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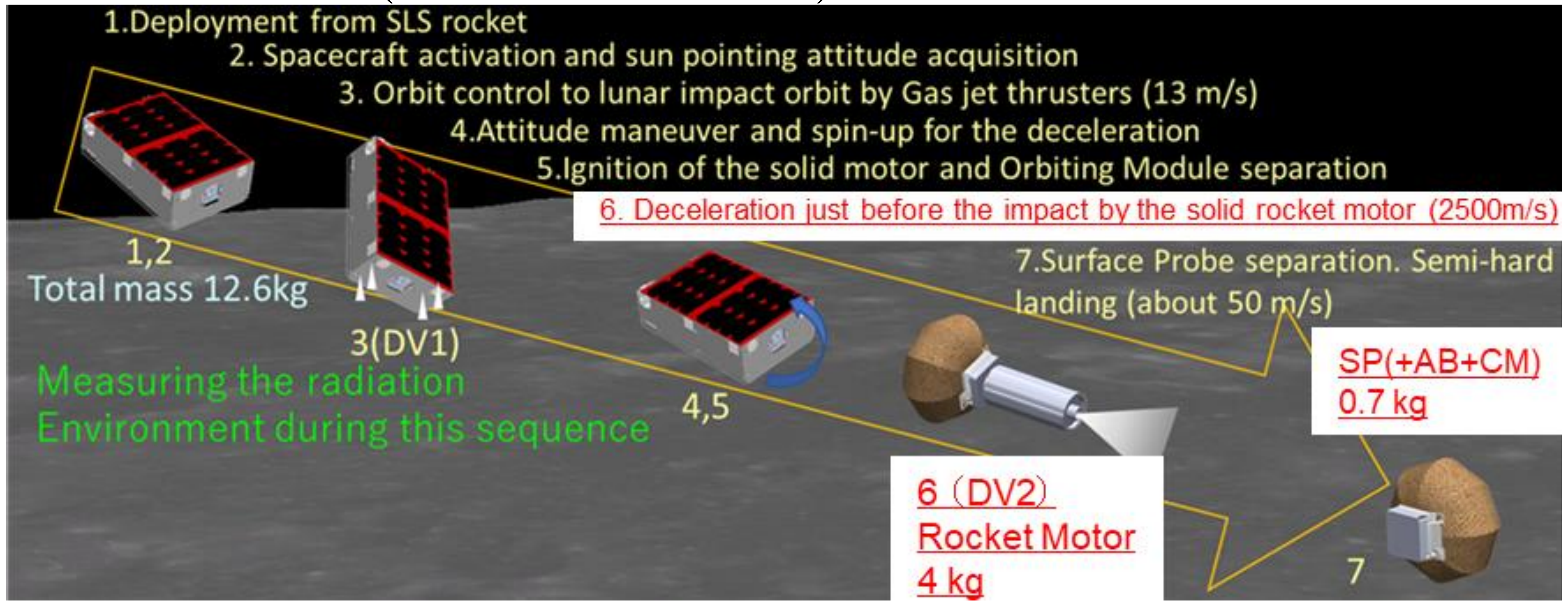
Development of a Super-Small Solid Rocket Motor for OMOTENASHI

Naoki Morishita†, Keiichi Hori, Junji Kikuchi and Tatsuaki Hashimoto‡ (Japan Aerospace Exploration Agency)
Yoshimichi Sago, Kiyoyuki Watanabe Wnd Hiroyuki Sasayama (Kawasaki Heavy Industries, Ltd.)
Hiroshi Sumida and Hirokazu Takuma (NOF CORPORATION)

1. Background: the OMOTENASHI Mission

-To be launched by NASA's SLS Artemis 1[1] in the early 2020s, ***OMOTENASHI*** will be one of the 13 CubeSats launched as secondary payloads.
-With a size of 6U (113×239×366 mm) and a mass of <14 kg CubeSat, it is ***the world's smallest moon lander***.
-Aims to land on the moon[2]. (See the mission overview below.)



2. Design and Key Technologies of the Super-Small Solid Rocket Motor

Requirements

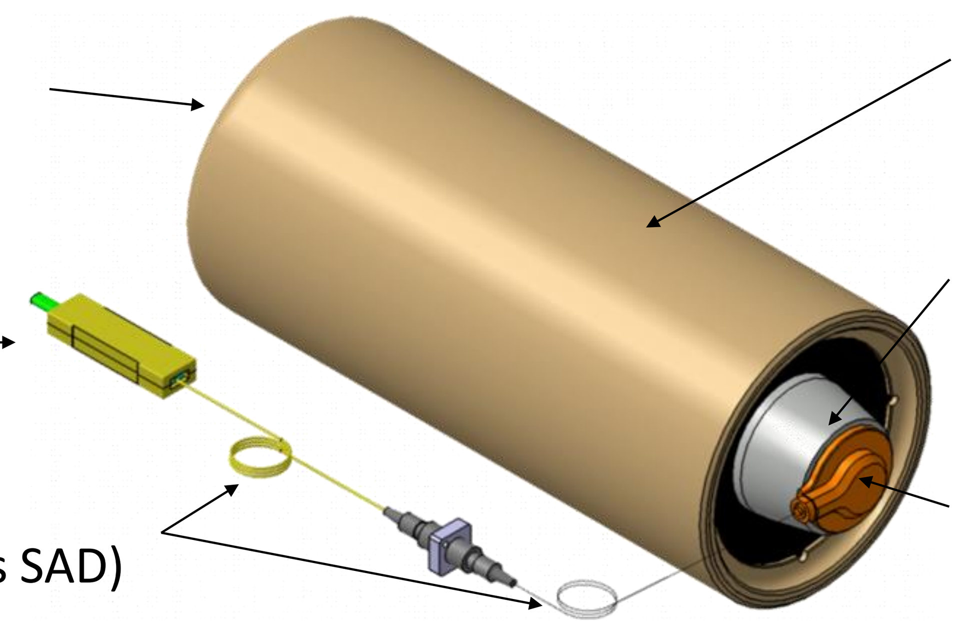
-Deceleration: 2,500 ± 25 m/s (±1%).
-Payload (Surface Probe (SP) + Airbag (AB) + Crushable Material (CM)) with a total mass of < 1 kg.
-Size must be <110 mm in diameter and <365 mm in length, and mass must be <6 kg.
-Dispersion of ignition delay <10ms.
-Safety requirements.

