Feasibility Study of Electrodynamic Tether Technology Demonstration on H-II Transfer Vehicle

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Background

- Space debris has been steadily increasing.
- Cascading effect by the collision between the objects would worsen the situation further in the orbit with high density debris.
- To ensure the safety of future space activities, aggressive measures to reduce debris is needed.

- JAXA R&D division has been investigating method to de-orbit these objects since 1990s
  - EDT propulsion is one of promising candidates for active deorbiting
- Now JAXA R&D and HTV program are collaborating to demonstrate EDT technology on-orbit by HTV before 2020.
ElectroDynamic Tether (EDT) Principle

- EDT utilizes Lorentz force by interaction between current on conductive tether and the geomagnetic field to generate propulsive force
  - Therefore this system does not require propellant to change orbit

- Magnitude of Electric Potential or ElectroMotive Force (EMF)
  \[
  V_{emf} = (v \times B) \cdot L \quad (1)
  \]
  \(v\) is velocity, \(B\) is magnetic flux per area, and \(L\) is the vector from one end of the tether to the other

- Lorentz force \(F\) is given by
  \[
  F = (I \times B) \cdot L \quad (2)
  \]
  where \(I\) is current flows in the tether
What’s HTV?

◆ Logistic Supply and Waste Disposal Vehicle for the ISS
◆ Developed by Japan Aerospace Exploration Agency (JAXA)
◆ Mission Summary of HTV
  • HTV-1: Sep. 11 to Nov. 2, 2009 (Demonstration Flight)
  • HTV-2: Jan. 22 to Mar. 30, 2011 (1st Operational Flight)
  • HTV-3: July. 21 to Sep. 14, 2012
  • HTV-4: Planed on Aug. 4, 2013
  • HTV-5 to -7: Planed in 2014 to 2016
## HTV Onboard System

| Dimensions          | Length: 9.2 m  
<table>
<thead>
<tr>
<th></th>
<th>Diameter: 4.4 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total mass full loaded</td>
<td>16.5 tons</td>
</tr>
<tr>
<td>Launch Vehicle</td>
<td>H-IIB launch Vehicle</td>
</tr>
</tbody>
</table>
| Target orbit        | Altitude: 350km~460km  
|                    | Inclination: 51.6deg |
| Cargo capability    | 6 tons in total   |
| Press.              | Up to 5.2 tons  
|                    | 8 ISPR equivalent racks  
|                    | 300kg potable water |
| Un-press.           | Up to 1.5 tons  
|                    | Up to 3 EF payloads  
|                    | Up to 6 Battery ORUs |
| Propulsion system   | Four 500N main engine |
|                     | Twenty eight 110N RCS thrusters |

[Diagram of HTV Onboard System]
HTV Operation System

- TDRS
- ISS
- WSC (White sands Complex)
- MCC-H @ JSC
- HTVCC (HTV Control Center)
- ISS Link
- TDRSS Link
- HTV
- Al point (-5 km)
- ISS (PROX) Link
- 23 km
- JEM Control Center
- HAM2
- TLM Send Back

@ JAXA Tsukuba
Restricted splashdown area for the HTV
1. ISS departure
2. Descent to parking orbit
3. Awaiting a timing of reentry
4. Reentry

ISS orbit (Altitude: 350~460km)

Parking orbit (Timing Adjustment)

140~150km

Reentry flight-path angle (-1.35 ~ -1.65 deg)

Reentry interface point
South latitude: 40deg,
Altitude: 120km

DSM1: Descending Maneuver#1
DSM2: Descending Maneuver#2
DOM1: Deorbit Preparation Maneuver#1
DOM2: Deorbit Preparation Maneuver#2
DOM3: Deorbit Maneuver

Reentry orbit

Yaw attitude around

De-orbit

ISS

KOS

AE

IDM1

IDM2

DOM3

DOM2

DOM1

JAXA

HTV Nominal ISS Departure and Reentry Flight Profile
Required Technology for Operational Debris Deorbit System

