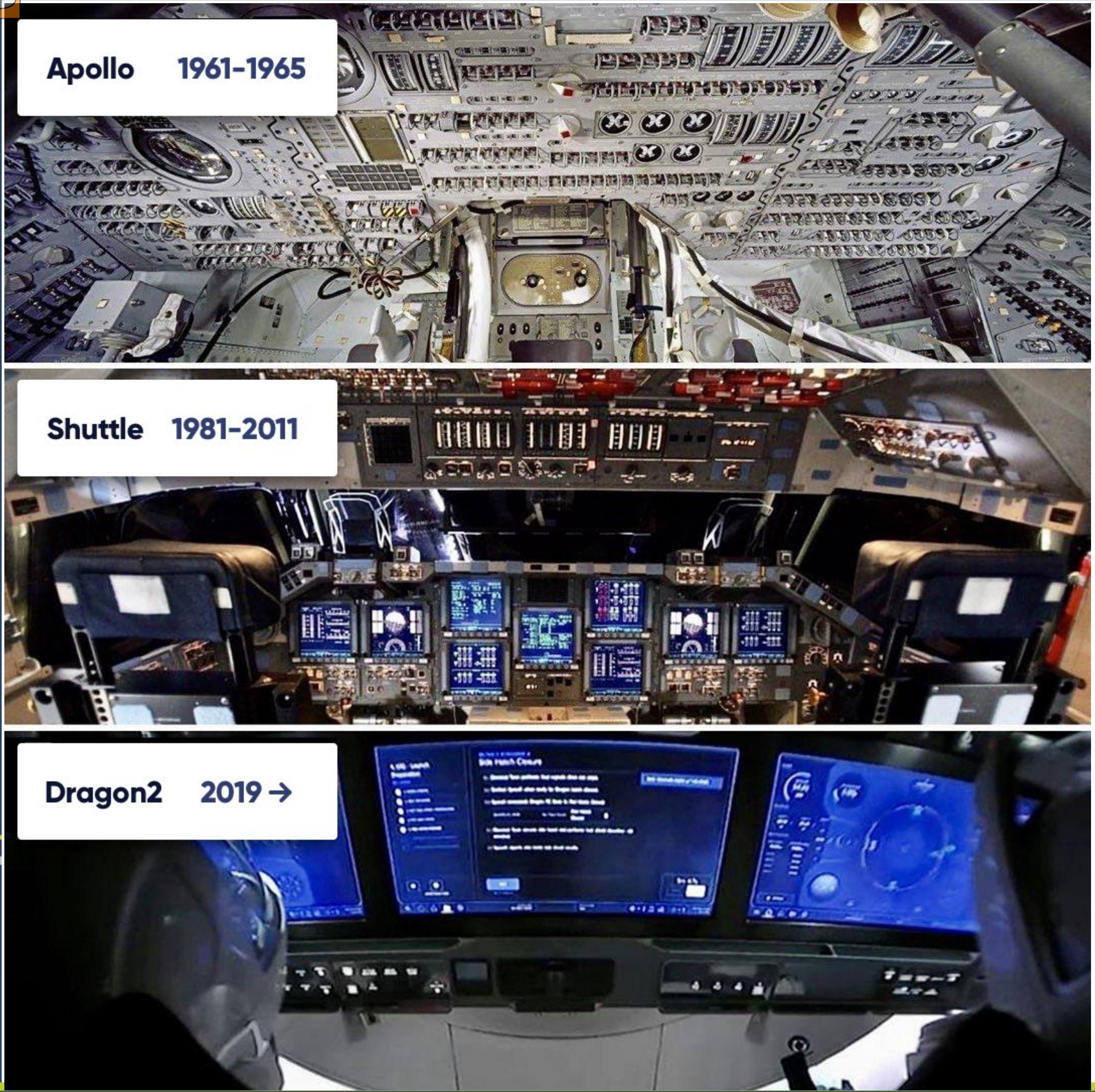
# Collaboration on Software Assurance ESA/JAXA/NASA Trilateral

**Tim Crumbley**
NASA
Office of Safety and Mission Assurance

**December 6-8, 2022**




ISWE

## Increasing Complexity of Software

| | KSLOCS |
|---|---|
| • Apollo | 40 |
| • Shuttle | 440 |
| • SLS | 158 |
| • EGS | 1500 |
| • Orion | 1000+ |

*What happened to the switches?*


# Collaboration on Software Assurance Accomplishments

- November - Assurance for Automatic Code Generation
- December - Updates to JAXA, ESA, and NASA Software Assurance Standards
- February - Software code quality, how can we determine if the software source code is of good quality and low risk?
- March - Software process audits by software assurance, how often should we audit the processes, and what strategy should the audit team use for assessing the software processes?
- April - Assurance of Programmable Device Logic (PDL)/ Hardware Description Language (HDL) (FPGA/ASIC)
- May - Assurance of Autonomous systems
- September - Determining the software risk likelihood levels

# Collaboration on Software Assurance Plans

**Potential additional software assurance topics to be addressed next:**

- Countermeasure of asynchronous defects
- Approach of Independent Verification and Validation
- RTOS and flight software certification for safety critical missions according to NASA NPR 7150.2D which introduced 100% MC/DC (SWE-219)
- Experience with frameworks for on-board control procedures/autonomy like uPython
- Approaches for assurance of machine learning systems
- Software requirements analysis and assurance
- Cybersecurity assurance approaches
- Software risk likelihood levels
- Defect density approaches
- Measurable software assurance process improvement
- Software assurance tools discussion, efficient and effective methods for software assurance
- Others

**The Cartwheel galaxy and its companion galaxies**
NASA, ESA, CSA, STScI, Webb ERO Production Team

# Questions

NASA Electronic Parts and Packaging Program

National Aeronautics and Space Administration

# NASA: Increasing the Utilization of COTS in Flight Hardware

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NASA/GSFC

To be presented by P. Majewicz at the 13th Trilateral SMA Summit, 6 December 2022

# Risk Classification for NASA Payloads NPR 8705.4A

CLASS D CLASS C CLASS B CLASS A









To be presented by P. Majewicz at the 13th Trilateral SMA Summit, 6 December 2022

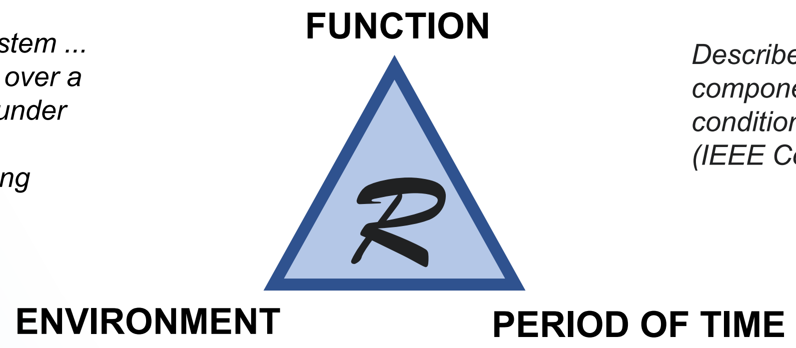
# Tailorable SMA Objectives by Mission Risk Classification

| SMA Area | Accepted Standard |
|---|---|
| Fault Tolerance (including SPFs), Reliability, and Maintainability | NPR 7123.1, Appendix G, NASA-STD-8729.1. |
| Environmental Test Program Verification and Validation | By Center |
| Electronics, Electrical, and Electromechanical (EEE) Parts | NASA-STD-8739.10, Electrical, Electronic, and Electromechanical (EEE) Parts Assurance Standard. |
| Materials | NASA-STD-6016, Standard Materials and Processes Requirements for Spacecraft. |
| Quality Assurance and Quality Engineering | NPR 8735.2, Hardware Quality Assurance Program Requirements for Programs and Projects. |
| Software | NPR 7150.2, NASA-STD-8739.8. |
| Risk Informed Decision Making (RIDM) and Continuous Risk Management (CRM) Processes2 | NPR 8000.4, Agency Risk Management Procedural Requirements |

# It's all about...

## *Reliability*

*The probability that a system ... will function as intended over a specified period of time under specified environmental conditions. (Human-Rating Requirements for Space Systems NPR 8705.2B)*

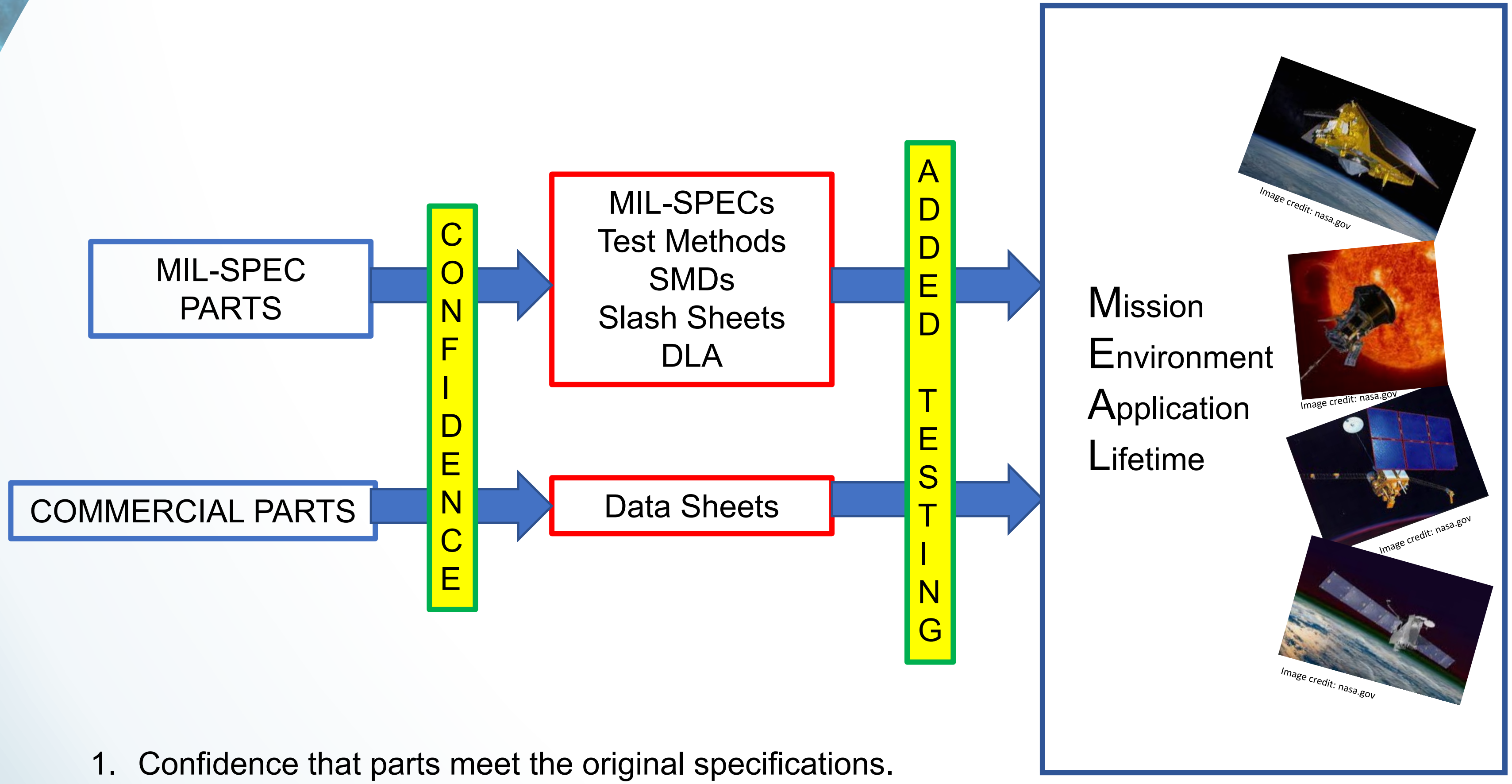



*Describes the ability of a system or component to function under stated conditions for a specified period of time. (IEEE Computer Dictionary)*

**Quality - Robustness - Screening - Qualification - Physics of Failure - Derating**

**Mission, Environment, Application and Lifetime (MEAL)**

# Concerns for Picking Parts



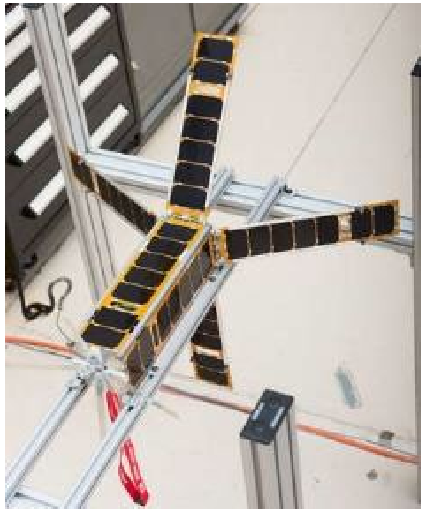

1. Confidence that parts meet the original specifications.
2. Analysis to ensure mission requirements are being met, especially if requirements are above data sheet/SMD limits.
3. Added testing should be done with extreme caution

# Modern COTS / ILPMs

- Numerous Reasons to Select Commercial Electronics
  - Increased Functionality
  - SWAP Benefits
  - Availability
- Designed for Specific Customers/Environments
  - Automotive, Medical
  - New Space
- Industry Leading Parts Manufacturers (ILPMs).
  - High volume automatic production
  - Process controls,  product screen & qualification testing
  - Implementation of the best practices for "zero defects"
  - Not all manufacturers are ILPM & not all product from an ILPM is intended for high reliability / quality operations.

# Radiation Concerns

- Parts levels in EEE-INST-002 and equivalent documents do not indicate the level of radiation tolerance, and thus the selection of parts level 1, 2, or 3 does not imply or provide any type of radiation hardness or mitigation of radiation effects.
- MIL-SPEC parts may or may not include a radiation hardness designator signifying TID performance but may be sensitive to SEE.
- Lot-to-lot variation of radiation sensitivity may be larger for non-radiation-hardness-assured (non-RHA) parts than for RHA parts, since space radiation tolerance is typically not designed and optimized for parts without radiation addressed in their datasheets.



ALBUS Cubesat Credit: NASA/GSFC

# COTS UTILIZATION STEPS

- Relationship with COTS manufacturers
  - Industry Leading Parts Manufacturers (ILPM)s
  - Data sheets
  - Process control data
  - Qualification & Screening
  - Sampling
  - Change process

- Parts Evaluation & Analysis Capability
  - Initial motivation for NEPP Program's predecessor in the 70s
  - Failure rate determination
    - Failure mechanisms/Physics of Failure/Acceleration Factors
  - Environmental testing geared towards NASA missions (MEAL)
  - Not re-inventing the wheel
  - Attempt at "Standardization" for generic mission profiles


To be presented by P. Majewicz at the 13th Trilateral SMA Summit, 6 December 2022

# Technical Assessment

The NASA Engineering and Safety Center (NESC) sponsored the assessment regarding the use of COTS parts in spaceflight systems and critical ground support equipment (GSE) at NASA Centers.

- Capture each NASA Centers' current practices, best practices, lessons learned and recommendations
- Provide recommendations and best practices based on the NESC team's discussion

*Recommendations on Use of Commercial-Off-The-Shelf (COTS) Electrical, Electronic, and Electromechanical (EEE) Parts for NASA Missions*

**NESC Document #: NESC-RP-19-01490**

https://ntrs.nasa.gov/search?q=20205011579

# Technical Assessment

*Recommendations on Use of Commercial-Off-The-Shelf (COTS) Electrical, Electronic, and Electromechanical (EEE) Parts for NASA Missions*

*PHASE II*

Properly selected COTS parts in appropriate applications can offer performance and supply availability **advantages compared to MIL-SPEC parts**. Their utility and demonstrated reliability results from large volumes and automated production and testing processes. However, careful review and a thorough **understanding of their specifications (i.e., datasheet limitations)** is needed, and verifying that manufacturer specifications and reliability **meet space hardware application needs** is necessary.

# Recommendations

- Programs/Projects should understand and effectively manage the risk of COTS, using a holistic approach. **Risk** should be considered in the **appropriate context**, based on knowledge of the parts being used, the manufacturers, and how the parts are being used.
- A **Mission, Environment, Applications and Lifetime (MEAL) assessment** should be developed and approved by Program/Project Managers with pertinent risks clearly identified, mitigated and accepted, when COTS parts are used in safety or mission critical applications.
- Procure COTS parts from OCMs and authorized distributers.
- Use more conservative derating for COTS parts in comparison to its MIL-SPEC counterpart
- Identify application-critical parameters and functionality for all parts in designs and verify by testing over application range

# Recommendations

- Identify environments that might be problematic for parts in their applications and verify by testing and analysis
- Select parts with "flight heritage" and ensure the MEAL for the new mission is within the bounds of the previous mission.
- Select COTS parts from ILPMs and the **highest commercial grades** parts available with each ILPM
- When using COTS parts, program/project should build **multiple engineering units** to start functional testing, environmental testing, qualification, and verification early in the design cycle so that any issue can be addressed to minimize the impact on system risk, cost, and schedule.

# Conclusion

- Numerous Reasons to Select Commercial Electronics
  - Increased Functionality
  - SWAP Benefits
  - Availability
  - These Trend are Increasing
- There are no "Short Cuts"
  - Review and analysis of datasheet limitations, establishment of confidence, and verification of MEAL requirements is vital.
- Any additional testing (above data sheet limits)
  - Communication with manufacturer
  - Based on MEAL requirements (as opposed to MIL-SPEC testing)
  - Qualification on samples recommended

# References / Links

- Recommendations on Use of Commercial-Off-The-Shelf (COTS) Electrical, Electronic, and Electromechanical (EEE) Parts for NASA Missions - NESC Document #: NESC-RP-19-01490
  - https://ntrs.nasa.gov/search?q=20205011579
- Guidelines for Verification Strategies to Minimize Risk Based on Mission, Environment, Application and Lifetime (MEAL), June, 2018. NASA/TM–2018-220074,
  - https://ntrs.nasa.gov/citations/20180007514
- NASA Procedural Requirements NPR 8705.4A, Risk Classification for NASA Payloads
  - https://nodis3.gsfc.nasa.gov/displayDir.cfm?t=NPR&c=8705&s=4A

# Questions?

# NASA Orbital Debris Program Office

**J.-C. Liou, PhD**

**Chief Scientist for Orbital Debris**

**National Aeronautics and Space Administration**

**13th Trilateral Safety & Mission Assurance Summit**
**NASA Johnson Space Center, 7 December 2022**

# Outline

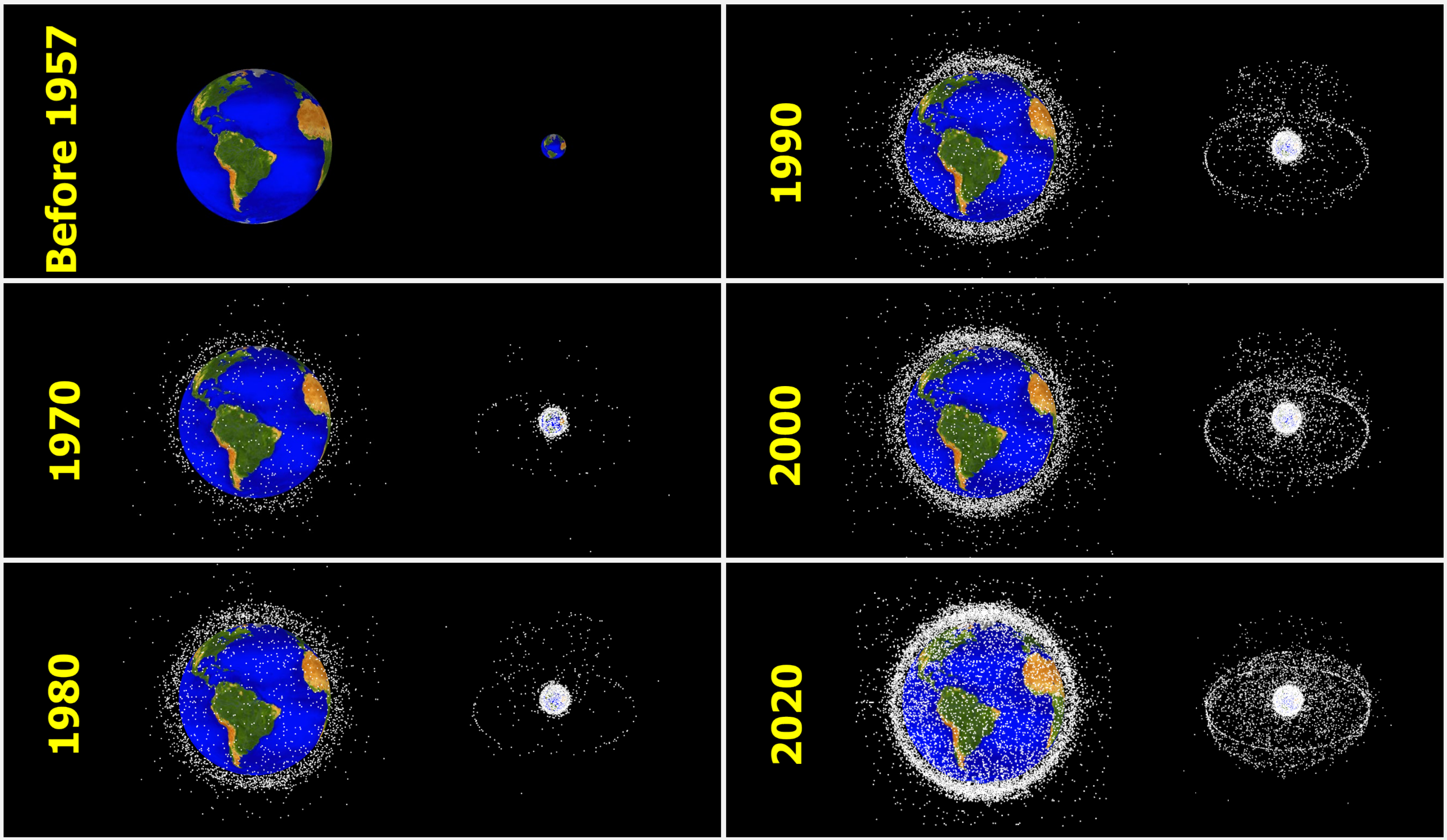
- **Orbital debris (OD) – an overview**
- **The NASA Orbital Debris Program Office (ODPO)**
- **Managing risks from orbital debris**

# The Space Age

- **The first human-made satellite, Sputnik, was launched to study the atmosphere by the Soviet Union on October 4, 1957**
- **Since then, more than 5800 launches have been conducted worldwide**
- **Benefits of space activities**
  - Communications
  - Environment monitoring
  - Explorations
  - Technology advancements
  - Many others
- **But…**


