

The YAOKI Lunar Rover

Shinichiro Nakajima, Alejandro Sela, Louis Burtz

Webinar | Lunar Ledger | First Dataset Release

Launching
to space:

SpaceX
Falcon 9



PHOTO CREDIT: SPACEX

Leaving Earth:

Intuitive Machines
IM2 Mission



Leaving Earth:

Intuitive Machines
IM2 Mission



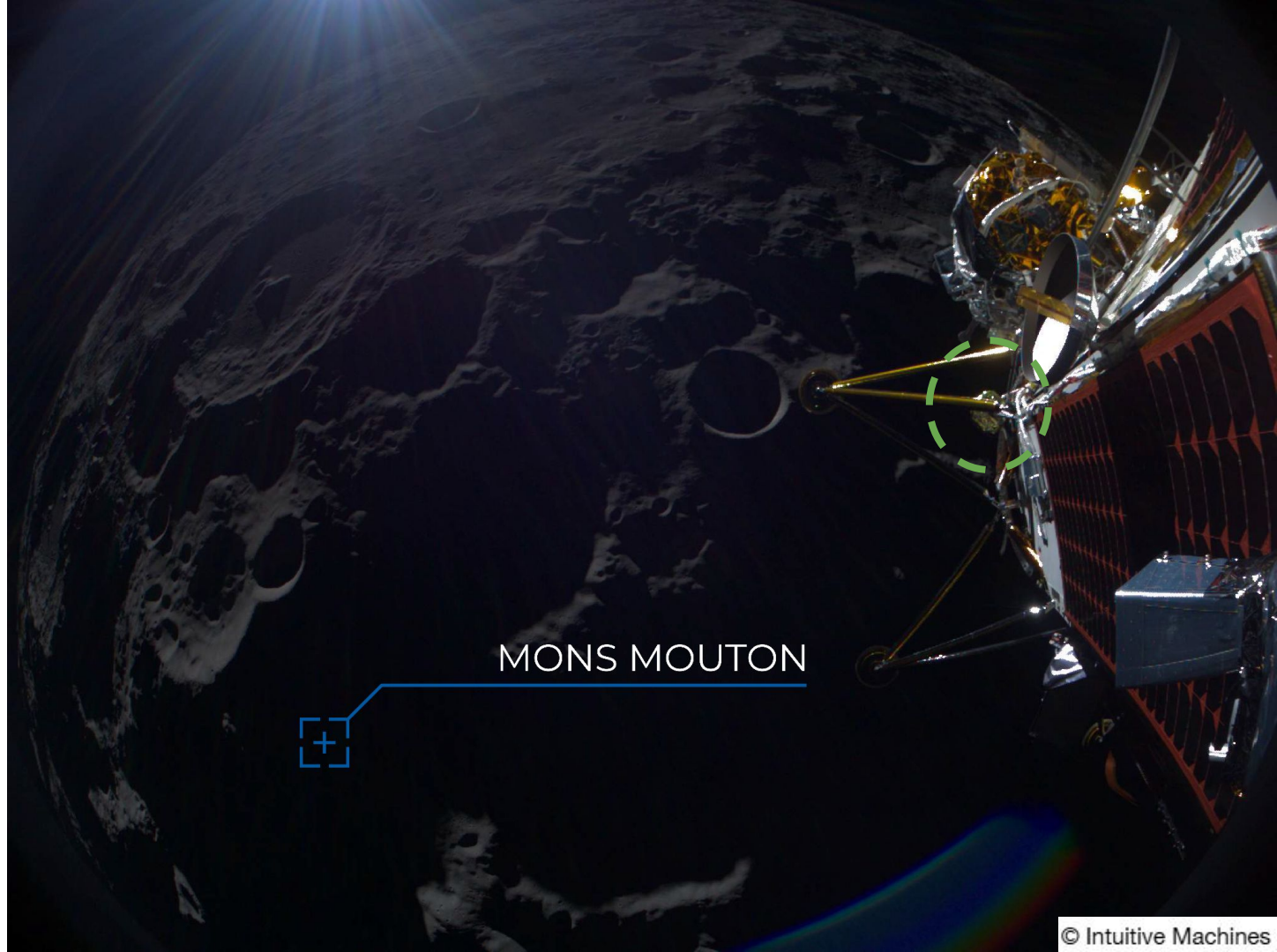
Arriving at the
Moon:

Intuitive Machines
IM2 Mission



Landing on the
Moon:

Intuitive Machines
IM2 Mission



Landing on the
Moon:

Intuitive Machines
IM2 Mission



LANDED
ON
THE
MOON
!!!



© Intuitive Machines

Landing Site

84.8 °S, 29.1°E

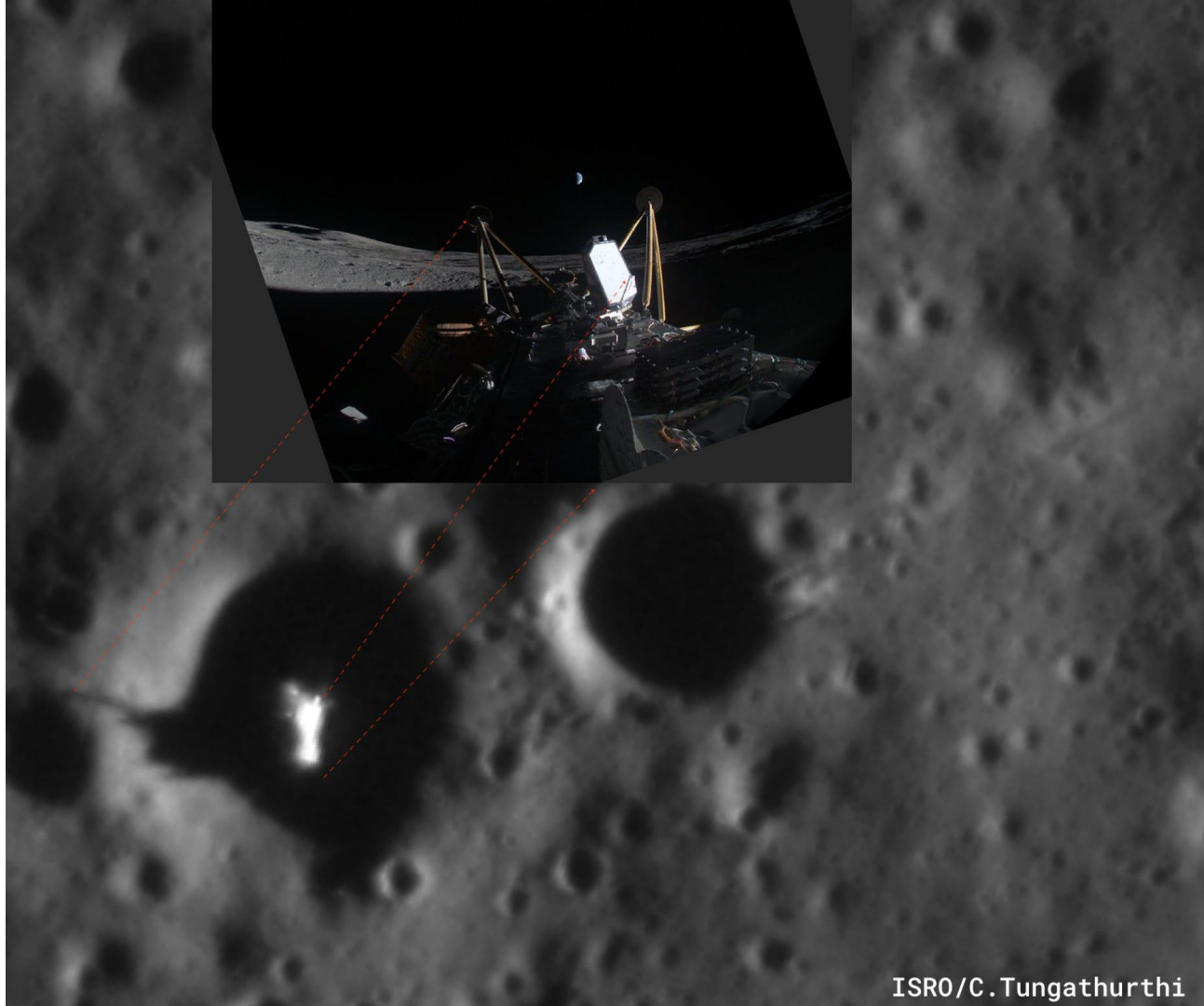
Distance from the
South Pole:

