TEXAS A&M UNIVERSITY

Laboratory for Uncertainty Quantification
Aerospace Engineering, Texas A&M University

Space Situational Awareness

U.S. Air Force Science and Technology 2030

Students: Niladri Das, Vedang Deshpande

Advisor: Raktim Bhattacharya

Department of Aerospace Engineering, Texas A&M University, College Station,TX

Debris Tracking

Inability to accurately know the precise location of space debris poses a major problem to all space related applications

Challenges:

- Increasing number of space debris objects coupled with uncertainty in their pose.
- Most of the space objects are smaller in size and non-cooperative, i.e. they are not equipped with tracking devices. We have to rely on passive tracking systems. And very few tracking sites are equipped for debris tracking.
- Increase in serious threat of collision with satellites or other operational spacecrafts
- Each collision generates new space debris that increases the likelihood of further collisions, known as **Kessler Syndrome**.
- Exact dynamic model of space debris is unknown because of orbital perturbations.
- Measurements are corrupted by systematic and random errors. Measurement data obtained for debris is generally sparse (one measurement every 24 hr). It makes problem of state estimation even more difficult.

The problem of collision can be mitigated if uncertainty associated with the location of space objects that are tracked is reduced. A reliable system which can provide precise ephemerides of space objects needs to be developed.

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Rapid Discovery of Evasive Satellite Behaviors

Space protection and situational awareness demands accurate and rapid space object behavioral and operational intent discovery.

Space systems are key assets for communication, navigation, weather forecasts, national security and many other things. Due to development of space technologies by many countries, space safety and security has always been a concern.

Challenges:

- Maneuvers in the 'blind-spot' of the given space surveillance system can go undiscovered.
- Space surveillance systems do not completely observe all space object variables and system parameters required to infer the intent of observed behavior.
- Space objects behaviors whether actively controlled by ground station or governed by interaction with the space environment, are inadequately characterized.
- Uncertainties in behavioral pattern models, states of space objects and observations.

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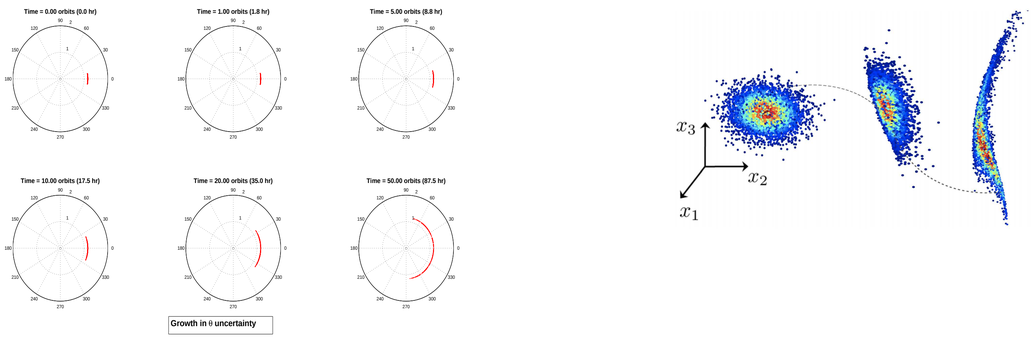
Partners: IFT, Texas A&M and Lockheed Martin

Orbit Propagation

- Non-linear Non Gaussian Propagation
- Perron Frobenious Based PDF propagation
- Modified Equinoctial Elements are used
- In-house orbit propagator is developed in MATLAB for LEO
- Major perturbation effects are considered



a. 2-D Orbit uncertainty b. PDF point cloud propagation

Figure 1: Uncertainty Propagation

Sensing Architecture & Scheduling

Optimal design of sensing architecture and synthesized sensor scheduling scheme will provide better state estimate solutions within a prescribed budget.

- The space surveillance system consists of heterogeneous sensors geo-spatially located.

