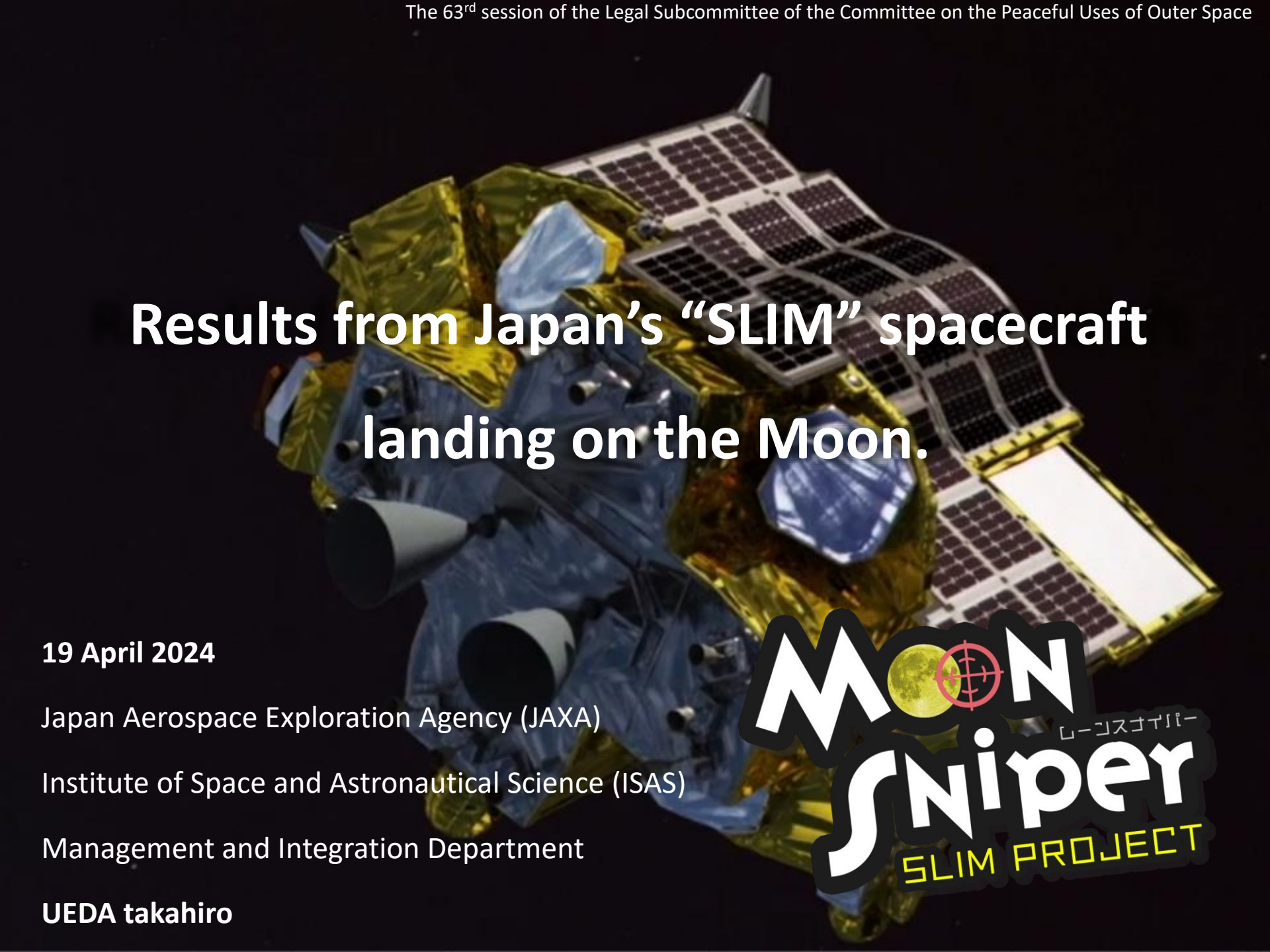
Results from Japan's "SLIM" spacecraft landing on the Moon.



19 April 2024

Japan Aerospace Exploration Agency (JAXA)

