Workshop
May , 2006

Robotic Lunar Exploration Scenario
— JAXA Plan —

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Question:
What is Space Exploration?

Answers:
There are as many answers as the number of the people who answer the question.

Examples:
-To extend human being's knowledge including the origin of Earth-Moon, Solar system, universe, and life.
-To explore the solar system as far as Pluto.
-To send astronauts to Mars.
-To build a man tended lunar base.
-To use space as commercial targets.

BASIC PHILOSOPHY

<<SCIENTIFIC EXPLORATION>>

Elucidation of Origin and Evolution of the Solar System

- -Empirical study on the origin of Solar System
- -Unraveling the diversity of the evolution of planets
- -Understanding the environment necessary for life to emerge and to evolve
- -Unified understanding of the physical steps of the solar system plasma phenomenon and planetary magnetospheres

<<EXPANSION OF HUMAN FRONTIERS>>

Expansion of human activities

- -Robotic exploration of planets
- -Human exploration of planets
- -Manned lunar base

(Common to both)

- -Intellectual surprise
- -Satisfaction of intellectual curiosity
- -Contribution to the world
- -National pride
- -Development of advanced technology

Question:

What is precursor missions ?

Answers:

There are many answers depending on the purpose of “Exploration”

Examples:

-Technology demonstration for future missions.
-Establish infrastructure for future missions.
-Investigation for surface environment including resource utilization for future missions.
-First step science for future top-science missions.

TECHNOLOGIES TO BE ESTABLISHED

Smart Landing

navigation sensors, autonomous obstacle avoidance, image-based navigation, landing legs.

Rover

locomotion for the unstructured terrain, navigation, autonomous path planning.

Survival Technologies on Lunar Surface

thermal control, power generation, communication.

Investigation

science observation, in-situ resource utilization.

Robotics

manipulator, tele-science, autonomy.

Return to the Earth

lift from the lunar surface, (docking with an orbiter), re-entry into the earth atmosphere.

INFLASTRUCURE TO BE CONSTRUCTED

Navigation

landing beacon, Lunar GPS?.

Communication

relay orbiter, surface-to-surface.

Power supply

power-generation plant, solar power satellite, power transmission.

Common-use facilities

human accommodation, observatory.

Transportation

Earth to Lunar orbit, orbit to surface, surface to surface.

SCIENCE OF MOON and …

Interior structure of moon

seismometer network (penetrater)

Interior material of moon

investigation of particular interesting area

Sample return

In-situ sample selection, detailed investigation in the ground facility.

<Mars and beyond>

Sample return from planets

Mars, moons of planets, asteroid, comets

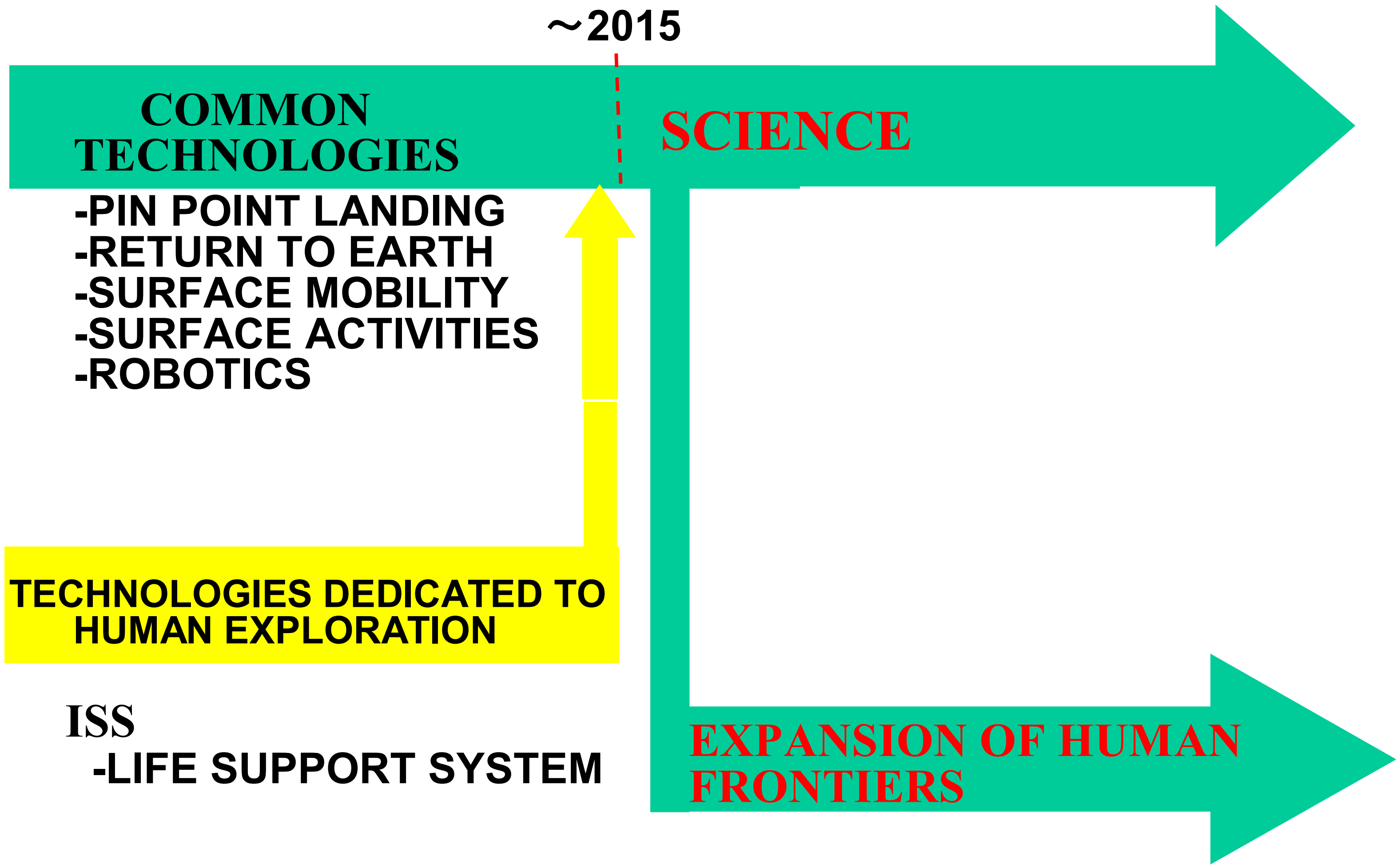
Solar plasma and planetary atmosphere

Earth&Moon, Mars, Venus, Mercury, …..