Sputnik
(58 cm diameter, 84 kg)

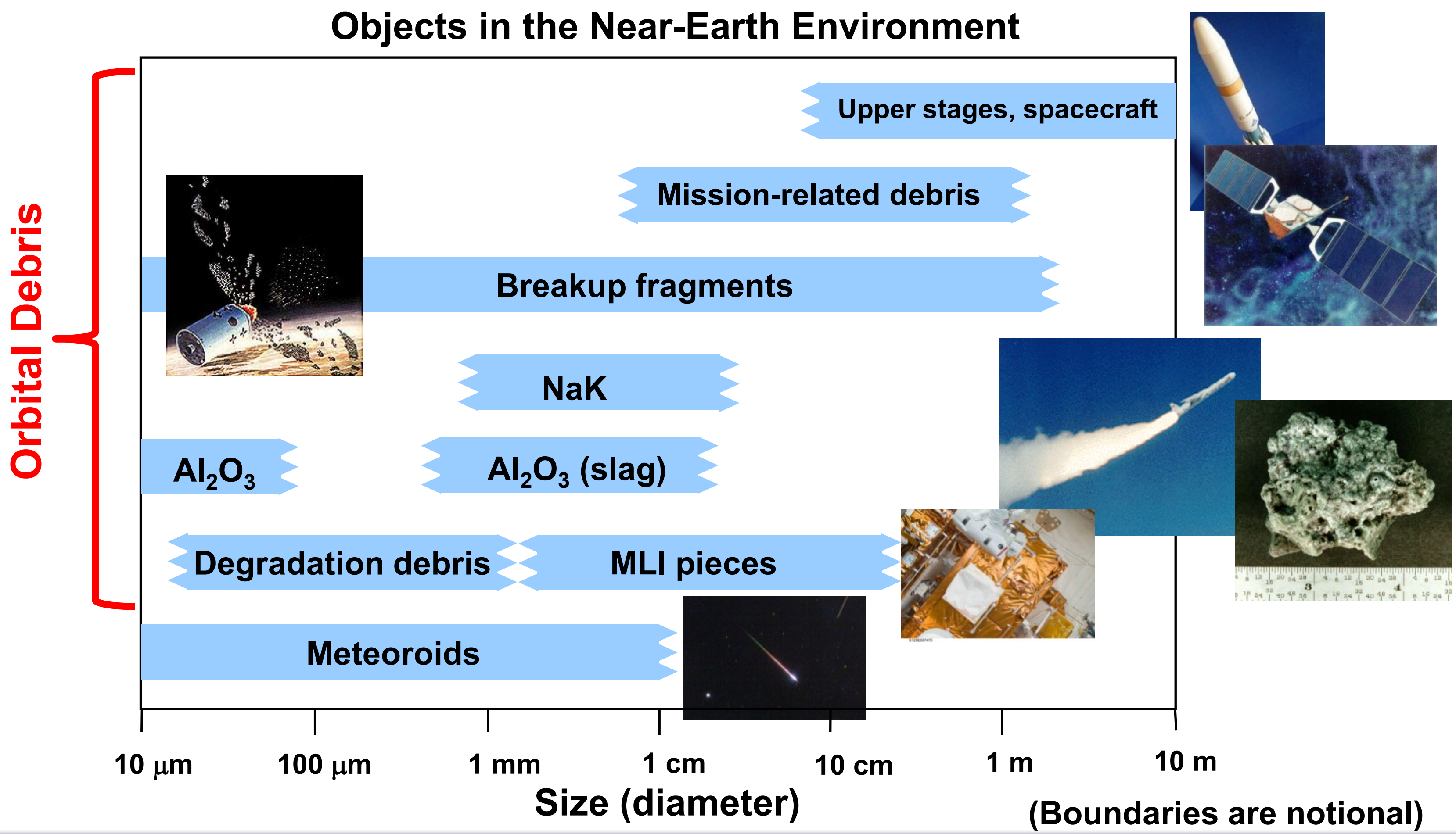
# The Historical Orbital Debris Environment




- **Only objects in the US satellite catalog (~10 cm and larger) are shown**
- **Sizes of the dots are not to scale**

# What Is Orbital Debris?

- **Orbital debris (OD) is any human-made object in orbit about the Earth that no longer serves any useful function**



# How Much Orbital Debris Is Up There?


**Baseball size or larger (≥10 cm): ~27,000**
**(tracked by Space Force's 18th Space Defense Squadron, 18 SDS)**

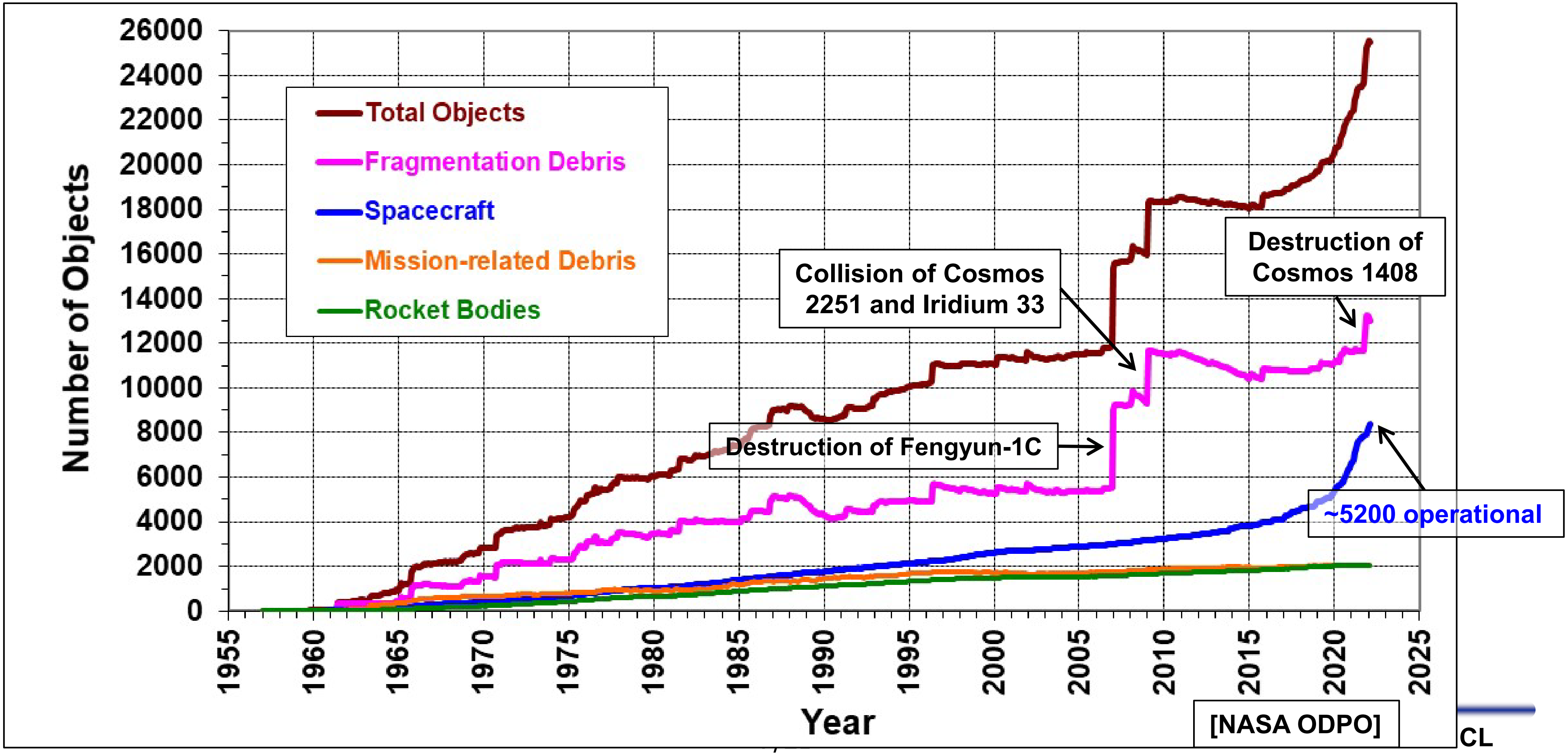

**Marble size or larger (≥1 cm): ~500,000**

**Dot or larger (≥1 mm): >100,000,000**
**(a grain of salt)**

- **Due to high impact speed in space (~10 km/sec in LEO), even sub-millimeter debris pose a realistic threat to human spaceflight and robotic missions**
  - **10 km/sec = 22,000 miles per hour (the speed of a bullet ~1,500 miles per hour)**
- **Mission-ending threat is dominated by small (mm-to-cm sized) debris impacts**
- **Total mass: >9000 tons LEO-to-GEO (~3800 tons in LEO)**

# Growth of the Cataloged Populations

- **The USSF 18 SDS tracks/catalogs the largest objects in space**
  - Such objects only represent the tip of the iceberg of the orbital debris population
  - ~100,000,000 additional debris too small to be tracked but large enough to threaten human spaceflight and robotic missions exist in the environment

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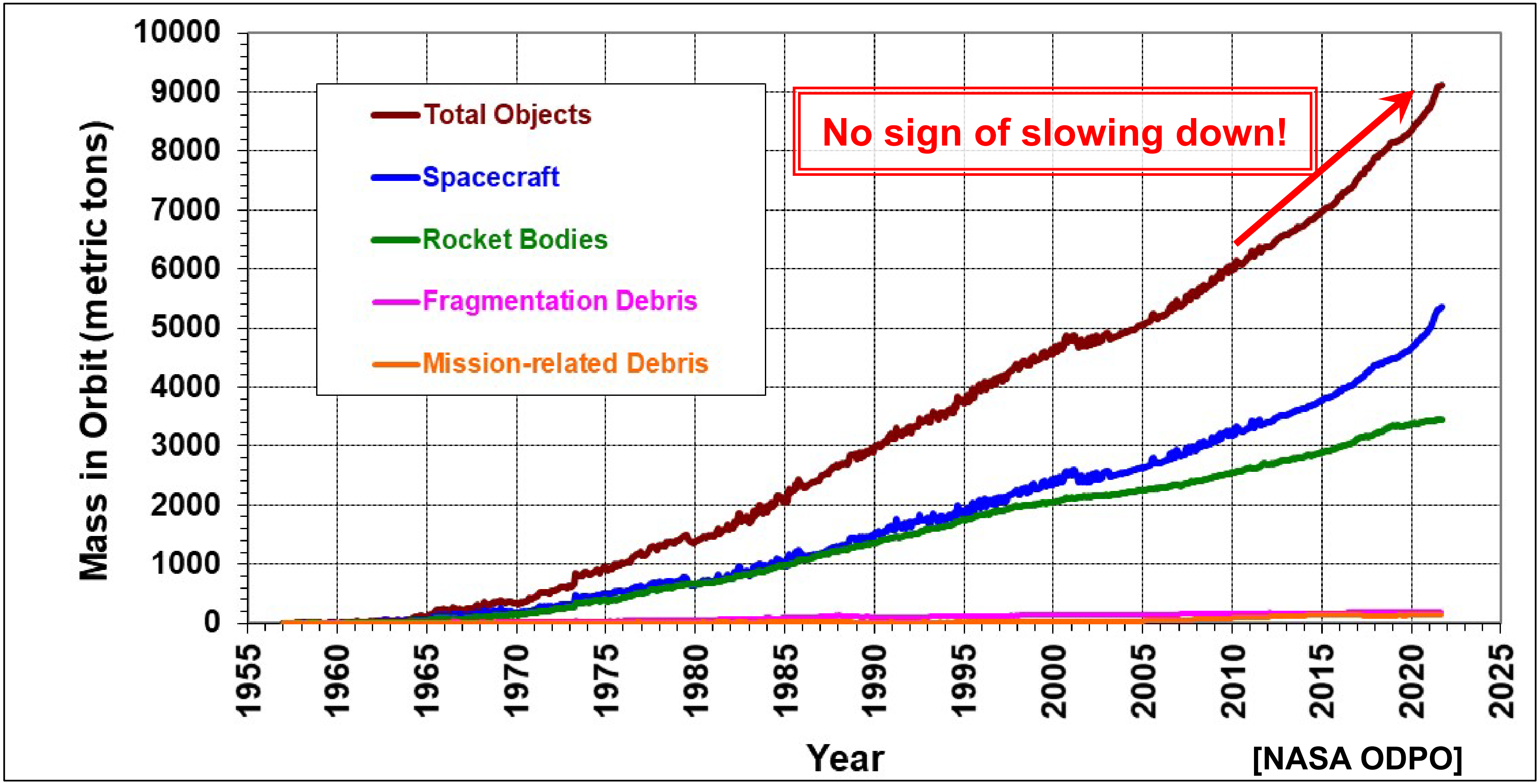
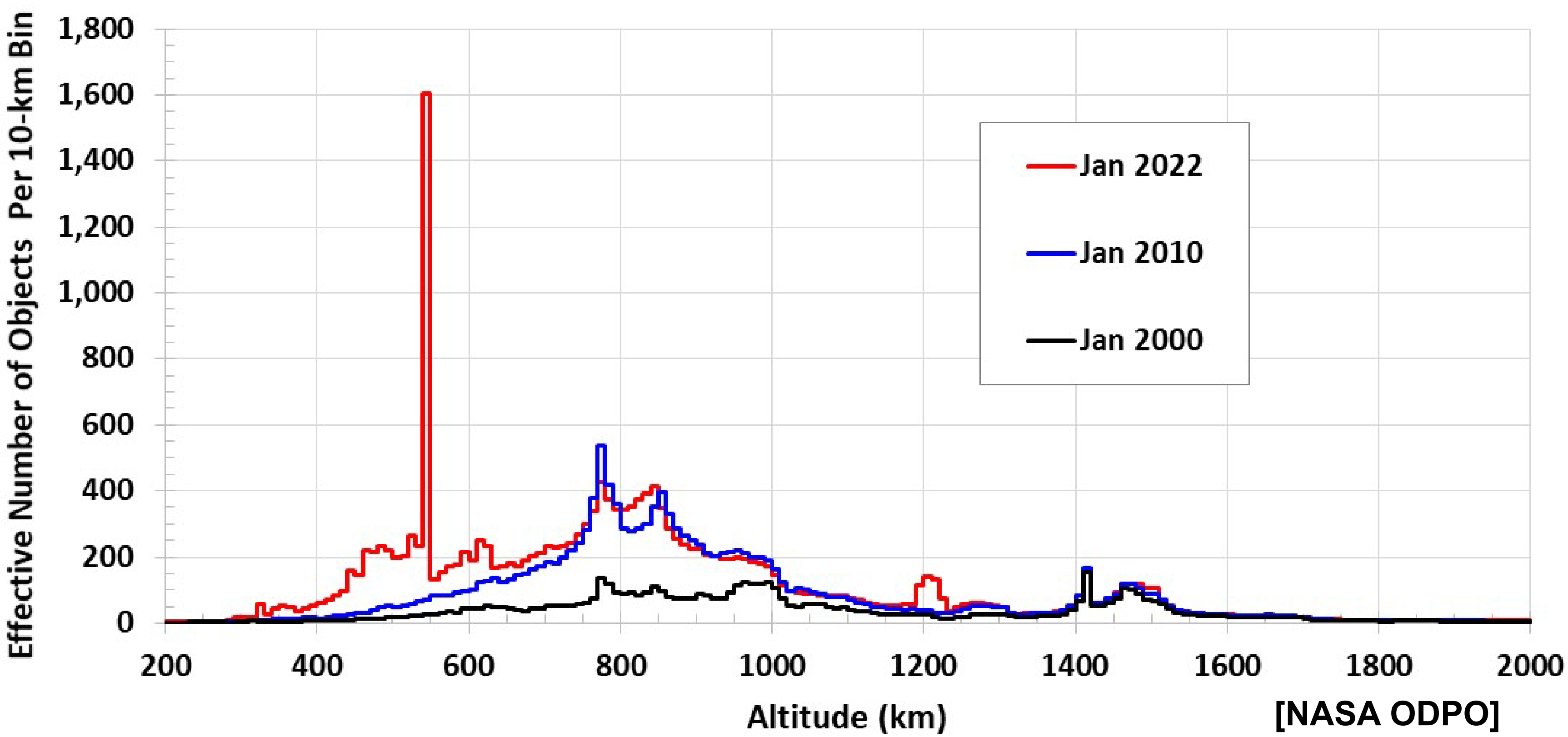
# Mass in Orbit Continues to Increase

- **The total mass of material has exceeded 9000 metric tons**
  - About 3800 tons of material is in low Earth orbit (LEO, the region below 2000 km altitude)



# Low Earth Orbit (LEO) Environment - From the year 2000 to 2022

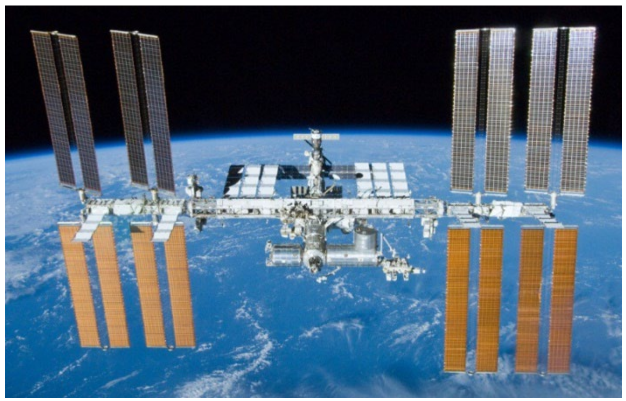
- **The LEO cataloged objects have significantly increased in 20 years**
  - 2000 to 2010: The Fengyun-1C anti-satellite (ASAT) test and the collision between Iridium 33 and Cosmos 2251 drove most of the increase
  - 2010 to 2022: Proliferation of CubeSats and deployments of large constellations were primarily responsible for the increase below ~700 km




[NASA ODPO]

# Protecting NASA Assets From Large Debris

- **NASA has established conjunction assessment processes for its human spaceflight and robotic missions to avoid accidental collisions with objects tracked by the 18 SDS**
  - NASA also assists other U.S. government spacecraft owners with conjunction assessments and subsequent maneuvers
- **The International Space Station (ISS) has conducted 32 debris collision avoidance maneuvers since 1999**
  - Twice in 2021: The avoided objects were (1) a fragment generated from the 2007 Fengyun-1C ASAT test and (2) a fragment from the explosion of a Pegasus upper stage in 1996
  - Twice in 2022: Both were against fragments generated from the Nov 2021 Russian Cosmos 1408 ASAT test



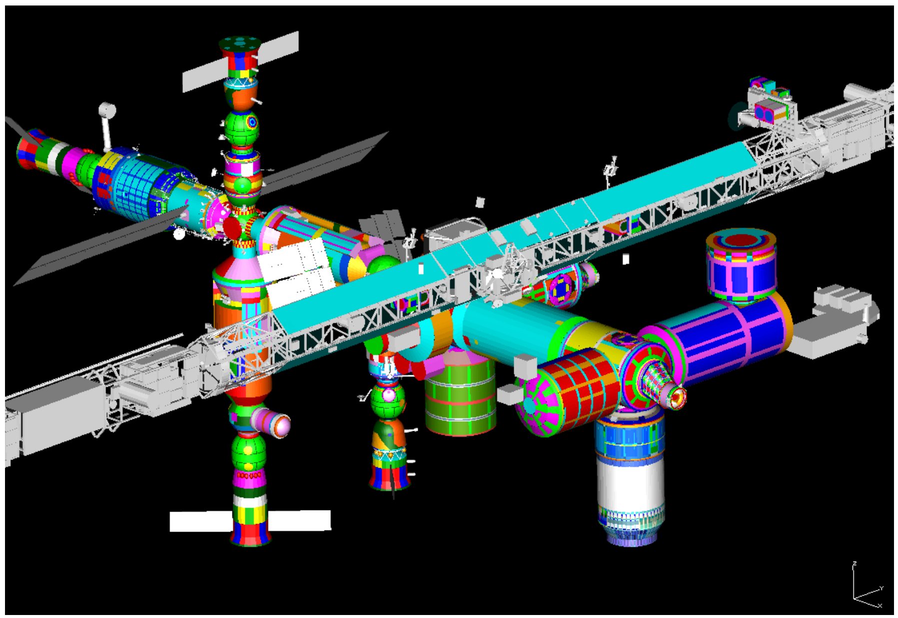
- **During 2021 NASA also executed or assisted in the execution of 13 collision avoidance maneuvers by robotic spacecraft**

# Protecting the ISS From Small Debris

- **The ISS is equipped with various MMOD impact protection shields**
  - The U.S. segments of the ISS are protected against orbital debris approximately 1 cm and smaller
  - The biggest threat to the ISS comes from orbital debris too small to be tracked by the 18 SDS but large enough to penetrate the protection shields (*i.e.*, debris between 1 cm and 10 cm for U.S. modules)

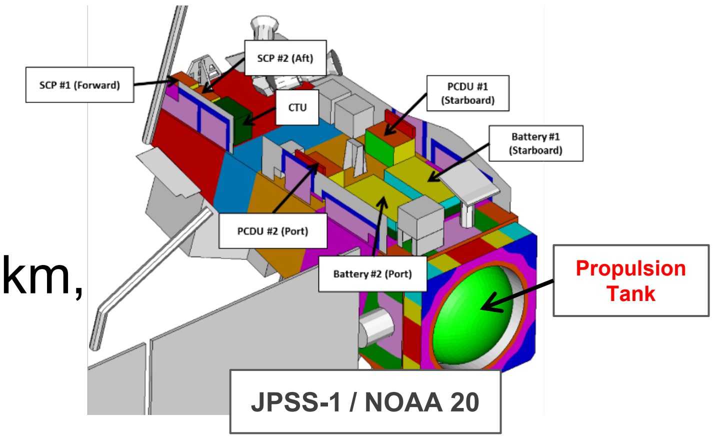
The ISS MMOD shielding models: each color represents a different MMOD shield configuration

About 500 different shields protect ISS modules and external pressure vessels



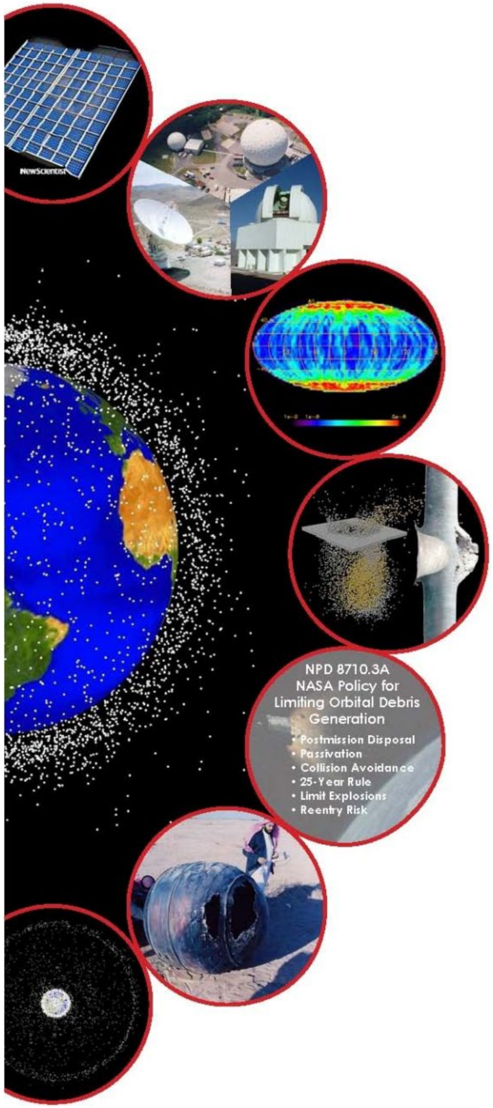
# Risk From Small Debris to Robotic Spacecraft

- **Millimeter-sized orbital debris represents the highest penetration risk to most operational spacecraft in LEO**
  - As concluded by a NASA Engineering and Safety Center panel study (NASA/TM 2015-218780)
- **Currently, more than 400 spacecraft operate at 600–900 km altitudes**
  - Including 18 NASA missions (A-Train@705km, NOAA@825km, IXPE@600km, *etc*.)



