SLIM Project

Press Kit

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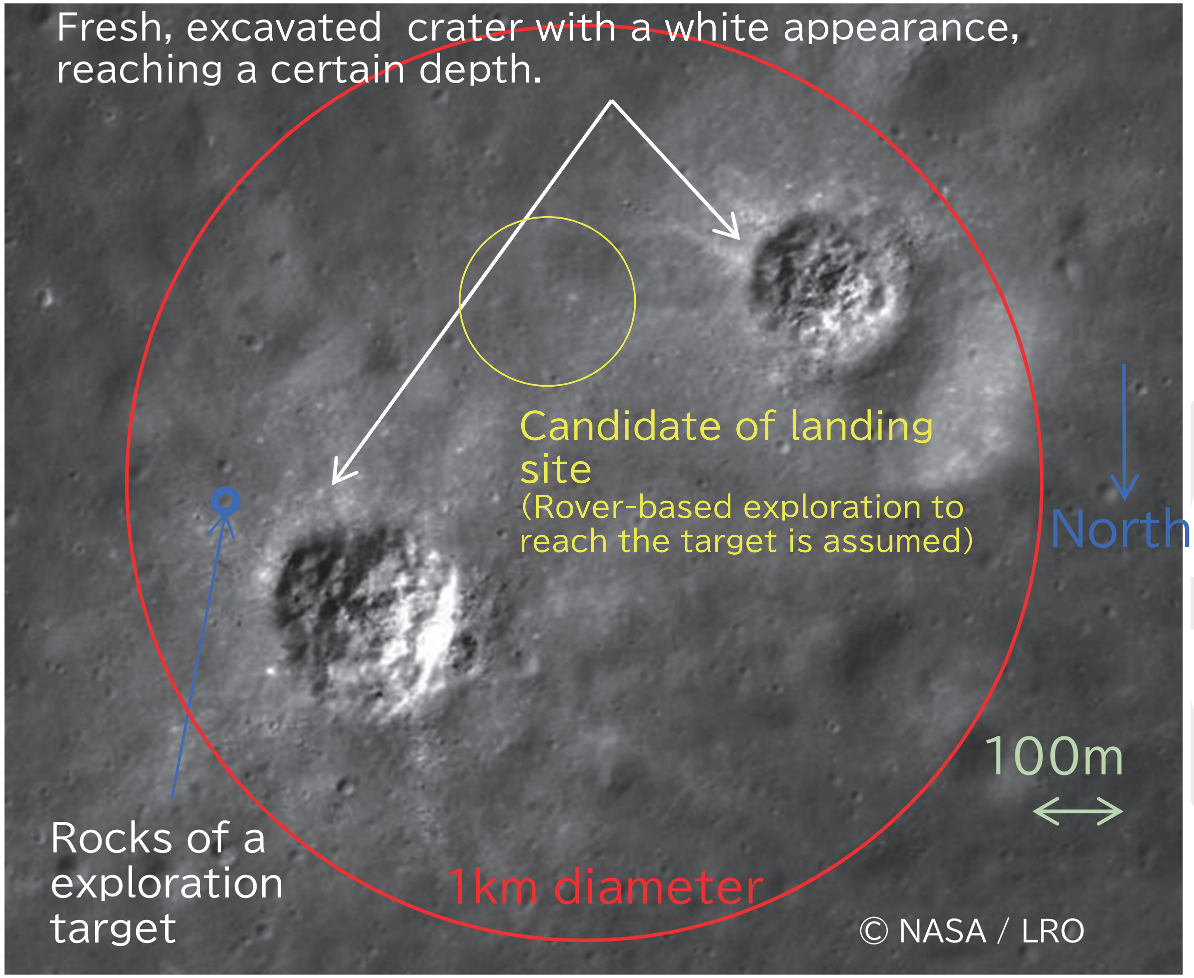
Importance of Pinpoint Landing

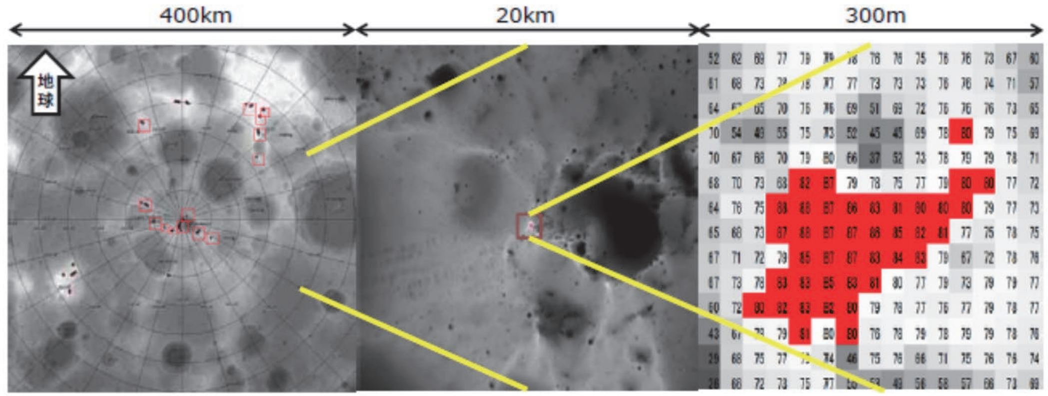


Candidate landing sites
(These are different from SLIM landing site)

As a result of the high-resolution lunar observation data brought in abundantly by the lunar orbiters "Kaguya" and "LRO," current lunar exploration missions involve discussions focused on individual rocks within specific images. In order to conduct such "in situ observations" for individual rocks, it is necessary to land the spacecraft precisely on a nearby flat terrain.

The left figure is an example of a landing point that is scientifically interesting. (Note that this is not the landing site for SLIM). While this example considers using a lunar rover to reach the exploration target, traversing steep slopes and rough terrain still poses a high difficulty level. Therefore, it is important to achieve pinpoint landing for effective exploration in the future.

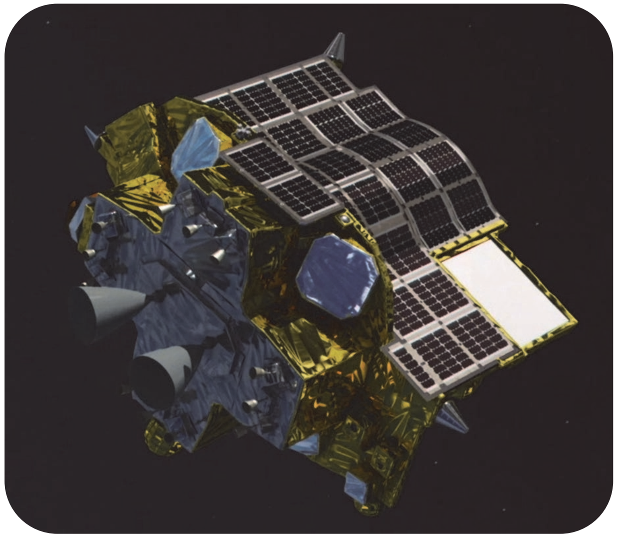
Importance of Pinpoint Landing



400km square area in the south pole region

Red squares show areas with 300 days of sunlight throughout the year.

Areas in the lunar polar regions with long periods of daylight



Lunar landing demonstration spacecraft: SLIM

Moreover, it is said that the favorable locations allowing sustainable water resource exploration in polar regions (such as areas highly exposed to sunlight), are limited to a very narrow area. On the other hand, there are no previous instances of pinpoint landing on celestial bodies with significant gravity such as the Moon.

This is why "SLIM" , a mission involving a small lunar lander to demonstrate pinpoint landing technology, is being carried out by ISAS/JAXA.

