JAXA Space Science Program and International Collaboration

Institute of Space and Astronautical Science (ISAS)
Japan Aerospace Exploration Agency (JAXA)

Yoshio Toukaku
Director for International Strategy and Coordination
ISAS/JAXA
May, 2019

From Heisei to Reiwa era

平成　　　令和

<Change of Japanese Emperor on 1st May 2019>

Heisei Emperor visited JAXA Tsukuba with King of Spain (Nov. 2008)

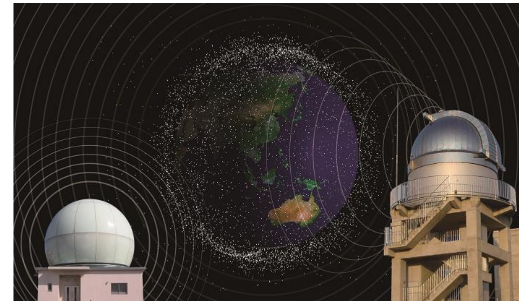
Reiwa Emperor visited JAXA Tsukuba with King of the Netherlands (both were Princes at that time) (Sept. 2010)

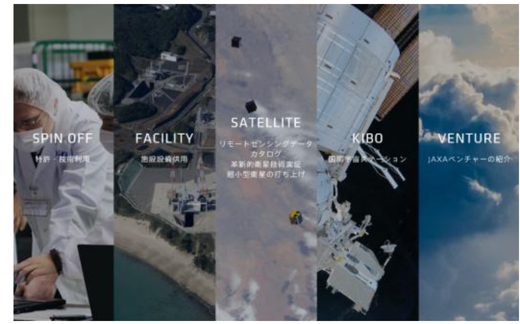
Heisei Emperor visited JAXA Tsukuba with Grand Duchess of Luxembourg (Nov. 2017)

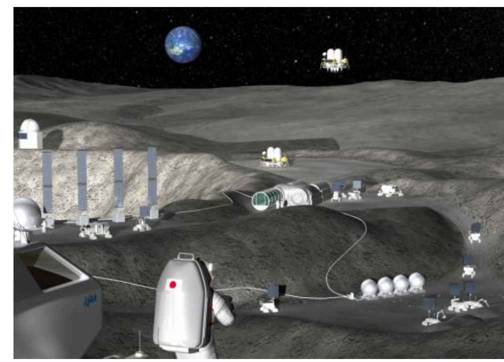
JAXA Medium to Long-term Plan

- FY2018 to FY2024

- To strengthen the cooperation with National Bodies of the national security affairs
- To extend Japanese space activities and related business by developing new partnerships with private companies
- To promote international space exploration program with Japanese space science and technologies with cutting edges
- To strengthen the international competitiveness in next-generation aircraft engine



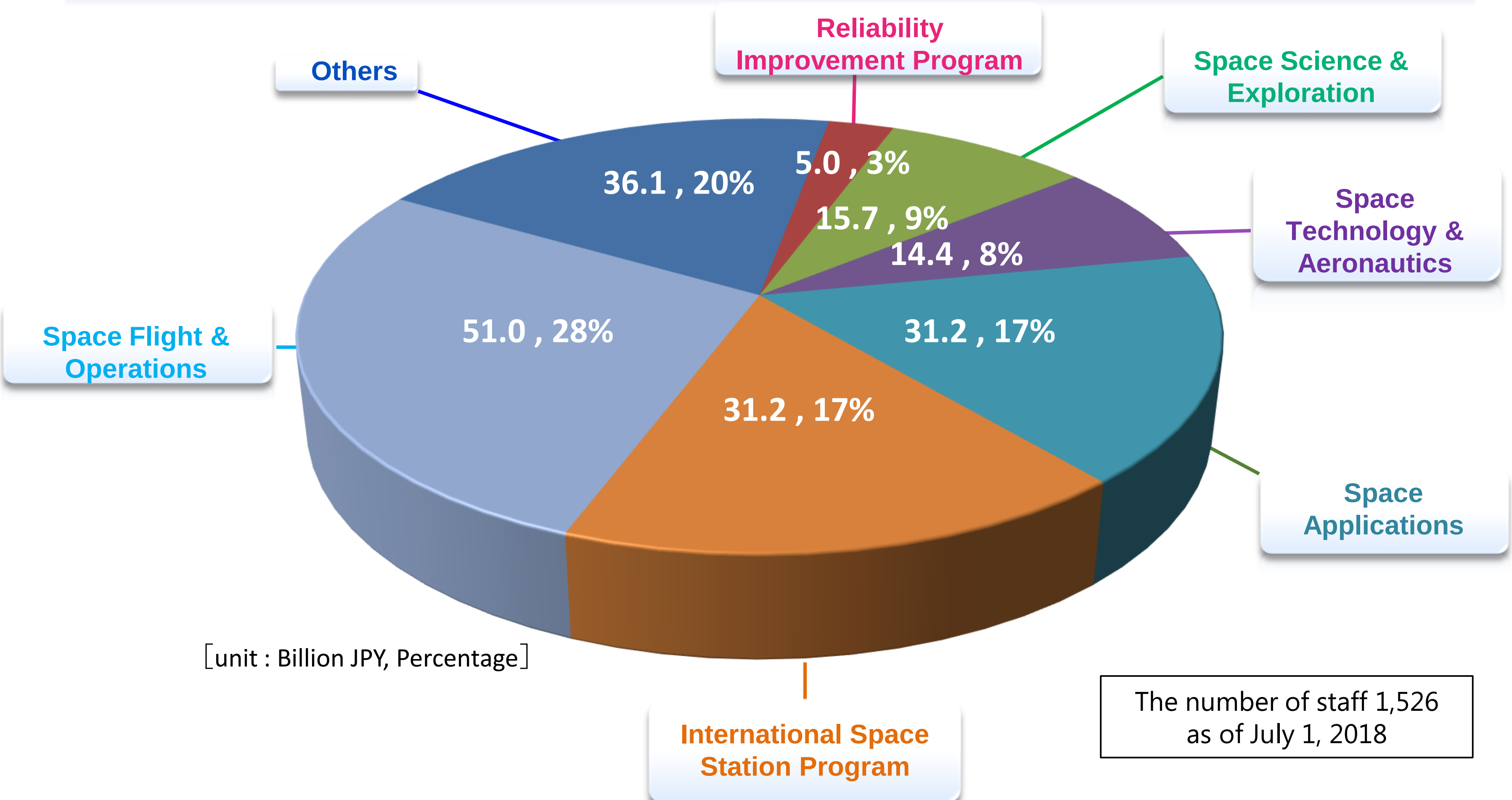




JFY2019 JAXA's Draft Budget

- ◆ JFY2019 JAXA Draft Budget : 184.6 Billion JPY (Approx. $1.68 B)
- ◆ Compared to the previous fiscal year: +0.8%

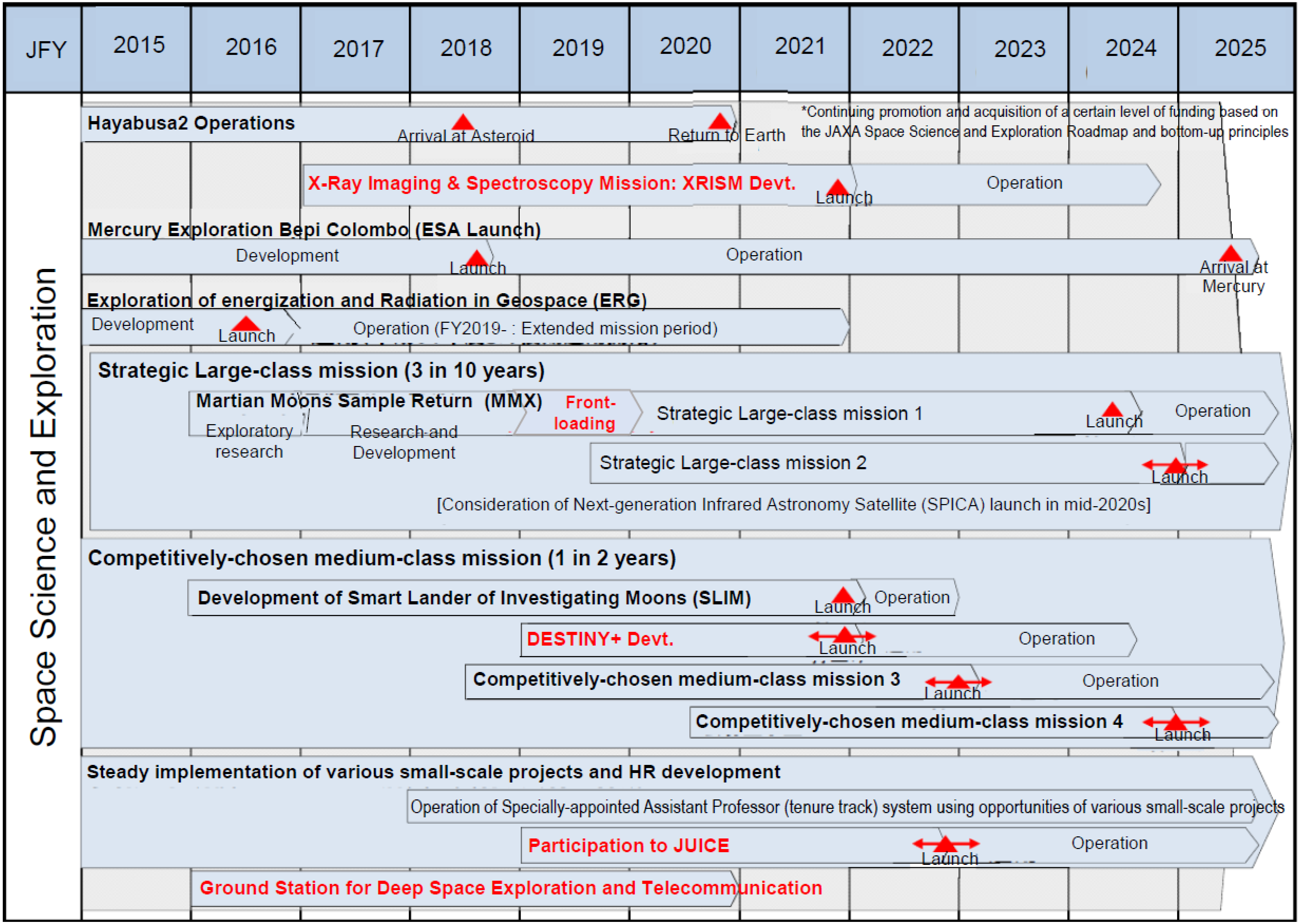
(including supplementary budget, $1=110 JPY)



［unit : Billion JPY, Percentage］

The number of staff 1,526 as of July 1, 2018

From "Basic Plan on Space Policy Implementation Schedule" (Rev. Dec. 2018)

