13th TRISMAC

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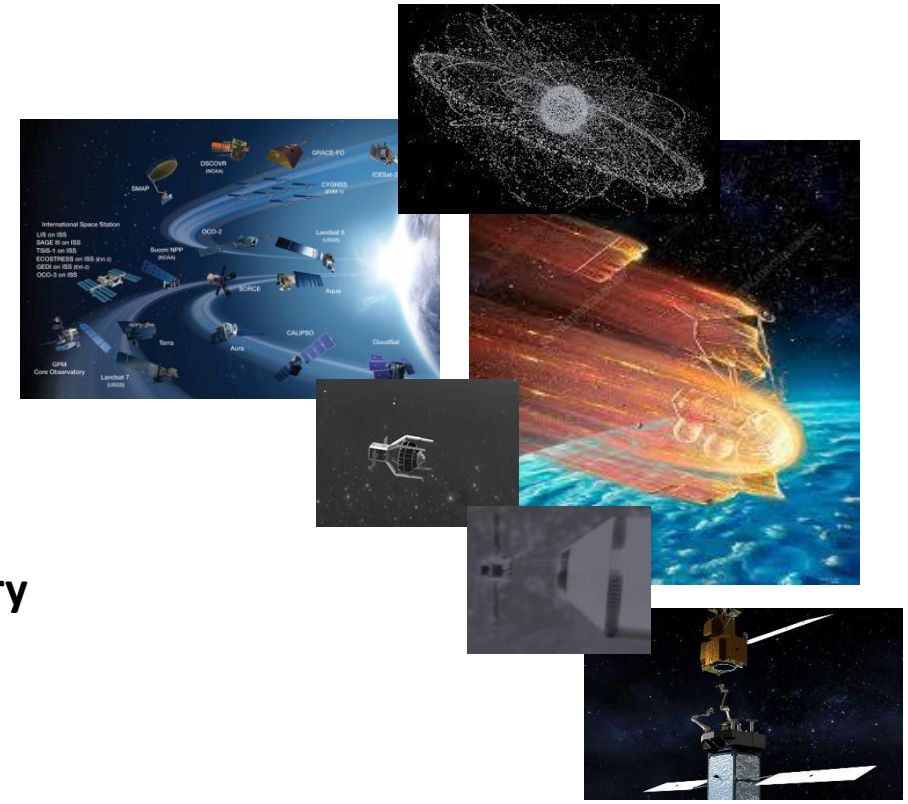
How can Mission Assurance support On-Orbit Servicing/ADR?

Trilateral Task Force Lead: Nancy J Lindsey (NASA – GSFC)

Members: Jesse Leitner (GSFC), Anthony DiVenti (NASA-OSMA), Toru Yoshihara (JAXA), Kenichi Sato (JAXA), Takashi Yamane (JAXA), Osamu Yamada (JAXA), Fabrice Cosson (ESA), Silvana Radu (ESA), Sergio Ventura (ESA), Antonio Harrison Sanchez (ESA), Todd Paulos (JPL)

Agenda



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

- **Servicing/ADR Support Discovery Process**
  - **Policies**
  - **Research**
- **Servicing/ADR Risk/Safety Support Codifications**
  - **Tactics**
  - **Tasks**
- **Summary**

Servicing/ADR Support Discovery Process

- **Servicing/ADR Support Discovery Process**
  - **Policies**
  - **Research**
- **Servicing/ADR Risk/Mission Assurance Support Codifications**
  - **Tactics**
  - **Tasks**
- **Summary**

Review and Compare Servicing/ADR Policies

- Servicing/ADR Support Discovery Process
  - Policies
  - Research
- Servicing/ADR Risk/Mission Assurance Support Codifications
  - Tactics
  - Tasks
- Summary

	International (IADC & ITU) [1, 20]	United States [10, 11, 13, 14, 17]	Japan [3]	France [19] (France is part of Europa but has specific National requirements as well)	Europe
Additional Spacekeeping (Servicing and Debris Removal)	**IADC 2007: "Retrieval is also a disposal option."** **ISO/CD 24330 (under development until 2022)** **Space systems — Rendezvous and Proximity Operations (RPO) and On Orbit Servicing (OOS) — programmatic principles and practices** **ISO (24113:2019) does not address servicing or proximity operations.**	**United States Government (USG) ODMSP –Rendezvous, proximity operations, and satellite servicing: In developing the mission profile for a structure, the program should limit the risk of debris generation as an outcome of the operations. The program should (1) limit the probability of accidental collision, and (2) limit the probability of accidental explosion resulting from the operations. Any planned debris generated as a result of the operations should follow the standard practices for mission-related debris set forth in Objective 1 - CONTROL OF DEBRIS RELEASED DURING NORMAL OPERATIONS.** **5-4. Safety of Active Debris Removal (ADR) operations: In developing the mission profile for an ADR operation on a debris structure, the program should limit the risk of debris generation as an outcome of the operation. The program should (1) avoid fragmentation of the debris structure, (2) limit the probability of accidental collision, and (3) limit the probability of accidental explosion resulting from the operations. Any planned debris generated as a result of the operations should follow the standard practices for mission-related debris set forth in Objective 1. The operations should be designed for the debris structure to follow applicable PMD practices set forth in Objective 4 - POSTMISSION DISPOSAL OF SPACE STRUCTURES** **2020 National Space Policy: "Evaluate and pursue, in coordination with allies and partners, active debris removal as a potential long-term approach to ensure the safety of flight in key orbital regimes."** **SPD-3: "The United States should pursue active debris removal as a necessary long-term approach to ensure the safety of flight operations in key orbital regimes. This effort should not detract from continuing to advance international protocols for debris mitigation associated with current programs. "** FCC: Proximity Operations 59 (FCC-CIRC1811-02). With increasing interest in satellite servicing and other non-traditional missions, there have been an increasing number of commercial missions proposed that involve proximity operations and rendezvous of spacecraft. We propose that applicants be required to disclose whether the spacecraft will be performing any space rendezvous or proximity operations. The statement would indicate whether the satellite will be intentionally located or maneuvering near another spacecraft or other large object in space. Such operations present a potential collision risk, and operators will need to address that risk, as well as any risk of explosions or generation of operational debris that might occur through contact between spacecraft, as part of debris mitigation plans. Accordingly, we propose a disclosure requirement regarding these types of operations FCC 20-54 Proximity Operations 122. In the Notice, the Commission noted the increasing number of commercial missions proposed involving proximity operations and rendezvous of spacecraft. The Commission proposed that applicants be required to disclose whether the spacecraft is capable of, or will be, performing rendezvous or proximity operations. The Commission also sought comment on whether the rules should include anything more specific regarding information sharing about proximity operations with the 18th Space Control Squadron or any successor civilian entity. We adopt a disclosure requirement that would identify situations where there are planned rendezvous and proximity operations and provide a vehicle for further review of those operations. **The disclosure requirement follows the general approach in the revised ODMSP of analyzing such operations within the framework of standard debris mitigation objectives—limiting debris release, preventing accidental explosions, and limiting collision risk.** Commenters generally supported this approach. We note the evolving and developing nature of these operations, and accordingly find that more specific technical or operational requirements are premature at this time. Member of CONFERS (The Consortium for Execution of Rendezvous and Servicing Operations) Studies	JERG-2-026 **On-orbit service:** Intentional interference by a servicing spacecraft with a client spacecraft for refueling, resupplying, adding or replacing functionalities and assisting PMD. Active Debris Removal (ADR) for inactive spacecraft / target debris and transportation to/from a space station is also a part of on-orbit servicing. ADR shall be taken in to **(1) Avoid unintended generation of debris caused by a collision upon RPO, physical contact and docking with a target as well as the loss of debris mitigation functions are defined as a critical hazard (e.g., serious effect on environment)**.(2) Conduct a hazard analysis of the entire system integrating a servicing spacecraft, target and ground system, and take safety measures to address the identified hazards and hazard causes based on fault tolerance. (3) Additional fault tolerance or equivalent measures are considered when a collision could lead to a catastrophic consequence such as serious threat to the manned spacecraft because of its size, orbit, and/or payload properties. (4) Avoid inducing failures direct or indirect (impingement, contamination, etc.) in servicing of client system. (5) Inability to separate client and servicing if required.	In 2019, France released its Space Defense Strategy, in which it acknowledged the increasing importance in-orbit services will have in the future due to the high number of objects in orbit and the need to remove debris. France is involved in the development of IOS in the field of Active Debris Removal, reconfiguration, and de-orbiting. France has contributed to the development of Space Debris Mitigation Guidelines of the Committee, the European Code of Conduct for Space Debris Mitigation, and the IADC Space Debris Mitigation Guidelines. The French Technical Regulation is consistent with these guidelines, as well as with the ISO 24113 standard. France is currently using debris mitigation policies to guide Close Proximity Operations (CPO) and RPO.	ESA's Close Proximity Operations (CPO) Working Group is preparing the safety/sustainability requirements (e.g. technical, operational, verification & validation) for non-human rated missions executing rendezvous, proximity and capture operations. The CPO Working Group will provide technical inputs to the European Cooperation for Space Standardization (ECSS) Space Traffic Management Working Group on technical aspects concerning the development of worldwide RPO) and OOS draft guidelines and best practices handbook for 2022 release. Currently using debris mitigation policy to guide CPO and RPO. Member of CONFERS

