Space Debris Mapping Services for use by LEO Satellite Operators

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ABSTRACT

Space situational awareness (SSA) is key to mission success for satellites operating across all orbital regimes. Current operators generally rely on government owned radars and services to provide conjunction data messages (CDMs) in order to perform conjunction assessment (CA) and protect their assets. These current services are limited in their transparency, timeliness, and machine-to-machine interactivity with an operator's CA system. However, new technology has been developed for operators with satellites in low earth orbit (LEO) which supplements existing services. Commercial space debris mapping services have the ability to provide operators with up-to-date information about any object currently tracked by their privately owned phased array radars. One of the many advantages of these new services is the ability for an operator to send requests and receive information about space objects without the need for human feedback loops, which can take hours or even days. By eliminating this need, operators can acquire accurate and timely information about a given space object, such as tracking data and ephemerides, providing the information necessary to confirm or deny the need for a collision avoidance (COLA) maneuver. Here we show, using real data and examples, the effects of space debris mapping services and their contribution to safe, responsible spaceflight operations in LEO.

1. INTRODUCTION

Since the start of the space age in the late 1950s, humans have been launching objects into space for military, commercial, and scientific purposes. With plenty of space above our skies, each unique mission has placed satellites into orbits suitable for their individual mission. Over the years, space has become crowded with thousands of payloads, along with the platforms used to support the payloads while being placed into orbit, the bodies of the rockets used to hurl the platforms and payloads into orbit, and finally the debris when parts are inadvertently separated from the payloads, platforms, or rocket bodies. Today, the United States Space Surveillance Network (SSN) is used by the Joint Space Operations Center[1] (JSpOC) for space object identification and tracking. The JSpOC maintains a catalog of space objects larger than 10 cm in Earth orbit and publishes that catalog publicly. Fig. 1 shows the trend of published space objects as a function of time.

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[1] As of July 18, 2018, the Joint Space Operations Center (JSpOC) has transitioned to the Combined Space Operations Center (CSpOC) to reflect multi-national collaboration in the space domain. [10]

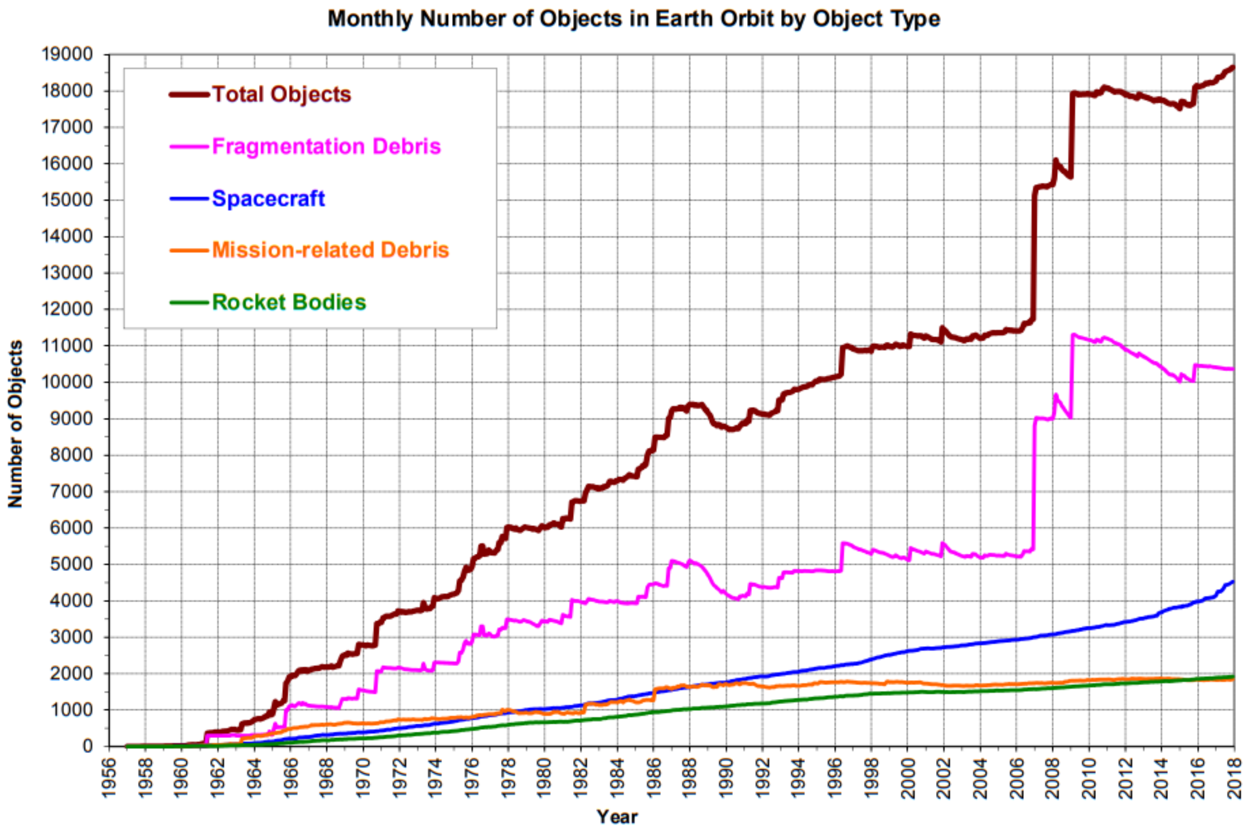


Fig. 1 – Evolution of published space object population and its composition by class. Credit: NASA Orbital Debris Quarterly News, Vol 22, Issue 1, Feb 2018

The number of objects in LEO is increasing at an alarming rate and the growth is only accelerating. This growth can be partially attributed to new, lower-cost launch opportunities and the increasing capabilities of CubeSats. In the coming years, many companies are planning large satellite constellations in LEO, with Table 1 listing only a handful of them. For all satellite operators in LEO, the possibility of collisions between satellites, active or defunct, is a growing concern.

Table 1 – A subset of proposed LEO Satellite Constellations [1][2]

Company	Number of Satellites
SpaceX	11943
Boeing	2956
OneWeb	2720
Hongyan	324
TeleSat	234
Kepler Communications	140

1.1 Space Debris Mapping Service Provider – LeoLabs

LeoLabs was founded to be the commercial provider of high-performance tracking and mapping data for LEO. This data will power a broad range of applications such as protecting satellites from collisions and informing best practices in LEO; tracking satellites immediately after deployment to assist with early operations; troubleshooting malfunctioning satellites by determining if they are tumbling, in a new orbit, or intact; and enabling accurate modeling of on-orbit risks. LeoLabs' mapping platform is designed to be the data layer of the software stack for LEO and these data will support and empower a new wave of application developers bringing new services to market.

LeoLabs operates a worldwide network of radars and the cloud-based software platform that turns this radar data into real-time, actionable information. This information is delivered through a RESTful application programming interface (API) and through web-based dashboards and visualization tools. The API enables full, end-to-end automation and can be integrated easily into custom applications.

As summarized in [3], LeoLabs' currently operates two radars to fuel its data services offerings, one near Fairbanks, Alaska and the other near Midland, Texas. Today, LeoLabs' two radars have visibility to more than 10,000 objects in LEO. These radars track objects at inclinations of 30º and higher, and objects that are 10 cm in size and larger. They are typically able to revisit these objects between 1 and 3 times per day when prioritized. With its two radars, LeoLabs can provide valuable tracking data and resolved state vectors on a subset of LEO objects. Beginning in 2019, LeoLabs will deploy several more radars that will increase the revisit rate to up to ten passes per day, and allow for the detection of small, currently untracked debris. When fully built out, LeoLabs' radar network will deliver the following capabilities which are critical for protecting satellites from debris:

1. Rapid revisits: revisits on most objects every few hours, leading to accurate ephemerides, prompt detection of new debris, and tracking of newly launched satellites;
2. Accuracy and precision: range residuals of better than 15 meters and Doppler uncertainties better than 10 cm/s, leading to ephemerides with typical uncertainties of 10s of meters;
3. Full coverage: measurements of RSOs in all inclinations and up to 2000 km altitude;
4. Small debris data: tracking data on objects as small as a few cm (estimated to be several hundred thousand objects).

LeoLabs' base data product is the dynamic map of LEO: the state (position and velocity) of objects along with uncertainty (covariance) and how those parameters evolve with time. LeoLabs also provides the measurement data (range, Doppler, RCS, etc.) that were used to form the state vectors. LeoLabs' API allows the user to programmatically query for high-precision ephemerides at user-specified time steps, allowing for easy integration into custom analysis tools. LeoLabs provides a number of additional services based on its data feed, including conjunction analysis and screening, which allows operators to screen ephemerides against LeoLabs' catalog for use in collision avoidance and maneuver planning applications. A list of current and planned data services is available on LeoLabs' platform at https://platform.leolabs.space.