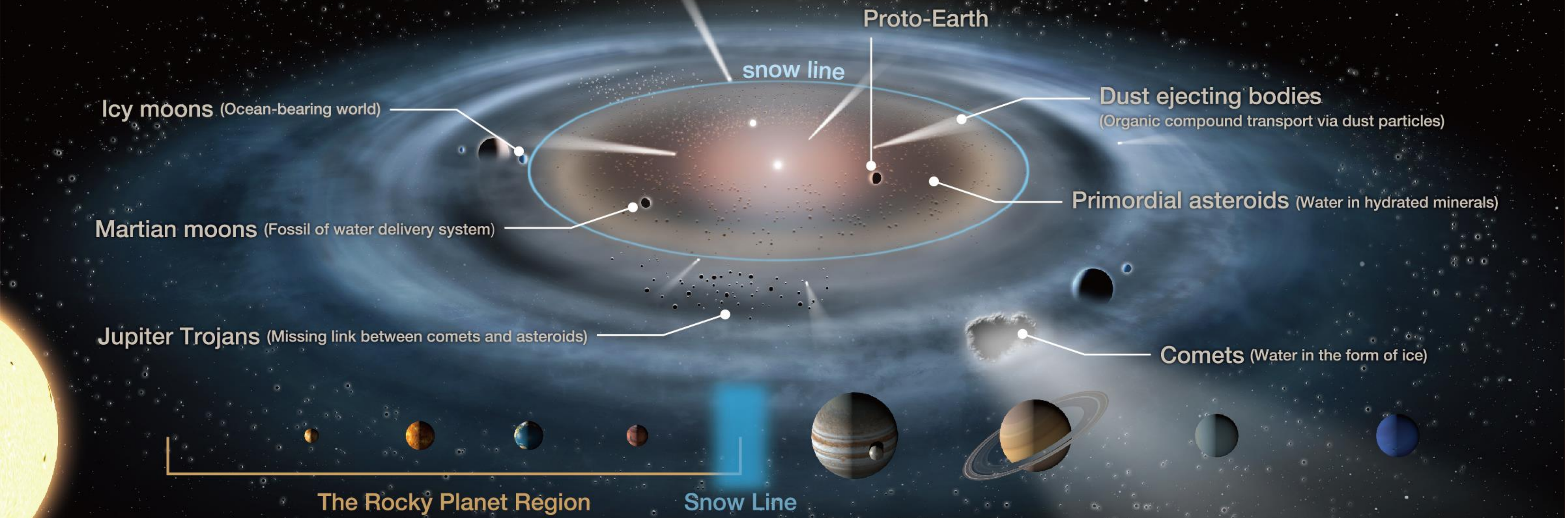


ISAS Small Body Exploration Strategy

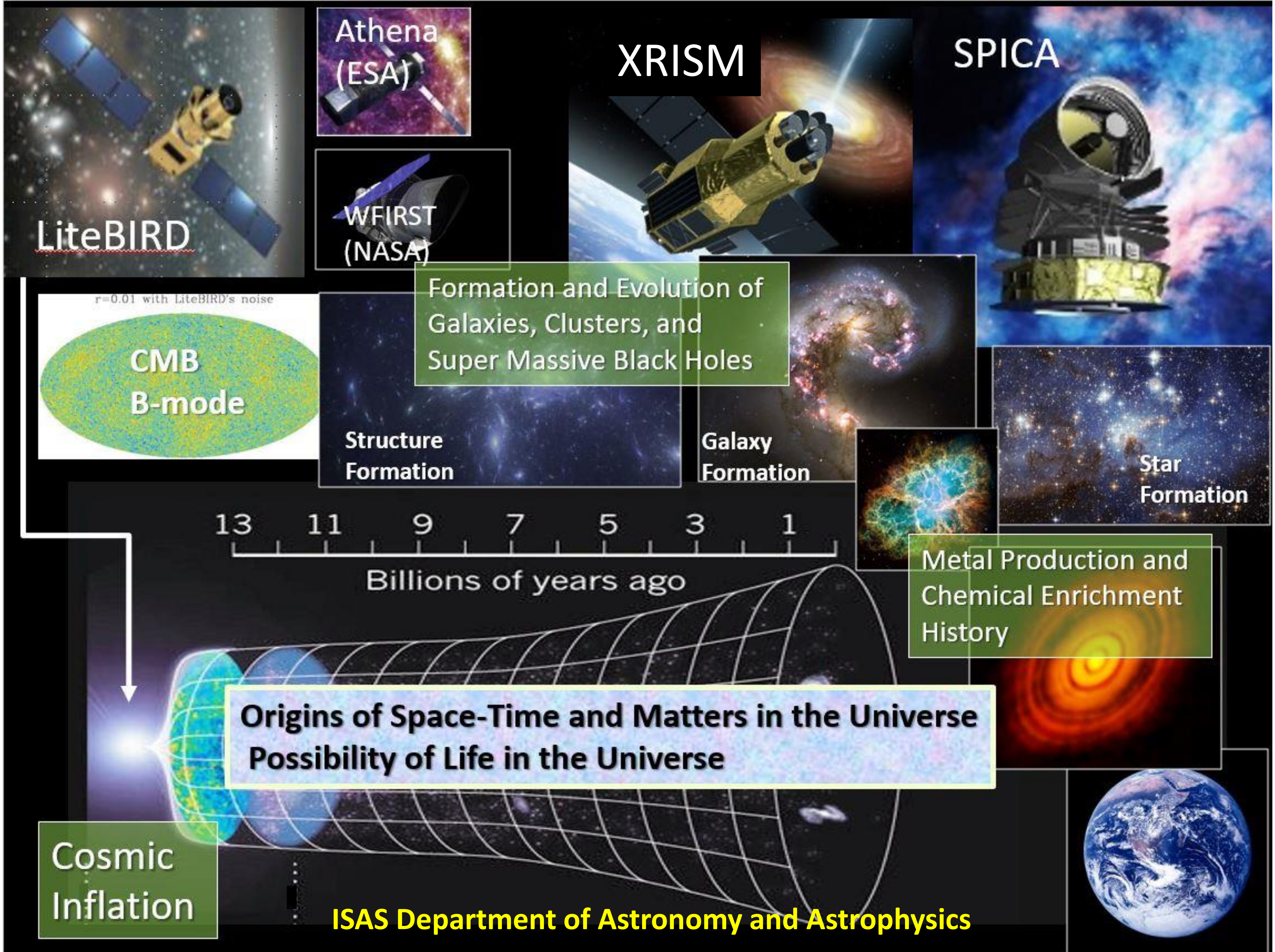
Many small bodies are born outside the snow line. These are initially comet-like but can evolve to show a variety of faces.

By delivering water and organic compounds, these small bodies may have enabled the habitability of our planet.

When, who and how?

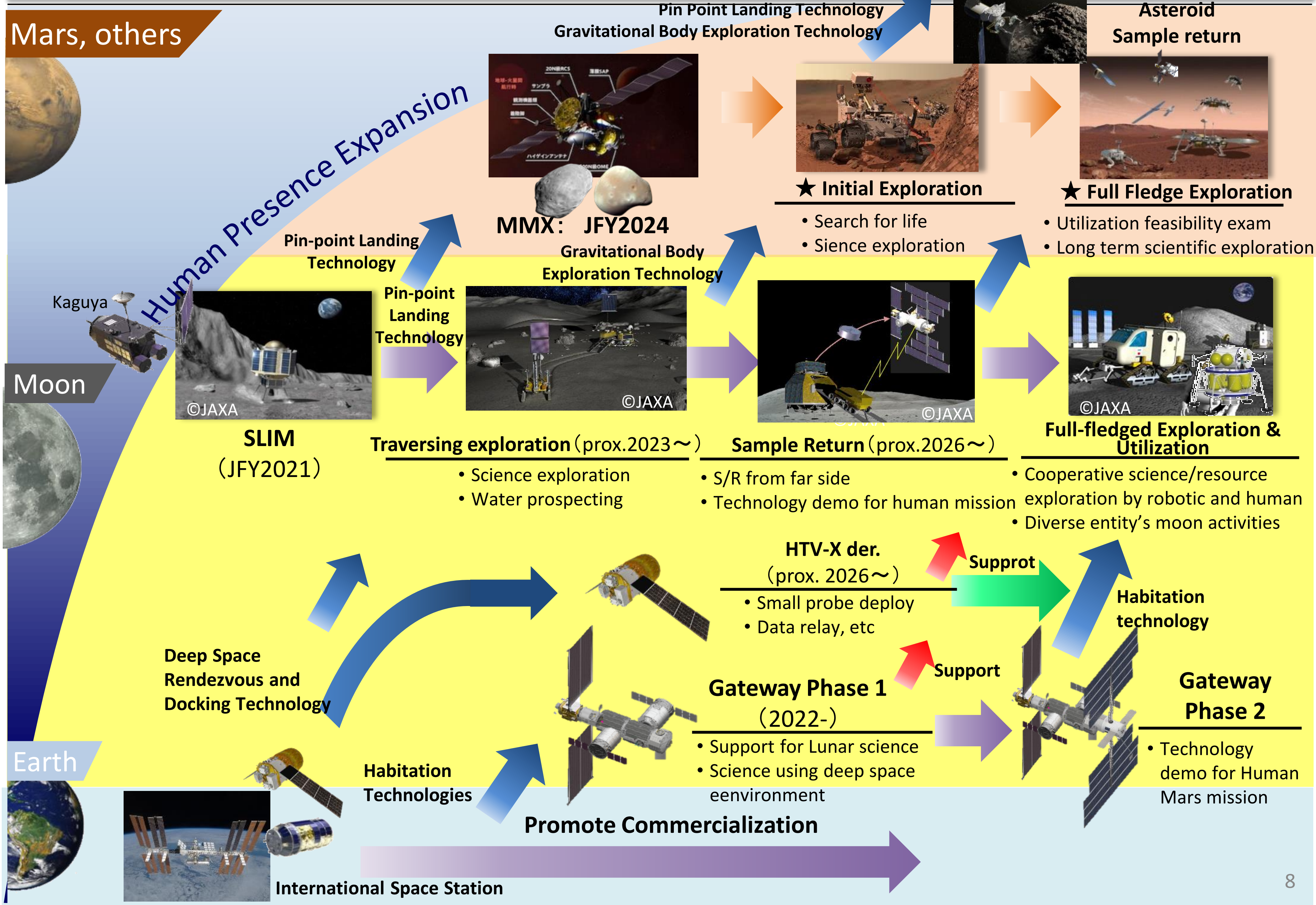


The fleet of ISAS small body missions explores these questions



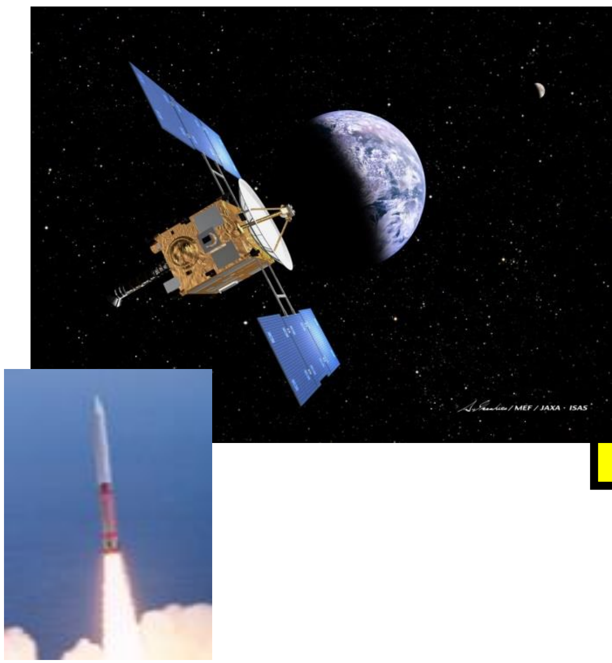
Athena (ESA)
XRISM
SPICA
LiteBIRD
WFIRST (NASA)
Formation and Evolution of Galaxies, Clusters, and Super Massive Black Holes
r=0.01 with LiteBIRD's noise
CMB B-mode
Structure Formation
Galaxy Formation
Star Formation
13 11 9 7 5 3 1
Billions of years ago
Metal Production and Chemical Enrichment History
Origins of Space-Time and Matters in the Universe
Possibility of Life in the Universe
Cosmic Inflation
ISAS Department of Astronomy and Astrophysics

JAXA's Overall Scenario for International Space Exploration



Promotion Strategies for Space Science and Exploration Projects

Based on strategies for execution of future projects in the space science and engineering fields amid harsh resource limitations, rather than the large-scale projects that have been strived for in the past, we will mainstream smaller projects in three categories: Large-scale satellites/explorers (launched on H2-class or larger rockets), medium-scale satellites/explorers (launched on Epsilon rockets), and various other small-scale projects.