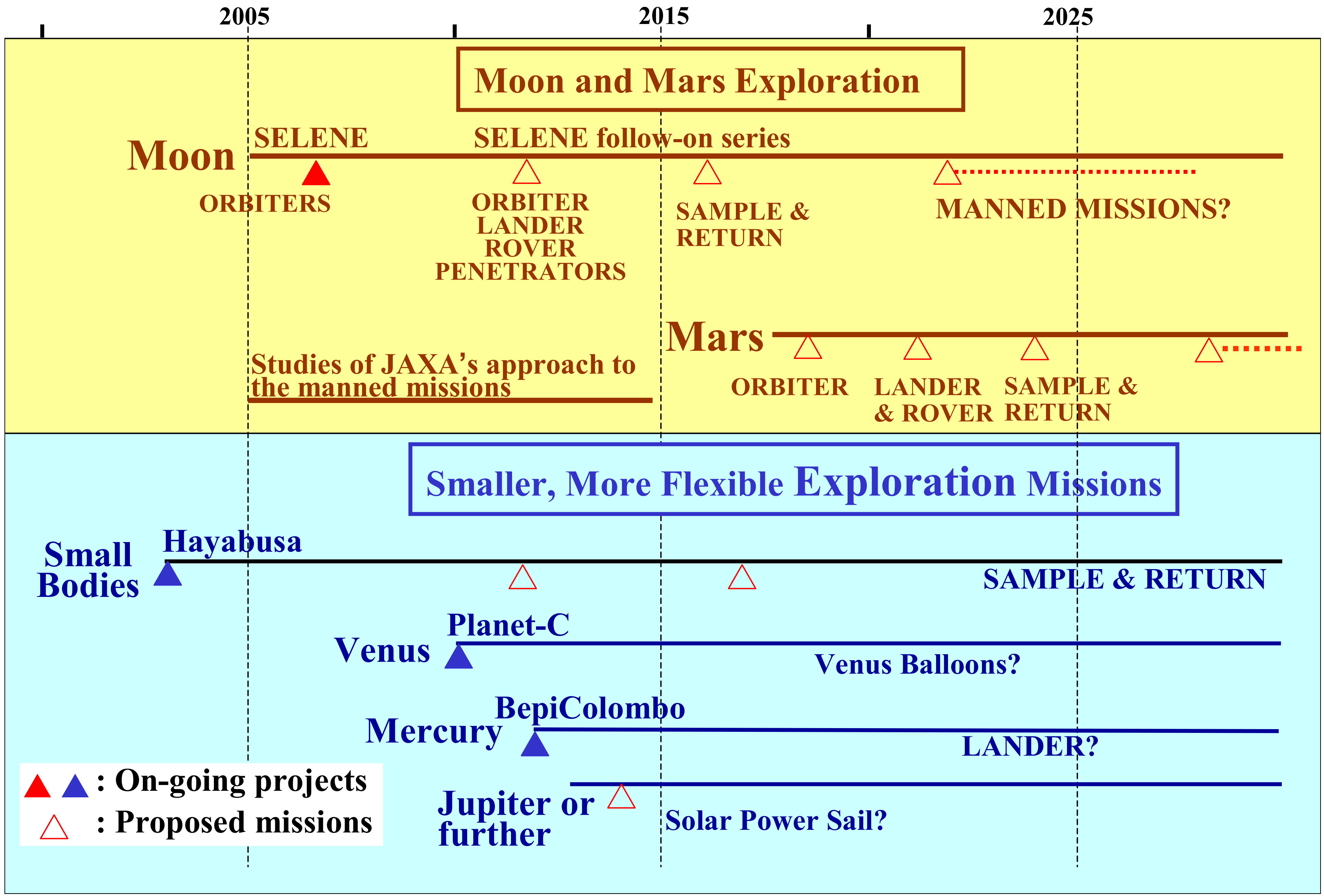
Searching "Life"

Mars, moons of planets, comets

JAXA Technology development and science observation scenario



Roadmap for Solar System Exploration Under Discussion



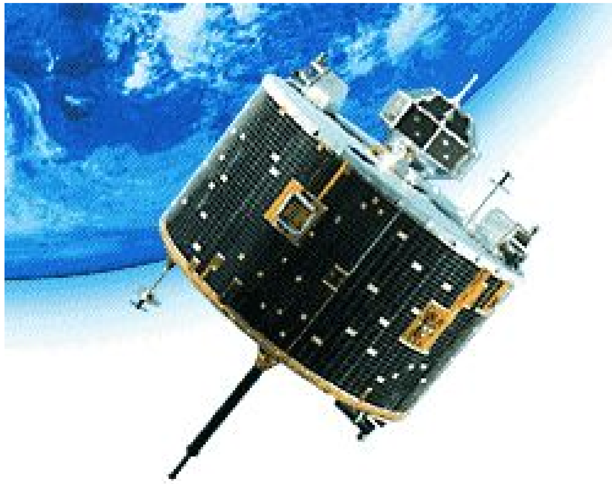
International collaboration candidates

from the view point of JAXA precursor missions

- Fundamental technologies such as landing or surface investigation instruments should be developed by each nation.
  - Some onboard instruments can be shared.
  - JAXA heritage and development plan are shown later.
- Candidates of international collaboration are:
  - Science (different landing area, different investigation target, different observation method)
  - Infrastructure (Navigation, Power, Communication)
  - Manned technologies
  - Ground test facilities
  - Ground tracking stations