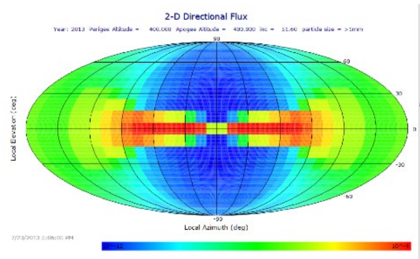

- **There is a lack of measurement data on millimeter-sized orbital debris above 600 km altitude**
  - Direct measurement data on such small debris is needed to support the development and implementation of cost-effective, protective measures for the safe operations of future missions

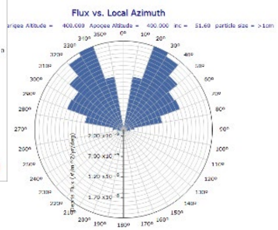
# NASA Orbital Debris Program Office

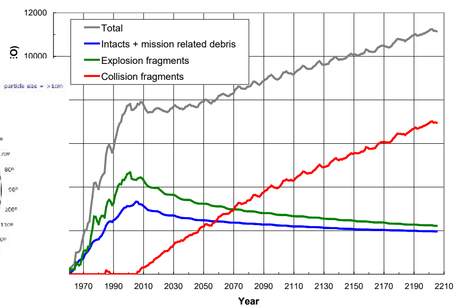



- **The ODPO is the only organization in the U.S. government (USG) conducting a full range of research on orbital debris**
  - This unique NASA capability was established at NASA Johnson Space Center in 1979
  - ODPO is a Delegated Program under HQ/OSMA
  - ODPO's roles and responsibilities are defined in NASA Procedural Requirements NPR 8715.6B
- **ODPO provides technical and policy level support to NASA HQ, OMB, OSTP, NSpC, and other USG and commercial organizations**
- **ODPO represents the USG in international fora (IADC, ISO, United Nations, *etc.*)**
- **ODPO is recognized as a pioneer and leader in environment definition and modeling, and in mitigation policy development**

# End-to-End Orbital Debris Activities at ODPO




## Measurements
**Radar**
**Optical**
**In-situ**
**Laboratory**

→

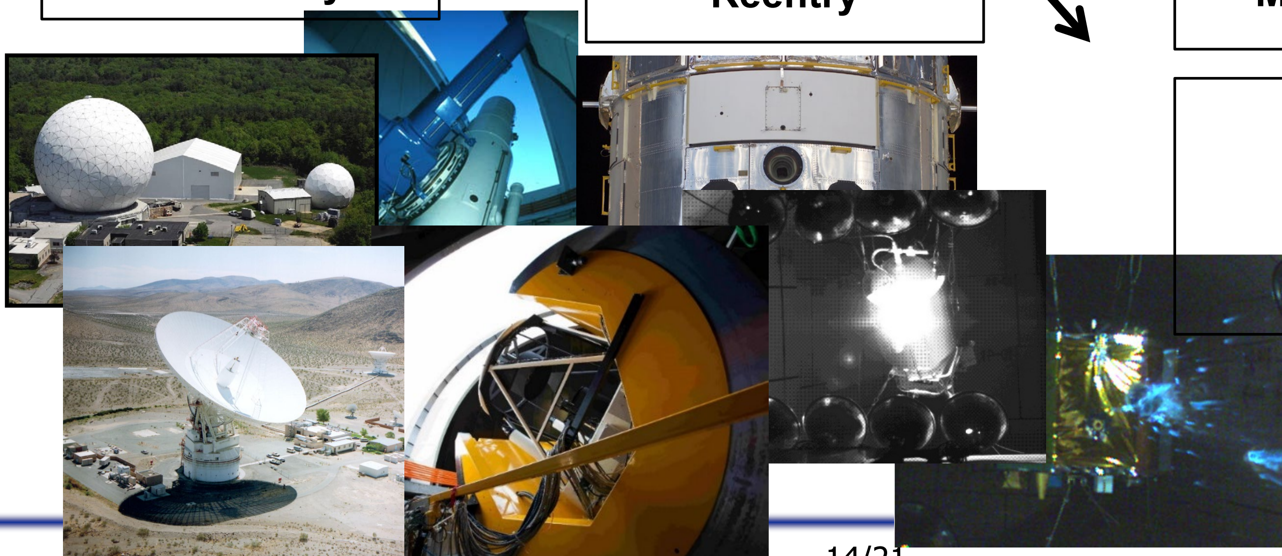
## Modeling
**Breakup**
**Engineering**
**Evolutionary**
**Reentry**

→

## Mission Risk Assessments
**NASA space assets**
**(ISS, Orion, robotic missions, *etc.*)**
**Reentry**

## Environment Management
**Mitigation**
**Remediation**
**Policy**
**Mission Requirements**

## Coordination
**U.S. Government**
**IADC, ISO**
**United Nations**



# ODPO's Roles and Responsibilities (1/3)

- **Monitor the ever-changing OD environment.**
  – ODPO has led the characterization of OD too small to be tracked by the DOD but large enough to threaten human spaceflight and robotic missions for more than 30 years.
    - **Collect/analyze radar measurement data on OD in low Earth orbit (LEO).**
    - **Build/operate telescopes, collect/analyze optical measurement data on OD from LEO to geosynchronous Earth orbit (GEO).**
    - **Collect/analyze space-based in-situ measurement data on sub-millimeter debris, develop in-situ sensor technologies in preparation for future mission opportunities to address the millimeter-sized OD data gap.**
    - **Design/conduct laboratory experiments and collect/analyze test data for debris characterization and assess risk from OD.**
  – Critical data gap: Millimeter-sized OD at 600-1000 km altitude. Such small debris drives the mission-ending risk to LEO spacecraft.

# ODPO's Roles and Responsibilities (2/3)

- **Develop and update OD modeling and mission support tools**
  - ODPO has led the development of OD environment, risk assessment, and mission compliance models and tools for more than 30 years
    - **ODPO models and tools are used by hundreds of operators (NASA, USG, commercial), academia, and research groups around the world**
    - **NASA only: Real-time risk assessments/mitigation after new breakups, MDA test planning/coordination, and TS/SCI support**
- **Provide OD mitigation mission support**
  - OSMA and ODPO oversee NASA mission compliances with OD mitigation requirements per NS 8719.14, which is NASA's implementation of the USG ODMSP
    - **Control the generation of mission-related debris**
    - **Limit accidental explosions (during and post mission)**
    - **Limit accidental collisions**
    - **Conduct post-mission disposal, limit reentry risk**

# ODPO's Roles and Responsibilities (3/3)

- **Provide USG interagency, international, commercial, and outreach support**
  - ODPO has led the development/implementation of OD mitigation best practices in the U.S. and has promoted the adoption of the USG ODMSP by the international community since 1995
    - **USG ODMSP (2001, 2019): ODPO led the interagency working group on the efforts**
    - **IADC OD Mitigation Guidelines (2002, 2020): ODPO leads the U.S. delegation to the IADC**
    - **UN COPUOS OD Mitigation Guidelines (2007) and UN COPUOS LTS Guidelines (2019): ODPO supports the U.S. delegation to UN COPUOS**
    - **ISO Orbital Debris Mitigation Standard (2010, 2019): ODPO supports the development of and update to the standard**
    - **Commercial support (via Space Act Agreements)**
    - **ODQN: more than 1700 subscribers from the global space community**
    - ***Etc.***

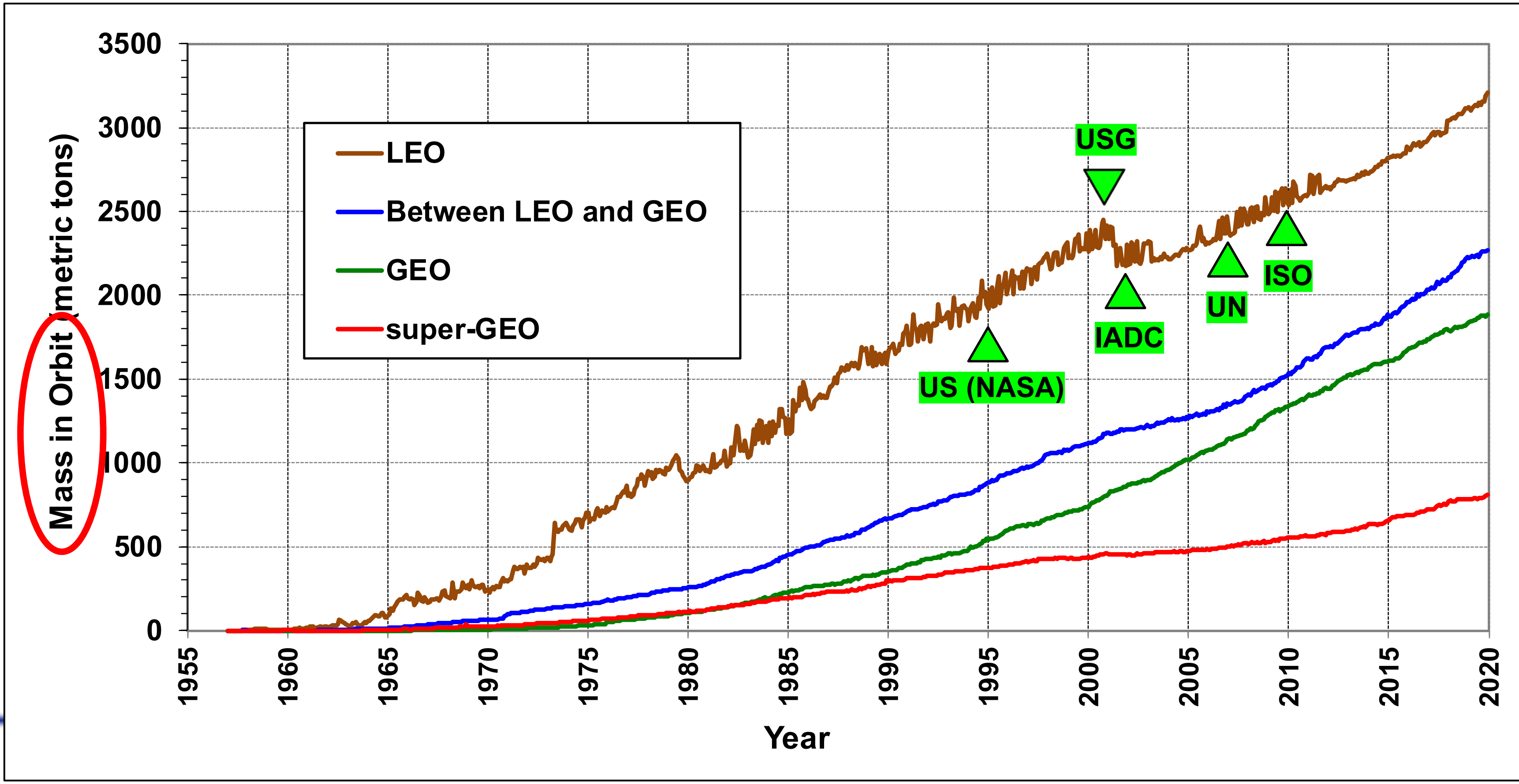
# The OD Problems

- **The long-term problem:** The OD population continues to increase over time despite decades of efforts to limit the generation of new debris

- **The near-term problem:** Mission-ending risk for most operational spacecraft is driven by small, millimeter-sized debris

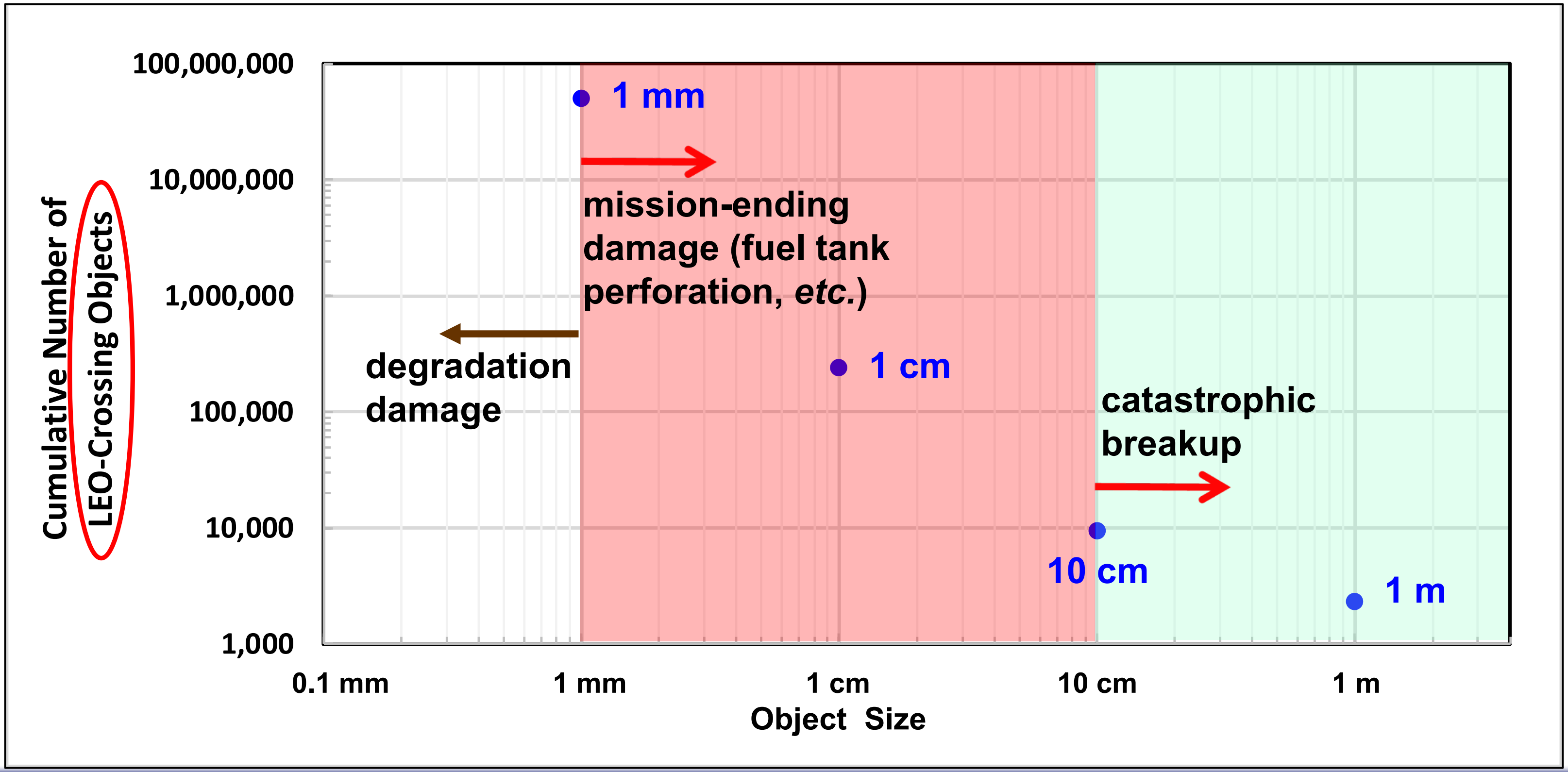
# The Long-Term Orbital Debris Problem

- **The OD population continues to increase over time despite decades of efforts to limit the generation of new debris**
  - Green triangles indicate when key OD mitigation guidelines and standard practices were first established
  - The global 25-year-rule compliance level has been <40% over the past 15 years



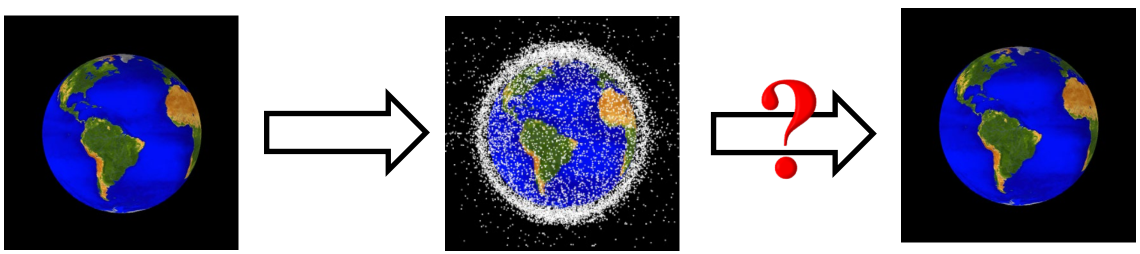
# The Short-Term Orbital Debris Problem

- **There is far more small debris than large debris**
  - Mission-ending risk is driven by millimeter-sized debris in LEO, but there is a lack of direct measurement data on such small debris
  - Conjunction assessments and collision avoidance against the large (≥10 cm) tracked objects only address <1% of the debris impact risk



# Forward Challenges

- **Key OD priorities to enhance the safety, stability, and sustainability of operations in the future space environment**
  - Improve space situational awareness on small debris, especially the millimeter-sized debris in LEO, to better protect future space missions
  - Promote better global compliance with existing mitigation best practices to slow down the debris population growth
  - Establish long-term goals, combining mitigation and remediation, to preserve the near-Earth space environment



# Assurance of Programmable Device Logic (PDL)/ Hardware Description Language (HDL) (FPGA/ASIC) ESA/JAXA/NASA Trilateral Collaboration on Software Assurance Taskforce

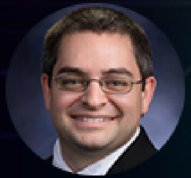
**Tim Crumbley**
NASA
Office of Safety and Mission Assurance

**December 6, 2022**

## Programmable Logic Devices

The Programmable Logic Devices Community of Practice covers all aspects of the design and use of electronics with user programmable or configurable logic functions, including but not limited to Field Programmable Gate Arrays (FPGA), Application Specific Integrated... READ MORE

**Jonathan Boblitt**
Lead



**Daniel Hoffpauir**
Facilitator

MANAGE MY SETTINGS

SITE SUPPORT

## News

SUBMIT NEWS STORY

**PLD Handbook out for Agency-wide review**

VIEW ALL NEWS

## Community Navigation

**Discussion**
Ask questions, share news, or carry on relevant conversations

**Events**
Future and past community-related meetings, conferences, workshops, etc.

**Contact List**
Have a question or need advice? Contact a PLD member

**Document Repository**
Document Library containing PLD materials

**Technical Presentations**
Presentations from past community meetings

**Best Practices and Guidelines**
Specific to PLD discipline

**Handbook Contact List**
Contact list of PLD Handbook contributors with bios

**Handbook Document Repository**
Members only documents

**Handbook Wiki**
For members only - To construct handbook

**High Profile Anomalies and Lessons...**
Lessons Learned

**Wiki**
View the Programmable Logic Devices Wiki

**Resources**
Find resources such as policy, lessons learned, interesting reading, tools, tutorials and more.

**Suggestions**
Have an idea or suggestion for the community? Let us know!

# NASA Software Engineering Requirements

NASA Procedural Requirements

**NPR 7150.2D**
Effective Date: TBD
Expiration Date: TBD

**Subject: NASA Software Engineering Requirements**

**Responsible Office: Office of the Chief Engineer**

| | METRIC/SI |
|---|---|
| NASA TECHNICAL HANDBOOK<br>National Aeronautics and Space Administration | NASA-HDBK-4008 w/CHANGE 1: REVALIDATED w/ ADMINISTRATIVE/ EDITORIAL CHANGES 2016-01-19 |
| | Approved: 2013-12-02 |

**PROGRAMMABLE LOGIC DEVICES (PLD) HANDBOOK**

**Programmable Logic Device.** A semiconductor device based on a matrix of configurable logic blocks connected via a configurable interconnect. The circuitry (combinational/sequential logic, memory/storage, input/output) in a PLD is configured to meet design requirements for a desired application after device manufacturing.

**Software.** In this directive, "software" is defined as (1) computer programs, procedures and associated documentation and data pertaining to the operation of a computer system (*IEEE 828-2012, 2.1)* (2) all or a part of the programs, procedures, rules, and associated documentation of an information processing system *(ISO/IEC 19770-5:2015, Information technology*, *3.34)* (3) program or set of programs used to run a computer (*ISO/IEC 26514:2008, Systems and software engineering–requirements for designers and developers of user documentation, 4.46)* (4) all or part of the programs which process or support the processing of digital information (*ISO/IEC 19770-1:2017, Information technology – IT asset management – Part 1: IT asset management systems--Requirements, 3.49)* (5) part of a product that is the computer program or the set of computer programs (ISO/IEC/IEEE 26513:2017, Systems and software engineering–requirements for testers and reviewers of information for users*, 3.34)*. This definition applies to software developed by NASA, software developed for NASA, software maintained by or for NASA, COTS, GOTS, MOTS, OSS, reused software components, auto-generated code, embedded software, the software executed on processors embedded in programmable logic devices (see NASA-HDBK-4008), legacy, heritage, applications, freeware, shareware, trial or demonstration software, and open-source software components.