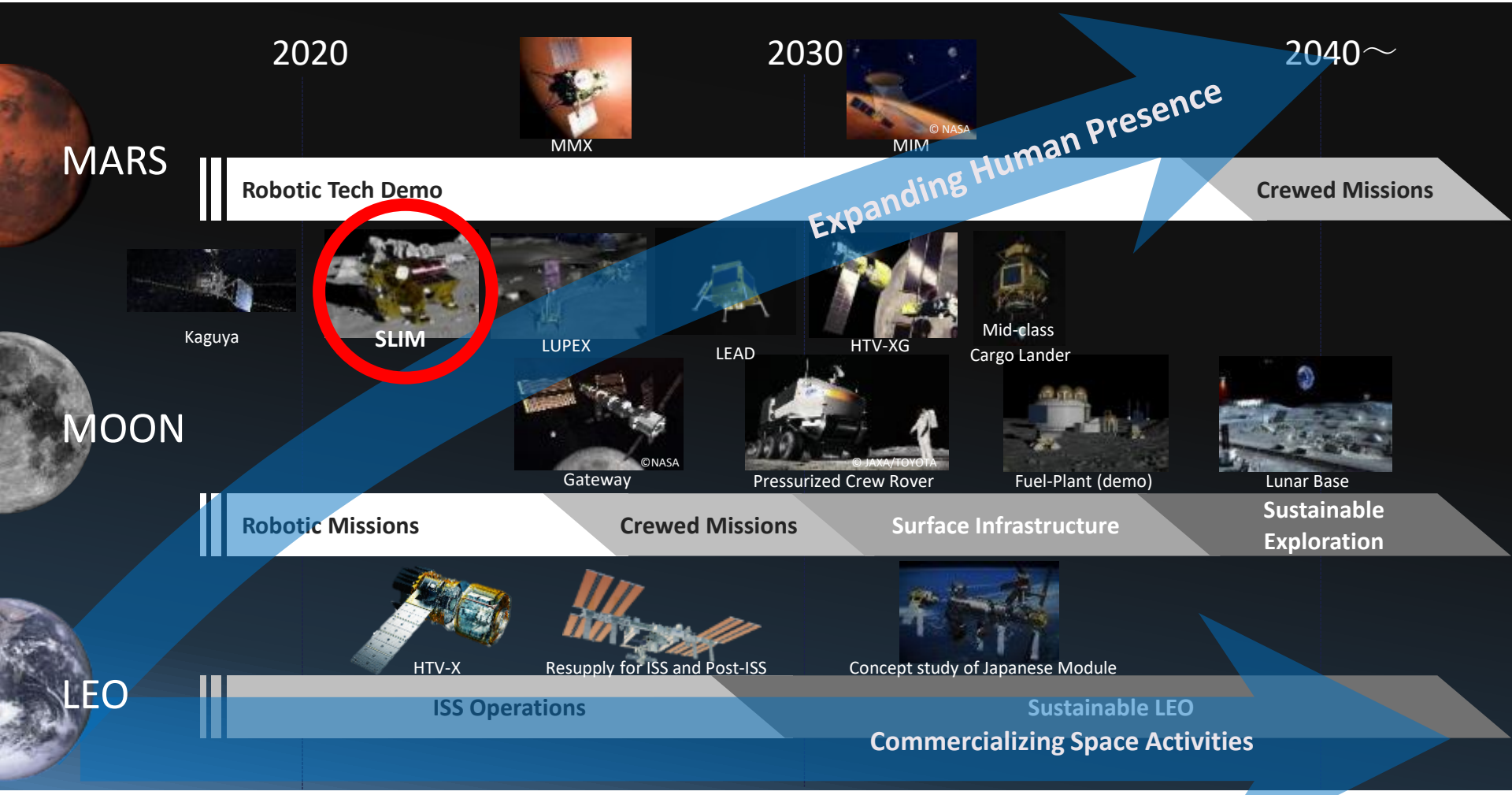
Institute of Space and Astronautical Science (ISAS)

Management and Integration Department

UEDA takahiro

Overview of JAXA Roadmap from LEO to Moon/Mars

Japan's "SLIM" spacecraft is a JAXA mission to lead activities on the lunar surface.



Mission Objectives of SLIM

Japan's "SLIM" (Smart Lander for Investigating Moon) spacecraft is aiming to contribute to future lunar and planetary exploration by **achieving the following two objectives**.

Objective A — Demonstration of high-precision "pin-point" landing technology on the Moon

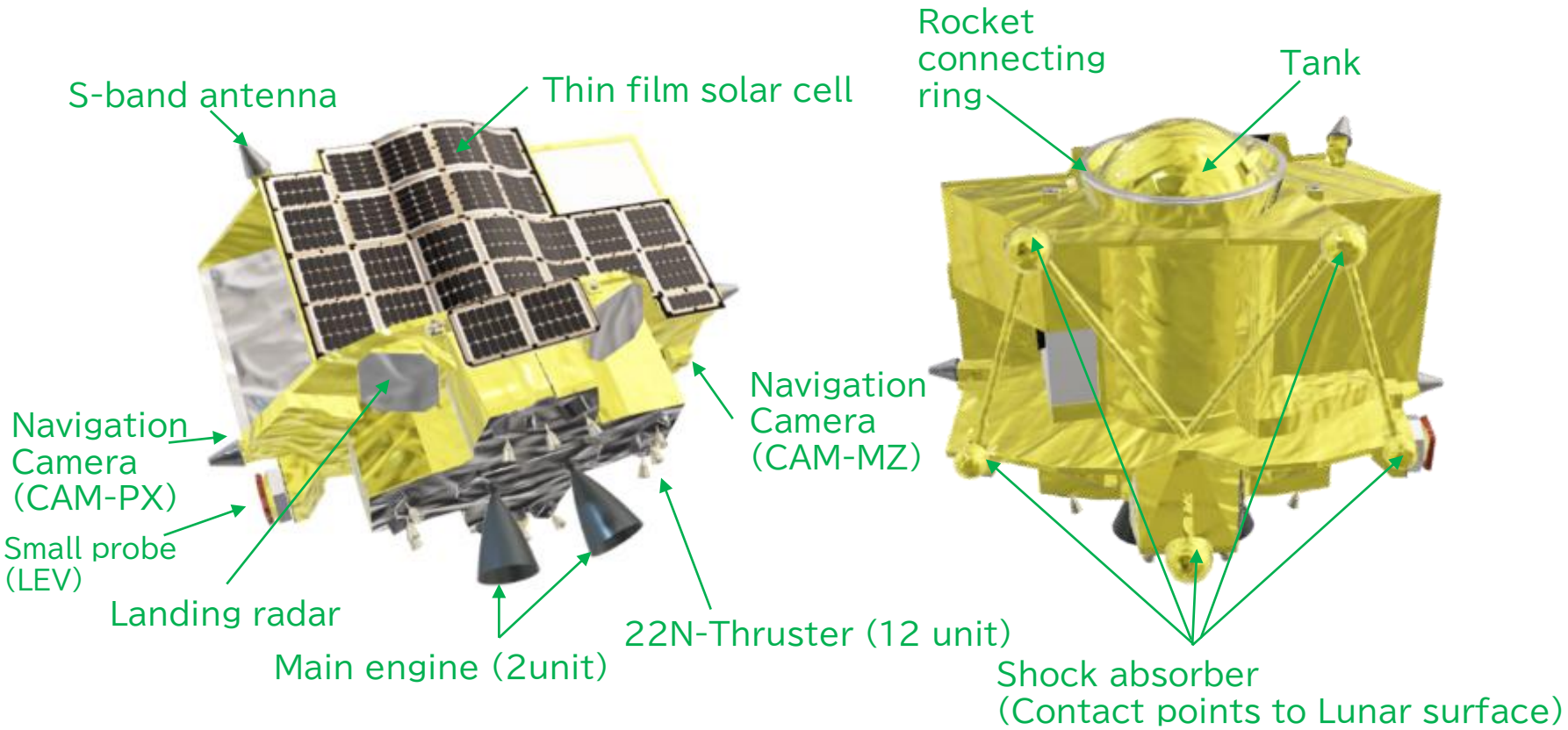
- Aim at a landing accuracy of 100m compared to the several kilometers to tens of kilometers of conventional lunar landers.
- Key technology includes "Vision-based navigation" and "Navigation, guidance and control"

