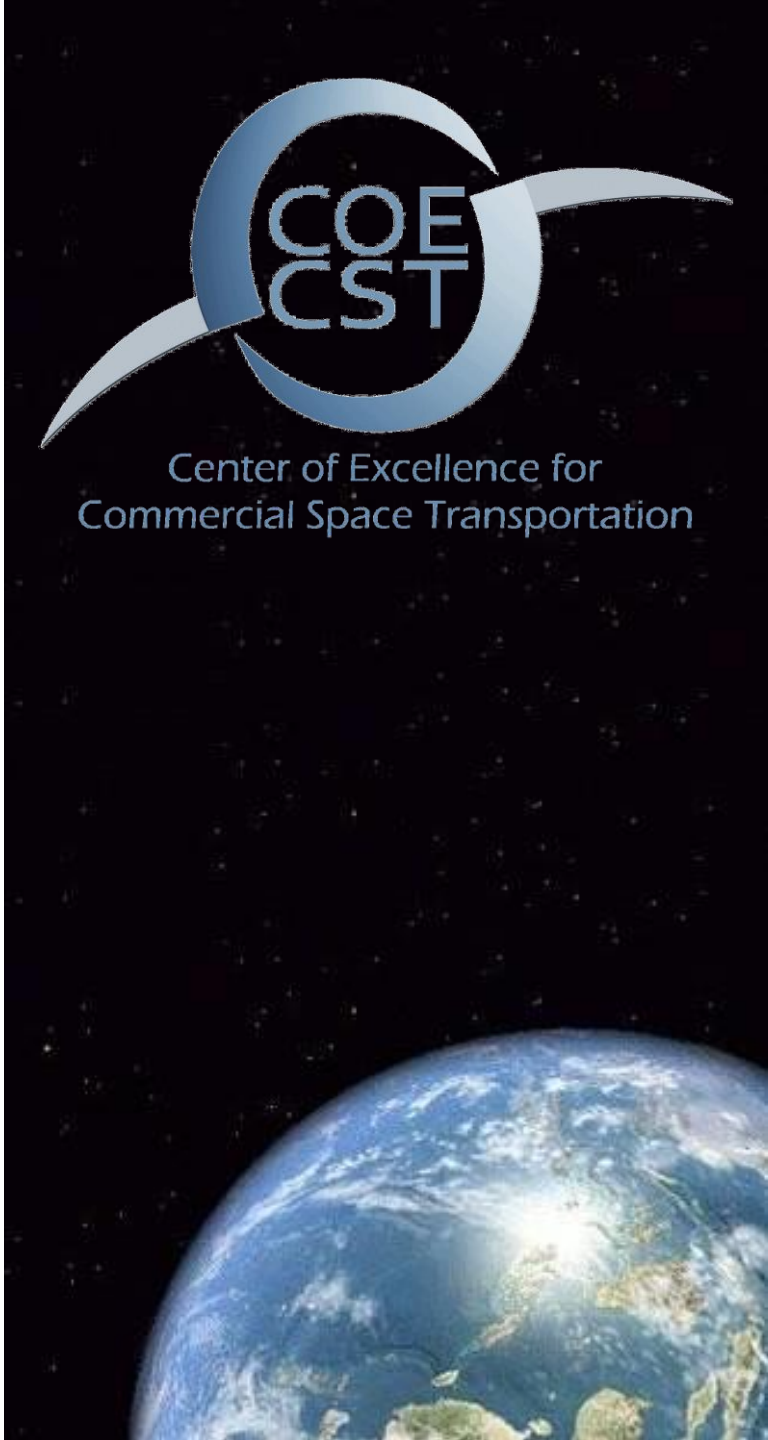
COE CST Tenth Annual Technical Meeting

TASK 327. RSO System Mechanics

Scheeres/Khatri



Team Members

- People
  - PI: Daniel Scheeres
  - GSRA: Yashica Khatri
- Organizations
  - University of Colorado Boulder

Goals

- Effective space situational awareness faces the challenge of bringing together observations from disparate sensors and sources, developing computationally efficient dynamic propagation schemes for orbits and their uncertainty distributions, and formulating accurate estimation methods for the purpose of quantifying and qualifying space-based activities.
  - Maximize the information extracted from usual sources of SSA data (minimize uncertainty)
  - Identify how data should be collected to maximize information content (maximize efficiency)
  - Recover and predict the space domain with more accuracy
  - Timely estimation of the space-based environment to create actionable information.