**7.7 Software Development for an Embedded Processor**

PLDs may contain one or more embedded processors, such as microcontrollers, central processing units (CPUs), graphics processing units (GPUs), and/or digital signal processors. These embedded processors execute software ranging from a simple series of instructions to an operating system running applications, which is separately developed from the PLD design code. This NASA Technical Handbook does not cover the development, verification, and validation of software for such embedded processors. All software will be covered by software requirements in NPR 7150.2, NASA Software Requirements.

| NASA HANDBOOK<br>National Aeronautics and Space Administration<br>Washington, DC 20546 | **NASA-HDBK 8739.23A**<br>Approved: 02-02-2016<br>Superseding: NASA-HDBK-8739.23<br>With Change 1 |
|---|---|

**NASA COMPLEX ELECTRONICS HANDBOOK FOR ASSURANCE PROFESSIONALS**



**A NASA Team is developing a NASA Standard for PLD Development**
**Available in 2024**

**We also have several Center processes for PLD development**

# Assurance of Commercial Space System/Service (New Space)

Johnny Nguyễn
Director, Missions and Programs Assessment Division (MPAD)
NASA Office of Safety & Mission Assurance (OSMA)

# Opening Statement

Challenging how mission assurance is and/or should be applied to commercial space systems.

United States policy requires and/or encourages growth in the domestic commercial space sector.

Procurement of commercial space products and/or services has a wide variety, with different risks and benefits.

Over the past decade, NASA has rapidly increased utilizing the commercial space sector to fulfill strategic objectives.

The mission assurance level of effort should align with the risk posture of the mission and the acquisition strategy.

Currently, in-work and future work include sharing S&MA lessons learned and best practices and ensuring future missions and their acquisition strategy match the risk posture.

# US Progression of Policy on Commercial Space

Commercialization of Space is a US procurement strategy to expand U.S. private sector involvement in civil space activities. Between 1963 and 1982, U.S. expendable launch vehicle (ELV) manufacturers produced vehicles only under contract to the National Aeronautics and Space Administration (NASA) or the Department of Defense (DOD).

Policy:

- July 4, 1982, President Ronald Reagan issued national security decision directive (NSDD) 42, "National Space Policy," stating that **expansion of U.S. private sector involvement in civil space activities was a national goal.**
- May 16, 1983, the President issued NSDD 94, "Commercialization of Expendable Launch Vehicles." This stated the **"U.S. Government fully endorses and will facilitate the commercialization of U.S. Expendable Launch Vehicles**. The U.S. Government will license, supervise, and/or regulate U.S. commercial ELV operations only to the extent required to meet its national and international obligations and to ensure public safety.
- Commercial Space Launch Act, enacted on October 30, 1984. This legislation addressed three substantive areas: **licensing and regulation; liability insurance requirements; and access of private launch companies to government facilities**. Informs regulations on commercial human spaceflight. Oversight was assigned to the DOT, later assigned to the FAA.
- February 11, 1988, President Reagan issued the "Presidential Directive on National Space Policy," **which required U.S. government agencies to purchases launch services from commercial companies.** The U.S.-licensed commercial space industry made its first launch in March 1989 when Space Service, Inc., sent a scientific payload on a suborbital trip aboard a Starfire rocket.
- U.S. Commercial Space Launch Competitiveness Act of 2015
  - Encourage commercial spaceflight and innovation by: **postponing significant regulatory oversight of private spaceflight companies until 2023**; extending the period during which the government indemnifies commercial spaceflight companies for third-party damages beyond the company's required liability insurance; and **granting private companies the right to own resources collected in space, such as materials from asteroid mining.**
- NASA Transition Authorization Acts of 2017
  - NASA authorization focused on *long-term deep space human exploration, investments in science, technology and aeronautics portfolios*, **and growing the commercial space sector**. The law emphasizes maintaining **NASA's continuity of purpose across presidential administrations**, and it also includes the TREAT Astronauts Act, which ensures medical treatment for astronauts whose health is affected by space missions.

# Procurement Arrangement Spectrum

**Public Sector** — **Degree of Control** — **Private Sector**

**Traditional Procurement**

**OCon**
Operation Concession

**PFD**
Partially Fund-Design-Develop

**PFD-FO**
Partially Fund-Design-Develop & Fully Own-Operate

**PF-FDO**
Partially Fund & Fully Design-Develop-Own-Operate

**Commercial Development**

**Traditional Procurement Arrangement**

**Non-Traditional Procurement Arrangements**

# Budget Requests 2013 for Projects

## Degree of Control

Public Sector ⟵⟶ Private Sector

### Traditional Procurement

- Crew Vehicle Dev
- Launch Vehicle Dev
- TDRS
- GPM
- GEMS
- IRIS
- JWST
- LDCM
- LADEE
- MSS
- NuSTAR
- OSIRIS-Rex
- RBSP
- SMAP
- SPP

### Non-Traditional Procurement Arrangements

**OCon**

- MAVEN
- ICESat-II
- OCO-2

**PFD**

**PFD-FO**

**PF-FDO**

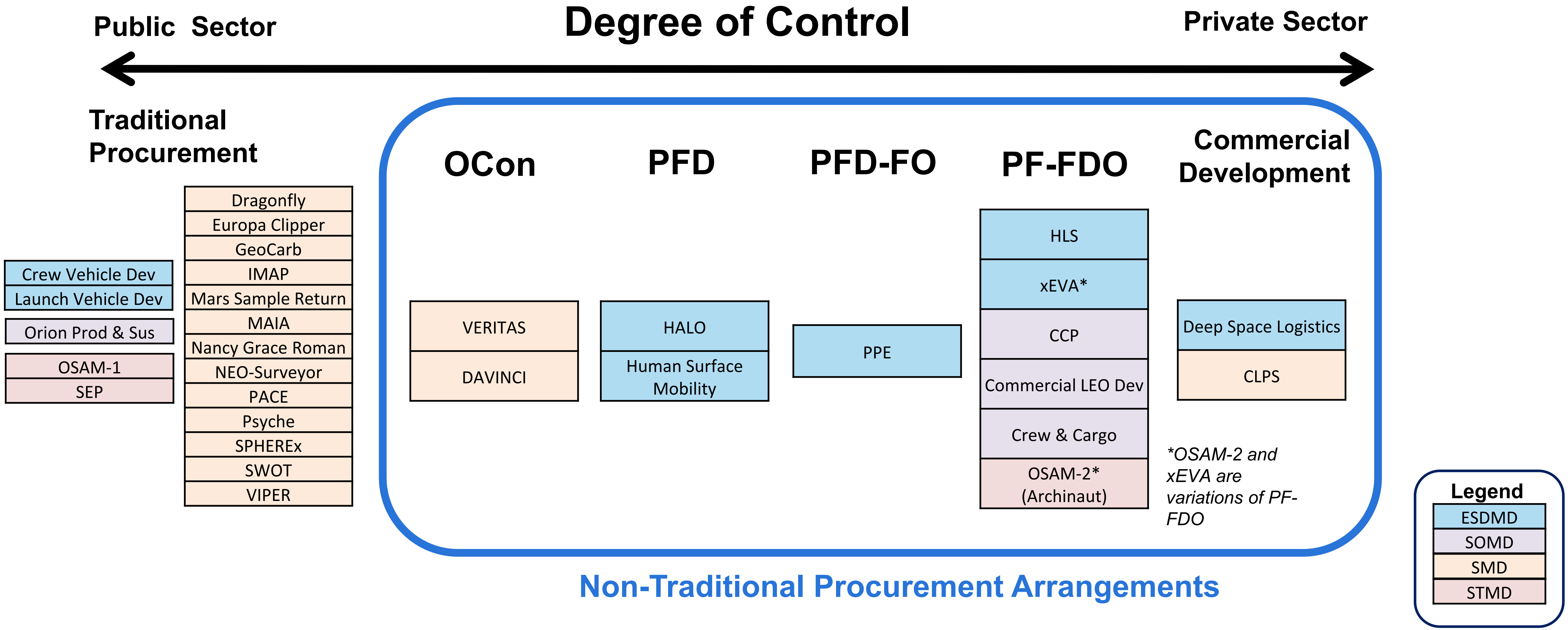
- Commercial Crew

**Commercial Development**

Legend:

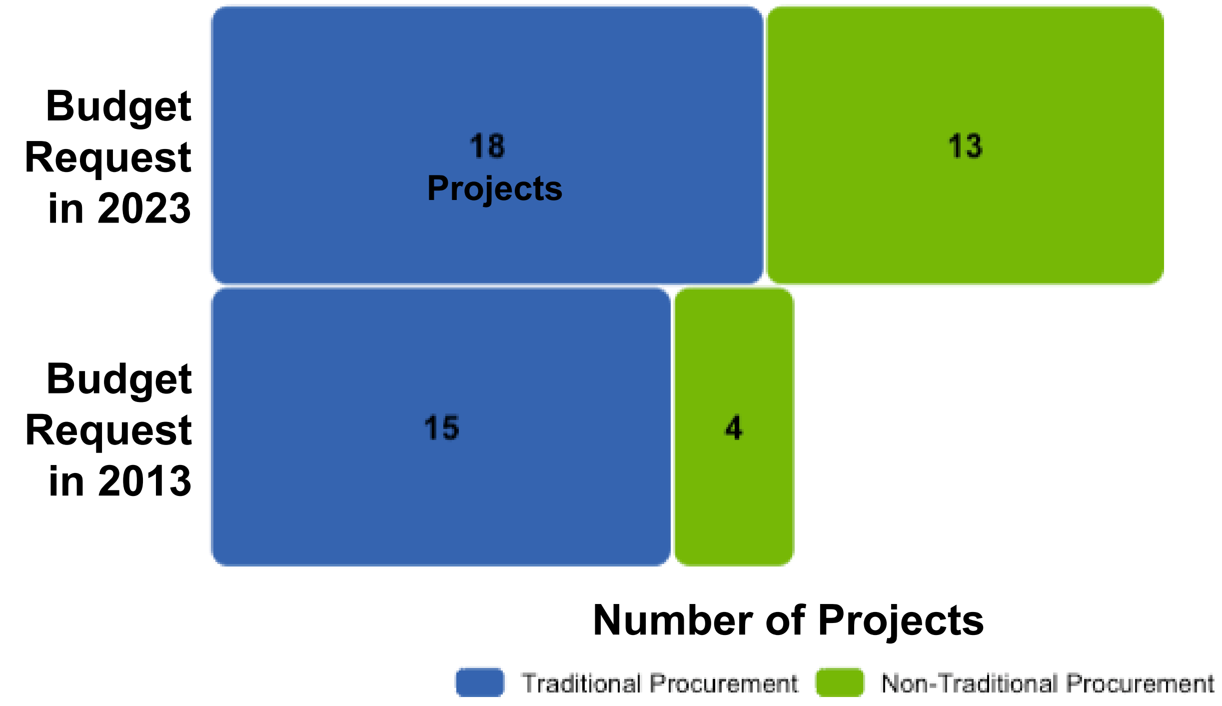
- ESDMD
- SOMD
- SMD
- STMD

# Budget Requests 2023 for Projects

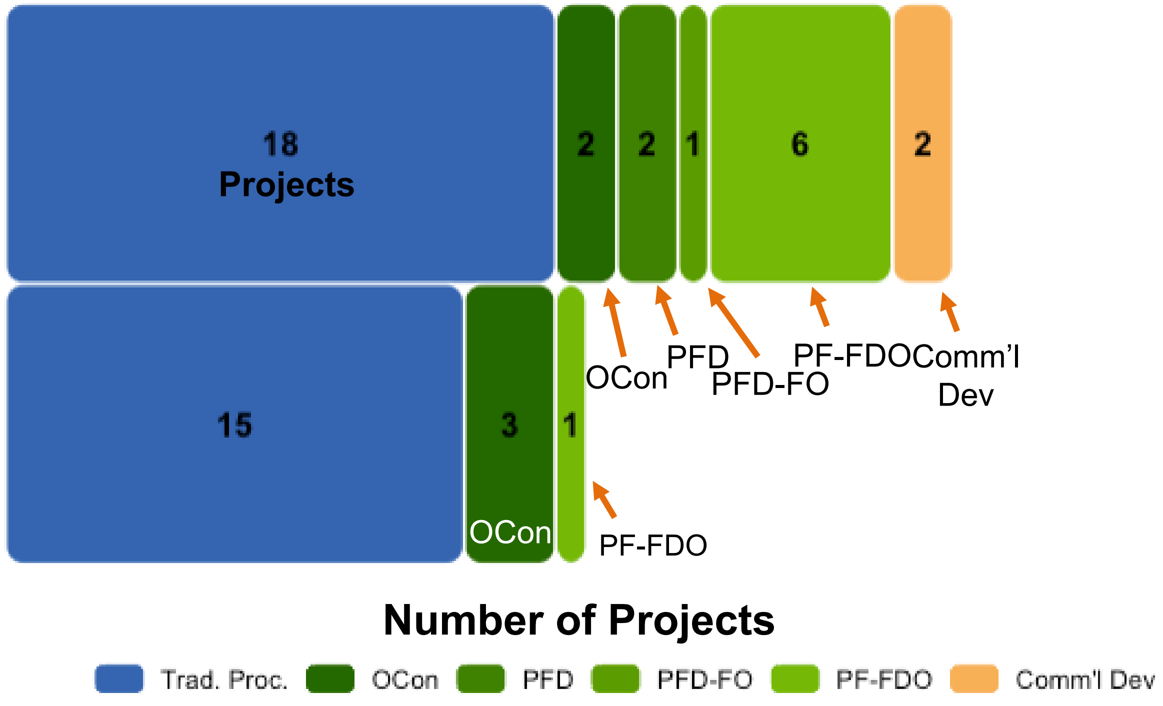


# Observations

## Types of Procurement Arrangements at NASA




## …Further Categorized by Non-Traditional Types




- **NASA now utilizes all types of Non-Traditional Procurement (NTP) projects, including Commercial Development**
  - Aligned with national space policy objectives to utilize the commercial space sector through industry collaboration and service acquisitions
- **99% increase in the proportion of number of NTP projects from 2013 to 2023**
- **77% increase in the proportion of budget for NTP projects from 2013 to 2023**

# Assessments

| Sample of Data Requirement Deliverables (DRD) | HLS | xEVAS | LTV | Gateway DSL |
|---|---|---|---|---|
| Safety and Mission Assurance (SMA) Plan | 2 | 1 | 2 | 1 |
| Safety and Health Plan | Not included | 1 | 1 | Covered under SMA Plan |
| Mishap Preparedness and Contingency Plan (MPCP) | 2 | Covered under Safety and Health Plan | 2 | 2 |
| Safety Data Package (SDP) | Not included | Not included | Covered under SSAR | 1 |
| System Safety Assessment Report (SSAR) | 1 | 1 | 1 | Covered under SDP |
| Failure Modes and Effects Analysis & Critical Items List | Covered under ISPA, HEA, and SMA Plan | 2 | Covered under ISPA, Reliability Allocation, Prediction, and Analysis Report | Covered under Safety Data Package |
| Micrometeoroid Orbital Debris (MMOD) Analysis and Assessment Report | 3 | Covered under Integrated System Performance Analysis (ISPA) | 3 | 1 |
| Planetary Protection Data | Not included | Not included | 3 | Not Included |
| Probabilistic Risk Assessment (PRA) | Covered under Human Error Analysis (HEA) Plan, Risk Management Plan | 3 | Covered under HEA Plan, MMOD | Not included |

## Types of DRD:

- **Type 1** requires NASA approval prior to release
- **Type 2** NASA reserves a time-limited right to disapprove
- **Type 3** does not require formal NASA review and approval.

## Observations:

- Gateway DSL is a full commercial development, yet requires more Type 1 DRD compared to the other Programs.
- Variation in Type 1, 2, 3, or not included despite similar risk posture.

MPAD

*References: Gateway Logistics Services Draft RFP Attachment 2 Data Requirements Description (DRD) - *Published: 6/14/19*, HLS Integrated Lander Attachment H, Data Procurement Document (DPD) *Published: 9/4/19*, Lunar Terrain Vehicle (LTV) Services (LTVS) Draft RFP J-01 Data Requirements Descriptions (DRD's) Published: *11/8/22*, Exploration Extravehicular Activity Services (xEVAS) Attachment J-01, Data Requirements Descriptions (DRD's) - *Published: 11/10/21*

# Conclusion & Next Steps

## Conclusion

- NASA is increasingly utilizing the commercial space sector to meet its wide variety of missions
- Requires changing SMA approach and culture, specific to each mission
- Requires flexible SMA services and products

***"No one size fits all."***

## Next Steps

- Feedback on what's working, what's not, and what could be improved
- Revise SMA policies, requirements, procedures, expectations
- Leverage best practices and lessons learned in current and future acquisitions

13th Trilateral

TRILATERAL2022

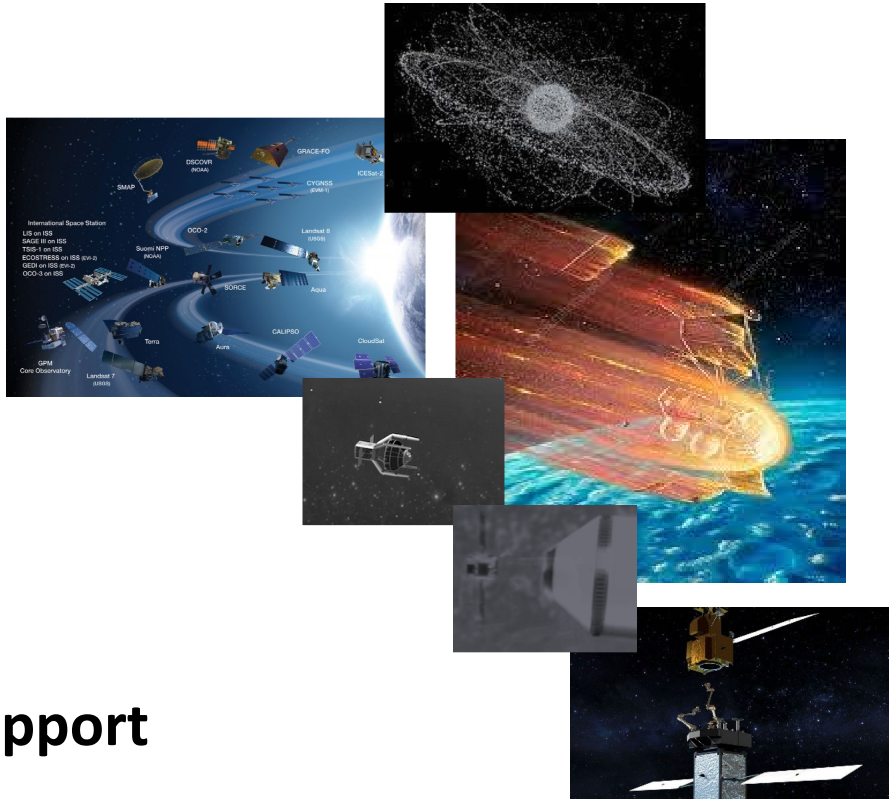
December 6-8, 2022

# Trilateral Task Force – On-orbit Servicing and Reliability Engineering and Mission Extension/Post Mission Disposal

**Lead** Nancy J Lindsey (NASA – OSMA/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



- **TOR Status**
- **PMD Consensus Documents**
- **Servicing/ADR Risk/Safety Support**
- **TOR Proposal**

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

# Reliability Task Force Status/Closure

- TOR Status
- PMD Consensus Documents
- Servicing/ADR Risk/Safety Support
  - Policies
  - Research
  - Codification
  - Conclusions
- TOR Proposal

## 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

✓ Create an International policy table
✓ Share Regulation/Policy and other documents
✓ Discuss similarities and differences
  - Policy
  - Plans/Techniques

## 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

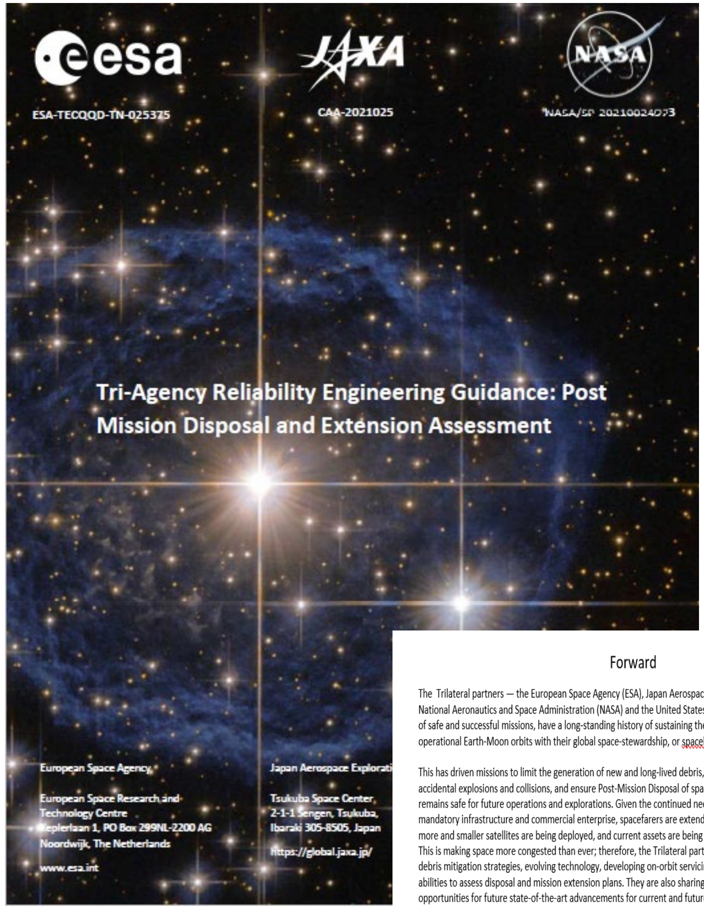
✓ Expand scope and participation (Design/Safety/Mainatainbilty/Etc.)