[Related Information]

- The landing accuracy of conventional lunar landers is several or sometimes a dozen kilometers.
- Hayabusa" and "Hayabusa2" achieved precise touchdown, but the dynamics are completely different since the gravity of asteroids is significantly lower than that of the moon and the earth. (Spacecraft can approach slowly and rise again if necessary.)

Mission Objectives of SLIM

SLIM (Smart Lander for Investigating Moon) is a JAXA project aiming to contribute to future lunar and planetary exploration by achieving the following two objectives.

Objective A Demonstration of high-precision landing technology on the moon

- Aimed landing accuracy of 100m compared to 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 core elements in most spacecrafts such as computers and power supply systems

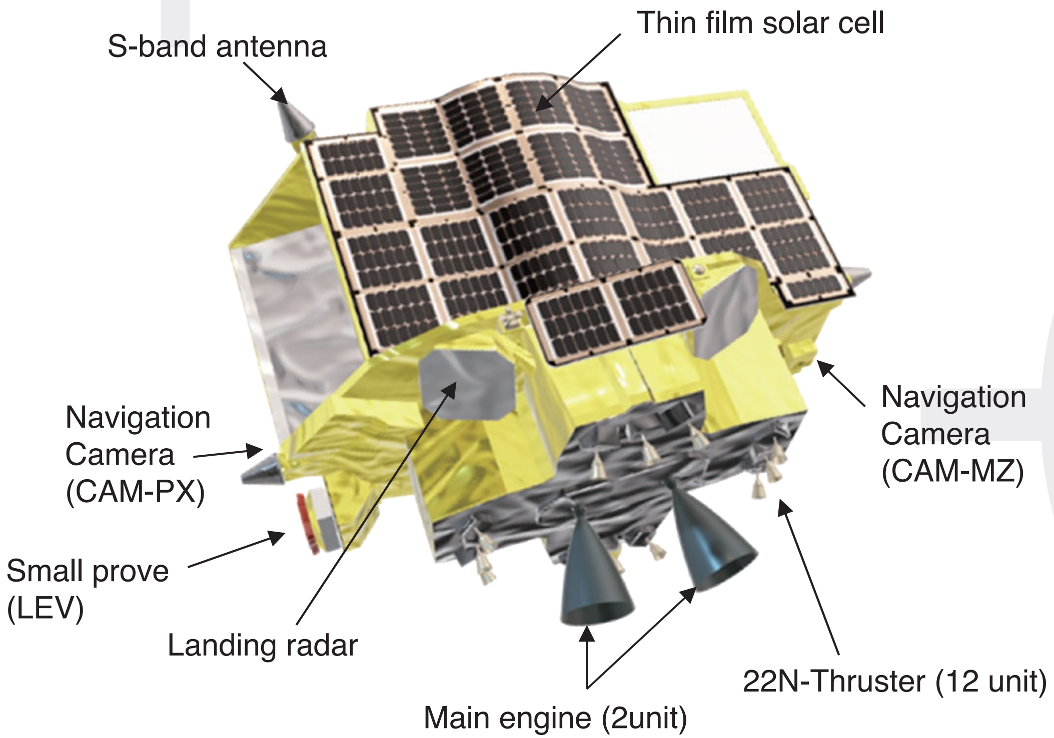
Success Criteria

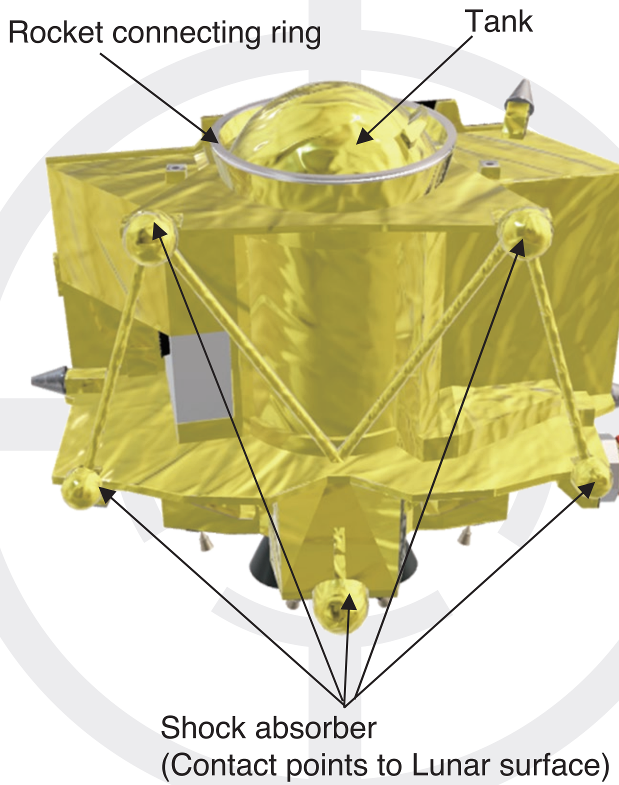
Success criteria of SLIM project are defined as follows.

Degree	Criteria
Minimum	Realize a soft landing on the Moon with a small and lightweight spacecraft. Accomplish the following two items. ● By conducting an actual lunar landing descent, verify the vision-based navigation, which is essential for high-precision landing ● Develop a lightweight spacecraft system and check its operation in orbit
Full	Achieve high-precision landing within 100m accuracy. The navigation system and the guidance rules operate normally, and the achievement of landing accuracy is confirmed by telemetry data after landing.
Extra	Continue activities on the lunar surface for a certain period of time until sunset. Carry out missions that operate on the lunar surface to obtain knowledge for lunar and planetary surface exploration in the future.

SLIM Configuration

- Mass：200kg（Dry）/ 700-730kg（Wet）
- Size: 2.4m x 1.7m x 2.7m





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

RCS 推進系

Propulsion system

22N Thruster (THR)

IHI AEROSPACE Co., Ltd.

A small-thrust bipropellant thruster with a thrust of 20 N. It consists of 12 units, and the combination of thrusters and various thrust patterns generates translational and rotational forces, assisting attitude control, orbit maneuvering, and precise landing.

Main Engine (OME)

Mitsubishi Heavy Industries, Ltd.
KYOCERA Corporation

A bi-propellant 500 N-class thruster used for orbital control and velocity regulation during lunar landing. It incorporates a domestically developed ceramic combustion chamber, enabling an unprecedented combination of "wide thrust range and pulse operation" not found elsewhere in the world. Its high performance also contributes to the overall mass reduction of the propulsion system.

Tank

Mitsubishi Heavy Industries, Ltd.
Chukoh Chemical Industries, Ltd.

This tank stores the propellant and oxidizer used in OME-THR. It is also used as the structure base of SLIM, making a significant contribution to the overall mass reduction. Additionally, a lightweight diaphragm made of newly developed PTFE is used on the oxidizer side.

Equipment for a Lightweight Spacecraft

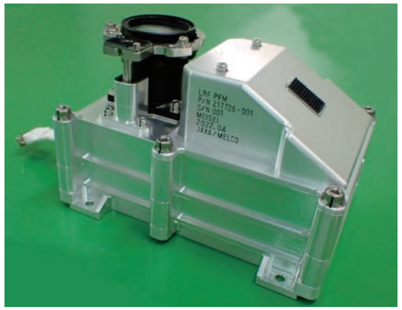
ISC 統合化制御系

Integrated spacecraft control system

Mitsubishi Electric Corporation
MITSUBISHI ELECTRIC
DEFENSE AND SPACE TECHNOLOGIES CORPORATION

Landing Radar

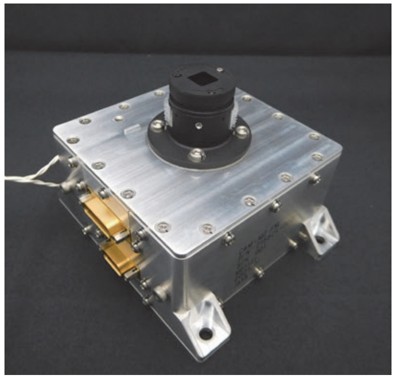
A sensor used to measure the altitude and velocity towards the lunar surface during the vertical descent phase. It emits microwave pulses toward the lunar surface and measures the round-trip time and Doppler frequency. It features multiple modes with different pulse widths and can be used in a range of several kilometers to tens of meters in altitude.



