SMBC × HAKUTO-R

VENTURE MOON

Mission 2 “SMBC x HAKUTO-R VENTURE MOON”

技術要因分析の報告会

Technical Cause Analysis



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June 6, 2025

Preliminary report

The following anomaly/event was observed

- The lander's attitude was confirmed to be nearly vertical
- A delay in obtaining valid measurements from the Laser Range Finder (LRF)
- The lander was not able to decelerate to the velocity required for lunar landing
- Thereafter, telemetry was lost

Result

- Assumed the lander likely performed a hard landing on the lunar surface
- Determined the completion of Success 9 was not achievable and to conclude the mission

June 24, 2025

Technical Cause Analysis

Technical Cause Analysis

- In-depth analysis of the event based on telemetry data
- ★ The technical cause was identified as a **"hardware anomaly in LRF"**
- ★ **Potential causes considered highly likely** to have led to the anomaly were identified and countermeasures examined
- ★ Assessed the potential **impact on subsequent missions**

Additional information

- Image captured by NASA LRO has been published
- The communication loss point was confirmed to be approx. 282m south and approx. 236m west of the targeted landing site

Going Forward

Implications for subsequent missions

Next action

- Following a review of the testing plans, the highly probable causes of the anomaly will be **verified and addressed through the development of subsequent missions**
- **An External Review Task Force** will be established to examine development measures for subsequent missions
- In preparation for subsequent missions, further technical improvements and organizational enhancements are being considered and implemented with the support and advice of third parties, including JAXA

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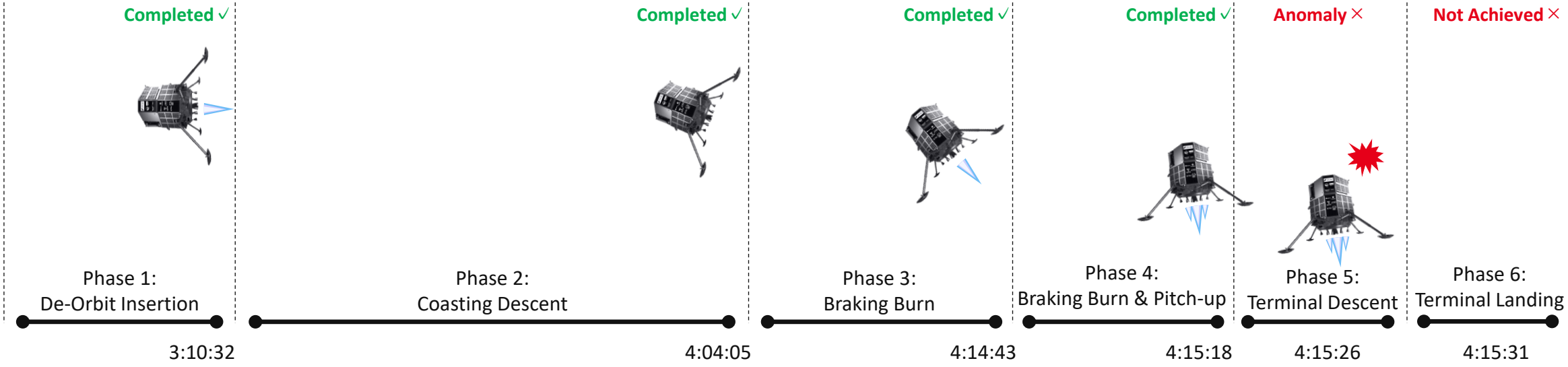
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Mission 2
Technical Cause Analysis

