Defense Readiness Agile Gaming Ops Networks (DRAGON) Army

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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. Designed to support the space domain awareness community, DRAGON Army creates applications through DevOps processes that demonstrate their efficacy by supporting the Joint Task Force Space Defense Commercial Operation (JCO) Cell in daily operations. In addition, DRAGON Army also sponsors the international Sprint Advanced Concept Training (SACT) experiment series [1]. The AFRL DRAGON Army agile software development framework enables advanced space domain awareness (SDA) and space traffic management (STM) collaboration by creating an operationally relevant space operations environment that fosters continuous learning. The DRAGON Army accomplishes this by bringing in operational applications and capabilities from commercial and DoD software factories into an open-architecture environment where they are made interoperable, and capabilities are validated through a cycle of experiments. The DRAGON Army Operations environment is a Live-Virtual-Constructive (LVC) simulation environment where simulated data is layered over real-world live data through a data gateway that emulates the Unified Data Library (UDL). This approach provides a simple plug-and-play functionality for vendor partners to test and receive data-driven feedback on emerging capabilities and technologies. This software environment facilitates a two-week development-deploy-feedback cycle which is constantly iterating and allows capabilities to mature based on live operational feedback. In partnership with allied militaries/commercial industry and the U.S. Air National Guard, the JCO seeks to expand operations among multiple coordinated operations centers globally. In support of this vision, the DRAGON Army Synchronization 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 which is critical to supporting the goal of 24/7 commercial space operations. In addition to the Synch Service, the DRAGON Army has created a suite of collaboration tools that provide a low-barrier-to-entry for vetting and integrating new capabilities including the White Cell LVC Architecture (Trogdor 2.0) and a management-layer tools for tasking, data visualization, product consolidation, and reporting (Mission Management Tool Suite). This methodology has led to some significant achievements for the DRAGON Army to include the expansion and growth of the SACT, which represents an integration of over 70 organizations across commercial, DoD, allied partners and academic institutions, and achieved unprecedented performance metrics for quality and timeliness, specifically in response to taskings and requests from our DoD centers during exercises and regular operations. This expansion resulted in a successful test of global distributed operations across three sun-synchronized cells during the SACT, which represents a large step in achieving the goals of international

partnerships and commercial and collaborative ownership of the STM mission. In addition to this, the DRAGON Army partnered with the Department of Commerce (DoC) by demonstrating potential concepts during the SACT exercise series that would support the transfer of the STM mission to the Office of Space Commerce (OSC). This paper shows how this novel "innovation pipeline" contributes to the SDA & STM mission, while enabling startup, commercial, academia, and allied collaboration.

1. INTRODUCTION / BACKGROUND

Traditional DoD Software Acquisitions utilizes the linear-sequential life cycle model, or waterfall model, as the software development cycle of choice. The waterfall model, while effective in some instances, does not allow for quick adaptations to the rapidly changing needs of the warfighter. Software in the waterfall model would be planned, developed, tested, and deployed without any warfighter feedback until the end of the development cycle, which could be 3-5 years. In the commercial world, technology advances rapidly and yesterday's technology quickly becomes outdated. To keep up with the fast pace of innovation, DoD technology needs to be developed, deployed, and altered at great speed to meet warfighter needs.

Gen. Raymond, the Chief of Space Operations, tasked the United States Space Force to become the first digital service to combat the growing threat from our adversaries. Under USSPACECOM, The National Space and Defense Center (NSDC), called initially Joint Interagency Combined Space Operations Center (JICSpOC), was opened on 1 October 2015 to unify space defense operations amongst DoD, IC, allied, and commercial entities. However, numerous barriers to innovation existed within the NSDC. Crucial data became siloed and inaccessible for machine-to-machine data flow, slowing operations. Traditional DoD acquisition models fueled software development which resembled the waterfall model rather than an agile one. This resulted in a lack of consistent user feedback and deployment of tools that failed to reflect operational needs. In addition, previous iterations failed because of a lack of a non-government-owned software baseline that could promote tools to higher classification levels. The task to conduct digital space defense operations would require significant innovations to the current tech baseline to enable the Space Force vision. Commercial sensor providers, application development teams, and modeling & simulation providers were developing promising capabilities quickly and the NSDC needed a way to properly leverage these capabilities into space operations. An opportunity existed to demonstrate an environment that would become a pipeline for commercial entities to demonstrate their capabilities in an operational environment that could provide immediate operator feedback that would in turn influence direct improvements.

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. The AFRL DRAGON Army's agile software development framework enables advanced space domain awareness (SDA) and space traffic management (STM) collaboration by bringing in operational applications and capabilities from commercial and DoD software factories into an open-architecture environment. From there, they are made interoperable, and capabilities are validated through a cycle of experiments (e.g. DRAGON Army Op's Days and SACTs). The DRAGON Army operates in two-week sprint cycles, utilizing agile methodologies to rapidly develop and integrate commercial capabilities. This rapid sprint cycle allows capabilities to constantly iterate and mature based on live operational feedback. Every two weeks the DRAGON Army conducts a DRAGON Army Operational Test Day (or DRAGON Army Ops Day) to enable continuous exposure of new development efforts and commercial technologies to relevant operational settings through live exercises and sim-over-live injects. The DRAGON Army program increment, a culmination of sprint cycles, is completed by conducting the international Sprint Advanced Concept Training (SACT) experiment series. Sponsored by DRAGON Army and conducted three times a year, the week-long space SACT operations event series includes a broad mix of over 70 organizations across commercial, government, and academic participants. All of these entities coalesce to execute multiple-day cycles of Space Domain Awareness exercises using all commercial data [1].

Both of DRAGON Army's exercise series are supported by DRAGON Army's Live-Virtual-Constructive simulation environment where simulated data is layered over real-world live data through a natively developed data gateway, called Trogdor, that emulates the Unified Data Library (UDL). Causing a collision, debris cloud, or break-up in space to test a new technological capability, would be at best considered a reckless act of endangerment. This "sim-over-live" capability allows for the generation of a variety of M&S scenario injects that exercise Space Domain Awareness (SDA) and Space Traffic Management (STM) activities including launch, various orbit transfers/maneuvers, rendezvous and proximity operations (RPO), collisions/debris/breakups and all permutations of

these. By utilizing Trogdor's plug-and-play functionality, integrating capabilities can be tested and receive data-driven feedback in an operational environment that resembles actual operations. DRAGON Army has evolved from Trogdor to Trogdor 2.0. Trogdor 2.0 provides the JCO, commercial entities, and allied partners with an accessible training and testing environment that supports relevant exercises with realistic outcomes on demand. The system abstracts away much of the specific and exquisite knowledge needed to set up and run complex modeling and simulation exercises in the space domain by providing templated events and training series. This opens the door for less experienced teams and team leaders to benefit from the experience of other teams more readily across the system.