Typical scientific satellite mission through the early 2000s, launched by M-V rocket

Strategic Large-class missions

With the goal of attaining first-class achievements, Japan will lead flagship missions in each field, assuming international cooperation in various forms.

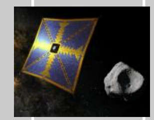
Competitively-chosen Medium-class missions

Aiming to create high-frequency results through flexibly implemented, challenging medium-scale missions. Flexibly implemented Earth-orbiting and deep-space missions. Taking advantage of experiences gained from current small-satellite projects, we will work on making lightweight and advanced functions through advancement of satellites and probes. Includes various projects of equivalent scale.

Various small-scale projects

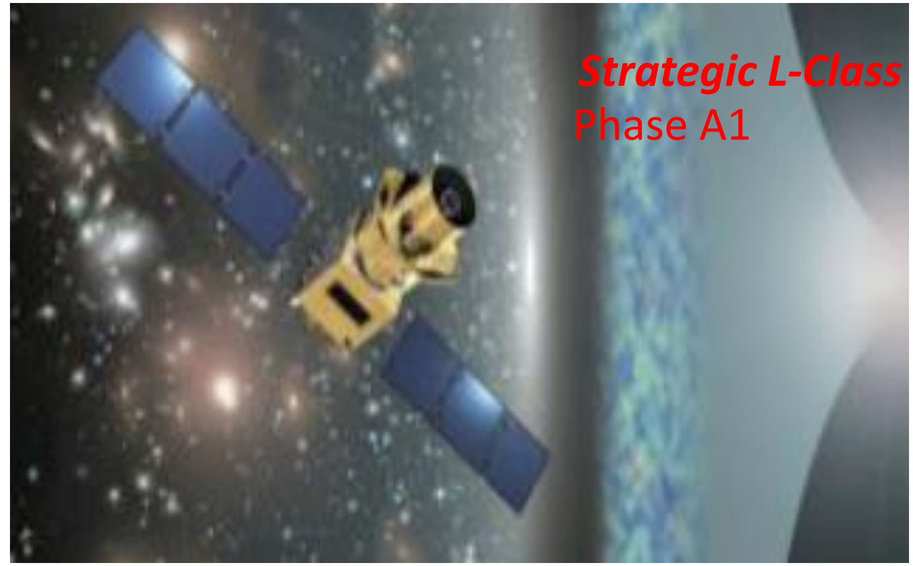
Maximize opportunities and generation of results through participation as a junior partner in overseas missions, domestic and international participation in flight opportunities such as satellites, small rockets and balloons, creation of small-scale flight opportunities, scientific research utilizing the ISS, etc.

Mission Roadmap for ISAS Space Science and Exploration Projects

Category	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024	FY 2025	FY 2026	FY 2027	FY 2028	FY 2029	FY 2030
Strategic Large Class		 Bepi Colombo			 XRISM			 MMX			 LiteBIRD OR  OKEANOS		 SPICA	
Competitive Medium Class					 SLIM	 Destiny+		scheduled Launch Candidates: • Small JASMINE • SOLAR-C EUVST • HiZ-GUNDAM			scheduled Launch		scheduled Launch	scheduled Launch
Participating as a junior partner in overseas missions						 JUICE					<Under Study> ATHENA WFIRST CAESAR etc  			

LiteBIRD

CMB B-mode polarization mission
Studies of B-mode polarization signals of comic microwave background radiation to detect evidence of primordial gravitational waves



■ **Science Objectives**

Search for primordial gravitational waves emitted during the cosmic inflation to test representative inflationary models.

■ **Primary Specifications**

Mission Devices: Polarization Modulator etc
Mass: 2.2 tons
Mission period: 3 years

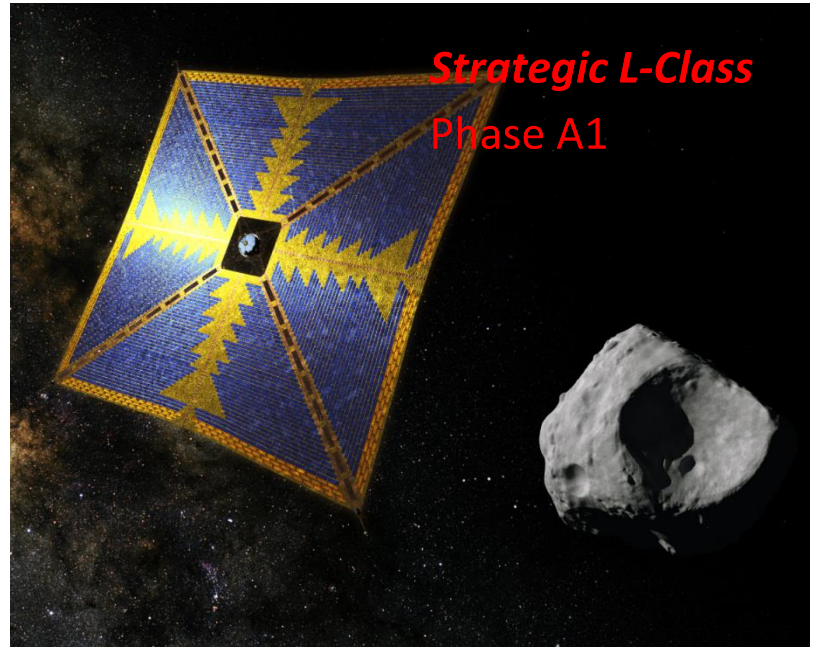
■ **Timelines**

FY2027 Launch (H3 Rocket)

■ **International collaboration with US and Europe**

Solar Power Sail Explorer (OKEANOS)

An engineering mission using a highly effective "hybrid" thrusting system to visit a Jupiter Trojan asteroid in the outer solar system without the RTG. Complementary to LUCY (multi-flyby of Jupiter Trojans, selected by NASA).



■ Science Objectives

1. Conduct an in-depth study of a Jupiter Trojan asteroid by remote sensing and in-situ measurements by astrochemistry oriented instruments onboard a lander.
2. Cruise science: Measurements are those that gain substantial benefit when made in the outer solar systems.

■ Primary Specifications

Mission setup:
Main Orbiter (Imager, LIDAR, NIR Imaging Spectrometer, MIR multiband imager & radiometer, Radar Tomographer, Radio Science)
Lander

Mass: 1.4 tons with a 100 kg lander

■ Timelines

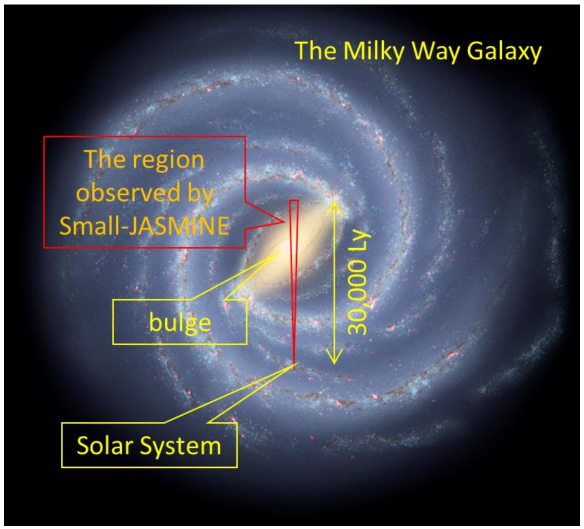
FY2027	Launch (Rocket TBD)
Launch + 5 year	Jupiter swing by
Launch + 11-12 years	Rendezvous a Trojan asteroid
Launch + 30 years	Sample return to earth (Optional)

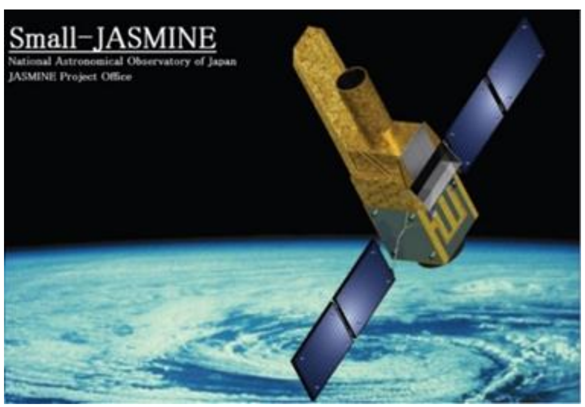
■ International collaboration

- DLR Lander（Under coordination)

Small-JASMINE (Japan Astrometry Satellite Mission for INfrared Exploration)
Infrared Astrometry Mission to Study Milky Way Formation

PI: Dr. N. Gouda (NAOJ)
ISAS Pre-Phase A2
(Mission Definition Phase)





Science Goals and Objectives, Uniqueness

- Studying the history of the formation and evolution of the Milky Way by high-precision ***astrometry*** of the bulge stars.
- Revealing the kinematical structure of the central 100-300pc; origins of inner bulge, bar, disk components, and the supermassive black hole.
- By observing in ***NIR*** wavelength, Small-JASMINE has the advantage in studying the Galactic central region attenuated by interstellar dust.
- Transit exoplanet observations of mid/late M-type stars as the secondary science target (in the period when the bulge is not visible)

- Precision goals: annual parallax 20μas for H_W<12.5 stars, and proper motion 125μas/yr for 12<H_W<15 stars
- Observation wavelength: 1.1-1.7um (H_W), 4Kx4K HgCdTe IR array
- Telescope: aperture size: 30cm
- Orbit: Sun Synchronous with the altitude >550km
- Mass of the satellite: about 400kg
- Launcher: **Epsilon** Launch Vehicle
- Observational period: 3 years

- Selection for JAXA Science Mission M-Class #3 (expected in 2019)
- Target Launch Opportunity: NET 2024
- Final catalogue release: 4 years after the launch

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Solar-C_EUVST

JAXA Epsilon M-class mission

A fundamental step towards answering how the plasma universe is created and evolves, and how the Sun influences the Earth and other planets in our solar system

Science objectives

I. **Understand how fundamental processes lead to the formation of the solar atmosphere and the solar wind**

II. **Understand how the solar atmosphere becomes unstable, releasing the energy that drives solar flares and eruptions**

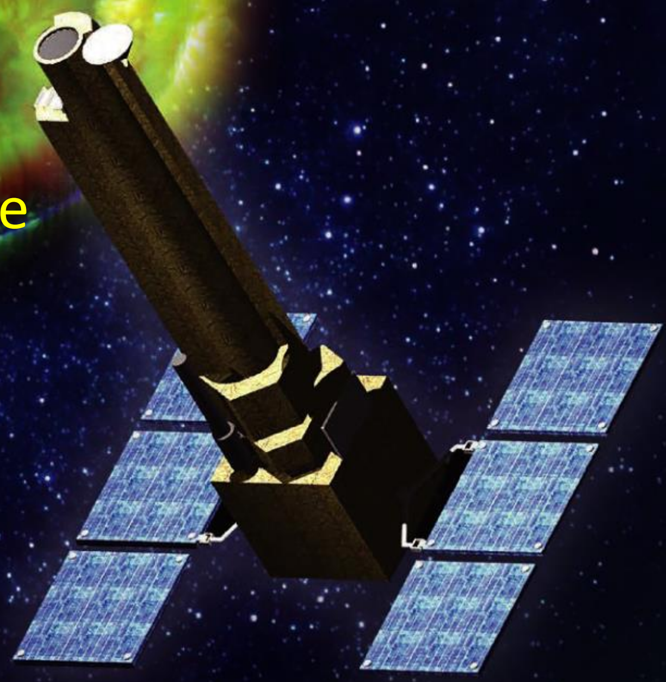
EUV high-throughput Spectroscopic Telescope

to quantify how mass and energy are transferred with 1st-ever capabilities to

A) Seamlessly observe the solar atmosphere as a single, coupled system from photosphere to chromosphere to corona and to flares (10^4-10^7 K)