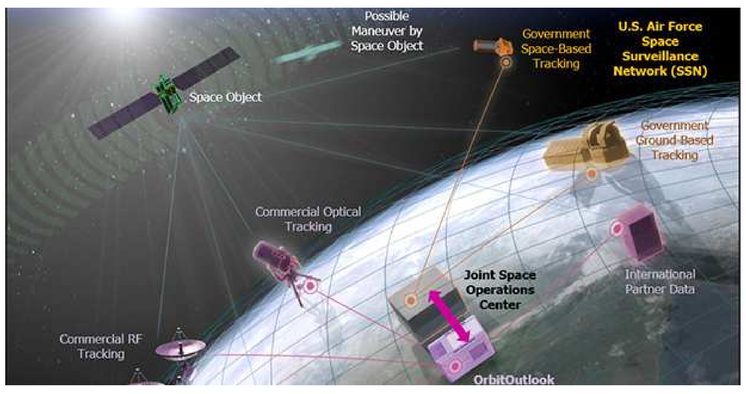
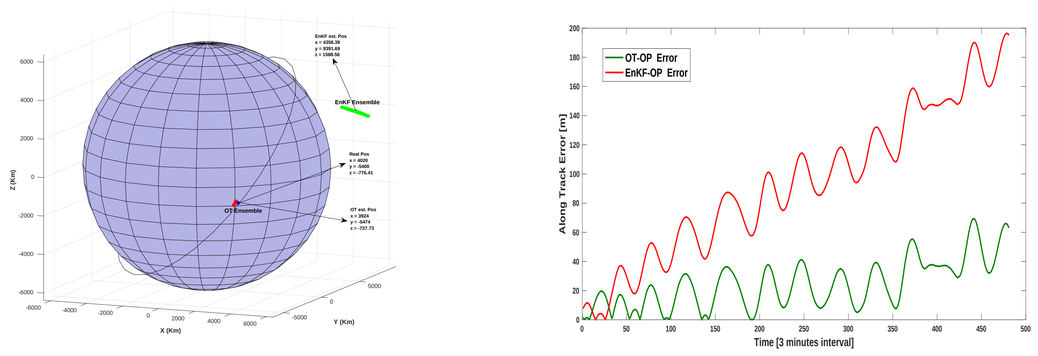


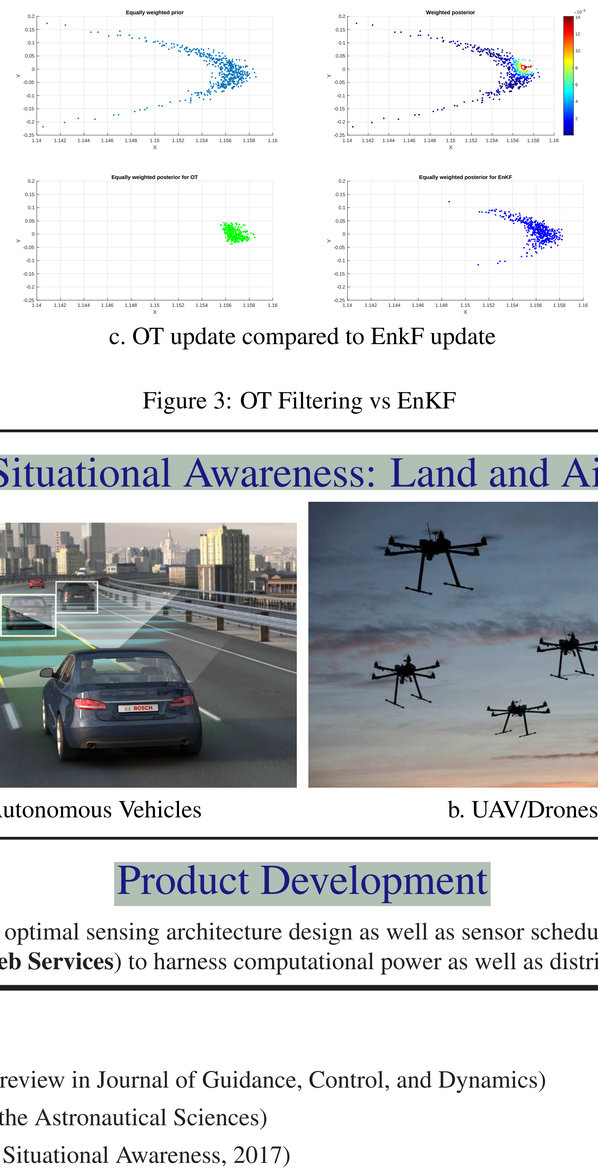
Figure 2: *
Unified Sensing Architecture for Space Applications (source by: `https://www.darpa.mil/news-events/2016-06-29`)

Data Assimilation / Estimation

- Non-linear Filtering
- R5xS manifold
- OT based Filtering
- OT vs EnKF



a. ISS state estimation b. Debris State Estimation



c. OT update compared to EnKF update

Figure 3: OT Filtering vs EnKF

Situational Awareness: Land and Air

a. Autonomous Vehicles b. UAV/Drones

Product Development

Implementing the OT filter, optimal sensing architecture design as well as sensor scheduling as a **Cloud based** interface (example: **Amazon Web Services**) to harness computational power as well as distributability.

Publications

- **Optimal Transport based Tracking of Space Objects using Range Data from a Single Ranging Station** (under review in Journal of Guidance, Control, and Dynamics)
- **Optimal Transport Based Tracking of Space Objects in Cylindrical Manifolds** (under review in The Journal of the Astronautical Sciences)
- **Sparse Sensing Architecture For Kalman Filtering With Guaranteed Error Bound** (IAA Conference on Space Situational Awareness, 2017)