Microgravity Deployment Test of an MMOD Impact Screen

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1993: Olympus anomaly

- Communications satellite in GEO
- Failed during Perseid meteoroid shower
- Experienced gyro shutdown
- Loss of mission due to fuel shortage

ESA
2009: Landsat 5 anomaly

- Observation satellite in LEO
- Failed during Perseid meteoroid shower
- Experienced extreme gyro rates
- Resumed operation after recovery ops

NASA
2002: Jason 1 anomaly

- Observation satellite at 1336 km altitude
- Detected impact event during Gamma Normid meteoroid shower
- Orbit semimajor axis changed by 30 cm
- Experienced power spike for 5 hours

NASA
2010: Galaxy 15 anomaly

- Communications satellite in GEO
- Stopped responding to ground control
- Drifted out of orbital slot
- Recovered after loss of power
- Failure attributed to ESD

Orbital Sciences Corp.
Hypervelocity Impact Model
Hypervelocity Impact Model

- **Impact:**
  Meteoroid hits spacecraft at speeds over 11 km/s (average 50 km/s)

- **Plasma formation:**
  Particle ionizes itself and part of the spacecraft forming a dense plasma

- **Initial electron motion:**
  Electrons outrun ions due to their higher mobility (lower mass)

- **Plasma expansion:**
  Ions expand outward at isothermal sound speed
  Electrons oscillate about the expanding ion front
Research Program

Question:

*Can meteoroid and debris impact cause electrical anomalies on spacecraft?*

Mechanism:

![Source → Path → Victim diagram]

Research components:

- In situ measurements
- Modeling and simulation
- Ground-based testing
In Situ Hypervelocity Impact Characterization

MEDUSSA:
Meteoroid, Energetics, and Debris Understanding for Space Situational Awareness

- 3U CubeSat mission
- Goal: Study electrical effects of impacts in space
- RF and plasma sensors
- Deployable 1 m × 1 m MMOD impact screen
- Expected detection rate of 1 impact per day from ng particle
Screen Deployment Test in Microgravity

- Goal: Study deployment dynamics of three different configurations
  - **Radial**: 0.001” membrane, with booms deploying straight out from a spool
  - **Thin spiral**: 0.001” membrane, wrapped around a central core
  - **Thick spiral**: 0.005” membrane, wrapped around a central core

- Result: Radial did not work, thin spiral quite successful, thick spiral promising but needs further work
FAST Program Offered Parabolic Flights

- NASA technology development program
- “The goal for FAST is to help emerging technologies move from TRL 4–5 to TRL 6–7.”
- September 27 – October 1, 2010, Houston, TX
- Two microgravity flights — 80 parabolas of 15–25 seconds each
- Flight crew: Shandor Dektor, Joseph Johnson, Nicolas Lee

Zero-G Corporation
Test Modules Designed for Repeated Deployment

- Rapid-prototyped cores
- Laser-cut panels
- Servo-actuated trigger
- B&D tape measure deployment booms
- Special fold pattern designed for 0.005” membrane
Thirty-seven Deployments Over Eighty Parabolas

Radial:
- 5 deployments
- Most modules contacted the ground during boom deployment
- All five deployments experienced boom buckling

Thin spiral:
- 22 deployments
- Tumbling and spinning initial conditions did not greatly affect deployment
- Most deployments were fully successful

Thick spiral:
- 10 deployments
- Innermost membrane region was too tightly packed to unfold
- Spinning and flattening out the membrane helped deployment
Radial Deployments
Thin Spiral Deployments
Thick Spiral Deployments
Future Work

- Maximize membrane thickness
- Test new materials
- Test deployment in vacuum
- Design full deployable prototype for MEDUSSA configuration
- Extend deployable applications to other space missions
Conclusions

- Spiral deployment was much more successful than radial deployment
- High level of confidence in spiral deployment method reduces mission risk
- Deployable systems are key to extending capabilities of CubeSats and other small satellites