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デブリ除去実現に向けたHTVによる導電性テザー実証実験

The Plan of Electrodynamic Tether Experiments on HTV for Debris Removal

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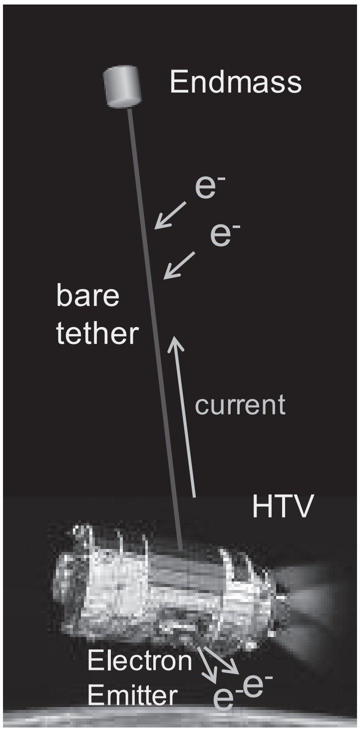
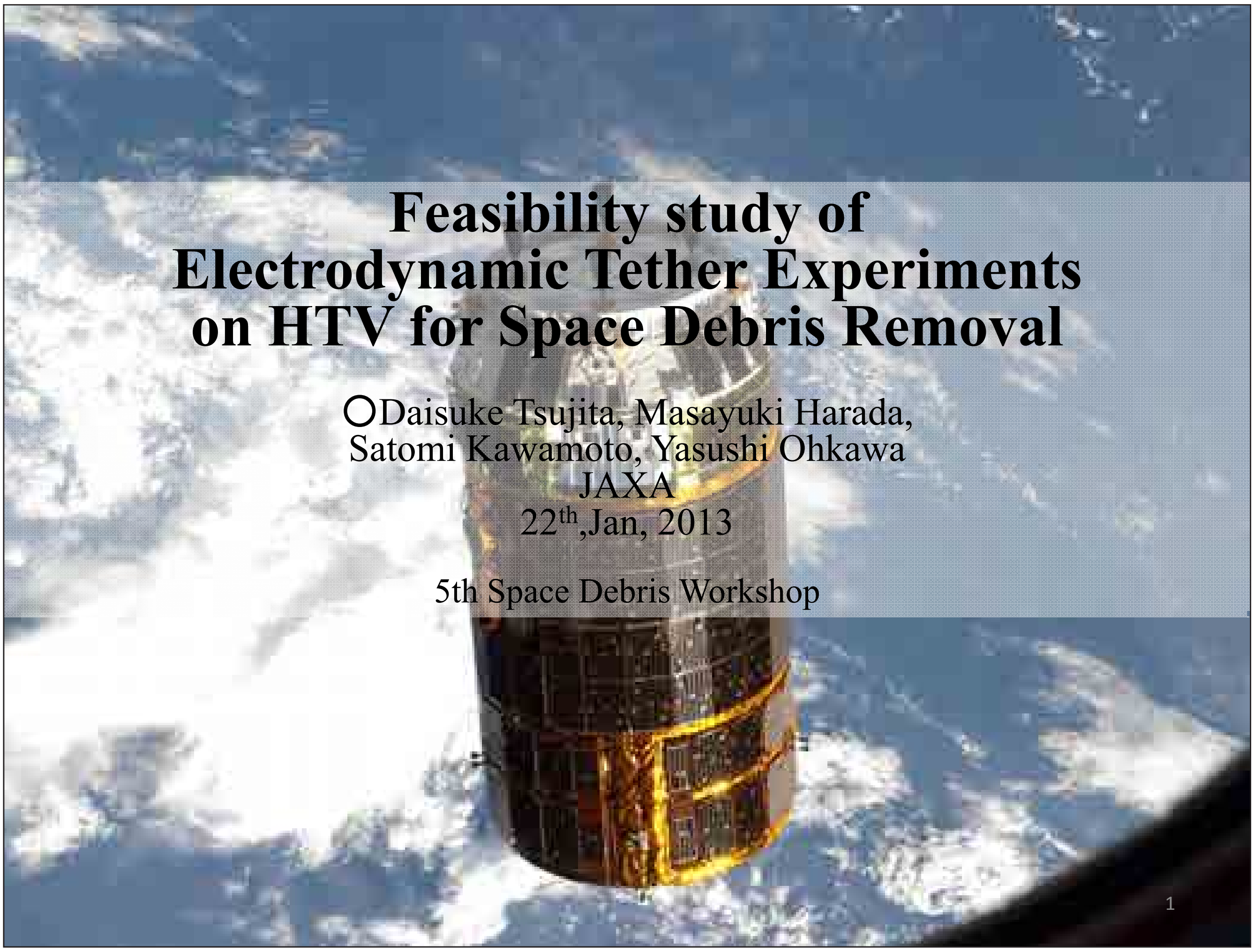
近年デブリの増加が大きな問題として認識されており、今すでに軌道上にあるデブリ同士の衝突によるデブリ数の自己増殖（ケスラーシンドローム）が低軌道で懸念されている。特に低軌道デブリを対象としたデオービット技術として、推薬不要な導電性テザーの利用を JAXA は検討している。その一環として既に 3 機打上実績のある HTV を実験プラットフォームとした導電性テザー実証実験の計画を発表する。

