National Aeronautics and Space Administration

DebriSat – A Planned Laboratory-based Satellite Impact Experiment

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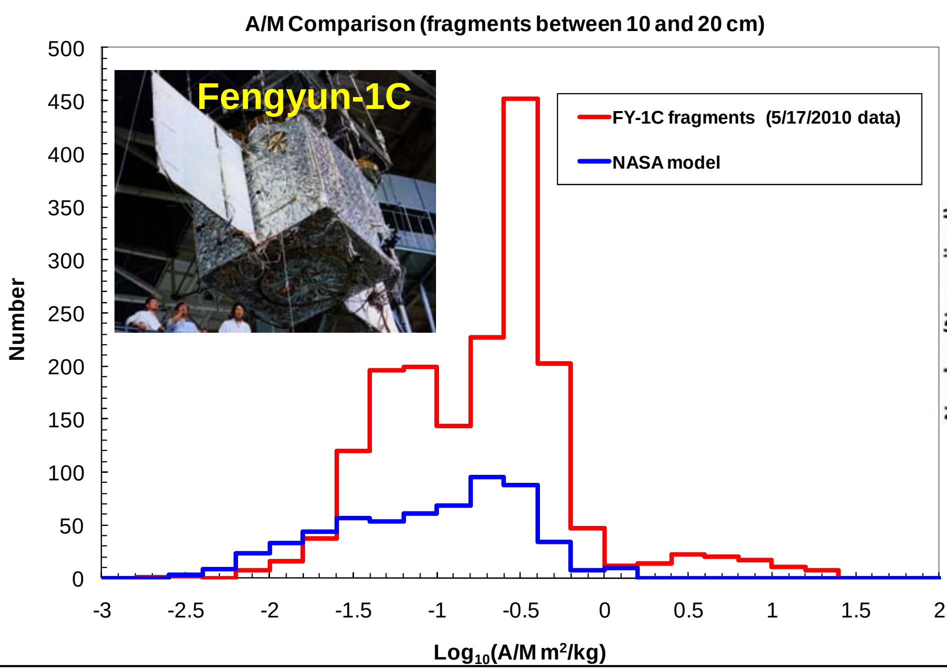
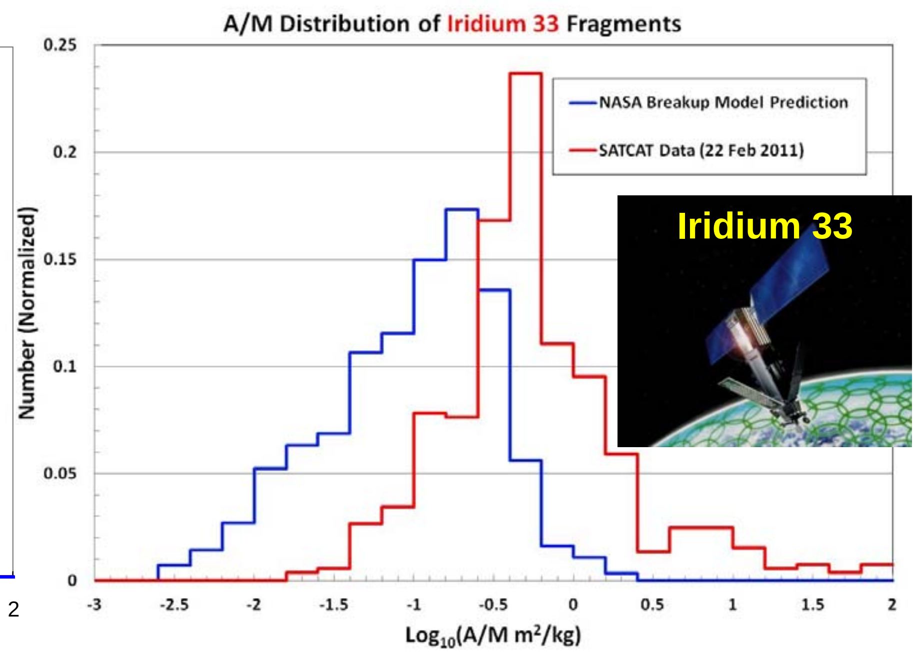
Motivations (1/2)