Objective B — Realization of a lightweight lunar and planetary probe system to allow more frequent lunar and planetary exploration missions

- Small, lightweight, and high-performance chemical propulsion system
- Weight reduction of the core elements in most spacecrafts such as computers and power supply systems

SLIM Configuration

- Mass： 200kg （Dry） / 700-730kg （Wet）
- Size: 2.4m x 1.7m

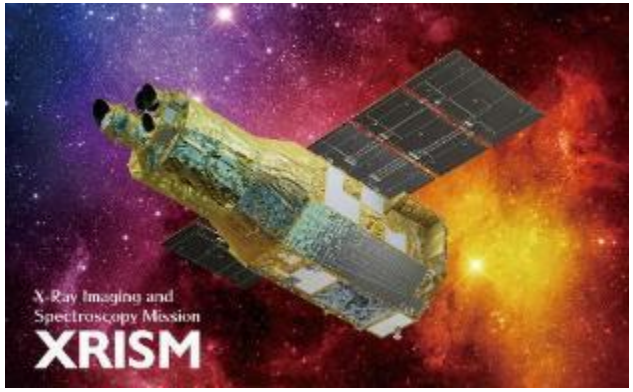


SLIM has adopted a fuel and oxidizer integrated tank to reduce weight. This cylindrical tank is also used as the structure base.

SLIM Story

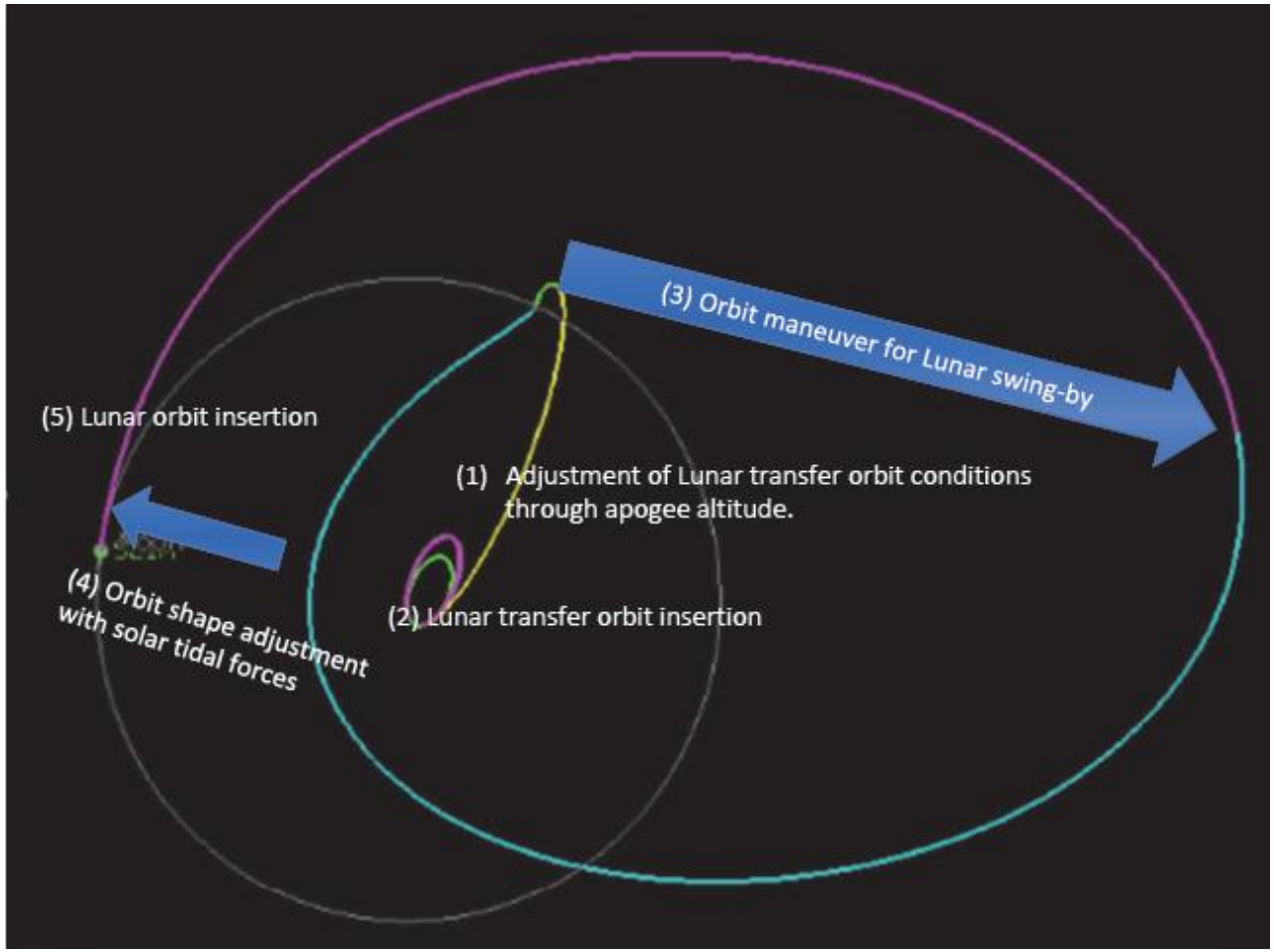
Launched 7 September 2023 at JAXA Tanegashima Space Center in JAPAN