Relevance

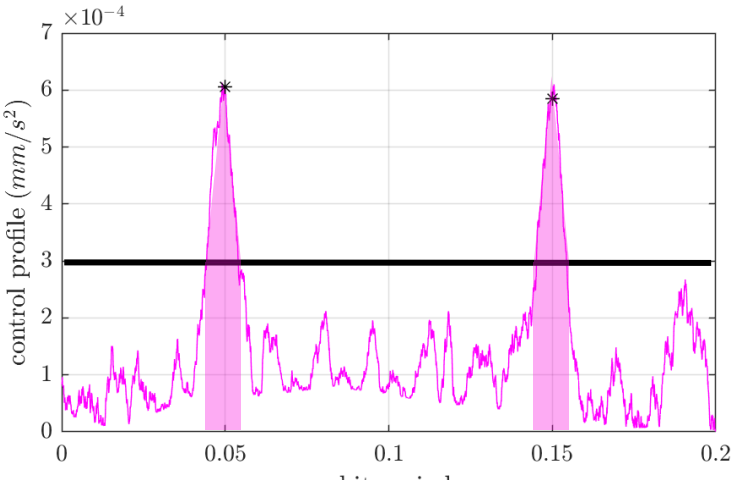
- Orbit debris remains a fundamental issue for all aspects of space utilization. Specific challenges remain in performing long-term forecasts for specific pieces of orbit debris. While the population of debris is relatively well understood — research advances continue to open new windows on this population.

Task 372: Past Research

- Resident Space Object (RSO) System Mechanics
  - Develop improved models for estimation of satellite drag, leveraging success in our SRP modeling work.
  - Use our previously developed semi-analytic orbit mapping techniques for rapid and accurate conjunction analysis of high-value assets with poorly constrained orbit debris.
  - Maneuver and event detection for crewed vehicles in Earth orbit and cis-Lunar orbits

Maneuver Detection in Cis-Lunar Space

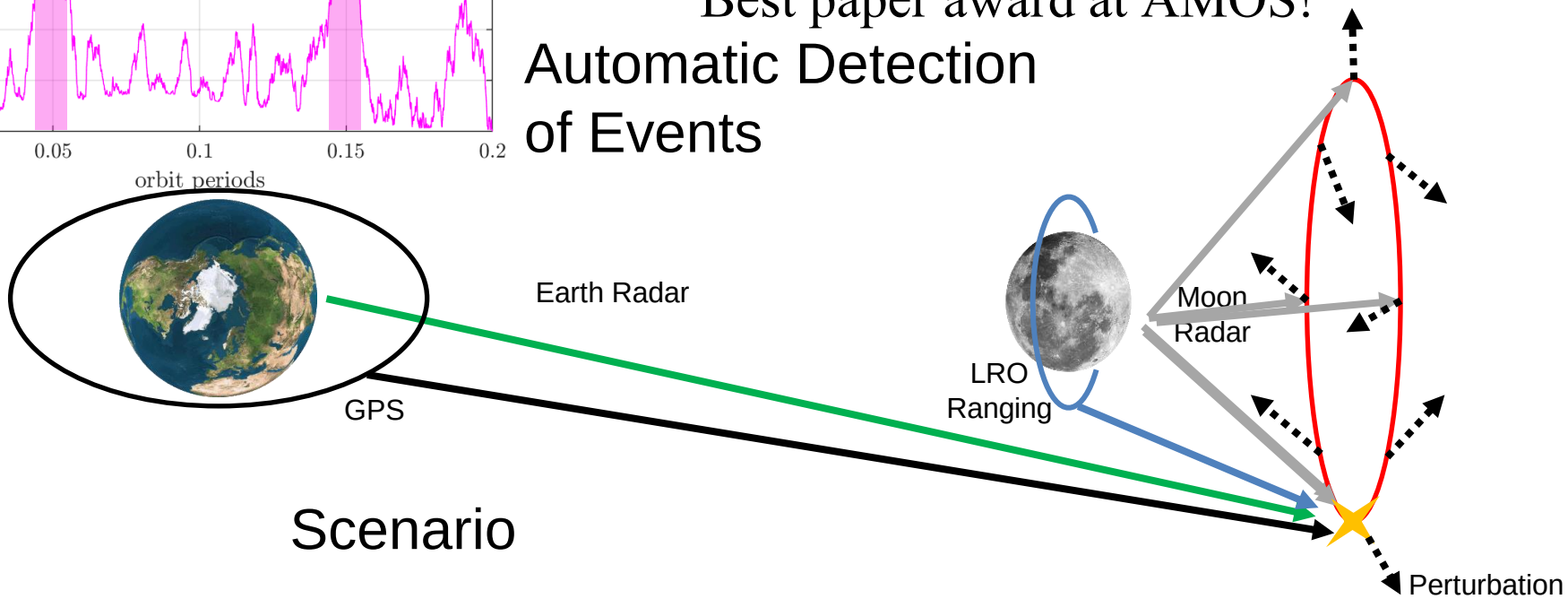
- Analysis of maneuver detection for S/C in a Halo Orbit near the moon



