Technical Demonstration of Mt.FUJI on HTV-X and Challenge of Attitude Estimation by SLR

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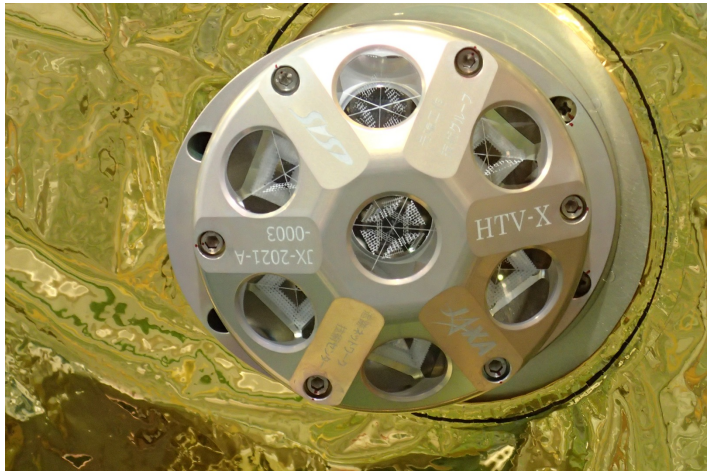
Background

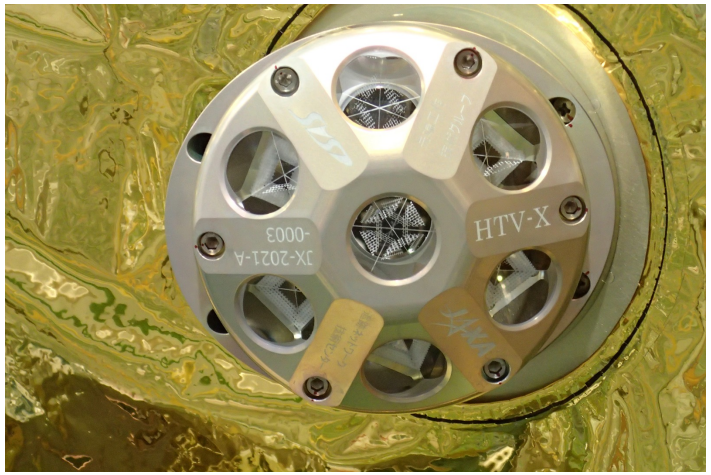
- As space becomes more crowded, the importance of **ADR (active debris removal)** and **SSA (space situational awareness)** is increasing. In ADR, it is important to grasp the orbit and rotational motion of debris before approaching to the debris.
- Rader/optical observations are common way to do this, but not sufficient resolutions for orbital/attitude estimation. So JAXA is focusing on **SLR (satellite laser ranging)** to grasp the orbital and **rotational motion of debris**.
- If all space objects have an SLR reflector, the visibility from the ground (or trackability) is ensured even after they become debris, resulting in keeping better orbital and rotational motion grasps.
- However, conventional reflectors are **large, heavy, and expensive**. This is one of the cause not so many satellites have an SLR reflector. That's why we developed a **small, light-wight, and inexpensive** SLR reflector, **Mt.FUJI**!!



Item	Specification
Target attitude (circular orbit)	≦ 800 km
Diameter	112 mm
Height	32 mm
Mass	260 g
CCR size	1 inch (25.4 mm)
Number of CCR	7
FOV of Mt.FUJI	45 degrees (each CCR with 15 degrees)

Mt.FUJI
JAXA developed SLR Reflector
with the concept of small, light-weight and inexpensive