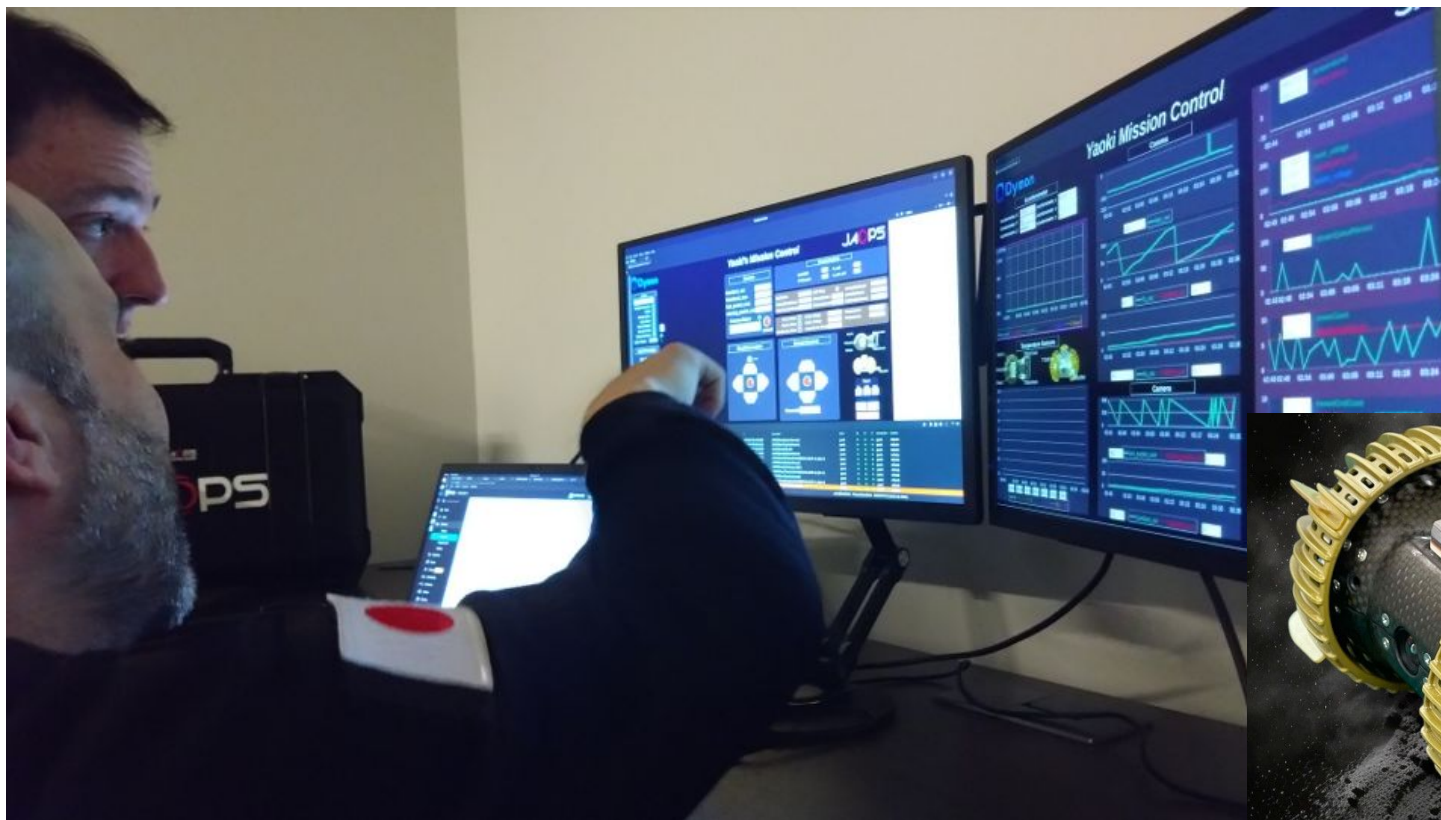
~160 km

Crater

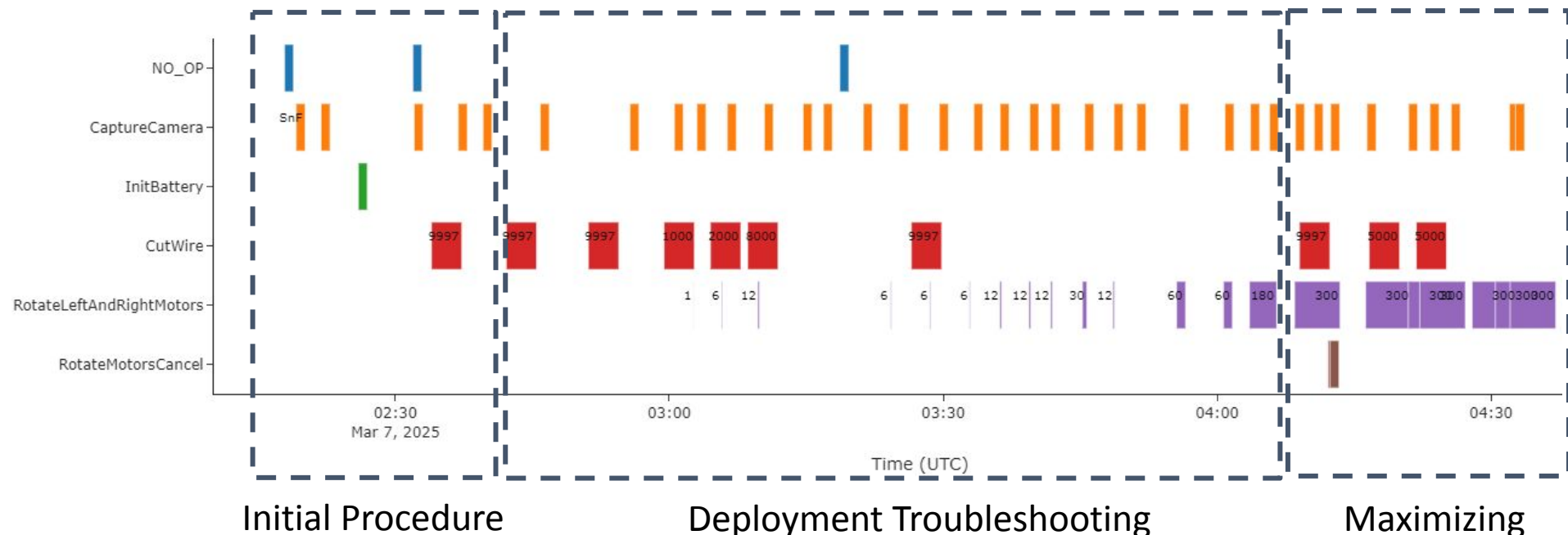
Temperature :

~ -100 °C

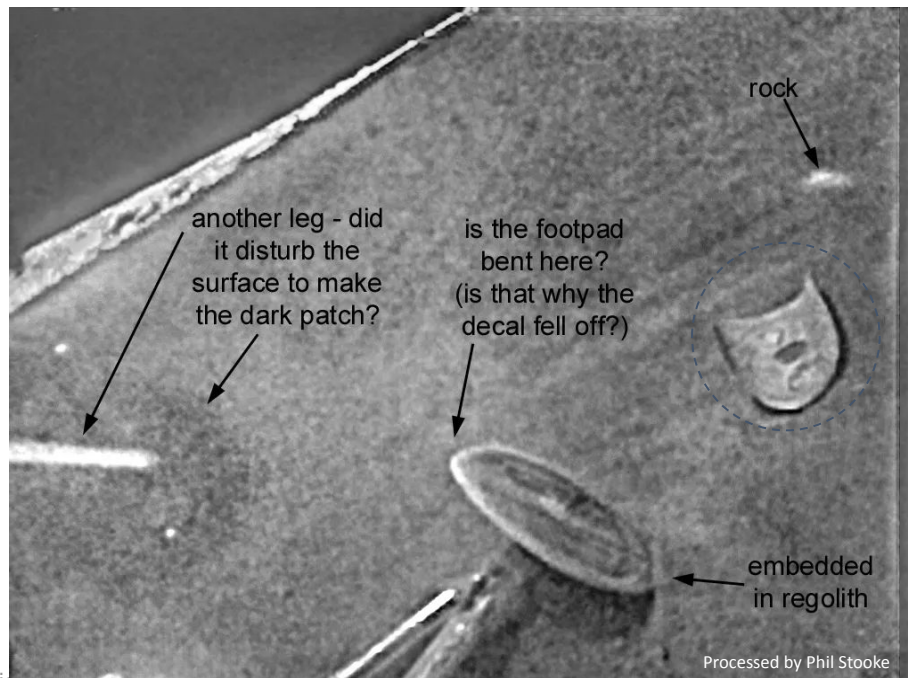




Timeline of Telecommands Sent



Images taken from the crater near the lunar South Pole



All 28 YAOKI Images:

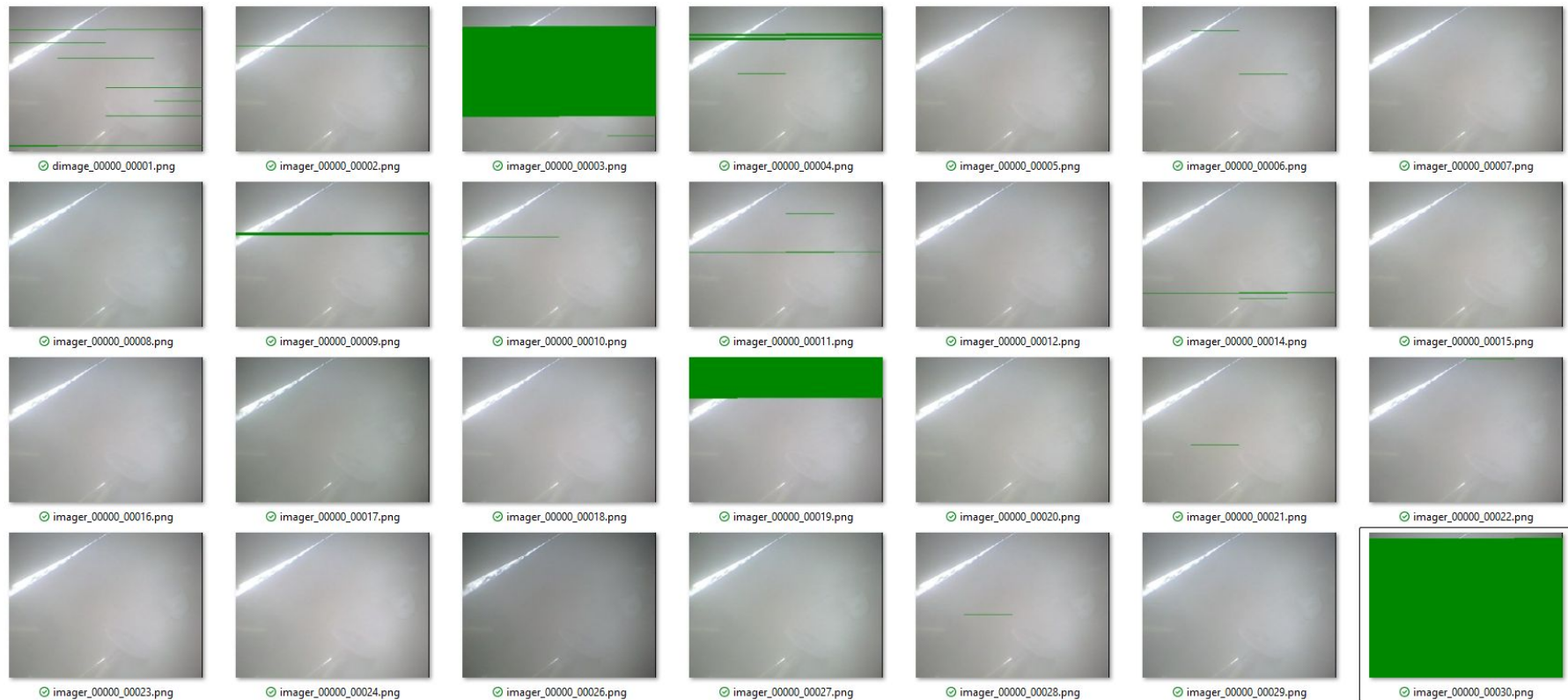
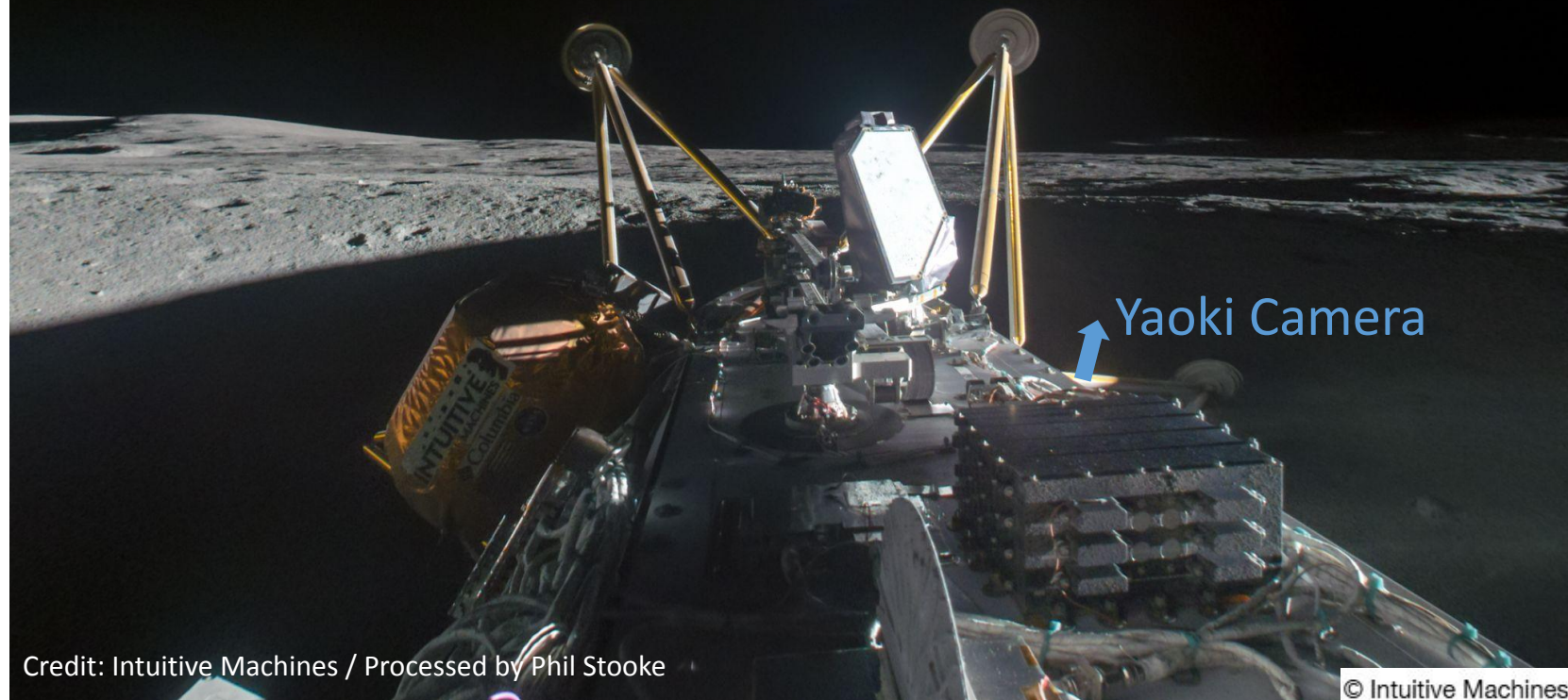


