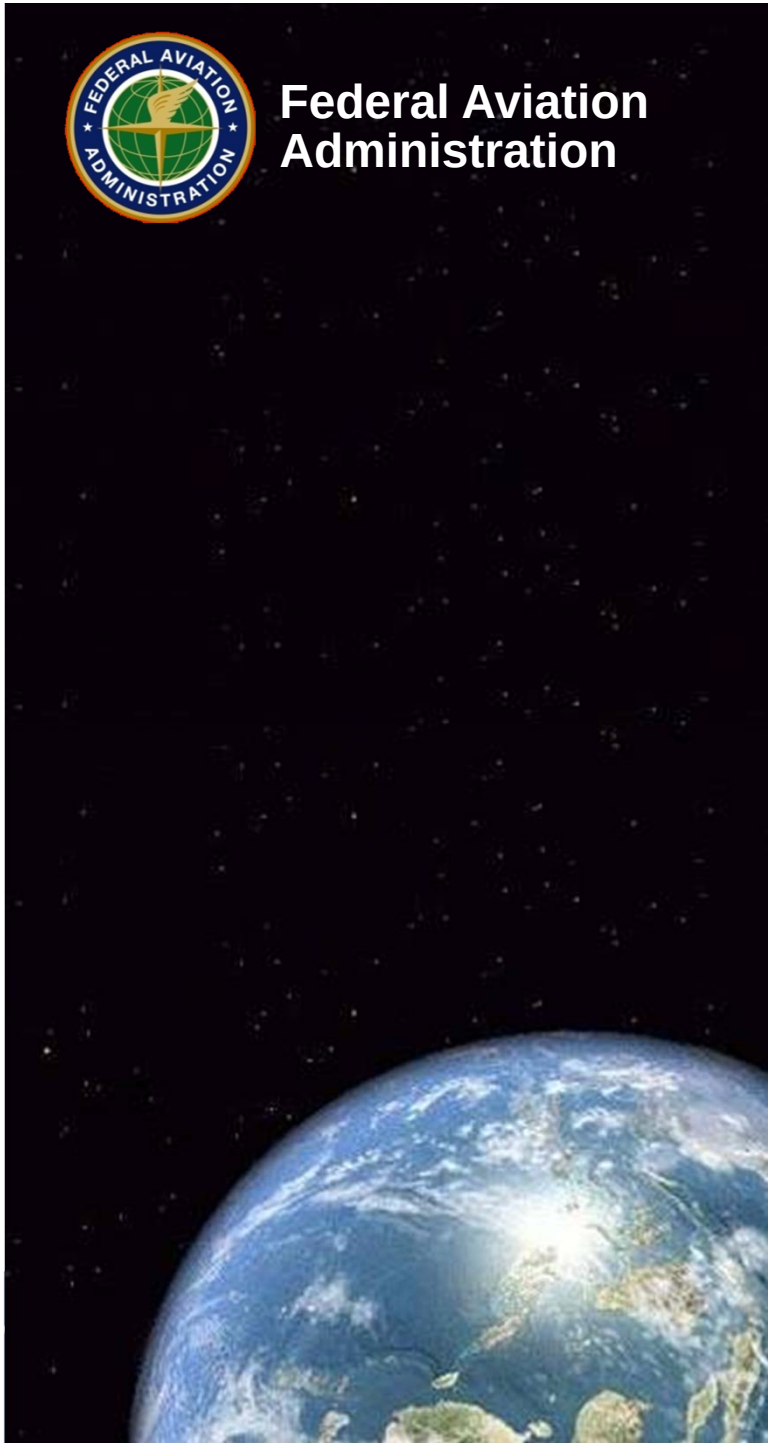
COE CST First Annual Technical Meeting:

Space Environment MMOD Modeling and Prediction

Sigrid Close

November 9, 2011



Overview

- Team Members
- Purpose of Task
- Research Methodology
- Results
- Next Steps
- Contact Information

Team Members

- **Sigrid Close, Stanford University**
- **Alan Li, Stanford University (graduate student)**

