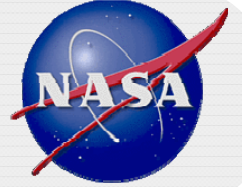


NASA Orbital Debris Program Office Overview

J.-C. Liou, PhD
NASA Orbital Debris Program Office

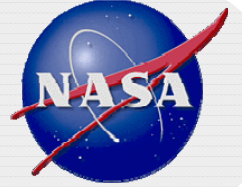
The ReDSHIFT Final Conference
Florence, Italy, 13-14 March 2019



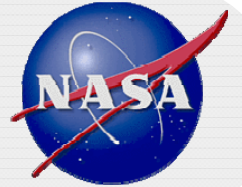
Outline

- **Roles and Responsibilities of the NASA Orbital Debris Program Office (ODPO)**
- **Key ODPO Activities**
 - Measurements
 - Modeling
 - Mission Support
 - Policy Support

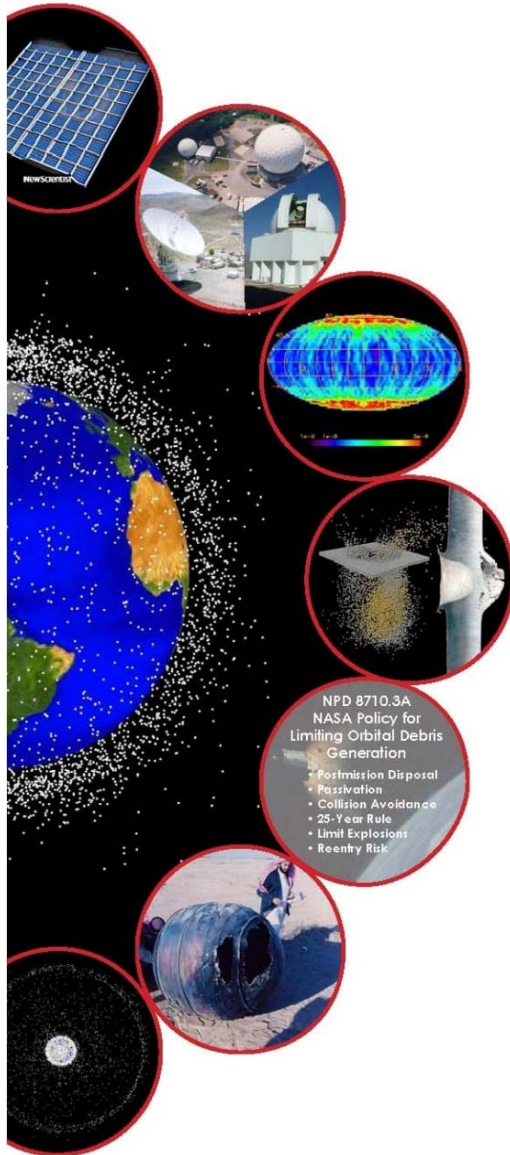
- Orbital debris is any human-made object in orbit around the Earth that no longer serves any useful purpose
- International community prefers to use the term “space debris”



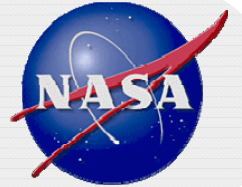
ODPO's Roles and Responsibilities



NASA Orbital Debris Program Office

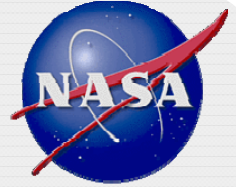


- **The ODPO is the only organization in the U.S. Government (USG) conducting a full range of research on orbital debris (OD)**
 - This unique NASA capability was established at JSC in 1979 (D. Kessler, J. Loftus, B. Cour-Palais, *etc.*)
 - ODPO's roles and responsibilities are defined in NASA Procedural Requirements NPR 8715.6B
- **ODPO provides technical and policy support to NASA HQ, OSTP, NSpC, and other USG and commercial organizations**
- **ODPO represents the USG in international fora (IADC, United Nations, *etc.*)**
- **ODPO is recognized as a pioneer and leader in environment definition and modeling, and in mitigation policy development**

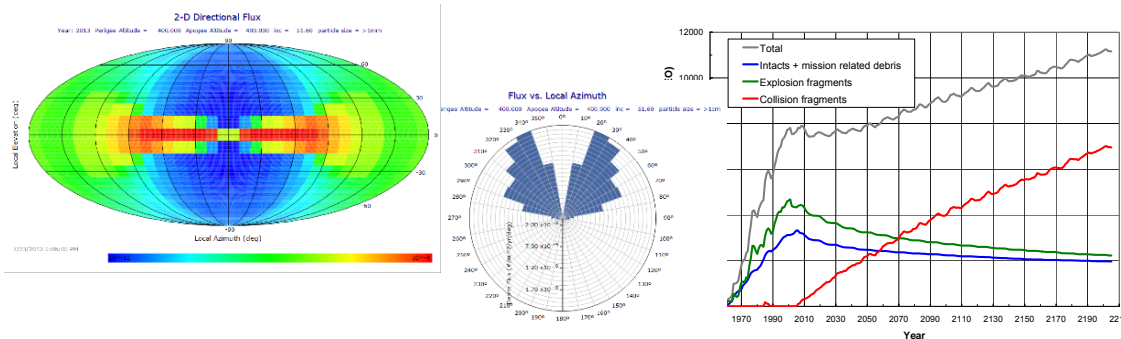


Roles and Responsibilities of the ODPO

- a. *Develops, maintains, and updates the orbital debris environment models and associated uncertainties to support the Chief, SMA, and programs and projects with the mitigation of orbital debris risk, and compliance with this NPR.*
- b. *Conducts measurements of the orbital debris environment and conducts other research as needed to support the development of the orbital debris environment models.*
- c. *Assists NASA mission project managers in technical orbital debris assessments by providing information and completing evaluations of the Orbital Debris Assessment Reports (ODARs) and End of Mission Plans (EOMPs) on behalf of the SMA Technical Authority.*
- d. *Assists the Department of Defense and other U.S. Government departments and organizations on matters related to the characterization of the orbital debris environment and the application of orbital debris mitigation measures and policies.*
- e. *Contributes to the determination, adoption, and use of international orbital debris mitigation guidelines through international forums such as the United Nations Committee on the Peaceful Uses of Outer Space, the IADC, and ISO.*



ODPO's End-to-End Orbital Debris Activities



Mission Risk Assessments

OD risk assessment tools for NASA missions (ORDEM, ORSAT, DAS, etc.)

