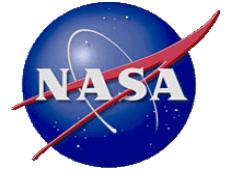


National Aeronautics and Space Administration



DebrisSat Project Status

Heather Cowardin, Ph.D.

Orbital Debris Research & Science Operations Manager

ODRSO Lead R&D

JACOBS JETS Contract

In support of the NASA Orbital Debris Program Office



*Presented at 37th Meeting of the IADC
7 to 10 May 2019 Rome, Italy*



Outline

- **DebrisSat Project Overview**
- **Status**
- **Plan Forward**





DebrisSat Project Team



JACOBS

- **NASA Orbital Debris Program Office (ODPO)**
 - Co-sponsor, project and technical oversight, data collection, data analyses, NASA model improvements



- **AF Space and Missile Systems Center (SMC)**
 - Co-sponsor, technical oversight



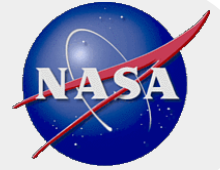
- **The Aerospace Corporation (Aerospace)**
 - DebrisSat design support, DebrisLV design & fabrication, data collection, data analyses, DoD model improvements



- **University of Florida (UF)**
 - DebrisSat design & fabrication, data collection, fragment processing and characterization

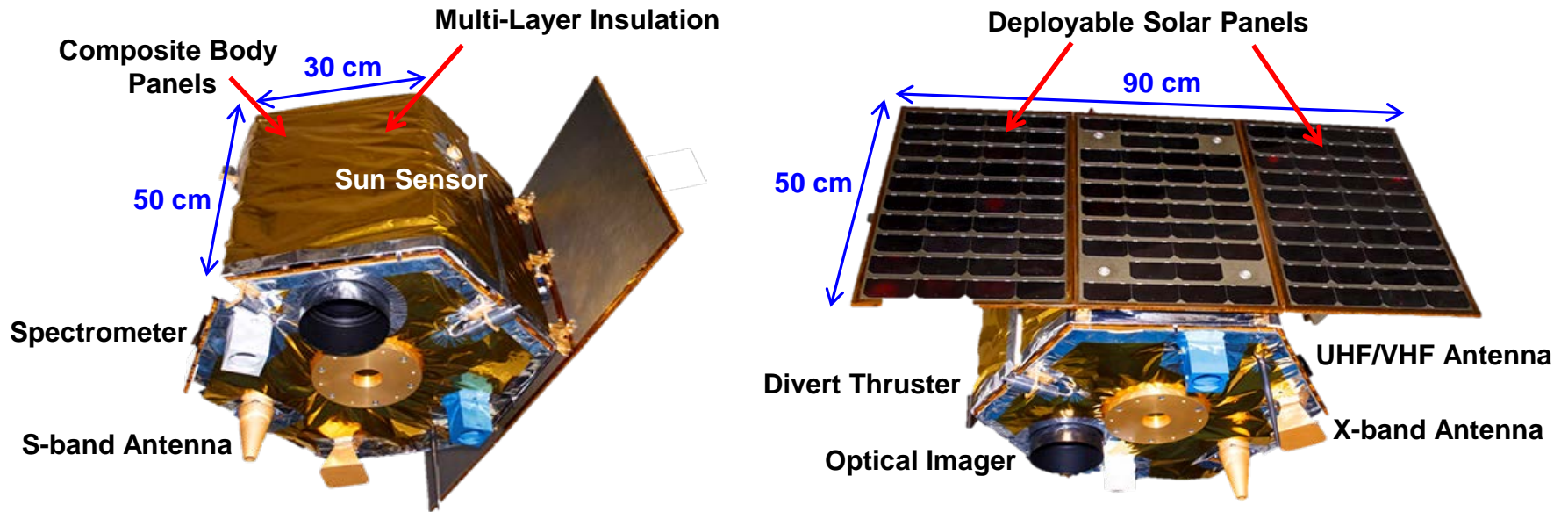


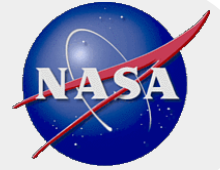
- **AF Arnold Engineering Development Complex (AEDC)**
 - Hypervelocity impact tests



Brief Intro

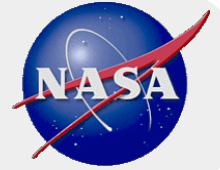
- The purpose of the DebrisSat project is to replicate a hyper-velocity fragmentation event using modern-day spacecraft materials and construction techniques to better improve the existing DoD and NASA breakup models