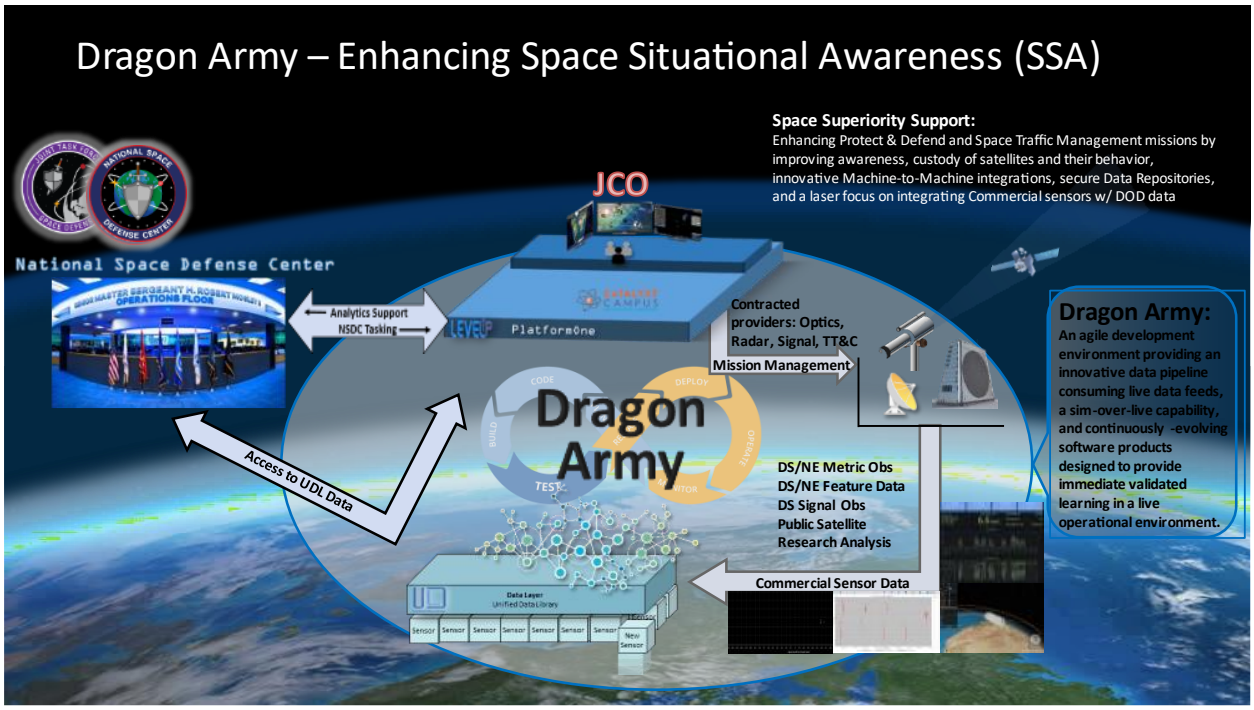


Fig 1. DRAGON Army Operational Impact to NSDC and JCO

Currently, the DRAGON Army Operations environment directly supports the JTF-SD Commercial Operation Cell (JCO) which currently conducts 8-hour/day 5-day/week Space Domain Awareness operations using only commercial data. After numerous Commercial SACT exercises, the JTF-SD Commercial Operations Cell stood up to take advantage of the substantial amount of Space Domain Awareness (SDA) capabilities that exist within the commercial world. The relationship between the DRAGON Army and JCO is symbiotic. The JCO provides the DRAGON Army with an operational community to test new capabilities in actual operations or sim-over live experiments. The DRAGON Army rapidly develops and integrates capabilities into its tech baseline directly augmenting JCO operations with new capabilities. The data is curated by JCO operators and input into a NOTSO, or (Notice To Space Operators). The NOTSOs serve as an alert for I&W and provide a publicly shareable report that directly augments NSDC operations. NOTSOs are created using applications developed and integrated from the DRAGON Army tech baseline. Fig. 1 shows the relationship of the DRAGON Army to its commercial providers, the JCO and the NSDC. The DRAGON Army is expanding support from the JCO to additional DoD organizations, allied mission partners, and the Department of Commerce. The future of DRAGON Army includes expanding into a DevSecOps pipeline that will facilitate the easy transition of tools from non-classified environments to classified networks. This will allow for not only a flow of data to augment NSDC operations but a pathway for commercial software capabilities as well. DRAGON Army will also expand to support operations as the JCO moves towards 24-hour global operations with Allied Militaries and the U.S. Air National Guard.

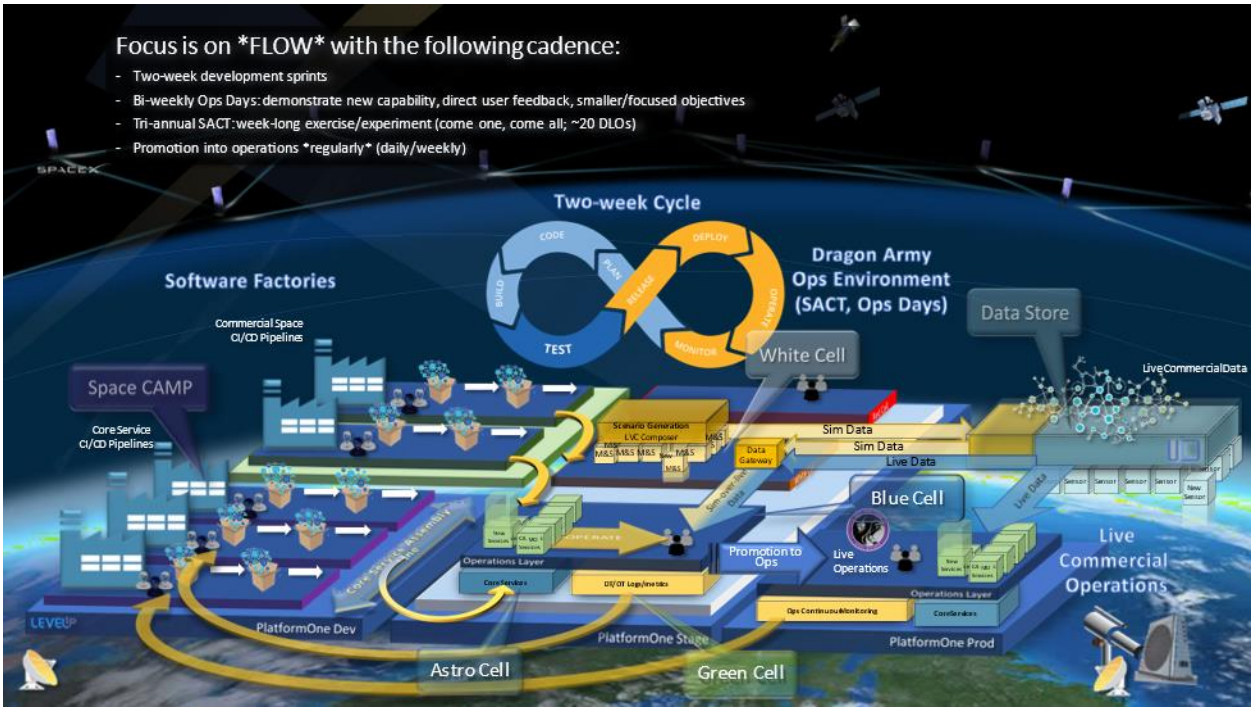


Fig. 2. DRAGON Army Ops Environment

Fig. 2 illustrates the Operational Viewpoint (OV-1) of DRAGON Army. The AFRL Space Vehicles Directorate's Space CAMP is the premier software factory for the United States Space Force. DRAGON Army is one many programs in Space CAMP's Portfolio. The DRAGON Army is broken up into 3 different development cells: DRAGON's Forge, Hydra, and White Cell. DRAGON's Forge oversees the development and integration of management-layer capabilities for mission tasking, data visualization, consolidation of products from commercial providers, and reporting. DRAGON's Forge also develops and integrates tools with a focus on measures of performance and measures of effectiveness with JCO operations. By utilizing these tools, JCO Operators can see the increase or decrease in performance based on the new capability integrated, new Tactics, techniques, and procedures (TTPs), or just track the performance of the operational cell over time. DRAGON Army's Hydra cell is in charge of developing and integrating capabilities into the government-owned tech baseline that allow for seamless data storage, flow, and synchronization between all DRAGON Army applications. In support of the JCO's goal of 24/7 Commercial space operations, Hydra has developed the DRAGON Army Synchronization Service (Or Synch Service) to enable real-time system-to-system synchronization of operator events and actions across a variety of capabilities for both U.S.-led and Allied-led operational cells. The DRAGON Army White Cell develops and integrates a system of Modeling and Simulation (M&S) tools to provide exercise scenarios to support product development and overall Training, Exercises, and Experimentation across all operational activities. Throughout this paper, a deep dive into the different capabilities of the DRAGON ARMY will be highlighted as well as the impact of the DRAGON Army on the Joint Task Force Space Defense - Commercial Cell (JCO), commercial, and international community.

2. DRAGON'S FIRE AND TABLEAU

2.1 Intro to DF and Tableau

Providing objective, data-driven, feedback on tools, data, and processes is a key objective of DRAGON Operations. To effectively achieve this goal, the environment needed the necessary data infrastructure to support data analytics projects. Using Amazon Web Services, the team has developed a database to store operational data, a set of data pipelines to extract, transform, and load data, and a suite of dashboards in Tableau to serve real-time performance analysis and reports to stakeholders. DRAGON Ops has also found value in leveraging the database and Tableau for

prototyping applications that are used in daily JCO operations. As a result of this initiative, JCO crew members, NSDC leadership, and commercial capability providers can glean insights from the data that help drive improvements to commercial capabilities and processes.

2.2 DRAGON Fire

DRAGON Fire is a smaller-scale data warehouse hosted in AWS Relational Database Service. Data published to the UDL, MMB, and Trogdor flows through the Sync Service and is stored in a PostgreSQL database where it can be consumed for reporting and analysis by data analysts and data scientists. Since these data sources are largely disparate, a key challenge is connecting the data through a set of unique identifiers to enable holistic analysis. For example, when a simulated event is orchestrated in Trogdor, an event record is stored in the database. Shortly after, the JCO crew responds to a tip, or queue, that a simulated event is in progress, and creates an MMB event to prompt the crew to begin analyzing the situation. Since Trogdor and MMB are not integrated, the event generated in Trogdor is not related to the event generated in MMB in any way. To connect data entities like this, relationships are established in the DRAGON Fire database. Some relations are made automatically while still relying on human-in-the-loop intervention to establish others. In the future, the goal is to integrate applications like Trogdor and the MMB so that data connections are made more efficiently. Once the data is stored and connected in DRAGON Fire, a comprehensive performance analysis can be executed and presented to stakeholders.

2.3 Performance Metrics and Dashboards

Fig. 3: Event Log Summary View

Providing objective feedback to the JCO crew and SACT participants is an important aspect of the DRAGON Operations environment. Real-time performance metrics and reporting tools are used to drive product and process improvements. Performance metrics are stored in the DRAGON Fire database and presented to stakeholders via Tableau dashboards. While DRAGON Ops is in the early stages of the analytics lifecycle, the goal is to eventually support targeted experimentation and evaluation where stakeholders can determine the statistical impact of incorporating a new commercial sensor, implementing a new product feature, adjusting a JCO process, etc. using methods like A/B testing. A few examples of the dashboards used today are described in the following paragraphs. The Event Log dashboard reports on active and completed events that the JCO crew has processed, including a comprehensive overlay of activity logs that explain the specific actions that crew members take while processing a given event. Specific activities include adding a product to the event, making comments on an event, completing checklist items required for closing an event, and publishing NOTSOs. There are several use cases that the Event Log serves. It provides operators a quick and intuitive view into the work performed by the JCO at any given time, enabling performance analysis on past events, real-time crew monitoring, and historical event look-up to aid the crew in processing similar events in the present. The summary dashboard below allows users to select an event that opens an Event Details dashboard with specific information for that event. In the future, the Event Details dashboard will include a performance score that is composed of a series of relevant metrics for that event. Users will have the ability to drill down further into this performance score to view the individual metric values, understand how the crew's performance stacked up when compared to other events of the same type (e.g. Launch events), and observe performance trends to understand crew improvement (or lack thereof) over time. The Event Log is currently in development with plans to evolve it into the primary performance analysis tool used by the JCO.