Measurements

Radar
Optical
In-situ
Laboratory

Modeling

Breakup
Engineering
Evolutionary
Reentry

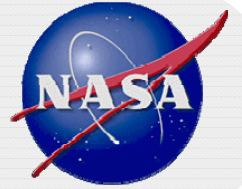
Environment Management

Mission Requirements
(ODARs, EOMPs)
Mitigation
Remediation
Policy

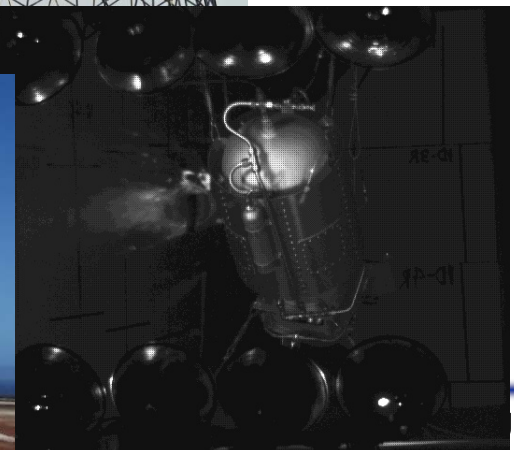
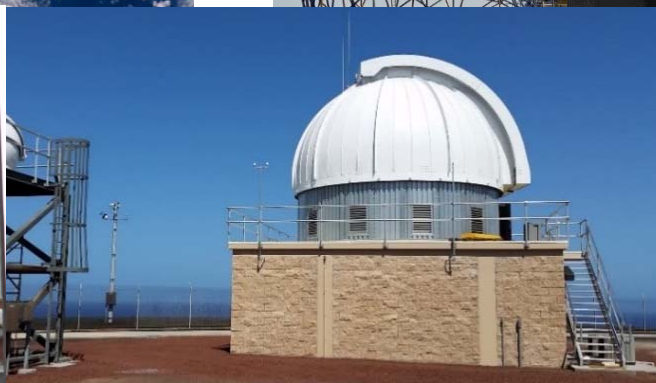
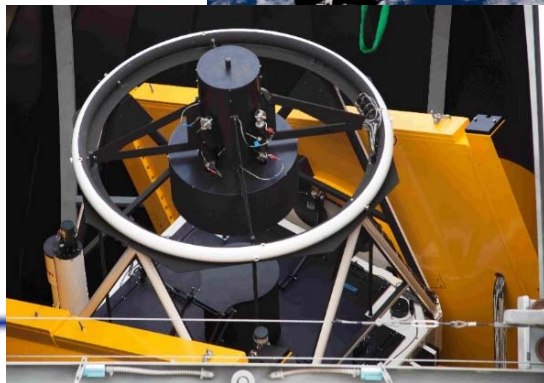
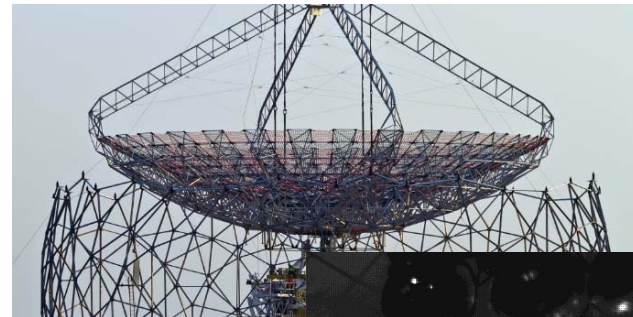
Coordination

U.S. Government
IADC, ISO
United Nations

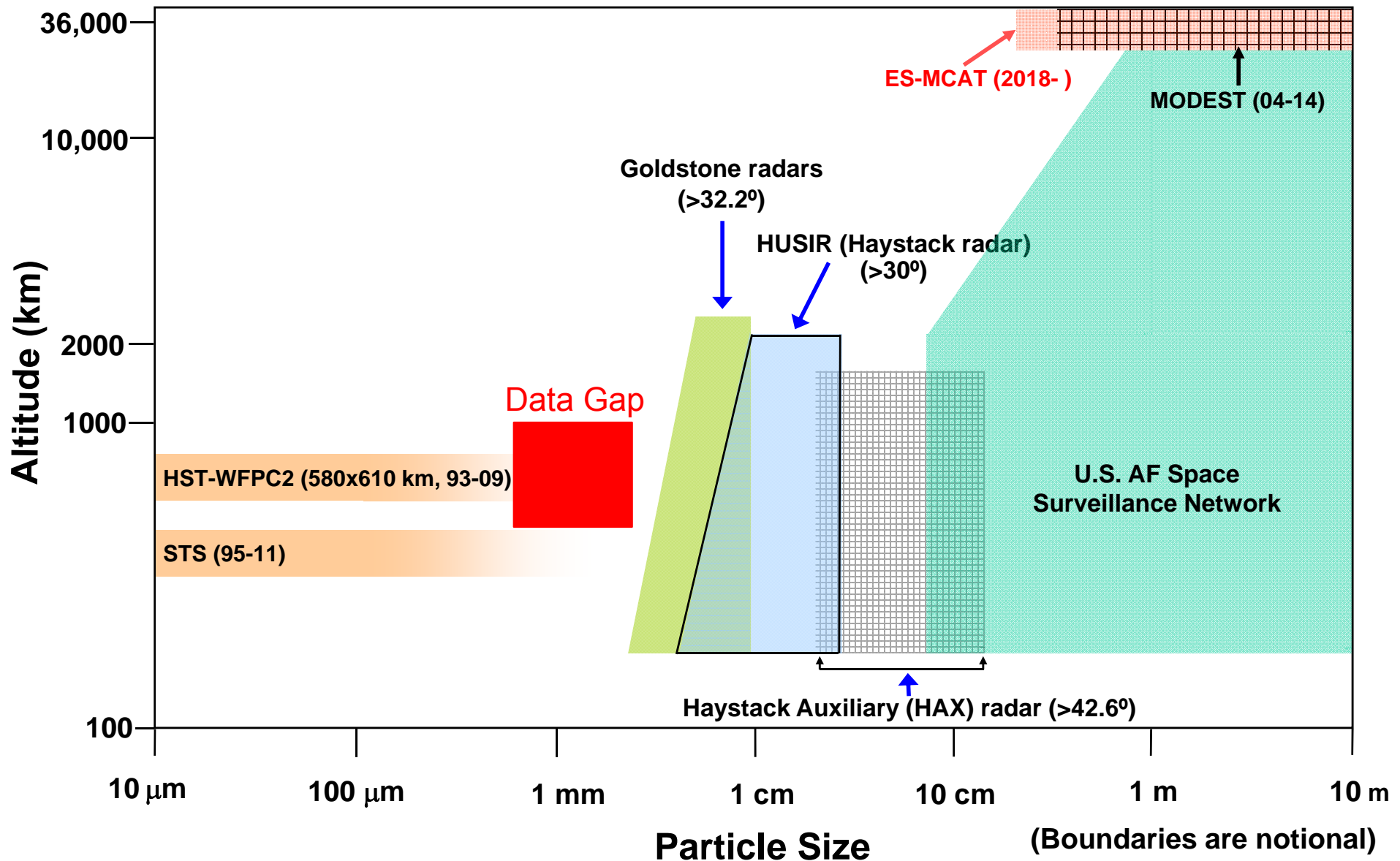


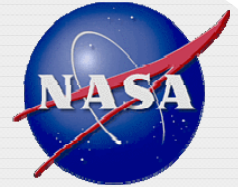


ODPO's Measurement Activities



NASA Measurement Coverage on Small Debris





HUSIR (Haystack), HAX, and Goldstone

- Data processing
- Object detection/correlation
- Debris size estimation
- Orbit assessment
- Environment definition

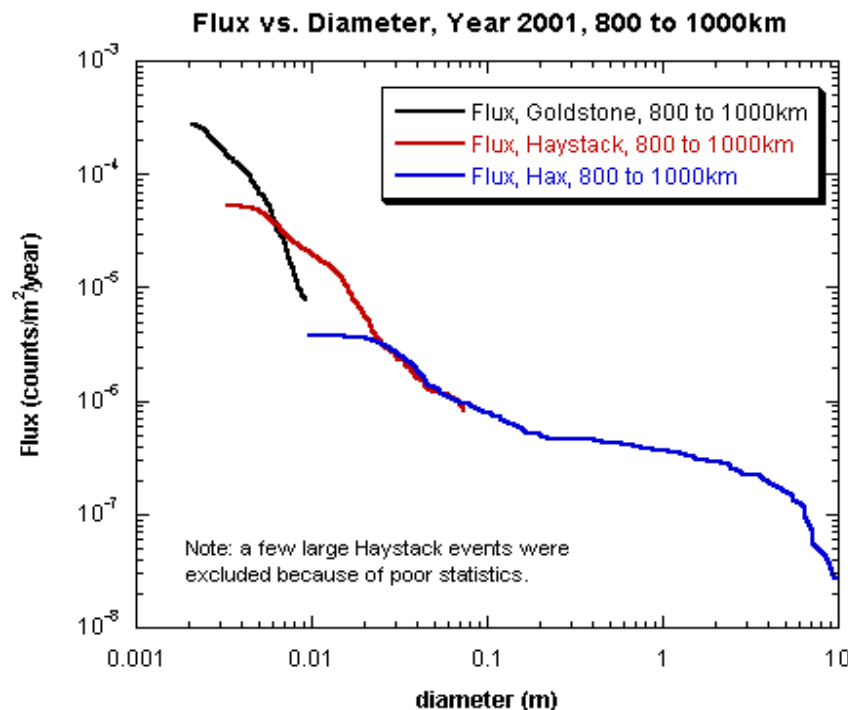
Goldstone
(NASA/JPL)