Common do no harm requirements: avoid debris generation

Common maintenance of compliance with debris mitigation policies

Slight variations in established policies

Common challenge of developing evolved reliability and hazard assessment tactics for Servicing/ADR

Research and Compare Plans, Goals, and Needs

- Servicing/ADR Support Discovery Process
  - Policies
  - Research
- Servicing/ADR Risk/Mission Assurance Support Codifications
  - Tactics
  - Tasks
- Summary

Name	Position	Relevant projects	Relevant Activities
Laura Delgado Lopez Frank Groen Matt Forsbacka/JC Liou Vicky Hwa	Senior Policy Analyst SMD/OTPS Dep Chief OSMA MASCD Director/ODPO Lead Sr Tech. Leader	N/A	Safe Rendezvous and Close Proximity Operations OSMA/MASCD/ODPO MPAD
Jason Emperador, Tammy L. Brown, Brian J Roberts	OSAM CSO OSAM Architecture Dep. Mgr, OSAM/NeXIS Dep. Program Mgr	RRM/OSAM projects	Safe Rendezvous and Close Proximity Operations
Ben Reed	Chief Technology Officer, Quantum Space	RRM projects	Safe Rendezvous and Close Proximity Operations Former Director of NASA's Exploration and In-Space Services Projects Division
Adina Cotuna	System Engineer	N/A	Safe Rendezvous and Close Proximity Operations Technical Lead of Close Proximity Operations (CPO) Working Group
Andrew Wolahan	System Engineer	ClearSpace-1 & other ADR / IOS projects	Safe Rendezvous and Close Proximity Operations Member of Close Proximity Operations (CPO) Working Group
Toru YAMAMOTO	Team Leader, Senior Researcher, Research Unit I, Research and Development Directorate	CRD2 (commercial removal debris demonstration)	R&D of - Active debris removal technologies - Guidance navigation and control technologies
Ryo NAKAMURA	Associate Senior Engineer, Research Unit I, Research and Development Directorate	CRD2 (commercial removal debris demonstration)	R&D of - Active debris removal technologies - Guidance navigation and control technologies

Stakeholder interviews led to identifying ADR/Servicing Objectives and that no new Reliability methods will be needed but current analysis methods will likely need to expand their scope to provide all the risk-to-value information needed.

- Servicing/ADR Support Discovery Process
  - Policies
  - Research
- Servicing/ADR Risk/Mission Assurance Support Codifications
  - Tactics
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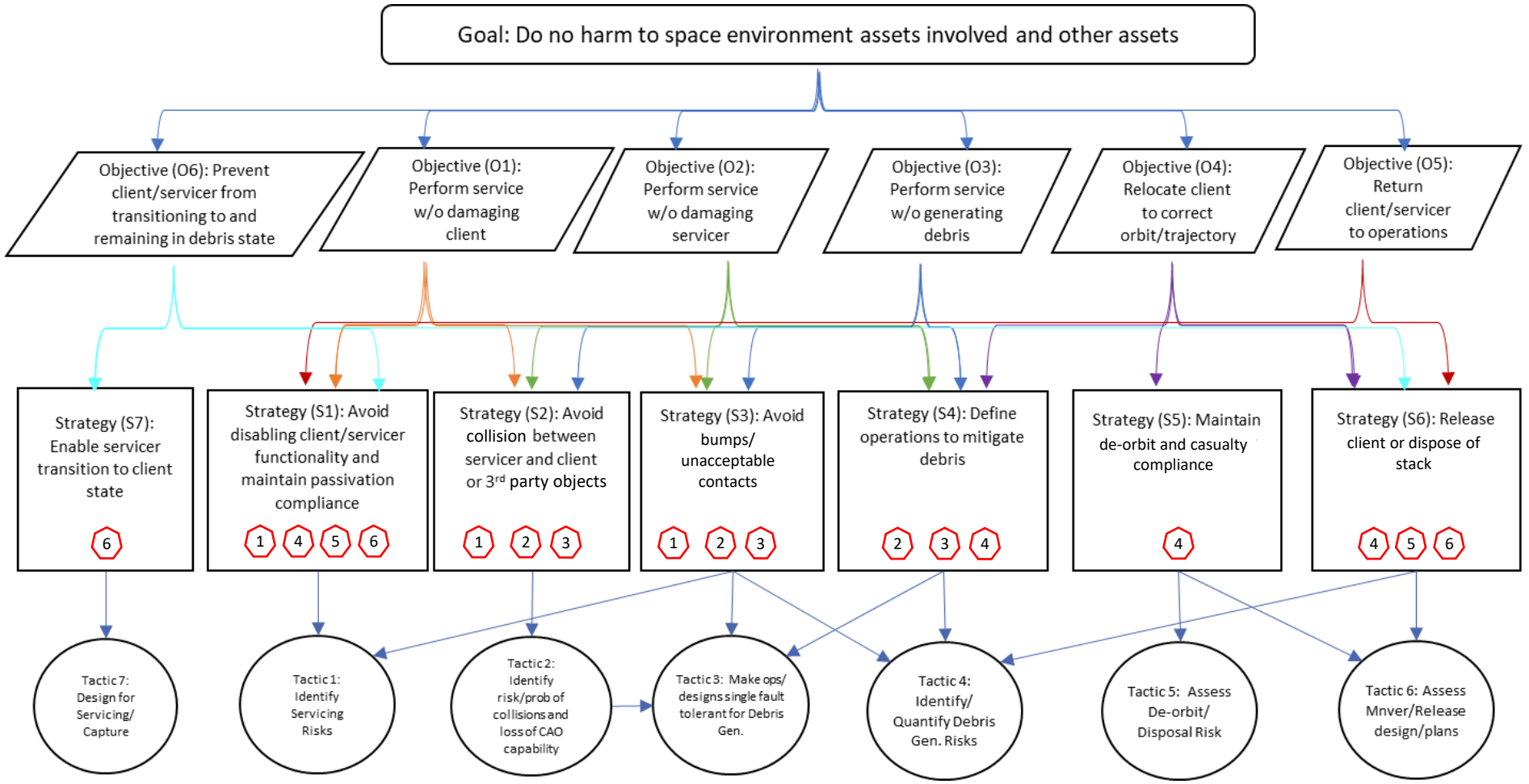
Tasks to Enable Viable Servicing/Active Debris Removal Objectives
(NASA/SP-20230002885, ESA-TECQQD-TN-2023-000647, CAA-2022037)



Reviewers and Mission Assurance Experts can support these solutions and tactics by performing expanded and novel tasks with appropriate knowledge.

