JAXA Space Science Program and International Collaboration

Institute of Space and Astronautical Science
Japan Aerospace Exploration Agency

Yoshio Toukaku
Director for International Strategy and Coordination
ISAS/JAXA

May, 2018

Japan's Space Activities Structure

Strategic Headquarters for Space Policy (Basic Plan for Space Policy)

Cabinet Office（National Space Policy Secretariat）

- **Space Policy Committee** *(Discussion on the Review of Basic Plan for Space Policy)*

Ministry of Education, Culture, Sports, Science and Technology (MEXT)

Ministry of Internal Affairs and Communications (MIC)

Ministry of Economy, Trade and Industry (METI)

Ministry of Defense

Other Ministries

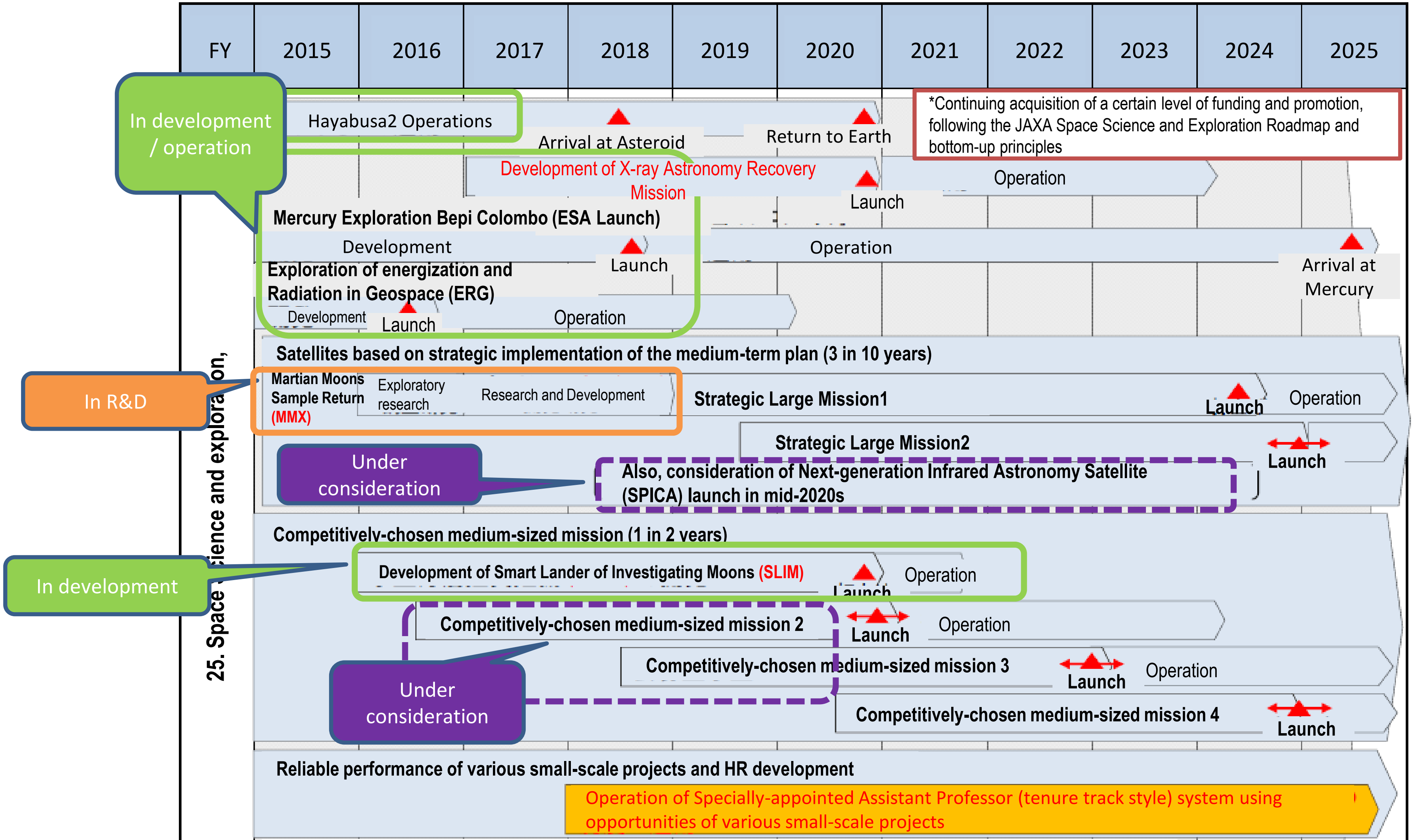
Mid-Term Goals

JAXA

Mid-Term Plan

From Space Basic Planning Schedule
(rev. December 12, 2017, Space Decelopment Strategy (HQ))

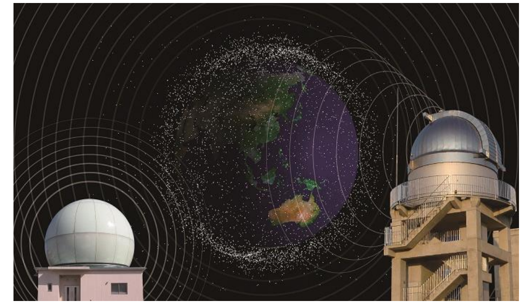
4.（2）① Space Science, exploration, and manned space activities

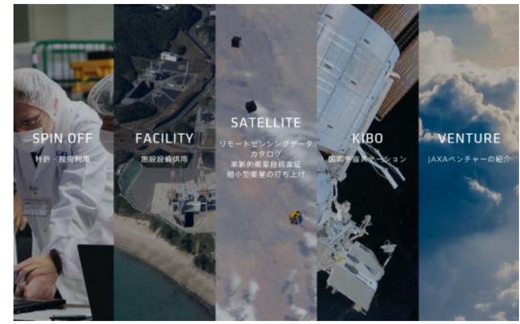


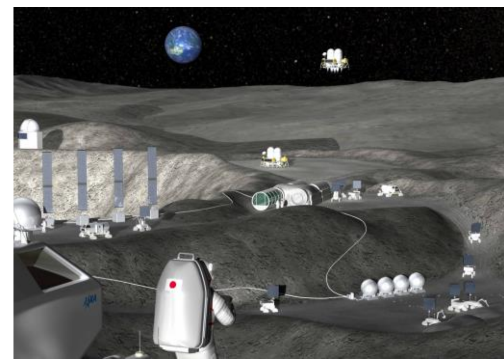
*In the field of solar explorer science, proceed with both bottom-up exploration and programmatic exploration
*All of the above by the Ministry of Education, Culture, Sports, Science and Technology

JAXA Mid-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







JAXA Organization Chart

Hiroshi YAMAKAWA
President

General Auditor — **General Auditor Office**

Shizuo YAMAMOTO
Senior Vice President

- Strategic Planning and Management Department
- Chief Engineer Office
- Safety and Mission Assurance Department

Yasuhiro FUNO
Vice President
Director General

- **Space Technology Directorate I**
- Spectrum Management Office
- Space Tracking and Communications Center
- Environmental Test Technology Unit

Ryoich IMAI
Vice President
Director General

- **Space Technology Directorate II**
- **Research and Development Directorate**
- Tsukuba Space Center Administration Department

Koichi WAKATA
Vice President
Director General

- **Human Spaceflight Technology Directorate**
- Exploration Innovation Hub Center