Mitsubishi Electric Corporation
MEISEI ELECTRIC CO., LTD.

Laser Range Finder(LRF)

An optical wave sensor used to measure the altitude above the lunar surface just before landing. It receives the modulated laser light reflected from the lunar surface and calculates the distance based on its phase. It is characterized by its compactness and lightweight qualities through functional distribution with SMU.



MEISEI ELECTRIC CO., LTD.

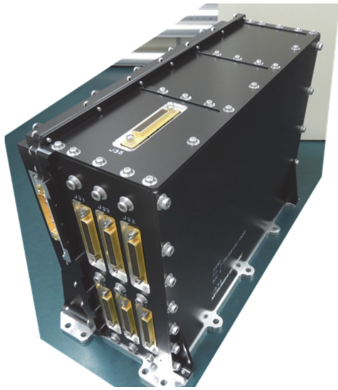
Navigation Camera (CAM)

A compact and lightweight camera used to image the lunar surface during the landing phase. It can simultaneously output uncompressed images for vision-based navigation and compressed images for downlinks. Two cameras are installed in different orientations and are used during the powered descent and vertical descent phases, respectively.

Equipment for a Lightweight Spacecraft

ISC 統合化制御系

Integrated spacecraft control system



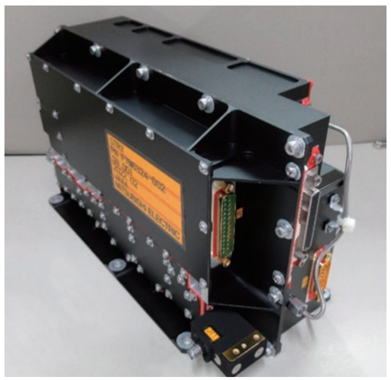
Mitsubishi Electric Corporation

Integrated computer (SMU)

An integrated computer that performs all computational functions to control SLIM. One of its distinctive features is that the calculations for both the data processing system and the navigation and guidance control system are handled by a single MPU within the SMU. Image processing for vision-based navigation is also performed on the FPGA within the SMU.

COM 通信系

Communication system



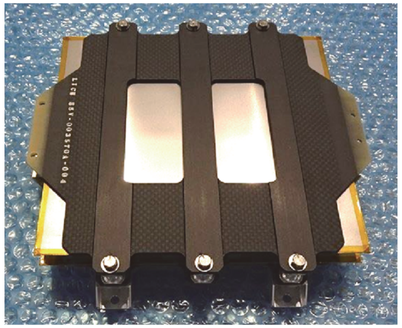
Mitsubishi Electric Corporation

S-Band Transponder(STRX)

This S-band transceiver is used to communicate with the ground station by SLIM. It incorporates advanced design features such as digitalization using FPGA and direct transmission signal output through high-speed D/A conversion, achieving a compact and lightweight design.

EPS 電源系

Electrical power system



The Furukawa Battery Co., Ltd.
Technosolver Corporation
SANKYO MANUFACTURING CO., LTD

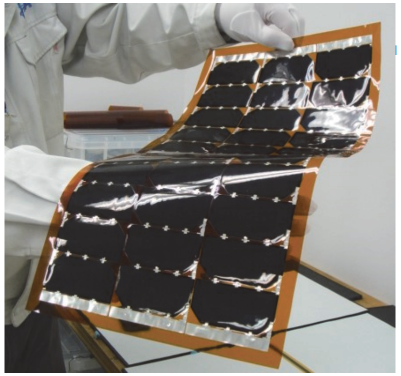
Lithium-Ion Cell Module (LICM)

To achieve miniaturization and lightweight design, SLIM utilizes SUS laminate battery cells with an outer casing made of SUS (Stainless Steel). Two sets of cells are securely bound by CFRP (Carbon Fiber Reinforced Plastic) plates to withstand vibrations, impacts during launch, and charging/ discharging in vacuum environment.

Mitsubishi Electric Corporation
MITSUBISHI ELECTRIC
DEFENSE AND SPACE TECHNOLOGIES CORPORATION

Integrated Power Control Unit (IPCU)

The IPCU is an innovative power control device that consolidates various functions including battery charging and discharging, regulation of solar power generation, power distribution, and control functions for thruster valve operation and heater control, which were previously handled by separate components. By implementing digital control for these operations, the IPCU achieves a significant enhancement in functionality and lightweight design compared to conventional analog control devices.



Sharp Corporation

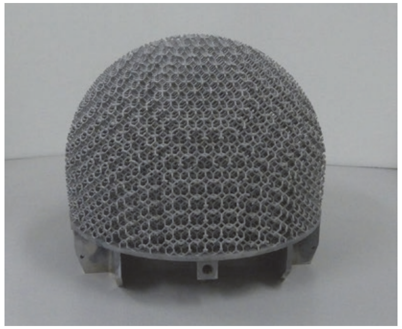
Thin Film Solar Cell

SLIM incorporates lightweight and highly efficient thin-film triple-junction solar cell sheets to achieve lightweight design. Leveraging their flexibility, they are installed on certain curved surfaces as well. In addition, for simplified processes, we have adopted an attachment method using Velcro.

Equipment for a Lightweight Spacecraft

ABS
衝撃吸収系

Shock-absorbing system



KOIWAI Co., Ltd.
JAMPT CORPORATION
Technosolver Corporation
ORBITAL ENGINEERING INC.

Shock Absorber (ABS)

SLIM is equipped with a mechanism to absorb the impact during landing at its five touchdown legs. The structure features an aluminum lattice pattern designed to absorb shocks efficiently with 3D printing technology.