Image from IM2 lander camera

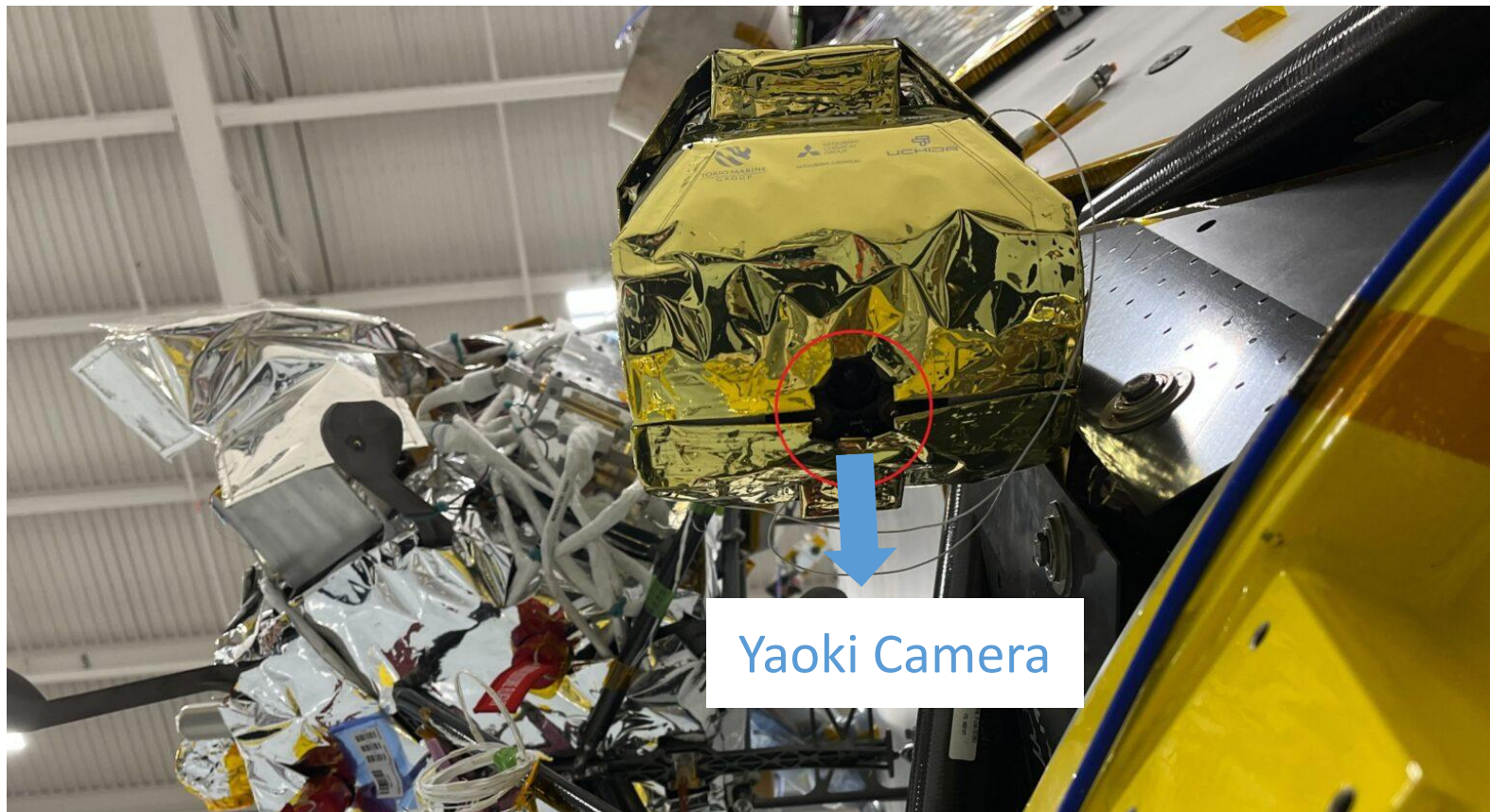


Credit: Intuitive Machines / Processed by Phil Stooke

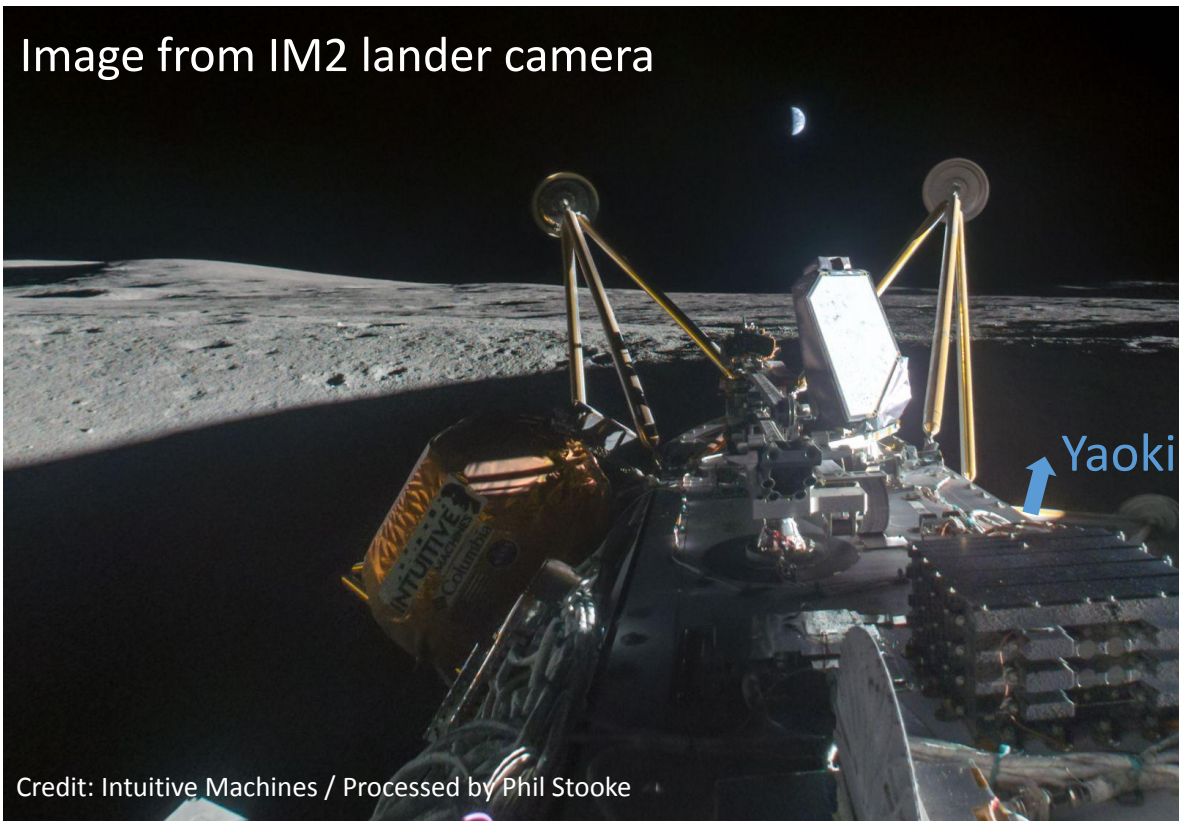
© Intuitive Machines

YAOKI
Rover
before
launch

Red Circle =
YAOKI
camera
view port



Yaoki Camera

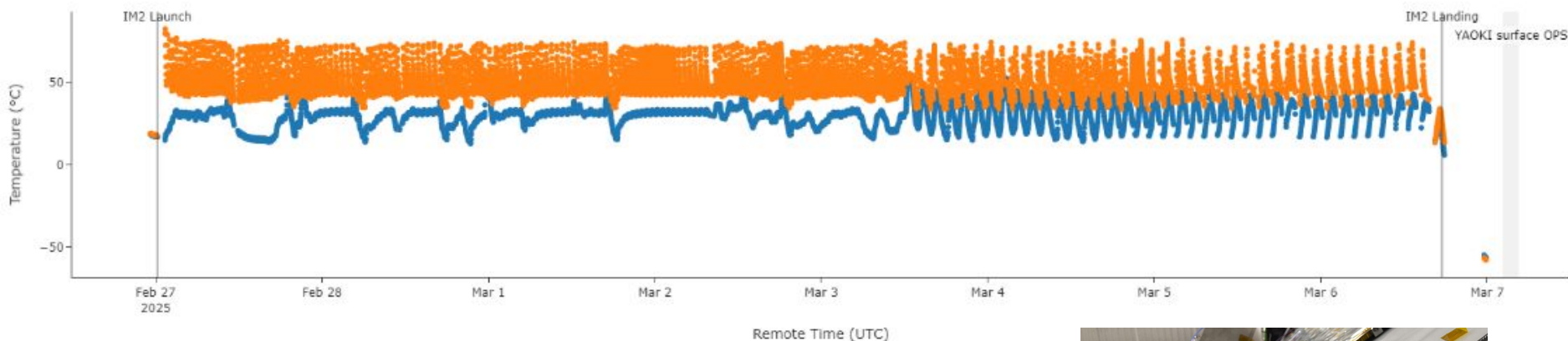


Yaoki Camera



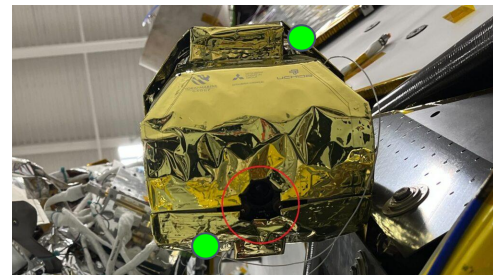
External Temperature Sensors (x2)

Temperature Telemetry over Time (cleaned)