Recently, space debris increase is recognized to be a growing problem and the concern for Kessler Syndrome on Low Earth Orbit(LED) is being threat for spacecrafts. In order to remove orbital debris on LEO, JAXA have been studying the usage of Electrodynamic Tether (EDT) as a deorbit method, which needs no propellant. We present the plan of EDT experiments on H-II Transfer Vehicle (HTV) as one of the studies. Note that HTV has already performed the mission three times successfully, and four HTVs will be launched every year.





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1. HTV Overview

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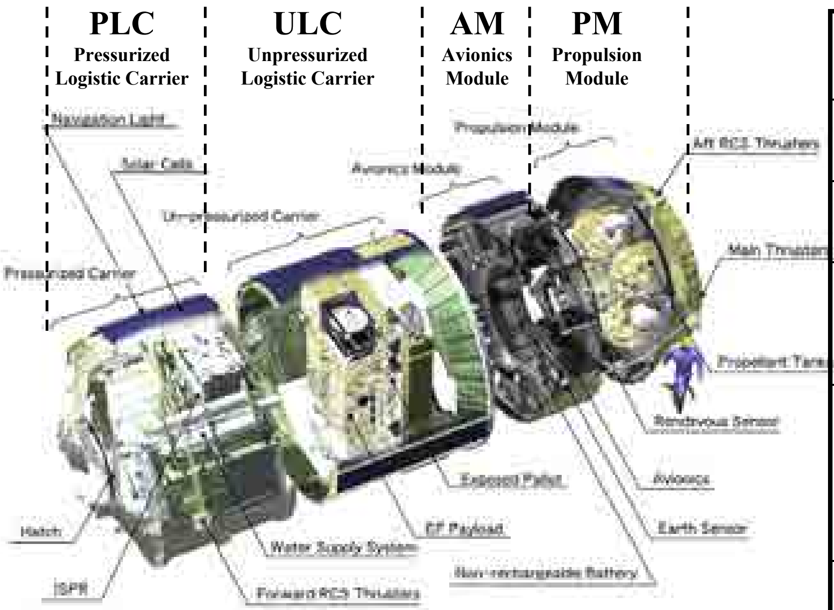
1.1 HTV Configuration Overview



HTV Characteristics

Dimensions		Length: 9.2 m Diameter : 4.4 m
Total mass full loaded		16.5 ton
Launch Vehicle		H-IIB launch Vehicle
Target orbit		Altitude: 350km~460km Inclination: 51.6deg
Cargo capability		6 ton in total
	Press.	Up to 5.2 ton
	Un-press.	Up to 1.5 ton
Propulsion system		Four 500N main engine Twenty eight 120N RCS thrusters