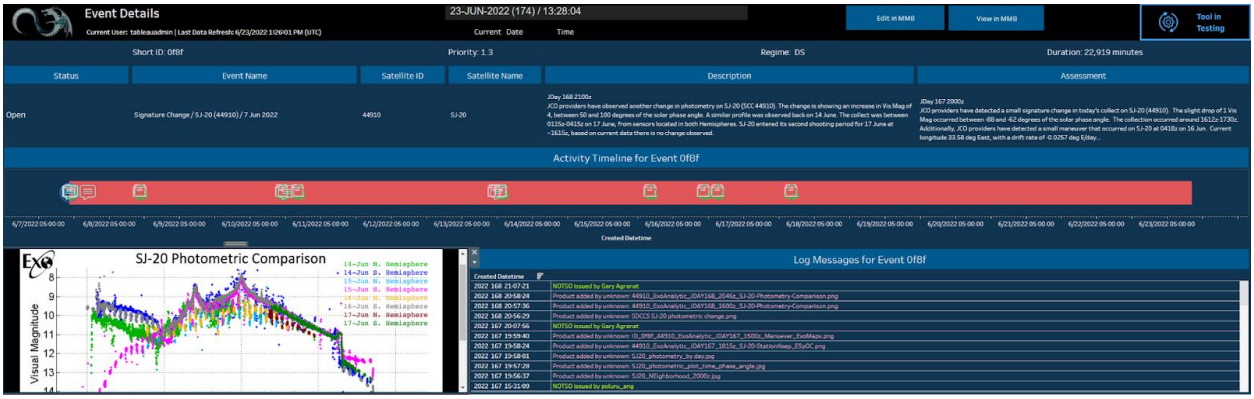


Fig. 4: Event Log Event Detail View

The HRR Coverage Gap and Violation Time dashboard continuously processes observations generated by sensor providers on the JCO High Rate Revisit objects, calculating coverage gap times for each object. The Tableau dashboard aggregates these calculations to provide average gap time and coverage violation time percentage metrics for each object as well as the HRR list as a whole. The purpose of this dashboard is to visualize and report on HRR object coverage sufficiency by the providers currently on contract for the JCO. Users can slice and dice the data by Orbit Regime and other attributes to determine sufficiency at more granular levels. For example, coverage performance on GEO objects may be insufficient for mission needs. Leadership could use this information to adjust their strategy for collecting in the GEO regime.

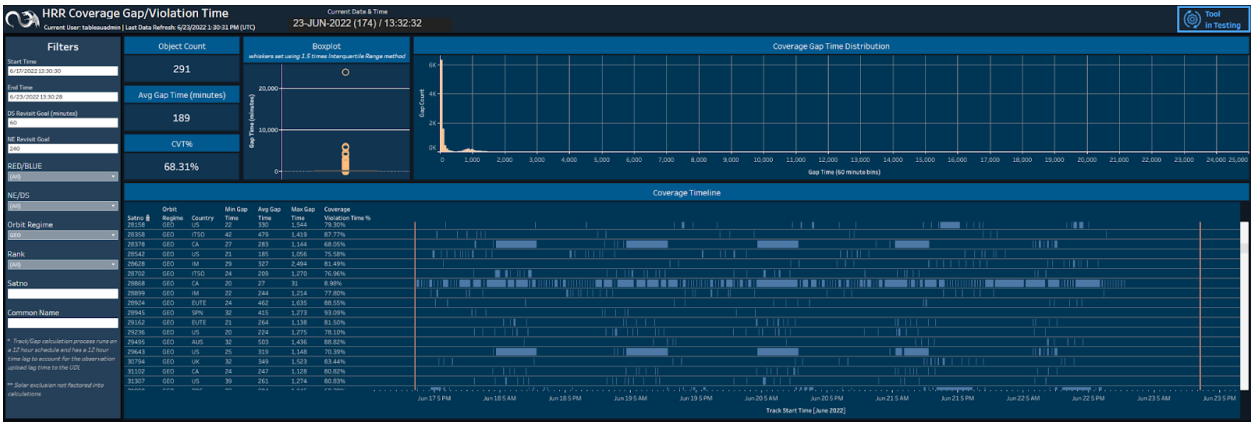


Fig. 5: HRR Coverage Gap / Violation Time dashboard filtered to GEO objects

The Maneuver Detection Assessment dashboard is used to assess the performance of commercial providers' maneuver detection capabilities. The DRAGON Army can receive maneuver plans from satellite owner/operators and visualize the maneuver times alongside the provider detections. Visually, it can be observed how quickly different providers detect maneuvers after they occur and subsequently notify the JCO. In the future, the DRAGON Army will automate metrics including *time from maneuver occurrence to detection notification*, *difference in detection delta-v*, and *true/false positive/negative detection rates*. Users have the ability to slice and dice the data by provider, orbit regime, etc. to investigate differences in performance. Leadership can use this dashboard to understand how quickly participating providers can detect maneuvers, on average, which provides information on how quickly the JCO can respond to threats. Furthermore, providers can use this dashboard to find opportunities to improve their maneuver detection capabilities.

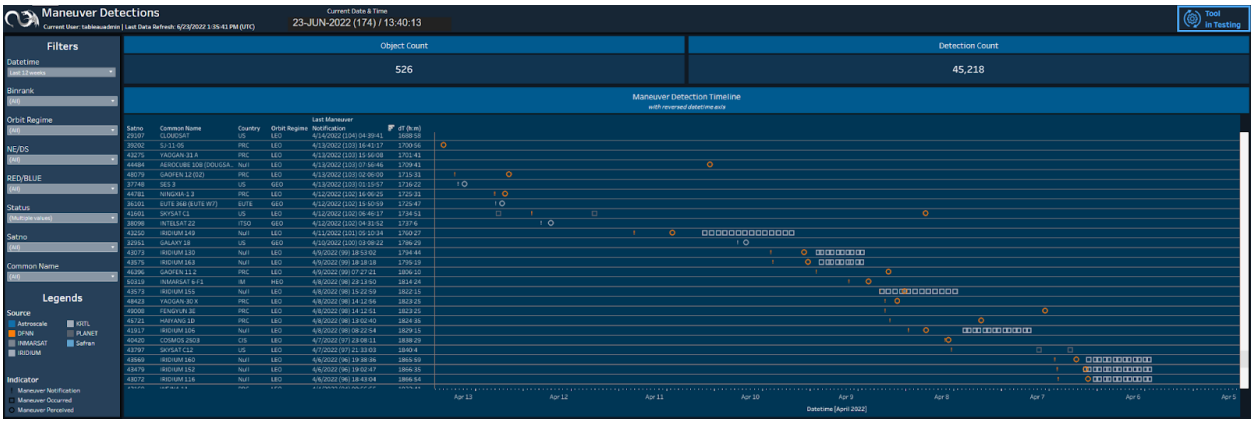


Fig. 6: Maneuver detection assessment dashboard visualizing maneuver times reported by satellite owner/operators and subsequent detections by DF&NN

2.4 JCO Operational Dashboards

In addition to performance dashboards, DRAGON Army also supports a set of operational dashboards used by the JCO to perform daily operations. Just to reiterate, all dashboards are developed and deployed in Tableau and powered by the DRAGON Fire database.

The Sensor Heartbeat dashboard provides an at-a-glance view of the current health of the commercial sensor network. The map shows all the sensor sites and different colored rings indicate how much time has passed since a sensor has received observations. The JCO uses this dashboard to quickly understand what sensors are actively collecting data and which sensors may currently be in daylight or weathered out.

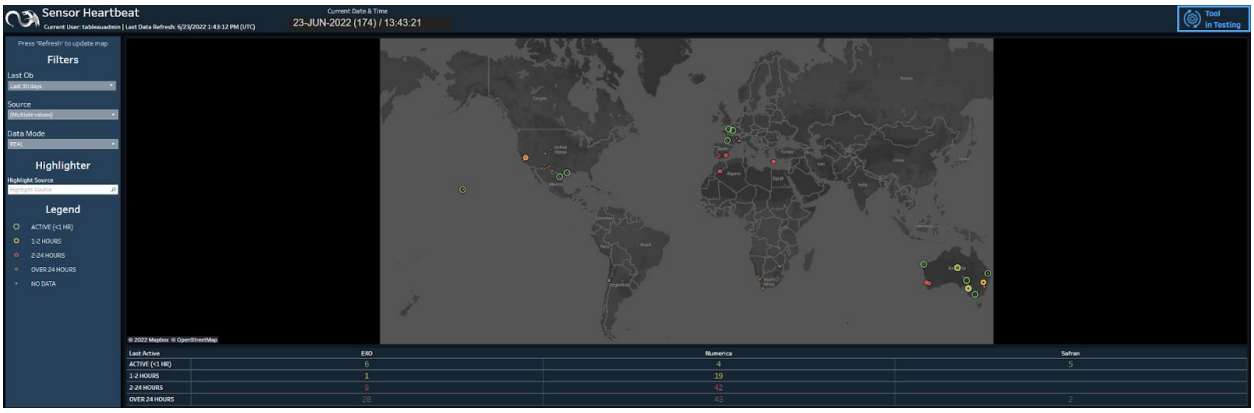


Fig. 7: Sensor Heartbeat dashboard

The GEO waterfall plot is used to perform analysis on GEO objects. Waterfall plots are used by operators to quickly identify maneuvers and determine if any objects in the vicinity that may be threatened by an adversary. It is also very useful for visually detecting break-up events as the pattern of observations resembles a branching tree from the point of collision. The JCO often receives requests for a *GEO-wide area search* from the NSDC that typically spans a 15-degree (?) longitudinal range. Honing in on this range in the waterfall plot gives operators a glance at activity in that range over the past 1-2 weeks so that they can report any abnormal maneuvers, presence of UCTs, etc. back to the NSDC for further analysis.

