SpaceOps-2023, ID #675

Spacecraft Safety Made Stronger: Taking the Space Data Center to the Next Level

Oltrogge, D.L.[a]*, Hall, R.A.[b], Nath, A.[c], Rossetto, Erika A. de Souza[d]

[a] *Chief Scientist and SDC Program Manager, Center for Space Standards and Innovation, COMSPOC Corporation, 124 Valley Creek Blvd., Suite 130, Exton, PA, 19341, dan@comspoc.com*

[b] *Operations Manager, Space Data Center, COMSPOC Corporation, 124 Valley Creek Blvd., Suite 130, Exton, PA, 19341, rah@comspoc.com*

[c] *Senior Advisory Software Developer, COMSPOC Corporation, 124 Valley Creek Blvd., Suite 130, Exton, PA, 19341, anath@comspoc.com*

[d] *Flight Dynamics Manager, Claro Corporation, Ave Presidente Vargas 1.012 Fl 6, Rio de Janeiro, Rio de Janeiro, 20000-000, Brazil, ERIKA.ROSSETTO@embratel.com.br*

* Corresponding Author

Abstract

The Space Data Association (SDA) has been providing reliable flight safety products for approximately 30 spacecraft operators for 12 years. The service provides conjunction warnings and operator points of contact for 786 spacecraft (513 spacecraft in LEO and MEO, and 273 spacecraft in GEO)[1]. The SDA's Space Data Center (SDC), built by Analytical Graphics Incorporated (AGI) and maintained and operated by COMSPOC Corporation, has a proven track record of providing high availability Space Traffic Coordination (STC) products since becoming operational on 15 July 2010. This SDC service pioneered many of the flight safety products and services and notifications that many accept today as foundational to conjunction assessment.

Today, the SDA and COMSPOC are pleased to announce major SDC upgrades to enhance and further strengthen the SDC. The SDC is transitioning over to be computationally hosted on COMSPOC's fully scalable SSA Software Suite (SSA Suite). Within the SSA Suite framework, the new SDC offers state-of-the-art conjunction assessment, single-stage screening against best available positional products, synthetic covariance generation and ingest, estimated actual collision probability and risk evaluations, the use of estimated space object sizes, and optional abilities to generate HiDeph ephemerides for SDA member spacecraft using native orbit determination capabilities.

Keywords: Space Data Association, Conjunction Assessment, Collaborative Flight Safety, Data Lake

Acronyms/Abbreviations

Analytical Graphics Incorporated (AGI)
High-Definition Ephemeris (HiDeph)
Special Perturbations/numerical integration (SP)
Space Data Association (SDA)
Space Data Center (SDC)
Space Traffic Coordination (STC)
SSA Software Suite (SSA Suite)
Two-Line Element or semi-analytic theory propagation (TLE)

1. Introduction

Formed in 2009, the Space Data Association (SDA) is a formal, non-profit association of civil, commercial, and military spacecraft operators that supports the controlled, reliable, and efficient sharing of data that is critical to the safety and integrity of satellite operations. The SDA has a legal structure and agreements that provide protections and enforcement mechanisms to ensure data is only used for intended purposes.

SDA has operators from different parts of globe, and the SDA and its participating operators are frequently in contact with a wide variety of organizations to discuss space safety. In 2021, SDA established an annual award (the T.S Kelso Award for Space Safety) to recognize and promote people who have made substantial contribution to space safety.

2. Material and methods

The SDA relies on its Space Data Center (SDC), operated by COMSPOC Corporation, for flight safety data exchange and processing. The SDC is reliable, geographically redundant, and secure. This SDC service pioneered many of the flight safety products and services, notifications, and traits that are now widely accepted as baseline requirements for capable conjunction assessment and STC, to include computationally and legally secure frameworks and format-agnostic ingest of operator data with machine-to-machine interfaces and verified data normalization converters. Since inception, it has provided an operator phonebook that is sufficiently granular by area of responsibility, location, and management level to allow operators to communicate efficiently. The SDC's extensive use of comparative SSA for ongoing quality control and to identify discrepancies allows SDC analysts to communicate regularly with both government and commercial SSA centers as well as spacecraft operators to alert them of any observed discrepancies and/or high-risk collision threats.

The SDC has provided reliable flight safety products for more than 12 years. The 32 global space operators participating in the SDC today operate spacecraft spanning all orbital regimes, form factors and mission types. Safety-of-Flight analyses are currently performed for 736 spacecraft (450 spacecraft in LEO and MEO, and 286 spacecraft in GEO). The SDC's innate ability to "crowd-source" space data from spacecraft operators and merge that with accurate space debris catalogs from the U.S. Air Force's space catalog has allowed the SDC to generate decision-quality STC analytics, serve as a distribution hub for space data, be a focal point for comparative SSA and quality control, and provide high-availability SSA and STC services. Originally built by AGI and now owned and operated by COMSPOC Corporation, the SDC has a proven track record of providing high availability STC products since becoming operational on 15 July 2010. The SDA has also constantly worked to support its participating operator community to address any operational issues and analyze collision threats. Technical and general SDA community meetings are held to share and promote space safety and sustainability approaches and concepts, discuss the equitable use of space. A number of satellite operators have provided positive feedback that this active SDA-hosted interaction makes the SDA unique and valuable.

Data sharing (when authorized by the operators) has allowed the SDC to be one of the largest contributors of space data from multiple operators to entities such as the 18SPCS. Behind-the-firewall SSA and STC processing ensures that operator-proprietary data is analyzed without unauthorized data release.

A foundational realization from this decade of SDC lessons learned is that rather than continuing to ask our community's long-standing question, "Is my SSA data better than yours," the SDC system acknowledges that the correct response is "neither" and embodies the notion that decision-quality SSA and STM are only achievable using advanced algorithms, assured processing and the aggregation and fusion of all-source data.

Asked at the ten-year anniversary how true long-term sustainability of space activities can be achieved, Pascal Wauthier, then Executive Director of SDA, stated that there are 4 required components based upon SDA/SDC lessons learned to date [1]:

1. Flight safety derives from the comprehensive aggregation of massive amounts of observations, data, environment, statistics, and risk assessment, and advanced analytics.
    a. We anticipate dramatic increases in the amount of information to be processed due to following two key changes:
        i. New Space's large constellations.
        ii. Improved SSA sensors and enlarged space catalog.
2. Data exchange will become increasingly important as the number of operational spacecraft dominate the known debris population.
3. Government SSA and STM initiatives should learn about the SDC system and its operational concept.
4. The need to mitigate LEO collision risk will continue to increase in importance as:
    a. De-orbit and disposal mandates are increasingly enforced.
    b. Satellite reliability requirements struggle to maintain pace with large constellation satellite failures.
    c. LEO satellites and CubeSats are required to have effective and timely collision avoidance maneuvering capabilities.

2.1 Major SDC Upgrade

Today, well-aligned with furthering goals (1) and (2) listed above, the SDA and COMSPOC are pleased to announce the first major SDC upgrade to enhance and further strengthen the SDC. The current SDC it will replace was originally developed from 2008 through 2010. Apart from a transition from physical hosting to a cloud environment in 2014, the SDC has not changed substantially since it was first developed. The SDC has stood the test of time from robustness, availability, and security standpoints, but it was not developed with New Space and large constellations in mind.

3. Theory and calculation

3.1 Current SDC operational framework

The currently operational SDC framework is depicted in Figure 1 . Note that all operator, SSN, and CelesTrak data are ingested directly into the SDC, where all computations take place and operators use multi-factor authentication to access, view, and interact with the SDC's database. The current SDC performs Conjunction Assessment (CA) screening using both TLEs (as a primary or "single-stage" screening mode) and SP screening/refinement (as a two-stage screening).

Each operator is free to define how often they will receive close approach notifications from the SDC, what screening threshold distances are applied, what distribution list to use, and several other customization settings to control the user/customer experience.

