

On-orbit Servicing and Assurance Engineering

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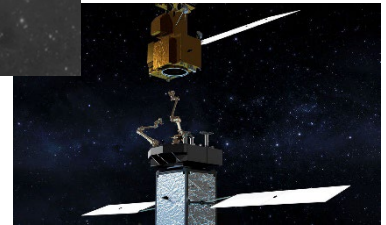
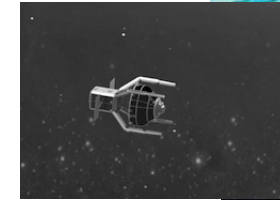
With the support of NExIS, JAXA, ESA, and Trilateral Reliability Task Force Participants



Agenda

How can Assurance Engineering support On-Orbit Servicing/ADR?

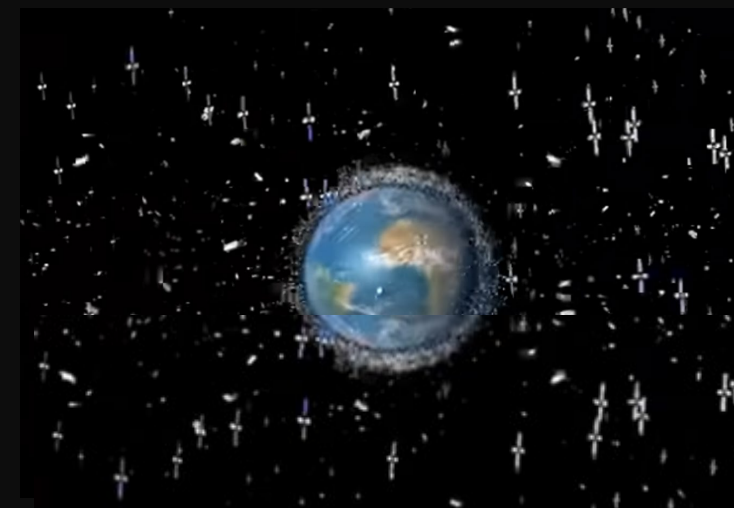
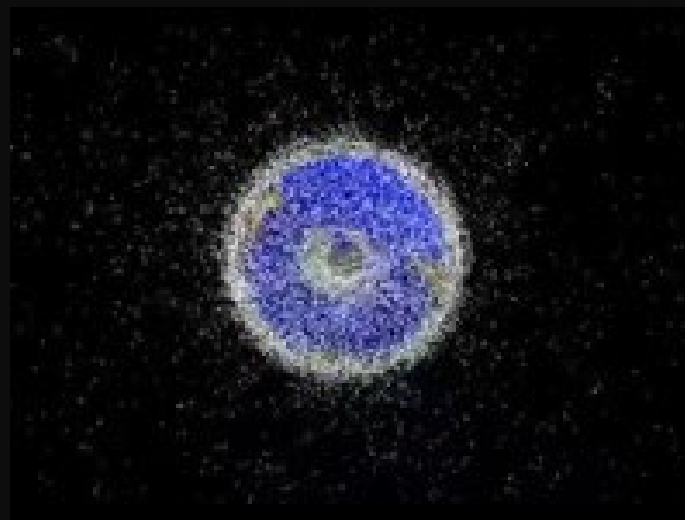
- Historical Perspective
- Current Spacekeeping Strategies
- Risk/Safety Support
- Conclusion

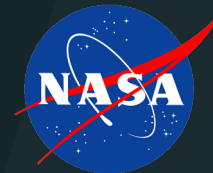




Historical Perspective on our Current Condition

- Currently over 128 million objects
- We have been ending satellites to space for over 60 years
- Thus far we have put 11,140 satellites in orbit. As of 8/19/21 Approximately 3,372 are active.
- In 2020 alone 1,283 satellite were launched.
- Constellation of 1000s to 42,000 are planned.





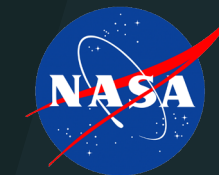
Current Spacekeeping Strategies

- **Code of Conduct (Policies/Requirements)**
- **Design for Servicing/ADR**
- **Servicing**
- **ADR**

- Mitigate Debris generation in deployment and operations
- Minimize on-orbit break-ups caused by propellants, batteries, pressure vessels, self-destruct, wheels, or any other stored energy by Passivation and design
- NASA/DOD/ESA/JAXA Disposal minimum probability 0.9 requirement
- Limit natural-decay time from LEO NASA/DOD/ESA/JAXA to 25 years
- Retrieval of unusable satellites (or relocating to non-useful regions) within 5 years while mitigating debris generation
- Allowances for > 100 years of orbital storage/disposal
- Conduct Servicing or Assisted Debris Removal (ADR) while mitigating debris generation and/or collision/explosion risks
- Conduct Servicing while avoiding damage to client or servicer.