2. DIGITALGLOBE CONJUNCTION ASSESSMENT

2.1 DigitalGlobe Constellation

Based in Westminster, Colorado, DigitalGlobe owns and operates the most agile and sophisticated constellation of high-resolution commercial Earth imaging satellites. Together, WorldView-1, GeoEye-1, WorldView-2, WorldView-3 and WorldView-4 are capable of collecting well over one billion square kilometers of quality imagery per year and offering intraday revisits around the globe. These satellites range in altitude from 496 km up to 770 km. Fig. 2 shows the DigitalGlobe constellation with respect to the spatial density of objects in LEO. WorldView-1 (WV01) is in orbit at a relatively low, 496 km altitude with a low spatial density of space objects while WorldView-2 (WV02) is in a much higher, 770 km orbit, which is at the peak of spatial density in LEO. The high density of objects at this altitude is the result of several breakups, one of which was an anti-satellite demonstration in 2007, and another was a collision between two full-size satellites in 2009. Every orbit regime provides unique challenges to operators and space object tracking systems. For example, WV01 is in a low altitude orbit. At this low altitude, there is far less debris in orbit, but the effect of atmospheric drag is significantly more substantial than at higher altitude. This increased drag creates uncertainty in the orbital predictions of tracked debris. As a result, data about the debris orbit may not be actionable, since the uncertainty may be too large to make an informed decision. On the contrary at WV02's high altitude, there exists far more debris in orbit, but the atmospheric drag is almost negligible, making orbital predictions more accurate, and data more actionable.

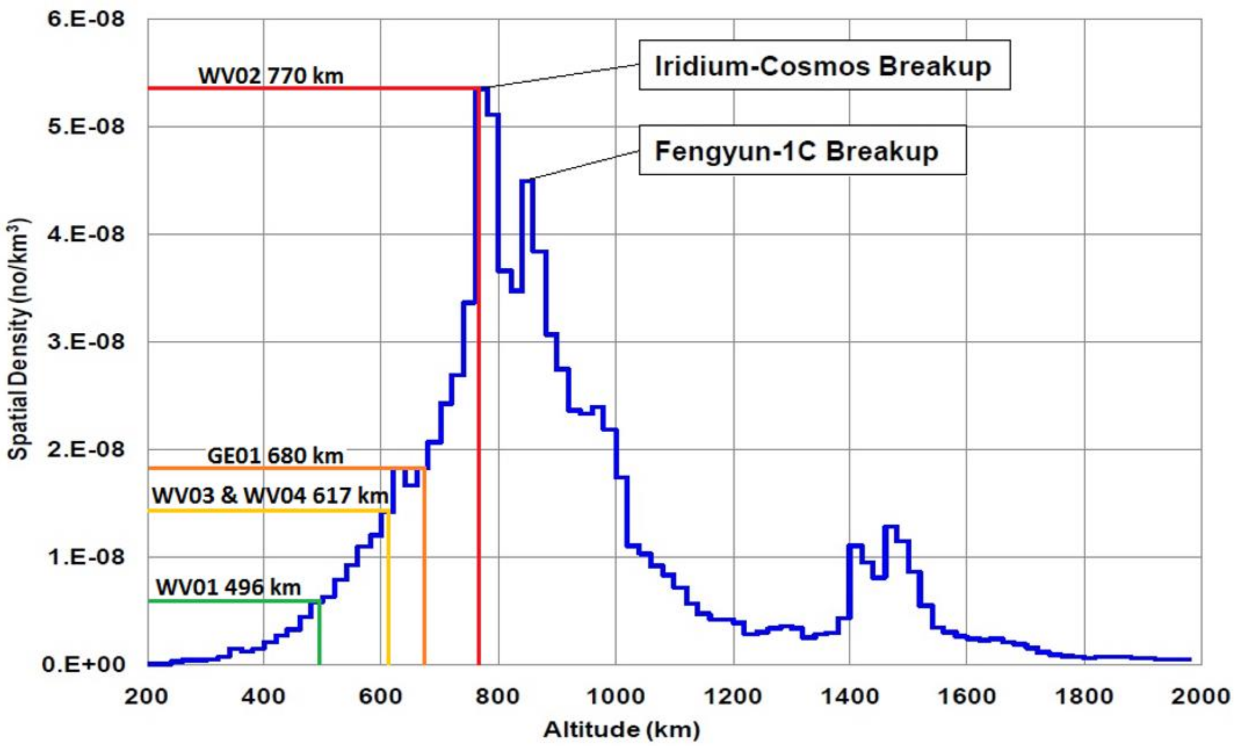


Fig. 2 – Spatial density of cataloged LEO objects in number of objects per km^3 as a function of altitude with DigitalGlobe satellite altitudes indicated.

2.2 Orbit Determination & Prediction

Each of DigitalGlobe's satellites are equipped with GPS modules and propulsion systems. The importance of these systems are often understated by the greater satellite operator community but are essential to safe and responsible spaceflight in LEO. Upon each telemetry downlink from each of DigitalGlobe's satellites, the most recent GPS data is used to perform a precision orbit determination, resulting in a sub-meter accuracy ephemeris providing information about the trajectory of the satellite as well as a drag coefficient tuned to current atmospheric conditions.

From the orbit determination, initial conditions and the tuned drag coefficient are used to seed prediction ephemerides. It is important to note here that all of DigitalGlobe's predicted ephemerides include planned maneuvers, for both collision avoidance (COLA) and orbital maintenance. Currently, DigitalGlobe creates 5 predicted ephemerides per satellite per day with a variety of lengths and purposes. First, a 24 hour predicted ephemeris is produced such that the following day's precision orbit determination can be used to verify the accuracy of the prediction. These accuracy analyses can be used to identify errors in the prediction process and/or deficiencies in atmospheric modeling. Second, a 30 day predicted ephemeris is produced and published publicly to DigitalGlobe's website (https://partner.digitalglobe.com/ephemeris/). This ephemeris provides other satellite operators with DigitalGlobe's flight plans, including planned maneuvers. Lastly, for conjunction assessment (CA), a 9 day predicted ephemeris is created and sent to the JSpOC every 8 hours to correspond to the CA screening schedule. These ephemerides are created immediately before each screening to ensure the latest data is used for the prediction and the highest accuracy is achieved. They are 9 days in length to ensure they span the entire 7 day screening with extra length in case delays are encountered.

To verify that DigitalGlobe's predicted ephemerides are accurate for the CA screenings, a simple analysis was performed where historical predictions were differenced against GPS precision orbit determinations. An example of this analysis is presented here using WV01 and WV02 as bounding cases. WV01 was chosen as DigitalGlobe's lowest accuracy predictions due to the high atmospheric drag and uncertainty at 496 km, and WV02 was chosen as a high accuracy case with low atmospheric influence at 770 km. Fig. 3 shows the results, for which 437 predictions are analyzed for WV01, and 340 are analyzed for WV02.