- **Collision fragments are expected to dominate the future orbital debris environment**
- **A higher fidelity breakup model to describe the outcome of satellite collisions is needed for**
  - Good orbital debris environment definition
  - Reliable short- and long-term impact risk assessments (from debris as small as 1 mm) for critical space assets
- **Laboratory-based satellite impact tests are necessary to characterize fragments smaller than 10 cm**
  - Size, mass, area-to-mass ratio, shape, composition, optical/radar properties, *etc.*

Motivations (2/2)

- **As new materials and new construction techniques are developed for modern satellites, there is a need to conduct additional laboratory-based tests and use the data to further enhance the existing breakup models**





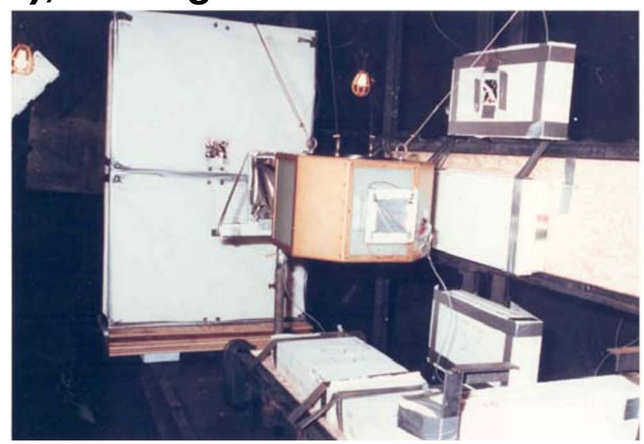
NASA model predictions match well with fragments generated from old satellites, but are noticeably different from fragments of more modern satellites (left: FY-1C, right: Iridium).

Roles and Responsibilities of the Team

- **NASA Orbital Debris Program Office**
  - Co-sponsor, project and technical oversight, data analyses, NASA model improvements: J.-C. Liou, J. Opiela
- **AF Space and Missile Systems Center (SMC)**
  - Co-sponsor, technical oversight, data analyses, DoD model improvements: T. Huynh, M. Sorge
- **University of Florida (UF)**
  - Design and fabrication of DebriSat, post-impact fragment characterization: N. Fitz-Coy, S. Clark, M. Werremeyer
- **AF Arnold Engineering Development Complex (AEDC)**
  - Hypervelocity impact: R. Rushing, M. Polk, B. Roebuck

A Key Test from the Past

- **A key laboratory-based test, SOCIT*, supporting the development of the DoD and NASA satellite breakup models was conducted in 1992**
  - Target satellite: A U.S. Navy Transit navigation satellite
    - **Dimensions and mass: 46 cm (dia) × 30 cm (ht), 34.5 kg**
    - **No Multi-layer Insulation (MLI)**
    - **Was built in the early 1960's**
    - **Was selected because of its availability**
  - Projectile: 4.7 cm diameter Al sphere
  - Impact speed: 6.1 km/sec
  - Post-test analysis
    - **Only ~10% of the fragments were measured (4761 in total)**
      - **Many were sieved and bagged together (up to 260 per group) to estimate the average properties of the groups**
    - **The results were scaled up by a factor of 10 to represent the distribution of the entire fragment set**



*SOCIT: Satellite Orbital debris Characterization Impact Test

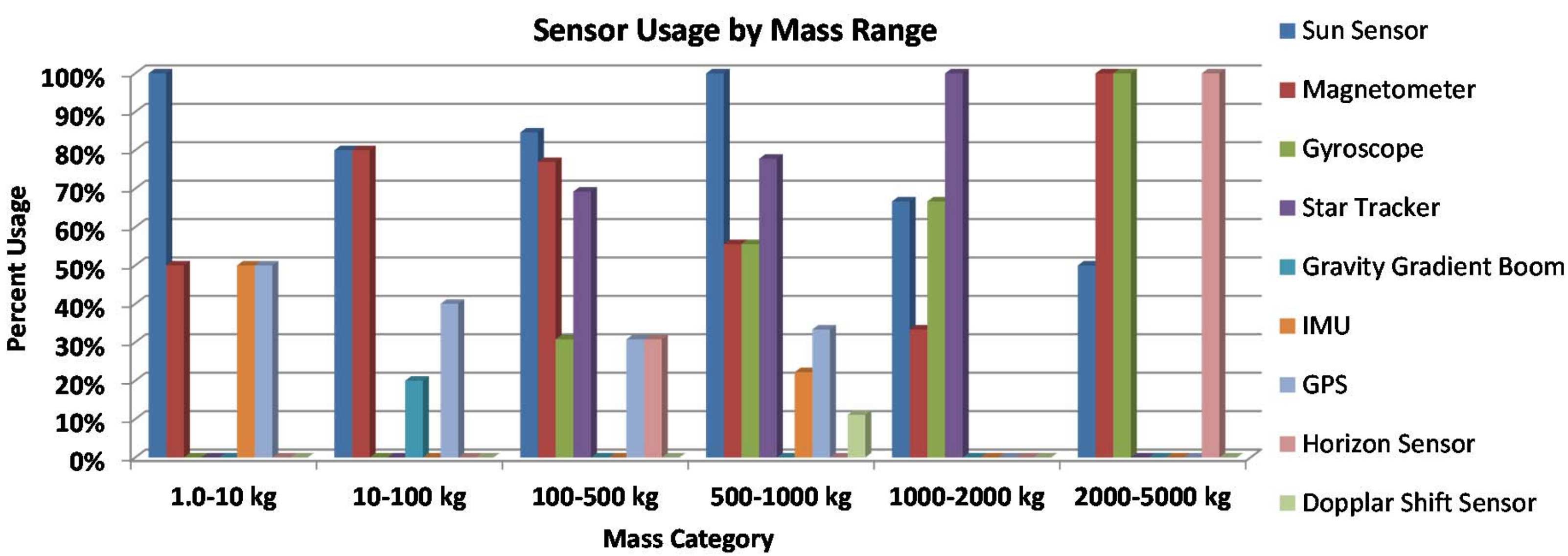
DebriSat versus Transit

- **DebriSat has a modern design and is 45% more massive than Transit**
- **DebriSat is covered with MLI and equipped with solar panels**

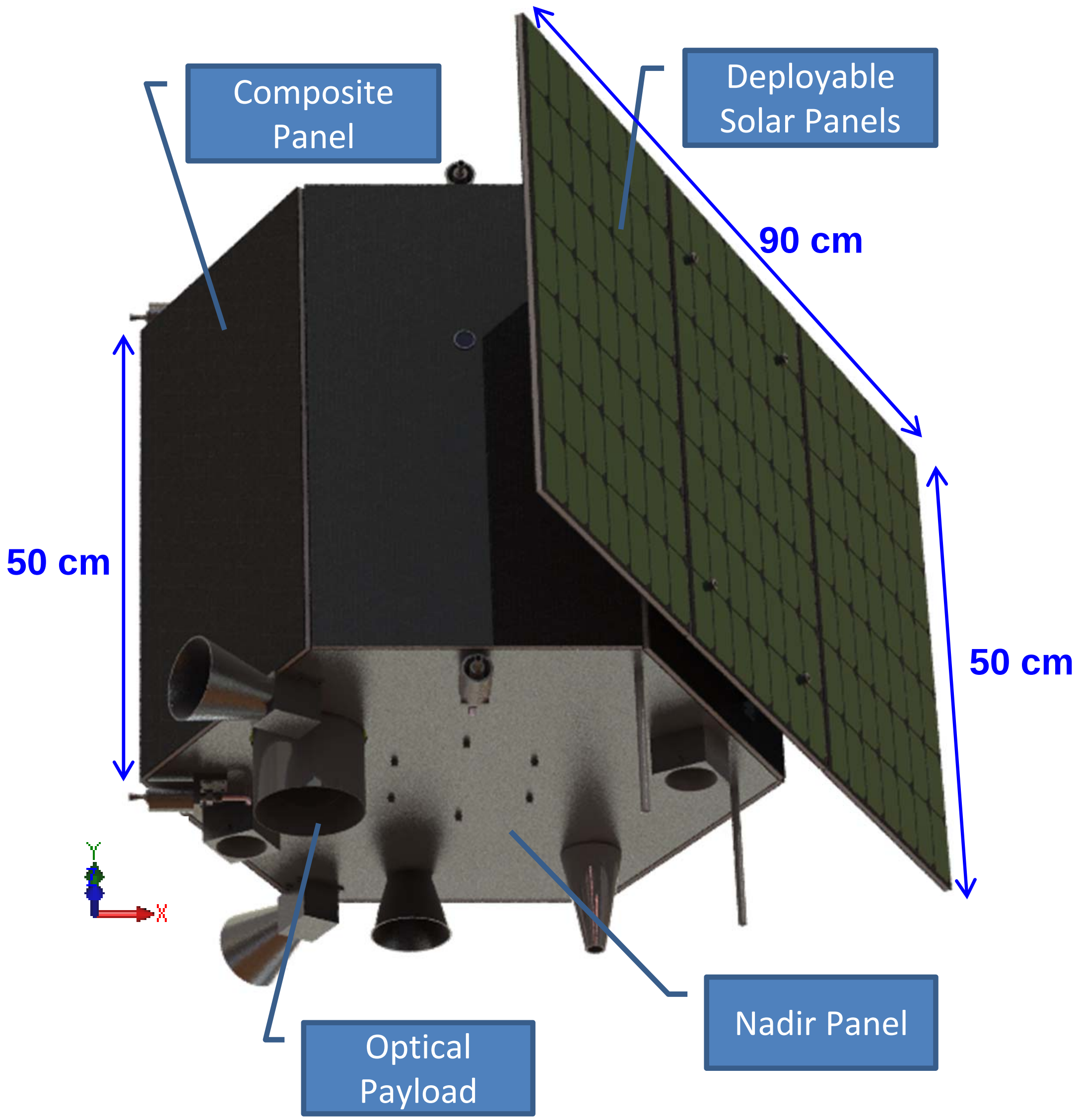
	Transit / SOCIT	**DebriSat**
Target body dimensions	46 cm (dia) × 30 cm (ht)	60 cm (dia) × 68 cm (ht)
Target mass	34.5 kg	50 kg
MLI and solar panel	No	Yes
Projectile material	Al sphere	Al sphere
Projectile dimension/mass	4.7 cm diameter, 150 g	5 cm diameter, 176 g
Impact speed	6.1 km/sec	7 km/sec
Impact Energy to Target Mass ratio (EMR)	78 J/g	86 J/g

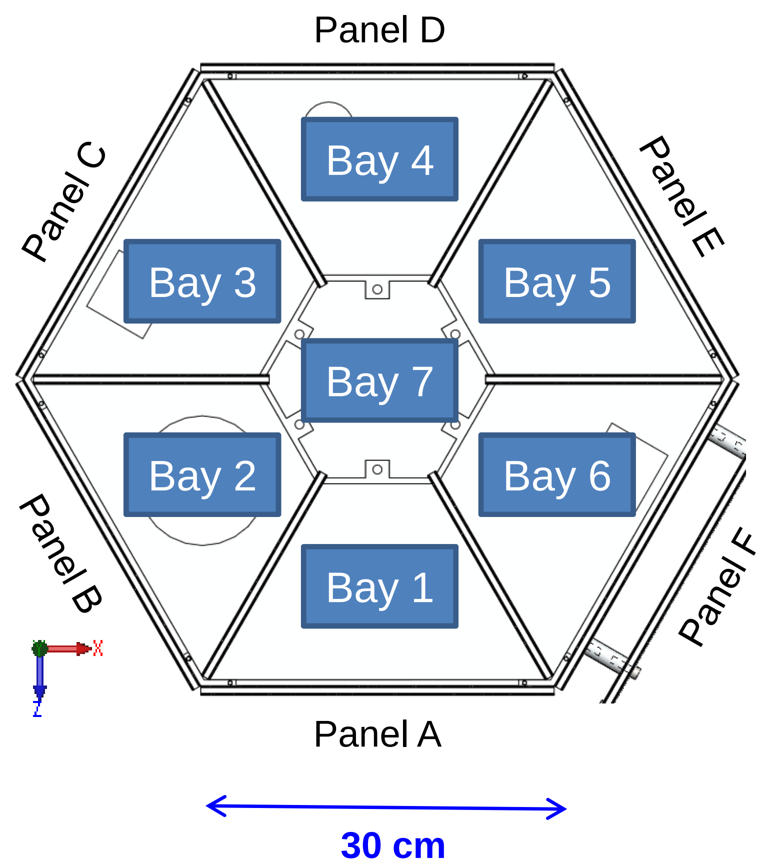
DebriSat Design (1/4)

- **DebriSat is intended to be representative of modern LEO satellites**
  - A survey of recent LEO payloads was conducted
  - 50 satellites were selected for analysis
  - Common subsystems, materials, mass fractions, structure, and construction methods were identified
  - Major design decisions were reviewed and concurred by subject matter experts from different disciplinary areas



