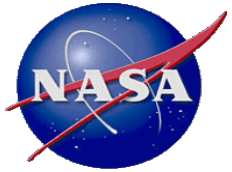
National Aeronautics and Space Administration



NASA's Measurement Activities

Radar, Optical, Laboratory Measurement Activities

Inter-Agency Space Debris Coordination Committee

IADC Working Group 1

April 16-19, 2024

National Aeronautics and Space Administration

Radar Measurements Status

Haystack Ultrawideband Satellite Imaging Radar (HUSIR)

Credit: Reprinted with permission Courtesy of MIT Lincoln Laboratory, Lexington, Massachusetts

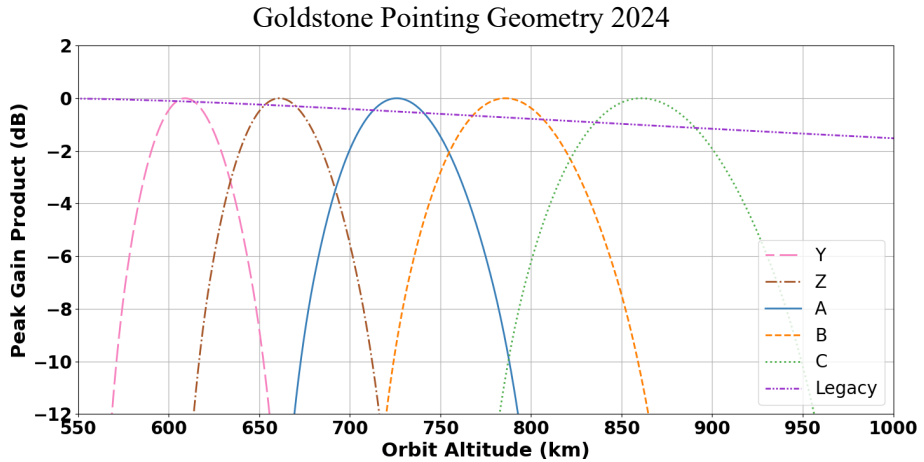
Goldstone Orbital Debris Radar

Credit: NASA/JPL-Caltech

Alyssa Manis, Ph.D.
NASA Orbital Debris Program Office
Radar and Optical Measurements Lead
alyssa.p.manis@nasa.gov

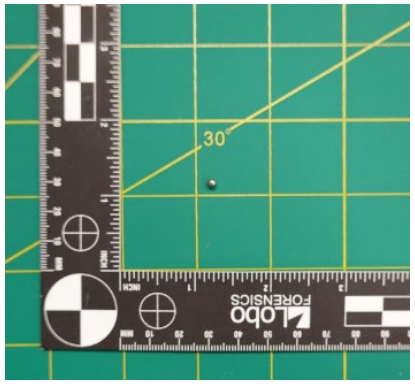
HUSIR/Goldstone Status

- **HUSIR hours of orbital debris (OD) data collected: ~407 in 2023, 70 in 2024 as of end of February**
  - HUSIR average transmitter power ~220 kW, sensitivity ~60 dB in 2023
  - Approximately 2/3 of data at 75° elevation, 90° azimuth (75E)
  - Approximately 1/3 split between 20° and 10° elevation, 180° azimuth (20S, 10S)
- **Goldstone Radar OD hours collected: ~302 in 2023, 48 in 2024 as of February**
  - Nearly 3 times as many hours collected in 2023 as in previous years, same planned for 2024
  - Goldstone average transmitter power ~360 kW in 2023, currently ~390 kW
  - Observation plan updated to five separate pointings to cover ~580 km – 975 km altitude
    - Previously used four different pointings to cover 660 km – 1100 km
      - Minimum completeness size of 2.2 mm at 1000 km altitude
  - New sawtooth waveform in development
  - Investigating capability for MEO observations

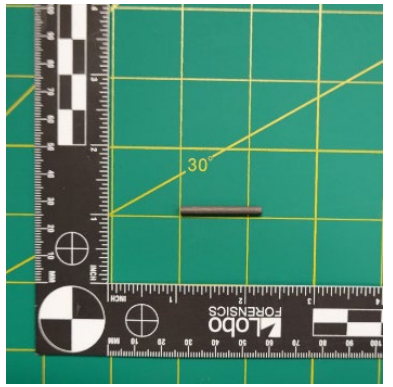


Other Radar Measurements

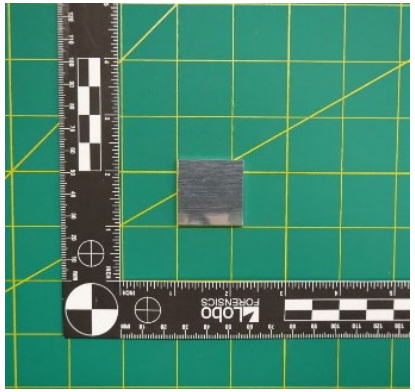
- **Laboratory Measurements**
  - Campaign to measure RCS of representative DebriSat fragments in radar range for updating the NASA Standard Satellite Breakup Model
  - Measurements of 16 calibration objects completed in the Ohio State University's ElectroScience Laboratory compact range
    - Represent sizes, materials, and shapes expected to be present in the subset of DebriSat fragments that will be chosen for future measurements
      - Sphere, plate, rod → Stainless steel, aluminum, CFRP, copper