- Servicing/ADR Support Discovery Process
  - Policies
  - Research
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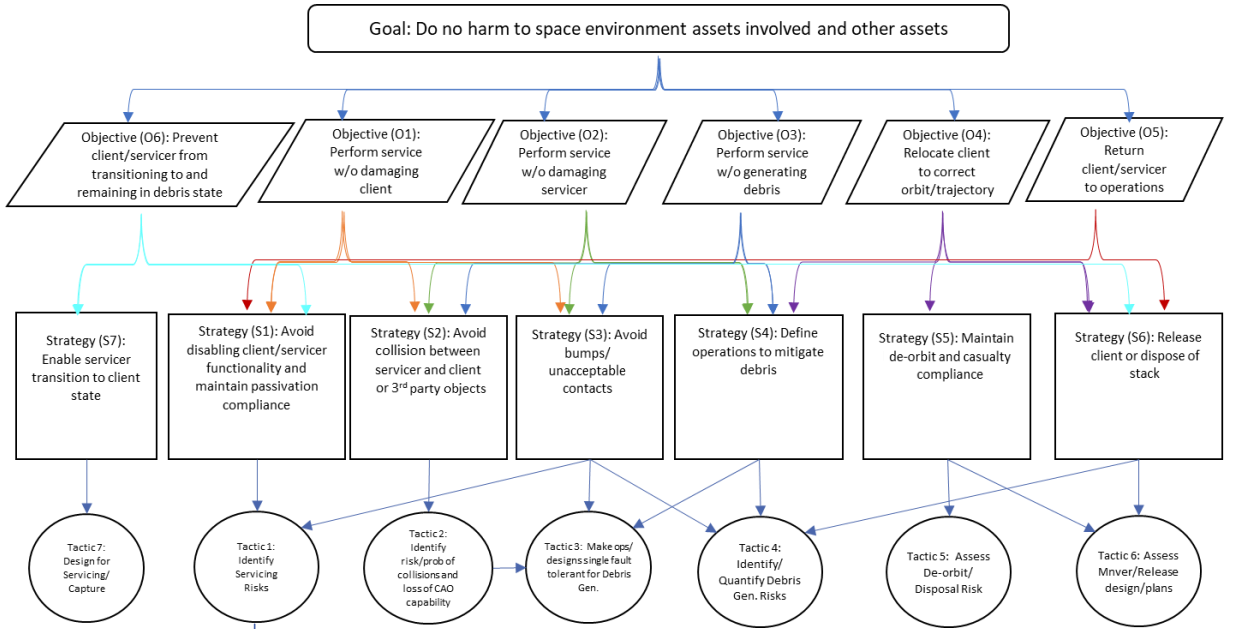
Tasks to Enable Identification of Servicing/ADR Risks



RE Tasks

Task 1: Perform DNH/Failure Analysis (FMECA/FTA)
Task 2: Perform Probabilistic Assessment
Task 3: Perform Process FMECA/FT

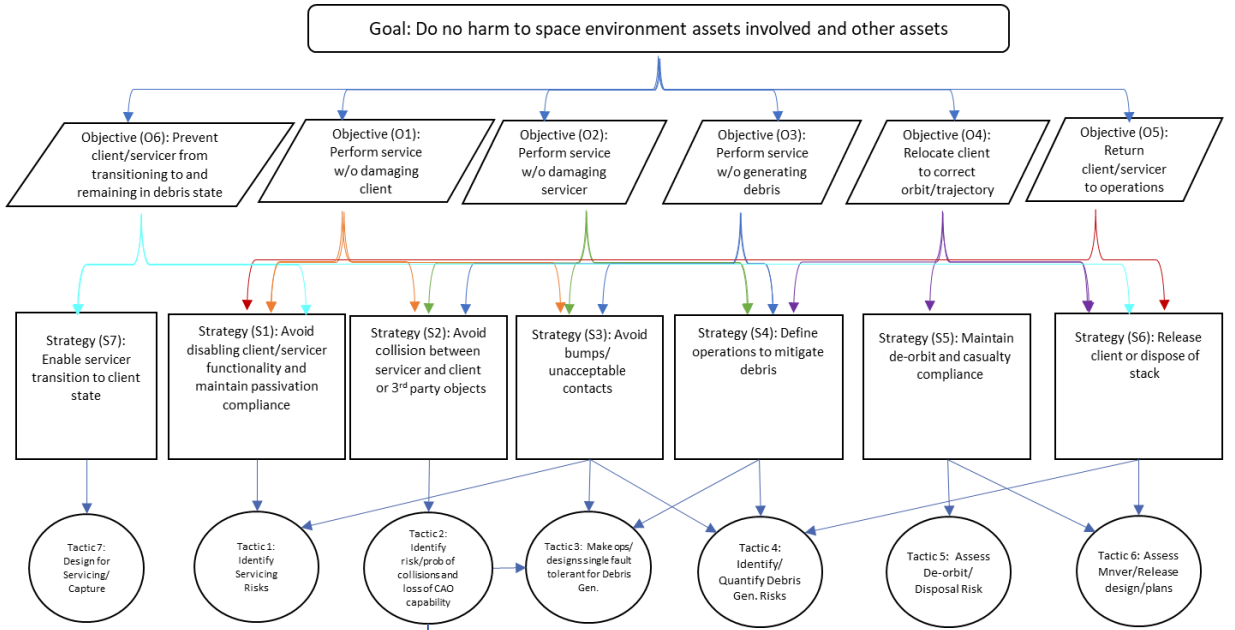
Knowledge Tasks

Task A: Life/Aging (systems/materials/structures) analysis of Client/Debris
Task B: Inspect Client from Ground, TLM, or On-orbit
Task D: Conduct Design Reviews to Ensure Serviceability Technology is present
Task E: Perform Orbit Analyses
Task G: Part/Material Testing/ Part/Material/Component Evaluation
Task H: Perform Entanglement/Release Risk and Hazard Assessments
Task I: Verify Trajectory is Safe
Task J: Perform collision avoidance operations
Task K: Select Capture method

Using failure and probability analyses to identify servicing/ADR risks is an achievable expansion in the practice (scope and focus) of the well-proven mission assurance methods.

Tasks to Enable Identification of Risk/Probability of Collisions and loss of CAO Capability

- Servicing/ADR Support Discovery Process
  - Policies
  - Research
- Servicing/ADR Risk/Mission Assurance Support Codifications
  - Tactics
  - Tasks
- Summary



RE Tasks

Task 2: Perform Probabilistic Assessment

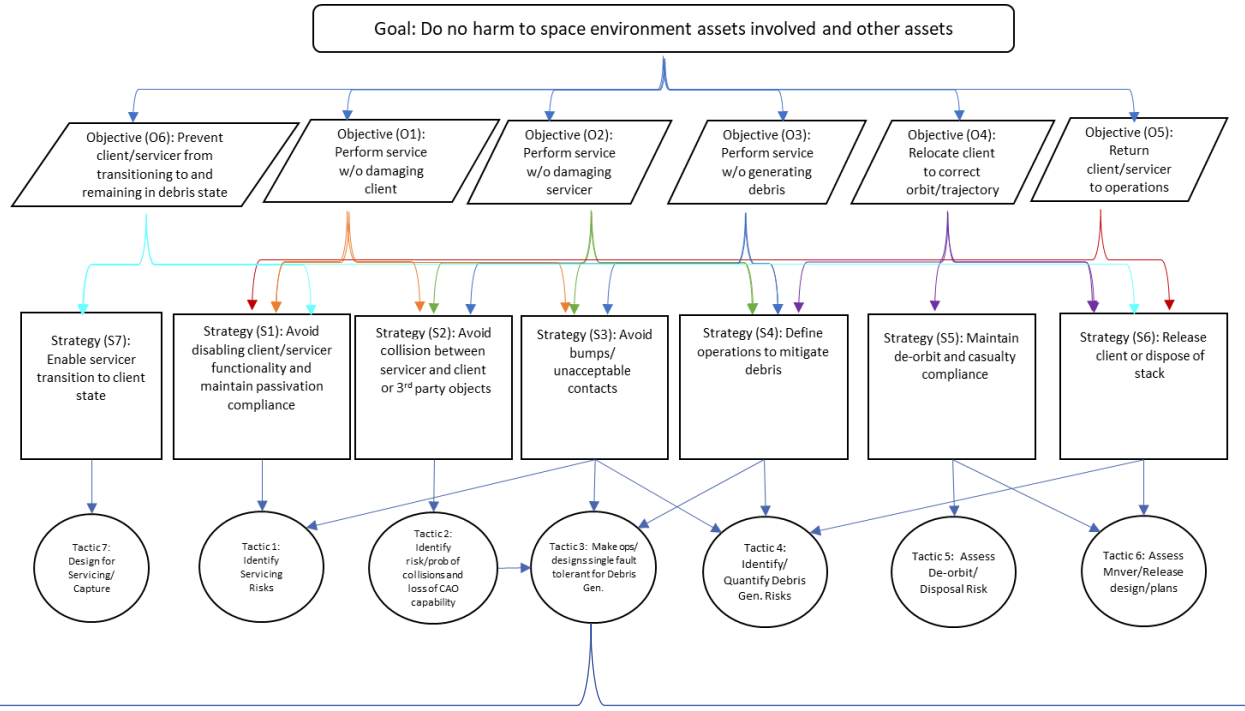
Knowledge Tasks

Task A: Life/Aging (systems/materials/structures) analysis of Client/Debris
Task B: Inspect Client from Ground, TLM, or On-orbit
Task E: Perform Orbit Analyses
Task G: Part/Material Testing/ Part/Material/Component Evaluation
Task I: Verify Trajectory is Safe
Task J: Perform collision avoidance operations

Applying probability analyses to assess collision risks is an achievable expansion in the practice (scope and focus) of the well-proven quantitative assurance methods.

