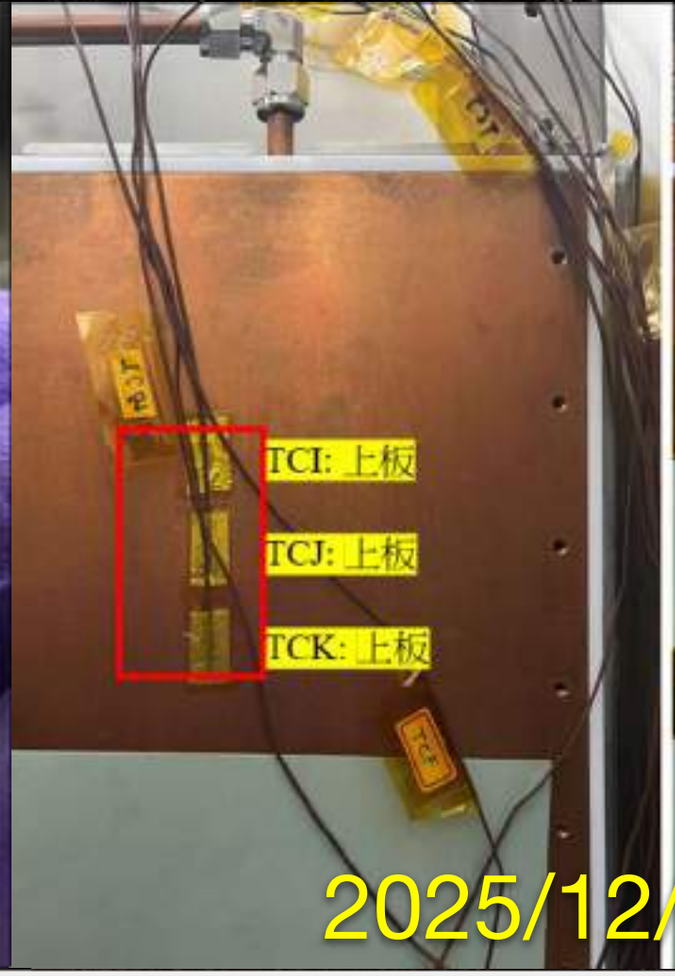


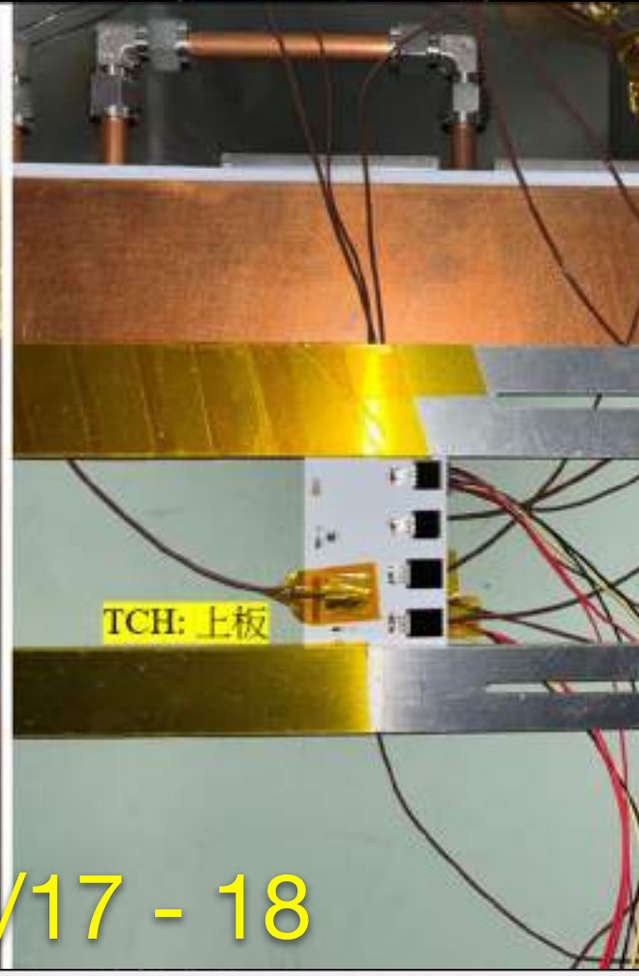
# PSC

太陽能電池技術展示酬載（**Payload for Solar Cells, PSC**）驗證國內廠商（分別為鋐泰光電 ET 與國家原子能科技研究院 NARI 物理研究所）自製太陽能電池在太空環境的效能變化。