## 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.

# Consensus Document and Example Addendum

- TOR Status
- **PMD Consensus Documents**
- Servicing/ADR Risk/Safety Support
  - Policies
  - Research
  - Objectives
  - Conclusions
- TOR Proposal




## Forward

The Trilateral partners — the European Space Agency (ESA), Japan Aerospace Exploration Agency (JAXA), and National Aeronautics and Space Administration (NASA) and the United States Government (USG) in their execution of safe and successful missions, have a long-standing history of sustaining the shared space environment of operational Earth-Moon orbits with their global space-stewardship, or spacekeeping, of these areas

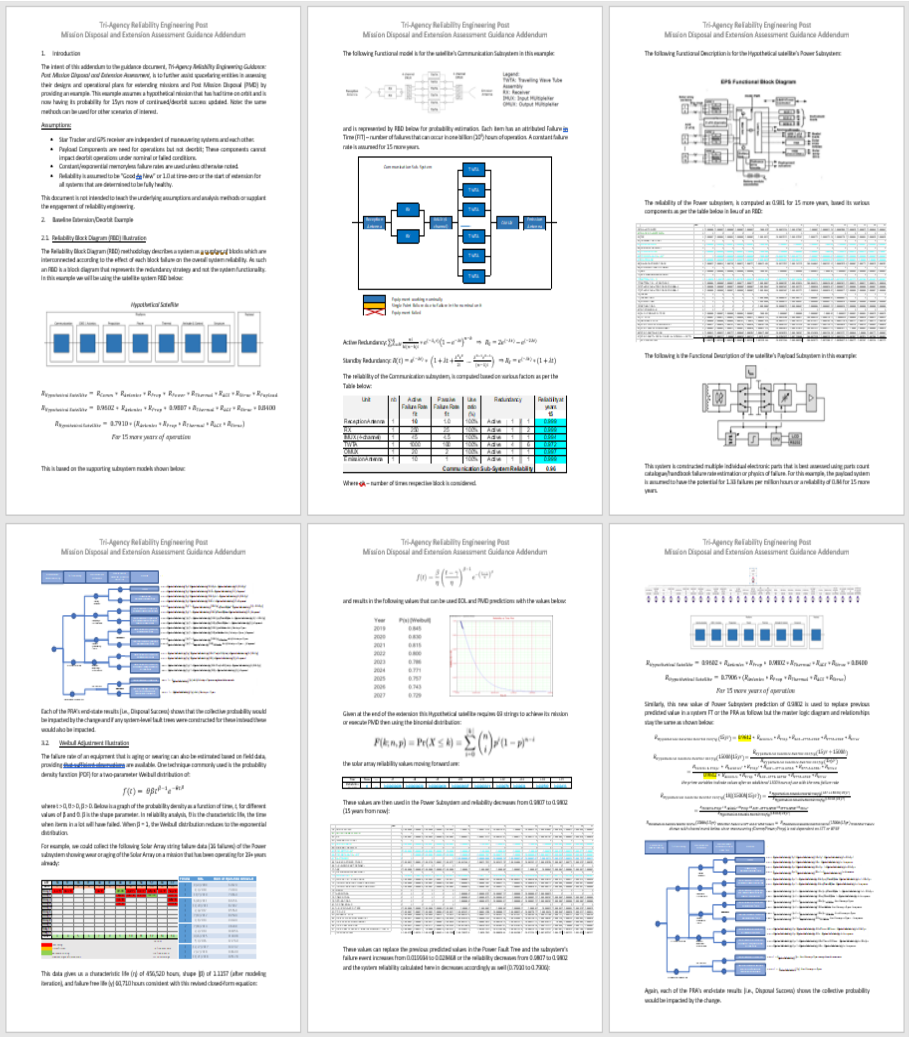
This has driven missions to limit the generation of new and long-lived debris, control debris releases, minimize accidental explosions and collisions, and ensure Post-Mission Disposal of space systems, so that the environment remains safe for future operations and explorations. Given the continued need for space systems to support global mandatory infrastructure and commercial enterprise, spacefarers are extending beyond the Trilateral partners, more and smaller satellites are being deployed, and current assets are being utilized much longer than expected. This is making space more congested than ever; therefore, the Trilateral partners are evaluating potential future debris mitigation strategies, evolving technology, developing on-orbit servicing capabilities, and advancing their abilities to assess disposal and mission extension plans. They are also sharing their lessons learned and identifying opportunities for future state-of-the-art advancements for current and future space enterprises.

Sustaining the space environment cannot be ensured by any one agency or country. Thus, the Trilateral authors have shared their lessons learned, insights, and guidance, herein, on disposal and mission extension assessment strategies with the gratitude of each agency. As such, this document is not prescriptive, but was formulated to enhance value-and-risk-balanced operational decision-making, support policy refinement, and guide spacefaring partners beyond these agencies to assess their activities in space with safety and a global space-stewardship, or spacekeeping, in mind. This includes not only the disposal and mission extension assessment addressed herein, but also preserving space history, ensuring collaboration/interoperability of technology, supporting fellow operators without interfering, and the utilization of in-situ resources for the common benefit of humankind.

It is the intention of the Trilateral partners that this document evolves based on community lessons learned and the introduction of new assessment methodologies. So, all readers are encouraged to share their insights with the authors from their own application of this guidance or other strategies to ensure each mission has a successful, safe, and judicious life and conclusion.

Released
January 1, 2022

Tri-Agency Reliability Engineering Post Mission Disposal and Extension Assessment Guidance Addendum



# Servicing/ADR Support Discovery Process

- TOR Status
- PMD Consensus Documents
- **Servicing/ADR Risk/Safety Support**
  - Policies
  - Research
  - Codification
  - Conclusions
- TOR Proposal

Review and Compare Servicing/ADR Policies

↓

Research and Compare Servicing/ADR Mission Plans, Goals, and Needs

↓

Identify and Codify Objectives, Strategies, and Support Solutions for assuring Servicing/ADR success

↓

Sharing Findings to enhance Servicing/ADR Practices. Designs, and Policies

# Review and Compare Servicing/ADR Policies

- TOR Status
- PMD Consensus Documents
- Servicing/ADR Risk/Safety Support
  - Policies
  - Research
  - Codification
  - Conclusion
- TOR Proposal

| | 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."**<br><br>**ISO/CD 24330 (under development until 2022)**<br><br>**Space systems — Rendezvous and Proximity Operations (RPO) and On Orbit Servicing (OOS) — programmatic principles and practices**<br><br>**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.**<br><br>**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**<br><br>**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."**<br><br>**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. "**<br><br>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<br><br>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.<br><br>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.<br><br>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.<br><br>France is involved in the development of IOS in the field of Active Debris Removal, reconfiguration, and de-orbiting.<br><br>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.<br><br>The French Technical Regulation is consistent with these guidelines, as well as with the ISO 24113 standard.<br><br>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.<br><br>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.<br><br>Currently using debris mitigation policy to guide CPO and RPO.<br>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

- TOR Status
- PMD Consensus Documents
- Servicing/ADR Risk/Safety Support
  - Policies
  - Research
  - Codification
  - Conclusions
- TOR Proposal

# Research and Compare Plans, Goals, and Needs

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

- TOR Status
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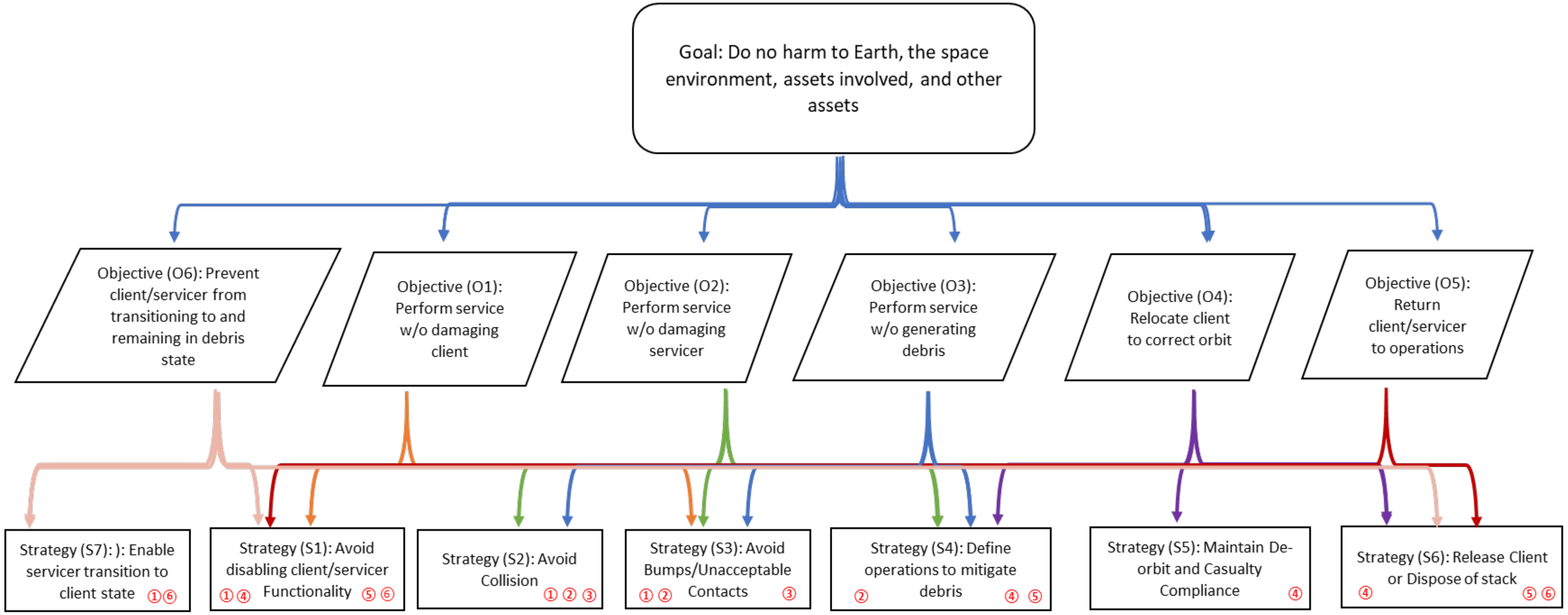
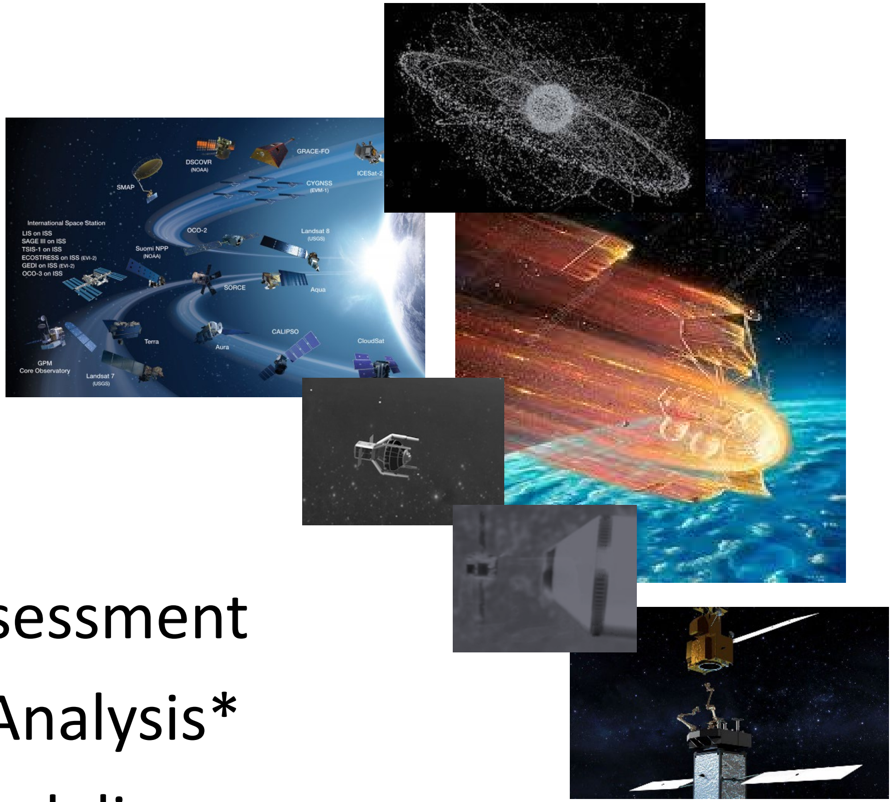
# Objectives to Enable Viable Servicing/Assisted Debris Removal




Reliability Engineering can support these solutions by performing expanded Maintainability/Serviceability Analyses, DNH/Ops/Process FMECA/FTs, and Probabilistic Servicing/De-orbit with appropriate knowledge.

# Conclusions



Engaging Reliability Engineering Support Provides:

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

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

- TOR Status
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# Recommended Path Forward

## 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

## Review/Explore operational and analysis Methods for Serviceability Analysis

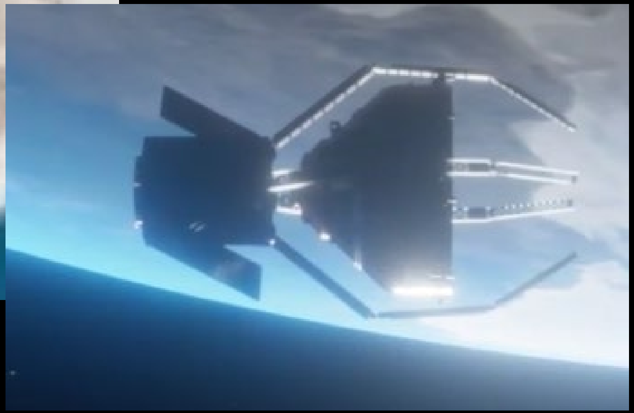
- Explore operational and analysis methodology advancements.
- Review/Establish best practice MTTF/MTTR /REL estimation
- Expand participation (Design/Safety/ Mainatainbilty/Etc.) for innovation, similarities and differences discussions

## Expand/Capture Comprehensive Knowledge Gathering/Sharing Solutions

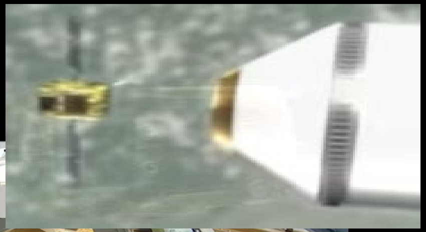
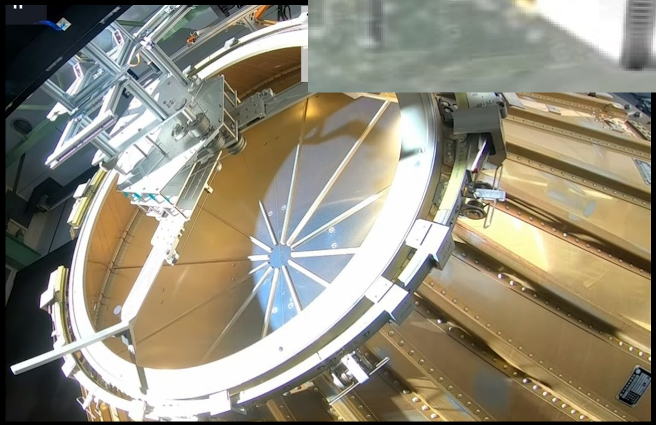
- Operations
- Integration and Test
- Design
- Sensor Optimization and Processing/Automation
- On-orbit Inspection
- Digital catalogs of knowns
  - In-orbit return of experience/lessons learned
  - Failure modes
  - Hazards

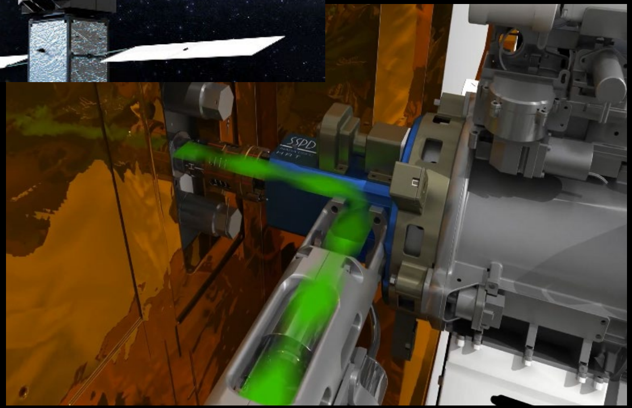
## Update guidance as warranted and best Practice/Policy Recommendations

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

# Questions



BACKUP

# 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 Assisted Debris Removal (ADR) while mitigating debris generation and/or collision/explosion risks
- Conduct Servicing while avoiding damage to client or servicer.

esa JAXA

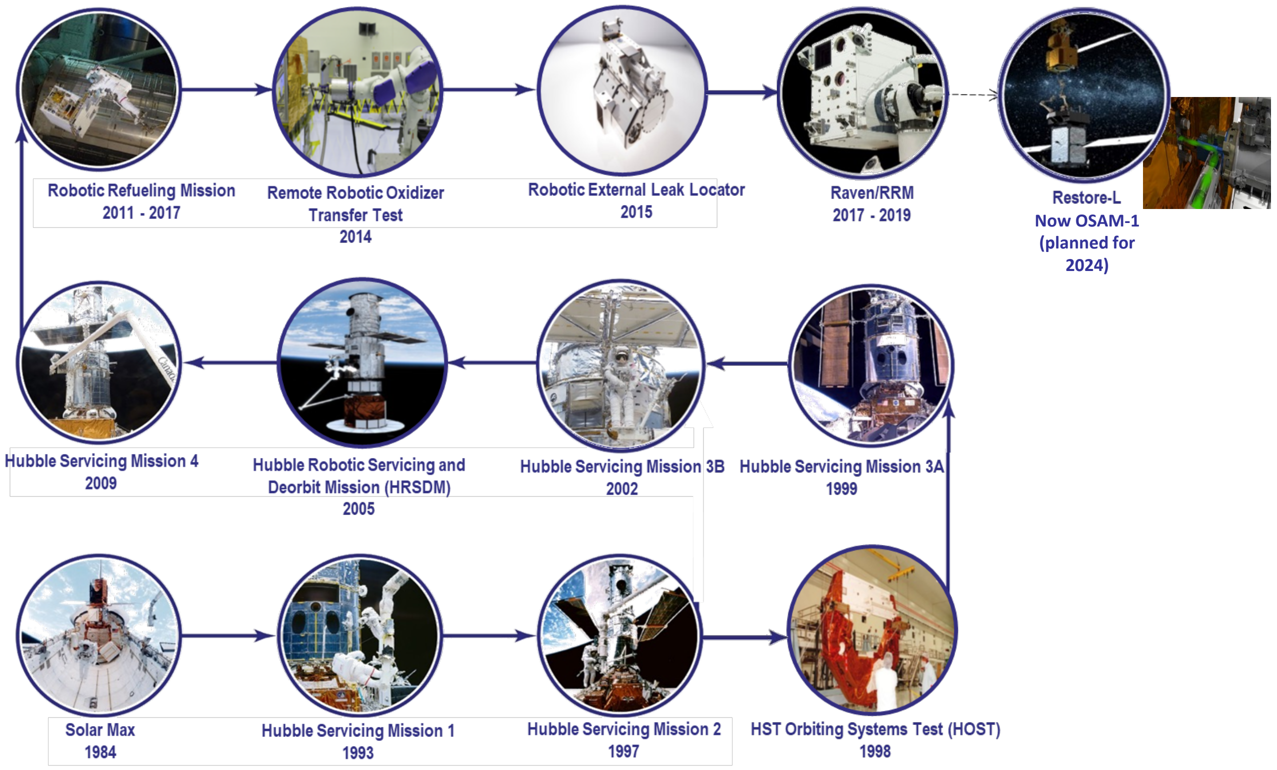
Jet Propulsion Laboratory
California Institute of Technology

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

Jet Propulsion Laboratory
California Institute of Technology

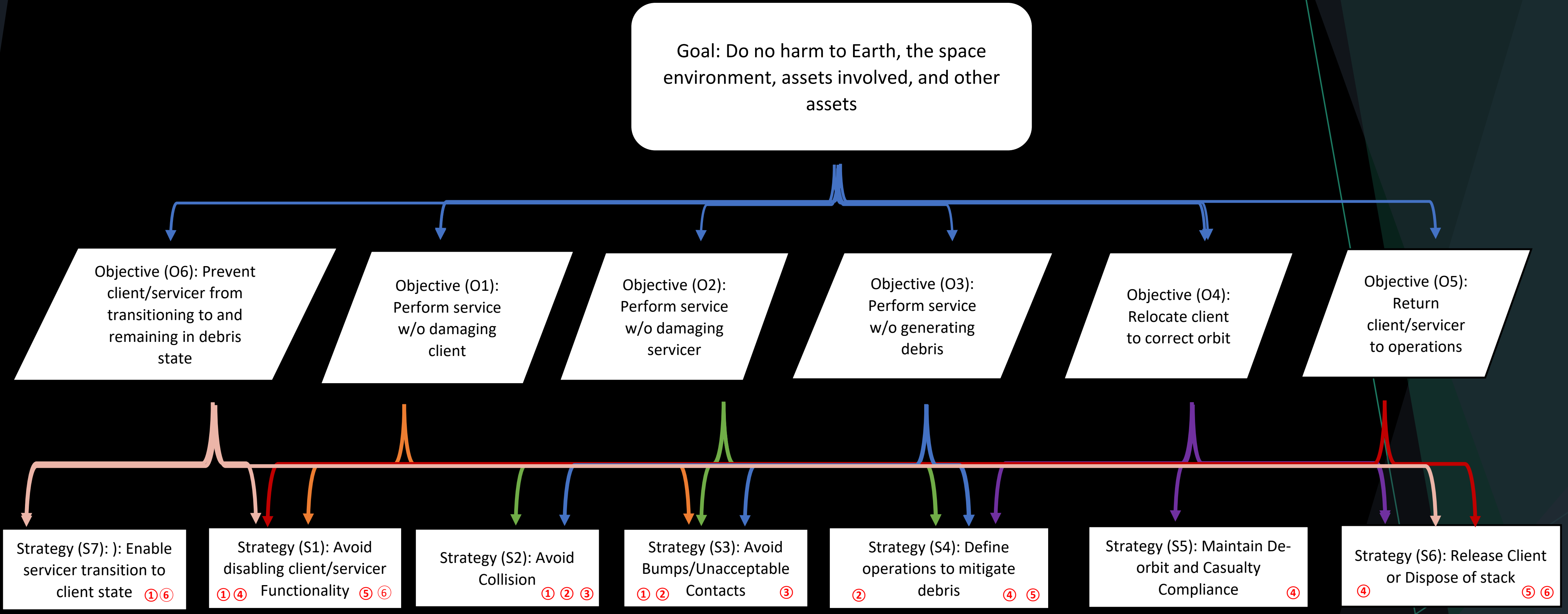
NASA

# 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:

# 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
- Enable servicer transition to client state

NASA/ESA/JAXA have or plan to:

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

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. Existing serviceability technology of client/debris

# 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
- Enable servicer transition to client state

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

- **Avoid disabling client functionality**
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iv. Conduct Client Serviceability/Maintainability Analysis
v. Develop Operations and Capture plans
vi. Estimate via testing/modeling debris generation results from operations

With knowledge of:

a. Grapple capture methods/limitations
b. Debris/Client's design (serviceability) and current state
c. Operations critical events and fault tolerance
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g. Existing serviceability technology of client/debris

Jet Propulsion Laboratory
California Institute of Technology

# 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**
- **Enable servicer transition to client state**

NASA/ESA/JAXA have or plan to:

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

esa JAXA

Jet Propulsion Laboratory
California Institute of Technology

NASA

# 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**
- **Enable servicer transition to client state**

NASA/ESA/JAXA have or plan to:

