DEBRISAT FRAGMENT CHARACTERIZATION SYSTEM AND PROCESSING STATUS

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The DebriSat Team

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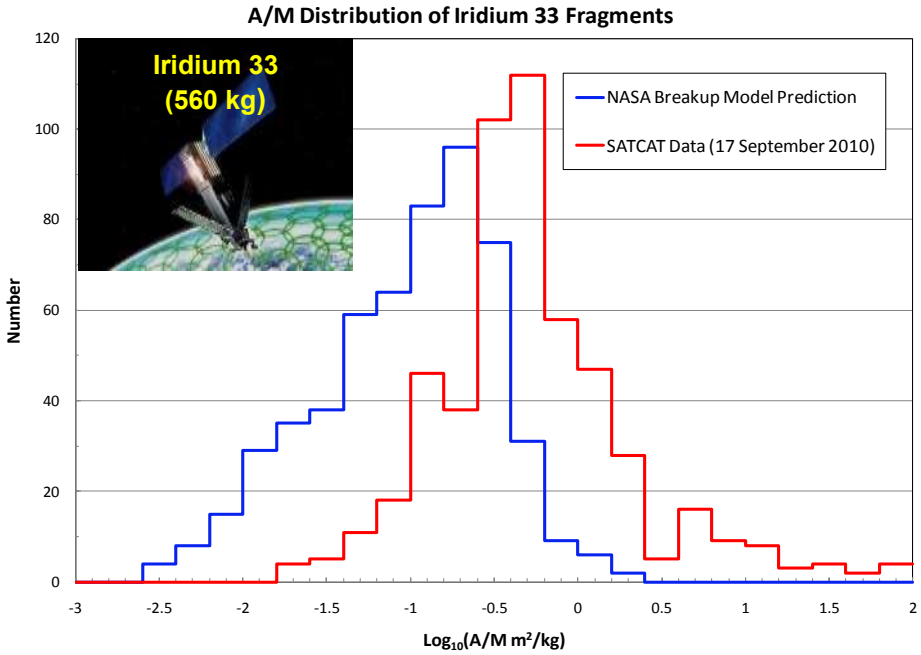
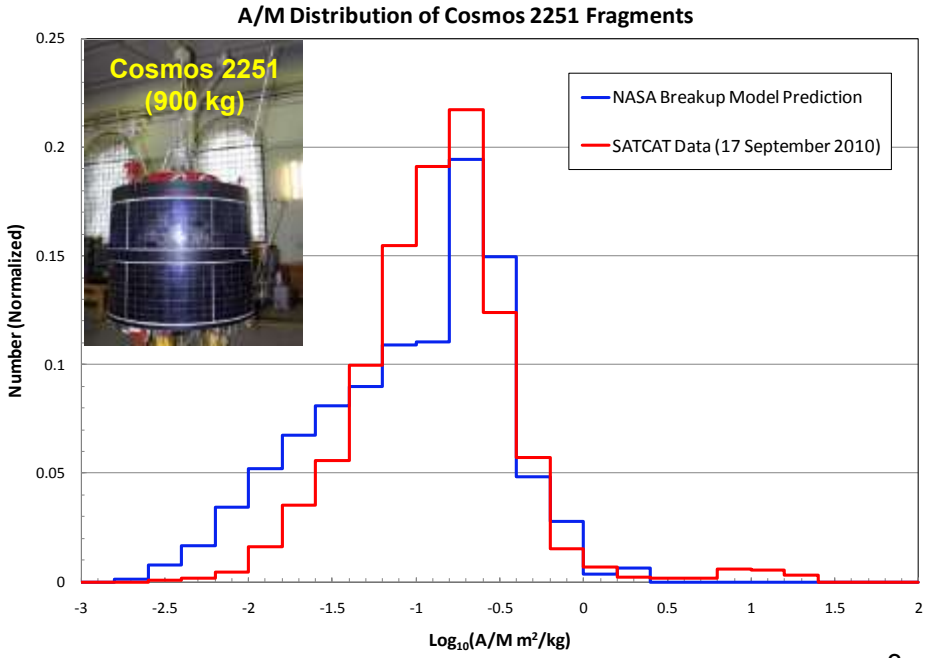
  - Co-sponsor, project and technical oversight, data collection, data analyses, NASA model improvements
- **USAF Space and Missile Systems Center (SMC):** T. Huynh, J. Edwards, J. Torres-Ramos, *et al*.
  - Co-sponsor, technical oversight
- **The Aerospace Corporation (Aerospace):** M. Sorge, B. Brady, P. Adams, G. Radhakrishnan, P. Sheaffer, *et al*.
  - Design of DebriSat, design/fabrication of DebrisLV, data collection, data analyses, DoD model improvements
- **University of Florida (UF):** N. Fitz-Coy and the student team
  - Design/fabrication of DebriSat, data collection, fragment processing and characterization
- **USAF Arnold Engineering Development Complex (AEDC):** R. Rushing, B. Hoff, M. Nolen, B. Roebuck, D. Woods, M. Polk, et al.
  - Hypervelocity impact tests

Background

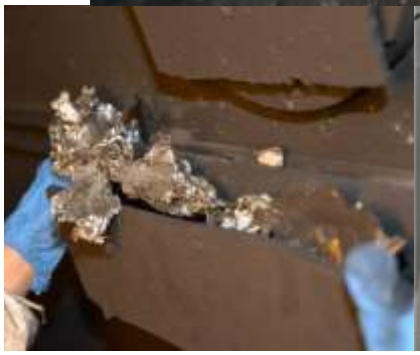
- Current DoD and NASA satellite breakup models are based on 1992 Satellite Orbital debris Characterization Impact Test (SOCIT) which used a U.S. Navy Transit satellite
- Collision in 2009 between Iridium 33 and Cosmos 2251 generated 2000+ trackable fragments and tens of thousands of small untrackable yet potentially damaging/lethal debris (as small as 1 mm)
- Newer materials and construction techniques utilized in modern satellites
  → need for updates to the existing satellite breakup models