Overview of Mt.FUJI Mission



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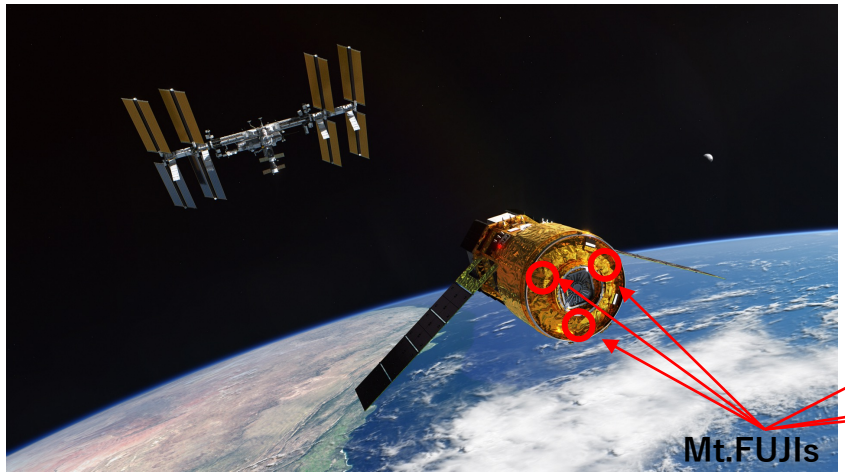
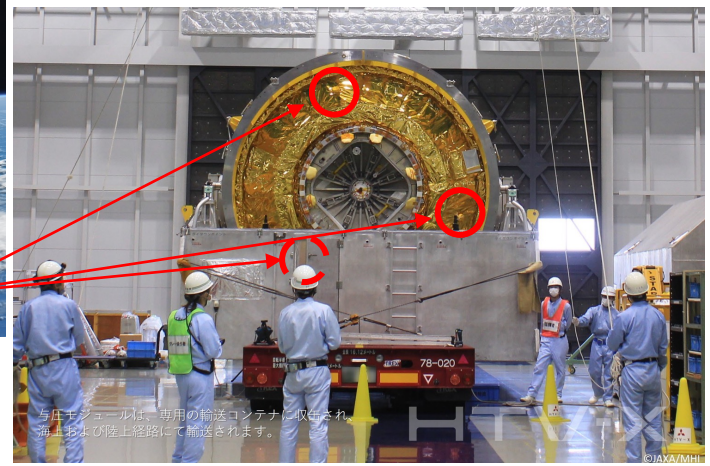


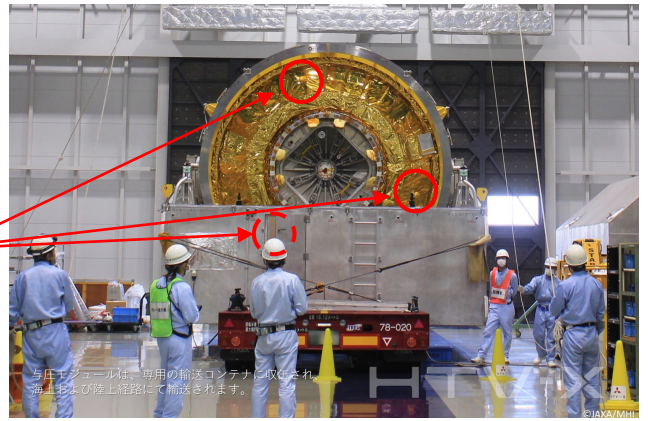
HTV-X
JAXA developed new unmanned spacecraft
as the successor to the HTV (Kounotori)