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

With knowledge of:

a. Grapple capture methods/limitations
b. Debris/Servicer'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
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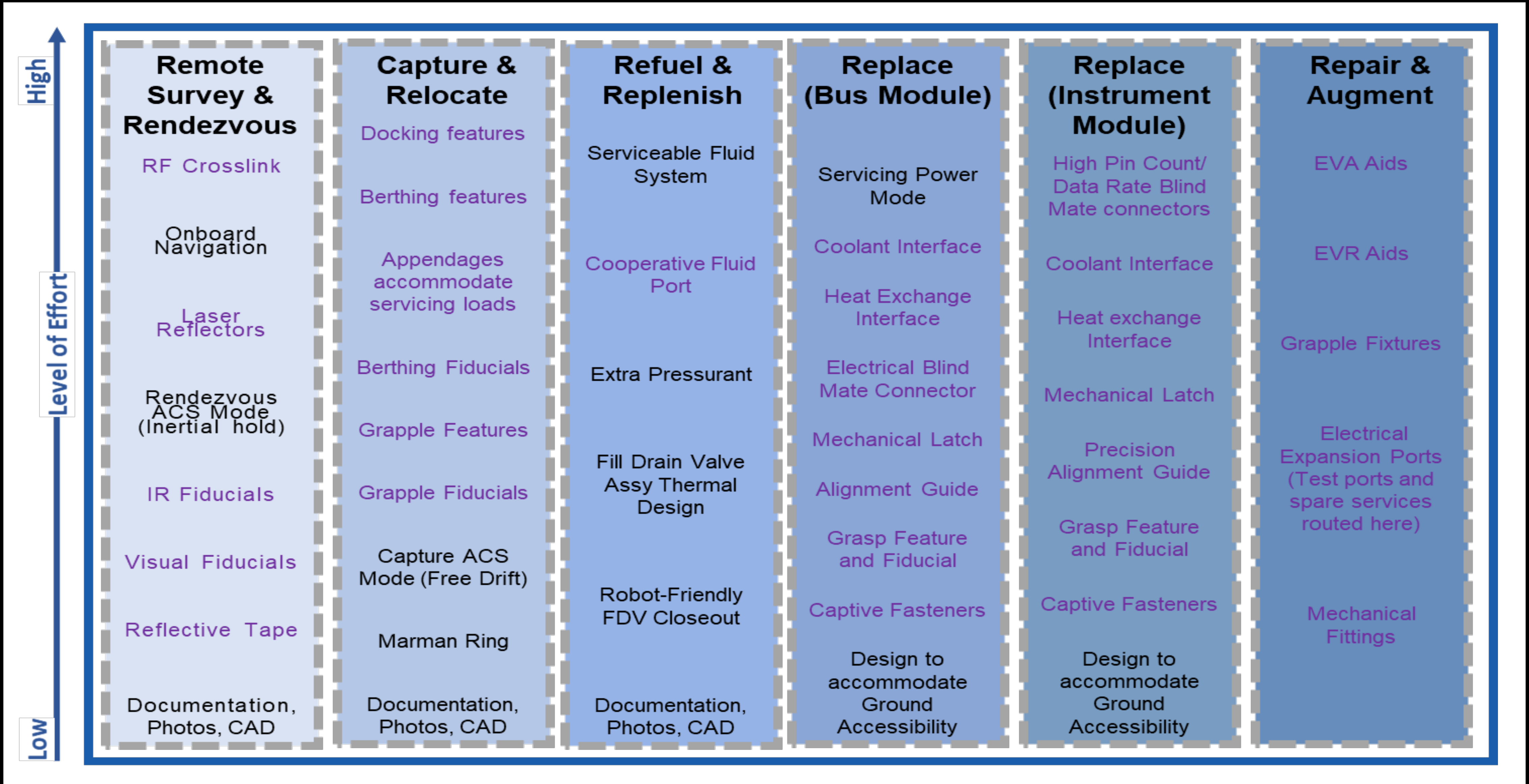

High
Level of Effort
Low
Remote Survey & Rendezvous
RF Crosslink
Onboard Navigation
Laser Reflectors
Rendezvous ACS Mode (Inertial hold)
IR Fiducials
Visual Fiducials
Reflective Tape
Documentation, Photos, CAD
Capture & Relocate
Docking features
Berthing features
Appendages accommodate servicing loads
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

# OSMA Supply Chain Risk Management (SCRM) Overview

Valle Kauniste

Trilateral

# Why SCRM?
# Strategic Situation / USG Policy

- NASA missions rely upon multitiered, interconnected and global supply chains of commercial, non-profit and government organizations to develop and operate complex, high-value and innovative systems for the nation
  - Dynamic array of technical, business, market and security risks threaten to disrupt or deny the timely, affordable provisioning of products and services as required for mission success
- Administration policies, including:
  - Executive Order 14005, Ensuring the Future is Made in All of America by All of America's Workers *(1/25/2021)*
    - *... the United States Government should ....maximize the use of goods, products and materials produced in, and services offered in, the United States.*
  - Executive Order 14017, America's Supply Chains *(2/24/2021)*
    - *The United States needs resilient, diverse and secure supply chains to ensure our economic prosperity and national security.*
  - United States Space Priorities Framework (12/2021)
    - .... *the United States will ... strengthen the resilience of supply chains across the nation's space industrial base.*

# Key SCRM Challenges

- **Build supply chain visibility** within and across projects to provide insights/situational awareness, identify/assess risks and support informed decision-making
- **Streamline the planning, resourcing** and performance of supplier quality assurance activities to optimize the reduction of priority risks (isolated and cross-cutting)
- **Improve interfaces** with established risk management and decision-making processes to anticipate, avoid and reduce supply chain risks
- **Enable continual improvement** of SCRM efforts through the recognition of shared concerns and collaborative solutions

# About the OSMA SCRM Program

OSMA
OFFICE OF SAFETY & MISSION ASSURANCE

- **Launched October 2019**

- **Holistic approach** to solutions for sustainable, effective SCRM:
  - Policy and processes
  - Information systems
  - Workforce expertise
  - Organizational culture

- **Key initiatives** include:
  - **Information Platform:** NASA Supply Chain Insight Central (SCIC) information services platform (operational since March 2021)
  - **Collaboration and Policy** enabling SCRM across the NASA enterprise

# OSMA/SCRM Overview

OSMA
OFFICE OF SAFETY & MISSION ASSURANCE

**Rules and tools:** Enhance tools, techniques and systems that and create process efficiencies and informed decision-making

- Enterprise-wide Digital Transformation: Machine Learning, Data capture, Data discoverability, Analytics, Automated workflows for GCQA efforts
- Platforms: Supply Chain Insight Central (SCIC), NANADARTS (Alerts/Advisories management)
- Templates, forms, compliance matrices, increasing FAR/NFS options, leverage OSMA quality audit process (QAAR), leverage OSMA independent assessment.
- Leverage industry-managed SCRM data (e.g, OASIS, GIDEP databases)
- New and improved standards: SAE (AS9100, AS9003, AS9018), Nadcap/PRI, AIA
- Leveraging Center/Program capabilities or initiatives for wider use: Open-source supplier risk indications (GSFC), QA data system (ESD, administered by ARC)

**Integrate QA with Procurement**: Collaborate with the Office of Procurement to enhance procurement strategies

- QA at the table during acquisition planning, FAR approach
- Requirements management: RFP/Contract QA clauses, flow down, surveillance plan template, QA Implementation Plan assessments, Prime Contractor QA metrics and reporting (holding Primes accountable)
- Past performance/risk to impending contract, Performance award fee inputs
- QA supplier surveillance budget process (CAAS) and delegations to DCMA

# OSMA/SCRM Overview (cont.)

**Workforce competency**:

- Training: FAR/NFS, contracts, legal liability re: DD 250, using rules and tools
- Leverage Quality Assurance Working Group
- Leveraging the QLF, NSC STEP, NSC Webinars

**Risk leadership in Supplier Surveillance** (includes improving leadership to DCMA)

- Improving the CAAS budgeting processes for GCQA Resource allocation across the supply chain
- Data driven: Increase Program Management insight to risks and threats.
- Hold Primes Accountable and develop a remedy for under-performing suppliers (CARs, Ratings)

**GIDEP**

- NPR 8735.1:
  - Policy for participation by NASA and its suppliers in the GIDEP Program; NPR 8735.1
  - NASA Advisories process; fills reporting gaps in GIDEP program
- NARS/NANADARTS
  - Data management platform
  - Automates closed loop GIDEP/Advisory research/reporting process
- Alert sharing with partners
  - Coordinates with Trilateral committee
  - Coordinates for Programs/projects with international partners

# OSMA/SCRM Overview (cont.)

**Counterfeit Avoidance:**

- FAR/NFS procedures, flowed into P/p via NPR 8735.2
- Leverage industry standards (30+ compliance standards, test methods, guidelines)
- Classroom training and on-demand Webinar
- Support to Office of Chief Counsel's Acquisition Integrity WG

**Support other Agency SCRM Efforts and Information Sharing:**

- HQ/AA Supply Chain Ecosystem Working Group
- OMB
- ICT SCRM: Carry requirements in quality policy, attend WG meetings as needed
- Space Industrial Base Working Group (SIBWG): Seeking integration to flag products known to be high risk
- Respond to inquiries from Legislative and Executive Branches, other Agencies including Dept. of Commerce
- NASA Enterprise Protection Working Group

# SCIC Information & Analysis Services
## Current State

Operational:

- Core platform functionality for integrated data management, display and utilization (initial March 2021 release)
- Application:  Contract Administration and Audit Services (CAAS) Quality Assurance Resource Planning
- Functionality:  NASA Critical At-Risk Industrial Technology List (CARITL) -- 63 items with 162 associated suppliers in SCIC
- Functionality:  OSMA SCRM Hot Topics
- Supplier Research & Analysis (SRA) service employing business intelligence techniques and information resources
  - e.g., Helium Shortage; Alpha Spectra -- domestic alternative to Ukraine source (Amcrys) of crystals and scintillator detectors for spacecraft instruments; financial capability assessments for high value procurements (NASA FAR Supplement 1809.105-1)
- 302+ authorized SCIC users (NASA civil servants & direct support contractors) across the agency
- 4,099+ supplier records with related supplier assessments (3,859+), supplier research & analysis reports (173+), and other reports (28+)

Ongoing / planned developments include:

- Application: NASA-Delegate (DCMA) Supplier Quality Assurance Reporting
- Application: Supplier Major Nonconformances Reporting
- Application: NASA Critical At-Risk Industrial Technology List (CARITL) Process
- Application: U.S. Civil Space Industrial Base Survey Data Management and Analysis
- Scale-up current SRA Dashboards (Global Risk / Foreign-Based Suppliers; AS9100 Certifications / Suppliers)
- Data connections with other information systems (e.g. Nadcap, OASIS, NASA GIDEP)
- Application:  Supply Chain Visibility Reporting portal

# Discussion / Next Steps

- Action plan to boost Supply Chain Visibility for pro-active SCRM
- Strengthen collaboration, interfaces and integrated management of data and information for SCRM analysis and decision-making
  - Use and build upon current and developing SCIC capabilities
- Foster a SCRM mindset and supporting best practices across the NASA Project Lifecycle
- OSMA SCRM resourcing

An Old Proverb

For want of a nail the shoe was lost;
For want of a shoe the horse was lost;
For want of a horse the rider was lost;
For want of a rider the battle was lost;
For want of a battle the kingdom was lost;
And all for the want of a horseshoe nail.

**Valle Kauniste**
Program Manager, HQ/OSMA Supply Chain Risk Management, valle.j.kauniste@nasa.gov


WE ARE GOING
NASA

# NASA Office of Safety and Mission Assurance Organizational Overview

## ESA/JAXA/NASA Trilateral SMA Meeting

December, 2022

OSMA IV&V NSC

# Office of Safety and Mission Assurance

Mr. Russ DeLoach
Chief, SMA

**CHIEF, SAFETY AND MISSION ASSURANCE**
W. Russ DeLoach

**DEPUTY CHIEF**
Frank Groen, Ph.D.

### NASA CENTER SMA DIRECTORS

- Ames Research Center: A. Demo
- Armstrong Flight Research Center: G. Graham
- Glenn Research Center: K. Martzaklis
- Goddard Space Flight Center: D. Healey
- Jet Propulsion Laboratory: M. Herman
- Johnson Space Center: W. Lyles
- Kennedy Space Center: R. Rodriguez
- Langley Research Center: C. Cockrell
- Marshall Space Flight Center: W. Hill
- Stennis Space Center: G. Benton

**Resources Management Office**
Melanie Osei-Acheampong

**Mission Assurance Standards and Capabilities Division**
Dr. Matt Forsbacka

**Missions and Programs Assessment Division**
Johnny Nguyen

**Institutional Safety Management Division**
Grant Watson

**NASA Safety Center**
Harmony Myers

**NASA Independent Verification and Validation Program**
Wesley Deadrick

## OSMA vs. Center Mission Assurance Roles

### OSMA:

- Lead SMA Technical Authority (TA).
- Manage SMA capability leadership.
- Review and assess the "big three" (Planetary Protection, Orbital Debris mitigation, Nuclear Flight Safety).

### Center SMA Organizations:

- Matrix support for Programs and Projects.
- Program- and Project-Level TA.

### Other Organizations:

- Office of the Chief Engineer: Space traffic management and mission security.

Full NASA organizational structure at https://www.nasa.gov/about/org_index.html.

# Office of Safety and Mission Assurance

# NASA Highlights

# Missions

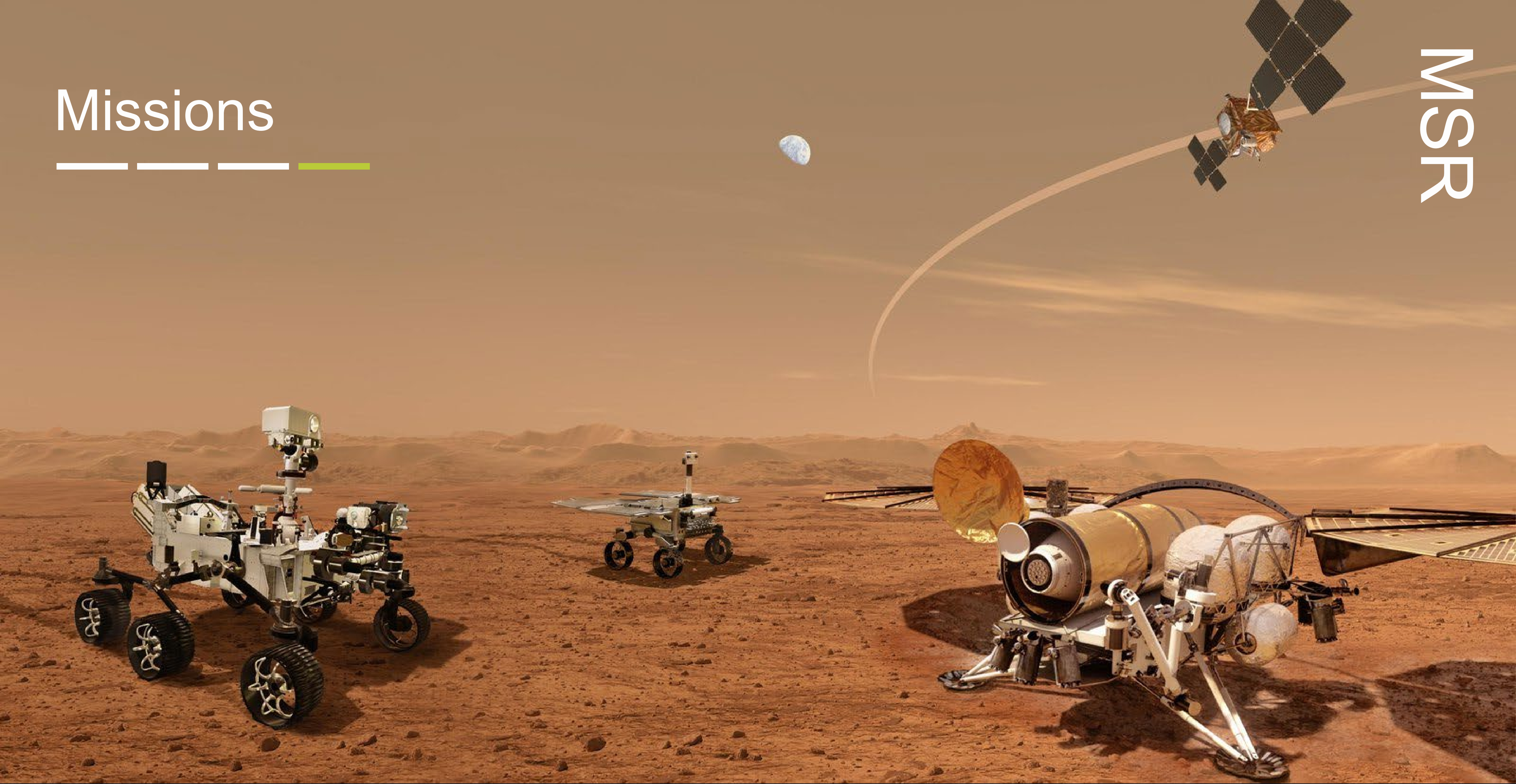

## Artemis/Gateway

# Missions

CCP

# Missions

MSR

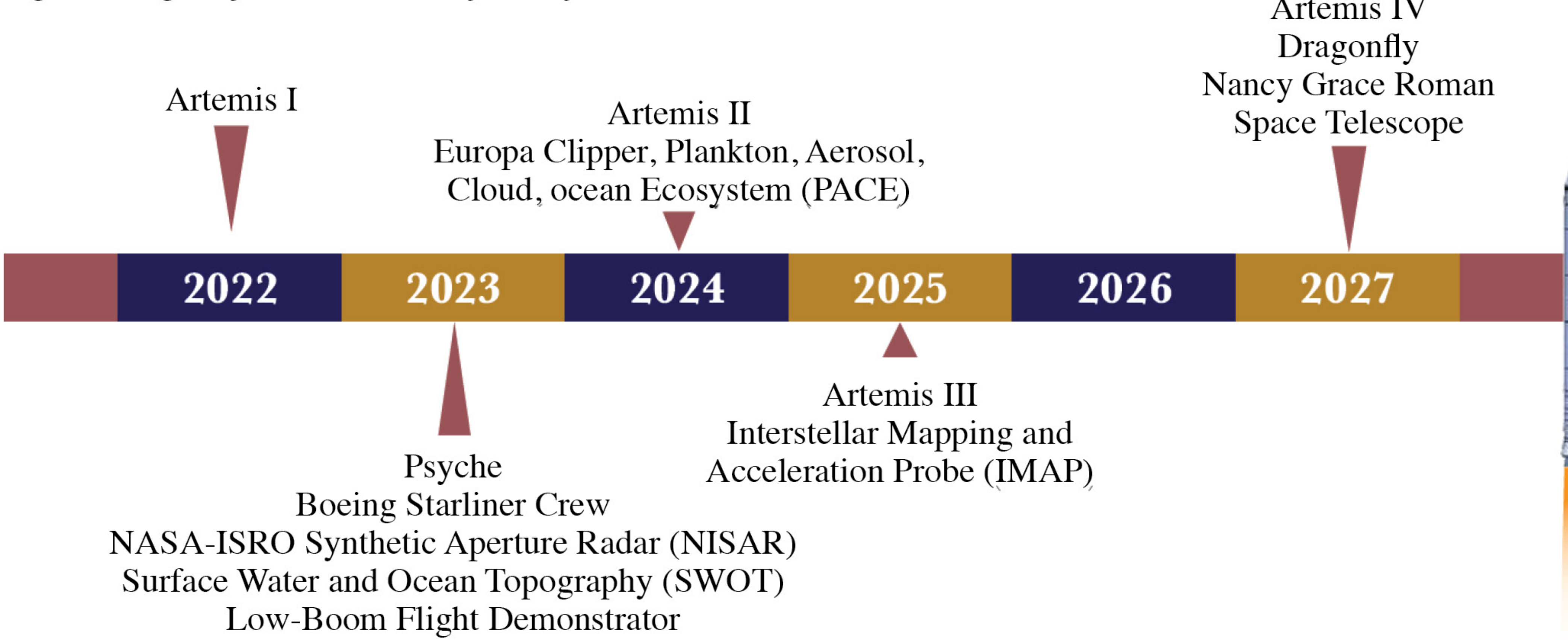


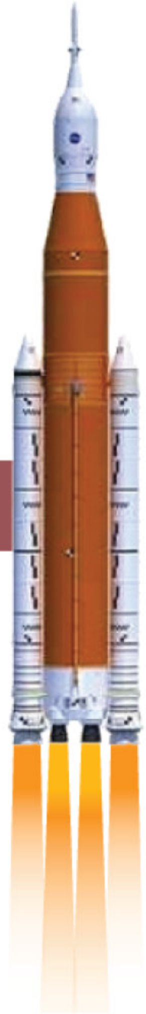
# Missions

X-59

# Major Upcoming Missions

*Figure 1: Agency Timeline of Major Projects and Missions*



# NASA Priorities and Initiatives

Coordinate w OIIR on inclusion of Artemis Accords and what to say

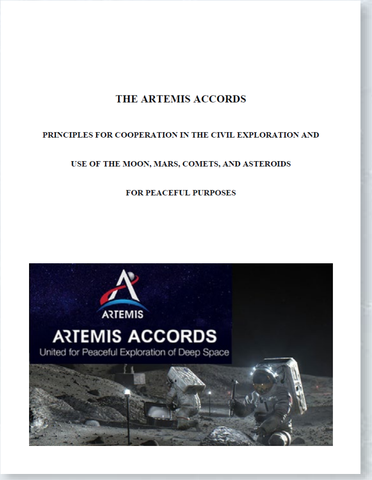
Underscores Administration's priorities: strengthening the United States' (U.S.) global leadership in space and aeronautics; tackling the climate crisis; building a sustainable human presence at the Moon and continuing human exploration on towards Mars; spurring innovation that builds back better and creates jobs; leading an alliance of international partners to enhance cooperation in space and stimulate commercial activities in low Earth orbit; and advancing diversity, equity, inclusion and accessibility in a way that inspires present and future generations.

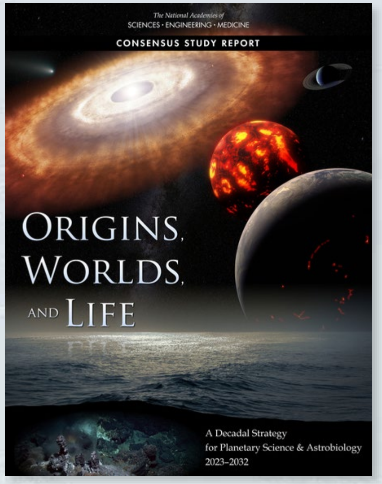


[This] objectives-based approach focuses on the big picture, the "what" and "why" of what NASA should be doing in terms of deep space exploration before prescribing the "how".

