COE CST Tenth Annual Technical Meeting

Ontological-Based Space Object and Event Knowledge Graph

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Agenda

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

Team Members

- People
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  - **Daniel Kucharski, Ph.D. (UT/Oden)**
  - **Shiva Iyer (UT/ASE-EM)**
  - **Nevan Simone (UT/ASE-EM)**
  - **Michael Reinhold (UT/ASE-EM)**
  - **Maria Esteva (UT/TACC)**
  - **Weijia Xu, Ph.D. (UT/TACC)**
- Organizations
  - Planet
  - LeoLabs
  - Maxar
  - JSC Vimpel
  - USSPACECOM
  - ESA

Task Description

- Develop an openly-accessible and transparent ontology-based knowledge graph for space objects and events that supports the needs of space traffic management, orbital safety, and long-term sustainability of space activities. Space Domain Digital Twin!
  - Take the initial steps to develop, implement, and federate a Space Traffic Management/Orbital Safety Digital Library. Set up an online searchable Digital Collection of these documents that is similar in capability to the Framework for Spaceport Operations.
  - Motivate “citizen Science” where people can donate their own sensor/telescope data. Leverage Blockchain technology as a method of STM “cryptocurrency”, authentication/identification, and transparent transaction records
  - Put together a collection of Open Source Software that can be used to support and enable space traffic management and orbital safety analyses and products. Gather tools like GMAT, Orekit, Tensor Flow, and others that are currently Open Source and leverage those to serve the needs of STM/Orbital Safety

