The Defense Readiness Agile Gaming Ops Network (DRAGON) Army Sync Service: **Enabling International Collaboration in the Space Situational Awareness Mission**

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Abstract

In September 2019, the Air Force Research Laboratory (AFRL) established a program called the DRAGON (Defense Readiness Agile Gaming Ops Networks) Army Operations to revolutionize the way the DoD (Department of Defense) develops, validates, and integrates operational software for the space warfighter. The DRAGON Army is designed to support the space domain awareness community with its creation of applications through DevOps processes demonstrating their efficacy by supporting the Joint Task Force Space Defense Commercial Operation (JCO) Cell in daily operations. In partnership with allied militaries/commercial industry and the U.S. Air National Guard, the JCO seeks to expand operations among multiple coordinated operation centers globally. To support this vision, the DRAGON Army Synchronization Service (SS) enables real-time system-to-system synchronization of operator events, analytical products, data-driven assessments, and actions to populate mission management tool suites for U.S. and Allied space operator teams. This paper will show how the SS provides simplified interoperability, a common standardized framework, and real-time communication across the disparate systems of the international community. The success from this integral communication capability is critical to achieving continuous global commercial space operations. And from the information provided within, this paper will clearly show that without the Sync Service in play, the JCO could not efficiently operate on the worldwide stage nor bring international partners into the fold with a lowered entry bar.

1.0 Origins

Established in 2019, as an experimentation series to demonstrate how to utilize rapid advancements in maturing commercial space operations to augment military and civil space organizations, the commercial Sprint Advanced Concept Training (SACT) has continuously served as an innovation and collaboration testbed for advancing space situational/domain awareness operations. After the success of numerous commercial SACT exercises, USSPACECOM stood up the Joint Task Force-Space Defense Commercial Operations Cell (JCO) to further U.S. Space Command's task to protect and defend the space domain by leveraging commercial providers to provide diverse, timely Space Domain Awareness (SDA) in direct support of the National Space Defense Center's (or NSDC) core protect and defend mission. Alongside the SACT, in the fall of 2019, The Air Force Research Laboratory Space Vehicles Directorate (AFRL/RV) established a program called the DRAGON (Defense Readiness Agile Gaming Ops Networks) Army. AFRL DRAGON Army provides a unique "validated learning" environment which streamlines R&D, enabling global space operations by integrating commercial SDA capabilities into a government owned technology baseline for U.S. Space Command, U.S. Space Force, and allied partners through dynamic experimentation, sim over live training, research initiatives, tool development, and rapid evaluation of emerging capabilities. The DRAGON Army rapidly develops, as well as validates and integrates, capabilities into its government-owned tech baseline thereby directly augmenting JCO operations with new capabilities on demand. Utilizing agile methodologies, the DRAGON Army operates rapid two-week sprint cycles that enables the maturation of capabilities through constant exposure to users based on operator feedback. Every sprint cycle ends in an operational test event, aptly named a DRAGON Army "Ops Day". Ops Days are like the commercial SACT event but are smaller in scale and are targeted to the development goals of the DRAGON Army. These events allow for capabilities to be tested by the JCO operators utilizing real or sim-over-live data, and exposes JCO operators to the most cutting edge tools and drives a feedback loop back to the DRAGON Army development team for continuous feature improvement.

2.0 Commercial Space Domain Awareness Operations

A key component to the mission of the JCO and the DRAGON ARMY and enabler to the success in growth of both organizations is the focus on sensor data derived not from military utilities but from commercial sources. According to 2021 market research report, the commercial space domain awareness market has grown rapidly since 2017 and is on pace to more than triple in size by 2028 (Fortune Business Insights, 2021).

The decision to leverage commercial data sources begets many benefits. Commercial Space capabilities advance fast and allow the government to test new technologies that may not be feasible to develop on the taxpayer's dime. The JCO can rapidly test the viability of commercial data providers by utilizing a test event like the SACT or Dragon Army Ops Day. The Dragon Army architecture also allows for the ease of rapid onboarding and offboarding of commercial data providers, analytical toolkits, and other software capabilities based on operational performance. Another benefit is the ability of the JCO to leverage best in class commercial capabilities which provide gap fill or augmentation capability to current military utility.

The most powerful benefit of commercial data is that is comes with no classification markings, as it was not derived from any government owned source. The commercial SDA data, along with social media data for context, is curated by the JCO operators and input into a NOTSO, or (Notice to Space Operators). The NOTSO serves as an indication & warning (I&W) alert for events of interest, directly augmenting NSDC operations as well as providing a publicly shareable report for allied and mission partners.

The shareability of the commercial SDA data has successfully provided the United States Space Force (USSF) with the means to become a leader in the international SDA community. The JCO has begun to successfully execute part of its plan to become JCO Global, a fully internationally enable 24x7 operations cell. The United Kingdom Space Operations Center (UKSpOC) has expanded its SDA capability through participation in the JCO Global operations construct. JCO-US was established in 2020 to augment the NSDC's Protect and Defend mission, providing indications of orbital activity derived through public research, commercial SDA sensors and analytical tools. JCO Global is envisioned to operate using three regional JCO Cells (JCO-Americas, JCO-Meridian, and JCO-Pacific) aligned by longitudinal time zone coverage to enable rotating 24/7 commercial operations by blending resources across each region's local daytime duty hours. As of June 26, 2023, the United Kingdom is the first nation to

formally join the JCO and will be a key partner for leading the JCO-Meridian cell. There is a plan for Australia and New Zealand to join JCO-Pacific in late 2023.

Truly, the Dragon Army technical baseline is composed of a wide variety of tools such as the White Cell Console, Mission Management Board, Trogdor, etc. (Patel, Tippets, Waterer, & Stout, 2022), and all of these tools are held together by one common framework back-end, the Dragon Army Synchronization Service.

3.0 Architecture

The Sync Service architecture was specifically selected in order to satisfy the integration of machine-to-machine availability/capability and allow international and independently developed tool suites that communicate situational awareness alerts and support a vibrant communication solution. The Service leverages Java and Confluent Kafka technologies to help facilitate a simple integration that distributes/propagates information from geo-spatial located teams (international, governmental, and commercially organized) to selected recipients at varying classification levels. Combining these aspects allows for effective collaboration amongst international partners and allies to support global awareness of the space domain.