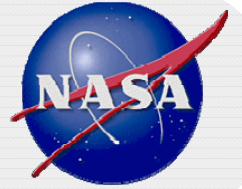


HUSIR and HAX (MIT/LL)



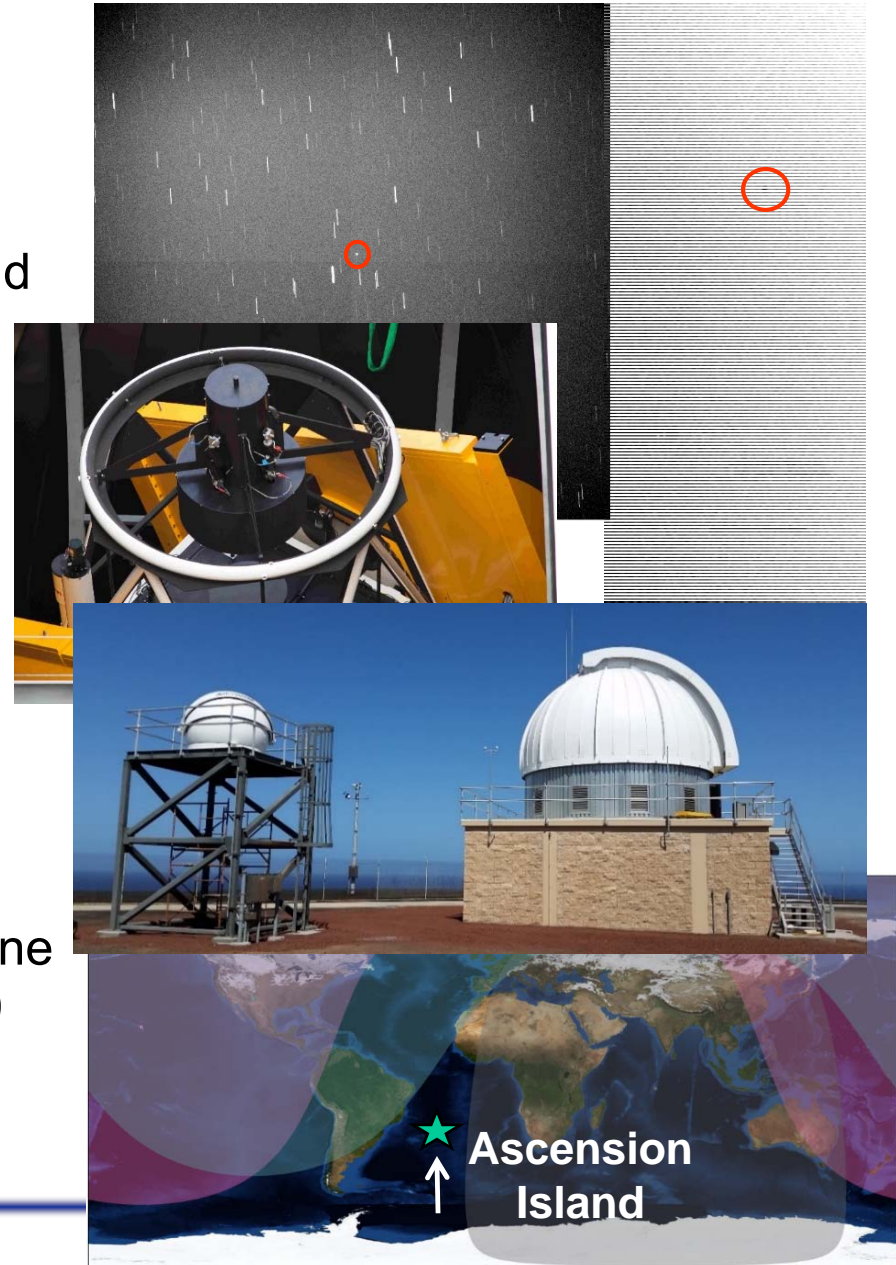
R: Haystack Ultra-wideband Satellite Imaging Radar (HUSIR)
L: Haystack Auxiliary Radar (HAX)

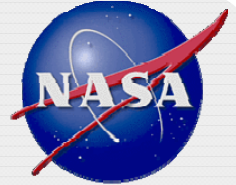




Eugene Stansbery Meter Class Autonomous Telescope (ES-MCAT)

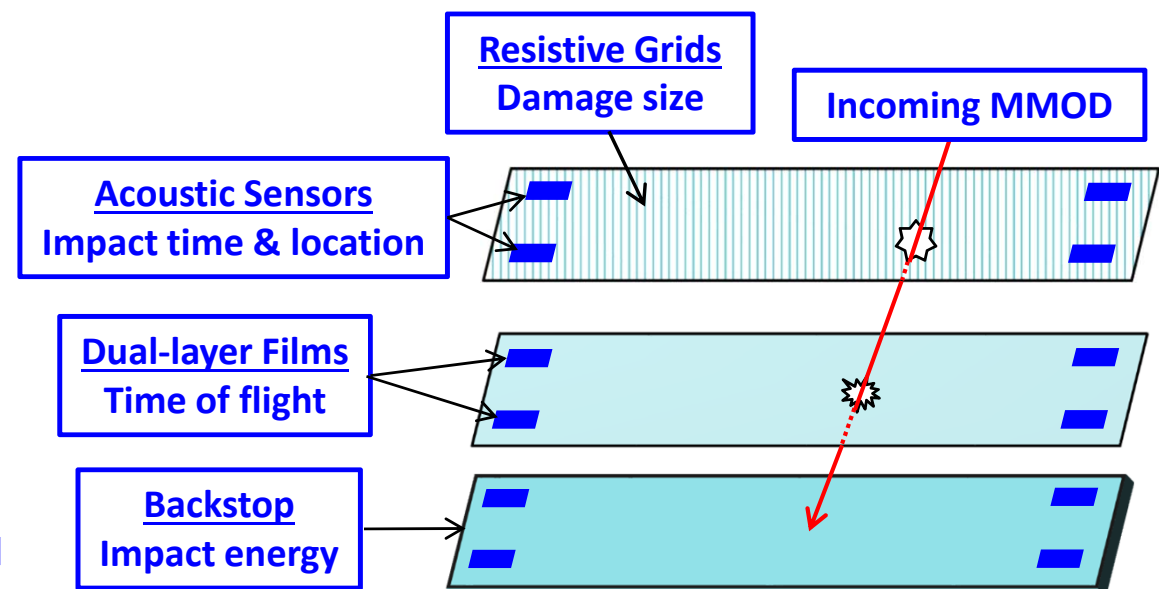
- **A NASA, Air Force, and Air Force Research Laboratory joint project since 2000**
 - Observatory is located on Ascension Island ($7^{\circ} 58' \text{ S}$, $14^{\circ} 24' \text{ W}$)
- **Two instruments at the facility**
 - ES-MCAT: a double horse-shoe 1.3-m telescope with a field-of-view of $41' \times 41'$
 - Benbrook: a 0.4-m telescope with a similar field-of-view
- **Goals of the project**
 - Reach full autonomous operations for routine surveys on small GEO debris by May 2019
 - Collect data on small GEO debris for ORDEM 4.0





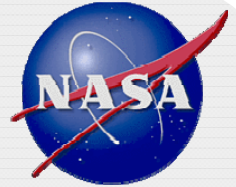
DRAGONS

- ODPO has led the development of innovative *in situ* measurement technologies **since 2002***
- **DRAGONS (Debris Resistive/Acoustic Grid Orbital NASA-Navy Sensor)**
 - Is designed to detect/measure MMOD in the ~millimeter size regime
 - Combines several impact detection technologies to maximize information that can be extracted from the detected impact events
 - impact time
 - impact location
 - particle size
 - impact speed
 - impact direction
 - impact energy / particle density



