UNITED NATIONS
Office for Outer Space Affairs

Promoting Space Sustainability

Slingshot Aerospace

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Implementation of the Guidelines for the Long-term Sustainability (LTS) of Outer Space Activities of the Committee on the Peaceful Uses of Outer Space

Operational Case Studies

[Operational case studies are drafted by the submitting entity in their own words using the following template. Please avoid using national jargon and spell out acronyms to assist readers from other jurisdictions. All case studies will be made publicly available to facilitate peer-to-peer exchange, share experiences and raise awareness.]

I. Short description of the outer space activity [*1000-word max.*]

[Include any relevant background or technical information that may be helpful.]

We rely on global connectivity more than ever before and space is the resource we exploit to make that possible. A recent search of space-track.org uncovered that over 7,000 active and inactive satellites are in orbit, with that number set to increase by 300% within the next decade. Furthermore, the vast majority of resident space objects (RSO) are debris, making the total tracked number of objects in orbit well over 20,000. Compounding that growth is increasing diversification amongst the space economy, improved onboard vehicle capabilities and immature regulation and policy. Estimates indicate 10,000 companies across 80+ countries are planning activities ranging from space tourism to off-earth mining to establishing bases and stations for long term operations and eventual interplanetary travel. A data-rich and collaborative approach to Space Traffic Management (STM) is necessary to ensure long-term, peaceful, sustainability for all of space. Protecting this vital resource is increasingly important to protecting our very future.

Space Situational Awareness: Determining precise location

Data provided by the U.S. Space Command is highly specified, verified, and validated, but such specification is impractical for the influx of commercial providers. With multiple state solutions, from multiple government and commercial providers, for a single RSO at any given instant in time, how can a satellite operator, orbit analyst, intelligence analyst, or decision maker determine which one is "correct?" There is a clear need to not only aggregate, but curate and fuse the data before analytics can be meaningfully applied.

Today those charged with discovering and investigating threats to on-orbit activities garner data from multiple data providers, encompassing multiple sources, formats and quality standards. While there is an ever-increasing wave of space domain awareness data to fold into this picture, assessing validity across the multiple data provider catalogs is increasingly difficult. Decisions are either based on a single source with little or no validation or on incorrect data or analysis. These shortcomings cause lost time, redundancy of effort, and result in suboptimal products.

Data fusion and calibration techniques

Spaceflight safety strongly depends on the accuracy of orbital data and the ability to share that information across the increasing number of multinational stakeholders from industry and government. From a technology perspective, the need for robust, scalable systems to fuse and aggregate the myriad data sources at near-real time speeds is well understood. Either way, because each data source has their own strengths and weaknesses in different settings (orbit regime, global coverage, RSO type, etc.), a scheme that coalesces the various satellite state estimates into one, most accurate solution is paramount.By curating, fusing, aggregating, and comparing multi-source data in near-real time, it is possible to identify potential issues from data providers whether due to calibration, hardware malfunctions or human error.

Once the data is in a normalized state for comparison, we can add in alerting frameworks and start to layer in algorithms and AI/ML to optimize and add efficiencies to analysis. Through our recent efforts with the AFWERX sponsored EngageSpace challenge, we discovered the benefits of implementing an alerting framework to validate a particular provider's data. For example, if one provider is affected by a terrestrial or space weather event, the community can receive an alert and reconsider the validity of data collected from that provider, over that time period. A provider-centric view of the data combined with the ability to quickly look up contact information, easily share data views and begin troubleshooting is a critical need as the space stakeholder landscape becomes increasingly diversified.

We observed through our participation in International Space Pitch Day, an effort supported by the United Kingdom's Defence and Security Accelerator (DASA) with assistance from U.S.- based Starburst Accelerator and funded by the United States' Air Force, UK's Defence Science and Technology Laboratory, and the Royal Air Force, the importance of trust in the pedigree of the data, in particular as solutions rely more on the application of Machine Learning and move towards autonomous AI. The data must be accessible with transparency and include a metadata tagged history of processing for a piece of data such that consumers of the data have the provenance necessary for decision making. Slingshot's tools ingest data from various sources in a near real time streaming manner, and process the data in an automated pipeline to transform data into a common data type and compute comparison results. To maximize transparency, Slingshot includes a feature that allows an analyst to understand how that specific data point was generated, including information prior to ingest (if available), ingest source and method, and all pipeline steps from curation to transformation to analytics, including software and assumptions used.

The role of commercial enterprise

We understand from our experience supporting Commercial Sprint Advanced Concept Training (SACT) exercises sponsored by the Department of Commerce and Department of Defense, the value commercial data can contribute by enriching and distributing the intelligence picture.

Given that much of the space economy is driven by governmental activity, the role of commercial and open source data offers an independent mechanism for emerging participants in the space economy to accurately understand the location of space objects and the risk they may or may not present. Motions like the NASA Space Act to encourage sharing of onboard ephemeris data through the Space-Track.org set necessary precedent for data sharing standards - in particular related to the sharing of onboard ephemeris data. Additionally, commercial providers offer space- and terrestrial-based networks. Electro-optical data from the terrestrial domain is available with the NUMERICA TELESCOPE NETWORK (NTN), French company, Safran's, WETRACK(™) service uses RF data to track active spacecraft and LeoLabs, Inc. is focused on the crowded and high risk Low Earth Orbit regime with its radar capabilities. The availability to fuse commercial data providers with government and open sources lowers the barrier of entry for developing nations and emerging organizations to establish a sovereign opinion of on-orbit activity and behavior.