Purpose of Task

- **Spacecraft are routinely impacted by space debris and natural impactors**
  - Mechanical damage: "well-known", larger (> 120 microns), rare
  - Electrical damage: "unknown", smaller/fast, more numerous
- **Debris vs. meteoroids threat to LEO spacecraft**
  - Mechanical threat: comparable
  - Electrical threat: dominated by meteoroids
- **Goal: Characterize impactor population through data analysis and modeling**

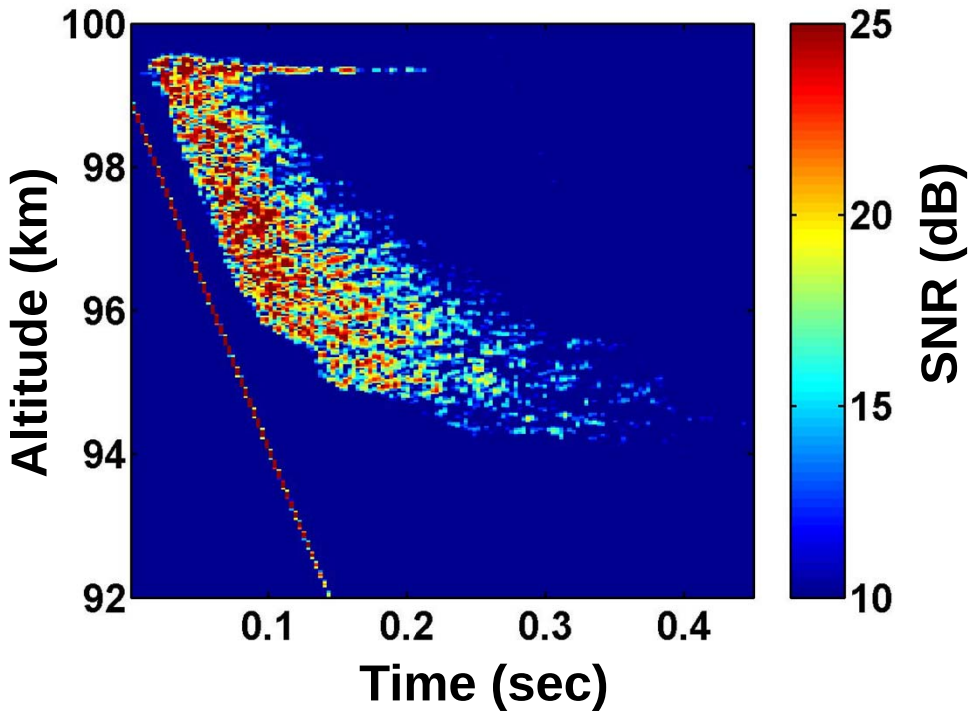
Impactors

- **Dust and Meteoroids**
  - Speeds
    - 11 to 72.8 km/s (interplanetary)
    - > 72.8 km/s (interstellar**)**
  - Densities
    - rocky or ice-like
  - Sizes
    - < 62 microns in diameter (dust)
    - 62 microns to 0.3 m in diameter (meteoroid)