Hitoshi KUNINAKA
Vice President
Director General

- **Institute of Space and Astronautical Science (ISAS)**

Hisashi SANO
Vice President
Director General

- **Aeronautical Technology Directorate**

Masato NAKAMURA
Vice President

- General Affairs Department
- Evaluation and Audit Department
- Public Affairs Department
- International Relations and Research Department
- New Enterprise Promotion Department

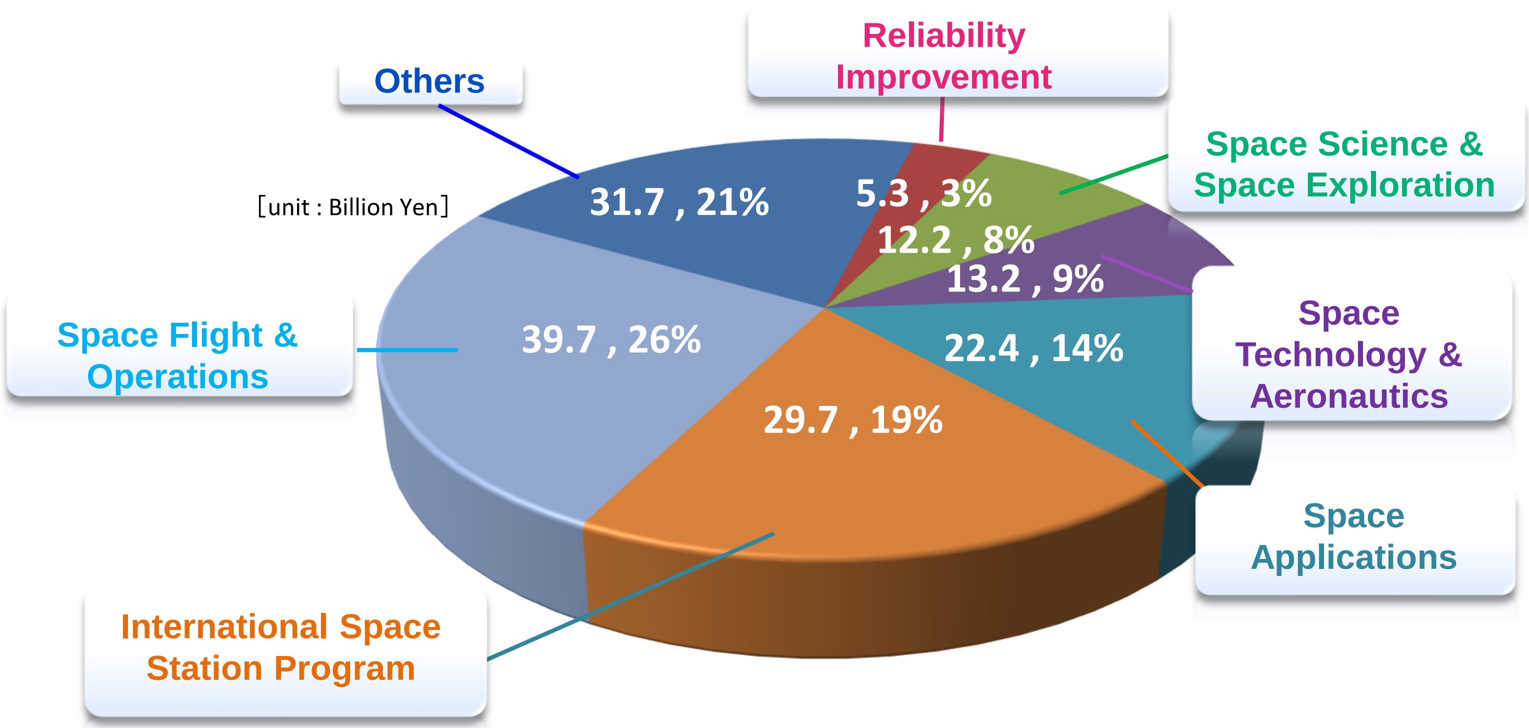
Kazuhiro SUZUKI
Vice President

- Human Resources Department
- Finance Department
- Procurement Department
- Ground Facilities Department
- Work-Life Support and Diversity Office
- Security and Information Systems
- Department Space Education Office

As of April 1, 2018

FY2018 JAXA Annual Budget

- FY2018 JAXA Budget : 183.1 Billion Yen (Approx. $1.66 B)
- Compared to the previous fiscal year: +0.8%

