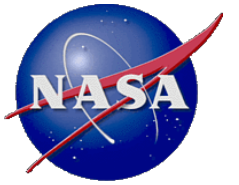
National Aeronautics and Space Administration



Highlights of Recent NASA Orbital Debris Program Office (ODPO) Activities

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Chief Scientist for Orbital Debris
National Aeronautics and Space Administration

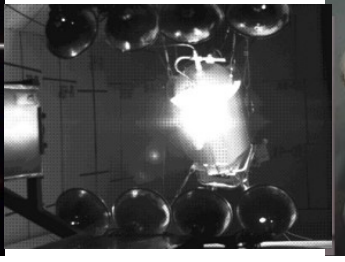
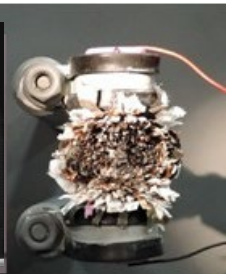
The 10th JAXA Space Debris Workshop
JAXA Chofu Aerospace Center, 28-30 November 2022

ODPO's Roles and Responsibilities (1/3)

- **Monitor the ever-changing OD environment**
  - The 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





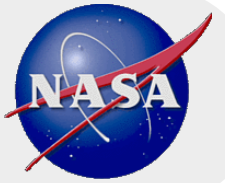



Credits, left-to-right: Reprinted with permission Courtesy of MIT Lincoln Laboratory, Lexington, Massachusetts; NASA (PIA13277); https://deepspace.jpl.nasa.gov/galleries/goldstone/#gallery; NASA ODPO; NASA (S125E007413); Arnold Engineering Development Complex/Air Force; NASA HVIT

ODPO's Roles and Responsibilities (2/3)

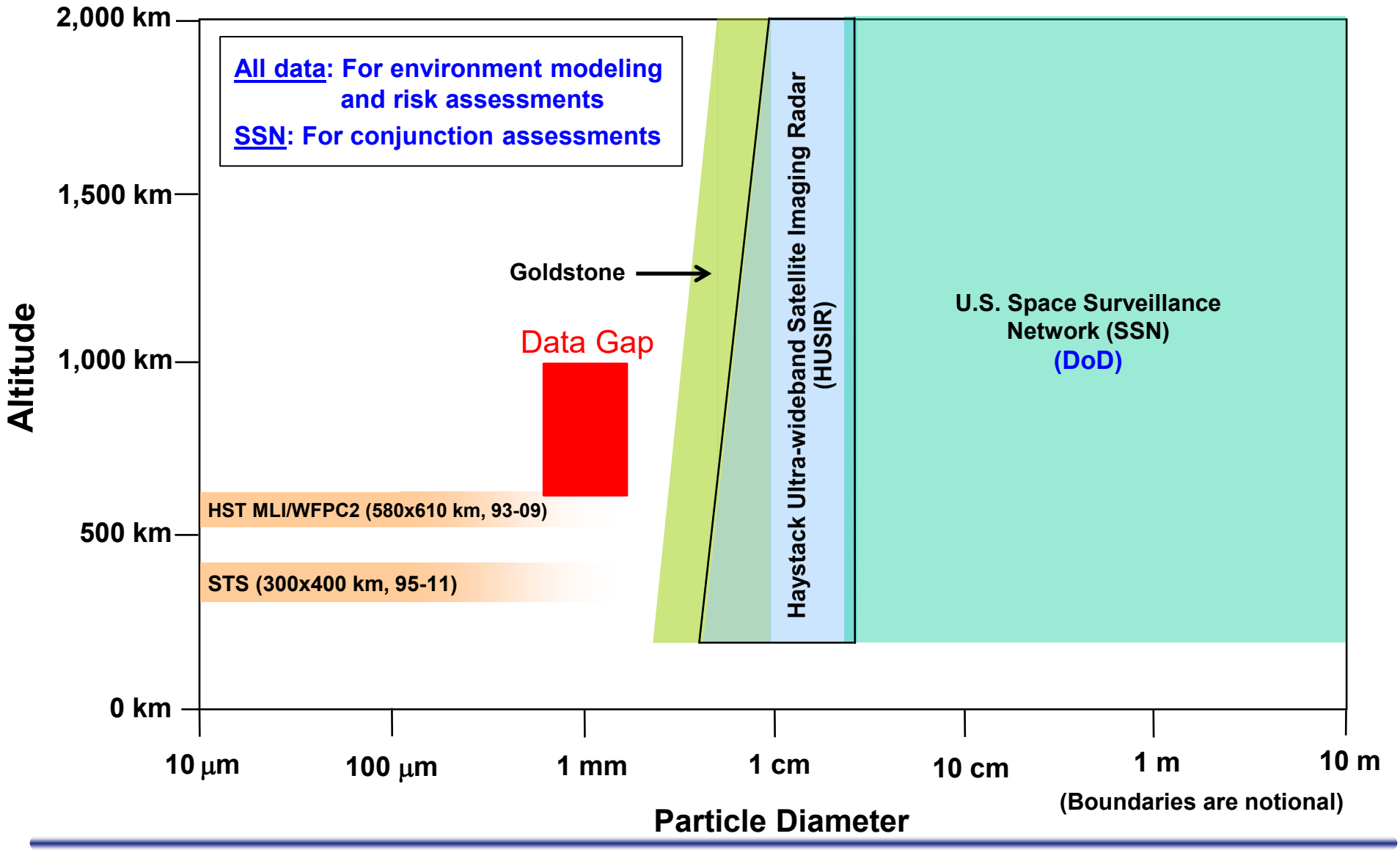
- **Develop and update OD modeling and mission support tools**
  - The ODPO has led the development of OD environment, risk assessment, and mission compliance models and tools for more than 30 years
    - **ODPO models and tools are used by hundreds of operators (NASA, USG, commercial), academia, and research groups around the world**
- **Provide OD mitigation mission support**
  - OSMA and the ODPO oversee NASA mission compliance 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)