J.A. Greaves and D.J. Scheeres papers presented at SciTech 2020, Orlando, FL and AMOS 2020, Virtual.

Best paper award at AMOS!

Automatic Detection of Events

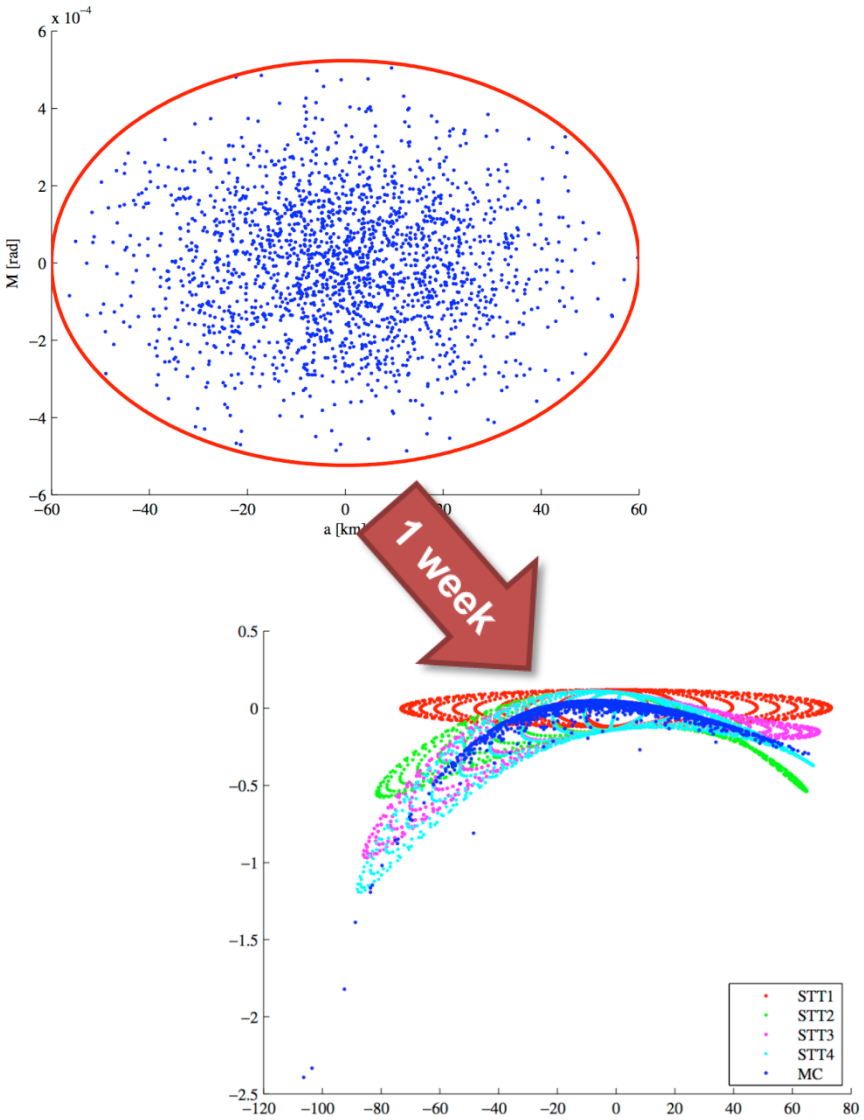


Scenario

Task 372: Current Research

- We are revisiting work performed by earlier PhD students Kohei Fujimoto and In-Kwan Park on propagation of orbit uncertainty and conjunction assessment
- This work combines several novel elements from our prior work to create a new capability
  - Rapid propagation of orbit uncertainty using semi-analytical methods
  - Use of Gaussian Mixture Models (GMMs) to accurately compute conjunction assessments
