Statement of
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to the
Committee on Science, Space, and Technology
Subcommittee on Space and Aeronautics
United States House of Representatives
on
Space Situational Awareness: Guiding the Transition to a Civil Capability
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Mr. Subcommittee Chairman Beyer, Mr. Ranking Member Babin, and other members of this subcommittee, thank you for the invitation to appear before you today to share my perspectives regarding salient issues on guiding the transition of space situational awareness to a civil capability. It is an honor to be seated at this virtual table with these great witnesses. It has been two years since I last testified, which was to the US Senate's subcommittee on Space, Science, and Competitiveness. My name is Moriba Jah. I'm an astrodynamicist and space environmentalist. My perspectives have been shaped through an over 20-year aerospace engineering career in government, industry and academia. I started my career as a member of the technical staff of the NASA Jet Propulsion Laboratory. Whilst there, I contributed to the navigation of a variety of spacecraft to Mars and Asteroid Itokawa, and also developed advanced spacecraft navigation algorithms toward autonomy and improved orbital knowledge, beginning with Mars Global Surveyor and ending with the Mars Reconnaissance Orbiter mission. After JPL, I worked as a Civil Servant in the Air Force Research Laboratory (AFRL), where I led the design, development, and implementation of algorithms that have successfully and autonomously detected, tracked, identified, and characterized human-made objects in space, so called "Anthropogenic Space Objects," to include orbital debris. My last position within AFRL was as the Mission Lead for Space Situational Awareness. I currently serve on the faculty of the Aerospace Engineering and Engineering Mechanics Department, in the Cockrell School of Engineering at The University of Texas at Austin. At UT Austin, where I lead a transdisciplinary research program focused on delivering pragmatic solutions to problems regarding space safety, security, and sustainability. Last year I co-founded Privateer Space along with Steve Wozniak (Apple Co-Founder) and Alex Fielding (Ripcord Founder) aimed to deliver the world's most useful digital platform that supports, inter alia, space situational awareness services and capabilities. I am a Fellow of several organizations and professional societies and serve as a chair and member of several major space-related national and international technical committees. However, I am here today as an individual citizen and the views I express are mine alone.

Executive Summary

Near Earth Space is (a) geopolitically contested (b) commercially contested and (c) a finite resource in need of environmental protection.

We are of course interested in having continuing supervision of the entire set of space events and processes that occur and can happen but this set is unknowable for a myriad of reasons, not the least of which that we, as a global community, still do not widely share our observations of the space domain. If we wish to know something, we must measure it and if we want to understand something, we must predict it. This knowledge regarding causal relationships for things in space is what I call Space Situational Awareness.

If we wish to protect ourselves from extraterrestrial hazards in the form of near-Earth asteroids, space environment effects and impacts on satellites and Earth-based infrastructure, as well as space activities and services from suffering a loss, disruption, or degradation, we must have timely and actionable Space Situational Awareness. Only a few months ago, Russia destroyed one of their satellites in an on-orbit anti-satellite (ASAT) test demonstration[1]. As a result of the harmful debris that this event created, our own US based Starlink satellites have evasively maneuvered nearly 2000 times to avoid a predicted likely chance of collision. Russia claims that no harm has been done by their ASAT test. To date, there is no publicly available evidence either way. Our actions in space are not based upon truth but rather upon our perceptions, and these are uniquely driven by the evidence we have at hand which is biased, incomplete, and corrupt, to include our flawed models of reality.

As an example, just a couple of years ago, a commercial entity predicted that two dead satellites in Low Earth Orbit had an alarmingly high probability of collision[2] but these probabilities were quite varied across the space object tracking community: one entity said 1 in 10, another 1 in 100, and another 1 in 1000. These are very different from each other and the actions a satellite operator would take would also vary as such.

Several months ago, China complained to the United Nations that the Starlink satellites were a hazard to their space station and that unable to get a hold of the SpaceX operators, they had to perform two evasive maneuvers to avoid collisions[3]. The response from the United States was that based on US evidence, there was no hazard or reason for alarm. A similar incident occurred between the European Space Agency and SpaceX to coordinate an evasive maneuver but

[1] https://aerospaceamerica.aiaa.org/departments/holding-russia-accountable-for-its-asat-test/

[2] https://spacenews.com/potential-satellite-collision-shows-need-for-active-debris-removal/

[3] https://spacenews.com/esa-spacecraft-dodges-potential-collision-with-starlink-satellite/

antiquated methods (relying on email) of communication conjured a systemic obstacle in meaningful space debris mitigation. The European Space Agency maneuvered Aeolus to prevent the predicted collision. SpaceX stated in hindsight that they would not have maneuvered anyway because their Space Situational Awareness and decision threshold indicated it not sufficiently risky to them.

Once again, the decisions anyone might make given each of these opinions is obviously extremely different. One issue that this underscores is a lack of consensus regarding operational decisions which detrimentally leads us away from a common practice in space. We wish to avoid “playing chicken” in our orbital commons. We have no joint and holistic space traffic coordination framework to mitigate these inconsistencies or competing and opposed hypotheses.

Another problem calling for Space Situational Awareness is in regard to Article 6 of the Outer Space Treaty which states that States party to the treaty are responsible for providing authorization and continuing supervision of space activities of non-governmental entities. The US White House recently delivered a strategy on In-Space Servicing, Assembly, and Manufacturing[4]. The need for continuing supervision could not be more important than this developing space sector. In order to meet the needs of this community, there must be an unambiguous and distributed immutable ledger of who did what to whom when and where. As of this very testimony, I would challenge any government to demonstrate that it is currently capable of delivering such a capability. More complaints of harmful interference, damage, and threats will be raised whilst we are left ill-prepared to assemble the evidence required to assess and quantify space events and activities.

Last but not least, the global Astronomy community has taken issue with the exponential growth of anthropogenic space objects as these “corrupt” their astronomical images and negatively impact the science[5,6]. Moreover, astronomers have already misidentified natural phenomena for what was later found to be a satellite reflecting light in a way that looked like an astronomical event of interest. This doesn’t even get into the fact that the added light pollution from these space objects makes it harder to detect near-earth asteroids that could be on a collision course with earth. Humanity cannot afford to suffer the consequences of these shortcomings.

A safe, secure, and sustainable space domain requires improved transparency, predictability and for us to develop an *independently corroborated* body of evidence of space activities, events, and

[4] https://www.whitehouse.gov/wp-content/uploads/2022/04/04-2022-ISAM-National-Strategy-Final.pdf

[5] https://www.nature.com/articles/s41550-022-01655-6

[6] https://www.forbes.com/sites/startswithabang/2020/01/30/dangers-to-astronomy-intensify-with-spacexs-latest-starlink-launch/#337a38a56a57

actor behaviors that can be used to hold people accountable and can inform meaningful space policies, rules, regulations, and norms of behavior.

U.S. National Space Policy Directive #3, signed by President Trump on June 18th of 2018, laid out very succinct goals to address these issues. Its first goal is to advance Space Situational Awareness and Space Traffic Management Science and Technology. It further states that the United States should continue to engage in and enable Science and Technology research and development to support the practical applications of Space Situational Awareness and Space Traffic Management. These activities include (a) improving fundamental knowledge of the space environment, such as the characterization of Anthropogenic Space Objects, (b) advancing the Science and Technology of critical Space Situational Awareness inputs such as an openly accessible and curated set of multi-sourced observational data, algorithms, and physics-based models necessary to improve Space Situational Awareness capabilities, and (c) developing open-source software to support big-data science and analytics. In summary, we must develop the required science and technology to reliably deter, predict, operate through, recover from, or attribute cause to the loss, disruption, or degradation of any given space service, activity, or capability. This means making space transparent and predictable, and having the evidence to hold entities accountable.

Beyond examples I previously listed, I can personally attest to the fact that we are significantly behind in this endeavor as evidenced by our inability to accurately and precisely infer unique or unambiguous causal relationships between space domain events and observed satellite anomalies. You can read about these in the news frequently these days. Satellites are experiencing malfunctions where the evidence could have more than one explanation: was it the environment? was it caused by another entity? If so, was it intentional? The information tasking, collection, processing, exploitation, and dissemination requirements for Space Situational Awareness does not end with collision risk assessments or re-entry predictions; they only begin there. The much more difficult and critical requirement is to assemble the evidence of events, processes, and activities in space that would need to be used to assign fault or negligent behavior, for instance, or assessing compliance or the lack thereof with space policies. Nobody is quantifying these needs. Every domain of human activity has experienced malicious behavior and to think otherwise is naïve at best. In the face of a next “space race” or “gold rush” equivalent, driven by global space commerce, it’s not a matter of if, but when. The space domain is holistically poorly monitored. We are unprepared and ill-equipped to deal with disputes resulting from space activities and events.

The U.S. is home to some of the world’s top-ranked research institutions; these should be brought to bear to, once and for all, bring us out of the dark ages in terms of space domain decision-making knowledge and actualize us in order to meet the great demands of space commerce, exploration, and other activities. A well-funded and dedicated Space Situational Awareness Institute could undertake the Science and Technology research and development we desperately require. Europe and other countries are becoming leaders in these endeavors. Academia, the source of the purported workforce to meet the demands of operating so-called mega-constellations, has been mostly neglected in this area, and even decimated. As a professor at a top-tiered research university, I alone find myself turning away over a dozen qualified U.S. citizens every year, from joining my research program due to an absence of resources and financial support to perform clearly needed research.

The National Science Foundation does not fund Space Situational Awareness research although there are many basic research problems still salient in this transdisciplinary area. The Air Force Research Laboratory and Air Force Office of Scientific Research have been the only real, and overwhelmingly underfunded, organizations making any semblance of investments in Space Situational Awareness research. I know this because I was the Mission Lead for Space Situational Awareness at the Air Force Research Laboratory for several years. The National Academies has several relevant boards that should be invoked to engage in studies that inform a nationally committed roadmap of Space Situational Awareness Science and Technology Research. I'd welcome the opportunity to serve on one or more of them. Moreover, these research outputs must be committed to being transitioned into operationally relevant environments that could directly support the U.S. Department of Commerce's stewardship of providing Basic Space Situational Awareness and Space Traffic Management services and products to the global community.

What are the next steps required to put this into effect?

- Begin collecting, curating, and exploiting multi-sourced anthropogenic space object (e.g. non-Space Surveillance Network tracking) data for orbital safety and sustainability purposes that is open and widely accessible, with multi-tiered access and dissemination (e.g. Open Architecture Data Repository).
- Create or expand the existing role of NASA to: 1) uniquely focus upon leading the **scientific and technical** requirements for a robust, effective, and meaningful Civil Space Traffic Management System, and 2) to work closely with other government agencies, industry, and academia.
    - Conjunction Analysis concerns itself with predicting so-called "close approaches" between any two Anthropogenic Space Objects[7]; it is a growing and changing field, and research into new methods is critical to keep up with the rapidly changing and marginally predictable space environment. NASA already has an effort in this area (the CARA Program at Goddard Space Flight Center) that can be leveraged along with 30+ years of developing and executing this capability for use by civil space operators. It is government's role to retire risk, invest in Science and Technology (S&T) Research and Development (R&D), and share the results with the community to encourage growth.
- Invest in and expand the role of University Affiliated Research Centers (UARCs) as foundational, dedicated, and focused government-academic partnerships to solidify science and technology (S&T) research and development for critical space-related core technical competencies and technology risk-retirement needed by the U.S. Space Exploration program and Commercial Space Industry[8].

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[7] http://astriacss03.tacc.utexas.edu/ui/min.html

[8] https://www.arlut.utexas.edu

- Engage and craft mechanisms for Industry to get their investment and participation in a Civil Space Traffic Management System:
    - Satellite manufacturers
    - Satellite launch providers
    - Space Insurance Brokers and Providers
    - Commercial Space Situational Awareness Providers
    - Space Angel Investors and Venture Capitalists
    - Space Service Users

At The University of Texas at Austin, we are taking our own steps in a meaningful direction by (a) being an academic partner to the USSPACECOM in Space Situational Awareness Data Sharing, (b) collaborating with the NASA CARA program, hosting their tools at the Texas Advanced Computing Center (TACC) and leveraging our large scale computing platforms to improve current state-of-practice regarding collision risk assessments, (c) finalizing a fully executed set of Cooperative Research and Development Agreements (CRADAs) with the Department of Commerce's space weather prediction center and NOAA satellite operations facility in Suitland MD, (d) advancing the state-of-the-art in developing the world's first crowdsourced space traffic monitoring system, ASTRIAGraph, initially funded by the Federal Aviation Administration and now transitioned to Privateer Space Inc. in Wayfinder[9], (e) leading a dedicated transdisciplinary academic programs in space safety, security, and sustainability.

Mr. Chairman, we have some wicked problems to solve in near earth space and we need Congress to act now. Perfect is the enemy of good enough! We know that we won't have a perfect system at the start but let's create a system that is agile and adaptive to meet the growing demands and as a community, we will iteratively refine our tradecraft and collaboration and get better. This committee should provide the required leadership; the opportunity to act is before you.

