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Space Environment and Satellite Systems

Microgravity Deployment Test of an MMOD Impact Screen

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STANFORD ENGINEERING

SSDL
Space and Systems Development Laboratory

Screen Deployment in a Microgravity Environment

1993: Olympus anomaly

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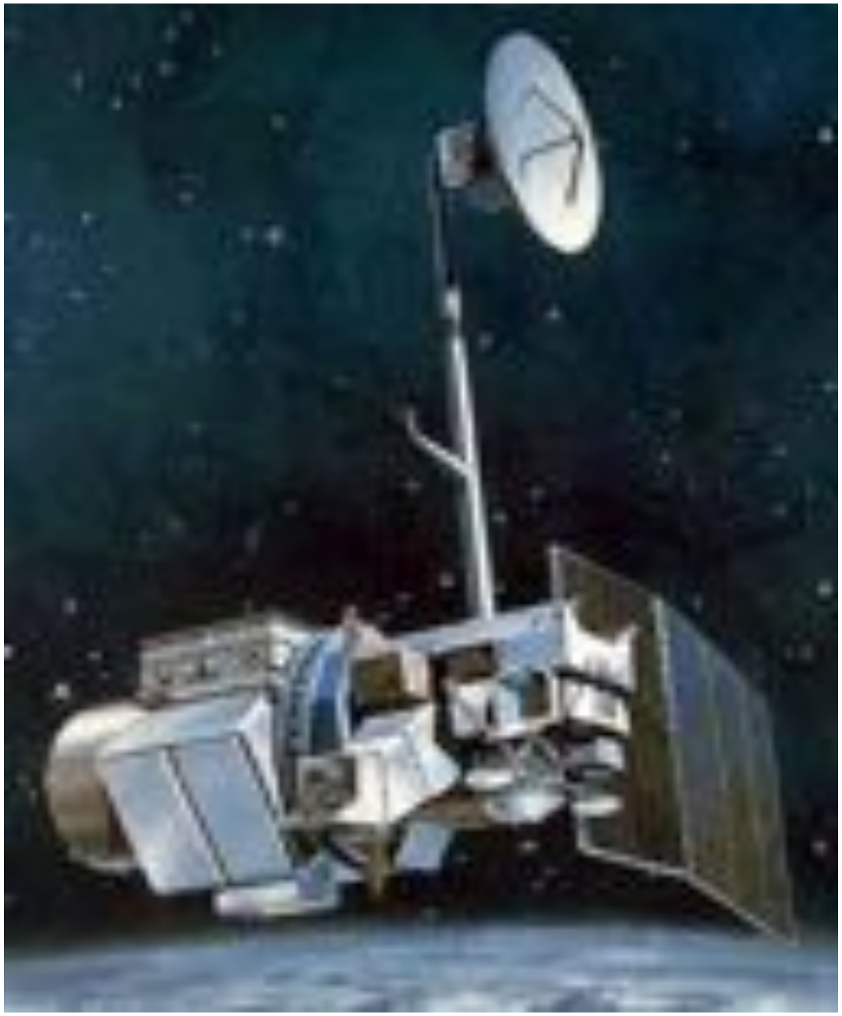
- Communications satellite in GEO
- Failed during Perseid meteoroid shower
- Experienced gyro shutdown
- Loss of mission due to fuel shortage