Tasks to Enable Operations/Designs to be Single Fault Tolerant for Debris Generation

- Servicing/ADR Support Discovery Process
  - Policies
  - Research
- Servicing/ADR Risk/Mission Assurance Support Codifications
  - Tactics
  - Tasks
- Summary



RE Tasks

Task 2: Perform Probabilistic Assessment
Task 3: Perform Process FMECA/FT

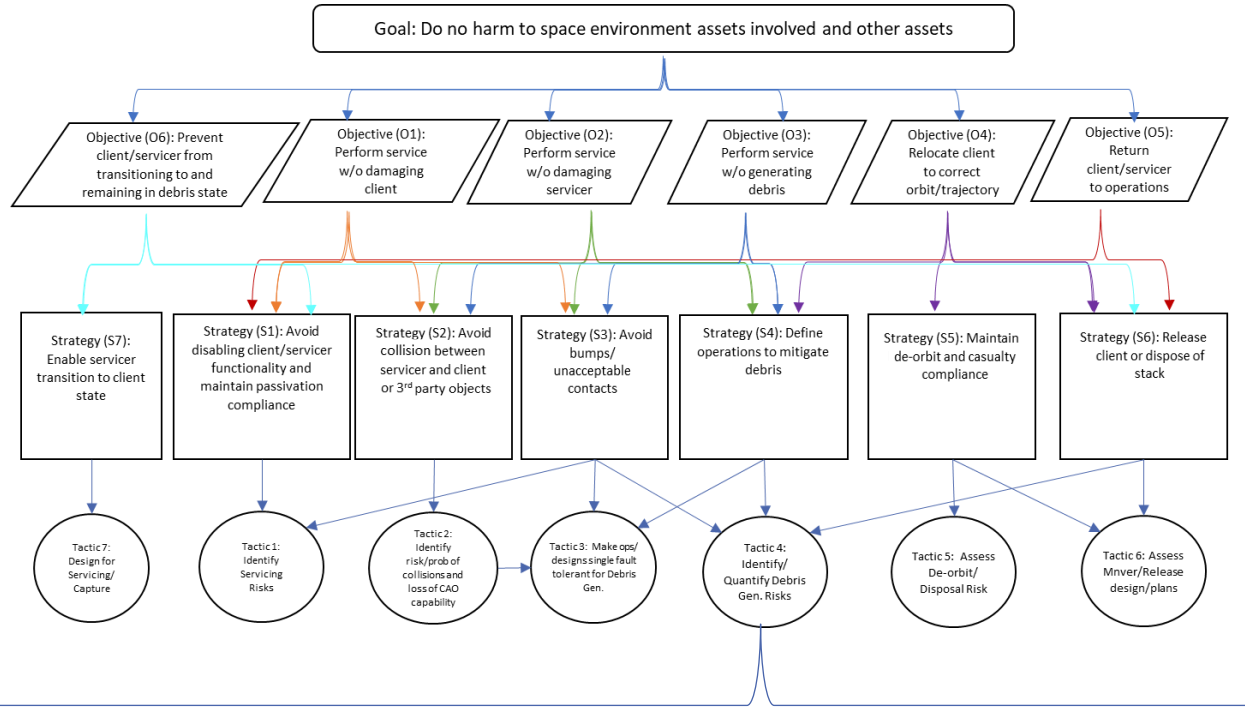
Knowledge Tasks

Task A: Life/Aging (systems/materials/structures) analysis of Client/Debris
Task B: Inspect Client from Ground, TLM, or On-orbit
Task C: Perform debris/break-up Testing /Modeling
Task D: Conduct Design Reviews to Ensure Serviceability Technology is present
Task E: Perform Orbit Analyses
Task G: Part/Material Testing/ Part/Material/Component Evaluation
Task H: Perform Entanglement/Release Risk and Hazard Assessments
Task I: Verify Trajectory is Safe
Task J: Perform collision avoidance operations
Task K: Select Capture method

Using hazard, failure, and probability analyses to refine designs/operations for minimum debris generation is an achievable with an expansion of the impact assessment focus.

- Servicing/ADR Support Discovery Process
  - Policies
  - Research
- Servicing/ADR Risk/Mission Assurance Support Codifications
  - Tactics
  - Tasks
- Summary

Tasks to Enable Identification/Quantification of Debris Generation Risks



RE Tasks

Task 3: Perform Process FMECA/FT

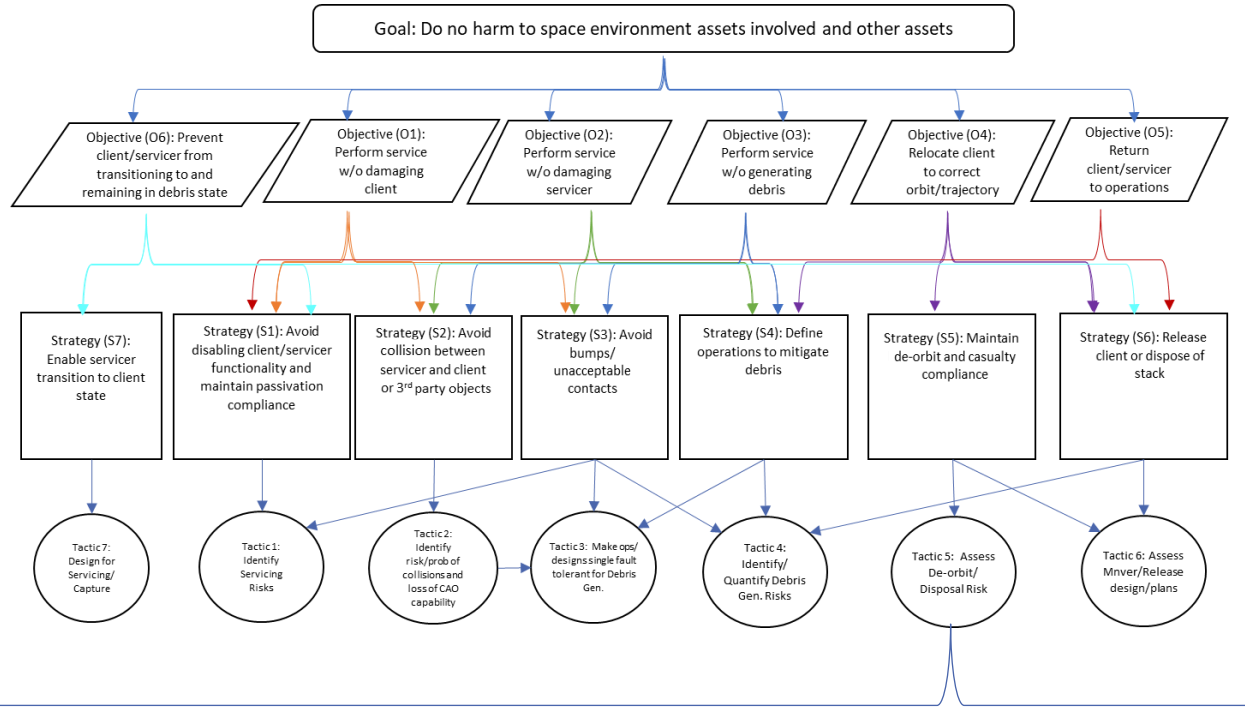
Knowledge Tasks

Task A: Life/Aging (systems/materials/structures) analysis of Client/Debris
Task B: Inspect Client from Ground, TLM, or On-orbit
Task C: Perform debris/break-up Testing /Modeling
Task D: Conduct Design Reviews to Ensure Serviceability Technology is present
Task G: Part/Material Testing/ Part/Material/Component Evaluation
Task H: Perform Entanglement/Release Risk and Hazard Assessments
Task K: Select Capture method

Using inspection and failure/hazard analyses to identify and quantify debris risks of a serving/ADR process is an achievable application of existing practices to a new question.