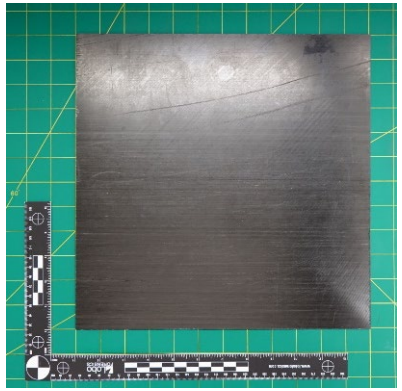


3 mm polished SS sphere

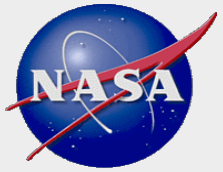


3 cm CFRP rod


3 cm polished Al square plate


30.48 cm unidirectional CFRP plate

Radar Measurements Publications

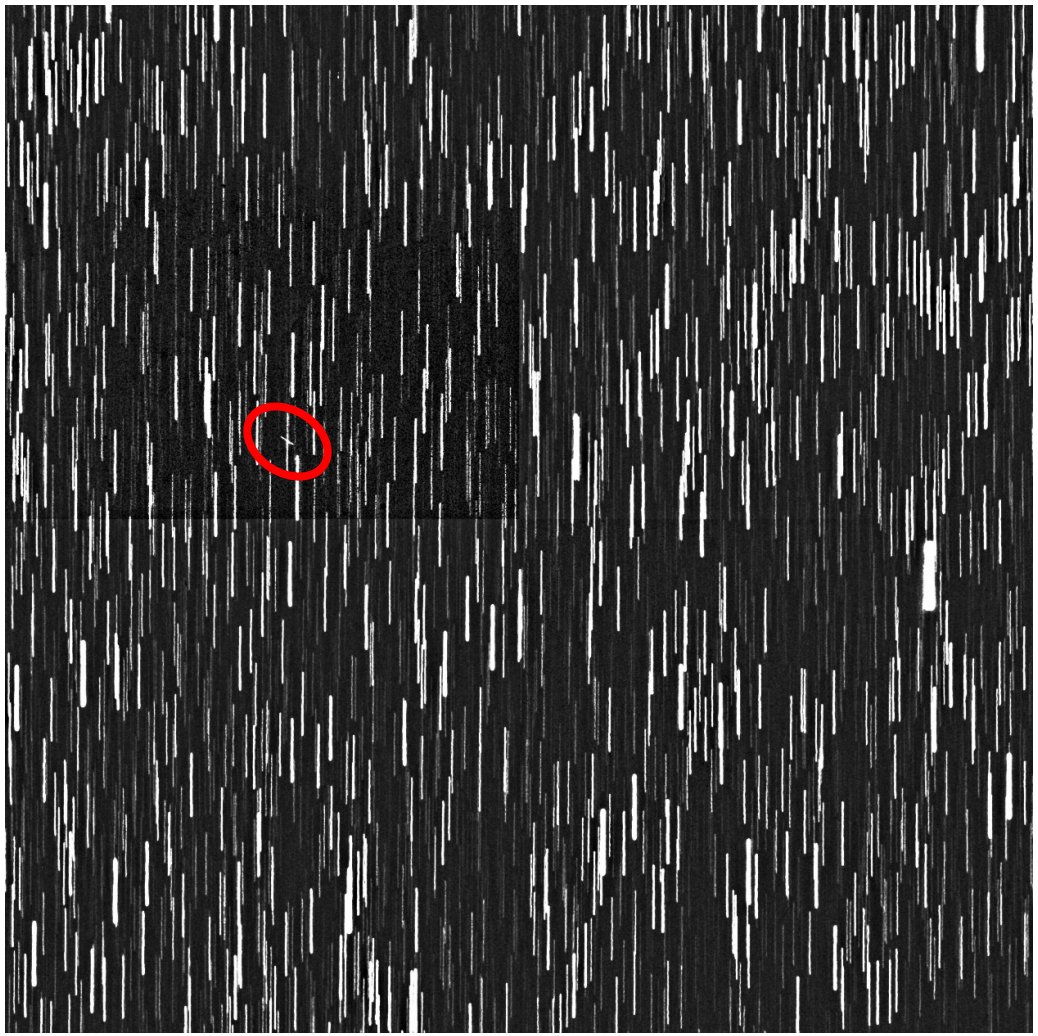


- **Publications**
  - An Overview of Ground-based Radar and Optical Measurements Utilized by the NASA Orbital Debris Program Office (IOC II)
    - https://www.hou.usra.edu/meetings/orbitaldebris2023/pdf/6045.pdf
  - Radar Measurements of Orbital Debris from the Haystack Ultra-wideband Satellite Imaging Radar (HUSIR): 2020-2021 (IOC II)
    - https://www.hou.usra.edu/meetings/orbitaldebris2023/pdf/6020.pdf
  - Optimizing Altitude Sampling and Sensitivity with the Goldstone Orbital Debris Radar
    - https://www.hou.usra.edu/meetings/orbitaldebris2023/pdf/6011.pdf
  - HUSIR Radar Measurements of the Orbital Debris Environment: 2022, October 2023
    - https://orbitaldebris.jsc.nasa.gov/quarterly-news/pdfs/ODQNv27i4.pdf
  - Goldstone Radar Measurements of the Orbital Debris Environment: 2022, February 2024
    - https://orbitaldebris.jsc.nasa.gov/quarterly-news/pdfs/ODQNv28i1.pdf

National Aeronautics and Space Administration

ES-MCAT Status

Credit: NASA



Credit: Ben Hanna

Eugene Stansbery-Meter Class Autonomous Telescope

(7° 58’ S; 14° 24’ W) ~350’ Elevation

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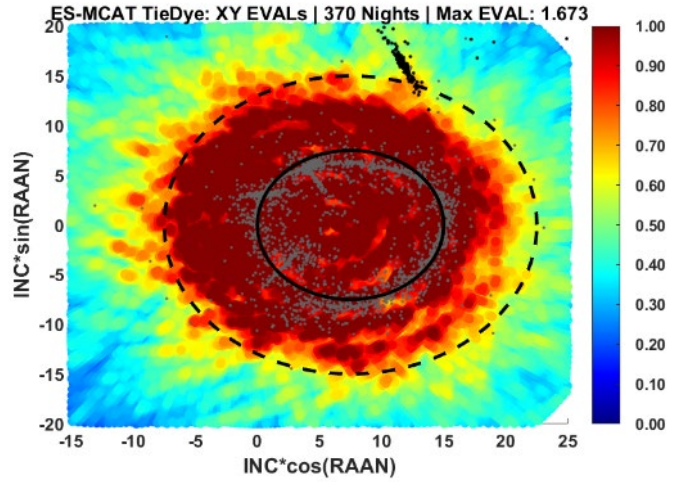
ES-MCAT Status