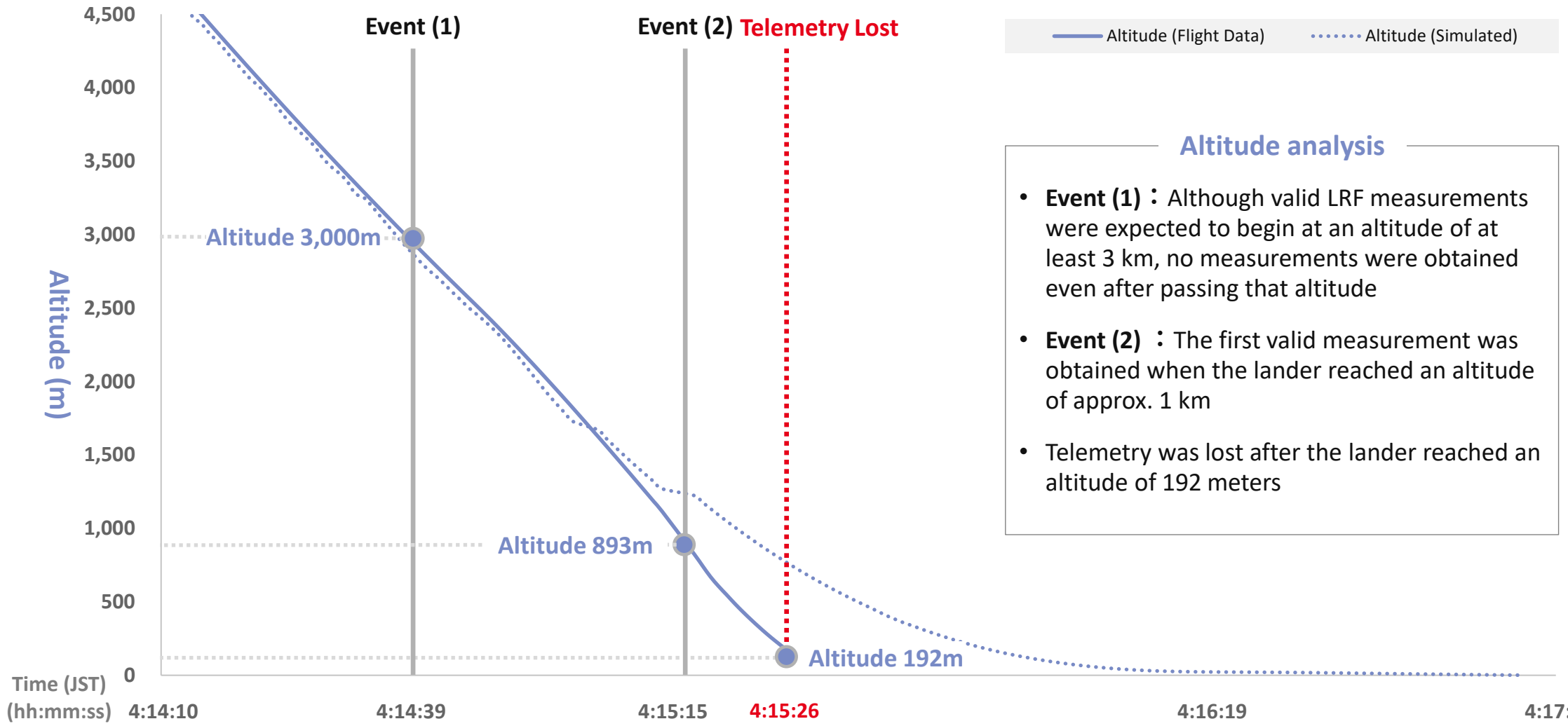
SMBC × HAKUTO-R
VENTURE MOON

Although the lander completed Phase 4 of the landing sequence and continued its Terminal Descent while maintaining a vertical attitude, an anomalous loss of telemetry occurred approx. two minutes before the scheduled landing time.

Phase 1 2025/6/6 3:10:32 (JST)	**Completed ✓**	The De-Orbit maneuver was executed, and the landing sequence toward the targeted landing site was initiated
Phase 2 2025/6/6 4:04:05 (JST)	**Completed ✓**	The coasting descent was completed
Phase 3 2025/6/6 4:14:43 (JST)	**Completed ✓**	Braking Burn phase was completed DGNC mode entered TERMINAL APPROACH Altitude: Approx. 2.8km. Vertical velocity: Approx. 63m/s
Phase 4 2025/6/6 4:15:18 (JST)	**Completed ✓**	Braking Burn and Pitch-up were completed
Phase 5 2025/6/6 4:15:26 (JST)	**Anomaly ×**	Telemetry was lost during Terminal Descent. Altitude: Approx. 192m. Vertical velocity: Approx. 42m/s
Phase 6 2025/6/6 4:15:31 (JST)	**Not Achieved ×**	The estimated time at which hard landing occurred. Terminal Landing phase was not achieved