The DRAGON Army (DA) was the ideal environment for developing the sync service due to its neutral position between DoD and international collaborative parties. This allowed the DA to provide an objective solution, take risks, and develop at a speed relevant to the global problem set of Space Domain Awareness needs. The DA team had a solution in place, at a technological level of maturity, that provided a realistic and economical foundation for a supporting framework (i.e., the Sync Service and other DA background entities) that supported the international standup and growth of their own systems. This approach has allowed the international communities to tie into a common framework without adjusting their technological stack and use sovereign capabilities at a more palatable resource commitment expectation. In essence, these teams can reasonably use what they have built for their Space Operational Centers (SpOCs) without requiring entirely new tech stacks, programs, and additional resources. Despite participating in the global community, this flexibility allows each participating group to distribute and act upon custom information without sharing decisions or processes. This is due to the flexibility that the Sync Service grants to teams allowing their independently developed software to tie into the global network with other like-minded teams quickly, while extending their ability to govern C2 decision-making chains independently.

The approach taken with the sync service was to provide a technologically agnostic solution that revolves around a central communication paradigm. The paradigm allows easy integration utilizing a standard messaging framework/bus/backend and has been a simplified approach to more traditional independently developed integrations by supplying the design and successful deployment of a fully deployed solution up-front. This approach has encouraged teams with less funding and staff to participate in global integration.

The result is a low bar for entry when utilizing the sync service for publication, space event data synchronization, and multi-team multi-party communications, which allows quick integration within a singular endpoint rather than a dozen entities. The Sync Service shields its subscribers by simplifying the integration with various international, DoD, and commercial entities. The low entry bar also inspires new companies, players, and entities with the ability to work globally and make an impact in assisting global space situational awareness using commercial and publicly available data to benefit the entire space community.

3.1 How the JCO Operator uses Sync Service

The JCO Americas operator primarily leverages a Mission Management Board (MMB) to coordinate their assessments and analysis of commercially available space object positional data. Through this interface, they pass information and products related to events they have categorized, derive products from that analysis, and chat about processing and preparing the notice for a NOTSO.

The JCO Americas COP stores these events in the MMB, as shown in Fig.1 below, allowing the operators to interact and review the status of events created by their team, as shown in Fig. 2, and those created by other operators through the data orchestration provided by the Sync Service. These include documented schemas of events such as time created, who created, high-level summary, the current status of the event, and the derived products stored on an Amazon S3 bucket, allowing the sync service to load the products once and pass around an URL for ease of use.

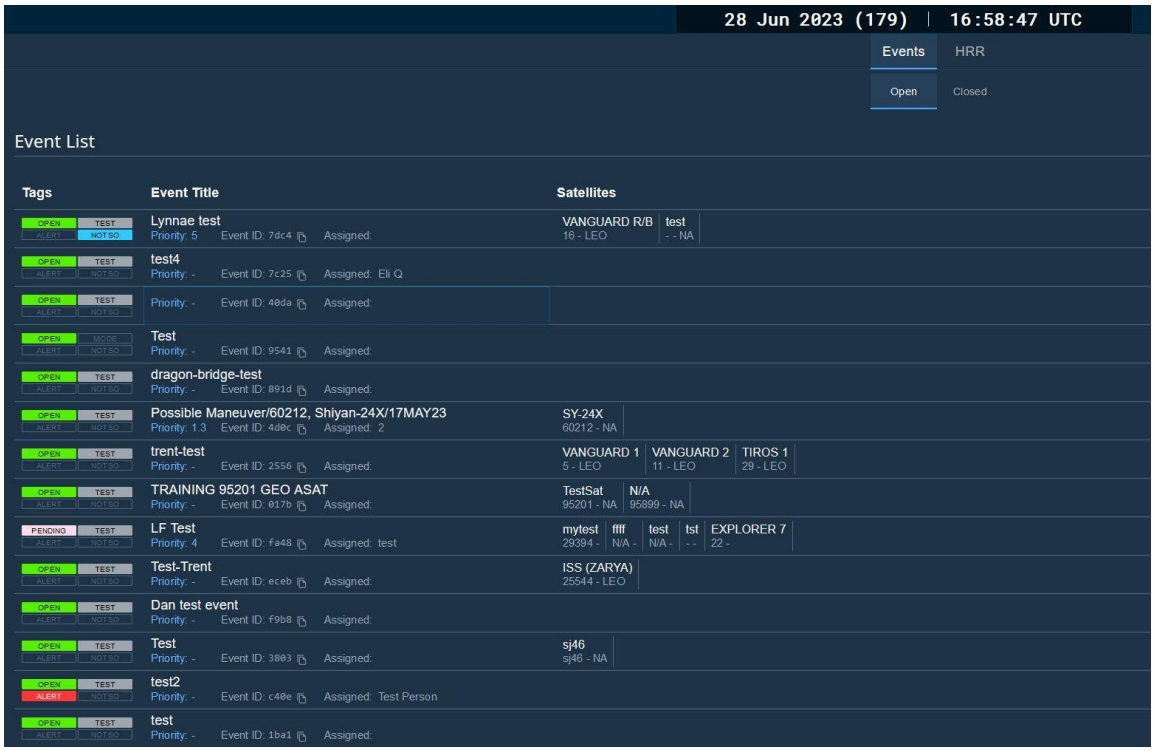

Figure 1: The JCO Americas Mission Management Board populated with test data.