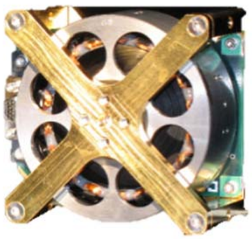
DebriSat Design (2/4)



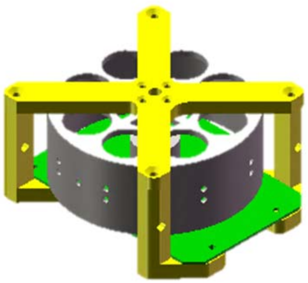


DebriSat Design (3/4)

- **DebriSat includes 7 major subsystems**
  - Attitude determination and control system (ADCS), command and data handling (C&DH), electrical power system (EPS), payload, propulsion, telemetry tracking and command (TT&C), and thermal management
  - Each system contains standard components, such as star trackers, reaction wheels, flight computer, data recorder, thrusters, antennas, avionics boxes, heat pipes, harnesses, *etc.*
  - To reduce cost, most components are emulated based on existing design of flight hardware and fabricated with the same materials



Reaction wheel (Credit: Sinclair Interplanetary)

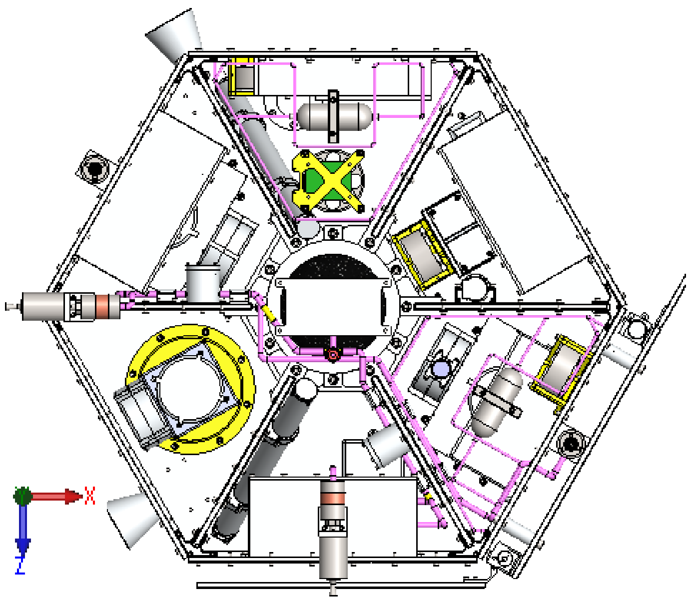


Emulated reaction wheel (CAD drawing)

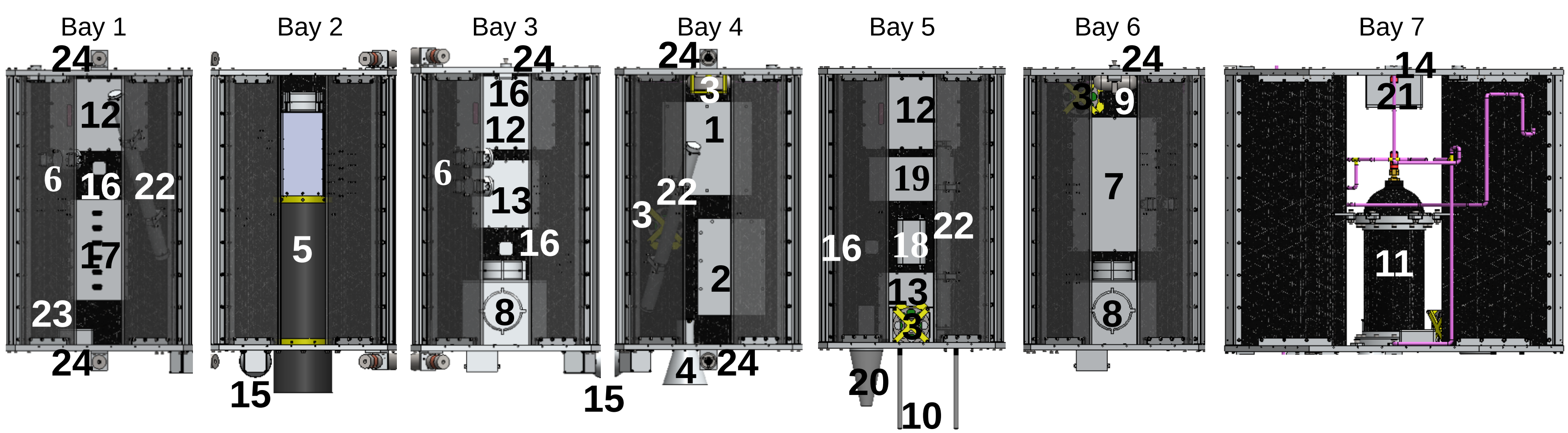
Magnetorquer (Credit: Sinclair Interplanetary)