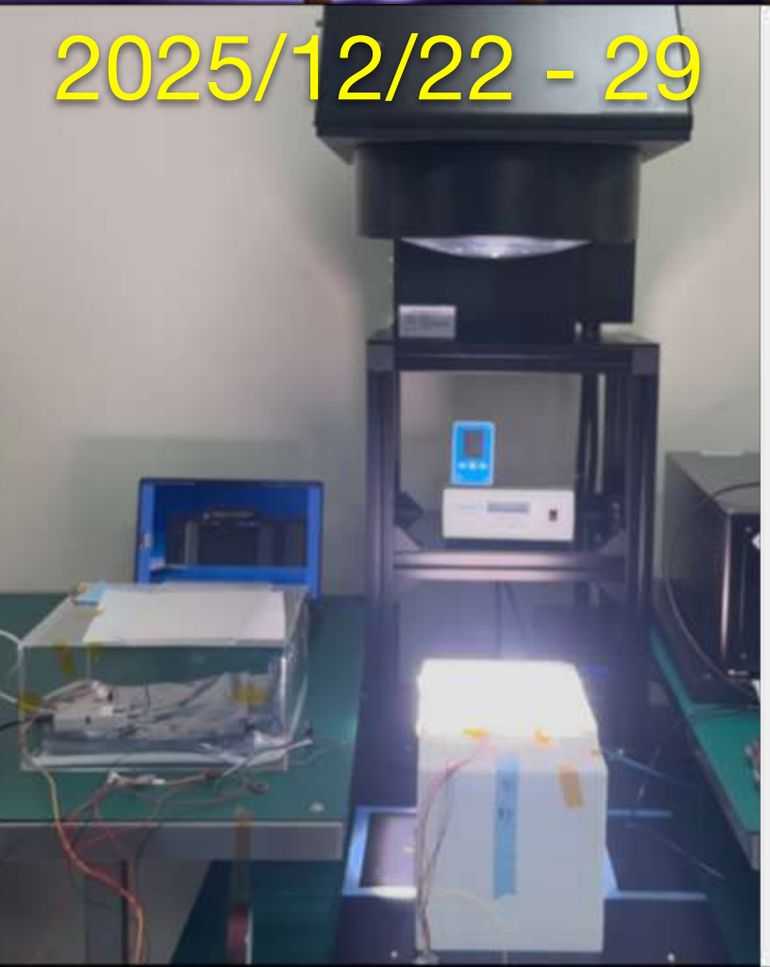




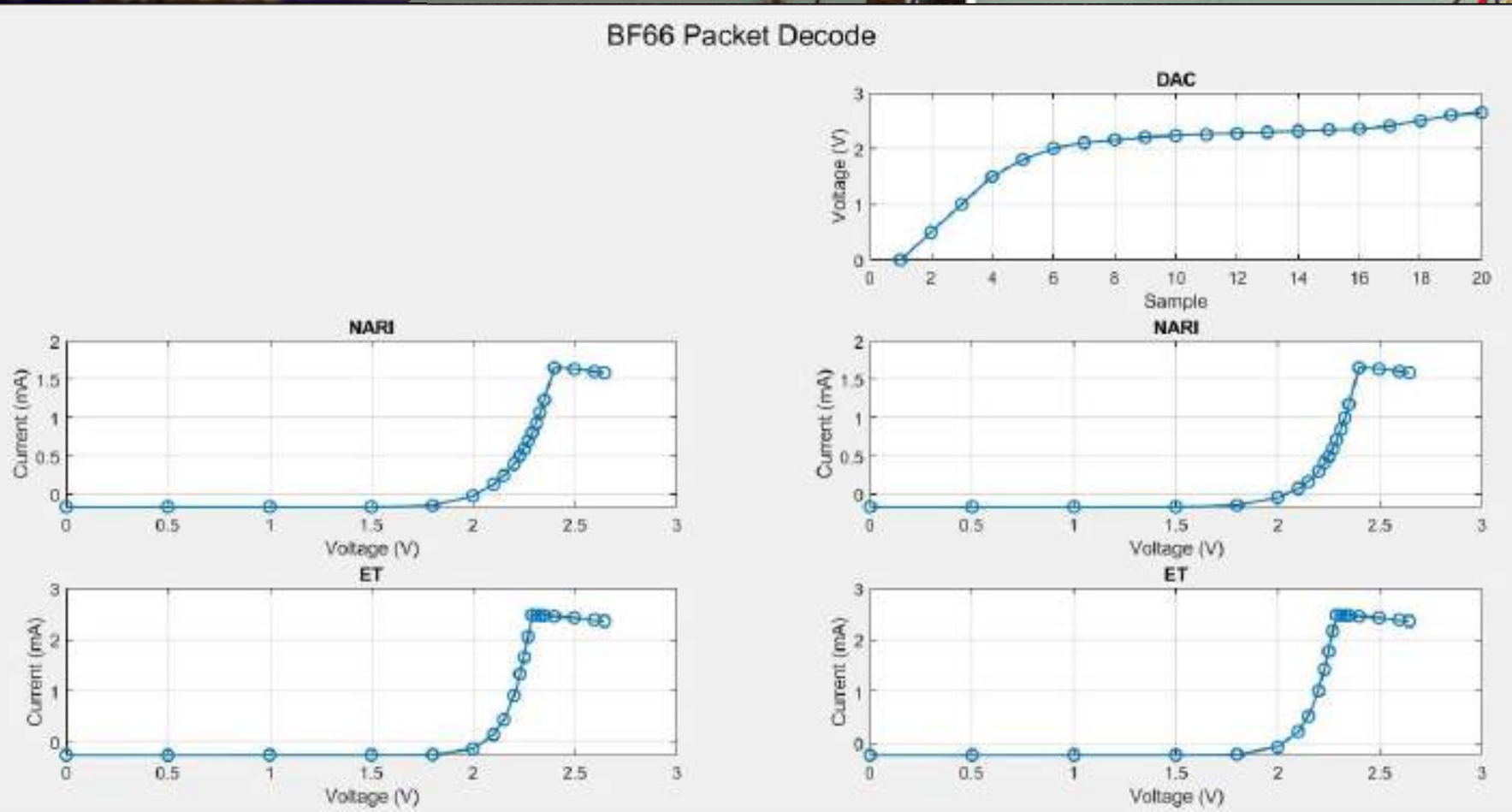




2025/12/17 - 18



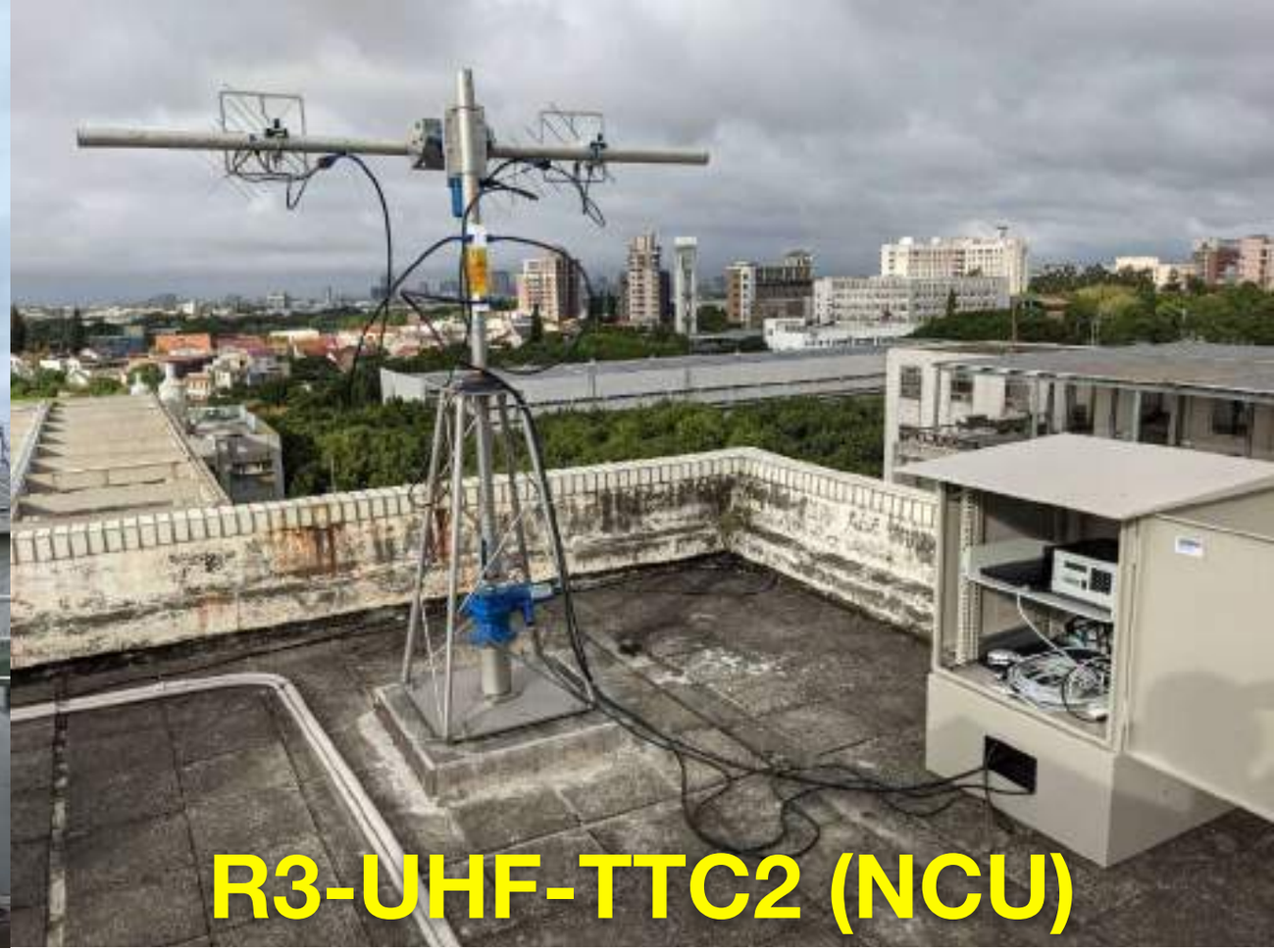
2025/12/22 - 29



# Mission controls and G/S

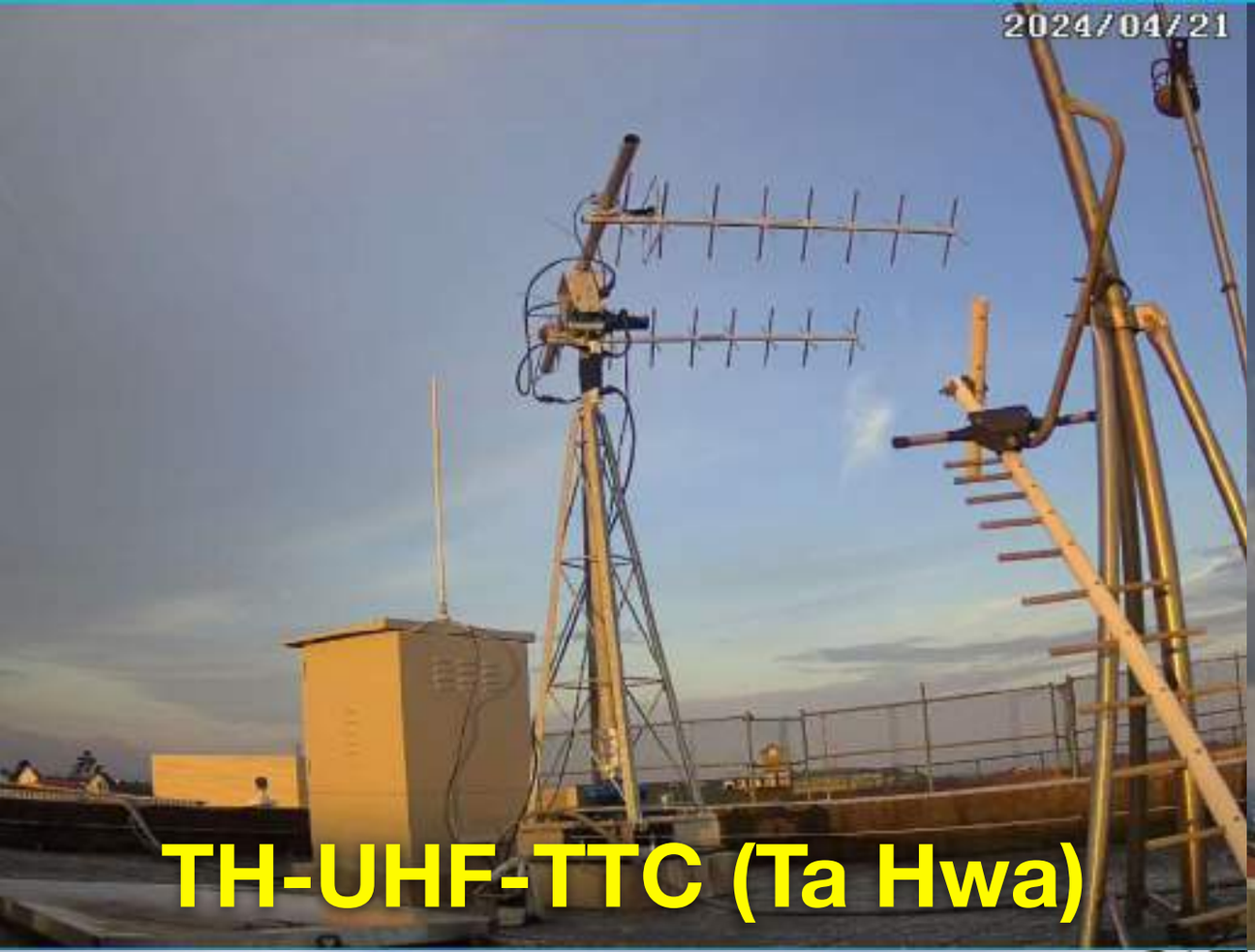
- Mission controls: NCU and HHRI using SpaceOps to control/ monitor the following ground stations.
- Ground stations:
  - NCU CSRSR: 2 x UHF and 2 x Ka-band UT
  - Ta-Hwa: 1 x UHF, 1 x S-band, and 1 x Ka-band UT (anticipated)
  - CWA Penghu station: 1 x Ka-band UT
  - HHRI: 1 x UHF and 1 x Ka-band UT
  - ATRDC: 1 x Ka-band UT (anticipated)
  - Ground Station as a Service (GSaaS) like KSAT, RBC Signals, etc.: multiple UHF and S-band.