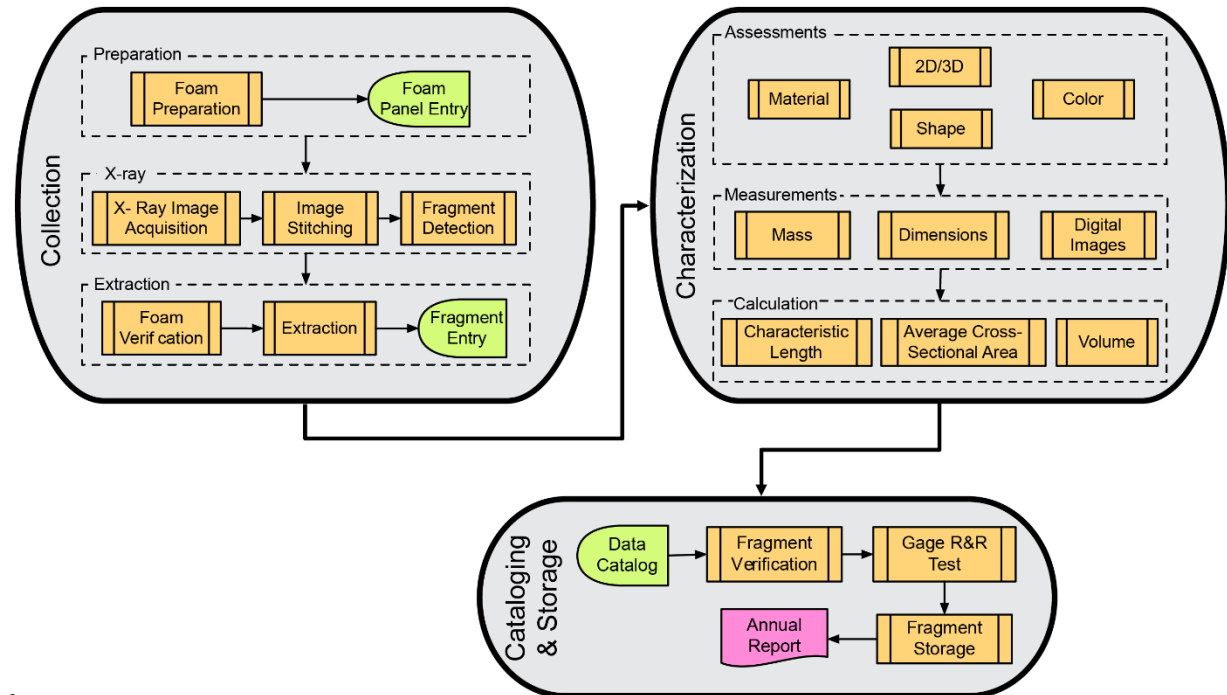
DebrisSat Project Motivation

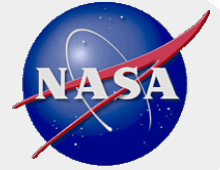
- **The need for laboratory-based impact tests was recognized by DoD and NASA decades ago**
- **Key impact test series, Satellite Orbital Debris Characterization Impact Test (SOCIT) was conducted by the Department of Defense (DOD) and NASA at AEDC in 1992 to support the development of satellite breakup models**
- **Breakup models based on SOCIT have supported many applications over the years**
- **As new materials and construction techniques are developed for modern satellites, there is a need for new laboratory-based tests to acquire data to improve the existing DoD and NASA breakup models and support space situational awareness (SSA) applications**



Fragment Characterization Plan

- **Collect, measure, and characterize all fragments, including MLI and solar panel pieces, down to ~2 mm in size**
- **Conduct radar, photometric, and spectral measurements for selected fragments**
 - Support improvements to radar and optical size-estimation models





DebrisSat Project Milestones

Collection-Characterization-Application

2014-present

- Fragment processing and characterization

Sep 2016

- Delivery of first set of measurement data

2016-2017

- Initial data analyses for model improvements

2018-2019

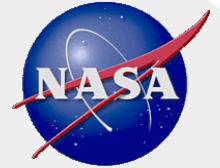
- Fragment radar and optical measurements