However, SDA requires that each operator shares their predicted ephemeris including future maneuver plans spanning the next 7 days. Members are also strongly advised to update the ephemeris as often as they can (at least daily), share their planned maneuvers as a separate product, and use the machine-to-machine REST services to automate the regular sharing of this information.

The operator can also receive analyses for collocated satellites (sharing the same longitude slot). In this case, if both of satellites are in SDC database, ephemeris provided by the operator will be used as the primary basis for the assessment.

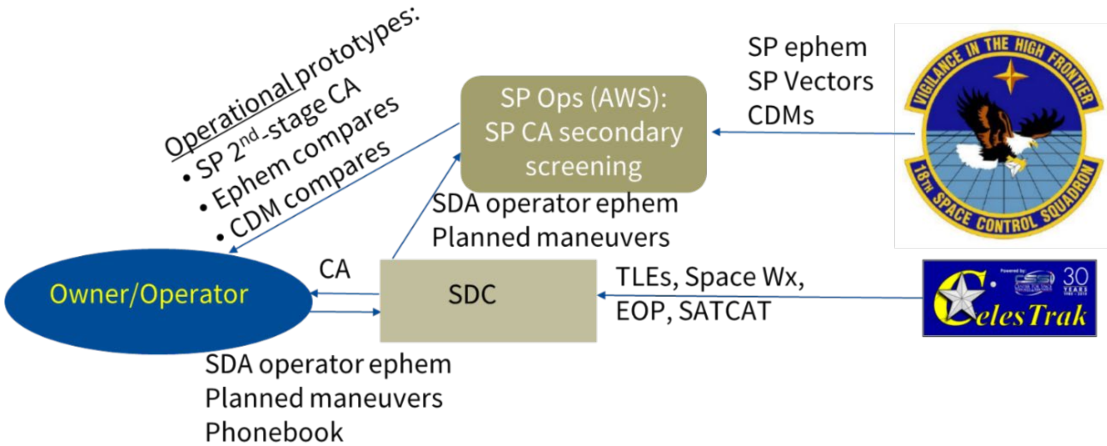

Figure 1: Today's SDC 1.0 framework.

3.2 Transition Phase 1: COMSPOC operational framework implemented in parallel to current SDC system

In the first SDC enhancement phase, COMSPOC's SSA Suite system serves as the primary computational CA analytics platform as shown in Figure 2. The COMSPOC SSA Suite system offers more than 99.95% availability with planned maintenance of ~ 3 hours every few months. In this first phase of the transition, the SDC becomes the front end that feeds its operator data to the COMSPOC SSA Suite system for CA computations and analytics. Note that the initial operational capability of the COMSPOC SSA Suite bypass implementation will initially be operated in shadow mode to ensure that the current SDC and the SSA Suite are producing consistent results and high availability.

This phase prioritizes hierarchical (waterfall) preferential use of positional data (e.g., operator ephemerides, then SP, then TLE), eliminates the two-stage SP screening of the current SDC, retires the old SDC analysis system and code base, and allows the computation of true collision probability based upon both spacecraft operator and DISCOS-based object sizes and precision-derived covariance information. Discrepancies between operator predictive ephemerides, SP ephemerides, and TLEs are monitored to help identify problems.

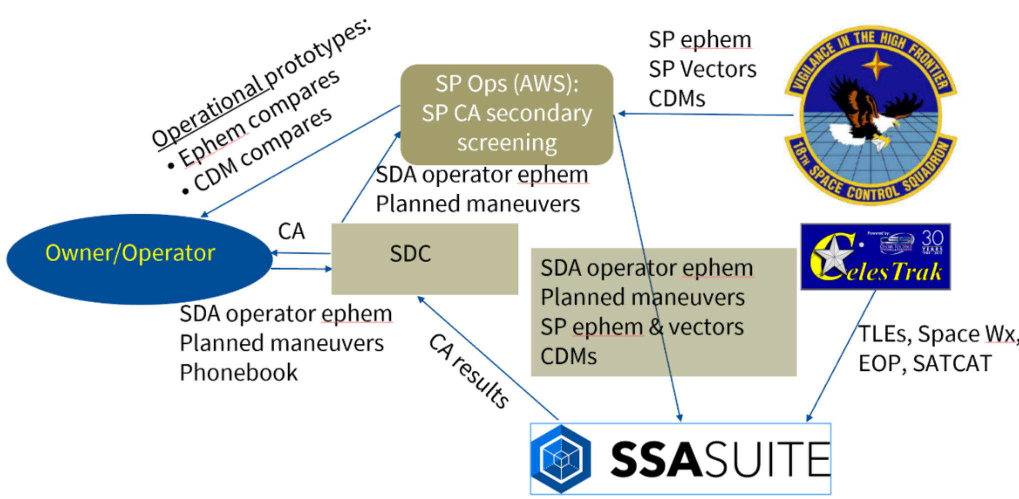

Figure 2: Phase 1: Transition to hybrid SDC front end with back-end CA processing done in SSA Suite.

The SDC's User Interface (UI) and web responsiveness also received major upgrades in this first enhancement phase.

3.3 Transition Phase 2: COMSPOC SSA Suite full replacement of current SDC computational framework

Upon completion of Transition Phase 1 and shadow-mode testing, verification, and certification of the new SSA Suite framework, the old SDC computational framework will be retired as shown in Figure 3.

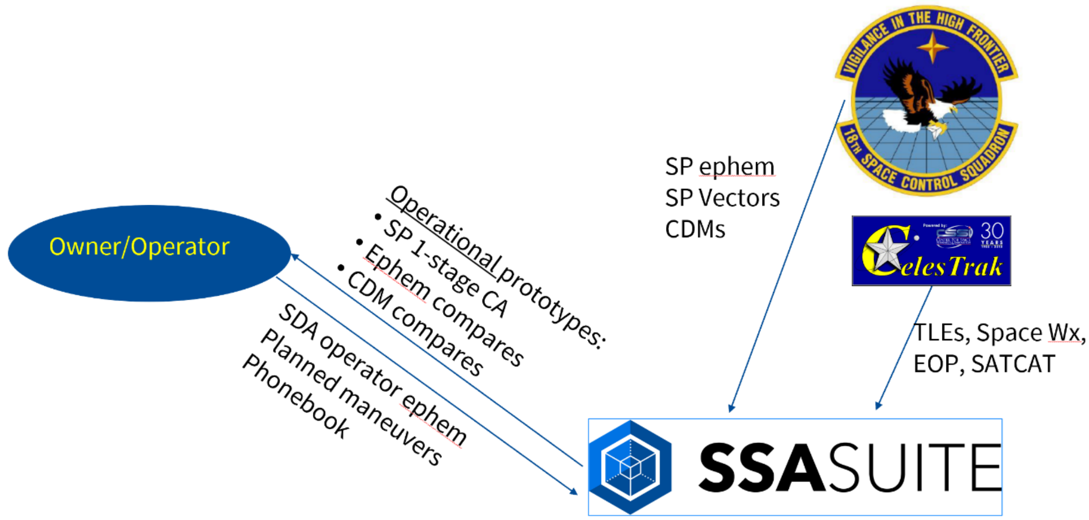

Figure 3: Phase 2: Full COMSPOC replacement of SDC 1.0 framework.

Upon completion of Transition Phase 2, the SDC is transitioning over to be computationally hosted on COMSPOC's fully scalable SSA Software Suite (SSA Suite). Within the SSA Suite framework, the new SDC provides scalable, state-of-the-art conjunction assessment, single-stage screening against best available positional products, synthetic covariance generation and ingest, estimated actual collision probability and risk evaluations, the use of estimated space object sizes, and optional enhanced capabilities to fuse multi-source observations and planned maneuvers to generate HiDeph ephemerides for SDA member spacecraft using native orbit determination capabilities.

Table 1 highlights SDC functional areas and compares the present capability with our current transition activities as well as capabilities that could rapidly support a USG STM system. In viewing this, we can see that this SDC transition is an evolutionary step towards such a STM prototype.