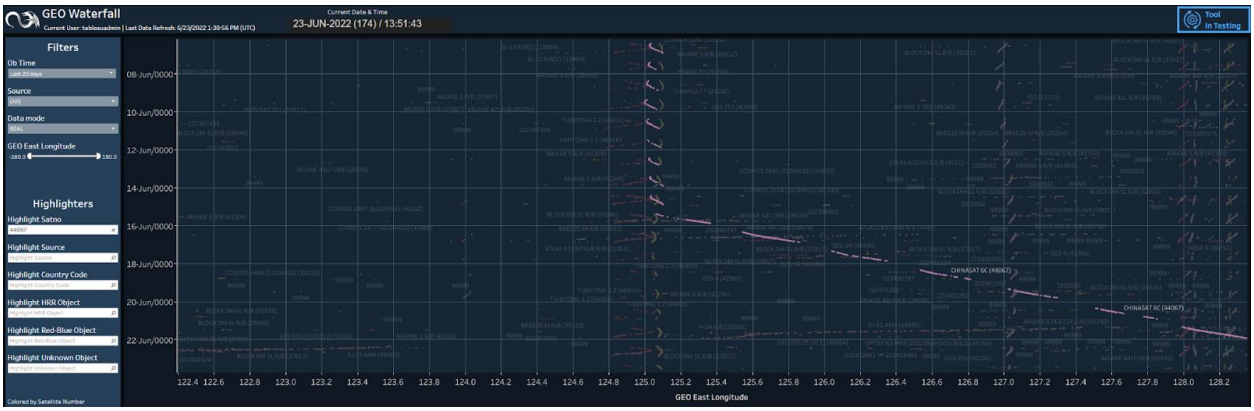


Fig. 8: Example of a maneuver visible in the GEO Waterfall (CHINASAT 6C 44067)

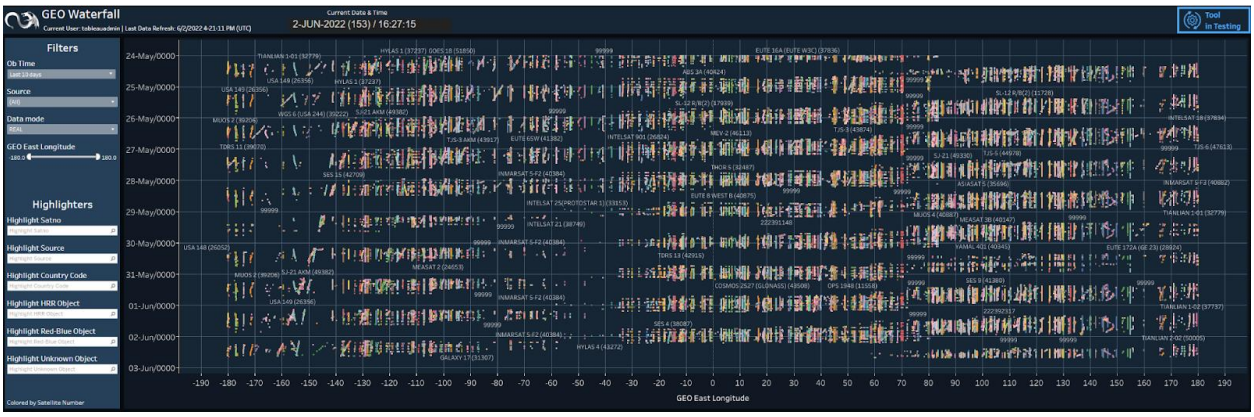


Fig. 9: GEO Waterfall dashboard

The Light Curve dashboard provides a set of visualizations that plot the visual magnitude of an object against its solar phase angle over a period of 20 days. This plot creates a sort of "fingerprint" for a satellite and any significant deviations from this fingerprint can indicate to the operator that something interesting is happening, such as an abnormal maneuver. Furthermore, light curves can be used to assess the stability of a satellite. If a satellite is tumbling, the pattern of observations will be much more sporadic and spread out instead of forming a nice peak-like pattern that can be seen below.

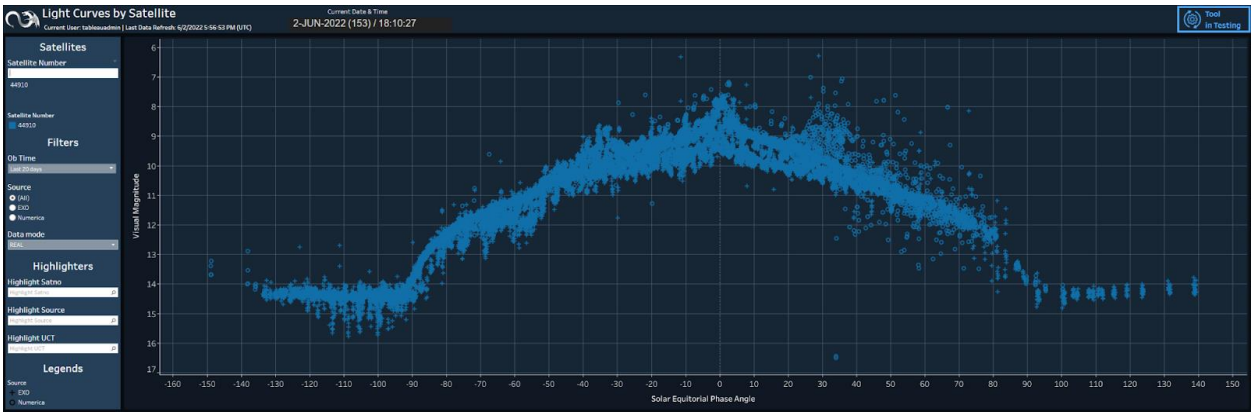


Fig. 10: Fairly stable light curve plot for 44910 SJ-20 captured on June 2, 2022

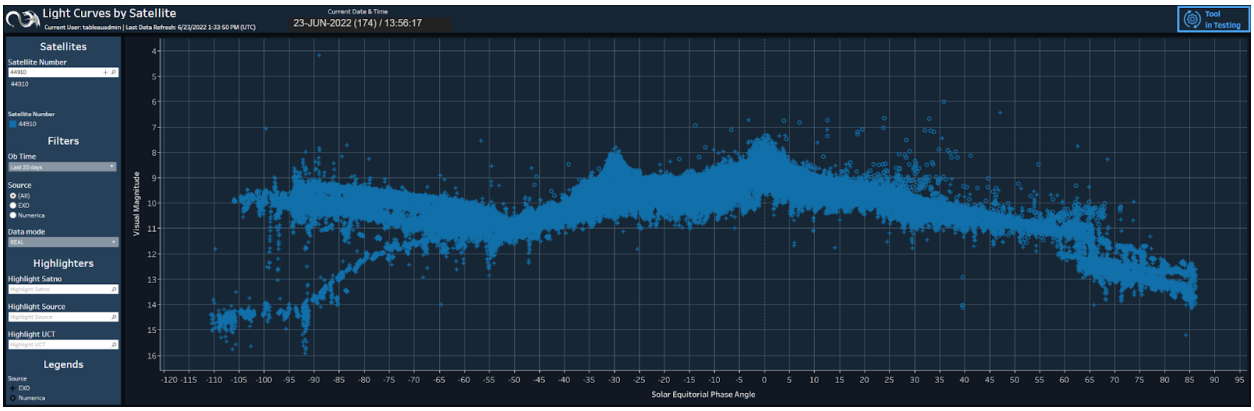


Fig. 11: Light curve plot for 44910 SJ-20 captured on June 23, 2022 showing a clear signature change