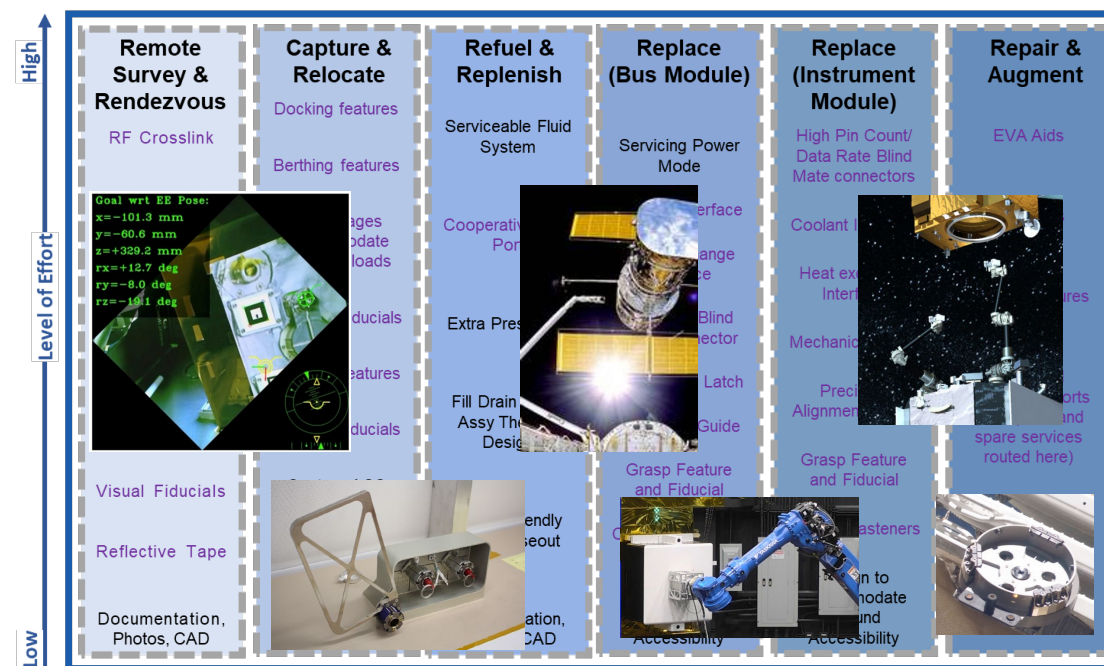


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- Servicing
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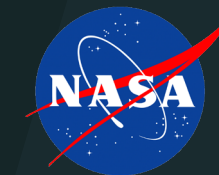
Designing a cooperative client or target by:



Serviceability spectrum from NASA's Exploration & In-space Services (NEXIS)