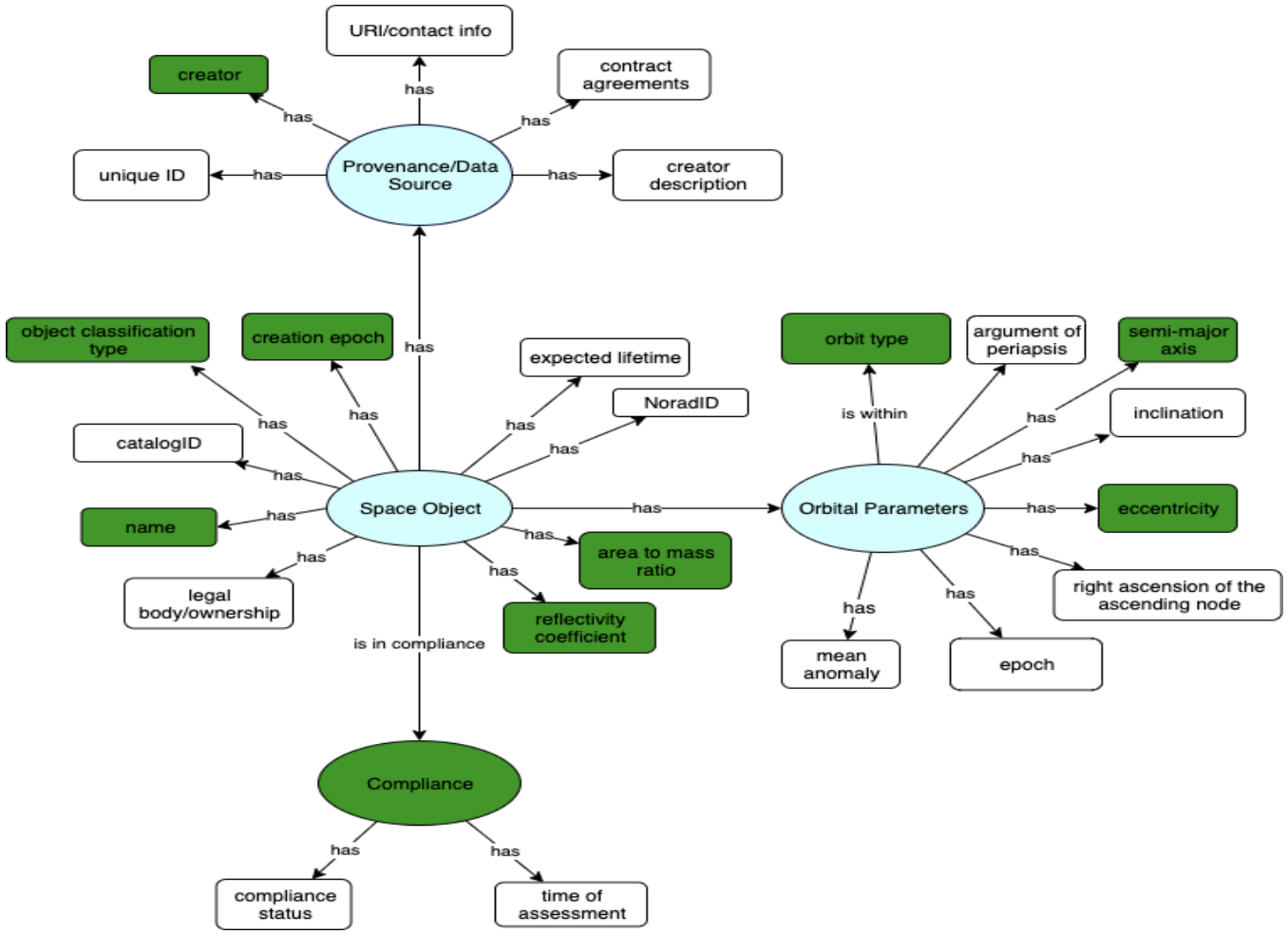
Schedule

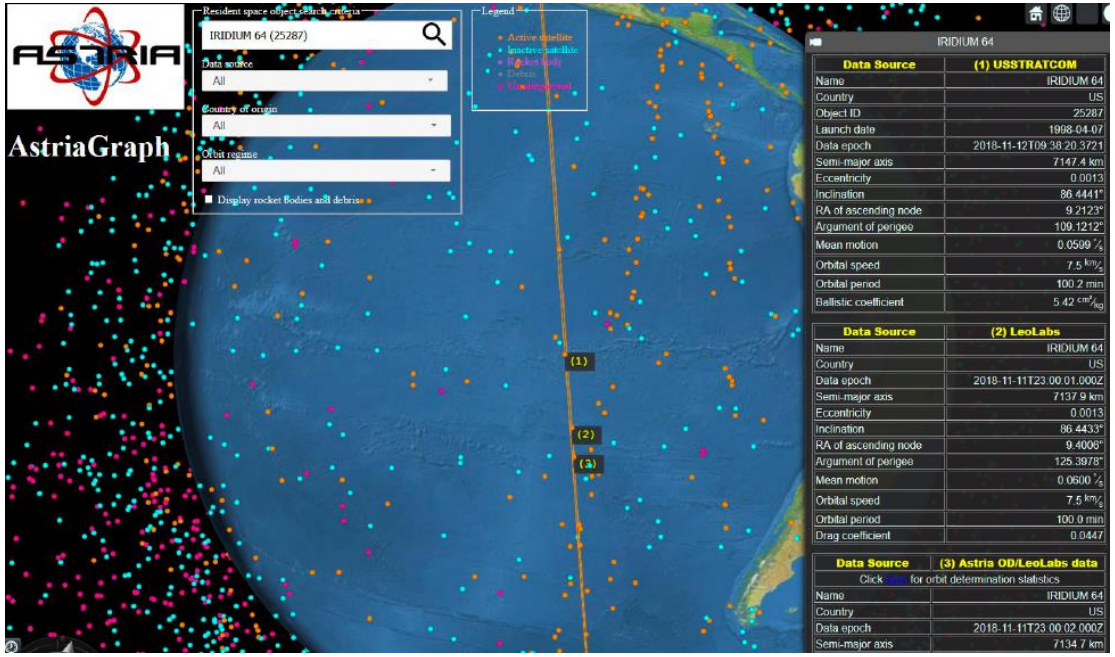
- Work with transdisciplinary team at UT Austin
- Identify and develop use cases that can help drive the ontology-based knowledge graph development
- Make use of industry and open-source information sources to input into the framework
- Develop and refine a Space Domain Digital Twin (i.e. virtual replica) to implement and test the approach
- Socialize with the community and demonstrate data analytics capabilities

Goals

- The methodology enables us to use an open architecture, with the capability to accept information from multiple sources, use interchangeable software modules to compute space traffic products and populate a master catalog (knowledge graph), and allow alternate approaches to predict and analyze potential space hazards and threats. This group of collaborators from government, industry and academia, is needed now as this is a long term solution to an already difficult problem facing the commercial space industry's ability to assure successful, safe, space operations.
- The approach has been designed to maximize the use of commercial capabilities.
- Transparency is a key principle; however, classified and/or sensitive U.S. space operations are protected appropriately, both by technical means and via operational procedures.