II. Connection with the LTS Guidelines [*500-word max.*]

The table below provides a mapping of Slingshot's applied technology to the LTS Guidelines.

Guideline	**Relevancy**	**Summary of relevancy**
	Direct	
	Indirect	
A. Policy and regulatory framework for space activities		
Guideline A.1		Slingshot uses a data-driven, open architecture, standards-based approach to encourage transparency, foster information sharing and support future policy for international and non-governmental stakeholders
Guideline A.2		
Guideline A.3		
Guideline A.4		
Guideline A.5		
B. Safety of space operations		
Guideline B.1		Slingshot Orbital enables data sharing and alerting for events of interest; relevant contact information is exposed through the application for immediate collaboration
Guideline B.2		Slingshot uses multiple sources and sensing modalities to reduce uncertainty in space object location data

Guideline B.3		Slingshot uses web-accessible, open architecture concepts; supports new data sources and information sharing
Guideline B.4		Slingshot augments the existing spacetrack.org by providing alternate means for performing conjunction assessments and other risk behavior
Guideline B.5		Slingshot Orbital and Slingshot Laboratory work together to provide a realistic environment for simulating events
Guideline B.6		Slingshot includes space and terrestrial weather data to identify and mitigate potential data degradation, differentiate between dynamic and media effects, and identify, characterize, and predict spacecraft and data anomalies.
Guideline B.7		Slingshot is a consumer of space weather models and informs through alerting framework on notable events and effects on provider data
Guideline B.8		Slingshot Laboratory provides a virtual sandbox to experiment and design space object operations
Guideline B.9		Slingshot has embedded communication and collaboration tools directly in our applications to expedite notifications and risk planning
Guideline B.10		Slingshot Orbital improves the understanding of on-orbit object that allow for improved planning and risk mitigation for the use of potentially destructive technology
C. International cooperation, capacity-building and awareness		
Guideline C.1		Slingshot develops and deploys dual-use, commercial technologies inclusive of open standards and other means
Guideline C.2		Slingshot developed a new methodology to validate commercial provider data for use thereby increasing persistent coverage of objects as well as working collaboratively with data providers to fix their data.
Guideline C.3		Slingshot Laboratory lowers the barrier of entry to astrodynamics concepts and the complexities of the space environment by providing a visually, immersive, tactile education and training experience

Guideline C.4		Slingshot is engaged with a broad swath of the space market - raising awareness through education and training and accessible visualizations
D. Scientific and technical research and development		
Guideline D.1		We are researching and prototyping the capability to identify patterns with AI/ML within historical and present data which in turn would help to determine the behavior of agents within the larger space population
Guideline D.2		Loosely coupled services, extensible architectures and accurate physics-environment for visualization encourages experimentation exploration of new methods and techniques

III. Lessons learned [*500-word max.*]

[Please share any information or observations that may assist others in their space activities.]

Our lessons learned, derived from two years experience supporting the operational community, have taught us the importance of incorporating technology that provides a complete digital twin of the space operating environment.

Collect

Diverse sources from earth and space domains are required to fuse together an accurate and objective data picture. Two-line element sets, state vectors, satellite contextual information, terrestrial and space weather, asset health, observations and ephemeris data all are valuable and available sources. Using Slingshot Orbital to bring together state vectors from multiple providers for a comparison-based quality check, for example, quickly surfaces potential issues to orbital analysts.

Analyze

The size and scale of the data is so vast that simply uniting the myriad data sources is not sufficient. Machine learning and advanced analysis techniques that surface alerts, identify outliers and provide a rich visualization framework are needed to optimize and scale. Additionally, as data for training models has limited availability, the ability to create synthetic training data for this purpose is essential. We have observed early successes with moderate-fidelity orbit simulations, inclusive of accurate measurements.

Simulate

Much like with the Air Traffic Management predecessor, Space Traffic Management, requires the ability to simulate various scenarios and outcomes. Dynamic, accurate models powered by live event data combined with a realistic, physics-accurate visualization environment is a solution to a somewhat common problem around conjunction assessment. When a potential conjunction is identified with two active maneuverable satellites, it is imperative that the simulation that indicated that alert is reliable. Additionally, as mitigating measures are determined and explored, simulation and modeling are at the core.

Collaborate and Communicate

Spacetrack.org issues over 4,000 alerts each day that present some level of conjunction threat. As data is collected and fused for analysis to inform simulations, courses of action are explored and considered. If it is deemed possible to preserve or maintain safety, then two or more entities collaborate, review vehicle capabilities and if possible, plan a maneuver. An easy-to-use, reliable collaboration platform integrated with secure chat that facilitates the exchange of complex information and includes real-time data integrations, fills a critical gap.

Optimize

Optimization of the environment is driven by a combination of persistent data coverage and the emergence of regulatory compliance standards and supporting policy. The government and industry must work together to create the necessary systems and technologies to facilitate adoption and growth.

Autonomy

The forecasted scale and complexity of the space operating environment requires automated and predictive analysis for cost-effective, long-term viability. One advantage with the increasing number of sources and modalities, onboard diagnostics and external vehicle sensing capabilities, is the vast array of data available; billions of pieces of time-stamped, metadata rich pieces of information can be interrogated to read signals and extract conclusions. Autonomy can automatically power down services not needed and extend the life of an asset or take shape in automated collision avoidance systems.