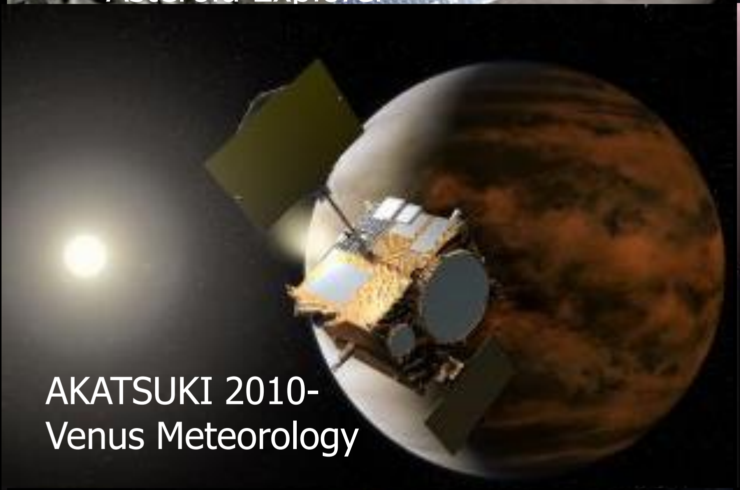


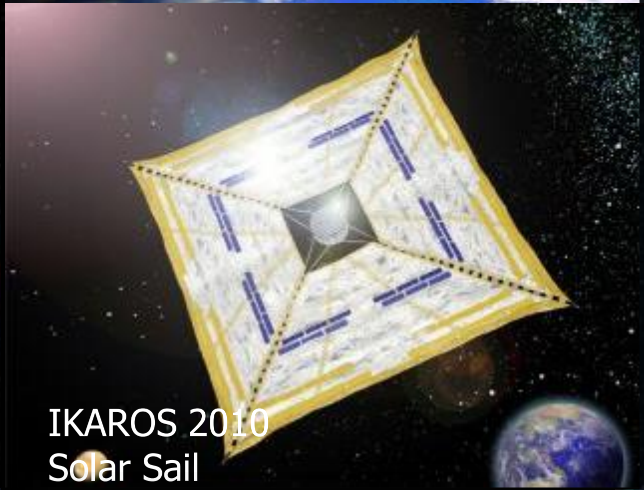
JAXA recent science missions

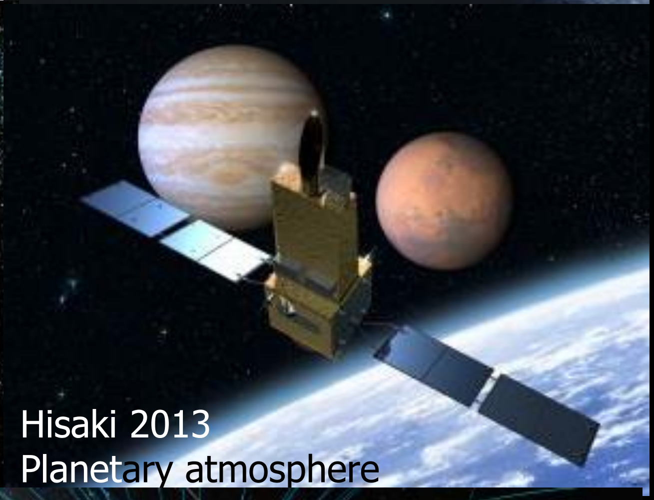

HAYABUSA 2003-2010
Asteroid Explorer


HINODE(SOLAR-B)2006-
Solar Observation

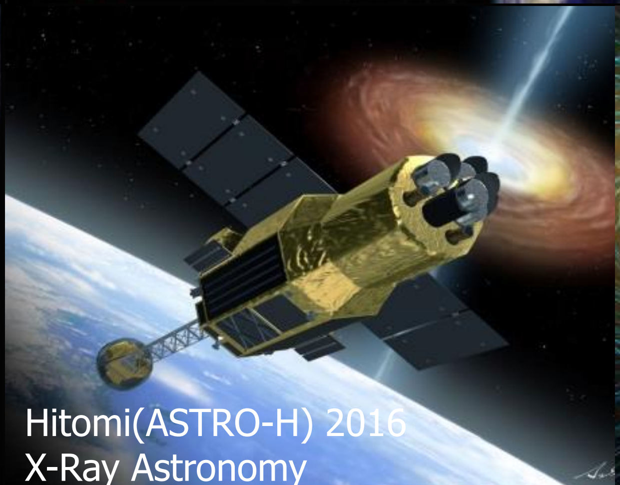

KAGUYA（SELENE)2007-2009
Lunar Exploration

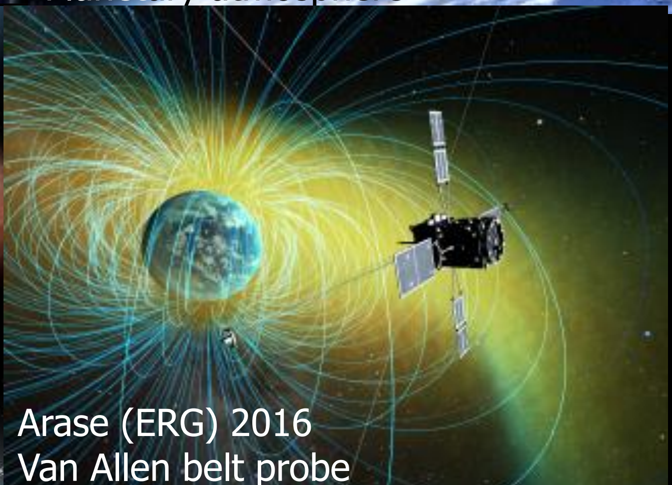

AKATSUKI 2010-
Venus Meteorology


IKAROS 2010
Solar Sail


Hisaki 2013
Planetary atmosphere


HAYABUSA2 2014-2020
Asteroid Explorer


Hitomi(ASTRO-H) 2016
X-Ray Astronomy


Arase (ERG) 2016
Van Allen belt probe

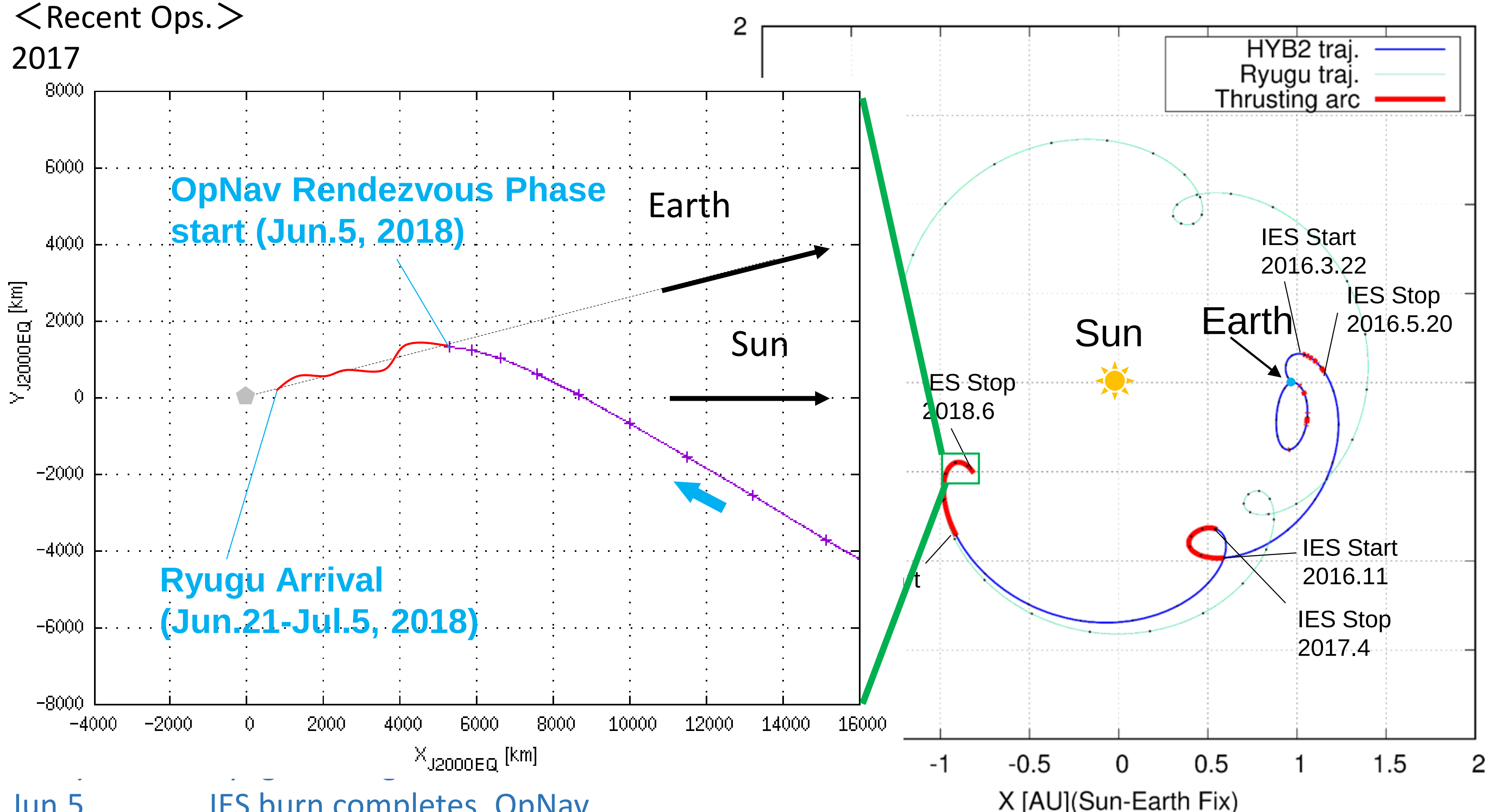
Hayabusa2

- ✓ Sample return from a primordial asteroid ***Ryugu*** (formerly 1999JU3).
- ✓ Small lander ***MASCOT*** provided by ***DLR/CNES*** for surface spectroscopy with microscope.
- ✓ ***Small Carry-on Impactor*** to expose fresh subsurface materials

Recent / Near Future Cruise Operation

＜Recent Ops.＞

2017



Jun.5 IES burn completes. OpNav begins.