Narrative

I recently read a draft bill titled "Space SSA Transition Act." In it, it states that the US government wants to make publicly and continually available, free of direct user fees, trusted, verified baseline space situational awareness services and information, enhanced by ongoing improvements in accuracy. I agree that this is needed but the details on this matter. Continually available means no interruption or downtime to query and access these baseline SSA services and information. The Depart of Commerce's Open Architecture Data Repository (OADR) must go beyond the current system employed by USSPACECOM whereby machine access is limited and of low bandwidth. The notion of trusted services and information is critical. There needs to be some part of the US government adequately resourced to do just this. Accuracy is also mentioned, but precision is not.

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[9] http://www.privateer.com

Information that is accurate and imprecise is not useful. Accuracy relates to error and precision relates to uncertainty around this error. Decisions are made based upon precision, uncertainty. We must seek to develop a system that is optimized to remove uncertainty and ambiguity. The OADR must, *inter alia*, be an ignorance removal system. The way to remove uncertainty is by aggregating, curating, and fusing massive quantities of disparate and independent observations. The you know that you have the world's most accurate clock is because we have hundreds of them, and the weighted combination of these results in a mean time with a distribution of times that represents the uncertainty.

The Space SSA Transition Act also states the desire to make available to governmental and non-governmental space operators space safety and sustainability tools, voluntary standards, and risk mitigation practices. This is also critical. In fact, the emergent behavior we desire of the space domain is that of common operational practice. However, common practice is impossible in the absence of common knowledge, so the knowledge must be made even across the operator community. Another point made was to support research and development to promote space safety and improve space situational awareness and space traffic coordination. Truth be told, we still have a lot of science yet to be done to understand the causal relationships existing in the space domain that could then promote improved predictability. The required research and development cannot be constrained to the hard sciences because coordination of space activities is also culturally nuanced. The research and development in this area must be transdisciplinary if the outcome is to effectively meet the US governments explicit desires and needs.

The US government also states its desire to develop and support ongoing mechanisms for transitioning into operational activities the research and development. This is an area of much needed attention as there is evidence that the US government is unskilled in this regard. The OADR was designed to have a so-called "sandbox" called the Advanced Research and Collaboration Applications Development Environment (ARCADE) which would serve as a mechanism to maximize success in transitioning the salient fruits of research and development into the operational system OADR proper. This could be solved by requiring that research and development be implemented in ARCADE prior to being proposed to the OADR.

Another point made was to support the use, where validated and practicable, of commercial technologies, data, systems, and services that can supplement and enhance United States Government-provided space situational awareness services and information. This is another critical item to be addressed as there are many commercial capabilities that far exceed anything the government has or could. These should be leveraged as a system of systems. Confidence, trust, and the best interest of the public is for the government to acquire and integrate these non-government technologies into the OADR framework to augment and improve inherently government capabilities.

Regarding the desire to promote and facilitate the development, demonstration, and ongoing use of voluntary standards and best practices for space situational awareness, this can only be achieved with open and wide collaboration. There must be leadership in developing use cases or scenarios that can be leveraged to drive this development and demonstration. For instance, focusing on exchanging data and information on rocket bodies in low earth orbit could rally a community together and the emergent result could be effective and longstanding practices with measured success in improving space safety, security, and sustainability.

With regards to leading international dialogue and collaboration toward implementing a framework for internationally harmonized space situational awareness and space traffic coordination, the US must go beyond so-called 5-Eyes and like-minded countries by leveraging its Track 2.0 Diplomacy instruments such as working with the National Academy of Sciences Committee on International Security and Arms Control (CISAC) which has a Space Security working group[10] as well as the Carnegie Endowment of International Peace (CEIP) which has a Space Project[11] dedicated to working with China, India, and Russia on theses SSA topics.

The Space SSA Transition Act mentions a Transition Plan which includes defining requirements for an Initial Operational Capability (IOC) and a Full Operational Capability (FOC) in terms of data, observations, tracking facilities, and services to be provided. Unfortunately, what is not mentioned is the need to concurrently and dynamically evaluate the data and observations in the context of so-called Dimensions of Data Quality (e.g. timeliness, accuracy, uniqueness, consistency, completeness, validity) critical to meet the needs of the community in both the IOC and FOC. This must be an inherently governmental function. In fact, given the process known as Observe-Orient-Decide-Act (OODA) pictured below, the OADR should serve principally as the Orient part of OODA. As such it should ingest, organize, curate and expose data and observations to space domain stakeholders to facilitate improved decision intelligence defined as the ability to manipulate data and information in such a way so as to maximize desired outcomes. In this case, the outcomes we seek are improved space safety, security, and sustainability by making the space domain more transparent, predictable, and developing a body of evidence that constitutes true continuing supervision.

[10] https://www.nationalacademies.org/our-work/space-security-working-group

[11] https://carnegieendowment.org/programs/technology/space/

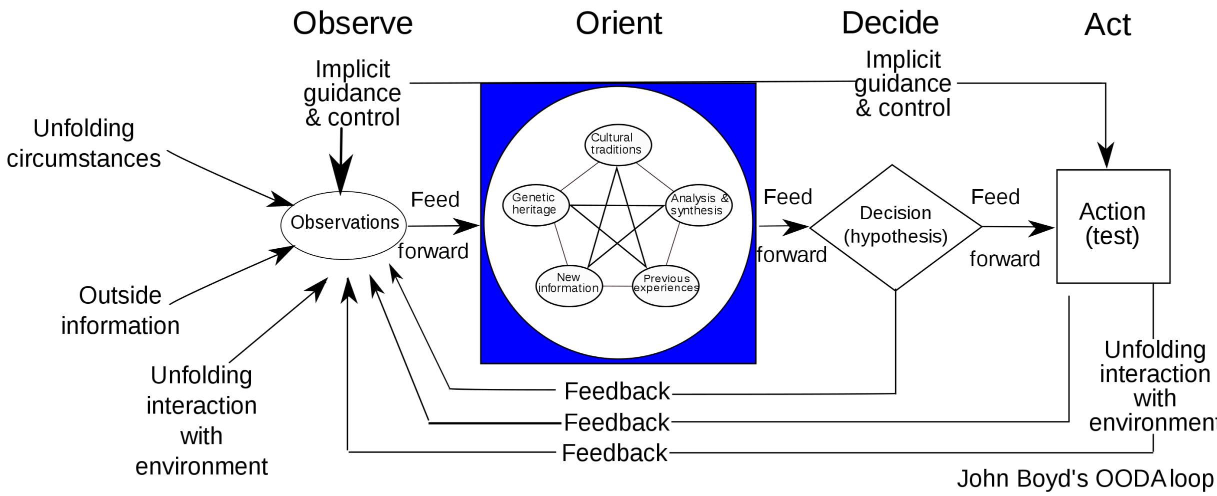

Figure 1. John Boyd's Observe-Orient-Decide-Act Framework
https://en.wikipedia.org/wiki/OODA_loop

Another way to understand this required data and information digital framework is pictured below with a snapshot of the live schema in ASTRIAgraph. There are many sources of data and observations available to the OADR which would be the yellow bubbles seen below on the left. Those in need of SSA/STM services and capabilities are the pink bubbles below on the right. These are the entities needing to make decisions and take actions. The Orient part of this resides in the middle (blue and green bubbles) below. This is what must be inherently governmental because it provides both due diligence in quality assurance ton the community and exposes the most useful and widest possibility of services and capabilities.

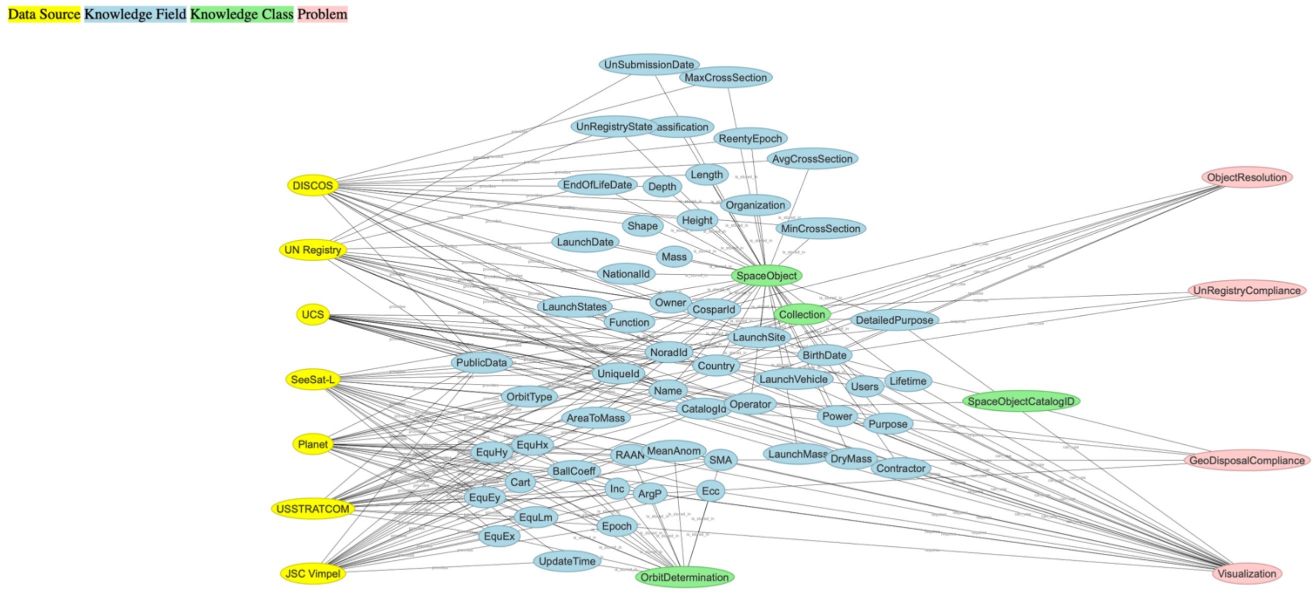

Figure 2. ASTRIAGraph's Live Schema http://astriaservices.tacc.utexas.edu/liveschema

In order to know something, one must measure it. The next figure provides a Space Domain Awareness Johari Window in terms of things we are aware of or not, and have measured or not. To wit, a Known-Known is something we are aware of having measured and this is the best place from here to make decisions and take actions. We also have thins we are aware of not having measured and for these things, Known-Unknowns, we must ascribe uncertainty to represent our ignorance and this uncertainty makes decision-making more challenging and with increased risk, but still quantifiable. The enigmas are the things we are unaware of and have not measured, making these unknowable, by definition. We have no way to protect ourselves against these things. Finally, we have the main importance of aggregating massive quantities of disparate and heterogeneous data into a properly data engineered framework, which is discovering otherwise hidden insights. These are the Unknown-Knowns or things we are unaware of having measured. Discovering this knowledge removes ignorance and improves space situational awareness and the services resultant from this.

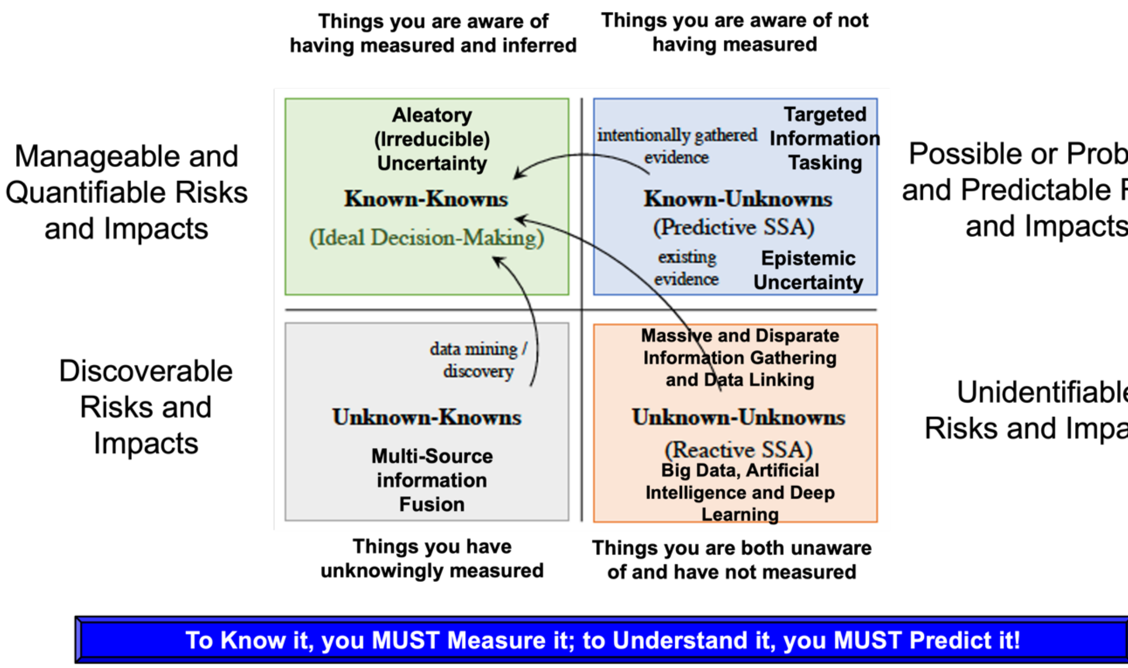

Figure 3. Space Domain Awareness Johari Window

For additional context, the US Space Command (USSPACECOM) currently has over 30,000 records active in its space situational awareness database, commonly referred to as the Department of Defense "catalog." Of these, well over 20,000 records correspond to well-tracked, well-understood Anthropogenic Space Objects in Earth-centric orbit, roughly 4,000 of which are operational satellites; the rest are so-called "space junk." The remaining records in USSPACECOM's active space situational awareness database are not as well-tracked or understood, which creates increased uncertainty when operational satellites are screened against them to identify possible orbital safety hazards, or conjunctions. The number of Anthropogenic Space Objects is increasing given an increase in launches, and on-orbit breakup events (i.e. when one Anthropogenic Space Object collides with another, a satellite explodes, or breaks on its own due to space aging and material fatigue and stresses). If we could track every detected object, we could wrap a sensible Space Traffic Management and Coordination system around that and even develop empirically-based policies and regulations. Unfortunately, it is hypothesized that we can only track a few percent of the total number of space objects that can cause loss, disruption, or degradation to critical space services, capabilities, and activities. In other words, we have an orbital iceberg equivalent of sorts. The ability to track an Anthropogenic Space Object depends on two main factors: our ability to detect the object AND our ability to uniquely identify the object. This is to underscore that <u>an object that is detectable does not imply it is trackable</u>, and this is a critical distinction to make moving forward.

