# Highlights of Recent Research Activities at the NASA Orbital Debris Program Office

**Matt Forsbacka, PhD**
**NASA Orbital Debris Program Executive**

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# Outline

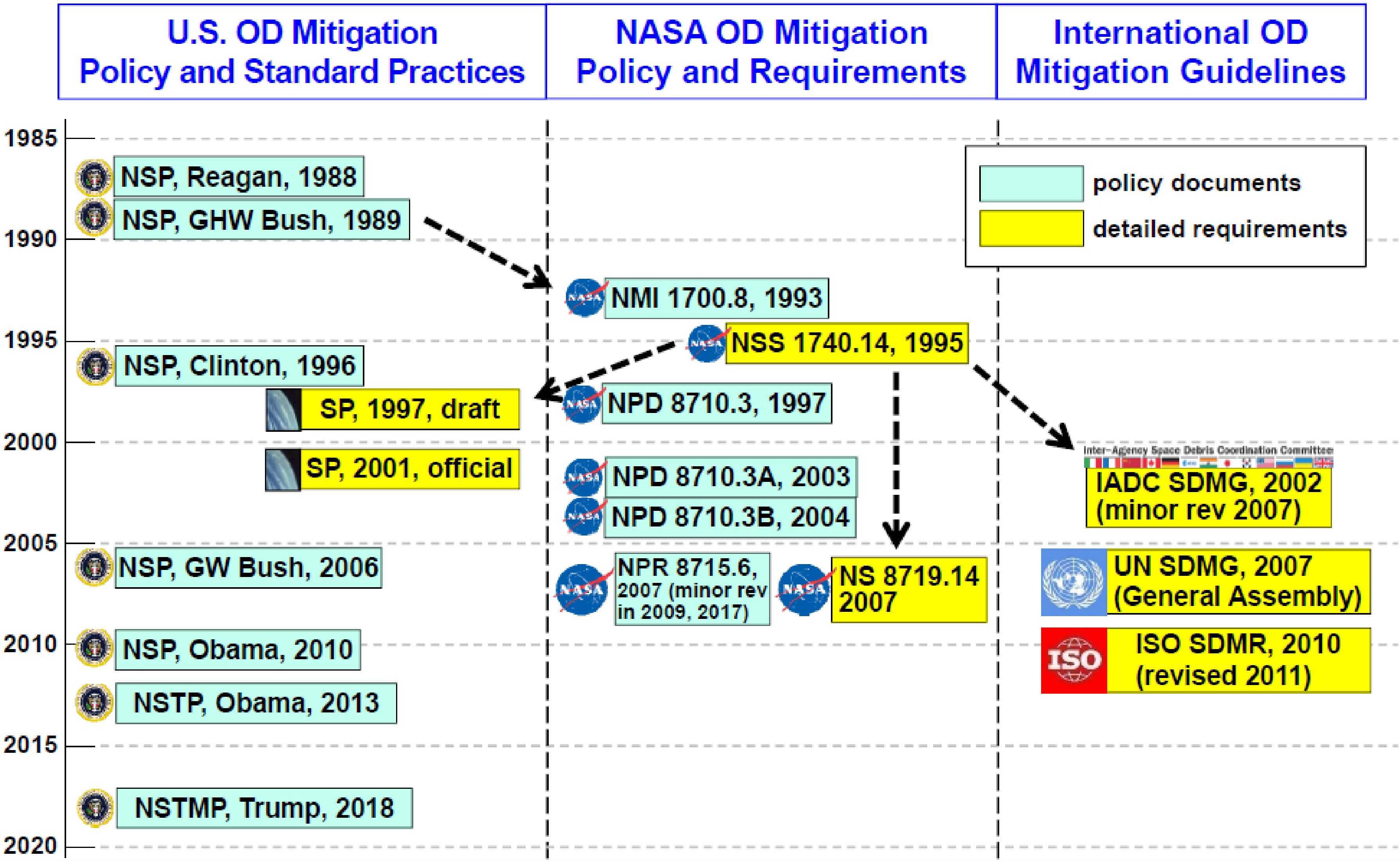
- **NASA Orbital Debris Policies and Directives**
  - History and background
- **Highlights of Recent Research Activities at the ODPO**
  - Eugene Stansbery Meter-Class Autonomous Telescope (ES-MCAT) and James R. Benbrook Telescope (Benbrook)
  - Space Debris Sensor (SDS)
  - DebriSat
  - Orbital Debris Engineering Model (ORDEM) 3.0
  - NASA Orbital Debris Mitigation Policy and Requirement Documents

Orbital debris = human-made debris in Earth orbit
Space debris = micrometeoroids and orbital debris (MMOD)

# NASA Orbital Debris Mitigation Documents

- **The first NASA mission requirements for orbital debris mitigation were established in 1995**
  - ODPO Established in 1978
- **The current policy and requirement documents are**
  - NASA Procedural Requirements for Limiting Orbital Debris and Evaluating the Meteoroid and Orbital Debris Environment, NPR 8715.6B
  - NASA Technical Standard, “Process for Limiting Orbital Debris,” NASA-STD-8719.14A
- **NPR 8715.6B became official in February 2017**
  - The updated version better clarifies the roles and responsibilities of different NASA organizations
- **The ODPO is leading an effort to update NASA-STD-8719.14A**
  - The focus is to provide more and better technical justifications for the existing requirements

# Policy → Detailed Requirements

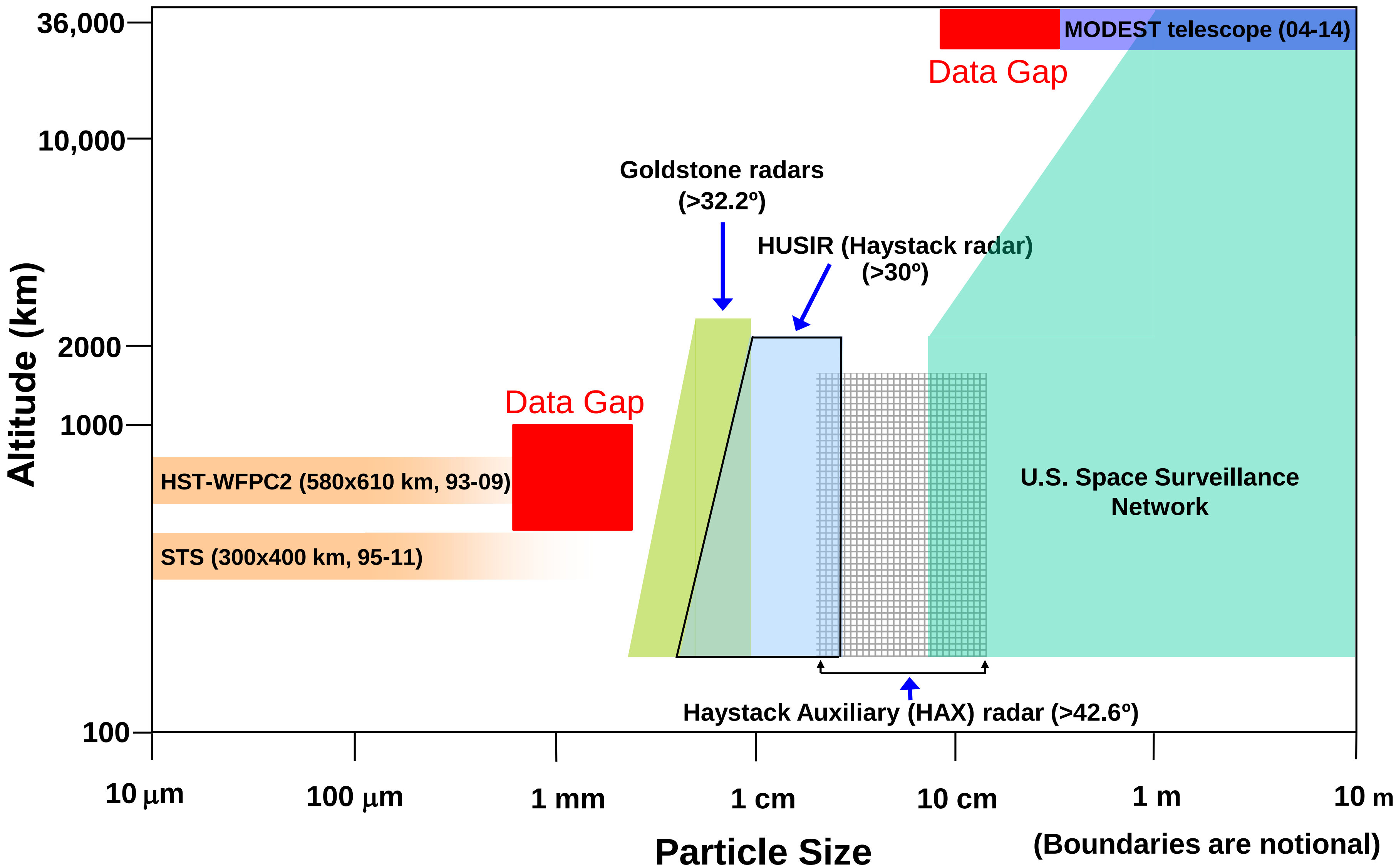


# Space Policy Directive-3: S&T Focus Area

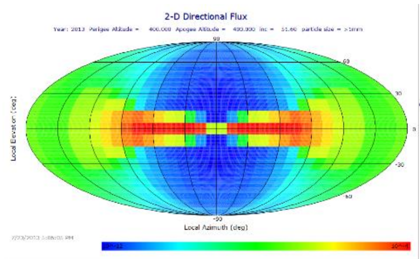
## Sec. 4. Goals

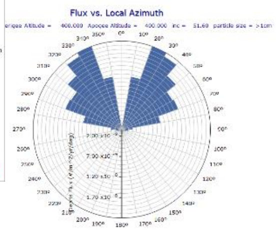
***(a) Advance SSA and STM Science and Technology. The United States should continue to engage in and enable S&T research and development to support the practical applications of SSA and STM. These activities include improving fundamental knowledge of the space environment, such as the characterization of small debris, advancing the S&T of critical SSA inputs such as observational data, algorithms, and models necessary to improve SSA capabilities, and developing new hardware and software to support data processing and observations.***

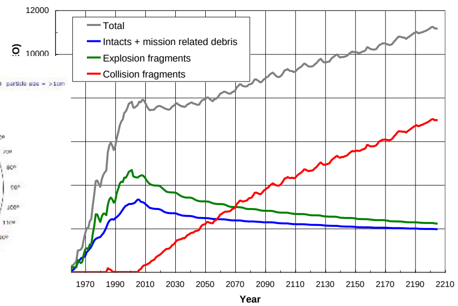
# Current NASA Orbital Debris Database



# End-to-End Orbital Debris Activities at ODPO




## Measurements

**Radar**
**Optical**
**In-situ**
**Laboratory**

## Modeling

**Breakup**
**Engineering**
**Evolutionary**
**Reentry**

## Mission Risk Assessments

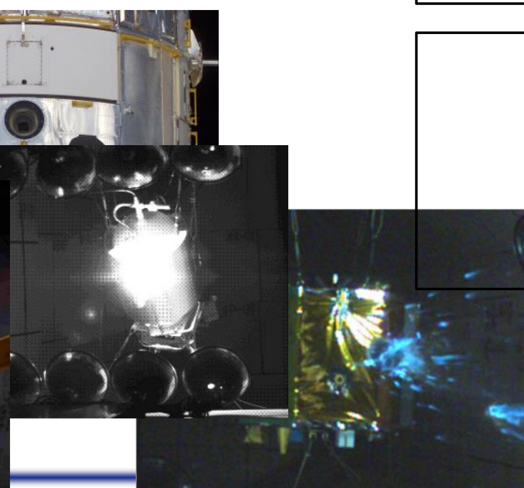
**NASA space assets**
**(ISS, Orion, robotic missions, *etc.*)**
**Reentry**

## Environment Management

**Mitigation**
**Remediation**
**Policy**
**Mission Requirements**

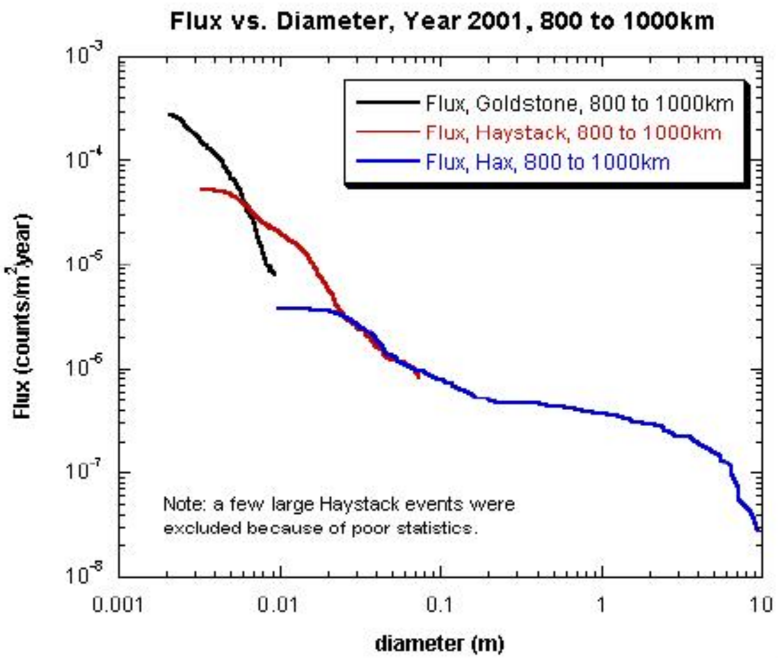
## Coordination

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



# HUSIR, HAX, and Goldstone

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




Goldstone (NASA/JPL)

HUSIR and HAX (MIT/LL)

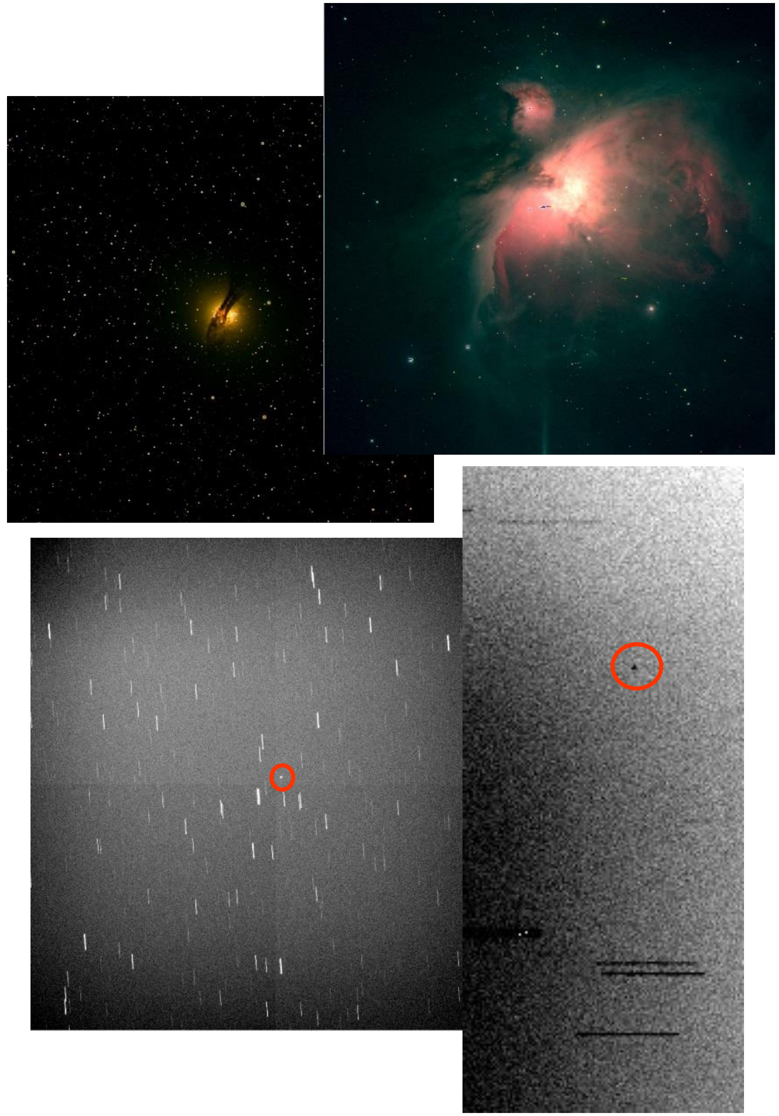
R: Haystack Ultra-wideband Satellite Imaging Radar (HUSIR)
L: Haystack Auxiliary Radar (HAX)

# ES-MCAT (1/2)

- **A NASA, Air Force, and Air Force Research Laboratory joint project**
- **The observatory is located on Ascension Island (7° 58' S, 14° 24' W)**
  - Unique location for US asset, provides Low Inclination, Low –Earth Orbit observation capability
- **Two instruments at the facility**
  - ES-MCAT: a double horse-shoe 1.3-m DFM telescope with a field-of-view of 41' × 41'
  - Benbrook: a 0.4-m telescope with a similar field-of-view
- **Goal of the project**
  - Two telescopes fully dedicated to orbital debris measurements of statistically under-sampled orbital regimes

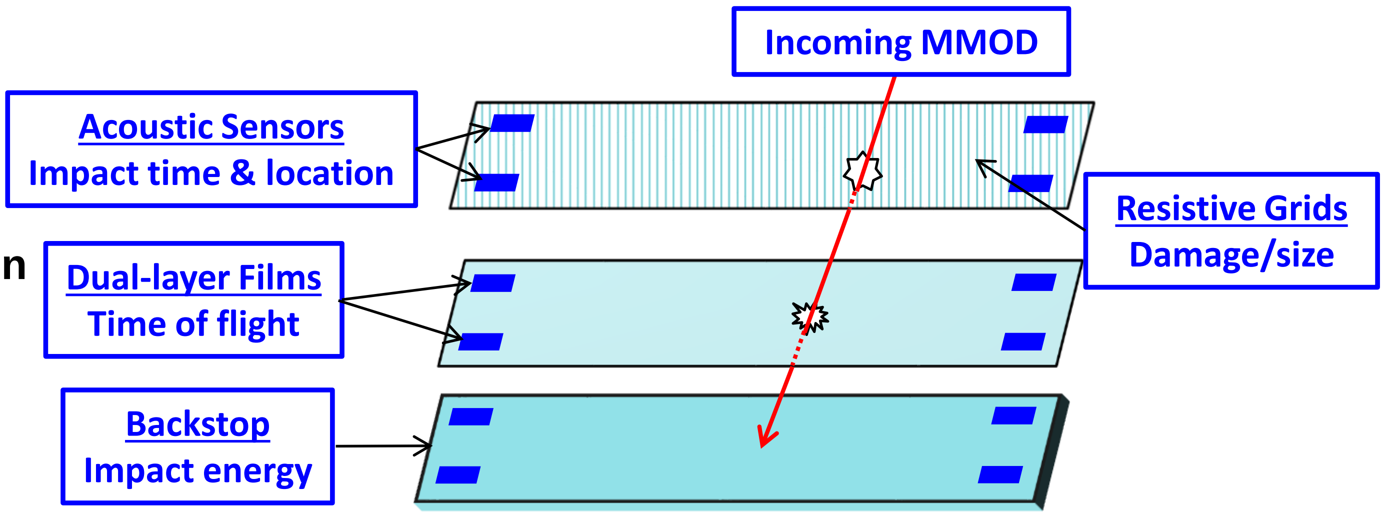
# ES-MCAT (2/2)

- **Data collections**
  - Conduct GEO and LEO statistical surveys
  - Detect faint debris in GEO
  - Characterize low inclination objects in LEO
  - Provide rapid break-up response
  - Support other Space Situational Awareness (SSA) applications
- **Accomplishments so far**
  - Achieved first light in 2015
  - Conducted User Readiness Review in 2016
  - Installed Benbrook in late 2017
- **Forward plan**
  - Reach full autonomous operations for routine GEO debris survey to extend data coverage in 2018-2019



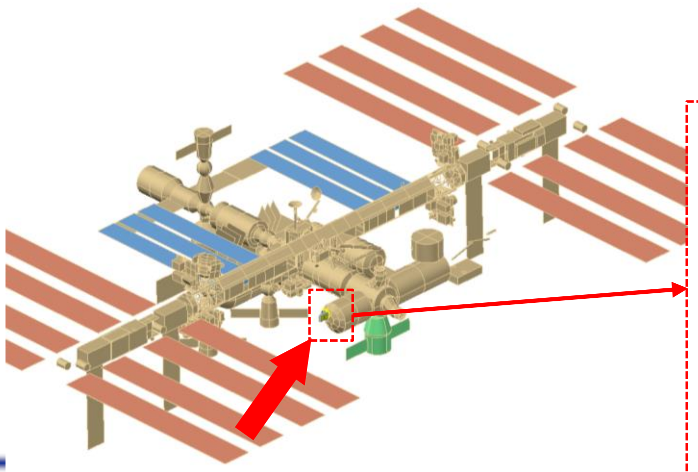
# DRAGONS

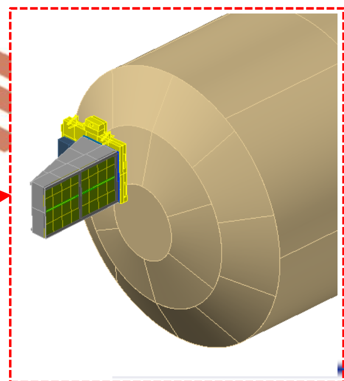
- **ODPO has led the development of innovative *in situ* measurement technologies since 2002**
- **DRAGONS (Debris Resistive/Acoustic Grid Orbital NASA-Navy Sensor)**
  - Is an *in situ* impact detector designed to measure micrometeoroids and orbital debris (MMOD) in the ~millimeter size regime
  - Combines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

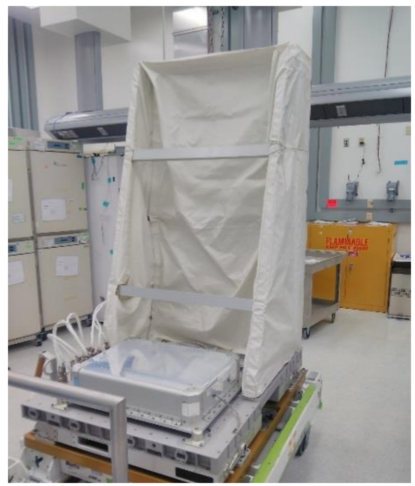


# Space Debris Sensor (SDS)

- **The International Space Station (ISS) Program funded the ODPO for a DRAGONS technology demonstration mission opportunity**
  - Objectives: (1) mature DRAGONS technologies and (2) characterize the sub-millimeter debris environment at the ISS altitude
  - Launched to the ISS on SpaceX-13 (November 2017) for a 2-year deployment
  - To avoid confusion with the SpaceX Dragon, the mission was renamed Space Debris Sensor (SDS)





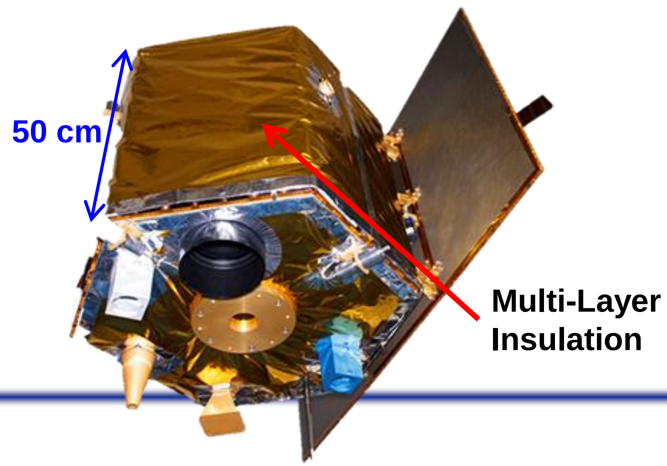
**SDS at NASA/KSC ready for launch**

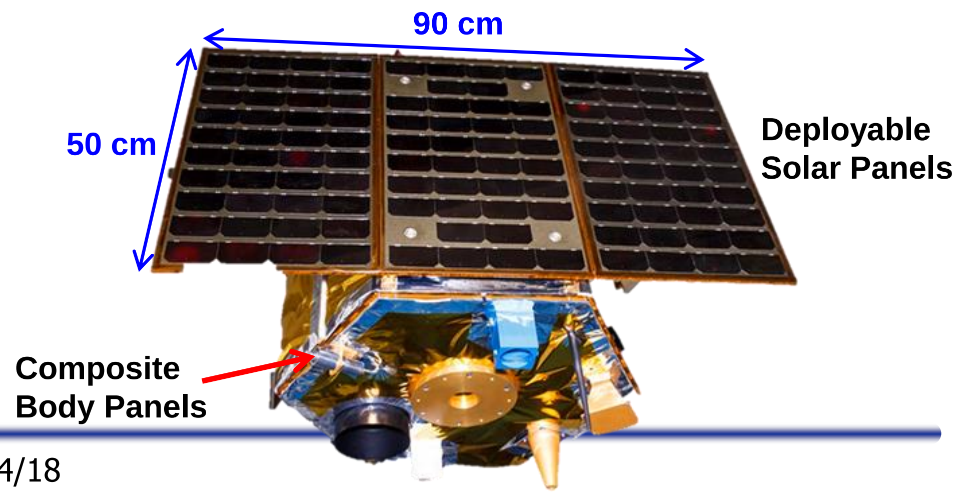
# A High LEO Altitude DRAGONS Mission

- **A 2015 NASA Engineering and Safety Center (NESC) study on the MMOD assessment for the Joint Polar Satellite System concluded that**
  - Particles <3 mm pose the highest penetration risk to most spacecraft
  - For the flux for particles <3 mm, orbital debris model validation for altitudes above 600 km is most effective using *in situ* data
  - There is currently no *in situ* data for particles <3 mm at altitudes above 600 km
- **NASA currently operates close to 20 missions at altitudes between 600 and 1000 km**
- **ODPO will continue to seek mission opportunities to deploy DRAGONS to characterize the millimeter-sized orbital debris populations at 600-1000 km altitude**

# DebriSat (1/2)

- **The DebriSat project is a collaboration among NASA, the Air Force, Aerospace, and the University of Florida for a laboratory-based hypervelocity impact experiment**
  - Design and fabricate a 56-kg class spacecraft ("DebriSat") representative of <u>modern spacecraft</u> 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 and other SSA applications

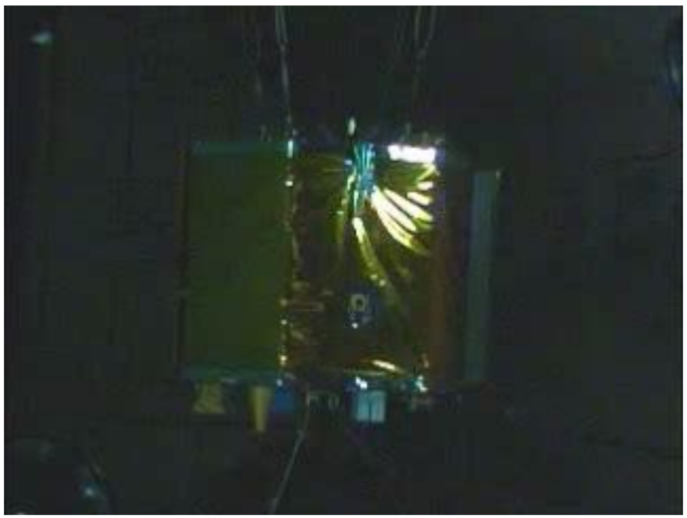


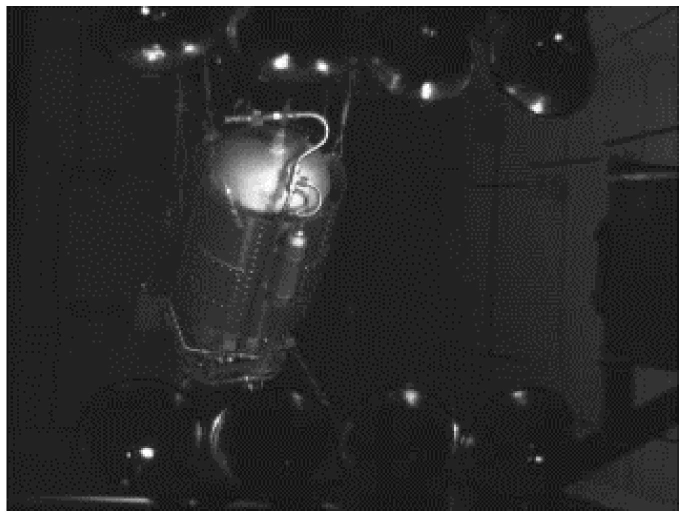
# DebriSat (2/2)

- **The DebriSat 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**
  - ~133,000 fragments (≥2 mm) extracted from foam panels so far
  - More than 10,000 fragments fully characterized

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

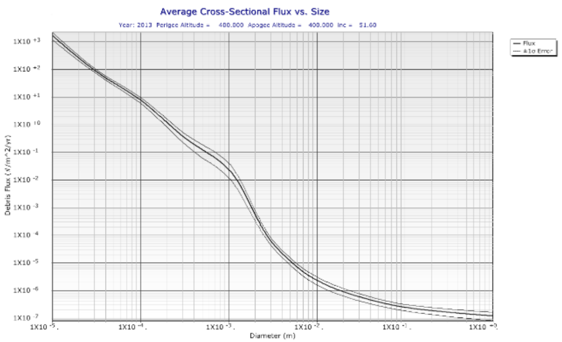


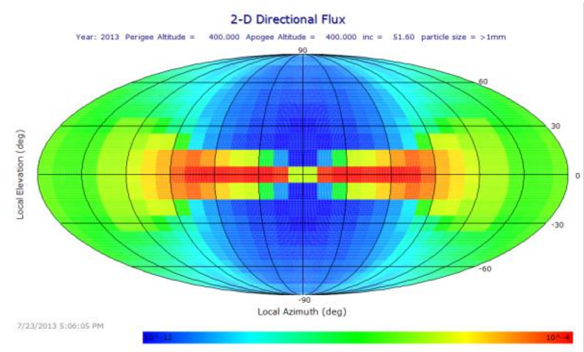
**A ~9 cm, 598-g projectile impacted DebrisLV at 6.9 km/s**

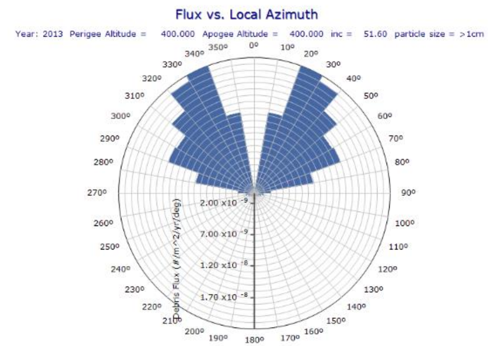


# ORDEM (1/2)

- **For satellite designers and users to estimate the orbital debris impact risks on their vehicles in Earth orbit**
  - 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**
  - The environment is dynamic and must be updated periodically
  - ORDEM is the end product of all of NASA and DoD's measurement and modeling activities - JSpOC catalog data, HUSIR/HAX/Goldstone radar data, MODEST telescope data, and *in situ* data from spacecraft (*e.g*., Shuttle) returned surfaces

# ORDEM (2/2)

- **ORDEM 3.0 covers the debris populations, from 10-μm to 10-m in size, from LEO to GEO**
  - A material density distribution is provided for different debris components (NaK, fragmentation, and degradation debris)
  - Uncertainties in the debris flux predictions are also included
- **Development of ORDEM 3.1 is underway**
  - Update debris populations with more recent measurement data
  - Is planned for release in December 2018
- **Future ORDEM will also incorporate the ES-MCAT, SDS, and DebriSat data**
  - Update debris populations with newer data
  - Explore the feasibility of adding a shape distribution and improving other model elements (material density, *etc*.)

# Looking Forward

- **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 DebriSat 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**