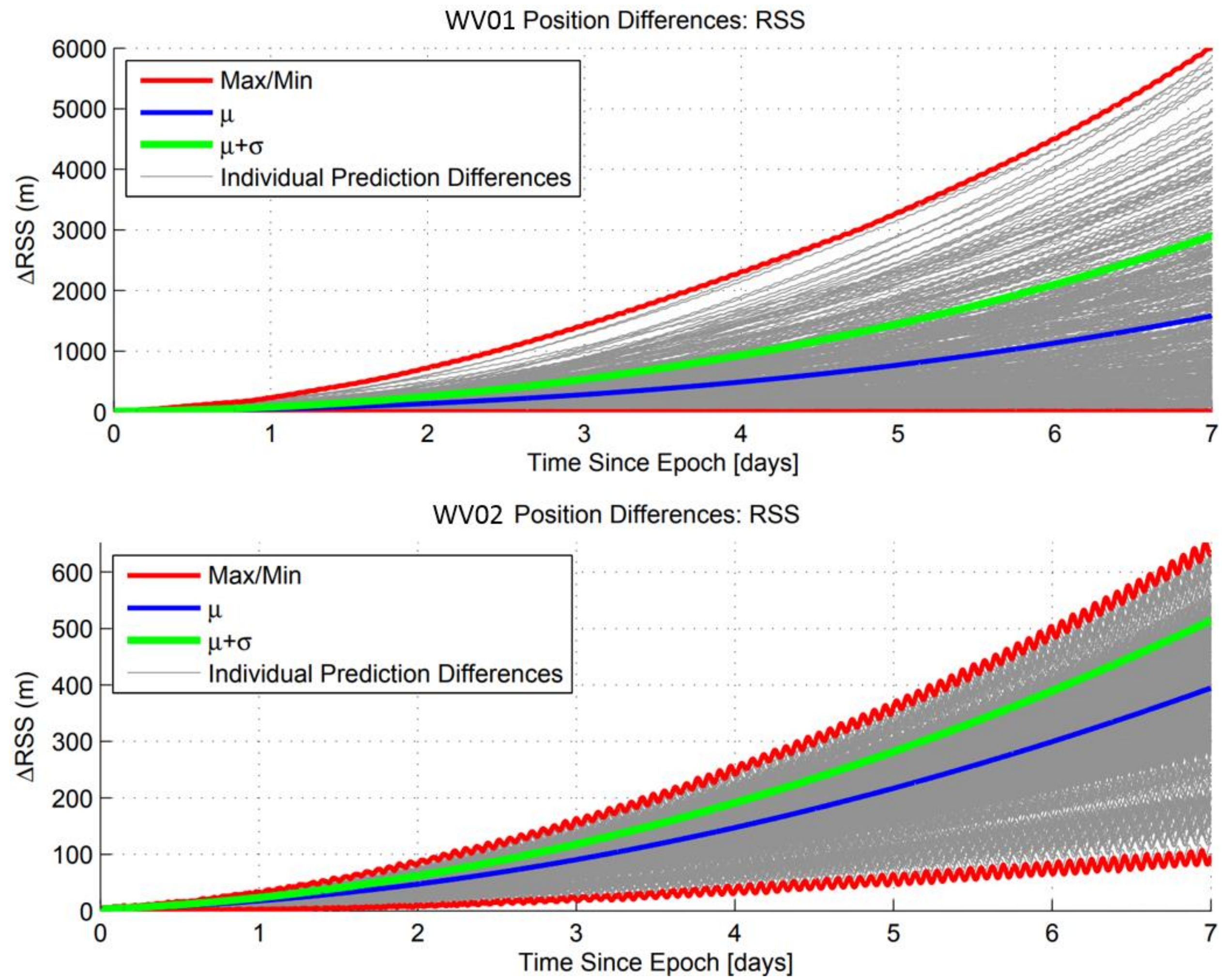


Fig. 3 – DigitalGlobe prediction accuracy analysis. Historical predictions were differenced with GPS precision orbit determinations with sub-meter accuracy and the statistics for the differences plotted. Top: WV01, 437 predictions analyzed. Bottom: WV02, 340 predictions analyzed.

2.3 Conjunction Assessment System

Since 2000, DigitalGlobe has been actively involved in the CA community, participating in workshops, working groups, and conferences throughout the world. Protecting the space environment for use by all mankind is the responsibility of all spacecraft operators. As such, DigitalGlobe encourages transparency and cooperation by each operator. Like many of today's satellite operators, DigitalGlobe works closely with the Space Data Association (SDA) and the JSpOC, coordinating orbital trajectories and maneuvers to ensure safe spaceflight for all. However, the JSpOC is a military organization, and their operational procedures do not always prioritize commercial satellite operations.

When a close approach, or conjunction, between one of DigitalGlobe's satellites and any other published space object is predicted, the JSpOC provides DigitalGlobe with conjunction data messages (CDMs). These messages provide information about an individual conjunction, including relative position and velocity, as well as state vectors and covariance for the primary and secondary objects at the time of closest approach (TCA). Two sets of CDMs are generated and delivered to DigitalGlobe by the JSpOC. The first set is based on the JSpOC's tracking and prediction for both the primary and secondary objects. Since the trajectory for the primary object is based solely on radar tracking, upcoming maneuvers are not included. The second set produced uses DigitalGlobe's predicted ephemeris for the trajectory source for the primary object. The benefit to this is that any upcoming maneuvers are screened for conjunctions before and after the maneuver. The number of CDMs DigitalGlobe receives varies from screening to screening, typically between 100 and 300 across the entire DigitalGlobe constellation. Automated processes in place at DigitalGlobe assess each CDM individually, and report a subset of those to operators in a summary known as the Critical Watch List (CWL). In order for a conjunction to qualify for the CWL, any of the following three criteria must be met:

1. Probability of Collision > 1e-10
2. Miss Distance < 1 km
3. Mahalanobis Distance[4] < 4.5

The criteria here are designed to be conservative, such that no threatening conjunction goes overlooked by operators. Based on these criteria, between 2% and 15% of conjunctions qualify for the CWL for any given screening. DigitalGlobe's automated CA system also produces tasking recommendations for secondary objects for upcoming DigitalGlobe conjunctions for which higher position accuracy is needed to better assess threat, and detailed analyses on each conjunction and how they trend with each new CDM. By taking into account conjunction geometry, the quality of the secondary object's orbit determination, probability of collision, and miss distance components, DigitalGlobe may perform COLA maneuvers to mitigate any conjunction posing a serious risk to a satellite. Fig. 4 shows a flow chart mapping how the DigitalGlobe CA system incorporates the DigitalGlobe team, the JSpOC, and in-house software.

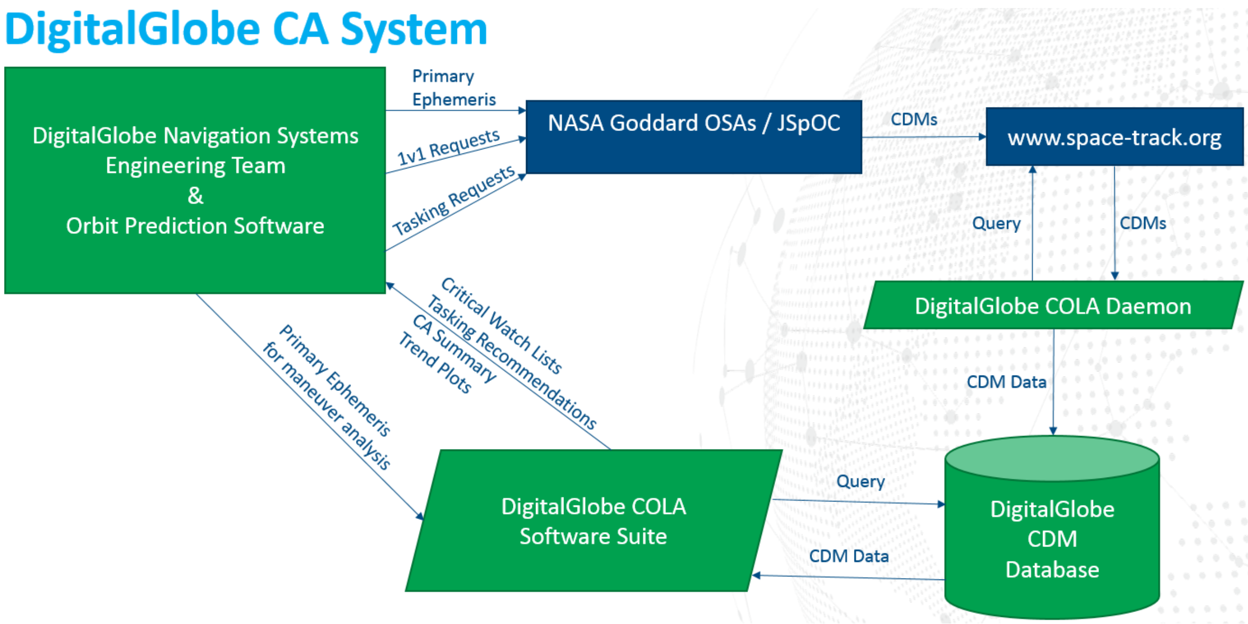


Fig. 4 – DigitalGlobe CA system flow chart before the addition of LeoLabs data services.

3. LEOLABS SERVICES INTEGRATION

3.1 Automation & Updated Information Flow

With the application programming interface (API) developed by LeoLabs, DigitalGlobe was able to seamlessly incorporate LeoLabs data into their CA system. Upon CDM retrieval from the JSpOC, DigitalGlobe's CA software automatically generates a CWL as discussed in section 2.3. To ingest LeoLabs data, a new process was set up where data for each secondary object currently or previously on the CWL is queried for through the LeoLabs API. This initial query returns all available orbital states, which are then inspected to determine if a propagation is available which spans TCA for the conjunction on the CWL. If a propagation is available spanning TCA for a given conjunction, the propagation is ingested into DigitalGlobe's CA software suite where it is screened against DigitalGlobe's most recent internal ephemeris using an enlarged screening volume. This screening produces CDM like products which are fed back into DigitalGlobe's CA system where the new data is combined with existing data from the JSpOC. The addition of this data supplies DigitalGlobe with a secondary source of information which can be used to validate and supplement existing CDMs, providing the operator with timely information that can make the difference between an actionable and unactionable scenario.

