# COE CST Tenth Annual Technical Meeting

# Task 186: Space Environment MMOD Modeling and Prediction


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Students: Lorenzo Limonta (and Glenn Sugar)

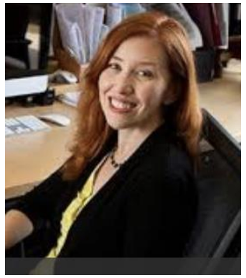
Stanford University

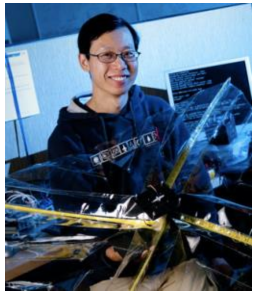

# Agenda

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

# Team Members

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



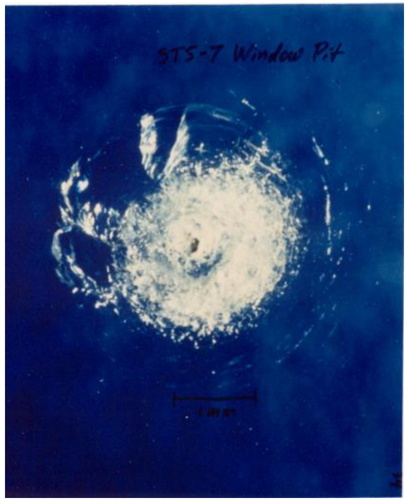


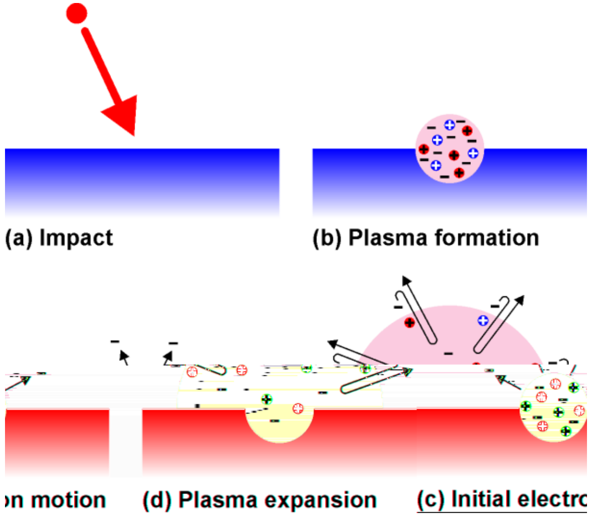
- **Graduate Students**
  - Lorenzo Limonta
  - Glenn Sugar

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

# Task Description

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




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

# Meteoroids and Orbital Debris

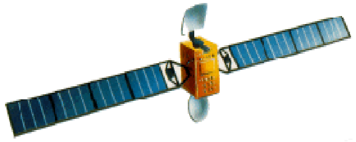
- **Meteoroids**
  - **Speeds**
    - 11 to 72.8 km/s (interplanetary)
    - 30-60 km/s (average)
  - **Densities**
    - ≤1 g/cm$^3$ (icy) or > 1 g/cm$^3$ (rocky/stony)
  - **Sizes**
    - < 0.3 m (meteoroid)
    - < 62 μm (dust)

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

# Goals

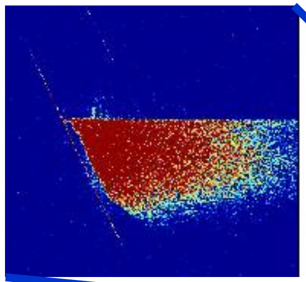
- **Particle impacts in atmosphere: probability of impact**
- **Particle impacts on spacecraft: effects of impact**