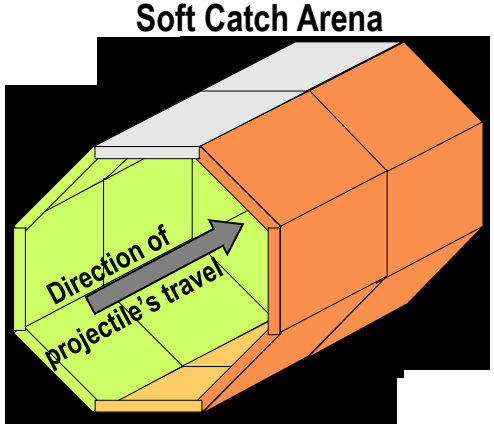


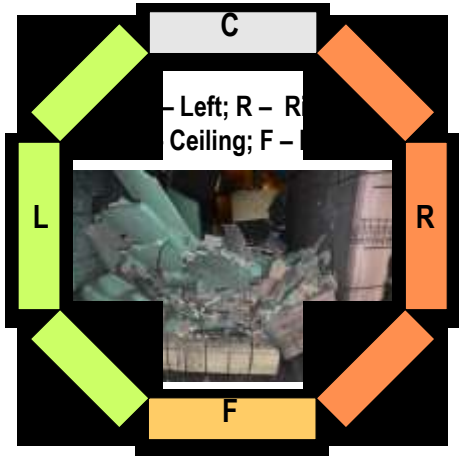
DebriSat Hypervelocity Test

- **DebriSat test article designed and fabricated as a "representative" modern LEO satellite with components typically found in modern LEO satellites (utilized materials and design/fabrication procedures commonly associated with modern LEO satellites)**
- **Test performed on April 2014 at AEDC**
  - Test article: 56 kg representative LEO satellite
  - Projectile: 570 g hollow cylinder
  - Impact speed: 6.8 km/s



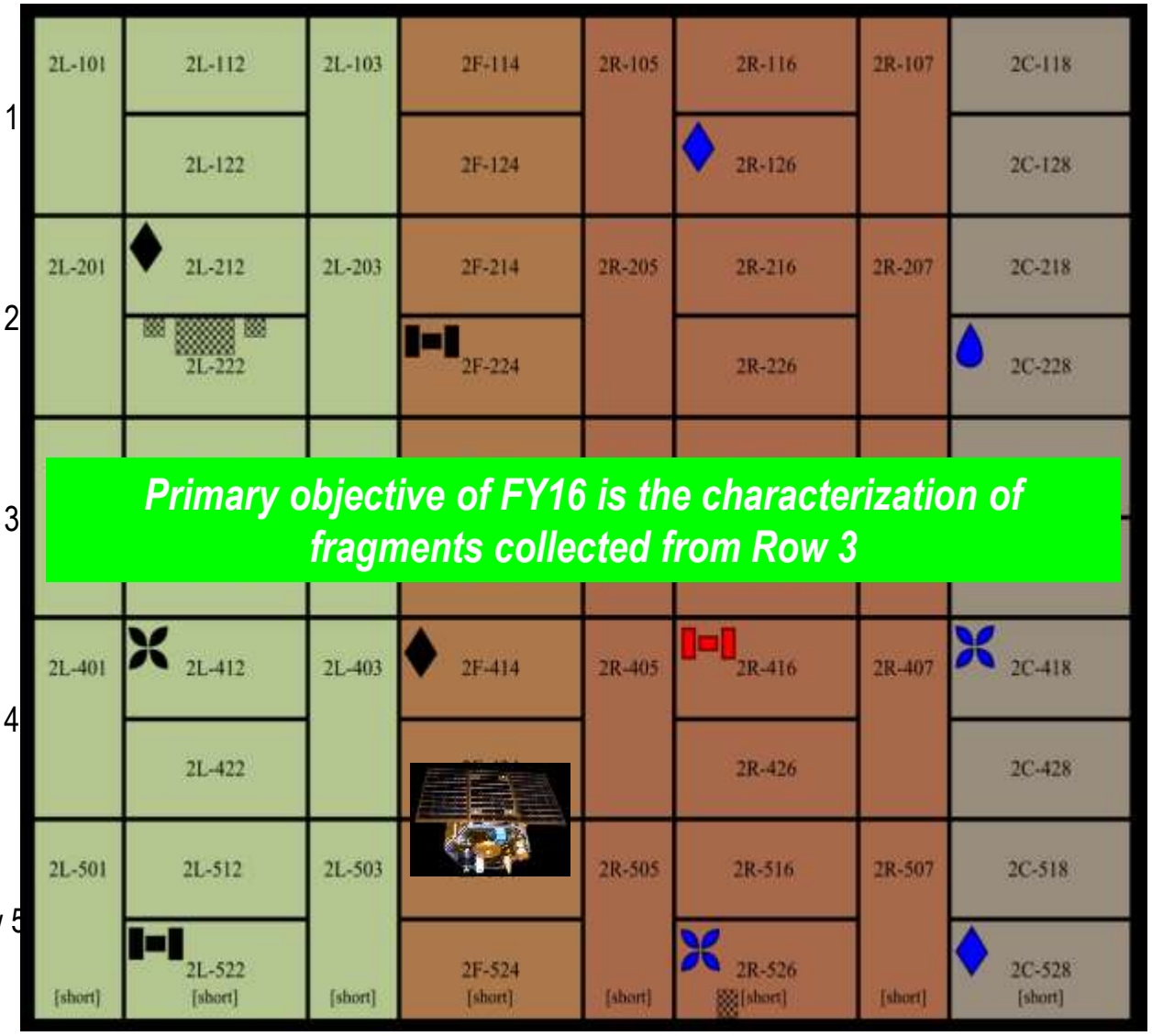
DebriSat Hypervelocity Test





Panel Identification: AB-CDE

- A – Test ID (1: DebrisLV; 2: DebriSat)
- B – Center/Floor/Left/Right
- C – Row #
- D – Sub-row designations (0: no sub row)
- E – Column #



Post-Impact Goals & Requirements

Overall

- Recover 90% of DebriSat's original mass
- Collect all debris fragments with at least one dimension ≥ 2 mm
- Damage no more than 1% of collected debris
- Characterize mass, physical size, material, shape of the debris fragments

FY16

- Characterize fragments collected from Row 3

Detection and Extraction

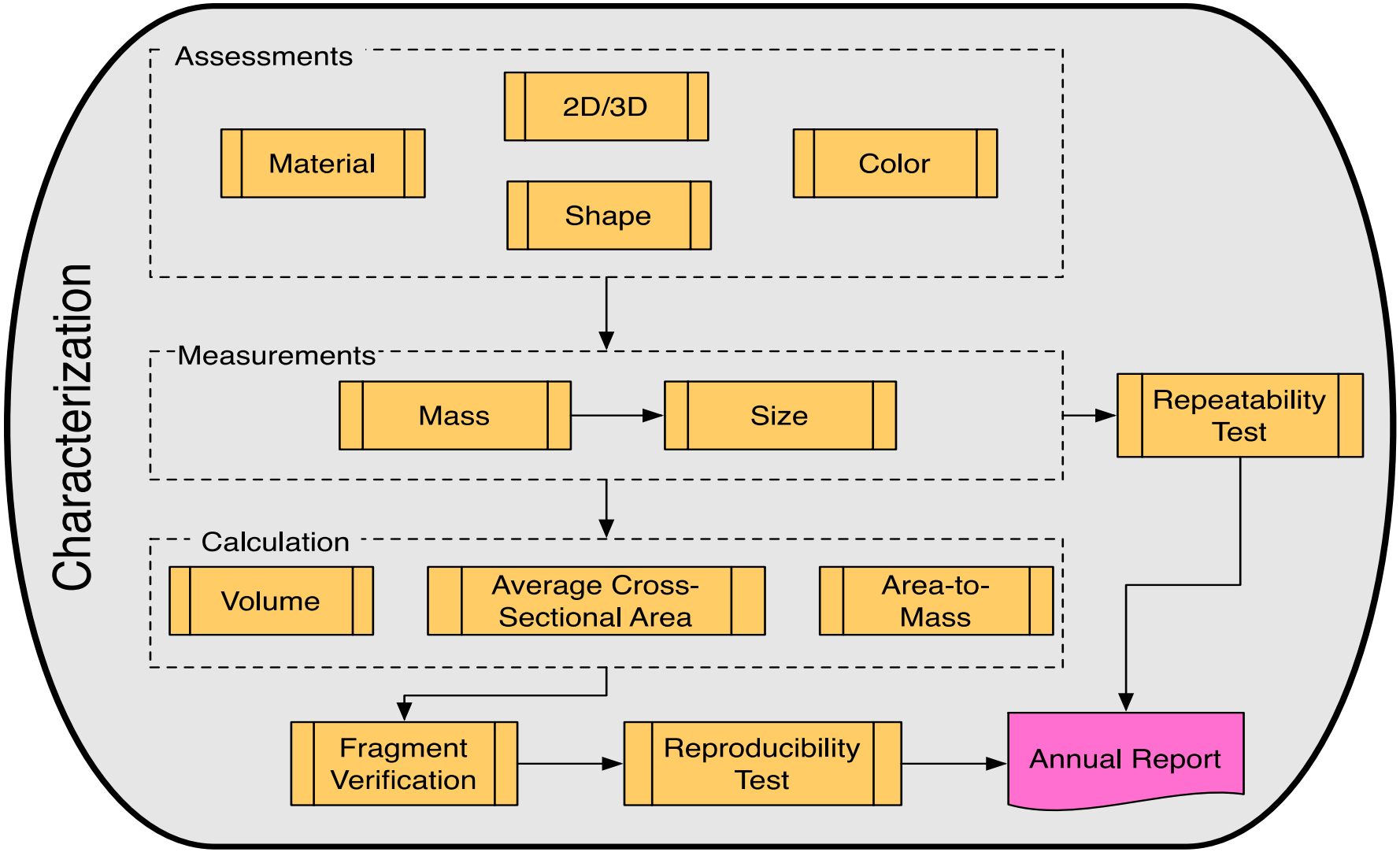
Detection

- X-ray foam panels
- Use object detection software to identify potential fragment

Extraction

- Map fragment location
- Excavate fragments
- Catalog fragments ≥ 2mm

Characterization



Characterization: Assessments

Size (2D or 3D)

Materials

- Based on DebriSat components
- Samples used to compare material content

Database designators

-AL- -MLI-
-CFRP- -SS-

Shape

- Based on inputs from SOCIT and subject matter experts
- Samples used for comparison

Straight Needle

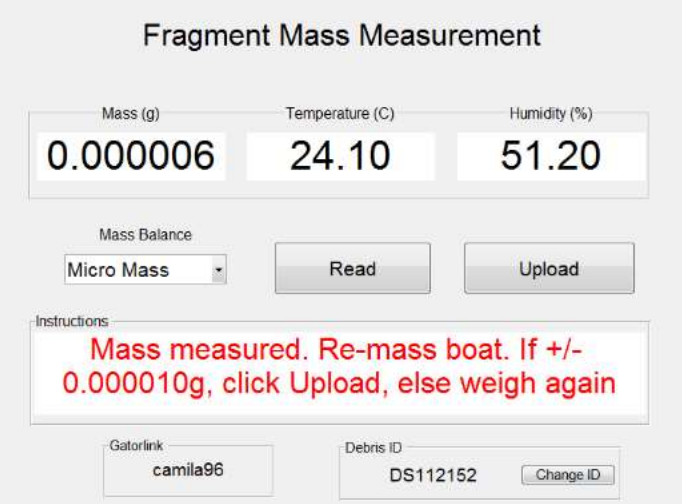
Flat Plate

Color

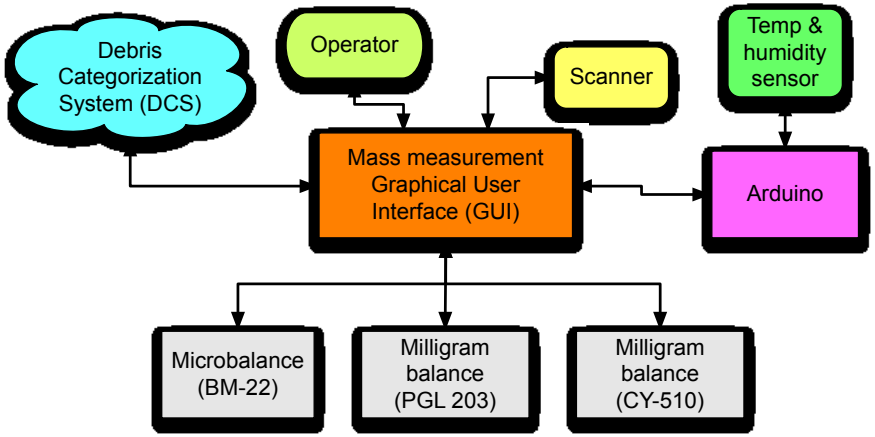
- Based on DebriSat components
- Aluminum components anodized based on location within satellite

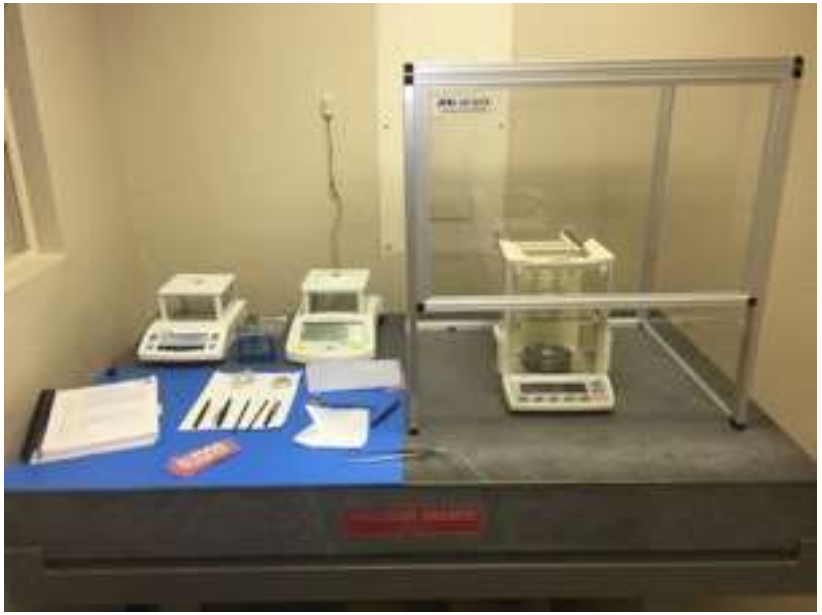
Silver Gold
Red Royal Blue

Characterization: Mass Measurement

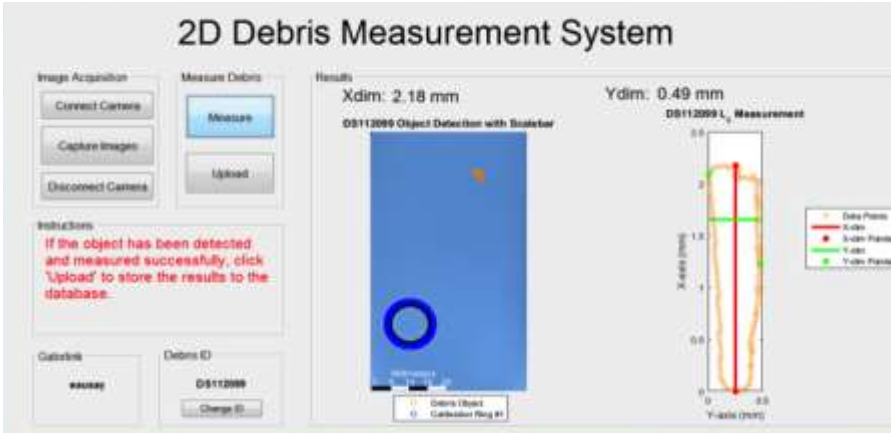


- **Mass Measurement System**
  - Integrated system that includes mass balances, temperature, and humidity sensor
  - For each mass measurement, the temperature and the humidity of the characterization room is also measured
  - Measurements are uploaded to the database through the GUI (i.e., automated system)

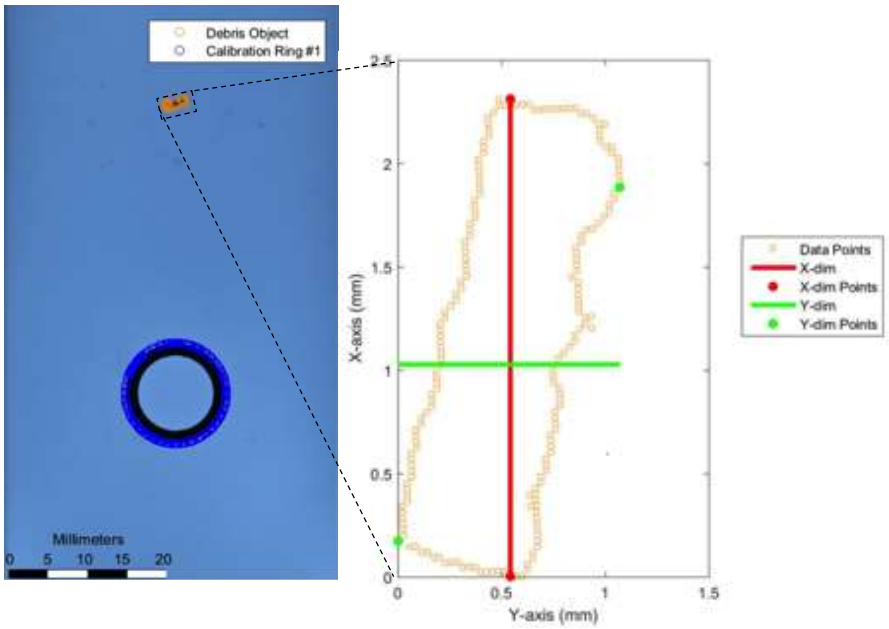


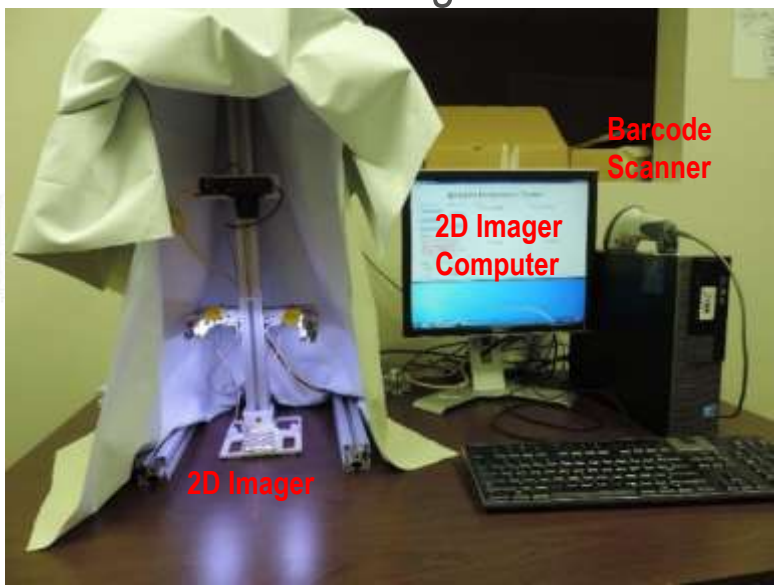


Characterization: 2D Size Measurement

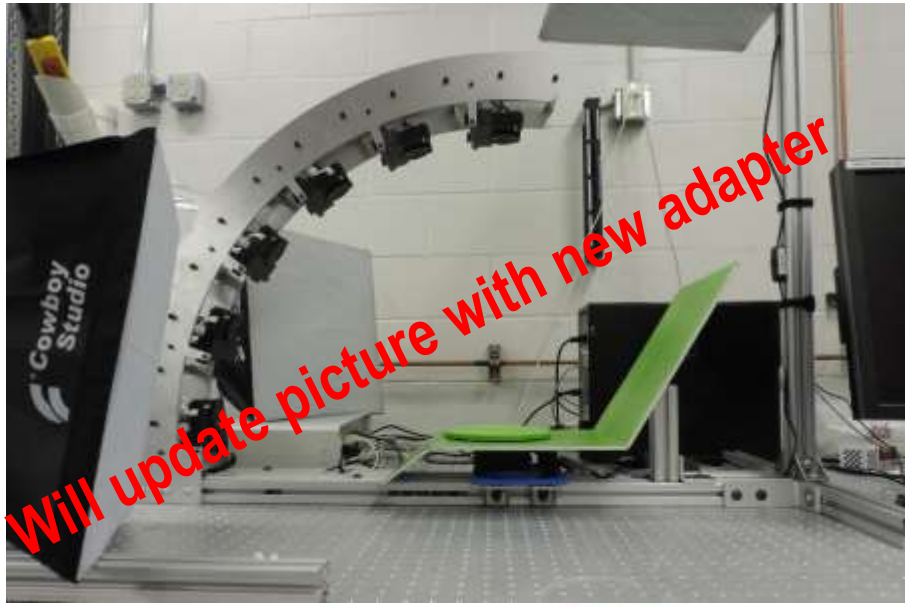


- **2D Imaging System**
  - Single camera with front/back lighting
  - Generate 2D point cloud from backlit image then compute X-dim, Y-dim, characteristic length (L_c), and area
  - Images, 2D point clouds, and computed dimensions are uploaded to the database through the GUI





