JAXA Space Science

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JAXA/ISAS
ISAS

• Institute of Space and Astronautical Science
• The science institute of the Japanese space agency JAXA

• ISAS is undergoing a big transformation in these five years.
Outline

• Where ISAS stands now
• ISAS style
• How ISAS used to be
• Modernizing the ISAS style
The drivers of the transformation

- Return to Earth of Hayabusa in 2010
- H-IIA launcher available for L-class space science missions
- Epsilon launcher available for M-class space science missions
- Becoming a visible member in the global space science landscape
- Then... the Hitomi mishap in 2016
• Return to Earth of Hayabusa in 2010
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Hayabusa
Hayabusa

• An asteroid sample return mission
• Being a big challenge, it was proposed as an engineering demonstration mission
• Interplanetary cruise by an ion engine, optical navigation, touch-and-go sampling on the surface of an asteroid, return cruise, Earth reentry-landing-recovery
• Big boom created (spontaneously) among the public.
Hayabusa

- It did bring back samples from the Asteroid Itokawa.
Hayabusa

- (Even though the public does not pay too much attention to this aspect), the powerfulness of sample return in planetary science was clearly demonstrated.
- Sets the strategy for ISAS-planetary that sample return from small bodies (with small gravity) is the mainstream.
• Return to Earth of Hayabusa in 2010
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The part imported technology from U.S.

Inertial guidance and control equipment

Technologies in all stages were developed in-house. Original purely Japanese-made Rocket

Parts etc. were partially imported.

### Rocket's Profile

<table>
<thead>
<tr>
<th>Stage</th>
<th>Profile</th>
<th>Propulsion System</th>
<th>Inertial Guidance and Control Equipment</th>
<th>Payloads (GSO)</th>
<th>Operational Period</th>
<th>Launch Records (failed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-1</td>
<td>Based on Thor-Delta Rocket, and only propulsion system in the second stage was developed in-house.</td>
<td>The first stage was manufactured under the license. Other parts were purchased from U.S. (no major in-house developed items).</td>
<td>The first stage was manufactured under the license. Inertial guidance and control equipment (parts were partially procured overseas) and propulsion systems in the second/third stage were developed in-house.</td>
<td>130kg</td>
<td>1975 ~ 1982</td>
<td>6/7</td>
</tr>
<tr>
<td>N-2</td>
<td></td>
<td></td>
<td>Technologies in all stages were developed in-house.</td>
<td>350kg</td>
<td>1981 ~ 1987</td>
<td>8/8</td>
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<tr>
<td>H-1</td>
<td></td>
<td></td>
<td>Technologies in all stages were developed in-house. Original purely Japanese-made Rocket</td>
<td>550kg</td>
<td>1986 ~ 1992</td>
<td>9/9</td>
</tr>
<tr>
<td>H-2</td>
<td></td>
<td></td>
<td>Technologies in all stages were developed in-house.</td>
<td>2ton</td>
<td>1994 ~ 1999</td>
<td>5/7</td>
</tr>
<tr>
<td>H-2A</td>
<td></td>
<td></td>
<td>Technologies in all stages were developed in-house. Parts etc. were partially imported.</td>
<td>2ton ~ 3ton</td>
<td>2001 ~</td>
<td>20/21</td>
</tr>
<tr>
<td>H-2B</td>
<td></td>
<td></td>
<td>Technologies in all stages were developed in-house. Parts etc. were partially imported.</td>
<td>4ton</td>
<td>2009 ~</td>
<td>3/3</td>
</tr>
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Hayabusa2 launch by H-IIA
Hayabusa2 launch by H-IIA

• Hayabusa2: The 2nd asteroid SR mission by ISAS, having NASA OSIRIS-REx as his brother.

• Targeting at a primordial asteroid, we expect the returned samples will tell how life-origin related materials formed in the solar system upon its formation.

• A more picky target asteroid, more challenging science themes.
Hayabusa2 launch by H-IIA

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Hayabusa2 launch by H-IIA

- Making ISAS missions bigger.
- Are we happier?
• Return to Earth of Hayabusa in 2010
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• Epsilon launcher available for M-class space science missions
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Promotion of Small Satellite Program

- **Epsilon Launch Vehicle** is a solid propellant rocket capable of launching a satellite weighing 1.2 tons into LEO.
- The first was launched on Sep.14 2013.
- With Epsilon Launch Vehicle, we intend to perform low-cost, focused missions in a timely manner.
Hisaki launch by Epsilon
Hisaki launch by Epsilon

- Hisaki: Earth-orbiting EUV spectrometer that is dedicated to stare at Jupiter (and others).
- Not as capable as Hubble Space Telescope, yet enabling long-term and continuous observations (that is not possible with large facilities such as HST) of Jupiter.
- A nice dataset in itself, and good partnership with large missions such as HST, CXO and JUNO (NASA’s mission that arrived at Jupiter this July).
Hisaki launch by Epsilon