63 objectives spanning multidisciplinary science, transportation and habitation, lunar and Martian infrastructure, operations, and a new domain: recurring tenets.

A shared vision for principles, grounded in the Outer Space Treaty of 1967, to create a safe and transparent environment which facilitates exploration, science, and commercial activities for all of humanity to enjoy.




Research strategy to maximize advancement of planetary science, astrobiology, and planetary defense in the coming decade. Relies heavily on inputs from the scientific community to establish the scientific basis and direction for its space-science flight- and ground-research programs and technology development activities.

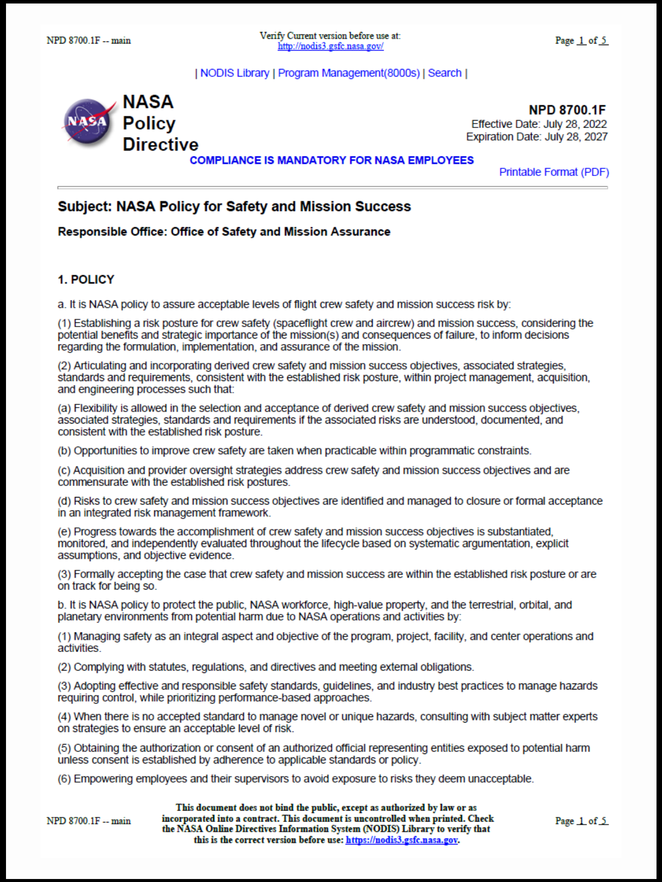
# OSMA Highlights

# OSMA Strategic Direction

OSMA formulating objectives to improve support of the next era of aerospace, e.g.:

- Enable missions and institutions to effectively and efficiently implement SMA
- Catalyze culture of risk leadership and management
- Make OSMA processes and services objectives-driven and risk-informed
- Cultivate technical and organizational excellence
- Adjust capabilities and tools to support emerging needs – move to a digital world

# NASA Policy for Safety and Mission Success (NPD 8700.1F - 2022)



NPD 8700.1F -- main | Verify Current version before use at: http://nodis3.gsfc.nasa.gov/ | Page 1 of 5

| NODIS Library | Program Management(8000s) | Search |

NASA Policy Directive

**NPD 8700.1F**
Effective Date: July 28, 2022
Expiration Date: July 28, 2027

**COMPLIANCE IS MANDATORY FOR NASA EMPLOYEES**

Printable Format (PDF)

**Subject: NASA Policy for Safety and Mission Success**

**Responsible Office: Office of Safety and Mission Assurance**

**1. POLICY**

a. It is NASA policy to assure acceptable levels of flight crew safety and mission success risk by:

(1) Establishing a risk posture for crew safety (spaceflight crew and aircrew) and mission success, considering the potential benefits and strategic importance of the mission(s) and consequences of failure, to inform decisions regarding the formulation, implementation, and assurance of the mission.

(2) Articulating and incorporating derived crew safety and mission success objectives, associated strategies, standards and requirements, consistent with the established risk posture, within project management, acquisition, and engineering processes such that:

(a) Flexibility is allowed in the selection and acceptance of derived crew safety and mission success objectives, associated strategies, standards and requirements if the associated risks are understood, documented, and consistent with the established risk posture.

(b) Opportunities to improve crew safety are taken when practicable within programmatic constraints.

(c) Acquisition and provider oversight strategies address crew safety and mission success objectives and are commensurate with the established risk postures.

(d) Risks to crew safety and mission success objectives are identified and managed to closure or formal acceptance in an integrated risk management framework.

(e) Progress towards the accomplishment of crew safety and mission success objectives is substantiated, monitored, and independently evaluated throughout the lifecycle based on systematic argumentation, explicit assumptions, and objective evidence.

(3) Formally accepting the case that crew safety and mission success are within the established risk posture or are on track for being so.

b. It is NASA policy to protect the public, NASA workforce, high-value property, and the terrestrial, orbital, and planetary environments from potential harm due to NASA operations and activities by:

(1) Managing safety as an integral aspect and objective of the program, project, facility, and center operations and activities.

(2) Complying with statutes, regulations, and directives and meeting external obligations.

(3) Adopting effective and responsible safety standards, guidelines, and industry best practices to manage hazards requiring control, while prioritizing performance-based approaches.

(4) When there is no accepted standard to manage novel or unique hazards, consulting with subject matter experts on strategies to ensure an acceptable level of risk.

(5) Obtaining the authorization or consent of an authorized official representing entities exposed to potential harm unless consent is established by adherence to applicable standards or policy.

(6) Empowering employees and their supervisors to avoid exposure to risks they deem unacceptable.

NPD 8700.1F -- main | **This document does not bind the public, except as authorized by law or as incorporated into a contract. This document is uncontrolled when printed. Check the NASA Online Directives Information System (NODIS) Library to verify that this is the correct version before use: https://nodis3.gsfc.nasa.gov.** | Page 1 of 5

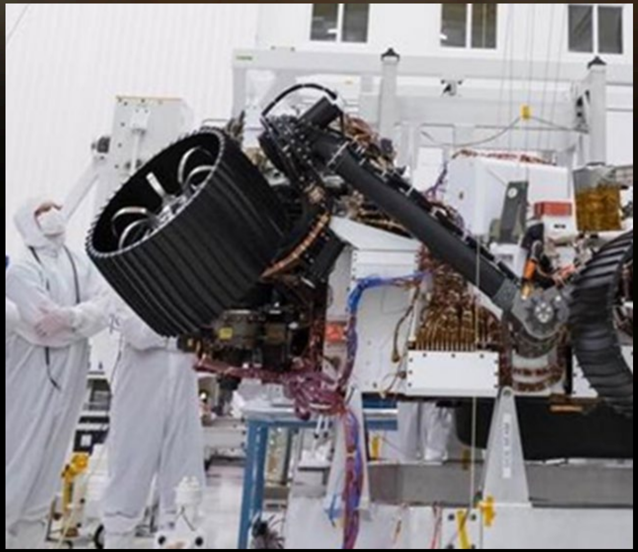
Organized around three policy objectives:

- Assure acceptable levels of flight crew safety and mission success risk
- Protect the public, NASA workforce, high-value property, and the terrestrial, orbital, and planetary environments from potential harm
  due to NASA operations and activities
- Cultivate a robust safety culture that values and pursues technical and organizational excellence in order to understand and reduce risk

Emphasizes objectives-driven, risk-informed, case-assured approaches

# Other Notable Directives and Standards Updates

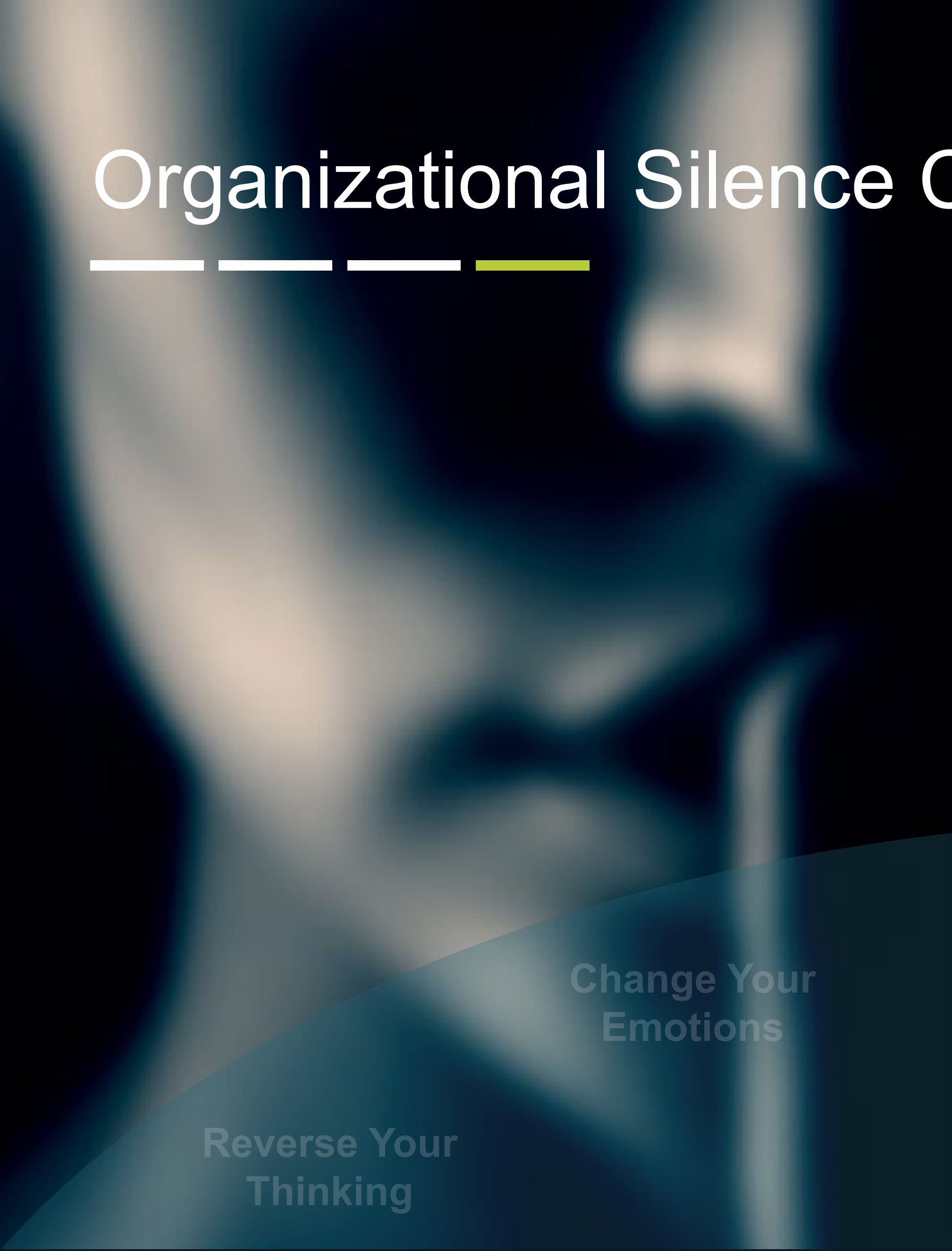
- **Nuclear flight safety** (NPR 8715.26)
  - Restructures nuclear flight authorization process consistent with NSPM-20
  - Recognizes Interagency Nuclear Safety Review Board; defines safety criteria and decision authorities
- **Planetary protection** (NPR 8715.24 / NASA-STD-8719.27)
  - Reflects “new” organizational structure; updates and restructures technical requirements
- **Risk management** (NPR 8000.4C)
  - Makes the subject of cybersecurity and cyber risk explicit within risk management requirements
- **Payload safety** (NASA-STD-8719.24A)
  - Reflects current revision of USSF SPFCMAN 91-710 (Space Force Range Safety User Requirements Manual)
- **Orbital Debris Mitigation** (NASA-STD 8719.14B)
  - Improves alignment with US Government Orbital Debris Mitigation Standard Practices
- All documents online in “NODIS library” and standards.nasa.gov



# Planetary Protection – COSPAR PP Policy Restructuring

- NASA has dissected the COSPAR PP Policy and is proposing a plan for modernizing and restructuring this policy at the upcoming COSPAR PP Panel meeting in Dec 2022.
- Driving needs for change
  - *Increased mission cadence and players in private sector, commercial space and member States.*
  - *Current policy lacks flow and contains redundant sections which are hard for end users to implement.*
  - *An opportunity exists to develop a structured policy to serve as a forward-leaning international standard.*
  - *Support by COSPAR PPP leadership to update.*
  - *Development of a policy framework to streamline onboarding of crewed mission guidelines upon knowledge gap closure.*
- Key proposal changes are to include rearranging policy into a logical flow, clarifying roles and responsibilities, changing policy language to reflect non-binding regulatory intent, seeking to define harmful contamination to ensure clear policy intent, defining objective requirements in the key guidance and moving prescriptive requirements to Appendices as supporting examples, updating references, cleaning up redundant sections and making policy hardware agnostic.

# Organizational Silence Course



Be Present

Invite Dialogue

Change Your Emotions

Intentionally Include

Reverse Your Thinking

Create a Positive Safe Environment

# Assisted Planning of Assurance Activities


# Future of Standards

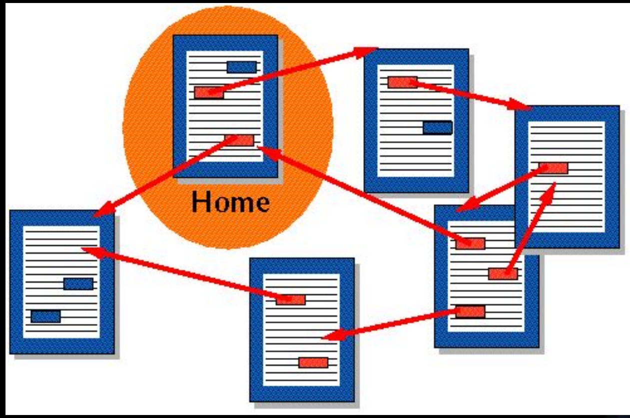
## ESA/JAXA/NASA Trilateral SMA Meeting

December, 2022

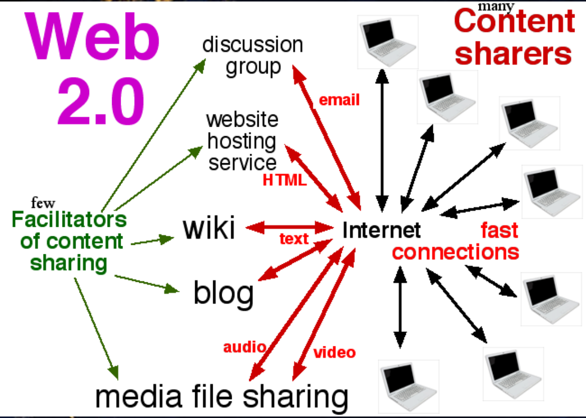
OSMA IV&V NSC

# Moving to a Digital World: A Zero Trust Perspective

Information Silos




Hard-Wired Digital Connectivity




App-Centric Managed Data

Semantic Web

High Reliability Organization: An organization with predictable and repeatable systems that support consistent operations while catching and correcting potentially catastrophic errors before they happen

# Vignette

Placeholder for graphics

# Planetary Protection Task Force Update On Proceeding Forward on a Mutual Certification of Joint Missions for PP

## ESA/JAXA/NASA Trilateral SMA Meeting

N. Benardini, K. Fujita, E. Seasly, and S. Sinibaldi

December, 2022

# Task Force Discussion from 2021

- JAXA presented a proposal for Agreements on acceptance/exemption of PP implementation and reviews in joint missions.
- While missions are aligned with COSPAR PP Policy as an international standard – JAXA would like to have more formal consensus document to streamline the certification process between the three agencies.
- **Short term task force was recommended to discuss how to proceed on a mutual certification consensus.**
- Discussion was that this should take place in addition to the existing communication/collaboration channels.

9. **Discussion: Mutual acceptance/exemption of reviews conducted by each agencies** *(Dr Elaine E. Seasly, Dr James N. Benardini, Dr Kazuhisa Fujita)*

This topic pertained to coordination between the agencies in the area of planetary protection.

Dr. Kazuhisa Fujita presented a proposal for Agreements on acceptance/exemption of planetary protection implementation & review in each joint international missions. The current implementation of planetary protection is conventionally carried out based on COSPAR Planetary Policy and Guidelines for each international missions, but JAXA would like to have a formal consensus document on basis and common rules for mutual certification of planetary protection review with three agencies to simplify the process.

While all agencies agreed this is an important topic that requires continuous communication and

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**12th ESA-JAXA-NASA S&MA Trilateral Meeting**
**June 16th – 17th 2021**
**Online Meeting (hosted by JAXA)**

collaboration among three agencies, the concern was raised on finding a common ground/filling the gap between the agencies on what the requirement should be. NASA mentioned the need to recognize other stakeholders involved in the US, including commercial entities, and ongoing developments regarding planetary protection policy. It also recalled the trilateral protocol regarding orbital debris mitigation as a possible model for moving forward. ESA mentioned that they need more time to get involved in the discussion.

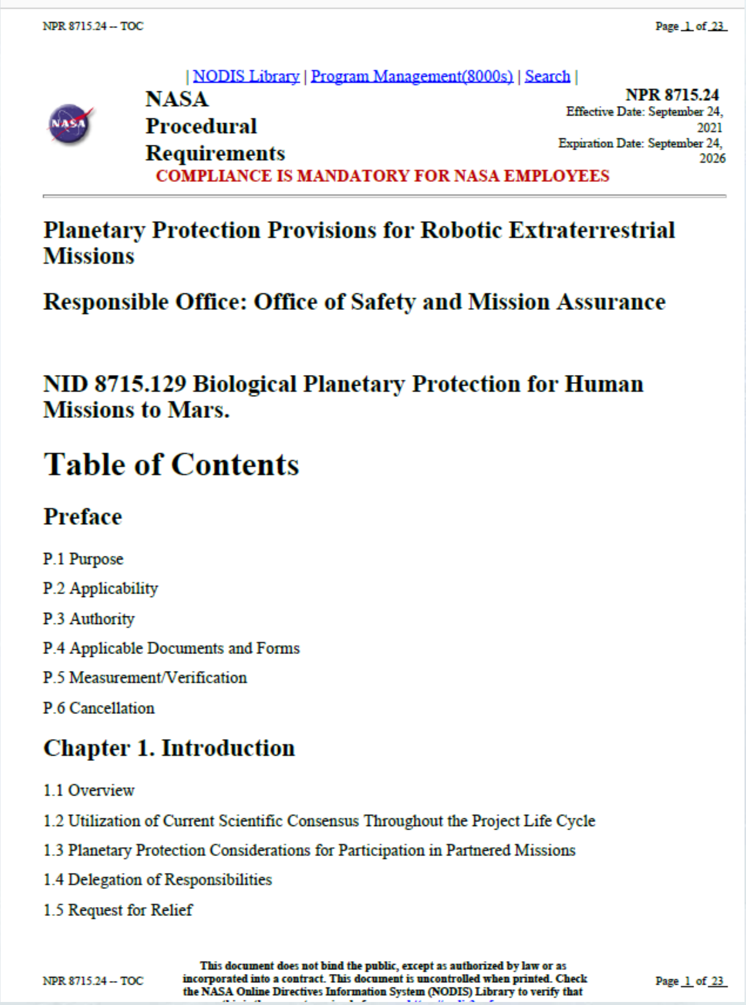
*Conclusion:*

It was agreed to explore the option to create a short-term TF in the next trilateral to discuss how to proceed on a mutual certification of joint missions for planetary protection (A/I 3). Meanwhile, the existing communication/collaboration channels should be maintained.

# Task Force Overview

- ESA, JAXA, and NASA Offices of Planetary Protections involved.
- Face to face meeting at the COSPAR General Meeting in Athens to kick off approach on establishing roles and responsibilities.
- Each agency completed evaluation of policy and mapping to generalized roles and responsibilities key areas.
- Several virtual meetings held to discuss and align mappings to key areas.
- Task force continuation and follow-on meetings recommended now that structure and roles and responsibilities have been established.