- **Space Debris**
  - Speeds: < 12 km/s
  - Higher densities
  - Varying sizes

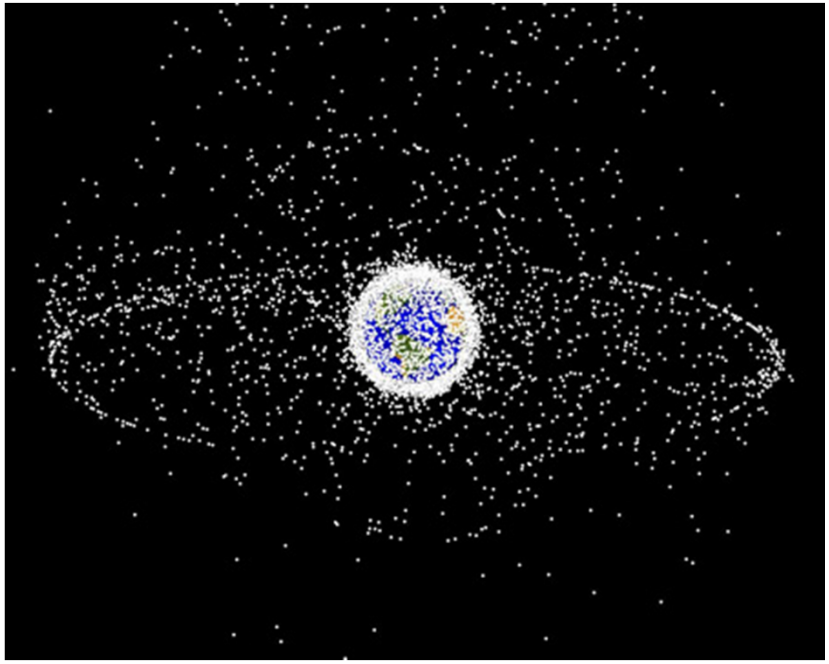
Methodology: Meteoroids

- **Models: Formation of plasma (PIC), Interaction of electromagnetic waves with plasma (FDTD), Atmosphere**
- **Data: Ground-based plasma, in-situ impact**
- **Research and Deliverables**
  - Flux
  - Mass, density
  - Velocity, orbit



Methodology: Debris

- **Models: Propagation of debris in space and time (Force Model), Atmospheric models (MSIS, Jacchia-Bowman)**
- **Data: Ground-based/in-situ impact for detection, Light-gas gun for debris source**
- **Research and Deliverables**
  - Flux
  - Source
  - Prediction