Design and Key Technologies

Laser ignition system:
In order to meet the stringent safety requirements of SLS, a laser ignition system is adopted. The system also reduces the weight of the rocket motor in flight.

Cigarette-burning propellant:
To maximize propellant mass under the strict size limit and flexibly respond to possibility of mass changes of the SP + AB + CM during development, the cigarette-burning design was adopted.

Short nozzle:
And to reduce mass and length, the nozzle was designed to be relatively short with a small area ratio. As a result, many static firing tests can be performed in the atmosphere using the same nozzle as the flight model.



Mechanical interface
(Bolted to SP +AB +CM)

Laser diode module
(Emits laser light)

Optical fiber
(Electrically insensitive, eliminates SAD)

Aluminum motor case
(Light and easy to manufacture)

2D C/C nozzle with CVD graphite coating

Nozzle closure
(Guides the laser light into the motor case, and contributes to weight reduction by detaching after ignition)

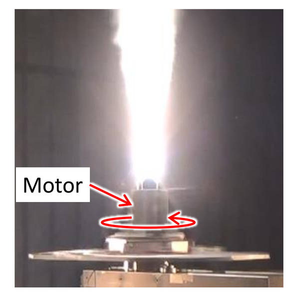
3. Development Tests

Key static firing tests

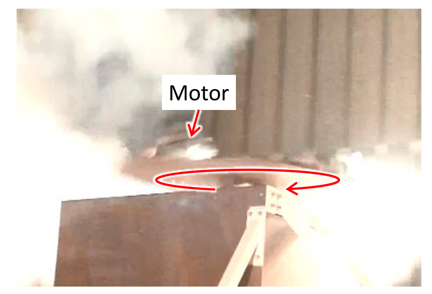
Test	Detail
Propellant & insulator performance test	Evaluating the performance of the propellant & insulator
Laser ignition system test	Evaluating the performance of the laser ignition system and the ignition delay dispersion (± 10 ms)
Firing test under low pressure (10 kPa)	Evaluating the nozzle efficiency in vacuum and laser ignition performance (@Akiruno Experiment Lab, ISAS/JAXA)
Side thrust measuring test	Evaluating the order of the side thrust and measuring the time history of side thrust
Spin firing test	Confirming that motor case and insulator can stand the 8.33 Hz spin
Firing test under acceleration	Confirming that motor case and insulator can stand the 30 G acceleration

--Environment tests (random vibration, thermal cycle, and vacuum) for the engineering models with the same lot models as the flight model
--Safety tests (UN tests for international transportation[3] and MSFC-3635 tests for treating the rocket motor in NASA's Kennedy Space Center[4])
These were also conducted.

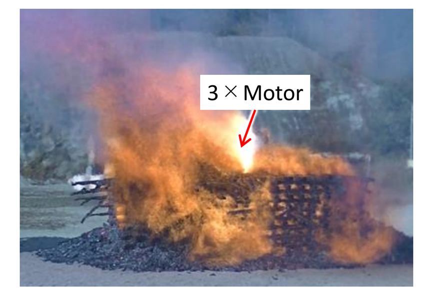

Firing test under low-pressure



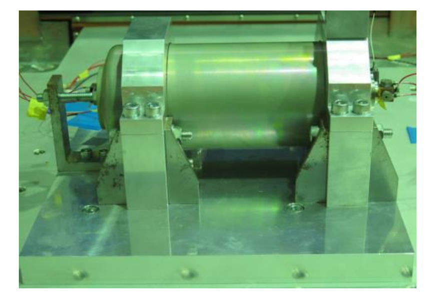
Spin firing test



Firing test under acceleration



UN test (External fire)


Environment test (Random vibration)

4. Results and Conclusions

-We have ***successfully developed a super-small solid rocket motor for the OMOTENASHI mission***.

-Our newly developed rocket is --
Compact, Safe, Flexible*, Powerful** and Low-Cost.

-We believe that ***our super-small rocket motor will become the new standard for space missions*** using small satellites that require large thrust.


Flight model

Final specs of OMOTENASHI's solid rocket motor

Dimension	Diameter: 110 mm Length: 300 mm
Total Mass	4 kg*
Propellant Mass	3 kg*
Payload (SP + AB +CM) Mass	0.7 kg*
ΔV	2500 ± 25 m/s*
Average thrust	500 N**
Specific impulse	270 s**
Burning duration	16 s*
Propellant	HTPB/AP/Al composite

*Values are roughly proportional to motor length

5. References

1) Artemis I, https://www.nasa.gov/artemis-1 (accessed May 28, 2020)
2) Hashimoto, T. et al., Nano Semihard Moon Lander: OMOTENASHI, IEEE AES Magazine, 34, 9 (2019) pp. 20-30.
3) UN Recommendations on the Transport of Dangerous Goods
4) MSFC-SPEC-3635 | NASA Technical Standards System (NTSS)

†morishita.naoki@jaxa.jp / ‡hashimoto.tatsuaki@jaxa.jp