**Threat Characterization** ← **Spacecraft Specifications**

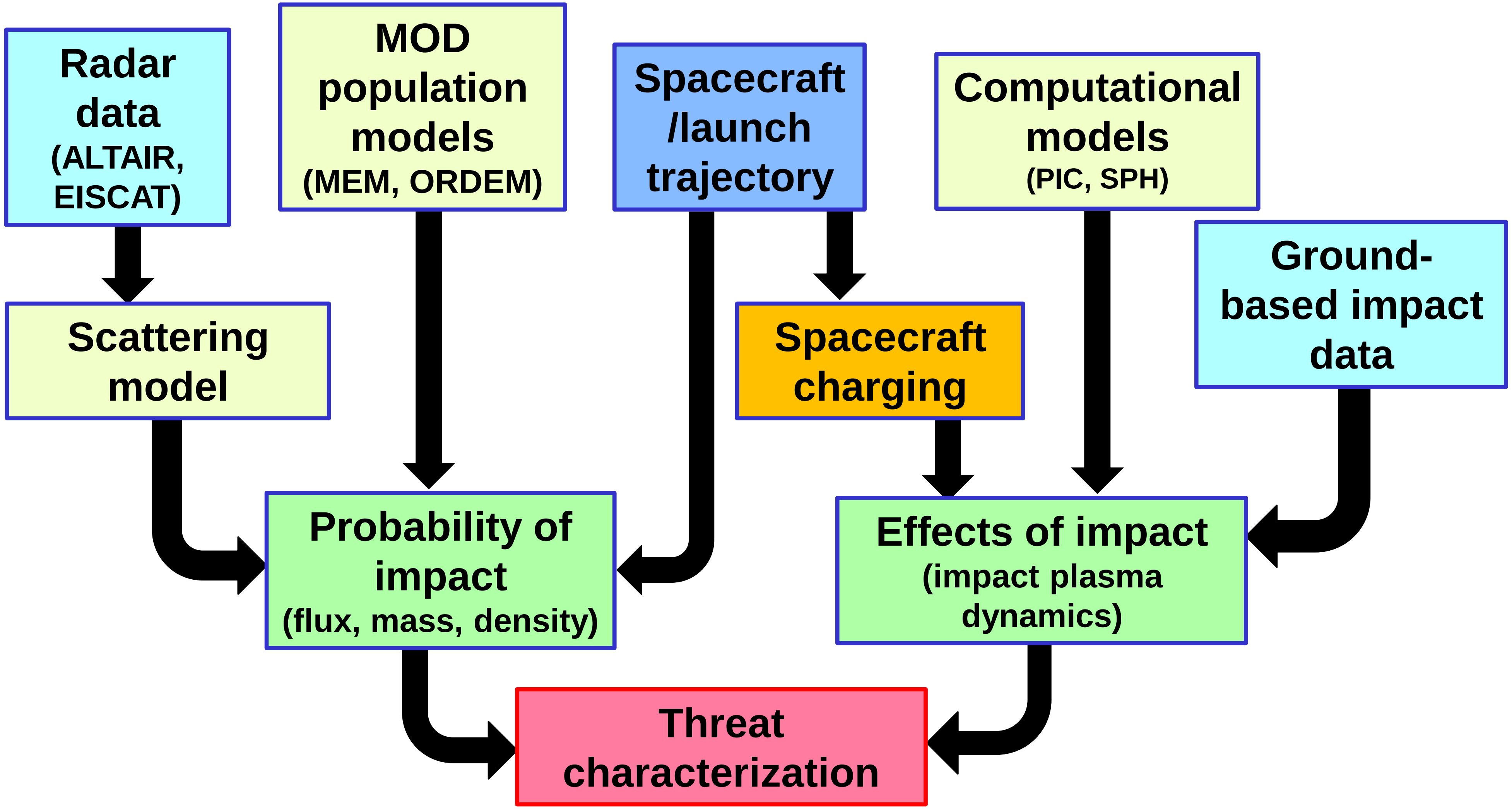


↑

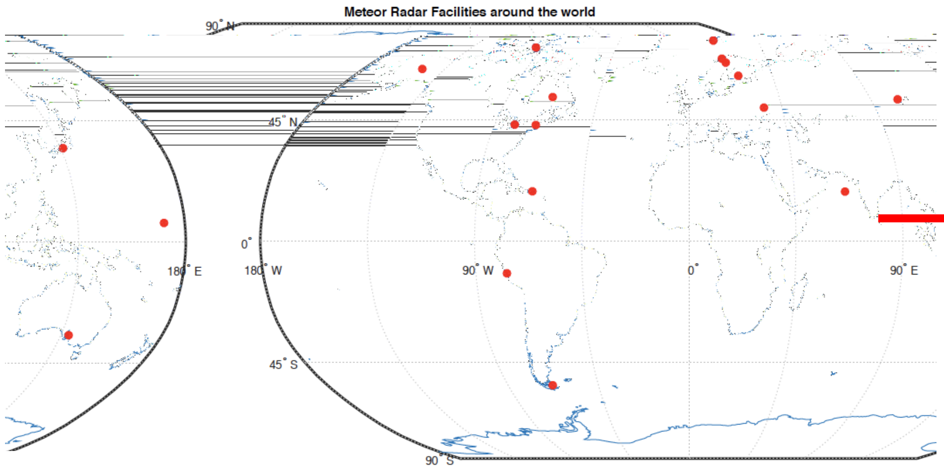
| Flux<br>Mass<br>Velocity | + | Plasma<br>Optical emission<br>RF emission |
|---|---|---|