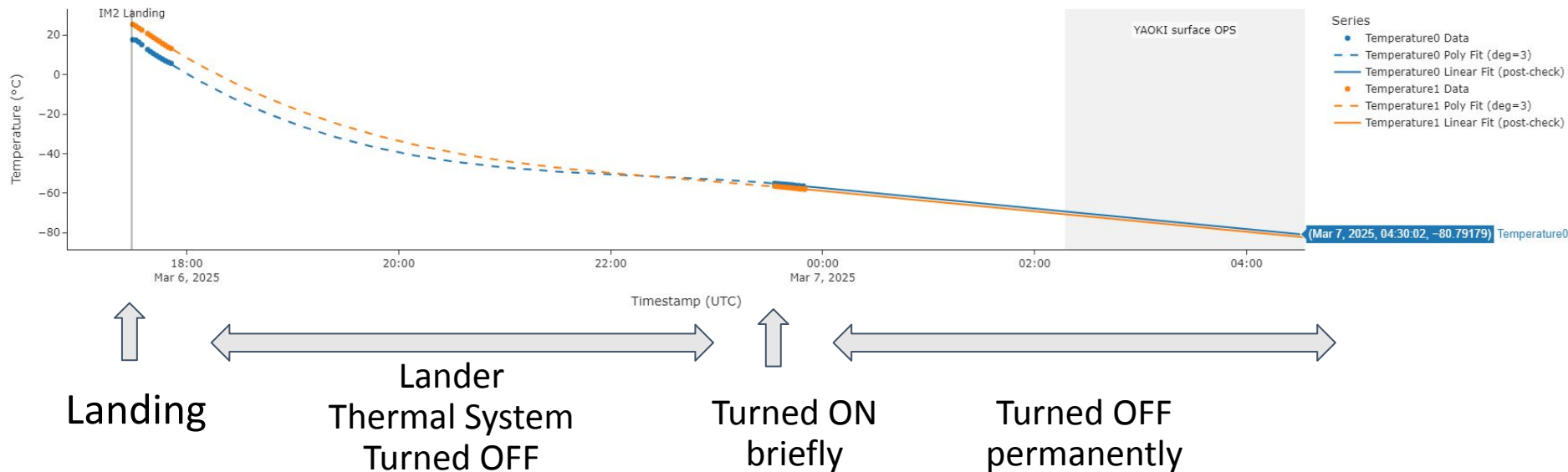
Green dots =

External temperature sensors

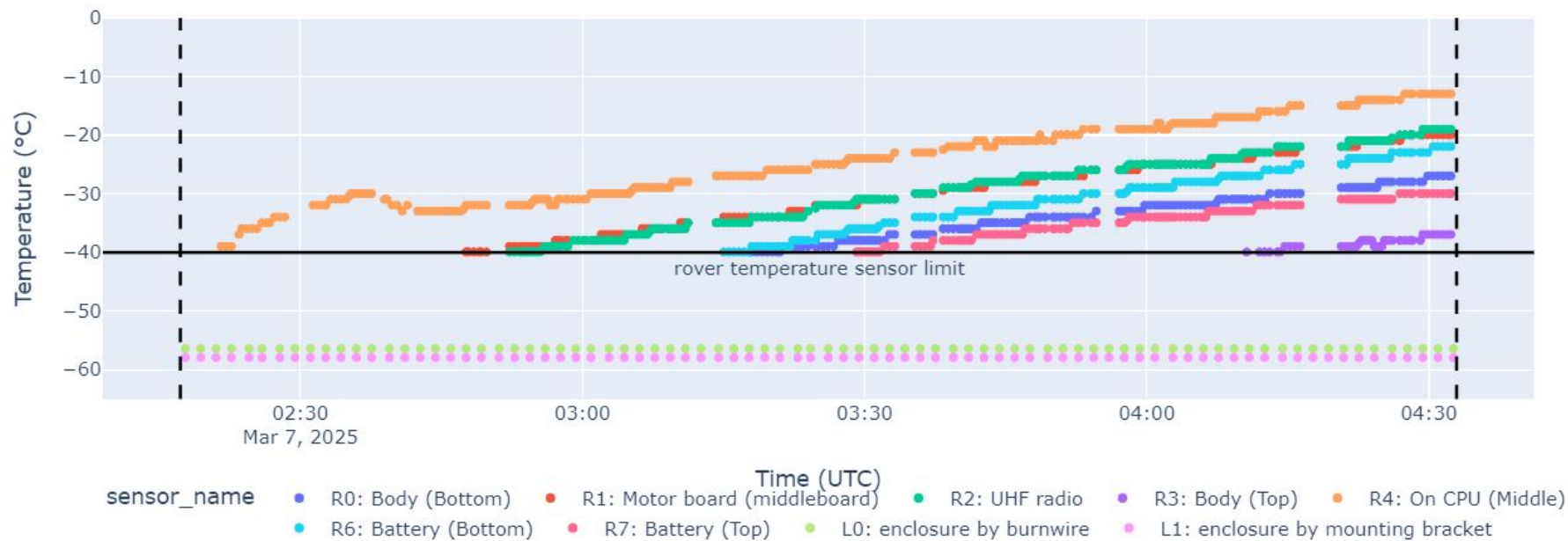


External Temperature Sensors (x2)

Temperature Fits: Polynomial (to last point) & Linear (post-check extrapolate)



Internal Temperature Sensors (x7)



- All telecommands sent
- All telemetry received
- All images received

Open Data on AWS



jaops-space / im2-yaoki-yamcs-public

- Raw format and processed format
 - Tools and tutorials of how to access and analyze the data
 - Description of each data item
-
- Configuration of the Yamcs Mission Control System
 - Mission Database
 - Data Archive
 - You can replay the data like it was received during the mission

Rover Name	Country (Entity)	Mission Name	Year
Lunokhod 1 and 2	Soviet Union 	Luna 17, 21	1970, 1973
Apollo Lunar Rovers	USA (NASA) 	Apollo 15, 16, 17	1971–72
Yutu and Yutu 2	China (CNSA) 	Chang'e 3, 4, 6	2013, 2019, 2024
Pragyan	India (ISRO) 	Chandrayaan-3	2023
SORA-Q (LEV-2)	Japan (JAXA) 	SLIM	2024
MAPP	USA (Lunar Outpost) 	Lunar Voyage 1 on IM-2	2025
YAOKI	Japan (Dymon) 	YAOKI on IM-2	2025

Only 10 successful rovers

Operated by JAOPS

First Japanese private-sector rover on the Moon
First images of dark crater near South Pole

**First lunar rover with open-source mission
operations software**

First dataset on the Lunar Ledger!

Surviving the launch, cruise and surface environments is hard

The accelerometer failed. But all other electronics worked well!

Not space-grade / multi-million dollar dedicated development

Sending data from the Moon is hard

Choose carefully what data to send, how much can be sent, how to send it

Always send raw data. Calibration only on the ground.

Software to re-configure data sending parameters

Landing on the Moon is hard

Record data in space before landing

Plan for contingency landing scenario together with the lander provider

Expect anomalies: design robust deployment system and data acquisition

Mission Operations are critical from the beginning of development

Hardware + Software + Mission Operations

Standards and heritage increase reliability and reduce development time

Yamcs Mission Control System

CCSDS communication protocols

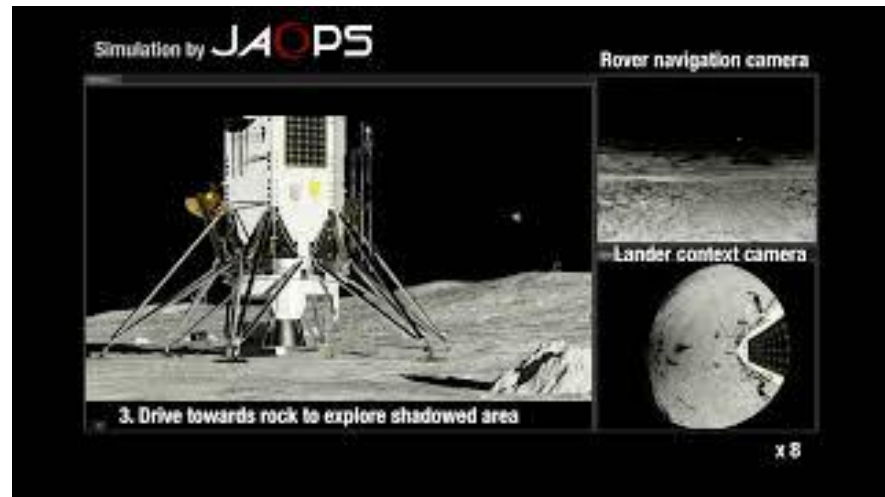
Deployment infrastructure

Test early, test often, test fully

Create (and budget) for several Flight Models

Leverage simulation from development to mission planning to testing to operator training to collecting scientific data properly

Expect and prepare for the unexpected





Why Join the Lunar Ledger?



1. Share this unique dataset
2. Share lessons learned
3. Empower others to analyze
4. Set a precedent

Vision of JAOPS:

JAOPS is committed to being a driver of safe, successful, and sustainable space mission operations by promoting best practices for the planning, collection, and delivery of lunar mission data.

Vision of Dymon:

Dymon continues to push the frontier through new missions that will collect valuable data and support humanity's expansion into space.

Vision of YAOKI:

Fall 7 times, stand up 8 times!