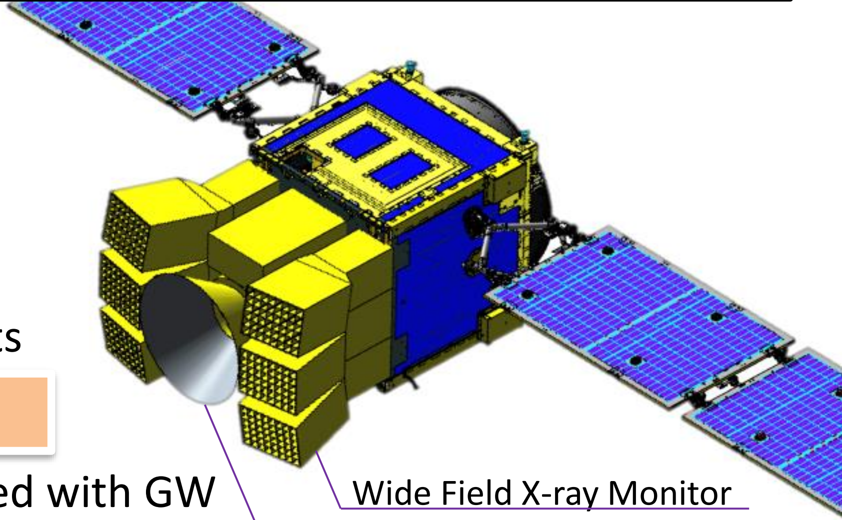
B) Resolve elemental structures and track their changes with sufficient cadence (0.4”, 1 sec cadence)

C) Obtain spectroscopic information on dynamics of elementary processes (V, ρ, T, composition, ionization)



High-z Gamma-ray bursts for Unraveling the Dark Ages Mission

Mission Aim: Strong Promotion of
"**Time Domain**" & "**Multi-Messenger Astronomy**".



Wide Field X-ray Monitor
- Lobster Eye Optics
- CMOS imaging sensor

Near Infrared Telescope
- Offset Gregorian Optics
- simultaneous 4-band photometry

Key Science1: Probing the Early Universe

- Detection of high-redshift GRBs ($9 < z < 12$)
- Probing the reionization history and first metal elements

Key Science2: Progress of Gravitational Wave Astronomy

- Localization of X-ray transient and macronova associated with GW
- Energy transition from jet – cocoon – macronova

Observation Strategy

(1) Discovery of high-energy transient with Wide Field X-ray Monitor
(2) Automatic/Comprehensive follow-up with Near Infrared Telescope
(3) Sending Quasi-Realtime Alert Messages
(4) Spectroscopy with Large Area Telescopes for selected events

Wide Field X-ray Monitor

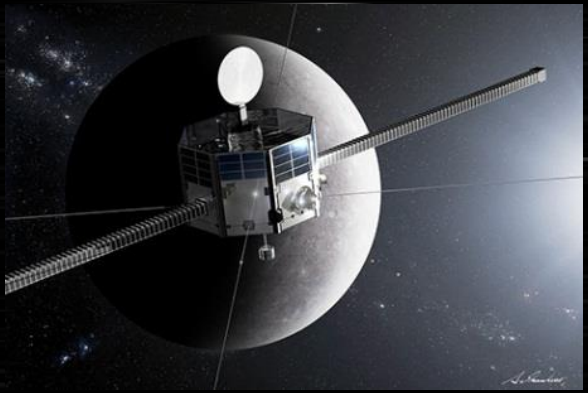
Items	Parameters
Energy band (keV)	0.4 – 4 keV
Field of View	~ 1.2 str (6 units)
Sensitivity	1e-10 (erg/cm2/s) For 100 sec exposure
Point Spread Function	3 arcmin
Angular accuracy	~ 60 arcsec

Near Infrared Telescope

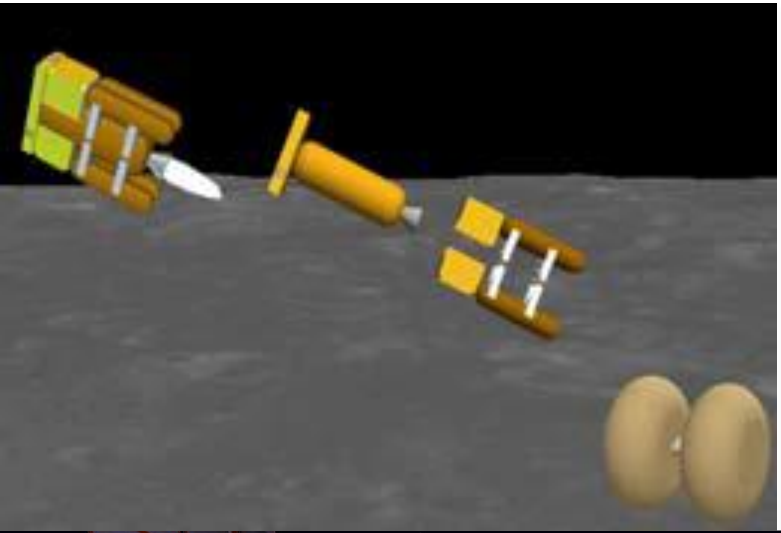
Items	Parameters			
Aperture size	30 cm			
Field of view	34 arcmin ×34 arcmin			
Integration time	10 minutes (2 minutes x 5 frames)			
Observation Band (μm)	0.5–0.9	0.9–1.5	1.5–2.0	2.0–2.5
Limiting Magnitude (AB) 10 min exposure, S/N=10	21.4	21.3	20.9	20.7

BepiColombo

- ✓ JAXA developed Mercury Magnetospheric Orbiter, named « MIO»
- ✓ launched from Kourou
  on Ariane 5, October 2018.
- ✓ Reaching Mercury in 2025

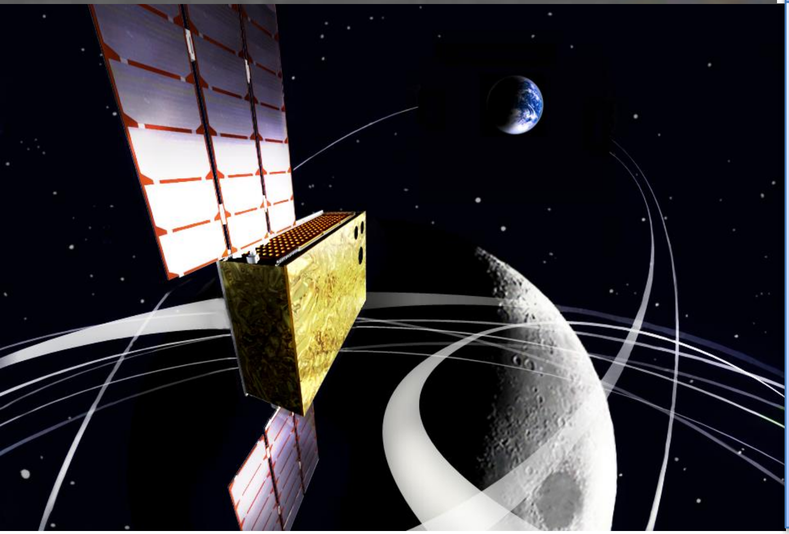


SLS-EM1 CubeSats (OMOTENASHI, EQUULEUS)



OMOTENASHI
(Outstanding MOon exploration TEchnologies demonstrated by NAno Semi-Hard Impactor)

Mission objectives
- ✓ Development of the smallest lunar lander in the world. The technologies will enable multi-point observation with low cost.
- ✓ Observe radiation environment in cis-lunar region.



EQUULEUS
(EQUilibriUm Lunar-Earth point 6U Spacecraft)

Mission Objectives
- ✓ Trajectory control demonstration within Sun-Earth-Moon region
- ✓ Imaging of the Earth's plasmasphere
- ✓ Lunar impact flash observation
- ✓ Dust detection at EML2

(Developed by JAXA and University of Tokyo)

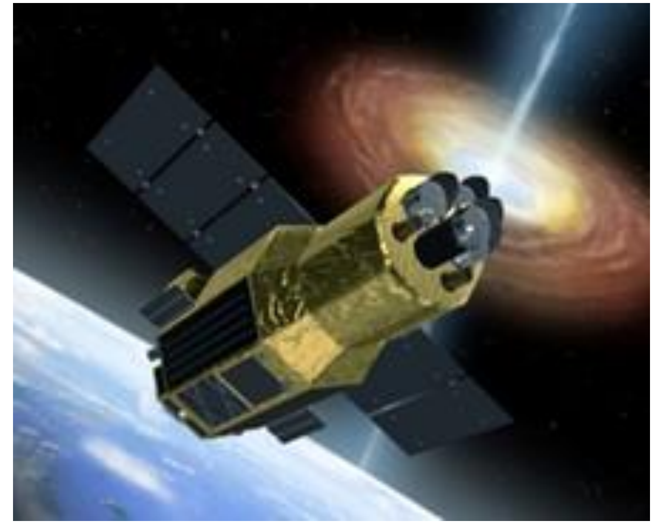
- ➢ Launch: 2020(!?)

X-Ray Imaging and Spectroscopy Mission (XRISM)

Recovery mission of the ASTRO-H.
Pioneering new horizon of the Universe with unprecedented high resolution X-ray spectroscopy

Strategic L-Class

Phase C



■ Science Objectives

1. Structure formation of the Universe and evolution of clusters of galaxies
2. Circulation history of baryonic matters in the Universe
3. Transport and circulation of energy in the Universe
4. New science with unprecedented high resolution X-ray spectroscopy

■ Primary Specifications

Mission Instruments: Soft X-ray Spectrometer, Soft X-ray Imager

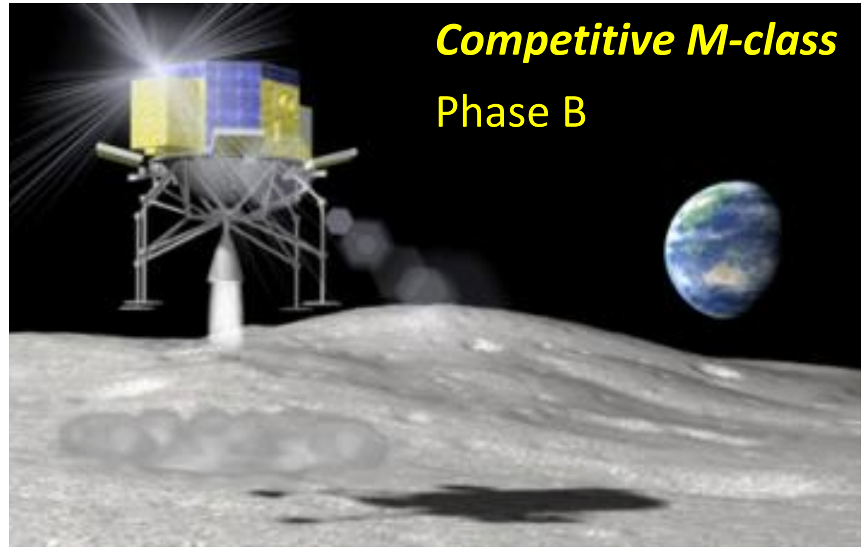
■ Timelines

FY2018 Transition to the JAXA project
FY2021 Launch on H2A (w/SLIM)

■ International collaboration with NASA and ESA (SRON)

Smart Lander for Investigating Moons (SLIM)

Technical demonstration of a precise lunar landing by a small spacecraft.
Reduce size and weight by adopting ideas from conventional satellite and explorer designs.
Application of private-sector technologies.