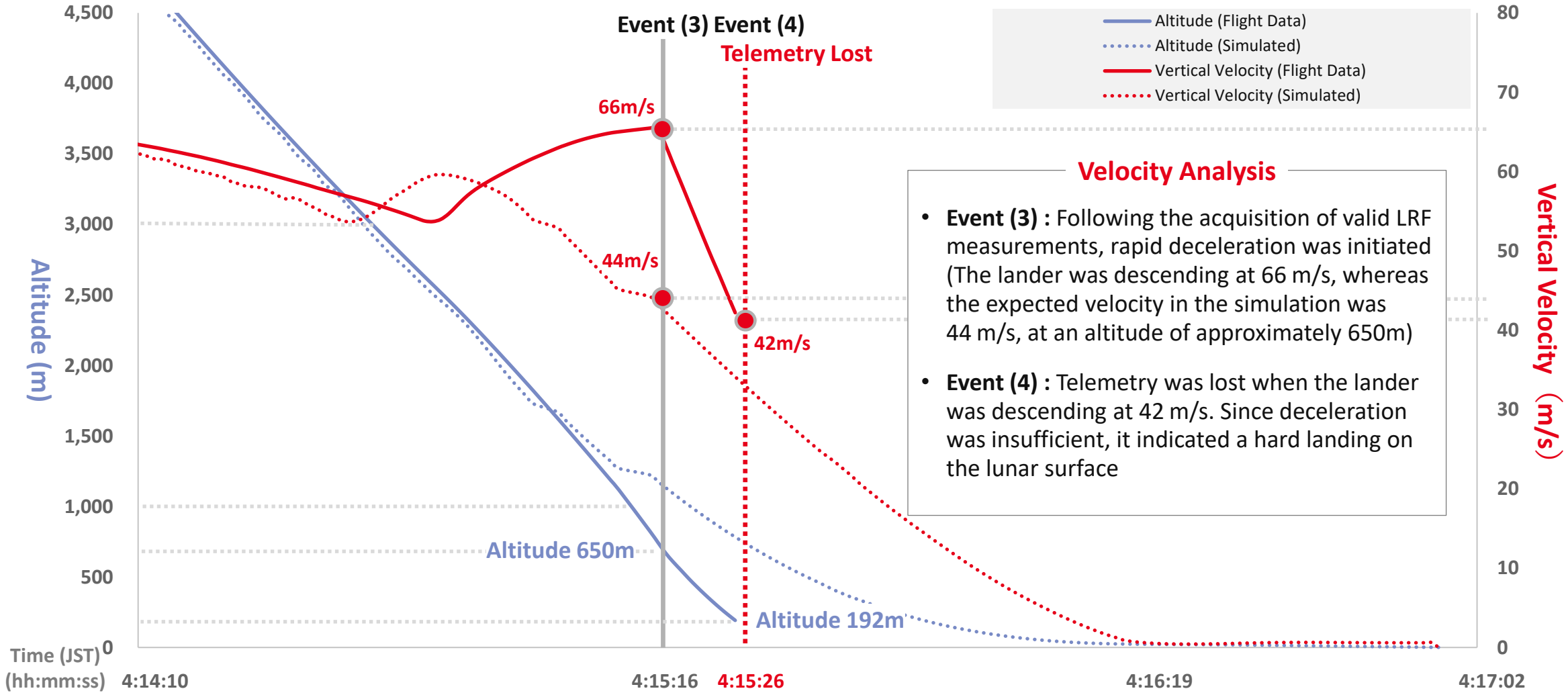
While the LRF was expected to activate at an altitude of at least 3 km above the lunar surface, no valid measurements were observed until the lander reached approx. 1 km



Altitude analysis

- **Event (1)**：Although valid LRF measurements were expected to begin at an altitude of at least 3 km, no measurements were obtained even after passing that altitude
- **Event (2)**：The first valid measurement was obtained when the lander reached an altitude of approx. 1 km
- Telemetry was lost after the lander reached an altitude of 192 meters

Rapid deceleration was initiated following the acquisitions of valid LRF measurements. However, the lander was unable to decelerate sufficiently to reach the required velocity for a nominal lunar landing



Velocity Analysis

- **Event (3) :** Following the acquisition of valid LRF measurements, rapid deceleration was initiated (The lander was descending at 66 m/s, whereas the expected velocity in the simulation was 44 m/s, at an altitude of approximately 650m)
- **Event (4) :** Telemetry was lost when the lander was descending at 42 m/s. Since deceleration was insufficient, it indicated a hard landing on the lunar surface

NASA*1 LRO*2 images confirmed topographical changes (a crater of approx. 16m in diameter) near the targeted landing site