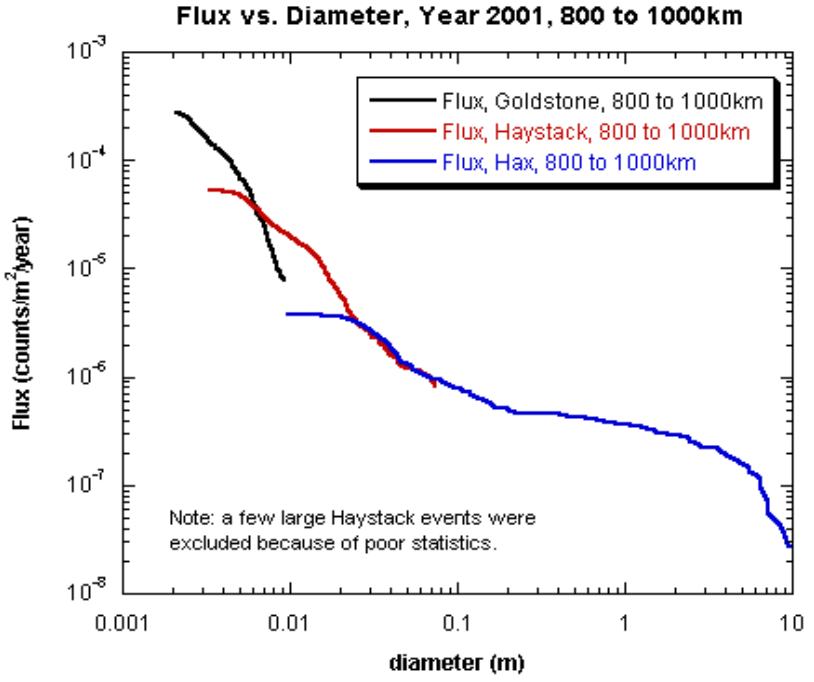
- **Provide USG interagency, international, commercial, and outreach support**
  - The ODPO has led the development/implementation of OD mitigation best practices in the U.S. and has promoted the adoption of the USG ODMSP by the international community since 1995
    - **USG ODMSP (2001, 2019): The ODPO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

Current NASA OD Measurements in LEO

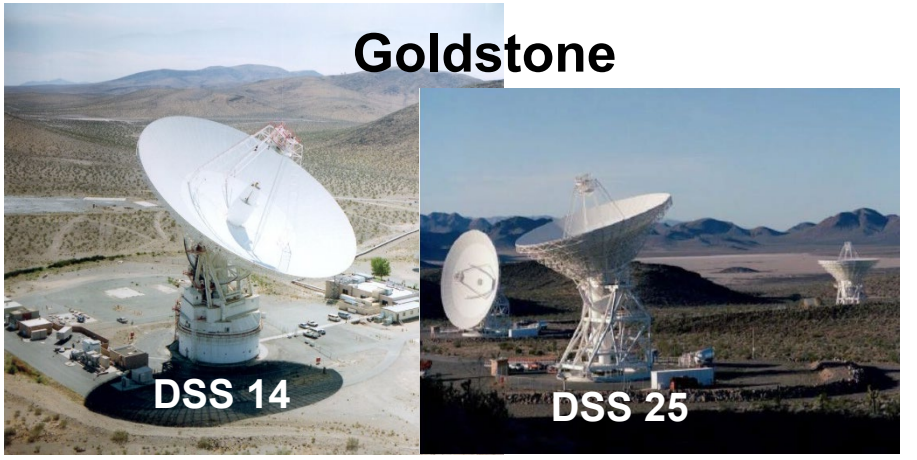


ODPO's Radar Measurements

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



Goldstone



Credit: Courtesy NASA JPL-Caltech, (left) https://deepspace.jpl.nasa.gov/galleries/goldstone/#gallery; (right) retrieved from https://www.gdscc.nasa.gov/wp-content/uploads/2018/12/BWG-Sign-2018-mm-2-27-18.jpg

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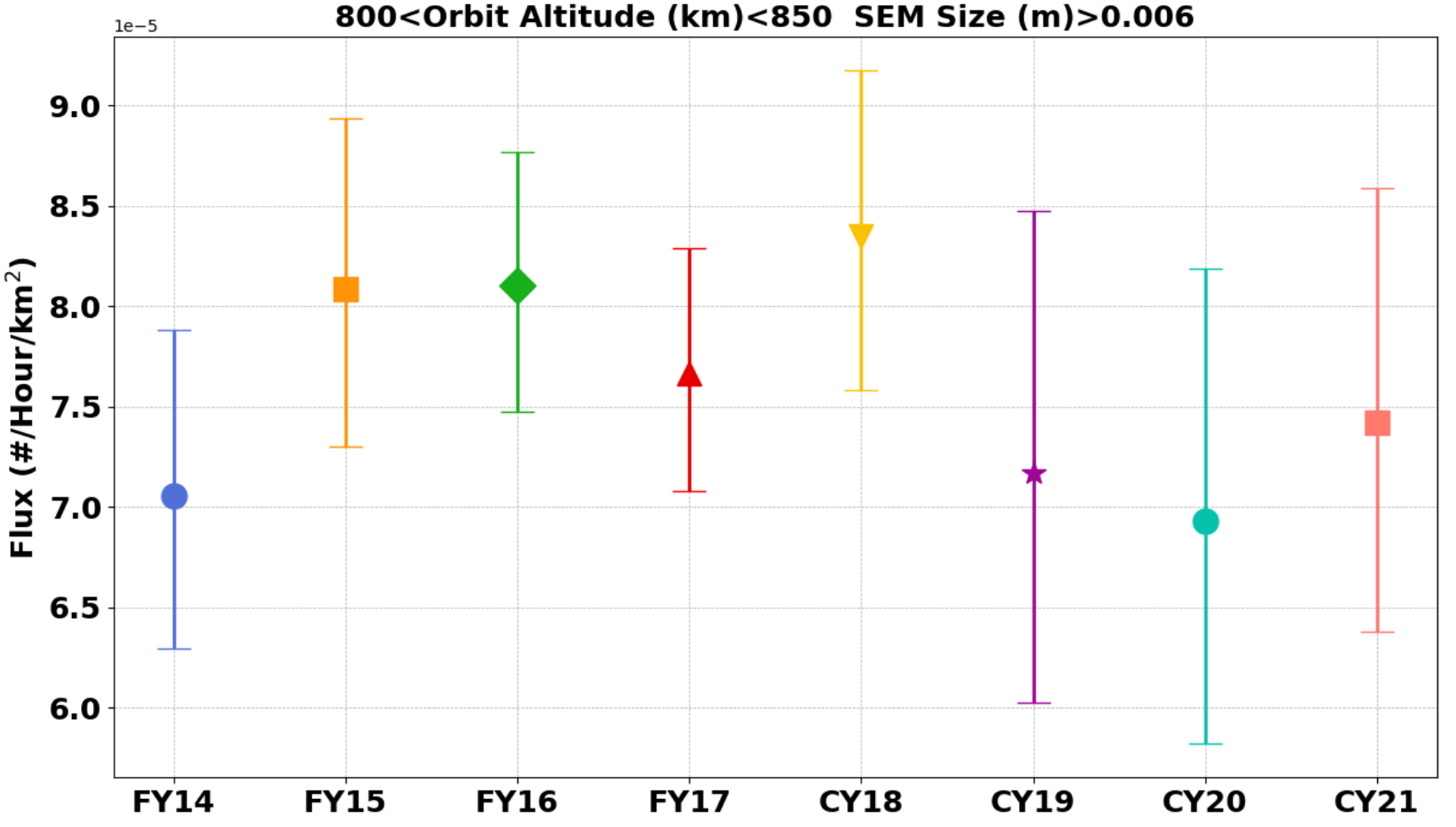
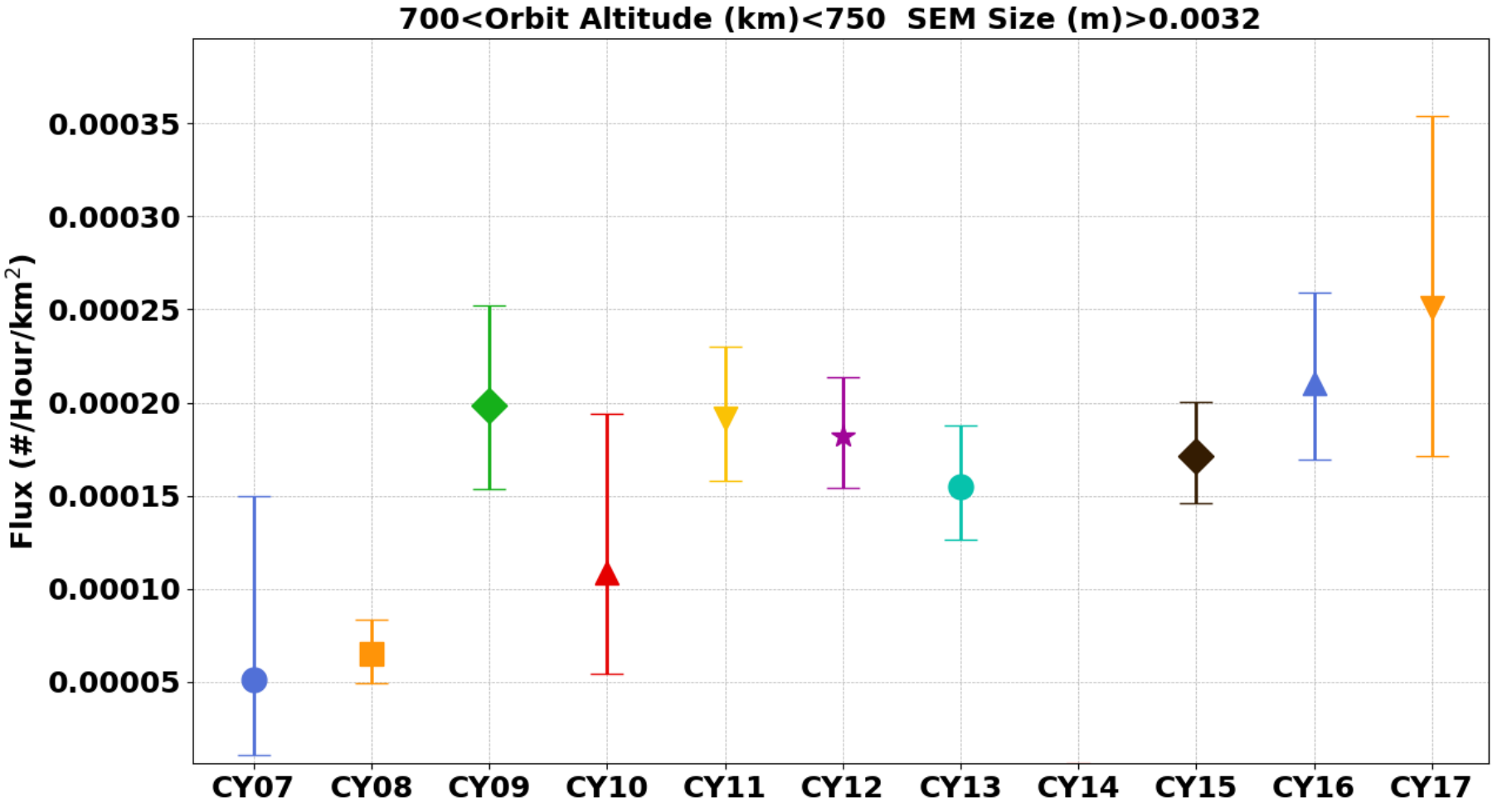
HUSIR Measurements, 2014-2021



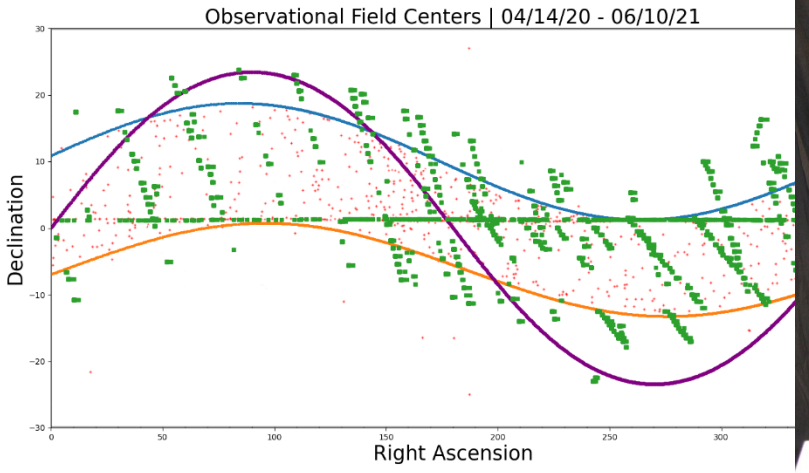
Goldstone Measurements, 2014-2021

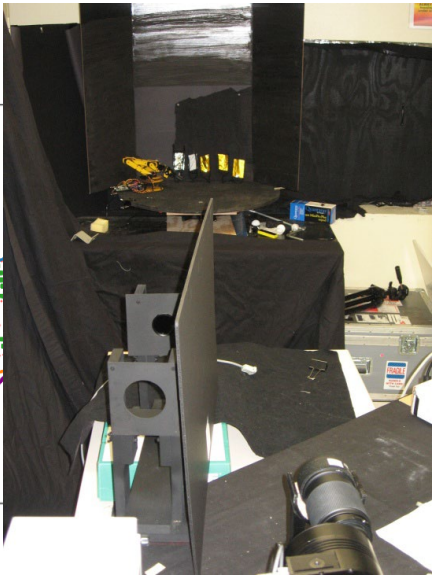


ODPO's Optical Measurements

- **Object detection and correlation**
  - Eugene Stansbery Meter Class Autonomous Telescope (ES-MCAT)
- **Orbit determination**
- **Environment definition**
- **Optical Measurement Center (OMC)**
- **Surface material identification**

Credit: Ben Hanna

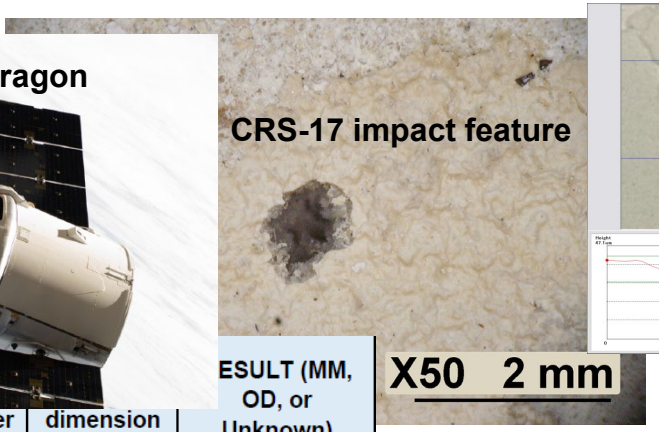


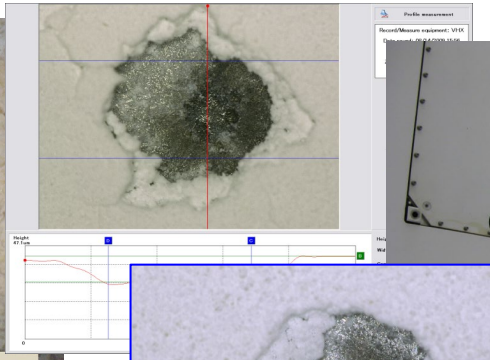


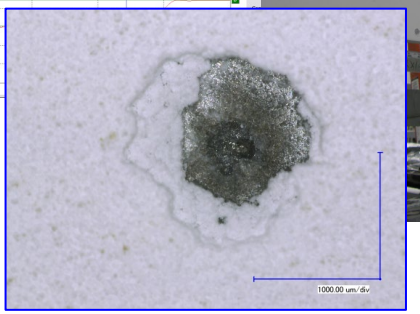
OMC

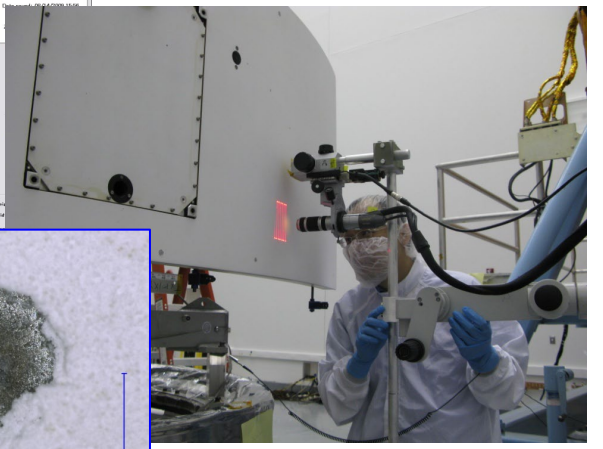
ODPO's *In-Situ* Measurements

- **The ODPO, in collaboration with the NASA Hypervelocity Impact Technology (HVIT) group at JSC, inspects hardware surfaces returned from space to characterize the small debris population**
  - Hubble Space Telescope Wide-Field Planetary Camera-2 radiator
  - ISS Pressurized Mating Adapter 2 blanket
  - SpaceX Dragon capsule from Commercial Resupply Service (CRS) mission







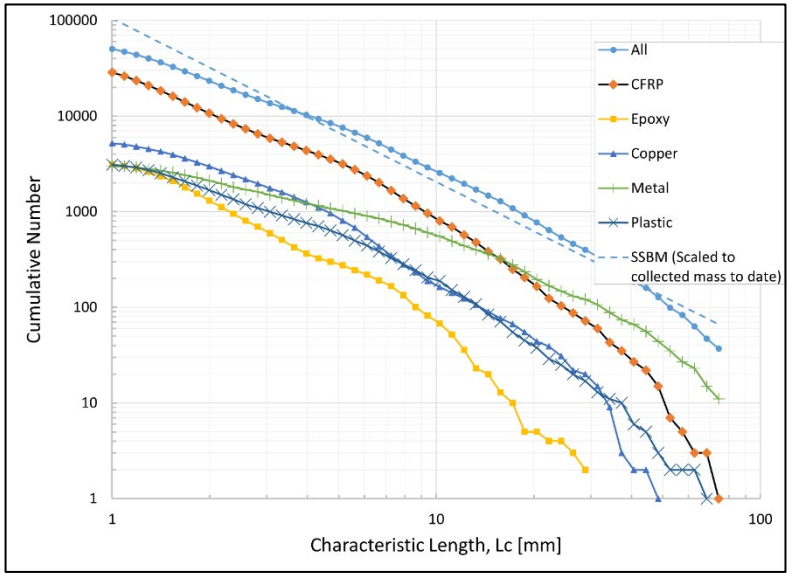


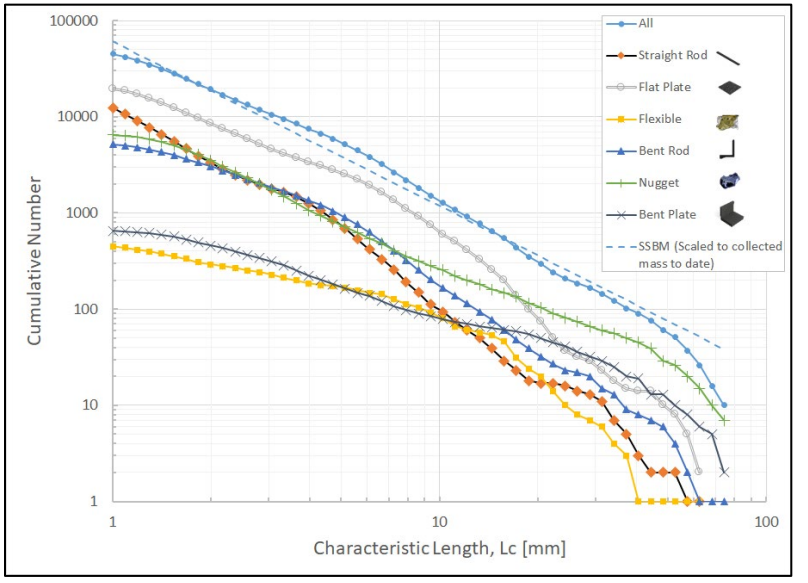
Credit: NASA ODPO

ID	Number	dimension (mm)	ESULT (MM, OD, or Unknown)
CRS-13	211	4.79	OD
CRS-15	226	4.15	MM
CRS-18	273	3.635	OD

ODPO's Laboratory Measurements

- **The DebriSat project aims to characterize fragments, large and small, generated from a laboratory-based impact test on a markup modern spacecraft**

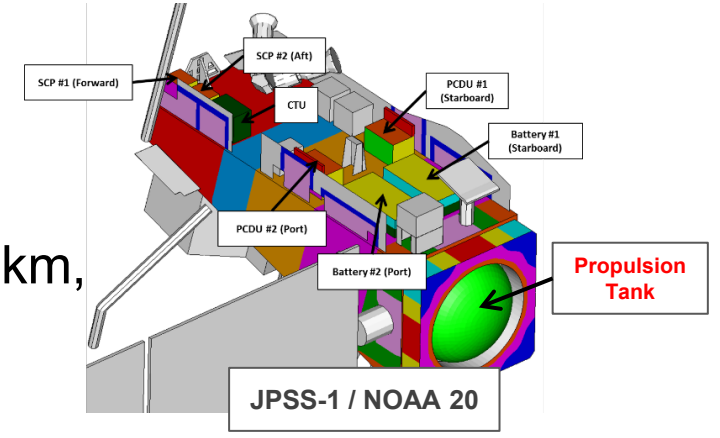




Credit: Arnold Engineering Development Complex/Air Force

Risk from Small Debris (1/2)

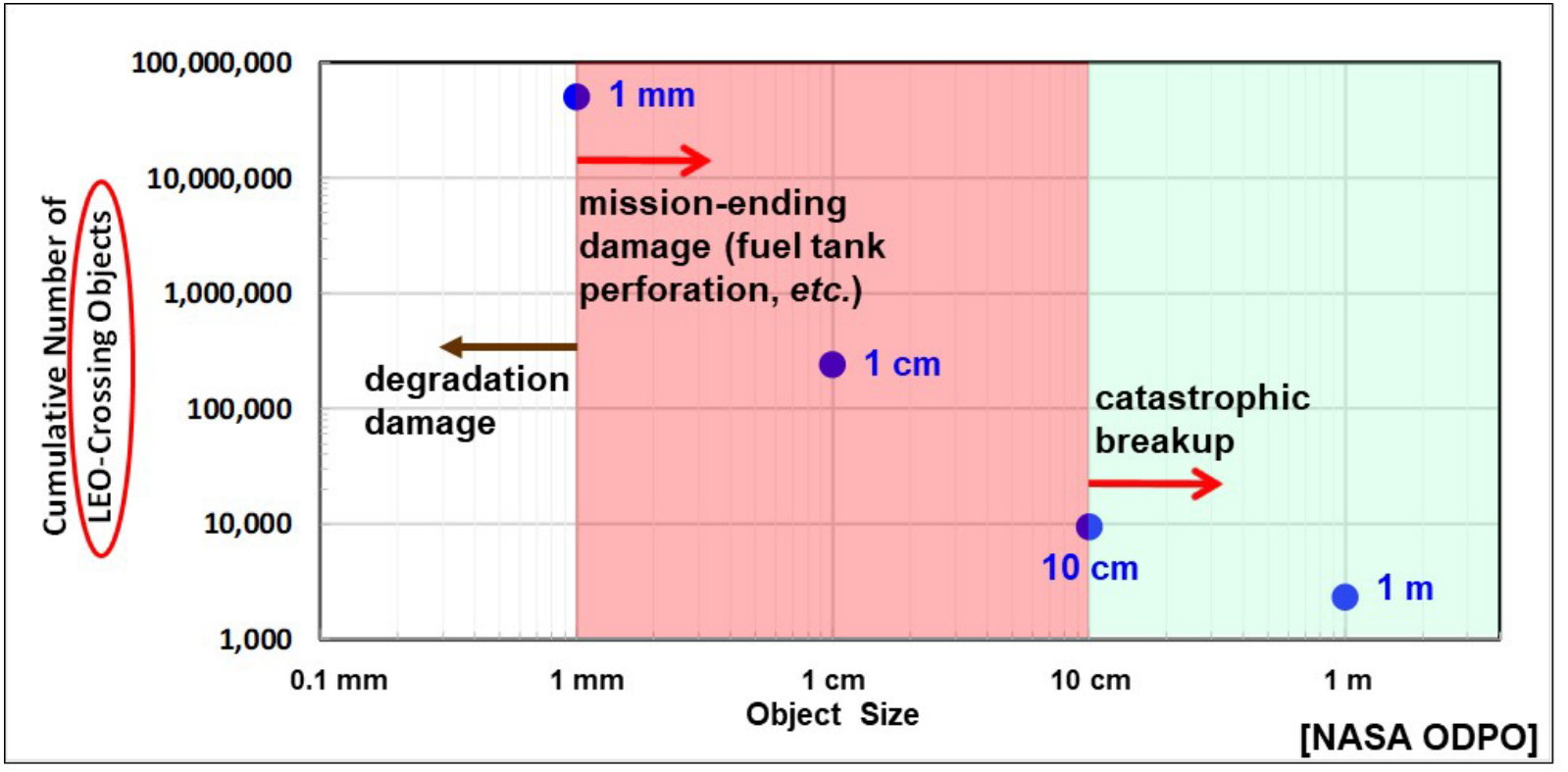
- **Millimeter-sized orbital debris represents the highest penetration risk to most operational spacecraft in LEO**
  - As concluded by a NASA Engineering and Safety Center panel study (NASA/TM 2015-218780)
- **Currently, more than 400 spacecraft operate at 600–900 km altitudes**
  - Including 18 NASA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

Risk from Small Debris (2/2)

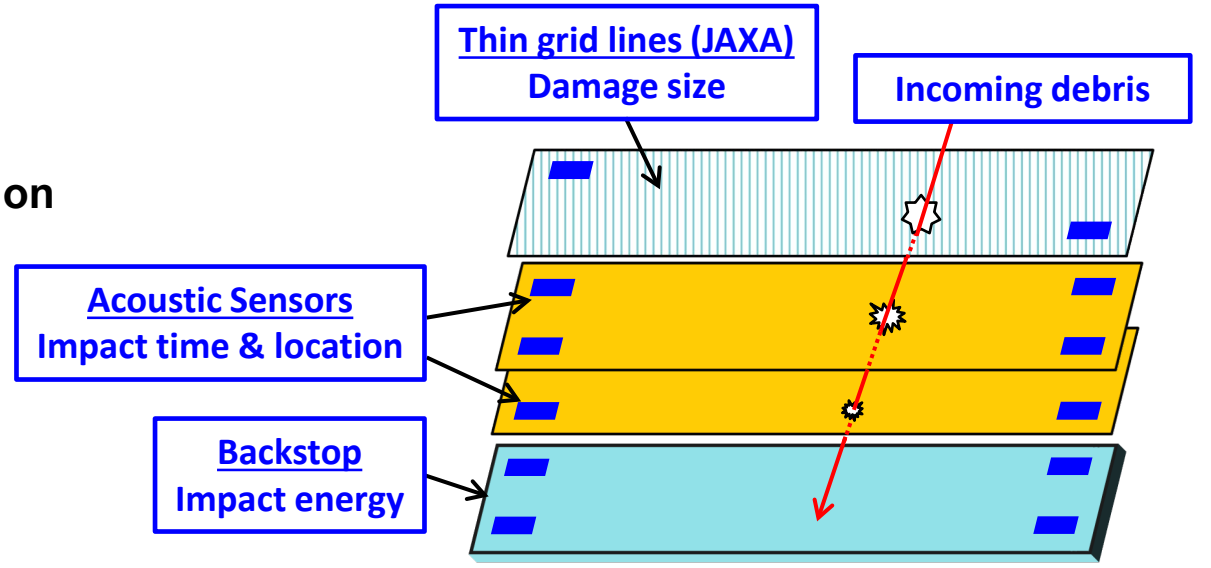
- **There is far more small debris than large debris**
  - Mission-ending risk is driven by millimeter-sized debris in LEO, but there is a lack of direct measurement data on such small debris
  - Conjunction assessments and collision avoidance against the large (≥10 cm) tracked objects only address 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



ODPO's In-Situ Measurements

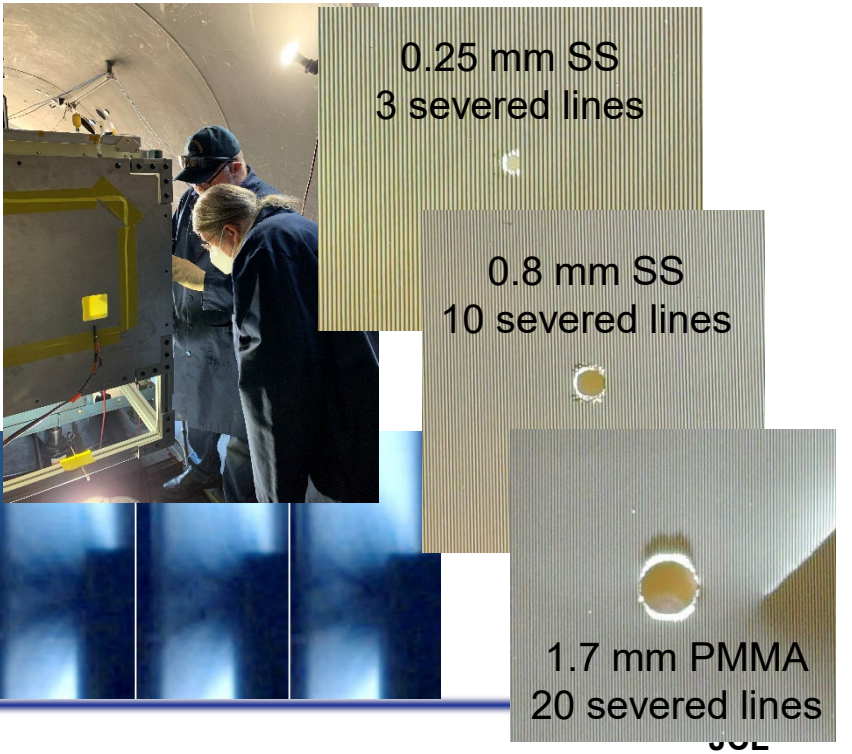
- **The ODPO has led the development of innovative *in-situ* measurement technologies since 2002**
  - In collaboration with NRL, USNA, VT, U. Kent, and JAXA
- **Multi-layer Acoustics & Conductive-grid Sensor (MACS)**
  - Designed to detect/measure debris in the millimeter-size regime
  - Combines several impact detection technologies to maximize information that can be extracted from the detected impact events
    - **Impact time**
    - **Impact location**
    - **Particle size**
    - **Impact speed/direction**
    - **Impact energy/ particle density**