■ Expected results

1. Acquire technologies that are essential to become a member in the international space exploration.
2. Pinpoint landing technologies.
3. Focused science enabled by precise landing to a spot of significant interest from planetary science perspective.

■ Timelines

FY2021 Launch on H2A (w/XRISM)

■ Primary Specifications

Mass: 120kg dry, 520kg with propellant
Operational period: Several months (Planned)
Science instruments:
Multi-band camera for mineralogical characterization
Science target:
Characterization of rocks from deep interior

Martian Moons eXploration (MMX)

Sample return from one of the two Mars satellites (Phobos and Deimos) to Earth for detailed analysis. A key element in the ISAS roadmap for small body exploration.

■ Science Objectives

1. Origin of Mars satellites.
   - Captured asteroids?
   - Accreted debris resulting from a giant impact?
2. Preparatory processes enabling to the habitability of the solar system.

■ Timelines

FY2024 Launch
2025 Mars Arrival
2029 Return to Earth

■ Launch Mass : 3400kg

Three stages system.
Return module: 1350kg
Exploration module: 150kg
Propulsion module: 1900kg

■ International collaboration

•CNES
- Near-infrared Spectrometer
- Flight Dynamics
- Small Rover (w/DLR)

•NASA
- Gamma-ray and Neutron Spectrometer (MEGANE)
- Use of DSN, Test Facilities, etc.

•ESA : Ka comm

•DLR :
- Rover (w/CNES),
- Test Facilities (incl. Drop Tower)

Destiny+

Acquire navigation and exploration technologies for leading space engineering
Contribute to the development of the next generation of deep space missions.
In-situ analysis of interstellar dust and interplanetary dust particles during the cruise, flyby observations of 3200 Phaethon, a dust releasing active asteroid.

■ **Expected results**

1. Expanding the range of applications for electric propulsion
2. Realizing compact avionics
3. Acquiring advanced fly-by exploration technologies
4. Elucidating the primordial material transport processes via dust particles (into the solar system and across the solar system)
5. The first observations of an active asteroid

■ **Timelines**

FY2021+ Launch

■ **International collaboration**

- DLR : Dust Analyzer

Next-Generation Infrared Astronomy Mission SPICA

***ESA-JAXA joint mission* for the next-generation large aperture cryogenic infrared telescope for astrophysics. SPICA studies enrichment of the Universe with metal and dust, leading to the formation of habitable worlds.**

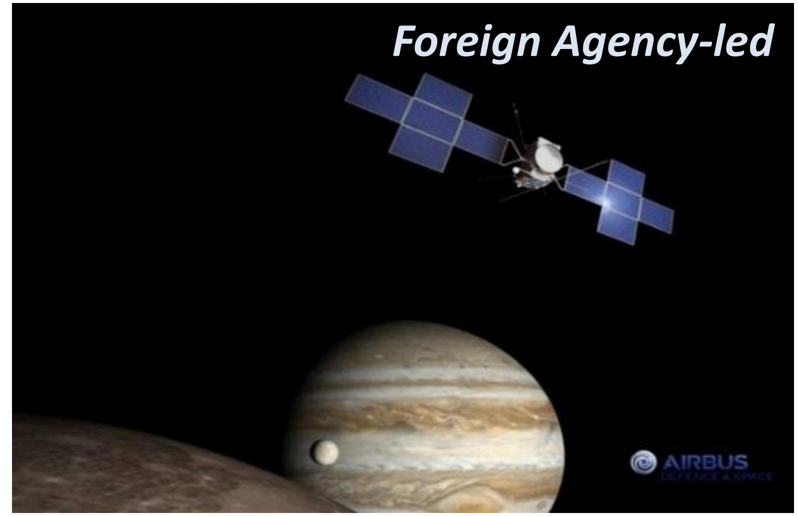
■ Science Objectives

1. Studies of the processes of metal and dust enrichment and their interplay with star formation and AGN activities through galaxy evolution.
2. Studies of the processes of gas dissipation and dust evolution in planet-forming disks at various stages.

■ Current Status

1. At JAXA, SPICA passed Mission Design Review and is conducting Phase A Study.
2. At ESA, SPICA was selected as one of candidates for Cosmic Vision M5.
3. Launch target: ~2030

Jupiter Icy Moons Explorer (JUICE)



Origin and evolution of large gaseous planet systems.
Formation conditions for subsurface oceans of icy moons.
Jovian magnetosphere, the strongest accelerator in the solar system.
JAXA will develop and supply 3 of the 11 observation instruments (RPWI, GALA, and PEP/JNA) and participate in science from 2 instruments (JANUS and J-MAG).

■ **Science Objectives**

1. Understanding the origin of Jupiter leading to a better understanding of exoplanet formation
2. Investigation of potential habitability offered in a shape totally different from the terrestrial case, leading to explorations of extraterrestrial life
3. Revealing cosmic particle acceleration processes in the Jovian magnetosphere, the strongest accelerator in the solar system

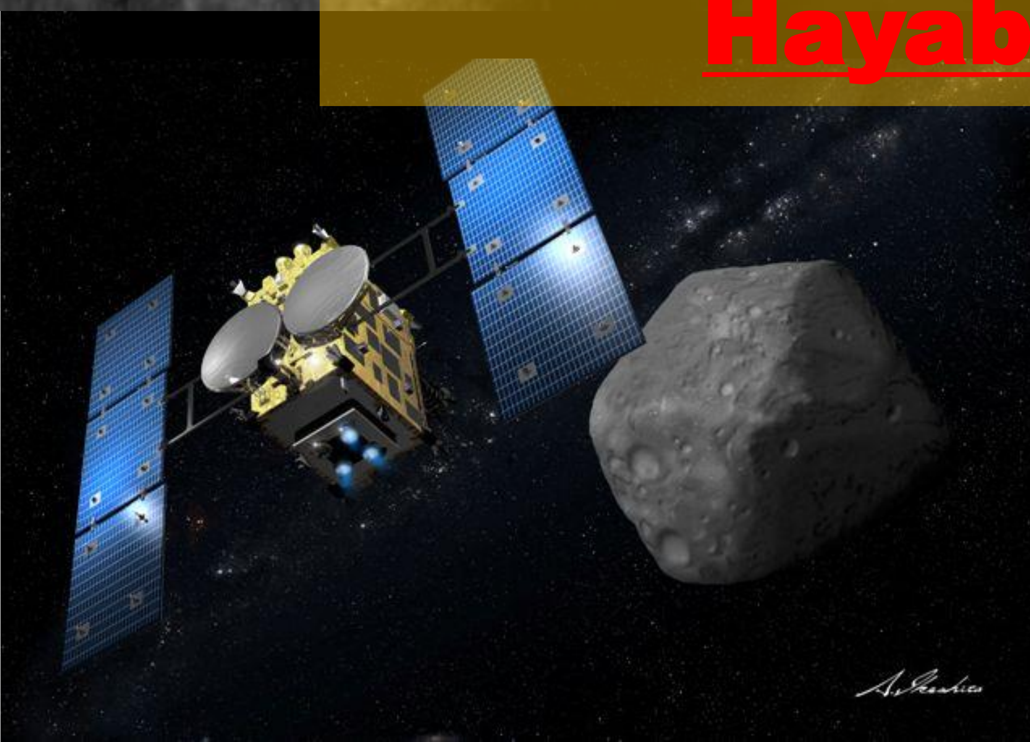
■ **Primary Specifications**

RPWI: Detection of radio signals emitted by particle acceleration processes
GALA: Measurements of tidal deformation of Ganymede to constrain the interior structure
PEP/JNA: Detection of neutral atoms coming from the surfaces of icy moons.

■ **Timelines**

2022	Launch (Rocket: Arian)
2030	Arrival at Jupiter
2032	Entry to orbit around Ganymede
2033	Mission completion

Hayabusa2

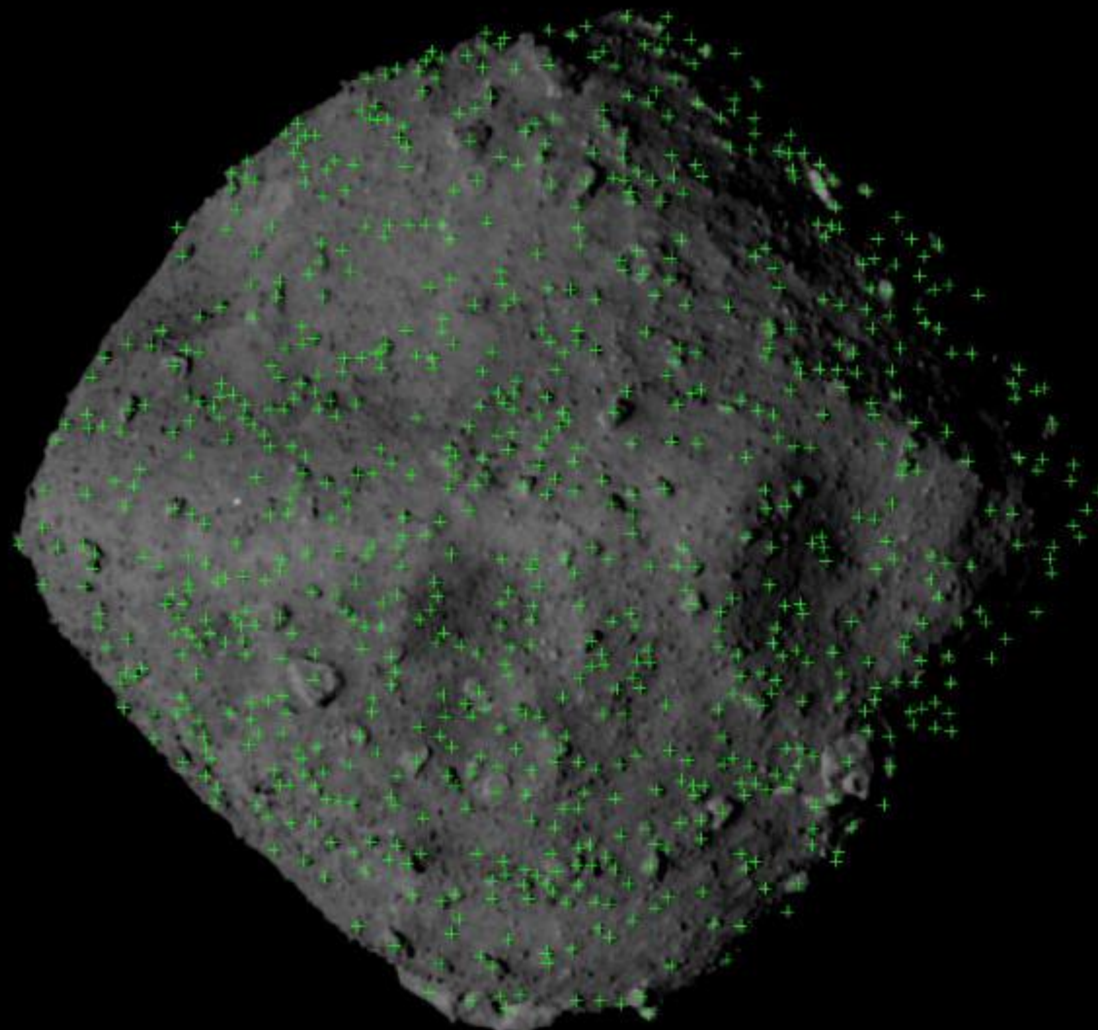


Arrival at Ryugu

Where are landing points???