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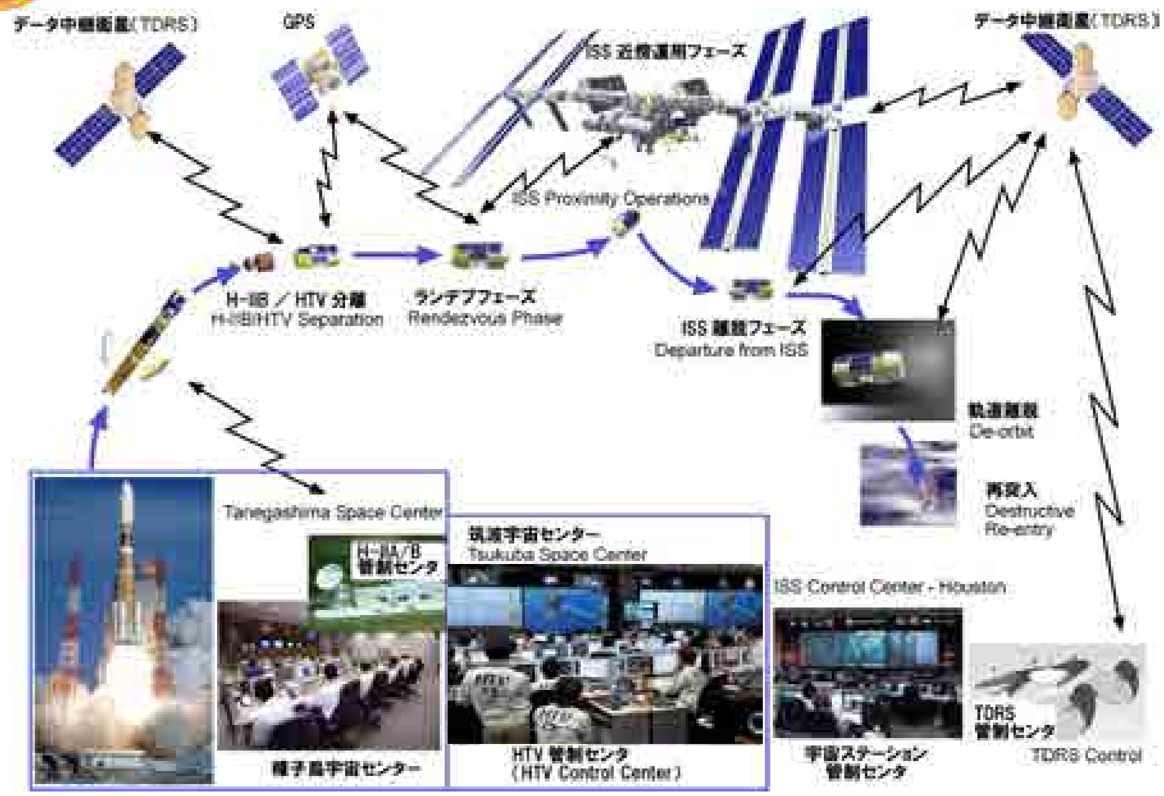
1.2 HTV Operation Overview



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2. HTV Debris Technique

2.1 Current Debris Technique

2.2 Study Items for Debris Technique

2.1 Current Debris Technique

A. Debris bumper

It is for shielding HTV M/OD critical items as follows.

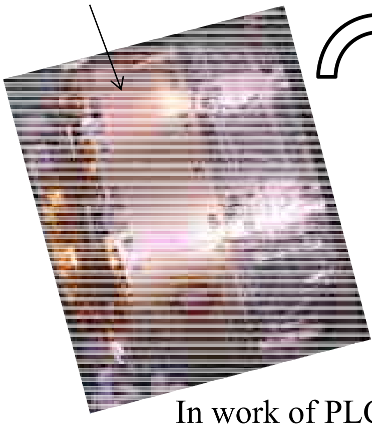
(a) Pressurized Logistic Carrier

(b) GHe pressure vessels in Propulsion Module

(c) Propellant tanks in Propulsion Module

 # HTV can perform Debris Avoidance Manuber based on tracking space debris data

Debris bumper (Al, thickness approx.1mm)



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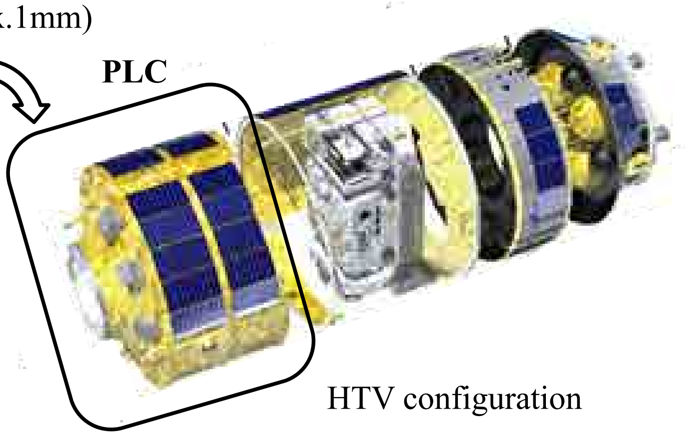

HTV configuration

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2.1 Current Debris Technique

B. Reentry

HTV can perform controlled reentry into the atmosphere to prevent HTV itself from becoming debris.