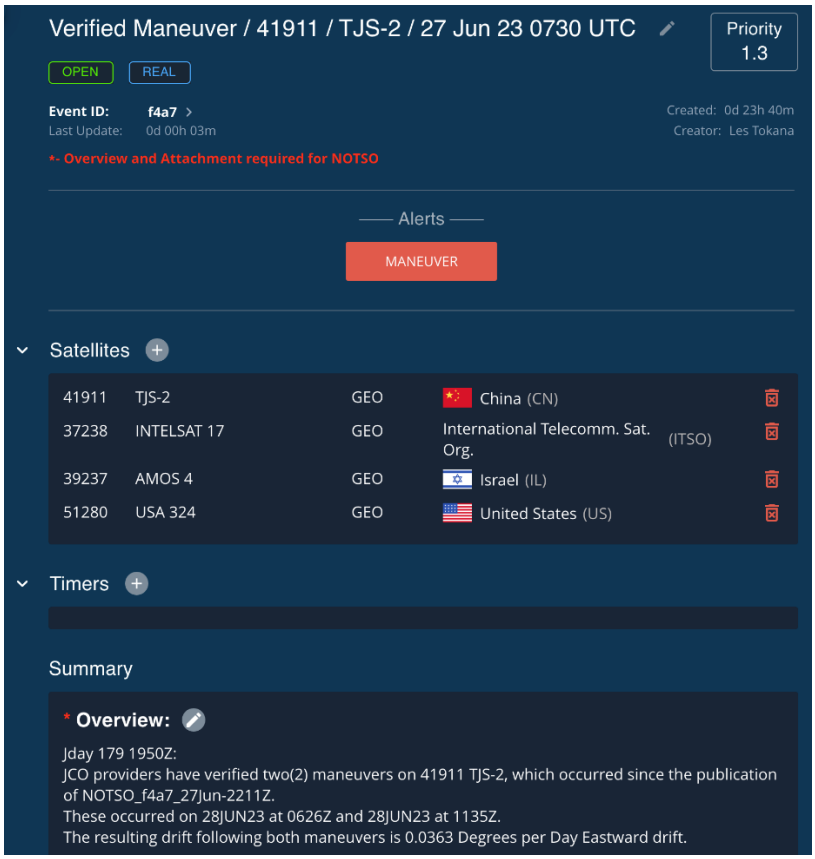

Figure 2: Single event details window

The JCO communicates and delivers functionality to the global community in many avenues and provides functional and operational awareness during the most important training and live events. The impact areas that it is focused on can be primarily segmented into three basic categories as follows:

- Chat
  - This functionality is used primarily as a conversational component in the event where JCO operators and commercial providers have a mechanism to interact and collaborate in situational awareness on the events playing out. This includes annotated and translated conversations as well as discourse between teams during their shifts.
- Derived Products
  - The commercial providers deliver a wide array of detailed analytical products for tasked assignments such as: neighborhood watch, wide-angle look, light curve analysis, and waterfall plots. These tasks are made available to the community and whoever within the community can supply the analyses to the JCO can accept the request.
  - Other derived products are indirectly related to the analysis or assessment of data. Still, they are tangentially relevant to the overall situational awareness, such as weather conditions, screenshots of social media that contain non-classified Space activity, environmental conditions, and social unrest.
- Events/Analysis
  - JCO-Events have required finite fields that must be populated before publishing. However, these do not restrict team members from providing analysis surrounding the overall situation of the space event.

- The assemblage of the analysis occurs during a state of refinement before its publication (if necessary) in a formal message structure to the assessment and warnings of the global community.
- The events must be operationally relevant. This means they must be posted on time and contain all pertinent supporting material, including event data and derived products in Space Situational Awareness.
- Events include a summary of what was accomplished and discussed during the shift. This summary data will be sent out via e-mail but also saved within a database for easy retrieval across shifts and subject to analysis by the DRAGON Army and JCO operators.

The DRAGON Army Sync Service enables the real-time system-to-system synchronization of operator events and actions to populate mission management boards for U.S. and Allied space operator teams. Furthermore, the Sync Service is architected with a hub and spoke methodology that allows third parties to publish their products and integrate into the operator loop with the appropriate authorizations. All MMBs, foreign and domestic, then receive the streaming information and create the event within their software suites, respectively. This allows each MMB to share data through the Sync Service and then rely on that service to manage the data flow, security, and authorization. This simplifies the process because independent teams only need to know how to interact with the Sync Service and are not required to author code, backbone architecture, or integration components that require custom levels of effort for each MMB tool suite (Patel, Tippets, Waterer, & Stout, 2022).

4.0 Machine-to-Machine Interaction

The Sync Service sits at the crux of four different user roles and their individual use cases. These following paragraphs will describe those roles and each of their use cases briefly, highlighting their needs for speed and automation using Machine-to-Machine (M2M) interactions. The design approach taken for the SS allows for the currently described use cases as well as being flexible enough to support additional anticipated use cases and new roles as the community may develop a need for them.

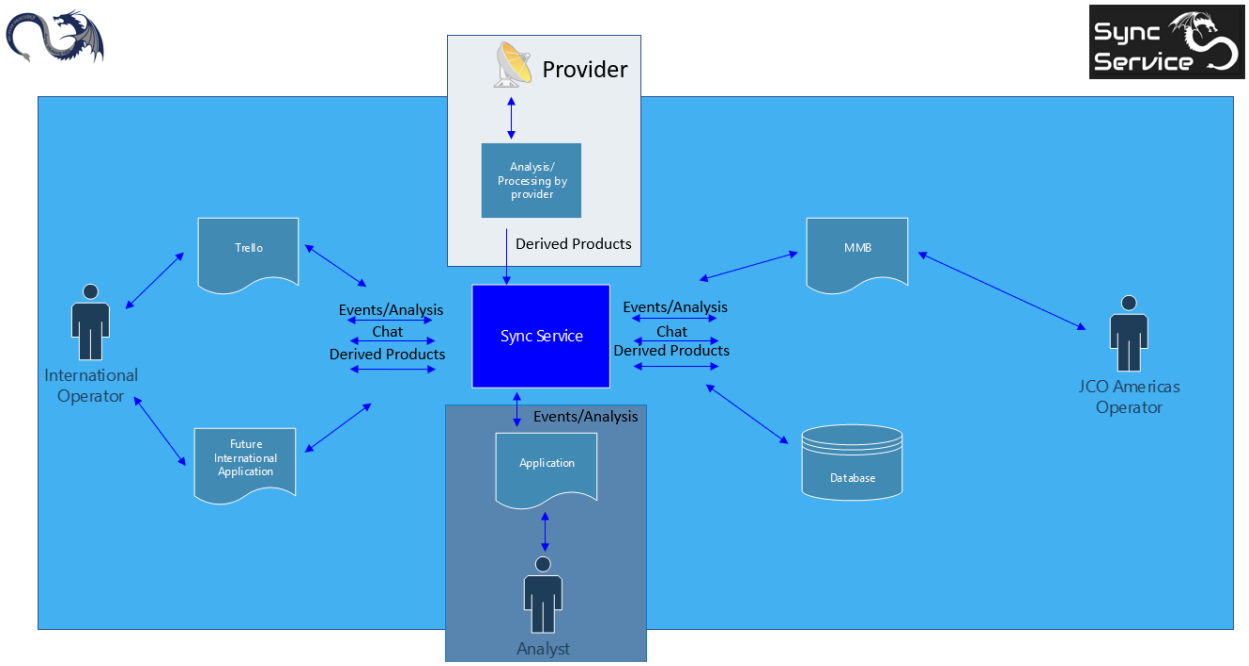

Figure 3: The JCO Operators use the Sync Service for diverse communication across the global community, interactions and data flow between the Analyst, Provider, Global Operator, and JCO Operator through the Sync Service.