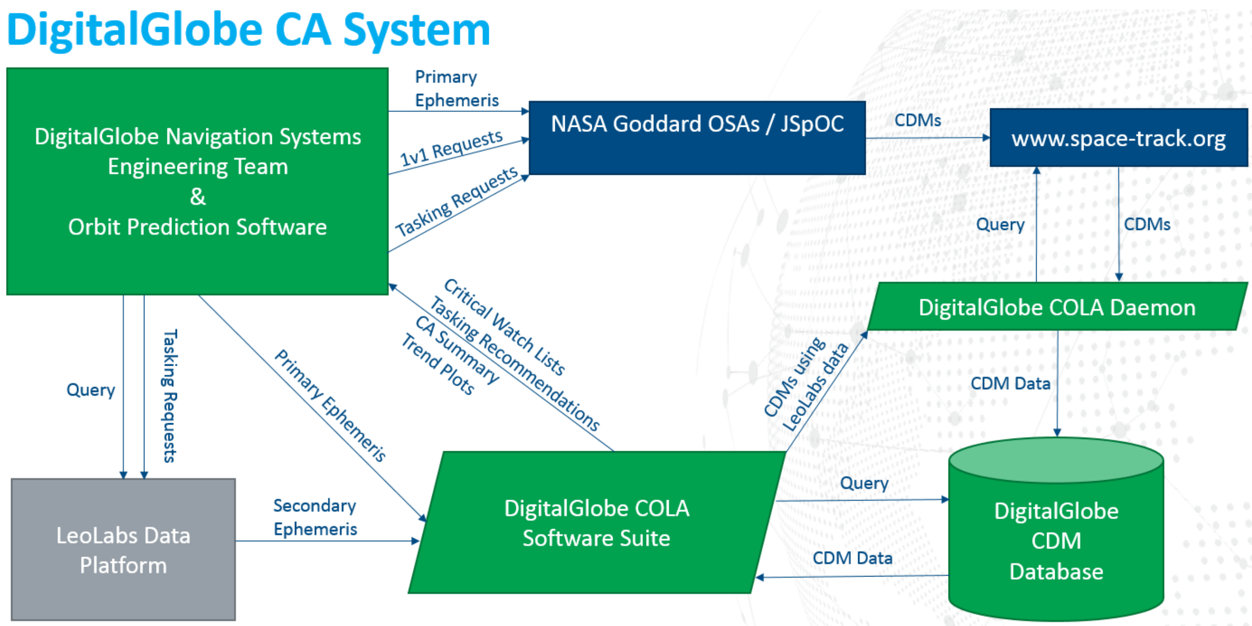


Fig. 5 – DigitalGlobe CA system flow chart with the addition of LeoLabs data services.

As mentioned in section 1, the JSpOC maintains a catalog of all space objects larger than 5-10 cm, and the published catalog now contains almost 20,000 objects [5]. However, debris environment models can be used to estimate total numbers, indicating that there are 29,000 objects larger than 10 cm, 750,000 from 1 to 10 cm, and more than 166 million from 1 mm to 1 cm [6]. Generally, smaller space objects are more difficult to track with ground-based radars. When small debris objects only have a few observations, orbit determinations may not be possible, and if they are, uncertainty in the solution and resulting prediction can be kilometers in magnitude. For operators, this can be problematic, specifically when the predicted state of the debris object has a small miss distance at TCA with an operator's active satellite and the Mahalanobis distance is small. One of the most effective ways to reduce uncertainty in an object's orbit determination is to incorporate additional radar measurements, especially when the additional measurements are provided from a different sensor, providing new geometric considerations [7]. Fig. 6 shows an example of how an additional radar measurement from a unique radar site can reduce the uncertainty of the predicted state of a debris object. For this conjunction plane, DigitalGlobe's active satellite is represented at the origin, the debris object's predicted state at TCA is represented by the colored point, and the ellipses represent the combined, primary and secondary uncertainties at TCA. The color of the data represents the amount of time between when the data was received and TCA in accordance with the scale at the top of the figure. For this example, between 2 and 3 days from TCA, an additional observation was made, and the reduced uncertainty ellipse can clearly be distinguished.

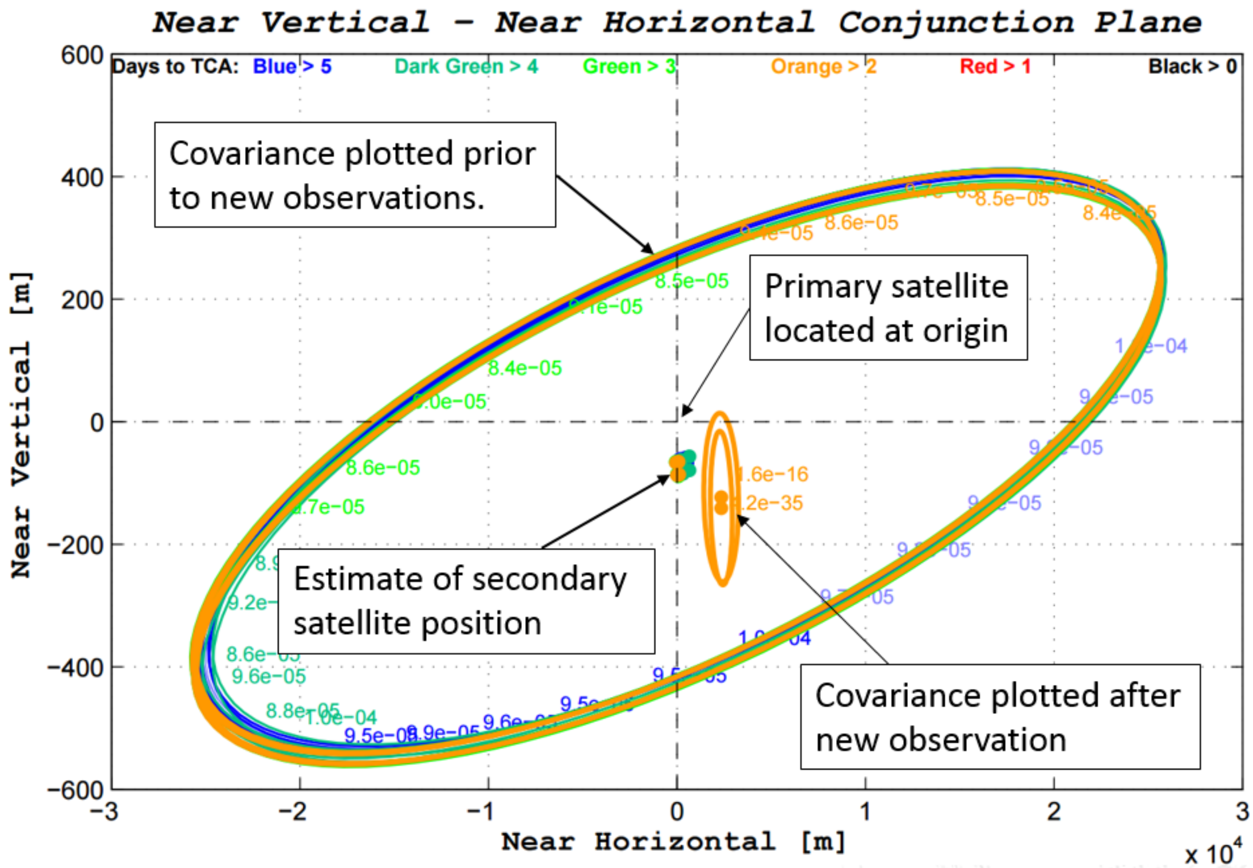


Fig. 6 – Conjunction plane illustrating the effect of additional observations on a poorly tracked debris object.

To produce results like these, DigitalGlobe requests tasking on select debris objects for which higher position accuracy is needed to better assess threat. When requesting tasking for these debris objects through the JSpOC, communication is sent via email. This requires an operator's time to produce, review, and add comments if needed, then time for the JSpOC to receive, process, and send the tasking to appropriate radar sites. This feedback loop can take hours, or even days. For CA, timing is critical, and minimizing the duration of this feedback loop can make the difference between getting a new radar measurement or not, and ultimately the difference between performing a COLA maneuver, and knowing that the conjunction will pass safely. A benefit to using an API is that tasking can be requested and sent to individual radar sites automatically, removing the feedback loop altogether.