Tracking an object means that we know where it was, a notion of where it is, and have some idea of what it is and where it will be. Think of how we track air traffic, where the aircraft is in the "custody" of someone who monitors its motion and relationship to other aircraft. The following

Figure (4) puts into perspective the problem we face in our inability to track more of the objects we can detect. It was generated from real data collected by the U.S. Space Surveillance Telescope, currently in Exmouth, Australia. It is worth mentioning that we have the long-awaited Space Fence on Kwajalein, and I've been told that the results are much like with the Space Surveillance Telescope, as seen in Figure (4). When one has an exquisite sensor and it's unique, you'll get very accurate observations during a very small part of the total orbit and you'll be observing things that other sensors will not or cannot.

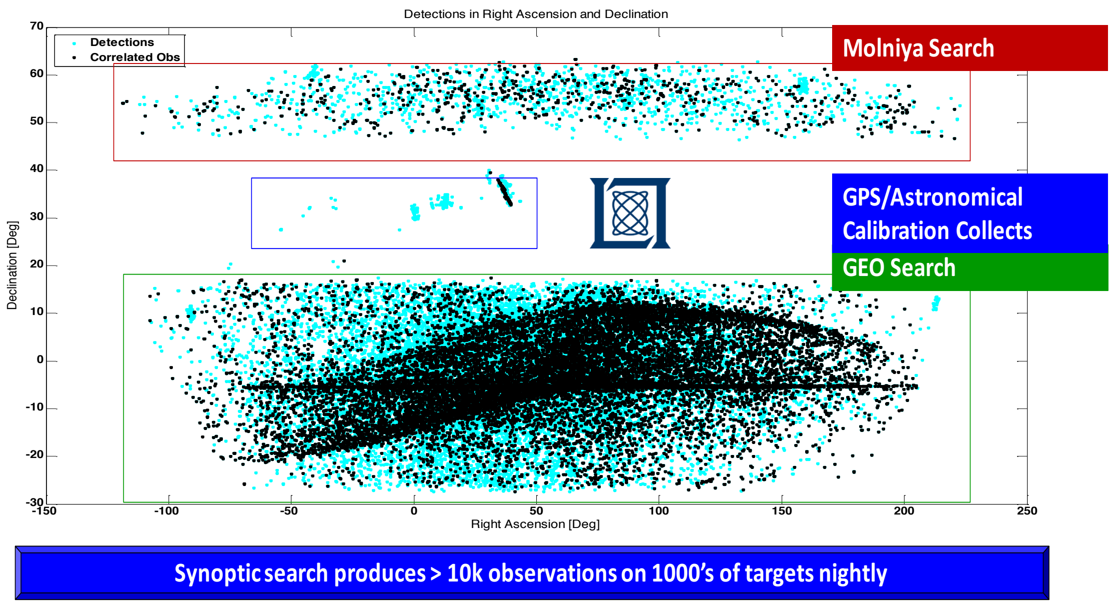

Figure 4. A Single Night's Worth of Anthropogenic Space Object (ASO Detections (for various orbital regions) from the U.S. Space Surveillance Telescope (SST) in New Mexico. Detections (dots) that are Black are those believed to be from known (cataloged) ASOs. All else (Cyan) are Detectable but Untrackable ASOs.

So, what prevents us from doing better at tracking objects in space? First, we don't have ubiquitous observations, meaning we don't persistently detect all objects all of the time. In fact, we generally have very sparse observations on any given object in space. Globally, we do not share observational data as a community. This lack of data sharing is perhaps the single biggest problem in us having a more robust space traffic monitoring and management capability. Secondly, every single object in the world's largest space object catalog (that of our DoD) is represented and modeled as a sphere, a cannonball in space. Needless to say, there aren't many human-made cannonball-shaped objects in space. Only those Anthropogenic Space Objects whose motion is not significantly different from that of a sphere in between observations, are ones we can "track." Gravity is what I call an equal opportunity accelerator: just tell me where you are and I will tell you your acceleration due to gravity, regardless of your size, shape, material constitution, orientation, etc. However, there are non-gravitational forces experienced by every single

Anthropogenic Space Object and all of these depend on the object's physical characteristics. Thus, the lack of a rigorous Anthropogenic Space Object characterization and classification scheme is a strong contributor to our inability to track more objects in space. When we wish to understand any population of things, we first "tag" individuals in that population and then "track" these individuals through time, space, frequencies, and evaluate their interaction with other individuals and their environment. We formulate hypotheses, test them, and draw conclusions based upon evidence. We do not do this, rigorously and scientifically, for Anthropogenic Space Objects, in great part because we cannot physically go to them and tag them. If we wish to someday have Norms of Behavior for Near Earth Space that led to safety, security, and sustainability, we will need to know how many classes or species of Anthropogenic Space Objects there are, and how each class or specie moves, behaves, is influenced by the local space environment, etc. Trucks carrying hazardous fuel are regulated differently than Vespa scooters, Oil Tankers on our seas are regulated differently than kayaks and canoes. So, why would we treat all Anthropogenic Space Objects as the same thing…cannonballs? The following figure (5) is a cartoon to show the difference between the limitations imposed by assuming space objects to be cannonball-like versus what they actually are like.

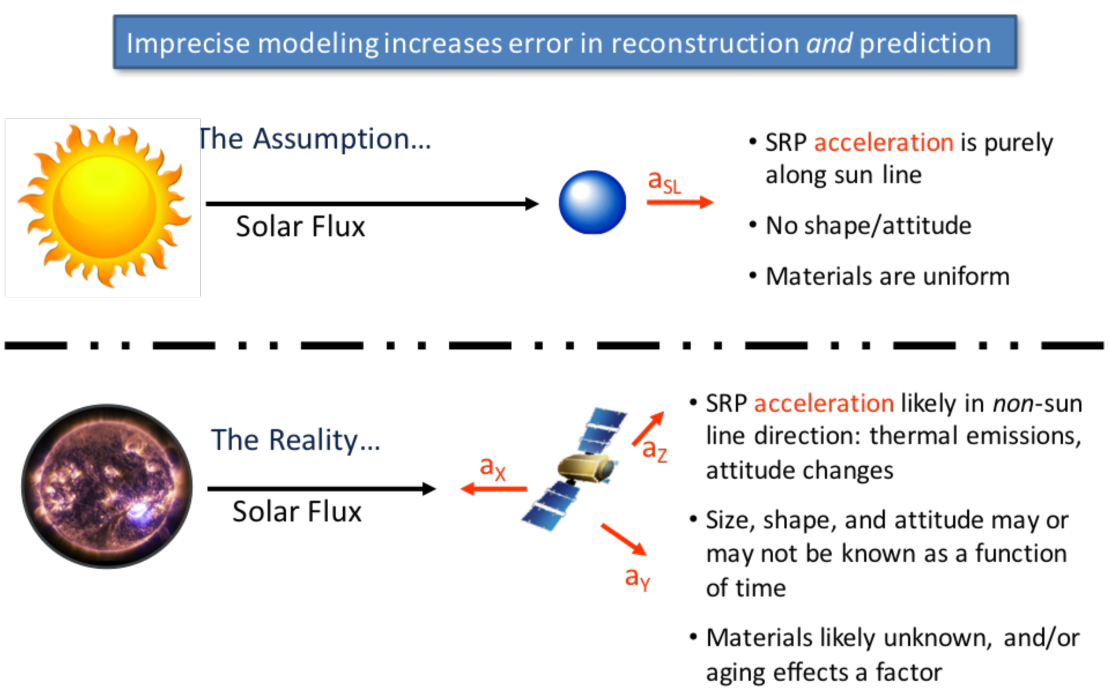

Figure 5. Difference between the motion experienced by a spherical (cannonball-like) space object and a satellite with realistic size, shape, orientation, and material properties. For the sphere, the acceleration due to the sun's effects are unidirectional. In reality, our tracking data informs us that objects experience accelerations due to the Sun's effects in 3-dimensional space (multi-directional).

Lastly, regarding our inability to track more objects in space, are the mathematics and physics we use to process the observed data and infer physical quantities regarding these objects. It really matters…call these our algorithms. Our representation of uncertainty is demonstrably and inarguably oftentimes flawed, unrealistic, and inconsistent amongst our software and tools. The following figure (6) shows a picture our current problem with having multiple detections at multiple times and having to find clever methods of uniquely identifying objects in order to make them go from detectable to trackable. Most Anthropogenic Space Objects are defunct and therefore do not self-report their identities.

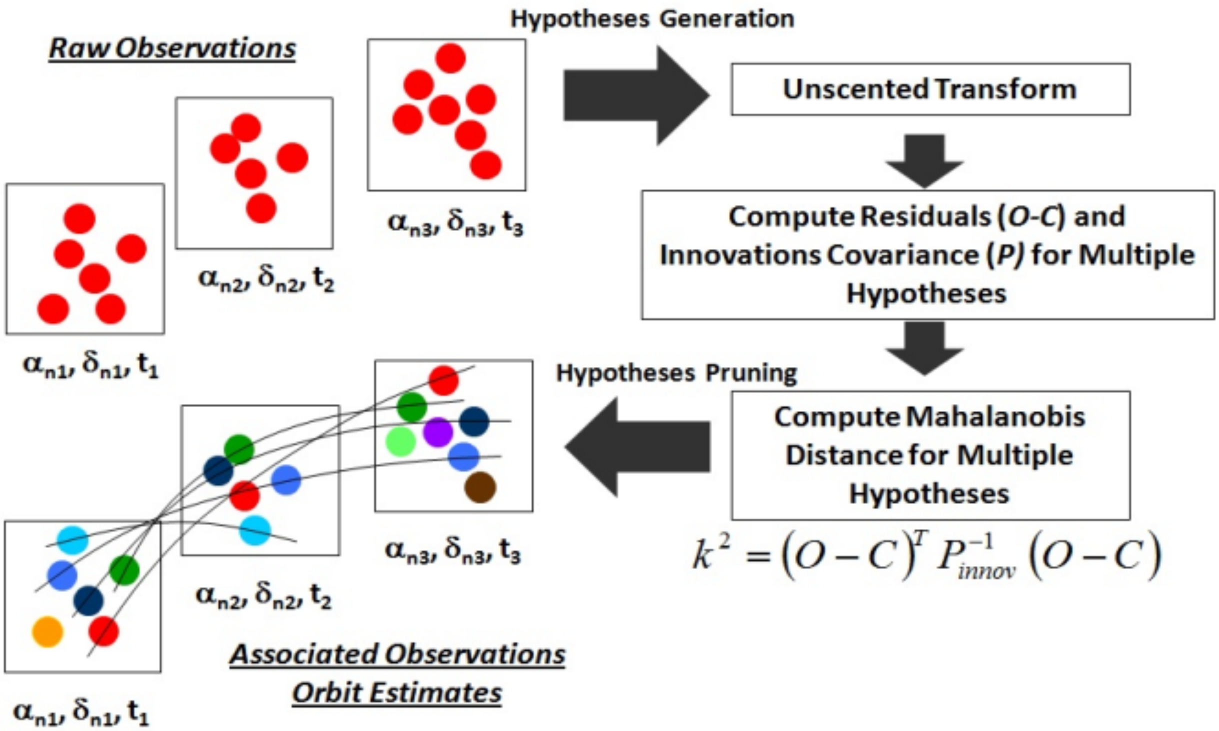

Figure 6. How to Uniquely Identify Space Objects from a Set of Unidentified Detected Objects in Order to Make Detectable Objects, Trackable. The method shown here is one of Multiple Hypothesis Testing as a mechanism to decide which detections should be paired to which objects.

If the Anthropogenic Space Object population was held constant, I'd say we'd might have more time on our hands to figure this all out. However, our global space environment is finite, getting increased traffic, and all in the absence of global governance related to safety and sustainability.