PLD
月面活動系

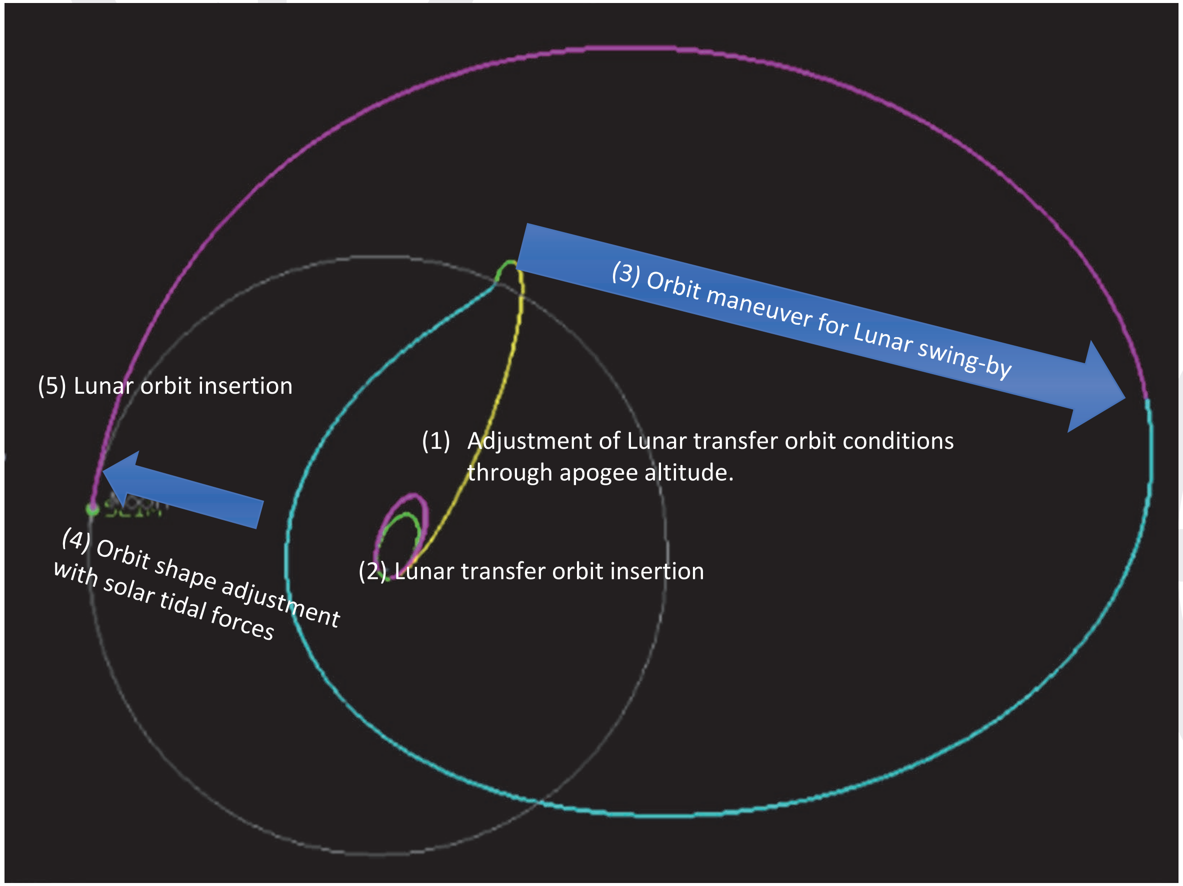
Payload mission system

MEISEI ELECTRIC CO., LTD. (MBC)

Multi-Band Camera (MBC)
Lunar excursion vehicle(LEV)
Laser Retro-reflector Array(LRA)

The Multi-Band Spectral Camera (MBC) is responsible for investigating the composition of the surrounding rocks after landing. By utilizing this instrument, we aim to obtain clues that could lead to unraveling the mysteries of Moon's formation. In addition, the SLIM mission also includes a small probe called the Lunar Exploration Vehicle (LEV), which separates from the main spacecraft just before landing and performs photo imaging. Furthermore, the mission incorporates a reflector (LRA) provided by NASA for precise measurement purposes.

Launch Vehicle and Orbit



The planned launch method is the "H-2A rideshare", where it will be launched simultaneously with the scientific satellite "X-Ray Imaging and Spectroscopy Mission(XRISM)" also currently under development by ISAS. The launch is scheduled for August 2023 or later.

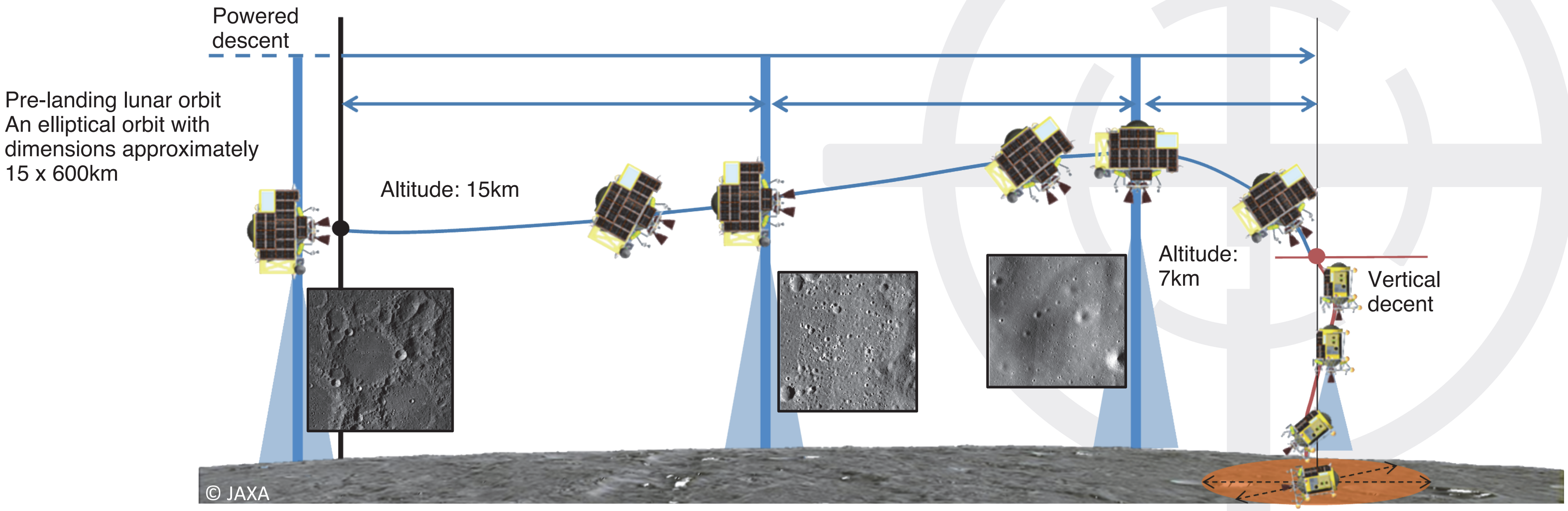
SLIM will use its own propulsion system to perform trajectory adjustments toward the Moon. Therefore, it adopts a trajectory design that minimizes propellant consumption. As a result, it will take several months to reach the Moon.

- Arrival in lunar orbit : 3 to 4 months after launch
- Lunar orbit : 1 month
- Landing descent : 4 to 6 months after launch

Landing Sequence

The landing sequence of SLIM will be conducted as follows:

1. Initiate the landing descent from lunar orbit and perform precise vision-based navigation to accurately estimate its own position. Utilizing navigation, guidance and control, it will approach the target location above the lunar surface.
2. From above the target location, precise measurements of altitude and terrain-relative velocity will be conducted using the landing radar, which will be integrated into the navigation and guidance system.
3. During the final approach, autonomous image-based obstacle detection and avoidance will be employed to ensure a safe landing, avoiding hazardous rocks and other obstacles.