4. CASE STUDIES

As discussed in section 3, DigitalGlobe automatically queries for and processes LeoLabs propagations for use in internal CA software. These propagations are screened against internal ephemerides to produce CDM-like products which feed directly into DigitalGlobe's CA software. The case studies presented here are real conjunctions between WV03 and other space objects, showing how operators can benefit from LeoLabs data. Three case studies are presented such that results from payloads, rocket bodies, and debris can all be examined. These different classes are defined as follows: Payloads may contain one or more functioning or non-functioning experiments [5]. Rocket bodies are used to place the payloads and platform (if one is used) into orbit [5]. Debris in orbit occurs when parts (nosecone shrouds, lens or hatch covers) are separated from the payload, when rocket bodies or payloads disintegrate or explode, or when objects are placed into free space from manned orbiting spacecraft during operations [5]. Active satellites are also classified as payloads under these definitions.

4.1 WorldView-3 vs Cosmos 2221 (TCA: 2018/08/07 06:38:37 UTC)

The first case study presented here is the case of an active satellite (WV03) as the primary object, and a payload class object, Cosmos 2221 (NORAD ID 22236) as the secondary object. This particular payload, launched in 1992 on a Tsiklon-3 launch vehicle from the Plesetsk Cosmodrome, was a Russian ELINT (Electronic and Signals Intelligence) satellite [8]. Fig. 7 shows the conjunction plane at TCA. For this conjunction plane, WV03 is represented at the origin and Cosmos 2221 with the combined, primary and secondary, covariance represented by the colored ellipses. The color of each ellipse represents the number of days before TCA the data was received according to the scale at the top of the figure. The JSpOC and LeoLabs data are clearly distinguished on this graph based on the orientation and shape of their covariance ellipses. Later, we discuss the advantages of these independent specifications.

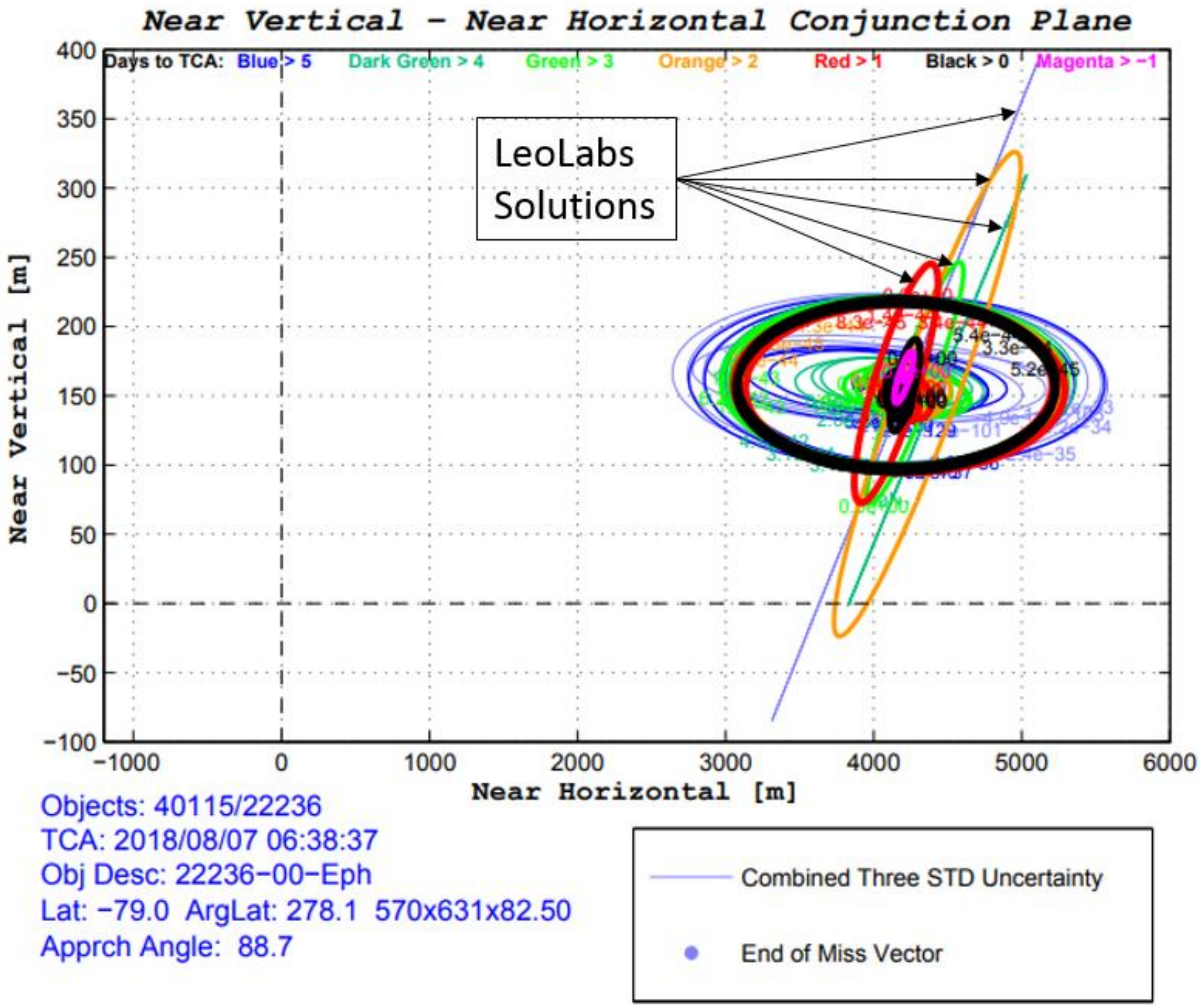


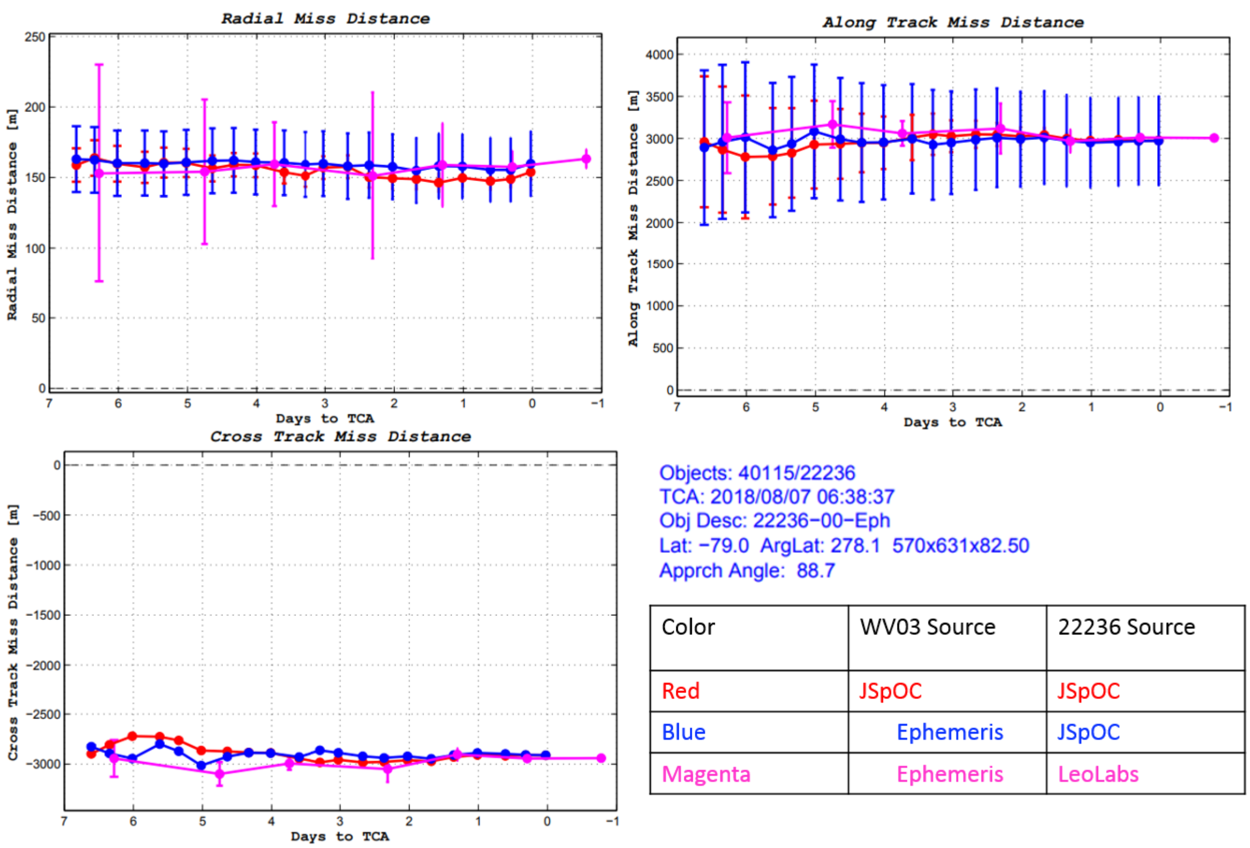
Fig. 7 – Conjunction plane visualization for WV03 vs Cosmos 2221 @ 2018/08/07 06:38:37 UTC.