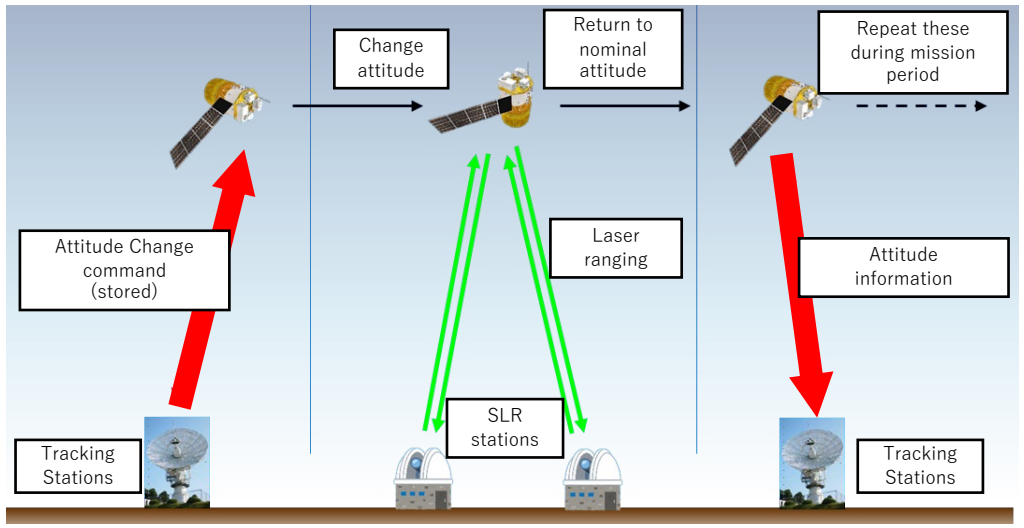


- In Mt.FUJI Mission, 3 Mt.FUJIs are mounted onto the backside of the HTV-X and fly in orbit!
  - Launch in **FY2024** (planned)
- The missions of the HTV-X are:
  - transporting cargoes to the ISS
  - providing experiment platform. After departure of the ISS, 3 different technical demonstrations will be performed
- The objectives of Mt.FUJI mission are:
  1. to verify Mt.FUJI in orbit → detect return signals
  2. to evaluate the accuracy of SLR-based attitude estimation using true data (telemetry of HTV-X) → see next slide
  3. to evaluate the accuracy of GPS receiver positioning by comparing with SLR data. → compare the GPSR receiver and SLR data

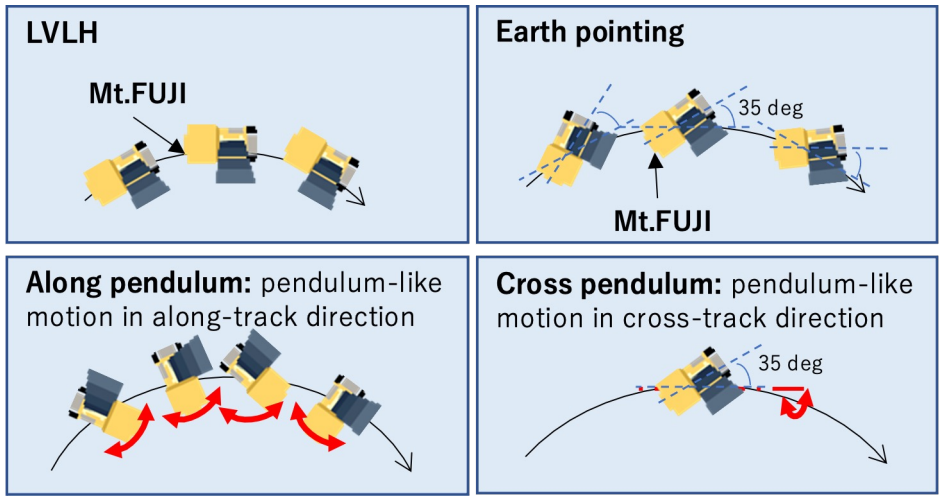
Overview of Mt.FUJI Mission

- To evaluate the accuracy of SLR-based attitude estimation using true data (telemetry of HTV-X),
  - (1) the HTV-X will fly in special attitude motion and SLR is performed and obtain SLR data affected by attitude motion
  - (2) downlink its telemetry data including attitude states
  - (3) attitude estimation based on obtained SLR data
  - (4) compare with HTV-X telemetry data as true values (**world-first quantitative evaluation**)
- 4 different attitude will be taken in orbit:
  - LVLH: nominal attitude
  - Earth pointing: one Mt.FUJI directs towards the Earth
  - Along/Cross pendulum: pendulum-like motion in along/cross – track direction
  - Space debris is considered to be flying in dynamic motion (like tumbling). This special attitude motion is kind of imitation of space debris motion. Such dynamic attitude motion cannot be achieved by ordinary spacecraft!