4.1 JCO Americas Operator

As highlighted earlier in this paper, the JCO Operator uses a Mission Management Board to coordinate their assessments and analysis of space events using commercially available space object positional data. This data could include potential events, analysis and subsequent products, chat details, and derived products. When the operator interacts with the MMB behind the curtain, their changes and updates are automatically sent to the Sync Service (SS) and relayed to appropriate subscribers. The SS validates parts of the data received, storing the data in its database for historical analyses and updating the event's current state, which is discussed in more detail later in this paper. In addition to storing the data, the Sync Service shares that information with those authorized to receive it. This interaction and data path are shown in Fig. 3.

4.2 Analyst

The Analyst interacts with the Sync Service via a machine-to-machine (M2M) connection submitting all their products related to space events or utilizing a manual approach in which they send their products via email, chat, etc., to an orbital analyst who then attaches them to an event within the MMB. As shown in Fig. 3, if the Analyst is using an M2M, then that tool, such as Alert Management System (AMS), can publish the information directly to the SS, and that information will flow to the appropriate Mission Management Boards and other tools and systems that are authorized. However, if the tool is not connected to the SS, then the events and analysis done by the analyst must be manually handed to the JCO operator through email, chat, or another mechanism to be added to the JCO-tracked space-based event.

4.3 Provider

Commercial providers of space observations support the JCO and are essential to its mission. These companies provide space observations supplementary to the established United States Government Space Surveillance Network (SSN) and deposit that information into the Unified Data Library (UDL). In addition to the raw data, many providers analyze it and provide derived products, such as a neighborhood watch report, wide-angle look or search, or plot showing positional deviation over time. As with the analysts, the commercial provider-derived products related to ongoing events are pushed directly to the Sync Service and distributed to the appropriate Mission Management Boards from those integrated providers, as we see in Fig. 3. Without this integration, these providers must use a manual process such as email or uploading via chat to deliver their derived products to the JCO Operators for use within the MMBs.

4.4 Global Operator

The Global operator is associated with the JCO and the Sync Service at their comfort level, technology readiness, and desire to use sovereign or JCO-based tools. This allows global operators to subscribe to only a selection of the data streams that route through the Sync Service, such as chat, NOTSO publication, and event modifications. The intent of this partial integration is to enable flexibility when tying into the SS. This encourages the participation of international partners and their sovereign technologies within the JCO community by reducing the minimum expectation of collaboration. When participating, this group has a similar experience to that of the analyst or JCO operator by being able to integrate into the SS directly, as seen in Fig. 3. Additionally, they may opt to take a manual approach for communicating changes, updates, and derived products.

5.0 Design Phases

The Sync Service was designed to support a requirement set that is in constant flux; this is possible not only because the underlying technology stack was carefully selected to support this work/project environment but also because the team can implement quickly. Some of the technologies used within the system include messaging transport, using

stream processors such as Confluent Kafka, a lightweight relationship database such as PostgreSQL, and the decoupling approach of APIs and microservices. The DRAGON Army team anticipates the creation of a technical white paper that dives deeper into these technologies in the next year. But the intent of this paper is to give a broad and high-level introduction to the Sync Service, and as such, this paper will refrain from including highly technical details of those components of the design and focus on their necessity of usage.

5.1 Phase One

The original design phase of the Sync Service was heavily focused on real-time streaming and processing of data, and while this was a practical approach and a solution that would work well, the result is that any application publishing data in real-time would take on the effort of data orchestration, validation, and authorization on who should receive data. To achieve the necessary goal the solution was designed with three major areas in mind: Logical Architecture, Kafka stream-processing, and necessary data storage.

5.1.1 Logical Architecture

JCO tracked space-based events are situations of concern to the global space community, such as an advertised space-based launch of satellites, the identified maneuver of a spacecraft, a conjunction of multiple satellites, or a spacecraft breakup. Depending on external criteria, these events can reference a single point in time or could span multiple days or weeks as the situation develops. The JCO Mission Management Board (MMB), see Fig. 1, tracks event details to provide an accurate analysis and an overall timeline of the situation's progression through a standardized messaging schema. Due to this mission need, the logical architecture of the Sync Service allows for US based, internationally based, commercial, or governmental entities to integrate at their comfort level and interest. Some entities might be only interested in a specific type of event, such as a launch event, while others might be only concerned about the detailed derived products developed during the analysis of the ongoing event.

The Sync Service logically breaks up a space event into five primary logical aspects. This primary separation consists of the event itself and the high-level summaries included such as any satellites with their associated common name, regime, and owned country are included in this breakout. Secondarily, the SS breaks out the derived products into a schema that contains the URL where the image is located, a caption, and tags associated with the product. The tertiary separation occurs to separate comments on the event to contain when the comment was made, by whom, and all the relevant comment details. The quaternary separation lies in the ability to independently store and update any checklists or process-driven lists created for the event. Finally, the Sync Service separates the Notice to Space Operator (NOTSO) details into its schema, as shown in Fig. 4.