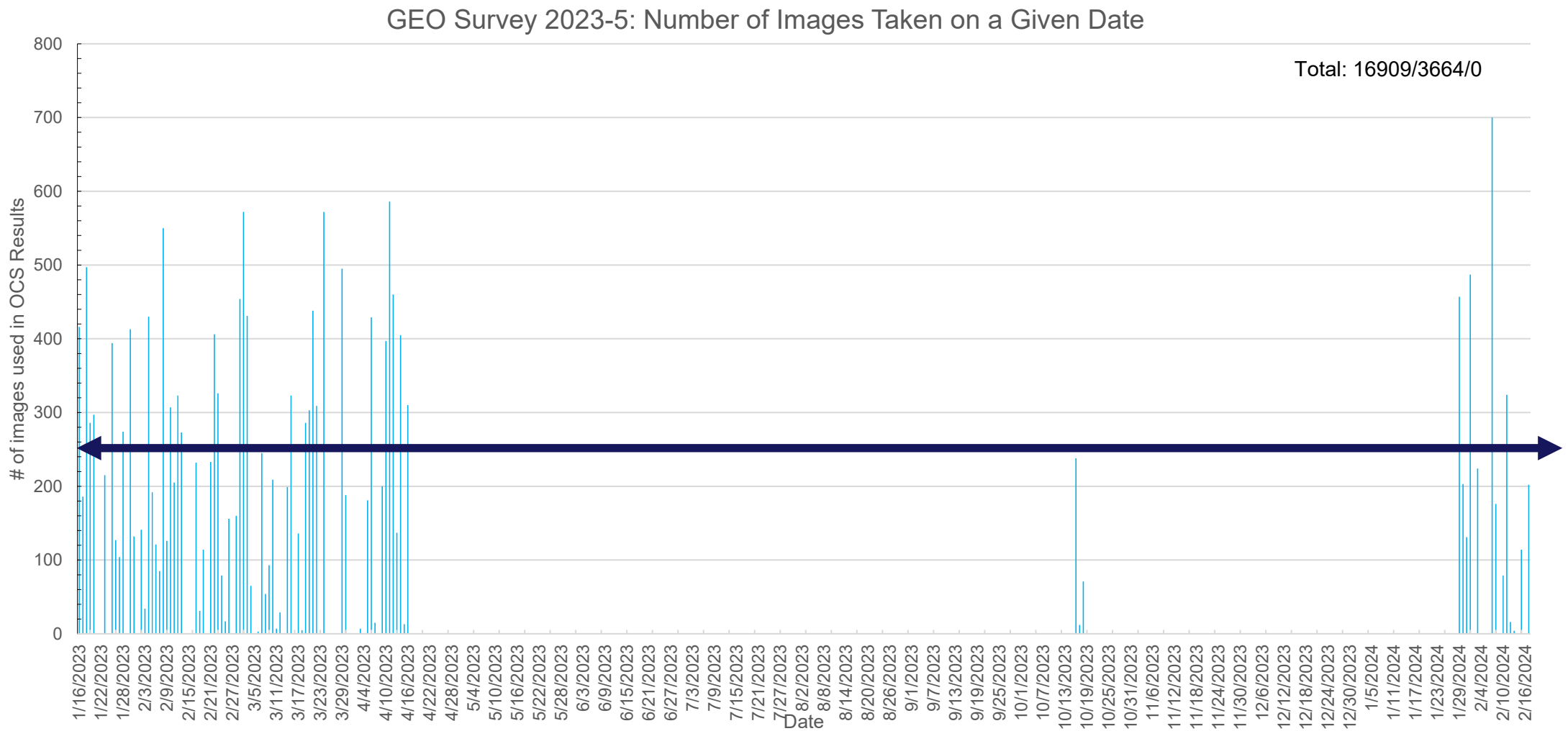
- **Second GEO survey began in January 2023**
  - Planned to continue until January 2025
  - Significant downtime in 2023 due to necessary facility repairs

Planned 2023-2025 survey coverage (avg weather)