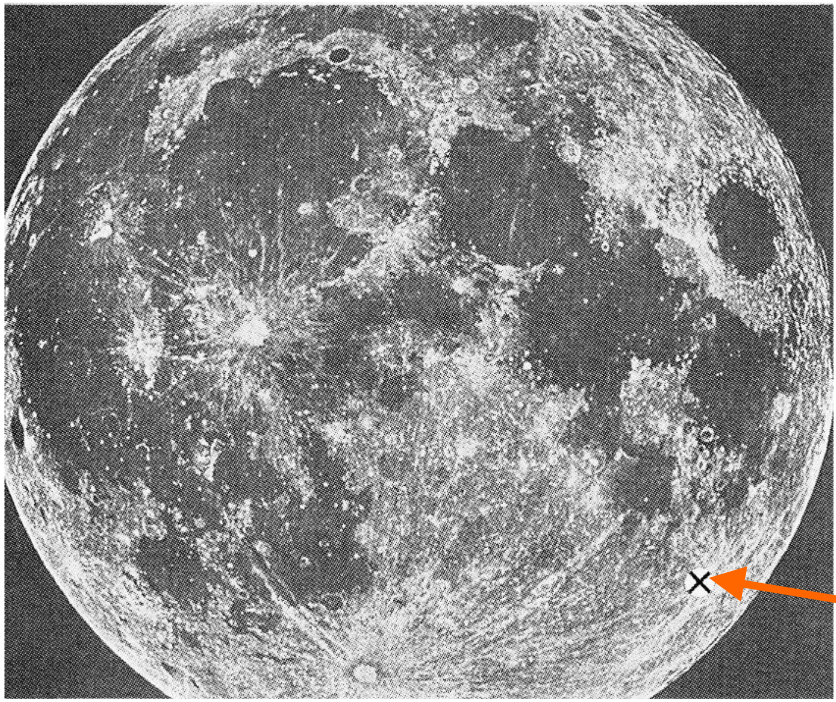
HITEN (MUSES-A)

Technology demonstration
- Lunar gravity assist
- Lunar orbit insertion
- Optical navigation
- Aero braking with earth atmosphere

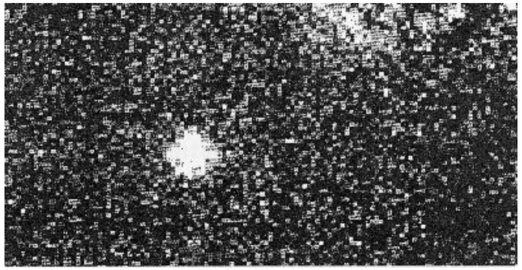


1990.1 Launch
1990.3 1st Lunar gravity-assist and HAGOROMO (small sat)
Lunar orbit insertion.
1991.3 1st aero-braking
1992.2 Lunar orbit insertion
1993.4 Hard-landing to the lunar surface

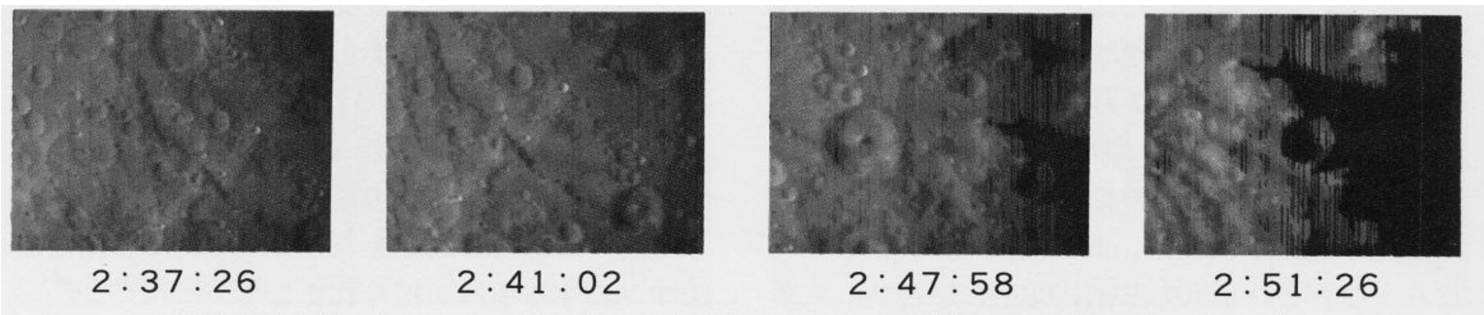
HITEN landing on 1993/4/10



Landing point



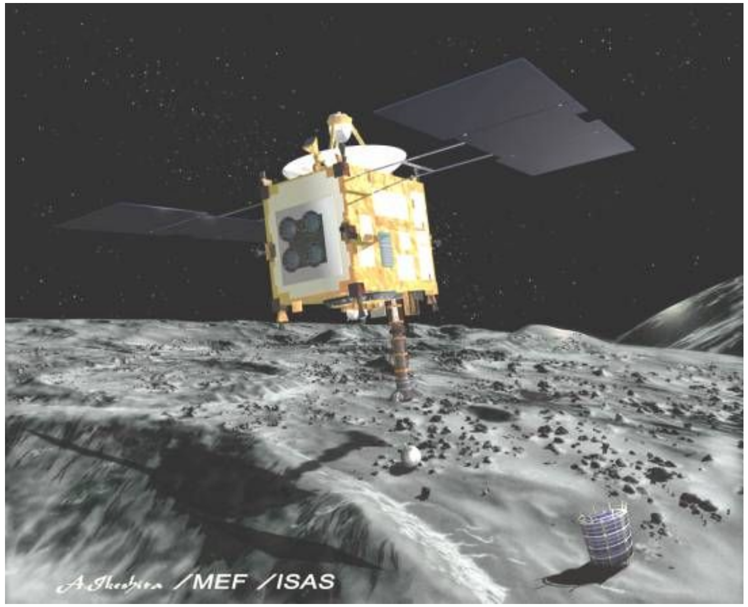
Impact image taken from
Australian observatory