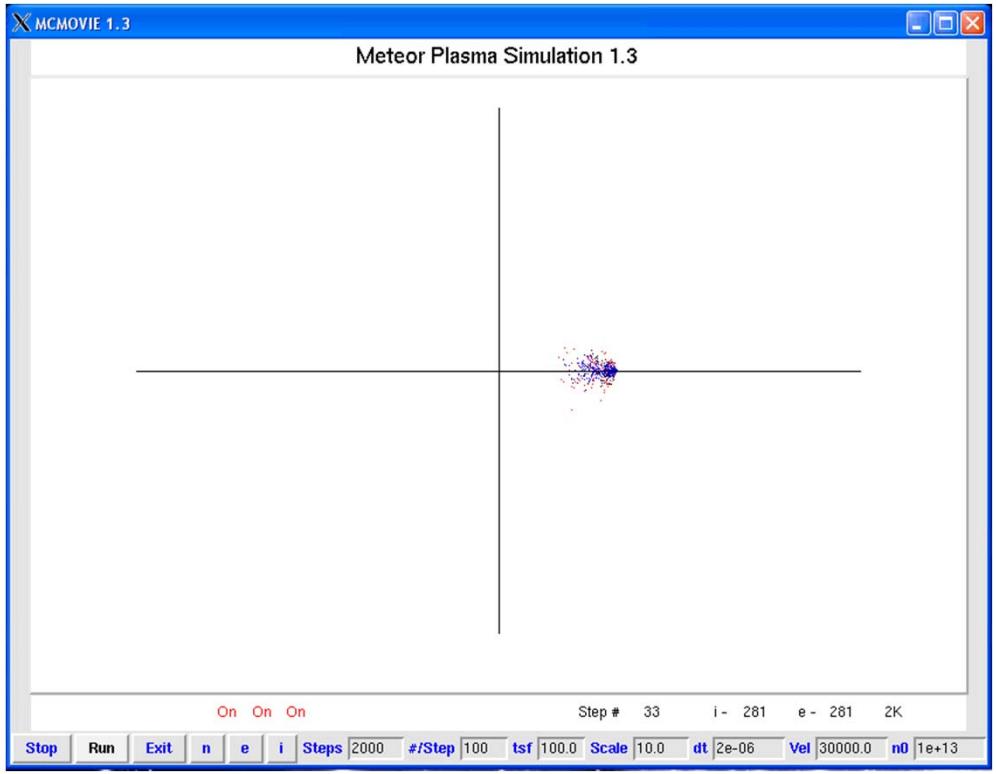


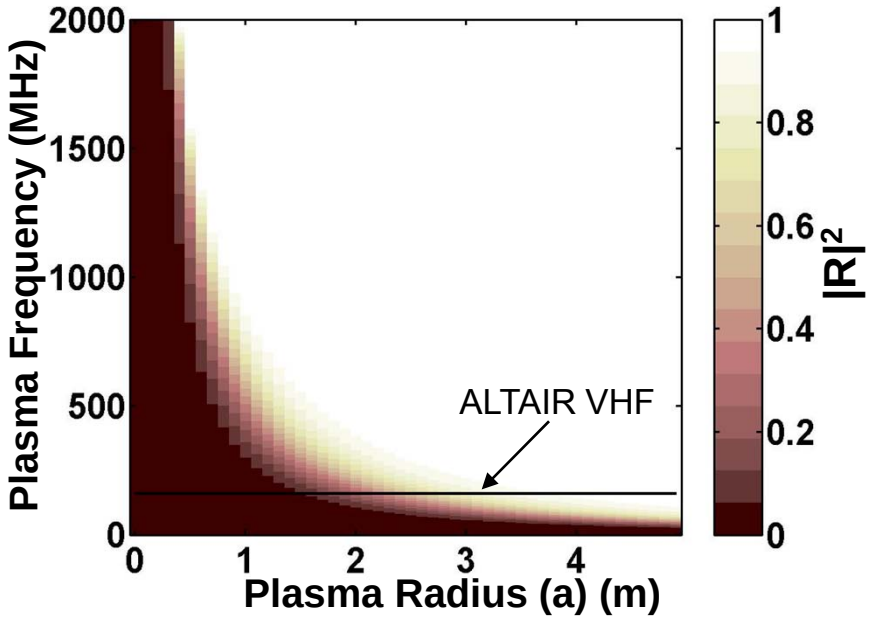
Radar Data

- **High-power ground-based meteor observations**
  - Multi-frequency, multi-polarization, high-sensitivity, high range resolution
- **Radars**
  - ALTAIR
  - Arecibo Observatory
  - MIT Haystack
  - EISCAT