OPEN LUNAR
FOUNDATION

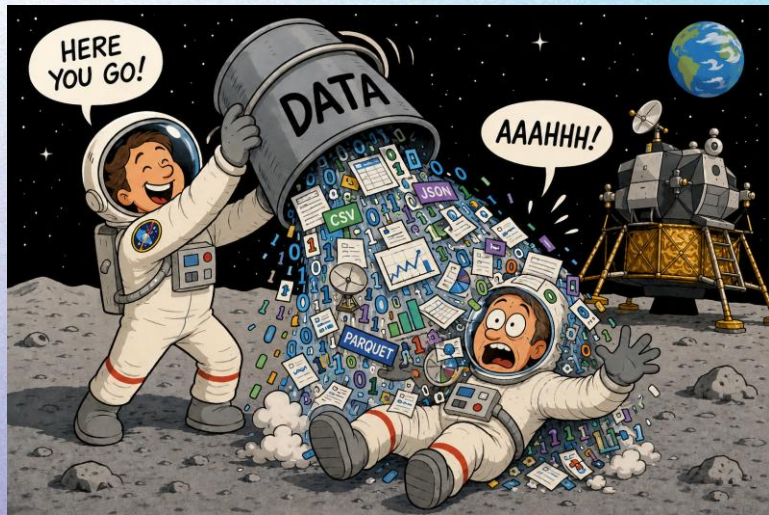
YAO KI Rover Dataset

Zack Gainsforth, Mehak Sarang | Open Lunar

Shinichiro Nakajima | Dymon

Alejandro Sela, Louis Burtz | JAOPS

July 1, 2026



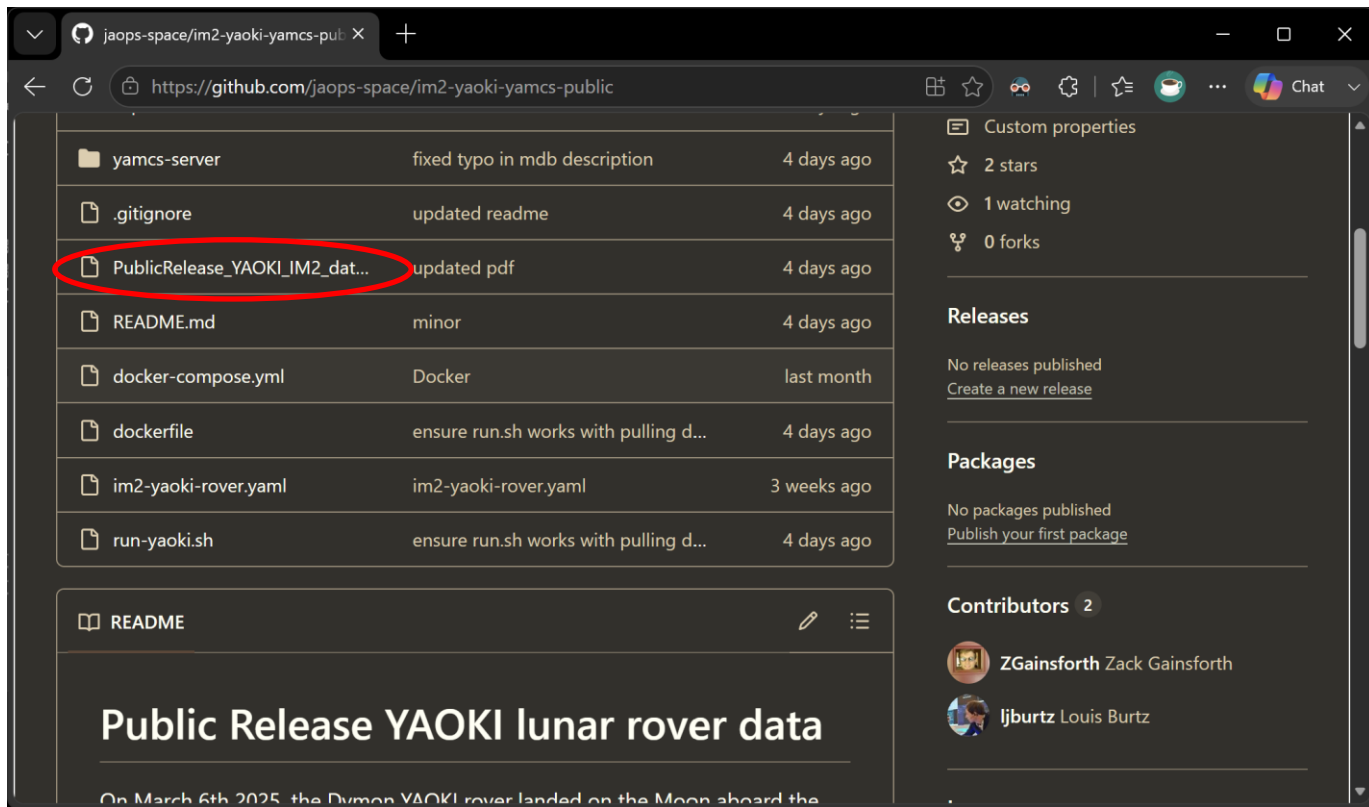
What does a data
release look like?

Where to start? <https://github.com/jaops-space/im2-yaoki-yamcs-public>



The easiest place
to start is the
Github!

Look for the PDF
in the main
directory.



jaops-space/im2-yaoki-yamcs-pub X +

https://github.com/jaops-space/im2-yaoki-yamcs-public

File	Description	Time
yamcs-server	fixed typo in mdb description	4 days ago
.gitignore	updated readme	4 days ago
PublicRelease_YAOKI_IM2_dat...	updated pdf	4 days ago
README.md	minor	4 days ago
docker-compose.yml	Docker	last month
dockerfile	ensure run.sh works with pulling d...	4 days ago
im2-yaoki-rover.yaml	im2-yaoki-rover.yaml	3 weeks ago
run-yaoki.sh	ensure run.sh works with pulling d...	4 days ago

Custom properties

- 2 stars
- 1 watching
- 0 forks

Releases

No releases published
[Create a new release](#)

Packages

No packages published
[Publish your first package](#)