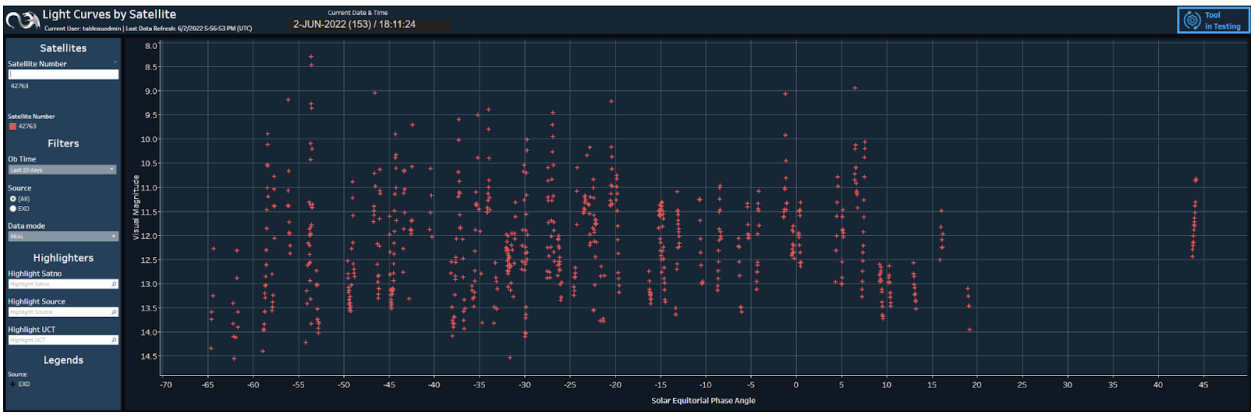
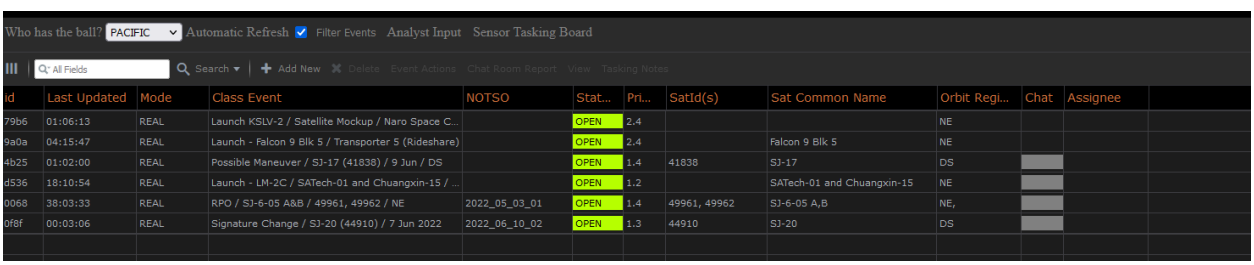


Fig. 12: Example of what a light curve looks like when a satellite is tumbling (42763)

3. MISSION MANAGEMENT BOARD AND SYNCH SERVICE

3.1 JCO Operational Dashboards

The JCO uses a Mission Management Board (MMB), Mission Management Tool Suite (MMTS), to keep track of current events. The MMB allows the JCO operators to upload products (such as images, documents, and movie clips), and comments and keeps track of a crew log. The MMB also allows a site director or a deputy site director to publish a Notice to Space Operators (NOTSO). This NOTSO publication is a notice to the community of a high-priority alert, which can include a notice of an uncooperative launch, a high-value asset involved in a close approach, or other instances.



id	Last Updated	Mode	Class Event	NOTSO	Stat...	Pri...	SatId(s)	Sat Common Name	Orbit Regi...	Chat	Assignee
79b6	01:06:13	REAL	Launch KSLV-2 / Satellite Mockup / Naro Space C...		OPEN	2.4			NE		
9a0a	04:15:47	REAL	Launch - Falcon 9 Blk 5 / Transporter 5 (Rideshare)		OPEN	2.4		Falcon 9 Blk 5	NE		
4b25	01:02:00	REAL	Possible Maneuver / SJ-17 (41838) / 9 Jun / DS		OPEN	1.4	41838	SJ-17	DS		
d536	18:10:54	REAL	Launch - LM-2C / SATech-01 and Chuangxin-15 / ...		OPEN	1.2		SATech-01 and Chuangxin-15	NE		
0068	38:03:33	REAL	RPO / SJ-6-05 A&B / 49961, 49962 / NE	2022_05_03_01	OPEN	1.4	49961, 49962	SJ-6-05 A,B	NE,		
0f8f	00:03:06	REAL	Signature Change / SJ-20 (44910) / 7 Jun 2022	2022_06_10_02	OPEN	1.3	44910	SJ-20	DS		

Fig. 13: MMB overview

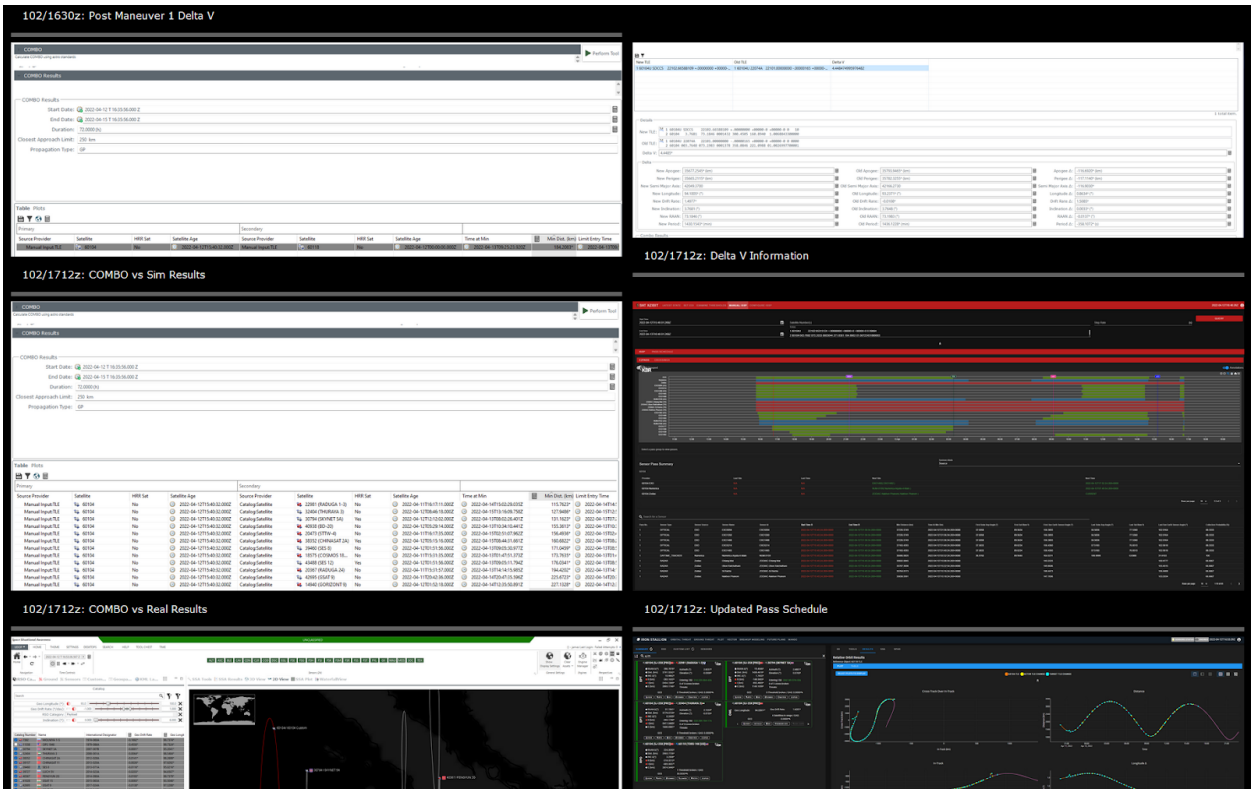


Fig. 14: Example of products produced during a SACT exercise and stored on the MMB for a particular event

EXERCISE EXERCISE EXERCISE JCO has analyzed that the maneuvers on SJ-25, causing it to initiate an eastward drift torwards TDRS-14X (60118). Delta V: 4.45 m/s Apogee Change: -116.6 km Perigee Change: -117.1 KM Inclination Change: 0.0 Drift Rate: 1.50 deg/day Latest state: 160104U22102.65315124+.00000000+00000+0+00000+0009994 260104003.7692073.20330003044271.8301184.890201.00722431000003 There is just over a 3 deg inclination difference between TDRS-14X and SJ-25X. Depending on the type of threat, this may require an inclination adjustment to SJ-25X to achieve WEZs. Based on this information, that would likely occur just after 2100z and 0900z. EXERCISE EXERCISE EXERCISE **EXERCISE EXERCISE EXERCISE** The JCO has detected multiple maneuvers on SJ-25X (SCC# 60104) that has caused it to initiate an eastwards drift at over 1 degree per day. Immediate closest target in the vicinity is TDRS 14X (SCC# 60118). Analysis is ongoing. Expect further NOTSOs. EXERCISE EXERCISE EXERCISE **2022-04-13 0033z Assessment:** GEO Waterfall Plot suggests SJ-25X (60104) drifting eastwards at 1deg/day towards TDRS 14X has been attached which suggests TDRS 14X is a possible target. COMSPOC does not report any conjunctions within 50km over the next 2 days. Latest assessment (2022-04-13 04:31Z) from COMSPOC states that the current approach distance of SJ-25X is approx. 345km. Final note, SJ-25X is drifting eastwards with unfavourable lighting geometry. **2022-04-13 1237z Assessment:**SJ-25X has executed a maneuver after passing TDRS 14X to ingress on Skynet 5A. It is probable that SJ-25X is now in RPO with Skynet 5A. Waiting for updated states to verify.

Fig. 15: an example of a NOTSO publication during an SACT exercise for a particular event

Since DRAGON Army involves international partners, there is a challenge when each country/cell uses its own MMB and software during the changeovers during the 24x7 SACT events. Whenever a new cell used a new software suite for the MMB, then the operators had to manually port over the data from one MMB and insert the events into the other software suite. Due to the manual process, many items were skipped or entered incorrectly. As such, the DRAGON Army built a middleware hub and spoke architecture, called the Sync Service, that allows communication across the MMBs. This architecture is designed in a way that most of the heavy lifting is done by the DRAGON Army and the various cells only need to construct an adapter that translates between the software of the MMB and the Sync Service. This allows for rapid deployment for each new cell that wants to participate with operators.

