
Today, satellite launches, on-orbit operations, and deorbiting by spacefaring countries are manually intensive and safe. However, projected increases in the number of spacefaring nations and the volume of space traffic will strain Space Traffic Management (STM) processes and operations, requiring increased automation. STM processes and operations require timely space object data for all objects, in the context of clear and unambiguous understanding of the current agreements and intents for maneuvering and operating active space objects.

The volume, types, and complexity of space object data are steadily increasing—for example, increasing number of space objects, including from mega constellations; increasing number of data types beyond Two Line Element set (TLE), such as intent to maneuver and health/status; increasing number of data sources, both commercial and national; and an increased need for cross-domain information sharing and integration across space, airspace, land, and maritime domains.

Increases in space object agreements are driven by a growing number of spacefaring and space-interested nations who enter into agreements that describe increasingly complex ranges and constraints of operational behavior. The ability to discover behavioral anomalies by comparing observed behavior to agreed and intended behavior is the foundation for encouraging good behavior and enforcing compliance.

BESTA (Blockchain Enabled Space Traffic Awareness) is a proposed framework for automatically detecting behavioral anomalies by comparing observations to agreements, then recording the anomalies on the BESTA blockchain as evidence dockets for subsequent adjudication. This is a first step toward automating key activities of STM. BESTA compares space object data to agreements to detect anomalies that represent potential non-conforming space object behavior. These anomalies, together with pertinent data and agreements, are captured in evidence dockets on the BESTA blockchain for subsequent adjudication, either human in the loop or automatic. Comparison of data and agreements requires provably correct provenance of both the space object observation and other data, and the applicable agreement documents. Further, the generated evidence docket must be protected against tampering. BESTA is an open source, permissioned blockchain-enabled capability suitable for international and commercial stakeholders, providing tamper-evident, attributed, resilient, and available data. We describe the high-level modular architecture and needed research to enable prototype implementations.

BESTA internal architecture is modular, enabling continuous evolution and improvement. Types of modules include: SDA Input Provenance; SDA Information Sharing; Agreements Provenance; Agreement Information Sharing; SDA and Agreement Comparison; Anomaly Evidence Preparation; and Anomaly Adjudication. For each type of module, there may be multiple instances of the module, with each instance dedicated to a type of data, such as TLE, frequency, etc. The instance of the module then uses instances of actual data at runtime.

BESTA’s aim is to enable voluntary information sharing and decision making to support international cooperative STM.

BESTA research topics inform modules such as anomaly discovery in the SDA and Agreement Comparison module, and evidence capture and secure storage in the Anomaly Evidence Preparation module. Discovery research includes automatic ingest of agreements, policies, and regulations into machine readable ontologies for later comparison to behavior observation data streams, as well as reconciliation of multiple and perhaps differing observation data (e.g., multiple catalogs). Evidence capture and secure storage research includes automatic preparation of evidence packages that contain relevant agreements and observations to be used in subsequent adjudication and mitigation activities. Results of discovery and evidence preparation must be trusted across all stakeholders, even in contested or adversarial environments (e.g., space and great power competition). Further, BESTA must be “brownfield”; that is, it must be able to be used in current contexts (agreements, data) with minimal disruption.

The vision for BESTA is a platform to enable safe and secure voluntary information sharing and decision making to support international cooperative STM. There are analogs to the envisioned information sharing model, such as the Aviation Safety Information Analysis and Sharing (ASIAS) and International Civil Aviation Organization (ICAO) operating models. BESTA blockchain nodes are owned and operated by participating spacefaring nations, ensuring tamper-evident and attributed data with resilience and availability against accident or attack. Use of the International Space Reference Architecture (ISRA, Dailey, Reed IAC 2019) to align policy, behavior, and lexicon can assure common understanding and meaning of discovered anomalies and evidence packages.

We also discuss a proposed information sharing model for STM that includes: foundational space sensor data (e.g. Space Surveillance Network); economically driven augmentation of foundational space sensor data with commercial and academic sensor data; and use of BESTA to reconcile multiple inputs of space object data, compared to prior agreements and statements of intent, automatically detecting anomalies and recording them in evidence dockets as they occur.

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