Characterization: 3D Size Measurement



Object

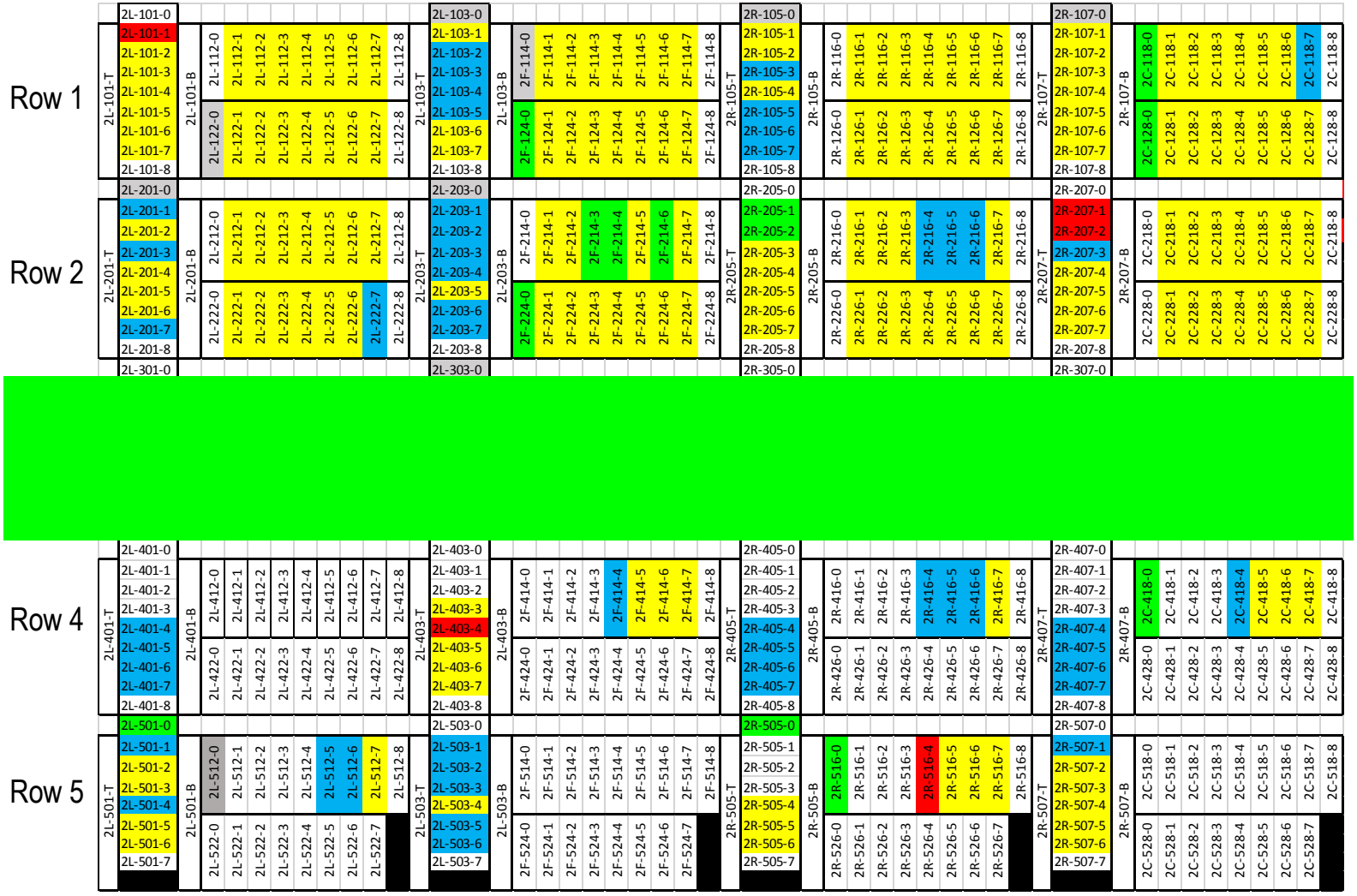
3D representation

- **3D Imaging System**
  - 6-camera system distributed evenly along a vertical arc
  - Green screen turntable
  - Constructs a 3D representation from multiple 2D images using space carving technique
  - From the 3D representation, the largest three orthogonal dimensions (X_{DIM}, Y_{DIM}, Z_{DIM}) are computed
  - Calculated values, images and the 3D point cloud are uploaded to the database through the GUI

Characterization: Calculation, Verification, and R&R

- Characteristic length
  - Average of the fragment's largest three orthogonal dimensions
- Volume and bulk density
- Average cross-sectional area
- Area-to-mass ratio
- Verification of fragment characteristics
  - All fragments are independently verified (measurements, images, etc.) and stored in database; cannot be modified once verified
- Measurement system validations performed
  - Repeatability and reproducibility (R&R) tests designed and implemented for data integrity

Current Processing Status



Panel status as of August 2016:

- Prepared
  - 375 panels
- X-rayed
  - 298 panels
- Extracted
  - 66 panels

- Over 125K fragments have been collected to date

Summary

- Post-impact activities continue (i.e., detection, extraction, characterization of fragments with one dimension ≥ 2 mm)
- A systematic characterization process using repeatable procedures and reliable equipment have been established
- FY2016 activities focused on the characterization of fragments from Row 3
  - Preparation: Completed all panels
  - X-ray imaging: 70 out of 71 panels
  - Extraction: 60 out of 71 panels
  - Characterization: 2389 fragments

Questions?

