Trash in the Skies II
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Trash in the Skies II: Industry Perspectives on Dealing with Space Debris

Speakers

- **Mr. Jonathan Goff**, President and CEO, Altius Space Machines
- **Dr. Tim Maclay**, Director of Mission Systems Engineering, OneWeb
- **Ms. Lauri Newman**, Conjunction Assessment Manager, NASA
- **Dr. James Vedda**, Senior Policy Analyst, Center for Space Policy & Strategy, Aerospace Corporation
- **Mr. Mike Vinter**, Executive Vice President, AON Risk Solutions
- Moderator: **Dr. Brian Weeden**, Director of Program Planning, Secure World Foundation

Brian Weeden: Good afternoon, I'm Brian Weeden. I'm the director of program planning at the Secure World Foundation. For those who don't know us yet, we are a private operating foundation dedicated to the long-term sustainability of space for benefits on Earth. That means that we care about how we continue to use space, and derive all sorts of great benefits from space, that improve lives here on Earth.

That's the topic that brings us here today, because space debris and congestion in space is one of the major challenges that we're tracking, that could hinder or impede that future sustainability of our orbit.

Five years ago, we had the first Trash in the Skies event. At that time, space debris was becoming more of a salient issue among set of operators, as well policy makers. There were a lot of discussion about what do we do about that both from the government side and both from the industry side.

During that discussion, there's lots of big questions about how do space debris impact satellite operations? How do we even know what's up there in the current surveillance capabilities and what should government policy be to help deal with it?

Five years later, I think we're still having a lot of the same discussions. In my opinion, I don't think there's been as much concrete progress as we had probably had hoped we would be have by now. There's still a lot of discussions about what is the nature of the problem, what can we do about it? What should the role of the government be, what should the role of the industry be?

At the same time, the problems become more complicated. There have not been any major on orbit collisions or debris events since 2012, but there's been a continued increase in the number of satellites being launched into space, the number of countries and companies that are active in space.

We started to see some new trends, being the increase in the number of CubeSats, which are now measuring in the hundreds, and commercial plans to launch satellite constellations measuring in the hundreds and thousands per constellation.

By some estimates, there's on the order of 16,000 new satellites planned to be launched in the next decade. That compares with the roughly 1,500 satellites currently in orbit. We're looking at an order of magnitude increase, possibly, in the next 10 years.

There's both some challenges and opportunities here. On the challenges side, if we haven't really dealt with this problem of space debris and congestion, then the increased number of satellites is going to make that problem much more difficult.

On the positive side, this growing commercial use of space theoretically means there are companies that now should care about and have an incentive in the long-term sustainability of space. If they can't fly satellites, they can't do their business models, and they can't make any money, so theoretically, they should have a vested interest in this.

How does that change things? What is the future going to look like with these new trends? That's what I want to discuss in the panel session today. I've got five great speakers with me that are hopefully going to tease out different aspects of this debate.

On my immediate left is Ms. Lauri Newman. She's the conjunction assessment manager for NASA Goddard, and she's responsible for helping protect all of NASA's robotic spacecraft from on-orbit collisions. I've asked her to talk about what is it like to be a satellite operator today in low-earth orbit, what is the operational impact.

Next to her is Dr. Jim Vedda. He's a senior policy analyst at the Center for Space Policy and Strategy at the Aerospace Corporation and a general guru of all things space policy. I've asked Jim to talk about what is the policy aspect of this, what is the US government doing, how are they addressing the situation.

Next to him is Dr. Tim Maclay. He's the director of mission systems engineering at OneWeb, who is one of the companies that are planning a constellation of several hundred satellites. He's in charge of helping architect their constellation and develop their mission operations to make sure they are operating responsibly.

Next to him is Mr. Jonathan Goff. He's the president and CEO of Altius Space Machines, which is a Colorado-based company that develops space robotics and orbital logistics. They're working on some technology related to dealing with space debris and debris removal.

Finally, Mr. Mike Vinter. He's the executive vice president of Aon Risk Solutions. They're one of the major insurance companies working the satellite industry. They've had a focus both on satellite operations and, recently, on dealing with space debris.

One reminder before we get started. This event is on the record. There's media present, and we're also going to be recording the conversation and posting it later.

The format for today is I've asked each of the speakers to give five minutes or so of open remarks. I've got a list of questions that I'm going to be asking them, but we're also going to be asking the audience for their questions, as well. Reminder, when you do so, please state who you are, where you're from and ask your question in the form of a question. With that, I'll turn it over to Lauri.

Lauri Newman: Good afternoon. As Brian said, I work at NASA, managing conjunction assessment for their unmanned missions. We began that program in 2005, and currently support about 65 civil space and partner assets. Our program is modeled after the one at NASA Johnson, which was developed for the human space flight program, back in the 1980s, so NASA has been doing this for a long time.

We receive our conjunction predictions from Vandenberg Air Force Base, where we have contractors out there, who do our screens for us. We receive the data back at NASA Goddard, and do some risk analysis and then work with the owner/operators to plan any mitigation strategies that are necessary.

Right now, our workload is large, and of course we're expecting it to grow. Across our LEO fleet alone, we see about 700 unique conjunctions per month, about 3,000 across all of our missions.

For the LEO fleet, about one conjunction, per month, per spacecraft, requires additional analysis and maneuver planning. That means about a staff week's worth of work for my team, and then the flight operations team also has to do their work to decide what maneuver to perform and support.

Only a small fraction of those events actually result in a maneuver. Despite the large amount of work that goes into the planning, last year there were about 20 avoidance maneuvers executed across all the missions that we support.

A lot of our system is automated as much as we can, but not all of it. Minimizing the number of maneuvers that have to be performed in order to conserve fuel and to remain within science constraints, means doing some extra analysis that's manual on the orbit determination solution and so forth, to make sure that only events that are truly threatening get responded to.

The space event environment has been changing and it will continue to evolve rapidly, these are all the things that Brian was talking about. In particular, the space fence, when that sensor comes online, it's expected to see things down to 5 centimeters in size, whereas the current space surveillance network advertises 10 centimeters. Just that change alone is expected to triple our workload at NASA.

There are many planned mega-constellations, thousands of objects, analyzing just one of those recently, we noticed that instead of seeing one event per month per spacecraft like we see today, we'll now be seeing an event every three days. Each of these constellations, as it comes in orbit, will be an impact to operations, even if it's very well-managed and communication's great and everything is done well.

Accessibility of CubeSats means that not a lot of operators are familiar with best practices. Commercial space operators are becoming a larger part of the space community, and they have different business models than government actors.

A lot of spacecraft are now moving towards electric propulsion and automated maneuver planning on-board. The current space object catalog that's passively tracking things to be created, won't know where those objects are at any given time, so how do you plan to avoid them? New methodologies will be needed for safety of flight.

One thing that could be very helpful is, what I'd been calling an orbital registry, but basically, a centralized repository where orbits can be analyzed, not after the mission is already launched, but at the beginning of the design phase, because moving the spacecraft by a couple kilometers to a different mission orbit can really minimize the number of conjunctions that are expected to occur.

If that's done in the design phase, then it's not going to impact the design of the mission, but once you get to...be ready to launch and apply for your launch license, it's too late to make those kind of changes.

Improved data sharing is certainly important. Right now, the 18th Space Control Squadron takes in ephemeris files from different missions, but they're not screened against each other.

Although that maybe true in the future, certainly having some kind of trusted way for operators to exchange ephemeris data will become critically important, and being able to get those ephemeris files from the operators where they model the electric propulsion and the maneuvers will be very, very important.

Best practices, in general, will be needed across the board. There's a lot of exciting growth opportunities but it's going to change things a lot. We need to be prepared for that.

Brian: Next up is Jim Vedda. I've asked Jim to give an overview of the policy side and how the government is currently dealing with some of these challenges.

Jim Vedda: You've heard a little bit about what the operators are facing out there. Now, I'll tell you what has been done over the years to put some policies in place to deal with it. Then, we'll probably be talking a lot about the questions of whether this is enough.

The attention to this problem really started to blossom in the 1990s. We saw in the early years of that, back in 1993, the formation of an international group called the Inter-Agency Space Debris Coordination Committee or IADC which consists today of 13 space agencies around the world. NASA being the US representative on that group.

They've been working diligently on the technical side of this ever since that time. Meanwhile, in the '90s DOD and NASA got together and came up with a set of orbital degree mitigation guidelines, which in December of 2000 the National Security Council declared to be national policy.

As a result of this becoming the National Guidelines for Orbital Debris this needed to be incorporated in agency documentation. Those who have relevant operations in space. Certainly because of their own operational needs and because of this policy being in place a number of things were put together at DOD.

I'll just give a few examples of this. This may not be comprehensive but it gives you the idea of what's out there.

DOD Instruction 30100.12 on spaceport addresses the issue of all the debris. The Air Force has its own instruction on space safety and mishap prevention. NASA has a series of documents on limiting orbital debris including procedural documents, requirements, handbook.

On the regulatory side, we have the FCC, which is responsible for licensing in communication satellites or NOAA which licenses remote sensing satellites, and the FAA which licenses launches and re-entries. All of them in the language that they have for licensing agreements has certain requirements for debris mitigation.

Basically, those are trying to do a very distinct set of things. First of all, minimize the amount of debris that occurs during normal operations. Also, obviously during the deployment of a spacecraft initially.

Also, minimize the amount of debris that occurs through accidental explosions if a battery or excess fuel in an old spacecraft happens to explode. Sometimes this can happen years after a spacecraft has ceased functioning.

Also, post-mission disposal. How do you move a satellite out the way? Either deorbit it or put it to a higher graveyard orbit or even retrieve it and recycle it.

Those are the things that are covered in our National Debris Mitigation Guidelines. The interesting part was that after these became national guidelines in 2000 we started shopping them around internationally. We did that through our membership in the IADC.

Eventually, a couple years later the IADC came up with its own set of guidelines that basically reflected the same type of thing that we had in our own, although they added some technical details to it.

Then, the next step was to go to UN Committee of Peaceful Uses of Outer Space and promote the guidelines in that form. They accepted their own version, not as technical as the one the IADC had. That was put in place around 2006. In 2007, we had the UN General Assembly give its blessing to those guidelines.

As you can see, both domestically and internationally we've had a lot of activity in the past 20 to 25 years in trying to address this problem. The obvious question becomes, "Is it enough?"

If you think that space development is going to be a steady-state thing that looks just like it is right now then it's probably pretty good although it may still not be enough. We have this anticipation that space activity is going to be growing substantially and actually adding new types of applications over the year that are going to involve more proximity operations.

If that is indeed going to happen then this is not enough. I will just give an example of something that some of my colleagues at Aerospace were studying. This is a study they did in 2011 asking, "What would you do if you had the capability to actually do active debris removal? How would you target the debris to make best use of your resources in doing that?"

They lined up the probabilities of what is likely to generate the most debris. That would be the objects that are the most massive and in the most popular orbits. They're most likely to get hit. Now, if you have a big massive object and it gets hit it could become thousands of little objects which is not a good thing.

They set up a hierarchy of probabilities of creating debris. I think they went with a couple of thousand pieces here but they put out a chart of what I call "The Hot 100." It's hot 100 pieces that you would like to get out of space to make sure that they don't become bigger debris problems.

Here's the interesting thing, on The Hot 100, 60 of them belong to Russia. Obviously, we need some international cooperation in doing this. We have to address those issues and international law that may stifle this effort a bit.

I have some ideas about that but I think my time is up. I'm going to stop there and hand it off. We can discuss more on that later.

Brian: Great. Thank you. Tim?

Tim Maclay: I'm going to start off with a little video if you can cue that up. Just get everybody grounded and let folks know what OneWeb is actually proposing in launching.

Brian: You've got a video. You just became the coolest guy here. I'm just saying.

Tim: I know.

[laughter]

Tim: That's why I didn't tell you. We'll have to be really quiet.

Brian: The sound is working again?

Tim: Yep.

[background sounds only]

[background conversations]

Tim: It's not going to work, so this is our CEO and chairman and founder, Greg Wyler, speaking to you inaudibly.

[laughter]

Tim: Why don't we skip that then and I'll just go straight to a description? I think it's important to let everybody know what OneWeb is actually pursuing. The mission is to bridge the digital divide, provide global Internet service, and the real passion...

Brian: Microphone.

Tim: Microphone? Sorry. The real passion of our founder, Greg Wyler, has been to connect all the schools in the world, or at least provide affordable Internet access to anybody who wants it.

To do that, we're launching a constellation that will begin with 648 satellites. That'll be deployed by the end of 2020. The satellites will be distributed in 18 orbital planes of 36 satellites each, with an operational altitude of 1,200 kilometers and an inclination of 87.9 degrees.

That architecture will be scalable, so as demand necessitates, we can add satellites to that architecture. Satellites themselves are 150-kilogram class small sets. They're fully capable with a number of redundancies.

They have electric ion propulsion, and the communications payload is in the Ku and Ka bands. To produce these satellites, we've entered into a joint venture with Airbus Defense and Space.

They are designing and building the first 10 pilot satellites in Toulouse at their facility. At the same time, we've broken ground on a high-production manufacturing facility in Florida.

That facility will be automated with robotic assembly techniques and its peak production rate will top out at about three satellites per day. The initial production run will be anywhere about 900 satellites.

A launch of that magnitude of a constellation, it takes a pretty significant launch campaign. For that, we have contracted with Arianespace for a firm order of 21 Soyuz launch vehicles.

We've got options for additional ones then as we need them. With a 98 percent success rate, Soyuz will be the real workhorse for doing the bulk of the heavy lifting of the constellation, carrying at least 32 satellites per launch.

We've also got a firm order with Virgin Orbit to use their LauncherOne vehicle. We've got an agreement now as well with Blue Origin for the new Glenn launch vehicle.

I'd like to take a couple of minutes to, given that as a backdrop, to go over the elements of what we view are responsible design and operations practices. For us, it begins with the orbit selection.

We're going to deploy off the rocket at 450 to 475-kilometer altitude. This is well above space station so if we have a problem, there's no immediate danger to the space station.

It's also below many of the high value assets that, for example, Lauri's group protects. It's a nice spot to kind of get started and do your LE-Ops in IoT. From there, we'll ascend the operational altitude of 200 kilometers.

1,200 kilometers is well above most of the high-density regions of low Earth orbit, so it's a nice, quiet place to be. We will have excellent positional knowledge from the time we launch until we reenter, thanks to redundant GPS receivers onboard.

That telemetry gets downloaded to automated, high-precision orbit determination processes on the ground. We're also not a teeny-tiny spacecraft, so we'll have a strong radar signature. It'll be very easily to trackable from the ground.

We can use that as verification of our onboard solutions. We're also quite happy to share that data. We've already got sharing agreements in with JSpOC and the 18th. We'll share that data directly with other operators as well.

It's in everybody's best interest to know where everybody else is, so we'll do that directly. We're also investigating value added outlets like the Space Data Center and ComSpOC as additional resources for distribution.

Of course, we'll be actively monitoring conjunctions with other objects. We'll do that right from launch all the way to reentry. We'll be reacting to those, so you hear a lot in disposal plans about passivation.

We don't intend to passivate because we intend to actively bring the satellites all the way down until they reenter.

We'll be able to conduct collision avoidance maneuvers and analyses all the way, even after we decommission, even after we bring perigees down until they deorbit. For maneuvering, we do have the high efficiency electric propulsion.

We also have global TTC visibilities. The combination of visibility and reactivity gives us really good maneuvering agility.

A lot of the discussion recently has to do with decommissioning and disposal. The real message is one where we are very committed to disposing of our assets properly when we're done with them.

The commitment we've made is to bring satellites out of orbit within five years of decommissioning. The current guidelines are 25 years. We think that's quite a bit longer than it should take, especially if you've already got a propulsion system onboard.

It's really a small mass penalty to drop that timeline pretty dramatically. We've committed to five years. In reality, it's probably going to be more like one to two. The operation takes a little bit longer than a year.

It's also worth noting that the subsystems on the spacecraft that are required to do that deorbiting operation are specced as the highest reliability functions on the entire spacecraft, even above that of the revenue generating.

That gives you a sense of the commitment that we've got to responsible operations. We're also designing for demise during atmospheric reentry. Once we do reenter, little to no mass is going to reach the ground, so there's virtually no casualty risk associated with our deorbit.

Finally, we're considering options for incorporating accommodations on the spacecraft to facilitate uncooperative capture. If there does come a time when ADR services are commercially viable, we'd like to take some steps up front to facilitate our use of those.

In closing, these are kind of the main elements of what we consider to be responsible design and operational practices. We certainly encourage other operators to take environmental stewardship as seriously as we do at OneWeb.

We truly believe that new environmental safeguards and responsible norms of behavior need to be established now in order to ensure the sustainability of future space activities for everybody. Thank you.

Brian: Thank you. Jon?

Jonathan Goff: I run a small company, Altius Space Machines out of Boulder Colorado area. We've been working on robotics for facilitating spacecraft capture. Primarily, we started out focused on in-space refueling, propellant depots, things like that.

In recent years, a lot of the technologies we've been working on have lead us towards looking at different ways of being able to deorbit, or perform mass debris removal for space objects and space debris.

Just a couple thoughts I wanted to start off with is that most of the debris out there is what we call non-cooperative objects. These are objects that weren't really designed with the idea of having another spacecraft be able to come up and stick to them, capture them, and manipulate them.

Those sorts of optical aids to make it easier to navigate nearby, capture targets or grapple fixtures, etc., pretty much everything that's up there right now fits under this category.

There's been a lot of work at NASA, DARPA, Naval Research Lab, and several commercial companies like Orbital ATK and SSL MDA, our company, and a few others focus on this idea of being able to service either a still living satellite, or be able to capture or orbit a dead satellite, or at least move it to a safe disposal orbit.

One of the things that we've found is that you can definitely do that. There's a lot of work that went in through, for instance, DARPA's SUMO friend, the DARPA Phoenix and their current RSGS program, as well as a lot of work over at the satellite servicing program office, primarily focused on GS satellites and servicing them, like going up to a satellite and being able to say, "Refuel them," or "Fix a stuck solar panel," or things like that.

One of the lessons that we've been learning is that there's a lot of things that you can do before satellite launches that can make your life a lot easier.

The robot arms that they're looking at for some of these satellite servicing missions are like $10 million robot arms. They're very, very, very nice robot arms.

[laughter]

Jon: They're having to go up and basically, most of them are focused on grabbing some sort of mechanical feature that the satellite already has to have. A lot of satellites have a clamp ring on the back that they use to attach to the launch vehicle that they're launching on.

A lot of these robot arms have a tool. They'll go up and very carefully grab that ring and try not to bump the satellite in the process. A lot of the reason why that's a $10 million robot arm is in all of the feedback, so that as you're touching, you can grab it before it bounces away.

Seven rad-hard computer processors and a bunch of other things go into that, but there's a lot of items that you can now added to the spacecraft to make that significantly easier.

There was a workshop over at Goddard a couple of months ago, a satellite servicing program office put on where they were sharing some of their lessons and some of the items some they've been developing for "cooperative servicing," is what they call it.

Some of these have almost no mass cost penalties relative to the current ways of doing things for making things easier, so a couple of examples they have, they have these decals that...I should have brought one with me.

But it's basically a sticker that you stick to the side of the spacecraft and has a pattern on it that a camera can basically be able to detect or recognize that, "Oh, this is a decal," and using machine vision algorithms, they can tell exactly where the two spacecrafts are relative to each other, how they are moving relative to each other.

That makes it a whole lot easier to do the final couple of meters of maneuvering and be able to reach out and grab the satellite. They've also been working on cooperative servicing valves, because their focus is on extending the life of existing satellites, so the current valves that they use to work propellers of these spacecraft, they're not designed ever to be opened in the green space.

They put multiple caps on these things, they have safety lock wire, and lots of redundant seals. It's the kind of thing that a skilled technician could probably get that off in maybe a minute with the right tools. Doing that robotically is extremely difficult task for something that Goddard's actually demonstrated on the space station.

They put up a test payload that they could use the robots on the space station. It took a whole bunch of different tools, one to cut the safety wire, one to remove one cap. They were able to do that.

While they were going through that process, they said, "This is really annoying. What if we made a valve that is the same size, same weight, and try to get the exact same interfaces, but is easy to interface with a robot that has the same levels of redundancy and everything else but is designed from the start, so a robot with the right tool can just click in, transfer, propel."

There are quite a few versions. I think the space stations already have another batch going up next year.

Then the other piece, one that Altius is working on, in addition to these cooperative servicing decals and servicing valves, is grapple fixtures. The way that one of the people there at the Goddard office is putting, he said, "Things like these Marman clamp rings."

They said, "They're OK targets." [laughs] They're not the easiest thing to stick to, so we're trying to find ways of making light-weight grapple fixtures basically that can allow you to stick to the spacecraft. In our case, at Altius, we're working on a magnetic concept, so basically, passive plates of soft magnetic alloy, so it's basically a fancy steel.

The plate also has those fiducial markings on it so that you can do the same thing that decals do. We've got a concept that we've been working on that's on the order of 250 grams, about half as much as a water bottle, and it cost less than $1,000 fully installed, so it's in the noise for even the mass-produced satellite.

You have this thing and then any sort of magnetic ripple can stick to it. There's also work being done by other groups with gecko-adhesives, like the static adhesives, those will work on this too. Even harpoons, one ESA group talked about harpooning satellites. This is basically all panel and some stand-off so you can harpoon it as well.

The thought is put something like this on there that doesn't hardly cost anything, doesn't weigh very much, but when you go to capture it, it makes everything much easier, so instead of using a $10 million robot arm, maybe you can do with $0.5 million robot arm.

Anyway, just one other thought I wanted to mention. One of the biggest challenges for active debris removal has been coming up with a business model for a commercial company. Ultimately, to provide a service, you've got to have a customer who is willing to pay.

That's some of the interesting opportunities now, in some of these low-Earth orbit constellations is that the altitudes they're working at, things that get left up there stay up there a long time, hundreds of years. It's in their best interest, so you actually have a customer.

It's in their best interest to keep their orbits clean. As Tim was mentioning, they're taking all sorts of precautions to make sure that their Plan A is really good. They're trying to make the propulsion systems, the most reliable parts of the spacecraft, but ultimately, we think that having a Plan B is really good too.

[laughter]

Jon: We think that, with the advent of these large constellations, that there's an opportunity here to actually create a market-driven industry for providing, you can think of it as space tow track services. Anyway, I'll leave it at that.

Brian: Great. Thank you. Mike, please, the insurance perspective on all of this.

Mike Vinter: Brian, thank you for arranging this. I think it's a very important topic, certainly for the space insurance community which I'll talk to you here in a second.

My company, AON, amongst other things, provides insurance and risk management services to the space industry. Our company represents many of the well-known satellite operators and launch providers.

I've prepared a few opening remarks just to set the stage and try and describe the space insurance market a little bit, so that will help facilitate the conversation as we go forward.

Insurance has been very important to the commercialization of space. Almost every commercial and many non-US government space projects procures space insurance. There are two primary types of space insurance coverage for satellite operators.

The first is often referred to simply as launch and in-orbit insurance. This is effectively an asset or property coverage, usually procured by the satellite operator to provide protection for the loss of or damage to their satellite. This coverage protects the insured from launch and commissioning failures in on-orbit anomalies.

The coverage is very broad, basically an all-risk policy. That includes coverage for the peril of debris. Underwriters, while they're primarily focused on the heritage and the liability of the satellite launch vehicle, debris is a factor. Debris is more of an issue in low earth orbit compared to GEO-stationary orbit, so most of my conversation today will focus on LEO.

Regarding debris and conjunctions, again focused on LEO, underwriters want to make sure that the satellite operator has systems, personnel, and procedures in place to minimize these risks.

Greater fidelity in predicting these potential for injunctions mutually benefits operators and insurers alike. Space situational awareness will become all the more important as new constellations, such as OneWeb, come online and new small launch vehicles which are dedicated to launching small CubeSats.

That's a very new and dynamic to the market as well. Suffice it to say, LEO is going to be very active in the next few years.

As I alluded to earlier, virtually every commercial satellite is insured for the launch coverage, and the reason being is some of these individual satellites can cost an excess of 400 million and LEO constellation can be even significantly more, so management, shareholders, investors just cannot really stomach the risk of putting all those assets on one launch.

In addition to launch insurance, there is another type of coverage and that's third-party liability, TPL, coverage. This protects the insured from bodily injury and the property damage that the insured may cause to third parties and for which they are legally liable.

Here in the US, launch providers are required to procure this coverage as part of their FAA launch licensing requirements. This stems from the Commercial Space Launch Act and its amendments. It should be known that satellite operators are included as additional insurance under this policy. Other countries have similar schemes in place.

In addition to this launch liability, many satellite operators procure TPL coverage in case their satellites cause damage to other satellites on orbit. We ask to make that 50 percent of GEO-operators procured as coverage. Those that buy this coverage tend to be conservative or they are be required by law as is the case with the United Kingdom regulation.

Many LEO operators also prefer this coverage as well. Fortunately, today, there has been very little, if any, third party liabilities claim activity for on-orbit operations. For on-orbit activities, which we noted that liability is fault based rather than the absolute liability imposed for damage caused on earth or to the aircraft.

Presumably, satellite operators must exercise some standard of care, but because of the lack of honorable third-party liability claims, there is no real legal precedent here. Let's just hope that remains the case.

In conclusion, the space insurance market has provided a valuable service and has been instrumental in the commercialization of space. LEO, in particular, offer some challenges in the coming years as the number of actors, satellites, and debris both increase in numbers, but I believe the space insurance industry will be there to serve and help this new growth in commercial space. Thank you.

Brian: Thank you. I'll point out that I'm the one that wrote, several years ago now, that I didn't think there was the prospect for, private sector solution was going to emerge because most of the insured value was in GEO, most of the money was made in GEO, and most of the people operating in LEO were governments doing "public good" sort of things.

But as we've see across the speakers here, that dynamics are changing a bit. If OneWeb or the others are successful in building businesses offering broad-band communications from LEO and if more LEO operators are making money in purchasing insurance, they might have an incentive to then fund some of the debris removal.

In the middle of this, you see a set of dynamics that could result in something happening without just relying on the government to fund it. I still think there's probably a role we'll talk about that a little bit here. But that's a significant change, I think just in the last five years, that nobody knew about what's going to come, five years ago.

Just a couple of follow up questions from me based on what you guys all said. Lauri, what's the emotional state of the operator, right now? Are they just running around, "This is crazy," or is it business as usual, mostly manageable? What is it like, and are they concerned about what's coming, down the road, with this growth in cubesats and large constellations.

Lauri: We speak to a lot of different operators and in general, most of them are concerned. Some of them don't like to do maneuvers, and so they want to minimize that as much as possible. Some don't mind but all the operators have to weigh the risk against other risks to their spacecraft and decide when it's appropriate to take the additional risk of performing a maneuver.

They're concerned about Space Fence coming online, about the increased number of maneuvers that there are going to be. Right now, there's no policy across the agency that establishes what level of risk all operators have to accept, so each mission is unique in that decision on their own, but in general, it's taken really seriously.

Brian: Space Fence, that's going to attract debris that's already there but that we don't know where it is. We just kind of don't deal with it, [laughs] but when it comes online, suddenly we're going to have hundreds of thousands of objects that we now know about, and so it's.

Jim, you mentioned that the kind of "as is" for space-driven mitigation is these voluntary guidelines and standards and you hinted you have some ideas on the international front for strengthening that. Can you elaborate on that a little bit?

Jim: One of the things I've always believed needs to change is the way we treat salvage in space, which, as you know, is not the same as salvage in international waters. When you salvage something in space, you do not get ownership. It still belongs to whoever put it up there.

That's enshrined in the Outer Space Treaty. We and other space foreign nations have decided that we don't want to be opening up the Outer Space Treaty and with good reason, because that could be a can of worms that we don't want to have to deal with.

There needs to be some way to efficiently allow the transfer of ownership of junk in space. An idea that I've been proposing for several years now is that you can look at another treaty, the 1975 Registration Convention and don't amend the treaty.

Just add a protocol to it that says that any of the countries that have registered spacecraft there which have now declared the spacecraft as essentially dead, they don't plan on using it, it's not functioning, they don't plan to retrieve it, they can declare it available for salvage. In other words, yield their ownership rights to anyone who wants to propose a retrieval mission.

If that can be agreed to, such a protocol would open the door for making it much easier for those spacecraft that were specifically chosen by their owners as salvageable and allow countries, for their private sector to go out and do salvage.

It wouldn't seem to be that difficult to come up with some type of agreement for an issue like this for which the global space community pretty much is an agreement that space debris is a problem and we have to do something about it. That's not controversial.

Yeah, the process in the international scene is always a long, drawn-out thing, but this shouldn't be as difficult as other issues that have given us problems over the years. For a detailed explanation, I'll give a little plug here, if you'll go to our company website, aerospace.org/policy, look at my paper on Orbital Debris Remediation. It explains this in detail.

Brian: I'll add there's another related step which is most of the space debris on orbit are not registered by a country as declaring, "We own this," so if you're going to go up and try and interact with a piece of space debris, the current setup is you have to get permission from the launching state, the country of ownership.

For much of the stuff up there that's not a big satellite, that could be very difficult to figure out, who do you even ask permission of? That's a corollary.

Jim: There's a question of if it's not specifically identifiable, do you have to ask anybody? If it's something that, even paint chips or whatever it is, not that you would go after paint chips, but if there is something that's flying round up there that is tracked, but not specifically identified with the source, do you need to get any permission to do that? We haven't really answered that question.

Brian: You're absolutely right, we have not, and that comes down to, is there a degree of size object to which those protections of a object having jurisdiction control and ownership don't no longer apply. If it's a paint chip treated the same as a dead satellite in terms of indefinite ownership. That's an unanswered question in the international arena.

Tim, you talked about all the things that OneWeb is doing to behave responsibly, but you're not going to be the only company up there managing a large constellation.

There are several others who are looking at constellations in the same or similar altitude orbits, we talk about what your engagement is with those other entities, who are competitors, but also who you need to interact with operationally.

Tim: Sure. Operationally, we'll treat it like any other operators, share data and coordinate conjunction maneuvers as necessary. We've been pretty public about our advocacy for some spacing regime. It's one thing to just have a large constellation under your own control and jurisdiction where you could do all the coordination yourself.

It's another to then place a second or a third constellation of a large magnitude in the same vicinity. You may be able to do adequate coordination while everything works well, but really, we think you've got to set up the structure and target the altitudes right from the beginning with a certain level of passive safety about it so that you're protected when things don't go well.

If you have failed satellites in two uncoordinated constellations that are both the same altitude, that's when you start having a problem. We've been an advocate for the establishing of buffer of 125 kilometers between the centers, not necessarily a dead space between, but between the centers of large space constellations.

We've actually coordinated very successfully with Boeing on that score, so they were one of the other applicants that had applied for approximately the same altitude. We entered discussions with them and they agreed to move to a lower altitude to give both constellations a little breathing room, so there's precedent for the cooperation. We just need to do things that make sense.

Brian: One more question for all of you that I'll open it up. Jim was talking about the national and the IADC debris mitigation standards and the core being there is this constant, the 25-year rule, that you should not leave stuff on orbit longer than 25 years.

It's not really a rule, because it's a voluntary guideline, although in some countries, including the US, require that operators provide a plan of how to abide by it, but there's not a ton of follow up and checking to make sure you did what you're going to say, that you actually did what you said you did.

The question to all of you is, is that 25 rule sufficient? I'll add, at the moment compliance is roughly 40 to 60 percent, depending upon how you measure. Today, 40 to 60 percent of operators actually comply with removing their stuff within 25 years of putting it up there. With all that said, what are your thoughts on whether or not that is good enough going forward as far as the international standard?

Anybody wants to chime in?

Tim: Sure.

[laughter]

Tim: We think it's too long.

Brian: You said you guys are shooting for five as the standard for your constellation.

Tim: Right. When you put it in perspective, 25 years...By the way, it's post-decommissioning. You could have a 10-year mission, doesn't mean you have to be out 15 after that. It's 25 from the end of your use.

What it means is you could have an experimental satellite of six-month duration and it winds up then being on orbit as a projectile for 50 times longer than it was useful.

We don't think that's a reasonable practice and we're advocating for folks to think about it in terms of the length of their useful mission. If you're a five-year mission then you ought to be out five years after you're done as a target. It's a starting point for discussion.

We'll probably be out in under two years, probably, closer to one after decommissioning, and prove things that have propulsion system. There really isn't that much of a mass penalty instead of bringing your perigee down to 600 kilometers, you bring it down to 200. Yes, it requires a little more money, and a little more fuel, but it saved you 25 years on orbit.

Jon: One point I'll make on the percentages of successful compliance with the 25-year rule that was pointed out to me is that some of those numbers are skewed by satellites that it's actually been designed, and pre-approved by regulators before the role, and into the fact, and we're actively trying to meet that.

With that in mind, some of the simulations I've seen...Up until about a year ago, most of the analysis I saw about the debris population, and how serious this problem is, and what to do about this, assumed that Iridium was the biggest constellation that was ever going to fly. The studies state here, that someone was mentioning earlier.

In that sort of an environment, the 25-year rule, with the levels of compliance we've been seeing, is borderline adequate. Once you start getting 16,000 new satellites up over the next 10 years, most of those, and a fairly narrow band of low Earth orbit, and near-polar orbit, saw that everything's crisscrossing.

I think that it's going to be critical to improve post mission disposal or reliability. The ESA study I saw was suggesting that if you had a large, low Earth orbit constellation of around 1,000 satellites, and those orbit levels that was only 60 percent reliable on post-mission disposal, which everyone's shooting for much better than 60 percent reliable, but the debris population goes hockey stick within about 30 years.

At those altitudes, that stuff's going to stay up there for hundreds of years. Live satellites can dodge objects, dead satellites can't. Your odds of secondary collisions and things causing problems go way up. I think that the operators are planning these large low Earth orbit constellations appreciate that.

They understand that that's an issue. This is a serious thing that they're going to pay the consequences if they don't take care of this before everybody else, but I do think that post mission disposable or reliability's going to be critical once you start looking at large constellations.

Brian: All right, great. I'll open up the question to the audience now. We don't have a microphone to pass around, so please stand up, state your name, where you're from, and ask it in form of a question. David?

David Heartshorn: Yes, I'm David Heartshorn, I'm from the Global VSAT Forum. Most, actually, all the rules made for satellite operators are members of our non-profit association. This is now squarely on our agenda. Brian, I think I have a question for you, and that is this, did I hear you correctly when you said it was approximately 40 to 60 percent of the operators who are compliant with 25-year rule?

Brian: Mm-hmm.

David: That's a big spread. 40 to 60 percent. Is that because you can't find out the reason, or is there another explanation? Secondly, as a follow-up, who are the worst actors?

[laughter]

David: Either by country, by type of institute, government, non-government? Do you have that data? If you have to take this offline, I'd be happy to sign an NDA.

[laughter]

Brian: The data comes from ESA. The ESA's Space Debris Office has done the most work I've seen on this particular topic, tracking compliance with 25-year guideline since the mid-'90s when this discussion started as Jim pointed out.

Holger Krag and the guys that work at ESA's Space Debris Office, they published a couple of summaries of this. The reason I say 40 to 60 is it depends on how you slice the data.

The answer is different in LEO versus GEO, and it's different whether you're talking about government or non-governmental satellites. The range, 40 to 60, encompasses all of that.

The data is still a little dirty, as they'll say in the data science world. They're still trying to work through exactly some of the reasons why not everything was disposed of, in accordance with the guidelines.

In some cases, it's because the satellite died early. That premature anomaly on orbit, and they weren't able to do it.

In some cases, the operator went to boost it, let's say, in the GEO graveyard orbit, but it ran out of fuel halfway there. It got out of the active belt, but didn't make it all the way to the 265 kilometer above GEO altitude, somewhere around there.

That's the source of the data. That's where the numbers are roughly 40 to 60 percent. I would direct further inquiries to the ESA debris office for the actual dataset on that.

Jim: Brian, isn't it a little early to be tabulating that data and putting much faith in it since it was 2000 when it became our national guidelines and 25 years haven't passed yet. A lot of the satellites that been up since they were designed and launched before the guideline was in place.

Brian: That's a very good point, in that, particular on the government side, when a lifespan of a satellite might be 10, 15 years and then it's got a long period after that. You're absolutely right that we're in the early phases, but then, again, it has then 17 years since this guideline's been adopted.

I wouldn't expect 100 percent compliance today, but the bigger point that I think is there is that this is for steady state.

If we're going into an environment where there's a lot more satellites, and there's a lot more debris, we hope to see a trend towards improvement. The ESA study has not seen a clear trend, a positive trend, over the last 17 years. It's been kind of steady state as a trend. Yeah, go on.

Bud Searles: Hi, I'm Bud Searles, Finance Technology Leverage. Brian, you've worked on the DARPA CONFERS program. Would you comment on that, and how that would have some beneficial effects on what's going on in the world of the debris world?

Brian: As it was mentioned earlier, DARPA has been working on, not actually debris removal, but satellite servicing concepts for the last several years. They have a program called Phoenix a few years ago that going to do servicing in GEO, the kind of program called RSGS.

It is going to do the same thing, servicing in GEO. DARPA has also announced an initiative. It's a consortium for something, the satellite servicing operations. The acronym is CONFERS and all good DoD acronymology.

The idea would be to have a government-industry consortium talk about standards for how to do rendezvous proximity operations and satellite servicing in a way that is safe and responsible, however you want to define those terms.

DARPA has put out an RFP end of last year, and they're currently working through how they're going to select, basically, to stand that up.

DARPA used that as a complement to their demonstration of the actual servicing that this consortium will kind of run parallel to it to solve, again, the standards and the behavioral aspect of things. That's what DARPA's working on there.

Is that a hand over here?

Jim: Any other questions for Brian?

[laughter]

Haris Durrani: Hi, my name is Haris Durrani. I'm Columbia law student. I'm here working for the summer as a summer associate. I'd like to ask about SSA and particularly the military context of some of it. From my understanding, most of the telescopes and radars used on the ground to observe debris in outer space are based on some kind of military infrastructure.

I know, I think for Russia, it's very similar. I'm curious, particularly in terms of transparency and confidence-building measures, are there any issues there in terms of sharing data? If so, what can we do to negotiate around those?

Brian: We can start with, who uses that data?

Lauri: [laughs] Yes, it's true. The space surveillance network is the primary source of data for the 18th Space Control Squadron Catalog that they maintain.

Most of those sensors have other missions, and so when they're tasked to track a particular object, it just, "Here's this list of 50 things. Go see what you can find today." You don't know for sure that you're going to get any one of those.

You're having a closed approach. You may or may not get the additional data that you need. Other than that, about the transparency...

[laughter]

Tim: It has been a topic.

Brian: I just want to add that on the one hand, the US government does publish the most data than any other country out there. They're the primary source of the data, but as Lauri hinted at, their main purpose is not on-orbit safety.

Their main purpose is national security function, so there is some tension there between putting out data so that people can operate responsibly and avoid collisions, but also not revealing capabilities of their own sensors.

What's changing is that in the last few years, we've seen some commercial and private sector entities that have started up to provide some of that same data, or in some cases some better data, and that is changing things, but it's in the process of changing things, so short answer.

Brian: Anyone else?

Josef Koller: I'm Josef Koller, OST Space Policy. The question is for the insurance representative. First of all, I want applaud the general industry and the operator wanting to be a good citizen and live life longer, but I'd like to see what's in place in the insurance industry.

There seems to be some leverage possible, but the question to you, have you thought about incentivizing good behavior? Or do you actually see that you have some leverage for the commercial operators?

Mike: The incentive will be in getting the adequate amount of insurance that you need and getting it at a reasonable price. If you're exercising proper due diligence, underwriters will recognize that you're taking the steps that you need to monitor your fleet, etc. That's going to be in your insurance premiums.

If somebody is going up there and maybe they don't have any propulsion. Maybe they're a little bit less concerned about that. I think that would be reflected in their pricing. I see the insurance premium as more of what you're looking for. I don't know if that quite answers your question, but...

It would be coverage and availability and pricing given to the operators.

Josef: It does, to some degree. I want to pull on that a little bit more. If, for example, you probably wouldn't give a discount, like you used an analogy for a car, but if a car has a seat belt, the car is required to have a seat belt, because the insurance policy doesn't provide a discount for having a seat belt.

The analogy to me would be, if you don't require a certain feature or a certain connectivity, the fact is that performing activity is following the procedure. You wouldn't give the discount in the insurance policy, but if it does not apply here, then you may be able to drive certain behaviors with the commercial standard operating. Do you see it in a similar way?

Mike: What I would say, maybe just looking at a real-life example. If we are representing a client and they're putting up satellites in LEO.

We're going to go to the underwriters and the underwriters are going to ask specifically, what are they doing to mitigate the risks? That type of thing. These underwriters, they are all either engineers themselves or they have engineers on staff.

They're going to be well aware of these issues and that's what they're going to do. There's going to be, particularly in LEO, a very thorough underwriting process, because there is concern about debris that maybe you don't quite have as much of an issue in GEO.

These underwriters don't have a rating book and they're going to say, "You're doing this and this, we're going to..." It's more of a more gonna kinda be baked into their offer and what they'll do as far as pricing, coverage, limitations, that type of thing.

Brian: If I can ask more up there, my understanding is traditionally, the insurance world works off of historical trends and statistics. Is that the case with the space world and does that mean that in this case, it's going to be reacting to what happened and not necessarily out ahead of things?

Mike: With respect to LEO, everyone has been keeping their fingers crossed. We just really haven't had a lot of activity there. I think if we start to all of a sudden have some collisions, we start to see the growth, then the underwriters will react very, very quickly, but right now, particularly with this, as far as third-party liability, there's really then nothing on-orbit to speak of.

GEO is its own little world. Everyone's comfortable. There's statistics there and analysis. What's going to be interesting for the insurance community are these new constellations that come on board. They're going to really have to analyze the situation carefully, but unfortunately, there's no relevant statistics, actuarial science that can do relative to LEO at this point.

Brian: The insurance company, in this case, is not likely to be proactive incentivizing behavior. They will be working off of if bad things do end up happening.

Mike: Yeah, insurance companies, with their own money, are actually very conservative. They have investment arms of insurance companies, so it's difficult for them to invest in space technologies and that type of thing.

Thomas Roberts: I'm Thomas Roberts, CSIS Aerospace. I have a question for Ms. Newman, [inaudible] constellation. You had something on your opening remarks that maybe it would be a better relationship or any relationship between a commercial constellation designer and your office or NASA in general.

If I were to ask you, what would that relationship look like? Would it be formalized? Would there be, I'm going to ask you permission to free license this application?

Right now, I'm asking to move by a kilometer, might not be very much, but in the future, in a crowded environment, that kilometer will not be there.

Lauri: I didn't mean to imply that that was a NASA function. Just in general, I think there needs to be some central repository for someone to do that kind of checking.

Most people know where the space station is, and they'll take active pains to avoid station when they're putting something up in space. A lot of people don't know where the other high value assets are. It's a lot of things in sun-synchronous orbit. We dirty up that orbit and it's a big problem.

Having someone who knows where those things are and who can tell you, "Hey, if you have some flexibility when you're designing your mission, here's a range that looks good. Here's a range that's not as good," not necessarily telling someone what to do, but offering them the choices, rather than have

someone pick an orbit randomly, and go and design their whole system, and then find out they're flying in the middle of some other constellation.

They're going to have all these conjunctions that both operators are going to have to deal with that could have been avoided very easily five years earlier.

Tim: I would just add that I think that kind of coordination does happen. Our conversations with Boeing resulted in a nice coordinated resolution. It's not that big of an industry, so we know Lauri's office.

We work with the folks at JSpOC and the 18th, so it's not like there needs to be a huge enforcing function. Everybody's working, I believe, toward the same environmental goals.

Everybody who wants to work in space needs to preserve the environment, so it's in everybody's best interest.

Brian: Caleb?

Caleb Henry: Caleb Henry with Space News. I was curious how much collaboration there is between the IADC and the Space State Association, if there's a meeting of the minds between the main space agency and the organization of the commercial sector.

Brian: Go ahead.

Lauri: I don't know for sure because I'm not a part of either of those groups, so I don't want to commit to something.

In general, the IADC is more about the space environment and looking at how that changes in the future, and modeling and that sort of thing, whereas SDA is more about discrete on-orbit events and protecting against conjunctions that are happening today with that set of data.

They're a little bit different.

Brian: I'll just add, I do know that there is interaction between the SDA and Vandenberg and the US Airforce. The US Airforce has the catalog of debris objects. The SDA has data on member satellites.

Those are two halves of a complete data set, so there is some interaction there between those two. The IADC is a bit different in that the IADC are mostly scientists, mostly from space agencies.

They tend to do more of, as Lauri hinted at, studies of the evolution of the debris environment, the debris population, and more of the scientific analysis and understanding, and not on the operational side of things.

Brian: Victoria?

Victoria: Victoria Samson, Secure World Foundation. I was interested to hear the discussion that 60 percent of the objects in orbit are Russian. I am curious to know, first of all, how involved they are in the IADC discussions.

Furthermore, are they involved in the international negotiations, or compromise on these issues, seeing as often times, at least within the United States, very sensitive space technology seems to be classified.

Jim: I'll give point of clarification about that study that I quoted. It's a 2011 study that looked at the highest probability of objects for generating debris.

It's not the total picture of everything we're tracking. It's what is the highest probability, which generally means the greatest mass in the most popular orbits.

Of the top 100 in that list, 60 are Russian, as of that 2011 study. Probably pretty close to the same today. Probably hasn't changed that much. As far as their level of activity in the IADC, I have no direct knowledge of that.

I don't know if Lauri has anything to...

Robin Frank: To go to your question a little bit, one of the places where Russia is quite active, I'm Robin Frank with NASA's Office of General Counsel, is in the Committee on Peaceful Uses of Outer Space, both the legal sub-committee and the science and technology committee. There, they kind of go up and down, most recently on issues such as long-term sustainability and work on guidelines in that regard.

After being obstructionists for several years, they've now become more constructive.

Likewise, in the legal subcommittee when you're talking about non-binding measures having to do with small satellites, having to do with orbital debris, they're playing a more constructive role.

Jerome Pearson: I'm Jerome Pearson from Star Technology and Research. We're a small business in Charleston, South Carolina. We have a design for a spacecraft which can actively remove debris or other non-controlled objects in space.

We're wondering if there is a possible market for our services with large constellation operators that might have satellites that failed to deorbit themselves as planned.

We're wondering if there might be the possibility of a possible application for our spacecraft. It's called EDDE, E-D-D-E, and...

Tim: We're very supportive of that whole nascent industry. I think the real challenge is probably one of economics. There are lots of proposals out there for various sorts of technology.

I have no doubt that we can perform one of those technologies and do all of the launch and rendezvous and prox ops and grappling and whatever you need to do to deorbit. That needs some work. Beyond that, there's really another challenge which is the economic viability of that business model.

There's no real precedent for that. If you were to ask me what's the price point before we would be interested, I'd probably have two answers which is, "Well, our plan A is to deorbit ourselves, so we're really hoping no to need your services. We will work toward that goal very hard."

In the event that we do have failed satellites on orbit that we feel we need to remove, then there's a question of price point. In our case, we're mass producing satellites. Satellite's going to cost under $1 million, so what's it worth to retrieve it?

Where does it make economic sense to do that? Are you going to pay 10 times the cost that it cost to produce the satellite in the first place, or is it 5x, or 1x? That's a largely untested question. I'm not sure I can give you an answer.

Jerome: I'll give you a follow-up question then. If you have a failed satellite and you would like to have it removed, what would it be worth to have it removed?

Tim: I think that's the same question.

[laughter]

Tim: I don't know.

Brian: Related to that, Mike, you mentioned standard of care. Can you explain what that is and why it really hasn't developed on this issue for satellites and what the prospects are for evolving to one?

Mike: I think from a regulatory standpoint, we've got this 25-year rule, but there's not really much going on other than that. The standard of care is, and I'm not an attorney, but it's more of a legal concept.

If I'm launching something, a constellation in space, I'd better do the proper things to make sure I'm deorbiting, and I'm coordinating with others, not purposely causing additional damage.

If I'm not doing that, then that makes me probably more liable if my satellite bumps into another satellite. I think that there's this certain due diligence, these standards that those that are operating satellites in LEO should follow.

If they don't, then it gets back to, maybe insurance underwriters don't want to insure them. From the regulatory regime, I guess I'd ask everyone on the panel, but it just seems like we've got this 25-year rule, but what else?

[laughter]

Mike: We probably should have something else, I would think, certainly for LEO.

Brian: Jim, then the question is, what do you think the prospects are of the US government putting in place something stronger at the national level that might require a higher standard of care or more requirements for operations?

Do you see that happening, and why or why not?

Jim: The government's going to be compelled to re-look at this whole situation in just a very few years.

If you remember, a few years back when we had our first high-resolution remote sensing satellites, suddenly everything was targeting a resolution that used to be considered spy-satellite-quality data.

They had to rethink all of the regulations of remote sensing. Same thing is going to happen here. Once you have the Space Fence coming online, which I think is actually targeted for 2019...

Lauri: 2018.

Jim: Very soon. You're going to have the Space Fence.

Brian: The IOC is 2018, right?

Lauri: Yeah.

Jim: Yeah, so that's only a couple of years out that you're going to have a new capability that is going to multiply the things that you're tracking.

At the same time, you have a number of organizations of both government and private sector that are looking at doing various functions that, in general include proximity operations.

Proximity operations are something that's been around since the beginning of the space age, but it's been few and far between. It's been space agencies doing specialized things like the Apollo missions to the moon and the building of the space station.

Proximity operations are going to be the next plateau of activity in cislunar space. There's going to be a lot more of it, and a lot more different players who are going to be involved in it.

This is going to call upon the US government to re-look at the whole situation. We're tracking more up there. There's more operators involved, and they're doing more different kinds of things like satellite repair, on-orbit construction, taking space tourists up, whatever it is that they're doing.

It's going to require a re-look at the whole picture, both for norms of behavior and operations, and how do we clean up the space debris that we can clean up?

Brian: Any questions? Go ahead.

Haris Durrani: I had another question also about SSA. I know that Boeing is working on their Space Based Surveillance System. I think they already have a satellite up for that, most of the ways that we monitor the air from the ground.

I'm curious to what benefit something like Boeing's Space Based Surveillance System, I know it has other purposes, but to what benefit will that be in terms of tracking debris? Is there anything significant we're about to get out of that, if at all?

[background conversation]

Brian: The system you're talking about, it already exists, it's called the Space Base Surveillance System, SBSS. It's made by Boeing for the US Air Force and it's currently part of the space surveillance network that Lauri mentioned earlier.

It's one of only a handful of on-orbit sensors. Most of them are radars and telescopes located on the ground. It's in low-earth orbit, it's going round and round, basically looking out towards GEO, doing broad surveys of all the stuff in the geostationary belt. That's 36,000 kilometers above the equator. What you're hinting at is that there is discussion about follow-on for that that the Air Force is considering.

A couple of points, one, yes, different types of data combined together give you a better answer. If you combine together telescopes and radars, that gives you a better answer, either one together. If you combine together ground based with space based, that gives you a better answer than either one together. It is definitely complementary capability.

What's changing is, as I mentioned at the start of this, there's this evolution of private sector SSA that is starting to happen. Most of that to date has been ground based. There are few companies that are considering a space based SSA capability that will do what SBSS does and other things.

That's still very nascent, none of it exists quite yet, but there's several companies that have stepped on the drawing board planning to launch the next two years. That might change things. Whether or not the US government and DoD will make use of that is a totally different question. The space based is an evolving market, I would say. Next question.

Charity Weeden: Charity Weeden, SIA. It seems to me that large constellations in LEO versus the GEO belt where the disposal ops are different, meaning dispose in LEO by the descending through the atmosphere and there's another way of doing it up in GEO.

Does there need to be different norms behavior for each of those orbital regimes, and attacking this problem, painting the wide brush for 25 years for both of them? Should there be a different solution, should be the same? Lauri.

Lauri: I definitely think it's reasonable to look at things by orbit regime and come up with different standards or best practices based on that. It makes a lot of sense.

Jim: Yeah. At least initially they're going to be happy to treat it differently because of the different circumstances. I think today, if we were conjuring up the debris guidelines today, we wouldn't have picked 25 years. The whole thought process has changed since 20 years ago when these were being formulated.

A lot of it is going to depend on how the industries that are targeting debris cleanup and satellite servicing evolve, whether they are active in both LEO and GEO, whether some governments are active doing the same types of things. There's a lot of variables.

In general, I would say yes, different orbital regimes have to deal with different situations, but we'll see when it happens.

Brian: Jon, relative to some of your competitors, you guys are a fairly small company. What is it like trying to come into this sector and trying to be innovative and trying to do some new stuff, with a customer base in the low-earth satellite companies and the governments that are not always very reactive to innovative ideas?

What is your experience then? What has that been like? Do you think it could be improved? Is it good?

Jon: Particularly in satellite servicing, post-mission, backup, end of our disposal area. We've been working with a lot of groups including OneWeb and some of the other constellations. Some take more seriously than others, to put mildly.

Probably one of the big challenges, for small companies trying to raise money on this is that there's different messages. Investors want to hear, "Here's this huge or shattering problem, that if it doesn't get solved everyone is going to die."

Everyone wants to pay lots and lots of money it and this is going to be a huge, huge market. The operators are trying to be good stewards and say, "We're not entirely sure how many we're going to need," and honestly no one does.

For constellations that know that they've got hit high post-mission disposal and liability for ongoing sustainability, they're going to try harder than a lot of these groups in the past. The question is, how successful is that going to be? Is that going to be 90 percent? Is it going to be 95, is it going to be 99? Is it going to be 70? [laughs]

That's been one of the bigger challenges is trying to navigate, figuring out. This is one of those where trying to characterize the market and the size and the opportunity. Is this a commercially viable thing that we can raise money for, and which methods for going about that?

That's probably been the biggest challenge. At least now, I think we're getting a lot of the people agreeing that, "Yeah, this looks like this is probably going to be necessary." A lot of people are starting to realize that the time to start developing active debris removal and getting that on the shelf, getting that on the market, is not after we have data on how good the post-mission disposal reliability is for these large constellations.

You don't want to wait 10 years from now, and it's like, "Oh, shoot! The number was X instead of one or two percent that needs the services, 10 percent." You don't want to be starting development of a solution at that point. You want to have it coming on market about the same time.

There's some definite fundraising challenges there, because we don't know how big the problem is. It's hard to quantify exactly how lucrative or not the market is. We're trying to make conservative investments on our end.

The other parts that Tim was pointing out is, they also don't know it's hard to quantify how valuable is the service. If it turns out that only one percent of their satellites die before they can do the disposal maneuver, then maybe it's not as valuable. If it's 10 or 20 percent it's really valuable because then you get most of those out of there.

Some ideas we've been looking at is trying to target a price point that's in the same ball park as the cost of launching a new satellite. That's definitely not how valuable the service is. There's a psychological benefit to...People who are launching a constellation know exactly how much a replacement satellite is going to cost them.

It's probably one of those numbers they have tattooed into their brain as like, "This is how much a new satellite cost to build and launch." We're trying to see if we can hit a price point below that, so that we're inexpensive enough that it makes sense to do that.

The one other piece is we're trying to get satellites to proactive put, or capture targets or dog tag, capture targets on vehicles in advance. Because if they can put those on in advance, then we can do the orbit with a vehicle that's going to cost two or three times less, substantially less.

Bud Searles: A follow-up on what Jon was saying, from our perspective as investors in satellite programs, the problem that he's got is you can't make a clear business case out of something like the debris removal. Not only do you not attract investors, but you won't attract money as the insurance guy. It's both of those elements.

What we've got to look at is, how do you take these things and make business cases out of them, make good business case, so that you show some return for it or haven't add on to something else, it's already in place. To double them, not only from the investor or from the insurance.

Brian: Would you...?

Jim: I've always seen on the commercial side the active debris removal as being a sideline. Because if you're going to be in the business of doing retrieval on-orbit servicing, you've got pretty much the collection of technologies that you need to do debris work as well.

If you have that capability and your on-orbit assets are otherwise inactive. Rather than having them sit there, you do the sideline business of debris cleanup. Maybe some governments will pay you to do that.

The other aspect is that, the business plan may not always be focused on, "Let's fix or revive a satellite for its original owner to continue to use." It may be, "Let's make that satellite available for somebody else who can't really afford to put up their own satellite but they're willing to buy a used one. A pre-owned one. I'm sorry, that's what they call them now. A pre-owned satellite.

Bud: Certified pre-owned.

Brian: Yeah, like a pre-owned rocket.

[laughs]

Jim: We have those now. You have a big space foreign country that has a lot of lucrative businesses working in space and a satellite dies and say, "That's old technology. We want to replace it with new stuff." Over here is the Dutchy of Grand Fenwick and they say, "Geez, we like to have your old satellite. If we refuel it and kick the tires a little bit and see if we can make it work for us."

There might be a pre-owned satellite market that would develop. That's one of those things we don't know if that can evolve in the next decade or two.

Bud: That's taking a pre-owned satellite in the orbital satellite that you have to own before you get a new satellite going.

Brian: That's a whole different cause of problems. I've got one more question, but I'll give one more opportunity, if anybody has any they want to ask on their own.

Christopher Simpson: I got one. This is a little bit more focused on, I'm Christopher Simpson with AI Solutions. Lauri, it's more in your realm. As far as you mentioned the missions right now, they do their own assessments as far as the probability of collisions certain percentage and they say, "OK, yeah. We're going to go ahead and make them move," or not. Is there any push to make that standard across all missions or even at the federal level?

Lauri: There hasn't been so far. Once we see this increase in work load with Space Fence and constellations and so forth, I think that at least from a NASA perspective we want to look into that, because it makes a lot of sense. This is something we did with launch COLA in the past.

How much risk does it make sense to accept given the accuracy that's achievable and that sort of thing? Then giving some guidance to the mission on what makes sense. They can always be more conservative, but some minimum standard makes sense.

Brian: That actually a good lead into the question I was going to ask. As it stands, every operator makes their own risk assessment based on their own private threshold of how much risk they're willing to accept. The challenge is that's their private risk.

There's also a public risk that, "I may not care if my satellite gets hit because I have 50 others. But my satellite gets hit, I generate debris. That impacts everybody else in my same orbit. I'm making decision that may lead to risk for them." That's the trickier question.

That leads into my final question for everyone is, what should the role of the government be then? What do you see the role of the US government should be on those question? Should it be totally hands-off and let the industry solve it?

Should it be, on the other spectrum, some tough regulation with punishment for those that don't behave according to some standard? Where is that threshold do you think the government should be involved?

Jim: I'll jump in there.

Brian: OK, go ahead.

Jim: To bring up again the notion that in very few years the government is going to have to relook at the whole regulatory framework for activities in space, because the activities are going to grow and change. That's inevitable.

As far as the task of doing debris tracking and management, clean up, that is going to have to be some manner of public-private partnership, because the governments have to be involved due to the legal issues and the need to coordinate behaviors, but they don't have resources to do what needs to be done.

Those resources are to be found in the private sector and the innovation that's needed to come up with the creative methods to do this. Couple them with other potentially money-making ventures to put together a whole package that actually works for everybody.

Yes, there is a role for government to continue its regulatory responsibilities. What we anticipate will be needed even in the next decade or so, is not something the government can do alone.

Brian: You have something to add, Lauri?

Lauri: Mm-mm.

Jon: I'm a bit on the libertarian side of things. You do try to think of ways that solutions can be done without adding new regulations to the book. I do think there's some things the government can do, and some they're already starting to do.

Championing best practices, especially some things, satellite servicing program officer that Goddard has been doing about trying to encourage people to start adding these cooperative features satellites to make it easier.

They can take the lead by doing that for their own satellites and they're already are. There's already, suddenly satellites are flying with these decals from Goddard and the valves and other pieces and

grapple-fixtures like the ones Altius is developing. NDA also has mechanical grapple-fixture design that's lightweight.

Taking the lead on that and saying, "We think that people should be doing this." Make your plan A as reliable as possible, but have a plan B. Just doing that already will...Suddenly that could be done without adding new laws or regulations and stuff.

This is something that the Air Force and NASA can...They're already starting to do some of that and I think continuing in that direction is helpful.

The only thing I can think on the regulatory side at this point, I don't think that it's yet appropriate to force...I don't think that the ADR side has proven now and the cost of that are quantified enough to justify saying, "If a satellite goes up, it has to come down" and putting serious teeth on the 25-year-old.

I do think that it would probably worth asking good questions, "What's your plan B? Your plan A is make your propulsion system super reliable, but you're going to be launching a whole bunch of new satellites into an orbit that if your satellite dies before it comes down, it's going to be up there for hundreds of years, 500 to 1,000 years."

The cost of learning on the job is fairly high. Just asking, "What's your plan B? What are you doing to be proactive on that?" Even without any new regulations or any enforcement on that, you're asking people to think that through and explain what they're doing. I think that would be helpful.

Mike: I would just add one point from the insurance perspective is, it would be nice. Obviously, the US government has lots of assets to look at conjunctions and whatnot that probably aren't available to the average commercial operator.

To the extent maybe the government can help in that avenue a little bit more. I know it's asking a lot, but that would be very helpful to the commercial sector.

Brian: With that, please join me in thanking our speakers.

[applause]

Brian: One final thing to put a plug in, we at Secure World released our “Handbook for New Actors in Space" over this year. It's basically if you're welcomed to the club book and what you need to know about international, national policy and space operations. We have a few more outside if you're interested.

We plan to post the recording of this and a transcript in our website in the very near future. Thank you all for coming today.

Transcription by CastingWords