3.4 Benefits of new system

The new SDC will upgrade the SDC's flight safety services to leverage a decade of continuous research, investment, and development of COMSPOC's SSA Suite system. A key tenet of the SSA Suite is its inherent scalability to accommodate not only current SDA member spacecraft loading, but also large constellations and space object catalogs of much larger size than we currently screen against today. The transition to an SSA Suite foundation also provides the SDA customer with the benefit of COMSPOC's continuous improvement and enhancement efforts (versus a static SDC architecture). Single-stage screening using the best positional knowledge pairings can eliminate the generation, transmission, and analysis of duplicate CA results, reducing FDS workload.

In terms of operations, the SSA Suite-based system allows for higher levels of operations support from a broader operations team and knowledge base working with a common tool set in support of the merged

COMSPOC and SDC operations. This may then allow for an expansion to 7-day ops support versus current five-day operations.

Table 1: Capability map for current SDC system (v 1.0) and next generation SDC in COMSPOC.

Capability	SDC 1.0	SDC Generation 2 (SDC in COMSPOC SSA Suite)	Enabling USG STM Prototype
Phonebook	●	●	●
Ephemeris sharing, normalization	●	●	●
TLE-based CA	●	(if SP unavailable)	
2nd-stage SP-based CA refinement	●		
Single-stage SP-based CA		●	●
HiDEph-based CA			●
Operator observations			●
COMSPOC SSA observations			●
RF Interference Mitigation			* (Emissions)
Max Probability	●	●	●
True/Actual Probability		●	●
Generation of SP Covariance		●	●
Distribution of Pc values (for SP-based CA)		●	●

✔ =Includes capability; *=Future option

Consolidation of the code bases for the SSA Suite and SDC also allows the merger and harmonization of operations teams to focus on research, development, and operations within a single framework, enabling better agility and responsiveness to future customer needs.

3.5 Proposed phased implementation approach and schedule.

The SDC's transition over to an SSA Suite-based framework is occurring using a phased implementation approach designed to minimize the impact to SDC's ongoing operations and services as shown in

Table 2: Phases of SDC transition over to SSA Suite framework.

Phase	Description	Target Date
I	SDC Conjunction Assessment and SDC UI to SSA Suite	15 Mar 2023
II	Synthetic covariances for SP, actual estimated Pc, Pc CDFs	15 May 2023

III	Transition from original SDC M2M interface to COMSPOC SSA services portal	15 Jul 2023

4. Results

4.1 SDC User Interface enhancements

The work to enhance and modernize the SDC User Interface (UI) is complete. Substantial upgrades to the SDC's UIs and database responsiveness have been accomplished as listed in Table 3. Associated figures demonstrating these UI features are provided in Annex A and cross-referenced in column 4 of Table 3.Table 1

Table 3: SDC 2.0 UI features and enhancements.

#	Feature	Description	See Annex A figure(s):
1	Grid	Ephemeris and Conjunction page data is displayed in a grid instead of using pagination. Now all the data retrieved is loaded in a grid which is scrollable. The data is also loaded much faster than before. Use up/down arrow keys or page up, page down keys to scroll using keyboard.	Fig. 6
2	Ephemeris Upload Modal	The ephemeris file can be uploaded via the new modal. The modal is like a popup that opens on top of the Ephemeris grid.	Fig. 7
3	Data Retrieve	Data in the grid can be retrieved based on Last 10, 20, 30 days or based on a date range with a maximum range of 6 months.	Fig. 8 - 10
4	Filter Panel	After data is retrieved in grid, the filter panel on left side provides ability to search values in the grid. There are some custom filter dropdowns also available.	Fig. 11
5	Column Sorting	The columns in the grid can be sorted by clicking the column header. They can be sorted by ascending or descending order. Multi-column sort can also be done by Shift + Click of column headers.	Fig. 12 - 13
6	Column Filter	A column filter is also available on each column of the grid.	Fig. 14 - 16
7	Grid Refresh	The filter panel has a Refresh button that can refresh the grid without having to reload the page.	Fig. 16

4.2 Application of SDA framework to support U.S. Department of Commerce (DOC) Pilot

SDA and COMSPOC infrastructures were utilized to provide positional knowledge on a set of 100 active spacecraft spanning 13 operators as shown in Table 4 to support the U.S. DOC's Pilot STM project. These infrastructures drew upon recent SDC and SSA Suite enhancements to comprehensively fuse multi-source observations (from spacecraft operators, commercial SSA data providers, and 3rd-party GNSS data) in keeping with the SDA goal to promote and enable crowdsourcing and fusion of diverse datasets to achieve actionable flight safety products.

Table 4: SDA/COMSPOC team delivered both reconstructed and 10-day predict ephemerides and maneuver plans for most of the selected 100 active spacecraft.

Sat #	Operator	Sat Name	SSC	SDA Participant
1	Avanti	Hylas 1	37237	●
2	Avanti	Hylas 2	38741	●
3	Claro (Embratel Star One)	Star One C2	32768	●
4	Claro (Embratel Star One)	Star One C3	38991	●
5	Claro (Embratel Star One)	Star One C4	40733	●
6	Claro (Embratel Star One)	Star One D1	41904	●
7	Claro (Embratel Star One)	Star One D2	49055	●
8	Eutelsat	Eutelsat 115 WEST B	40425	●
9	Eutelsat	Eutelsat 117 WEST B	41589	●
10	Eutelsat	Eutelsat 174A	28924	●
11	Eutelsat	Eutelsat 65 WEST A	41382	●
12	Eutelsat	Eutelsat 7 WEST A	37816	●
13	Eutelsat	Eutelsat 70B	39020	●
14	Eutelsat	Eutelsat 7B	39163	●
15	Eutelsat	Eutelsat 7C	44334	●
16	Eutelsat	Eutelsat 8 WEST B	40875	●
17	Eutelsat	Eutelsat HOTBIRD 13B	29270	●
18	Eutelsat	Eutelsat HOTBIRD 13C	33459	●
19	Eutelsat	Eutelsat HOTBIRD 13E	28946	●
20	Eutelsat	Eutelsat KONNECT	45027	●
21	Eutelsat	Eutelsat QUANTUM	49056	●
22	Japan	QZS-3 (MICHIBIKI-3)	42917	
23	Inmarsat	INMARSAT 3-F1	23839	●
24	Inmarsat	INMARSAT 3-F2	24307	●
25	Inmarsat	INMARSAT 3-F3	24674	●
26	Inmarsat	INMARSAT 4-F1	28628	●
27	Inmarsat	INMARSAT 4-F3	33278	●
28	Inmarsat	INMARSAT 5-F2	40384	●
29	Inmarsat	INMARSAT 5-F4	42698	●
30	Intelsat	ASIASTAR	26107	●
31	Intelsat	DIRECTV 8	28659	●
32	Intelsat	DIRECTV 9S	29494	●
33	Intelsat	GALAXY 11 (G-11)	26038	●
34	Intelsat	GALAXY 12 (G-12)	27715	●
35	Intelsat	GALAXY 14 (G-14)	28790	●
36	Intelsat	GALAXY 15 (G-15)	28884	●
37	Intelsat	GALAXY 16 (G-16)	29236	●
38	Intelsat	GALAXY 19 (G-19)	33376	●
39	Intelsat	GALAXY 30 (G-30)	46114	●
40	Intelsat	HORIZONS-3E	43633	●
41	Intelsat	INTELSAT 15 (IS-15)	36106	●
42	Intelsat	INTELSAT 16 (IS-16)	36397	●
43	Intelsat	INTELSAT 17 (IS-17)	37238	●
44	Intelsat	INTELSAT 18 (IS-18)	37834	●
45	Intelsat	INTELSAT 19 (IS-19)	38356	●
46	Intelsat	INTELSAT 22 (IS-22)	38098	●
47	Intelsat	INTELSAT 30 (IS-30)	40271	●
48	Intelsat	INTELSAT 31 (IS-31)	41581	●
49	Intelsat	INTELSAT 33E (IS-33E)	41748	●
50	NOAA	GOES 16	41866	●
51	NOAA	GOES 17	43226	●
52	PRC	BEIDOU 16	38953	
53	PRC	BEIDOU 3	36287	
54	PRC	BEIDOU-2 G7	41586	
55	SES	AMC-1 (GE-1)	24315	●
56	SES	AMC-15	28446	●