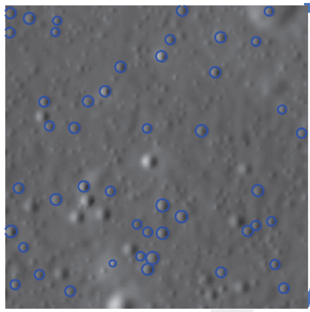


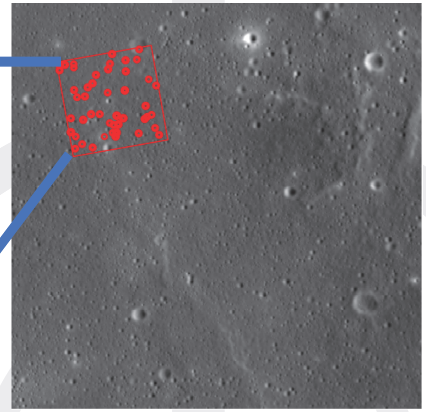
Landing sequence during powered descent

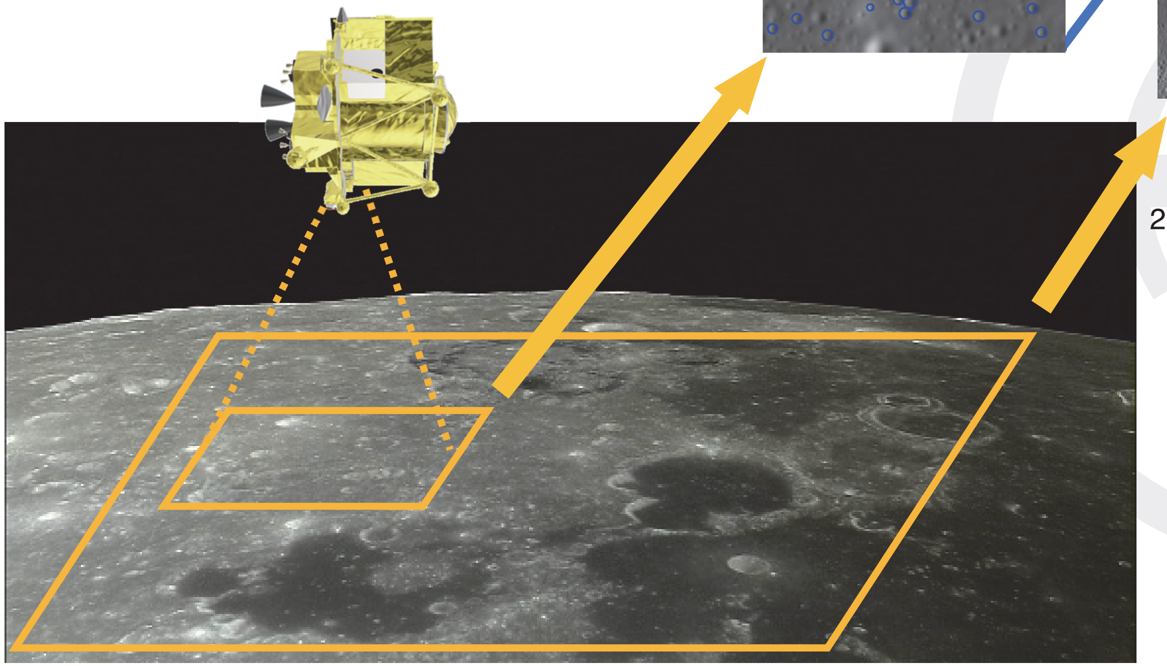
Vision-based Navigation

SLIM will achieve pinpoint landing by measuring and correcting its own position by "vision-based navigation."

1. Vision-based navigation system processes the captured images to identify "crater positions." (Creator identification)







2. From a broad map encompassing the spacecraft's location, the system identifies locations that match the crater patterns composed of multiple crater positions. (Crater Matching)

Vision-based Navigation

To achieve "vision-based navigation," processing time is a crucial factor. The current space-grade CPUs have only about 1/100th of the capability compared to those used on the ground. Therefore, we have developed image processing algorithms specifically designed for space-grade FPGAs, enabling vision-based navigation to be accomplished within a few seconds.

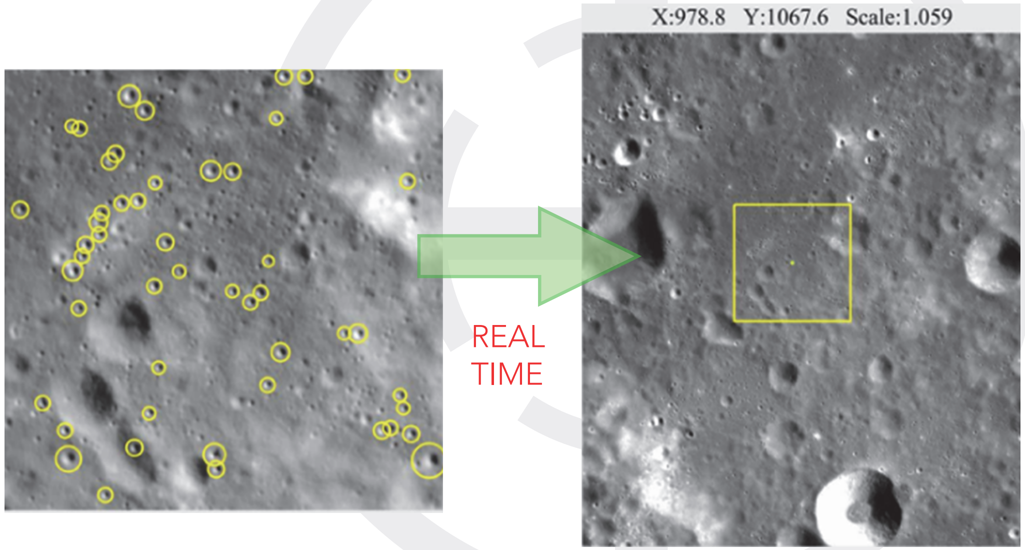
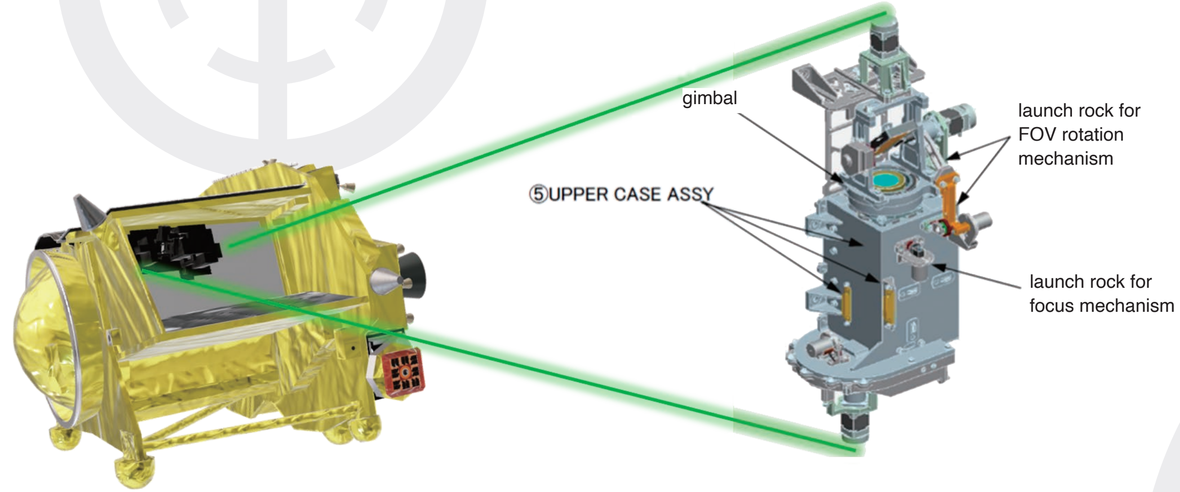


Image captured by handheld camera

Camera imaging position identified through "Vision- based navigation" system

ISAS/JAXA Exhibition demonstration (2018)