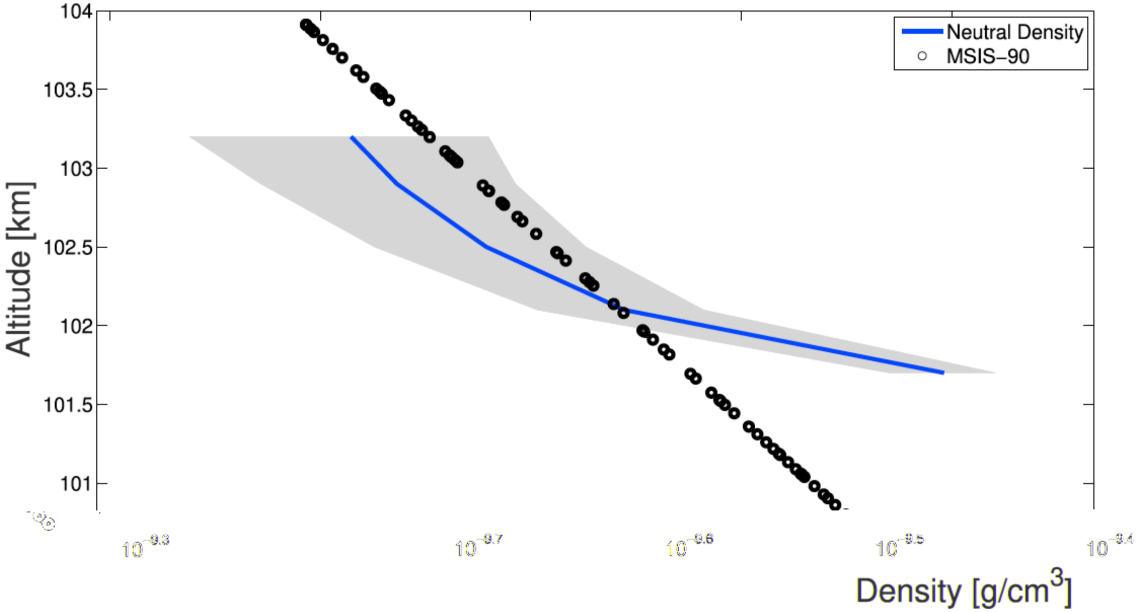


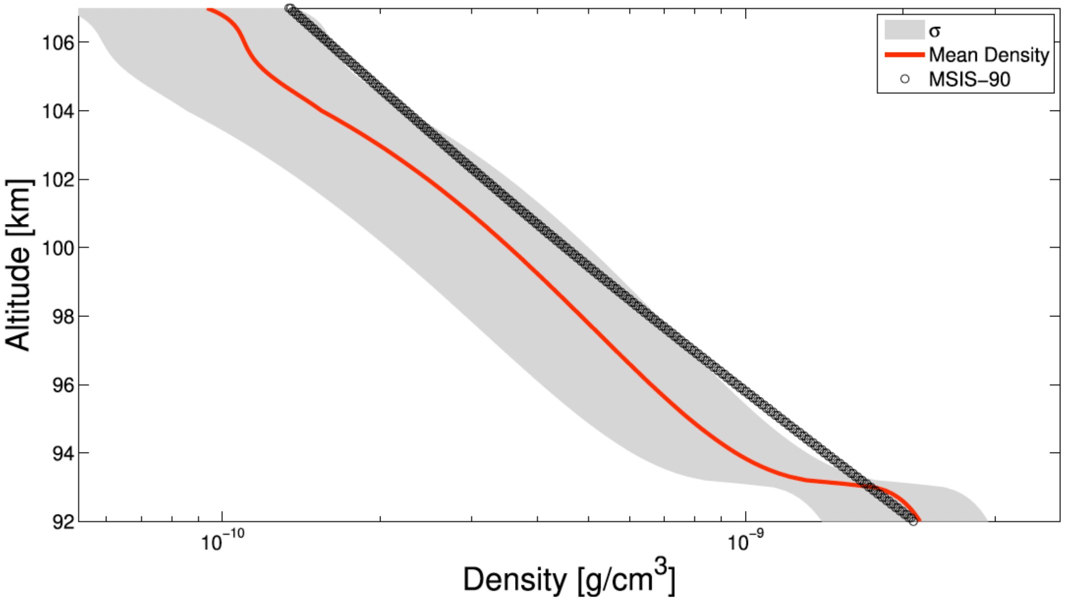
# Methodology



# Results: Neutral Densities



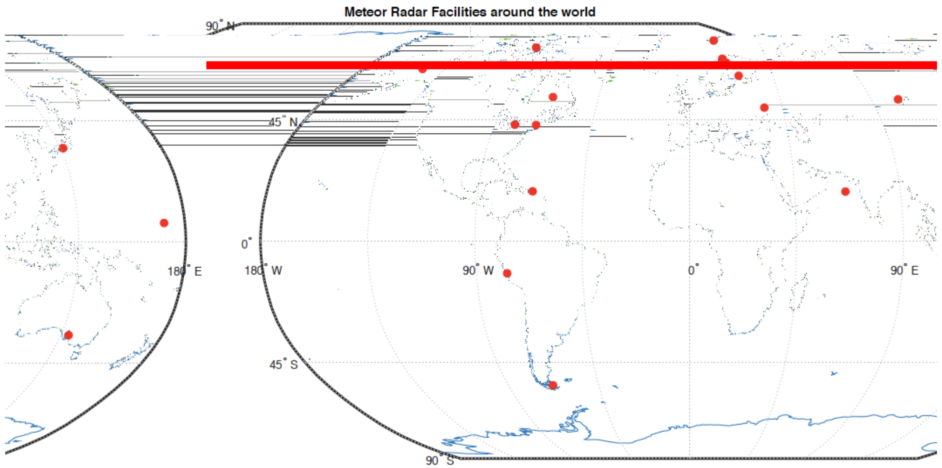



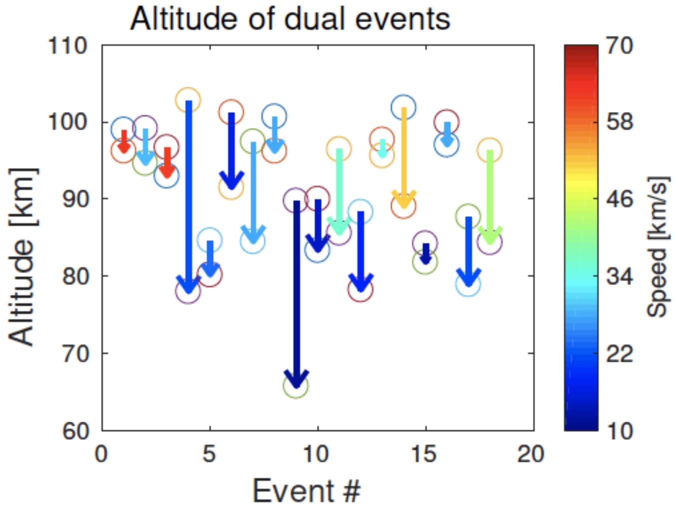



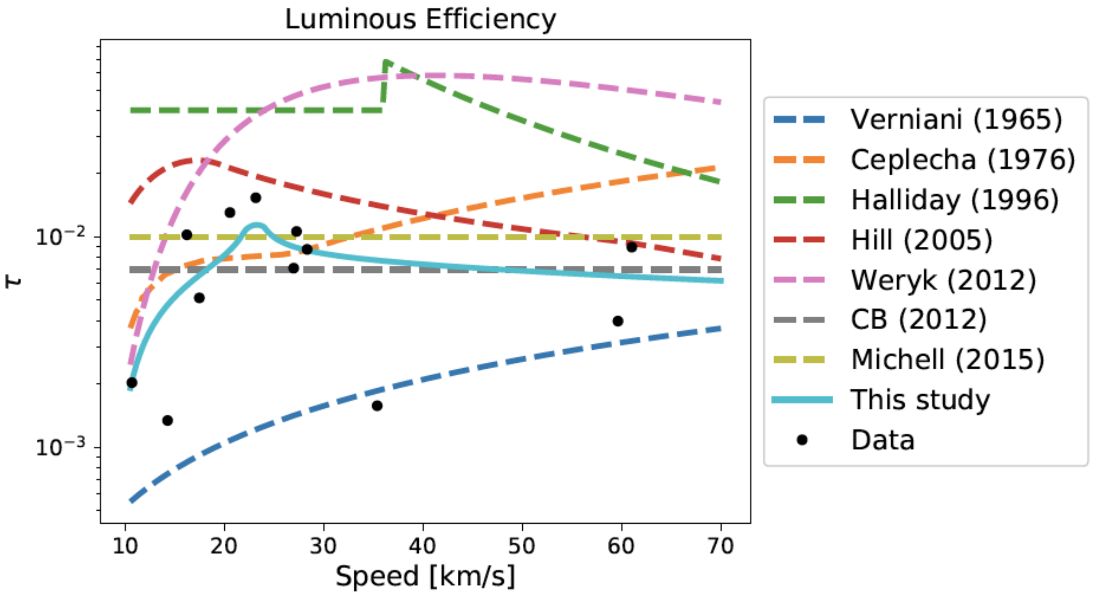
# Results:  Ionization and Luminous Efficiency

$$\frac{dm_m}{dt} = \frac{\mu q v}{\beta}$$

$$I = \frac{\tau}{2}\frac{d(m_m v^2)}{dt}$$



# Publications and Presentations

**PUBLICATIONS**

Sugar, G., M. M. Oppenheim, Y. S. Dimant and S. Close (2018), “Formation of plasma Around a small meteoroid:  Simulation and theory”, JGR Space Physics, Vol. 123(5), pp. 4080–4093, https://doi.org/10.1002/2018JA025265.