As the cost of access to space is decreasing, the number of space actors is increasing. It's like what the Transcontinental Railroad did for helping businesses explode, connecting the East Coast and Western Frontier. As was experienced in the Western Frontier of old, the environmental impact of runaway mining and prospecting was harsh and detrimental in many instances. Examples are mercury poisoning, silt in our water sources, etc. Our space environment is becoming much more commercially driven and populated. Many "New Space" companies or start-ups are getting significant investment from Angel Investors and Venture Capitalists who are focused on getting a Return On Investment (ROI) within a few years, believing Space Traffic and Orbital Safety to be someone else's problem. I have personally found an absence of space operations expertise amongst the workforce driving some of these "New Space" ventures, causing me further concern regarding orbital safety and long-term sustainability of space activities. There is a mentality of "take risks and fail often." While this worked well for software companies in Silicon Valley, we can't afford to have this mentality in space.

We should look to so-called tenets of Traditional Ecological Knowledge (TEK) as a model for achieving space sustainability. Some of our indigenous peoples have learned how to become sustainable over many millennia. One tenet underscores the need to quantify the carrying capacity of the environment before making decisions on how to interact with it. My personal experiences have shown me that "Mother Nature" tends to seek states of equilibrium. Do we know what the carrying capacity is for different orbits? If we launch 60+ satellites every several weeks, do we know what the equilibrium state of the environment will be? We are operating in the space domain well beyond our ability to make sound and sustainable decisions, and this will be to our eventual detriment.

I fully support Congress moving to create a Civil Space Traffic Management (CSTM) system led by the Department of Commerce (as directed by national space policy) that will:

- Accelerate the pace and reduce the costs of Civil Space Traffic Management development by modernizing approaches to Space Situational Awareness and Space Traffic Management, with focus on long-term sustainability of space activities, through the creation of new federated data standards, measurement standards, models and ontologies, open source software, and big-data management and analysis techniques that aid in the scientific evaluation of the efficacy and safety of space operations, and attendant policies.
- Act as an entity that could create consortia of industry, academia, and government for collaboration and sharing of databases, computational techniques, and standards.
- Operate a Civil Space Traffic Management system that provides the accuracies and products necessary to safely enable innovative and non-traditional commercial uses of space.

The Civil Space Traffic Management Mission should be to:

- Assure the safety of operations in space.
- Maximize, encourage, and incentivize the use of commercial capabilities and data sources.
- Provide transparency, advocacy of informed guidelines, and safety services as a public good to preserve the space environment.

The Civil Space Traffic Management Primary Functions would be to:

- **Observe and Monitor:** Space Domain and Traffic Observations, Space Situational Awareness (SSA)
- **Track and Catalog:** Identify, Characterize, and Catalog Objects; Relational Statistics, Catalog Updates, Traffic Attribution, Achieve Track “Custody”
- **Analyze and Inform:** Information Dissemination, Safety Products, Conjunction Data Messages

The Tenets of a Civil Space Traffic Management system would be to provide and incentivize:

- **Open observational data** - All collected or acquired data will be made open and available for 3rd party analysis to improve learning and enable high Quality of Service domain analysis.
- **Open catalog of space objects and events** - All derived conclusions from Civil Space Traffic Management data will be made open and available for 3rd party verification and peer-review of results and conclusions.
- **Open Safety Advisory Services** - As these services are intended to be a global public good, they will be made available to the world.
- **Open and objective verification of data and analyses** - As the Civil Space Traffic Management capabilities and processes improve, impartial feedback will be made available to all service providers in the spirit of achieving increasingly effective Quality of Service.
- **Open Market** - It is not the role of the Department of Commerce to define the economics of the data and/or analysis marketplace. The intent of the Civil Space Traffic Management is to empower industry to stay involved in the provision of service to all space domain actors.
- **Open Workforce Development** - It is to the benefit of all for the specialized skills required of effective space traffic managers to proliferate globally. To this end this Civil Space Traffic Management will support mechanisms which result in the education of additional skilled space traffic managers and analysts.

The Benefits of a Civil Space Traffic Management system are that it would:

- Provide standard and benchmark data sets that enable quantifiably consistent comparative analyses between competing tools, techniques, and algorithms.
- Provide the government with a transparent mechanism to guide and exploit Civil Space Traffic Management activities and capabilities AND a sustained/focused investment in STEM education.
- Provide industry with a free foundational Civil Space Traffic Management service and a marketplace of focused, cost-shared and openly available sciences and technologies that it can “pick up” and operationalize/commercialize for its own profit.

- Provide academia with a sustained scientific and technological Civil Space Traffic Management research and educational investment, to ensure that the U.S. is stocked with capable and skilled workforce to handle the scientific and technological problems of tomorrow.

How does industry profit from such an activity, financially? It can easily wrap profit-making services around the foundational “for public good” layer of basic space situational awareness and space traffic management services and products. It lowers the bar for entry for new space initiatives as they don’t need to shoulder the burden of self-providing of these basic space situational awareness and space traffic management services. It’s like the benefit of the U.S. developed, owned, and operated Global Positioning System (GPS)! Think of not only the paradigm-changing science but explosion of commerce that has resulted from this U.S. Government investment and service. Many companies have developed profit-making applications which exploit the layer of foundational service provided by GPS.

I also propose that the U.S Government create the NASA Space Situational Awareness Institute using Cooperative Agreements (like the NASA Astrobiology Institute) as a mechanism under which an academic consortium could be assembled, invested in, and properly leveraged to deliver on goal #1 of Space Policy Directive #3. The funding would need to be appropriated and delivered to NASA with a strategic roadmap on how the S&T is developed and transitioned to both government and industry. Several University Affiliated Research Centers (UARCs) should also be invoked, invested in, and leveraged, to be foundational partners in this NASA Space Situational Awareness Institute. The UARCs could provide foundational capabilities and sciences to NASA and those Space Situational Awareness Institute academic members could then focus uniquely on SSA needs and requirements, working closely with the government and commercial communities.

Exploration is critical to who we are as a species; it drives our growth and evolution. When our minds and bodies are idle, we tend to self-defeating behaviors. What brings out the best in us? Rising to great challenges, and working as a nation to overcome them. What got us to the Moon and back, safely and repeatedly? Government, Industry and Academia working seamlessly, together. No one sector could do it by themselves.

The motto of my research program at UT Austin is:

Ex Coelestis, Scientia…Nihil Arcanum Est! This loosely translates to, “from the heavens, knowledge…nothing hides!”

As Ever,

Moriba Jah

Moriba K. Jah, Ph.D.

THE UNIVERSITY OF TEXAS AT AUSTIN
Cockrell School of Engineering
Resume

FULL NAME: **Moriba Kemessia Jah** **TITLE:** **Associate Professor**

DEPARTMENT: **Aerospace Engineering and Engineering Mechanics**

EDUCATION:

Embry-Riddle Aeronautical University	Aerospace Engineering	B.S.	1999
University of Colorado (Boulder)	Aerospace Engineering Sci	M.S.	2001
University of Colorado (Boulder)	Aerospace Engineering Sci	Ph.D.	2005

PROFESSIONAL REGISTRATION: **Not Registered**

CURRENT AND PREVIOUS ACADEMIC POSITIONS:

Associate Professor (with Tenure), The University of Texas at Austin,
- Department of Aerospace Engineering and Engineering Mechanics, September 2020 – present
- Mrs. Pearlie Dashiell Henderson Centennial Fellowship in Engineering

Affiliate Faculty, The University of Texas at Austin
- Environmental Sciences Institute, October 2019 – present

Affiliate Researcher, Massachusetts Institute of Technology
- Jan 2021 - Present

Visiting Professor, Australian National University
- Research School of Aerospace, Mechanical, and Environmental Engineering (RSAMEE), July 2019 –Jan 2021

Core Faculty, The University of Texas at Austin,
- Oden Institute for Computational Engineering and Sciences, August 2018 – present

Director, The University of Texas at Austin,
- Oden Institute Computational Astronautical Sciences and Technologies Group, August 2018 - present

Associate Professor (Tenure-Track), The University of Texas at Austin,
- Department of Aerospace Engineering and Engineering Mechanics, April 2017 – September 2020
- Statistics and Data Science Department (Courtesy), October 2017 – present

Program Lead and Distinguished Scholar, The University of Texas at Austin,
- Robert Strauss Center for International Security and Law: Space Security and Safety, March 2017 - present

SERC-Funded Visiting Fellow, Royal Melbourne Institute of Technology University (Melbourne, Australia), May 2016 and May 2017

Adjunct Professor, Royal Melbourne Institute of Technology University, School of Science, SPACE Research Centre, 2016 – Present

Associate Research Professor (Continuing-Status/Tenure-Equivalent), The University of Arizona,
- Geosciences Department (Courtesy), March 2016 – April 2017
- Aerospace and Mechanical Engineering Department (Courtesy), September 2016 – April 2017
- Electrical and Computer Engineering Department (Courtesy), April 2016 – April 2017
- College of Engineering, January 2016 – April 2017

Rector-Funded Visiting Fellow, University of New South Wales (Canberra, Australia) May-June 2014

OTHER PROFESSIONAL EXPERIENCE:
U.S. Air Force Security Police, October 1988 – October 1992 (Honorably Discharged)
NASA Space Grant Researcher, January 1996 – May 1999
Microcosm Inc., Space Mission Design and Orbital Analyst, May 1997 – May 1999
NASA Jet Propulsion Laboratory, Spacecraft Navigator, May 1999 – August 2006
Oceanit Laboratories, Maui Division, Senior Scientist, August 2006 – October 2007
Air Force Research Laboratory, Directed Energy Directorate, Team Lead, Astrodynamics Program, October 2007 – June 2010
Air Force Research Laboratory, Space Vehicles Directorate, Technical Advisor, Guidance, Navigation, & Control Program, June 2010 - September 2014
Air Force Research Laboratory, Space Vehicles Directorate, Mission Lead, Space Situational Awareness, September 2014 - January 2016
Director of Space Object Behavioral Sciences Initiative, The University of Arizona, Defense and Security Research Institute, January 2016 – April 2017
Expert Contributor "Source of the Week," National Public Radio (NPR) (2019 – present)
Contributing Writer "Jahniverse," Aerospace America, American Institute of Aeronautics and Astronautics (AIAA) (2020 – present)
Host "Space Café: Moriba's Vox Populi," SpaceWatch Global Webcast Series (2020 – present)
Executive Mentor, Patti Grace Smith Fellowship (2021 – present)
Executive Mentor, Zed Factor Fellowship (2021 – present)
Non-Resident Fellow, United Nations Institute for Disarmament Research (UNIDIR) (2019 – present)
Non-Resident Scholar, Carnegie Space Project, Carnegie Endowment for International Peace (2021 – present)
Co-Founder and Chief Scientist, Privateer Space Inc. (2021 – present)

MAJOR CONSULTING PROJECTS
Slingshot Aerospace, Technical Advisor, 2019 – Present
NorthStar Earth & Space, Technical Advisor, 2021 – Present
Privateer Space Inc., Chief Scientific Advisor, 2021 - Present

HONORS AND AWARDS:
Senior Airman "Below-the-Zone" promotion, 1990
1990 Strategic Air Command, SP Airman of the Year
National Defense Service Medal (1991)
Honorable Discharge, U.S. Air Force (1992)
2001 *NASA Group Achievement Award* and *Aviation Week & Space Technology Laurel Award* for the superb navigation of the Mars Odyssey spacecraft to Mars
2005 *NASA Group Achievement Award* for the flawless navigation of the Mars Reconnaissance Orbiter to Mars
2007 *NASA Space Act Award* "for the creative development of a scientific contribution which has been determined to be of significant value in the advancement of the space and aeronautical activities of NASA, and is entitled: Inertial Measurements for Aeroassisted Navigation (IMAN)"
2009 *NASA Group Achievement Award* for the Nanosail-D mission support

2009 *AFRL R. Earl Good Award* "for significant team contributions to the AFRL mission or image outside of AFRL and for accomplishments that have had a significant impact and enhanced the creditability of AFRL."
Hayabusa Certificate of Appreciation (2010): "in recognition of your significant contributions to the completion of Hayabusa's round trip space mission in 2010."
Elected to Senior Member of the IEEE, 2010
Elected to Associate Fellow of the AIAA, 2011
2013 *AFRL International Award*
2013 *AFRL/RV Technology Transfer/Transition Achievement Award*
Elected as Fellow of the RAS, 2014
Elected as Fellow of the AAS, 2014
Elected as Fellow of the IAASS, 2015
Elected as Fellow of the Air Force Research Laboratory (AFRL), 2015
University of Colorado Distinguished Engineering Alumni Award (DEAA), 2016
AIAA Momentum Member Spotlight – June 2016
(http://www.aiaa.org/memberspotlightJune2016/)
Elected as Corresponding Member of the IAA, 2018
Elected as Fellow of the AIAA, 2019
Selected as Fellow of TED, 2019
Elected as Member of the IISL, 2019
Selected as Fellow of The Op-Ed Project, Public Voices, 2020
Selected as Individual Member of the IAU, 2020
Mrs. Pearlie Dashiell Henderson Centennial Fellowship in Engineering
Elected as Full Member of the IAA, 2020
Embry-Riddle Aeronautical University Distinguished Alumni Award, 2021
Elected as Fellow of the Explorers Club, 2021
Selected as Explorers Club 50: 50 People Changing The World, 2022