3.2 DRAGON Army Synchronization Service

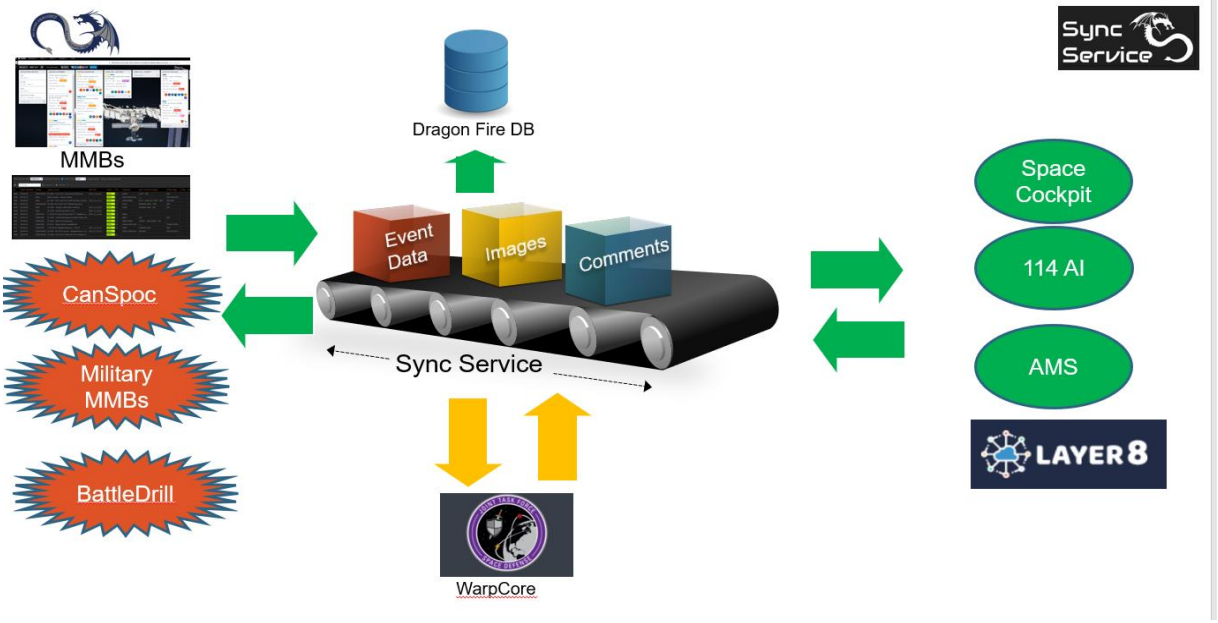


Fig. 15: Sync Service

The DRAGON Army Synchronization 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, this hub and spoke architecture allows third parties to provide their products easily and integrate into the operator loop with the appropriate authorizations. As an example, a site director or deputy site director can log into AMS and create an event in the MMBs from within AMS when they observe something unusual that needs to be tracked. To accomplish this, AMS interfaces with the Sync Service and publishes a create event based on the data that AMS contains. When the credentials have been authorized, the Sync Service publishes the events within the system. All MMBs then receive the streaming information and create the event within their software suite. This allows AMS the ability to publish the data to the Sync Service, and then rely on the Sync Service to manage the data flow, security, and authorization. This simplifies the process because AMS only needs to know how to interact with the Sync Service and doesn't need to write code or integration pieces that require custom integration aspects for each MMB. The Sync Service handles all other aspects of this architecture.

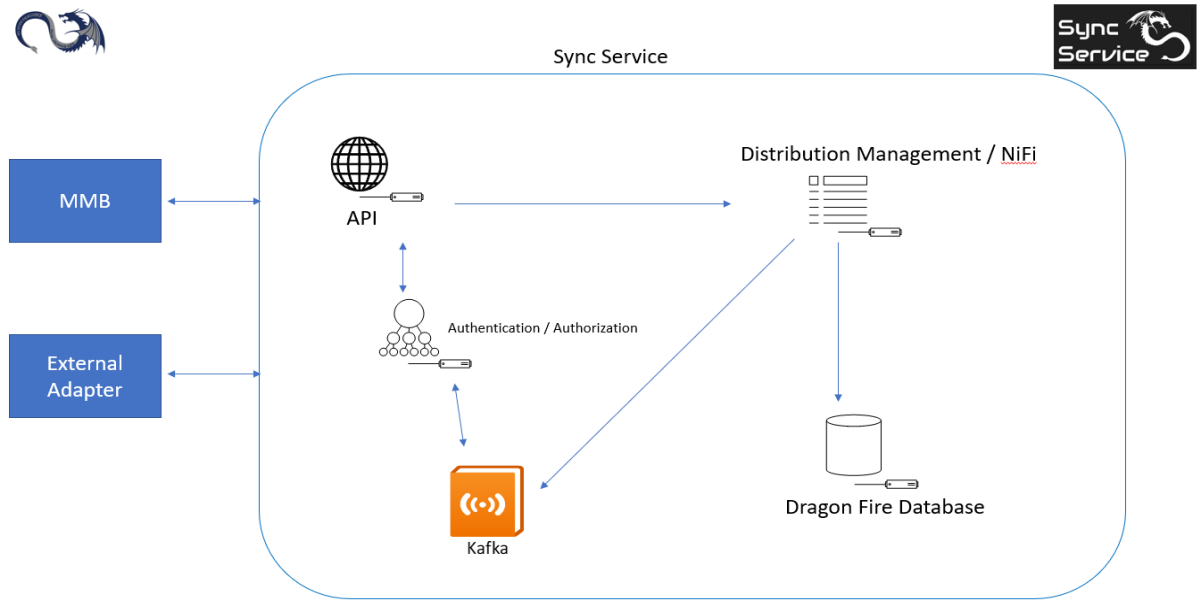


Fig. 16: Sync Service Image Architecture

The DRAGON Army has integrated multiple third-party companies that are capable of creating events, and publishing images or comments based on the operators and their needs. Some of these companies are international companies such as Saber Astro and 114 ai. The DRAGON Army is looking for other companies willing to integrate and publish data that makes the operator's jobs easier.

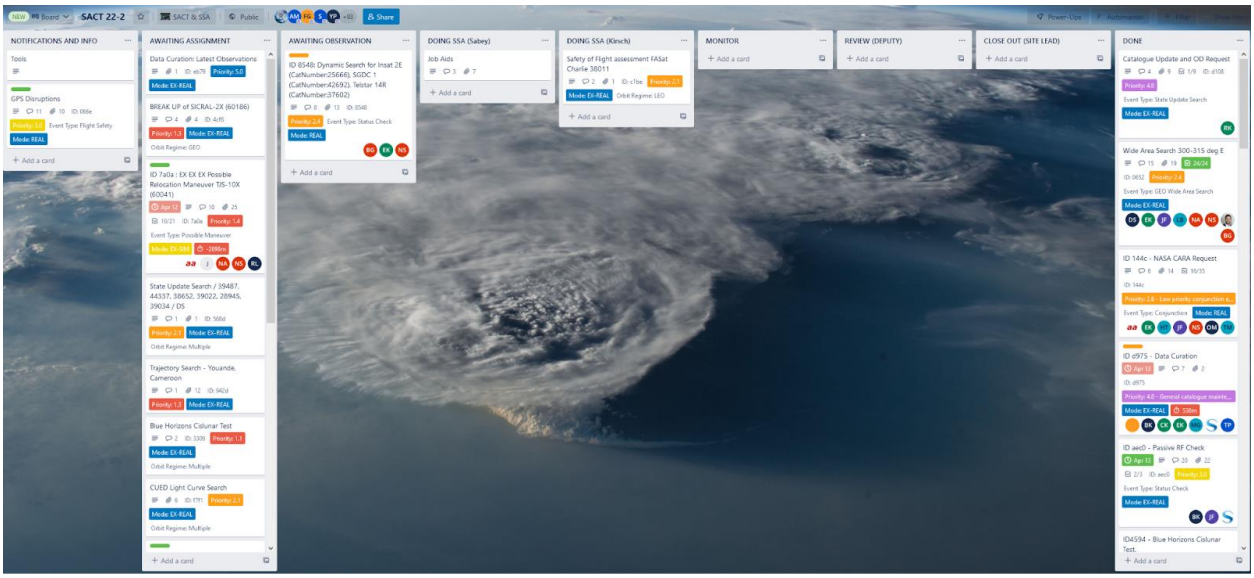


Fig 17. Example of Trello being used as a MMB for the Australian RSOC during SACT 22-2

4. M&S TOOLKIT

4.1 Trogdor

The JCO and allied partners supporting the space traffic management mission cannot cause dangerous space events to transpire to have the training and testing opportunities that they require for their staff and toolsets. While using live situations to train and calibrate their capabilities would be ideal, it would require a closed and fully contained stage (such as a test range for weapons testing), which is not feasible in the space domain. This lack of opportunity to put both people and software through their paces for space scenario training brings to light the need for complex training capabilities for all interested parties.

The joint demand for a unified training solution supporting the space traffic management mission brings with it a myriad of requirements from the US government agencies, commercial entities, and international partners. These requirements range from data interface design to data representation, and the need for a unified data stream from cooperative exercises. The challenge of coordinating this collaborative environment is made more problematic when considering the complexities of the space domain. To address these complexities an intricate system needs to be implemented supporting modeling and simulation challenges of sensors, space objects, and ad hoc human intervention events.

The Trogdor 2.0 controller mimics the UDL by weaving simulated space events into the live UDL query responses. This system allows the JCO and interested parties the ability to set up, configure, and play through on-demand training situations where they need them in space and when they want to do them in time. Trogdor 2.0 has drastically reduced the need to manage the risks of live event coordination by allowing training for the STM mission to take place virtually.