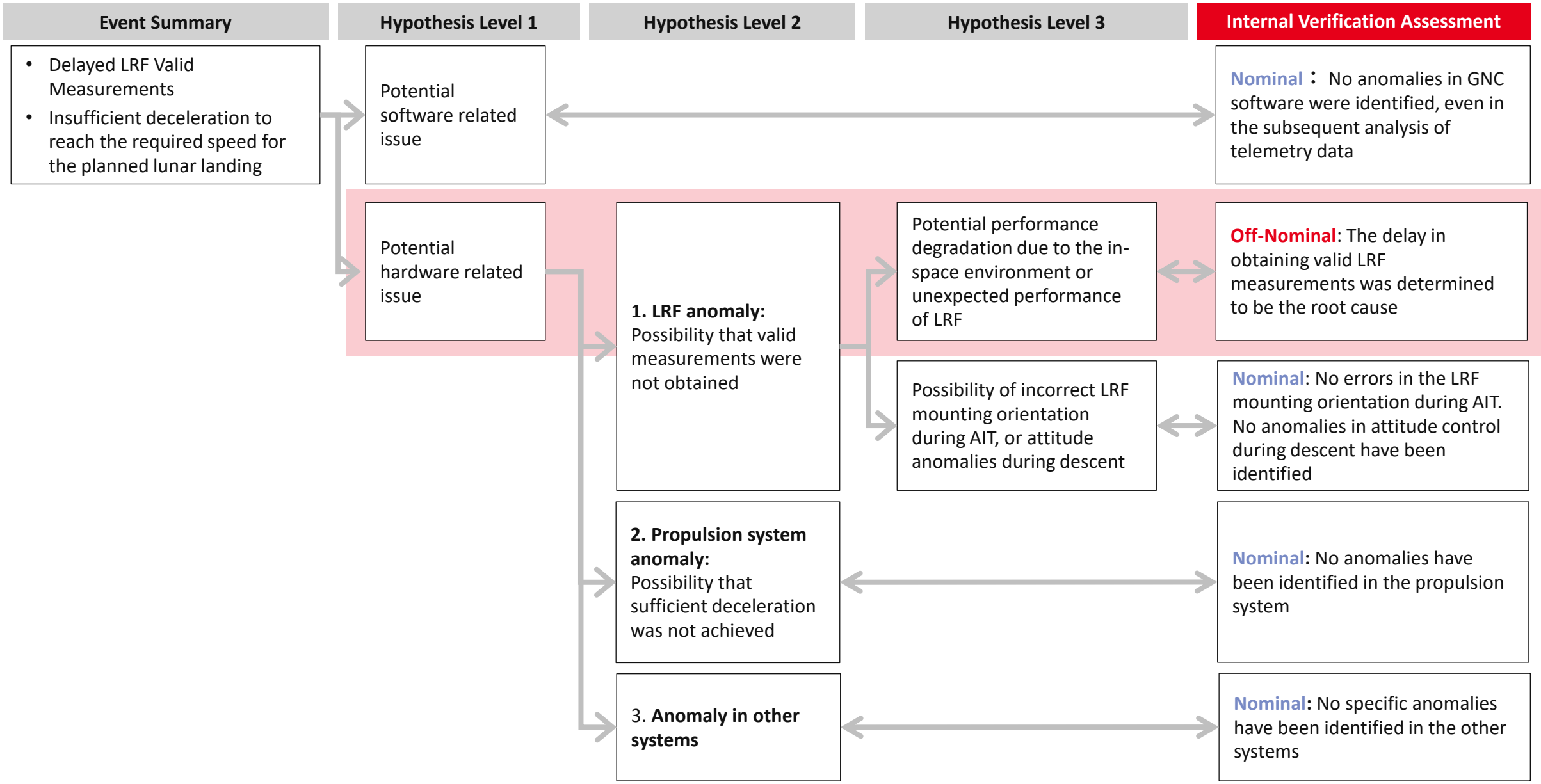


Orbit Data Analysis

- The lander hard landed at a location near 60.44N, 4.6W
- A new terrain feature, a crater approximately 16m in diameter, was identified
- Location of the feature is approx. 282m south and approx. 236m east of the targeted landing site

*1 NASA: National Aeronautics and Space Administration
*2 LRO: Lunar Lunar Reconnaissance Orbiter

The technical cause was identified as a “LRF hardware anomaly” using the following verification process