MEMBERSHIPS IN PROFESSIONAL AND HONORARY SOCIETIES

Fellow, International Association for the Advancement of Space Safety (IAASS), Member 2015 - Present
Fellow, American Astronautical Society (AAS), Member 2004 - Present
Fellow, Royal Astronomical Society (RAS), Member 2014 – Present
Fellow, American Institute of Aeronautics and Astronautics (AIAA), Member 1996 - Present
Senior Member, Institute of Electrical and Electronics Engineers (IEEE), Member 2010 - Present
Member, International Society for Information Fusion (ISIF), Member 2009 – Present
Corresponding Member, International Academy of Astronautics (IAA), 2018 – 2020
Full Member, International Academy of Astronautics (IAA), 2020 – Present
Member, International Institute of Space Law (IISL), 2019 – present
Individual Member, International Astronomical Union (IAU), 2020 – present
Fellow, Explorers Club, 2021 - present

UNIVERSITY COMMITTEES/ADMINISTRATIVE ASSIGNMENTS:

Cockrell School of Engineering

Member, Diversity and Inclusivity Committee, 2017 – Present

Aerospace Engineering & Engineering Mechanics
Member Social Platform Committee 2021 - Present

PROFESSIONAL SOCIETY AND MAJOR GOVERNMENTAL COMMITTEES, EDITORIAL BOARDS, AND CONFERENCES ORGANIZED/CHAIRED:

Outside Committees
Chair, AAS Space Surveillance Technical Committee (2009 – 2016)
Chair, AIAA Astrodynamics Technical Committee (2016 – 2018)
Member, International Academy of Astronautics (IAA) Space Debris Permanent Committee (2014 - Present)
Chair, NATO SCI-ET-003 Technical Solutions to a Common Operating Picture for Space Domain Awareness Exploratory Team, (2014 – 2015)
Chair, NATO SCI-279-TG Technical Solutions to a Common Operating Picture for Space Domain Awareness Task Group, (2015 – 2018)
Member, NATO SCI-ET-036 Collaborative Space Domain Awareness Data Collection and Fusion Experiment (2017 – 2018)
Member, NATO SCI-311-RTG Collaborative Space Domain Awareness Data Collection and Fusion Experiment (2018 – Present)
Chair, NATO SCI-ET-056 Role of Data and Decisions on the Space Operations Floor Exploratory Team, (2020 – Present)
Member, International Astronautical Federation (IAF) Astrodynamics Committee (2014 - Present)
Member, International Astronautical Federation (IAF) Space Security Committee (2018 - Present)
Member, International Astronautical Federation (IAF) Space Traffic Management Committee (2020 - Present)
Member, AAS Space Flight Mechanics Technical Committee (2006 – 2011)
Technical Chair, 21st AAS/AIAA Space Flight Mechanics Meeting (2011)
Member, Research Council, Research Initiative of Sustainable Space Logistics (RISSL), Ecole Polytechnique Federale de Lausanne (EPFL) Space Center (eSpace) (2020 – Present)
Member, National Academy of Sciences Engineering and Medicine (NASEM) Committee on International Security and Arms Control (CISAC) Space Security Working Group (2020 – Present)
Chair, International Academy of Astronautics (IAA) Space Traffic Management Permanent Committee (2020 - Present)
Chair, AIAA Goddard Astronautics Award Subcommittee (2020 – present)
Member IEEE AESS Judith A. Resnik Space Award Subcommittee (2020 – present)

Conference Activities
Member, NSSDF Technical Committee (2012 – 2015)
Technical Committee Member, International Society of Information Fusion Conference (2010, 2012, 2013)
National Chairperson, Space Debris, 35th Annual AAS Guidance and Control Conference (2012)
Organizer and Moderator, 1st AAS Space Surveillance Workshop, London, UK (2011)
Session Chair, AAS; AIAA; IAC; ISIF conferences and symposia (2002 – present)

Journal Activities
Associate Editor, Advances in Space Research (Elsevier), Journal of the Committee on Space Research (COSPAR), a Scientific Committee of the International Council for Science (2017 – Present)
Co-Editor, Acta Astronautica (Elsevier), Transdisciplinary Astronautical Arts, Sciences, and Engineering, Journal of the International Academy of Astronautics (IAA) (2020 – present)
Field Editor, Journal of Space Safety Engineering (Elsevier), Journal of the International Association for the Advancement of Space Safety (IAASS) (2021 – present)
Guest Editor, AIAA Journal of Guidance, Control, and Dynamics Special Issue: Space Domain Awareness
Associate Editor, IEEE Transactions on Aerospace and Electronic Systems (2011 – 2017)
Associate Editor, IEEE Aerospace and Electronic Systems Magazine (2011 – 2017)

OTHER PROFESSIONAL HIGHLIGHTS:
Invited External Reviewer for Montana NASA EPSCoR Research Award Selection (2016)
Secretary of the Air Force Invited Member, US Air Force Science & Technology Investments 2030 Expert Recommendations Panel, Science and Technology Policy Institute, Washington DC, July (2018)
Chair, NASA Space Weather to Research (SWO2R) Satellite Drag Review Panel, Headquarters Heliophysics Science Mission Directorate (2021)

Current Review Activities:
AIAA *Journal of Guidance, Control, and Dynamics*
IAA *Acta Astronautica (Elsevier)*
COSPAR *Advances in Space Research (Elsevier)*
AFOSR Proposals

PUBLICATIONS:

Refereed Journal Publications

1. Antreasian, P. G., Baird, D. T., Border, J. S., Burkhart, P. D., Graat, E. J., **Jah, M. K.**, … Portock, B. M. (2005). 2001 Mars Odyssey orbit determination during interplanetary cruise. *Journal of Spacecraft and Rockets*, *42*(3), 394–405. http://doi.org/10.2514/1.15222
2. **Jah, M. K.**, Lisano, M. E., Born, G. H., & Axelrad, P. (2008). Mars aerobraking spacecraft state estimation by processing inertial measurement unit data. *Journal of Guidance, Control, and Dynamics*, *31*(6), 1802–1813. http://doi.org/10.2514/1.24304
3. Wetterer, C. J., & **Jah, M.** (2009). Attitude estimation from light curves. *Journal of Guidance, Control, and Dynamics*, *32*(5), 1648–1651. http://doi.org/10.2514/1.44254
4. Kelecy, T., **& Jah, M.** (2010). Detection and orbit determination of a satellite executing low thrust maneuvers. *Acta Astronautica*, *66*(5–6), 798–809. http://doi.org/10.1016/j.actaastro.2009.08.029
5. Tombasco, J., Axelrad, P., & **Jah, M.** (2010). Specialized coordinate representation for dynamic modeling and orbit estimation of geosynchronous orbits. *Journal of Guidance, Control, and Dynamics*, *33*(6), 1824–1836. http://doi.org/10.2514/1.48903
6. Kelecy, T., & **Jah, M.** (2011). Analysis of high area-to-mass ratio (HAMR) GEO space object orbit determination and prediction performance: Initial strategies to recover and

predict HAMR GEO trajectories with no a priori information. *Acta Astronautica*, *69*(7–8), 551–558. http://doi.org/10.1016/j.actaastro.2011.04.019

7. Kelecy, T., **Jah, M.**, & DeMars, K. (2012). Application of a Multiple Hypothesis Filter to near GEO high area-to-mass ratio space objects state estimation. *Acta Astronautica*, *81*(2), 435–444. http://doi.org/10.1016/j.actaastro.2012.08.006
8. DeMars, K. J., **Jah, M. K.**, & Schumacher Jr., P. W. (2012). Initial orbit determination using short-arc angle and angle rate data. *IEEE Transactions on Aerospace and Electronic Systems*, *48*(3), 2628–2637. http://doi.org/10.1109/TAES.2012.6237613
9. DeMars, K. J., & **Jah, M. K.** (2013). Probabilistic initial orbit determination using Gaussian mixture models. *Journal of Guidance, Control, and Dynamics*, *36*(5), 1324–1335. http://doi.org/10.2514/1.59844
10. DeMars, K. J., Bishop, R. H., & **Jah, M. K.** (2013). Entropy-based approach for uncertainty propagation of nonlinear dynamical systems. *Journal of Guidance, Control, and Dynamics*, *36*(4), 1047–1057. http://doi.org/10.2514/1.58987
11. Früh, C., Kelecy, T. M., & **Jah, M. K.** (2013). Coupled orbit-attitude dynamics of high area-to-mass ratio (HAMR) objects: Influence of solar radiation pressure, Earth's shadow and the visibility in light curves. *Celestial Mechanics and Dynamical Astronomy*, *117*(4), 385–404. http://doi.org/10.1007/s10569-013-9516-5
12. Früh, C., **Jah, M.**, (2013). Attitude and Orbit Propagation of High Area-to-Mass Ratio (HAMR) Objects Using a Semi-Coupled Approach. *Journal of the Astronautical Sciences*, pp. 1-19, published 9 July 2014.
13. Früh, C., & **Jah, M. K.** (2014). Coupled orbit-attitude motion of high area-to-mass ratio (HAMR) objects including efficient self-shadowing. *Acta Astronautica*, *95*(1), 227–241. http://doi.org/10.1016/j.actaastro.2013.11.017
14. Wetterer, C. J., Linares, R., Crassidis, J. L., Kelecy, T. M., Ziebart, M. K., **Jah, M. K.**, & Cefola, P. J. (2014). Refining space object radiation pressure modeling with bidirectional reflectance distribution functions. *Journal of Guidance, Control, and Dynamics*, *37*(1), 185–196. http://doi.org/10.2514/1.60577
15. Vishwajeet, K., Singla, P., & **Jah, M.** (2014). Nonlinear uncertainty propagation for perturbed two-body orbits. *Journal of Guidance, Control, and Dynamics*, *37*(5), 1415–1425. http://doi.org/10.2514/1.G000472
16. DeMars, K. J., Cheng, Y., & **Jah, M. K**. (2014). Collision probability with Gaussian mixture orbit uncertainty. *Journal of Guidance, Control, and Dynamics*, *37*(3), 979–984. http://doi.org/10.2514/1.62308
17. Linares, R., **Jah, M. K**., Crassidis, J. L., & Nebelecky, C. K. (2014). Space object shape characterization and tracking using light curve and angles data. *Journal of Guidance, Control, and Dynamics*, *37*(1), 13–25. http://doi.org/10.2514/1.62986
18. Kelecy, T., **Jah, M.,** Baldwin, J., & Stauch, J. (2014). High Area-to-Mass ratio object population assessment from data/track association. *Acta Astronautica*, *96*(1), 166–174. http://doi.org/10.1016/j.actaastro.2013.11.037
19. Linares, R., **Jah, M. K.**, Crassidis, J. L., Leve, F. A., & Kelecy, T. (2014). Astrometric and photometric data fusion for inactive space object mass and area estimation. *Acta Astronautica*, *99*(1), 1–15. http://doi.org/10.1016/j.actaastro.2013.10.018
20. Leve, F., & **Jah, M.** (2014). Spacecraft actuator alignment determination through null-motion excitation. *IEEE Transactions on Aerospace and Electronic Systems*, *50*(3), 2336–2342. http://doi.org/10.1109/TAES.2013.120187

21. Stauch, J., & **Jah, M.** (2015). Unscented schmidt-Kalman filter algorithm. *Journal of Guidance, Control, and Dynamics*, *38*(1), 117–123. http://doi.org/10.2514/1.G000467
22. DeMars, K. J., Hussein, I. I., Frueh, C., **Jah, M. K**., & Erwin, R. S. (2015). Multiple-object space surveillance tracking using finite-set statistics. *Journal of Guidance, Control, and Dynamics*, *38*(9), 1741–1756. http://doi.org/10.2514/1.G000987

Refereed Journal Publications (while in rank at UT Austin)[UT Austin students UT Austin PostDocs UT Austin Faculty]

