Orbital debris removal by the active maneuvering spacecraft with tether net/gripper

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Outline

➤ Introduction
➤ Status of Home and Abroad
➤ Study Contents
➤ Current Status
➤ Next Steps
➤ Conclusions
Introduction

Background and Requirement

- **Increase in number.** Orbital debris will become a serious problem for low Earth orbit (LEO) and for the geosynchronous orbit (GEO).
  - Defunct satellites (either complete propellant reserve or fail)
  - Launch vehicle upper stages
  - Could not be re-orbited

- **Dangerous:**
  - Pose a serious collision risk
  - Generate a number of smaller bits of debris between large Orbit debris

- **Need for mitigation:**
  - Effective measures
  - Reasonable measures
Introduction

Objective

• Active removal of large orbit debris (LEO,GEO):
  – Avoid the excessive growth of orbit debris
  – One of most practical strategies

• Active maneuvering spacecraft:
  – Rendezvous and capture an inert, tumbling and non-cooperative target
  – Tow it to a graveyard orbit
  – Possess orbital maneuvering capability
  – Bus design
  – Payloads: tether net/gripper systems
Status of home and abroad

**ESA: ROGER**

- **Robotic Geostationary orbit Restorer:**
  - Approach and capture defunct satellites in GEO
  - Transfer it to a graveyard orbit
- **ROGER study (payload):**
  - Tether-net system
  - Tether-gripper system
Status of home and abroad

ESA: ROGER

Tether-net system

Tether-gripper system
Status of home and abroad

TECSAS

- **TEChnology Satellite for demonstration and verification of a Servicing System**
  - German Space Organization (DLR)
  - Canadian Space Agency (CSA)
  - Russian Mission Control Center (MCC)

- **Main objective:**
  - Unmanned on-orbit assembly
  - Unmanned on-orbit servicing
Status of home and abroad

TECSAS

- Demonstrate:
  - Far rendezvous
  - Close approach
  - Inspection fly around
  - Capture of a non-cooperative and cooperative client
  - Stabilization and identification of the behavior of the coupled satellites
  - Flight maneuvers
  - Manipulation on the captured client
  - Attitude changes by manipulator motions
  - Decoupling of service and client satellites
  - Formation flight
Japan: Space debris removal system

• Mission
  – Rendezvous with a target
  – Fly around it for inspection
  – Transfer the target to a disposal orbit

• Key technologies:
  – Cost-effective orbit transfer
    (electrodynamics tether)
  – Rendezvous
  – Angular momentum dissipation
  – Robot operation
Status of home and abroad

➢ Trend (Large orbit debris)

• Active removal
  – Active maneuvering spacecraft
  – Possible measure

• Key technologies:
  – Orbit rendezvous
  – Close approach and Station keeping
  – Capture
  – Transfer

• Payloads:
  – Tether net system
  – Tether gripper system
  – Robotic arm
Study contents

► General system argumentation
  • Concepts design and technical index
  • Spacecraft bus design
    – Based on a new design, payload accommodation
  • Payloads:
    – Tether net system
    – Tether gripper system

► Key component technologies
  • Exploration and identification of large orbit debris:
    – Radar sensors
    – Vision sensors (optical and infrared sensors)
  • Orbital rendezvous of large orbit debris:
    – Long-range (absolute navigation)
    – Short-range (relative navigation)
Study contents

- **Close approach and station keeping of large orbit debris:**
  - A very close distance (within the reach of tether net/gripper)
  - Strictly control to avoid collision
  - Satisfy the requirements of releasing attitude

- **Capture operation of large orbit debris:**
  - Tumbling and non-cooperative target, capture device
  - Attitude stabilization

- **Orbit transfer of large orbit debris:**
  - Transfer to a disposal orbit
  - Short tether
  - Pose a serious collision risk
  - To avoid collision
  - To tow the target, adjust the control system
Study contents

➢ Simulation

• **Numerical Simulation:**
  – Verify key technologies
  – Evaluate the controller’s performance
• **Hard in the loop Simulation:**
  – Exercise hardware-software interfaces
  – Assess the efficacy of algorithms
  – Expose algorithm to hardware error characteristics

➢ Experimental verification

• Capture operation experiment
• Payload releasing experiment
Current Status

• The major assumptions and requirements are as follows:
  – Removal targets: large orbit debris
  – Types of debris orbit: GEO, LEO
  – Graveyard orbit: IADC guidelines
  – Mass of targets: 1000kg~3000kg
  – Number of targets: approximately 5
  – Payloads: tether net/gripper systems

• Current work:
  – General system argumentation
  – Key technology
Next Steps

• Numerical Simulation:
  – Software design
  – Software test

• Hard in the loop Simulation:
  – Navigation devices
  – Payloads
Conclusions

• **Main missions**
  – Active maneuvering spacecraft with tether net/gripper system
  – Controlling the threat from large orbit debris

• **Review**
  – Related studies

• **Discuss**
  – Study contents, Key technologies, Next steps

• **Development issues**
  – Payload design
  – GNC during rendezvous, capture and towing phase
Thank you for your attention!