57	SES	AMC-21	33275	●
58	SES	AMC-3 (GE-3)	24936	●
59	SES	ASTRA 1G	25071	●
60	SES	ASTRA 1KR	29055	●
61	SES	ASTRA 1L	31306	●
62	SES	ASTRA 1M	33436	●
63	SES	ASTRA 1N	37775	●
64	SES	ASTRA 2A	25462	●
65	SES	ASTRA 2F	38778	●
66	SES	ASTRA 2G	40364	●
67	SES	NSS-7	27414	●
68	SES	NSS-9	33749	●
69	SES	O3B FM13	43234	●
70	SES	O3B FM14	43233	●
71	SES	O3B FM15	43231	●
72	SES	O3B FM16	43232	●
73	SES	O3B FM17	44114	●
74	SES	O3B FM18	44115	●
75	SES	O3B FM19	44113	●
76	SES	O3B FM2	39190	●
77	SES	O3B FM20	44112	●
78	SES	O3B FM4	39189	●
79	SES	O3B FM5	39188	●
80	SES	O3B PFM	39191	●
81	SES	QUETZSAT 1	37826	●
82	SES	SES-1	36516	●
83	SES	SES-11 (ECHOSTAR 105)	42967	●
84	SES	SES-15	42709	●
85	SES	SES-2	37809	●
86	SES	SES-3	37748	●
87	Space Logistics	MEV-1 (901)	#N/A	●
88	Space Logistics	MEV-2 (10-02)	#N/A	●
89	Telesat	AMSC 1	23553	●
90	Telesat	Anik F1R	28868	●
91	Telesat	Anik G1	39127	●
92	Telesat	TELSTAR 18V (APSTAR 5C)	43611	●
93	US	NAVSTAR 57 (USA 183)	28874	
94	US	NAVSTAR 58 (USA 190)	29486	
95	US	NAVSTAR 60 (USA 196)	32260	
96	US	NAVSTAR 61 (USA 199)	32384	
97	US	NAVSTAR 62 (USA 201)	32711	
98	US	NAVSTAR 69 (USA 248)	39533	
99	ViaSat	Viasat-2	42740	●
100	ViaSat	WildBlue-1	29643	●

Data fusion and track processing achieved for these 100 space objects is shown in Figure 4. "Box" symbols located in the "Processed Tracks" column indicate that spacecraft owner/operator (O/O) tracking observations are being ingested by the SSA Suite and data fusion is accomplished in the Orbit Determination (OD) process. As noted in the header, the absence of a symbol in the "Upcoming Maneuvers" box does not indicate that we aren't incorporating maneuvers into the solution, but rather that during the time period in question, it can also indicate that the operator did not plan any maneuvers.

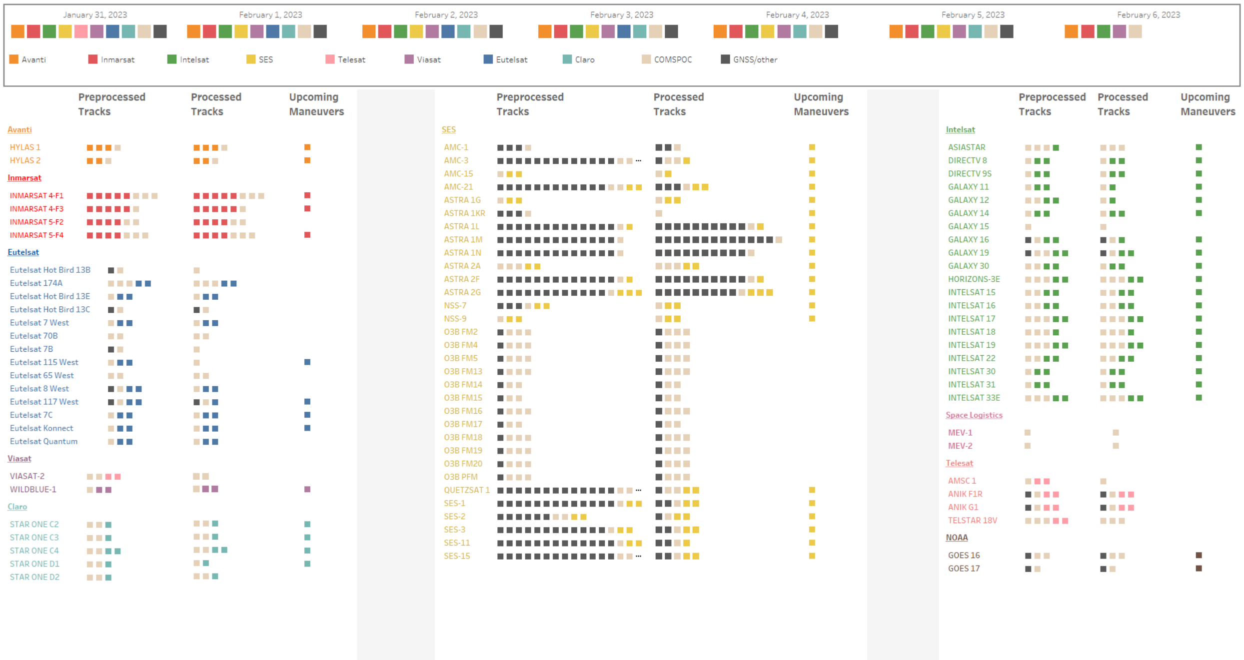

Figure 4: Satellite-specific data fusion achievements in the DOC Pilot project.

4.3 Asteroid 2023 BU screening for SDA Participants

Though a rare event, the passage of asteroids through the Earth's spacecraft protected regions occasionally does occur and satellite operators are naturally concerned about the risk of collision with their spacecraft. Using ephemeris obtained from the Minor Planet Center [2], we determined that the passage of Asteroid 2023 BU occurred at a radius of 9420 km with a corresponding closest height above the Earth's surface of only 3,048 km on 27 Jan. at 00:33:20 UTC, making it the 4th closest recorded asteroid passage (excluding those – five – discovered just before their impact)[3]. Were a collision to occur, average closing velocity with an Earth-orbiting space object is estimated to range from 5 to 15.2 km/s.

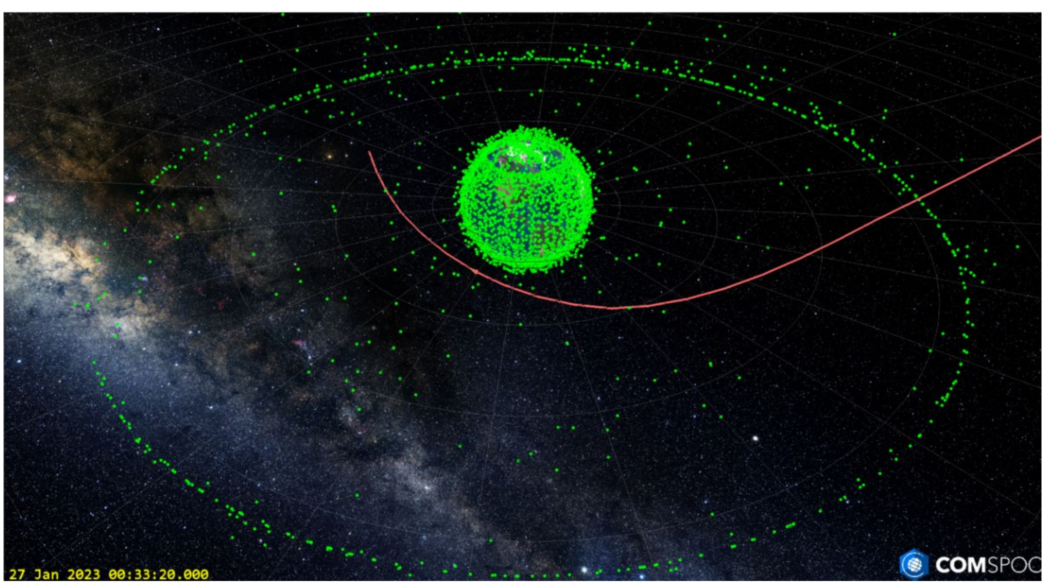

Figure 5: Asteroid 2023 BU transit through the global active spacecraft population

The SDC analysis team obtained an orbit ephemeris for Asteroid 2023 BU for a two-day timespan surrounding this transit event. As shown in the figure below, Asteroid 2023 BU passed well within the geosynchronous belt but fortunately travelled through a relatively unoccupied portion of the active spacecraft population as depicted by the green dots. The SDC Team determined that the asteroid did not pose a threat to those spacecraft participating in the SDA.