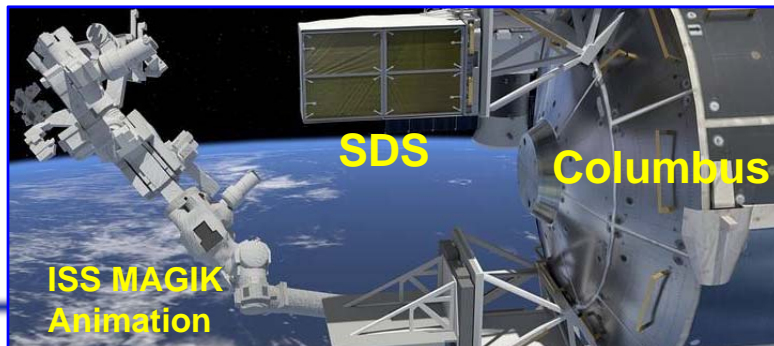
*2003-2005: SMD PIDD award

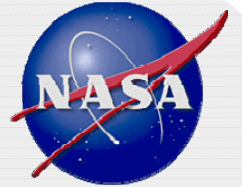
*2009-2012: SMD/ESMD LASER award



Space Debris Sensor (SDS)

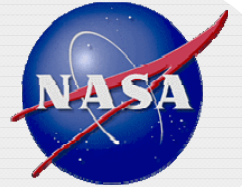
- **The ISS Program approved the ODPO's proposal for a DRAGONS technology demonstration mission in 2014**
 - Objectives: (1) mature DRAGONS technologies and (2) characterize the sub-millimeter debris environment at the ISS altitude.
 - To avoid confusion with the SpaceX Dragon, the mission was renamed Space Debris Sensor (SDS).
 - SDS was installed on the ISS and began data collection on Jan. 1, 2018, but experienced two serious anomalies and ceased to function on Jan. 26, 2018. Last attempt to recover SDS failed on Jun. 26, 2018.
 - The ODPO continues to seek opportunities to deploy DRAGONS to collect direct measurement data on the millimeter-sized debris at high low Earth orbit (LEO) altitudes





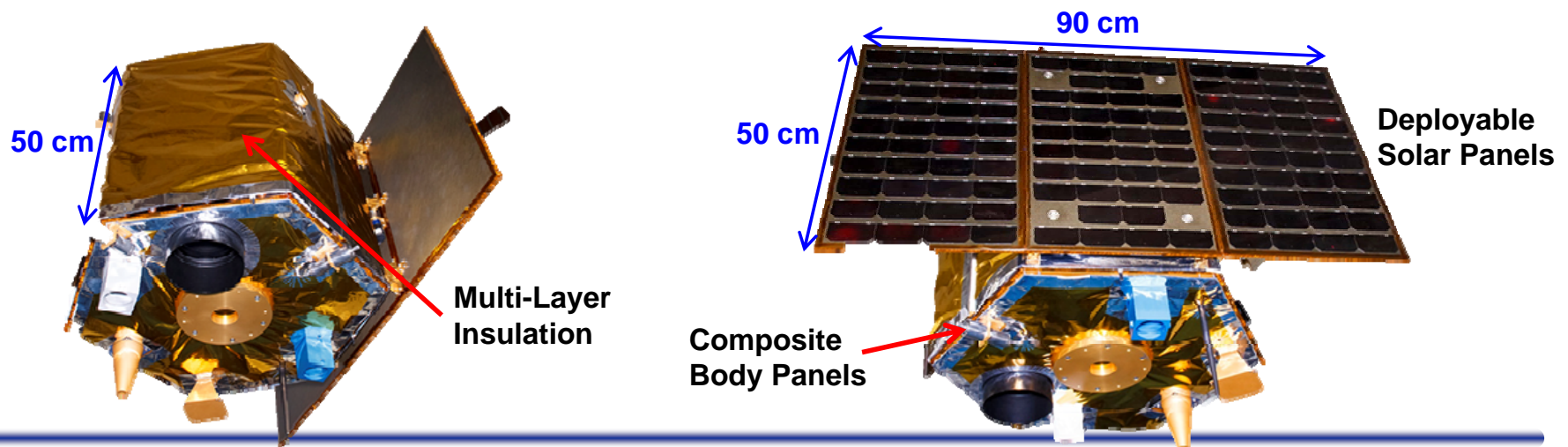
Highest Risk to Space Missions in LEO

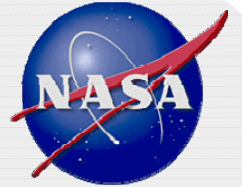
- **Millimeter-sized orbital debris represents the highest penetration risk to most operational (robotic) spacecraft in LEO**
 - As concluded by a recent NASA Engineering and Safety Center panel study (NASA/TM 2015-218780)
- **Currently, more than 400 missions operate between 600 and 1000 km altitudes**
- **There is a lack of data on such small debris above 600 km altitudes**
 - 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



DebrisSat (1/2)

- **The DebrisSat project is a collaboration among NASA, the Air Force, Aerospace, and the University of Florida**
 - Design and fabricate a 56-kg class spacecraft (“DebrisSat”) representative of modern spacecraft in LEO
 - Conduct a hypervelocity impact test to catastrophically break it up
 - Collect fragments as small as 2 millimeters in size
 - Measure and characterize the physical properties of the fragments
 - Use the data to improve satellite breakup models, ORDEM, and other space situational awareness applications

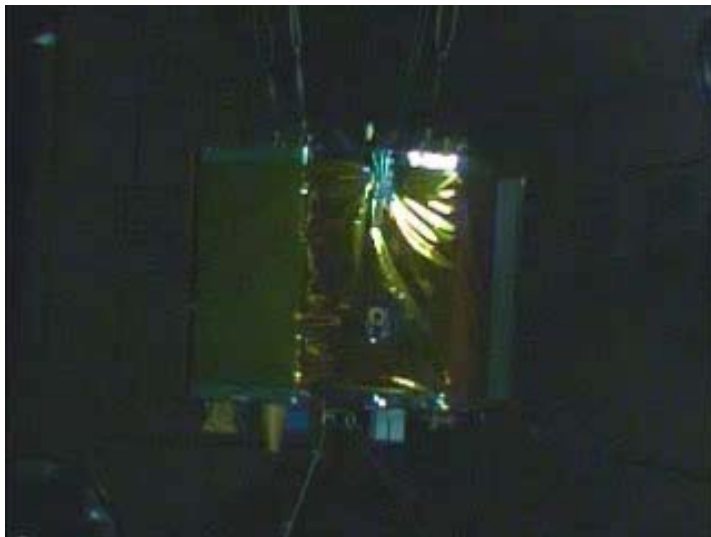




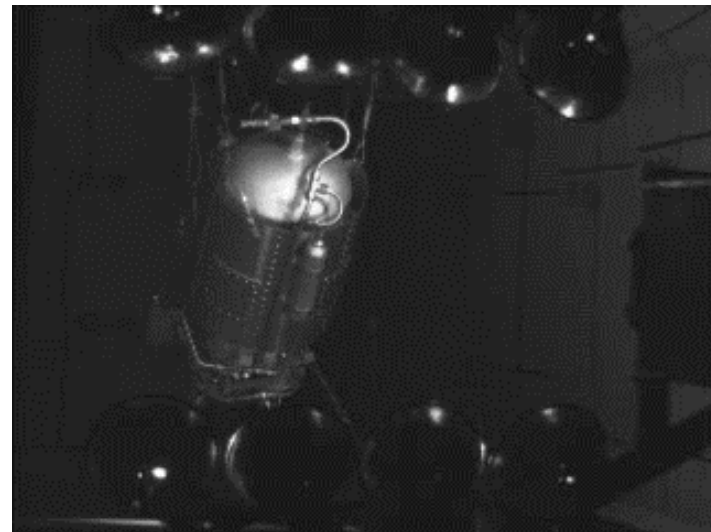
DebrisSat (2/2)