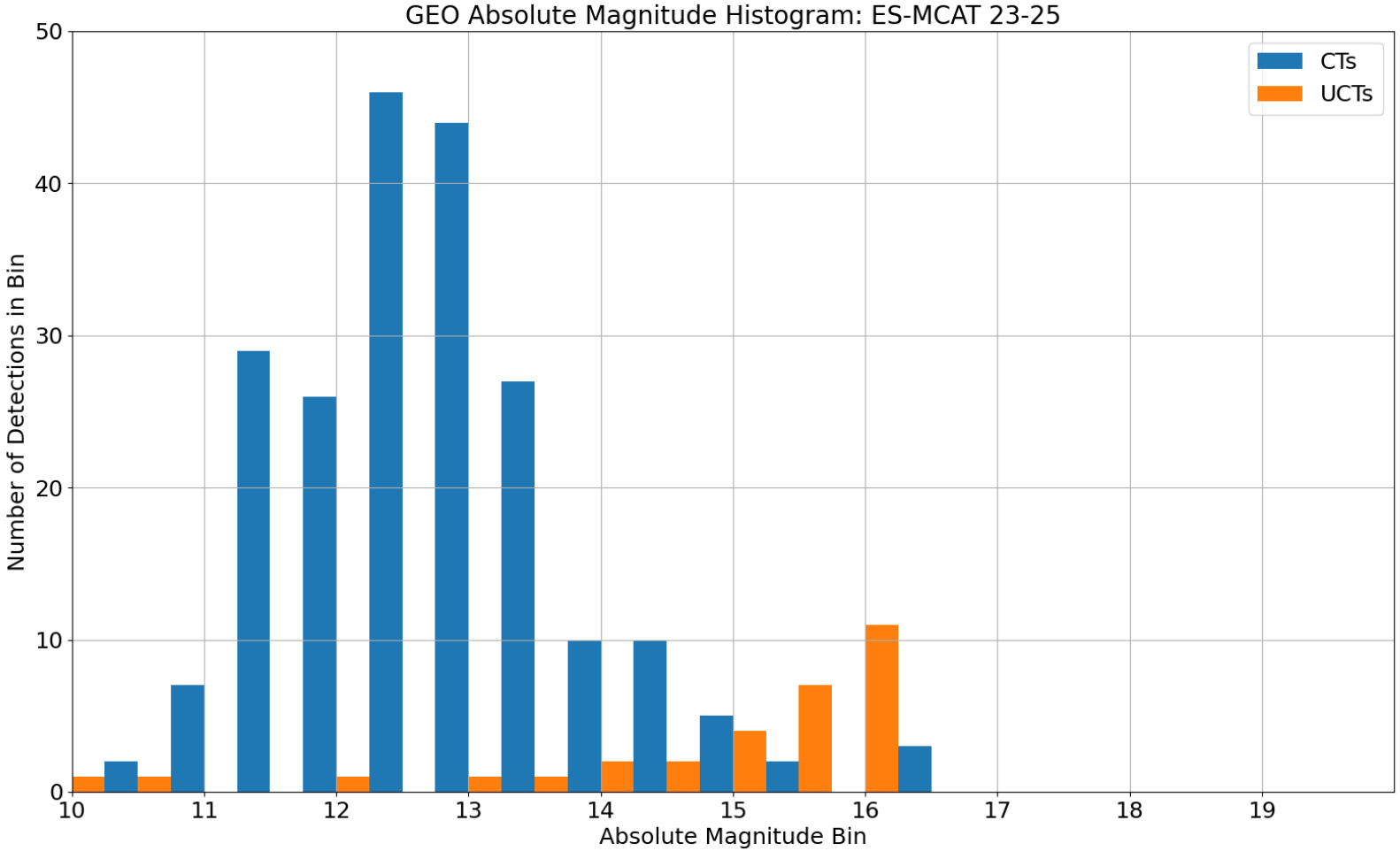


- **Publications**
  - An Overview of Ground-based Radar and Optical Measurements Utilized by the NASA Orbital Debris Program Office (IOC II)
    - https://www.hou.usra.edu/meetings/orbitaldebris2023/pdf/6045.pdf
  - The Completion of a Geosynchronous Earth Orbit Survey with the Eugene Stansbery-Meter Class Autonomous Telescope (IOC II)
    - https://www.hou.usra.edu/meetings/orbitaldebris2023/pdf/6153.pdf