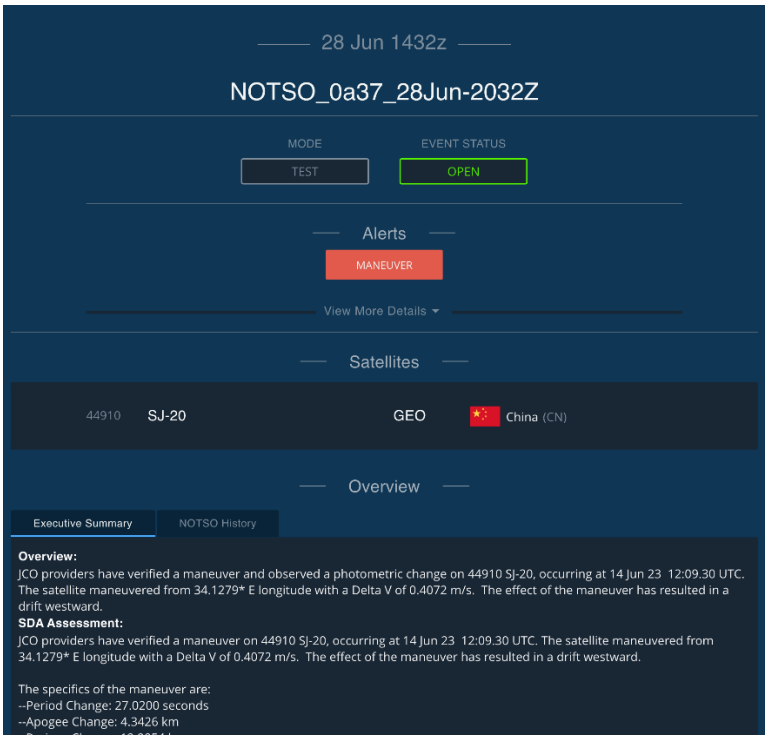

Figure 4: The NOTSO popup from MMB.

By strategically breaking the underlying structure within the architecture and separating the details into distinct pieces, external parties can subscribe to and receive just the messages they are interested in. This feature is important since some parties are solely interested in listening to a particular event type and publishing updated comments for JCO operator benefit without having to process and monitor the entire event and its updates, while other parties want to contribute more fully by taking an event from its creation to its final updates. The performance advantage of this approach is achieved by breaking the overall message structure into those previously described smaller portions, which allows faster transmission, delivery, and processing of the messages.

The combination of these architectural choices made for the Sync Service and its elegant design allows the JCO and the DRAGON army to flexibly adapt or update small pieces quickly without affecting the entire message structure. For example, when the DRAGON army tackles language translation later this year, the message schema will go under minor modification to add a field that captures the identified base language of the message, and since the schema can accommodate this new capability without impacting previous usage there is an impactful reduction in amount of rework and risk associated with this feature improvement. Furthermore, the adaptability of the Sync Service is demonstrated through the automatic conversion of products submitted that consist of multiple image file types to a standardized Portable Network Graphics (PNG) format. This decision allows for consistent resolution, sizing, and the display of derived products regardless of their file type origin. Overall, the logical and physical architecture allowed the system to add these new capabilities without forcing changes that impact the entire community.

In summary, the Sync Service breaks out the schema and model into bite-sized chunks that allow for ingestion and integration at the level of comfort of the consuming party, and not only does the architecture permit integration at various levels but it also significantly reduces the size of the messages and allows for the dynamic addition of capability without forcing system-wide changes that require internal and third-party development. As will be highlighted in the later success stories section of this paper, the Sync Service has demonstrated success in this arena.

5.1.2 Kafka

Confluent Kafka is a fast and highly efficient messaging system designed to handle large volumes of data in real-time. It is built on the open-source Apache Kafka platform, which provides the underlying distributed messaging

framework. Confluent Kafka extends Kafka's capabilities by adding additional features and tools to simplify deployment, management, and operations. Confluent Kafka adds additional strengths that extend the platforms usage.

One of these critical strengths of Confluent Kafka is its speed, because it is designed to process and deliver messages quickly, even sharing billions of messages an hour. Confluent Kafka achieves this by combining techniques, including data compression, partitioning, and replication. This makes the platform highly scalable, moreover, it can be configured to scale up and down based on usage, thus allowing users to add or remove resources as needed to meet changing demands. Fortune 500 companies such as Uber, Lyft, and LinkedIn rely on Confluent Kafka for their entire business structure. To showcase this capability, LinkedIn published a blog post indicating they handled over 7 trillion messages daily using Kafka (Lee, 2019).

Confluent Kafka is also highly efficient, since it uses a publish-subscribe model to allow multiple consumers to subscribe to a data stream without each consumer needing to receive a copy of the entire data set. This reduces the amount of data that needs to be transmitted and received and leads to faster and more efficient processing. Additionally, Confluent Kafka uses a distributed architecture that allows it to distribute data processing across multiple nodes in a cluster, which further improves performance and efficiency.

The DRAGON army selected this tool partly because Confluent Kafka is approved for use by the Department of Defense in multiple environments, including classified environments. To facilitate Confluent Kafka within the DoD, Confluent publishes verified Docker container images that have been hardened and are available on public repositories such as Iron Bank (Platform One, n.d.). Overall, Confluent Kafka is a robust messaging system that offers a range of benefits for organizations, like the DRAGON Army, looking to process large volumes of data in real-time. Its scalability, speed, reliability, flexibility, management, and monitoring capabilities make it an ideal choice for the Sync Service, the DRAGON Army, and the JCO.

5.1.3 Data Storage

The Sync Service leverages a relational database to store the data associated with space-based events tracked by the JCO. A relational database has multiple advantages when dealing with consistent types of data, due to its organized table structure data can be efficiently stored and retrieved, thus ensuring consistency and accuracy through constraints and relationships.

The Sync Service stores the current data associated with an event and tracks the historical changes over time of event data. With every update to an event, the Sync Service stores the current information in the event table within the database and stores a copy in an event history table for long-term analysis. By using a combination of what an event currently looks like and a historical, changing view of the evolution of an event, the Sync Service can meet the different needs and desires of the community. For example, if there is an outage for any reason, an entity can request the current state of the event to recover quickly without having to parse all the real-time events to catch up to the current state, enabled in iteration four of the Sync Service.

Because the Sync Service stores all the changes to an event over time, the DRAGON army metric team can analyze and provide feedback on responsiveness on events, operators, or providers. For example, the DA can analyze an event in detail and provide analysis on when Trogdor published an observation, how long it took the operator to notice this publication through the tools that they are using and compare how long it took the event to be created, and what steps were taken (if any) to process the event. Combining all these factors enables long-term analysis of operators, providers, and tools.

5.2 Phase Two

The second phase of the Sync Service design and development included an Application Programming Interface (API) that can validate data and reject requests that do not meet the verification criteria. Validation in an API is essential to maintain data integrity, enforce business rules, ensure system stability, improve error handling, and enhance security, while additionally promoting a robust and reliable API ecosystem that benefits the API provider and its consumers. An API also provides numerous benefits to developers, businesses, and users by serving as a

bridge between different software systems and allowing seamless integration and communication. APIs promote interoperability, efficiency, and collaboration, ultimately driving technological advancements and empowering the global JCO community.