Sugar, G., M. M. Oppenheim, Y. S. Dimant and S. Close (2019), “Formation of plasma around a small meteoroid:  Electrostatic simulations”, JGR Space Physics, Vol. 124(5), pp. 3810–3826, https://doi.org/10.1029/2018JA026434.

Limonta, L., Close, S., and Marshall, R.A. (2020), A technique for inferring lower thermospheric neutral density from meteoroid ablation, Planetary and Space Science, Vol. 180, 104735, https://doi.org/10.1016/j.pss.2019.104735.

Limonta, L. (2018), “Experimentation and Simulation of Meteoroid Ablation”, Ph.D. Thesis, Stanford University, purl.stanford.edu/wh601yb5230.

Sugar, G. (2019), “Meteoroid Mass from Head Echoes Using Particle-in-cell and Finite-difference Time-domain Simulations”, PhD. Thesis, Stanford University, purl.stanford.edu/nz604gp3764.

**PRESENTATIONS**

American Astronomical Society (Invited), April 2017

# Conclusions and Future Work

- **Characterize ablation parameters of MOD**
  - Meteoroid:  remote sensing of plasma and scattering model provides flux, mass, bulk density and neutral density
  - Space debris:  remote sensing of particles and shape modeling provides flux, mass
  - Simultaneous optical-radar experiments provide cross calibration of ionization and luminous efficiency
- **Future work**
  - Continue to refine new neutral density estimation algorithm
  - Apply orbital dynamics to correlate bulk density with source