Onboard camera images while descending

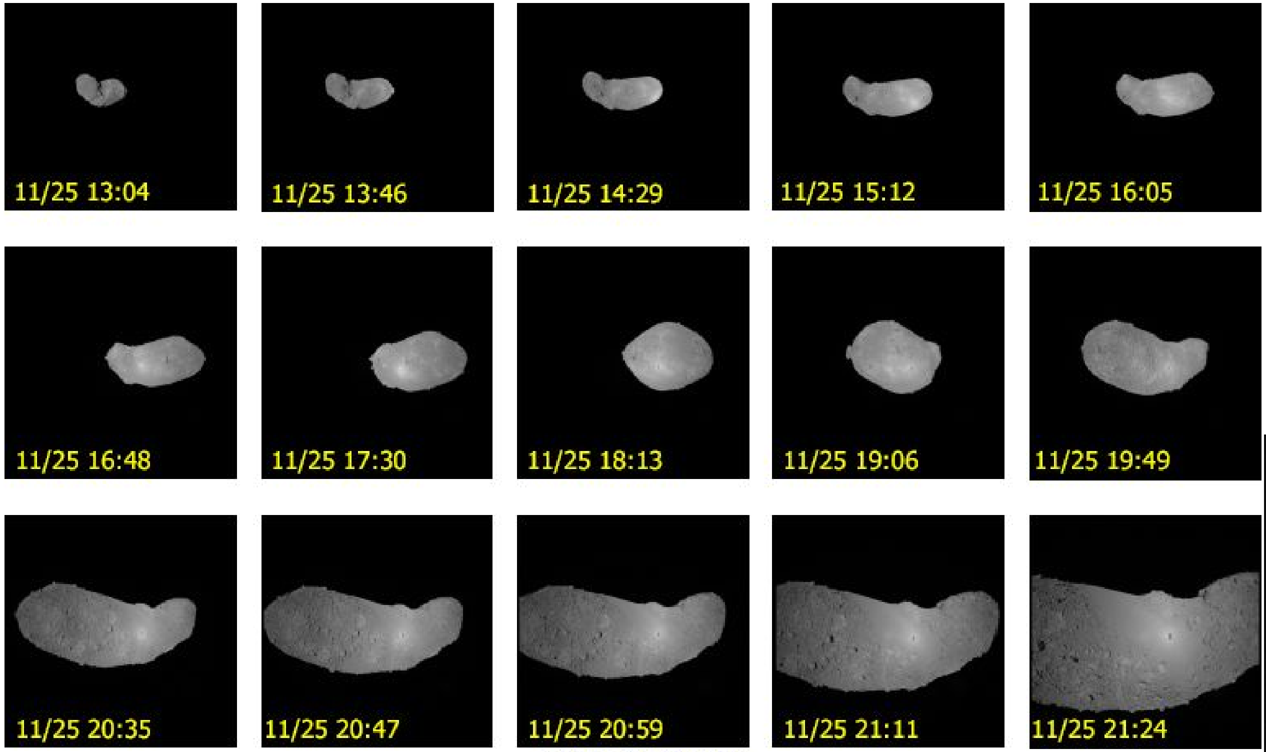
HAYABUSA (MUSES-C)

Technology demonstration
- Electric propulsion
- Autonomous approaching and landing to asteroid
- Sampling mechanism
- Re-entry capsule

