COE CST Seventh Annual Technical Meeting

Task 186: Space Environment MMOD Modeling and Prediction

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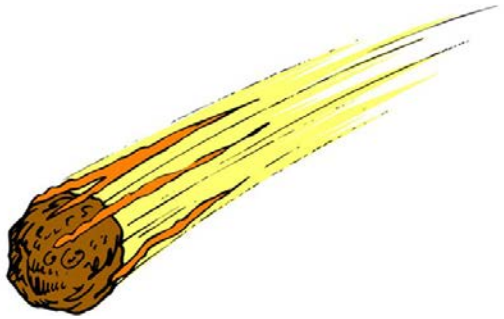
Center of Excellence for Commercial Space Transportation

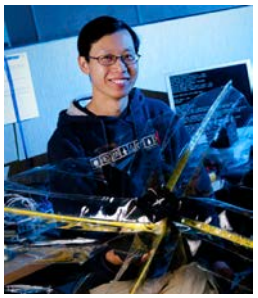
Agenda

- Team Members
- Task Description
- Goals
- Results
- Conclusions and Future Work



Team Members

- **PI: Sigrid Close**
- **Research Staff: Nicolas Lee**

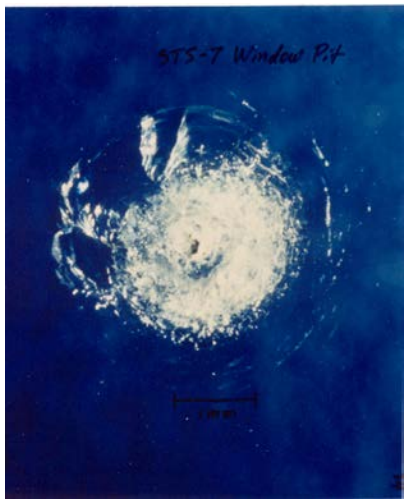


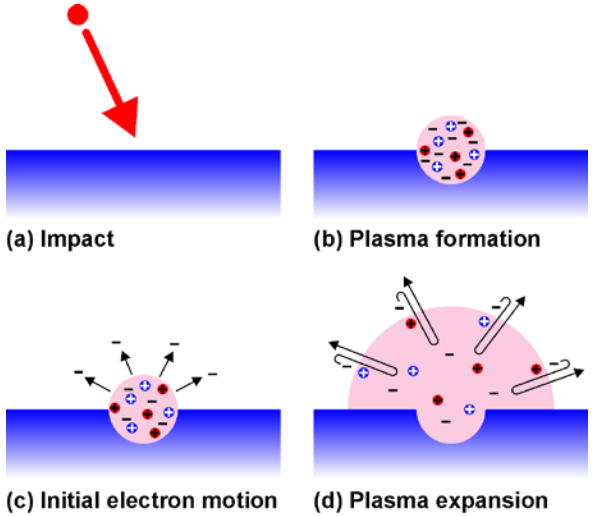
- **Graduate Students**
  - Diana Hernandez Juarez-Madera
  - Lorenzo Limonta (supported by NSF)

- **Collaborators**
  - University of Western Ontario
  - NASA Marshall Space Flight Center

Task Description

- **Spacecraft are routinely impacted by micrometeoroids and orbital debris (MMOD)**
  - Mechanical damage: "well-known", larger (> 120 microns), rare
  - Electrical damage: "unknown", smaller/fast, more numerous





- **Growing need to characterize MMOD down to smaller sizes and provide predictive threat assessment**