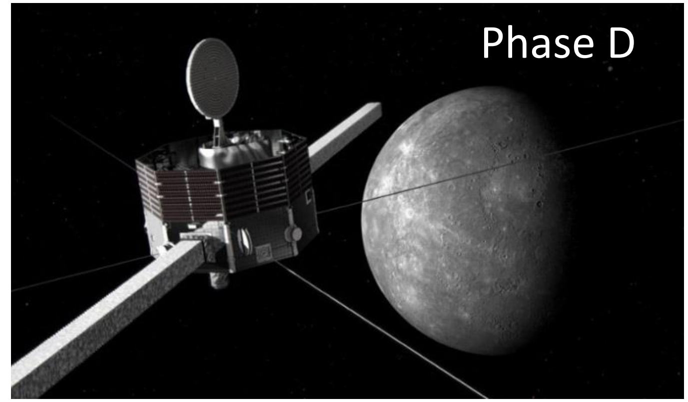
Proximity Operation Plan

Typical plan, Actual schedule fixed after arrival

Spacecraft 'hovers' at 20km altitude. All descent ops listed here are *critical* operations.

Bepi Colombo

The two spacecraft mission to the mysterious planet Mercury to make comprehensive observation of its magnetic field, magnetosphere, interior, and surface layer.
First full-scale international joint mission between Japan and the European Space Agency (ESA).



■ Contribution by JAXA / ESA

Japan: Mercury Magnetospheric Orbiter (MMO) (Dedicated observations of solar wind, magnetic field, magnetosphere, atmosphere and space weather effects)

ESA: Mercury Planetary Orbiter (MPO) (Full-sphere measurements of Mercury's surface topography, mineral and chemical composition, and gravitational field)

■ Science Objectives

1. Provide a big leap forward in understanding of the universality or specificity of planetary magnetic fields and magnetospheres.
2. Contribute to the elucidation of solar system formation, especially the origin and evolution of Earth-like planets.

■ Primary Specifications

Mass	280kg
Orbit	Elliptical polar orbit
Observation period	1 year

■ Timelines

2018/10	Launch (Arian 5)
2025	Arrival at Mercury

Promotion Strategies for Space Science and Exploration Projects

From the Space Policy Committee 7th Meeting of Space Science and Exploration Committee（19 Sep 2013）Material 1, “Space Science and Exploration Roadmap”)

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-scale missions

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

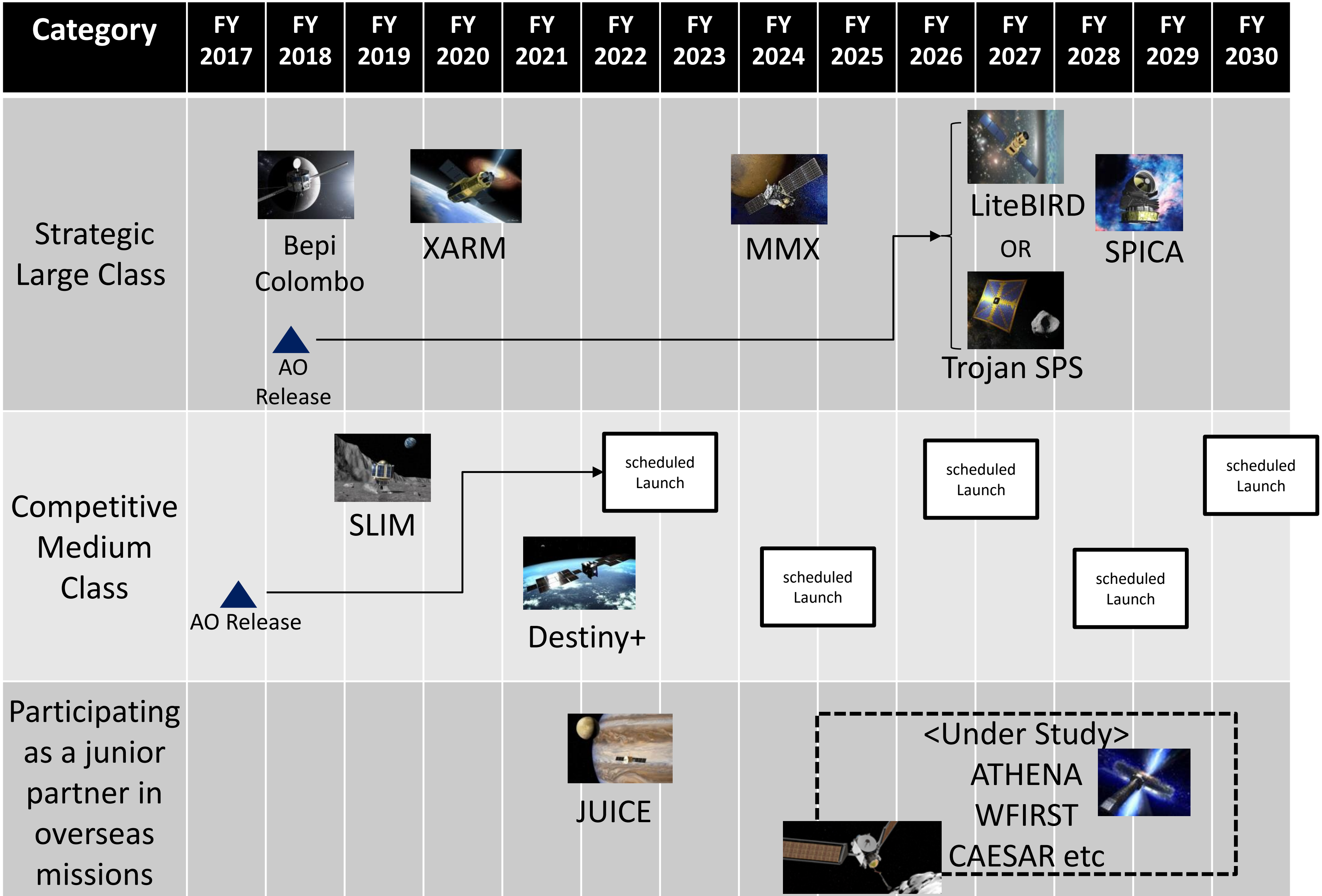
Competitively-chosen Medium-scale missions

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.