5. Conclusions

The SDA and COMSPOC Corporation are collaboratively continuing to improve flight safety for the global space community. The transition of the SDC from its original native CA analysis infrastructure to one based upon the COMSPOC SSA Suite will yield valuable scalability, maintainability, accuracy, and capability enhancements to help the SDC retain its world leading conjunction assessment capability based upon comprehensive data sharing and best-of-breed data hierarchies.

Acknowledgements

COMSPOC Corporation and SDA would like to thank the operators who support and promote this important flight safety work.

References

[1] Wauthier, P., "Operations Impact of SDA/SDC Services: AGI's Contribution to STCM thru a Decade of Safety of Flight Services," AMOS Webinar, 3 Sep 2020.

[2] International Astronomical Union Minor Planet Center, https://www.minorplanetcenter.net/ , accessed 26 Jan. 2023.

[3] "Near-Earth Asteroid 2023 BU extremely close encounter: image, video, and podcast – 26 Jan. 2023," The Virtual Telescope Project 2.0, https://www.virtualtelescope.eu/2023/01/27/near-earth-asteroid-2023-bu-extremely-close-encounter-image-video-and-podcast-26-jan-2023/ (accessed 29.01.23).

17th International Conference on Space Operations, Dubai, United Arab Emirates, 6 - 10 March 2023.