UpTime of GEO Survey: 16 January 2023 – 20 February 2024

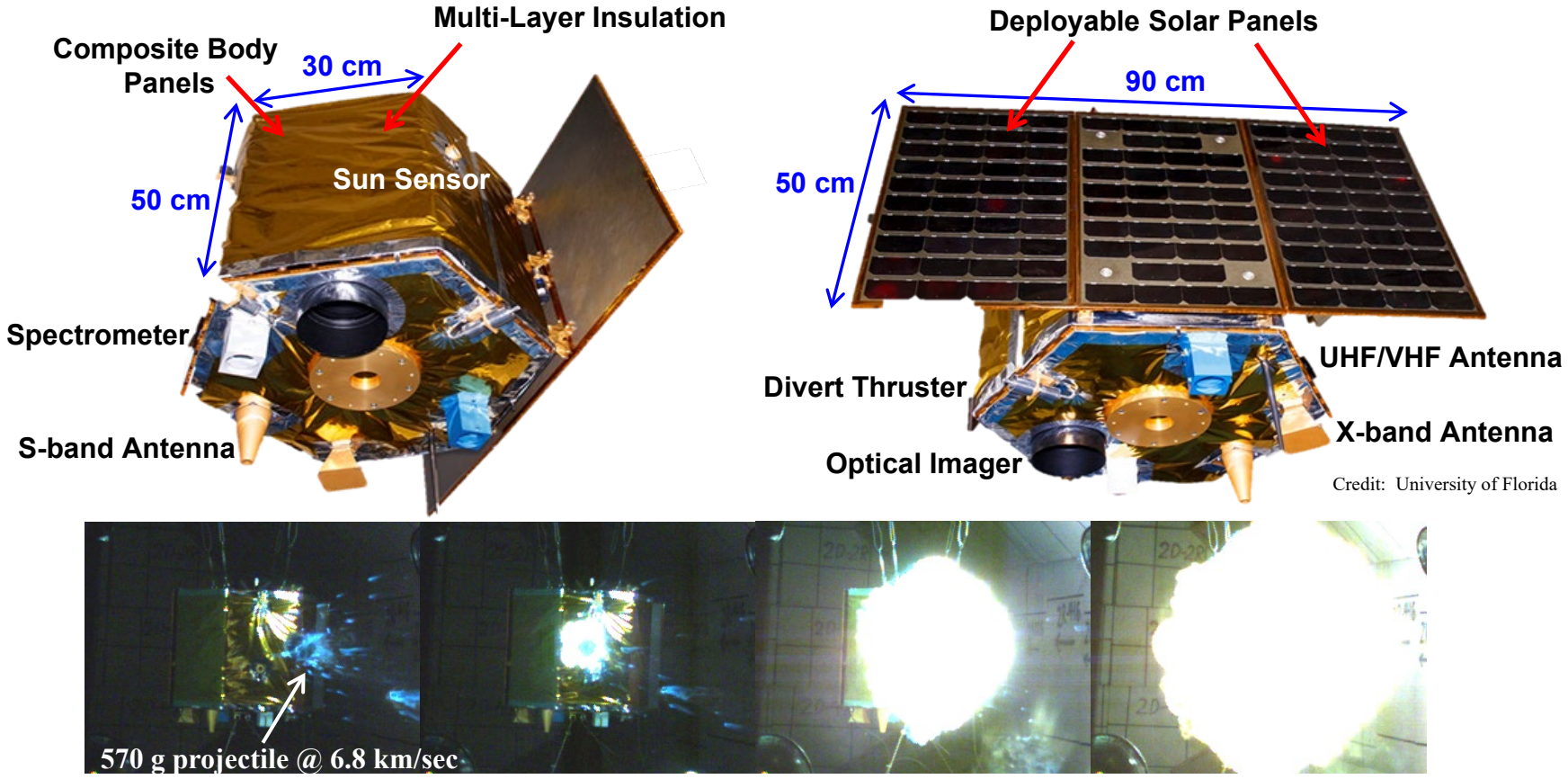


Magnitude Distributions



*Detections as of 16 April 2023

DebriSat Project Status



Credit: University of Florida

Credit: University of Florida

Credit: Arnold Engineering Development Complex/