  - Incorporation of higher-order averaging theories into our secular dynamics models

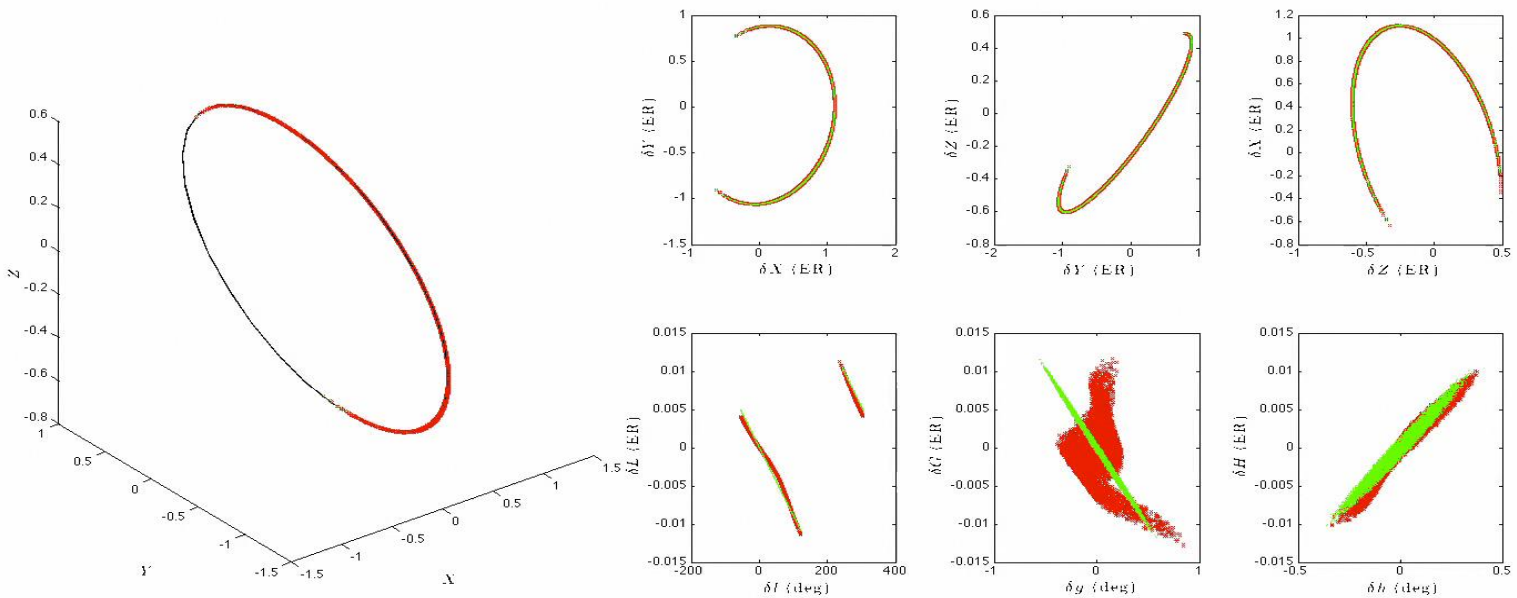
Analytic Propagation of Uncertainty



- Prior research by Kohei Fujimoto
- Rapid non-linear uncertainty propagation
  - Special soln. to the Fokker-Planck eqn. for deterministic systems
  - State transition tensor description of the solution flow
- Non-gravitational effects added
  - Atmospheric Drag
  - Solar radiation pressure
- Developed new approach to conjunction analysis
  - Mixes the use of analytical theories and GMMs