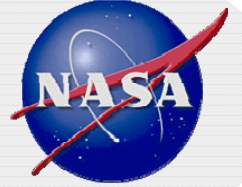
- The DebrisSat test and a pre-test shot on a small launch vehicle markup (“DebrisLV”) were conducted in 2014
- Post-test fragment processing and characterization efforts are underway
 - ~172,000 fragments (≥ 2 mm) extracted from foam panels so far
 - More than 26,000 fragments fully characterized

A ~9 cm, 570-g projectile
impacted DebrisSat at 6.8 km/s



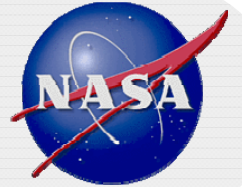
A ~9 cm, 598-g projectile
impacted DebrisLV at 6.9 km/s





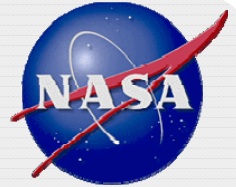
ODPO's Modeling Activities





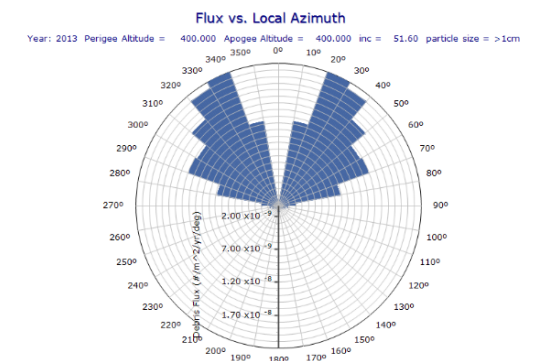
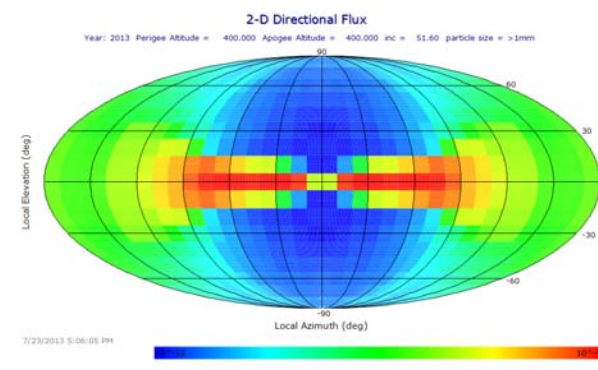
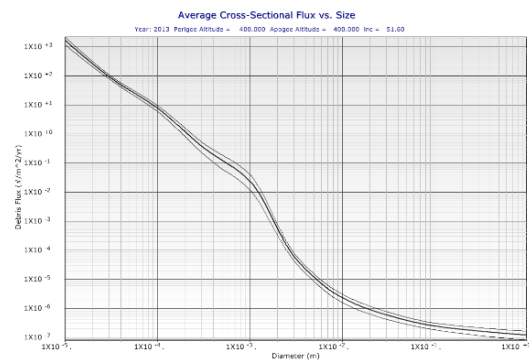
Major ODPO Modeling Tools

- **ORDEM: an orbital debris engineering model**
 - Is a mathematical model capable of predicting OD impact risks for space assets (ISS, A-Train, *etc.*)
- **LEGEND: an orbital debris evolutionary model**
 - Is a physical model capable of predicting the future debris environment based on user-specified scenarios (mitigation and remediation measures, CubeSat and mega-constellation deployment, *etc.*)
- **ORSAT: an object reentry survivability assessment model**
 - Provides high fidelity object reentry risk analyses
- **DAS: a software tool for ODAR and EOMP preparation**
 - Is designed to assist NASA missions in performing orbital debris assessments with respect to NS 8719.14 for compliance

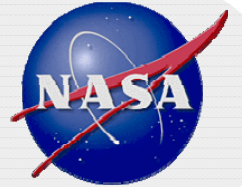


ORDEM – A Mission Support Tool

- **Satellite designers and operators use ORDEM to estimate the OD impact risks on their vehicles in Earth orbit**
 - ORDEM provides information on debris impact rate as a function of size, material density, impact speed, and direction along mission orbit

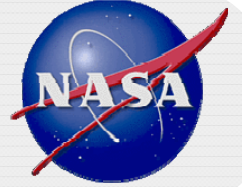


- **ORDEM 3.0 (2013) represents NASA's best estimate of the current and near future orbital debris environment**
- **Since the orbital debris environment is dynamic, ORDEM must be updated periodically to better reflect reality**



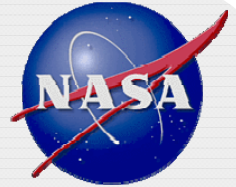
ORDEM 3.0

- **ORDEM 3.0 (2013) is the end product of all of NASA and DoD's measurement data**
 - JSpOC catalog, HUSIR/HAX/Goldstone radars, MODEST telescope, post-flight inspection of the Shuttle window and radiator panels
- **ORDEM 3.0 covers the debris populations, from 10- μ m to 10-m in size, from LEO to GEO**
 - A material density distribution is provided for different debris components (fragmentation, NaK, and degradation debris)
 - Uncertainties in the debris flux predictions are included as well
- **Development of ORDEM 3.1 is underway**
 - Objective: update debris population files with recent measurement data (optical, radar, HST WFPC-2)
 - Release schedule: Dec 2019