# Agency Roles and Responsibility Mapping



NPR 8715.24 -- TOC | Page 1 of 23

| NODIS Library | Program Management(8000s) | Search |

NASA Procedural Requirements

NPR 8715.24
Effective Date: September 24, 2021
Expiration Date: September 24, 2026

COMPLIANCE IS MANDATORY FOR NASA EMPLOYEES

**Planetary Protection Provisions for Robotic Extraterrestrial Missions**

**Responsible Office: Office of Safety and Mission Assurance**

**NID 8715.129 Biological Planetary Protection for Human Missions to Mars.**

## Table of Contents

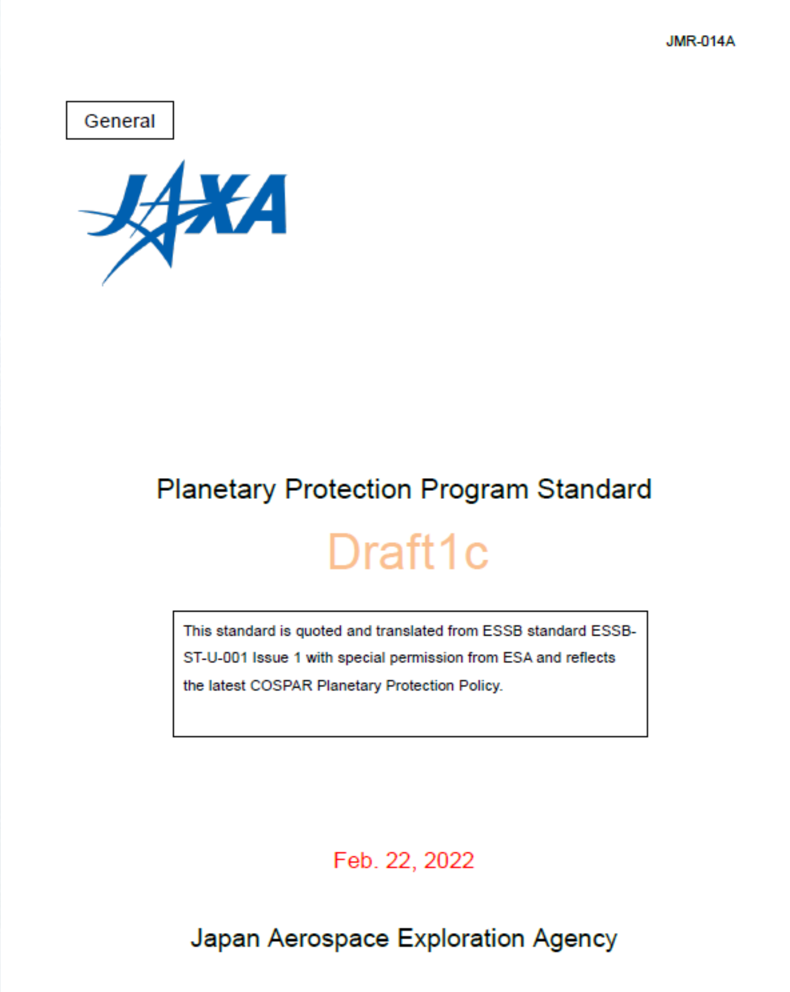
### Preface



### Chapter 1. Introduction



NPR 8715.24 -- TOC | This document does not bind the public, except as authorized by law or as incorporated into a contract. This document is uncontrolled when printed. Check the NASA Online Directives Information System (NODIS) Library to verify that | Page 1 of 23



JMR-014A

General

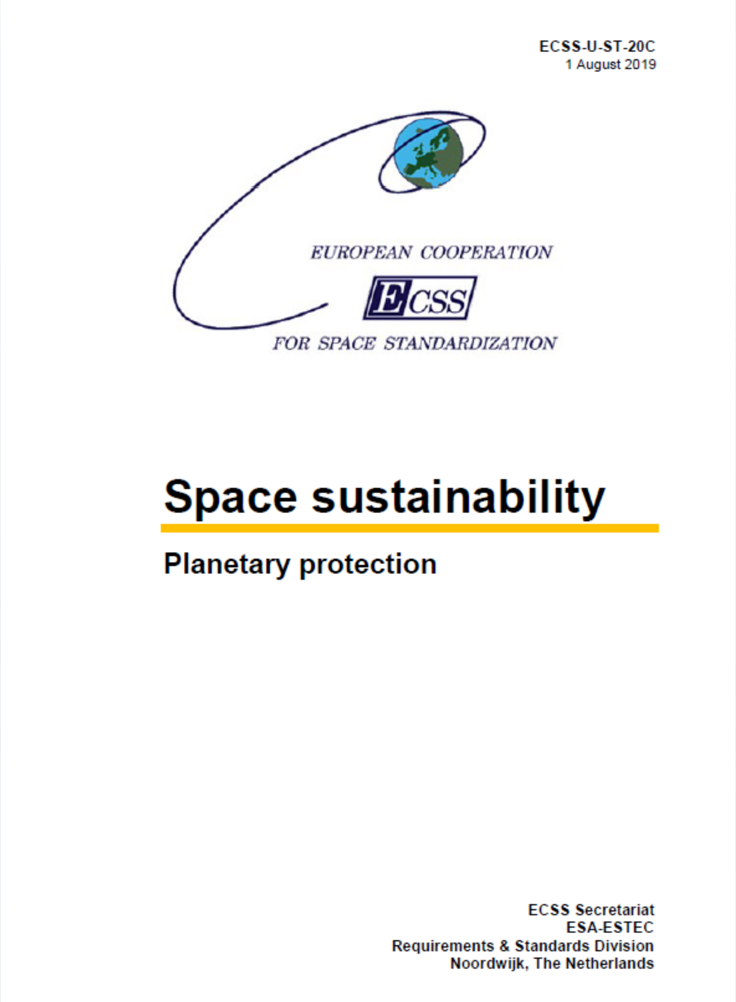
Planetary Protection Program Standard

Draft1c

This standard is quoted and translated from ESSB standard ESSB-ST-U-001 Issue 1 with special permission from ESA and reflects the latest COSPAR Planetary Protection Policy.

Feb. 22, 2022

Japan Aerospace Exploration Agency



ECSS-U-ST-20C
1 August 2019

EUROPEAN COOPERATION FOR SPACE STANDARDIZATION

**Space sustainability**

**Planetary protection**

ECSS Secretariat
ESA-ESTEC
Requirements & Standards Division
Noordwijk, The Netherlands

# Mapping Overview

## Roles and responsibilities mapped to 12 key areas

1. Safety office consults on biosafety/public health for control/containment of restricted return
2. Safety office advises MDAA on partnered missions
3. Reviews project's preliminary PP mission categorization request
4. After review, PPO provides implementing consultation throughout life cycle
5. PPO advises projects on Agency requirements and international agreements
6. PPO oversees project's identification of requirements and accepted standards
7. PPO verifies project's implementation plan and use of alternative approaches complies with Agency reqs
8. PPO oversees project's execution of PP plan by coordinating for compliance
9. Independent verification assays of environments, facilities, flight hardware
10. Monitoring activities and facilities; recommending best practices
11. Observe significant development/qualification tests to verify conformance to plans
12. PPO oversees project's identification of PP requirements for extended mission activities

Copy of Copy of Copy of Matrix of OSMA and PPO Responsibilities from

| | A | B | C | D |
|---|---|---|---|---|
| 1 | | NASA | ESA | JAXA |
| 2 | | OSMA Chief and PPO Responsibilities | Indipendent Safety Office (TEC-QI) and PPO responsibilities | S&MA Director and PPO Responsibilities |
| 3 | Safety office consults with other offices on biosafety/public health and for control/containment of restricted Earth return samples | Chief of the safety office consults with chief of the health and medical office on biosafety/public health and consults with chief of the engineering office on robust control and containment of restricted Earth samples. 2.3.1.b | Indipendent Safety Office TEC-QI conduct safety assessment consulting relevant experts (including publich health when necessary) to assure break-of-the chain on restricted Earth return sample missions. (4.1.2 & ECSS-U-ST-20_1430001) | At this moment, S&MA office does not have a definit procedure to consult with other offices on biosafety/public health for control/containment of restricted Earth return samples, since JAXA has no experience and ongoing plan of Category IV mission and sample return from protected solar system bodies |
| 4 | Safety office advises MDAA on partnered missions | Chief of the safety office advises the Mission Directorate AA and other organizations in the negotiation of a mission specific process for **partnered missions** with the appropriate interagency, commercial, and international partners. 2.3.1.f | Head of Indipendent Safety Office advice process on responsibilities and requirements to be applied and documented in relevant MoU (Memorandum of Understanding) to ensure compliance with ESA PP policy. | S&MA Director and PPO advises JAXA HQ and other govermental organizations in the negotiation of a mission specific progress for partnered/unpartnered missions with the appropriate interagency, commercial, and international partners (4.1.1). |
| 5 | Reviews project's preliminary PP mission categorization request | PPO reviews preliminary PP mission categorization. PPO reviews 1 and 2; OSMA Chief for 3 and above. 2.4.1.c | Specific projects propose (tailored) ECSS requirements and mission categorisations. PPO reviews and approve (with chief of Indipendent Safety Office and Head of TEC-Q informed/copied). 4.1.2 | PPO reviews preliminary PP mission categorization (1.2, 5.1). S&MA Director with Safety Review Board (SRB) reviews and approves PPPR at around SRR (5.6). |
| 6 | After review, PPO provides implementing consultation throughout life cycle | PPO reviews for concurrence the project's/proposer's PP mission categorization request, with ongoing consultation on implementation throughout the project life-cycle. 2.4.1.d | Mission Planetary Protection day-to-day activities are managed by a Project-appointed PP System lead. PPO is attending key reviews/milestone (i.e. PDR, CDR, MRR, ...), managing independent reviews, insitigate ad-hoc studies , reviewing / approving PP implementation | PPO with PPRB reviews for concurrence the project's/proposer's PP mission categorization request, with ongoing consultation on implementation throughout the project life-cycle (5.5, 5.6). |

# Mapping (1 of 3)

| | NASA | ESA | JAXA |
|---|---|---|---|
| | OSMA Chief and PPO Responsibilities | Indipendent Safety Office (TEC-QI) and PPO responsibilities | S&MA Director and PPO Responsibilities |
| Safety office consults with other offices on biosafety/public health and for control/containment of restricted Earth return samples | Chief of the safety office consults with chief of the health and medical office on biosafety/public health and consults with chief of the engineering office on robust control and containment of restricted Earth samples. 2.3.1.b | Indipendent Safety Office TEC-QI conduct safety assessment consulting relevant experts (including publich health when necessary) to assure break-of-the chain on restricted Earth return sample missions. (4.1.2 & ECSS-U-ST-20_1430001) | At this moment, S&MA office does not have a definit procedure to consult with other offices on biosafety/public health for control/containment of restricted Earth return samples, since JAXA has no experience and ongoing plan of Category IV mission and sample return from protected solar system bodies |
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# Mapping (2 of 3)

| | A | B | C | D |
|---|---|---|---|---|
| 7 | PPO advises projects on Agency requirements and international agreements, including tailoring of PP documents and implementation plan | PPO advises projects to comply with Agency PP reqs and international agreements, including tailoring of PPRD and PP Implementation Plan. 2.4.1.e | PPO reviews and approves PPRD, Plans and guide Project complying with PP requirements and international agreements. 4.1.2 | PPO advises projects on Agency requirements and international agreements, including tailoring of PP documents and implementation plan (4.1, 5.1e, 5.5). |
| 8 | PPO oversees project's identification of requirements and aceepted standards | PPO oversees project's identification of Agency PP requirements, such as accepted standards, consistent with PP mission categorization. 2.4.1.f | PPO supervises requirements from early phases (i.e. attendace to SRR), review and approves PP-related documentation (plans, tailores ECSS,...). 4.1.2 | PPO oversees project's identification of PP category, associated COSPAR PP requirements, aceepted standards, and agency PP requirements (4.1). |
| 9 | PPO verifies project's implementation plan and use of alternative approaches complies with Agency reqs | PPO verifies project's implementation plan and use of alternative approaches complies with applicable Agency PP req. 2.4.1.g | PPO verifies compliance is achieved against each PP requirements via VCB - verification control board process. 4.1.2 | PPO with PPRB verifies project's implementation plan and use of alternative approaches complies with COSPAR & Agency PP requirements (4.1.1, 5.6, 5.7). |
| 10 | PPO oversees project's execution of PP plan by coordinating with project manager to verify compliance, conduct independent verification/assurance activities by: | PPO oversees project's execution of PP implementation, by timely communication and coordination with project manager, to verify compliance with Agency PP reqs by defining and conducting ind verification and assurance activities, including: 2.4.1.g | PPO supervises implementation of PP requirements, anticipates activities/studies for compliance to requirements, manage indipendent reviews (i.e. biodiversity, safety board when needed) in coordination with Project functions. 4.1.2 | PPO with PPRB oversees project's implementation of PP plan by communication and coordination with project manager and planetary protection manager to verify compliance with COSPAR & Agency PP requirements by conducting independent verification/assurance activities (4.1, 5.5, 5.6). |
| 11 | Inpedendent verification assays of environments, facilities, flight hardware | Performing independent verification assays of environments, facilities, and flight hardware independent of assays conducted by the project. h(1) | Indipendent verification assays, including biodiversity or cleanliness knowledge are coordinated / managed by PPO. ECSS-U-ST-20_1430007 | PPO and its agents shall perform independent verification assays of environments, facilities, and flight hardware independent of assays conducted by the project (5.2.2). |

Sheet1

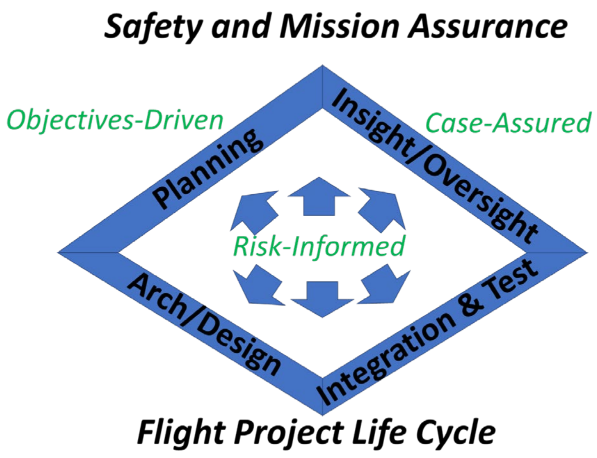
Ready

# Mapping (3 of 3)

| | A | B | C | D |
|---|---|---|---|---|
| 11 | Inpedendent verification assays of environments, facilities, flight hardware | Performing independent verification assays of environments, facilities, and flight hardware independent of assays conducted by the project. h(1) | Indipendent verification assays, including biodiversity or cleanliness knowledge are coordinated / managed by PPO. ECSS-U-ST-20_1430007 | PPO and its agents shall perform independent verification assays of environments, facilities, and flight hardware independent of assays conducted by the project (5.2.2). |
| 12 | Monitoring activities and facilities; recommending best practices | Monitoring activities and facilities using baselines and trends in project data and recommending appropriate project actions based on accepted best practices. h(2) | PPO attends FRR - Facility Readiness Reviews, key manufacturing and design reviews, organises audits/visits as required to supervises implementation of PP requirements and commissioning of facilities | Monitoring activities and facilities using baselines and trends in project data and recommending appropriate project actions based on accepted best practices (5.4). |
| 13 | Observe significant development/qualification tests to verify conformance to plans | Observing significant development and qualification tests and project operations to verify conformance with planned activities. h(3) | PPO responsibility is to ensure qualification tests and operations envelop Planetary protection needs (i.e. qualification to ensure compatibility of hardware/materials to sterilisation processes). Specific project requirements, as well as 4.1.2 | Observing significant development and qualification tests and project operations to verify conformance with planned activities (5.2.2). |
| 14 | PPO oversees project's idenitification of PP requirements for extended mission activities | PPO oversees project's idenitification of PP requirements for extended mission activities if project plants to extend mission or add to mission objectives. 2.4.1.i | PPO supervises changes in mission goals, extensions and ultimately requirements. 4.1.2, ECSS-U-ST-20_1430006 | PPO oversees project's idenitification of PP requirements for extended mission activities if project plants to extend mission or add to mission objectives (5.5, 5.6). |

# Task Force Next Steps

- Continue communication and collaboration between ESA, JAXA, and NASA PP offices
  - *Mapping exercise sparked helpful conversations on how each agency oversees and implements PP*
- Follow on conversations entail
  - *Need to have specific conversations on independent verification and assurance activities.*
  - *Need to have detailed conversations on spacecraft certification process.*




# Trilateral Summit

Risk Classification Panel Session

NASA OSMA

December 6, 2022

Anthony (Tony) DiVenti

Anthony.j.diventi@nasa.gov

# Risk Informed Planning Overview

Risk Appetite → **Risk Classification**

*Defined by Mission Directorates*

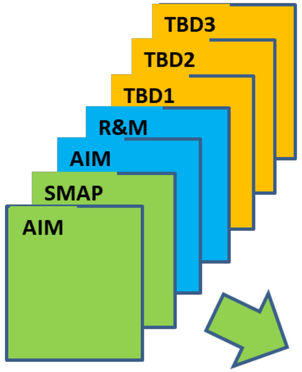
**SMA POLICY**
Objectives Driven Reqts, Accepted STDs


## Machine-Assisted Products

### *Assurance Implementation Matrix (AIM)*

| Objectives | Applicable Standards | Risk Classification (A-D) Expectations | Project Alternative Approaches/ Standards |
|---|---|---|---|
| SMA Discipline 1<br>SMA Discipline 2<br>⋮<br>SMA Discipline N | NASA<br>- R&M STD 8729.1A<br>- other<br><br>Industry<br>- AS9100<br>- other | Class A – Lowest Risk Tolerance<br>⋮<br>Class D – Highest Risk Tolerance | |

### *SMA Plan (SMAP)/ Discipline Plans, Mission Assurance Reqts (MAR), Statement of Work (SOW)*




*Tailored, Traceable Products*

**User Editable formats (pdf, word, other)**

*Establishes Project Unique Execution Approach and Activities*

# Where we are today

***Evolutions***

Policy **Roles** and **Responsibilities** Clarification (NPD 8700, NPRs 8705.2, 8705.4)

Transition from **"Prescriptive"** to **"Objectives-Driven"** Policy and Accepted STDs

**Modeling Frameworks**

- GSN
- Assurance Case
- UML/SysML/RAAML

**Machine-Assisted Products (e.g., APPG)**

- AIM / SMAP
- SOW/Contract Clauses

***Emerging Benefits***

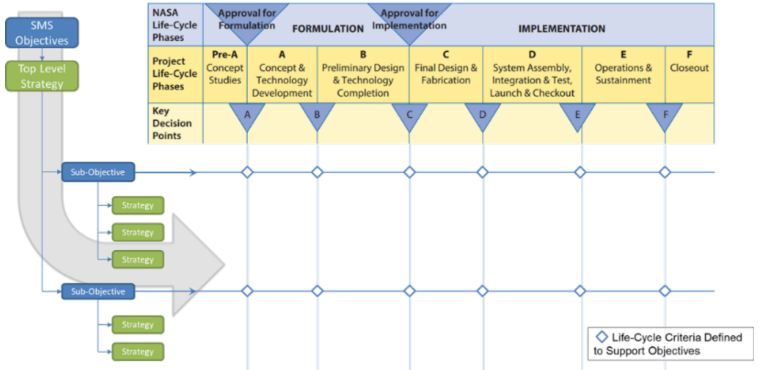
- "Risk Appetite" – Mission Directorate
- "Project" – Execution
- "Assurance" – SMA TA
- *Clearer delineation between Mission Directorate (AIM) and Project (SMAP) development*

- Flexibility
- Enables innovation and novel approaches

- *Complimentary integration between Planning (GSN) and Execution (Assurance Case)*
- Interoperability with MBSE and Digital Engineering environment
- Model-Based Acquisition

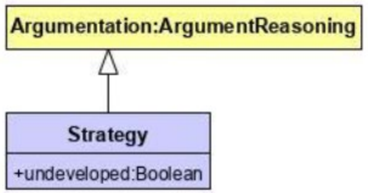
- Eliminates Human "dog-work"
- *Rapid Plan generation*
- Correct by Construction
- Authoritative Sources of Truth
- "Strengthens" Agreements

*AIM*




*SMAP*

*Goal Structuring Notation (GSN) underlying Assurance Case Development and Integration*





# Challenges

Cultural

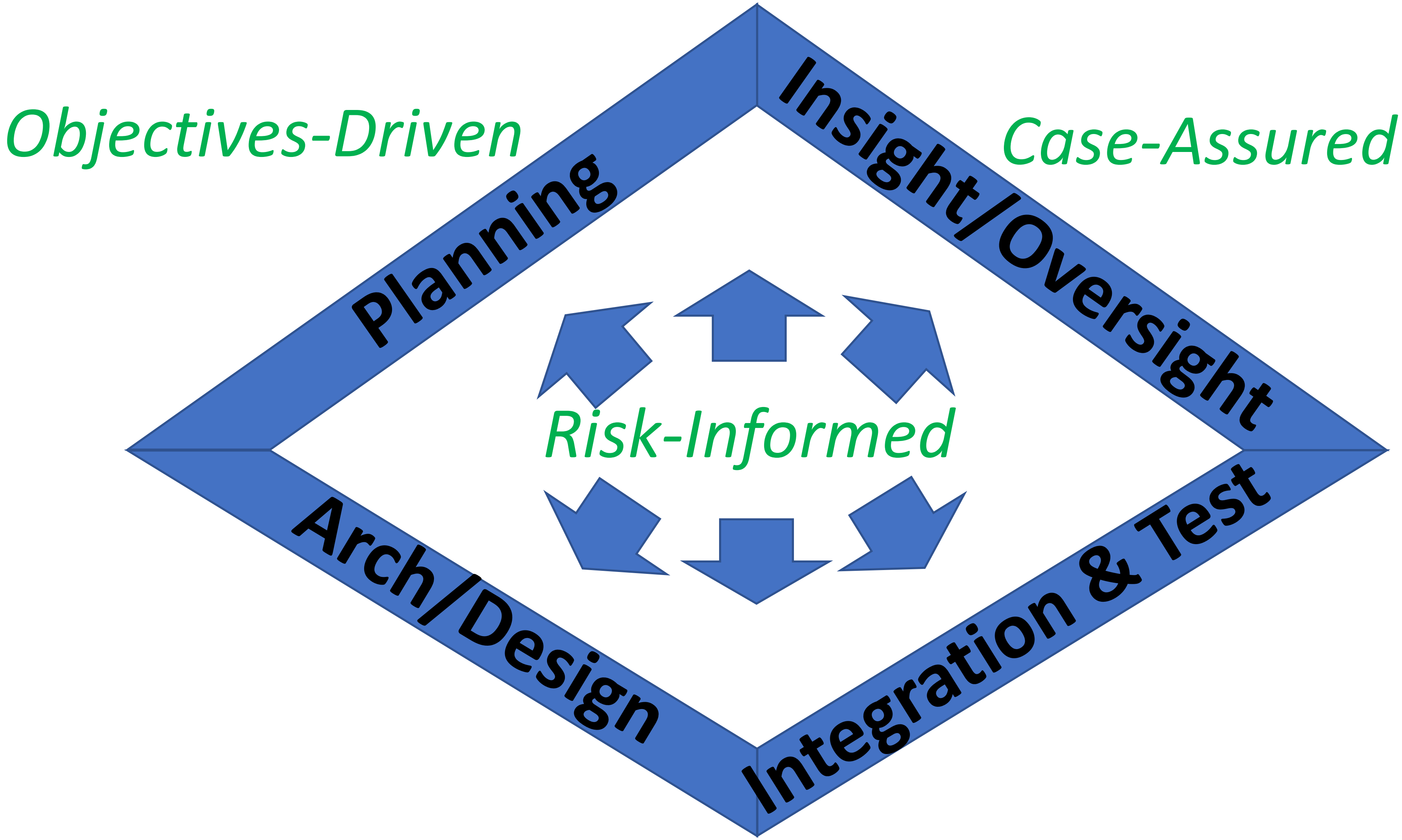
- “Formulating Objectives” vs “Prescriptive Expectations” (e.g., COTs Type Parts)
- Architectural (.e.g, two “class B” elements to establish a “Class A” mission) vs “Holistic” Classification approach
- Use and Trust of Enterprise “Model-Based” Planning Resources
- Understanding of Objectives Driven Planning (e.g., Goal Structure Notation (GSN)) and Assurance Case development
- SMA Community, Mission, and Programmatic Adoption
- Practitioners comfort with the old ways, old tools, old processes

Technical

- Modeling / Semantic-Based Interoperability STDs
- Standard Data Sets (e.g., MetaModels)
- Standard Interfaces (e.g., API’s)
- Well-defined Domain Representations (e.g. Semantics, Ontology)

# BACK-UP

# Safety and Mission Assurance




# Flight Project Life Cycle