H-IIA Flight# 47 With XRISM (X-Ray Imaging and Spectroscopy Mission)



SLIM Story

- **SLIM's trajectory design minimizes propellant consumption**. As a result, it took several months to reach the Moon. **It reached lunar orbit on December 25, 2023.**
- Lunar orbit : December 25, 2023 - January 20, 2024

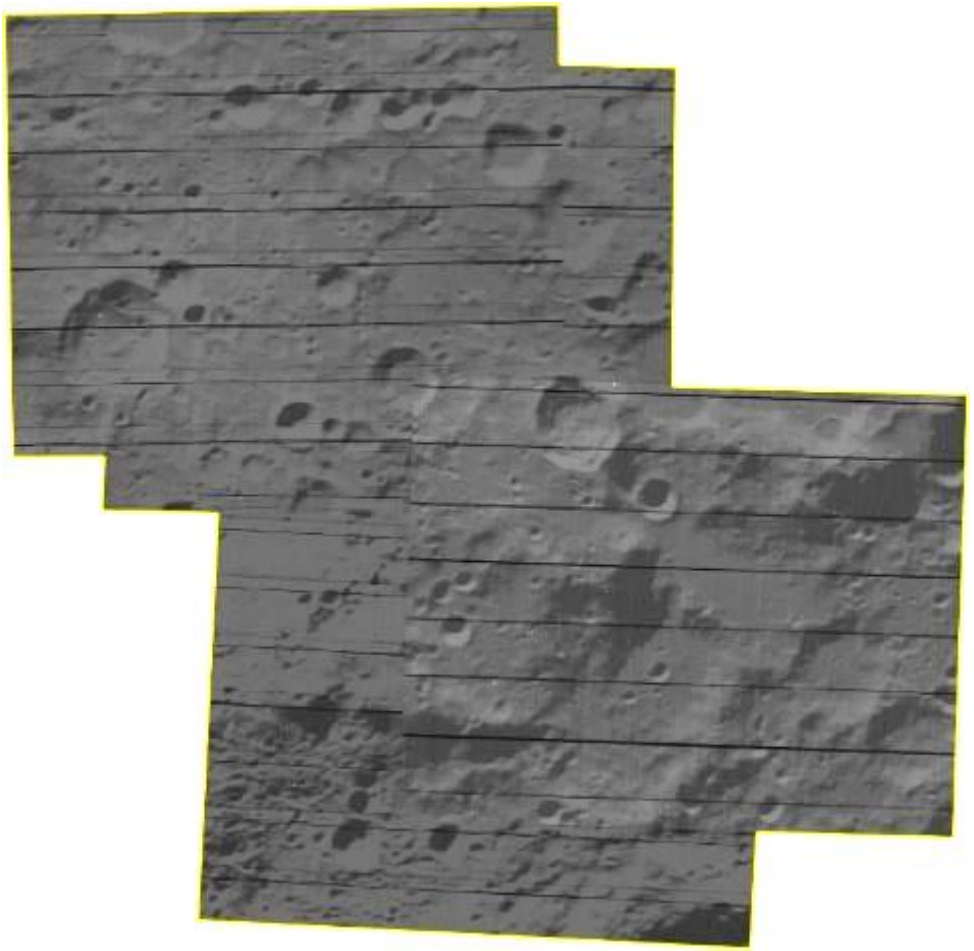


SLIM's trajectory design overview

The detailed orbit shape depends on the launch time.

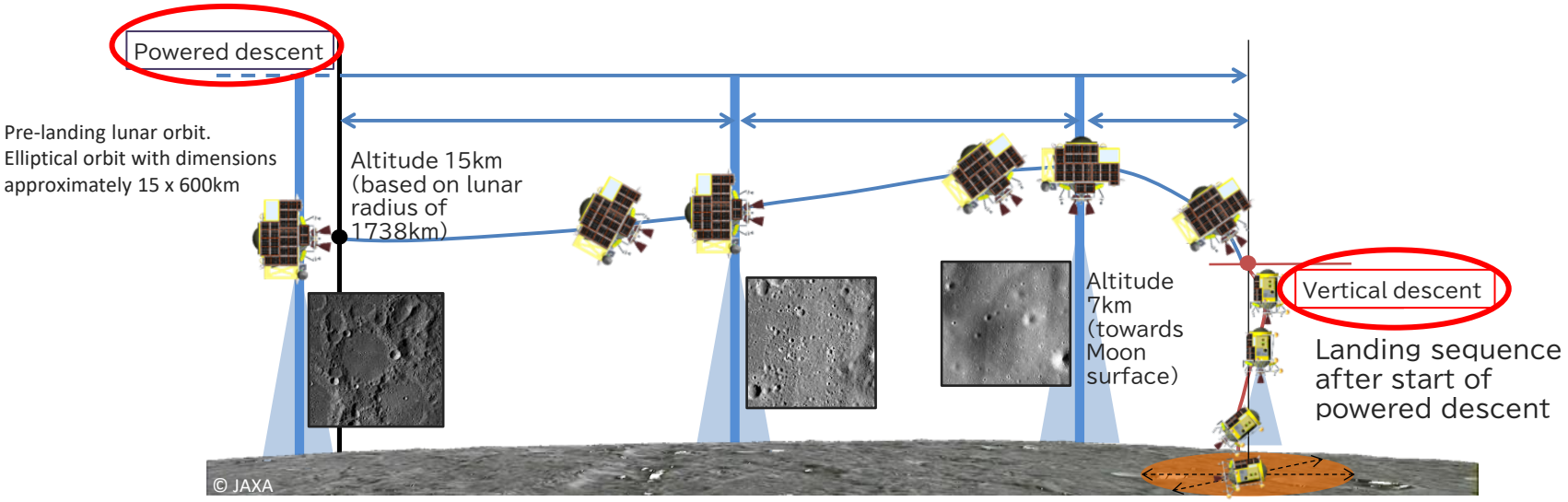
SLIM Story

- **Left image : Moon image captured at the time of Lunar Orbit Insertion(LOI)**
- **Right image : Images of the lunar surface captured by the onboard Multi-Band spectroscopic Camera (MBC) after LOI.**



LANDING on the lunar surface.