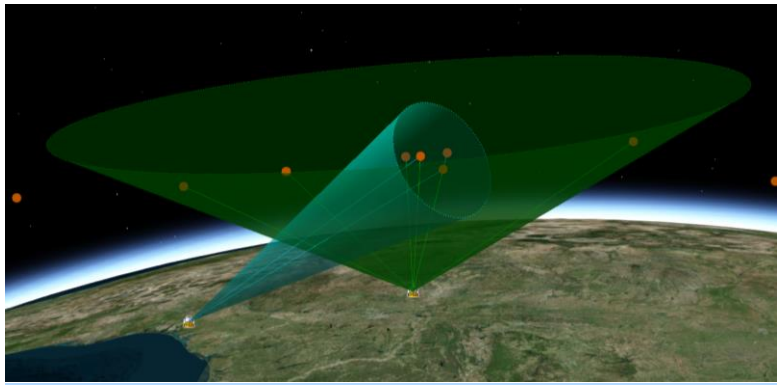
Results



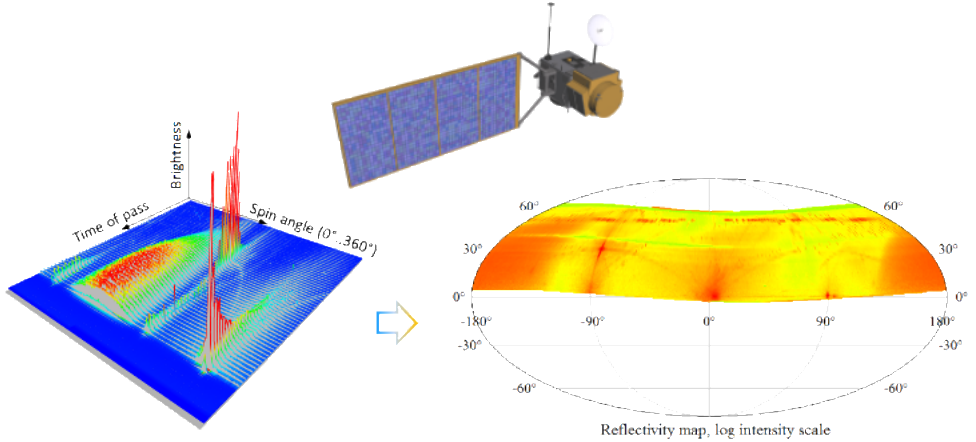


Problem Classification	Sample Problem
Anomaly Detection	Given demographic data about a set of customers, identify customer purchasing behavior that is significantly different from the norm
Association Rules	Find the items that tend to be purchased together and specify their relationship – market basket analysis
Clustering	Segment demographic data into clusters and rank the probability that an individual will belong to a given cluster
Feature Extraction	Given demographic data about a set of customers, group the attributes into general characteristics of the customers