Sep 2020

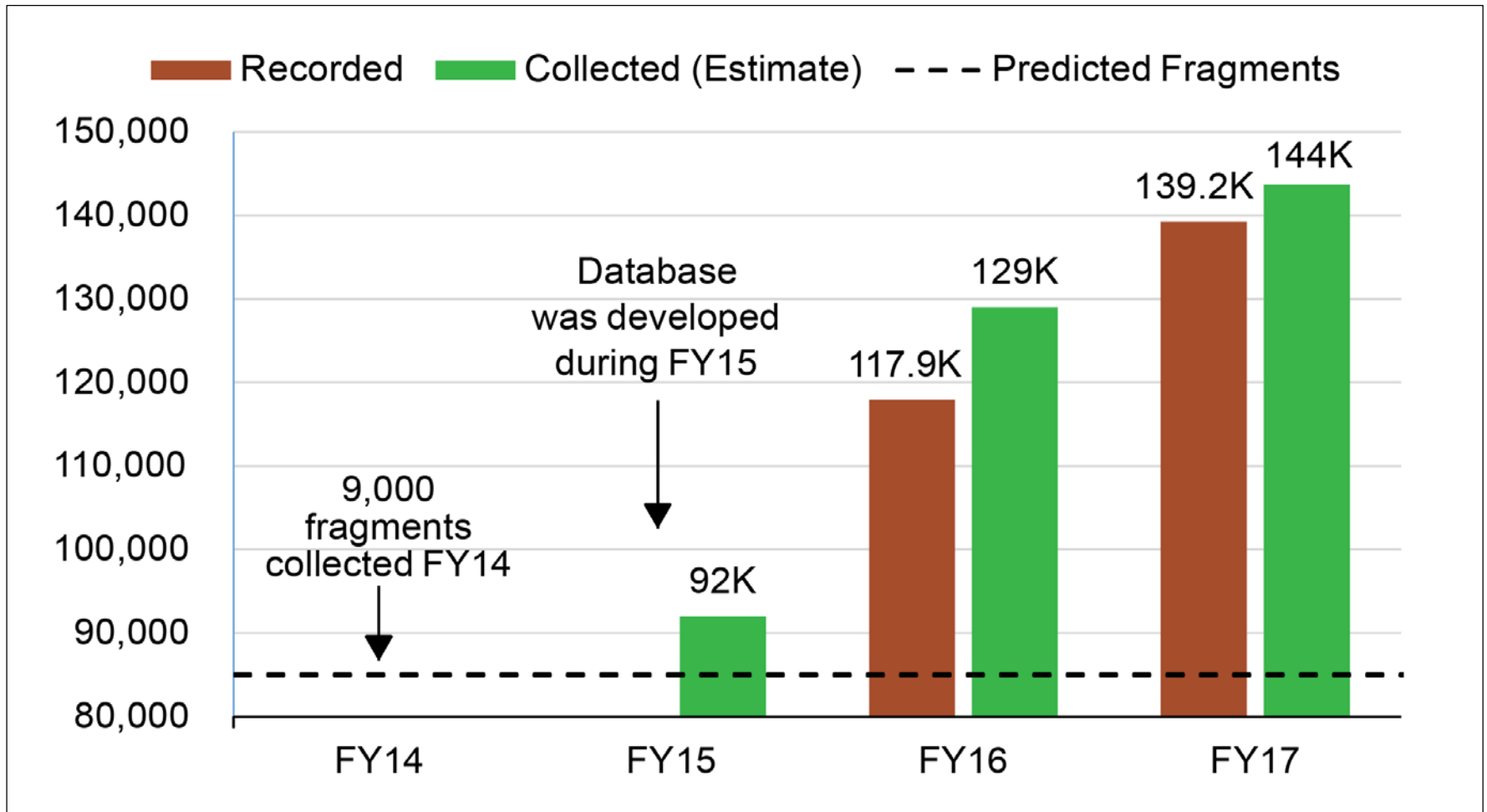
- Complete measurement data

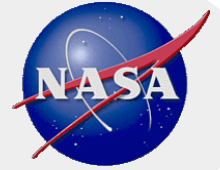
2018-2020

- Debris model and SSA application updates

