

2019-2020 Grand Challenge Award Final Report

Awardee: **Moriba Jah, Associate Professor
Aerospace Engineering & Engineering Mechanics**

Research Award Title: **Robust Space Situational
Awareness via Hard/Soft Information Fusion
in the Presence of Uncertainty**



Research Summary

The proposed research set out to focus on three basic tasks: (a) High/multi-fidelity physics modelling of the space environment interactions with anthropogenic space objects (b) Computational representation of behavioural scientists, social scientists, anthropologists, and (geo)political scientists (c) hard/soft information fusion and data science/analytics.

The work performed was mostly able to address (a) and (c) with initial progress in (b).

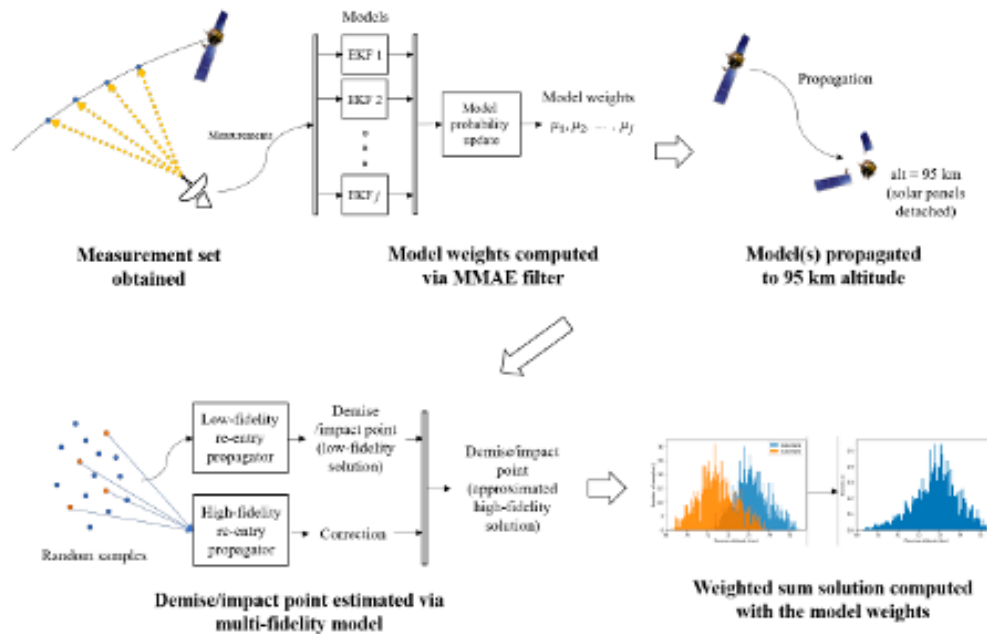
High/Multi-Fidelity Physics Modeling of the Space Environment Interactions with Anthropogenic Space Objects

We had several visiting researchers from the Korean Advanced Institute of Science and Technology (KAIST) to contribute to this collaborative research topic. Prof. Brandon Jones, affiliate faculty in the Oden Institute played a Co-PI role with me on this. Our work resulted in the development of an algorithm to characterize a re-entering space object and estimate the demise altitude and the impact point on the Earth's surface with multiple-model approaches. The number of objects that have the potential to re-enter is expected to increase with the number of anthropogenic space objects launched by private space industries in the next few years. Accordingly, methods to track and estimate the re-entry behavior with given data are required for situational awareness. In our research, multiple-model adaptive estimation was used with the extended Kalman filter to classify the anthropogenic space object into different classes and the multi-fidelity modeling approach was applied to the re-entry analysis. Two case studies were simulated for a scenario of an anthropogenic space object at low Earth orbit with an initial altitude of 300 kilometers. The results of our research show the applicability of the multiple model Kalman filter approach to infer the characteristics of the anthropogenic object and a maximum of 86.3% reduction in the computation time for the re-entry analysis as a consequence of implementing a multi-fidelity stochastic collocation method. The following figure shows a process workflow of this specific topic area.