R3-UHF-TTC1 (NCU)


R3-UHF-TTC2 (NCU)


R3-Ka-UT1 (NCU)


KNS
R3-Ka-UT2 (NCU)




TH-UHF-TTC (Ta Hwa)


TH-S-TTC (Ta Hwa)


Penghu Weather Station

# Scheduling

**ncu-uhf-01**
ID: 2d7af05f-185e-48fe-b47a-26ace4cff975
07 Mar 2026 21:00:00
07 Mar 2026 21:05:00
14.24°
FINISHED SUCCESSFULLY

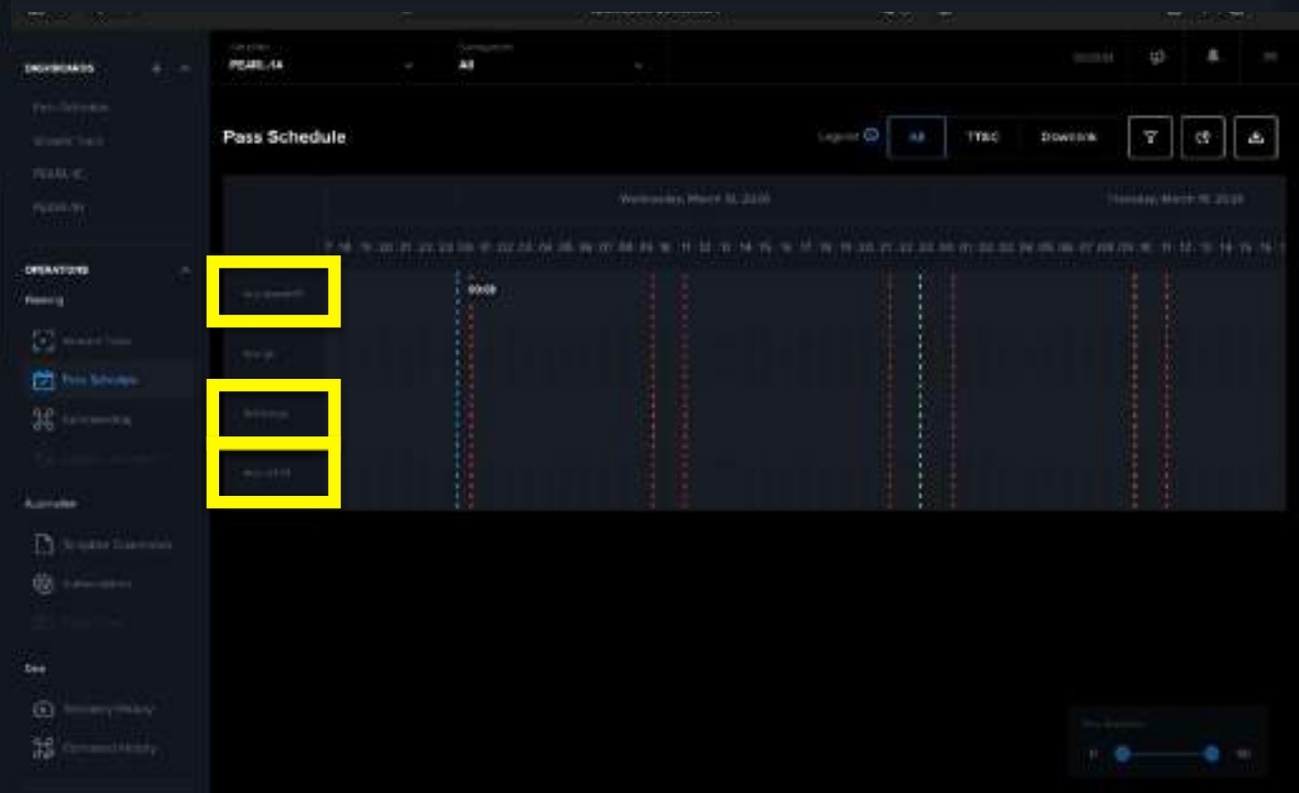
| | | | | |
|---|---|---|---|---|
| set_time<br>PEARL-1A › Onboard Computer › New Fid v0.1 | Priority<br>30000 | Execution time<br>07 Mar 2026... | Requested for pass<br>07 Mar 2026... | SUCCESSFUL |
| Upload schedule_0307.sch<br>PEARL-1A › Onboard Computer › File Manager ... | Priority<br>29000 | Execution time<br>07 Mar 2026... | Requested for pass<br>07 Mar 2026... | SUCCESSFUL |
| set_active_schedule<br>PEARL-1A › Onboard Computer › onboard_sch... | Priority<br>28000 | Execution time<br>07 Mar 2026... | Requested for pass<br>07 Mar 2026... | SUCCESSFUL |
| get_active_schedule<br>PEARL-1A › Onboard Computer › onboard_sch... | Priority<br>25000 | Execution time<br>07 Mar 2026... | Requested for pass<br>07 Mar 2026... | SUCCESSFUL |
| set_scheduler_state<br>PEARL-1A › Onboard Computer › onboard_sch... | Priority<br>22000 | Execution time<br>07 Mar 2026... | Requested for pass<br>07 Mar 2026... | SUCCESSFUL |