1. Psiaki, M. L., Weisman, R., **Jah**, **M.,** (2017). Gaussian Mixture Approximation of the Angles-Only Initial Orbit Determination Likelihood Function. *Journal of Guidance, Control, and Dynamics*, Vol. 40, 2807-2819. https://doi.org/10.2514/1.G002615
2. Coder, R., Holzinger, M., **Jah**, **M.,** (2017). Space Object Active Control Mode Inference Using Light Curve Inversion. *Journal of Guidance, Control, and Dynamics, Special Issue on Space Domain Awareness*, 1-13. https://doi.org/10.2514/1.G002224
3. Coder, R., Wetterer, C., Hamada, K., **Jah**, **M.,** Holzinger, M., (2017). Inferring Active Control Mode of the Hubble Space Telescope Using a Rao-Blackwellized Particle Filter. *Journal of Guidance, Control, and Dynamics, Special Issue on Space Domain Awareness*, 1-7. https://doi.org/10.2514/1.G002223
4. Stauch, J., Bessell, T., Rutten, M., Baldwin**,** J., **Jah**, **M.,** Hill, K., (2017). Joint Probabilistic Data Association and Smoothing Applied to Multiple Space Object Tracking. *Journal of Guidance, Control, and Dynamics, Special Issue on Space Domain Awareness*, 1-15. http://arc.aiaa.org/doi/abs/10.2514/1.G002230
5. Holzinger, M., and **Jah**, **M,** (2018). Challenges and Potential in Space Domain Awareness. *Journal of Guidance, Control, and Dynamics*, Vol. 41, No. 1, pp. 15-18. https://doi.org/10.2514/1.G003483
6. Mallik, V., **Jah, M.K.**, (2018). Reconciling Space Object Observed and Solar Pressure Albedo-Areas Via Astrometric and Photometric Data Fusion. *Elsevier Advances in Space Research*, Vol. 63, Issue 1, pp 404-416. https://doi.org/10.1016/j.asr.2018.08.005
7. Delande, E., Houssineau, J., **Jah, M.**, (2018) Physics and Human-Based Information Fusion for Improved Resident Space Object Tracking. *Elsevier Advances in Space Research*, Vol. 62, Issue 7, pp 1800-1812. https://doi.org/10.1016/j.asr.2018.06.033
8. Kelecy, T., Lambert, E., Sunderland, B., Stauch, J., Mallik, V., **Jah, M.**, (2019). Automated near real-time validation and exploitation of optical sensor data for improved orbital safety, *Acta Astronautica*. https://doi.org/10.1016/j.actaastro.2018.12.043
9. Do, H., Chin, T., Moretti, N. **Jah, M.**, & Tetlow, M. (2019). Robust Computer Vision Algorithms for GEO Object Detection, *Elsevier Advances in Space Research*, Vol. 64, Issue 3, pp 733-746. https://doi.org/10.1016/j.asr.2019.03.008
10. Delande, E., Houssineau, J., Franco, J., Frueh, C., Clark, D., **Jah, M.** (2019). A New Multi-Target Tracking Algorithm for a Large Number of Orbiting Objects. *Elsevier Advances in Space Research*, Vol. 64, Issue 3, pp 645-667. https://doi.org/10.1016/j.asr.2019.04.012
11. Kucharski, D., Kirchner, G., Otsubo, T., Kunimori, H., **Jah, M.**, Koidl, F., Bennett, J., Lim, H-C., Wang, P., Steindorfer, M., Sosnica, K. (2019). Hypertemporal Photometric Measurement of Spaceborne Mirrors Specular Reflectivity for Laser Time Transfer Link Model, *Elsevier Advances in Space Research*, https://doi.org/10.1016/j.asr.2019.05.030

12. Skinner, M., **Jah, M.**, McKnight, D., Howard, D., Mukrami, D., Kai-Uwe, S. (2019). Results of the International Association for the Advancement of Space Safety Space Traffic Management Working Group, *Elsevier Journal of Space Safety Engineering*, https://doi.org/10.1016/j.jsse.2019.05.002
13. 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
14. 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
15. 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
16. 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
17. Spurbeck, J., **Jah, M.**, Kucharski, D., Bennett, J., Webb, J. (2021). Near Real Time Satellite Event Detection, Characterization, and Operational Assessment Via the Exploitation of Remote Photoacoustic Signatures, *AAS Journal of Astronautical Sciences*, https://doi.org/10.1007/s40295-021-00252-5
18. Palmroth, M., Tapio, J., Soucek, A., Perrels, A., **Jah, M.**, Lönnqvist, M., Nikulainen, M., Piaulokaite, V., Seppälä, T., Virtanen, J. (2021). Toward Sustainable Use of Space: Economic, Technological, and Legal Perspectives, *Elsevier Journal of Space Policy*, Volume 57, 2021, https://doi.org/10.1016/j.spacepol.2021.101428
19. Kucharski, D., Kirchner, G., **Jah, M.**, Bennett, J., Koidl, F., Steindorfer, M., Wang, P. (2021). Full attitude state reconstruction of tumbling space debris TOPEX/Poseidon via light-curve inversion with Quanta Photogrammetry, *Acta Astronautica*, https://doi.org/10.1016/j.actaastro.2021.06.032
20. Zucchelli, E.M., Delande, E.D., Jones, B.A., **Jah, M.K**. (2021). Multi-Fidelity Orbit Determination with Systematic Errors. *J Astronaut Sci* 68**,** 695–727. https://doi.org/10.1007/s40295-021-00267-y

Refereed Conference Proceedings

1. **Jah, M.K.**, (1998). *Simulated Lunar Design and Modeling Assisted by Satellite Tool Kit (STK)*, 6th International Conference and Exposition on Engineering, Construction, and Operations in Space, held in Albuquerque, NM, April 26-30.
2. **Jah, M.K**., Potterveld, C., Rustick, J., Madler, R. (1999). *Use of Lunar Gravity Assists for Earth Orbit Plane Changes*, Part I, Advances in the Astronautical Sciences, Vol. 102, pp. 95-107, Univelt, San Diego. AAS Paper 99-107.
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4. Halsell, C. A., Bowes, A. L., Johnston, M. D., Lyons, D. T., Lock, R. E., Xaypraseuth, P., Bhaskaran, S. K., Highsmith, D. E., **Jah, M. K**. (2003). *Trajectory Design for the Mars Reconnaissance Orbiter Mission*, Part III, Advances in the Astronautical Sciences, Vol. 114, pp. 1591-1607, Univelt, San Diego. AAS Paper 03-211.
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Book/Chapters (Authored/Co-Authored, Edited/Co-Edited)

1. Space India 2.0, Chapter on Space Situational Awareness (2016) https://www.orfonline.org/wp-content/uploads/2017/02/Space2.0_Final_23Feb.pdf
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Notable Position Papers, Reports, and Congressional Testimonies

1. O. Brown, T. Cottom, M. Gleason, M. Hallex, A. Long, E. Rivera, D. Finkleman, T. Hitchens, **M. Jah**, D. Koplow, R. Sedwick, (2016). *"Report on Space Traffic Management Assessments, Frameworks, and Recommendations,"* In Reply To: Public Law No. 114-90, "U.S. Commercial Space Launch Competitiveness Act" Title I, "Spurring Private Aerospace Competitiveness and Entrepreneurship" Section 109, "Orbital Traffic Management", 21 November.
2. **M. Jah**, Congressional Witness, invited by U.S. Senator Ted Cruz (R-Texas), chairman of the Subcommittee on Space, Science, and Competitiveness, to provide testimony at the Reopening the American Frontier: Promoting Partnerships Between Commercial Space and the U.S. Government to Advance Exploration and Settlement, 13 July 2017
3. **M. Jah**, D. Greiman, M. Sengupta, S. Magnus, P. Melroy, S. Helms, M. Brown, "*Space Traffic Management (STM): Balancing Safety, Innovation, and Growth; A Framework for a Comprehensive Space Traffic Management System,*" An Institute Position Paper, The American Institute of Aeronautics and Astronautics, October 2017
4. S. Pagano, with input from **M. Jah et al.,** "*Taking Up (Outer) Space: An Exploration of Definitional Issues: A Virtual Think Tank Report*," Produced by **NSI** in the support of the Strategic Multilayer Assessment (SMA) Office (Joint Staff, J39), December 2017
5. B. Bragg, with input from **M. Jah et al.,** "*Use of the Commercial Space Industry for Military Purposes by Non-Western States: A Virtual Think Tank Report*," Produced by **NSI** in the support of the Strategic Multilayer Assessment (SMA) Office (Joint Staff, J39), December 2017
6. A. Astorino-Courtois, with input from **M. Jah et al.,** "*Space and US Deterrence: A Virtual Think Tank Report*," Produced by **NSI** in the support of the Strategic Multilayer Assessment (SMA) Office (Joint Staff, J39), December 2017
7. A. Astorino-Courtois, with input from **M. Jah et al.,** "*Contested Space Operations; A Strategic Multilayer Assessment: A Virtual Think Tank Report*," Produced by **NSI** in the support of the Strategic Multilayer Assessment (SMA) Office (Joint Staff, J39), November 2017
8. J. Stevenson, with input from **M. Jah et al.,** "*Effectiveness of International Agreements in Space: A Virtual Think Tank Report*," Produced by **NSI** in the support of the Strategic Multilayer Assessment (SMA) Office (Joint Staff, J39), February 2018
9. A. Astorino-Courtois, B. Bragg, with input from **M. Jah et al.,** "*Commercial Space Actors: Disruptors or Solid Partners for National Security: A Virtual Think Tank Report*," Produced by **NSI** in the support of the Strategic Multilayer Assessment (SMA) Office (Joint Staff, J39), February 2018
10. J. Stevenson, with input from **M. Jah et al.,** "*Principles of Response to Aggression in Space: A Virtual Think Tank Report*," Produced by **NSI** in the support of the Strategic Multilayer Assessment (SMA) Office (Joint Staff, J39), February 2018
11. N. Peterson, with input from **M. Jah et al.,** "*Commercial Companies' Perceptions of Security in Space: A Virtual Think Tank Report*," Produced by **NSI** in the support of the Strategic Multilayer Assessment (SMA) Office (Joint Staff, J39), March 2018
12. B. Bragg, with input from **M. Jah et al.,** "*Allocation of Commercial Space Industry Components: A Virtual Think Tank Report*," Produced by **NSI** in the support of the Strategic Multilayer Assessment (SMA) Office (Joint Staff, J39), April 2018

13. J. Stevenson, with input from **M. Jah et al.,** "*Effects of Investment on Pathways to Space Security: A Virtual Think Tank Report*," Produced by **NSI** in the support of the Strategic Multilayer Assessment (SMA) Office (Joint Staff, J39), April 2018
14. **M. Jah**, Congressional Witness, invited by U.S. Senator Roger Wicker (R-Miss.), chairman of the Committee on Commerce, Science, and Transportation, to provide testimony at the Space Missions of Global Importance: Planetary Defense, Space Weather Protection, and Space Situational Awareness, 12 February 2020
15. **M. Jah et al.**, *"Technical Considerations for Enabling NATO-Centric Space Domain Common Operating Picture,"* NATO STO Technical Report STO-TR-SCI-279 (2020) https://www.sto.nato.int/publications/STO%20Technical%20Reports/STO-TR-SCI-279/$$TR-SCI-279-ALL.pdf
16. Walker, C. (NSF's NOIRLab), Hall, J. (Lowell Observatory), Allen, L. (NSF's NOIRLab), Green, R. (U. Arizona,), Seitzer, P. (U. Michigan), Tyson, A. (UC Davis/Rubin Observatory), Bauer, A. (Vera C. Rubin Observatory), Krafton, K. (AAS), Lowenthal, J. (Smith College), Parriott, J. (AAS), Puxley, P. (AURA), Abbott, T. (NSF's NOIRLab), Bakos, G. (Princeton University), Barentine, J. (IDA), Bassa, C. (ASTRON), Blakeslee, J. (Gemini Observatory/NSF's NOIRLab), Bradshaw, A. (SLAC), Cooke, J. (Swinburne University), Devost, D. (Canada-France-Hawai'i Telescope), Galadí, D. (Icosaedro working group of the Spanish Astronomical Society), Haase, F. (NSF's NOIRLab), Hainaut, O. (ESO), Heathcote, S. (NSF's NOIRLab), **Jah, M**. (University of Texas at Austin), Krantz, H. (U. Arizona), Kucharski, D. (University of Texas at Austin), McDowell, J. (CfA), Mróz, P. (Caltech), Otarola, A. (ESO, TMT), Pearce, E. (U. Arizona), Rawls, M. (U. Washington/Rubin Observatory), Saunders, C. (Princeton University), Seaman, R. (Catalina Sky Survey), Siminski, J. (ESA Space Debris Office), Snyder, A. (Stanford University), Storrie-Lombardi, L. (Las Cumbres Observatory), Tregloan-Reed, J. (U. Antofagasta), Wainscoat, R. (U. Hawai'i), Williams, A. (ESO) and Yoachim, P. (U. Washington/Rubin Observatory) Appendix B and C *"Impact of Satellite Constellations on Optical Astronomy and Recommendations Toward Mitigations"* https://aas.org/sites/default/files/2020-08/SATCON1-Report.pdf and https://aas.org/sites/default/files/2020-08/SATCON1-WG-Tech-Reports_0.pdf

INVITED TALKS/LECTURES:

1. NASA Jet Propulsion Laboratory. November 2007. *Air Force Maui Optical and Supercomputing Site (AMOS)*
2. 19th AAS/AIAA Space Flight Mechanics Meeting, Savannah, GA. February 2009. *Advanced Sciences & Technology Research Institute for Astrodynamics (ASTRIA)*
3. Liceo Militar Pedro Ma. Ochoa Morales, Los Teques, Venezuela. June 2009. *Introduction to Astrodynamics and Orbit Determination*
4. Universidad Simon Bolivar, Caracas, Venezuela. June 2009. *Introduction to Astrodynamics and Orbit Determination*
5. 1st TechHui Conference, O'ahu, Hawai'i. Keynote Speaker. July 2009. *Astrodynamics and the Maui Space Surveillance Systems Branch*
6. University of Bern, Bern, Switzerland. September 2009. *Orbit Determination Performance for High Area-to-Mass Ratio Space Object Tracking Using an Adaptive Gaussian Mixtures Estimation Algorithm*