- Servicing/ADR Support Discovery Process
  - Policies
  - Research
- Servicing/ADR Risk/Mission Assurance Support Codifications
  - Tactics
  - Tasks
- Summary

Tasks to Enable Assessment of De-orbit/Disposal Risk



RE Tasks

Task 2: Perform Probabilistic Assessment
Task 4: Assess Probability of De-orbit

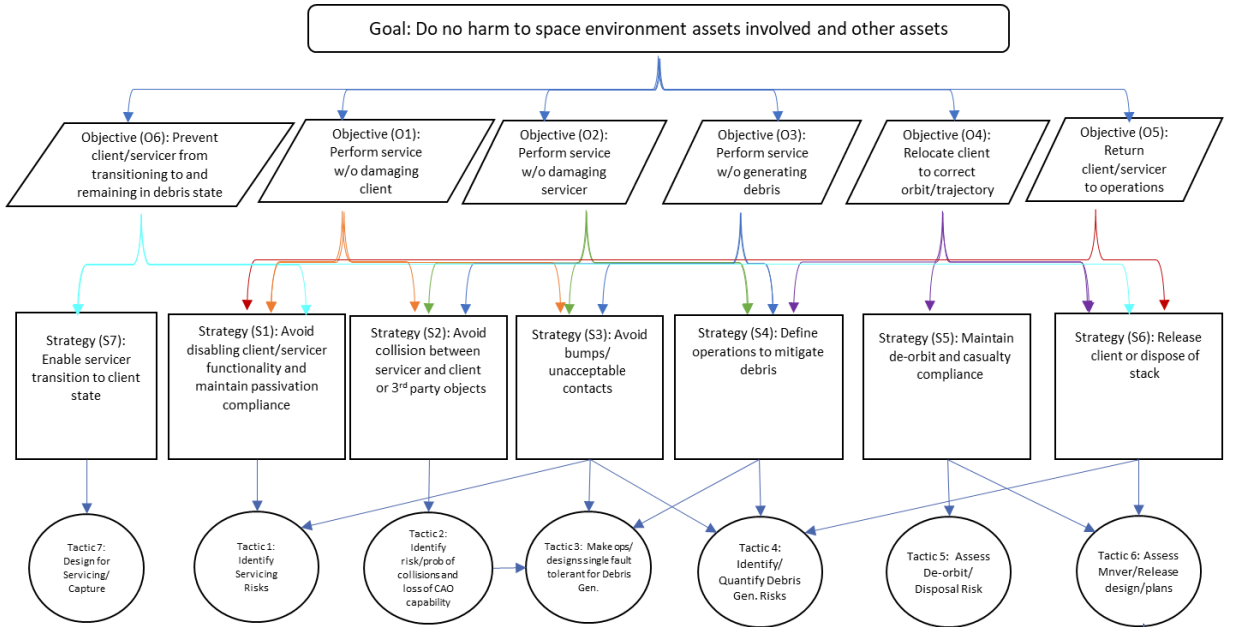
Knowledge Tasks

Task A: Life/Aging (systems/materials/structures) analysis of Client/Debris
Task B: Inspect Client from Ground, TLM, or On-orbit
Task E: Perform Orbit Analyses
Task F: Perform Casualty Analyses
Task G: Part/Material Testing/ Part/Material/Component Evaluation
Task I: Verify Trajectory is Safe
Task J: Perform collision avoidance operations

Servicing and ADR plans impact disposal risks. Assessing these risks is achievable by using proven methodology as documented in the Tri-Agency Reliability Engineering Guidance: Post Mission Disposal and Extension Assessment consensus document.

- Servicing/ADR Support Discovery Process
  - Policies
  - Research
- Servicing/ADR Risk/Mission Assurance Support Codifications
  - Tactics
  - Tasks
- Summary

Tasks to Enable Assessment of Maneuver/Release Plans



RE Tasks

Task 6: Perform Release Operations Risk Assessment

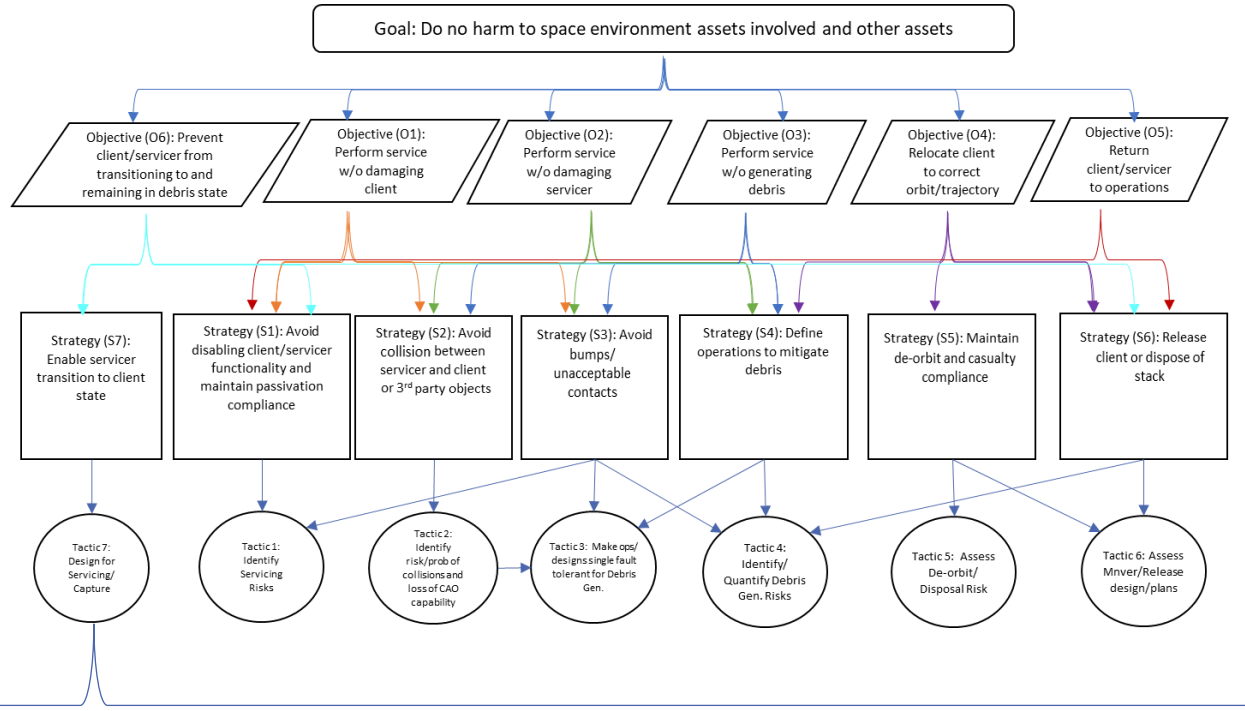
Knowledge Tasks

Task A: Life/Aging (systems/materials/structures) analysis of Client/Debris
Task B: Inspect Client from Ground, TLM, or On-orbit
Task C: Perform debris/break-up Testing /Modeling
Task E: Perform Orbit Analyses
Task G: Part/Material Testing/ Part/Material/Component Evaluation
Task H: Perform Entanglement/Release Risk and Hazard Assessments
Task K: Select Capture method

Using hazard, failure, and probability analyses to identify release/maneuvering risks is an achievable application of existing process assessment practices to new questions.

Tasks to Ensure Servicing/Capture Feasibility (Or Tasks to Assure Design Serviceability)

- Servicing/ADR Support Discovery Process
  - Policies
  - Research
- Servicing/ADR Risk/Mission Assurance Support Codifications
  - Tactics
  - Tasks
- Summary



RE Tasks

Task 1: Perform DNH/Failure Analysis (FMECA/FTA)
Task 5: Perform Serviceability/Maintainability Analyses

Knowledge Tasks

Task A: Life/Aging (systems/materials/structures) analysis of Client/Debris
Task B: Inspect Client from Ground, TLM, or On-orbit
Task D: Conduct Design Reviews to Ensure Serviceability Technology is present
Task E: Perform Orbit Analyses
Task G: Part/Material Testing/ Part/Material/Component Evaluation
Task H: Perform Entanglement/Release Risk and Hazard Assessments
Task I: Verify Trajectory is Safe
Task K: Select Capture method

Using hazard, failure, and probability analyses to identify servicing risks is an achievable application in focus of existing process assessment practices. While Serviceability/ Maintainability Analysis is a new process (not a stand-alone event).