Four possible factors of a “LRF hardware anomaly” occurrence

Possible Factor	Detailed Possible Factor	Our Assessment	
Unexpected performance of LRF during the descent phase	Lunar surface reflection was lower than expected	• Although the albedo (lunar surface reflection) characteristics of the landing site were within the expected range based on prior analysis, the possibility cannot be ruled out that the actual regolith exhibited unexpected properties	**Likely** to be a Direct Cause
		• The possibility cannot be ruled out that the relatively shallow laser incidence angle compared to M1 contributed to the reduced reflectivity • The possibility cannot be ruled out that the lower laser power, compared to that used in M1, contributed to the reduced reflectivity	**Likely** to be a Direct Cause
	High speed during the descent caused poor performance	• The possibility cannot be ruled out that performance at higher speeds may have been lower than expected, based on the prior field test results	**Likely** to be a Direct Cause
	Vibration during the descent caused poor performance	• The valid measurements were still obtained during the terminal descent phase under altitude of 1km	**Unlikely** to be a Direct Cause
Hardware failure or performance degradation of LRF during the flight	Degradation by space environment (radiation, temperature, vacuum conditions etc.)	• The thermal vacuum and thermal cycle test showed no performance degradation • While radiation testing confirmed performance degradation under extreme exposure, such conditions are unlikely in a lunar mission. However, the possibility cannot be entirely ruled out	**Likely** to be a Direct Cause
	Degradation by other external factors (contamination, launch vibration etc.)	• No performance degradation was observed in prior thermal vacuum testing • Both LRFs reported consistent measurement results • The PR camera operated without any issues	**Unlikely** to be a Direct Cause

Based on multiple static and dynamic tests, and the LRF supplier's specifications, a 3 km altitude was set for the DGNC design as the worst-case maximum measurement range

Albedo Condition		Static Conditions	Dynamic Degration
Nominal Case: 0.1~0.3 (The pre-estimated albedo value of the landing site was 0.2)	Supplier Info	• **Supplier's Specification:** Maximum measurable distance up to 14km	• **Supplier's Test:** Confirmed no degradation reported at an altitude of 1.5km with 320km/hr (88.8m/s)*1 • **Degration during higher speed:** According to the supplier, performance may **degrade by up to 30%** under dynamic conditions compared to static performance, as a worst-case estimate
	ispace	• **Field Test (Mt. Takao / Tokyo Bay) :** Confirmed maximum measured distance of approx. **7.5km**	Full-scale testing using aircraft and other methods was considered, but ultimately not conducted due to feasibility concerns. Alternative tests were performed instead
Sub-Nominal Case: 0.05~0.1	ispace	• **Field Test (Hachioji) :** Confirmed maximum measured distance of approx. 4.5km • **Field Tests (Mt. Fuji / Mt. Houei) :** Confirmed maximum measured distance of approx. 3.0km	• **Field Test (Shirosato Test Center) :** Confirmed no degradation reported at an altitude of 1.5km with 200km/h (55.5m/s) • **Field Tests (Mt. Fuji / Mt. Houei) :** The test was not conducted due to inadequate site conditions and unfavorable weather

Dynamic Condition
Altitude: 3-10km with 250-720km/h (70-200m/s)

Dynamic Degration:
60% reduction (x40%), set more conservatively compared to supplier's info

×

Static Conditions:
7.5km, Confirmed by ispace's field test

=

3km

*1 Testing beyond 1.5 km was not feasible due to operational constraints.

While the cause of the soft-landing failure in Mission 1 was software, the cause of the failure in Mission 2 was hardware. Although both involved the same aspect of altitude measurement, the causes were different

Category	Mission 1	Mission 2
Cause location	Software (Landing and descent algorithm)	Hardware (LRF)
Cause	• Incorrect estimation of the altitude due to the terrain	• Delay of valid LRF measurements • Insufficient deceleration due to the delay
Factor	• The consideration of the terrain constraint along the landing approach path was missing • Insufficient consideration of the effect of the terrain in the software validation and verification	• LRF performance (the possibilities of having being degraded by in-flight environment or/and operational condition) • Insufficient consideration, awareness, validation of the LRF performance under the dynamic conditions • Effect of uncertain factors such as the lunar surface albedo
Result (Vehicle behavior)	• Continued unexpected hovering at the altitude of 5km for the terminal landing • Resulted in the excessive propellant usage, free-fall from the 5km altitude	• Continued full-throttle braking from the altitude of about 1km with higher velocity (than designed) • Resulted in hard landing due to the shortage of the deceleration distance • The terminal speed (at the contact with the surface) was estimated as 50-72km/h
Evaluation of the lessons from the previous mission	N/A	• No terrain interference to the final approach performance • The correct altitude estimation was kept with the good accuracy • The algorithm modifications functioned properly