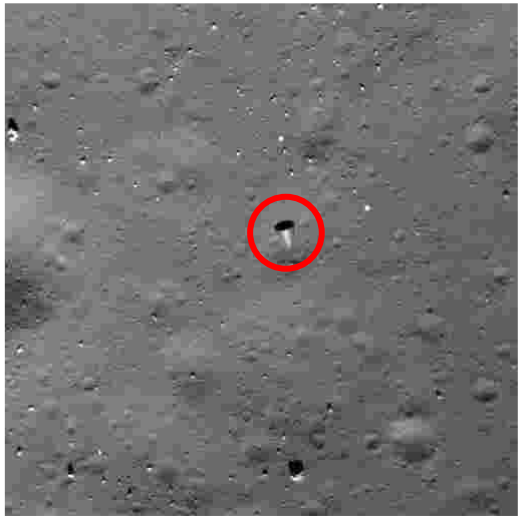
- The final decision to begin landing descent was made at around 23:59 JST (Japan Standard Time: UT+9h) on January 19, 2024.
- The main engines began to fire as planned, and the powered descent phase (the first half of the landing descent sequence) began at 23:59:58 JST.
- **The powered descent phase was successful.** The vertical descent phase then began.



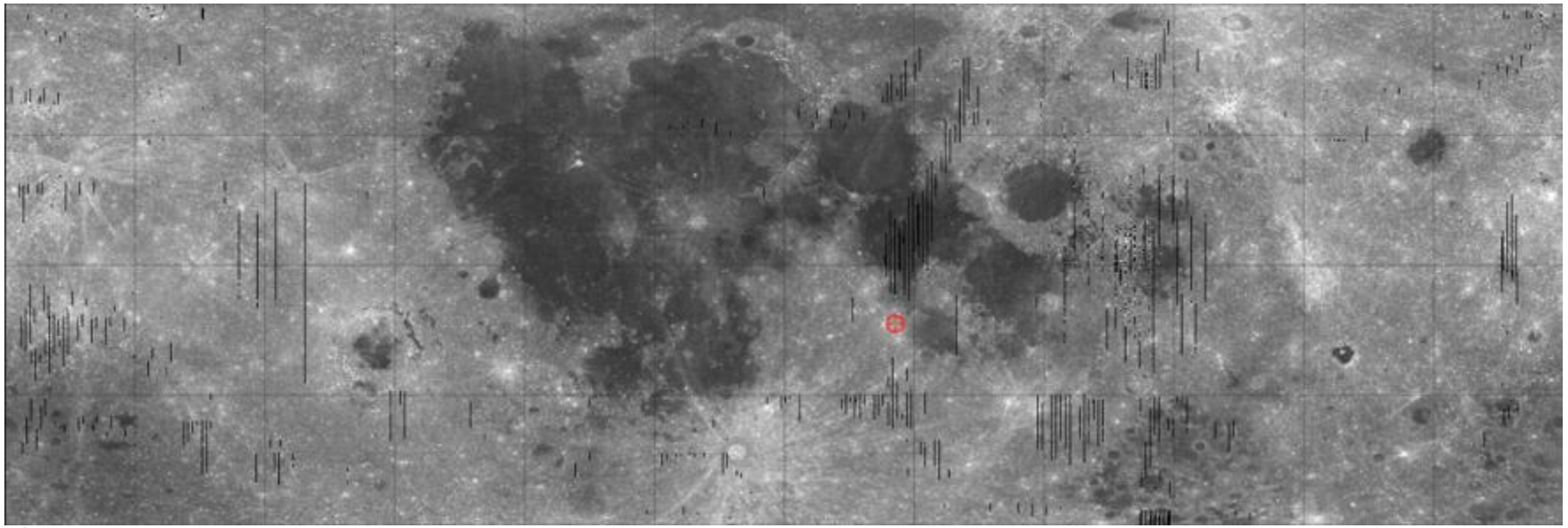
Landing sequence during powered descent and vertical descent

LANDING on the lunar surface.

- **At an altitude of approx. 50m during the vertical descent phase, the main engine thrust suddenly decreases.**
- Immediately after this abnormality, as you can see a nozzle-like shape in the image. It is assumed that **some kind of abnormality occurred near one of the two main engines, causing the nozzle to break and fall, resulting in the loss of most of the thrust generated by that main engine.**