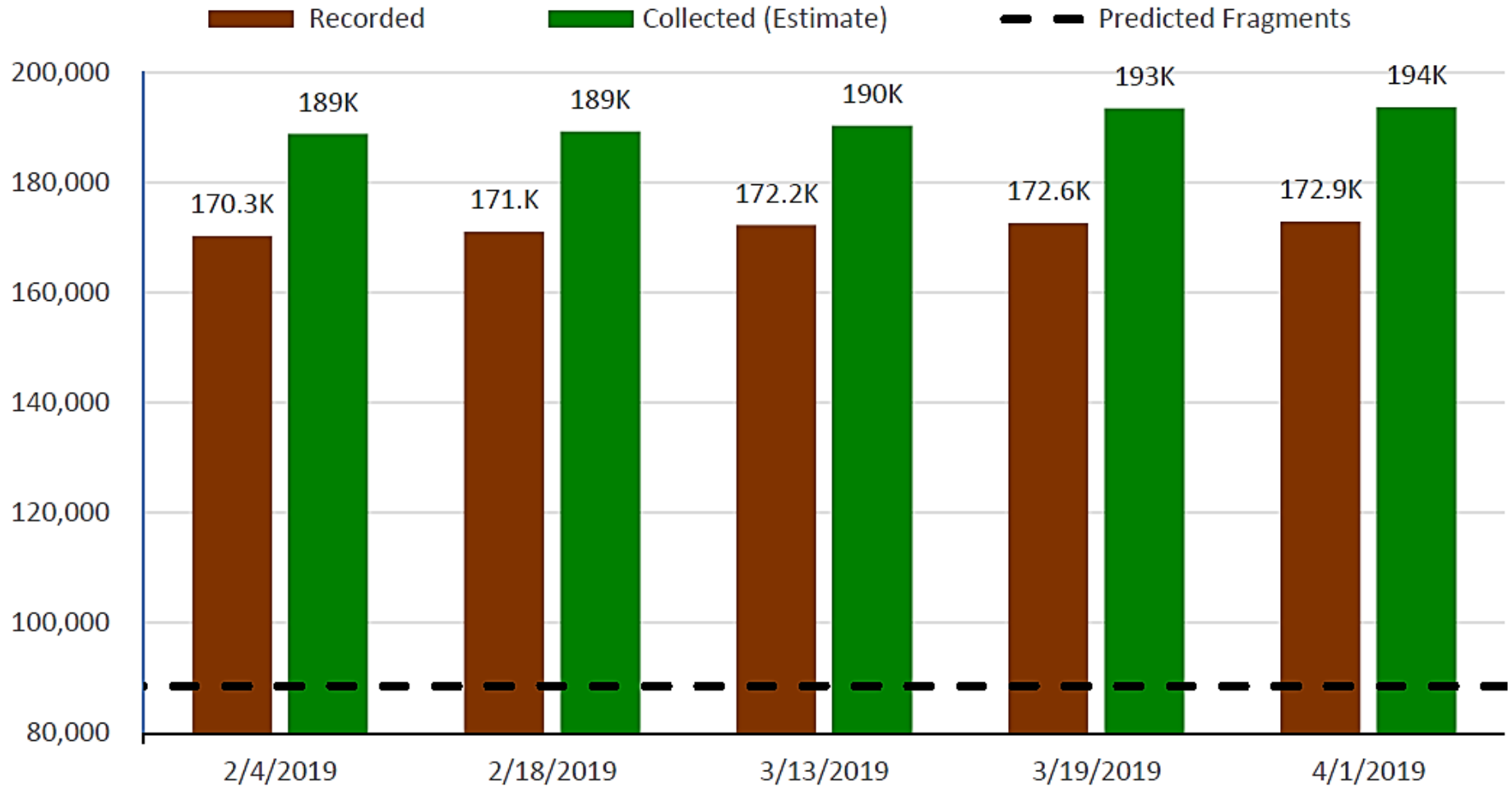


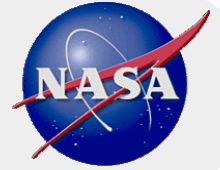
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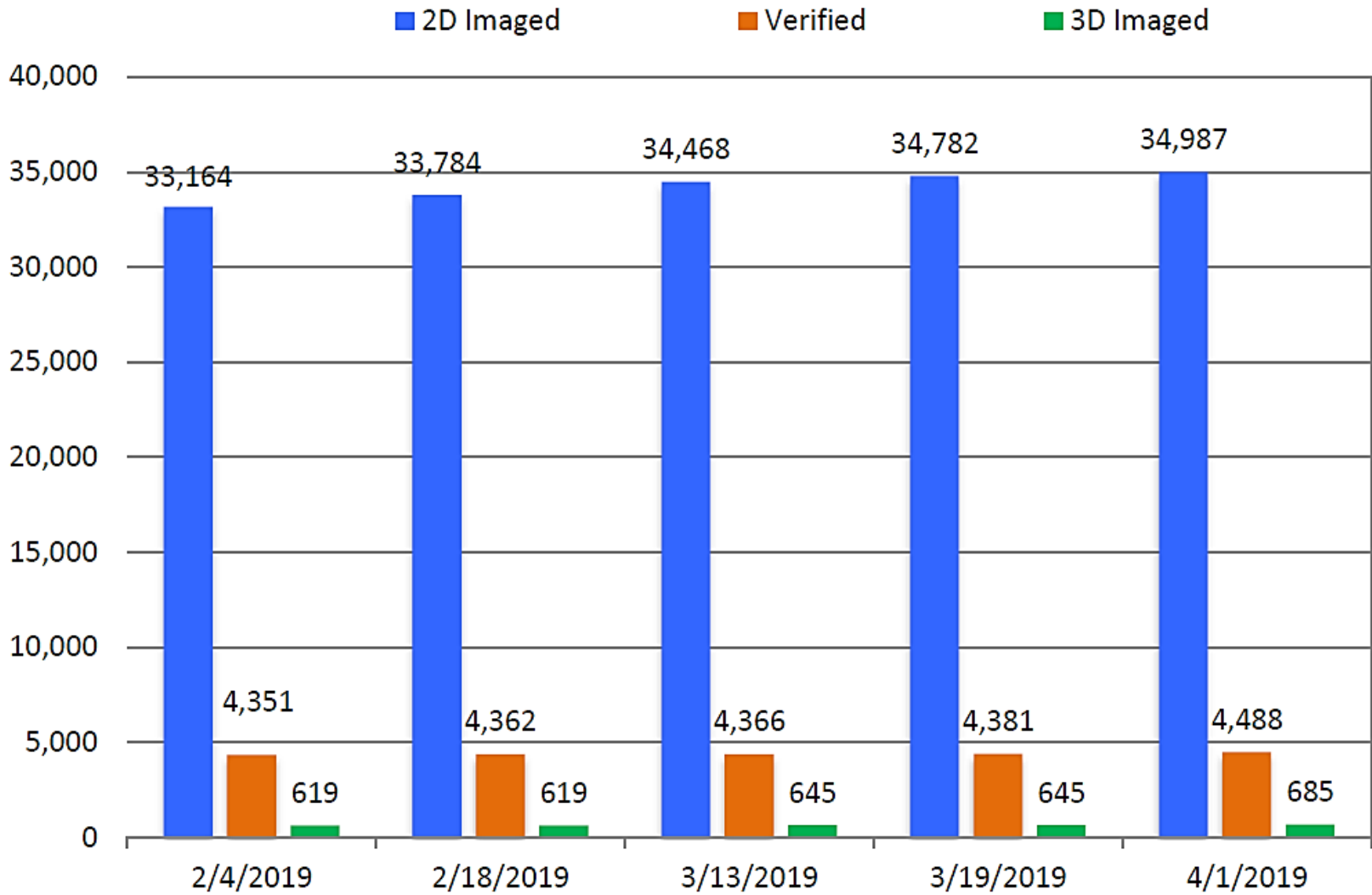