ESA

2009: Landsat 5 anomaly

SESS

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

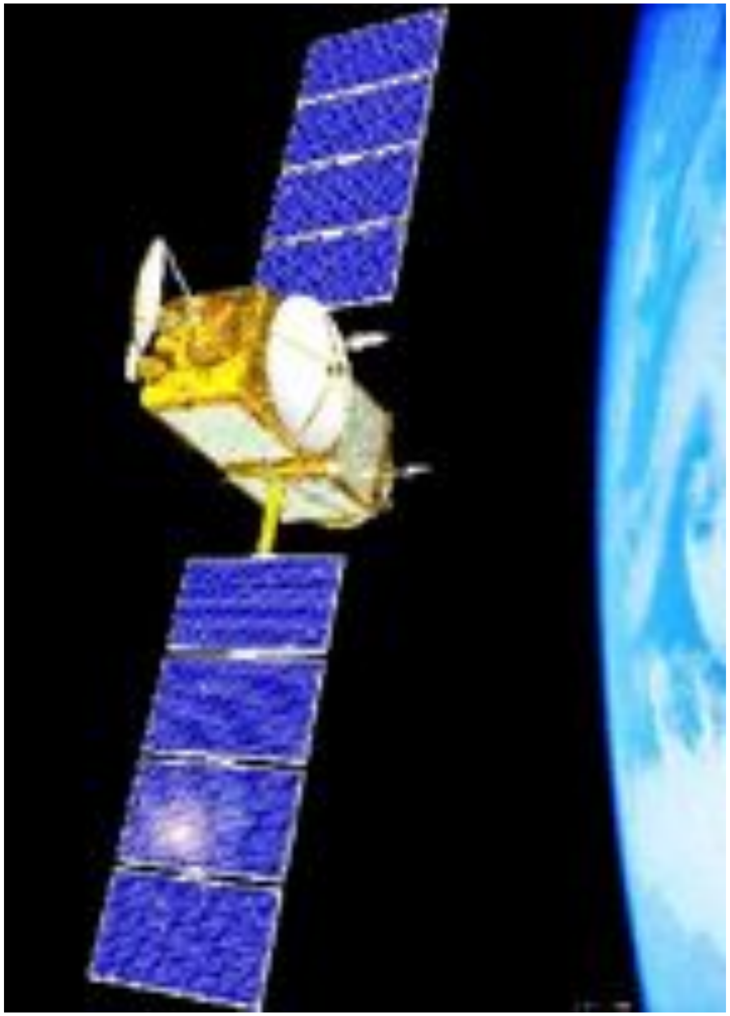


NASA

2002: Jason 1 anomaly

SESS

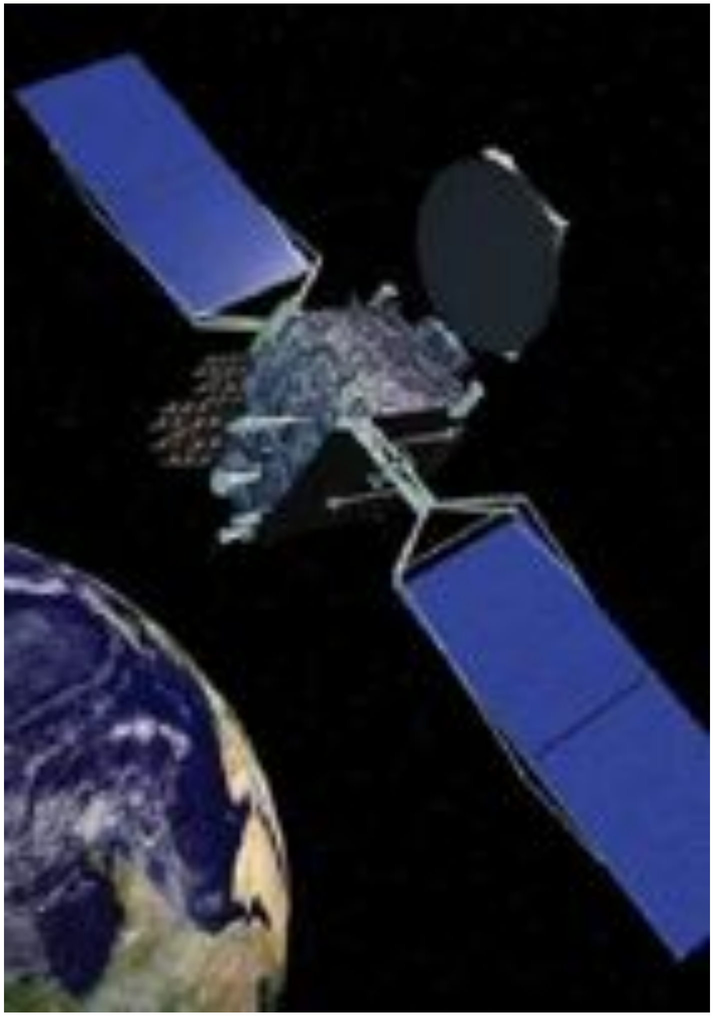
- Observation satellite at 1336 km altitude
- Detected impact event during Gamma Normid meteoroid shower
- Orbit semimajor axis changed by 30 cm
- Experienced power spike for 5 hours