- Servicing/ADR Support Discovery Process
  - Policies
  - Research
- Servicing/ADR Risk/Mission Assurance Support Codifications
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  - Tasks
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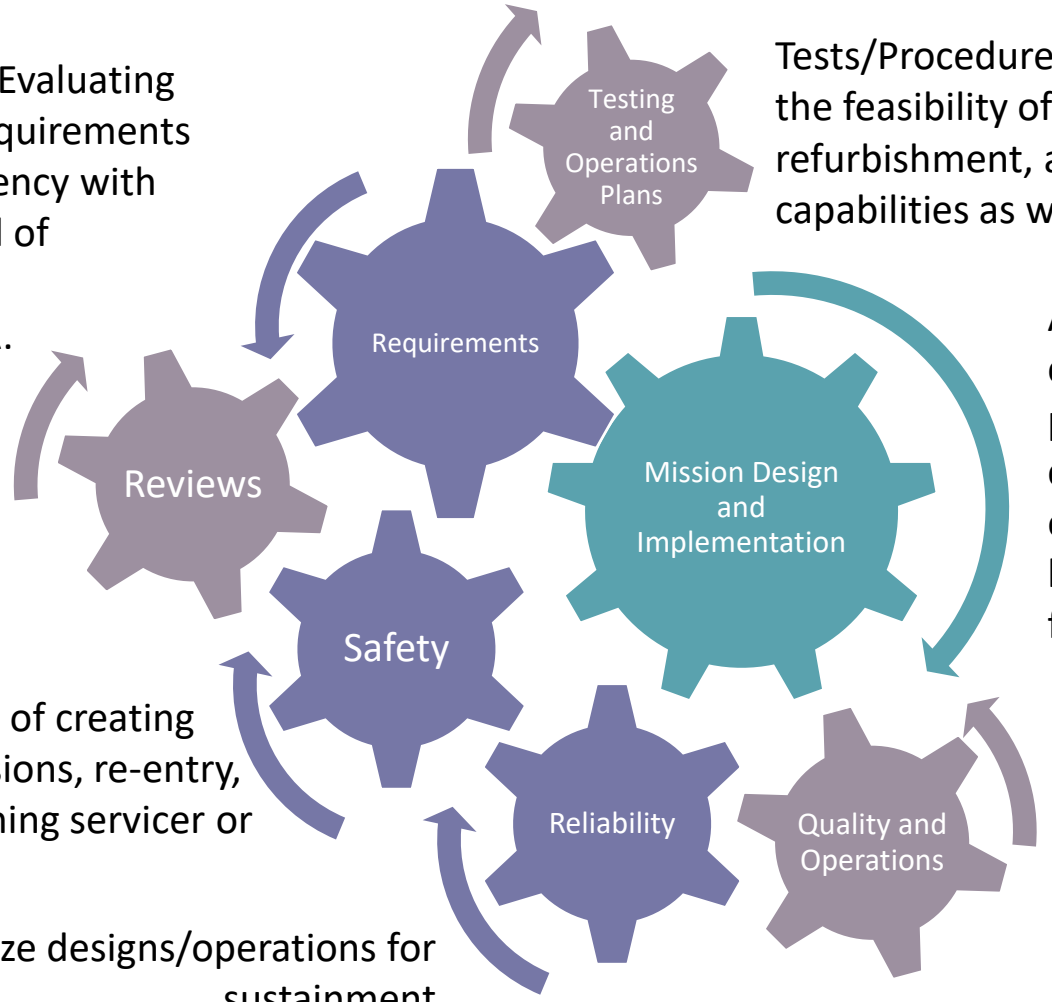
Serviceability Assessment/Maintainability Analysis

Developing and Evaluating concepts and requirements for their consistency with the desired level of accessibility and Evolvability/ADR.



Tests/Procedures capture plausibility and the feasibility of contingencies, repair, refurbishment, and enhancement capabilities as well as system functionality;

Adopt servicer-cooperative ports/fittings, connectors, and ergonomic and location/capture features

Find the risk of creating debris, collisions, re-entry, and/or harming servicer or client.

Optimize designs/operations for sustainment

Verification and documentation of cooperative servicing/ ADR features and their functionality;

Serviceability Assessment/Maintainability Analysis will likely require multi-discipline expansion of proven methods and practices to assess adequacy, safety, and maintainability of designs, implementations, and operational/servicing plans.

Notional Task Planning to Enable Viable Servicing/Active Debris Removal Objectives

- Servicing/ADR Support Discovery Process
  - Policies
  - Research
- Servicing/ADR Risk/Mission Assurance Support Codifications
  - Tactics
  - Tasks
- Summary

Mission Phase / Task Recommended	Client Conceptual Design	Client Preliminary Design	Client Detailed /Critical Design	Client Implementation & Testing	Client Launch & Early Ops	Servicer Conceptual Design	Servicer Preliminary Design	Servicer Detailed Design	Servicer Implementation & Testing	Servicer Launch & Early Ops	Pre-Service & Proximity Ops: Client/ Servicer Ops	Pre-Service & Proximity Ops: Rendezvous & Inspection	Approach and Capture	Servicing	Re-orbit and/or Deorbit
Task 1: Perform DNH/Failure Analysis (FMECA/FTA)						Created	Update	Update	Update	Final		Update	Use as Anomaly Diagnostic tool		
Task 2: Perform Probabilistic Assessment															
Task 3: Perform Process FMECA/FT															
Task 4: Assess Probability of De-orbit		Created	Update												
Task 5: Perform Serviceability/ Maintainability Analysis	Created	Update	Update												
Task 6: Perform Release Operations Risk Assessment															
Task A: Life/Aging (systems/materials/ structures) analysis of Client/Debris		Created	Update												
Task B: Inspect Client from Grnd, TLM, or On-orbit															
Task C: Perform debris/break-up Testing/Modeling*			Created												

Mission Phase / Task Recommended	Client Conceptual Design	Client Preliminary Design	Client Detailed /Critical Design	Client Implementation & Testing	Client Launch & Early Ops	Servicer Conceptual Design	Servicer Preliminary Design	Servicer Detailed Design	Servicer Implementation & Testing	Servicer Launch & Early Ops	Pre-Service & Proximity Ops: Client/ Servicer Ops	Pre-Service & Proximity Ops: Rendezvous & Inspection	Approach and Capture	Servicing	Re-orbit and/or Deorbit
Task D: Conduct Design Rvws to Ensure Serviceability Technology is present	Created	Updated	Updated	Updated	Updated	Created	Updated	Updated	Updated	Updated					
Task 1: Perform DNH/Failure Analysis (FMECA/FTA)						Created	Update	Update	Update	Final		Update	Use as Anomaly Diagnostic tool		
Task 5: Perform Serviceability/ Maintainability Analysis	Created	Update	Update	Update	Final		Created	Update	Update	Final	Update	Update	Use as Anomaly Diagnostic tool		
Task D: Conduct Design Rvws to Ensure Serviceability Technology is present	Created	Updated	Updated	Updated	Updated	Created	Updated	Updated	Updated	Updated					
Task E: Perform Orbit Analyses	Created	Updated	Updated	Updated	Updated	Created	Updated	Updated	Updated	Updated	Updated Client	Updated (both)	Update (both)		Update (both)
Task F: Perform Casualty Analyses		Created	Updated	Updated			Created	Updated	Updated						Updated/ Verify

Approach and Capture	Servicing	Re-orbit and/or Deorbit
Update (both)		Update (both)
		Updated/ Verify
	Update	Update
Update/ Verify		Update/ Verify
		Update/ Continues
Update/ Verify	Conditional	Update/ Continues
Verify		

Reviewers and Mission Assurance Experts can support these solutions by performing expanded and novel Reviews, Hazard Analyses, Maintainability/Serviceability* Analyses, DNH/Ops/Process FMECA/FTs, Probabilistic Servicing/De-orbit Analysis, Ergonomic/Accessibility Testing, and Inspections with appropriate knowledge.