7. University College London, London, Great Britain. October 2009. *Orbit Determination Performance for High Area-to-Mass Ratio Space Object Tracking Using an Adaptive Gaussian Mixtures Estimation Algorithm*
8. 2011 European Geophysics Union Meeting, Vienna, Austria. May 2011. *Improved Methods for Tracking and Characterizing Inactive Resident Space Objects*
9. 28th International Symposium for Space Sciences and Technology, Okinawa, Japan. June 2011. *Special Panel on Space Debris*
10. 2011 Students for the Exploration and Development of Space (SEDS) conference, Boulder, CO Oct 2011. *Special Panel on Space Debris*
11. 39th COSPAR Scientific Assembly, Mysore, India. July 2012. US Keynote Speaker. *Special Panel on Space Situational Awareness*
12. 2012 AIAA GNC/Astrodynamics Conference, Minneapolis, MN Aug 2012. *Special Panel on Space Situational Awareness*
13. 1st Australian Space Situational Awareness Meeting, Canberra, Australia Apr 2013. US Keynote Speaker
14. 24th AAS/AIAA Space Flight Mechanics Meeting, Santa Fe, NM Jan 2014. *Special Panel on Air Force Space Command's Astrodynamics Innovation Committee*
15. 2nd IAA Conference on Dynamics and Control of Space Systems, Rome, Italy Mar 2014. *Special Panel on Astrodynamics Needs in Space Situational Awareness and the Air Force Space Command's Astrodynamics Innovation Committee*
16. 2nd Australian Space Situational Awareness Meeting, Canberra, Australia Jun 2014. US Keynote Speaker
17. AIAA Space 2014, San Diego, CA Aug 2014. *Mutual Application of Joint Probabilistic Data Association, Filtering, and Smoothing Techniques for Robust Multiple Space Object Tracking"* Co-authors: J. Stauch, J. Baldwin, T. Kelecy, K. Hill
18. TEDxABQ Salon, Albuquerque, NM Aug 2014. *Space Junk: The Unknown Orbital Iceberg Equivalent*
19. Space Situational Awareness 2014, London, UK, Nov. *US Representative Panelist*
20. Space Security, Wilton Park, West Sussex, UK, Mar 2015. US Space Situational Awareness technical expert
21. Space Situational Awareness 2015, Maryland, May. *Chair, Keynote Speaker, and Panelist*
22. 3rd Australian Space Situational Awareness Meeting, Canberra, Australia Sep 2015. US Keynote Speaker
23. 1st Air Force Research Laboratory (AFRL) Inspire talks, Dayton OH Oct 2015. *Space Junk: The Unknown Orbital Iceberg Equivalent*
24. Institute for Defense Analyses, Science and Technology Policy Institute: Invited lecture on Space Object Behavioral Sciences and Applications to Space Situational Awareness and Space Traffic Monitoring, Jan 2016
25. Martin Luther King Day Invited Speaker: Army Research Laboratory, Adelphi MD, Jan 2016
26. Embry-Riddle Aeronautical University Honors Lecture, Prescott, AZ. Mar 2016
27. 32nd Space Symposium Panelist on Congestion in Space, Colorado Springs CO, Apr 2016
28. Defense Strategies Institute (DSI) 2nd Annual Space Resiliency Summit, Alexandria VA, June 2016. Keynote Speaker
29. NATO SCI-292-LS Lecture Series, Lead Lecturer, Ankara (Turkey), Rome (Italy), Munich (Germany), and Washington D.C.(USA), June-July 2016. *Space Domain Awareness*

30. 2nd Space Technology and Investment Forum, San Francisco CA, July 2016. Keynote Speaker
31. NPR Arizona Science: *Episode 48 Rules of the Road are Needed in Outer Space*, https://radio.azpm.org/arizonascience/, Sep 2016
32. Space Advocates Seminar, US. House Science Committee, Washington, D.C., Oct 2016. *The Role of Academia in Space Situational Awareness and Global Space Traffic Management*
33. International Symposium for Personal and Commercial Spaceflight, Las Cruces NM, Oct 2016. Keynote Speaker
34. TEDxDayton, Dayton, OH, Oct 2016. *Space Traffic and Avoiding the Tragedy of the Commons*
35. The Space Show, http://thespaceshow.com/show/18-oct-2016/broadcast-2796-dr.-moriba-jah, Oct 2016
36. University of Texas at Austin, Aerospace Engineering and Engineering Mechanics Department, 28 Oct 2016. *Space Traffic Management and the Tragedy of the Commons*
37. University of Colorado at Boulder, Aerospace Engineering Sciences Department, 2 Feb 2017. *Adaptive Entropy-based Gaussian-mixture Information Synthesis for Improved Space Situational Awareness*
38. 3rd ORF Kalpana Chawla Space Dialogue, 15-18 Feb 2017, New Delhi, India. Invited Speaker and Panelist
39. Future In-Space Operations (FISO) seminar, 1 Mar 2017. *Space Traffic and the Tragedy of the Commons*. http://spirit.as.utexas.edu/%7Efiso/telecon.htm
40. World Space Risk Forum, Panel on Space Debris Challenges and Dangers, 15 June 2017, London, UK. Keynote Speaker
41. 29th International Summer Symposium on Science and World Affairs, Union of Concerned Scientists, 24-31 July 2017, Technical University of Darmstadt, Germany
42. 15th Reinventing Space Conference, Glasgow Scotland, Oct 24-26 2017, Keynote Speaker
43. 1st International Academy of Astronautics (IAA) Conference on Space Situational Awareness, Orlando FL, Nov 2017, Keynote Speaker.
44. Challenges in Space Traffic Management and Situational Awareness, Virginia Tech, March 9, 2018.
45. 1st Indian Workshop on Space Situational Awareness, New Delhi, June 2018, Keynote Speaker.
46. Astrodynamics Challenges for Space Situational Awareness, Space Advocates, U.S. Congressional Staff, June 2018.
47. Space Surveillance and Tracking Short Course, Shanghai Jiao Tong University, Aerospace Engineering, June 2018.
48. Space Surveillance and Tracking Short Course, Beijing Institute of Technology, Aerospace Engineering, June 2018.
49. Advanced Space Object Tracking Methods, Chinese Academy of Sciences, National Astronomical Observatories, Beijing, China, July 2018.
50. 4th Australian and New Zealand Workshop on Space Situational Awareness, UNSW/ADFA, Canberra, Australia, July 2018, Keynote Speaker.
51. 3rd Global Space Traffic Management workshop, Edinburgh, Scotland, Keynote Speaker, August 2018.
52. Space Debris Workshop, International Workshop for Laser Ranging, Canberra, Australia, Keynote Speaker, November 2018.

53. Invited Panelist, Outer Space Institute inaugural conference and meeting, University of British Columbia, Vancouver, B.C Canada, November 2018.
54. The Journey of an Astrodynamicist, McCallum High School, Austin, TX, November 2018.
55. The Journey of an Astrodynamicist, Cedar Creek High School, Houston, TX, December 2018.
56. The Journey of an Astrodynamicist, National Society of Black Engineers, The University of Austin, Austin, TX, December 2018.
57. 2018 Eilene Galloway Symposium, Keynote Speaker and Panelist, Washington D.C., December 2018.
58. The Journey of an Astrodynamicist, Molokai High School, Molokai, HI, January 2019.
59. 1st Finnish Space Sustainability Workshop, Aalto University, Espoo, Finland, February 2019, Keynote Speaker.
60. United Nations Committee On Peaceful Uses of Outer Space, Scientific and Technical Sub-Committee meetings, *AIAA Member Contributions to the Long Term Sustainability of Space*, Vienna, Austria, AIAA Representative Speaker on the United States Delegation to the United Nations, February 2019.
61. Invited Seminar Lecture, Stanford University, Aerospace Engineering Department, February 2019. *Advanced Methods of Resident Space Object Characterization and Uncertainty Quantification*.
62. Invited Seminar Lecture, Texas A&M University, Aerospace Engineering Department, February 2019. *Advanced Methods of Resident Space Object Characterization and Uncertainty Quantification*.
63. Invited Seminar Lecture, Georgia Institute of Technology, Aerospace Engineering Department, March 2019. *Advanced Methods of Resident Space Object Characterization and Uncertainty Quantification*.
64. TEDxUTAustin, Austin, TX, April 2019. *ASTRIAGraph: Space Traffic Monitoring at UT Austin*.
65. Salt Spring Forum, Salt Spring Island, B.C., April 2019. *The Journey of an Astrodynamicist: Science, Space Junk, and Environmentalism on the Final Frontier*.
66. TED, Vancouver, B.C., April 2019. *ASTRIAGraph: Towards a Crowdsourced Space Traffic Monitoring System*.
67. United Nations Disarmament Institute (UNIDIR), 2019 Space Security Conference, Geneva, Switzerland, May 2019. *ASTRIAGraph: Space Traffic Monitoring at UT Austin*.
68. US-Japan Conference on Cultural and Educational Interchange (CULCON), Beyond 2020: Paving the Way for the Next Generation and U.S.-Japan Collaboration, Speaker and Panelist, Austin, TX, June 2019. *US-Japan Areas for Scientific Collaboration Regarding Space Situational Awareness and Space Sustainability*.
69. The Journey of an Astrodynamicist, Huston-Tillotson University Elementary School Summer Program, Austin, TX, June 2019.
70. Invited Highlight Lecture, 2nd IAA/AAS SciTech Forum, Moscow, Russia, June 26-29 2019. *Advances in Space Object Characterization and Uncertainty Quantification for Space Situational Awareness*.
71. Space Traffic Management Workshop, Royal United Services Institute (RUSI), London, UK, July 2019, Keynote Speaker.
72. 10th International Workshop on Satellite Constellations and Formation Flying, Glasgow, Scotland, July 2019, Keynote Speaker.

73. ArmadilloCon 41, Austin, Texas, August 2019, The Science Guest.
74. 70th International Astronautical Congress, Washington DC, October 2019, Invited Panelist. *Artificial Intelligence in Space*.
75. 70th International Astronautical Congress, Washington DC, October 2019, Moderator. *Space Traffic Management*.
76. 70th International Astronautical Congress, Washington DC, October 2019, Invited Panelist. *34th IAA/IISL Scientific-Legal Roundtable "Mega-Constellations."*
77. 2019 swissnexDay, EPFL, Lausanne, Switzerland, December 2019, Keynote Speaker.
78. Outer Space Institute Workshop on Space Debris, Salt Spring Island, BC, Canada, January 2020
79. DLD Conference, Munich, Germany, January 2020, Invited Panelist.
80. 2020 AAAS Meeting, Seattle, WA, February 2020, Invited Topical Lecture.
81. 2020 Arizona Space Grant Symposium, 30th NASA Space Grant Anniversary, April 2020, Keynote Speaker.
82. Co-creator of the AIAA ASCEND Space Traffic Management Diverse Dozen, October 2020.
83. Given COVID-19 and use of Zoom/Teams/etc., too many to list for the remainder of 2020.
84. Guest Lecture, *"Space Environmentalism,"* Warwick University and University of Oxford Aerospace Societies, January 2021.
85. Computational Astronautics Lecture, International Space University, January 2021.
86. Chair's Distinguished Seminar Lecture, *"Traffic in Near-Earth Space: A wicked problem of a complex system requiring a transdisciplinary solution,"* University of Michigan Aerospace Engineering Department, January 2021.
87. Verification of 21st Century Arms Control Treaties, Space Security, Stanford University Guest Lecture, January 2021.
88. 2021 Data Harmony Update, Keynote, February 2021.
89. Guest Lecture, SPACE LAB at Morgan State University, February 2021.
90. 6th Japanese National Space Policy Secretariat Symposium on Ensuring the Safe and Sustainable Use of Outer Space, Invited Speaker, March 2021.
91. Global Explorers Summit (GLEX2021), Lisbon, Portugal, July 2021, Invited Panelist.