**ta-hwa-gs**
ID: 6e2f588e-df3b-46f4-bdce-d0334534c223
06 Mar 2026 13:49:30
06 Mar 2026 13:59:30
11.96°
FINISHED SUCCESSFULLY

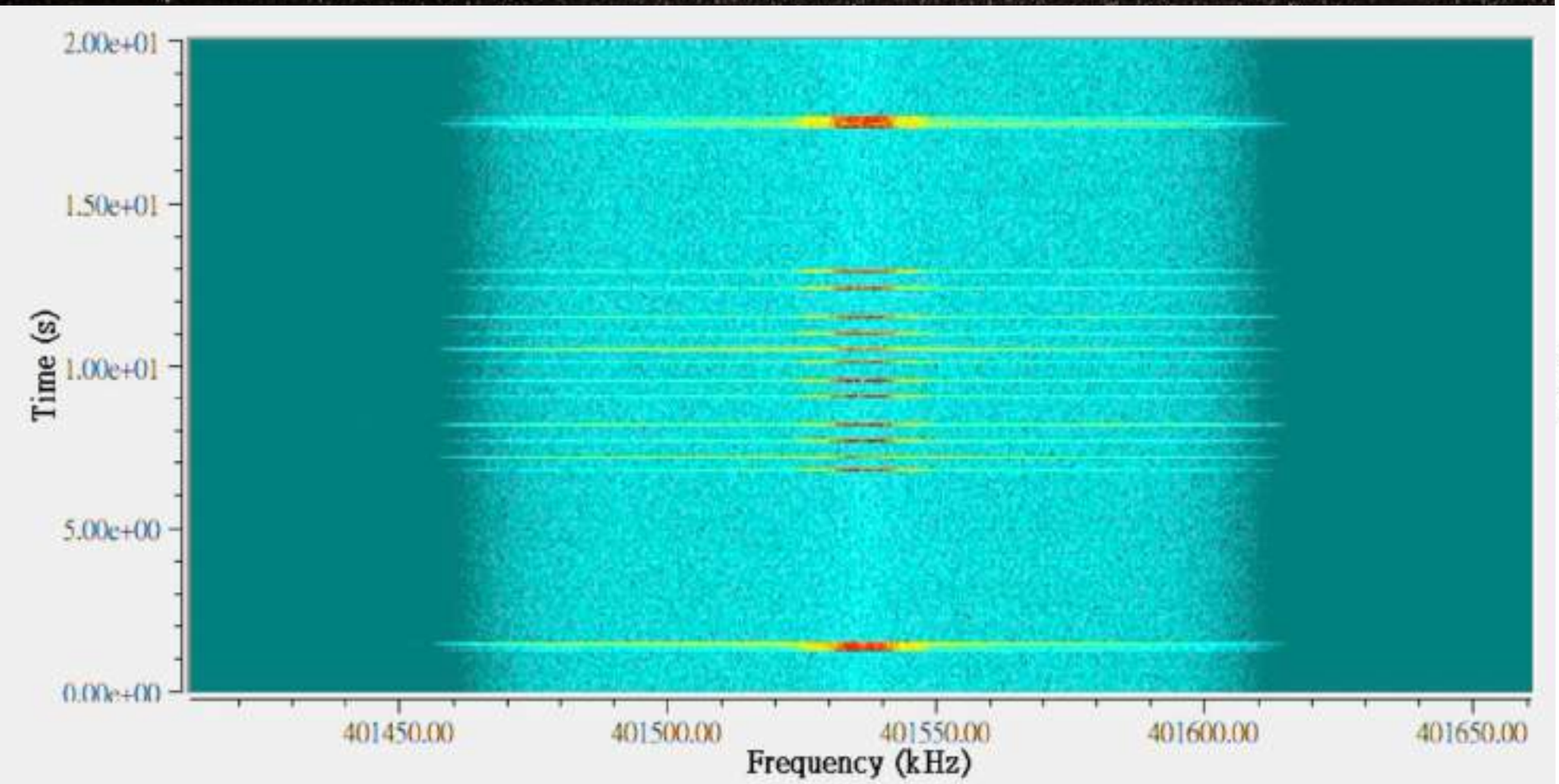
| | | | | |
|---|---|---|---|---|
| ReadSCW<br>PEARL-1A › UHF Transceiver II › UHF Fid v0.5 | Priority<br>9999 | Execution time<br>06 Mar 2026... | Requested for pass<br>06 Mar 2026... | SUCCESSFUL |
| ReadUpTime<br>PEARL-1A › UHF Transceiver II › UHF Fid v0.5 | Priority<br>9990 | Execution time<br>06 Mar 2026... | Requested for pass<br>06 Mar 2026... | SUCCESSFUL |
| ReadSatConfig<br>PEARL-1A › UHF Transceiver II › UHF Fid v0.5 | Priority<br>9980 | Execution time<br>06 Mar 2026... | Requested for pass<br>06 Mar 2026... | SUCCESSFUL |
| ReadCipherKeySlotStatus<br>PEARL-1A › UHF Transceiver II › UHF Fid v0.5 | Priority<br>9970 | Execution time<br>06 Mar 2026... | Requested for pass<br>06 Mar 2026... | SUCCESSFUL |
| get_uptime<br>PEARL-1A › Onboard Computer › obc Fid v4.1 | Priority<br>9950 | Execution time<br>06 Mar 2026... | Requested for pass<br>06 Mar 2026... | SUCCESSFUL |