4.2 Architecture Overview

The main product of the DRAGON Army Modelling and Simulation (DA: M&S) cell is the Trogdor 2.0 (T2) controller. This system is a simulation controller that is capable of dynamic communication with a host of available APIs and data sources, to construct simulations and inject that data into the live Unified Data Library (UDL) stream, which is then passed back to the data consumer. This process of injection involves suppression and replacement of the live data and the delivery of fully constructed exercise object states to encourage a seamless obfuscation of the information.

This design was chosen to allow T2 the ownership of the middle ground, thus maintaining control of the data in play from the various vendors to fit the form needed by the data source. This requires entity simulators to provide their key features in the form of web services so they can be called on-demand and yet remain independent from the T2 code base. Utilizing this design allows for vendors and data sources alike to be agnostic and for the system to be flexible enough to ensure quick onboarding and integration of new vendors and features.
Data used by T2 can range from event generation (i.e., object breakups, satellite maneuvers, and rocket launches), simulated sensor networks viewing those events, and customized scenario ephemeris sets. This data is all provided live during the scenario lifetime via calls to the respective data source through T2 as a middleman so that operators can do active analysis for object and event recognition as if they were receiving the information from the live source. Additionally, it is collated and provided to an external database after scenario completion as a complete data dump for post-scenario analysis.

A companion product of T2 is the White Cell Console (WCC). The WCC is a web-developed frontend that interfaces directly with T2 for ease of scenario/event creation and management. This piece was designed separately from T2 to allow the clients to utilize the frontend if they would like or allow them the flexibility to use their own internally developed frontend. The WCC is a user-based system that is extensible to provide the platform for future Red Vs Blue wargaming formats. Currently, this system supports White Cell Coordinator efforts by displaying all scenario and event information immediately and provides a Gantt chart system for event deconfliction.

The interaction between T2 and the WCC lies at the center of the DRAGON Army's modeling and simulation capabilities. These two products help to tie the system together and truly coordinate and control the simulation training efforts.

4.3 M&S Architecture

The diagram in Fig 18. is a high-level representation of the T2 system design and the connectivity between the controller and its environment.

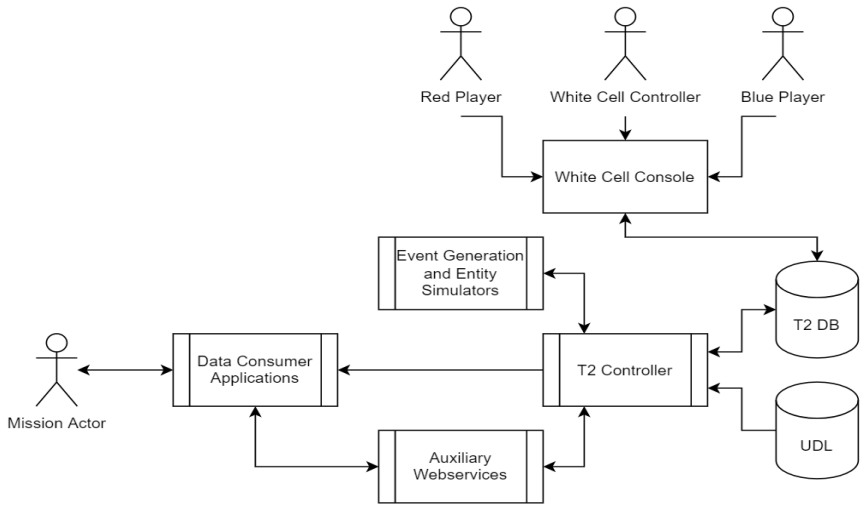


Fig 18. The Design Diagram for the Modeling and Simulation functionality of the DRAGON Army

In practice, the White Cell Controller will utilize the WCC to enter a scenario that addresses an identified training need. This configured series of events is deposited into the T2 internal database for automated and manual review. Once approved, and upon entering scenario start time, the T2 controller will contact the Event Generators and Entity Simulators to pass event data and calculate object trajectories supporting the scenario and consume the resulting simulation artifacts. The T2 controller then interlaces the synthetic information about the scenario with the live data stream from the UDL for consumption by the Mission Actor and Data Consumer Applications.
Data Sources

Primarily, T2 was designed as a working concept to communicate directly with the UDL as a data source, but this design was created to be flexible enough that it can easily integrate other data sources with only the knowledge of the communication schema involved. This flexibility allows T2 to be a viable and resilient product now and into the future. The methodology used to integrate the UDL as the current data source relies on a two-fold approach: mimicry of the data source, and the ability to stream data alongside the source. This approach makes it easily integrate other data sources and keeps it flexible enough to make changes quickly as the data source changes.
T2 mimics the schema of the UDL exactly, to provide the seamless integration needed for obfuscation of the simulation data. This ensures that operators of the training applications can't tell the difference between the truth data and the injected simulation over live data. When operators identify that a simulation event is taking place, they are required to act upon the event as if it is happening alongside the live events and must be reacted to accordingly. The second portion of this methodology is the ability to stream alongside the source. This means that the source must still be pure and untouched, so T2 controls the source output as a middleman proxy that is able to inject the simulation information on the data return instead of relying on the source to contain the simulation data. This allows for the T2 information return to be manipulated while the source remains unaffected.

This methodology makes it easy to incorporate new data sources, and to be able to support multiple data sources if needed. The extensibility of this methodology ensures that T2 can grow and support for the future need.

4.4 Modularity, Flexibility, and Adaptability

Every aspect of T2's design has taken modularity, flexibility, and adaptability to heart. To address the needs of the client, the system was created as a decoupled network of compartmentalized features, ones that can be swapped out for competitive products with ease. This decision on the design was essential due to the JCO's need for a "try before you buy" experience with new capabilities. T2 as the heart of the system allows for the flexible configuration and execution of custom-tailored events. The system has shown to be highly flexible during its week-long semi-annual advanced concepts training where applications and operators are put through a series of rigorous scenarios and exercises, to prove the value of the capabilities available on the current marketplace.

4.5 M&S Toolkit Ideation and Future Plans

Trogdor 2.0 provides the JCO, commercial entities and allied partners with an accessible training and testing environment that supports relevant exercises with realistic outcomes on demand. The system abstracts away much of the specific and exquisite knowledge needed to setup and run complex modeling and simulation exercises in the space domain by providing templated events and training series. This opens the door for less experienced teams and team leaders to benefit from the experience of other teams more readily across the system.

The anticipated scaling of the Space Traffic Management (STM) mission over the next few decades requires more involvement from nations and organizations across the globe and a unified proving ground for tools, procedures, and communications. Trogdor 2.0 provides the ability to coordinate synthetic training at the local team level and at a coordinated global level within the same system reduces onboarding and configuration time, as well as lowering the bar of entry for new participants.

Trogdor 2.0 is uniquely situated to evolve under the umbrella of competition. From its origin it has been developed with flexibility and integration in mind. Its decoupled design enables a "plug-and-play" configuration of experiments where providers of any modular feature set can be swapped out for that of a competitor. This approach allows for incremental and parallel development efforts while minimizing design conflicts and streamlining the integration of new capabilities.

There are plans to expand the interactive nature of the software to include multi-team perspectives and their ability to inject reactions and changes to ongoing scenarios. This support will allow the direct comparison of competitive software products in support of the STM mission. Such a capability will provide an “apples to apples” comparative data set that can be analyzed for performance and mission satisfaction, where the dynamic intent of the live simulation environment to comes to life. Future versions of Trogdor will support red vs. blue wargaming as well as non-conflict multi-party coordinated training opportunities.

5. OPERATIONAL IMPACT

The DRAGON Army software development supports a variety of efforts, primarily those of the Joint Task Force Space Defense Commercial Operations (JCO) and the Sprint Advanced Concept Training (SACT) experiment series. The JCO and SACT are conducted for the National Space Defense Center (NSDC) at Schriever Space Force Base and the US Department of Commerce (DOC).. The JCO provides “commercial augmentation to military operations” to aid the NSDC Protect and Defend mission under the JTF-SD. The SACT is an international experiment series in collaborative SDA that is conducted over one week and performed three (3) times annually. The SACT runs virtual space operations centers, or SpOC, in multiple time zones including Sydney, Australia; Colombelles, France; Santiago, Chile; and Colorado Springs, United States. The format of the operations is virtual remote, enabling attendees from all over the world to participate. During the SACT experiment, the teams are challenged with various designated learning objectives (DLO) including: GEO wide area search, closely space object (CSO) detection, launch processing, advanced light curve characterization, break up analyses, pointing navigation and timing (PNT), data curation for sensor noise and bias assessment, conjunction assessment, search and recovery of satellite in lost and attention list, and many others. The operations are conducted over two (2) separate twenty-four (24) hour vulnerability windows. The primary control is divided into three 8-hour shifts and generally follows the format Pacific (Australia, New Zealand, Japan) to Meridian (United Kingdom, France, Spain) to Americas (United States, Chile, and Canada). With control handover periods between major cells, this format allows continuous SACT operations while attendees only need to participate during their normal business hours. The DRAGON Army facilitates the development of integration software that allow these international teams to conduct seamless operations transitions throughout the 48-hour exercise. Fig. 19 below illustrates the teams on station during the events.