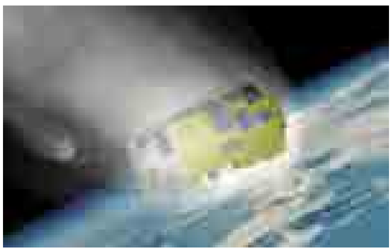

Fig. HTV Controlled Reentry Image

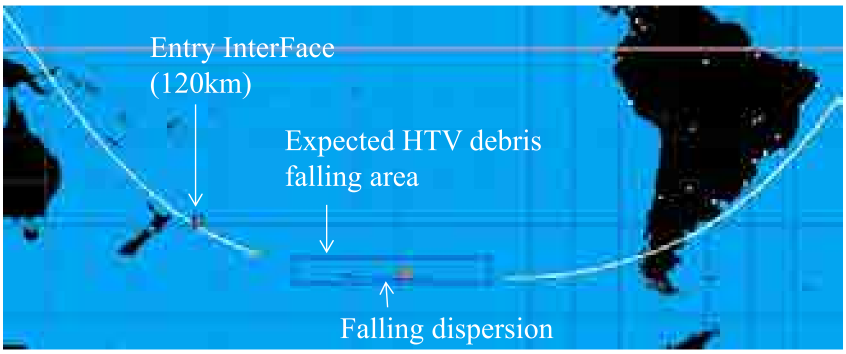

Fig. HTV's Projected Reentry Path

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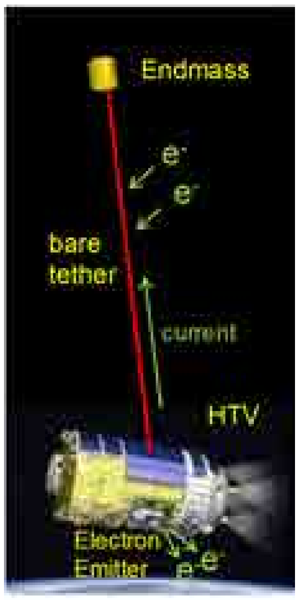
2.2 Study Items for Debris Technique

A.Debris Measuring Sensor

The sensor to be in replacement of a SAP

B.ElectroDynamic Tether(EDT) Experiment



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3. Feasibility Study of EDT Experiments on HTV

3.1 Introduction of Feasibility Study

3.2 Study of Configuration

3.3 Study of EDT Experiments Window

3.4 Study of EDT Experiments Sequence

3.5 Usage of HTV function on EDT Exp

3.1 Introduction of Feasibility Study

Status

HTV1 through HTV3 completed the missions successfully, and the plan of HTV4 and subs are proceeding steadily.

Characteristics

HTV has high quality, high reliability, promised launch opportunity and the operation skills matured at high level

HTV appears to be a good on-orbit platform and is very attractive for users who hope to make their instruments flight-proven.
We are studying some items for realizing the expectation, and introduce one of study results i.e. EDT experiments on HTV.

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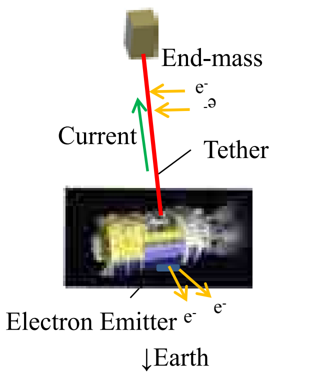
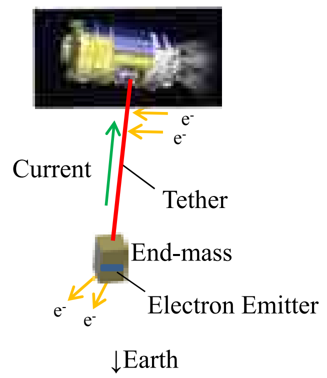
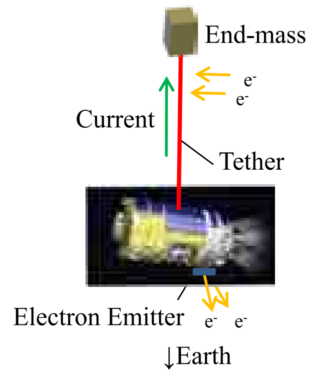
3.2 Study of Configuration

Prerequisites

-End-mass with tether should be ejected and deployed from HTV.
-Electron emitter should be positioned on the tether end toward the earth.
Reason) Lorenz force to be worked for the opposite flight direction by driving the current on the tether from nadir to zenith.