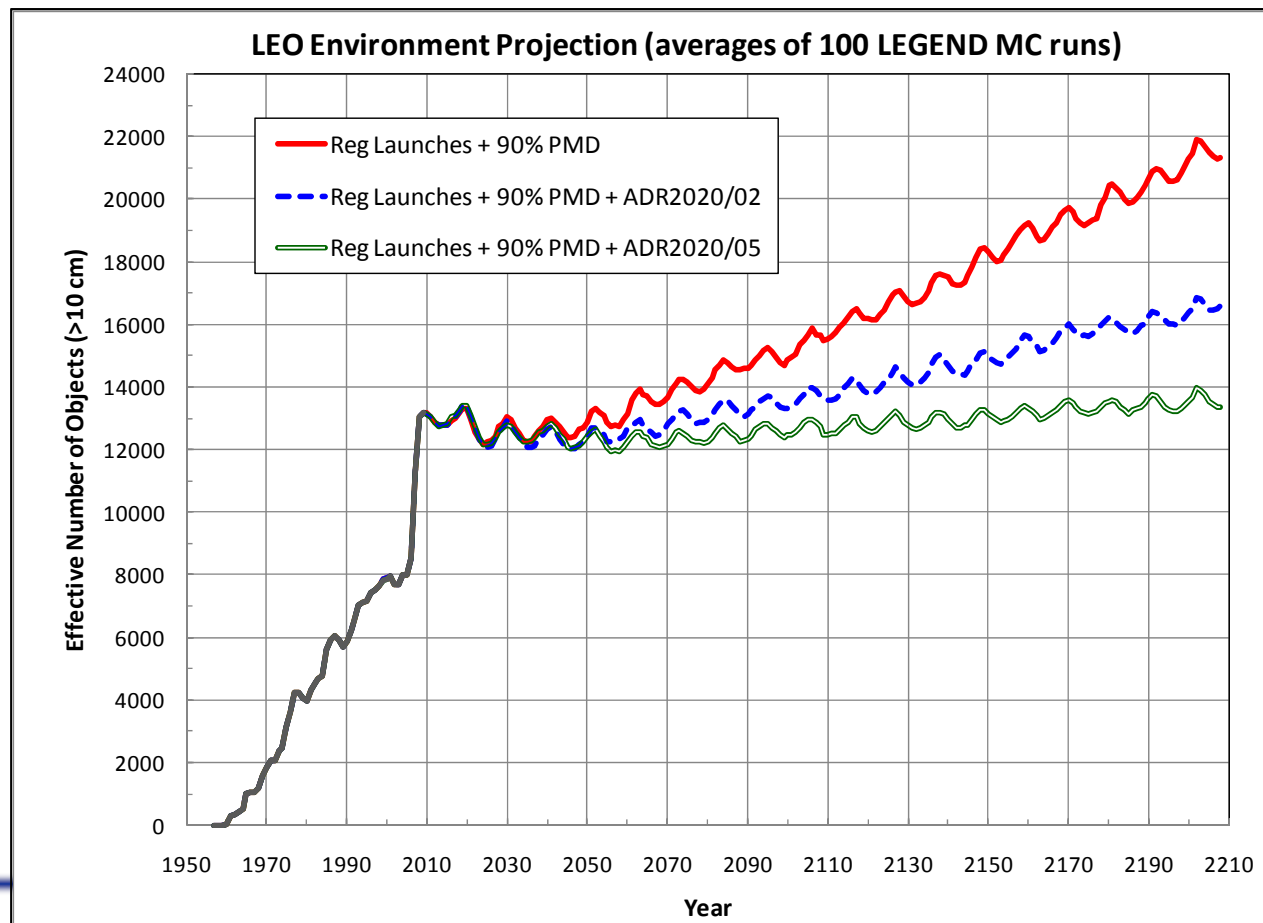
Future ORDEM Update Plan

- **ORDEM 3.x**
 - As needed (e.g., major breakups)
- **ORDEM 4.0**
 - Update debris populations with new data (catalog, HUSIR/HAX, Goldstone, ES-MCAT, returned surfaces)
 - Incorporate debris shape distribution (DebriSat)
 - Improve debris density distribution (DebriSat)
 - Consider other options (a new model architecture, change to a mass-based model, *etc.*)



LEGEND – An Environment Management Tool

- **LEGEND simulates the future debris environment based on user-defined scenarios**
 - Supports development of the orbital debris mitigation/remediation policy (25-year rule, active debris removal, large constellations, *etc.*)





ORSAT – Object Reentry Survivability Model

- **Reentry risk assessments are required for all NASA missions**
 - For uncontrolled reentry, the risk of human casualty from surviving debris shall not exceed 1 in 10,000 (NASA Standard 8719.14A)
- **Object Reentry Survival Analysis Tool (ORSAT) is a high fidelity reentry model developed/maintained by the ODPO to support NASA missions**



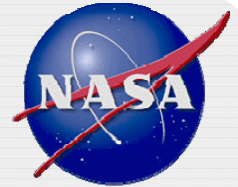
Delta II propellant tank
(Georgetown, TX, 1997)



Titanium casting of STAR-48B SRM
(Saudi Arabia, 2001)



Titanium casting of STAR-48B SRM
(Argentina, 2004)



DAS

- The Debris Assessment Software (DAS), developed and maintained by the ODPO, helps project offices assess their mission compliance with the NS 8719.14A orbital debris requirements

Mission Definitions
Mission Name: Purple Shade Inc. Satellite Launch 1998 Launch Year: 1998.9

Mission Components

- Payloads
 - Indigo 67
 - Indigo 68
 - Marcelas 3
- Rocket Bodies
 - Lifter R/B 2nd Stage
- Mission-Related Debris
 - Lens Caps
 - Straps
 - Staging Bolts
 - LEO-GEO Debris

Define Payload Properties

Row	Payload	Mission	Operational	Operational
	Name	Duration (yrs)	Perigee Alt (km)	Apogee Alt (km)
1	Indigo 67	2	774	781
2	Indigo 68	1	35785	35785

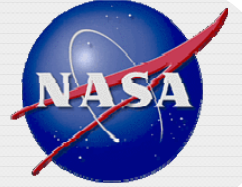
Output

Row	Debris	Compliance	Lifetime (yrs)	Object Time (obj-yrs)
1	Lens Cap	Non-Compliant	40.1	40.0
2	Stage Bolts	Compliant	1.9	5.7
3	Straps	Compliant	0.1	0.2

TOTAL OBJECT TIME:
45.9 obj yrs

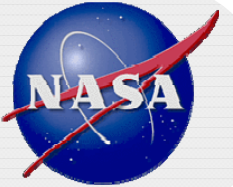
Messages
Requirement 4.3-1
Non-Compliant Row: 1

NOTE: For Non-Compliant Status - Refer to Help or Analysis section within Science and Engineering Utilities



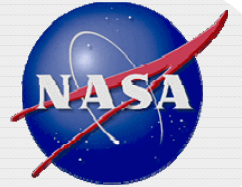
ODPO's Mission Support





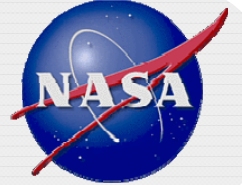
Orbital Debris Assessment Reports (ODARs)

- **NASA Requirement for preparation of ODARs is specified in NPR 8715.6B, Section 3.2**
 - Content and format for ODARs are provided in NS 8719.14A
- **Project Manager shall, in coordination with the Mission Directorate, distribute and obtain concurrence on the mission ODARs**
 - Launch vehicle portion of the ODAR is provided by the Launch Services Program (LSP)
- **Submission Schedule**
 - Initial ODAR: Mission Concept Review (MCR)
 - First ODAR: Preliminary Design Review (PDR)
 - Updated ODAR: Critical Design Review (CDR)
 - Final/Pre-launch ODAR: Safety and Mission Success Review (SMSR)



End-of-Mission Plans (EOMPs)

- **Requirement for preparation of EOMPs is specified in NPR 8715.6B, Section 3.2**
 - Content and format for EOMPs are provided in NS 8719.14A
- **Project Manager shall, in coordination with the Mission Directorate, distribute and obtain concurrence on the mission EOMPs**
- **Submission Schedule**
 - Initial EOMP: Final/Pre-launch ODAR
 - Updated EOMPs are required at least once every two years and
 - when a spacecraft condition or event occurs that significantly reduces the likelihood of successful postmission passivation or disposal maneuvers
 - in conjunction with any decision to extend the mission or change the procedures for mission termination or decommissioning of space systems
 - Final EOMP is to be submitted with the end-of-mission notification

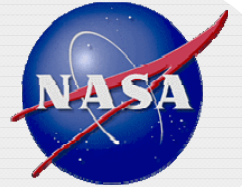


ODAR, EOMP, DAS, and ORSAT Support

- **The ODPO provides technical reviews of the ODARs and the EOMPs on behalf of the HQ/OSMA**
- **The ODPO provides DAS and ORSAT support to NASA missions**
- **The ODPO occasionally provides ORSAT assessments for commercial organizations via reimbursable Space Act Agreements**