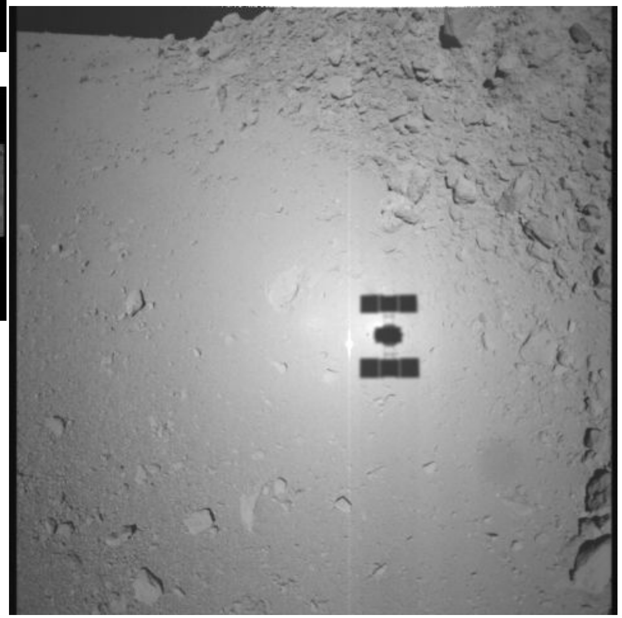


2003.5 Launch
2004.5 Earth gravity-assist
2005.9 Arrived at asteroid Itokawa
2005.11 Land to Itokawa
2010.6 Earth return

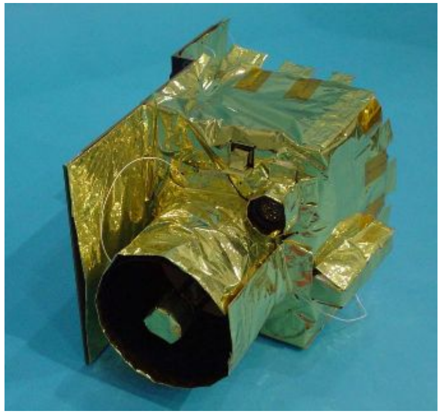
HAYABUSA landing on 2005/11/25



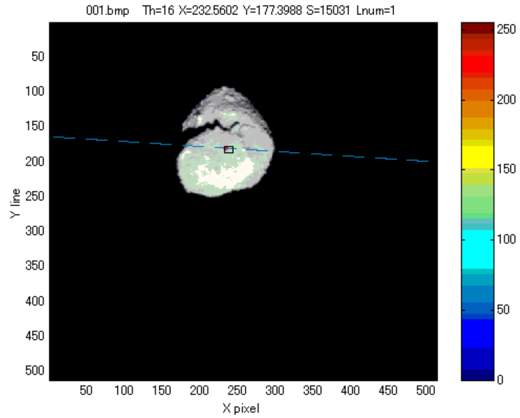
21:03に垂直降下開始



Demonstrated technologies by HAYABUSA

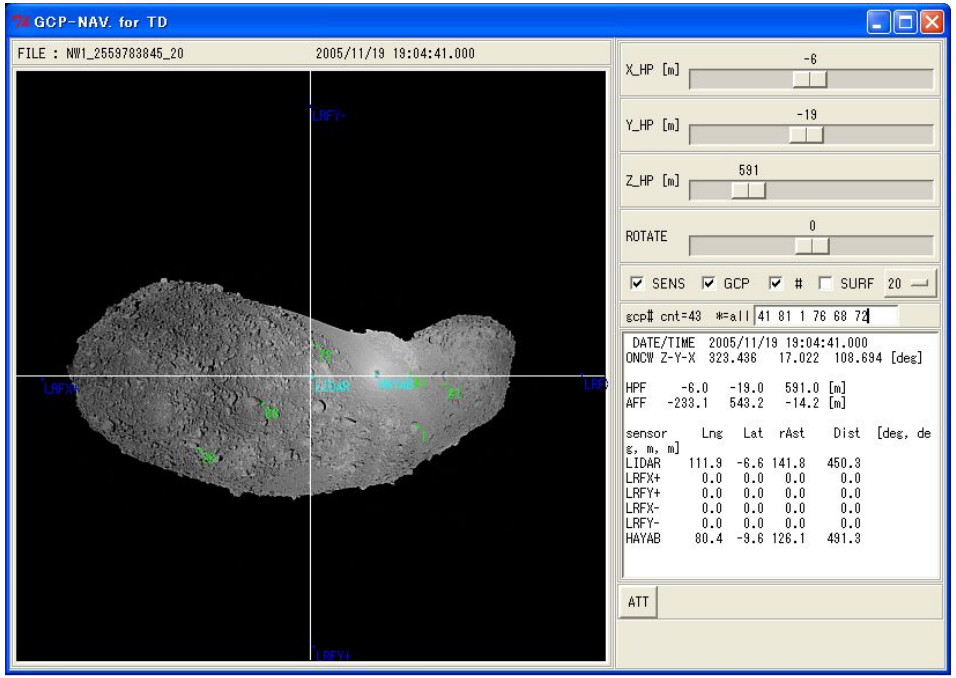


Laser altimeter
(50km to 50m)



Navigation camera and onboard image-processing

Short-range laser sensor
(120m to 3m)



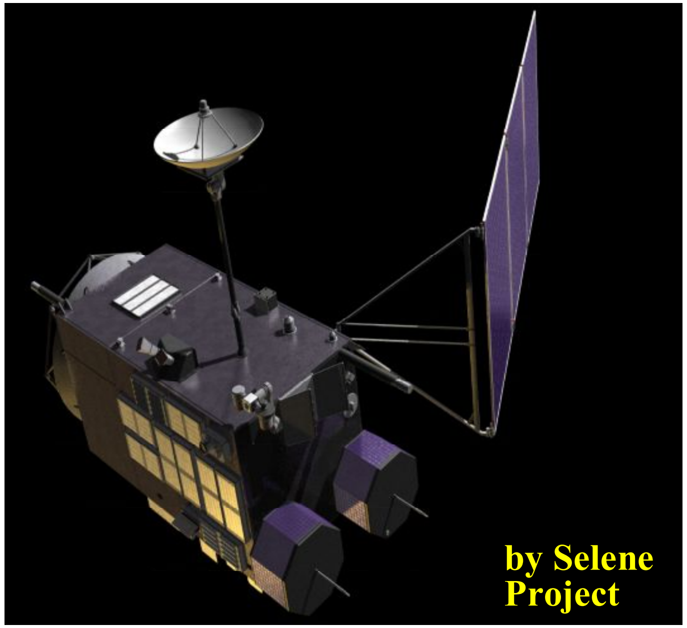
Landmark navigation (ground-base)

SELENE

- -Mission:
  Lunar remote-sensing
- -Lunar Orbiter Satellite
  + two Sub Satellites
- -Launch : 2007
- -Mass : 2885 kg
- -14 science instruments for measurements:
  elemental abundance, mineral composition, topography, geological structure, gravity field, magnetic field, plasma environment, and terrestrial atmosphere

SELENE Mission

- The largest and the most comprehensive Lunar mission after Apollo
- Mission: Global observation of the Moon
  - Study on the origin and evolution of the Moon
  - Research on the future lunar utilization and activities on the moon
  - Technology development for future planetary exploration