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

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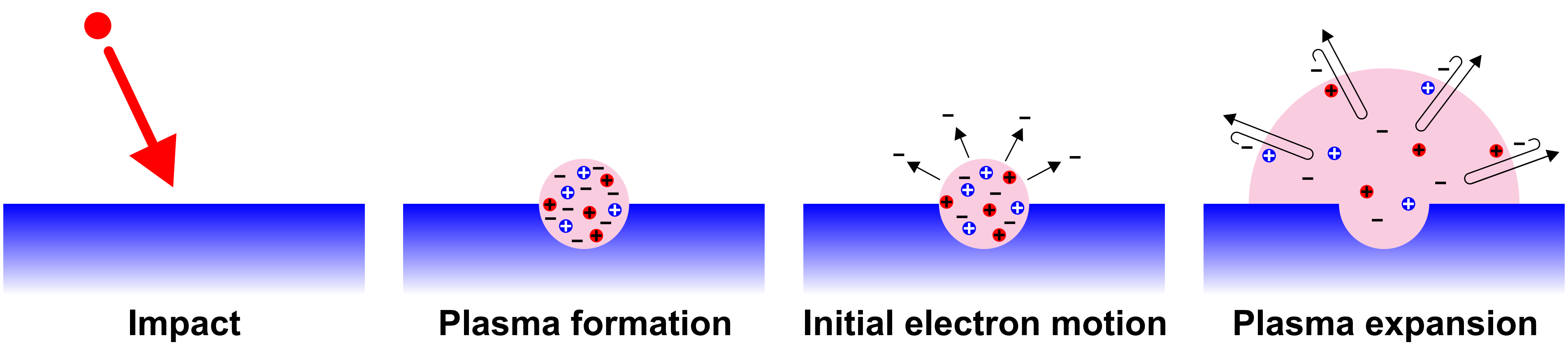
- **Impact:**
  Meteoroid hits spacecraft at speeds over 11 km/s (average 50 km/s)
- **Plasma formation:**
  Particle ionizes itself and part of the spacecraft forming a dense plasma
- **Initial electron motion:**
  Electrons outrun ions due to their higher mobility (lower mass)
- **Plasma expansion:**
  Ions expand outward at isothermal sound speed
  Electrons oscillate about the expanding ion front



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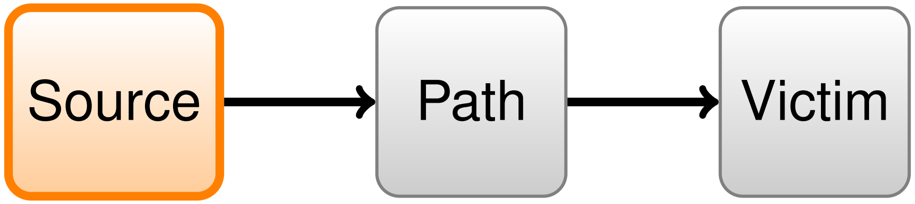
Research Program