- Servicing/ADR Support Discovery Process
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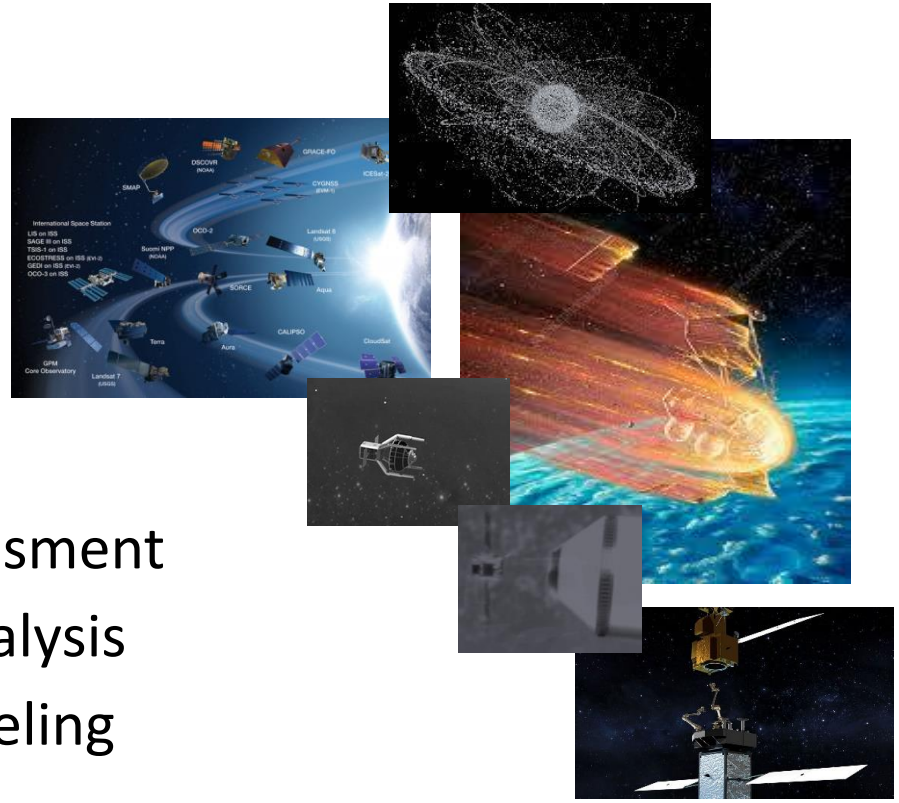
Summary



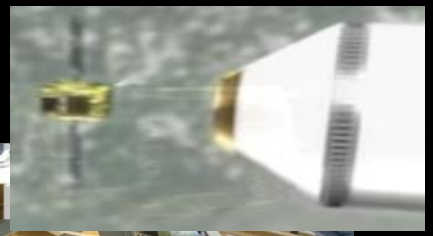
Engaging Mission Assurance Support Provides:

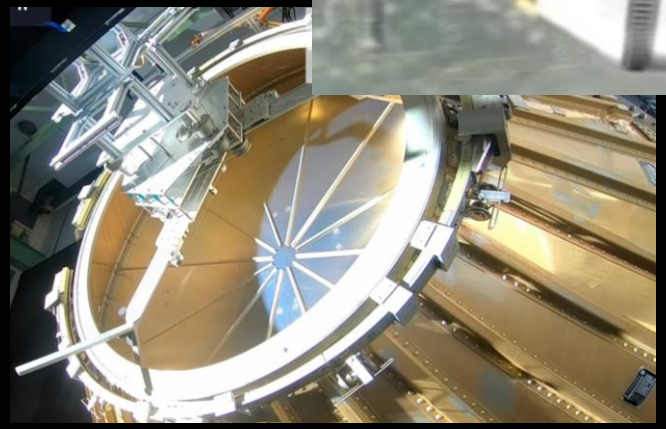
- Enhanced Failure Analysis
- Heightened Scenario Analysis
- Complex and Continual Asset Assessment
- Serviceability and Maintenance Analysis
- Situational Debris Generation Modeling and Testing
- Assurance of Servicer Viability and Feasibility

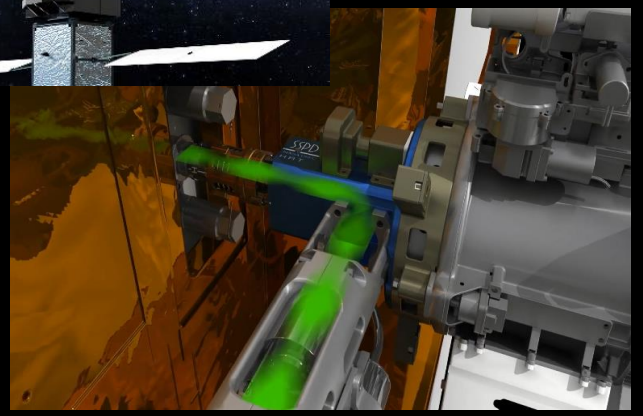
And assures Servicing/ADR feasibility, success, and safety.

But all disciplines of Assurance Engineering need to support On-Orbit Servicing/ADR as early in the mission planning and formulation as possible.

Questions







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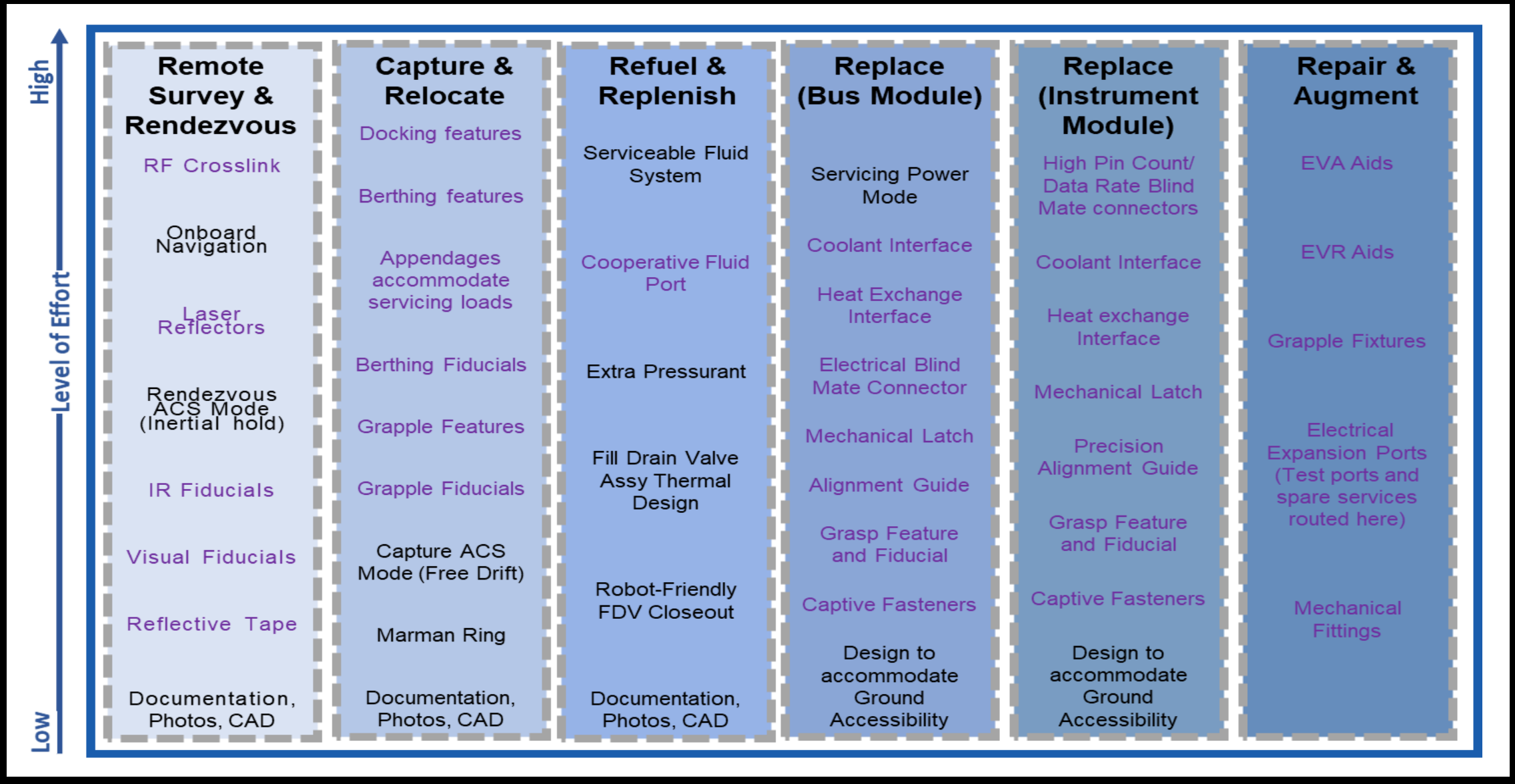
High
Level of Effort
Low
Remote Survey & Rendezvous
RF Crosslink
Onboard Navigation
Laser Reflectors
Rendezvous ACS Mode (Inertial hold)
IR Fiducials
Visual Fiducials
Reflective Tape
Documentation, Photos, CAD
Capture & Relocate
Docking features
Berthing features
Appendages accommodate servicing loads
Berthing Fiducials
Grapple Features
Grapple Fiducials
Capture ACS Mode (Free Drift)
Marman Ring
Documentation, Photos, CAD
Refuel & Replenish
Serviceable Fluid System
Cooperative Fluid Port
Extra Pressurant
Fill Drain Valve Assy Thermal Design
Robot-Friendly FDV Closeout
Documentation, Photos, CAD
Replace (Bus Module)
Servicing Power Mode
Coolant Interface
Heat Exchange Interface
Electrical Blind Mate Connector
Mechanical Latch
Alignment Guide
Grasp Feature and Fiducial
Captive Fasteners
Design to accommodate Ground Accessibility
Replace (Instrument Module)
High Pin Count/ Data Rate Blind Mate connectors
Coolant Interface
Heat exchange Interface
Mechanical Latch
Precision Alignment Guide
Grasp Feature and Fiducial
Captive Fasteners
Design to accommodate Ground Accessibility
Repair & Augment
EVA Aids
EVR Aids
Grapple Fixtures
Electrical Expansion Ports (Test ports and spare services routed here)
Mechanical Fittings

Reliability Task Force Status/Closure

- **Previous TOR Status - Complete**

Capture a Comprehensive set of Regulations/Documents on Spacekeeping.