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Orbital Debris and Hypervelocity Integration Portfolio Scientist
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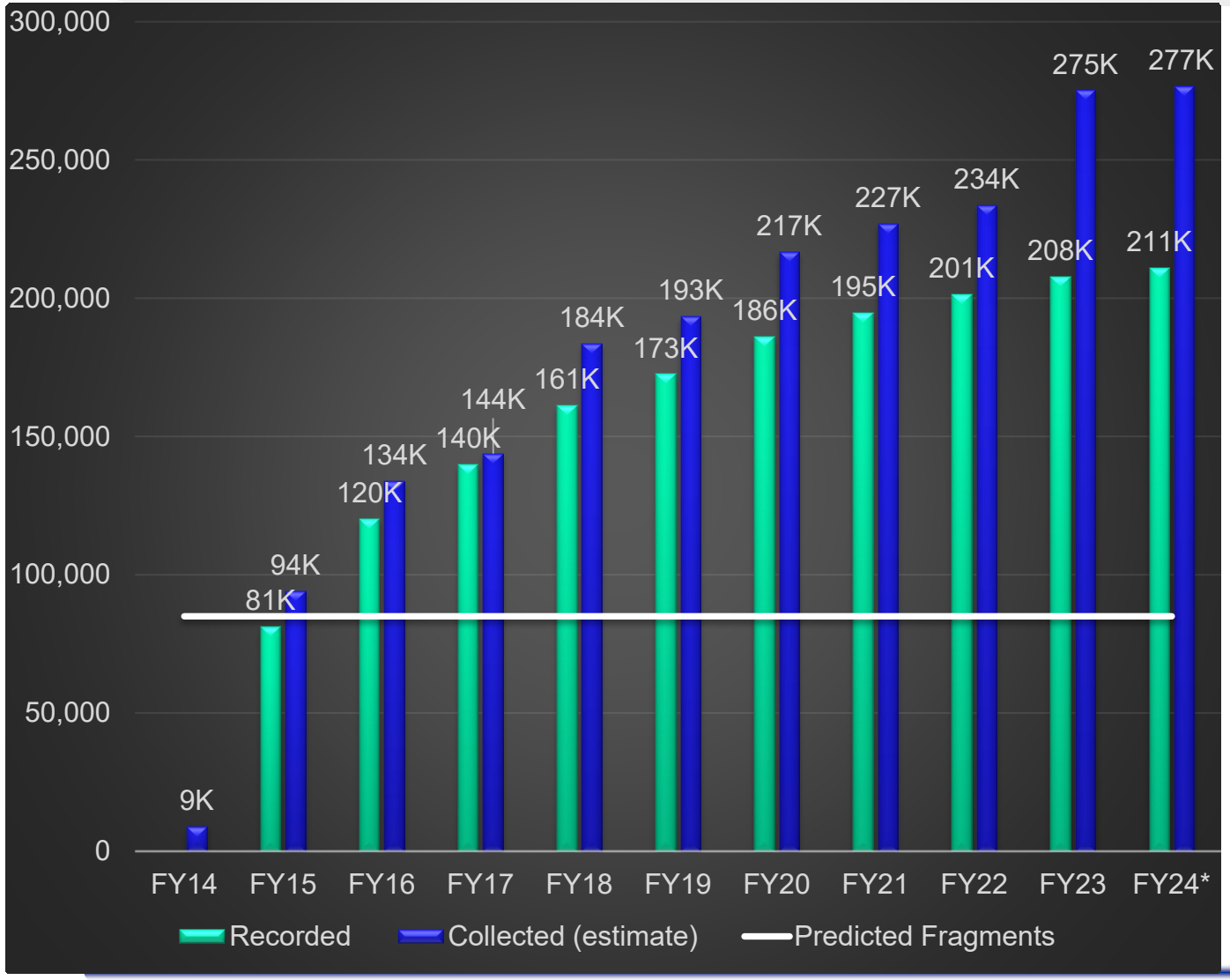
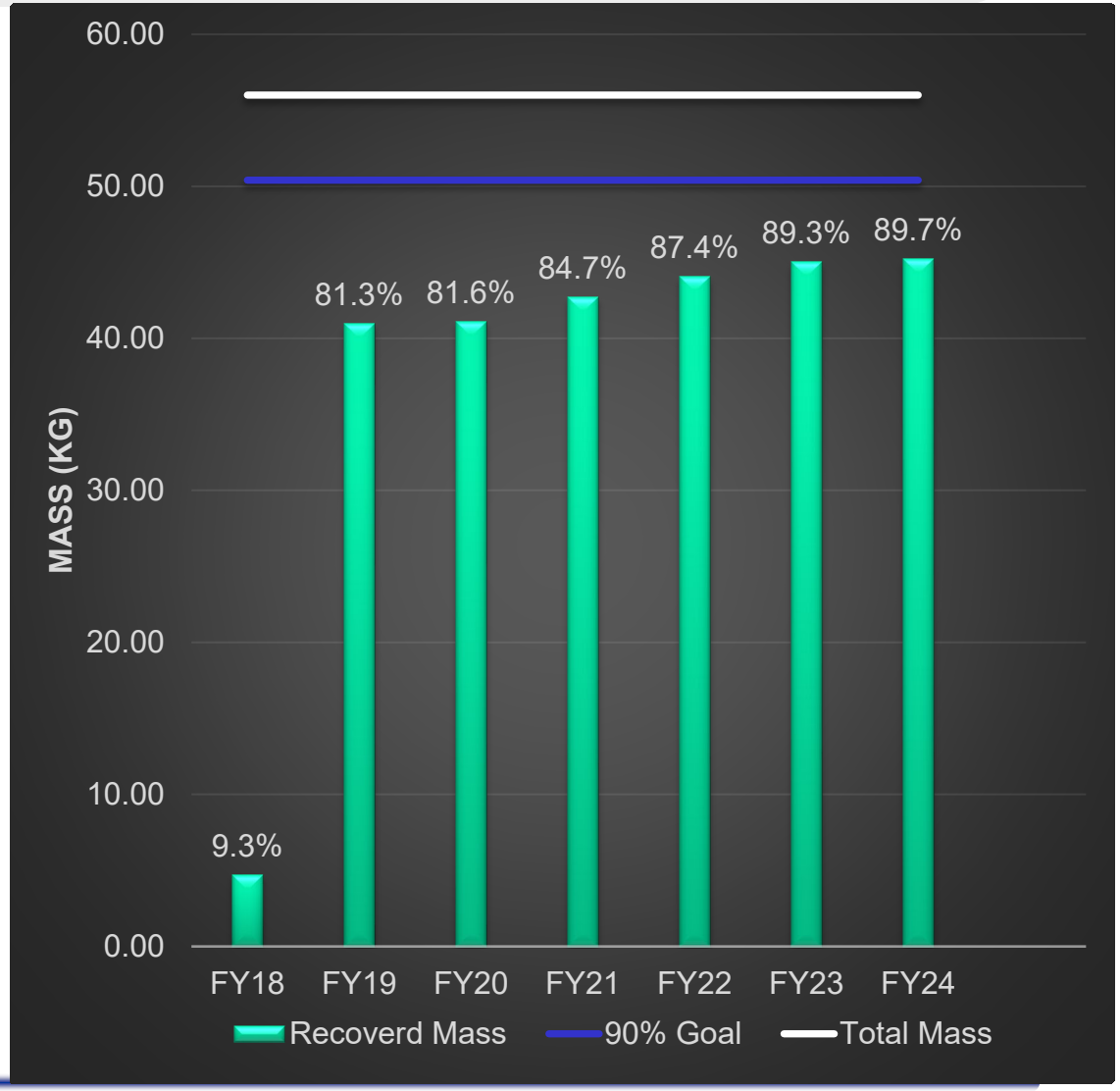
Metrics