Operation overview in Mt.FUJI mission phase

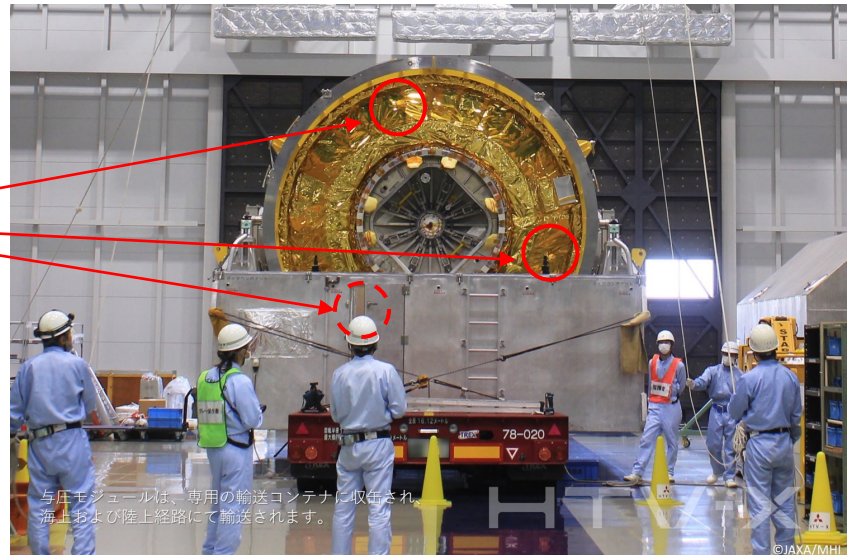


Attitude motion in Mt.FUJI mission phase

Overview of Mt.FUJI Mission

- Mission period: totally 4~5 weeks (Phase A: 3 weeks + Phase B: 1~2 weeks)
  - Phase A: 3 weeks, starts after 1~2 weeks later departing from the ISS (berthed duration is up to 6 months and difficult to predict now)
  - Phase B: 1 ~ 2 weeks, before ISS approaching or after complete of all demonstration missions.
- Restriction:
  - SLR should be performed at an elevation angle of at least 20 degrees to protect HTV-X's STT.
  - HTV-X will not take attitudes that any SLR stations enter the field of view of the STT as long as SLR is preformed at the elevation over 20 degrees.
- Current status:
  - Complete Mt.FUJI attachment to the HTV-X
  - Continuing to coordinate of the experiment procedures and operations with HTV-X mission
  - Submit MSRF and under review