RESEARCH TOPICS

Astrodynamics
Statistical Orbit Determination and Prediction
Space Situational Awareness
Space Traffic Management
Spacecraft Navigation
Multi-Source Information Fusion
Space Surveillance and Tracking
Orbital Safety
Long-Term Sustainability of Space Activities

GRANTS AND CONTRACTS

While in rank at The University of Texas at Austin: *Total:$5,898,761 (Jah's Share: $5,019,169)*

1. “Development of a GEO Space Object Catalog,” Air Force Research Laboratory via Applied Defense Solutions, $159,974 (Jah’s Share $159,974), Mar 2017 – Mar 2018, Principal Investigator.
2. “Hallmark – Testbed,” DARPA via Ball Aerospace, $215,000 (Jah’s Share $215,000), Aug 2017 – Oct 2018, Principal Investigator.
3. “Spacecraft Navigation Independent Verification and Validation Analyses via JPL’s Monte,” NASA Jet Propulsion Laboratory, $101,985 (Jah’s Share $101,985), Sep 2017 – Sep 2018, Principal Investigator.
4. “Space Object and Event Knowledge Graph for Space Traffic Management, Phase1” Federal Aviation Administration via NMSU, $68,896 (Jah’s Share $68,896), Nov 2017 – May 2018, Principal Investigator.
5. “Space Domain Awareness Collaborative Research Infrastructure,” Air Force Research Laboratory via the University of Arizona, $589,884 (Jah’s share $196,628), Mar 2017 – Mar 2020, Principal Investigator (Co-Is Ryan Russell and Brandon Jones).
6. “Track Custody at GEO,” Air Force Office of Scientific Research via University College London, $67,268 (Jah’s Share $67,268), Jan 2020 – Jun 2020, Principal Investigator.
7. “Optical Express,” Air Force Office of Scientific Research via Applied Space Solutions Ltd., $45,000 (Jah’s Share $45,000), Feb 2018 – Feb 2019, Principal Investigator.
8. “AF17-CT02 Rapid Discovery of Evasive Satellite Behaviors,” Air Force Research Laboratory via Applied Defense Solutions, $45,000 (Jah’s Share $45,000), Apr 2018 – Jan 2019, Principal Investigator.
9. “AF17-CT02 Rapid Discovery of Evasive Satellite Behaviors,” Air Force Research Laboratory via Data Fusion and Neural Networks LLC, $50,000 (Jah’s Share $50,000), Apr 2018 – Jan 2019, Principal Investigator.
10. “Refinement and Validation of Radiation Pressure Models for High-Area-to-Mass-Ratio Objects for Improved Characterization, Tracking, and Orbit Prediction,” Air Force Office of Scientific Research, $616,336 (Jah’s Share $330,000; Co-I Renato Zanetti), Jun 2018 – Jun 2021, Principal Investigator.
11. “Deep Learning for Space Domain Awareness,” Air Force Office of Scientific Research via Applied Space Solutions Ltd., $200,000 (Jah’s Share $200,000), Apr 2018 – Jan 2020, Principal Investigator.
12. “Robust and Adaptive Machine Learning,” Air Force Office of Scientific Research via Applied Defense Solutions, $42,600 (Jah’s Share $42,600), Aug 2018 – April 2019, Principal Investigator.
13. “Improved Resident Space Object Tracking Via Advanced Estimation Methods, “ Tau Technologies, $276,535 (Jah’s Share $276,535), Aug 2018 – Sep 2019, Principal Investigator.
14. “Harris Advanced Space Situational Awareness Research and Development,” Harris Corp., $445,000 (Jah’s Share $445,000), Dec 2018 – Dec 2021, Principal Investigator.
15. “Space Object Maneuver Definition and Quantification,” Air Force Research Laboratory via CUBRC Inc., $80,514 (Jah’s Share $80,514), Apr 2019 – Jun 2020, Principal Investigator.
16. “AF17-CT02 Rapid Discovery of Evasive Satellite Behaviors: Phase 2,” Air Force Research Laboratory via Data Fusion and Neural Networks LLC, $223,814 (Jah’s Share $223,814), Nov 2019 – Aug 2021, Principal Investigator.

17. "Tactical Space Domain Awareness for Advanced and Actionable Space BMC2," Lockheed Martin Corp., $400,000 (Jah's Share $400,000), Aug 2019 – Aug 2021, Principal Investigator.
18. "Space System Modeling," Lockheed Martin Corp – Missile Fire Control, $92,289 (Jah's Share $92,289), Jun 2020 – Aug 2021, Principal Investigator.
19. "Research Fellow at Oden Institute for Computational Engineering and Sciences," SERC: Space Environment Research Centre, $80,000/year for Daniel Kucharski salary (all benefits included), June 2018 -March 2020, Research Fellow Supervisor.
20. "Robust Space Situational Awareness via Hard/Soft Information Fusion in the Presence of Epistemic Uncertainty," 2019 Moncrief Grand Challenge Faculty Award, Oden Institute for Computational Engineering and Sciences, $41,315 (Jah's Share $41,315), Spring 2020, Principal Investigator.
21. "Resident Space Object Tracking and Classification Using Methods in Geometric Statistics and Computational Topology," Air Force Office of Scientific Research, $195,000 (Jah's Share $195,000), Aug 2019 – Jul 2022, Principal Investigator.
22. "Space Object Gerontology," Air Force Office of Scientific Research, $225,000 (Jah's Share $225,000), Aug 2019 – Dec 2022, Principal Investigator.
23. "Transparency in Space Dashboard," Smith Richardson Foundation via Secure World Foundation, $87,089 (Jah's Share $87,089), Sep 2019 – Jan 2022, Principal Investigator.
24. "Space Data Prescriptive Analytics," Slingshot Aerospace, $150,000 (Jah's share $150,000), March 2020 – Feb 2023, Principal Investigator.
25. "Space Object and Event Knowledge Graph for Space Traffic Management, Phase1" Federal Aviation Administration via NMSU_Phase II, $273,430 (Jah's Share $273,430), Aug 2017 – Aug 2022, Principal Investigator.
26. "Ontology Derived Multi-Fidelity Space Object Catalog" Air Force Research Laboratory, $65,000 (Jah'sShare $65,000), Sep 2019 – Sep 2022, Co-PI.
27. "Quantification of Measurement Scheduling Effects on Orbit Determination Performance" DoD STTR via Orbit Logic Inc., $61,832 (Jah's Share $61,832), Aug 2020 – Aug 2021, Co-PI.
28. Autonomous Onboard Angles-Only Orbit Determination" Ball Aerospace Corp., $100,00 (Jah's Share $100,000), Jan 2021 – Dec 2021, Co-PI.
29. "Patterns of Life Assessment for Space" DOD STTR via O-Analytics, $150,000 (Jah's Share $150,000), Mar 2021 - Jan 2022, Principal Investigator.
30. "ACCESSED - Autopilot Commander Conjunction-assessment Enabling a Starling and a System for Exchange and Deconfliction" NASA STTR via Emergent Space Technology, $220,000 (Jah's Share $220,000), Oct 2021 – Mar 2023, Principal Investigator.
31. "Civil SSA/STM Sandbox for the OADR" Dept. of Commerce, NOAA via UT-ARL, $450,000 (Jah's Share $150,000), Dec 2021 – Dec 2022, Principal Investigator

<u>While at the Air Force Research Laboratory:</u> Total: $51,500,000 (Jah's Share: $28,000,000)

1. DARPA Orbit Outlook Program, $10M (Jah's Share $5M), Technical Lead (2014-2015).
2. Various Air Force SBIR/STTR Programs, $15M (Jah's Share $15M), Technical Lead (2010-2015).
3. DARPA Ibex Program, $20M (Jah's Share $1.5M), Technical Lead and PI (2010-2012).

4. Satellite and Missile Systems Center (SMC), $1.5M (Jah's Share $1.5M), PI (2010-2012).
5. Air Force Office of Scientific Research (AFOSR), $1.5M (Jah's Share $1.5M), PI (2009-2013).
6. AFOSR International, $1.5M (Jah's Share $1.5M), Technical Lead (2009-2013).
7. National Research Council (NRC) Research Associateship, $2M (Jah's Share $2M), Adviser (2009-2015).

PH.D. SUPERVISIONS COMPLETED:

1. Samantha Le May (co-supervised) [Royal Melbourne Institute of Technology – Australia](2021)

M.S. SUPERVISIONS COMPLETED:

1. Justin Spurbeck [University of Texas at Austin] Thesis Option (2019)
2. Marcus Bever [University of Texas at Austin] Thesis Option (2020)
3. Vivek Desai [University of Texas at Austin] (2020)
4. Vishnuu Mallik [University of Texas at Austin] (2021)
5. James Crowley [University of Texas at Austin] (2021)
6. Michael Reinhold [University of Texas at Austin] (2021)

PH.D. SUPERVISION IN PROGRESS:

1. Shiva Iyer [University of Texas at Austin] (2018 – present) [Candidacy Reached June 2019]
2. Benjamin Miller [University of Texas at Austin] (2019 – present) [Candidacy Reached June 2021]
3. Apoorva Karra [University of Texas at Austin] (2019 – present) [Candidacy Reached June 2021]
4. Nevan Simone [University of Texas at Austin] (2019 – present)
5. Tiffany Phan [University of Texas at Austin] (2021– present)
6. Keith Poletti [University of Texas at Austin] (2021– present)
7. Qing Zhu [University of Texas at Austin] (2021– present)

M.S. SUPERVISION IN PROGRESS:

N/A

PH.D. COMMITTEES:

1. Kyle DeMars, University of Texas at Austin (2010).
2. Jill Tombasco, University of Colorado at Boulder (2011).
3. Aaron Rosengren, University of Colorado at Boulder (2014).
4. Richard Linares, University of Buffalo (2014).
5. Antonella Albuja, University of Colorado (2015).
6. Ryan Coder, Georgia Institute of Technology (2016).
7. Vitali Braun, Technische Universitat Braunschweig (2016).
8. Patrick Kenneally, University of Colorado at Boulder (2019).
9. Kerianne Hobbs, Georgia Institute of Technology (2020).
10. Kirsten Tuggle, University of Texas at Austin (2020).
11. Nicholas Ravago, University of Texas at Austin (2018-present).

OTHER STUDENT RESEARCH COMMITTEES (Current):

Ph.D. Committees - 0
M.S. Committees – 0

Moriba Jah, Associate Professor

The University of Texas at Austin
Department of Aerospace Engineering and Engineering Mechanics
Mrs. Pearlie Dashiell Henderson Centennial Fellowship in Engineering

Dr. Moriba Jah is the Director of the Computational Astronautical Sciences and Technologies (CAST) group within the Institute for Computational Engineering and Sciences at The University of Texas at Austin, where he is also an Associate Professor of Aerospace Engineering and Engineering Mechanics in the Cockrell School of Engineering. He holds the Mrs. Pearlie Dashiell Henderson Centennial Fellowship in Engineering and trains a new generation of astrodynamicists and space traffic leaders through research and education at the intersection of engineering, policy, and commercialization. He has authored more than 100 scientific articles, columns, and book chapters, including a handful of op-eds. A highly sought public speaker, he has given more than 50 lectures, speeches, and invited talks in the last few years, such as testimony for hearings of U.S. Senate committees, keynotes for business meetings, plenary lectures for scientific conferences, lecture series for NATO's Science and Technology Organization, TED and TEDx talks, and the Air Force Research Laboratory's INSPIRE series. Dr. Jah has served as a member of the U.S. delegation to the United Nations Committee on the Peaceful Uses of Outer Space (UN-COPUOS) and is the chair of the NATO SCI-279-TG activity on defining a Common NATO Space Domain Awareness Operating Picture. Dr. Jah is also the Chief Scientific Advisor for Privateer Space Inc., a company focused on delivering bespoke decision intelligence at the speed of relevance addressing space safety, security, and sustainability needs.

As a professor, Dr. Jah has taught undergraduate and graduate courses at UT Austin related to space and astronautical sciences. Dr. Jah's research focuses on the convergence of policy, technology, and security related to space traffic management and space situational awareness. Government agencies such as the Department of Defense, Air Force Research Laboratory, and others as well as non-governmental organizations and private industry have featured Dr. Jah's research in their own decision-making processes. His expertise, opinions, and research have been published, cited or featured in many media outlets, including the SpaceWatch Global, pace News, Wired, ROOM, NatGeo, NPR, BBC, ABC, and others.

Prior to being at UT Austin, Dr. Jah was the Director of the University of Arizona's Space Object Behavioral Sciences with applications to Space Domain Awareness, Space Protection, Space Traffic Monitoring, and Space Debris research. Preceding that, Dr. Jah was the lead for the Air Force Research Laboratory's (AFRL) Advanced Sciences and Technology Research Institute for Astronautics (ASTRIA) and Technical Advisor to the Guidance, Navigation, and Control Program at AFRL's Space Vehicles Directorate. He received his B.S. in Aerospace Engineering from Embry-Riddle Aeronautical University, Prescott, Arizona, and his M.S. and Ph.D. in Aerospace Engineering Sciences from the University of Colorado at Boulder specializing in astrodynamics and statistical orbit determination. Before joining AFRL in 2007, he was a spacecraft navigator for NASA's Jet Propulsion Laboratory (JPL) in Pasadena, CA, serving on Mars Global Surveyor, Mars Odyssey, Mars Express (joint mission with ESA), Mars Exploration Rovers, Hayabusa (joint mission with JAXA), and the Mars Reconnaissance Orbiter. Dr. Jah founded the American Astronautical Society's (AAS) Space Surveillance Technical Committee and Chaired the AIAA Astrodynamics Technical Committee. He is a member of the Astrodynamics Committee of the International Astronautical Federation (IAF) and a permanent member of the Space Debris Committee of the International Academy of Astronautics (IAA). Dr. Jah is an elected member of the International Academy of Astronautics (IAA), a TED Fellow, a Fellow of the American Institute of Aeronautics and Astronautics (AIAA), the International Association for the Advancement of Space Safety (IAASS), the AFRL, the AAS and the Royal Astronomical Society (RAS), as well as an IEEE Senior Member, Associate Editor of Elsevier's Advances in Space Research, Acta Astronautica, and Space Safety Engineering Journals.