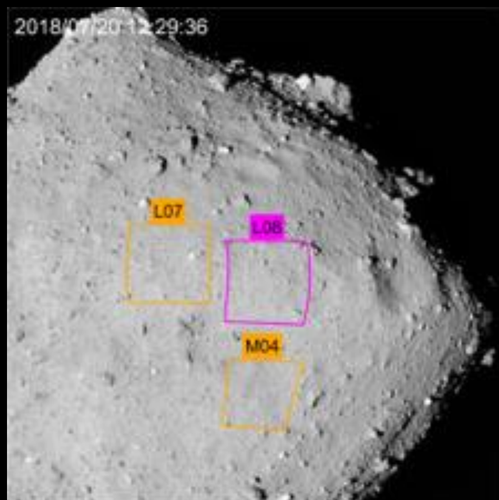
High boulder coverage

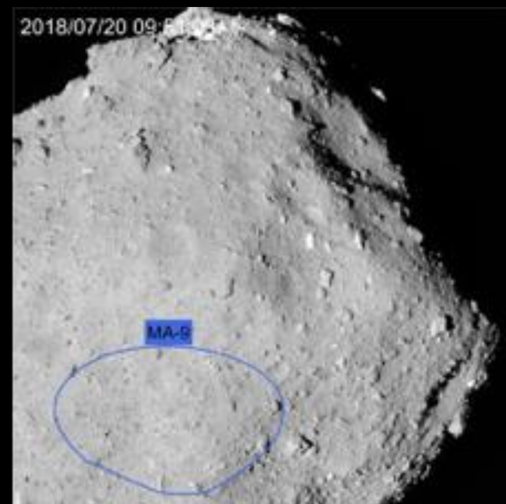
(Green marks identified boulders between 8m to more than 10m)

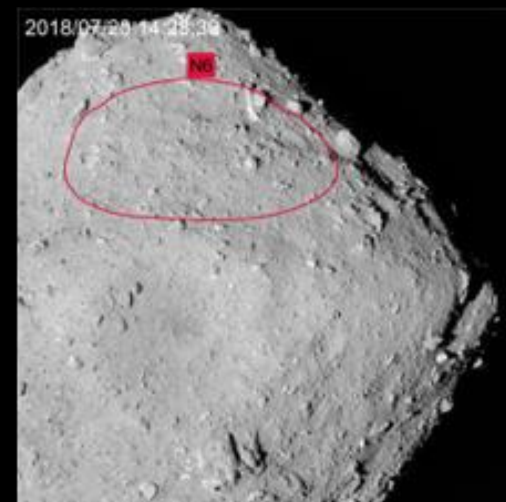


(JAXA, University of Tokyo and collaborators)

Initial Targets were selected.







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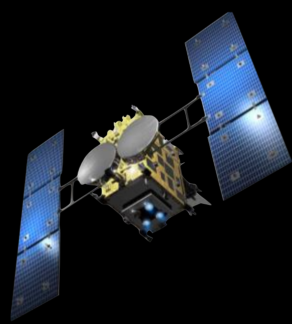
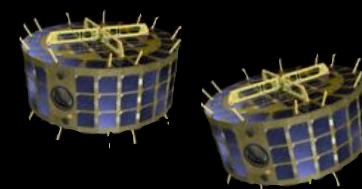


Mascot

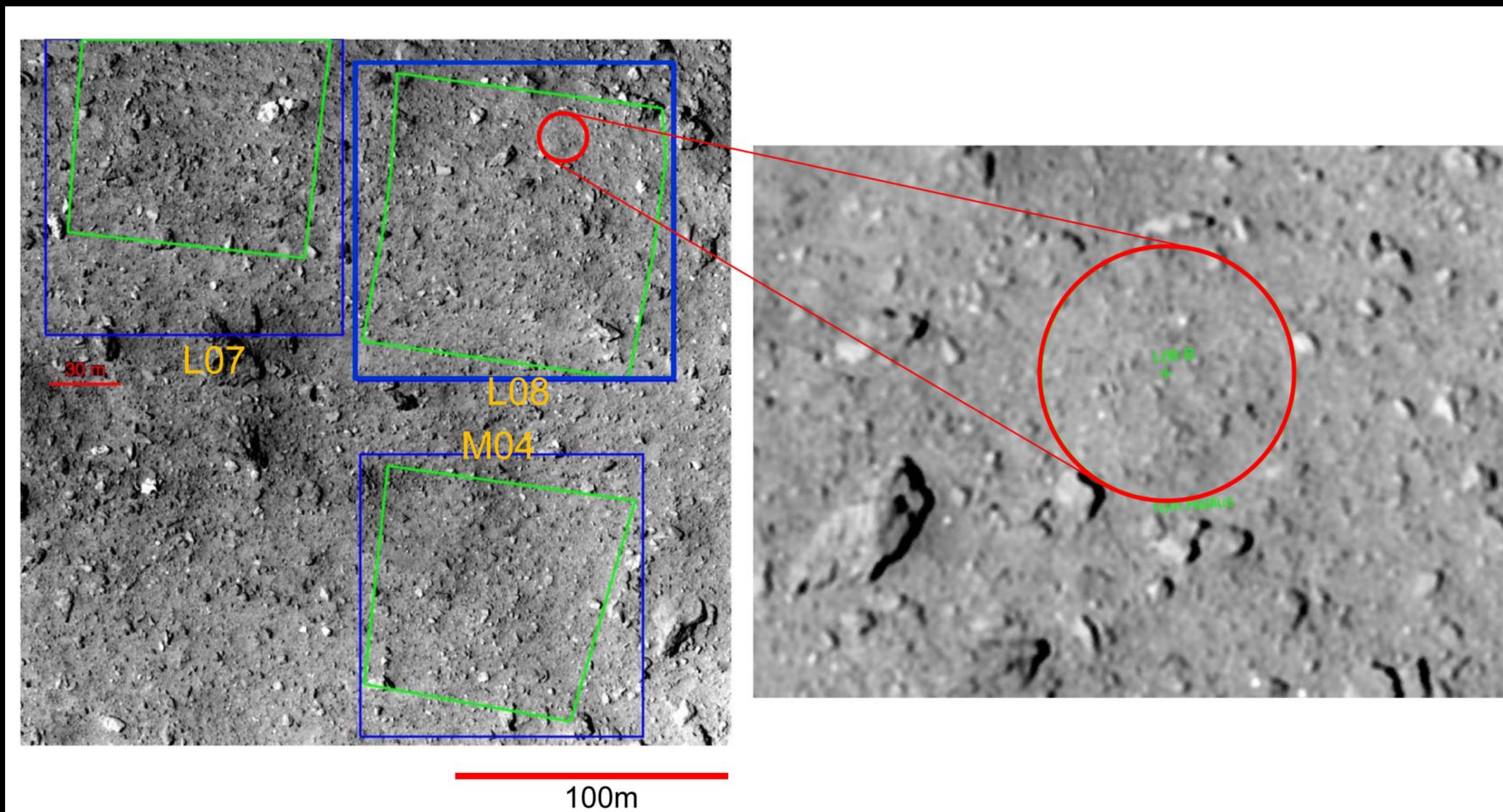


MINERVA-II
1a/1b

RYUGU Surface View from MINERVA-II 1

September 23, 2018: Rover-1B

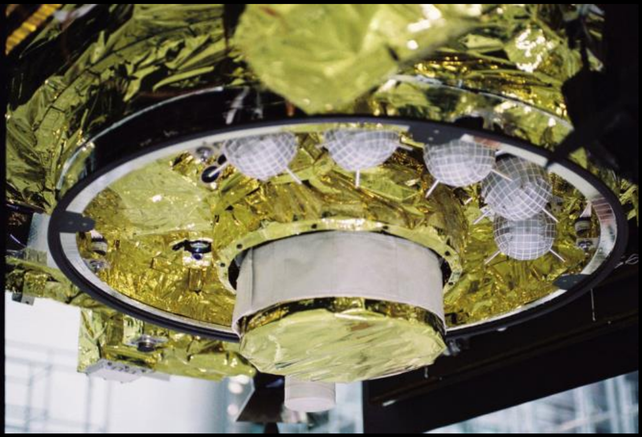
Landing/Touchdown site:
Original Allowance 100m x 100m
→ Narrowed down to 20m diameter circle

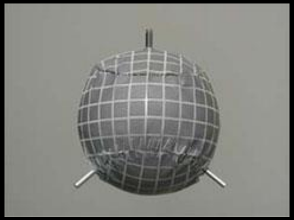


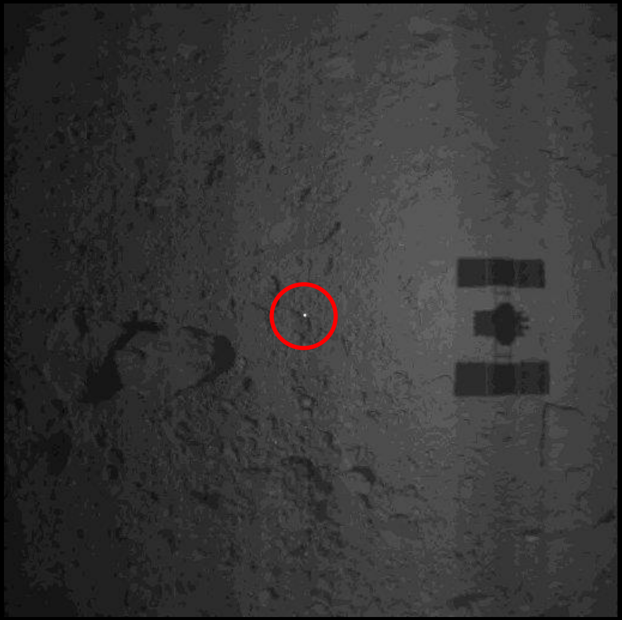
The original plan:
- First Touch-Down (TD1) and sampling at the end of Oct 2018
- Three TDs in total
- Pin-point landing utilizing a Target Marker (TM) to be performed at the TD3 (after creating a crater by impactor)

The team changed the plan to
- Postpone TD1 to early 2019
- Introduce pin-point landing technique for TD1

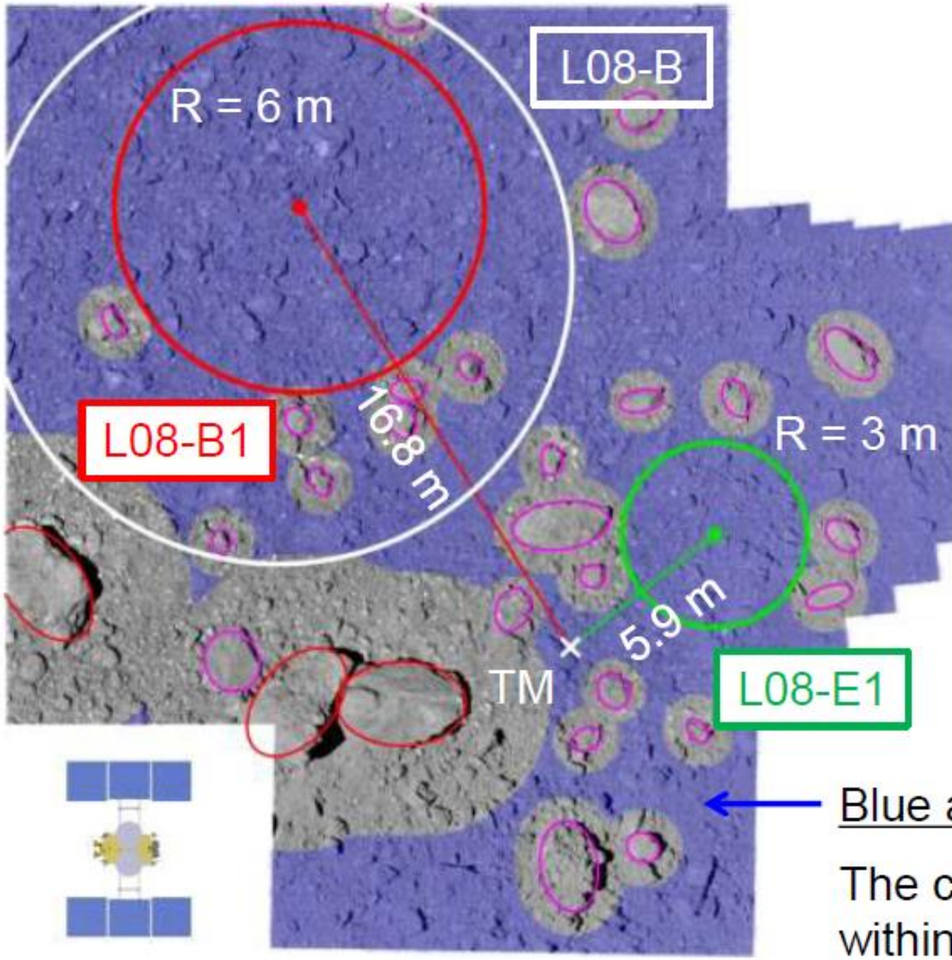
The first Target Marker (TM) was released late Oct 2018.