DigitalGlobe first received a CDM for this conjunction from the JSpOC on 2018/07/31 at 16:02:02 UTC. Shortly afterwards, at 23:56:16 on the same day, LeoLabs published a state from which a propagation was made with a timespan covering TCA. DigitalGlobe used this propagation in combination with their in-house ephemeris to create a resulting CDM. In total, 49 CDMs were received/generated for this conjunction:

Table 2 – CDMs received for WV03 vs Cosmos 2221

Quantity	Primary Source	Secondary Source
7	DigitalGlobe Ephemeris	LeoLabs Propagation
21	DigitalGlobe Ephemeris	JSpOC Special Perturbations
21	JSpOC Special Perturbations	JSpOC Special Perturbations

This case demonstrates an advantage the LeoLabs data offers: post TCA state analysis. Using a state published after TCA, a propagation back to TCA was possible and provides information about the state with minimal uncertainty. In the conjunction plane in Fig. 7, the post-TCA data is magenta in color, and is in agreement with the predictions made prior to TCA, with a correspondingly small covariance ellipse. Fig. 8 shows the radial, in-track, and cross-track miss distances with associated uncertainties as a function days before TCA the data was received, including the post-TCA data indicated between 0 and -1 days before TCA. Overall, the results using the two different sources of data on the secondary object are very consistent, and increase operator confidence in the assessment of the conjunction. For each of the radial, in-track, cross-track miss distance component figures presented in this paper, the blue data uses a conservative, default covariance and the enlarged error bars can be distinguished. The artificially enlarged errors are used to ensure the calculated probability of collision and miss distances are not underestimated.



Color	WV03 Source	22236 Source
Red	JSpOC	JSpOC
Blue	Ephemeris	JSpOC
Magenta	Ephemeris	LeoLabs

Fig. 8 – Radial, in-track, and cross track miss distance components with associated error bars for WV03 vs Cosmos 2221.

4.2 WorldView-3 vs Tsyklon-3 Rocket Body (TCA 2018/08/14 05:58:00 UTC)

The second case presented here is a conjunction between WV03 as the primary object and a Tsyklon-3 rocket body (NORAD ID 11267) as the secondary object. Large and unmaneuverable, rocket bodies in orbit pose a significant threat to the space environment, as a collision with a satellite or even a large piece of debris will produce an amount of debris comparable to the debris causing events discussed in section 1. Most rocket bodies decay within a short time after the payload (and platform) have achieved orbit [5]. However, launched in 1979, this rocket body is currently in a 581 km perigee by 612 km apogee orbit, and will remain in orbit for many years to come. The CDMs received for this conjunction indicate the radar cross section (RCS) for this rocket body is 3.8617 m^2. As a comparison, a standard king size mattress has an area of 3.923 m^2 [9]. Fig. 9 shows the conjunction plane at TCA with all available data plotted.

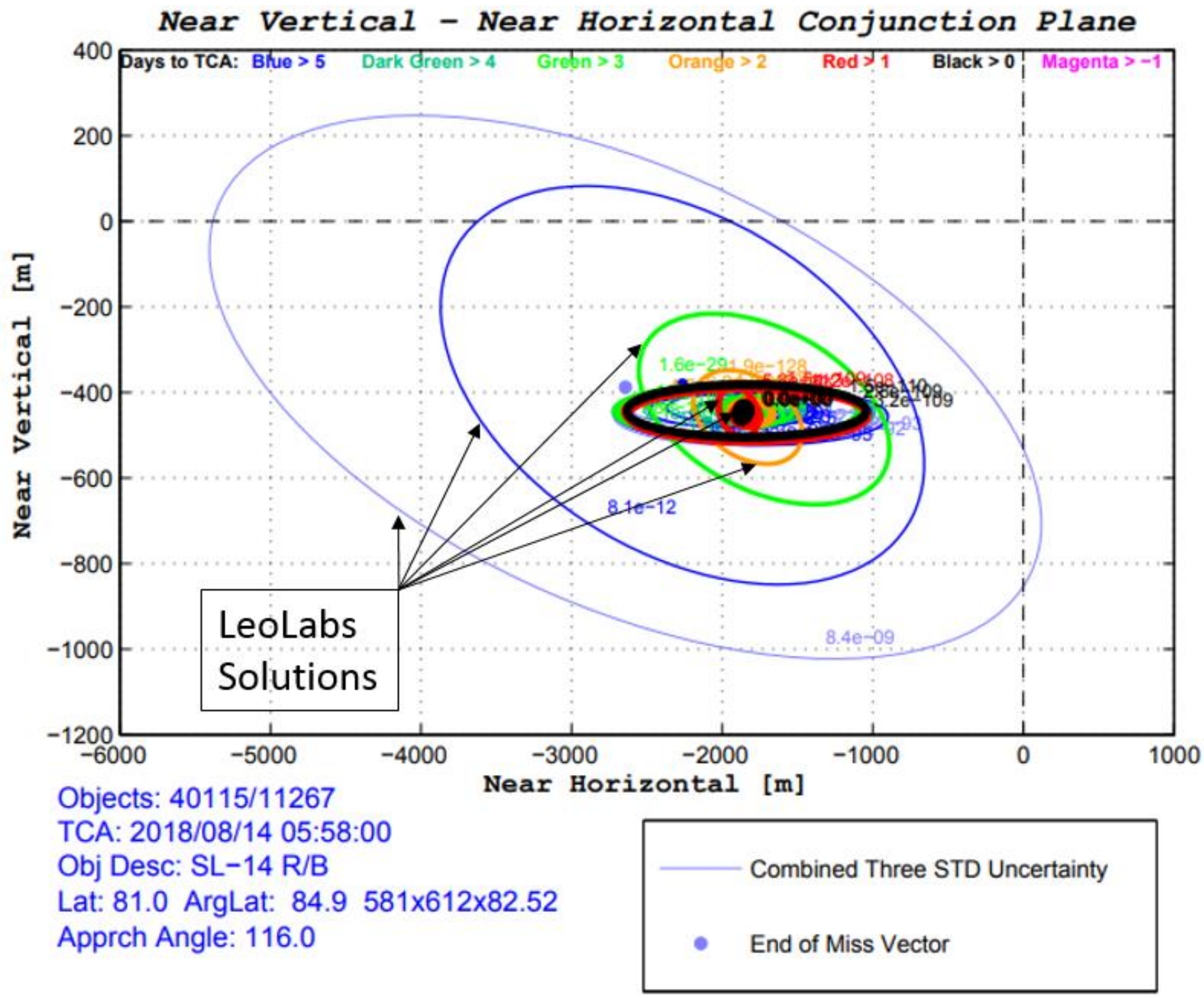


Fig. 9 – Conjunction plane visualization for WV03 vs Tsyklon-3 Rocket Body @ 2018/08/14 05:58:00 UTC