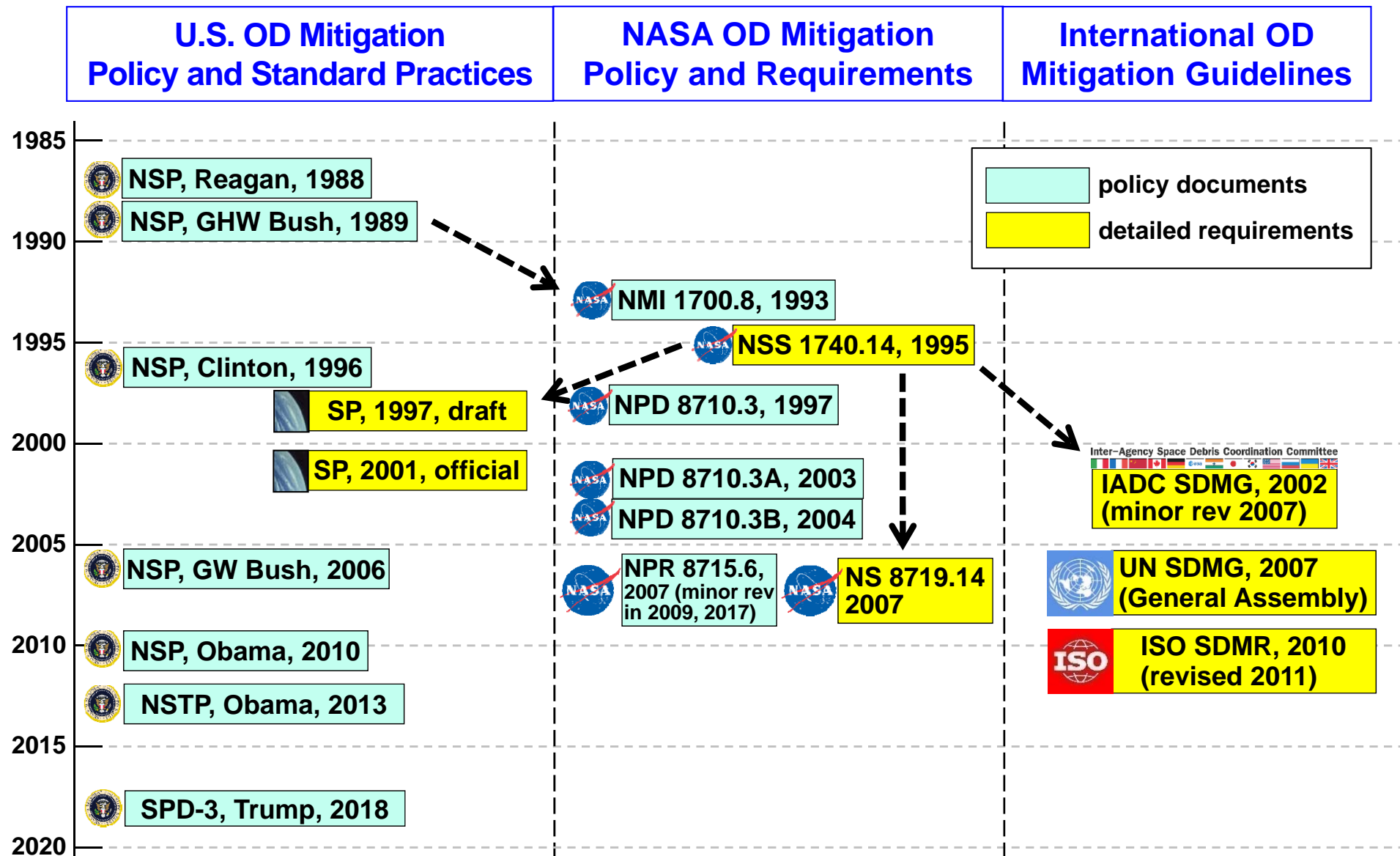
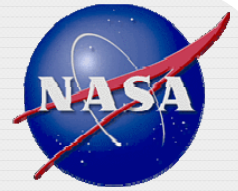
ODPO's Policy Support

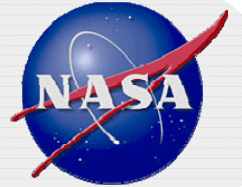


Orbital Debris Environment Management

- **“Prevention is better than cure”**
 - (*Prov.*) It is better to try to keep a bad thing from happening than it is to fix the bad thing once it has happened.
- **“An ounce of prevention is worth a pound of cure”**
 - (*Prov.*) It is better/cheaper to stop something bad from happening than it is to deal with it after it has happened.
- **Orbital Debris Mitigation = Prevention**
- **Orbital Debris Remediation = Cure**

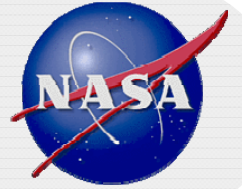
History of NASA, USG, and International OD Mitigation Policies and Requirements





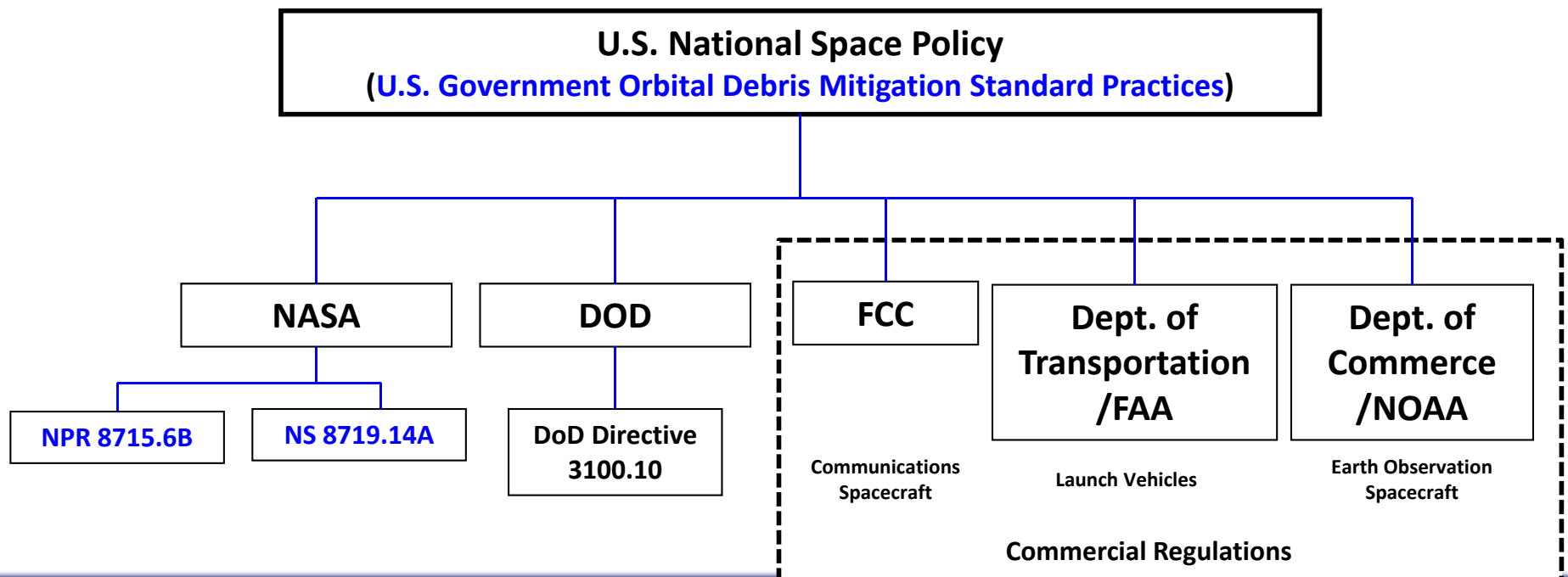
Orbital Debris Mitigation at NASA

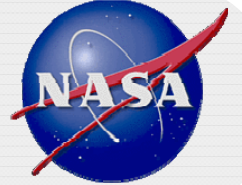
- **NASA was the first organization in the world to develop orbital debris mitigation policy and guidelines in 1990s**
 - NASA Management Instruction (NMI) 1700.8 “Policy for Limiting Orbital Debris Generation” was established in 1993
 - NASA Safety Standard (NSS) 1740.14 “Guidelines and Assessment Procedures for Limiting Orbital Debris” was released in 1995
- **The current NASA orbital debris mitigation policy is documented in NASA Procedural Requirements (NPR) for Limiting Orbital Debris, NPR 8715.6B (2017)**
 - Specific mission requirements are defined in NASA Technical Standard NS 8719.14, which is under revision



USG Orbital Debris Mitigation Standard Practices

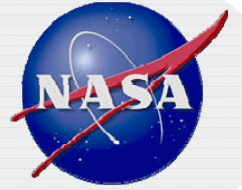
- **NASA and DOD led the effort to establish the USG Orbital Debris Mitigation Standard Practices (2001)**
- **The U.S. National Space Policies of 2006 and 2010 direct agencies and departments to implement the USG Orbital Debris Mitigation Standard Practices**





NASA-DoD OD Working Group

- **The NASA-DOD OD Working Group was established in 1997 in response to recommendations in the 1995 USG Interagency Report on Orbital Debris**
 - The objectives are to share information and exchange data on orbital debris measurements, identify methods to improve orbital debris detections, share information and exchange data on orbital debris modeling, share information on orbital debris mitigation requirement implementation, *etc.*
 - Co-chaired by the NASA ODPO and the DoD AFSPC Operational Assessments Division

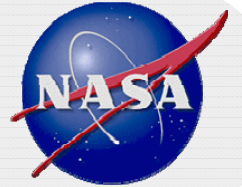


Inter-Agency Space Debris Coordination Committee (IADC)

- **The IADC is an international forum of national and multi-national space agencies for the coordination of activities related to space debris**
 - The IADC was founded by the national space agencies of U.S., Russia, Japan, and the European Space Agency in 1993.
 - Current IADC members (13): ASI, CNES, CNSA, CSA, DLR, ESA, ISRO, JAXA, KARI, NASA, ROSCOSMOS, SSAU, and UKSA.
 - NASA leads the U.S. Government delegation to the IADC. [The ODPO leads the NASA delegation](#), which also includes representatives from OSD, AFSPC, AF/SMC, FAA, FCC, and State.
 - IADC holds its annual meeting with all Steering Group and Working Group members around April-May.
 - IADC Steering Group members also meet for one day during the IAC.