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The impact and implications for subsequent missions

Based on the technical cause analysis of Mission 2, the following two corrective actions are planned

Corrective Action 1

Enhancement of verification strategy and plan for landing sensors, including LRF

- Incorporating external expertise, the current field-testing plan for the LRF will be reviewed and the verification methodology under high-speed and low-albedo conditions will be enhanced through comparisons with previous cases
- For landing sensors other than the LRF, the verification plans will be re-evaluated and improved using external expertise and lessons from prior cases
- Based on the results of the re-testing of the LRF used in Mission 2, the verification plan for the LRF to be used in Missions 3 and 4 will be improved

Corrective Action 2

Improvement of the selection, configuration, and operation of landing sensors, including LRF

- The selection criteria for landing sensors, including LRF, will be improved by actively incorporating external expertise, including consideration of space-proven technology, to enable the procurement of more reliable sensors
- While new landing sensors—such as vision-based navigation cameras and LiDAR*1—will be introduced starting with Missions 3 and 4, the sensor configuration and operational approach will be re-evaluated to ensure a more robust and reliable landing

*1 LiDAR: An abbreviation for "Light Detection and Ranging," LIDAR is a radar-like system that uses laser light to measure distance.

The following broader enhancement measures will be implemented in the development of subsequent missions

Establishment of an “External Review Task Force” including third-party experts

- Based on the technical validation conducted to date, an external review task force including third-party experts will be established to examine development measures for subsequent missions
- Candidate selection is underway, focusing primarily on current and former personnel from space agencies such as JAXA and NASA

Expansion of technical support from the Japan Aerospace Exploration Agency (JAXA)

- While third-party advice has been incorporated as needed to date, greater involvement from JAXA is planned, with the aim of further enhancing technical capabilities during the development phase
- An MoU has been signed with JAXA. Technical collaboration for the development of the Mission 4 lander has already begun through ongoing discussions since 2025
- The probability of a future successful landing is expected to increase, based on technical support and contribution of landing technology know-how, obtained by JAXA through their SLIM mission

Although certain financial impact is anticipated, there will be no impact on the current schedule of Mission 3 and 4. The impact on the company's disclosed earnings is currently considered to be limited

Expected financial impact

Based on two main factors below, a combined increase in development costs of **up to 1.5 billion JPY is expected for Missions 3 and 4**:

- Increased procurement costs due to re-selection of landing sensors, including the LRF—opting for a space-proven, higher-quality unit
- Additional costs associated with review and expansion of testing

However, since these expenses will be recognized incrementally over the mission implementation period, the impact is not expected to necessitate a revision to the earnings forecast for the current fiscal year

Expected development impact

As a result of the review of the development plan—taking into account the LRF re-selection analysis and associated procurement lead time, as well as the revision and expansion of testing

- **No impact on the current schedule is currently anticipated for Missions 3 and 4*1**

*1 The impact from the joint engine development with Agile, which has already been disclosed, is currently being examined separately.

Achievement 1

Demonstrated consecutive reliable transportation capability to lunar orbit

Following Mission 1, Success 8—completion of all orbital control maneuvers in lunar orbit—was achieved again in Mission 2, demonstrating the repeatability and reliability of transportation capability to lunar orbit

Achievement 2

Acquired landing sequence data under different conditions through two separate missions

Mission 1 did not achieve a soft landing due to a software issue that caused the lander to free-fall from an altitude of approx. 5 km. Based on the lessons learned, Mission 2 confirmed that the software functioned as designed, allowing the lander to descend while maintaining its landing attitude. Landing sequence data under different conditions was acquired through two separate missions

Achievement 3

The deviation from the target landing site was within a 1 km radius, demonstrating the effectiveness of the guidance, navigation and control system

Based on image of the landing site captured by LRO, the lander impacted at a location near 60.44N, 4.6W. Approx. 282m south and approx. 236m east of the target landing site. This confirms that the guidance, navigation and control system performed as expected up to the final descent phase