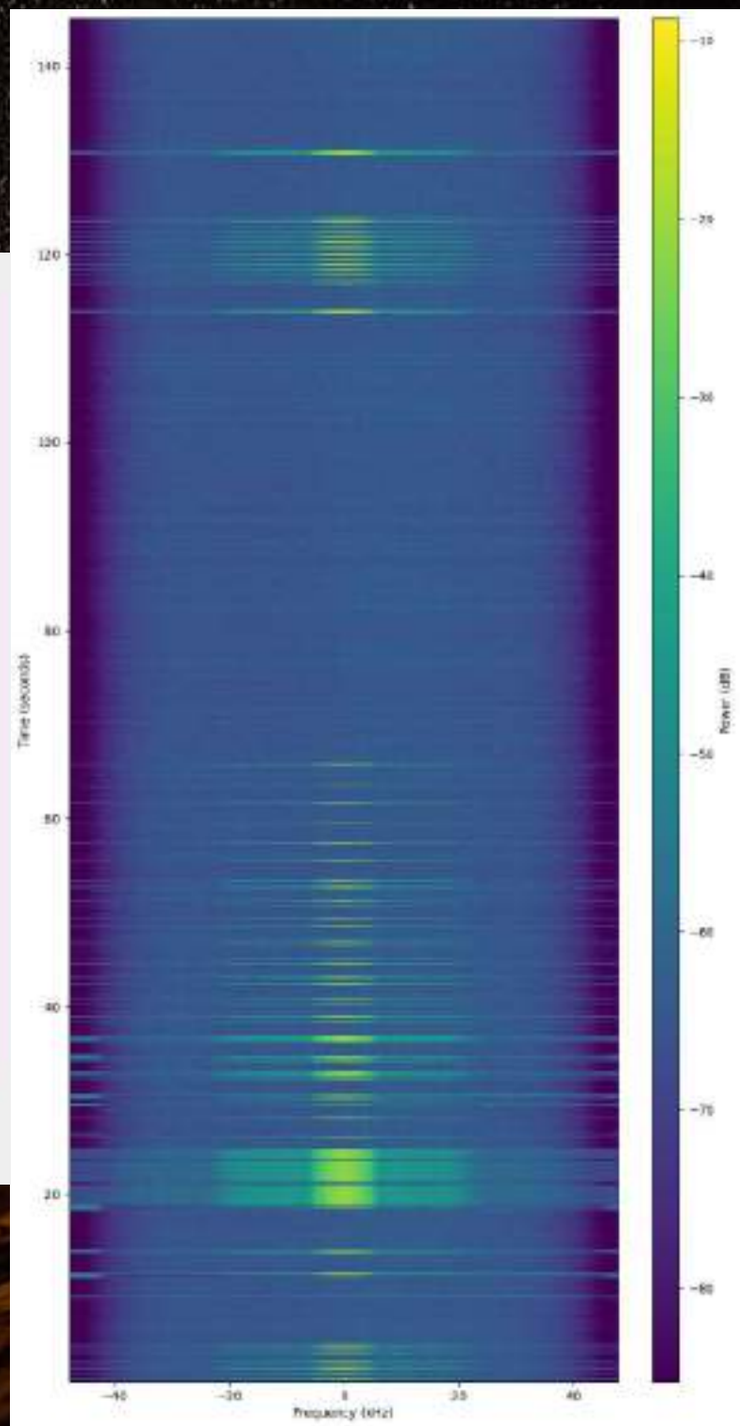
**ncu-sband-01**
ID: 8c614b66-f415-482a-875e-08ff4d8c69dd
06 Mar 2026 12:32:30
06 Mar 2026 12:35:30
11.96°
FINISHED SUCCESSFULLY

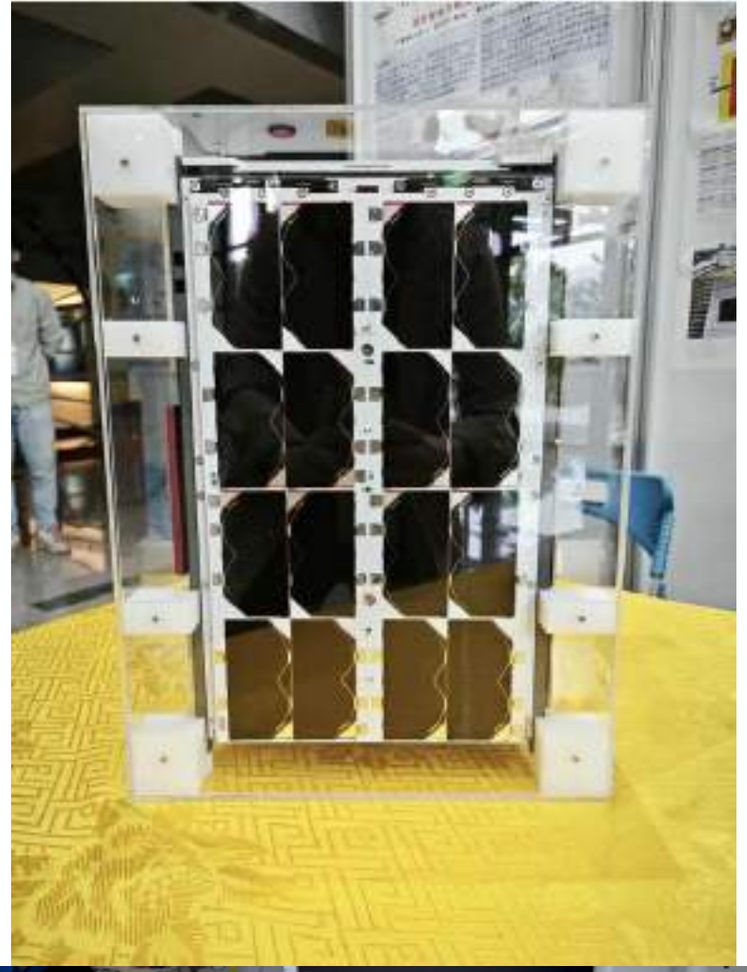
| | | | | |
|---|---|---|---|---|
| ReadCounters<br>PEARL-1A › UHF Transceiver II › UHF Fid v0.5 | Priority<br>9999 | Execution time<br>06 Mar 2026... | Requested for pass<br>06 Mar 2026... | SUCCESSFUL |
| ReadSCW<br>PEARL-1A › UHF Transceiver II › UHF Fid v0.5 | Priority<br>9999 | Execution time<br>06 Mar 2026... | Requested for pass<br>06 Mar 2026... | SUCCESSFUL |
| ReadRfConfig<br>PEARL-1A › UHF Transceiver II › UHF Fid v0.5 | Priority<br>9998 | Execution time<br>06 Mar 2026... | Requested for pass<br>06 Mar 2026... | SUCCESSFUL |
| ReadSWVersion<br>PEARL-1A › UHF Transceiver II › UHF Fid v0.5 | Priority<br>9990 | Execution time<br>06 Mar 2026... | Requested for pass<br>06 Mar 2026... | SUCCESSFUL |
| ReadBeaconMessageBetweeenTxPeriod...<br>PEARL-1A › UHF Transceiver II › UHF Fid v0.5 | Priority<br>9980 | Execution time<br>06 Mar 2026... | Requested for pass<br>06 Mar 2026... | SUCCESSFUL |