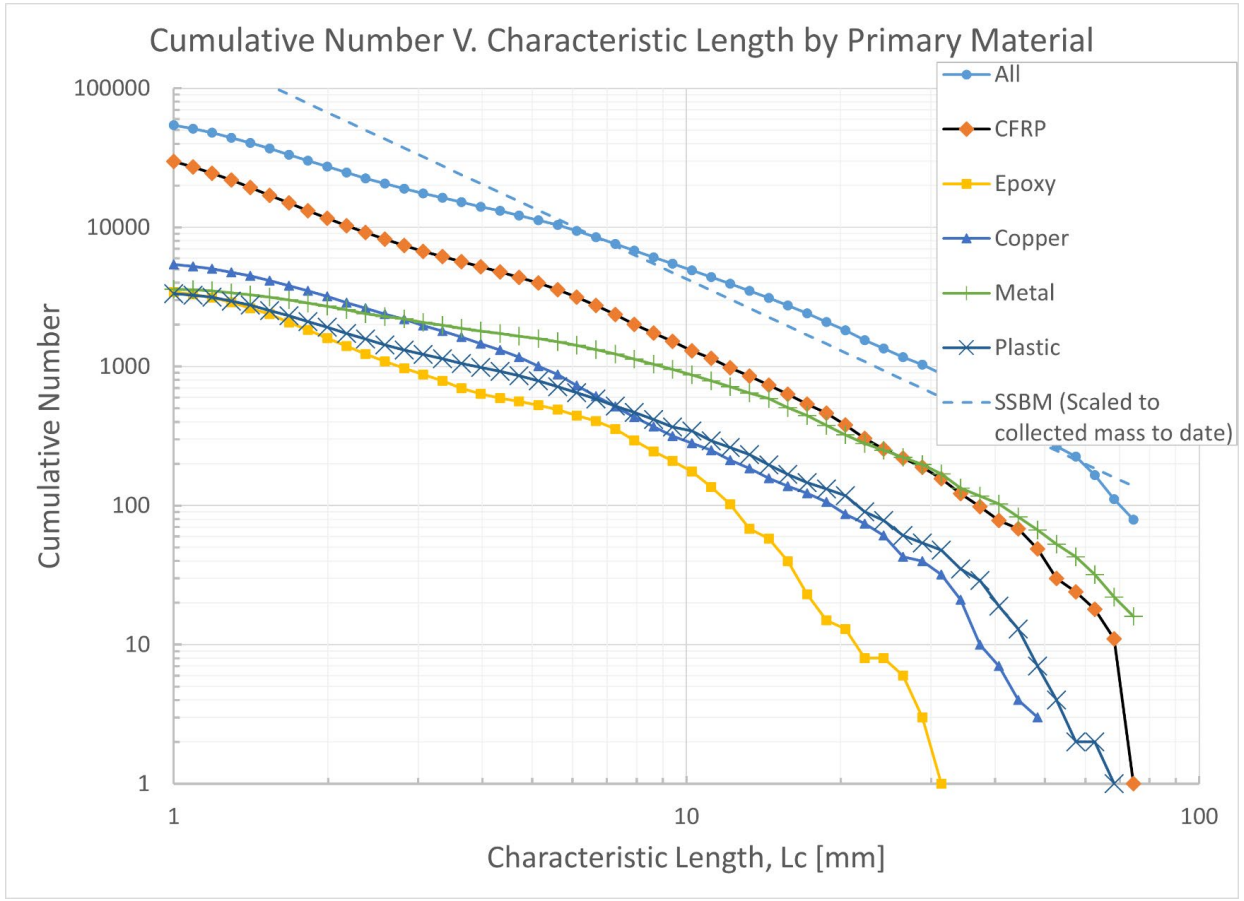


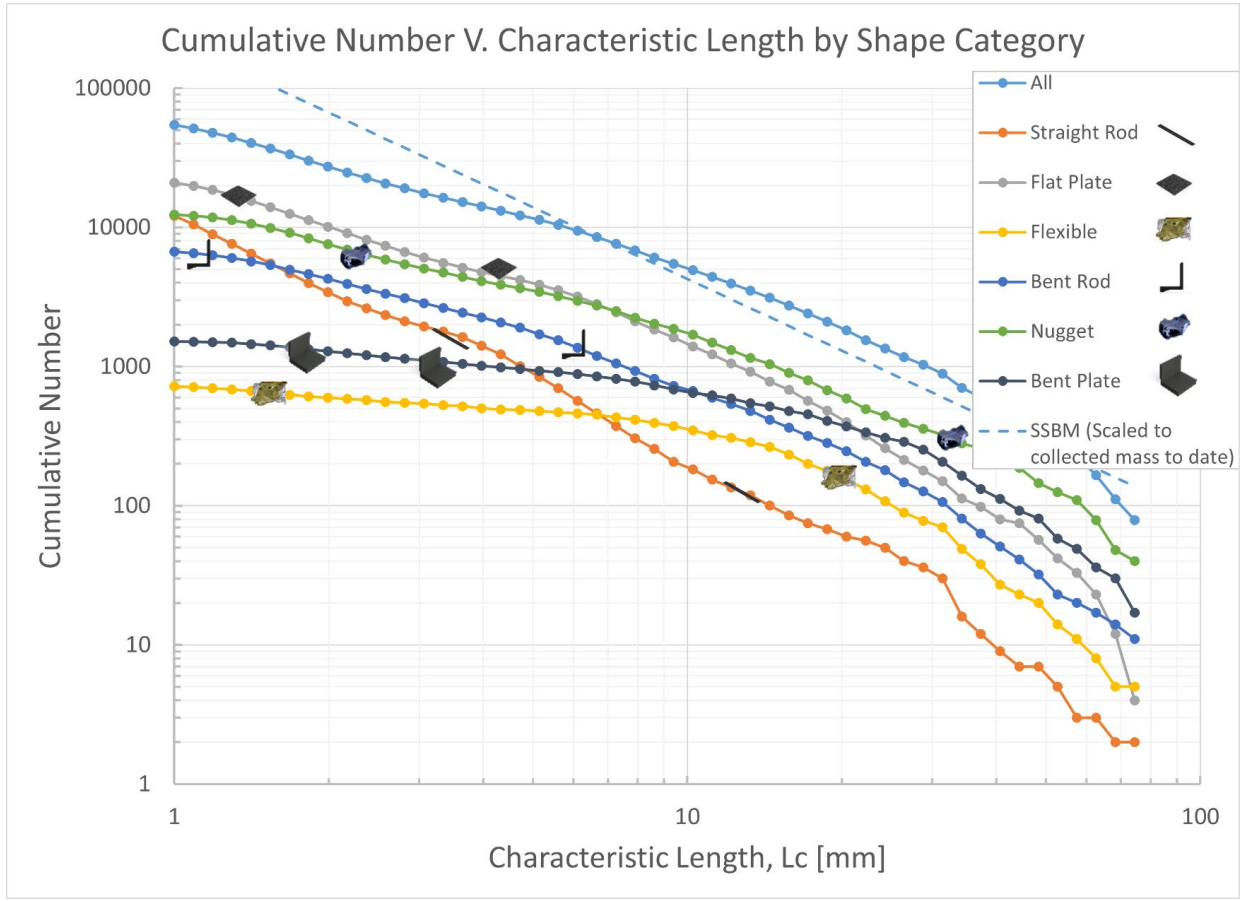


*Current as of (3/6/24)

Cumulative Number vs L_c (Materials and Shape)