a nozzle-like shape in the navigation camera image

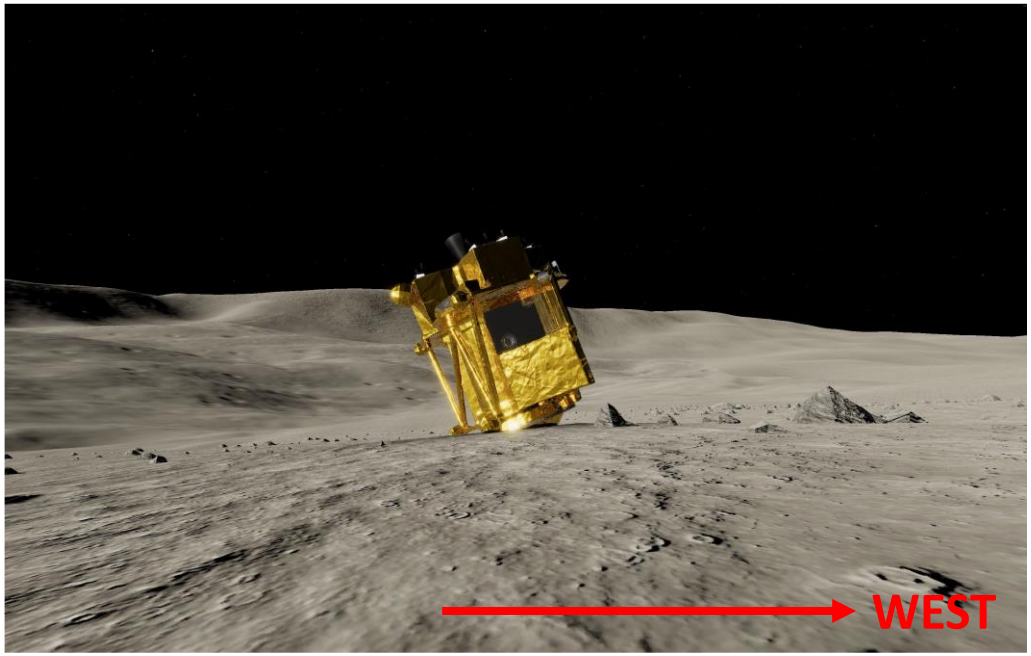


Lunar Map: The center of the red mark is the SLIM landing site (around the SHIOLI crater) © SELENE/JAXA
Source: November 6, 2019. Name of crater at SLIM landing target site https://www.isas.jaxa.jp/topics/002261.html

SLIM Story

LANDING on the lunar surface.

- At an altitude of approx. 50m, **the onboard navigation guidance control system detected an abnormality and executed a mode transition.** SLIM continued to fire the remaining main engine while changing the attitude to reduce lateral movement, and **autonomously proceeded with the sequence towards the landing mode sequence**.
- **SLIM landed slowly** but with a lateral velocity in an almost upright standing position (at about 00:19:52 JST).
- Landing conditions such as the lateral velocity and attitude exceeded the specified range, and **produced a large attitude fluctuation after landing** resulted in a settled attitude different to expected.



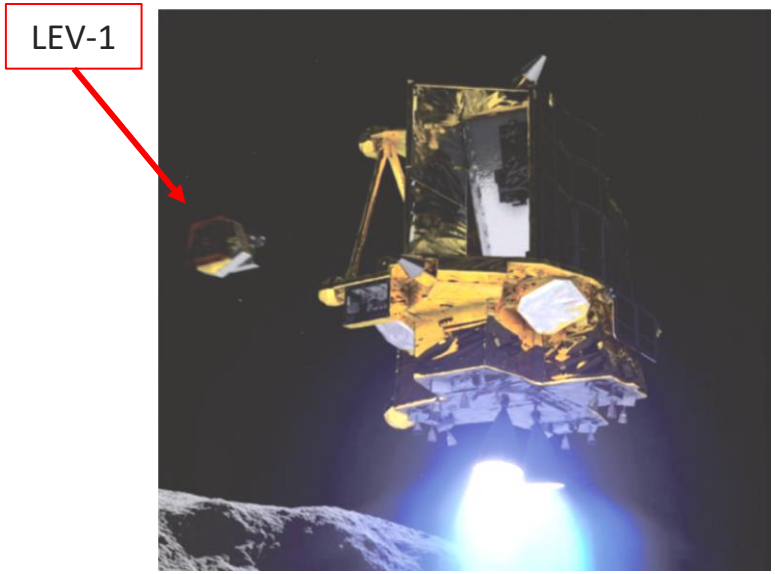
CG image created from the estimated landing position and attitude
Credit：JAXA / CG Production：Mitsubishi Electric Engineering Corporation

SLIM Story

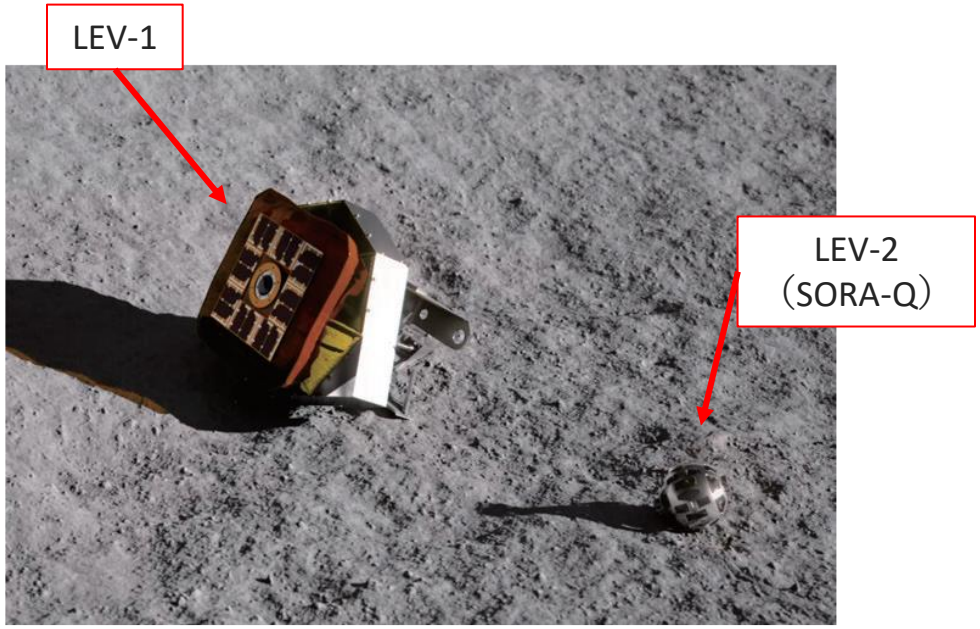

Landed 20 January 2024
This photo shows SLIM on the lunar surface taken by LEV -2 (SORA-Q), a small robot released from SLIM.
©JAXA/TOMY/Sony Group Corporation/Doshisha University

After landing on the Moon.