Imaged on Oct 25, 2018, 11:47 JST.
Hayabusa2 altitude 20m.



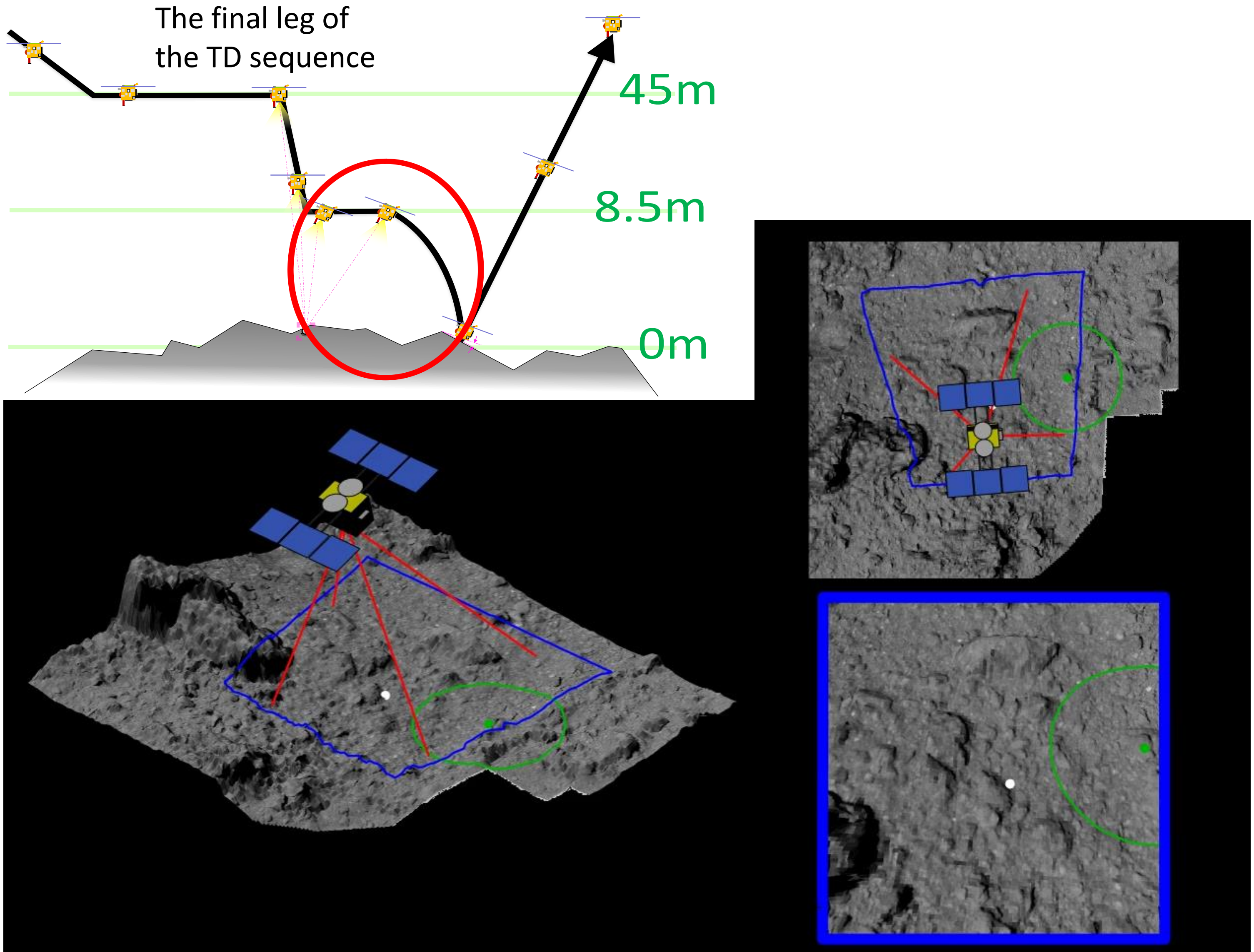
Feasible landing sites:

I. L08-E1 ← TD1 target

~~II. L08-B1 (with an additional TM)~~

Blue area = Safe area

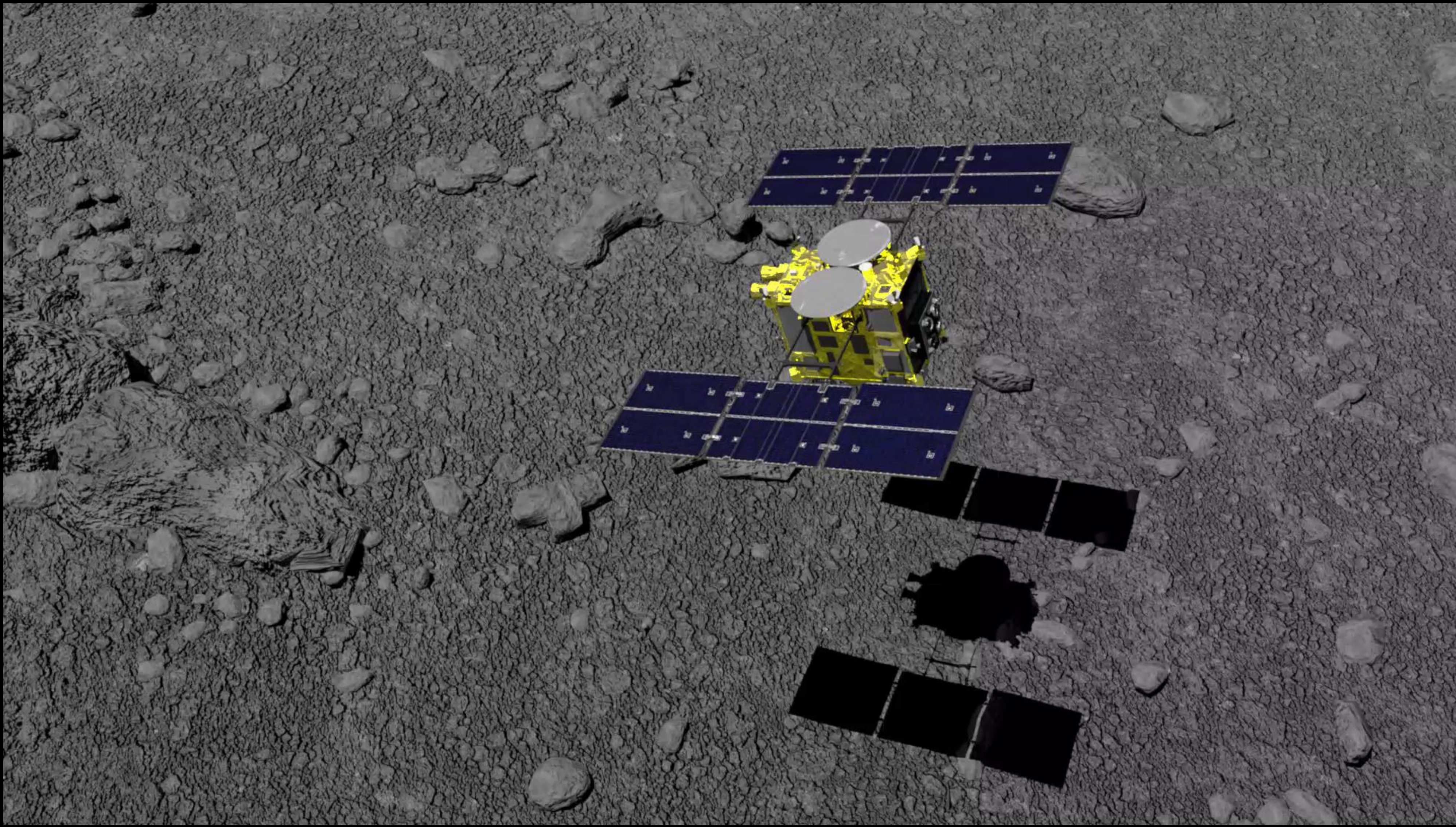
The center of the s/c must be located within this area.



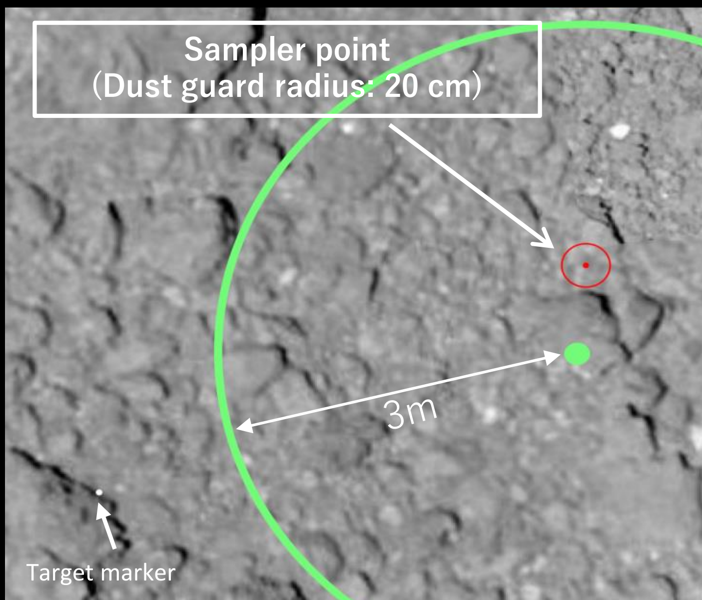
JAXA)

The Moment of Touchdown!
(22 February, 2019)

The touchdown should have happened like;