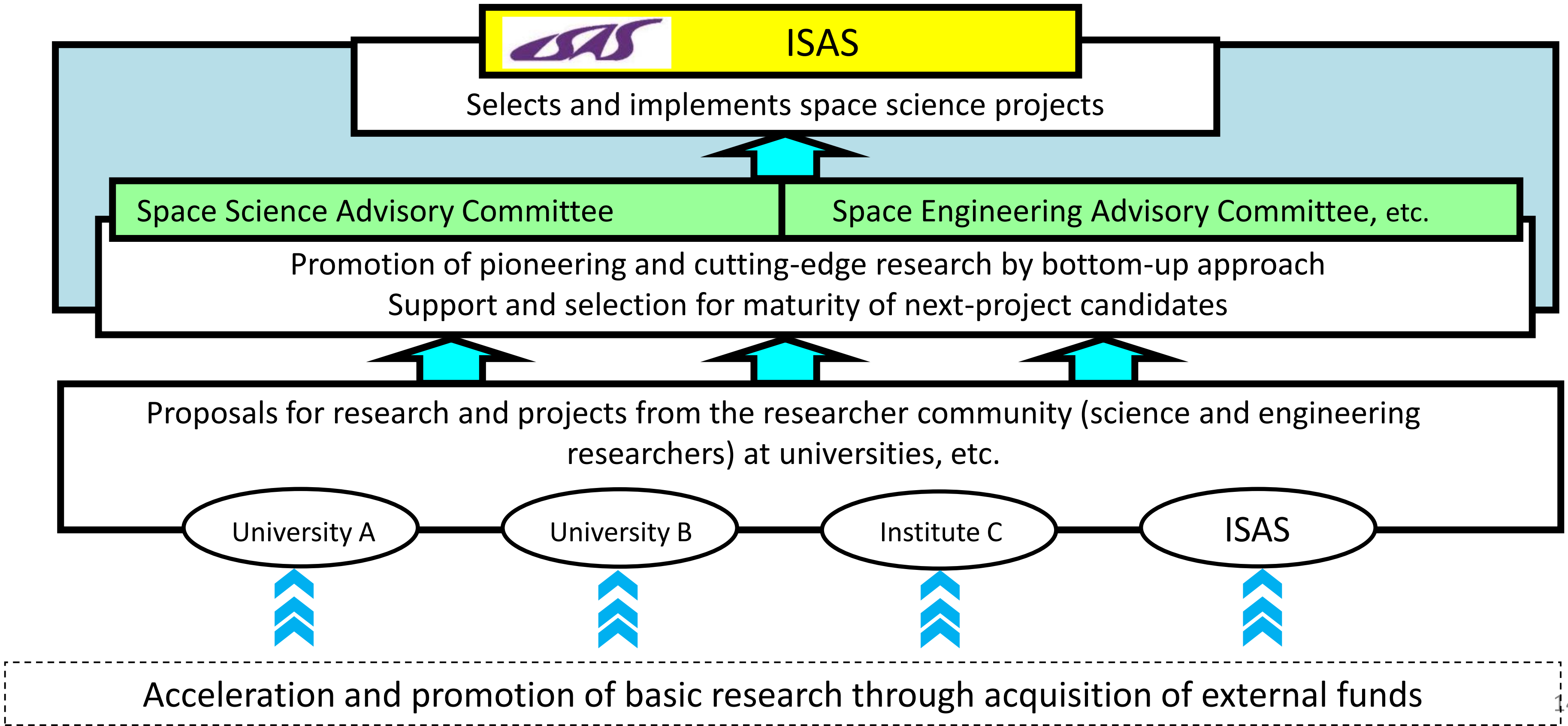
Mission Roadmap for ISAS Space Science and Exploration Projects



Mechanism to Facilitate Generation of Results: Implementation Method for Space Science in Japan

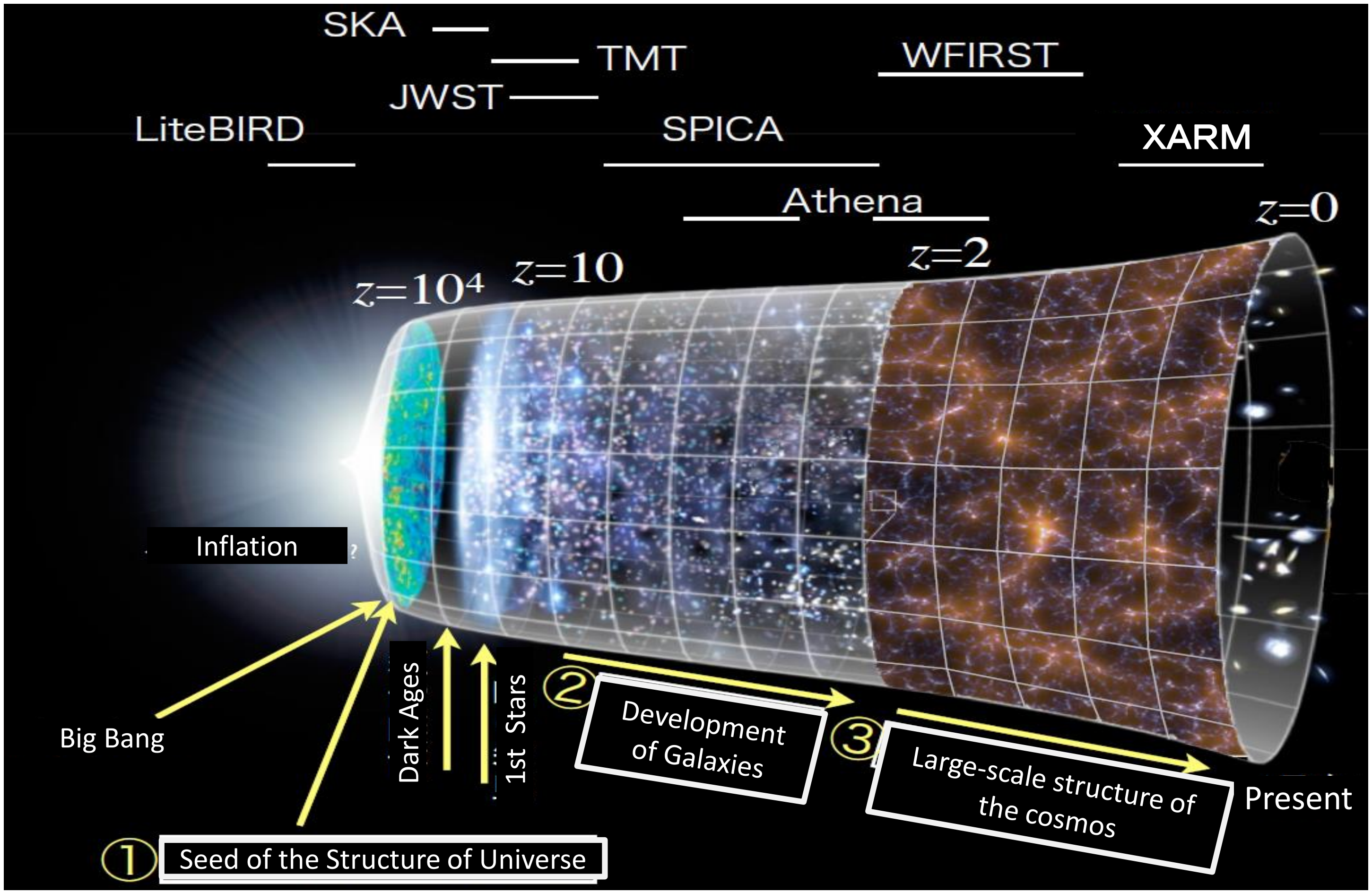
For academic research concerning space science in collaboration with universities or other facilities (as stipulated in Article 4 of the JAXA Act), the university shared-use research system brings to ISAS the wisdom of researchers from across Japan and generates various academic research results through implementation of science projects.

Research activities, project creation, and environment for competitive selection under the university shared-use research system



Astrophysics Strategy and SPICA/LiteBIRD

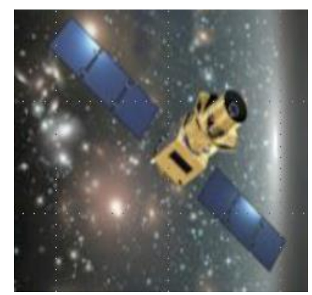
By addressing following three questions and through international cooperation, Astrophysics Strategy aims to shed light on the origins of the universe and structural formation from a galaxy to planets. 1. How did the universe begin? 2. How did the universe evolve?, and 3. Elucidating formation process, diversity, and universality of the structure of universe.