Trade-off

	Option1	Option2	Option3
Brief	End-mass should be deployed to the zenith from the open area of ULC	End-mass should be deployed to the nadir from the open area of ULC	End-mass should be deployed to the zenith from the back of ULC
Config			
Evaluation	×	×	○

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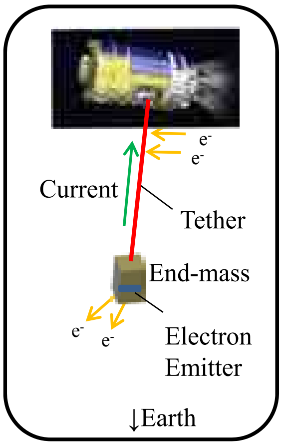
3.2 Study of Configuration

●Option1: ×

Impossible. The reason is why HTV is designed to fly with the ULC open area toward Earth.

●Option2 : ×

The end-mass system would be complex to install electron emitter and some support equipments.



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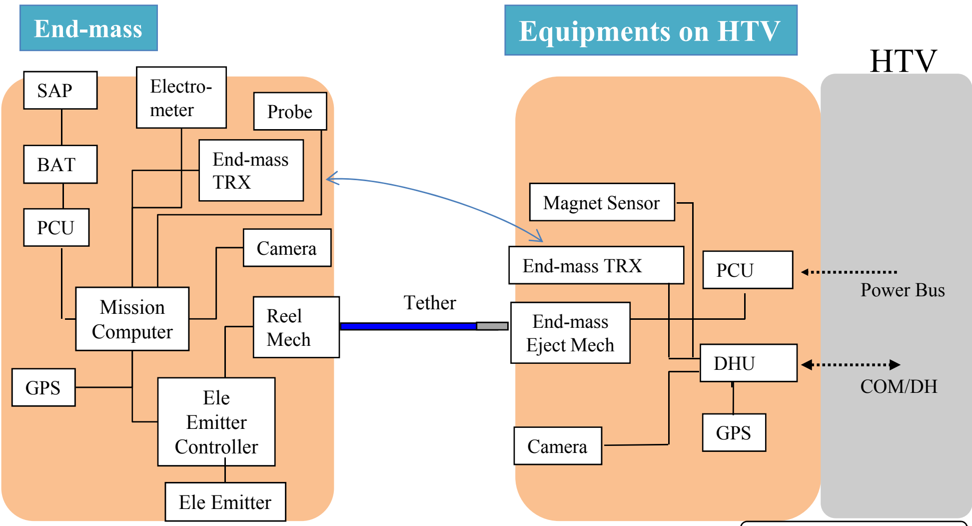

Fig. System Block Diagram

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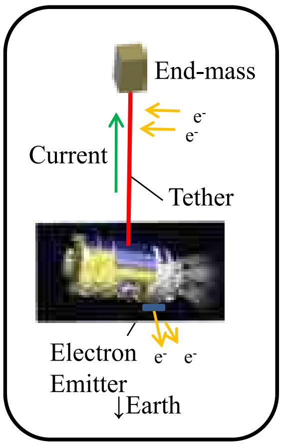
3.2 Study of Configuration

●Option3: ○

A solar array panel on the back of ULC could be removed based on power resource experience on HTV1 through HTV3. Then the end-mass could be deployed from there. And, the backside on HTV is covered by the rendezvous sensor (RVS) which is used in approaching ISS. The RVS could monitor the end-mass motion. Therefore, GPS for monitoring the end-mass position and transponder for transmitting the information would be unnecessary. As a result of that, EDT system could be much simpler.