Emulated Magnetorquer (CAD drawing)

DebriSat Design (4/4)

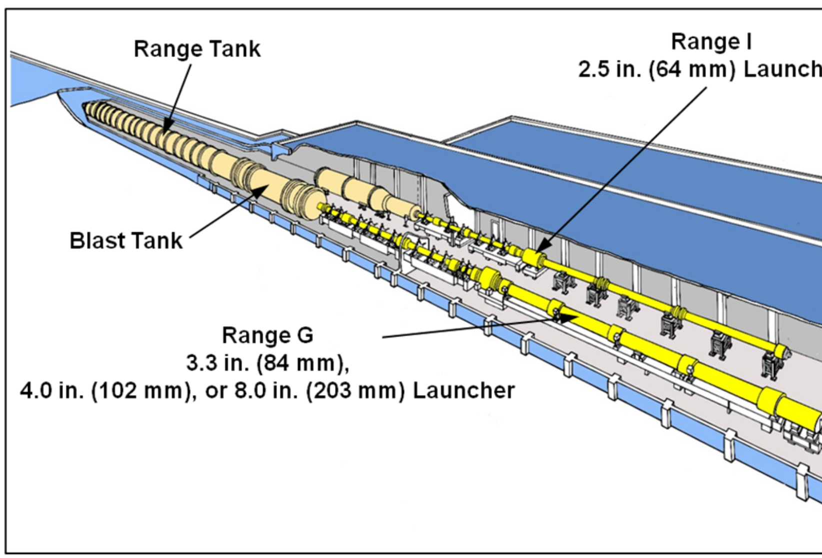


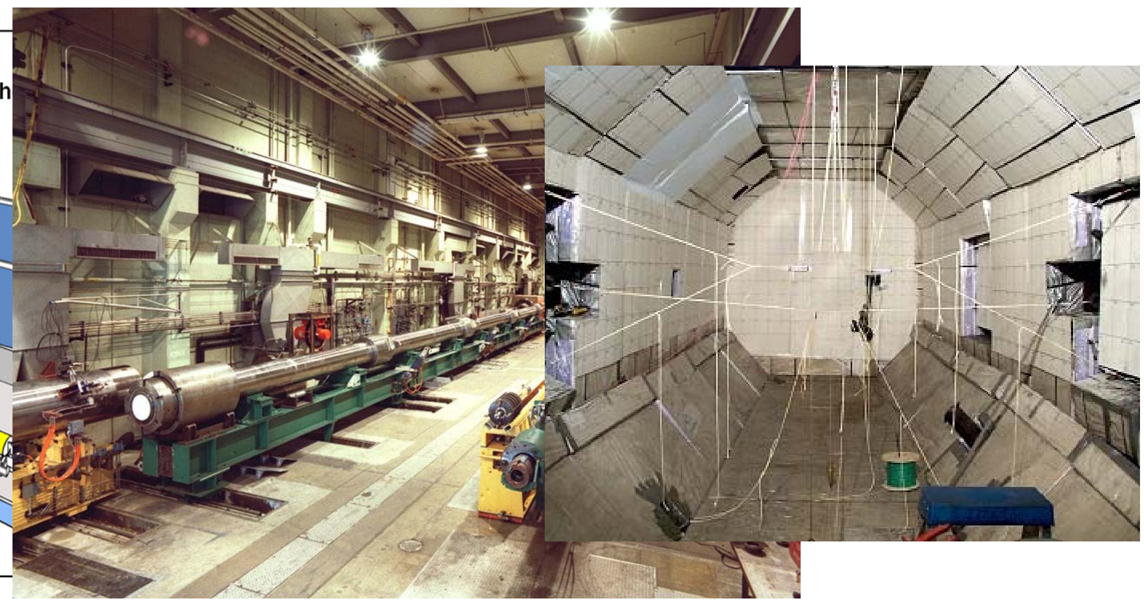
Component Identification	
1 – Flight Computer	13 – Telemetry Avionics (2)
2 – Data Recorder	14 – Fill Drain Valve
3 – Reaction Wheel (4)	15 – Star Tracker (2)
4 – X-Band Conical Feed Horn Antenna	16 – Sun Sensor (4)
5 – Optical Imager	17 – Payload Support Module
6 – Solenoids (3)	18 – Magnetometer
7 – Power Conditioning and Distribution	19 – ADCS Avionics
8 – Spectrometer (2)	20 – S-Band Helical Antenna
9 – Thermal Reservoir	21 – Propulsion Avionics
10 – Omni-Directional Antenna (2)	22 – Magnetorquer (3)
11 – COPV	23 – Inertial Measurement Unit
12 – Li-ion battery box (3)	24 – Thrusters (6)