Hard/soft information fusion and data science/analytics

Near-earth space is geopolitically and commercially contested, and in need of environmental protection. To achieve space safety, security, and sustainability, we are developing ASTRIAGraph (<http://astria.tacc.utexas.edu/AstriaGraph/>), a framework that enables monitoring, assessment, and verification of space actor behavior in the context of legal and policy instruments. We have been able to demonstrate how the ASTRIAGraph toolset can improve space management accountability for the United Nations Office for Outer Space Affairs (UNOOSA) via the collection, curation, and fusion of heterogeneous (hard/soft) data. In order to achieve this we developed an ASTRIAGraph data model and along with information extraction and curation processes. Moreover, we successfully applied methods for

measuring and reporting the reliability of these processes. The work showed that by combining fields from different sources such as the UN registration documents and USSPACECOM data, it is possible to visualize space objects registered with the UNOOSA, identify ASO Launch States' liability, assess trends in the registration patterns of these Launch States, and even compute Anthropogenic Space Object (ASO) identity resolution amidst mismatched or missing different information provided by the disparate sources. These data are then able to be analyzed and communicated through graphs and plots, which highlight the liability and compliance of a nation or organization, whether it is done by evaluating the lag (difference between the date of launch and the initial registration submission date) and plotting its spread for that given state or entity, or if one were to analyze their trends in compliance over time. In addition, using different registration information fields, interested users are able to query the ranking of Launch States in relation to registration promptness. These rankings, set between one and five stars, are first given to individual objects, but countries with many registered ASOs often have outliers with large registration lag. As such, the rankings are scaled higher for states which register larger numbers of ASOs to prevent undue punishment of these countries for their compliance. We weren't able to get to the computational representation of behavioral scientists, social scientists, anthropologists, and (geo)political scientists but this work is the foundation in order to achieve it.



Presentations Made

- ArmadilloCon 41, Austin, Texas, August 2019, The Science Guest.
- 70th International Astronautical Congress, Washington DC, October 2019, Invited Panelist. *Artificial Intelligence in Space.*
- 70th International Astronautical Congress, Washington DC, October 2019, Invited Panelist. *34th IAA/IISL Scientific-Legal Roundtable "Mega-Constellations."*

- 2019 swissnexDay, EPFL, Lausanne, Switzerland, December 2019, Keynote Speaker.
- Outer Space Institute Workshop on Space Debris, Salt Spring Island, BC, Canada, January 2020
- DLD Conference, Munich, Germany, January 2020, Invited Panelist.
- 2020 AAAS Meeting, Seattle, WA, February 2020, Invited Topical Lecture.
- 2020 Arizona Space Grant Symposium, 30th NASA Space Grant Anniversary, April 2020, Keynote Speaker.

Given COVID-19 and use of Zoom/Teams/etc., too many to list for the remainder of 2020.

Publications

- 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>
- Nevan Simone, Kartik Nagpal, Amit Gupta, Maria Esteva, Weijia Xu, Moriba Jah (2021). Transparency and Accountability in Space Domain Awareness: Demonstrating ASTRIAGraph’s Capabilities with the United Nations Registry Data. *Texas Scholar Works*. doi: 10.26153/tsw/11754
- Esteva, M., Xu, W., Simone, N., Gupta, A., Jah, M., (2020) “Modeling Data Curation to Scientific Inquiry: A Case for Multimodal Data Integration” *Proceedings of the 2020 IEEE Joint Conference on Digital Libraries (JCDL2020)*, Xi’an, China, August 1 – 5 <https://doi.org/10.1145/3383583.3398539>
- Jah M. (2020) Space Object Behavior Quantification and Assessment for Space Security. In: Schrogl KU. (eds) *Handbook of Space Security*. Springer, Cham https://doi.org/10.1007/978-3-030-22786-9_103-1

Awards/Recognitions Received

- Invited by name to specifically present this work at the World Space Forum by the United Nations Office of Outer Space Affairs, Dec 2020
- Chosen to lead a NATO science and technology organization activity centered upon this work
- Associated Grants/Contracts:
 - “Transparency in Space Dashboard,” Smith Richardson Foundation via Secure World Foundation, \$87,089 (Jah’s Share \$87,089), Sep 2019 – Jan 2022, Principal Investigator.
 - “Space Data Prescriptive Analytics,” Slingshot Aerospace, \$150,000 (Jah’s share \$150,000), March 2020 – Feb 2023, Principal Investigator.
 - “Space Object and Event Knowledge Graph for Space Traffic Management, Phase1” Federal Aviation Administration via NMSU_Phase II, \$204,533 (Jah’s Share \$204,533), Feb 2020 – Aug 2022, Principal Investigator.