5.2.1 Authentication/Authorization

To enable the required authentication that the API validation system needed a Single Sign-On methodology was implemented. Single Sign-On (SSO) offers numerous programmatic benefits including improved user experience, enhanced security, increased productivity, simplified user management, centralized access control, and integration flexibility. These advantages make SSO a valuable solution for organizations aiming to streamline authentication and access control while enhancing user satisfaction and security. The DRAGON army and the JCO chose to use Keycloak as their SSO solution.

Keycloak offers comprehensive security features to protect the process of user authentication and authorization. It supports various authentication mechanisms, including username/password, social logins (e.g., Google, Facebook), and multi-factor authentication (MFA). Providing centralized access control, Keycloak allows administrators to define fine-grained permissions and policies and offers features like user federation, role-based access control, and token-based authorization. Keycloak's security-focused design helps organizations strengthen their security posture and safeguard sensitive user data.

The features of an SSO system, such as Keycloak, allow the DRAGON Army and the JCO to limit access rights as appropriate. The Sync Service leverages Keycloak to authenticate and authorize systems and people to tie into the activities of the JCO. One of these activities, a Notice to Space Operators (NOTSO), is a communication or advisory issued by a space agency or regulatory body to inform operators of space systems or satellites about specific space events, activities, or changes that may impact their operations. Due to the nature of this communication the ability to publish a NOTSO is limited to specific roles granted by a System Administrator with approval from JCO leadership to those authorized to publish a NOTSO. Only the Sync Service has the authority to publish NOTSOs and relies on the SSO, Keycloak, to ensure only identified parties can distribute that message.

SSO also offer additional benefits including improved user experience, increased productivity, simplified user management, and integration flexibility. By leveraging Keycloak as an SSO, the DRAGON Army has reduced half a dozen individual profiles and sign-on to a single user sign-on for all DA products. This approach significantly reduces developer time managing user authentication, profiles, and authorization, freeing up precious time to develop forward-leaning feature sets. Users of the DRAGON army avoid multiple redundant and repeat login fatigue by using Keycloak and enjoy an elegant user-profile design. In a recent show of integration success an Australian-based group, Saber Astro, used DRAGON army SSO to rapidly integrate with the Sync Service and successfully distribute NOTSOs to the global space community.

Keycloak, the SSO chosen by the DRAGON Army and the JCO, provided a comprehensive set of security features, such as support for centralized access control, simplified user management and authentication, and flexible integration, all of which helped to strengthen security and protect sensitive user data. The DRAGON army depends on this SSO approach to secure data and users without excluding international partners from potential integration and utilizes this balance between integration and inclusion as a cornerstone of the DRAGON Army mission and a key tenant of its ability to continue expanding and reaching its global partners.

5.3 Phase Three

The third phase in the design and development of the Sync Service was to include a methodology for data orchestration. The DA team quickly realized it was far too easy in a real-time system to create infinite loops accidentally, because when one person is speaking, they may hear their own voice, but they don't respond to that voice. In essence, this is what needed to change to prevent any infinite loops that were occurring. To implement this change, the Sync Service introduced a microservice that handled data orchestration that could solve this issue. As a

result, any contributors to the data pipeline only need to worry about publishing data instead of taking on the validation of the data, orchestration of the data, and who should receive the data. But that wasn't the only benefit gained from instituting data orchestration.

In addition to the prevention of infinite loops, the data orchestration aspect of the Sync Service enables a finer grain control on who gets access to what pieces of data. The Sync Service can limit the publishing of specific data to specific partners if necessary. The Sync Service limits access and control based on the tool connecting to the system. For example, during the triannual SACT global training events hosted by the DA, an instance of the Sync Service supports and hosts complex training exercises from live operations. Though the Sync Service does not pass the raw training data (Patel, Tippets, Waterer, & Stout, 2022), it does facilitate operator participation in simulated mission management. The Sync Service is also slated to support the independent operation of international teams such as the UK, New Zealand, and Chile. Globally shared events are distributed among each global team, whereas sovereign events are only delivered to the interfaces of the respective countries. The design of the Sync Service has the potential to extend this functionality to include custom teams such as red vs. blue within the JCO global community.

Integration into the Sync Service has demonstrated that integrating into the JCO is accomplished at the level of comfort and participation that external parties might desire. The Sync Service leverages a documented and distributed framework so that independent and third-party tools and teams can easily budget for and execute integration tasks with the JCO without necessitating the construction of the underlying framework. Third parties and international groups only need to worry about the integration point of the Sync Service rather than concern themselves about the architecture's design or the integration mechanism into all collaborating parties. Without the Sync Service's current architecture, the JCO's progression to around-the-globe operations would not be possible since all the artifacts would need to be moved by hand.

5.4 Phase Four

The fourth phase of the design and development of the Sync Service tackled the ability to retrieve the current mission state from its API without requiring the receiver to process all previous messages stored within Confluent Kafka. While the current state was stored through individual messages within Confluent Kafka, the transmission and processing of this became burdensome for long periods. This became particularly interesting when the user base requested the ability to recover from a "cold start" or no current information. This resulted in an enhancement to the Sync Service that exposed a current internal snapshot previously unavailable to the user base and provided a backup copy of ongoing events. This allows for quick recovery from downtime and the ability to verify and validate that consumers are at the current mission state, or to deploy a new node quickly.

6.0 Summary of Architecture and Design

The Sync Service architecture was intended to facilitate ease of use and standard integration at a level that the partners and tools can use within their needs and comfort zones, as well as providing for the specific amount of participation that they desire. The design was approached in such a manner as to always be scalable and quickly able to adapt to the ever-changing needs of the community by using current technology that has been proven successful in industry by high impact providers. This approach was selected to include the broadest international audience with diverse interests and funding levels to facilitate the global integration of a global problem. This architecture and design enable 24 hour, five days a week operations of Space traffic management and has helped to bring multiple international allies, partners, commercial entities, and governmental agencies together to fight for the greater good.