DebriSat Hypervelocity Impact

- **Facility: AEDC Range-G**
- **Diagnostic instruments: X-rays, high-speed cameras, lasers, *etc*.**
- **Fragment collection: Foam panels will be installed inside the range tank to “soft catch” fragments**

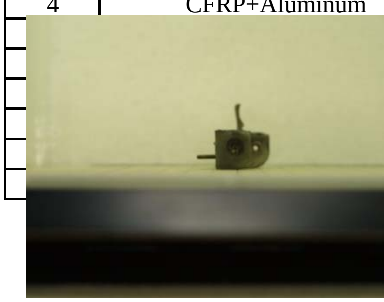


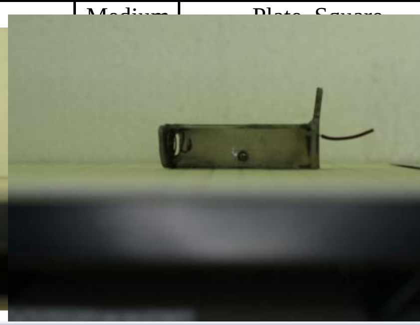


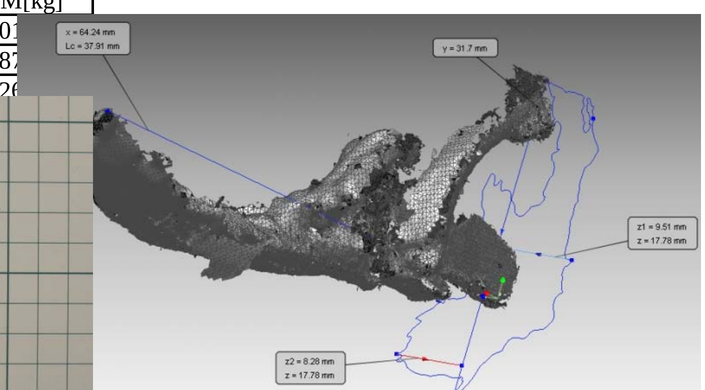
Fragment Characterization Plan

- **Measure fragments, including MLI and solar panel pieces, down to ~2 mm in size**
  - Dimensions, mass, shape, density, composition, photos
- **Obtain 3D scanning data for selected fragments**
  - Cross-sectional area, A/M, bulk density
- **Conduct radar, photometric, and spectral measurements for selected fragments**
  - Radar and optical size estimation models

No	Characteristic	Label	Shape	x[m]	y[m]	z[m]	M[kg]
1	CFRP+Aluminum	Medium	Plate_Square	0.28284	0.28284	0.03031	2.01
2	CFRP+Aluminum	Medium	Plate_Square	0.28284	0.28284	0.02186	8.87
3	CFRP	Low	Plate_Square	0.28284	0.28284	0.00167	6.26
4	CFRP+Aluminum	[illegible]	[illegible]				







Project Status

- Project kickoff – Sep 2011
- Preliminary design – Jun 2012
- Final design – Jan 2013
- Complete fabrication of DebriSat – Sep 2013
- Vibration and thermal vacuum tests – Oct 2013
- Hypervelocity impact – Feb/Mar 2014
- Complete fragment measurements – Dec 2014
- Process/analyze data for model improvements – 2015