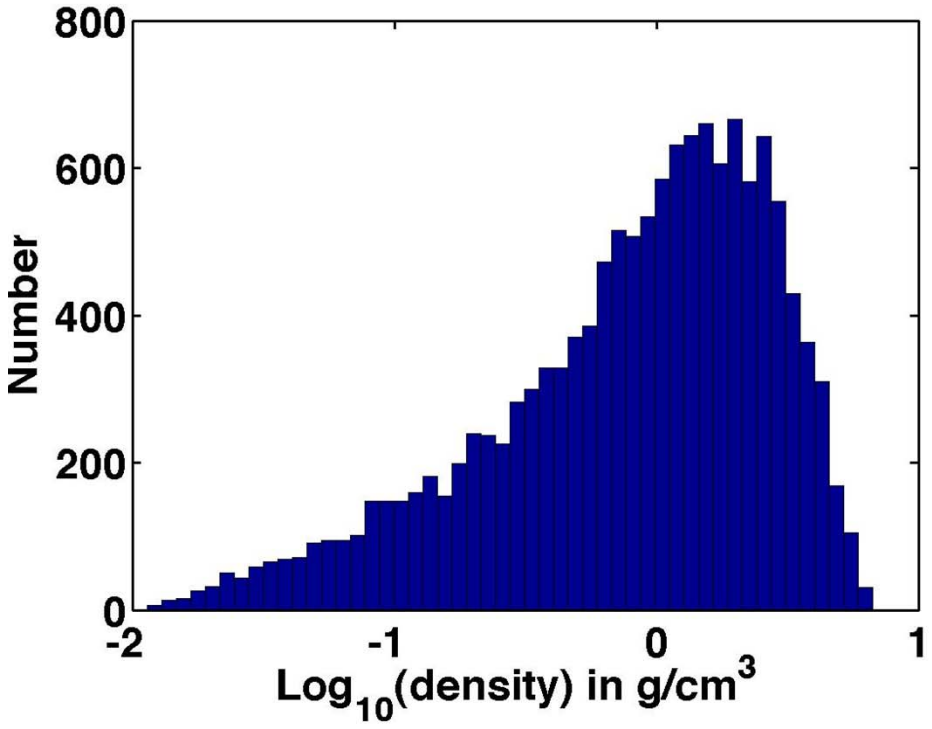


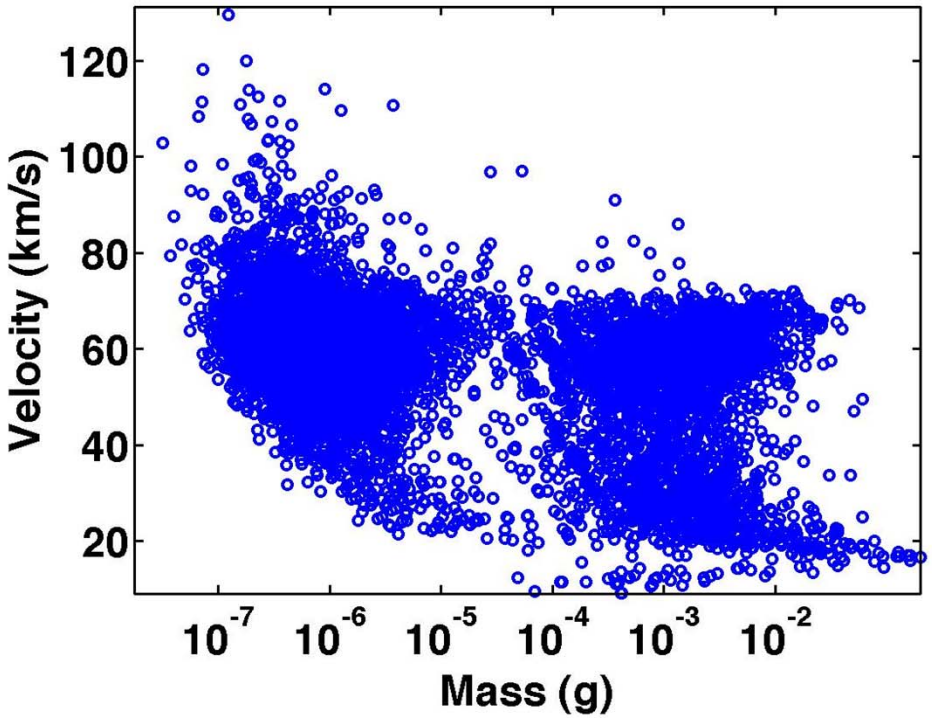

Meteoroid Plasma Modeling





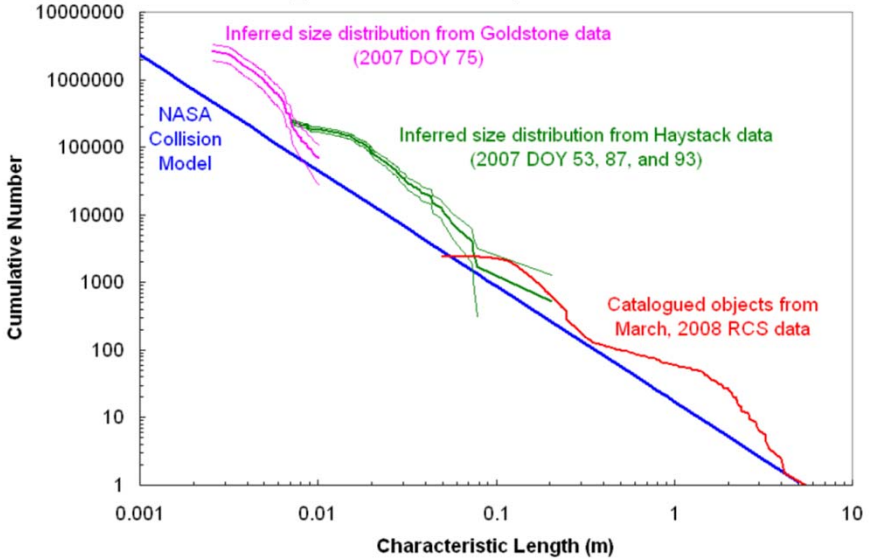
Meteoroid Results





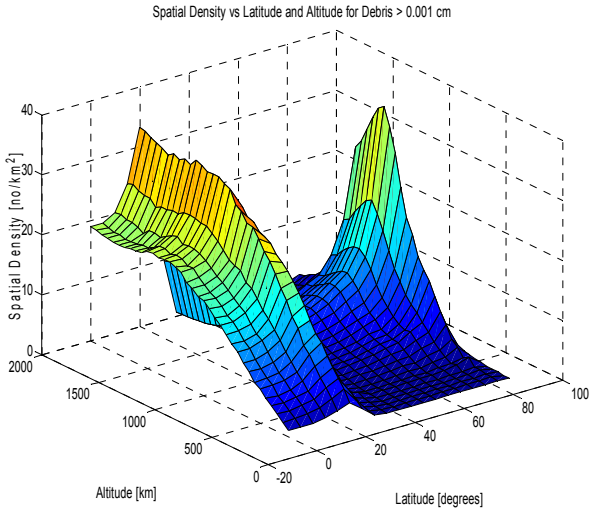
Debris Modeling

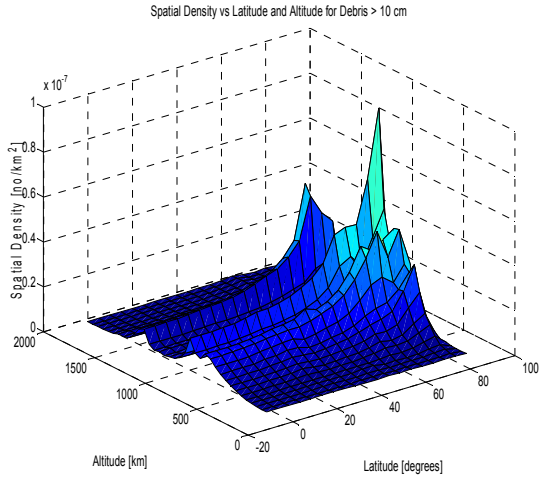
- **NASA: ORDEM, LEGEND**
- **ESA: MASTERS**
- **Modeling from sources, propagation, conjunction**
- **Newer sources (perhaps hybrids), newest atmospheric models (Jacchia-Bowman)**
- **NASA collision model (inadequate in many areas)**
  - No material dependence
  - No size and shape factor dependence
  - Velocity distribution inadequate



Debris Results