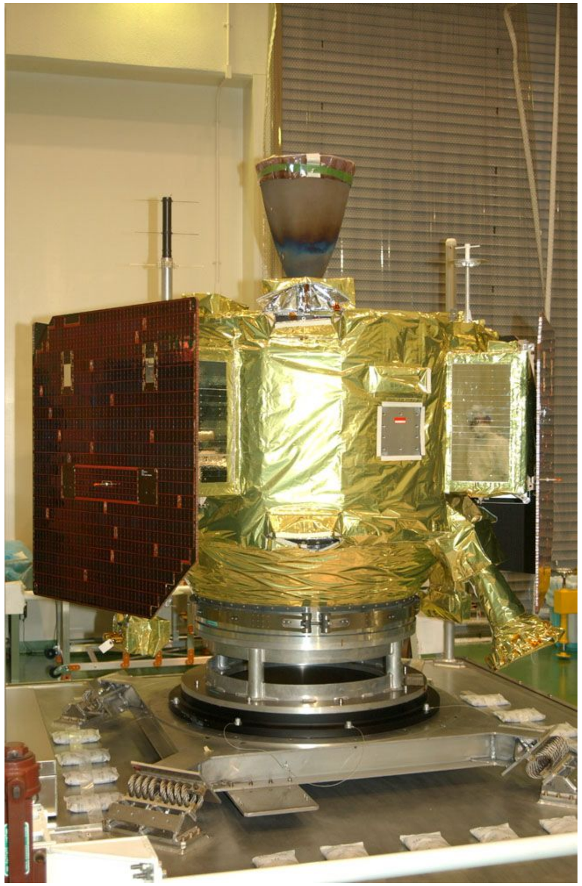


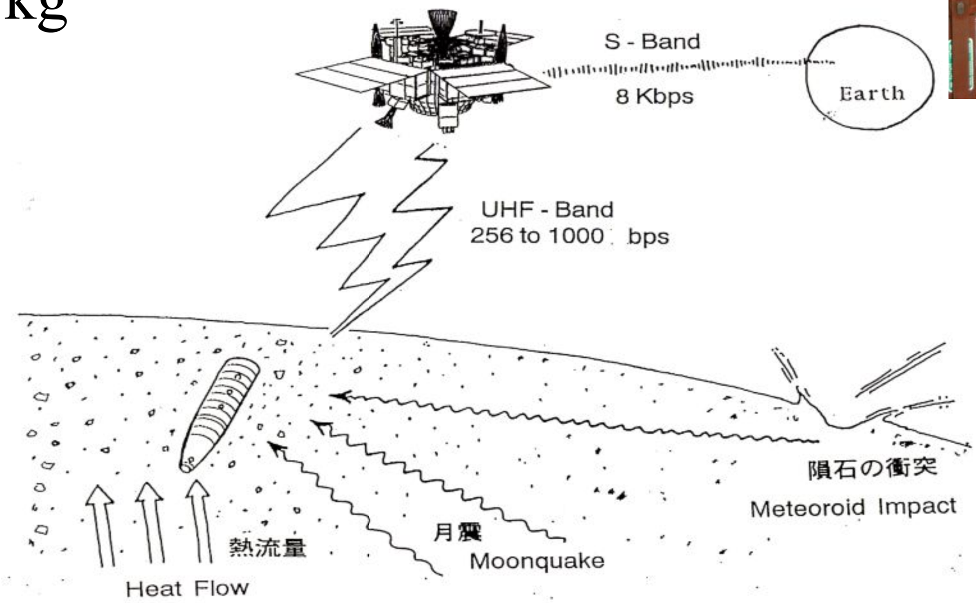
SELENE Mission Instruments

	Observation	Instrument and Characteristics
Main Orbiter	Chemical elements distribution	**X-ray Spectrometer** (Al, Si, Mg, Fe distribution, spatial resolution 20 [km]) **Gamma-ray Spectrometer** (U, Th, K distribution, resolution 160 [km])
	Mineralogical distribution	**Spectral Profiler** (Continuous spectral profile λ = 0.4 to 2.6 [μm], spatial resolution 500 [m]) **Multi-band Imager** (UV-VIS-IR imager, λ = 0.4 to 1.6 [μm], 9 bands, spatial resolution 20 [m])
	Surface structure	**Terrain Camera** (High resolution stereo camera, spatial resolution 10 [m]) **Lunar Radar Sounder** (apparent depth 5 [km], resolution 100 [m]) **Laser Altimeter** (height resolution 5 [m], spatial resolution 800 [m])
	Surface environment	**Lunar Magnetometer** (Magnetic field measurement, accuracy 0.5 [nT]) **Plasma Imager** (Observation of plasmasphere of the earth, XUV to VIS) **Charged Particle Spectrometer** (Measurement of high-energy particles) **Plasma Analyzer** (Charged particle energy and composition measurement) **Radio Science** (Detection of the tenuous lunar ionosphere)
	Imaging	**High Definition Television camera** (Images of the earth and the lunar surface, for public outreach)
VRAD satellite	Gravitational field distribution	**VLBI Radio-source** on the VRAD satellite (Near-side gravity field) (VRAD = VLBI RADio source)
Relay satellite	Gravitational field distribution	**VLBI Radio-source** on the Relay satellite (Near-side gravity field) **Relay Sat. transponder** (Far-side gravity field using 4-way range rate from ground station to Orbiter via Relay Satellite)

LUNAR-A

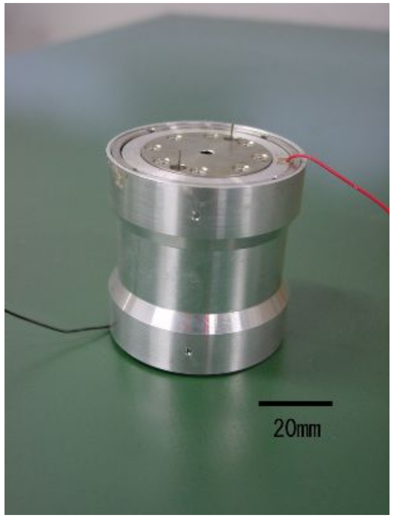
- Lunar orbiter with communication relay capability and a visible camera.
- Deploy two of penetrators with seismometers and heat-flow probes.
- Using moonquake, interior structure of moon will be investigated.
- Launch date is TBD.
- Mass: 540 kg