Achievement 4

Significant improvement in both development and operations through the lessons learned from Mission 1

Development Period Reduced: Approx. 40%

- Reducing Non-Recurring Engineering Tasks by using the same model as M1
- Lessons learned from M1 have led to improvement of manufacturing, assembling and testing procedures. Fewer defects during development, as well as improvement of delivery management of procured goods

Development Cost Reduced: Approx. 50%

- Reducing Non-Recurring Engineering Costs by using the same model as M1
- Based on the experience of M1, more efficient project management reduced engineer's working hours and related labor costs

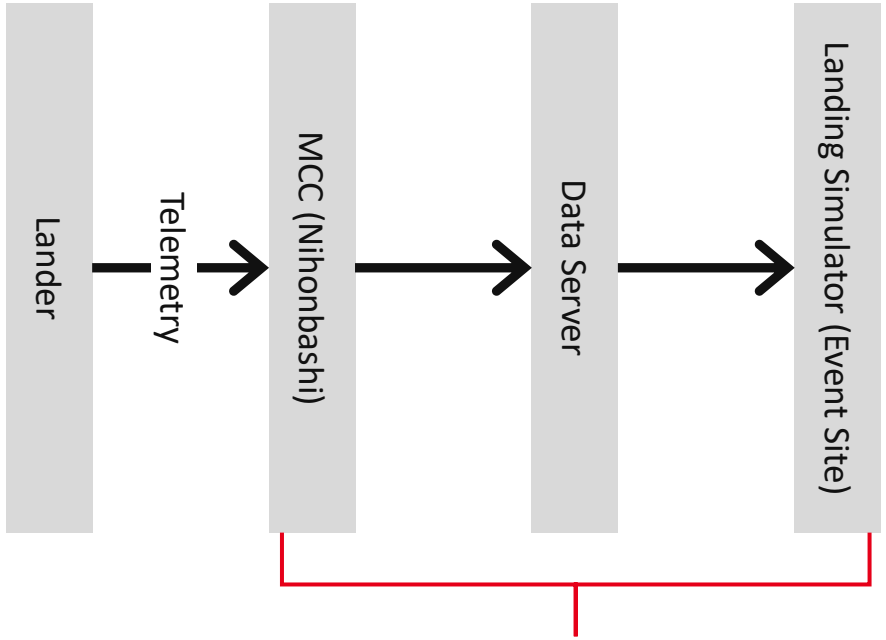
Period from Launch to Initial Operational Phase Completion Reduced: Approx. 60%

- Improved operations until the completion of the initial operational phase by applying lessons learned from M1 to M2
- M2 operation progressed smoothly and its initial operational phase occurred at the earliest expected timeline after the launch

APPENDIX

The telemetry displayed on the landing simulator was based on actual telemetry received by our Mission Control Center (MCC); however, in the event of telemetry loss, the system was designed to supplement the display with simulated data

