Development of the Space Debris Sensor (SDS)

Joe Hamilton
SDS Principal Investigator
January 31, 2017
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Background

• DRAGONS concept and technology has been under development with intermittent grants since 2002
• The goal of DRAGONS is to provide in-situ statistical data on the debris population that is too small for ground-based remote sensing to accomplish.
  – Results would be used to update the Orbital Debris Engineering Model (ORDEM)
  – Current estimate of the small debris population is based on inspection of exposed surfaces returned on Shuttle (Retired 2011)
• The DRAGONS team includes the NASA Orbital Debris Program Office, the NASA Hypervelocity Impact Technology group, the NASA/JSC Engineering Directorate, Jacobs, the United States Naval Academy, the Naval Research Lab, Virginia Tech, and the University of Kent.
Orbital Debris Measurement Coverage

- Goldstone radar
- Haystack radar
- Haystack Auxiliary (HAX) radar
- U.S. Space Surveillance Network
- MODEST telescope

Data Gap

- HST-WFPC2 (580x600 km, 93-09)
- STS (300x400 km, 95-11)

Particle Diameter

Altitude (km)

(Boundaries are notional)
What is SDS?

- DRAGONS is an impact sensor designed to detect and characterize collisions with small orbital debris.
  - 50µm to > 1mm debris size detection
  - Characterize debris size, speed, direction, and density
- The Space Debris Sensor (SDS) is a flight demonstration of DRAGONS on the International Space Station
  - Approximately 1 m² of detection area facing the ISS velocity vector
  - Minimum two year mission on Columbus External Payloads Facility (EPF)
  - Minimal obstruction from ISS hardware
  - Development is nearing final checkout and integration with the ISS
  - Current launch schedule is SpaceX 13, ~ Sept 2017, or SpaceX 14, ~ Jan 2018
Detection Principles

- SDS combines dual-layer thin films, an acoustic sensor system, a resistive grid sensor system, and sensored backstop
- Impact detection and recording capability
  - Impact time, particle size, impact speed, impact direction, and impact energy/particle density
Example 0.4 mm 30° Stainless Steel 7 km/s

Layer 1 hole
Broke 3 lines

Filtered Acoustic Data

Location
Red = Layer 1;
Blue = Layer 2

Resistance change consistent with 3 line break
Steel maintains shape throughout
No visible break up of particles during impacts
Steel shots produce significant secondary ejecta from Lexan back plate
Ejecta has enough velocity to penetrate and dimple Kapton layer in wide arc downstream from shot
Straight-on shots produce halo around entry hole; As shot angle increases the damage moves further away from hole
• Aluminum particles show break-up after first layer  
• Amount of break up varied in the three shots  
• One shot left a clean crater on Lexan back plate  
• Two other shots had a collection of smaller craters  
• No sign of ejecta damage on Kapton layer
Plastic particles broke up significantly after impacting the NCAS grid.

‘Half circle’ hole pattern on Kapton layer with largest hole at bottom of the circle.

Same break up pattern for all shots - ~25mm wide by 20mm tall area of holes.

- Only one plastic shot showed up on the Lexan back plate.
- No craters on Lexan – only residue.
**SDS Concept of Operations**

- **Launch Vehicle I&T at KSC**
- **Launch on SpaceX**
- **SpaceX Rendezvous With ISS**
- **SpaceX Powered Flight**
- **C&DH Verification Testing on PRCU**
- **SDS Unberth and Install on EOTP**
- **Install SDS on Col-EPF SOX**
- **2-3 Years On-Orbit Operational Life**
- **MMOD Impact**
  - Impact produces acoustic waves and resistance changes
- **End of Mission Uninstall and Disposal**
- **Controllers at JSC**
  - Monitor SDS Status and Send Commands via TReK; Analyze Data
- **POIC Monitor Health & Status Plus Control Command And Data Paths**

**Notes:**
- SDS - Space Development System
- Col-EPF SOX - Commercial Capability to the Extra-Vehicular Mobility Unit (EVA) Space Outpost (EPF) System Oceanic Experiment (SOX) Module
- MMOD - Man-Made Object Debris
- POIC - Planetary Object Impact Casualty
SDS on Columbus-External Payload Facility
SDS ISS Orientation

Grid line orientation

Zenith

Col-EPF

Nadir

Starboard

Port
Orbital Debris Engineering Model (ORDEM 3.0)

2-D Directional Flux
Average 2017-2018  a = 6794.635  e = 0.000368  inc = 51.65  Particle Size ≥100um

Local Elevation (deg)
Local Azimuth (deg)

Flux (no/m²/hr)

10^{-11}  10^{-1}
2-D Directional Flux – MEM 2.0

Micro-Meteoroid Engineering Model (MEM 2.0)

2-D Directional Flux

Year: 2017  \(a = 6794.635\)  \(e = 0.000368\)  \(\text{inc} = 51.65\)  \(\text{Particle Size} \geq 124\mu\text{m}\)
Predicted Flux vs. Velocity

Average MMOD Flux vs. Velocity, ISS 2017-2018

- ORDEM ($\geq 100 \mu m$)
- MEM ($\geq 124 \mu m$)
Conclusions

• SDS is the top priority for NASA ODPO development of orbital debris monitoring capability
  – Addressing a gap in detection coverage
  – SDS will inform the design of future DRAGONS

• The NASA ODPO will use the experience from SDS to improve the detection and characterization technology.
  – Improved grids with 50µm width lines
  – Larger detection areas
  – Improved acoustic algorithms for speed, direction, and density calculations

• The NASA ODPO is pursuing additional flight opportunities to put DRAGONS at higher altitudes
  – Targeting flights in the 700 to 1000 km altitude region
  – Sun-synchronous orbits
Questions?