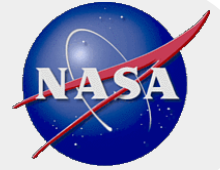
Status- Recorded/Collected



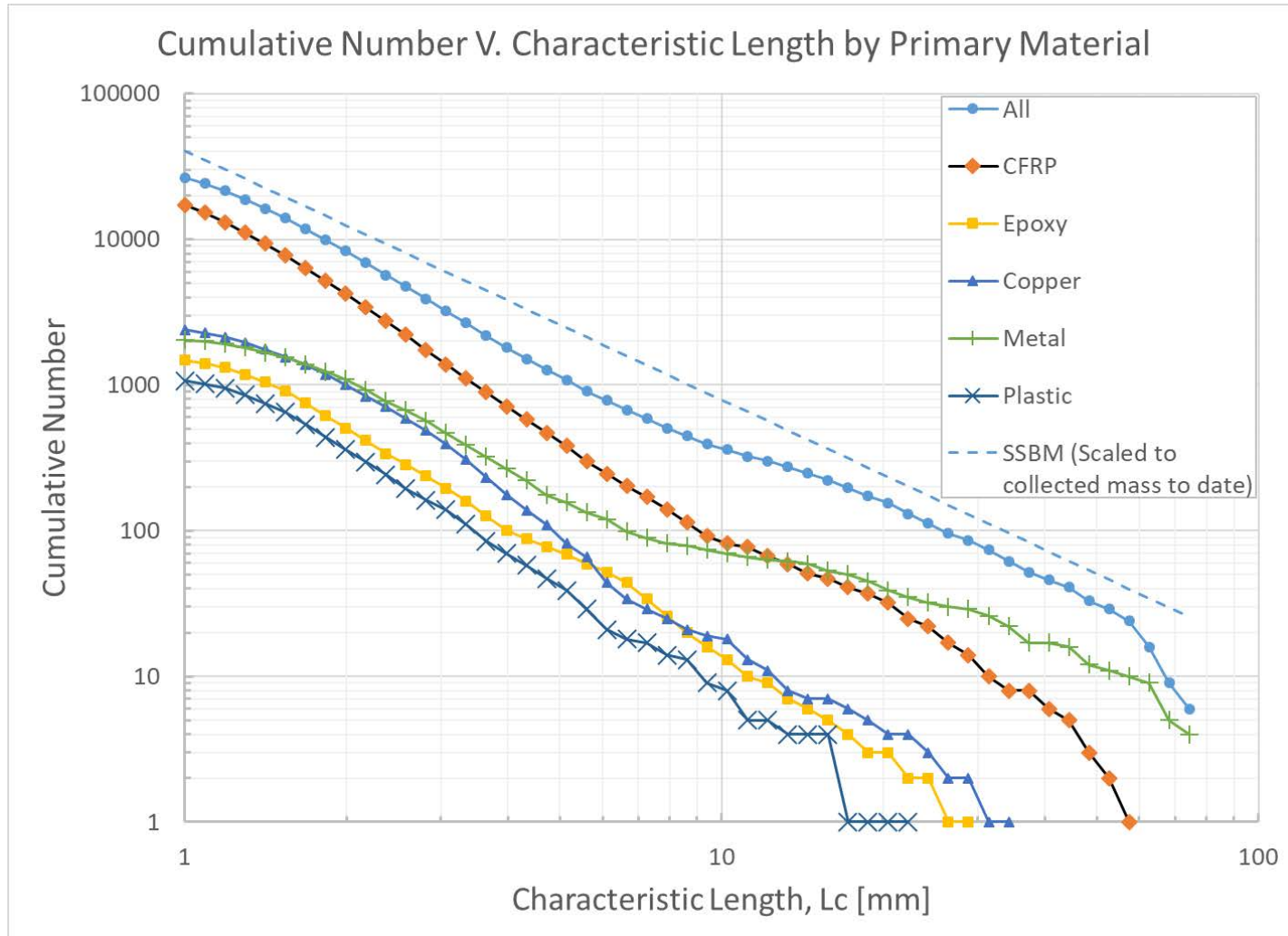


Status-2D/3D

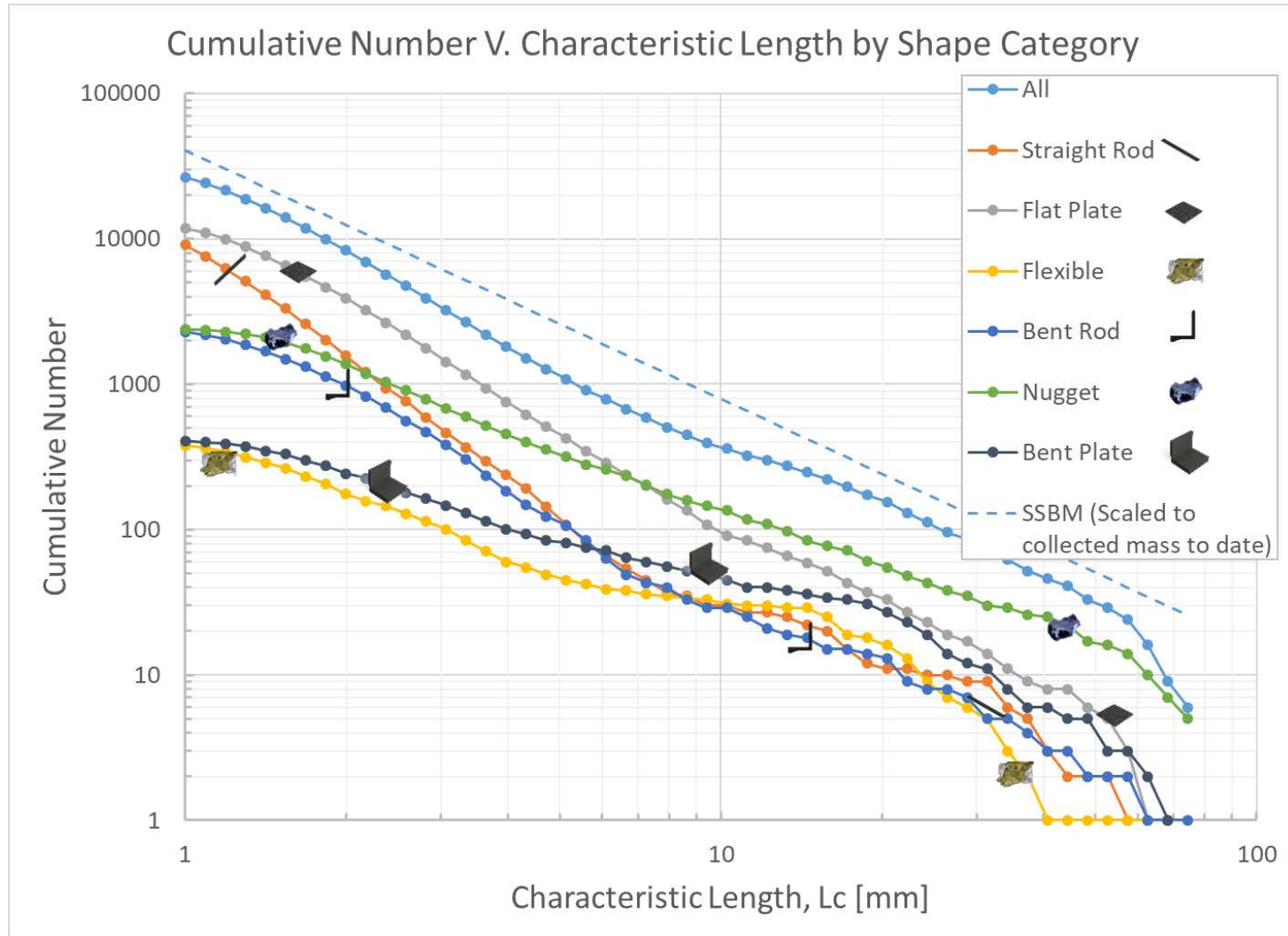
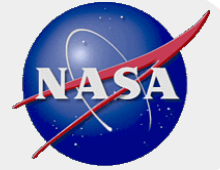