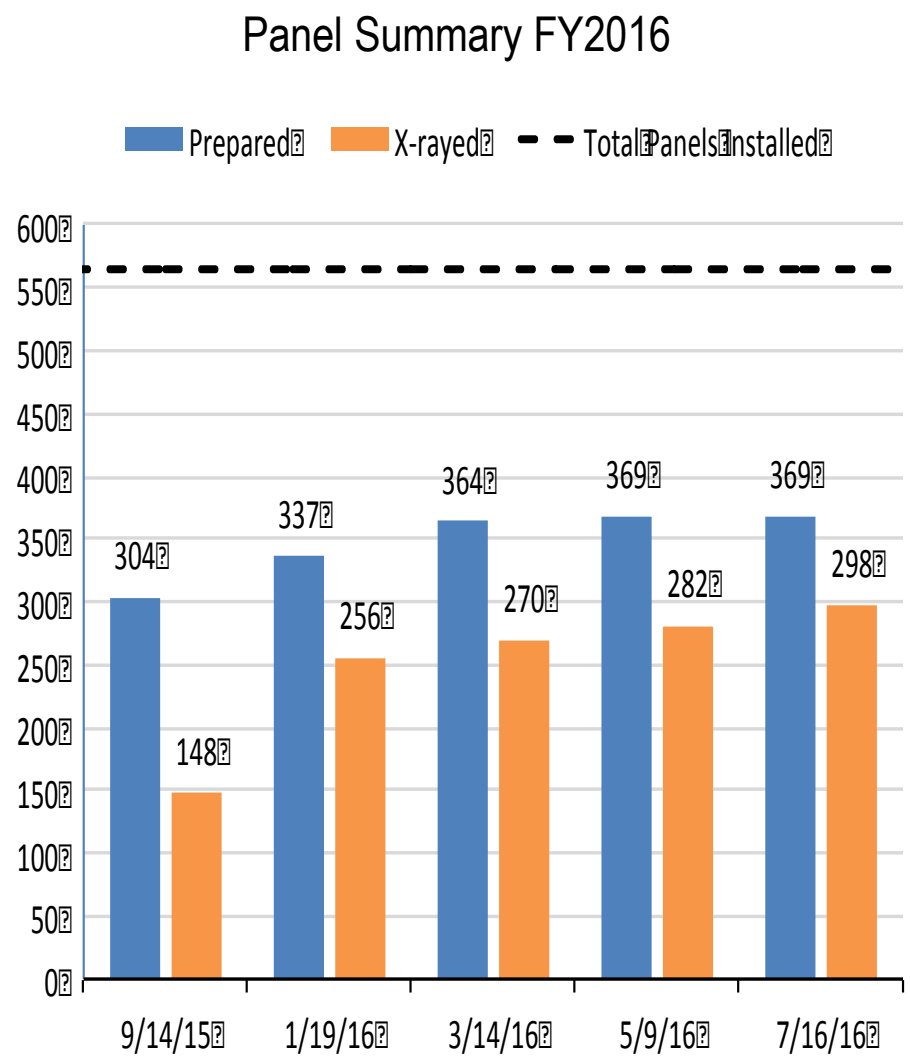
Examples of Fragments

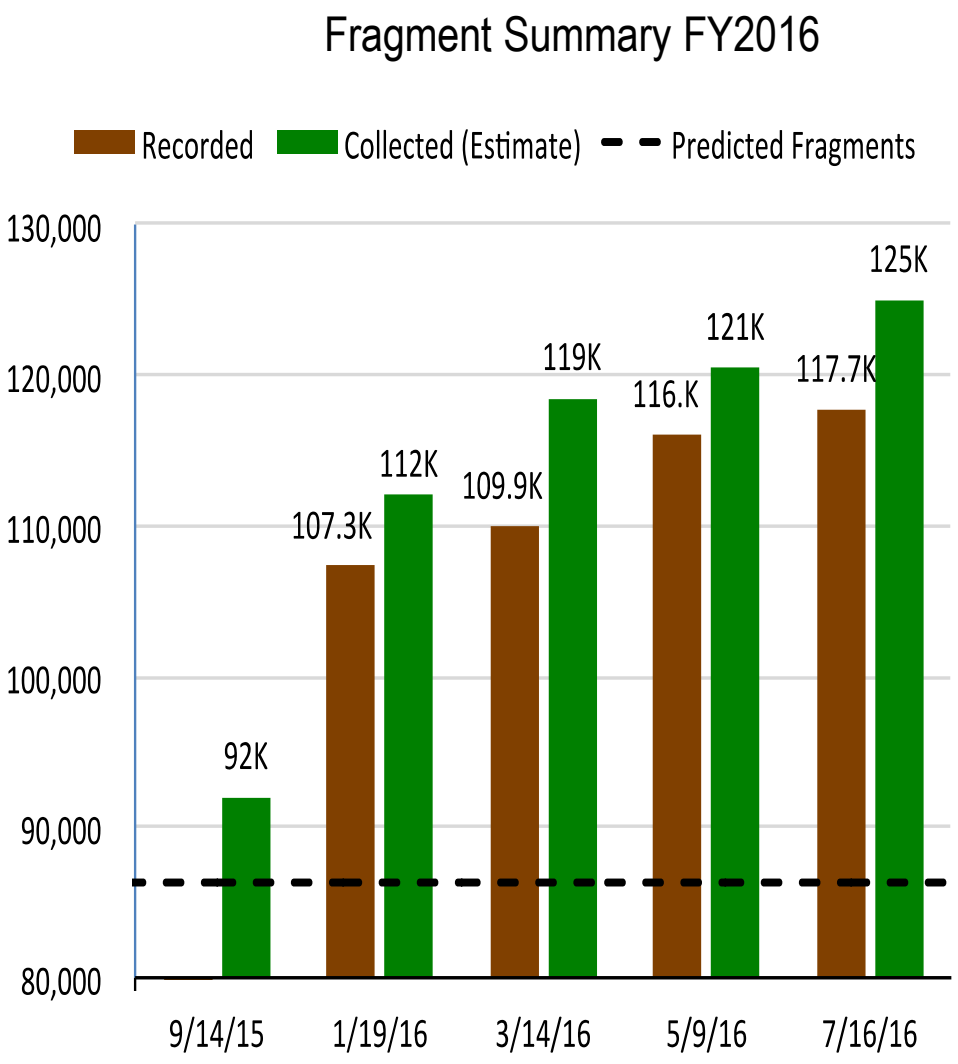
Current Processing Status

Panels Prepared	369 of 564*
Panels X-rayed	298
Panels Extracted	62
Debris Collected	125 000
* Not all 564 panels remained intact post-impact; processing of broken panels is in planning	

Activity	# of Panels	Avg. Time/Panel (hr)
Preparation	369	3.0
X-ray imaging	298	0.5
Extraction	62	
Low Density Panels	12	15.2
Medium Density Panels	43	11.6
High Density Panels	7	9.4