Annex A: SDC 2.0 UI Features

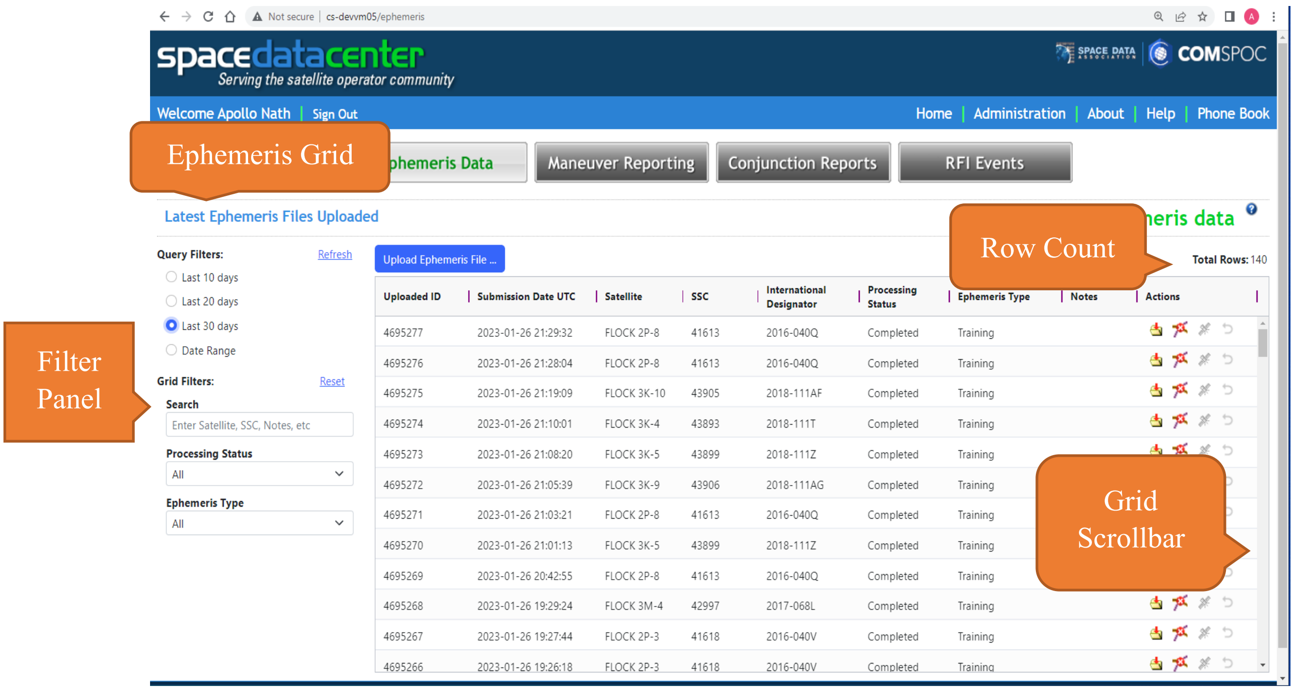

Figure 6: SDC 2.0 capability to grid filter on specific column

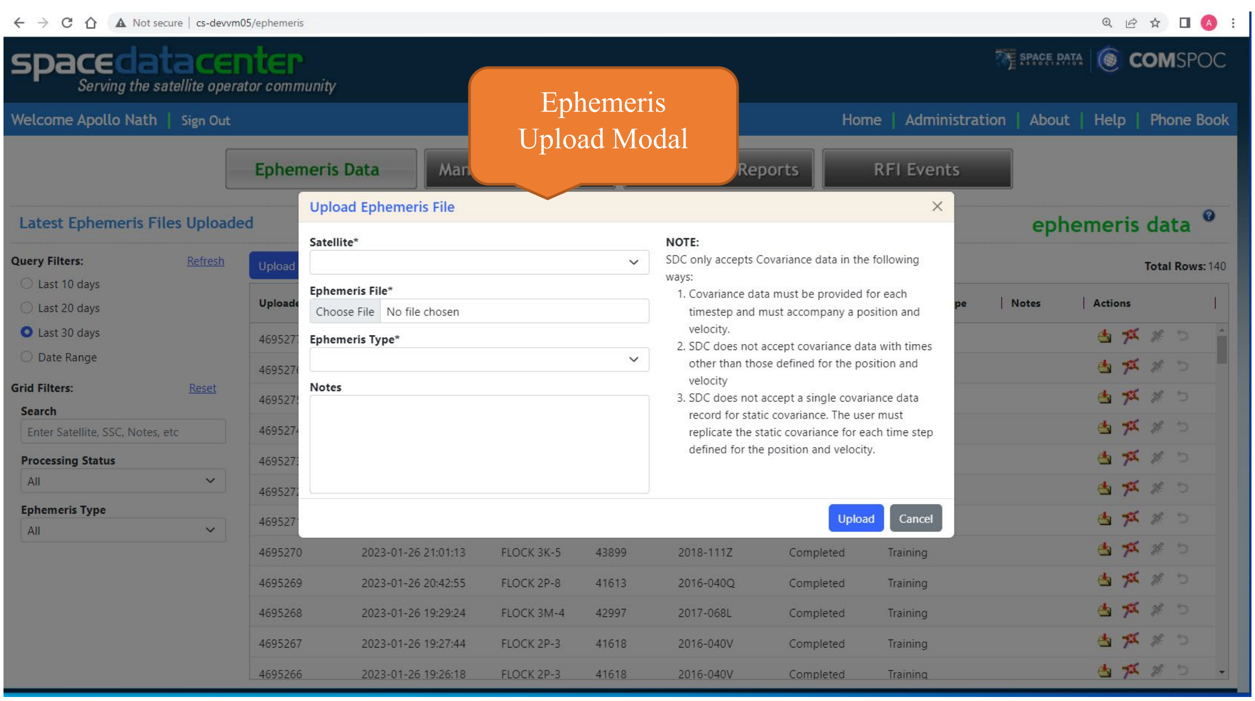

Figure 7: SDC 2.0 Ephemeris File Upload Modal

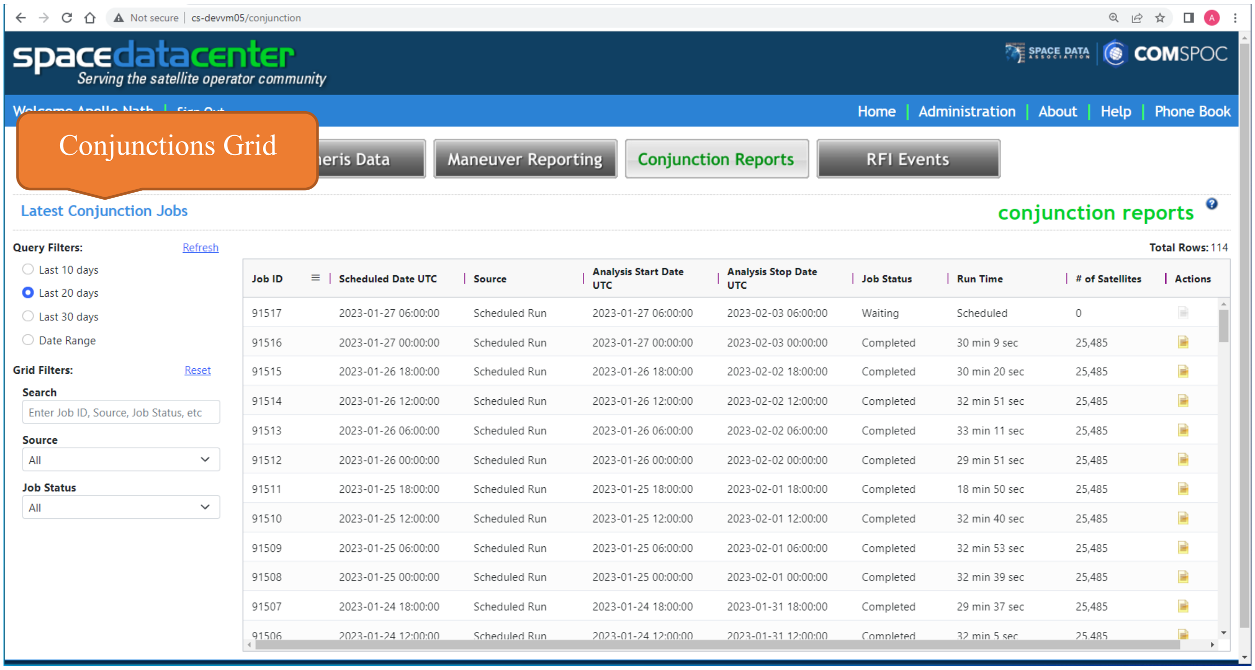

Figure 8: SDC 2.0 Main Conjunction page with Grid Layout

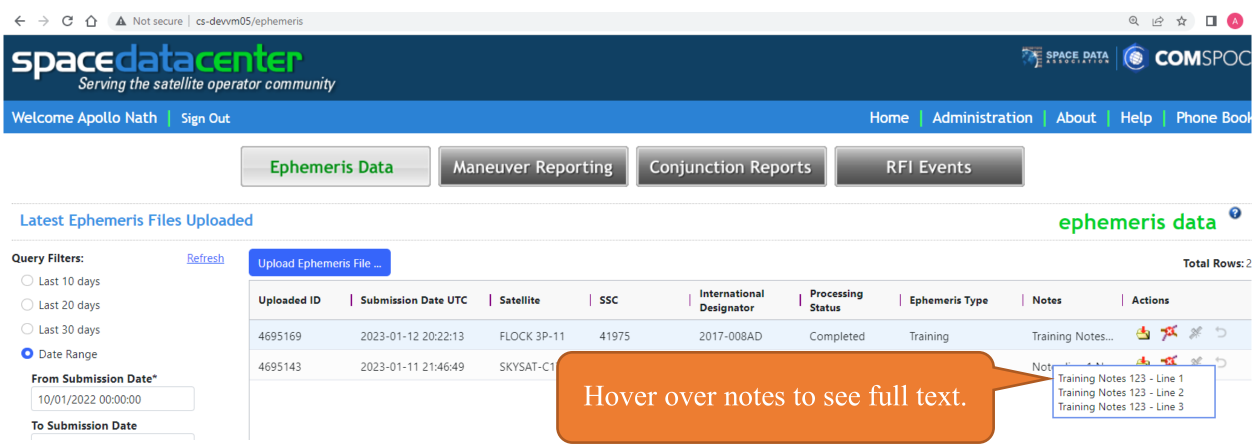