7.0 The Beneficiaries

The JCO's success is rooted in its ability to exist outside of the classified fortresses within the DoD and successfully contribute to the global awareness of space object patterns of life. This environment of inclusion and collaboration that the JCO provides allows the DoD to leverage and explore commercial capabilities to support the DoD mission in a non-threatening environment utilizing publicly available raw data to support their greater mission scope. Commercial entities such as Saber Astro, which supports the RSOC, leverage the Sync Service to collaborate with the US and other international partners to gain greater visibility of space situational awareness and contribute to the

overall capabilities of the global commercial community. Based upon the success of the DRAGON Army framework, more governments and international companies have showcased tools at various levels of integration to a wider audience of potential consumers than would have otherwise been possible using historical approaches.

Additionally, in the United States space traffic management is shifting from DoD responsibility to the DoC soon. Traditionally, the DoC has focused on terrestrial traffic management (air, land, sea) and has had little to no experience handling the intricacies of space-based traffic management. This shift of focus has led the DoC to reach out to the JCO and other DoD groups that work in the space-based community to potentially leverage their tools and capabilities (currently being used for space traffic management by the DoD) to discuss modifying the JCO tool suite for civilian use. This collaboration between the DoD, JCO, DoC, and DRAGON Army is ongoing to streamline the learning curve and give the DoC the highest chance of early success.

Like the United States, the global space community is also shifting non-military space operations to associated non-military management organizations, and this fundamental change requires the persistence of non-classified data sharing across international partners. The DRAGON Army is one of several entities leading the charge to develop and deliver software capabilities and training for this rapidly expanding group. Government and commercial space traffic can be managed at a non-classified level because the new space frontier is a shared resource between allied nations. With the sheer congestion of the orbital regimes resulting from exponential growth of the number of launches, the number of deployed satellites, and the number of owner/operator countries, it is paramount that work like that of the DRAGON Army takes root and bears fruit within the space community to support the ever-increasing challenge of space traffic management.

In addition to the core operations, the DRAGON Army is exploring and actively pursuing, collaboration with commercial monitor groups such as the National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), Global Positioning System (GPS), European Space Agency (ESA), and other commercial entities interested in global alerts on space objects.

8.0 Success Stories

The following section shows that the Sync Service has found utility outside of its initial design. First, the JCO global community has used the Sync Service to streamline their increasingly common changeovers as they approach a 24-hour, 7-day future completely operational status. Second, the need for machine-generated analysis has been regularly increasing over the existence of the JCO, and the ability to integrate those products requires a framework like the Sync Service. Finally, there is a need for the JCO community to provide and execute training for JCO operators without interrupting real-world operations.

Government Success Story

The JCO is targeting a 24x5 global operation by the end of October 2023, which will increase the frequency of the changeover process between the 8-hour shifts. The 24 hours of the day are broken up into 8-hour shifts following local daylight hours. I.E., the Meridian/European team hands off to the Americas team at the end of their shift. The handover process could include cold starting (hard reset) or using different or sovereign tools and processes to support the mission within that time region. Initially, the changeover was done manually during the SACTs. It took over one hour to exchange and copy the necessary information, including analyses, derived image products, and verbal descriptions of the events. With the introduction of Sync Service (Sync Service), the changeover within the SACTs became notably more efficient and effective. The time needed during the changeover dropped to only 15 minutes and only included verbal discussion of the events.

This demonstrated that a capability such as the Sync Service was necessary to streamline mission management information across teams, tools, and international borders with the data and derived products already synced, the teams can focus on verbal handoff of the important events. Moreover, the Sync Service allows teams to work in parallel and collaboratively assess and analyze current and potential space events, which was not previously possible with disparate tools and isolated groups.

The Sync Service leverages a documented and distributed framework so that independent and third-party tools and teams can easily budget for and execute integration tasks with the JCO without necessitating the construction of the underlying framework. Individual groups can collaborate through a standardized backend without requiring heavy co-dependence amongst international teams. Third parties and international groups only need to worry about the integration point of the Sync Service rather than concern themselves about the architecture's design or the integration mechanism into all collaborating parties.

The Sync Service allows integration to be paced by the partners and their development teams per their level of comfort and the level of participation that they desire. This was critical to allow for the gradual adoption of the JCO philosophy. For example, the UK wanted to avoid creating and hosting sovereign capability but instead wanted to mirror the choices of JCO Americas and staff their team within their Space Operational Center (SpOC). In contrast, the Responsive Space Operations Centre (RSOC) wanted to learn from the JCO tool suite, processes, and procedures while pursuing their sovereign capability aligned with the mission.

Commercial Successes

Saber Astro was able to leverage the "other operator", as shown in Fig. 3, path to the Sync Service and was able to provide their tools to successfully participate in the mission of the JCO via the Sync Service.

In 2021, Saber Astro began to build an integrated interface supporting mission management without connecting to the Sync Service. While the first iteration was deemed a success, it was deemed insufficient since it required the manual moving of data, derived products, and comments from the JCO Americas MMB to their tool and vice versa. Additionally, due to human error, information related to JCO-tracked events was lost in transit. Such a shortcoming highlighted the need for a machine-to-machine data transfer between the various mission management boards.

The current iteration of the Saber Astro Mission Management Tool is fully integrated with the Sync Service to allow the sharing of the event data from the RSOC tool, Atlassian's Trello. This allowed the Australian RSOC to gradually tie into the global JCO community while using their products and processes. They took these lessons from Trello and the integration of the Sync Service and are building a new, custom Mission Management Board for their use at the RSOC. During April 2023, the RSOC demonstrated the value of this approach by being the first non-US team to utilize their tools to publish a NOTSO to the broader community leveraging the Sync Service. The assembly and publication of a NOTSO by the RSOC team are considered achievements and are representative of their tools' maturity and their teams' capability to participate within the JCO Global community. They are currently the only international partner participating with an independent tool suite.

The Alert Management System (AMS), a tool developed by Data Fusion and Neural Networks (DFNN), is used by the JCO operators to visualize and review automatically determined abnormalities within the space catalog. AMS uses neural networks to establish the baseline patterns of life of the entire space catalog and visually identify anything unusual. The JCO operators can take these indicators and create a JCO-tracked space event via the Sync Service within the MMBs without copying and pasting data manually, avoiding potential human error.