Credit: NASA / WMAP Science Team

X-ray Astronomy Recovery Mission (XARM)

Space Infrared Telescope for Cosmology and Astrophysics (SPICA)



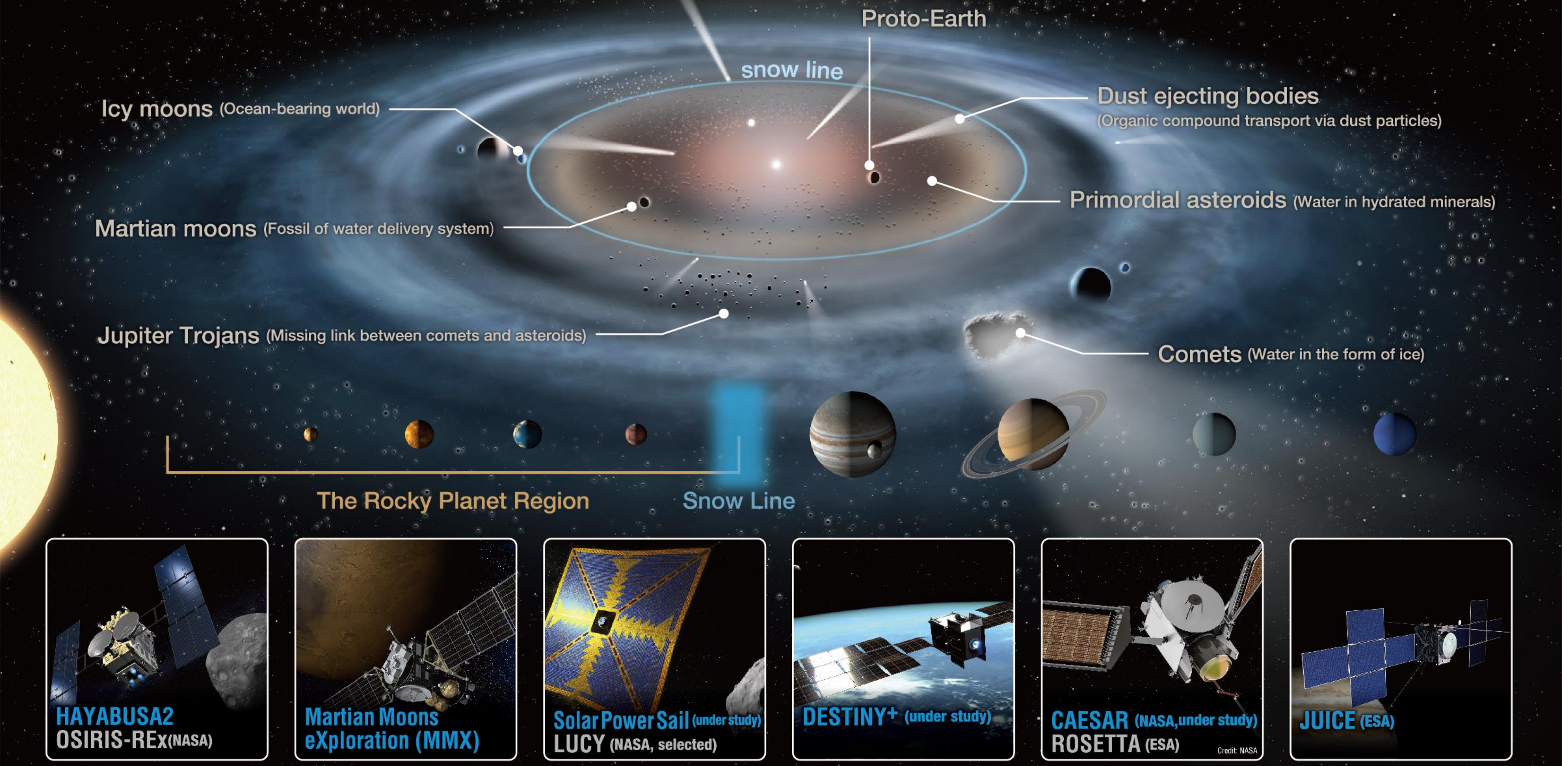
Light satellite for the studies of B-mode polarization and Inflation from cosmic background Radiation Detection (LiteBIRD)

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?