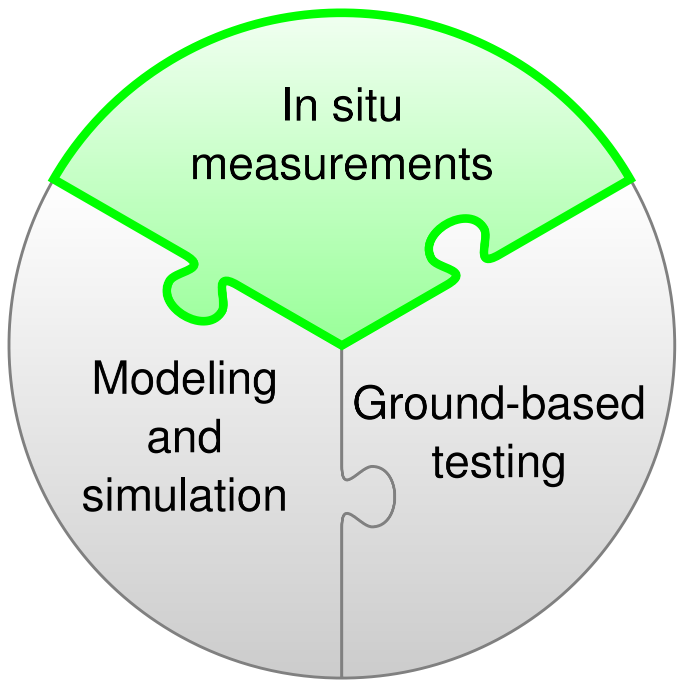
Question:

Can meteoroid and debris impact cause electrical anomalies on spacecraft?

Mechanism:



Research components:

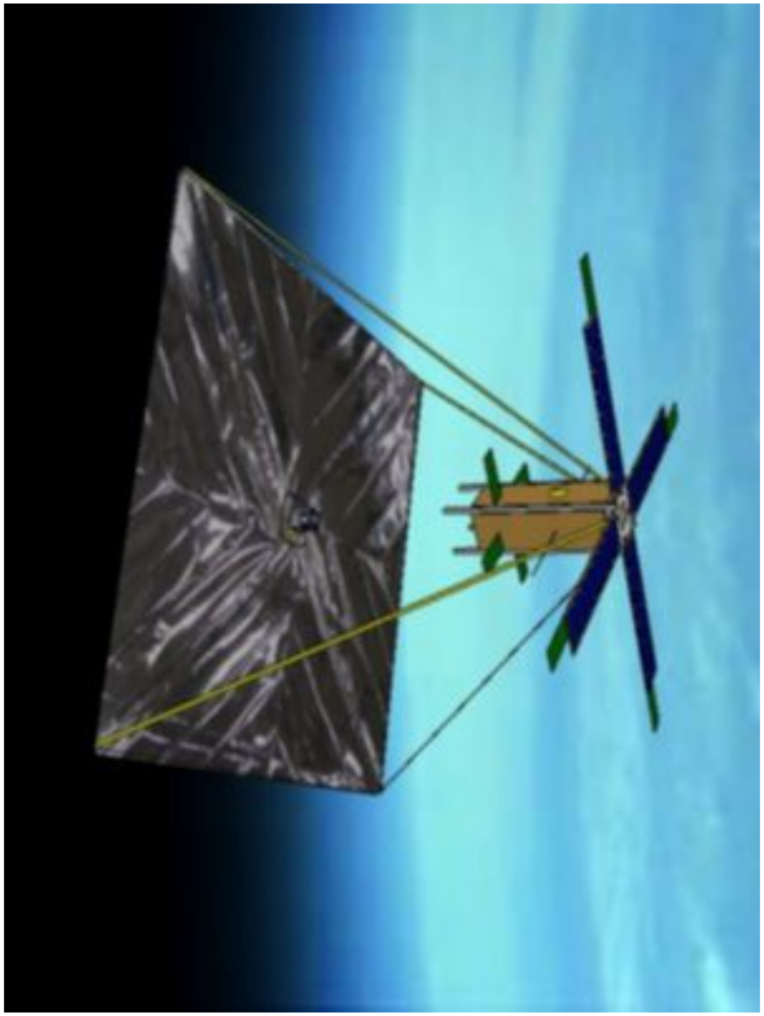


In Situ Hypervelocity Impact Characterization

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 $\times$ 1 m MMOD impact screen
- Expected detection rate of 1 impact per day from ng particle