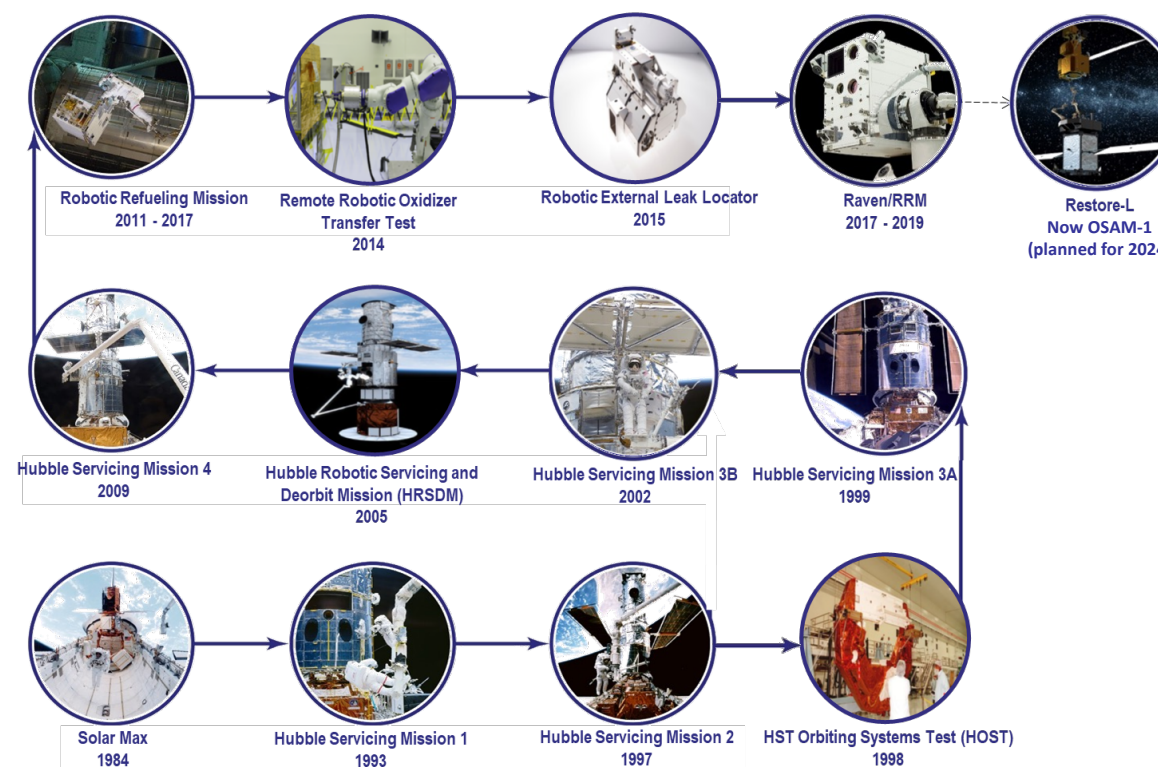


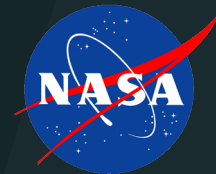
Current Spacekeeping Strategies



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- ADR

NASA has a long history of servicing and is continuing to advance those techniques:

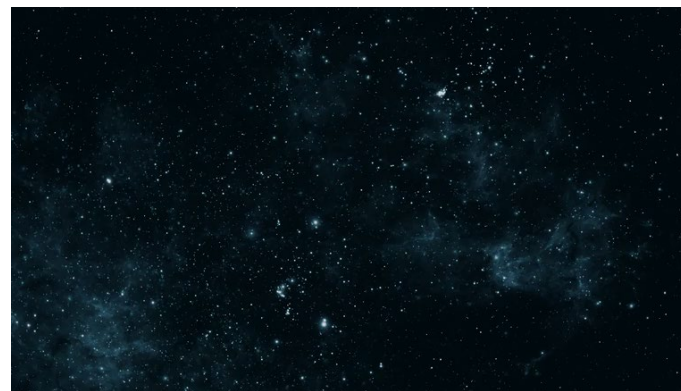


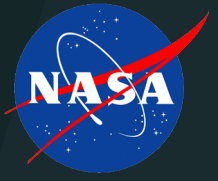


Current Spacekeeping Strategies

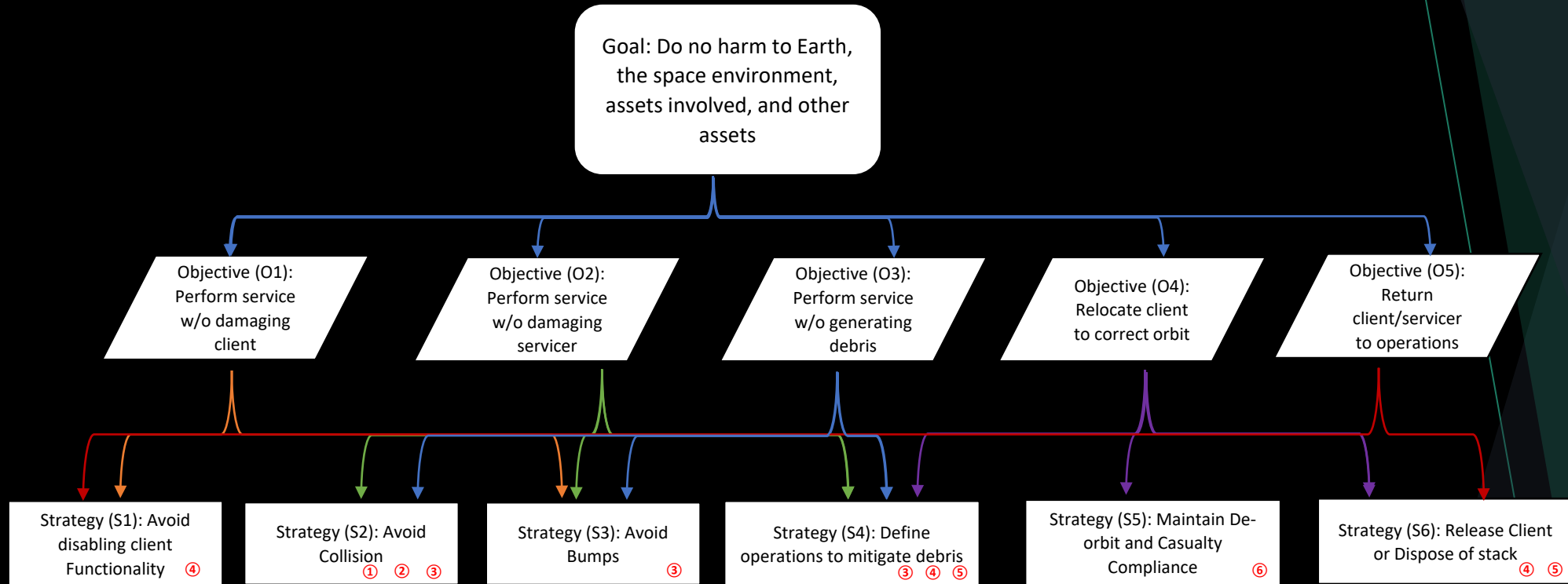
- **Code of Conduct (Policies/Requirements)**
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ESA/JAXA are advancing ADR techniques with ClearSpace-1 and CRD2:



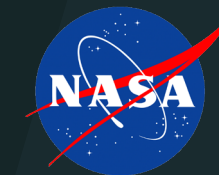


Risk/Safety Support





Risk/Safety Support



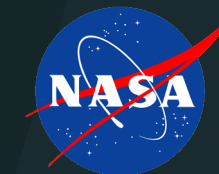
- **Avoid disabling client functionality**
- **Avoid collisions**
- **Avoid bumps**
- **Define operations to mitigate debris**
- **Maintain De-orbit and Casualty Compliance**
- **Release Client or Dispose of stack**

NASA/ESA/JAXA have or plan to:

- Perform Do No Harm FMECA/FT of Servicing/ADR operations
- Inspect Client/Debris from Ground, Telemetry, or On-orbit to determine current state (Attitude, damaged/dangling equipment)
- Conduct Aging (systems/material) analysis of Client/Debris
- Conduct Maintainability Analysis
- Develop Operations and Capture plans

With knowledge of:

- Grapple capture methods/limitations
- Debris/Client's design (serviceability) and current state
- Operations critical events and fault tolerance
- Doing Nothing Cost/Risks and insurance limitations
- Servicer capabilities including fail-safes/overrides
- System/part failure rates and expirations
- Existing serviceability technology of client/debris



Risk/Safety Support

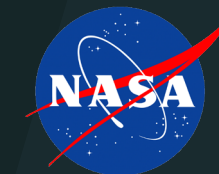
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NASA/ESA/JAXA have or plan to:

- i. Perform Operations Process FMECA/FT or STPA Hazard Analysis of Servicing/ADR operations
- ii. Perform Probabilistic Risk Assessments (PRA) of all or critical events (rendezvous-capture)
- iii. Inspect Client/Debris from Ground, Telemetry, or On-orbit to determine current state (Attitude, damaged/dangling equipment)
- iv. Develop Operations and Capture plans
- v. Estimate via testing/modeling debris/break-up results from bumps/collision and perform Causality Analyses

With knowledge of:

- a. Grapple capture methods/limitations
- b. Debris/Client's design (serviceability) and current state
- c. Operations critical events and fault tolerance
- d. Doing Nothing Cost/Risks and insurance limitations
- e. Servicer capabilities including fail-safes/overrides
- f. System/part failure rates and expirations
- g. Client/Debris material aging



Risk/Safety Support

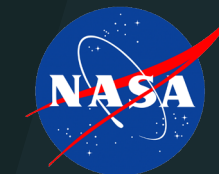
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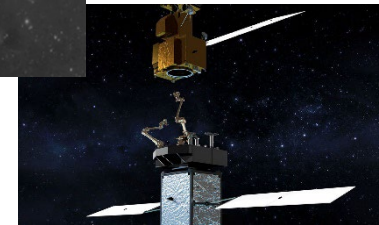
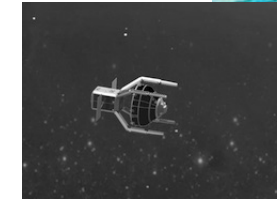
- i. Assess De-orbit Probability, Duration, and Survivability
- ii. Perform orbit analyses of stacked and unstacked configurations (orbit parameters and impact location)
- iii. Inspect Client/Debris from Ground, Telemetry, or On-orbit to determine current state (Attitude, damaged/dangling equipment)
- iv. Develop Operations/Disposal plans (maneuvers/release)
- v. Perform Causality Analyses

With knowledge of:

- a. Stacked and unstacked mass and maneuverability
- b. Debris/Client's design (serviceability) and current state
- c. Operations critical events and fault tolerance
- d. Doing Nothing Cost/Risks and insurance limitations
- e. Servicer release capabilities including fail-safes/overrides
- f. System/part failure rates and expirations
- g. Client/Debris material aging

Conclusion

- Provide Risk/Safety Support
 - Enhanced Failure Analysis
 - Heightened Scenario Analysis
 - Complex and Continual Asset Assessment
 - Serviceability and Maintenance Analysis
 - Situational Debris Generation Modeling and Testing
- Assure Servicer Viability and Quality



**How can
Assurance
Engineering
support
On-Orbit
Servicing/ADR?**

Questions

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