• Making smaller yet more frequent missions available
• Are we happier?
• Return to Earth of Hayabusa in 2010
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Intl collaboration

• BepiColombo: ESA-JAXA two-spacecraft mission to explore the planet Mercury, to be launched in 2018.
• Has been subject to delay, which made <old> people at ISAS to complain “No more intl collaboration, please.”
• Given how mandatory intl collaboration is these days, we could have gone into a super-wrong direction.
• Now ISAS has formally set the path for intl collaboration to be pursued smoothly.
• ISAS alone can never fly a mission like this.
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Hitomi
Hitomi

• Supposed to be the X-ray mission of the decade, the only one for the global X-ray astrophys community, and the path finer for a larger mission to be led by ESA in a decade later (ATHENA).
• A large instrument that is the key to the next generation X-ray astrophys was provided by NASA
• Launched successfully in Feb 2016.
• Initial obs shows the NASA instr to be in perfect shape (See a paper published in Nature)
• Lost contact at the end of March.
Hitomi

• What went wrong: attitude control went wrong to spin up the spacecraft until a solar array paddle was detached.
• The background: Operation scheme too optimized for science (to minimize the dead time for obs), not enough attention paid to the safety aspect.
• Lessons: More solid management while keeping the essential minimum of the <ISAS style>.
• Intl aspect: There was a role for us to play in the intl landscape. How to live up to the expectation? How to maintain the partnership?
Space science at ISAS

• Covers space-astronomy, heliophysics (space around planets, interplanetary space and the solar physics), planetary science and ISS-related space experiments

• Most successful are: X-ray astronomy, solar physics, magnetospheric physics and asteroid exploration (sample return)
Space science at ISAS

• Members at ISAS: Scientists, space-engineering researchers and engineers
• Space engineering researchers have cutting-edge ideas that they wish to fly.
• It is the style of ISAS to try to blend their wish into a mission.
• This makes planetary exploration missions to be the symbol of ISAS, which trend is getting stronger since the Hayabusa’s return to Earth.
ISAS: a unique combination of space science and space technology

**Technology driven**
Leading and creating space science programs

**Science driven**
Stimulate and encourage new technology research

**Space Science Divisions**
- Space Astronomy Astrophysics
- Solar System Science
- Interdisciplinary Space Science

**Space Technology Divisions**
- Space Flight Systems
- Spacecraft Engineering
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How it used to be at ISAS

• The MV launcher was the only vehicle for space science.

• It was a single straight path story to plan a mission: Construct a good mission plan that flies on MV.
MV missions

• Hayabusa: Sample return mission from an asteroid ➔ Funaki-san’s talk
MV missions

- Hinode: Solar physics
From planning to proposal: how it used to be

• A person who wishes to fly a mission forms a Working Group.
• The WG applies for ISAS funding to perform a PrePhaseA study.
• As the study by WG matures, they become ready to draft a proposal.
• The proposal is submitted upon AO issued by ISAS.
• Up to the proposal, it is a committee formed by peers, not ISAS, that navigates the process.
• When selected, the leader himself reforms the WG to a mission team and the implementation phase starts.
Good old MV days

• Nice missions
• A launch every year by the ISAS-owned rocket
• <My> mission: doing everything by yourself, from the WG to the scientific publications
• Would be nice if a mission of this size that can be run by minimum management continues to be truly competitive scientifically...
The reality: Now H-IIA, not MV

Pure bottom up, from the beginning to the end.
• No room for ISAS to arrange intl collaboration via agency-agency dialogue.
• No room to inject guidance from ISAS at earlier phase of the study.
• No room for ISAS to inject management upon formation of a mission team.

Needs modification to fablicate a good mission plan that matches up with the boundaries that ISAS is embedded in.
The reality: Now Epsilon, not MV
# JAXA Solid Propellant Rockets

## Rocket’s Profile
- **L-4S**: Launched Japan’s first artificial satellite OHSUMI
- **M-4S**: Launched the first scientific satellite SHINSEI
- **M-3C**: Improved orbit-injection accuracy by Thrust Vector Control
- **M-3H / M-3S**: Improved payload to LEO
- **M-3S II**: Launched the first and second Japanese interplanetary probes SAKIHAKE and SUISEI
- **M-V**: The best solid-propellant rockets in the world launched Asteroid Explorer HAYABUSA
- **Epsilon**: Solid propellant rocket under development aims at mobility and efficiency

## Payload to LEO
- **L-4S**: 26kg
- **M-4S**: 180kg
- **M-3C**: 195kg
- **M-3H / M-3S**: 300kg
- **M-3S II**: 770kg
- **M-V**: 1800kg
- **Epsilon**: 1200kg