Contributors 2

- ZGainsforth Zack Gainsforth
- ljburtz Louis Burtz

README

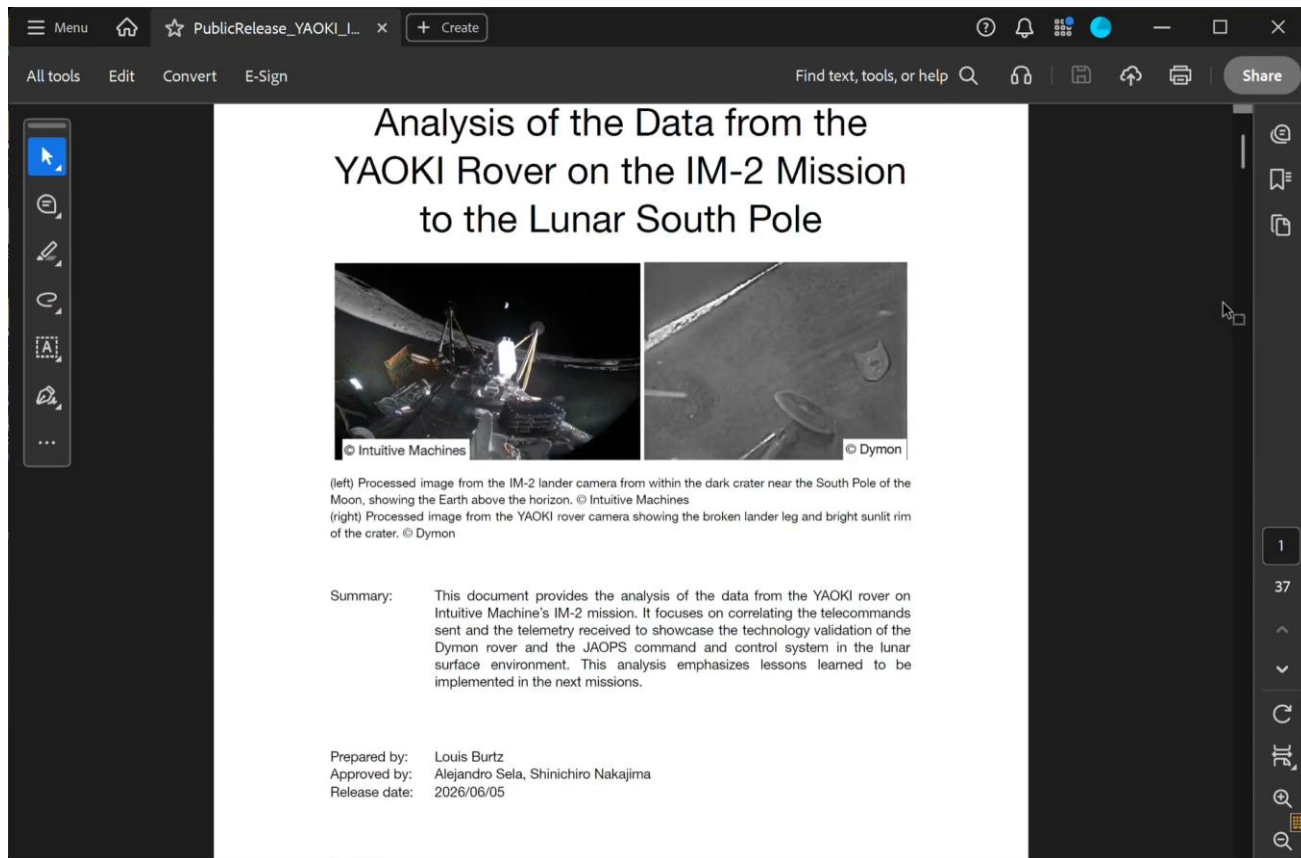
Public Release YAOKI lunar rover data

On March 6th 2025, the Dymen YAOKI rover landed on the Moon aboard the

Where to start? <https://github.com/jaops-space/im2-yaoki-yamcs-public>

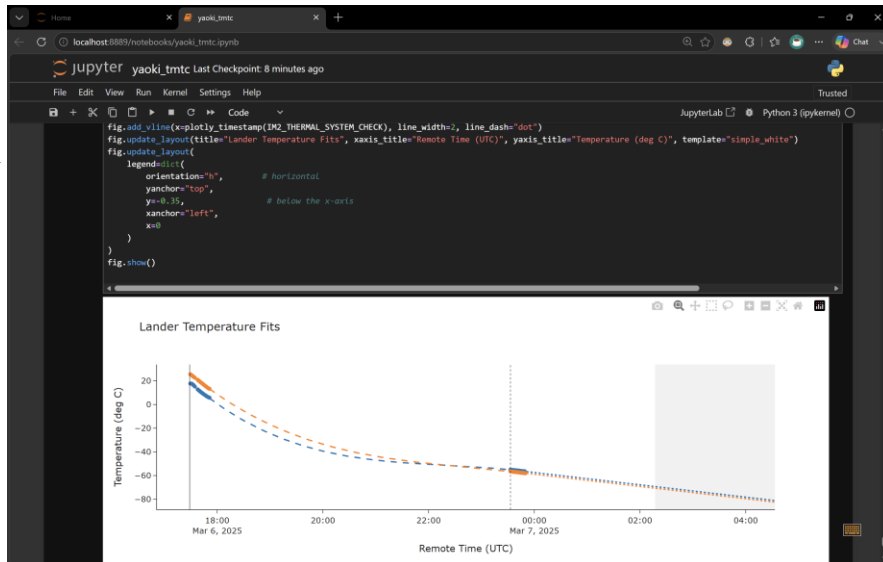
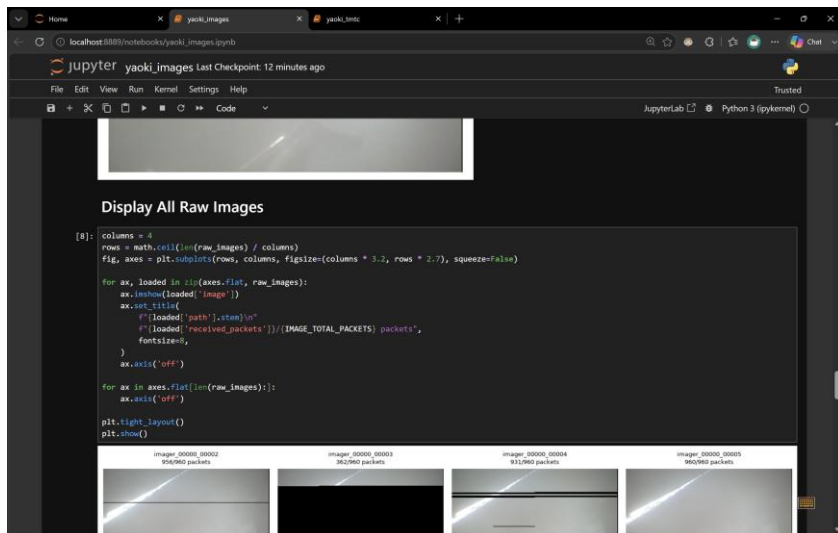
The easiest place
to start is the
Github!

**Look for the PDF
in the main
directory.**



Use Python Jupyter notebooks to play with data

Yaoki_tmtc downloads the
Telemetry and Telecommand data.
The code shows basic operations.



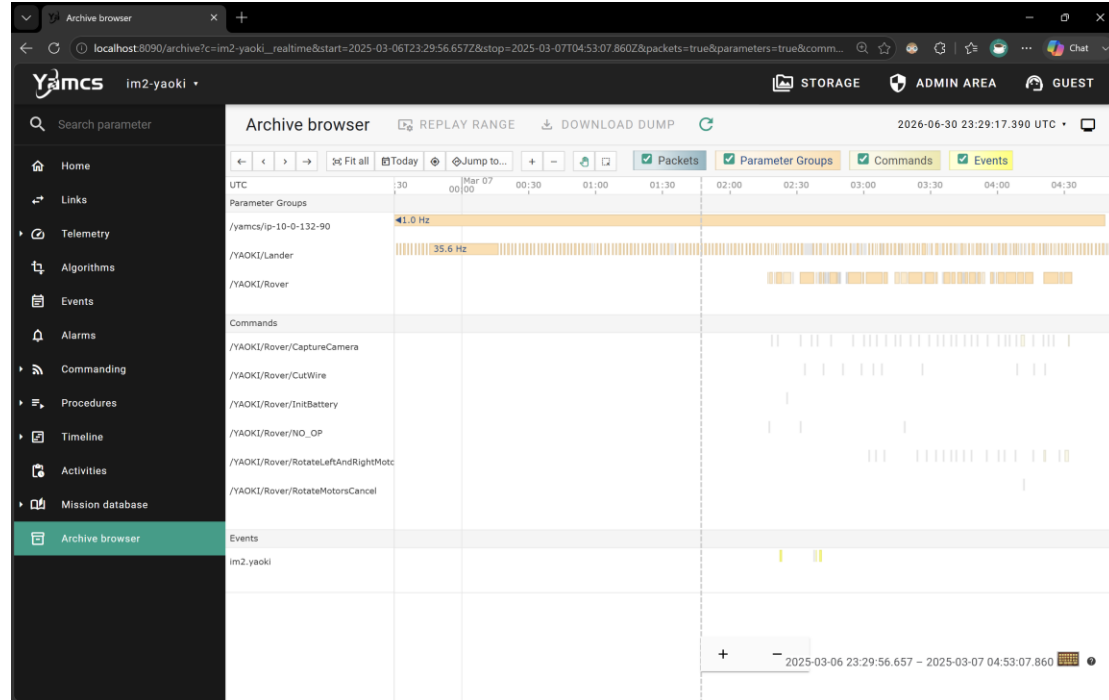
Yaoki_images downloads the
camera data. The code shows
basic operations.



The Yamcs database is included



The rover was controlled using the Yamcs mission control software. The database can be used to simulate any portion of the mission in realtime.



Ensure Easy Long-term Access for Everyone



In order to ensure the data is easily accessible using an **industry standard, open-source format**, all mission data was additionally converted to Apache Parquet.

This code for this conversion exists in the export subdirectory of the github repository.



Ensure Easy Long-term Access for Everyone

```
! YAOKI_Rover_ADC_TEMP4.metadata.yaml
1  kind: telemetry
2  source_name: /YAOKI/Rover/ADC_TEMP4
3  description: ''
4  rows: 399
5  fields:
6    generation_time:
7      description: UTC timestamp assigned when this
8      telemetry sample was generated.
9      dtype: datetime64[us, UTC]
10     observed:
11       null_count: 0
12       non_null_count: 399
13       min: '2025-03-07T02:17:15.150000+00:00'
14       max: '2025-03-07T04:32:56.331000+00:00'
15   acquisition_time:
16     description: UTC timestamp when the sample was
```



Each TMTC stream has a text file (yaml) describing the data format.

Each TMTC stream has a parquet file with the raw data.



YAOKI_Rover_ADC_TEMP4.parquet

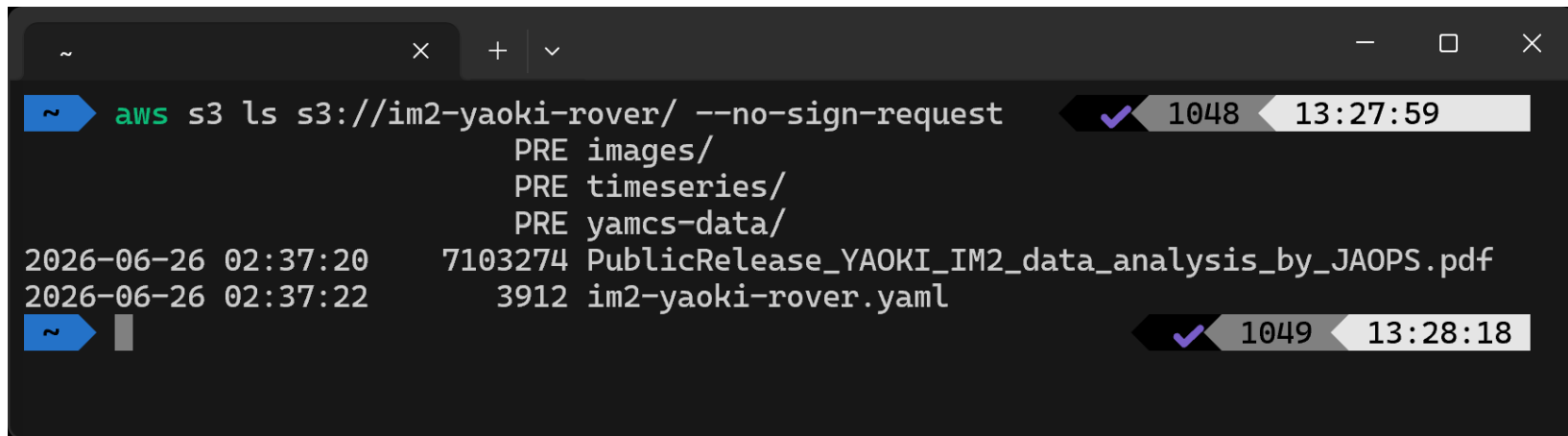
YAOKI_Rover_ADC_TEMP4.... (399 rows)