Results



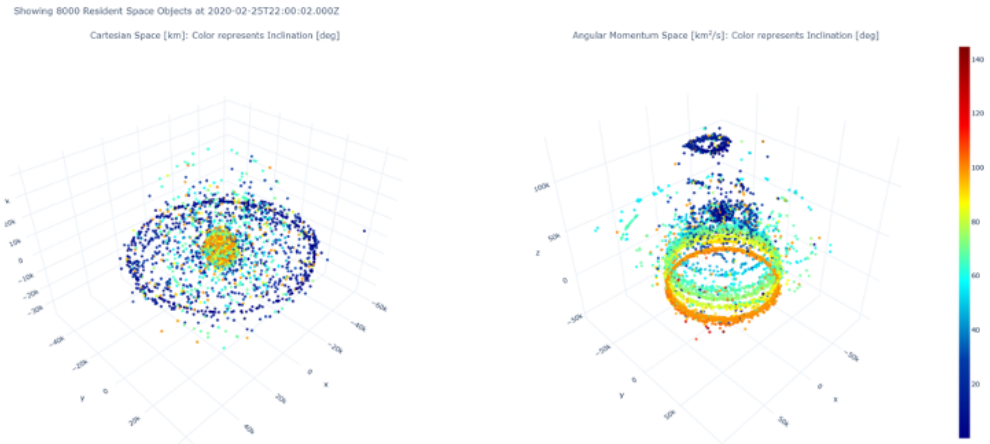
Space catalog maintenance through realistic uncertainty quantification



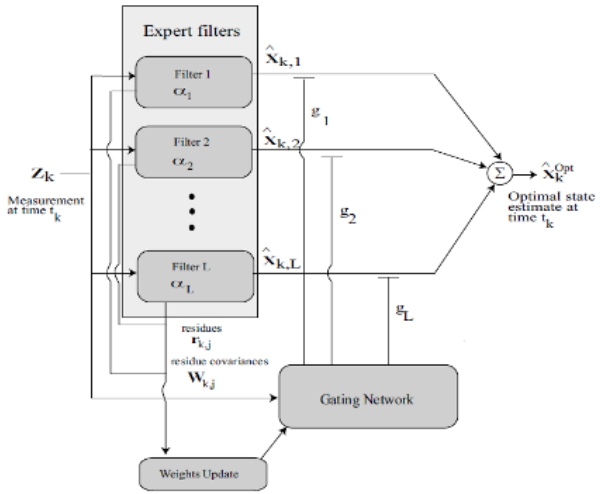
(Left) Spin phase folded light curve of TOPEX/Poseidon (~10 minutes pass).

(Right) The light curve projected onto the phase vector in the satellite body (-fixed and -centered) coordinate system.

Hypertemporal light curve of defunct TOPEX/Poseidon



RSO Population in cartesian space compared to angular momentum space. Color represents inclination



Logical Structure of a Single-Layer Gating Network used in Hierarchical Mixture of Experts

Journal Articles, Presentations

- Presentations: Too many, including podcasts, webcasts, and op-eds!
- Kucharski, D., Kirchner, G., Otsubo, T., Flegel, S., Kunimori, H., **Jah, M.**, Koidl, F., Bennett, J., Steindorfer, M., Wang, P. (2020). Quanta Photogrammetry of Experimental Geodetic Satellite for remote detection of micrometeoroid and orbital debris impacts, *Acta Astronautica,* https://doi.org/10.1016/j.actaastro.2020.04.042
- Le May, S., Carter, B., Gehly, S., Flegel, S., **Jah, M.** (2020). Representing and Querying Space Object Registration Data Using Graph Databases, *Acta Astronautica,* https://doi.org/10.1016/j.actaastro.2020.04.056
- Cai, H., Yang, Y., Gehly, S., He, C., **Jah, M.** (2020). Sensor tasking for search and catalog maintenance of geosynchronous space objects, *Acta Astronautica*, Volume 175, October 2020, pp 234-248, https://doi.org/10.1016/j.actaastro.2020.05.063
- Cai, H., Hussein, I., **Jah, M.** (2020). Possibilistic Admissible Region Using Outer Probability Measure Theory, *Acta Astronautica*, Volume 177, December 2020, pp 246-257, https://doi.org/10.1016/j.actaastro.2020.07.041

Conclusions and Future Work

- Developing and delivering a body of evidence of space activities and behaviors, modeled and curated in a Space Domain Digital Library (ASTRIAGraph), that can support Space Domain Decision Intelligence
- Developing and implementing a Space Domain Digital Twin for Hard/Soft (Multi-Source) Information Fusion
- Advancing realistic uncertainty quantification
- Developed a Biometrically-Inspired Space Object Recognition (BISOR) system
- Engaging the community in the process via collaborative experiments and information exchanges