## Operational Period
- **L-4S**: 1966 ~ 1970
- **M-4S**: 1970 ~ 1972
- **M-3C**: 1974 ~ 1979
- **M-3H / M-3S**: 1977 ~ 1978, 3S: 1980 ~ 1984
- **M-3S II**: 1985 ~ 1995
- **M-V**: 1997 ~ 2006
- **Epsilon**: 2013 ~

## Launch Records (Succeed/Launched)
- **L-4S**: 1/5
- **M-4S**: 3/4
- **M-3C**: 3/4
- **M-3H / M-3S**: 3H: 3/3, 3S: 4/4
- **M-3S II**: 7/8
- **M-V**: 6/7
- **Epsilon**: -
The reality: Now Epsilon not MV

• Tougher boundary requiring yet harder thinking to come up with a nice mission idea that is doable.

• Should ISAS leave it to a pure bottom-up process and just wait for a good proposal to be submitted?
ISAS now

Keywords

• Mission categories clearly defined.
• More intl elements.
• More channels by which ISAS strategy can be blended into the bottom-up efforts.
ISAS mission categories

• L-class to be launched by H-IIA/III
• M-class to be launched by Epsilon
• Opportunities for grand missions to be led by foreign agencies
• S-class incl those onboard suborbital and ISS programs.
L-class

• Akatsuki: Venus Climate Orbiter
  ➔ Ueno-san’s talk

• MMX: Martian Moons eXploration
Martian Moons eXplorer (MMX)
JAXA’s exploration of the two moons of Mars, with sample return from Phobos
• The objective: To understand the origin of Phobos
• The goal: To understand how the habitability of the solar system was enabled
• Rocky planets that are in the habitable zone were born inside the snow line: They must have been born dry. Needs transport of water from outside the snow line to enable the habitability of the solar system.
• Small bodies would have played the role of delivery capsule of water.
• Mars at the outer-edge of the rocky planet region must have witnessed the transport process.
• Phobos could have been a delivery capsule that was captured by Mars during its inward journey.
Mission scenario

(1) Mars orbit insertion
(2) Transfer to a quasi-satellite orbit around Phobos for close-up observations
(3) Landing and sampling from Phobos
(4) Transfer to Deimos for multi-flyby observations (or from a quasi-satellite orbit).
(5) In-situ space observations and Mars remote sensing observations for Mars atmospheric science themes while the spacecraft is within the Mars gravitational sphere.
(6) Departure from Mars and return to Earth
(7) Recovery of samples and initial analysis
Understanding the origin of Phobos via analyzing its samples leads to understanding of how the habitability of our solar system is enabled.
M-class

- SLIM: Precisely targeted landing on the lunar surface
- Precision=100m
- Was a technology demonstration, now a small science payload onboard
• Was a technology demonstration, now a small science payload onboard: Land in an area where ejected interior material is known to exist on the surface, and make a spectroscopic observation of them to learn about the early thermal (cooling) history of the Moon formed by the giant impact.
How to secure a smooth path for intl collaboration in L and M classes

In the process of finding the way that works...

MMX case: Has been extremely well because ISAS stepped in an early stage for coordination with foreign agencies (NASA, ESA, CNES, DLR).

SLIM case: <Is a good planetary mission possible at all?> is still the biggest question. Brain-storming meeting in the US will be tried.
Joint ISAS-LPL Workshop on Planetary Science Enabled by Epsilon Class Missions
With a hope to gain enough momentum to push it back…

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Participation in foreign grand missions

• The biggest launcher for us is H-IIA/III
• The sexiest missions such as a Mars lander are barely doable.
• Yet, Japanese community begs for a chance to be a part of them.
The solution is:

- The mission slot that provides chances to participate in these grand missions are established.
- While keeping the bottom-up backbone, dialogues and other necessary arrangements between the agencies will be taken care of by ISAS.
Precursor:
BepiColombo: ESA led, Mercury

Ongoing:
JUICE: ESA led, Icy moons of Jupiter

Under discussion:
ATHENA: ESA led, X-ray astrophysics grand observatory
WFIRST: NASA led, IR astronomy grand observatory
NewFrontiers4: a billion USD planetary mission, NASA hosted competitive process, Japanese participation in a few proposal foreseen
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Summary

• The ISAS style: Blending the wish of the space engineering researchers into missions

• Lessons learnt (Hitomi mishap): More management without spoiling the essential minimum of the <ISAS style>.

• Not 100% bottom-up anymore, but mission incubation/guidance from ISAS to a WG in an early phase of a study

• Strategic international partnership: Give-and-take on the whole scale, not balancing within a single mission. Early phase conversation.
Give and take on the whole scale

- The Hitomi mishap