Table Charts SQL Export CSV Export JSON Polars Python

Schema		generation_time	acquisition_time	raw_value	eng_value
Column	Type	filter	filter	filter	filter
generation_time	TIMESTAMP WITH TIME ZONE	1741314214408	null	-37	-37
acquisition_time	TIMESTAMP	1741314239147	null	-36	-36
raw_value	DOUBLE	1741314273038	null	-36	-36
eng_value	DOUBLE	1741314299309	null	-36	-36
		1741314329405	null	-36	-36
		1741314359189	null	-35	-35
		1741314389313	null	-35	-35
		1741314419329	null	-35	-35
		1741314449279	null	-34	-34
		1741314479322	null	-34	-34
		1741314510344	null	-34	-34
		1741314689916	null	-32	-32

The Raw Data is on Amazon

We are using a publicly accessible Amazon S3 bucket.
It is **accessible world-wide** and **permanent**. You can access it
through AWS tools, python or a browser.

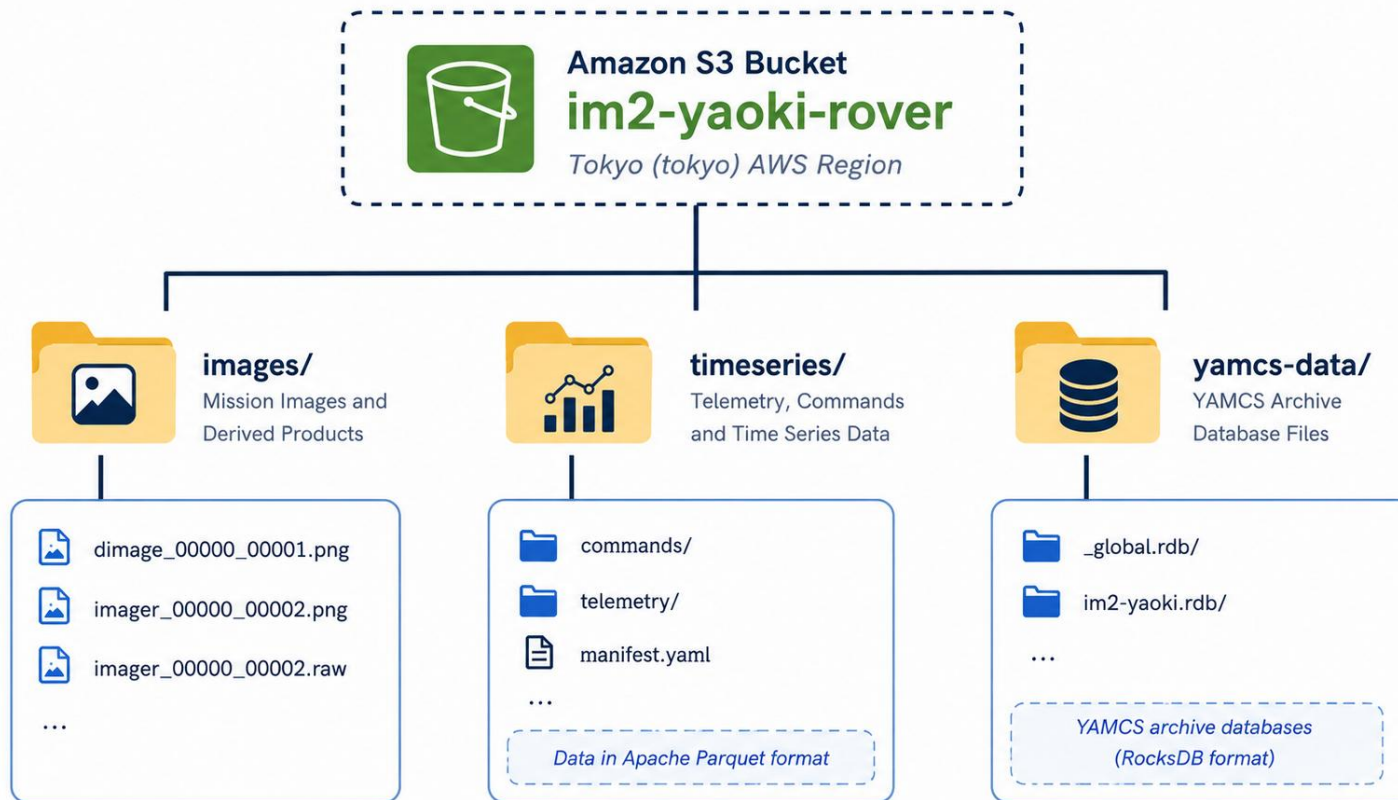


```
~ x + v - □ ×  
~ ➤ aws s3 ls s3://im2-yaoki-rover/ --no-sign-request ✓ 1048 13:27:59  
    PRE images/  
    PRE timeseries/  
    PRE yamcs-data/  
2026-06-26 02:37:20 7103274 PublicRelease_YAOKI_IM2_data_analysis_by_JAOPS.pdf  
2026-06-26 02:37:22 3912 im2-yaoki-rover.yaml  
~ ➤ █ ✓ 1049 13:28:18
```

The image shows a terminal window with a dark background. At the top, there are window control icons (close, maximize, zoom) and a tab labeled '~'. The terminal prompt is '~ ➤'. The command entered is 'aws s3 ls s3://im2-yaoki-rover/ --no-sign-request'. The output shows a directory listing for the S3 bucket 'im2-yaoki-rover'. It lists three prefixes: 'images/', 'timeseries/', and 'yamcs-data/'. It also lists two files: 'PublicRelease_YAOKI_IM2_data_analysis_by_JAOPS.pdf' (7103274 bytes) and 'im2-yaoki-rover.yaml' (3912 bytes). The terminal shows the command was executed successfully, indicated by a green checkmark and the number '1048' and the time '13:27:59'. The second line of the output shows the file 'im2-yaoki-rover.yaml' with a size of 3912 bytes and a timestamp of '2026-06-26 02:37:22'. The terminal prompt is now '~ ➤' followed by a cursor. A second status bar at the bottom right shows a green checkmark, the number '1049', and the time '13:28:18'.



Data structure of the Amazon Data



Data Archival - media



High quality hard disk drives are chosen for sedentary robustness, not performance.

Different manufacturing batches and manufacturers.

Also archive hardware for reading the drives!

Later evolutions to include additional media types.



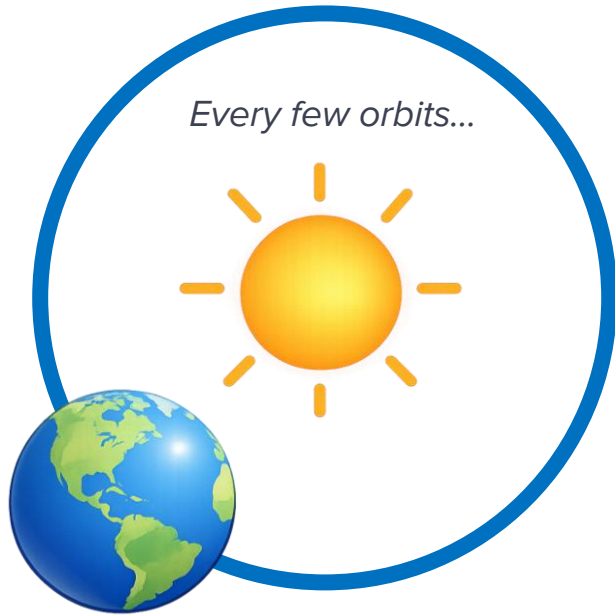
Data Archival - Duplication



Each location has multiple backups.
Multiple locations provides high redundancy.



Data Archival – Periodic data verification



Each backup uses parity codes for error correction.

Every few years, an operator checks data integrity and transfers data to new media when appropriate.



We are excited
to see what the
community
does with this
data!



Questions?
(Code demo next)



You can also email me:
data@openlunar.org