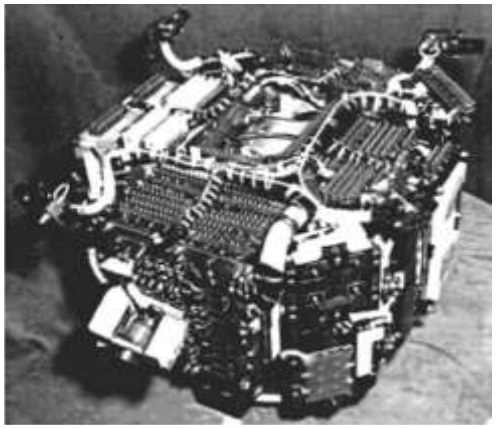
Expectations and Progress





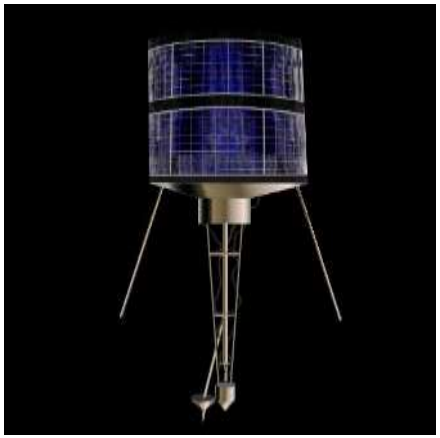
Background

- **1992 Satellite Orbital debris Characterization Impact Test (SOCIT) used U.S. Navy Transit navigation satellite to develop the DoD and NASA satellite breakup models**
  - 34.5 kg target fabricated in the 1960s
  - 150 g Al sphere projectile
- **The accidental collision between Iridium 33 and Cosmos 2251 in 2009 generated 2000+ trackable fragments and tens of thousands of small untrackable-yet-potentially-damaging/lethal debris (as small as 1 mm)**



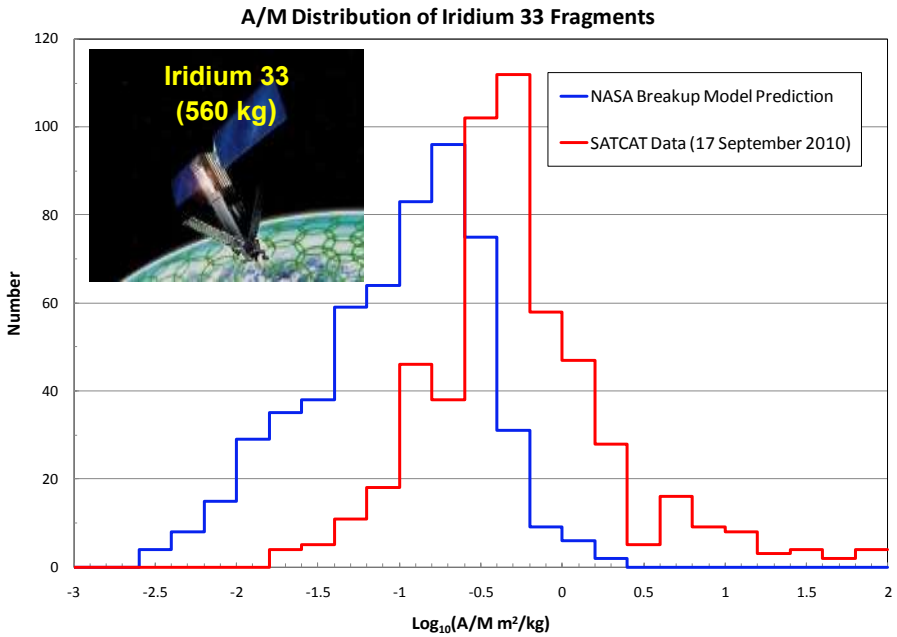
U.S. Navy Transit satellite from SOCIT4

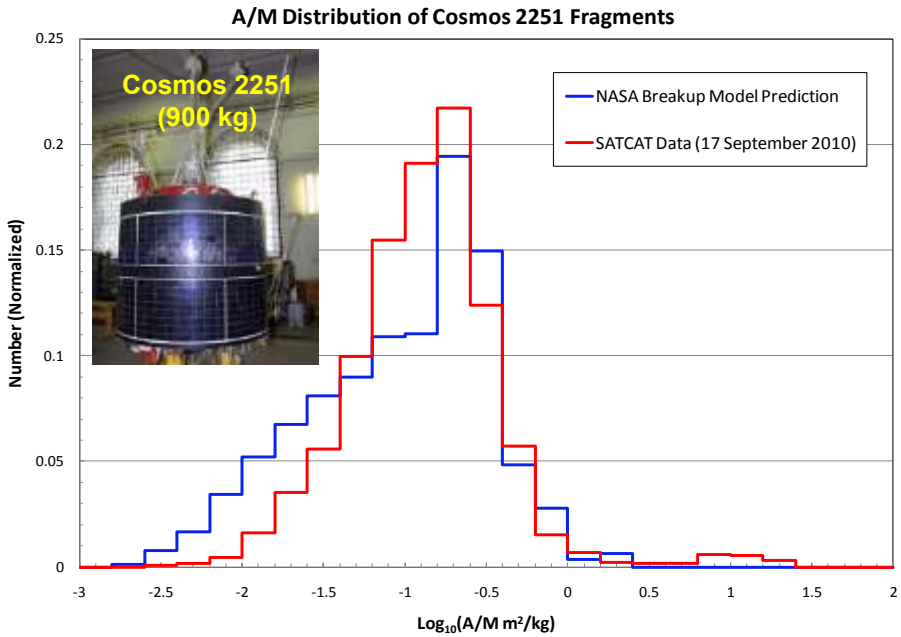
Iriidium-33
https://en.wikipedia.org/wiki/Iridium_33



Strela-2M satellite similar to Cosmos-2251
https://en.wikipedia.org/wiki/Kosmos_2251

Background





- The A/M distribution of the Iridium 33 fragments appears to be systematically higher than the NASA model prediction
- Lightweight composite materials were extensively used in the construction of the vehicle

- The A/M distribution of the Cosmos 2251 fragments matches well with the NASA model prediction

As new materials and construction techniques are developed for modern satellites, there is a need for new laboratory-based tests to improve the existing DoD and NASA breakup models.