MACS
MULTILAYER ACOUSTIC CONDUCTIVE-GRID SENSOR



MACS Developments

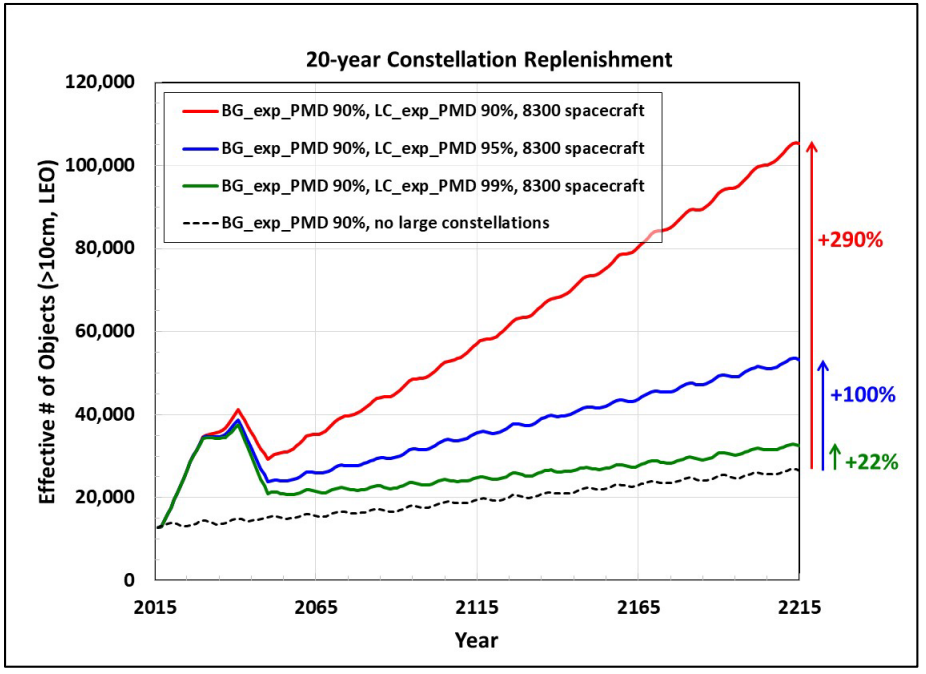
- **The MACS prototype unit has been designed, built, and tested in 2021-2022**
  - Ten-week hypervelocity impact test series at White Sands
  - Component-level environmental testing (vibration, thermal-vacuum, shock)
  - A week-long mission architecture study at Goddard's Mission Design Lab

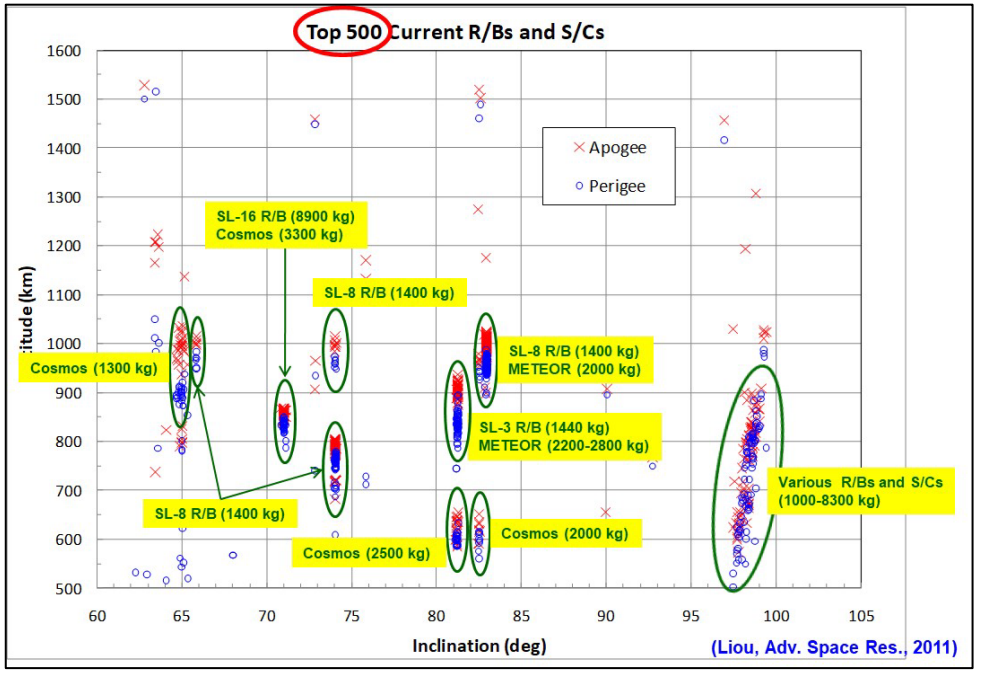


Credit: NASA ODPO and HVIT

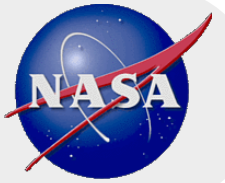
ODPO's Modeling Activities (1/2)

- **Modeling**
  - Long-term environment modeling
    - **Assess impacts from new missions and operations (CubeSats, large constellations, *etc*.) to the environment**
    - **Assess the effectiveness of various mitigation and remediation measures to support policy development**





ODPO's Modeling Activities (2/2)