Mission on the Lunar Surface



Placement of MBC

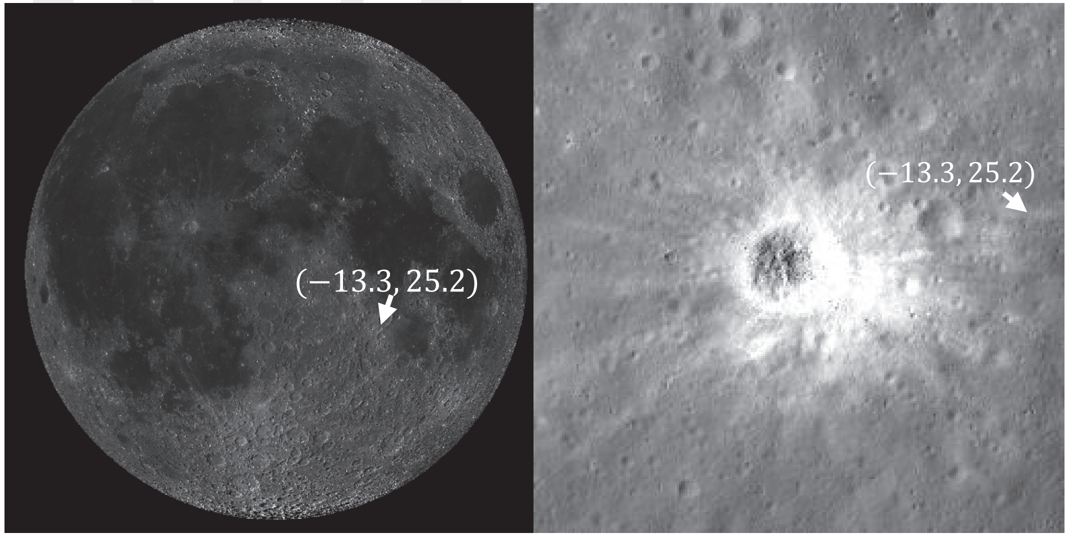
After a successful landing, our mission aims to unravel the origins of the Moon through composition analysis of rocks estimated to be derived from the lunar mantle using a “multi band spectral camera." To achieve this, it is essential to land in the vicinity of the targeted crater, enabling precise observations that can only be accomplished through pinpoint landing. This observation is included in one of the “extra success” criteria.

Small probe ejection (left) Small probes on Lunar surface (right)

Furthermore, SLIM is loaded with two probes equipped with the following features:

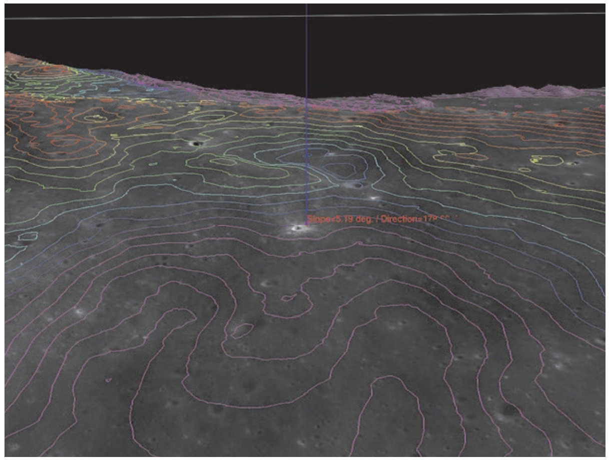
- Mission status monitoring after landing
- Imaging of the landing scene from an external perspective (still images)
- Independent communication system for direct communication with Earth

Landing Site



Source : NASA/LRO

SLIM landing site
(Left: Position on the Moon, Right: Expanded view)



The area, located in a low-altitude region known as the “Sea of Nectar”, have relatively constant slope of 15 degrees or less. (13.3degS/25.2degE)

As a suitable location for spectroscopic camera observations and for demonstrating landing technologies, we have selected a site neighboring the SHIOLI crater near the "Sea of Nectar" as the landing target site.

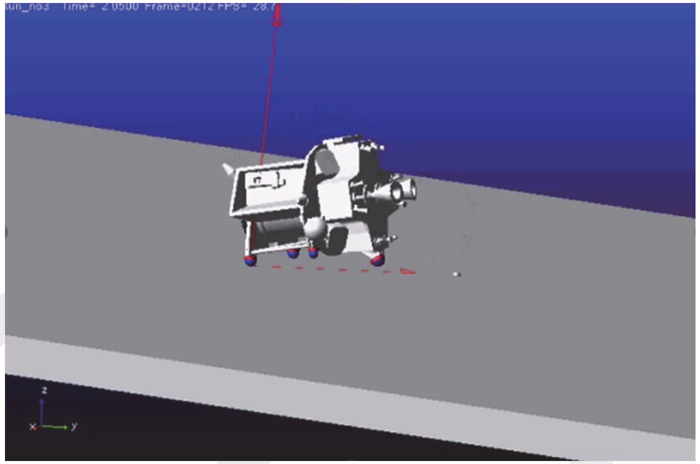
- Landing targets that can provide new insights through spectroscopic camera observations are limited to a very specific region on the lunar surface. Therefore, conducting such observations requires "pinpoint landing" capability to be in place.
- Consequently, landing on the “slopes” near the crater became necessary.

"Two-step Landing"

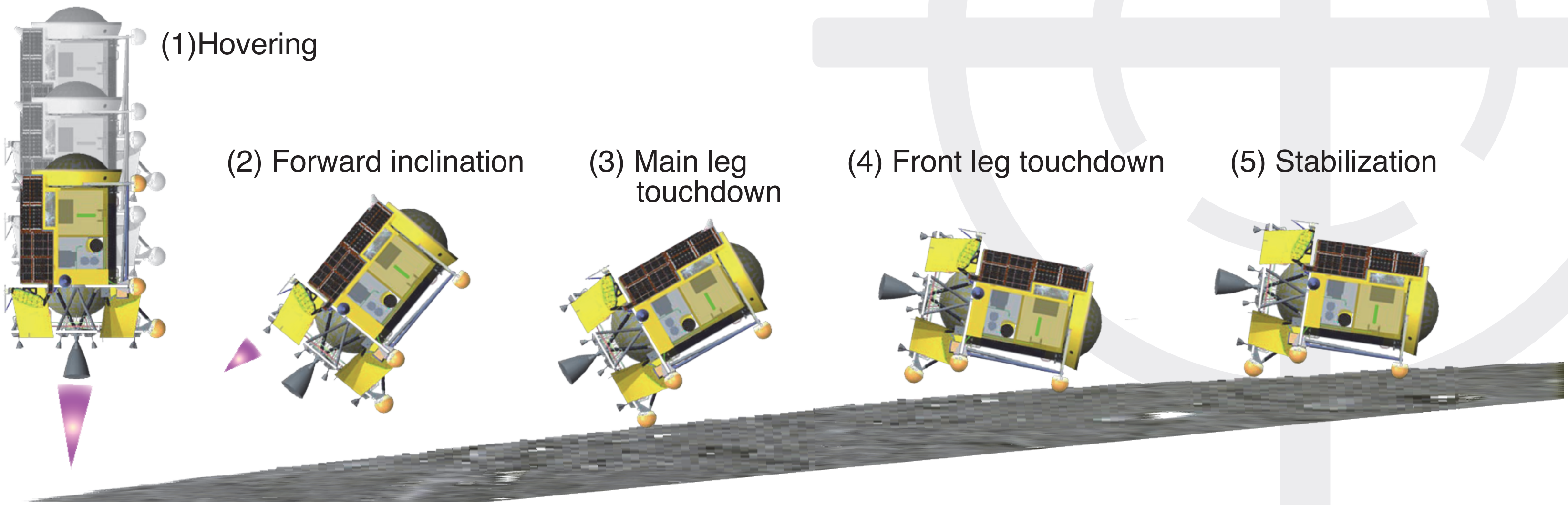
Because the landing site is located near a crater, the surrounding area is sloped to approximately 15 degrees. Therefore, the method of landing safely on such a slope becomes important.

As science and exploration objectives become more sophisticated, landing on such sloping area will be increasingly required in the future.

Especially for the case of a SLIM-scale spacecraft, the "two-step landing method", in which the main landing gear first touches the ground and then rotates forward to stabilize, has shown excellent reliable landing results through simulation.