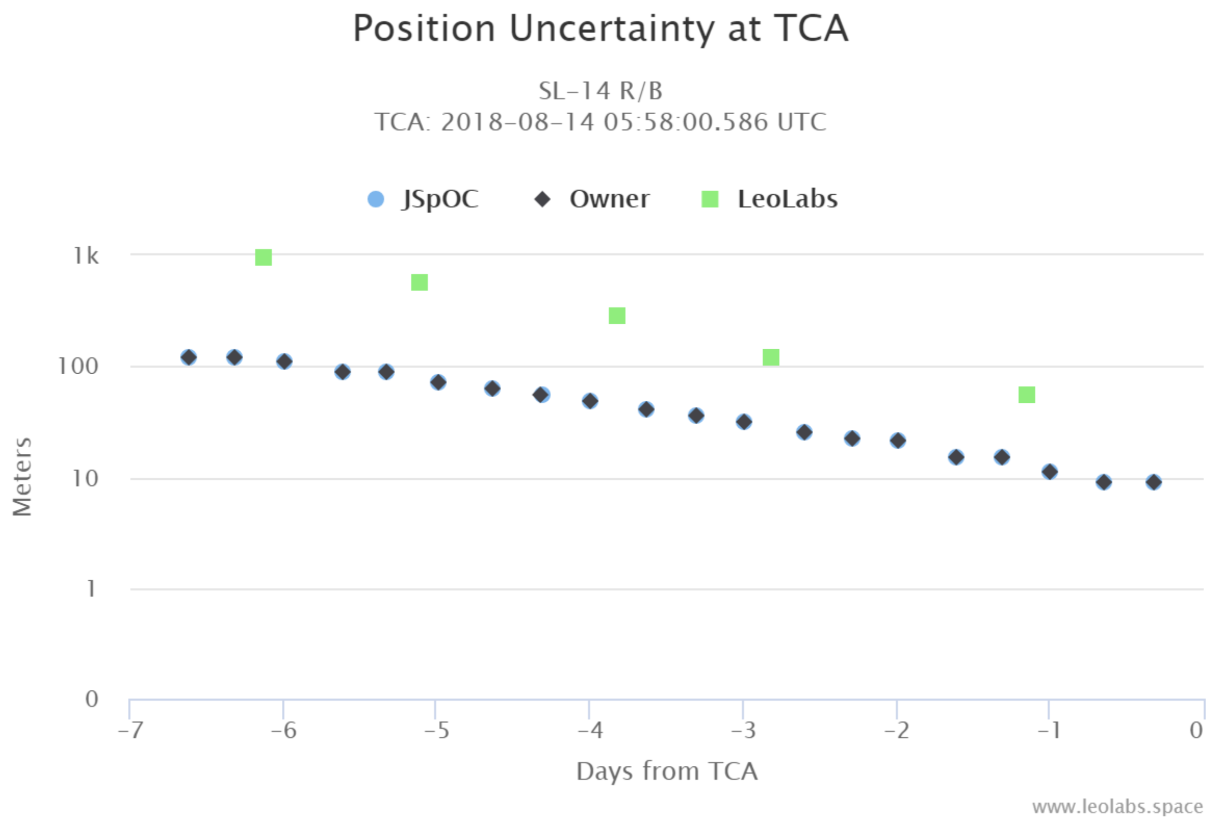


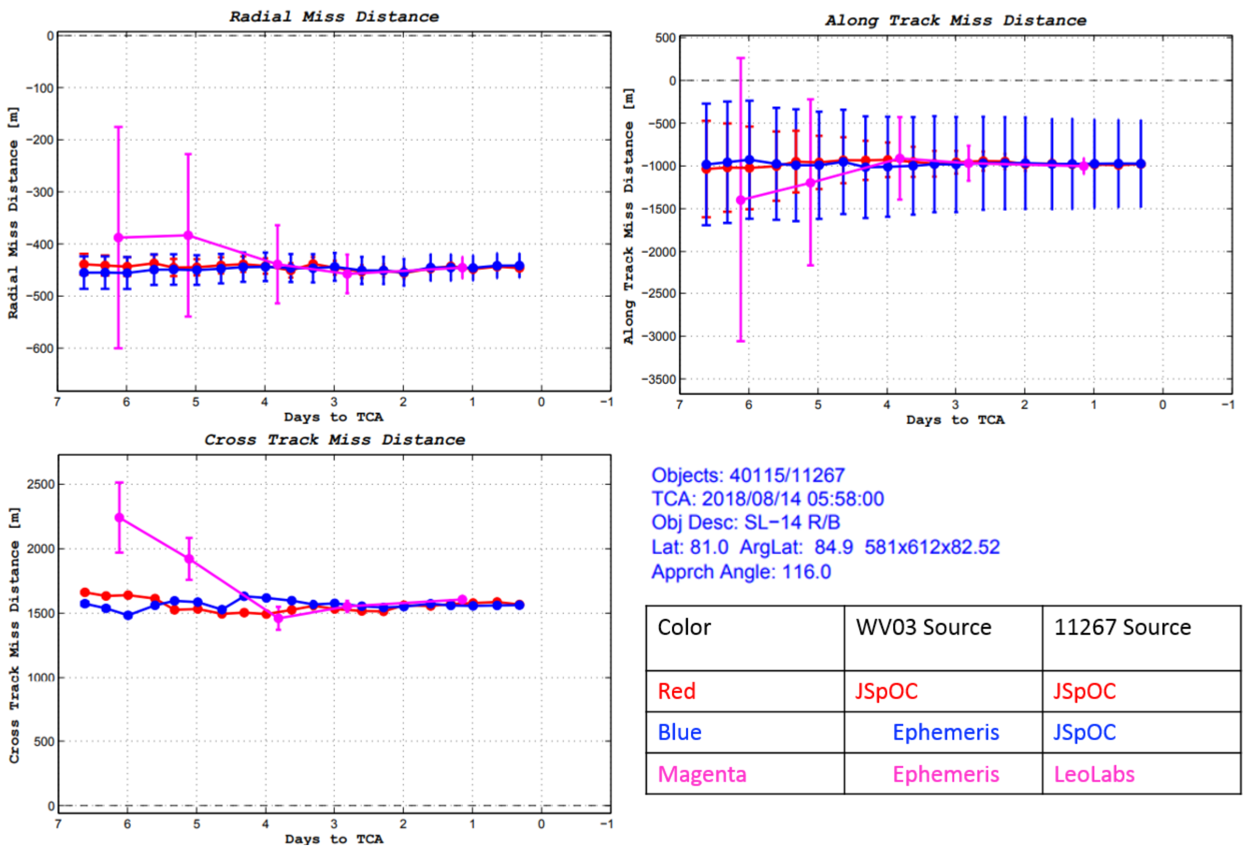
Fig. 10 – Final state uncertainty of Tsyklon-3 Rocket Body at TCA

For this conjunction, a total of 46 CDMs were received/generated. However, a post-TCA state was not available for analysis.

Table 3 – CDMs received for WV03 vs Tsyklon-3 Rocket Body

Quantity	Primary Source	Secondary Source
6	DigitalGlobe Ephemeris	LeoLabs Propagation
20	DigitalGlobe Ephemeris	JSpOC Special Perturbations
20	JSpOC Special Perturbations	JSpOC Special Perturbations

This case demonstrates an ideal tracking and uncertainty reduction scenario. As shown in Fig. 9, each successive solution has nested covariance, and the predicted state at TCA is fairly constant. Also note in Fig. 10 that each successive LeoLabs propagation used for CDM generation has decreasing final state uncertainty, starting at 976 meters at 6 days to TCA, dropping to only 55 meters 1 day to TCA.



Color	WV03 Source	11267 Source
Red	JSpOC	JSpOC
Blue	Ephemeris	JSpOC
Magenta	Ephemeris	LeoLabs

Fig. 11 – Radial, in-track, and cross-track miss distance components for WV03 vs Tsyklon-3 Rocket Body

4.3 WorldView-3 vs Cosmos 2251 Debris (TCA 2018/07/27 23:15:43)

The final case presented here is a conjunction between WV03 as the primary object and a piece of debris from Cosmos 2251 (NORAD ID 33981). This piece of debris, now in a 561 km perigee by 667 km apogee orbit, originated from the 2009 Iridium-33 and Cosmos 2251 collision. Details about the collision will not be presented here as they are well documented in other scholarly articles. According to the CDMs received by DigitalGlobe from the JSpOC, this particular debris object has an RCS of 0.0739 m^2. For comparison's sake, an everyday object with a similar area is a medium, 12 inch pizza with an area of 0.0730 m^2. The conjunction plane in Fig. 12 shows this unique conjunction, and how the different sources of data can provide different behavior in the covariance of the secondary object. Similar to the first case shown, the orientation and shape of the covariance ellipses produced by JSpOC and LeoLabs are substantially different. The fact that they overlap at the predicted miss point increases confidence that the conjunction does not require any operator action.