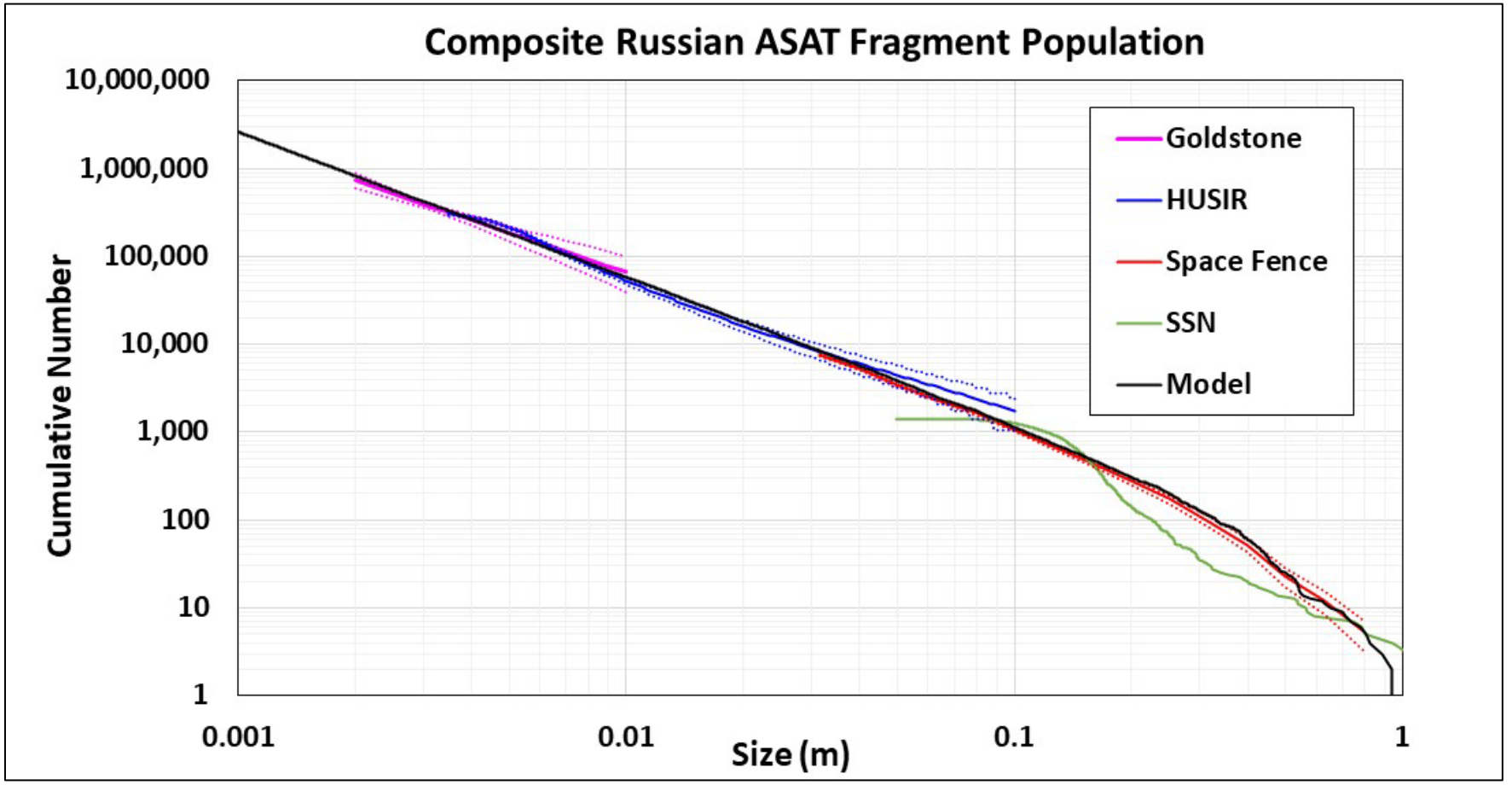
- **Modeling**
  - Engineering modeling (Orbital Debris Engineering Model, ORDEM)
    - **Predict OD impact risk for mission support**
    - **ORDEM is used by hundreds of operators (NASA, USG, industry), academia, and research groups around the world**
    - **ORDEM 3.2 was released as a cloud-based application in March 2022**
  - Short-term risk assessment tool
    - **Calculate impact risk from new breakup events to critical NASA assets**
  - Debris Assessment Software (DAS)
    - **Assess mission compliance with orbital debris mitigation requirements**
    - **The No. 1 requested software in NASA Software Catalog**
  - Object Reentry Survival Analysis Tool (ORSAT)
    - **Model human casualty risk from satellite reentries**

Cosmos 1408 Measurements and Modeling

- **The Russian ASAT test on Cosmos 1408 (1750 kg, 490 x 465 km altitude) occurred on 15 November 2021**
- **The ODPO led efforts to assess risks from Cosmos 1408 fragments to the ISS and supported mitigation measure development to protect the crew**
- **The ODPO also made special arrangements to collect timely radar measurement data on small Cosmos 1408 fragments immediately after the R-ASAT test occurred**
  - MIT/LL's Haystack Ultrawideband Satellite Imaging Radar (HUSIR)
  - JPL's Goldstone radar
  - DOD's Space Fence
- **The ODPO used the measurement data to validate its risk assessments and to update ORDEM with a new Cosmos 1408 fragment component**

Cosmos 1408 Fragments – Data and Model

- The ODPO's prediction matches the radar measurement data well
- The updated ORDEM 3.2 with a new Cosmos 1408 fragment component was released in March 2022



ODPO's Near- and Long-Term Priorities

- **Measurements**
  - Collect radar and optical measurement data with improved sensing capabilities to update the environment definition
- **Modeling**
  - Update ORDEM to 4.0 with new measurement data and a fragment shape distribution
  - Upgrade ORSAT with new capabilities and lab-based experimental data on composite materials
- **Millimeter-sized debris data gap**
  - Advance MACS development to an engineering unit
  - Pursue a MACS mission opportunity
- **Environment management**
  - Support USG and the international community to improve orbital debris mitigation and manage the orbital debris problem for the long-term sustainability of the near-Earth space environment

The 2nd International Orbital Debris Conference (IOC II)

- **Preparation is underway for the 2nd International Orbital Debris Conference (IOC II)**
  - This quadrennial conference will take place in Sugar Land, Texas (greater Houston area), 04-07 December 2023
  - The four-day conference will cover all aspects of micrometeoroid and orbital debris research, mission support, and other activities
    - **Measurements, modeling, hypervelocity impacts, operations and mission support, and environment management**

All are invited to attend the 2023 IOC!