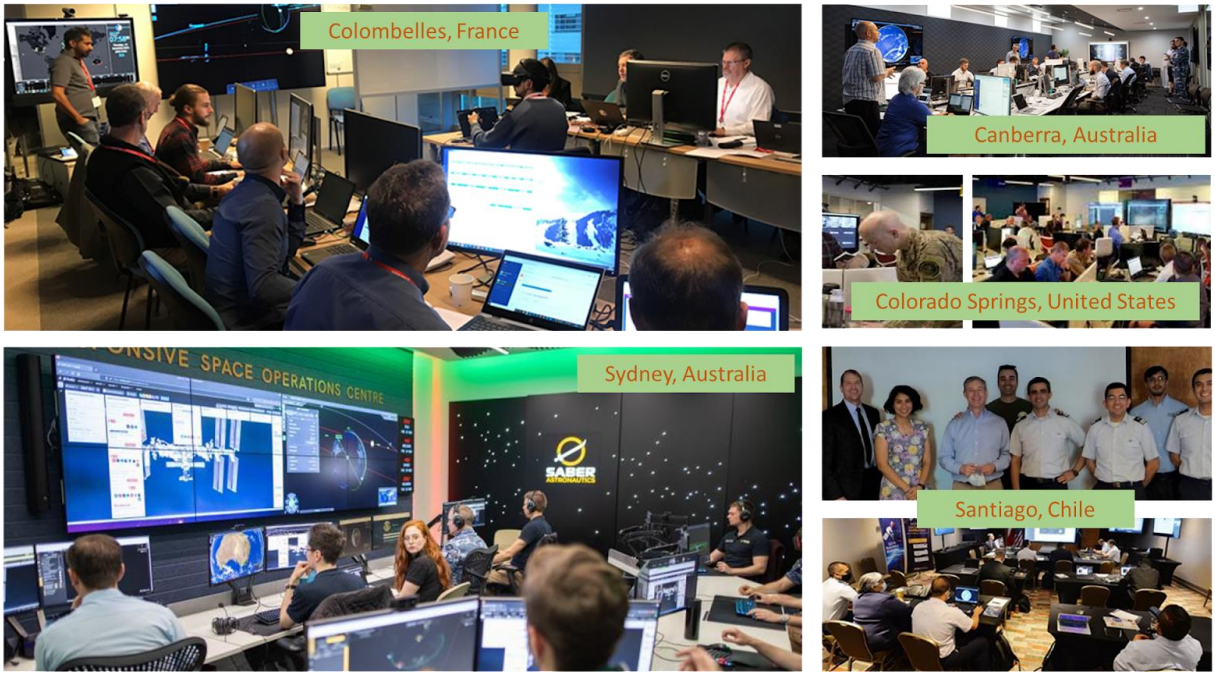


Fig 19: SACT Teams from around the globe conducting operations within their respective countries

The SACT and JCO have demonstrated sufficient success that other countries are now actively pursuing the instantiation of their own JCO. The Australian Responsive Space Operations Center (RSOC), a division under the Australian Space Agency (ASA) has been conducting handovers with the JCO America's cell daily as of mid 2021. The United Kingdom (UK) Space Operations Center (SpOC) anticipates having established a JCO by August of 2022. France, Chile, and South Korea are sending officers to the United States for JCO Initial Qualification Training (IQT) before the end of 2022. Additionally, the United States Air/Space National Guard (ANG) have recently become very involved in supporting the JCO. The ANG have completed two classes of IQT and now contribute a permanent Site Director to the JCO effort to assist in manning during America's shifts. The America's JCO intends to extend its international hours with the assistance of the ANG by utilizing staff deployed remotely including Guam and Austria.

Currently the JCO is funded by JTF-SD and, therefore, its mission is almost exclusively 'Protect and Defend'. Therefore, the JCO focuses daily operations on the monitoring and characterization of adversary satellites in an effort to provide tip-and-cuing about potentially dangerous situations for friendly US and Allied satellites. As such, the JCO focuses surveillance resources on approximately 850 satellites of interest. In support of the Department of Commerce (DOC) and DEL 2 (18th/19th Space), the US government is considering extending the role of the JCO to include more missions including satellite catalog maintenance, lost and attention list, conjunction assessment, and others. This shift in mission sets would increase the active number of satellites the JCO teams around the world are required to monitor. Fig. 20 below illustrates a small gallery of the applications that the DRAGON Army has developed which would be appropriate for use in the Civil Space Mission within the DOC.

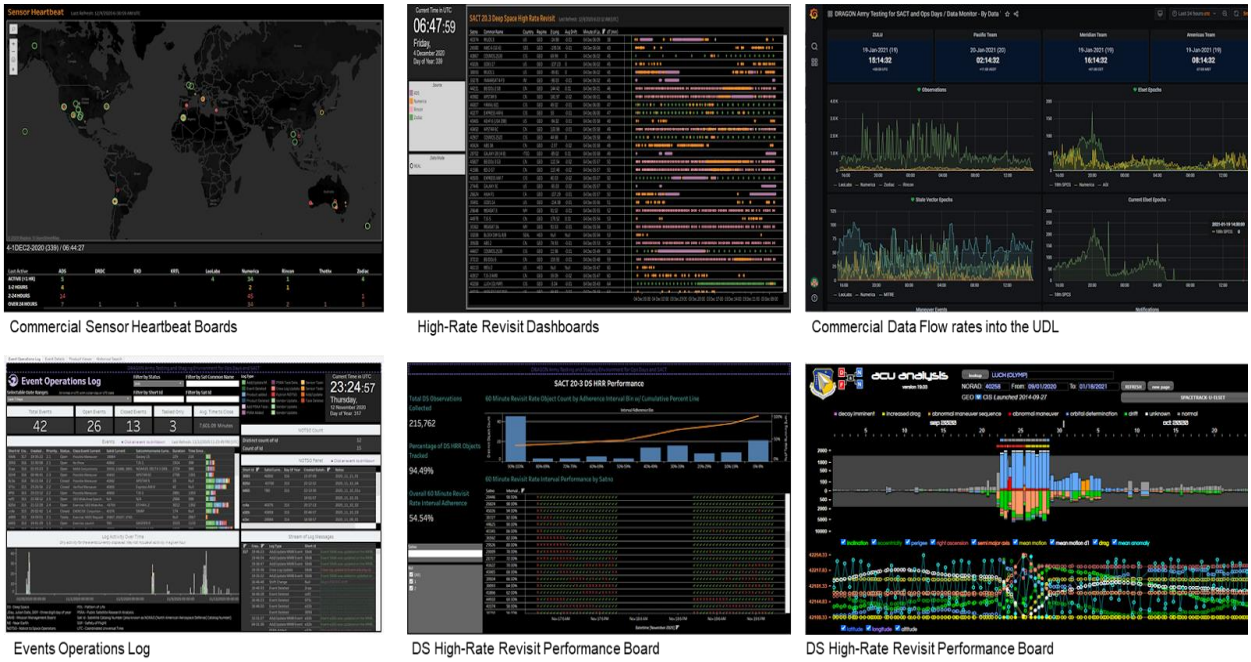


Fig. 20: Sample of some of the DRAGON Army Tools suitable for support to DOC.

Applications above include the Machine Learning / Artificial Intelligence (ML/AI) satellite profiling tool Alert Management System (AMS) that will provide autonomous maneuver detection of satellites and continuously monitor them for any anomaly alerts.

An initial element of that support will include the DRAGON Army's close collaboration and integration into the DOC Open Architecture Data Repository (OADR). In early 2021, the DOC released a vision statement for how it would slowly absorb civil space flight safety tasks.

The intent is that the JCO become one element of the DOC OADR architecture and support them with Space Flight Safety as well as modeling and simulation, via Trogdor, to help advance surveillance studies to understand sufficiency metrics in scaling commercial operations to support civil missions.

The operational impact the DRAGON Army, JCO, and SACT have is difficult to quantify as it is hard to understand impact the events, Notice to Space Operator (NOTSO) alerts, and Weekly Activity Reports (WAR) have on second and third order effects throughout the space community. Anecdotally, it can be inferred that the positive reaction based on the growth of the SACT experiment series in 2019 from eight (8) companies in Colorado Springs to the massive international event it is today with contributions from United Kingdom, Canada, Chile, France, Australia, Netherlands, South Korea, Japan, India, Spain, and many others. Commercially and academically, the participation in the SACT have grown to include some form of collaboration from over 70 stakeholder entities around the world including: University of New South Wales, Australia; University of Santiago, Chile; SAFRAN, France; Seradata, United Kingdom; NORSS, United Kingdom; 114.AI, India; Kratos, United States; NEC, Japan; and many others.

6. **Conclusion**

The DRAGON Army program has been successful in developing and transitioning numerous capabilities from prototype to operational. The success of this program has not gone unnoticed by United States Space Force. The DRAGON Army has been given numerous recognitions from USSF and DAF Leadership including written support from Maj Gen Pringle. As the Dragon Army Cells Hydra, Dragon's Forge, and M&S continue to develop and integrate capabilities, Space CAMP is developing a platform called Gravity which will give all onboarded tools a continuous authority to operate (C-ATO). Once DRAGON Army tools are onboarded to Gravity, they can be deployed into high-side (or classified) environments. Classified data combined with commercial data flow into DRAGON Army tools could augment high-side operations. Other, future work could include integration with Department of Commerce's Office of Space Commerce, Space Training and Readiness Command STARCOM, and the Tools, Applications & Processing (TAP) Lab.

7. REFERENCES

[1] Sprint Advanced Concept Training (SACT): A renaissance in collaborative international space operations. (n.d.). https://amostech.com/TechnicalPapers/2020/SSA-SDA/Gerber.pdf