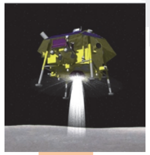


Landing simulation for SLIM



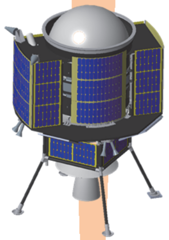
Development History of SLIM

The development history of the SLIM project can be summarized as follows. It originated from the SELENE-B project around the year 2003, and since then, it has been under continuous design study up to the present day.



2002 SELENE-B plan

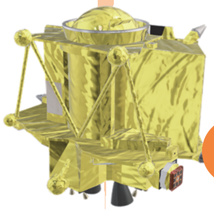
2012 SLIM Project Proposed



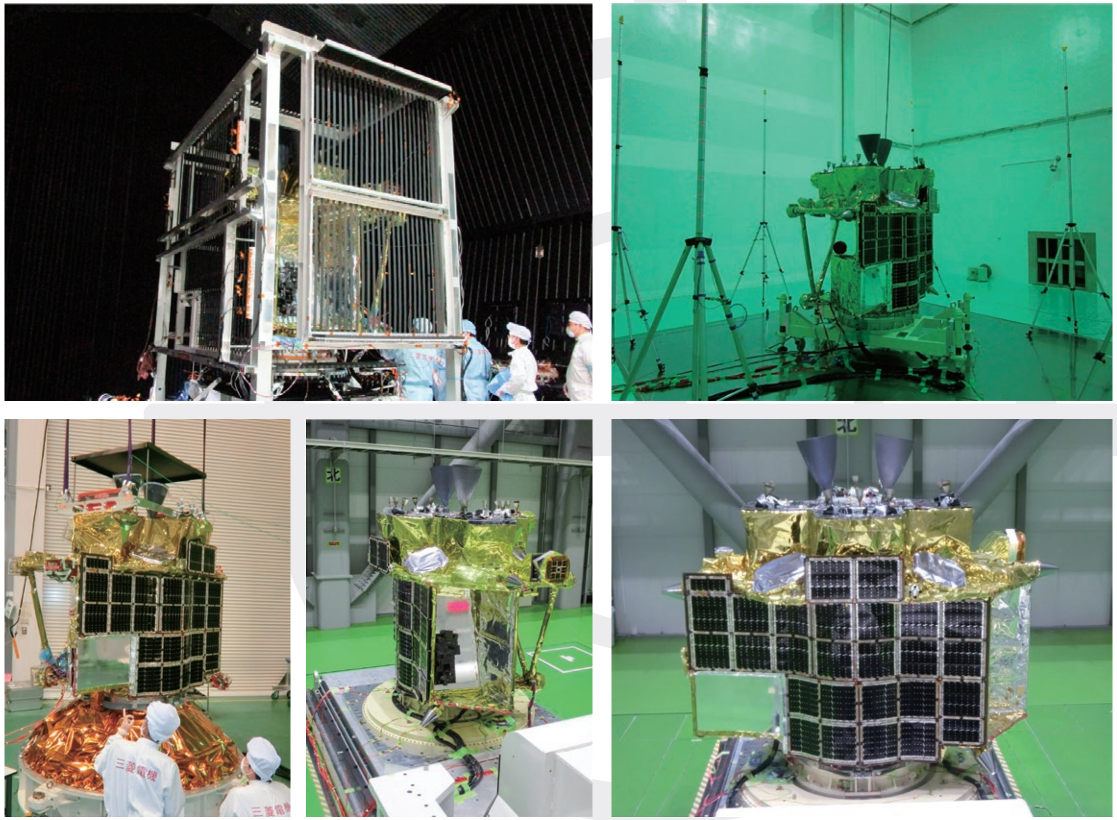
2016 System Definition Review
2016 Project Transition Review