- Small probes LEV-1 and LEV-2 (SORA-Q) were separate from SLIM at an altitude of about 5m from the lunar surface.
- LEV-1 and LEV-2 (SORA-Q) worked fine, and as shown on the previous page, **LEV-2 took a picture of SLIM and sent it wirelessly to LEV-1, while LEV-1 sent the image directly to Earth. LEV-1 and LEV-2 operated autonomously on the lunar surface**.



Small probe ejection

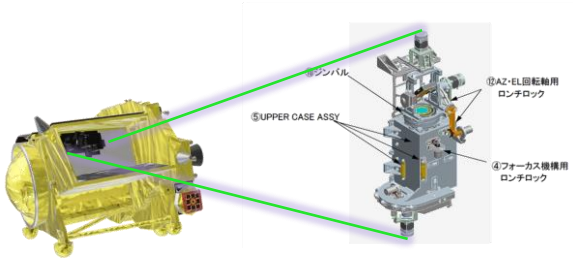


Small probes on Lunar surface

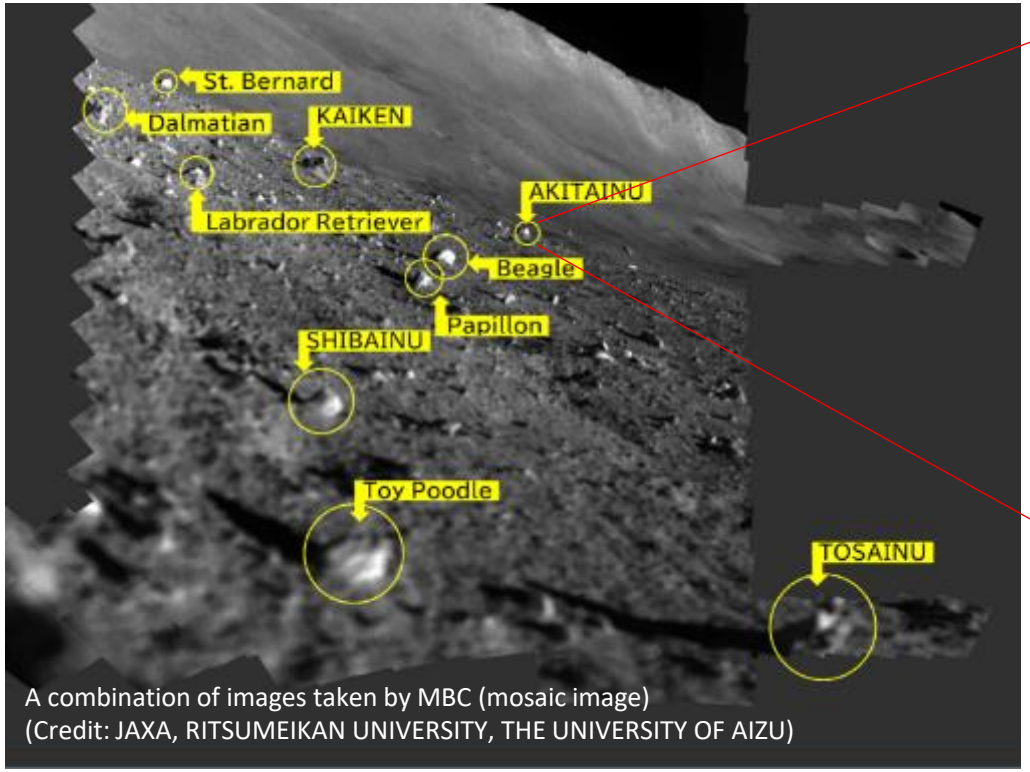
SLIM Story

After landing on the Moon.

- The **Multi-Band spectroscopic Camera (MBC) on SLIM successfully completed the planned 10-band spectroscopic observation** on the Moon.
- The MBC science team is sorting out rocks of interest, assigning **"dog breed"** nicknames to each of them.
- We will **estimate the chemical composition of the rock minerals, which will help probe the mysteries surrounding the origin of the Moon.**