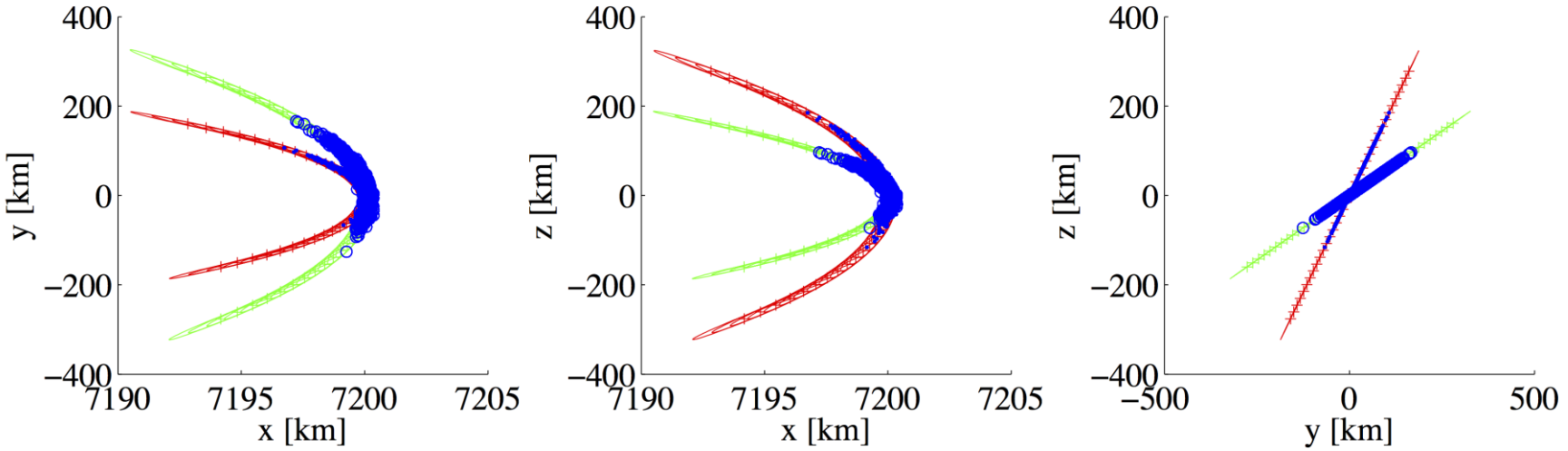
Averaged Uncertainty Mapping

- Prior research by In-Kwan Park:
- Averaged orbit dynamics mapping provides a semi-analytical approach to propagating orbits, albeit at reduced accuracy.
- Such approximate dynamics can still accurately capture the overall uncertainty propagation *if* short-period variations are added.
- Implications: Computationally fast theories can capture debris uncertainty, motivating new approaches to conjunction analysis



Current Research Activity

- The analyses by Fujimoto and Park are being combined by Khatri to provide a capability to accurately and rapidly model future conjunctions
- ***Rapidly***: The use of averaging theories and semi-analytic approaches to describe orbital motion opens up an ability to compute future / past orbit states without needing numerical integrations
- ***Accurately***: The use of higher-order expansions in propagating orbit uncertainty can capture non-linearities in a natural way
- ***Conjunctions***: The use of Gaussian Mixture Models (GMMs) enables the use of analytical probability integrals to be integrated with the above methods to rapidly compute and evaluate conjunction probabilities.



Conclusions and Future Work

- Task 372: RSO Mechanics
  - Poised to continue our research with a focus on improving long-term conjunction analysis
  - New student Yashica Khatri is fully focused on these tasks through the next year