- **Based upon three primary sources**
  - US Space Command Catalog, Haystack Radar, and in-situ
  - Auxiliary data provided by HAX radar, Goldstone radar, returned solar array from Hubble Space Telescope
- **Extrapolation based upon EVOLVE for ranges of debris where data is scarce**





Next Steps

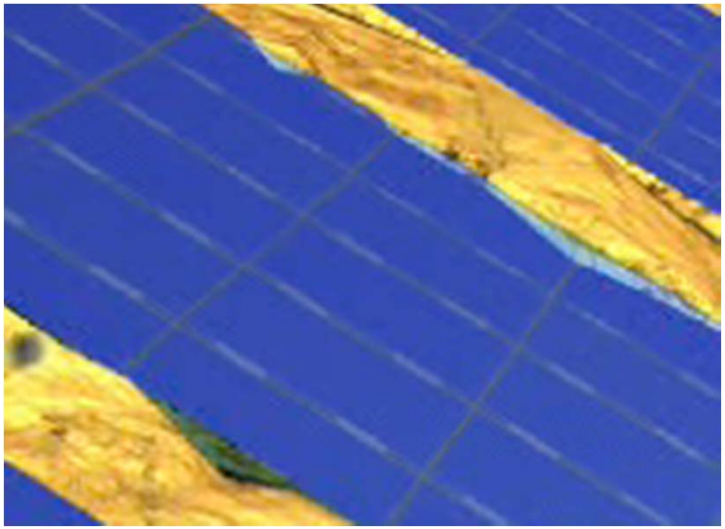
- **Meteoroids**
  - Compressed sensing techniques for improved detection/analysis
  - Force modeling for improved orbit determination
  - Electromagnetic scattering models for plasma diagnostics
- **Debris**
  - Characterization of all sources/breakups
  - Comparison between MASTERS/ORDEM
  - Propagation and atmospheric models