Screen Deployment Test in Microgravity

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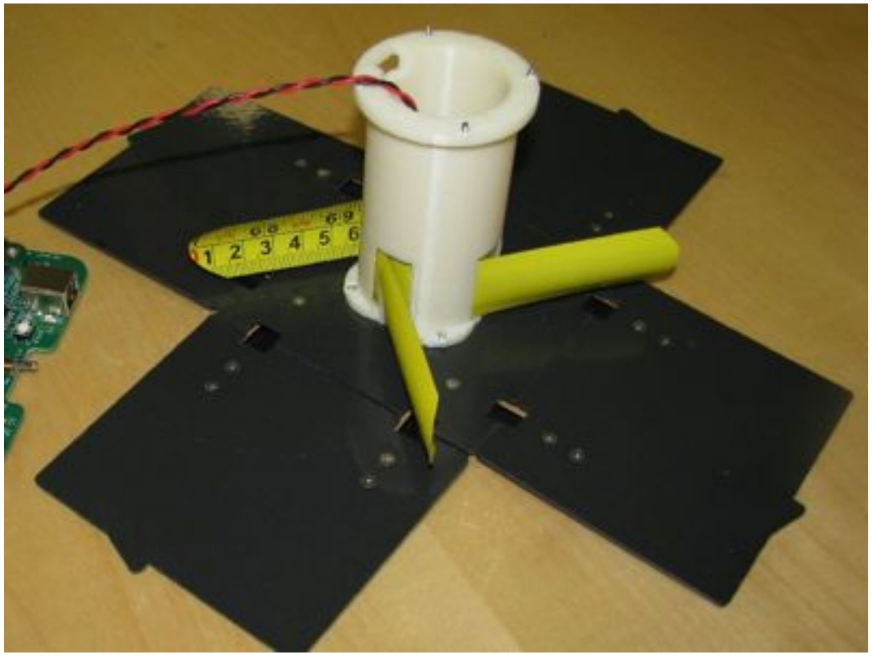
- Goal: Study deployment dynamics of three different configurations

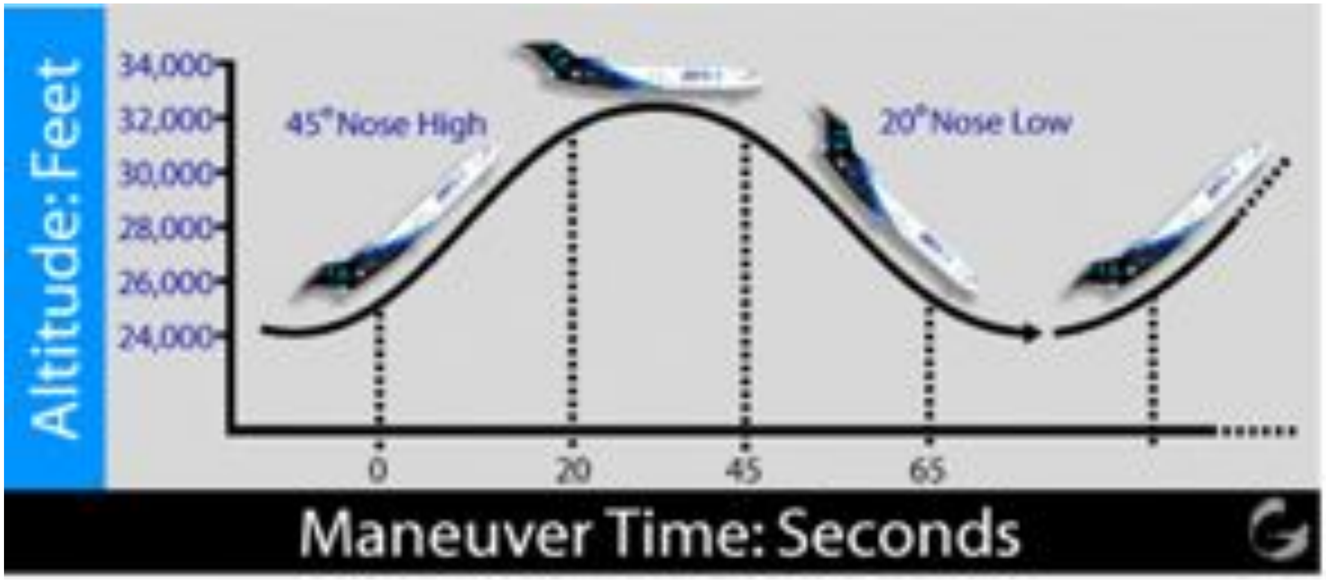
  Radial: 0.001” membrane, with booms deploying straight out from a spool
  Thin spiral: 0.001” membrane, wrapped around a central core
  Thick spiral: 0.005” membrane, wrapped around a central core