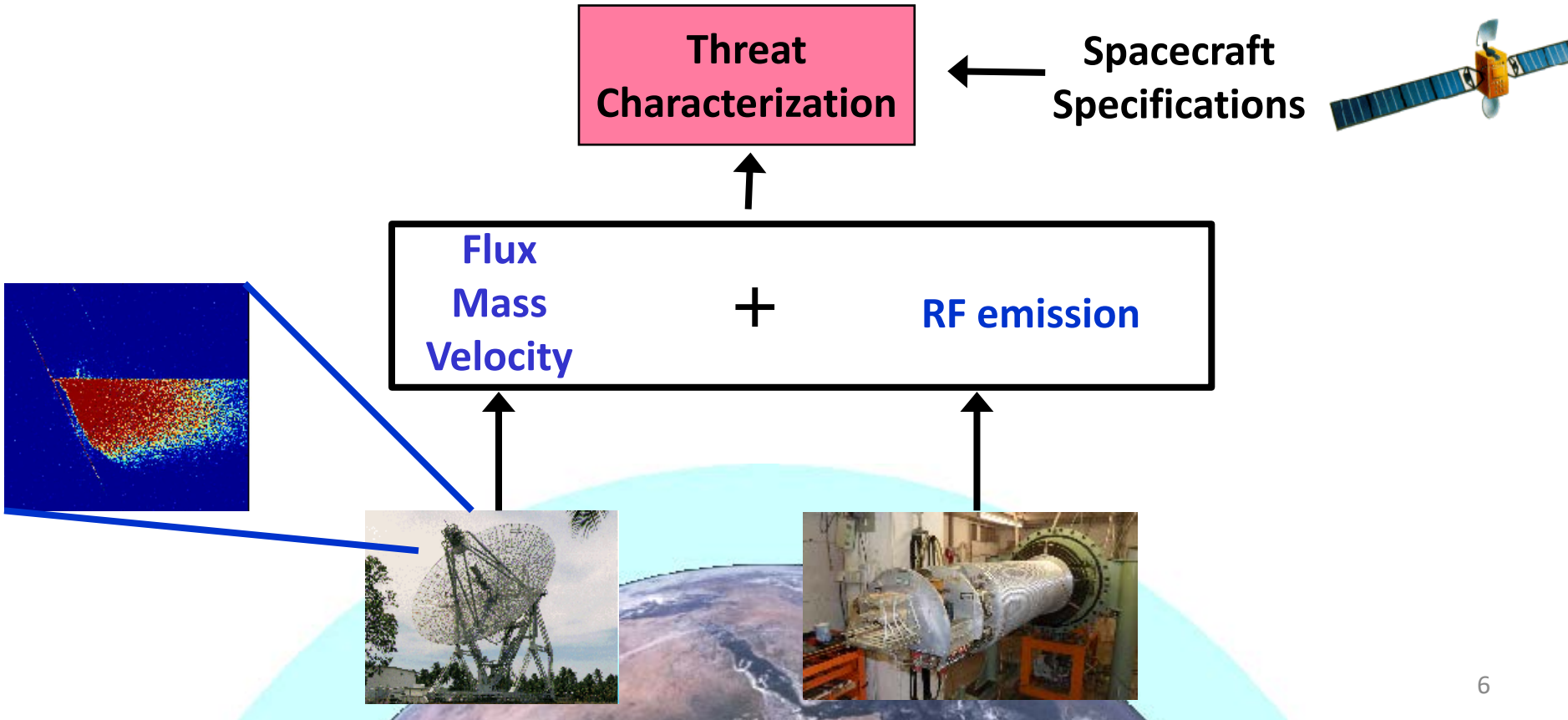
MMOD – Classification

- **Meteoroids**
  - **Speeds**
    - 11 to 72.8 km/s (interplanetary)
    - 30-60 km/s (average)
  - **Densities**
    - ≤1 g/cm^3 (icy) or > 1 g/cm^3 (rocky/stony)
  - **Sizes**
    - < 0.3 m (meteoroid)
    - < 62 μm (dust)