This demonstration of linking an independent (non-government) tool to a government-developed system screen highlights the ability to fuse third-party developed technologies and include machine-generated alerts to JCO floor operators. Integrating with the Sync Service via a machine-to-machine option allows non-human-generated alerts, notifications, and points of interest to arrive quickly before a JCO operator. Having mission-relative information passively brought to

their attention significantly reduces the overall assessment time required as it is faster for a JCO operator to acknowledge or disregard an alert vice discovering unexpected space object behavior.

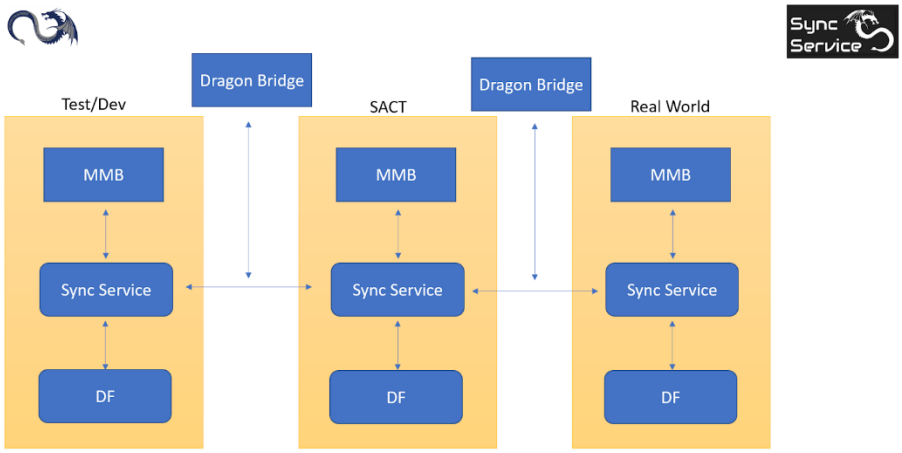

Figure 5: Dragon Bridge connecting the separate and distinct environments.

The DRAGON Army isolates the development, exercise, and real-world environments to facilitate and preserve software development, testing during SACTs, and real-world processing data. Due to this isolation approach, the DRAGON Army team had to develop a capability to replicate the real-world environment of MMB's current state to other environments on demand and vice versa. While running SACTs, the JCO operators expressed displeasure at monitoring multiple MMB environments. DRAGON Bridge, the internal tool that bridges environments, handles the replication of the live environment on behalf of the JCO operators during exercise periods.

Dragon Bridge solves the problem of needing multiple mission management boards to support training exercises, as shown in Fig. 5, by allowing the Site Leads (SL) and Deputy Site Leads (DSL) at the beginning of an exercise event period to move the data from the real world to the exercise environment. During the exercise event, the JCO Operators track exercise events and monitor the real-world events within the same Mission Management board. At the end of the exercise event, the appropriately identified, live JCO-tracked events will be moved from the exercise environment to the real-world one.

The ease with which another commercial entity can integrate with the Sync Service was demonstrated with Layer 8, a social media data aggregator. Within two months, Vigilant, the creators of Layer 8, took their tool, created to scrape social media sites, and adapted it to provide value to the JCO on specific space events. Vigilant took their product originally scoped for a very different purpose, i.e., data aggregation and pattern analysis, and adapted that technology to identify space-based events (launches, re-entries, vehicle positions), and through integration with the Sync Service they were able to provide their services rapidly to the JCO.

The DA Sync Service has shown value and merit beyond its original scope. The improvement in efficiency and effectiveness of the changeovers for the JCO global community has reduced the burden of knowledge transfer and opened additional time for operators to assess current catalog conditions. Incorporating machine-generated alerts and messages have opened new opportunities for JCO operators and commercial contractors to bring low-latency cultivated information to the operators. Internal tools such as the Dragon Bridge utilize the Sync Service to span distinct and separate environments, allowing the operators to use a single Mission Management board during training exercises. With these accomplishments, the DRAGON Army team has slated several additions to its current capability, including integrated chat, additional data types, object ranking criteria, and other analysis-related information. We anticipate that the success stories highlighted above will be complimented by many more in the coming year.

9.0 Conclusion

DRAGON Army's mission-set is ever expanding to accommodate the growing needs of the JTF-SD. The future of the JCO includes integrating more foreign mission partners, porting emerging technologies into higher classifications and an expansion of the commercial mission to include overhead Surveillance, Reconnaissance and Tracking (SRT). The SS lies at the heart of the success to enable these capabilities. As more foreign mission partners becoming integrated, there is a growing demand of language translation capabilities to ensure low barriers to entry for prospective partner nations. The growing successes of the JCO sparked a hunger from operational centers at higher classification levels for emerging technologies. To posture for this, the DA will utilize a CI/CD pipeline to be able to port all of its programs to higher classification levels and to meet the security requirements. Since inception, the SS has provided critical yet simplified interoperability, and real-time communication across the international community to achieve continuous global commercial operations. To support the future, the SS along with other DA tools such as the Mission Management Board and operational metrics tool will continue to evolve to meet the needs for the JTF-SD and commercial SDA and SRT operations.

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Abbreviations and Acronyms

AFRL/RV	- Air Force Research Laboratory Space Vehicles Directorate
AMS	- Alert Management System
CANSpOC	- Canadian Space Operational Center
COP	- Common Operating Picture
DA	- DRAGON Army
DF	- Dragon Fire
DFNN	- Data Fusion and Neural Networks
DoC	- Department of Commerce
DoD	- Department of Defense
DRAGON	- Defense Readiness Agile Gaming Ops Network
DSL	- Deputy Site Lead
ESA	- European Space Agency
JCO	- JTF-SD Commercial Operations
JTF-SD	- Joint Task Force – Space Defense
GPS	- Global Positioning System
M2M	- Machine-to-Machine
MMB	- Mission Management Board
NASA	- National Aeronautics and Space Administration
NOAA	- National Oceanic and Atmospheric Administration
NOTSO	- Notice to Space Operators
RSOC	- Responsive Space Operations Centre
SACT	- Sprint Advanced Concept Training
SL	- Site Lead
SpOC	- Space Operational Center
SS	- Sync Service
SSN	- Space Surveillance Network
SSO	- Single Sign-On
UDL	- Unified Data Library
UKSpOC	- United Kingdom Space Operational Center

Logos

Dragon Army Logo

Hydra Team Logo

Sync Service Logo