Inter-Agency Space Debris Coordination Committee





IADC Space Debris Mitigation Guidelines

- **The IADC is recognized as the technical authority on orbital debris by the international community**
- **The IADC established the first international consensus-based space debris mitigation guidelines in 2002**
 - The IADC guidelines became the foundation of the United Nations COPUOS guidelines endorsed by the General Assembly in 2007
- **The IADC is in the process of updating its Space Debris Mitigation Guidelines**

Inter-Agency Space Debris Coordination Committee

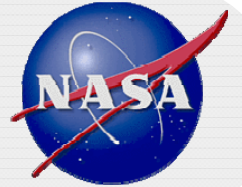




Orbital Debris at the United Nations (UN)

- **Orbital debris has been on the agenda of the Scientific and Technical Subcommittee (STSC) of the UN Committee on the Peaceful Uses of Outer Space (COPUOS) since 1994**
- **STSC Member States adopted a set of space debris mitigation guidelines similar to the IADC guidelines in Feb. 2007, followed by adoption by COPUOS in Jun. 2007 and by the full UN General Assembly in Dec. 2007**
- **The ODPO supports the U.S. Government Delegation on orbital debris related activities**
 - Annual Orbital Debris statement, technical presentations, *etc.*



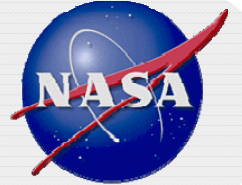


Space Policy Directive-3

- On June 18, 2018, during the third meeting of the National Space Council, the President signed Space Policy Directive-3 (SPD-3), the first National Space Traffic Management Policy.
- The policy provides guidelines and direction on space traffic management generally, and **contains key references and guidelines specific to orbital debris.**
 - NASA is assigned the responsibility to update the USG Orbital Debris Mitigation Standard Practices. The ODPO is leading the efforts.

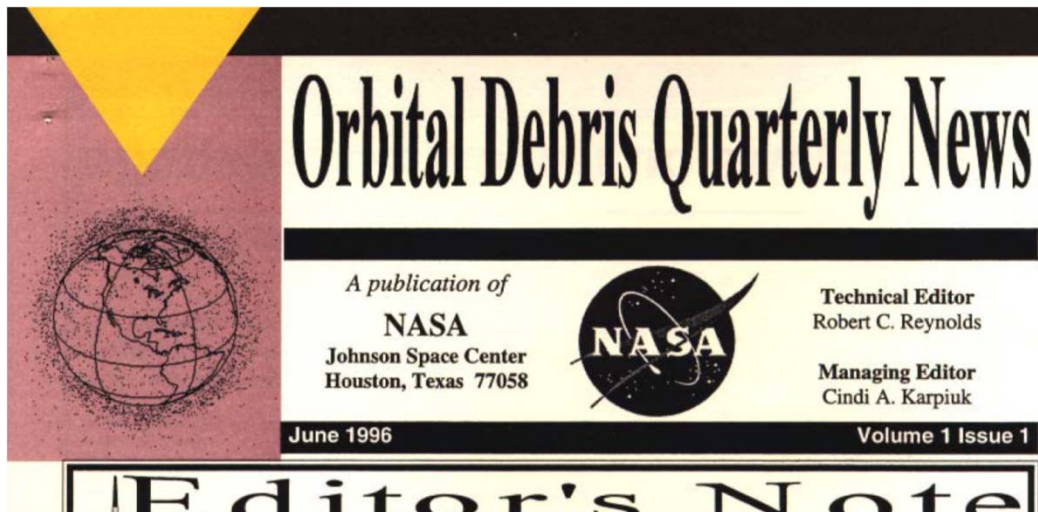
Orbital debris and SPD-3

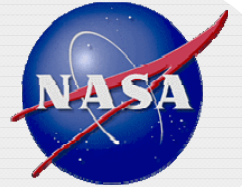
- The term “orbital debris” or “debris” appears 32 times in SPD-3
- The term “safe” or “safety” appears 30 times in SPD-3



Inquiries and Outreach

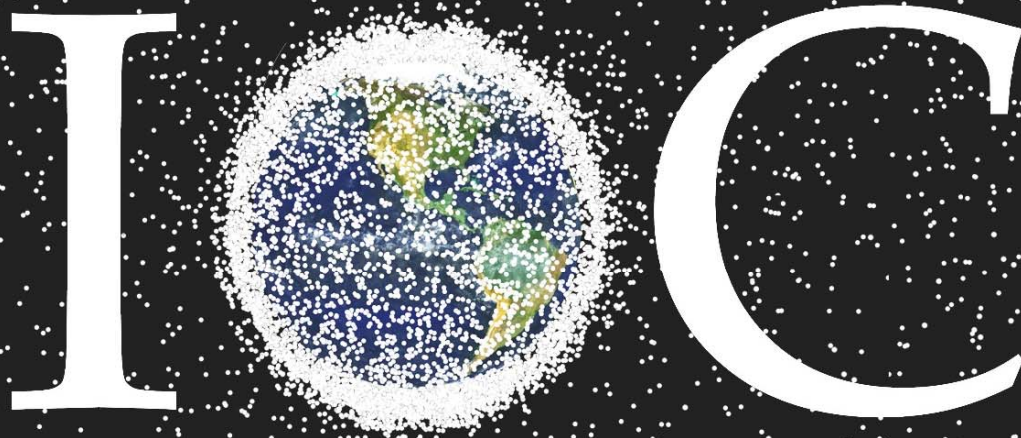
- The ODPO responds to inquiries from USG (Congress, OMB, OSTP, *etc.*) and media on a regular basis
- The ODPO maintains a website and publishes the NASA Orbital Debris Quarterly News (ODQN)
 - ODPO's website: <https://orbitaldebris.jsc.nasa.gov/>
 - ODQNs cover the latest events in orbital debris news, research, statistics, project reviews, meeting reports, and upcoming events
 - There are 1650+ ODQN subscribers from the global space community





Forward Challenges for the ODPO

- **Expand the LEO-to-GEO debris measurement coverage for better environment definitions**
 - Conduct *in situ* measurements on millimeter-sized orbital debris at 600-1000 km altitude to address the top risk for NASA missions
- **Advance modeling capabilities to improve orbital debris impact risk assessments for future missions**
 - Utilize DebrisSat data for the shape distribution and other improvements for ORDEM 4.0
- **Work with the U.S. and international communities to improve the global orbital debris mitigation efforts to better preserve the near-Earth space environment**



1ST INTERNATIONAL ORBITAL DEBRIS CONFERENCE



DECEMBER 9–12, 2019
SUGAR LAND, TEXAS, USA

- **The 4-day conference will cover all aspects of micrometeoroid and orbital debris research, mission support, and other activities**
 - Measurements: radar, optical, in-situ, laboratory, *etc.*
 - Modeling: engineering, long-term environment, reentry, *etc.*
 - Operations and mission support: hypervelocity impact and protection, satellite anomalies, conjunction assessments, *etc.*
 - Environment management: mitigation, remediation, policy, *etc.*
- **Website:** <https://www.hou.usra.edu/meetings/orbitaldebris2019/>
- **Abstract submission deadline:** [April 22, 2019](#)

All are invited to attend the 2019 IOC!