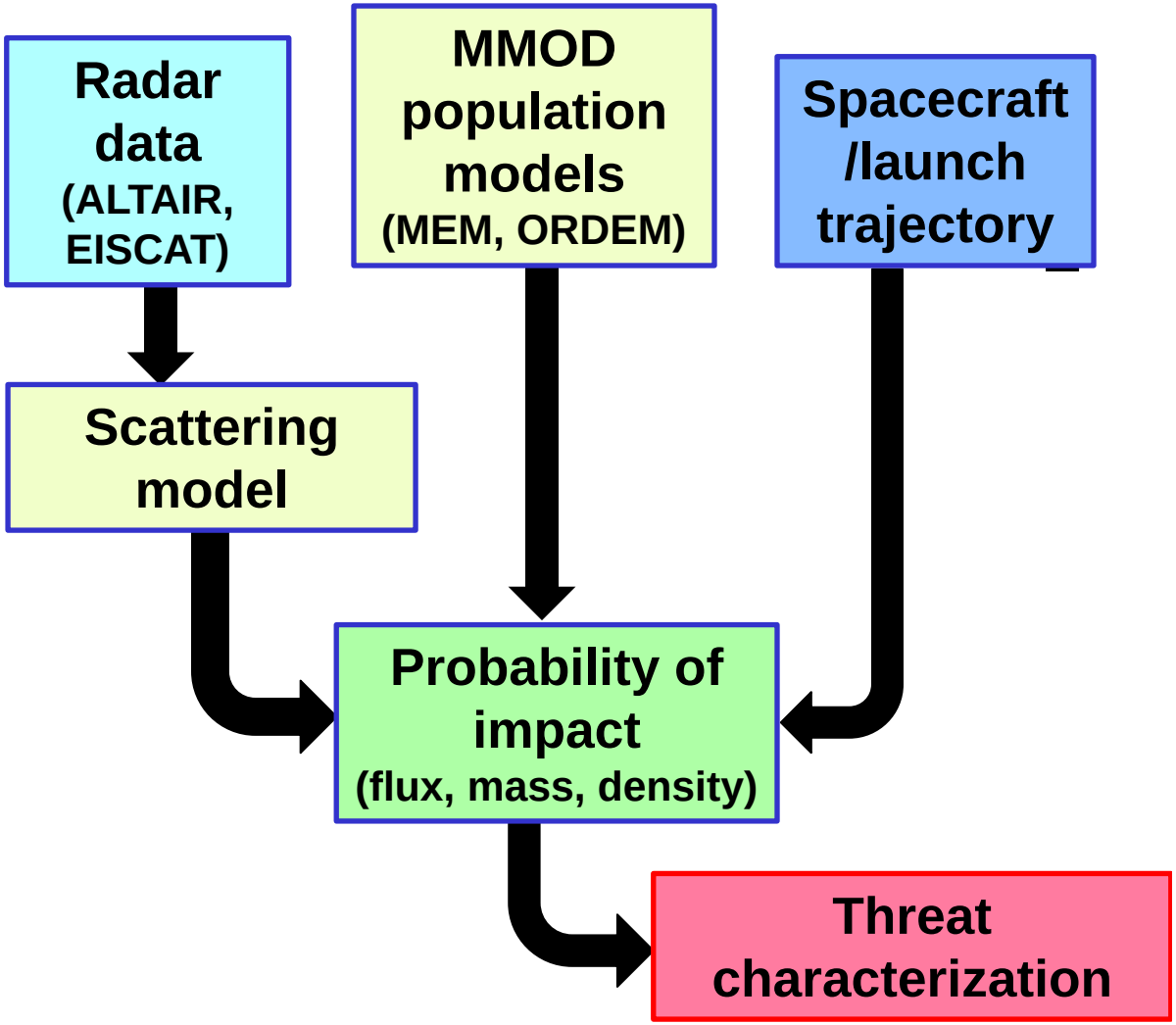
- **Space Debris**
  - **Speeds in LEO**
    - < 12 km/s
    - 7-10 km/s (average)
  - **Densities**
    - > 2 g/cm^3
  - **Sizes**
    - < 10 cm (small)

Goals

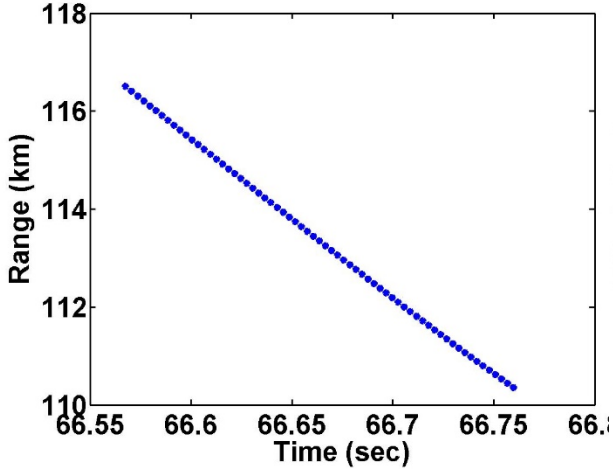
- **Particle impacts in atmosphere: probability of impact**
- **Particles impacts on spacecraft: effects of impact**