Data flow

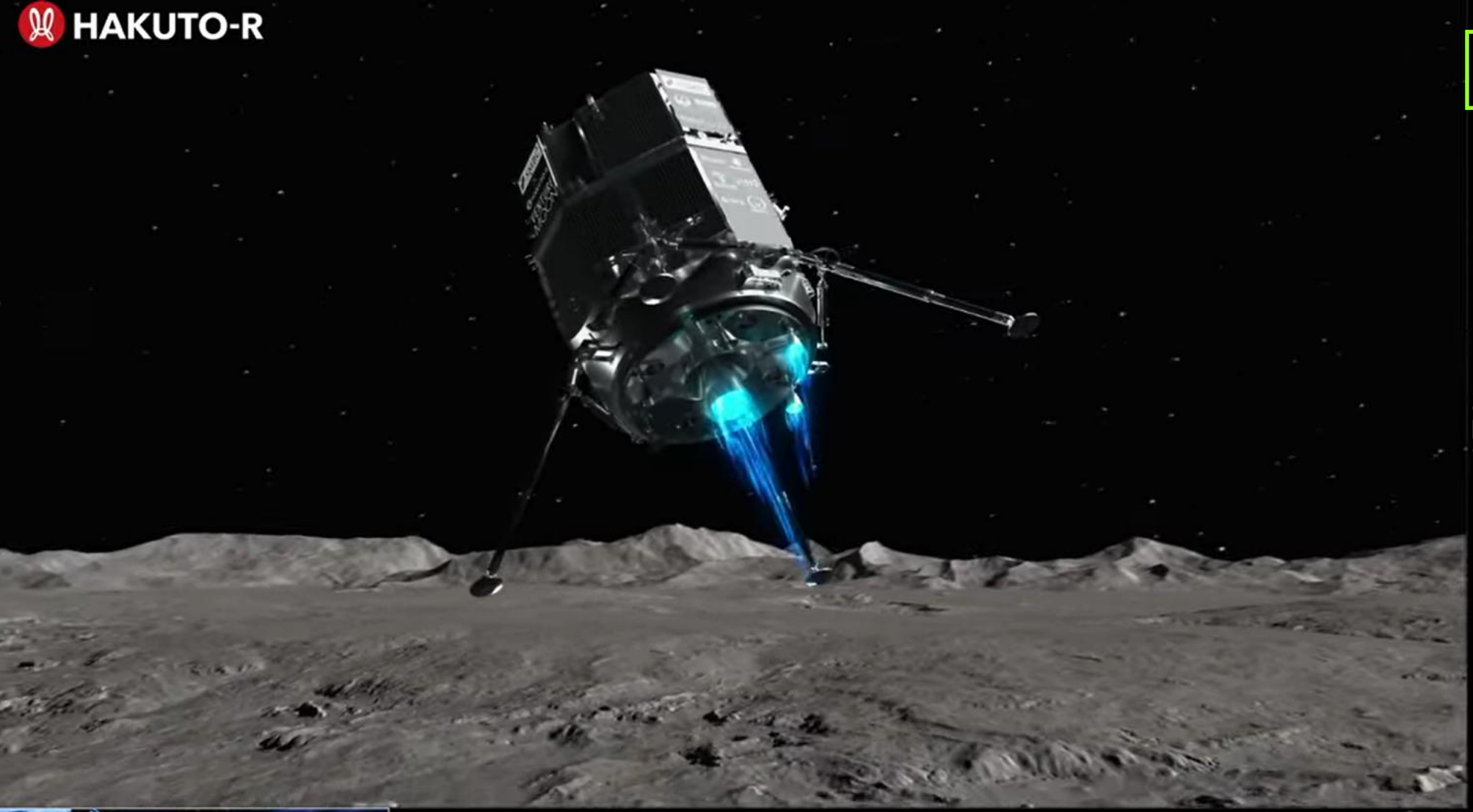


Due to a few seconds of delay in reflecting the telemetry received by MCC onto the simulator, the simulator was configured to display telemetry data at intervals of a few seconds.

Vertical Altitude: Actual Telemetry and Supplemented Display

Time	Actual Telemetry (m)	Telemetry on the simulator (m)	Time	Actual Telemetry (m)	Telemetry on the simulator (m)
4:15:08	**1,311**	1,311	4:15:19	548	
4:15:09	1,246		4:15:20	488	
4:15:10	1,181		4:15:21	433	
4:15:11	1,116		4:15:22	380	
4:15:12	—		4:15:23	**329**	329
4:15:13	—	992	4:15:24	—	
4:15:14	—		4:15:25	235	
4:15:15	**824**	824	4:15:26	192	**Telemetry loss thereafter**
4:15:16	746		4:15:27	—	
4:15:17	671		4:15:28	—	52
4:15:18	**606**	606	4:15:29	—	

When telemetry could not be received from the lander, the system was configured to linearly extrapolate values based on the previous five telemetry cycles → An altitude of 192 meters was the last confirmed telemetry



simulation

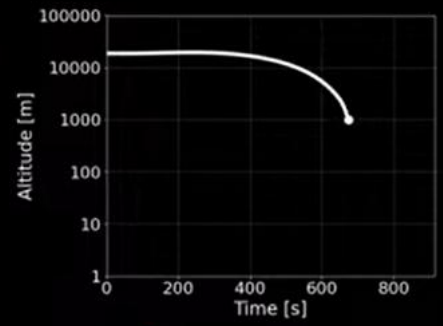
LANDER TELEMETRY

237
KM/H
SPEED

992
M
ALTITUDE

TIME TO TOUCHDOWN 00:02:00
*estimated

Main
Asst.1
Asst.2
Asst.3
Asst.4
Asst.5
Asst.6





③Braking Burn Phase
減速噴射

④Pitch-up Phase
減速噴射および姿勢変更

⑤Terminal Descent Phase
最終降下

⑥Terminal Landing
最終着陸

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