Current as of 01 November 2023



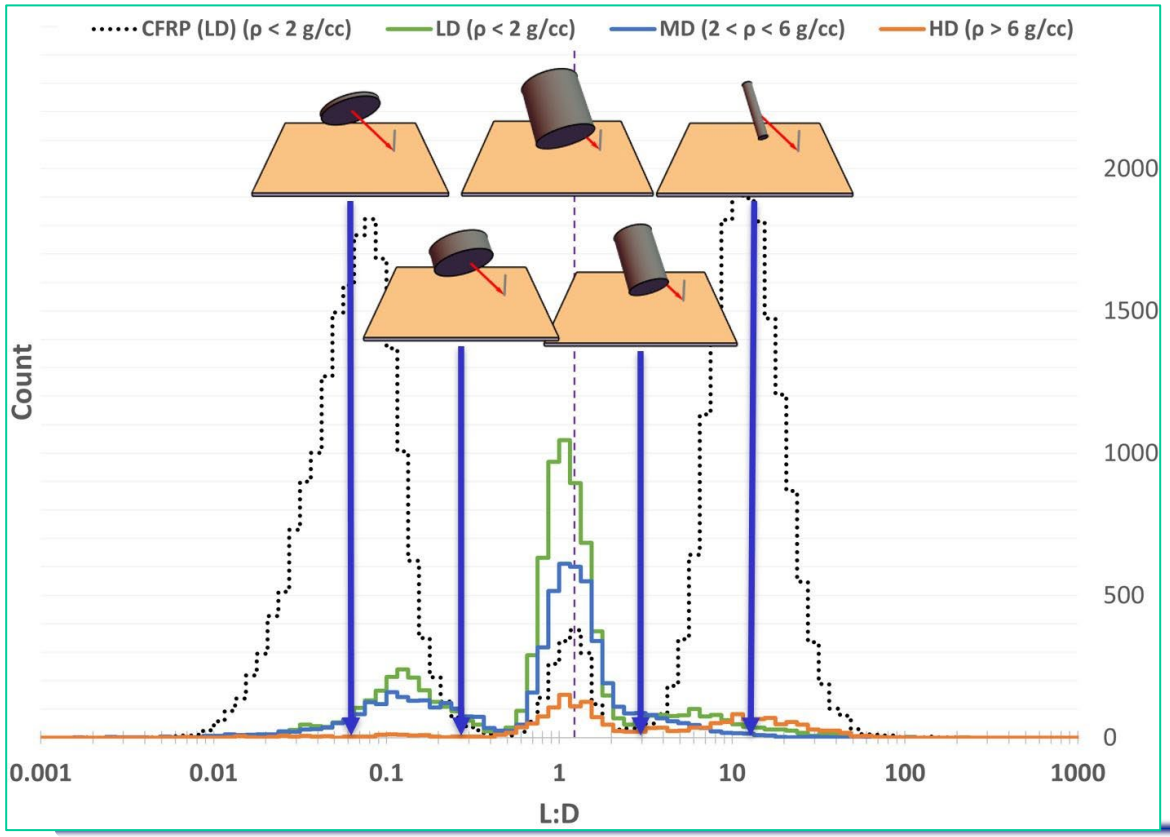


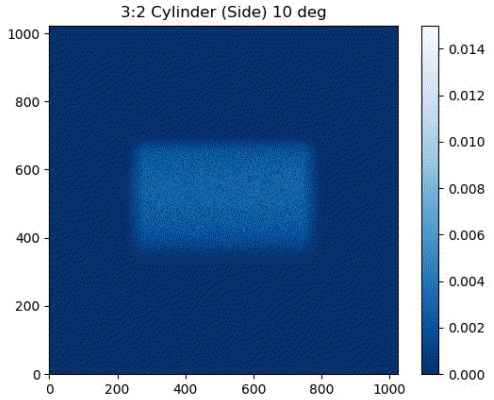
- Focus on larger fragments and verification
- > 30 mm fragments dominated by metal category; CFRP dominates small population
- Plates dominate shape category for smaller fragments, transition to nuggets ~7 mm
- Majority of all needle-like fragments are CFRP

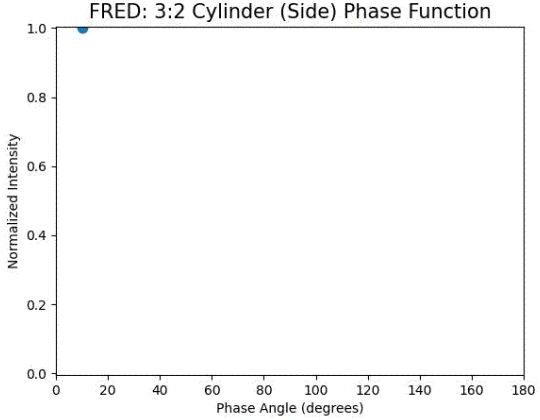
Shape Applications within Optical Measurement Center

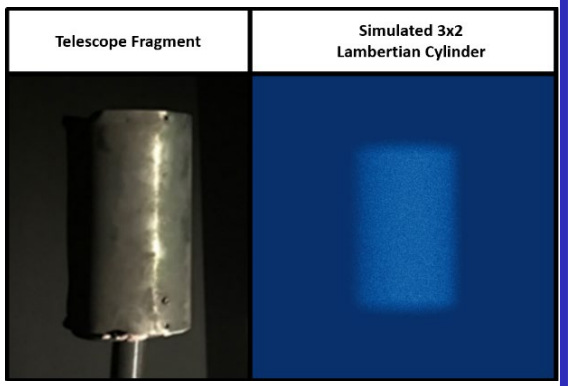
Right-Circular Cylinder (RCC) Approximations

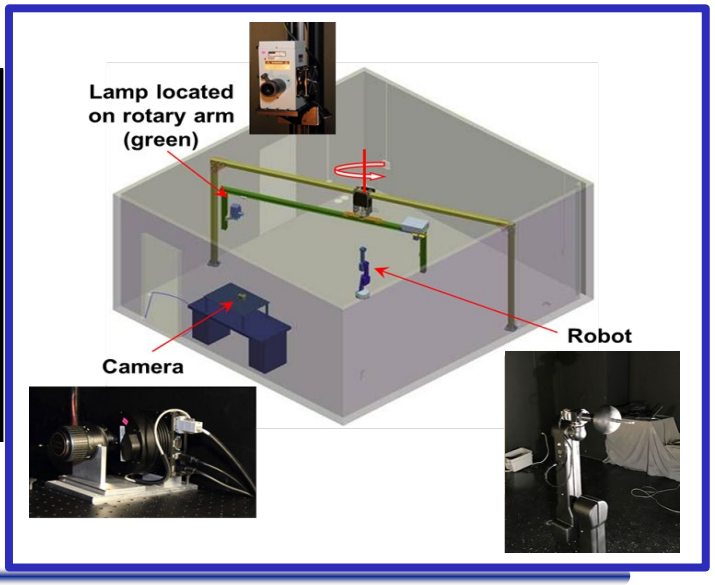
- 6 complex shapes now fit into 3 simplistic shapes
- Simplifies, using Length–to–Diameter ratios
- Able to physically test in hypervelocity impact tests
- Fits experimental impact tests' distributions well



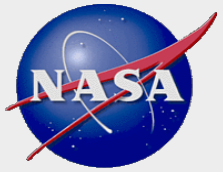








Recent DebriSat Publications



- **IOC II (*more available on website: https://www.hou.usra.edu/meetings/orbitaldebris2023/*)**
  - "Highlights of NASA's Orbital Debris Program Office In Situ and Laboratory Measurements"
    - https://www.hou.usra.edu/meetings/orbitaldebris2023/pdf/6101.pdf
  - "An Approach to Shape Parameterization Using Laboratory Hypervelocity Impact Experiments"
    - https://www.hou.usra.edu/meetings/orbitaldebris2023/pdf/6145.pdf
  - "Using Machine Learning to Infer Material Properties of Debris Fragments from X-ray Images in the DebriSat Project"
    - https://www.hou.usra.edu/meetings/orbitaldebris2023/pdf/6154.pdf
- **AMOS 2023**
  - "Orbital Debris Shape Effect Investigations for Mitigating Risk"
    - https://amostech.com/TechnicalPapers/2023/Space-Debris/Cowardin.pdf
- **International Journal of Impact Engineering**
  - "Updates on the DebriSat Hypervelocity Experiment and Characterization of Fragments in Support of Environmental Models"
    - https://doi.org/10.1016/j.ijimpeng.2023.104669