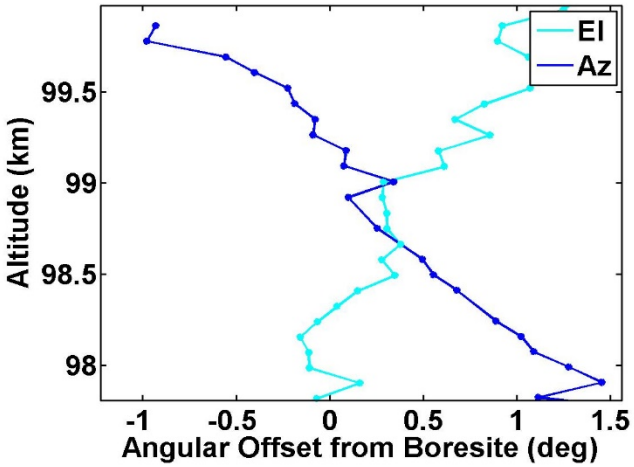


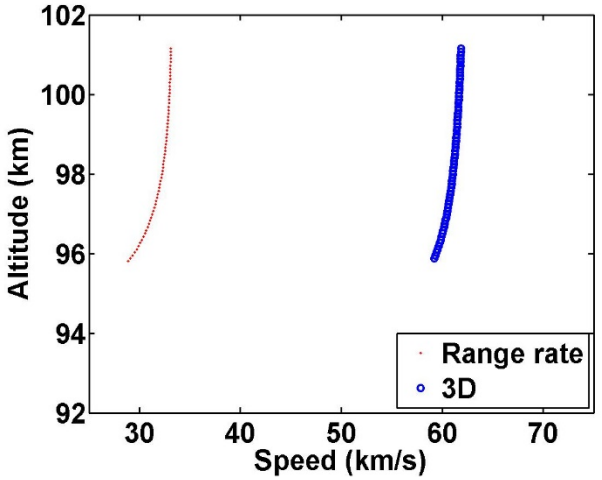
Methodology

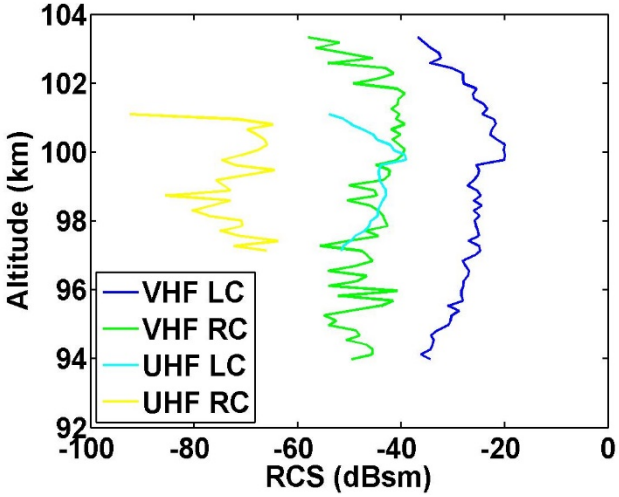


Results: Probability of Impact

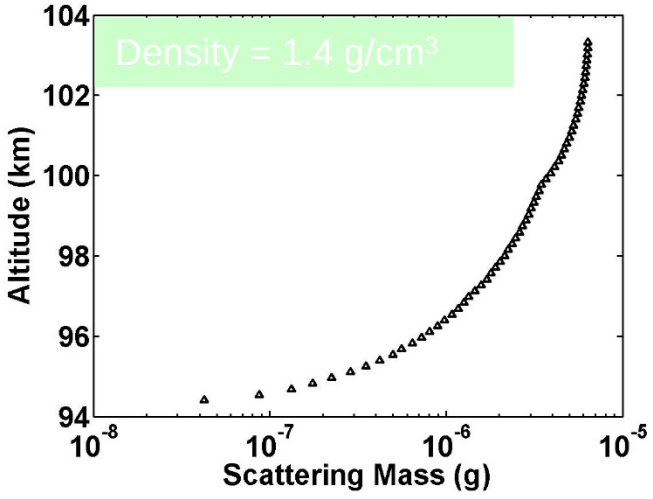




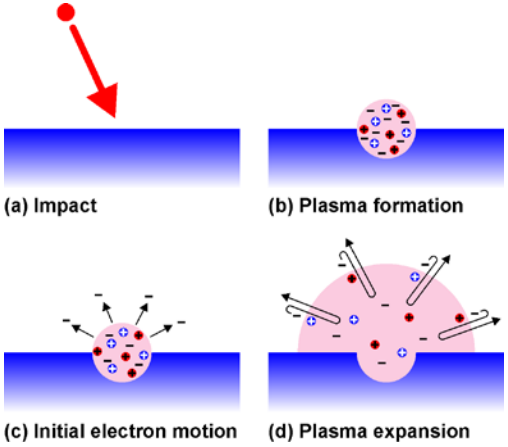




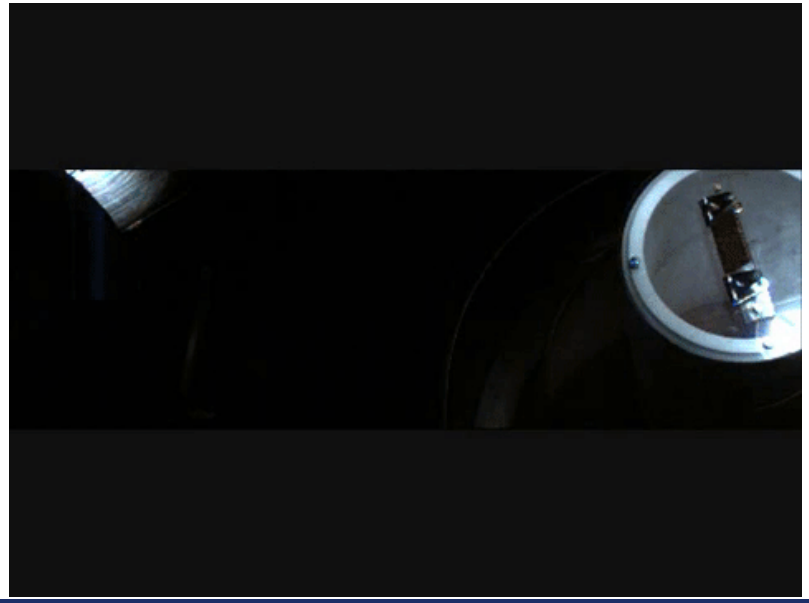
$$-\frac{1}{R_n} = 2 - \frac{n h_n^2(kr) A_n r^{2n+1}}{2(n+1) j_n(kr) B_n}$$

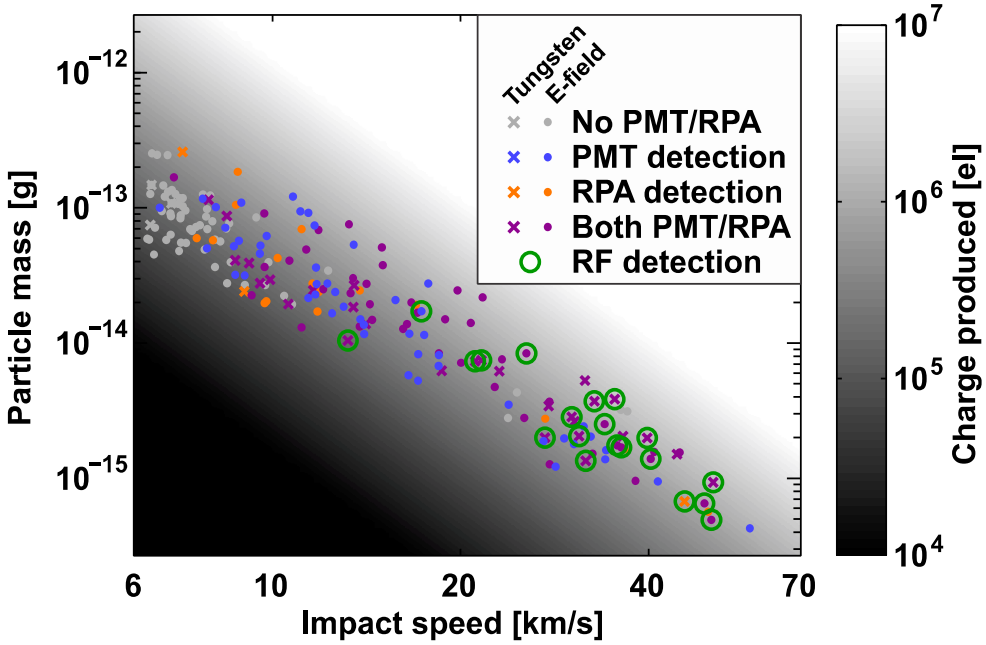


Results: Effects of Impact



$$P = \frac{\omega_{p,o}^4 \left(\frac{v_{th,e}}{\omega_{p,o}}\right)^2 e^2 N \sin^2\left(\omega_{p,o}\frac{r_0}{c_s}\left[1+\frac{2c_s t}{r_0}\right]^{-1/2}\right)}{6\pi e_0 c^3 \left(1+\frac{c_s t}{r_0}\right)^{9/2}}$$





Conclusions and Future Work

- **Characterize probability of MMOD impact**
  - Meteoroid: remote sensing of plasma and scattering model provides flux, mass, density
  - Space debris: remote sensing of particles and shape modeling provides flux, mass
- **Characterize effects of MMOD impact**
  - Space debris: Light-gas gun experiments + impact/plasma modeling
  - Meteoroid: Van de Graaff experiments + impact/plasma modeling
- **Future work**
  - Plasma limit equation
  - Orbital dynamics