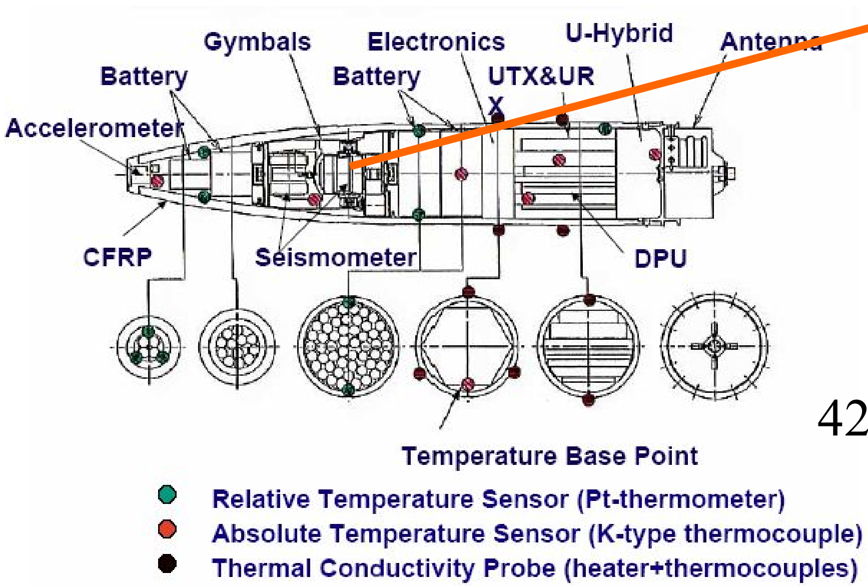


Penetrator

- Presently, modification of electronic circuits and improvement of communication performance are tried.
- Penetration test of full configuration will be done on May 31st, 2006.
- Final penetration test for improved model will planed in July, 2007.



Seismometer



42 kg

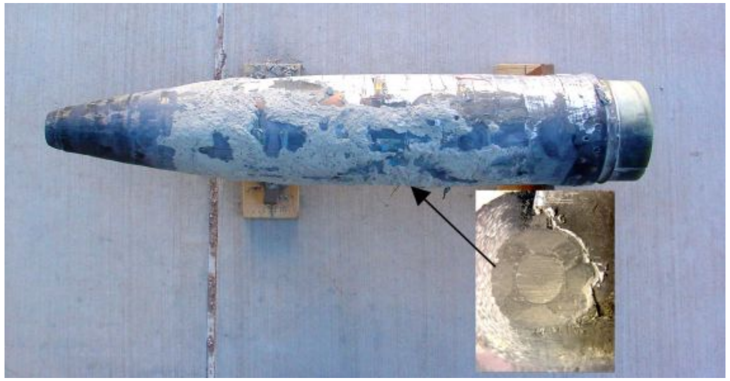


Photo after high-G impact test

Small Orbiter with a Penetrator
(A candidate of SELENE series payload)

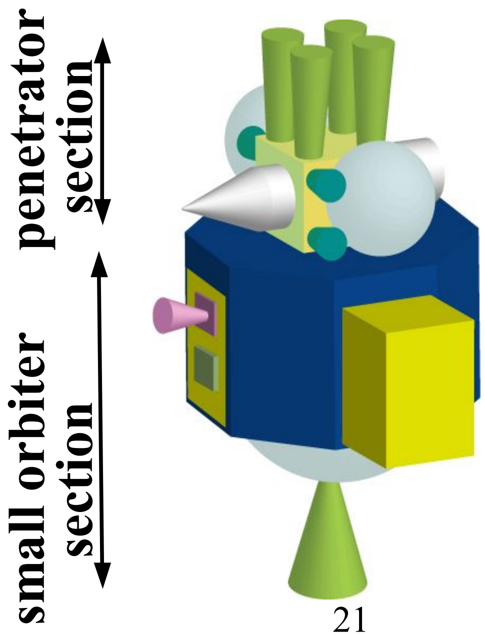
Overview:

- A penetrator is released from orbiter at the altitude of 100 km.
- The penetrator is de-orbited and free-falls to be injected onto the lunar surface.
- Small orbiter is used for communication relay.

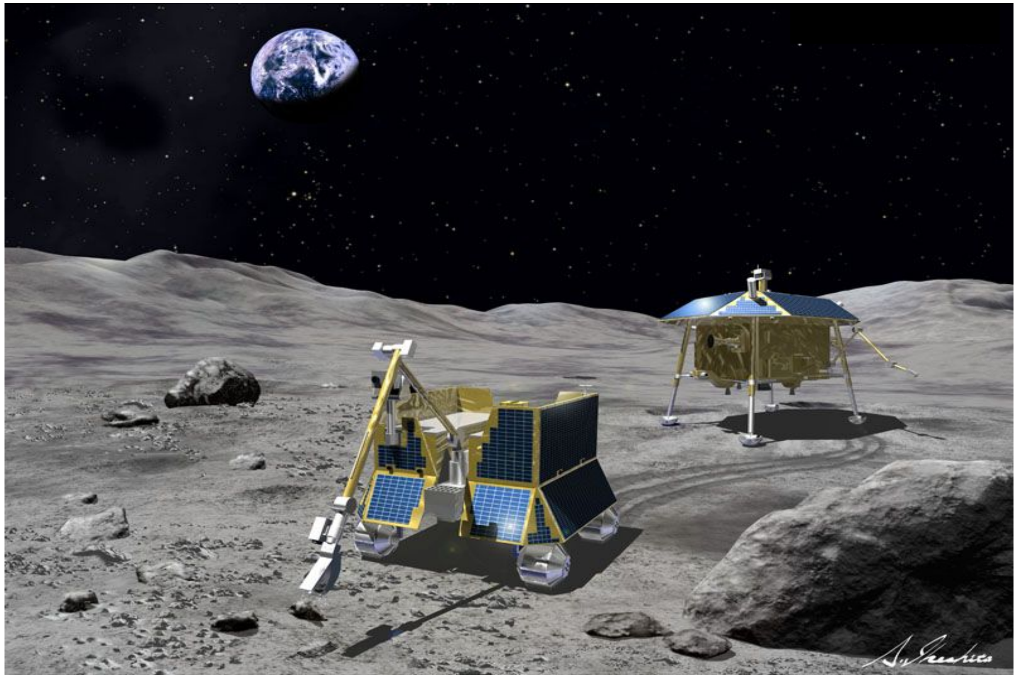
Spacecraft:

- Weight: 300 kg including penetrator

Penetrator system



SELENE series candidate #1



Mission:

-Technology validation
-Understanding the moon and its environment

Configuration :

lander and rover
[option]
relay orbiter, penetrator

Landing site:

Sun light portion of the Polar region

Launch: early 1910's

Launcher: H2A or H2B

SELENE series
candidate #2

Mission:

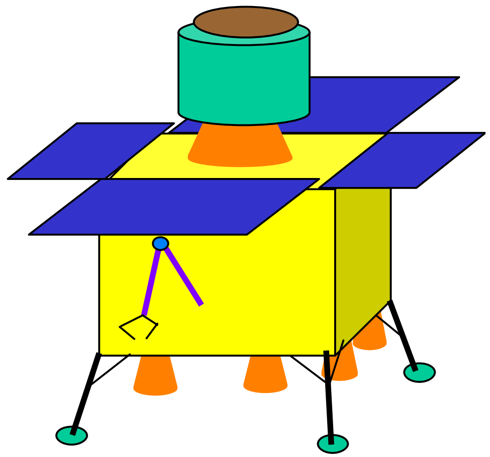
- **Validation of technologies for sample & return**
- **In-situ analysis and returned sample analysis**

Configuration :

lander, rover and re-entry capsule

Landing site: **TBD**

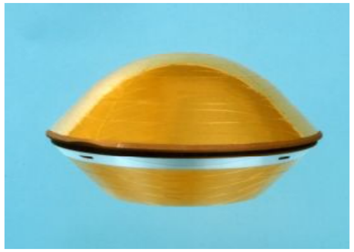
1) far-side: SPA (South Pole-Aitken)
2) nea-side: PKT (Procellarum KREEP Terrane)



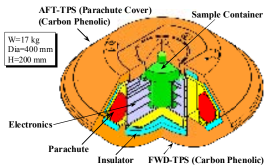
Launch: **mid-2010s**

Launcher: **H2A or H2B**

Sample return option



Direct re-entry capsule developed by HAYABUSA



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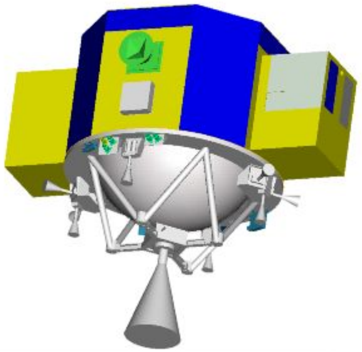
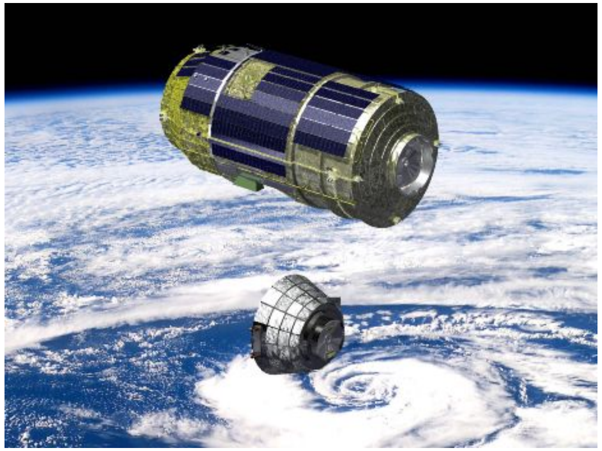


Direct return option



Using HTV option

Rendezvous and docking was demonstrated by ETS-VII（1997-1999)

Re-entry was demonstrated by OREX (1995) and USERS (2002)

Technologies to be validated by SELENE series

- **Integrated landing system**
- **Navigation system for pin-point landing & autonomous obstacle avoidance**
- **Power generation system for an extended period of time**
- **Surface mobility to support material sampling/analysis and instrument setting**
- **In-situ resource utilization**
- **(Penetrator and seismometer)**
- **(Data relay from lunar surface)**
- **(Sample and return)**

JAXA heritage and plan toward Mars

1. Landing and surface exploration technologies
   - ✓ Applying Hayabusa and SELENE follow-on series technologies
   - ✓ Lander & Rover missions, Sample Return missions, or Seismometer Network can be considered.
2. Small body science
   - ✓ From asteroids to Martian satellites (Phobos, Deimos).
   - ✓ Micro-rover, miniature instruments.
3. Solar plasma and planetary atmosphere science
   - ✓ Total study of solar system compared with Earth (GEOTAIL, etc.), Moon (SELENE), Venus (Planet-C), Mercury (BepiColombo)
   - ✓ Nozomi was launched in 1998, but failed to put into Martian orbit in 2003 at 1000 km from the Mars.
   - ✓ Revenge mission of Nozomi is considered.