Publications

- **Close *et al*., "Determining Meteoroid Bulk Densities Using a Plasma Scattering Model with High-Power Large-Aperture Radar Data", *Icarus*, in review, 2011**
- **Reference: National Academies Report: "Limiting Future Collision Risk to Spacecraft: An Assessment of NASA's Meteoroid and Orbital Debris Programs"**

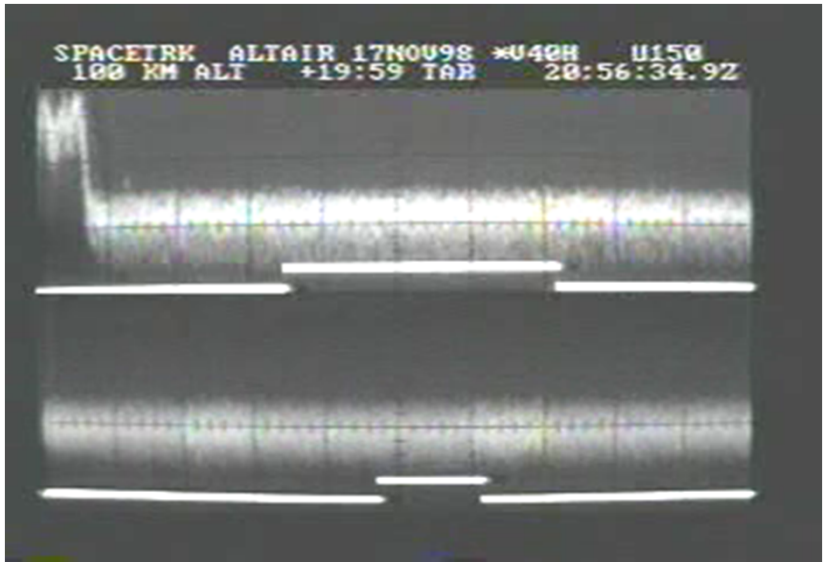
Thank You!

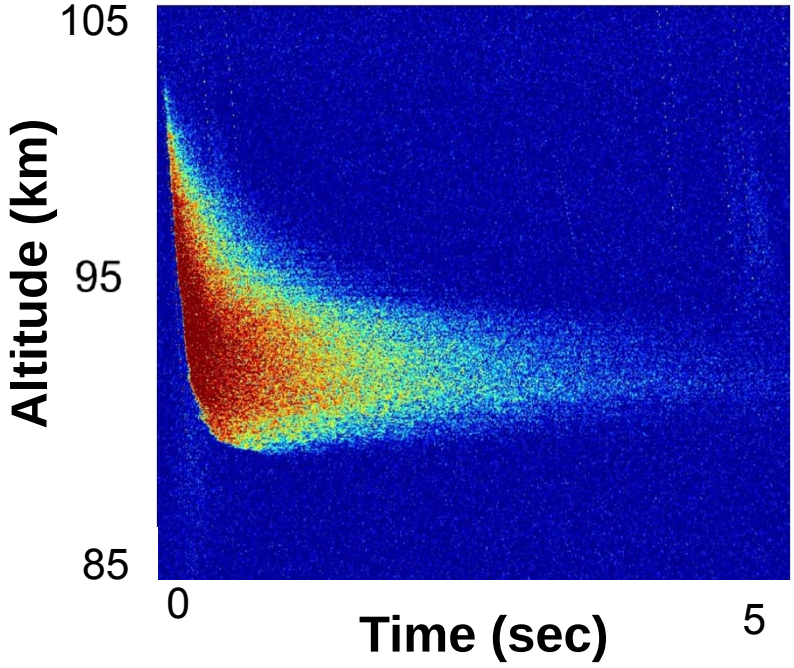
- **Sigrid Close (sigridc@stanford.edu)**
- **Alan Li (alanli@stanford.edu)**



Backup

ALTAIR Radar Data





Mechanical and Electrical Damage