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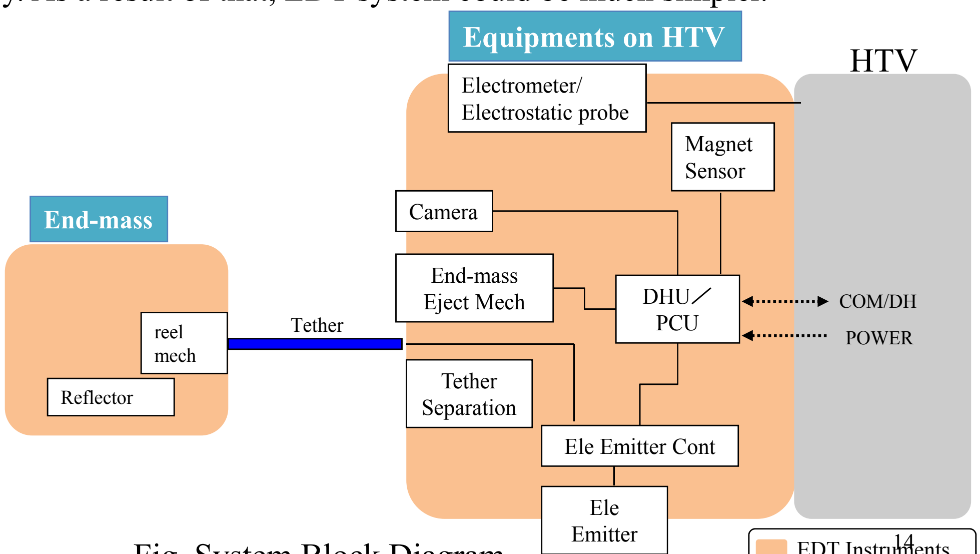

Fig. System Block Diagram

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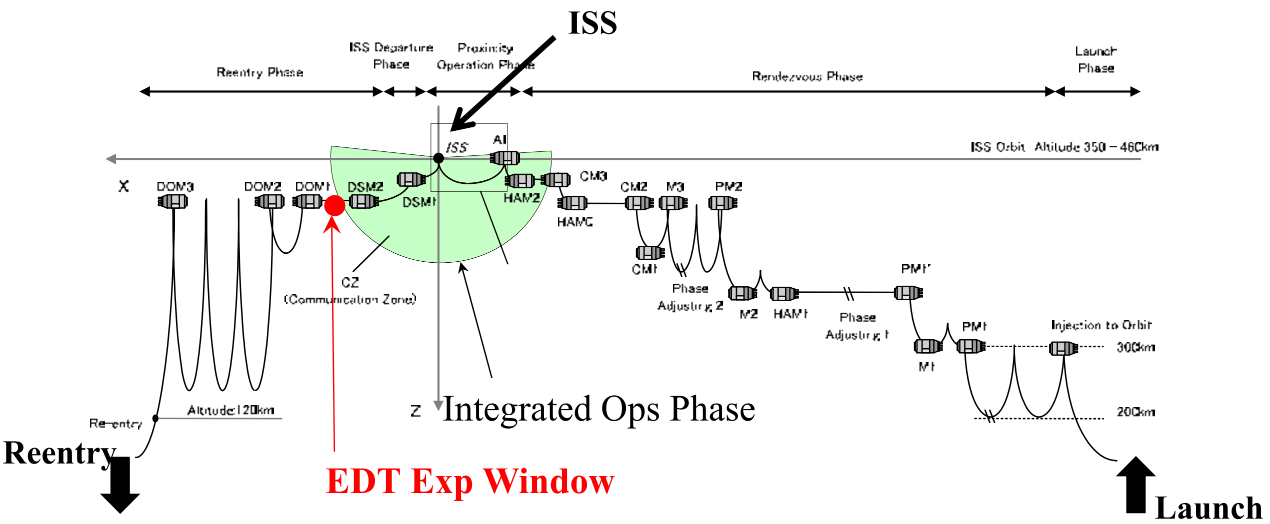
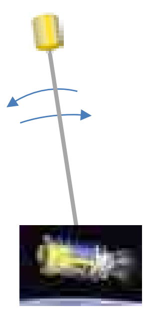
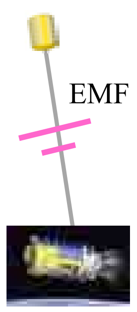
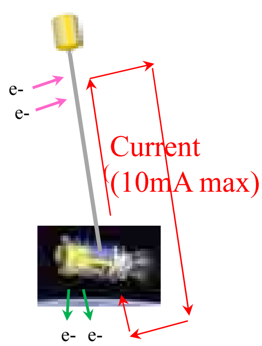
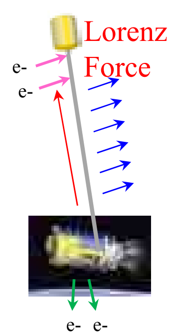
3.3 Study of EDT Exp Window

By prioritizing the HTV mission objective i.e. transport of cargo/supplies to the ISS, EDT Exp should be performed from the end of integrated operation until reentry.