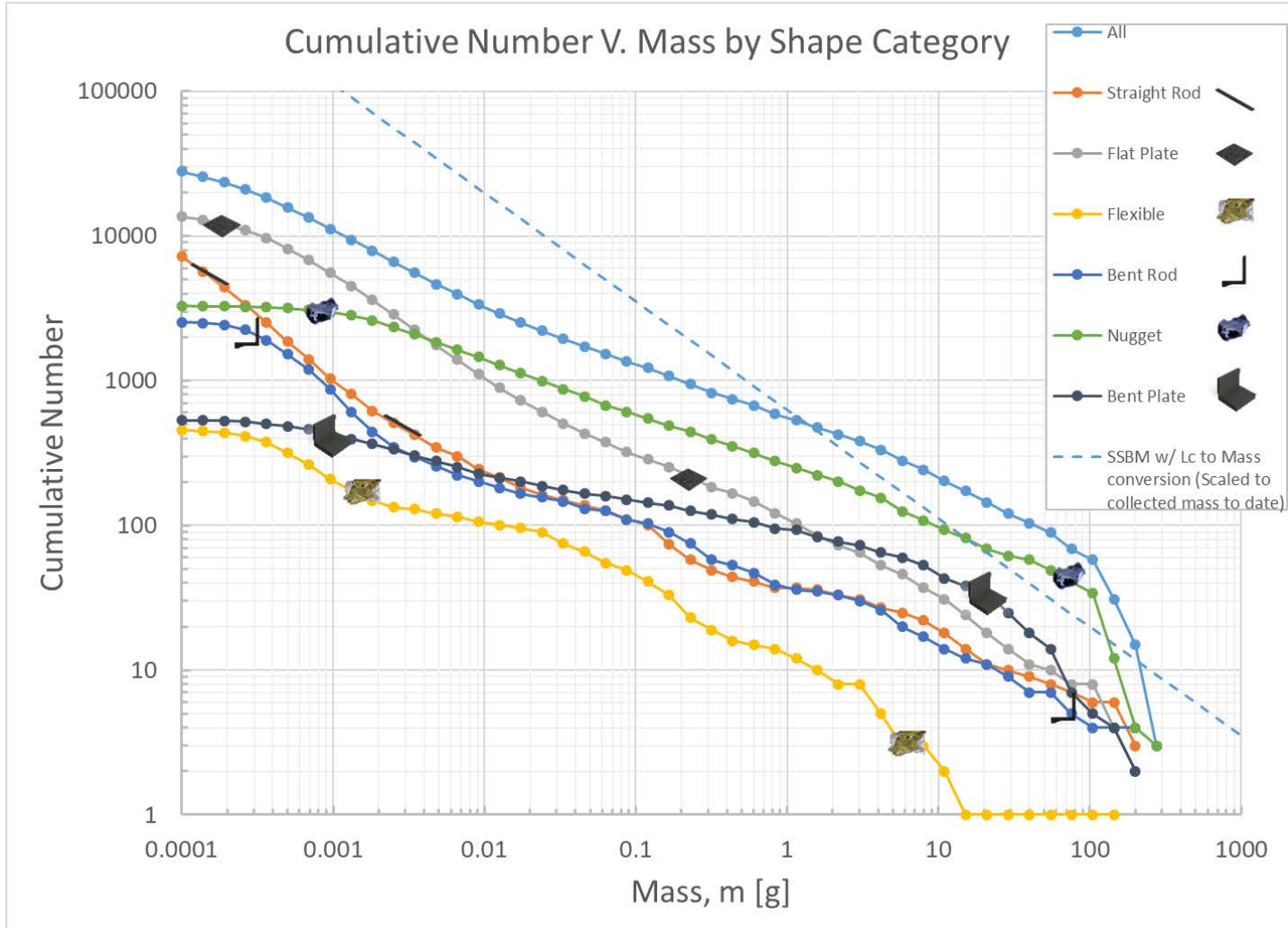
Status- Size as of 01/23/2019

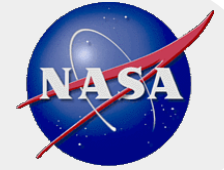


Status-Shape as function of L_c as of 01/23/2019



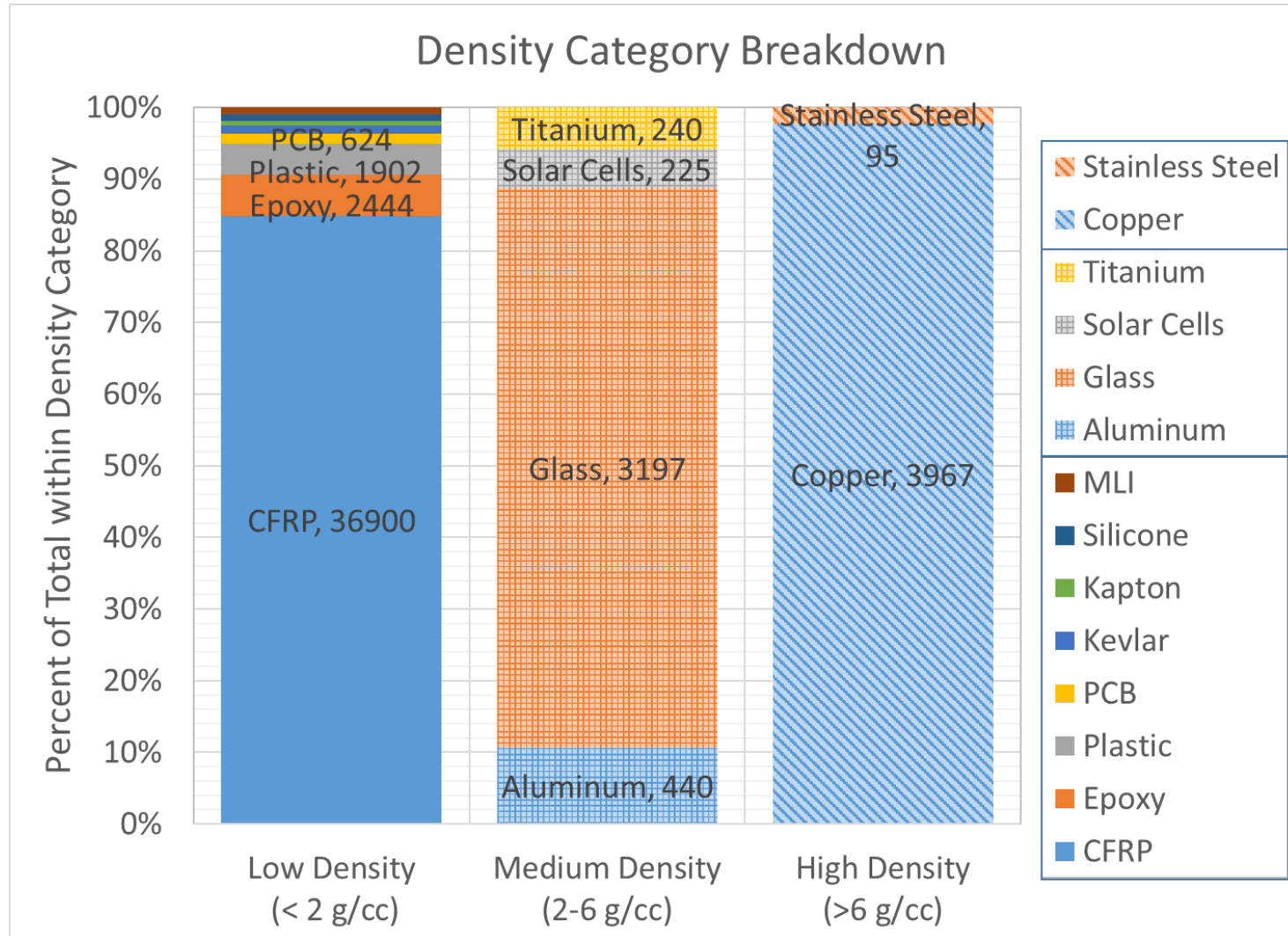
Status-Shape as function of Mass as of 01/23/2019

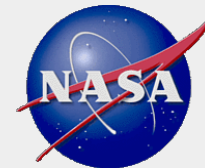




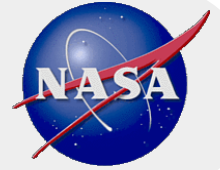
Status-Density

as of 01/23/2019





Plan Forward- Prepping for Next Measurements

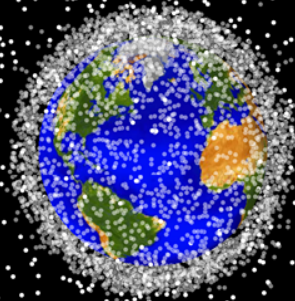
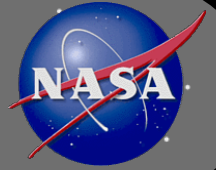


Next steps- near term

- **On-going research focus**
 - Current data is heavily biased towards CFRP, focus on larger fragments
 - Using X-ray imagery to extract number of fragments in intact soft catch panels
 - Mass all 3D fragments
 - Collect subset of fragments to collect laboratory-based optical measurements and radar measurements to compare optical inferred sizes and radar cross sections
 - Data will be used in the development of ORDEM 4.0