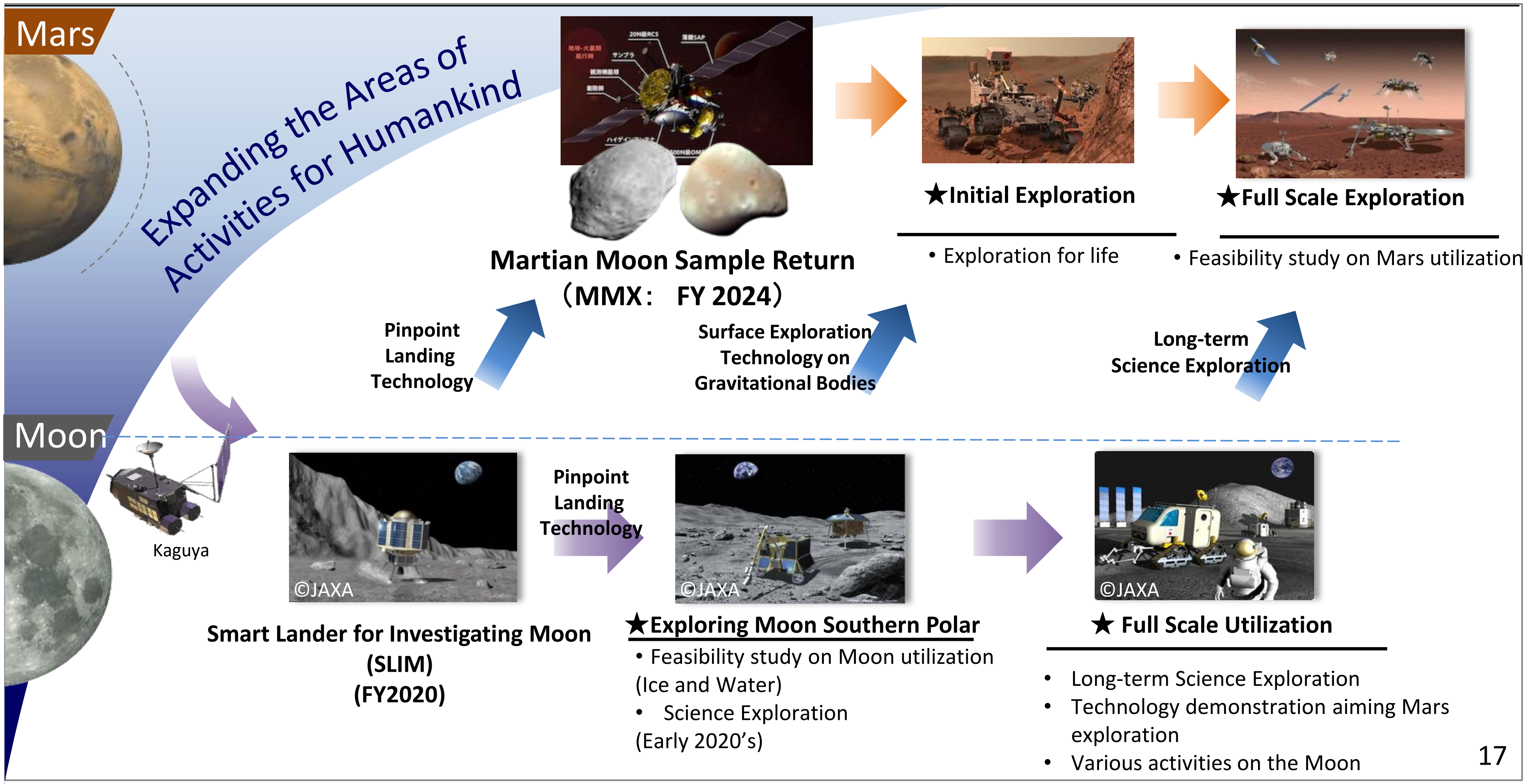


The fleet of ISAS small body missions explores these questions

Exploring Gravitational Bodies and SLIM / MMX

In the field of the solar system exploration, unmanned probe that realizes efficient and effective exploration will be promoted based not only on the bottom up discussions but also on programization. Programization requires long term efforts in the aim of landing and exploring the gravitational bodies including Moon and Mars; therefore, it is important to foster necessary human resource with academic and big-picture point of view in a planned and consistent manner.

Quoted from Basic Plan on Space Policy (April 1, 2016)

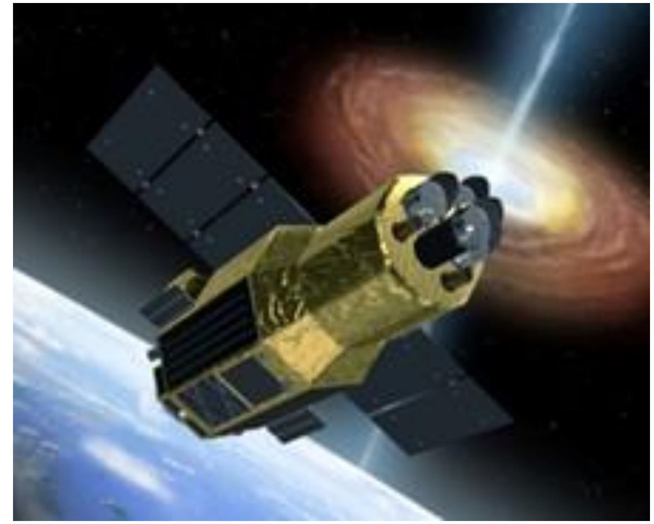


X-ray Astronomy Recovery Mission (XARM)

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

Strategic L-Class

Phase A



■ **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

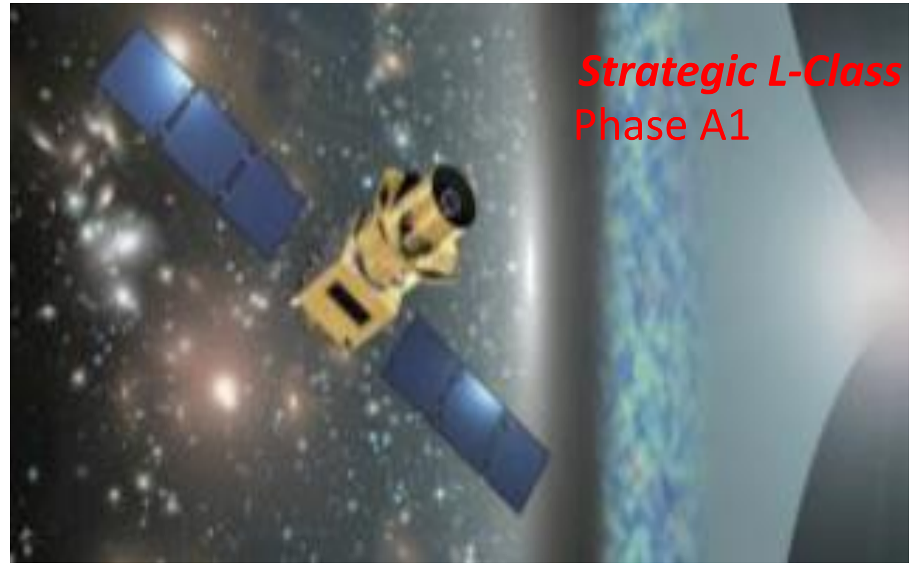
■ **Timelines**

FY2017 Contractor selection
FY2018 Transition to the JAXA project
FY2020 Launch

■ **International collaboration with NASA and ESA**

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**
（Under coordination)

Next-Generation Infrared Astronomy Mission SPICA

<u>ESA-JAXA joint mission</u> 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.

■ **<u>Science Objectives</u>**

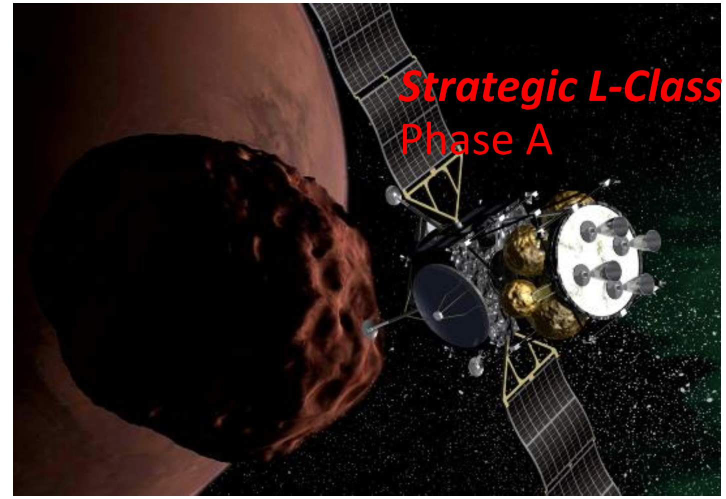
1. Studies of the processes of metal and dust enrichment and their interplay with star formation and AGN activities through galaxy evolution.
2. Studies of the processes of gas dissipation and dust evolution in planet-forming disks at various stages.

■ **<u>Current Status</u>**

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

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

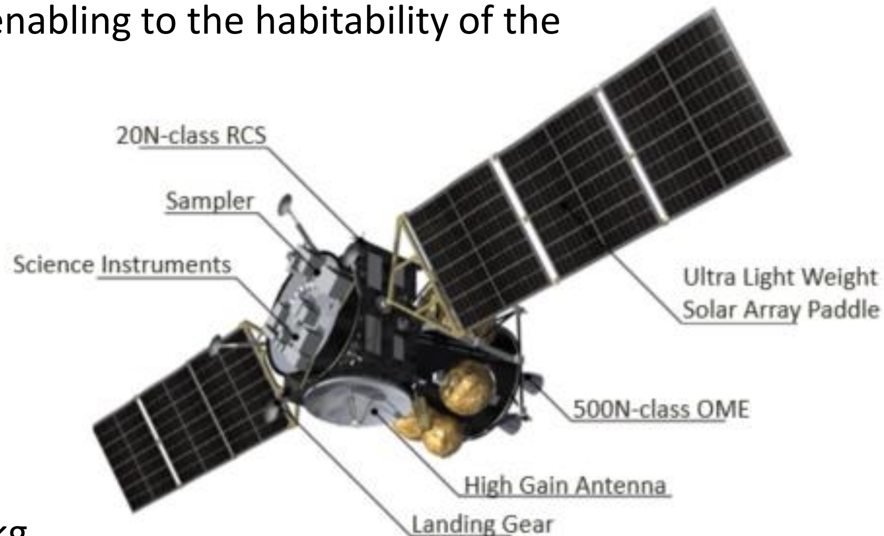
1. Origin of Mars satellites.
   - Captured asteroids?
   - Accreted debris resulting from a giant impact?
2. Preparatory processes enabling to the habitability of the solar system.