Figure 9: SDC 2.0 Ephemeris Notes Tooltip

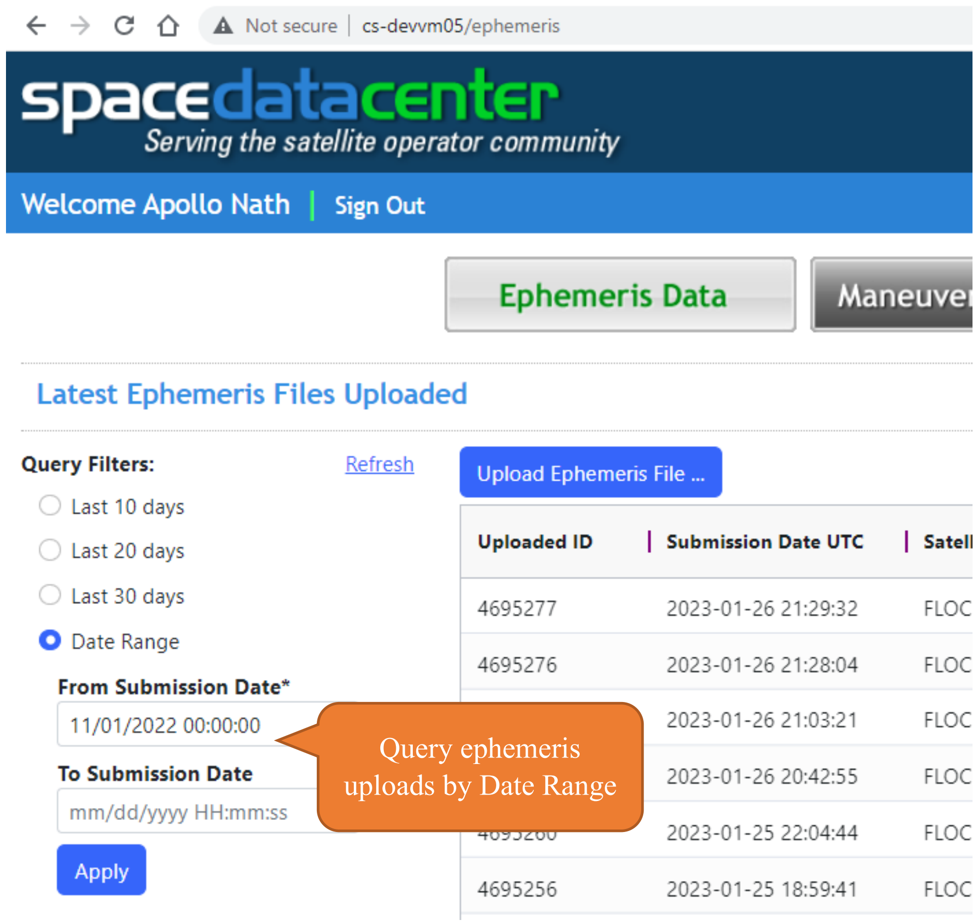

Figure 10: SDC 2.0 Query by Date Range

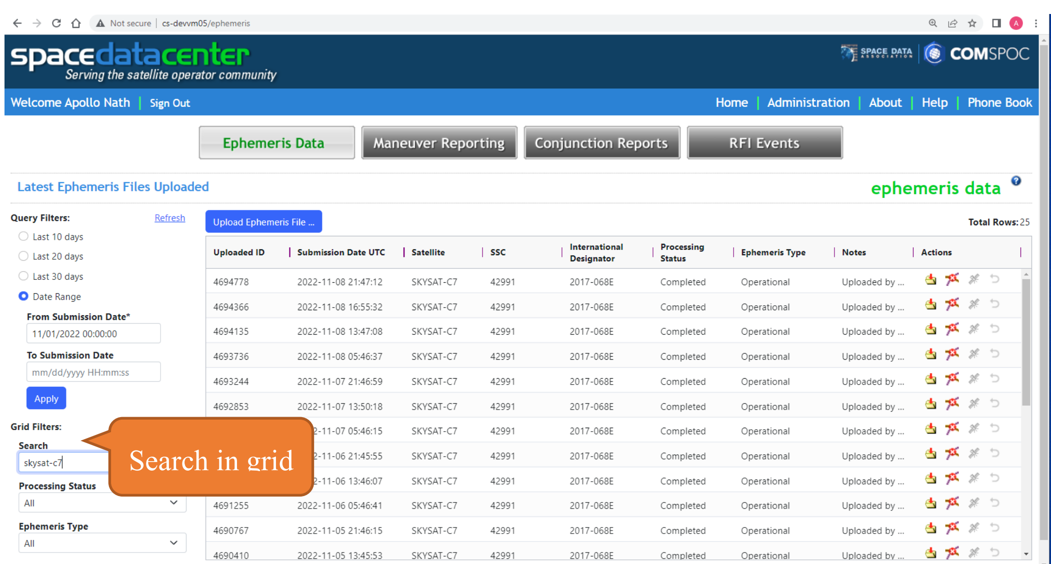

Figure 11: SDC 2.0 Filter Panel with Search capability in Grid

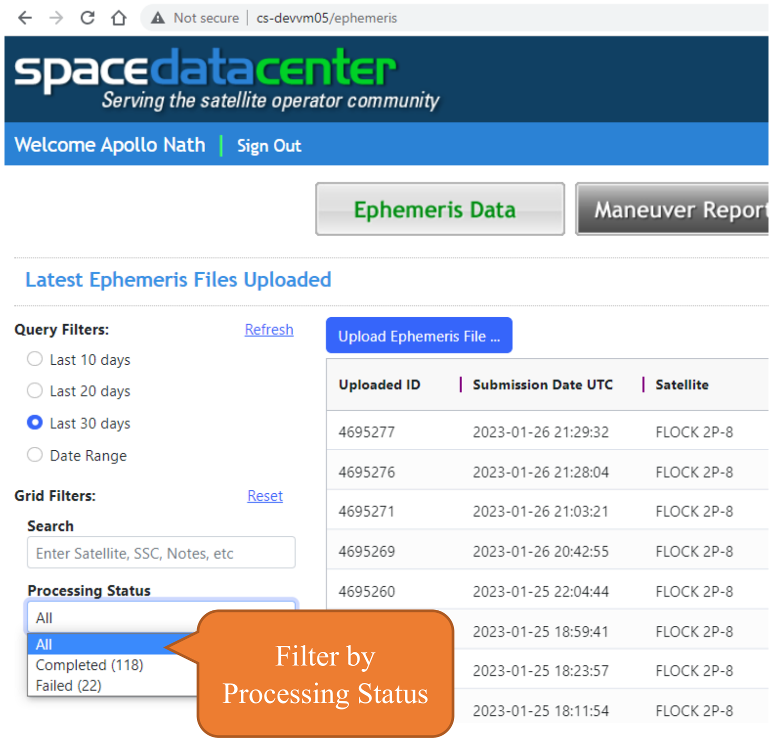

Figure 12: SDC 2.0 Filter Dropdown on Processing Status