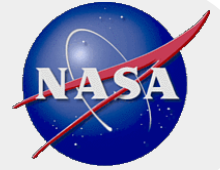
- **Continue investigating non-spherical projectiles with various densities improve damage equations**
 - HVI test program, in support of the Orbital Debris Program Office (ODPO), is investigating the damage characteristics of non-spherical particle impacts into US lab type whipple shields.
 - Projectile = Al 2024-T3 non-spherical projectiles; Velocity = 7 km/s; Impact angle = 0°

Thank you





Back-Up

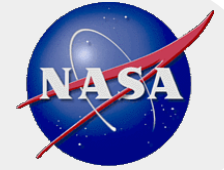


Previous Laboratory Impact Test

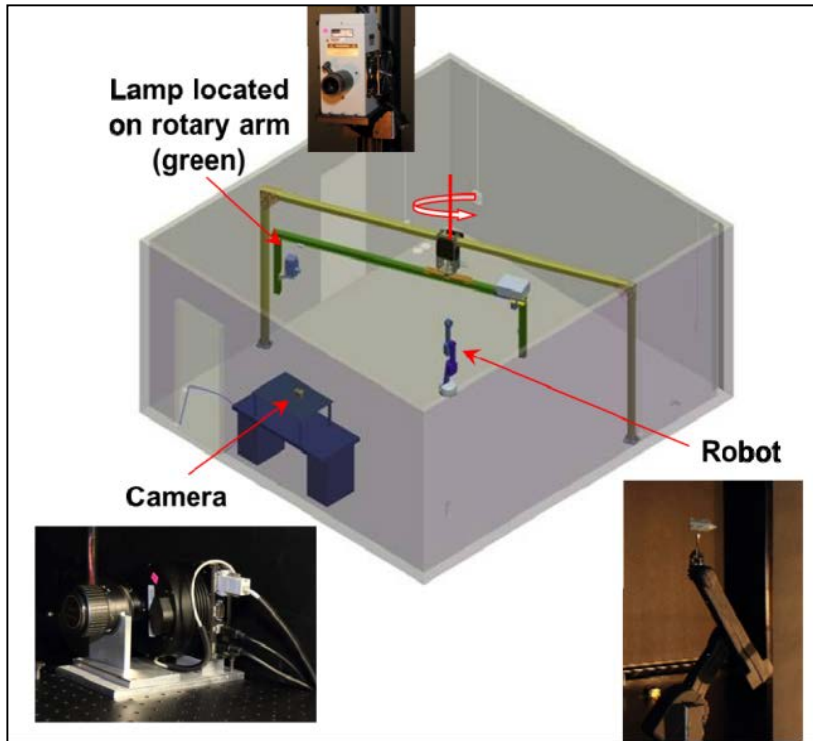
SOCIT vs DebrisSat

	SOCIT U.S. Navy Transit 1960's era satellite	DebrisSat Representative modern spacecraft in LEO	Before
Target body dimensions	46 cm (dia) × 30 cm (ht)	60 cm (dia) × 50 cm (ht)	
Target mass	34.5 kg	56 kg	
MLI and solar panel	No	Yes	
Projectile material	Al sphere	Hollow Al cylinder with attached nylon bore-rider	
Projectile dimension/mass	4.7 cm diameter, 150 g	8.6 cm × 9 cm, 570 g	
Impact speed	6.1 km/sec	6.8 km/sec	
Impact Energy to Target Mass ratio (EMR)	81 J/g (2.8 MJ total)	235 J/g (13.2 MJ total)	

See Ausay, E., "A Comparison of the SOCIT and DebrisSat Experiments"



Optical Laboratory Data Analyses: Optical Measurement Center (NASA/JSC)



- **ASD field spectrometer:** high-resolution reflectance spectrometer .
- **SBIG CCD camera and attached filter wheel,** which uses Johnson/Bessell BVRI and SDSS $g'r'i'z'$
- **75 W Xenon arc lamp**
- **R17 robotic arm (5 DOF)**
- **Rotary arm with potentiometer**

- Goal: develop optical size estimation model eliminating need for assumptions in current calculations

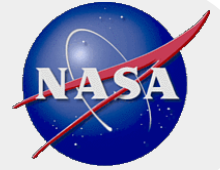
$$d = \frac{2 \cdot R}{[\pi \cdot A_g \cdot \Psi(\alpha)]^{0.5}} \cdot 10^{\left[\frac{M_{\text{abs}}(v) + M_{\text{sun}}(v)}{-5.0}\right]}$$

R: 36,000 Km

A_g : geometrical albedo=0.175

$\Psi(\alpha)$, Lambertian Phase Function

- Acquire empirical-based bidirectional reflectance distribution function measurements to eliminate need to have aspect angle dependencies
- Upgraded robotic arm with 6 DOF is now underway; expected completion by end of FY18



Radar Facility Data Analyses

Historical:

- 1990s physical measurements acquired (L_c , area, and mass)
- Majority of objects investigated were aluminum or steel
- Radar measurements were taken at multiple angles in order to avoid undersampling the RCS aspect angle variations
- Data were taken at a wide range of frequencies from 2.4 to 18 GHz (S, C, X and Ku bands)

Plan Forward:

- Repeat the 1990s experiment with more modern materials, a large frequency sweep, and collect RCS measurements in various aspect angles – *radar facilities are currently being assessed for cost, resources, and availability*
- Similar to previous analysis, the physical parameters will be compared with RCS measurements to investigate the relationships for a broader subset of materials/shapes
- The DebrisSat fragments will provide the opportunity to compare optical measurements against optical inferred sizes and radar cross sections