MBC and its mounting position on SLIM



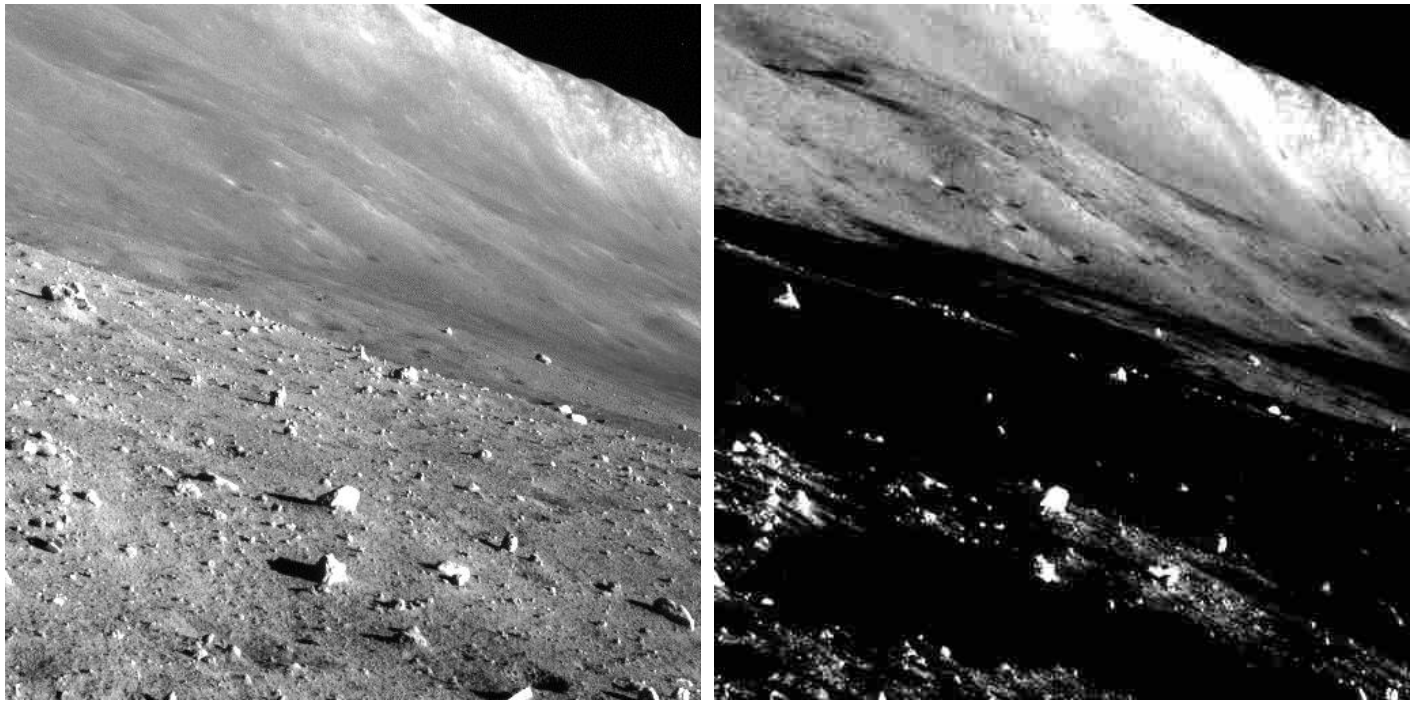
A combination of images taken by MBC (mosaic image)
(Credit: JAXA, RITSUMEIKAN UNIVERSITY, THE UNIVERSITY OF AIZU)

Detailed observation of "AKITAINU" (wavelength 1.65μm) in the near-infrared (Credit: JAXA, RITSUMEIKAN UNIVERSITY, THE UNIVERSITY OF AIZU)

SLIM Story

After landing on the Moon.

- On January 31, 2024, SLIM went into hibernation after sunset, and **on February 25, communication with SLIM was established again, and operation after surviving the lunar night was confirmed.**
- **Even more surprising, communication with SLIM was established again on March 28 , so SLIM resumed operations twice after spending the night on the Moon !!**

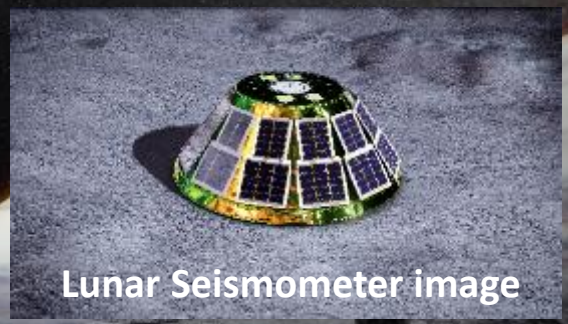


Images by the navigation camera on SLIM after the first night and before the second night began.
(Left) taken on February 25, 2024, shows a lunar afternoon. (Right) a view taken before sunset on February 29, 2024.

After SLIM, for the Future

JAXA/ISAS hopes to achieve the following,

- Application and development of "pin-point" landing technology utilizing the results of SLIM in the Artemis program.
- Contribution to the Artemis program by implementing the following "Science on the lunar surface",
  i. Astronomical observations from the lunar surface (Lunar Observatory),
  ii. Selection, collection, and analysis of lunar rock samples that provide important scientific insights,
  iii. Understanding of the lunar structure by the Lunar Seismometer Network.
- International cooperation through the Artemis program



Lunar Seismometer image

Lunar Observatory image

Appendix. SLIM Mission data

item	description
Name	SLIM (Smart Lander for Investigating Moon) ※ 1
Launch date and location	8:42:11 A.M. (JST) September 7, 2023 Yoshinobu Launch Complex at the JAXA Tanegashima Space Center※ 1
Launch vehicle	H-IIA Launch Vehicle No. 47 ※ 1
State (country) of registry	JAPAN ※ 2
Space object owner or operator	Japan Aerospace Exploration Agency (JAXA)※ 2
General nature of activities	- Demonstration of high-precision landing technology on the moon. - Realization of a lightweight lunar and planetary probe system to allow more frequent lunar and planetary exploration missions. ※ 1
Landing date	January 20, 2024 12:20 am (JST) ※ 3
Duration of activities	Continue activities on the lunar surface for a certain period of time until sunset.※ 2
Landing location(s) Mean earth/polar axis	Near the SHIORI crater in the Sea of Nectar 25.2degE/13.3degS ※ 2
Anticipated landing accuracy (meters/kilometers)	Accuracy around 100 meters ※ 2
Spacecraft mass at landing	About 200kg ※ 2
Item(s) being deployed	2 small probes (LEV-1, LEV-2) ※ 2
Activity/activities location(s), if different from landing(s)	N/A
Information related to scientific aspects or special considerations of activities	N/A
Plans for end of mission disposal	Pressure will be vent and transmitter will be off the air

Related links:
※1) https://www.isas.jaxa.jp/en/missions/spacecraft/current/slim.html
※2) https://global.jaxa.jp/countdown/slim/SLIM-mediakit-EN_2308.pdf
※3) https://global.jaxa.jp/press/2024/01/20240120-1_e.html

Image credit throughout this document is JAXA (unless otherwise stated)