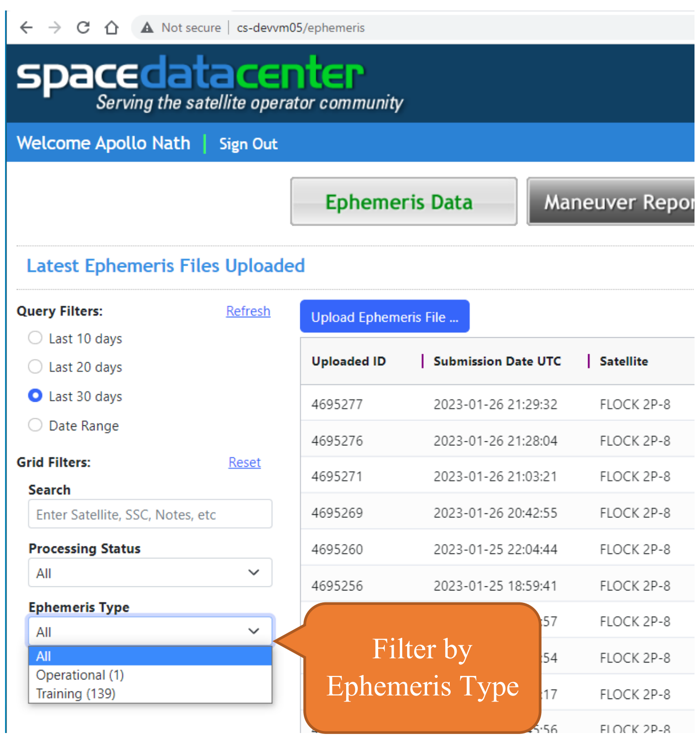

Figure 13: SDC 2.0 Filter Dropdown on Ephemeris Type

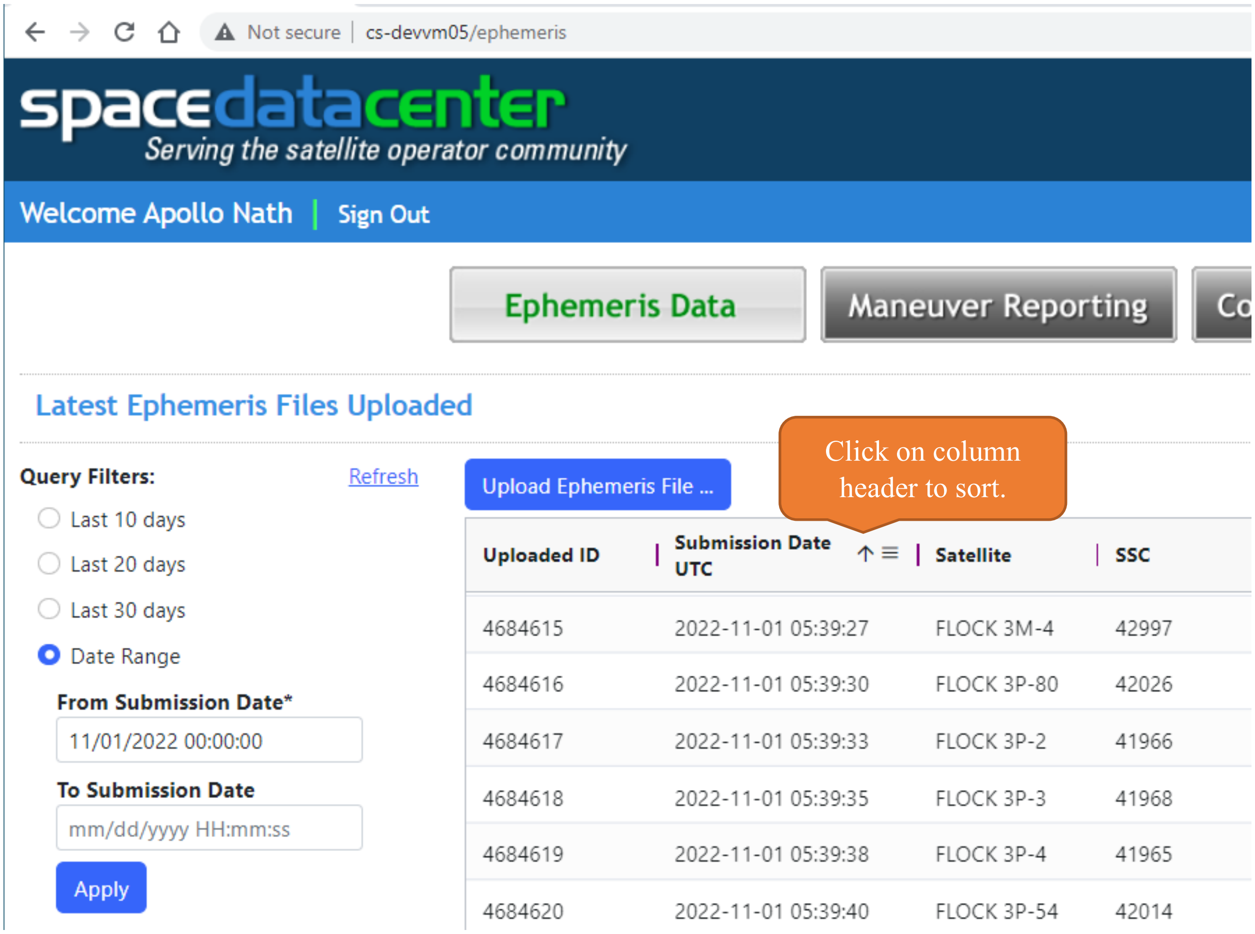

Figure 14: SDC 2.0 Grid Column Sort

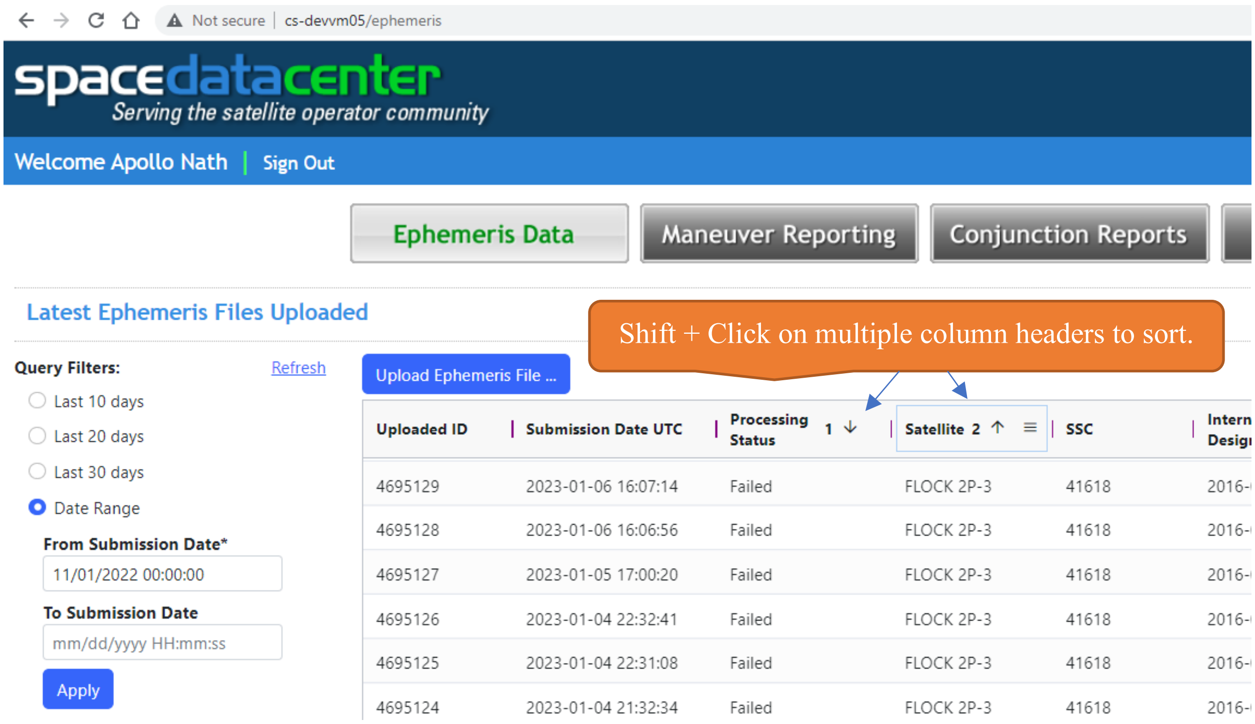

Figure 15: Grid Multi Column Sort

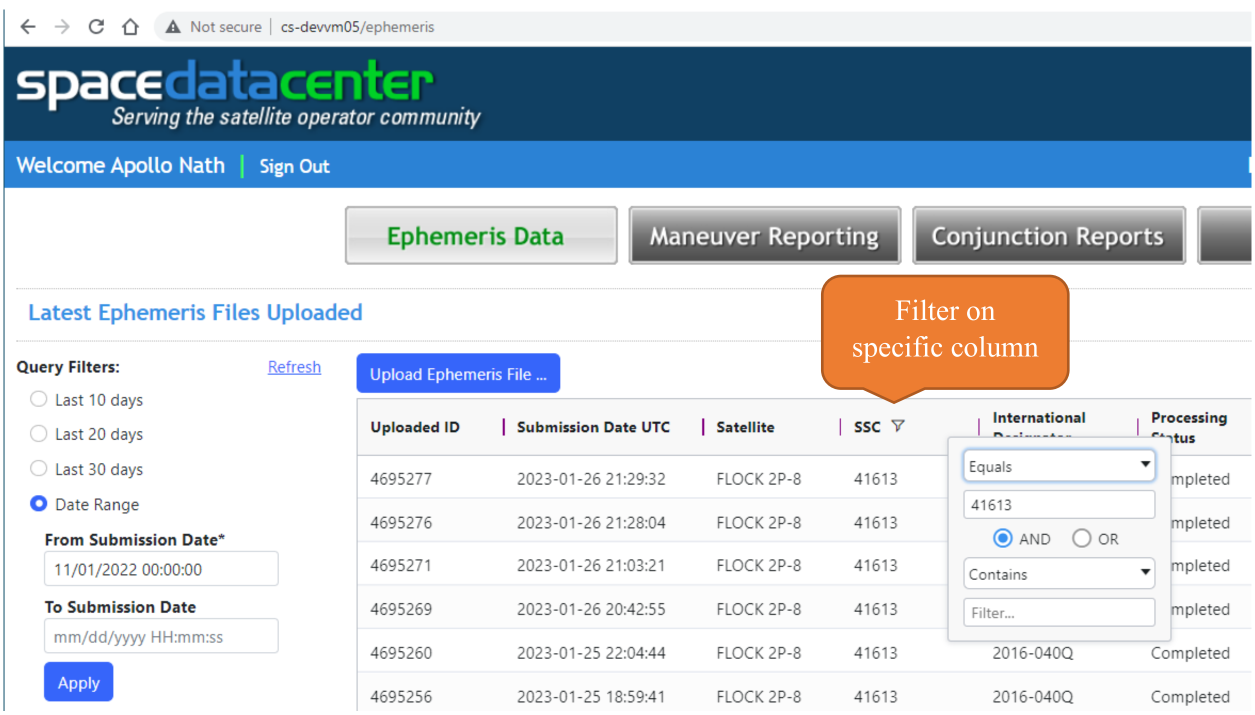

Figure 16: SDC 2.0 Grid Filter on specific column