■ 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
- Feasibility of the Small Lander

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

•ESA, DLR : under coordination

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.

■ <u>**Expected results**</u>

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

■ <u>**Timelines**</u>

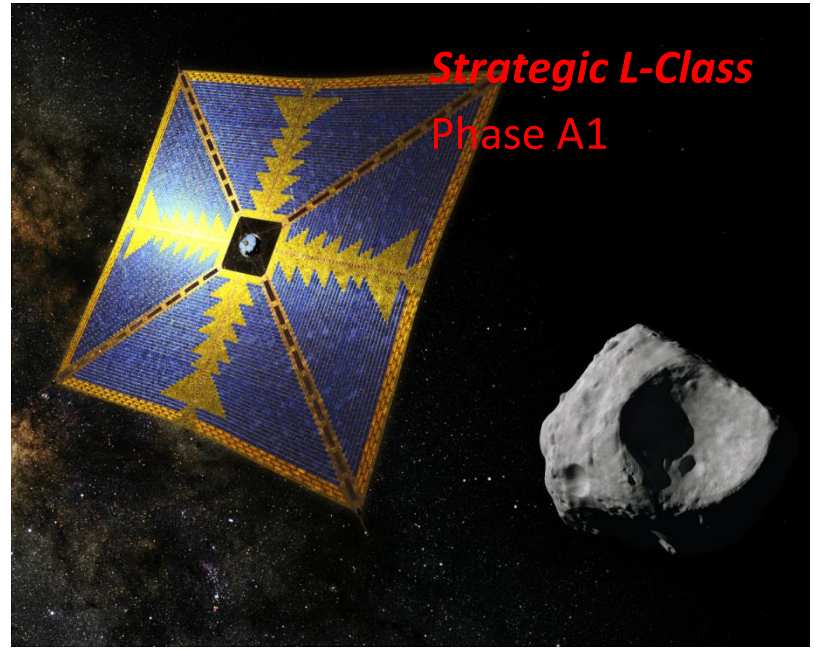
FY2021-22 Launch

■ <u>**International collaboration**</u>

- DLR : Dust Analyzer

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 (Sampling device, high-resolution Mass Spectrometer, Hyperspectral Microscope & panoramic imager, Close-up Camera, Thermal radiometer, Magnetometer, Raman Spectrometer)
Mass: 1.4 tons with a 100 kg lander

■ Timelines

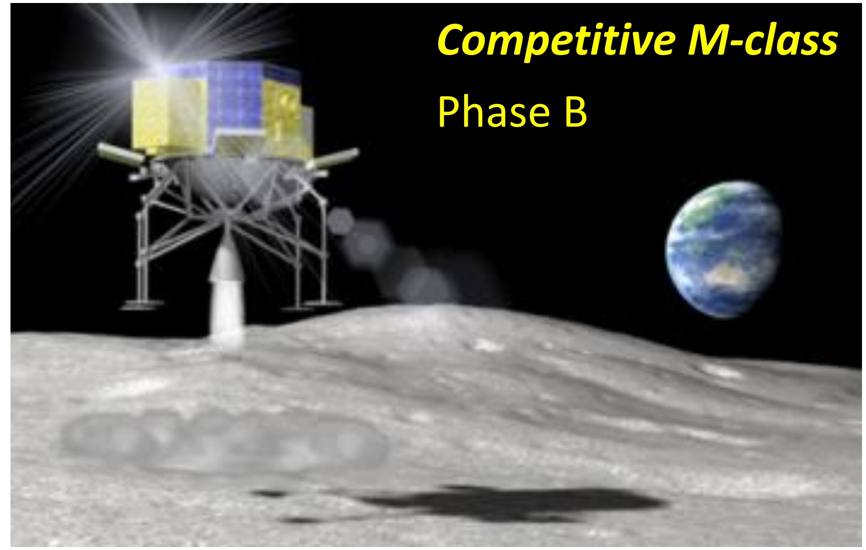
FY2027	Launch (Rocket TBD)
Launch + 5 year	Jupiter swing by
Launch + 11-12 years	Rendezvous a Trojan asteroid
Launch + 30 years	Sample return to earth (Optional)

■ International collaboration

- DLR Lander（Under coordination)

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

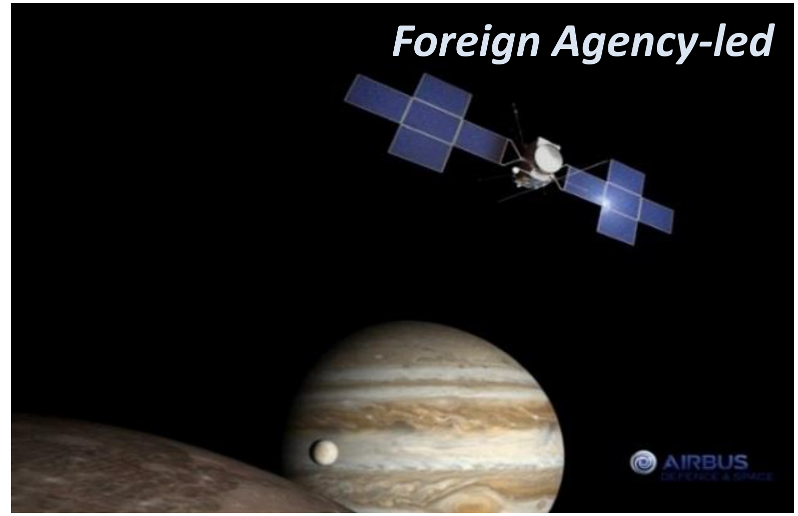
FY2020 Launch

■ 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

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

Summary

2018 Highlights of ISAS/JAXA

- Hayabusa 2 arrival and touchdown on Ryugu asteroid with CNES/DLR Lander
- Bepi Colombo launch and departure for 7-year journey to the Mercury with ESA.

- ISAS/JAXA puts the highest importance on international collaborations.
  - Foreign Partners join ISAS/JAXA lead Missions
  - ISAS/JAXA joins Foreign Agency lead Missions
  - Joint missions between ISAS/JAXA and other agencies
- ISAS/JAXA continues to promote international collaborations in order to maximize the outcome from the missions in efficient manner within allocated resources.

1) Realize highest outcome of the space science missions in efficient manners
2) Maximize the opportunities to conduct/participate Missions
3) Promote proactive communications among international space science community

JAXA Lead Mission

XARM
w/ NASA, ESA

MMX
w/ NASA, CNES, ESA, DLR

DESTINY+
w/ DLR

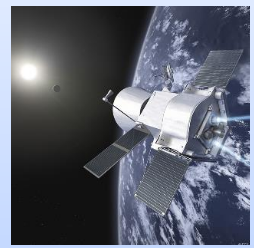
Join Foreign Lead Mission

JUICE
by ESA

CAESAR
by US

Joint Mission

Bepi Colombo
ESA/JAXA



SPICA
ESA/JAXA