3.4 Study of EDT Exp Sequence

Phase	Deployment	Stable Libration		Electron Emitter Ops		
Phenomena	Eject & Deploy	Libration	EMF	Emission	Collecting	Lorenz Force
Config	700m deployment 					
Outcome	Acquire the characteristics - tether deployment - libration during deployment	Acquire the characteristics of libration after deployment	Confirm Mutual characteristics between orbital motion and generated voltage	Confirm driving current by emitting and collecting electron		Confirm Lorenz force

3.5 Usage of HTV function on EDT Exp

Monitor the end-mass motion by RVS

The RVS filed of view is plus/minus 20 deg, and end-mass with tether could librate with plus/minus 60deg (max) in plane. RVS could trace the end-mass motion by controlling the HTV pitch angle via ground commands.

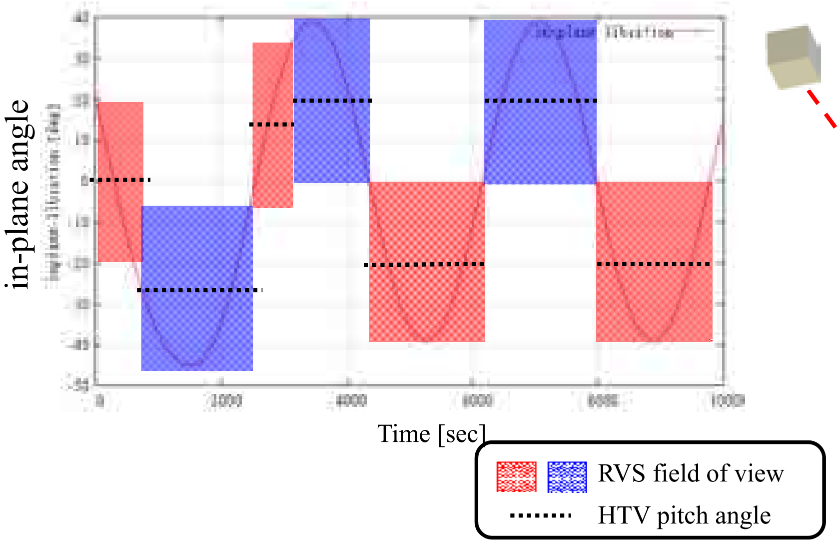


Fig. pitch angle control sequence

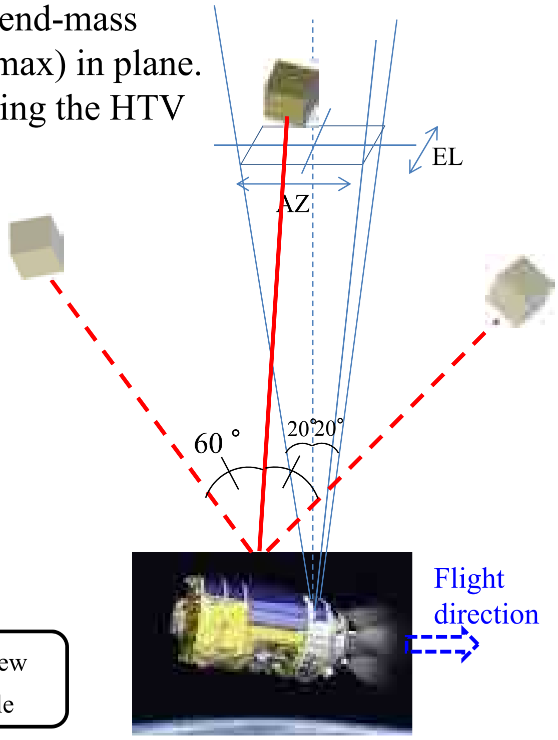


Fig. RVS field of view

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4. Summary

- HTV is originally designed with consideration for space debris because it has pressurized section where crews enter.
- As above, Space Debris has to be considered with making human space ship fly into space.
- We would like to continue the study to contribute solving the space debris problem.

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