- ISO 24113:2019
- JMR-003C/D
- JERG-2-026
- NASA STD 8719.14b
- ODMSP
- 2020 National Space Policy (US)
- 2018 Space Policy Directive-3 (US)
- NPR 8715.6B
- AF91-202
- ESSB-ST-U-007
- Space Activity Act
- FCC 20-54/04-130

Establish Similarity/Differences in Regulations/Documents on Spacekeeping.

- ✓ Created/updated an International policy table
- ✓ Shared Regulation and Policy documents
- ✓ Discussed similarities and differences

Compare reliability estimation methods for mission extension and post mission.

- ✓ Conducted methodology sharing briefings from each agency
- ✓ Shared example analyses
- ✓ Discussed similarities and differences

Establish common framework for extension and post mission disposal analysis.

- ✓ Draft a Trilateral PMD/Extension Analysis Guidance Document
- ✓ Share the Draft Trilateral PMD/Extension Analysis Guidance Document (internally)
- ✓ Acquire each agency's release authorization
- ✓ Share the Trilateral PMD/Extension Analysis Guidance Document (externally)

https://ntrs.nasa.gov/api/citations/20210024973/downloads/Methodology%20Consensus%20Guidance%20Document%20(signed)1_19_22.pdf
https://ntrs.nasa.gov/api/citations/20220017699/downloads/Example%20Addendum%20(Final).pdf

Reliability Task Force Status/Closure

- **Current TOR Status - Complete**

Capture a Comprehensive set of Regulations/Documents on Servicing

- JERG-2-026
- IDA - On-Orbit Manufacturing and Assembly of Spacecraft
- IADC-02-01(2007)
- ISO/CD 24330
- 2020 National Space Policy (US)
- ODSMP
- 2018 Space Policy Directive-3 (US)
- Planned ECSS/ESA CPO Guidance Handbook
- NASA On-Orbit Satellite Servicing Study Project Report
- NASA COLA Handbook

✓ Review/Establish Similarity/Differences in Regulations/Documents on Servicing Reliability

Complete Recommendations for Agency Servicing/ADR Servicing/ADR Documents

- ✓ Codify technical considerations and reliability analyses for servicing/ADR
- ✓ Document Codifications
- ✓ Acquire each agency's release of
  - ✓ Reliability Servicing/ADR Support White Paper
  - ✓ Tri-Agency Reliability Engineering Post Mission Disposal and Extension Assessment Guidance Addendum

Provide Recommendations to Agency and ISO Efforts for Servicing Documents

- ✓ Codify technical considerations and analysis for reliability and viability of servicing
- ✓ Discuss analysis approach similarities and differences for serving for:
  - Mission Operations
  - Mission Disposal
- ✓ Expand scope and participation (Design/Safety/Mainatainbilty/Etc.)

Released
https://ntrs.nasa.gov/citations/20230002885

Release/Enhance PMD/Extension common guidance and examples

- ✓ Acquire each agency's release authorization
- ✓ Share the Trilateral PMD/Extension Analysis Guidance Document (externally)
- ✓ Provide/supplement the guidance document with examples.
- ✓ Engage in example discussions to share value assessments and approaches (common learning)
- ✓ Explore operational and analysis methodology advancements and update guidance as warranted and found via expanded data sharing.

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Recommended Path Forward

Leverage TF Servicing/ADR Documents to guide agency and commercial space system/service providers.

- Refine current Code of Conduct (Policies/Requirements)
- Share codifications for Servicing/ADR with the greater space community via presentations/discussions

Review/Explore operational and analysis Methods for Serviceability Analysis

- Explore operational and analysis methodology advancements.
- Review/Establish best practice MTTF/MTTR /REL estimation
- Expand participation (Design/Safety/ Mainatainbilty/Etc.) for innovation, similarities and differences discussions

Expand/Capture Comprehensive Knowledge Gathering/Sharing Solutions

- Operations
- Integration and Test
- Design
- Sensor Optimization and Processing/Automation
- On-orbit Inspection
- Digital catalogs of knowns
  - In-orbit return of experience/lessons learned
  - Failure modes
  - Hazards

Update guidance as warranted and best Practice/Policy Recommendations

- Provide/supplemental guidance
- Provide roadmap of Serviceability assessment
- Provide Policy/practice recommendation to each agency
  - Reliability
  - Design
  - Operations
  - And others

Current Spacekeeping Strategies

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

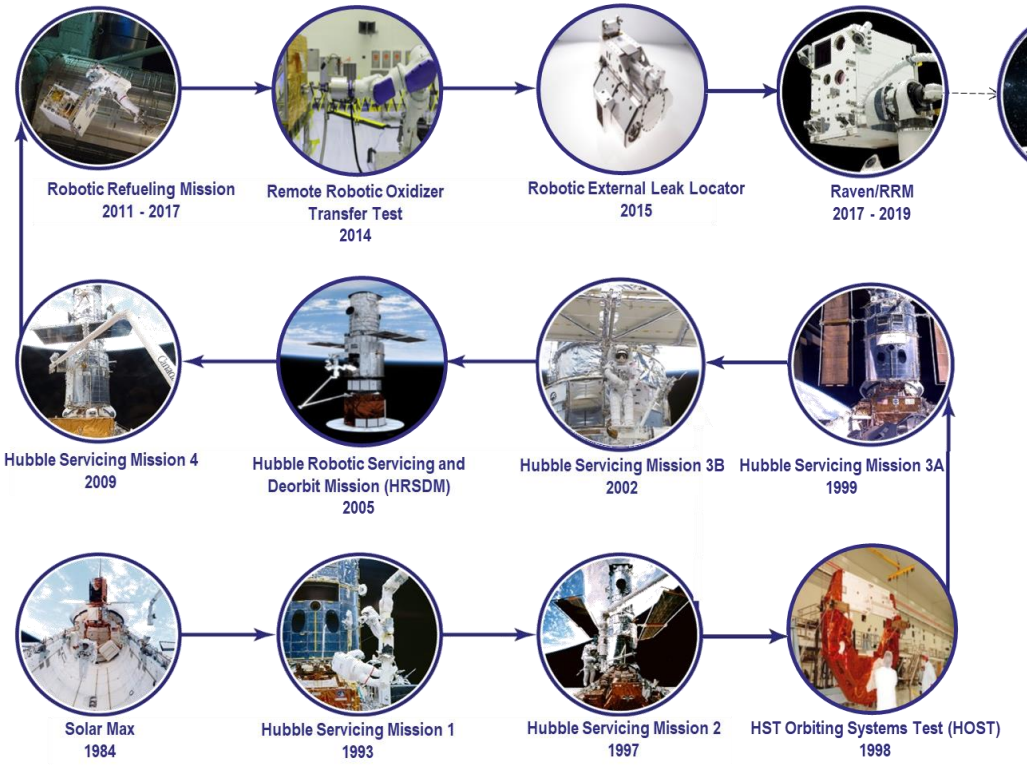
- Mitigate Debris generation in deployment and operations
- Minimize on-orbit break-ups caused by propellants, batteries, pressure vessels, self-destruct, wheels, or any other stored energy by Passivation and design
- NASA/DOD/ESA/JAXA Disposal minimum probability 0.9 requirement
- Limit natural-decay 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 Active Debris Removal (ADR) while mitigating debris generation and/or collision/explosion risks
- Conduct Servicing while avoiding damage to client or servicer.

esa JAXA JPL Jet Propulsion Laboratory California Institute of Technology NASA

Current Spacekeeping Strategies

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

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



esa JAXA

JPL Jet Propulsion Laboratory California Institute of Technology

NASA

Current Spacekeeping Strategies

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

ESA/JAXA are advancing ADR techniques with ClearSpace-1 and CRD2: