Safety of Spaceflight: Looking Back at the Past Decade, Looking Ahead at the Next Five Years

Panelists:

- **Mrunalini Deshpande**, Researcher
- **Mark Dickinson**, Space Data Association Executive Director and Deputy CTO, VP Space Segment – Inmarsat
- **Mark Mulholland**, retired USAF and retired NOAA; currently a consultant to the Director, Office of Space Commerce
- **Daniel L. Oltrogge**, Space Safety Coalition and SDC Program Mgr.
- **Regina Peldszus**, Senior Policy Officer, DLR, and co-chair, EU SST
- **Victoria Samson (Moderator)**, Washington Office Coordinator

Victoria Samson: [Welcome]

Our mission is to work with governments, industry, international organizations, and civil society to develop and promote ideas and actions to achieve the security of sustainable and peaceful use of outer space, again, benefiting Earth and all its peoples. We are dedicated to the establishment of an effective and efficient systems of governance for outer space and improving the safety operations in Earth orbit.

This effort includes developing the tools of governance that lead to reducing the threat of orbital debris, promoting international civil space situational awareness to improve knowledge and transparency, and preventing the creation of additional debris through hostile acts.

Today, you have the slide here overhead to ask questions. We will be accepting questions in the Q&A portion. You can see step one by the Q&A button, click on it. You can see if someone's asked the question you want to ask.

If you see any questions that are interesting, we can upload them by clicking the happy thumb. Then if not, then just put in the question that you want to have answered and we'll go from there. Please don't put any questions in the chat itself. Gentle reminder, if there is a chat, everyone can see everything.

I'd like to say as well, this event is on the record. It is being recorded. The video will be up on our website in a couple days. It will have a transcript made and media have been invited. The format for today is we're going to have a keynote speaker give a presentation and then a panel, and after which the Q&A will be held for all, for the keynote and the panelists.

You have plenty of time to be thinking of great questions and with this group of experts at the end. With that, get right to the meat of it. I'd like to go to our keynote speaker. The Space Data Association is one of the first efforts by industry to share space situational awareness data and coordinate efforts to enhance the safety of spaceflight.

Its space data center is now 10 years old as of this month. Happy belated birthday, SDC. Our keynote speaker, Pascal Wauthier, will now discuss how the organization was created and how it evolved over the past decade.

Pascal joined SES in 1990 as a flight dynamics engineer, and is currently leading SES space operations, where he is responsible for safely operating SES GEO and MEO O3b satellites, more than 70 satellites. In November 2019, he was elected the chairman of the Space Data Association. Pascal, take it away.

Pascal Wauthier: Thanks a lot, Victoria. Maybe you can go to the presentation. OK, next slide. Starting with the quote. "Since 2005, the number of satellites launched into space has been increasing regularly year on year. Last year, MIT Technology Review predicted that the number of satellites orbiting Earth could quintuple in the next decade."

Proliferation of small satellite project [inaudible 3:10] of course the key driver of this increase. This has a huge potential to cause defragmentation events and severe congestion be on the scale ever seen before.

Of course, tracking these satellites will become extremely complex, emphasizing the importance of continuing to feed and share accurate, actionable data via independent repositories like the Space Data Center, SDC, which, as already mentioned by Victoria, celebrates this year its 10 years of flight safety services.

In the next 50 minutes or so, you will learn how the SDA and SDC tackle the flight safety gaps, the lessons learned from these 10 years of SDC operations, and the changes that SDA would expect to see in the coming 10 years. Next slide, please.

Let's go back to 2009, 2010. What triggered the creation of the SDA and SDC? This is very well described in the quote from TS Kelso, a worldwide recognized expert in space traffic management, so-called STM, when he presented a "Look Back on STM from 2029" in a "looking back" panel at the AMOS Conference in 2019.

Here is what he's saying. That started in 2008 with pioneers like Intelsat, Inmarsat, SES, and Telesat, doing something that in 2019 might be called crowdsourcing. We realized that STM, unlike ATC, is not geographically limited and that any accidents would affect the global space commons.

That meant STM was an international issue and an international organization, SDA in this case, was formed to manage data collection, quality control, analysis, and reporting. Satellite operators realized that STM was truly a collaborative effort and that individual operators or countries could not do it alone. Next slide, please.

Back in 2010, the existing products and services for flight safety didn't meet satellite operator needs. Why not? What were the gaps? The main gap is that only few operators had the capability to monitor close approaches using publicly available SpaceTracks information or had a separate agreement with JSpOC.

These free legacy SSAS or space situation awareness services were intended as heads up notice of an oncoming close approach but because the notice was considered as not verified therefore not

trusted, it was not acted upon. Why did the operators not trust those close approaches notices? Here are two main reasons.

The first one, SSA products and services were unnecessarily degraded by simplification, faulty assumption or lack of quality control. Comparison of SSA data with operator space data in all key five issues like unrealistic position, velocity, [inaudible 6:44] . Errant observational and orbital association is the object mean to represent.

Second reason. SSA products failed to incorporate spacecraft operator data. In particular, the close approach notice failed to consider station keeping maneuvers which are quite frequent on GEO satellite for example, typically, once per week so generating misleading or errant threat warnings but more alarming, missing two close approaches.

Also back in 2010, lot of close approaches coordination was launched through personal contacts between various flight analyticals. Next slide please. Before describing how the SDC filled these gaps I just described, let me first describe what the SDA and SDC do provide.

Formed in 2009, the Space Data Association is the 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.

SDA has a legal structure and agreements that provide protections and informed mechanisms to ensure that data is only used for intended purposes. Another key purpose of the SDA is to promote responsible behaviors from operators in all orbital domains to ensure the protection of key assets and the space environment.

SDA works also with all interested parties' entities to help define the next generation of STM systems and capabilities. Next slide please. Finally, the Space Data Association relies on the Space Data Center, famous SDC operated by AGI for flight safety data exchange and processing.

Who are the user of the SDC system? The SDC system provides services to 30 global operators of spacecraft spanning all orbital regimes, form factors and mission types. The SDC system performs safety-of-flight analyses for nearly 800 spacecraft.

About 500 spacecraft in LEO and MEO orbits and to more than 270 spacecraft in the GEO orbit. Next slide please. Let's describe briefly the current SDC 1.0 System that are referred to the drawing there. I will discuss the data flow from left to right.

On the left, has the data contributors which are either the SDC members who upload, either manually or using a machine-to-machine interface, the maneuver plan or ephemerides with maneuver plans backed in or the US government space data with CDMs or space shuttle [inaudible 9:45] ephemerides, of course pending the SSA data-sharing agreement with the JSpOC.

Then all the option is a serious track database for TLE elements mainly for debris. The SDC system is then processing this data using two integrated subsystems. We have the SDC system, which is a lower box on the right, which is performing TLE-based flight safety warnings.

That means it's performing conjunction assessment using operator ephemerides and TLEs for debriefs, and issue notification to the members.

The SDC-Ops subsystem is the box on top. It's performing a second stage SP refinement SDC TLE-based conjunction assessment. That means it's processing the SP data and the CDM from US government and compare with the operator ephemerides conjunction assessment and issue result of this comparison to the operator. The operator has full visibility of this comparison.

Of course, these are also the SDC operator AGI to do an effective quality of control of the data. We'll come back on that. Next slide, please. No, back. Maybe we go on Slide 8, please. No, we're not on Slide 8. Can you go on Slide 8? Yes, thank you.

Back to the key question, how did the SDA and SDC change SSA? Let me start with what I think are the two main contributions of SDA. Can you go back one slide? I think you jumped again one slide. [laughs] OK, thank you.

Let me start what I think are the two main contributions of SDA. First by providing interfaces to JSpOC and space tracks and by developing an efficient monitoring and loading system using operator operational information. SDA has been providing effective conjunction assessment capabilities to a large number of operators. I recall that until 2010, only a few larger operator had effective SSA capabilities.

Second key contribution, during the last 10 years, the SDC and AGI experts have demonstrated that effective SSA relies on using the best available data to manage close approaches. In fact, for active satellite, SDA and AGI have demonstrated the importance of using the operator information about the maneuver plans, which could be quite complex for [inaudible 12:41] every day. Next slide, please.

I would like now to discuss three key elements of the SDC services, which significantly changed SSA. First, the SDC was upfront on data exchange technology. Indeed, the SDC framework emphasizes and facilitates broad crowdsourcing data exchange for the purpose of safety of flight similar to a data-led construct.

Second key element, the SDC system benefits from AGI experts who are closely monitoring the data quality by comparing information from different sources. This comparison has given many discrepancies in SSA and operator space data project.

JO operator discovered, for example, that certain of their satellites were operated a few hundreds of a degree away from their nominal on duty slot due to ranging biases. The system issues also notification in case of discrepancy or expired SSA input data.

Third, key element. Through the SDC services, the SDA is significantly contributing to improve SSA capabilities by, for example, encouraging JSpOC to publish CDM with covariance matrix, by working with JSpoC and SATCOM to pioneer application of SPA families in 2014 for best of bridge flight safety services.

Next slide please. To complete the presentation of SSA changes triggered by the SDA, let me quote two SDA director colleagues and download work from AGI CSSI.

First quote, "the SDA [inaudible 14:35] operator that it was possible to screen all on all object under a strong, legal framework. It also forced cooperation between operators even though they were competitors in the same market space."

I will complete on this quote by saying that SDC provides a computationally secure framework on top of the legally secure framework, protecting operator populated data to prevent unauthorized release and providing control, reliable and efficient sharing of information.

Note also that SDC provides a granular operator phone book by area of responsivity, location and management level.

Second quote. "It feed the need to have a commercial solution that is independent on a given nation's desire to provide a free, non-optimum service. It underpins the need of a shared approach for the utilization of near-earth space," which is a finite resource, as we all know.

Third quote, "it leap frogs the institutional services by providing more reliable, conjunction warning." We can go to the next slide. I've described the SDC and SDA and how they're effectively contributing to flight safety.

The true question is, how do we achieve true, long term sustainability of space activities? Here are three elements of answers based on SDA, SDC lessons learned during the last 10 years.

First, flight safety derives from the comprehensive aggregation of massive mode of observation, data, environment statistics and risk assessment and of course advanced analytics. Second element of answer highlights the importance of data exchange becoming increasingly important as the number of operating a space craft dominate the non-debris population.

During the last, 10 years, the SDA numerous champion collaboration and information with SDC systems. It is this model which continued to mitigate risk for all operators.

Third element of answer is in fact an advice. Government SSA and STM machine initiatives should learn about the SDC system and its operational concept.

In particular about SDC innate ability to crowdsource space data from spacecraft operator and merge them with accurate space debris catalog, from the USA Air Force, for example, which has allowed SDC to generate decision quality space traffic coordination and manage analytics to support STCM.

Serve as a distribution hub for space data. Be a focal point for comparative SSM quality control and finally, provide high availability SSA and STC services.

Next slide. To conclude my presentation here, I will try to answer the following question. What changes would SDA like to see in SSA in the coming 10 years? I will focus on three changes.

First, ultimate goal is to support a safe and sustainable operating environment, realized by a globally relevant, readily available safety of flight services that espouse and incorporates space data exchange, commercial SSA and STM services that pair new sensor technology with advanced data fusion algorithm to dramatically improve SSA solution and prediction.

Second change related to the above, evolve flight safety policies which are not yet equipped to accommodate the rapid change associated with, first, the new space's large constellation and second, improve SSA sensor and enlarged base catalog.

What's the effect of these two changes? They will overwhelm the operator with conjunction alarms perhaps by a factor of 50 or even 100. How to avoid and manage that situation.

This can be resolved by A, greatly improve SSA accuracy, completeness, timeliness and transparency to limit alarms to those requiring an action and B, once the assisted data is improved enough to support it, introducing new safety concepts to include for example, autonomous SSA.

Next slide please. As the third change, let me share with you the SDA vision. Our vision is to promote and support the application of advanced SSA analytics and sensor types through commercial SSA services, crowdsourcing on a global scale, sensor-agnostic data fusion, in new government SSA and STM initiatives.

In particular, we want to support the US Department of Commerce initiative to provide Space Traffic Coordination and Management services as well as other government initiatives like the European Space Surveillance and Tracking system so called, EUSST.

Finally, I would like to complete the presentation by thanking Dan Oltrogge for major CSSI for his value and input to this keynote speech. Thanks all for your attention.

Victoria: Thank you Pascal. Really appreciate having that insight to how SDA evolved and the taking through the processes that you guys created over the past 10 years. Now we are looking forward to having our panel speak. Here is a slide with our panelist.

We have them mostly alphabetically, but just to shake things up, I want to introduce them in the order in which they'll be speaking. Our first speaker will be Mark Mulholland.

Mark has held a wide range of satellite for acquisition in space operation jobs dating back to 1976. He's had careers in the US Air Force, National Reconnaissance Office and then the National Oceanic and Atmospheric Administration.

He's currently a consultant, the director of the Office of Space Commerce and the US Department of Commerce. Mark, it's all yours.

Mark Mulholland: Thank you, Victoria. Good morning, afternoon and, I guess, evening, everyone. Thanks once again to Secure World Foundation for putting together a great virtual [inaudible 21:23] .

The big thing I miss about gathering at your DC headquarters are your great receptions and the opportunity to talk to old friends and to make new acquaintances. Keep doing what you're doing, please.

Because we're here to mark the 10th anniversary of the Space Data Association, I'd like to spend a few minutes looking back before actually doing what Victoria asked us to do by looking forward. One of the highlights of my NOAA career was that we were the first government agency to join the Space Data Association.

After several meetings at the working level, senior SDA officials soon found themselves in the office of the NOAA administrator at the time, Dr. Kathy Sullivan. Kathy certainly understood the value of safe space operations because on three separate occasions, she used an orbiting space object, herself.

For NOAA, joining SDA was a no-brainer. Despite the wheels of government turning slowly, NOAA became an SDA member finally in May 2012. Shortly afterwards, NASA joined. Shortly after NASA, NOAA's European mission partner, EUMETSAT, asked NOAA if they should join as well.

I'll summarize our conversation as one in which I said, "You're crazy if you don't join." In the eight years that NOAA has been an SDA member, NOAA had great success using the capabilities that SDI and the AGI Commercial Space Operation Center provided for space flight safety of the NOAA geostationary weather satellite constellation called GOES.

The dedicated and hardworking people at the 18th Space Control Squadron are at the limit of their capabilities to keep up with the rate at which commercial space operators are changing the spacescape, to coin a phrase, of near-Earth orbit.

SDA, through their operational partners, were able to relieve a huge load off the 18th, especially the geostationary orbit regime. The accuracy of the observations combined with the confidence that the SDA members dramatically improved geostationary operations.

Here are some examples from NOAA's experience. Before transitioning to the SDA for primary geostationary support, NOAA received, during a two-year period, over 17,000 conjunction warnings for its four GOES satellites. That's 21 warnings per day if you're playing along at home.

In the last two years of relying on calm spot warnings, NOAA has received exactly one warning. I can't even begin to fathom how much critical weather data would have been lost if NOAA had taken those satellites offline to perform needless collision avoidance maneuvers for even half of those 17,000 warnings.

NOAA operates its eastern satellite, goes east at 75 degrees west longitude, occupying 75 west, where Brazilian government communication satellites. Based on SDA support, NOAA and Brazil have safely operated up to four satellites within one half of degree of each other since 2008. NOAA also shares its three other geostationary slots with at least one other spacecraft.

Annual SDA member meetings have allowed NOAA to learn in advance of new neighbors moving into their geostationary positions, and to begin early operational collocation planning. I could talk all day about how NOAA's membership in SDA has enabled their mission, however, the task at hand is to look five years into the future.

We have talked about the future of SSA and spaceflight safety in the Department of Commerce, Office of Space Commerce on almost a daily basis, since the release of Space Policy Directive-3 in June 2018, and of course, for many years earlier in international and domestic settings. As a matter of fact, judging from Pascal's charts, he could have written SPD-3.

The clear objective is to transition the commercial and international SSA mission from the US Department of Defense to the Department of Commerce. SPD-3 mandates that this transfer take place by 2024.

According to NASA and ISA statistics, it took about four years to increase the number of active satellites from about 2000 to today's rough total of 3000. We are looking at adding another 1000 in just this year alone, and the number will accelerate every year in the future.

By 2025, very conservative estimates predict anywhere from 10,000 to 15,000 new active satellites, if just a handful of companies come close to their projected launch schedules.

The numbers tell just a small part of the story. Many of these large constellation operators will be constantly launching and be orbiting satellites. There will be a large number of satellites always going up and always coming down and passing through numerous operational orbits.

New low thrust propulsion systems and maneuvering by differential drag make traditional conjunction analysis techniques pretty much incompatible with how operators are flying satellites today. We are already seeing new commercial missions emerge, satellite servicing, commercial human spaceflight, space tourism, and missions beyond geostationary orbit, to name a few.

We need help from the commercial operators as well. They need to make it easier for the SSA infrastructure to find and catalog their satellites. They need to tell us what they're going to do and when they're going to do it. We need a new and unprecedented level of transparency, including redefining traditional definitions and boundaries of proprietary information.

At the very least, operators perhaps even competitors need to talk to each other in the coming era where there will be more conjunctions between active satellites than between satellites and debris.

The best way and perhaps the only way to maintain and improve safe operations is to enable industry itself to quickly develop and implement a new SSA infrastructure within the commerce industry partnership. The space sector is much more able to adapt quickly to a changing environment than any government agency.

We need improved sensors that reduce position errors to the minimum amount possible. We need conjunction assessment tools that keep up with satellite design and operations. We need to automate as much of the spaceflight safety infrastructure as possible using every tool at our disposal.

We are establishing a cloud-based open architecture data repository for commercial space operators under a light touch level of supervision and standards, to manage safe spaceflight operations and develop new tools and techniques in a collaborative sandbox on the cloud.

SPD-3 requires us to offer a basic service free of charge, and to enable private industry to develop and market advanced services to companies performing complex space operations.

I'll conclude by saying that I'm glad I went first, because I want to hear from industry and our international partners present today about how they do it the next five years, so that we in the space commerce can keep up with them. Thanks very much.

Victoria: Thank you, Mark. That was a great kickoff to our panel. Our next speaker is Mrunalini Deshpande. Mrunalini has a master's degree in defense and strategic studies and started as a research fellow with the International Strategic and Security Studies Program in [inaudible 29:47] , Bangalore until 2019.

She was briefly associated with the Center for Air Power Studies in New Delhi. Currently, she's pursuing her plans for a PhD in the field of space security and policy. Mrunalini take it away.

Mrunalini Deshpande: Thank you, Victoria. I hope I'm audible.

Victoria: Speaking to you great.

Mrunalini: At the outset, I would like to thank the Secure World Foundation for giving me this opportunity to provide an Indian perspective on today's topic, because of the time constraint, I'm going to dive straight into it.

In recent years, India space activities have seen an increase in both magnitude and frequency. India's space budget this year is in the region of $1.8 billion, and India currently has a fleet of 64 active satellites. Today, India launches 10 to 12 satellites per year. This capacity is likely to increase in the future.

In addition to deep space missions and human spaceflight, India has also planned the space docking experiment in the near future.

The government has also provided separate funds to launch vehicle production to cater to domestic and commercial launches. Steps have been taken to get private players and startups to invest in space. Now, a robust space program of this nature obviously, necessitates an equally robust SSA capability.

India continues to be dependent on foreign data for its SSA needs. There have been instances in the past where India has temporarily lost track of its satellite due to mission related causes, and had to obtain services of friendly agencies to locate them.

India regularly uses the NORAD data to perform the collision avoidance analysis prior to each launch. Based on the NORAD [inaudible 31:29] , the Indian Space Research Organization has developed various mathematical models to predict and evaluate the trajectory of reentering spacecrafts and rocket bodies.

In addition to this, ISRO has also developed several models to study the evolution of space debris environment, collision probability analysis, and reentry predictions.

[inaudible 31:50] to broadly classify components of SSA into data collection, data fusion analytics, and decision making tools, it would seem that until recently, India has been solely focusing on the analytics and decision-making component, while primarily relying on foreign data. However, in recent years, India has made an effort to build its own SSA capability.

Presently, India has only one ground base that are dedicated for SSA for the multi-object tracking radar, commissioned in 2015, is currently used for space debris analysis in the power and orbital phases during satellite launches and re-entry prediction of debris.

In addition to the MOTR, India also holds a number of optical telescope facilities on its mainland. These telescope facilities fall under the aegis of the Indian Institute of Astrophysics, and the primary focus is astronomical observations. However, a few of the telescopes from these observatories have been used to track satellites on a need basis.

In 2019, ISRO set up a directorate of space situational awareness and management. The activities mandated to be taken by the DSSAM, include protection of Indian space satellites, assimilate and analyze tracking data of an active satellite from indigenous observation facilities, enable research activities pertaining to an active debris removal, space debris modeling and mitigation.

For countries like India was still developing their SSA capabilities, there will always be trade offs between more data collection and theory-based prediction algorithms. Therefore cooperation and sharing of SSA data is most favorable.

In June 2020, ISRO signed the MOU with the [inaudible 33:31] Research Institute of Observational Sciences. It is to facilitate the establishment of optical telescope facilities for tracking space objects and to promote studies related to space weather, astrophysics, and near-Earth objects.

In addition to this, ISRO has also signed a MOU with the University of Texas to enable collaboration with respect to SSA activities.

Actionable data sharing with other spacefaring entities, nations and independent repositories would only enhance India's current capabilities with respect to satellite orbit determination, conjunction assessment, collision avoidance, and satellite anomaly detection.

Reciprocity is fundamental to cooperation and collaboration, and India has undertaken substantial efforts to expand the scope of its current SSA activities. The consequences of activities in space are inherently international and it is important to ensure equitable access to the benefits of exploration and use of outer space for peaceful purposes.

Achieving long-term sustainability in space would require a global effort towards augmenting current space debris mitigation and space debris removal techniques, cataloging of space objects, and most importantly, sharing of information. Active debris removal techniques and on orbit servicing involve rendezvous and proximitate maneuvering.

Recently, the deployment of Russia's space-based anti-satellite weapon raised red flags in the international community. Today, it is easy to detect an international maneuver in space. However, the time required to catalog it is still longer than desired. Similarly, sensors are able to detect maneuvers in space, but often the intentions of such operations are not clear and are difficult to determine.

Unexpected orbital behavior can be misconstrued as belligerent, giving room for misperceptions and misunderstandings. On a global level, this underscores the vital need to develop an established international norms [inaudible 35:29] in space.

Unpredictable movements in space will only fuel misperceptions and therefore information sharing, and engagement and cooperation between spacefaring nations becomes important. This calls for a comprehensive and holistic approach to SSA.

Very technical tracking and monitoring is complemented with the intelligence during diplomacy and strategic dialogue tools for cooperation. Developing international norms that clearly define what is acceptable and unacceptable behavior in space is necessary. The effectiveness of military operations too in space is very much dependent on the development of these norms.

In 2018, during an SSA workshop by the Secure World Foundation and [inaudible 36:15] , the importance of cross-cultural communication was highlighted. It was reiterated again during the 62nd session of the Committee on the Peaceful Uses of Outer Space in 2019.

Along with transparency and data sharing, and increased accuracy of data, practicing culture, and when communicating with other operators will go a long way in mitigating threat perceptions and avoiding acts.

Lastly, the growing role of private players in the space arena cannot be overlooked. It needs to be complemented with the development of domestic space policies that would ensure that private satellite operators adhere to the global space sustainability standards by possessing current robust collision avoidance, data sharing, and debris mitigation strategies.

Economic growth in the space sector should not be at the cost of lack sustainability measures. Thank you.

Victoria: Great. Thank you so much Mrunalini. That was good insights. So glad to have an Indian perspective.

Our next speaker is Mark Dickinson. Mark joined Inmarsat in 2000 and is currently the Vice President of Space Segment, and deputy CTO. He is Inmarsat's Executive Director on the SDA, and was the Association's Chairman from March 2017 until September 2019. Mark?

Mark Dickinson: Thank you very much, Victoria. Thank you for Secure World Foundation for running this very interesting webinar. Thank you all to Pascal who did a great job in presenting the SDA. I'm not going to repeat what he said. I thought I'll take a slightly different approach to looking at this issue.

Rather than just look back over the last 10 years, I'll look back over the last 180 years and see what lessons we can learn from the development of the collision regulations for the sea, and how they could be on those lessons could be applied and how they're relevant to what we're looking at today.

Particularly how technology is a disrupter, and how we need to have a framework that can adapt to this new technology as it comes along.

Going back to 1840, a long time ago, 180 years ago, there were no collision regulations for vessels at sea. Basically, you trusted people to know how to sail. They knew where the wind was.

You would knew that vessels could only sail at that time, and that you can sail into the wind. Therefore, people could make educated guesses about what's going to happen to avoid collisions, but collisions did happen.

Then, some technology came along, which was a disrupter. The invention of steam-powered vessels, and how these could sail now through the wind, directly into the wind, which was never

possible before. Now, collision avoidance took on a whole new and different concept. People realized that the assumptions that they had before, they were no longer relevant.

In mid 1840s, the treaty house in London develops a set of collision regulations, essentially what's known today is as pass port, port side to port side as a framework for how people can avoid these collisions. A couple years later, they also realized they needed to deploy some conventions around using lights to indicate where vessels were, and importantly, which direction vessels are moving in.

Unfortunately, as is the case with regulations like this, essentially, almost treat as recommendations, they weren't enforced in any serious manner. They continue to be a number of serious collisions. In fact, there was a major one in River Thames in London in 1878, I think it was, where 700 people lost their lives in the [inaudible 40:15] collision.

It was those big events, which forced people to have some enforcement behind these regulations. I think the parallel here for spaces is important. We want to avoid having a major event, which we can react to subsequently want to be able to be proactive here, while than reactive as has been pointed out.

If we pollute various orbital regimes, it's going to cause us long-term problems, and these problems are for everyone.

Then, it wasn't until the 1970s that the IMO introduced the, what's known as the Collision Regulations At Sea, which were implemented in 1977. The administration of those regulations were passed in the local administrations.

Those administration's can be thought a bit like the space agencies who are looking to implement the recommendations that we have today for collision avoidance and best practice for satellite operations.

I checked on Wikipedia a couple of days ago, and there are currently 61 space agencies around the world who have obligations around satellite operations. That highlights that this is a true international issue that needs to be managed.

No one single entity can do it all. It's about having administration's who have the ability to oversight and enforce these recommendations and regulations.

We've seen on the shipping side the development of AIS. This is technology to allow people to be able to see in an open source way where vessels are, and where they're heading to, and various details about it. That information has helped greatly in the management of where shipping goes and has helped reduce collisions.

Now, shipping is looking at things like autonomous shipping. The IMO will now need to look about how they manage things like redundancy on board and sensors that were required to manage autonomous shipping. A number of these points have strong parallels to the issues that we face today.

Technology is a disrupter. The new space era now with constellations, with CubeSats, with on orbit servicing, these are all new exciting innovations that are happening in the space.

We need a framework that allows the safe operations for this innovation to make sure that we don't cause collisions or cause a pollution of the space environment, because we need the space environment to be operational forever. We can't cause lots of pollution now, because it's not going to be easy to clean up.

As Pascal has highlighted, we need the ability to have knowledge about where satellites are and what their intentions are in terms of where they're going to be in the future to allow effective mitigation measures.

As been highlighted this new technology, they're around low thrust systems, how they need to be managed and how they need to be modeled, to make sure that we can effectively perform conjunction assessments.

The onus on us is to be proactive here. We don't want the equivalent of a large collision at sea to force us in space, so we have to tidy up after ourselves. This is something we take very seriously now and have enforcement measures to make sure that people are abiding by the regulations.

We should use science and engineering as best we can to guide what those regulations should be. We need to have a way of measuring risk in a common way to make sure that we're making intelligent assessments of where the risk lies.

We also need to look at what technology...There's a huge amount of technology that the commercial sector has, whether it's SSA sensors or whether its ability to build to provide information regarding where an asset is, and what's its intention in the future, the equivalent to AIS space.

It's capabilities like that, that when we fuse together, we'll be able to mitigate and provide a safe operational environment. Government's role is vital in this.

Just as the coast guards maintain the safety of the sea, we need governments to also maintain space and agencies to maintain safety in orbit. Before that they need as well as their own sensors. They need to be able to take sensor data from many sources, commercial government, and from operators.

This isn't something that we can wait years to do. This is something we need to act upon quickly. Otherwise, we're going to be looking back in five years time wishing we had done things now, because we have caused a big problem for future generations to manage. Back to you, Victoria.

Victoria: Thank you so much, Mark. I was willing to look back to see what lessons can you learn from other share domains. You're absolutely not reinventing the wheel of this discussion. Thank you.

Our next speaker is Regina Peldszus. Regina is a Senior Policy Officer with the DLR Space Administration, Department of Space Situational Awareness, where she leads the German delegation to the EU Space Surveillance and Tracking or EU SST. Co-chairs its decision making body and handle studies on emerging issues at the intersection of space security, governance, and infrastructure.

Prior to joining DLR, Regina was an internal research fellow with ISA at the European Space Operations Center, Studies in Special Projects Division, focusing on the resilience of critical operations from a human systems integration perspective. Regina take it away.

Regina Peldszus: Thank you so much for the introduction, Victoria, and also for having us with you today. Good afternoon to everyone. Before I start and after Mark's, we can't be optimistic, I guess at this point, but nevertheless, we'd like to extend our best wishes from EUSST, to everyone at the SDA today. Both of our initiatives address similar issues, are safe, secure, and sustainable over to environments.

We both have complementary approaches, as you highlighted by either pooling data on spacecraft by operators in SDA or data from ground-based sensors of SSA and EUSST. Of course, we also share many of the same partners and organizations who either use or contribute both our efforts, and so very happy birthday to you from us.

For the occasion today, I'd like to share some thoughts on where we're at in Europe at this point in time and on the foreseeable future. Particularly, from the vantage point of European Union Space Surveillance and Tracking or EUSST.

Very briefly EUSST is a European Framework based on a law that was issued in 2014. It's going to be soon a program for a multilateral capability in space situational awareness here. It's overseen by the European Union, the European Commission, and it's implemented by a group of now eight member states in cooperation with the EU satellite center.

Together we put our existing sensors together, and we share data through a dedicated platform. We use that to provide services including collision avoidance, free of charge currently to European users.

Right now, Europe is experiencing a really interesting point in time. It's a crucial time for space in the juncture. As many of you will have noticed when you perhaps observe the European Council recently, we are in the process of finalizing and ratifying a new multi-annual budgets in the European Union, which includes the space budget.

With this, we're also at the cusp of a new European Union space program. That's set to start next year. In addition to the big navigation and observation programs, Galileo, [inaudible 49:18] , and Copernicus, the program will also include two new so called new security components, which is Government Communications and SSA.

SSA will be a successor program of EUSST, both for space security, but also as an operational building block for future STM contributions from the European side. This will be fleshed out further in the coming months and throughout next year.

This autumn is important for us, because of that, and all of this on the ground is happening against the backdrop of our orbital domain undergoing changes that are not only profound, but also very dynamic and completely unprecedented at this point.

What do we need to do in the next five years? I want to highlight three points that from our vantage point, we believe need to be tackled in any multilateral setting in Europe, but also absolutely beyond.

First of all, we need to ensure that we put in place adequate resources, so we can implement what we set out to do an SSA. Financially, these resources are to a great extent public in Europe, rather than private investment at this stage in time.

These needs to also include attention and dedication, because compared to a space application, such as Galileo or GPS, which you can take if you switch on your phone or you could look at Earth observation data from various different sources, SSA today is simply not as tangible and directly experiential in people's everyday lives.

Framing the issue that we face in orbit through the lens of space traffic management is very evocative, and can help us as a community of operators and agencies and industry to make our case. It also highlights the fact that this is a complex challenge and a interdisciplinary area where we have an operational dimension, but of course also need regulatory provisions.

Second, we need to work out ways of governance that bring those on board who are currently not engaged in the area of SSA yet, but who wish to contribute.

The problem we're looking at is so considerable and potentially protracted that there must be a place for everyone at the table who has expertise to bring. Not to say, of course, that everyone needs to have the full capability from sensor hardware churning out data to the algorithms and the services.

With organizations such as SDA and EUSST, we've seen two models, for instance, in the past 5 to 10 years where we see how collaboration can work and how trust can be built between different and very heterogeneous actors.

In EUSST, for instance, we work with really diverse actors from SSA op centers and sensors that are civilian, military, civilian-military, from commercial industry, or academia, so very, very varied.

Getting all of these different actors and interests under one roof and under one hat means constant and often painstakingly detailed dialogue, but it also allows everyone to do what they do best.

It allows us to tap into the entire ecosystem that we have at our hands here, while at the same time preserving some fundamental interests in the security area that today cannot be met by one type of actor alone.

Speaking of which, security interest, that's my third and final point. Whether you do SSA, STM, STC, SDA, domain awareness, traffic coordination, whatever we want to call it at this point, we need to be really crystal clear about where our security concerns are specifically, and where, if you will, safety of flight stops and where security starts.

I'm speaking here, of course, from an institutional agency perspective, although of course, there's also, as we've heard, sensitive data that private operators would wish to protect, and only share in a certain defined circle.

This not only relates to data sharing and data policy, but it also relates to sensor ownership and control and who has access to certain aspects of the ground infrastructure. It's very easy to say, but the reality today is that we do still have a very varied security architecture globally, and especially multilaterally, very different configurations.

This is important, especially, as we branch out to collaborate across the entire spectrum of partners, who on the one hand have operational legacies of decades with maneuverable assets and orbit, and on the other hand of the spectrum, who have new satellites, perhaps, but still something valid to contribute to the domain of SSA and STM.

If we articulated and pinpointed those aspects that truly merits protection from an individual active security perspective, then that means that beyond that threshold, everyone can do their job with the broadest possible application and transparency. With this, I conclude and look forward to your question. Thank you.

Victoria: Thank you so much, Regina. It was great to hear the parallels between SDA, the EUSST. Looking forward to hearing from your perspective during the Q&A.

Our last speaker is Dan Oltrogge. He is the Director of AGI's Center for Space Standards and Innovation, Program Manager of the Space Data Association, Analyst and Space Policy Expert for AGI's Commercial Space Operations Center.

Technical Author, Founder, and Administrator of the Space Safety Coalition, which [inaudible 55:00] was happy to have signed on too as well, and the author of numerous international space standards and best practices. Dan?

[background sounds only]

Victoria: Daniel?

[background sounds only]

Victoria: [inaudible 55:23] .

Daniel L. Oltrogge: Can you hear me now?

Victoria: We can hear you now. Great. Thank you.

Daniel: Great. Sorry about that. Thanks, Victoria. My thanks to the Secure World Foundation for inviting me to speak at this important event marking the 10-year anniversary of safety flight operations at the Space Data Center.

This is a truly remarkable accomplishment from my perspective. The many pioneering achievements of the SDC that Pascal highlighted earlier are noteworthy. I serve as a program manager of the SDC at AGI. My role in this panel is a bit broader than the SDC. Then, I also represent the Space Safety Coalition or SSC, what the acronyms going on here.

The SSC is an industry formed entity that endorses and strives to implement not only international treaties, guidelines and standards, but additionally to aspire to even more stringent levels of compliance and safety.

Before new SSC endorsees, including two recently from Asia, our participating set of space entities has quickly expanded to 44. This SSC initiative continues to resonate well across the space community. I'll put in my shameless plug here for the SSC, which is that you can find more information out about the Space Safety Coalition at spacesafety.org. We'd love to have your participation.

When you consider an aggregate, the commercially self-formed space data association, paid for entirely by the commercial and government operators that participate in the SDA services. As well as the commercially-formed SSC and the additional space safety initiatives and best practices championed by ISOLA and SIA, and CSF, and others.

You can gain an appreciation for the positive flight safety energy that the commercial space industry is bringing to the long-term sustainability of our space activities.

In truth, our international treaties guidelines and standards are struggling to keep up with the explosive growth and technical innovations of today's space economy and the countless ways that it is addressing human needs and activities, especially now during the pandemic.

Treaties are designed to be broad agreements amongst state actors with top-level normative content that is designed to be interpreted and instantiated by national laws by the countries that have ratified those treaties.

The recent adoption last year of 21 new LTS guidelines is also a very positive step forward, but it will take law and policymakers time to implement this guidance across the space enterprise via top-down regulations.

This is where the commercial space industry can and already has come in to capture, promote, and implement aspirational best practices through commercial self-formed entities, such as the SDA and SSC, as a part of that implementation and in advance of legal governance.

If we can start the video, please. It is an exciting time with the much discussed large constellations now well underway. We recently updated our CSSI statistics and associated video we posted in January 2020, depicting all of the spacecraft that have been applied for through the SCC and/or ITU.

In the space of a few years, Planet, SpaceX and OneWeb, have recently grown to operate a quarter or 751 of today's 3000 active spacecraft population. In this new version of the video, we depict the 107,641 spacecraft that have been applied for through 2029, to be operated by up to 68 large constellation operators.

Four of these large constellation operators comprise over 90 percent of all of these large constellation applications. US and UK space companies account for about 95 percent of all large constellation spacecraft applied for.

Everyone wonders the basic question here. What portion of these applications are "real," leading to operational spacecraft? Also, what will that realize population mean for Space Situational Awareness or SSA, and Space Traffic Coordination and Management or STCM, and collision risk?

There's no doubt that large constellations will have, and in fact already have had a dramatic impact on SSA and STCM. Within 10 years, we can expect up to two and a half million close calls per year in the most congested orbital regimes, leading to over 40 collisions annually, if these threats are not effectively managed and mitigated. Stop the video please. Thank you.

Having participated in designing, developing, and operating flight safety systems for many years, I can attest to a human tendency to be proud of accomplishing the rollout of the space safety system without paying sufficient attention to whether it provides on a sustained basis, comprehensive, accurate, and timely answers.

This upcoming large constellation environment points to the need for automated collision avoidance systems. In like manner, it cannot be all too easy to assemble an autonomous avoidance system without ensuring that it is effective in the operational context. Our focus needs to be on ensuring that SSA and STCM capabilities and services not only exist and are accessible, but also effective.

Space safety is comprised of a long chain of components in my opinion, and the chain is no stronger than its weakest link. In order to be effective, we need to think about the especially big gaps we have in our current processes.

There are plenty of ways to strengthen this chain. For example, by bringing advanced algorithms and analytics from the commercial and academic arenas, to bear in the SSA and STM environment.

These can augment or replace some of today's SSA processes to eliminate unnecessary simplifications and faulty assumptions, while enhancing overall SSA service level availability, timeliness, accuracy, and completeness.

If you haven't read last week's Washington Post article by Chris Davenport, I recommend it to you. We need to get past our current as US STCM log jam and quickly transition advanced capabilities and analytics into operations for safety of flight.

If you listen closely to Pascal's keynote remarks, you'll have noted how a central tenant of the SDA is data providing the framework for secure legally protected pooling of proprietary space data, for the express purpose of promoting the safe and efficient use of space.

Today, we have far too many stovepipe SSA and spacecraft operations systems, where the global aggregate set of space data is either not shared, not used, or not used effectively. Space safety can be dramatically improved if we open up the floodgates on space data in a crowdsourcing approach, alleviating some of today's stovepipe SSA processes.

In summary, we need to take a holistic approach to realizing LTS. It's not just about treaties, guidelines, and standards. It's all of those, plus commercial best practices with aspirational goals of not only meeting but exceeding minimum consensus requirements.

The time to address the many gaps in our LTS strategies is now, especially, in view of our ever increasing use of space. Thanks, and I look forward to your questions.

Victoria: Thank you, Dan. I'd like to welcome the panel back. If you guys could all turn your cameras back on. Thank you. We have quite a bit of questions in the queue. I want to start off by, oftentimes, we've used SSA and STM interchangeably, but they are obviously very different.

I'm curious to know from the panel perspective, how do you envision a space traffic management regime looking at the next five years or so? Will it look like now, but even more so? Will you have, maybe regional hubs of excellence? Will it be entirely commercial? How do you incorporate new actors and whatever this STM regime it could be? Any thoughts in the panel?

Daniel: I could start.

Victoria: Start with Dan, and then go into Mark Mulholland.

Daniel: I was looking at this question in earnest here, and starting an answer to it. To address the lingo a bit, I recently drafted up a proposed standard for space traffic coordination and management, to address and reach out to the international community, recognizing that coordination and management are parts of what various countries focus on.

STCM I see is an inclusive term, I'd like to promote that to the community. What does an STCM thing look like in the next five years? I would say that we have a running start with the Space Data Association. We have come up with a framework that has been effective now for a decade.

I think that this framework is something that everyone can look at and embrace, and look to crowdsource data into that framework. It's also a good model for the inevitable multiple STCM centers that we'll have amongst like-minded countries and like-minded companies for a while.

Maybe in the long-term, there'll be some vision of a more centralized international thing, but for quite a long time, we're going to have the country's providing an STCM system that meets their needs. Thanks.

Victoria: Thank you, Dan. Mark Mulholland, and then Regina, I think wanted to add something.

Mark Mulholland: We certainly have the same vision in space commerce. Part of I mentioned earlier that we're setting up in the cloud-based OADR what we're calling a sandbox. We're encouraging any and all to basically play in the sandbox.

We're looking at that capability as a means to develop new algorithms, as a means of evaluating new data sources, and do it in a collaborative and collegial environment, where when something is ready for prime time as a new tool, it will go through some sort of peer review, and then be put into the operational system.

We see a lot of parallels with how we do weather forecasting today. As a matter of fact, we've spent a lot of time talking over these ideas with the National Weather Service.

One of the best approaches to use different data sources in different algorithms is what the weather world calls ensemble modeling. Probably the best example of that is, if you look at a plot of a hurricane, you see all of the paths and what is affectionately called the spaghetti models.

It turns out that for the life of Atlantic hurricane, forecasters used something 14 different models. Some are more effective at the beginning of the storm. Some are more effective over open ocean. Some are more effective towards landfall.

Ensemble modeling provide you with the best overall picture without having to decide which model and which forecast is the best, because in fact, they're all good at different times. We see that as a fundamental way of working through all the different data sources.

Victoria: Thank you, Mark. Regina?

Regina: Thanks, Victoria. Just to compliment, our understanding is that you need SSA as a fundamental capability in order to do STM. You would need it for other activities such as characterization, which maybe is not or is not for us right now, a part of STM.

Since you asked how we may bring about or may bring in other actors who wish to contribute to this area, we currently use a model where we split on different functions. Not everyone is doing the entire capability. Not every everyone's doing everything, but we split our functions between different operational sense and processing aspects.

For instance, not everyone who may have something to contribute to the domain wants to invest in a huge surveillance sensor. We also don't need surveillance sensors which are hugely expensive. We don't need them everywhere. We have seen very new and interesting models in the past five to six years on how they're different ways that even cheaper sensors.

There's a huge mosaic and a huge puzzle of things that we need. There should be something for everyone. There's algorithms, there's data processing software. There are different sensor classes ranging from things that you can develop or that you need to develop over decades perhaps, and others that you can procure off the shelf.

If we understand SSA as the fundamental building block to do STM and various other things, then there's lots of ways that different actors can slot in.

Victoria: Interesting. Any other thoughts from the panelists? No. Moving on, [inaudible 70:56] a lot of good questions in the queue. We can try and get through as many as you can. We're now in the end of the session. There's an interesting question. It's specifically it's for Dan, but I'd be curious to hear any of the panelists take on this is.

Is there any threshold with a number of satellites in low Earth orbit that would make impossible make it impossible to operate because there's so many collision warnings, despite communicating the data? What's our breaking point there?

Daniel: Good question. I think there is a workload that the operators can sustain, which is driven by how many conjunction warnings they have.

Rather than answer the question directly, I'm going to just offer that, that workload you can then flip the question around and say, "This is what we can sustain. This is the resources we have. You have a not a knob you can turn to control how many warnings you get."

That's by trying to get more accurate orbits on your object and on the offending object, if you will, the secondary that you might collide with. This knob affects a change in how many warnings you have to sift through. It is a squared relationship, which means if you double the number of warnings, double your inaccuracy, that means you have four times the warnings.

It's a sensitive knob. If we can focus more on getting accurate orbits up front, then we can control how many realistic risks and collision threats we have to sift through. That's the focus.

Yes, there is a threshold if you will, and I would again say it goes back to what the operator can sustain, but that in turn should be the driver for one of the other questions in the Q&A chat window, which is how many collision risk there are and how do we control that?

The point being if we can improve our risk, we will dramatically allow ourselves to address those real collision threats and ignore the false ones, if you will. Thanks.

Victoria: Thank you, Dan. Mark Dickinson.

Mark Dickinson: I was going to follow on from Dan's comment in terms of...I think the answer to that is, the more accurate we have the orbits and the more accurate we know the knowledge of the [inaudible 73:47] for these objects, will allow us to run more effectively. If not just maneuverable, then you have a way of getting out of the way if there's a conjunction.

I see the problem coming is [inaudible 74:04] objects, which can't be maneuvered, we can't mitigate the risk of collision there. It's important that we minimize the number of unmaneuverable objects as they are tieded up. If I want to create more debris, then we can have the concept of debris on debris. That's when it starts getting out of control.

While objects are maneuverable, and you have knowledge about them, and you have operating information, and you have officers that can do something and respond to the warning, then that allows things to be managed. Once you start having objects which are essentially either dead or have no maneuverable capability, that's when things start getting very difficult to manage.

Victoria: Thank you, Mark. The other Mark I believe on that has.

Mark Mulholland: I was going to raise the issue that Mark raised about how we need to get better in tracking debris on debris and or non-operational satellites. I think too, that the threshold is somewhere that we remember that risk has two components.

It's not only the likelihood, which we in this world measure as probability of collision. There's also a consequence that's assigned to a particular risk, on most days of the week, 2U CubeSats colliding.

Although the likelihood goes up, because there's going to be so many of them. The consequence isn't nearly as great as two rocket bodies colliding or an active spacecraft and a rocket body colliding. If we calibrate the resources that we have and that we anticipate that we'll have, and start to factor in the consequences component, we may be able to do a more efficient job.

[background sounds only]

Daniel: Victoria...

Victoria: Dan, you want to jump in?

Daniel: Yeah.

Victoria: Sorry.

Daniel: I wanted to dovetail on something. The first, Mark was bringing up is that we will have a lot of collisions and close approaches, especially moving forward. I do have some analysis we've done which looks at today, the collision risk as a function of is it active on active, is it active on inactive, or is it debris on debris, which the first, Mark was bringing up?

As we go into this new space era, those statistics are going to dramatically change Yes, there are debris on debris up there and they're serious. You can talk to Darren McKnight, for example, to see some of the very serious risks we face.

As we get all these many more active spacecrafts up there, we're going to be driven by active on inactive and active on active, which drives the need for a comprehensive STCM system, where data exchange is the fundamental currency. Thanks.

Victoria: Thank you, Dan. There's a question specifically for the STC folks, we've go into. STC currently fuses data for their own operators, [inaudible 77:53] track, but given the growing commercial SSA capabilities, are there any plans to use data from other sources in the future, i.e. commercial catalogs or observations? If so, what timeframe? I need STC folks, who want to take that one?

Mark Dickinson: I kind of, unless Pascal is online and he would like to. There's something we have looked at in the past. We've looked at fusing third-party catalogs into STC, which is technically possible.

We've typically hit some issue regarding how we fund that, how we source that, because on most commercial process, their commercial business, they want money for their sensor information to be put into the system.

We have found being able to get one members to agree to fund that system to bring in that data, logistically, reasonably challenging to do. It's something that we certainly aspire to. We all agree that the fusing of the data and the more that the more data the better is something that would be a benefit.

What we do see is we are supporting certainly only the government initiatives and the agency initiatives like EUSST, and the [inaudible 79:20] , in terms of providing our data to them, and allowing them to use their data with it.

It's important that when, for example, Department of Commerce may pick up this activity, that they're able to be able to take sensor data from many different commercial providers and perform that fusing activity. It's a bit like my analogy back to the maritime world.

You have government agencies maintaining the maritime spacing, for example. They use sensor data, whether its AIS data or other sensor data that they can fuse together to be able to provide that management of traffic lane segregation for example. That's the way we see it going forward.

Victoria: Thank you, Mark. Anyone else from the STC want to add to that. Looks like we're good.

Another question. We focused a lot on the SSA systems and STM systems that we have currently looking specifically at Earth orbit, but as brought out, there is a growing interest in cislunar issues. As nations look toward a more permanent, robust cislunar and lunar presence, how do we build a comprehensive international STM infrastructure who features that space machines? Mark Mulholland already popped up his hand, so Mark.

Mark Mulholland: [laughs] I admit, I was looking ahead at the questions earlier. I'll point out one aspect that is beginning to happen. That is an awareness of the hazards of space weather, especially as you go beyond geostationary orbit. We've had several new companies come to us and talk about that kind of thing.

A couple of examples is that the emerging commercial human spaceflight and space tourism industry needs to understand and use space weather. You certainly don't want to send up a bunch of space tours right in the middle of a solar flare, because they won't be in such good shape when they come back.

Also, with the emerging of commercial space stations, perhaps permanent bases on the Moon, then you create problems of how do you protect those people.

We've had, again, I mentioned, companies who want to use space weather data to do things like work with industry that are trying to design new spacesuits and materials for space habitats.

If you envision, for example, a commercial lunar base with a whole bunch of people out on their lunar buggies, if solar flare starts heading towards Earth, you have eight minutes to get presumably inside your shelter that protects you. If you're walking around on the Moon, or in your buggy, you basically have no protection.

There's companies that are starting to take a look at that aspect. That's kind of a emerging business model that's coming out of the desire to go beyond Earth orbit. To do that successfully and safely, you need to design better materials that protect your people.

Victoria: Thank you, Mark. Any other thoughts on the panelists? There's one other question I thought was pretty interesting. When we talk about SSA considerations on an issues, we tend naturally to focus on the technical and engineering aspects, but of course, information is only as good as what we do with it. This question gets the heart of that.

One other issue that doesn't get discussed is what happens when new sensors come online? More objects will be tracked driving more conjunction warnings. How do operators react to more warnings? The objects were already there, they just didn't know about them. The risk has not changed necessarily, but still the awareness of that risk. Dan?

Daniel: I tried to lay the groundwork on a earlier response. I don't know if I did it well, but the point is that operators, especially in certain orbit regimes are already swimming in alerts.

If you on top of that add maybe 10 times the number of active spacecraft, and then improve the knowledge of things that are already up there by perhaps a factor of 10, you're looking at in certain

orbits 100 fold increase in conjunction risk. Therefore, conjunction notifications and things people have to sift through.

Again, it's the same answer I brought up before, is that we need to have more accurate data, dramatically improved data quality and better metrics of algorithms, to assess that. Not only the collision probability, but also as Mark Mulholland pointed out the consequence of that and factor that into the equations.

To get something that's sustainable and something green we can operate for spacecraft operators. Thanks.

Victoria: Thanks, Dan. Both Marks want to add something here. Let's go with Mark Dickinson, and then Mark Mulholland.

Mark Dickinson: I was going form the point that Dan was making there. More sensor information should allow you to have more accurate orbit knowledge. What more accurate orbit knowledge should allow you to do essentially have less warnings, then you can make your conjunction uncertainty smaller.

By adding to Dan's point, create more objects that you can see a cascade effect there. The fact of adding more sensors shouldn't be seen as a negative. It will be positive in the sense that it will hopefully allow cross calibration of other sensors and lower uncertainties regarding orbit knowledge.

From that will allow you to react to the meaningful conjunction events rather than the ones which maybe the missed distance is far bigger than what you would normally perform an advance maneuver for.

Victoria: Thank you. The other Mark.

Mark Mulholland: I was going to add that this emerging capability also plays right into the academic and science work done in debris characterization. Again, that gets into the overall risk management realm.

To come up with a short example, if I'm driving down the road, and I see an object to half a mile in front of me, I'd like to know whether it's a plastic grocery bag or leaf spring of tractor trailer, because in each case, knowing what the debris is, I'll take a different action.

I think concurrent with bringing these new sensors and this new observational capability online, there also has to be a lot of work done in debris characterization, because people will be making different operational decisions based on the debris object.

Victoria: Thank you, Mark. Regina.

Regina: Thanks. Since Mark mentioned characterization, I think that's a crucial aspect. If we have more accurate ways to begin to understand to characterize events, and not even just attribute, but to characterize and describe them, we will avoid something that Mrunalini highlighted earlier when she's spoken about misperceptions and mishaps.

I don't know if it's Mark, but it was Mark Dickinson. I don't know if it's one or two anymore, but you mentioned these so-called normal accidents, inevitable accidents in complex domains. Some of these were caused by mishaps and misperception. We know this from other domains. I just wanted to highlight this and bring these points together.

Victoria: Thank you. Mrunalini you want to jump in here?

Mrunalini: Yeah. I wanted to ask them. This might be a bit of a digression, but given the expertise of the rest of the panelists, I wanted to ask a question related to government regulations for private industry, encouragement of private industry.

All of us agree that government regulation should not be stifling. Given this background, how does one nation ensure promotion of private business, while simultaneously abiding by global sustainability standards in space? Any of the panelists [inaudible 89:08] .

Victoria: Guys, you have one minute. Who wants to take that one? Let see. Regina, did you have your hand raised?

Regina: Actually, no. I think [inaudible 89:24] . I'm super sorry.

Victoria: OK. Last one, Dan, or Mark Mulholland.

Daniel: Just to say, this again goes back to the Space Safety Coalition and the commercial industry taking their own initiatives to promote long-term sustainability. That's what we call a bottoms-up approach. There's also the top-down approach that the government comes up with, which is laws and so forth.

These things both contribute to long-term sustainability. I want to point out again back to Mark Mulholland's comment, the risk and time's consequence thing. If you look at long-term sustainability, the metrics you might use to quantify risk and consequence can be different than those that an operator uses to assure their mission.

There needs to be some sort of handshake there. I'll see it the rest of my time. [laughs] Thanks.

Victoria: Thank you. Mark Mulholland gives his final remarks. I'm going to share my screen one last time. Go ahead Mark.

Mark Mulholland: Certainly there is some external influences from, for example, the insurance industry and in the investment industry that can along with industry help to dictate proper norms of behavior. Again, just to piggyback on what Dan said, the best improvements in the history of the space program have almost always happened from the bottom-up.

Victoria: Thank you, Mark. We've got a little over our time, but I just wanted to thank our panel of experts for giving us such a thoughtful discussion of the issues surrounding the safety of spaceflight.

I'm sorry, we weren't able to get it to everyone's questions, the fact that there was such a volume of interest shows that we have not thoroughly finished this conversation. With that, I'd like to point out the Secure World Foundation is hosting its second summit for space sustainability.

We'll be going into some of these issues that are raised today and a bunch more related to the future of sustainably [inaudible 91:31] outer space. You can find out more information at our website, swfsummit.org. It will be virtual, September 9th through 11th, so a little over a month away. With that, I thank you all for joining and I wish everyone good day. Thank you.

Daniel: Thank you very much.

Mrunalini: Thank you very much.

Mark Mulholland: Thanks everybody.

Transcription by CastingWords