1. Non-cooperative Rendezvous Technique to Debris
2. De-orbit Technique, such as EDT, Chemical Propulsion, etc.
3. Technique to attach EDT on the target or capture the target by Robotics
4. Total design of Debris Deorbit System
5. International Cooperation Framework for Debris Disposal

◆ Our team is now proposing EDT is a good solution for deorbiting
◆ At initial study, we put target on the deorbit technology demonstration, as JAXA’s first attempt for on-orbit tether system, as below;
  ➢ Demonstrate tether propulsion capability for subsequent whole deorbit technology demonstration
    • Demonstrate tether extension and observe tether with end-mass motion to verify dynamics model
    • Control EDT current and observe its influence on EDT motion
Feasibility Study for on-orbit Demonstration of EDT

• First JAXA studied about hosted vehicle
  ➢ Several options were investigated, such as installing on the rocket second stage, microsatellite configuration, and etc.
  ➢ One possible option: Install EDT system as a piggyback payload
  ➢ Advantages of piggyback configuration:
    • Minimize system development element by utilizing the hosted vehicle function, such as power, data processing, and communication system
    • Opportunities of launch can be easily secured

• HTV is a possible candidate of hosted vehicle
  ➢ Yearly flight is planned from 2014 to 2016
  ➢ Natural waste to the atmosphere of the experiment system is expected after demonstration
First Concept of EDT demonstration on HTV

- End-mass is deployed from the open area of HTV Unpressurised Carrier section toward the nadir.
  - Natural current generates decelerate force on tether
- To generate EDT force to decelerate HTV, End-mass was required like a full satellite functions.
  - Not feasible in view of cost and short development period
Updated Concept of EDT demonstration

• To simplify the experiment system
  ➢ Utilize HTV’s LIDAR (RVS) to track end-mass
  ➢ Change direction for deploy to the Zenith
    • By removing several solar arrays on HTV
  ➢ Only laser reflector is needed on the End-mass
HTV’s RVS

- LIDER (Light Detection and Ranging)
  - Measure range and line of sight angle to the target
- Developed and Manufactured by Jena Optronik GmbH, Germany
  - Utilizes 910 nm Semiconductor Laser
  - Field of View (FOV): +/- 20 degrees in both Azimuth/Elevation
  - Maximum operation range is 730 meter with corner cube reflector
  - Track target reflectors installed on the ISS
  - Co-developed by ESA ATV/JAXA HTV program

- Electric Tether length will be less than 730m
- JAXA expects 700m is enough in consideration of purpose of the first on-orbit demonstration
Safety Consideration for EDT Demonstration

• ISS Safety is one of the most important considerations.
• One of possible hazard is collision of tether with the ISS, therefore unintended release of tether shall be avoided vicinity of the ISS.
• Also, at either intended or unintended release of tether with end-mass after HTV arrives demonstration area, possibility to get into the trajectory which penetrates the ISS should be avoided.
  ➢ In order to maintain safe trajectory after tether release, JAXA plans to conduct EDT demonstration 20 km lower than the ISS orbit.
  ➢ Tether is released after demonstration to secure active HTV reentry
The Latest Status of EDT Demo on HTV

- JAXA is now studying below in detail;
  - HTV/EDT system interface design
  - Mission profile & required days for the demonstration
  - Safety design
- The goal of study is to demonstrate the EDT by HTV-6 or HTV-7 in 2015-2016 period
- After studies, detail demonstration plan will be proposed and reviewed JAXA internally
Conclusion

- JAXA’s On-orbit EDT Demonstration Plan was Introduced
  - EDT is a candidate of propulsion system to de-orbit debris
  - JAXA’s feasibility study of EDT demonstration is on-going
  - One of possible candidate of hosted vehicle is HTV6 or HTV7
  - By utilizing HTV bus system, experiment system will be simplified and it will enforces mission practicability

Thank you very much for your attention