# UHF beacons & spectrum monitoring



Object Browser

PEARL-1AB

PEARL-1AB

Basic
Orbit
Attitude
Pass Br...
Mass
Lighting
Refere...
Ground...
Descrip...
2D Graphics
Attribut...
Time E...
Pass
Contours
Range
Lighting
Swath
Ground...
Radar...
3D Graphics
Pass
Orbit S...
Attitud...
Vector
Proximity

Propagator: HPOP — Initial State Tool...

Interval: PEARL-1AB AnalysisInterval

Step Size: 60 sec

Orbit Epoch: 24 Apr 2026 04:00:00.000 UTCG — Semimajor Axis: 6968.14 km

Coord Epoch: 24 Apr 2026 04:00:00.000 UTCG — Eccentricity: 5.54911e-16

Coord Type: Classical — Inclination: 97.7532 deg

Coord System: TrueOfDate — Argument of Perigee: 0 deg

Prop Specific: Force Models... — RAAN: 17.2048 deg

Integrator... — True Anomaly: 3.41374e-15 deg

Covariance...

# Orbit Wizard

Type: Sun Synchronous

Satellite Name: PEARL 1AB

## Analysis Time Period

Interval: PEARL-1AB AnalysisInterval

## Graphics

Show All Objects

Color:

3D Model: satellite.glb ...

Lat,Lon: (74.15493, 164.18278)