- 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

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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

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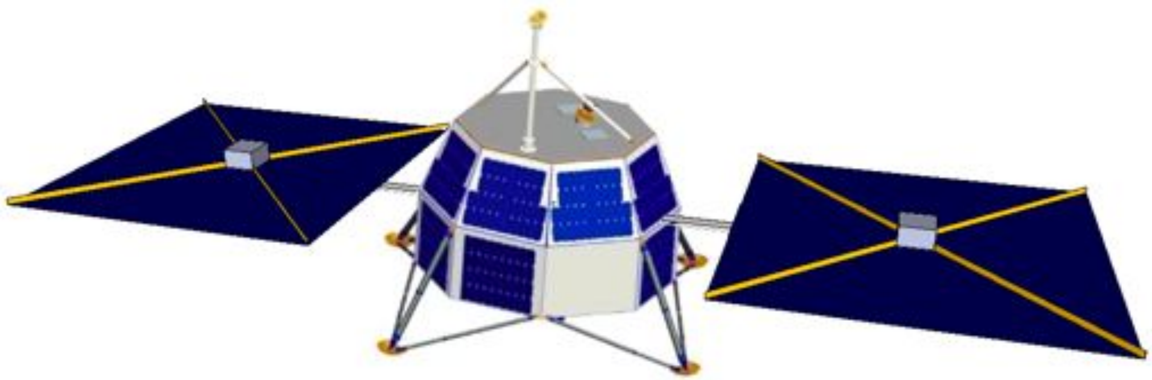
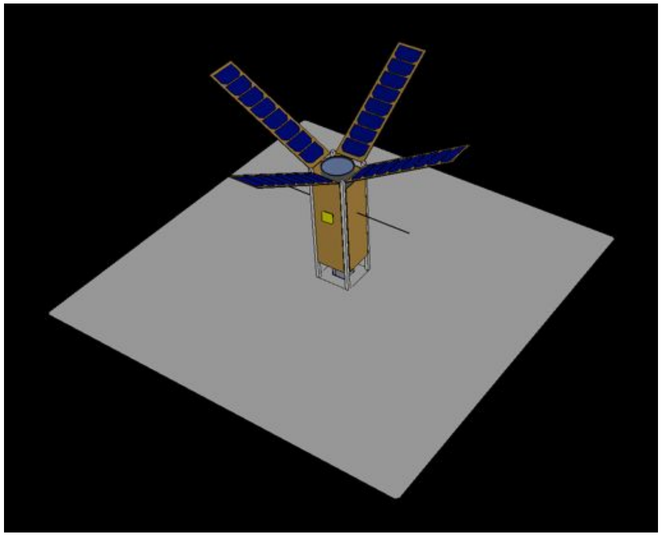
- Maximize membrane thickness
- Test new materials
- Test deployment in vacuum
- Design full deployable prototype for MEDUSSA configuration
- Extend deployable applications to other space missions





Conclusions

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- 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

Slide Index