2018 Preliminarily Design Review

2019 Critical Design Review

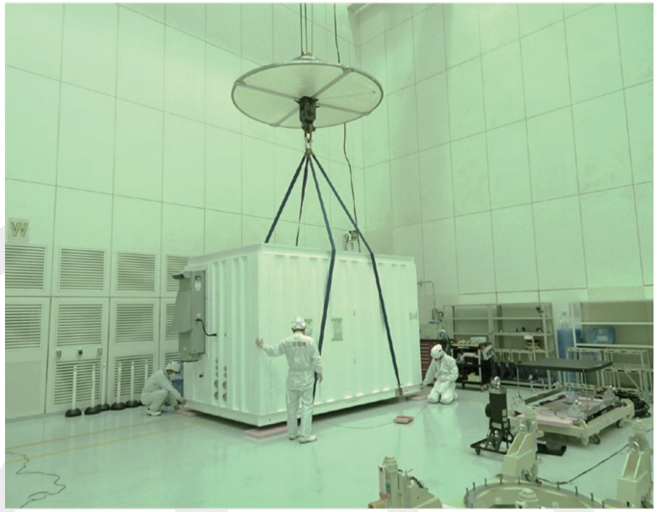


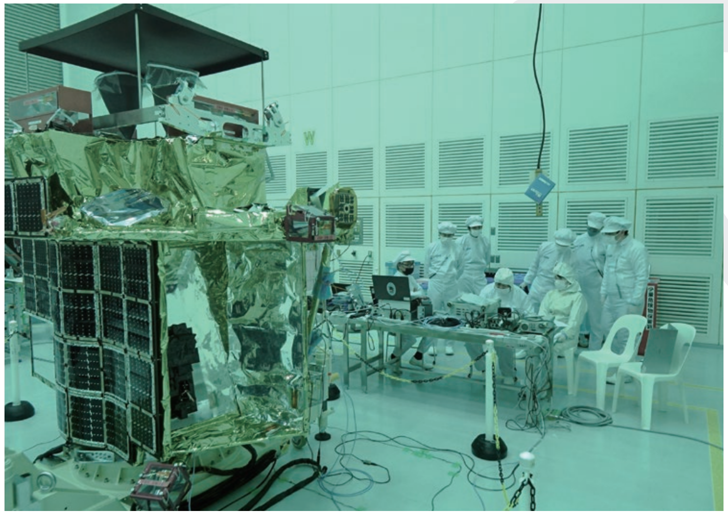
2023 Post Qualification-test Review



System test for flight model

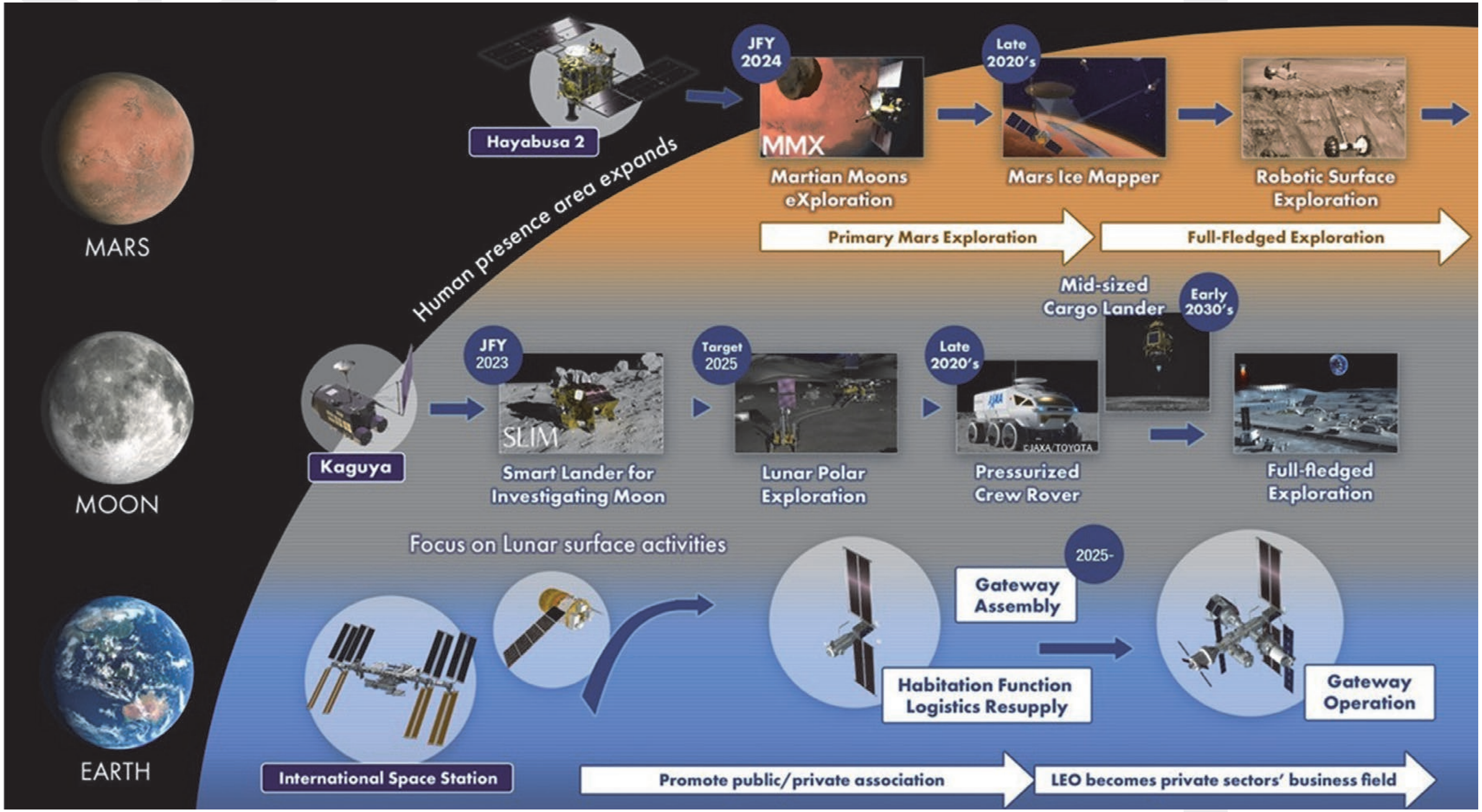
Pictures at the Launch Site





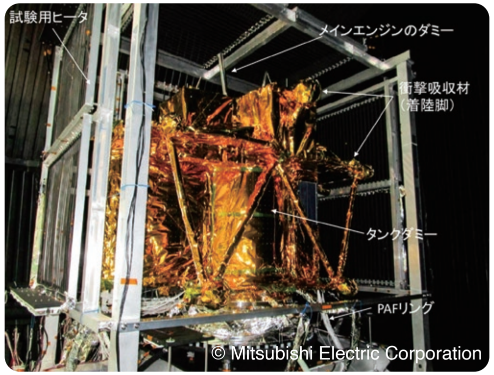
Role of SLIM in JAXA Exploration

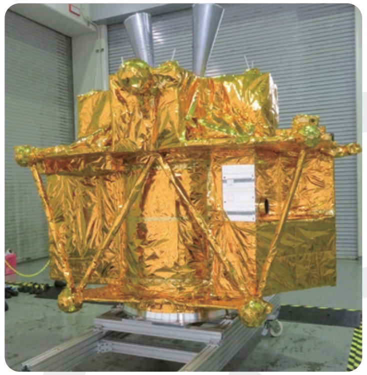
"SLIM" is a technology demonstrator, and the expertise gained in precision landing and other technologies will be inherited by future missions such as the Martian Moon eXploration (MMX) and lunar polar missions.



Reference Information

We have refurbished the models (MTM, TTM) used for thermal vacuum and mechanical environmental testing and put them on display at the Sagamihara Campus!





SLIM Project website

https://www.isas.jaxa.jp/home/slim/SLIM/index.html

SLIM on Twitter

@SLIM_JAXA

Related organizations

JAXA, and numerous universities and institutions, have been actively engaged in researching and developing various technologies to achieve the SLIM mission.

＊ Arrangement in no particular order

Abbreviations

略称	名称（英語）	名称（日本語）
AANT	RAV Altimeter ANTenna	着陸レーダ高度測定用アンテナ
ADM	Apolune Descending Maneuver	遠月点降下マヌーバ
BAT	BATtery	バッテリ（二次電池セルモジュール）
CAM	navigation CAMera	航法カメラ
COM	COMmunication system	通信系
CSS	Coarse Sun Sensor	粗太陽センサ
DSN	Deep Space Network	深宇宙用追跡ネットワーク
EPS	Electrical Power System	電源系
FLT	FiLTer	フィルタ
GFD	Gas Fill and Drain valve	ガス系注排弁
GN	Ground Network	追跡ネットワーク
IMU	Inertial Messurement Unit	慣性基準装置
INT	INTegration hardware	計装系
IPCU	Integrated Power Control Unit	電力制御分配器
ISC	Integrated Spacecraft Control system	統合化制御系
LEV	Lunar Excursion Vehicle	小型プローブ
LOI	Lunar Orbit Insertion	月周回軌道投入
LRA	Laser Retro-reflector Array	リフレクタ（NASA JPL）
LRF	Laser Range Finder	レーザレンジファインダ
LRO	Lunar Reconnaissance Orbiter	ルナー・リコネサンス・オービター
MBC	Multi-Band Camera	分光カメラ
NPV	Non-Pyro valve	ノンパイロ弁
OME	Orbit Maneuvering Engine	メインスラスタ
PAM	Period Adjustment Maneuver	周期調整マヌーバ
PD	Powered Descent	動力降下
PDM	Perilune Descending Maneuver	近月点降下マヌーバ
PFD	Propellant Fill and Drain valve	液系注排弁

略称	名称（英語）	名称（日本語）
PLD	PayLoaD mission system	月面活動系
PT	Pressure Transducer	圧力センサ
RAV	Radio Altimeter and Velocity meter	着陸レーダ
RCS	Reaction Control System	推進系
REU	Rav Electorical Unit	着陸レーダ電気ユニット
SABS	Shock ABSorber	衝撃吸収材
SANT	S-band ANTenna	S バンドアンテナ
SAP	Solar Array Panel	太陽電池パネル（薄膜太陽電池シート）
SDIP	S-band DIPlexer	S バンドダイプレクサ
SHYB	S-band HYBrid	S バンドハイブリッド
SLIM	Smart Lander for Investigating Moon	小型月着陸実証機 SLIM
SMU	System Management Unit	統合化計算機
SSW	S-band SWitch	S バンドスイッチ
STR	STRucture system	構造系
STRX	S-band TRansponder	S バンドトランスポンダ
STT	STar Tracker	スタートラッカ
SWB	lunar SWing-By	月スイングバイ
TCS	Thermal Control System	熱制御系
THR	THRuster	補助スラスタ
TLI	Trans-Lunar Injection	月遷移軌道投入
TNK	fuel TaNK	推進薬タンク
TOR	Trim ORifice	トリムオリフィス
UDSC	Usuda Deep Space Center	臼田局
USC	Uchinoura Space Center	内之浦局
VANT	RAV Velocity meter ANTenna	着陸レーダ速度測定用アンテナ
XRISM	X-Ray Imaging and Spectroscopy Mission	X 線分光撮像衛星


From the era of "Landing where we can"
to "Landing where we want."
Just a little more until launch!
Smart Lander for Investigating Moon
SLIM
LEV SORA-Q