Displaying: 1 Rev

## Geometry Definition

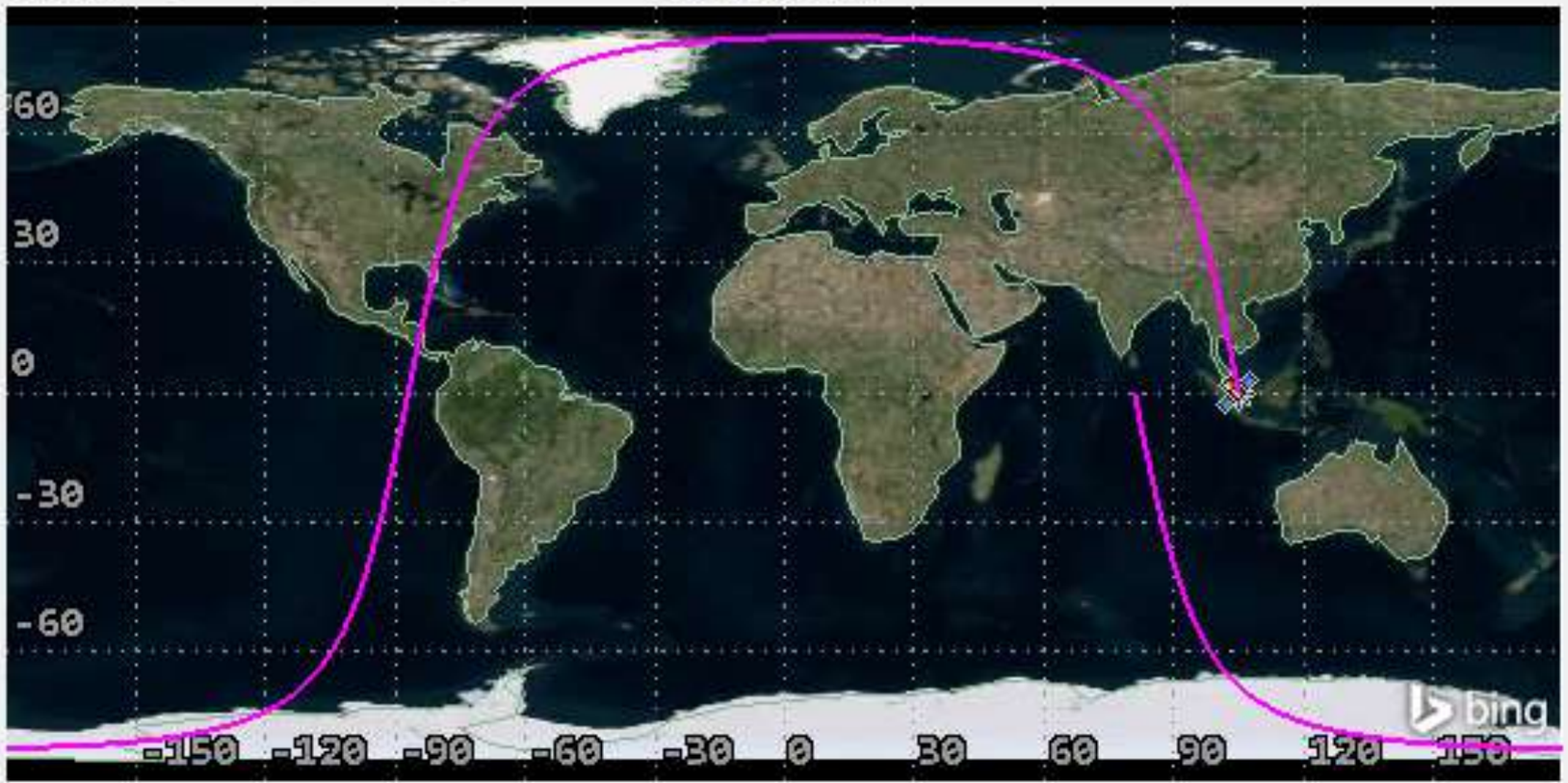
Inclination: 97.0346 deg

Altitude: 590 km

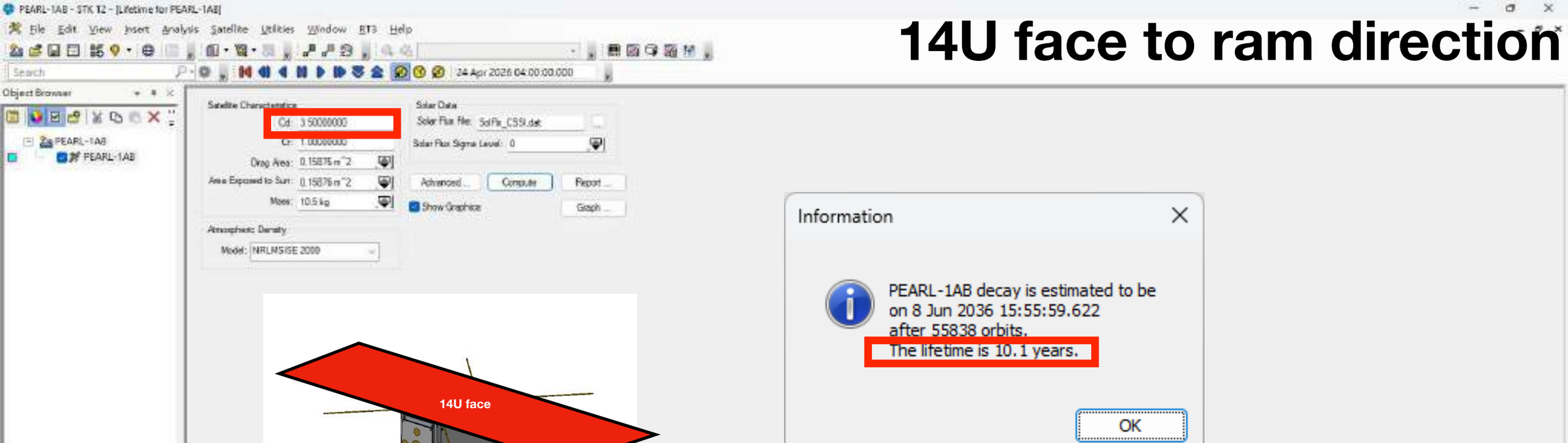
## Node Definition

Local Time of Ascending Node: 11:00:00.000 HMS

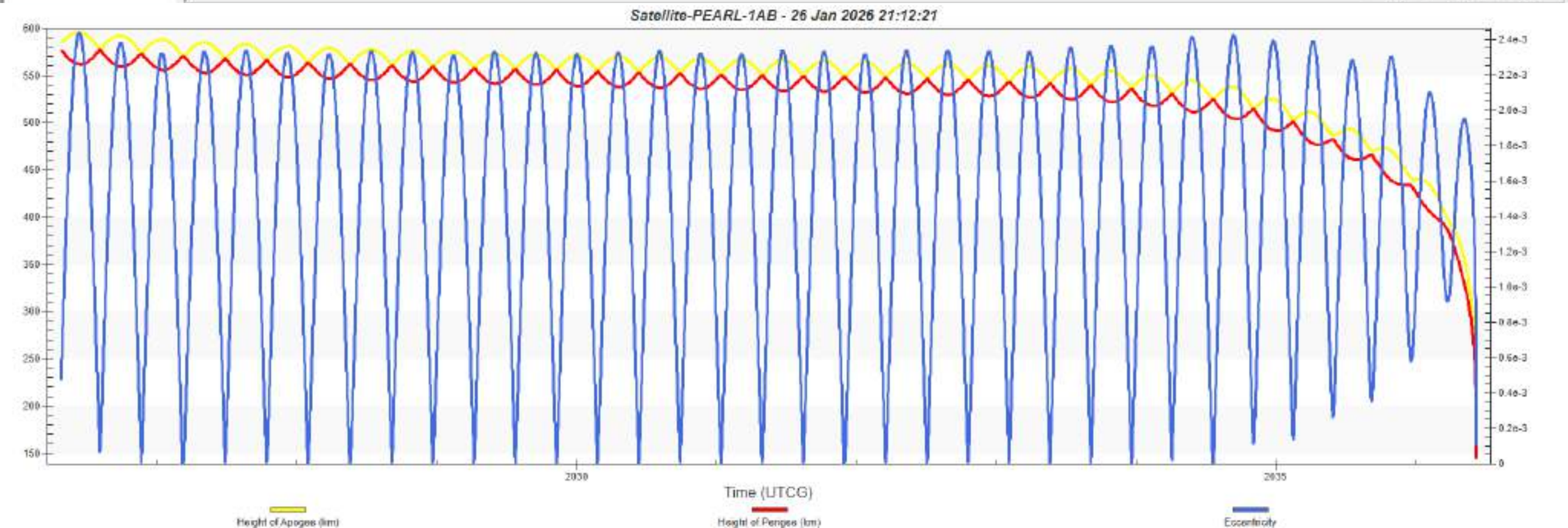
Local Time of Descending Node: 12:00:00.000 HMS



# 14U face to ram direction




**The drag coefficient (Cd) for satellites in Low Earth Orbit (LEO) is generally assumed to be around 2.2, a standard value used for compact, spherical, or randomly tumbling objects. However, this value varies based on atmospheric density, altitude, and satellite orientation, typically ranging from 1.4 to 4.0 for specific, non-spherical geometries. (Wang et al., 2024, Space Weather)**



# Summary

- **PEARL-1A/1B** will equip **ISL**, **CIP**, and **PSC** to operate Ka-band broadband ISL, communication environment monitoring, and solar cells technical demo in space.  All the Ka-band UTs are ready for the 1st contact with PEARL-ISL.
- All existed **UHF TT&C G/S** have been migrated from amateur-band to commercial-band. A new **S-band TT&C G/S** has been established and integrated with SpaceOps using a modified SDR.
- PEARL-1A/1B have been shipped to **VSFB** and will be for final integration test this week.  It was scheduled to launch onboard SpaceX **CAS500-2** mission in 2026Q2.