Mt.FUJI



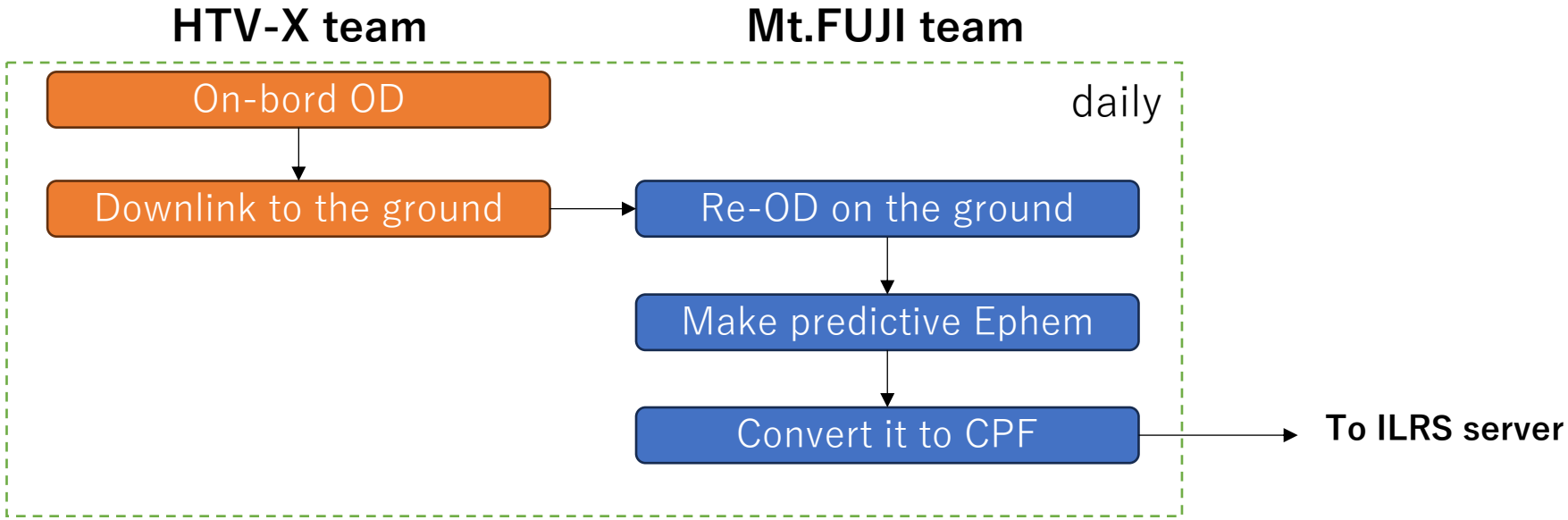
Operational Plan

- The success of SLR to HTV-X depends on **how accurate CPF is** and **how well communication to SLR stations is**.
- The next two slides describes the operation plans to provide accurate CPF and good communications to SLR stations in order to for SLR stations plan their operations and set prioritizes.

Operational Plan

Operation for accurate CPF

- The HTV-X has GPSR and will determine its orbit by on-board (order of several tens meter accuracy).
- JAXA plan to downlink the on-board determined position data, and re-orbit determination on the ground by using those position data as observables, and then create a predictive ephemeris.
- Finally, it is converted into a CPF format, then distributed to SLR stations via the ILRS server.
- As these procedures will be performed daily, the accuracy of the CPF is expected to be several hundred meters.



Operational Plan

Operation for good communications to SLR stations

- The current plan is as follows (X means the day of performing SLR):

1. By X-8W: calculate the HTV-X passes, choose periods of experiments and SLR stations which JAXA would like to perform SLR, and inform passes and stations which we would like to perform SLR (ex. GRZL: 2024/1/1 0:12:56 ~ 0:15:50 UTC, MATL: 2024/1/1 0:09:02~ 0:11:20 UTC) by using a mailing list.

2. Daily from X-1W to X-2D: re-analyze the passes, experiment periods, and SLR stations, and inform re-analyzed results via the mailing list.

3. Dairy from X-1W to X-1D: create a CPF, deliver to the ILRS server, and re-inform and request SLR stations which we would like to perform SLR. We plan to contact each SLR station on an ongoing basis well in advance of ranging to inform them of the expected ranging time and the stations we would like them to SLR.

Note: There is the possibility that return signals cannot be detected depending on HTV-X's attitude. You may obtain the return in the latter part of a pass. But this is natural behavior in the Mt.FUJI mission. Please do not stop performing SLR if you cannot detect the return signal from the HTV-X in the former part of the pass, and please continue performing SLR until the designated pass will end.

Proposal From JAXA

- **How about an international competition through an HTV-X angular velocity estimation experiment?**
- **Purpose:**
  - JAXA can obtain the exact angular velocity (correct answer) coming down from HTV-X by telemetry. To challenge the angular velocity estimation with SLR analysts from around the world and find out how accurately SLR technology can determine the angular velocity.
- **Where it will be applied:**
  - Increasing need for space debris tumbling estimation. The reliability of its angular velocity can be confirmed by this experiment.
- **Methods:**
  - Declare your willingness to participate in this international competition; contact JAXA.
  - Estimate the angular velocity with the data you downloaded from the ILRS server.
  - Notify the result to JAXA.
  - JAXA will release the results and answers when the results of the angular velocity estimation experiments by each institute are available.
  - Unfortunately, please understand that JAXA cannot prepare a prize for the winning analyst.

- Note: JAXA can share the data such as HTV-X's definitive orbital and attitude ephemeris after the mission ends (maybe 6 month later) by SFTP or somehow. If you are interested in those data for your research, please let me know.

To ILRS members

- For Mt.FUJI mission success, we need to obtain sufficient SLR data as many as possible. SLR is essential to achieve Mt.FUJI mission. We believe that ILRS members are interested in this mission, especially evaluating the absolute accuracy of attitude motion determination by SLR.

- We really appreciate it if we could receive the ILRS supports and perform the world-wide SLR campaign for Mt.FUJI mission!

thank you

If you have questions or concerns, please e-mail me.

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