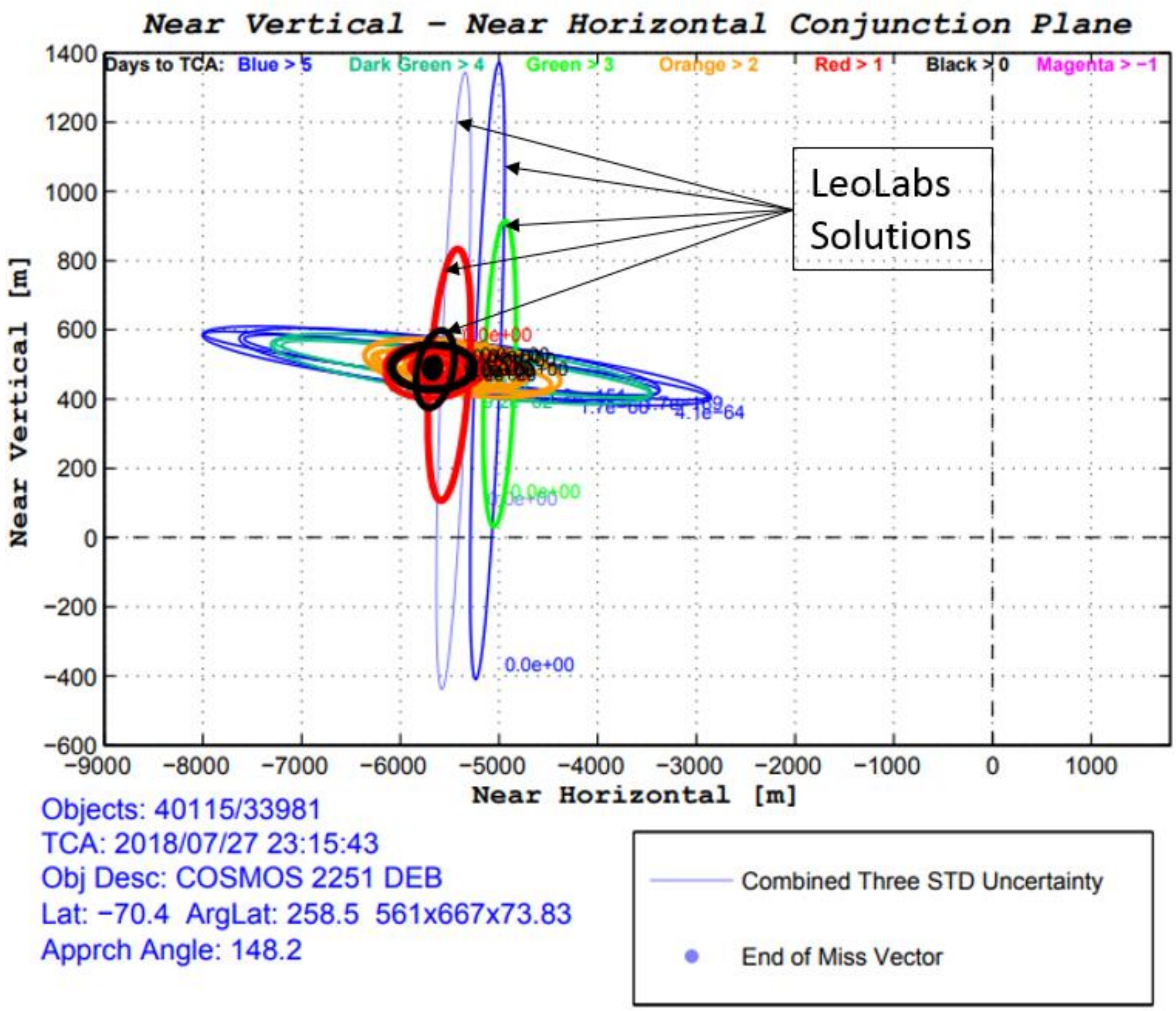


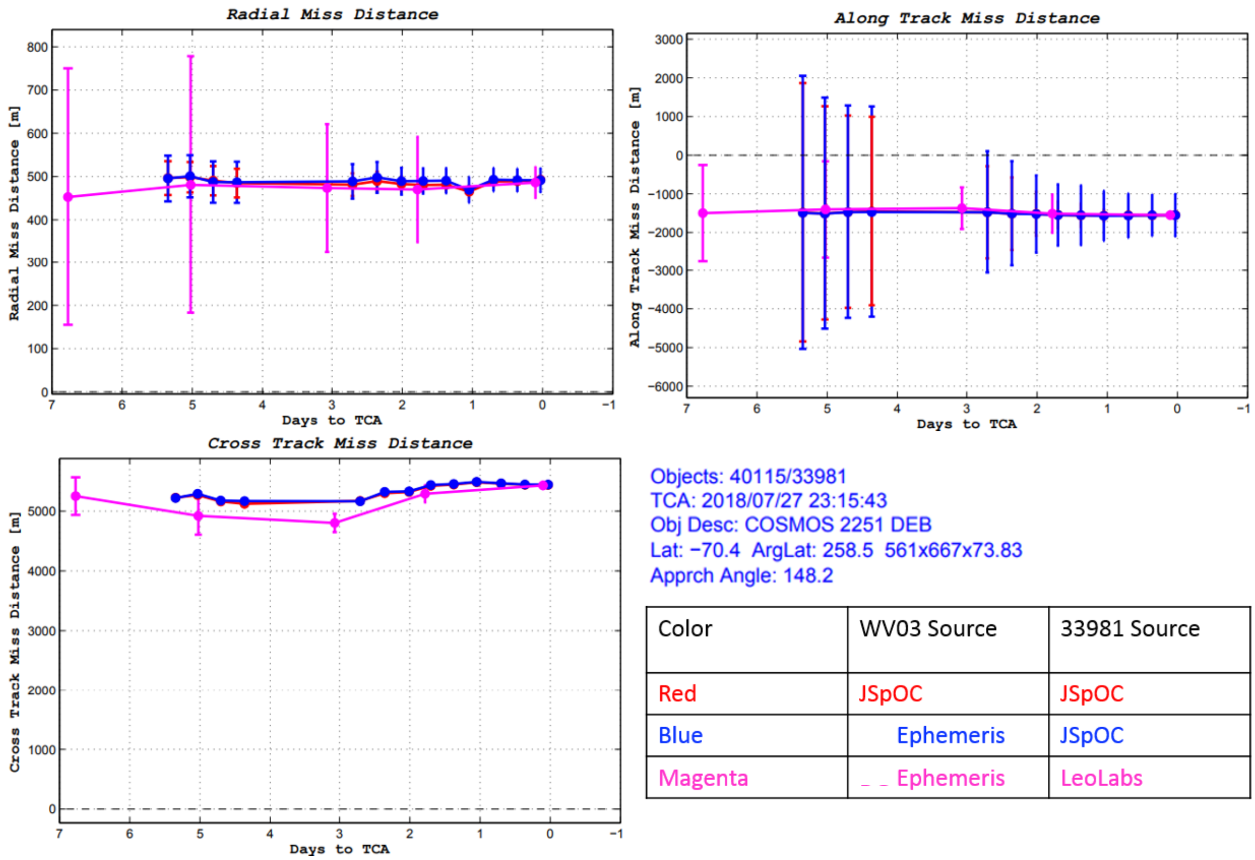
Fig. 12 – Conjunction plane visualization for WV03 vs Cosmos 2251 Debris @ 2018/07/27 23:15:43 UTC

For this conjunction, a total of 31 CDMs were received/generated.

Table 4 – CDMs received for WV03 vs Cosmos 2251 Debris

Quantity	Primary Source	Secondary Source
5	DigitalGlobe Ephemeris	LeoLabs Propagation
13	DigitalGlobe Ephemeris	JSpOC Special Perturbations
13	JSpOC Special Perturbations	JSpOC Special Perturbations

Compared to the 49 and 46 CDMs received for the previous conjunctions presented in sections 4.2 and 4.3, respectively, the count of CDMs for this conjunction is much lower at 31. A brief explanation for this is because the relative position of the Cosmos 2251 debris with respect to WV03 at TCA was outside of the JSpOC's radial screening volume (0.5 km). In other words, at TCA, the Cosmos 2251 debris was too far above WV03 for the JSpOC to issue a CDM. As an operator, this can be problematic in scenarios where any component of the predicted miss distance of the secondary object is outside of JSpOC's screening volume but the three-sigma uncertainty region associated with the prediction still encompasses the primary object. This case provides an example conjunction where the radial miss distance was right on the cusp of the JSpOC screening volume, such that CDMs were not always received.



Color	WV03 Source	33981 Source
Red	JSpOC	JSpOC
Blue	Ephemeris	JSpOC
Magenta	Ephemeris	LeoLabs

Fig. 13 – Radial, in-track, and cross-track miss distance components for WV03 vs Cosmos 2251 debris

5. SUMMARY

The space environment is becoming increasingly crowded, and it is the responsibility of satellite operators to maintain space as a valuable resource available to all. DigitalGlobe owns and operates 5 satellites in LEO, and works closely with the JSpOC, LeoLabs, and other satellite operators to protect their satellites from collision. The purpose of this paper is to demonstrate, using real data and examples, the effects of space debris mapping services and their contribution to safe, responsible spaceflight operations in LEO. Previously, DigitalGlobe relied solely on the JSpOC for CA data through CDMs. As a step forward, DigitalGlobe seamlessly integrated LeoLabs' API into their CA software to supplement data received from the JSpOC. The three case studies presented each demonstrated unique advantages to its use including automated tasking, post-TCA state analysis, data retrieval in the absence of JSpOC data, and decreasing state uncertainties. Data received from LeoLabs is in agreement with data received from the JSpOC through CDMs, and the products provide operators with accurate, timely, and actionable information.

As the number of satellites and satellite operators in LEO grows, so will the need for automated CA systems. LeoLabs' data platform provides a solution to integrate space object data with any operator's CA system. As LeoLabs deploys more radar sensors capable of tracking smaller debris, and introduces new services for collision avoidance and conjunction screening, operators can begin relying on these services to operate safely and responsibly as congestion increases.

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