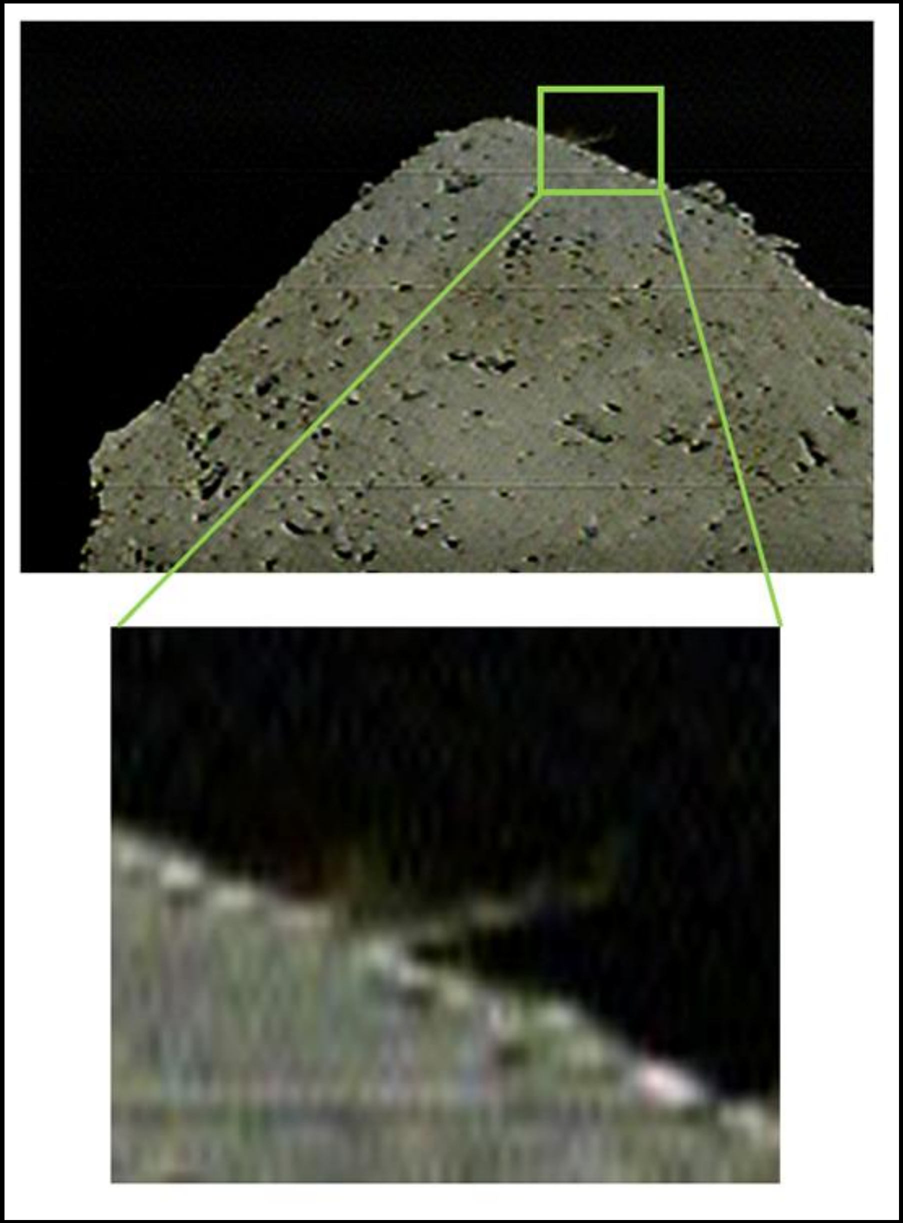


Images taken during the ascent



Landing error 1.08m

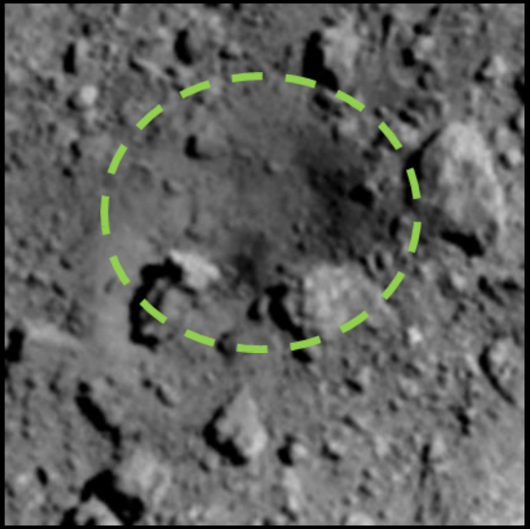
The next exiting operation;
Impactor to create a crater on the surface (5th April, 2019)



Ejection was observed!

And..., we made it!!

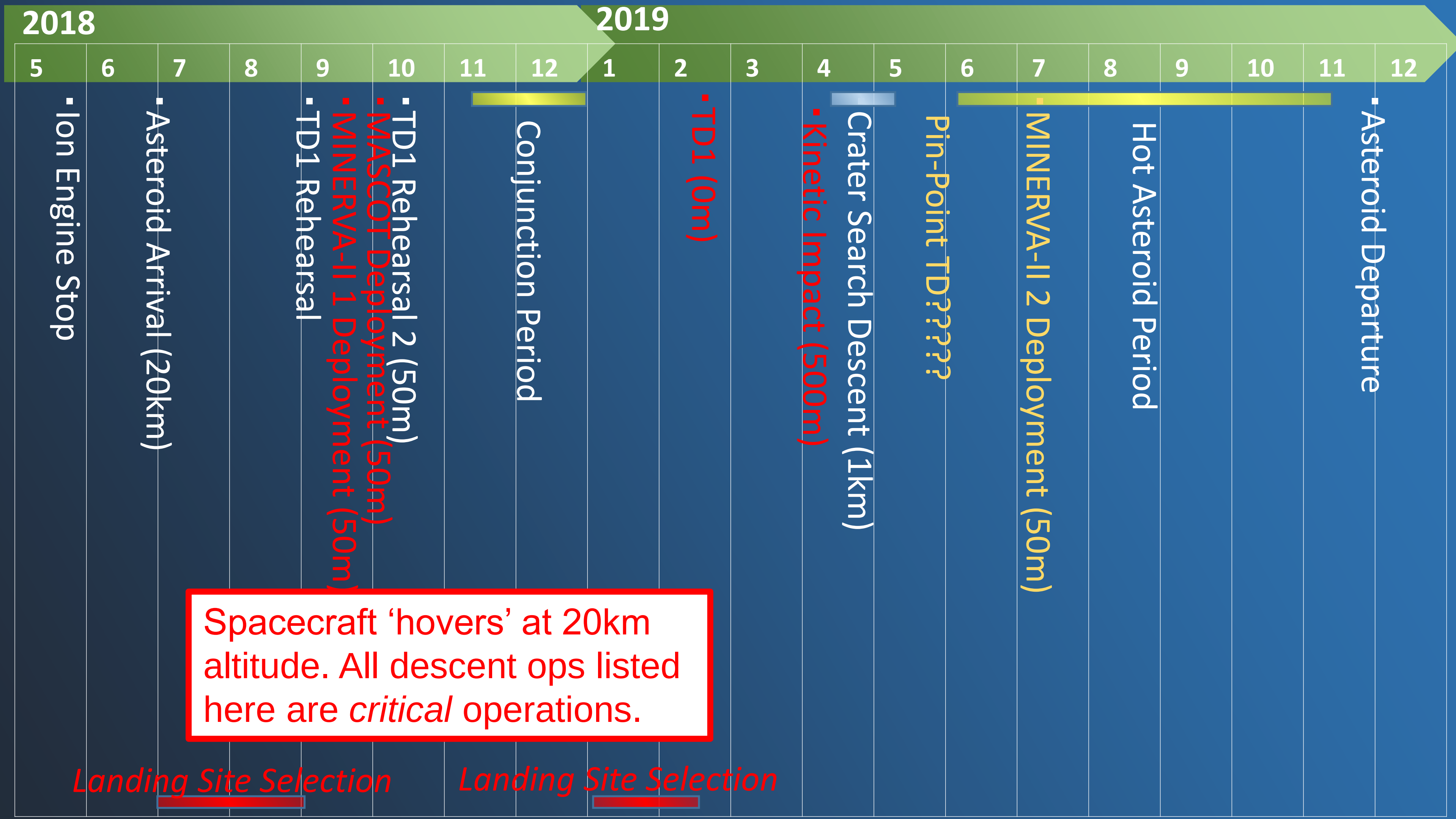
Before [22 March]



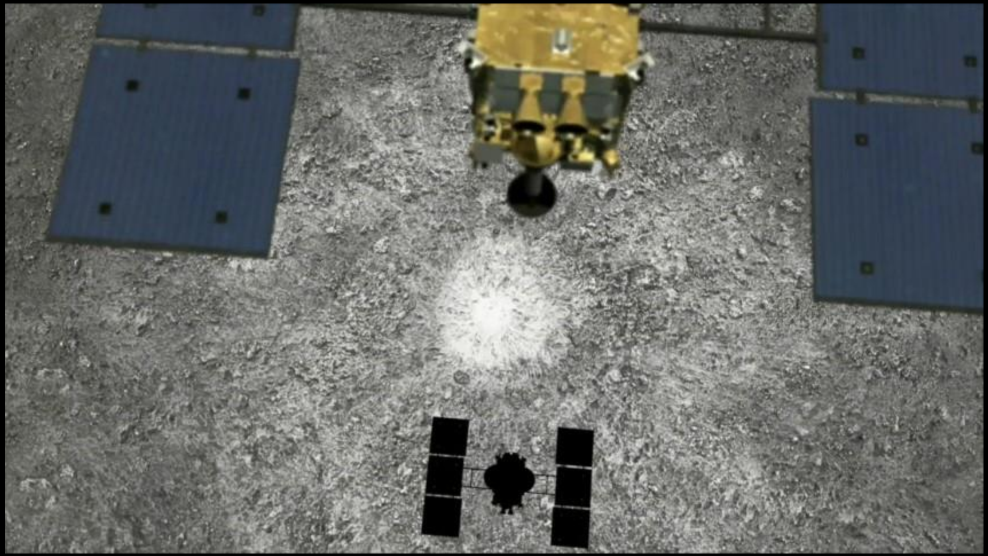
After [25 April]

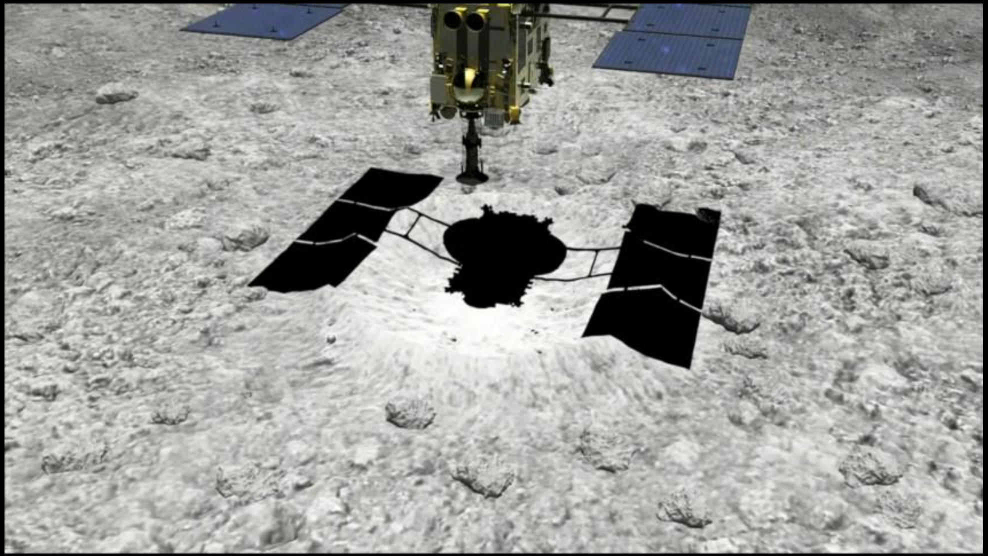
Crater was confirmed on the surface!!

Proximity Operation Plan



We are discussing;
Whether/Where/When/How to land next?





We'll keep you updated at;
http://www.hayabusa2.jaxa.jp/en/