Panel 3: Activating Active Debris Removal

Spotlight Talk Speaker: Darren McKnight, Senior Technical Fellow, LeoLabs

Moderator: Ian Christensen, SWF Director of Private Sector Programs

Panelists:

- Asha Balakrishnan, Research Staff Member, Science and Technology Policy Institute
- Clelia Iacomino, Research Fellow, SEE Lab SDA Bocconi
- Luc Piguet, CEO & Co-founder, ClearSpace SA
- Charity Weeden, Vice President, Global Space Policy, Astroscale US

Darren McKnight: Hello, my name is Darren McKnight, senior technical fellow for LeoLab, and I have the pleasure of starting off the session on "Activating Active Debris Removal."

The vast majority of the debris generating potential in low-Earth orbit, or LEO, resides in a few hundred massive derelict objects often abandoned in tight altitude clusters that amplify the probability of a significant debris-generating event.

As early as 2000, all of the major spacefaring agencies identified this pool of several hundred objects. This list provided a clear story, but did not provide actionable priorities. Recent analysis by a team of 19 global experts from 13 countries reduced this longer list into the top 50 prioritized list.

The top 20 objects were 20 SL-16 rocket bodies. 18 of which are centered at 840 kilometers altitude. As a side note, the top 50 objects were roughly 80 percent abandoned before 2000, roughly 80 percent rocket bodies and roughly 80 percent of Russian Soviet origin.

Further, this year, a new analytic tool was created, the LEO collision risk continuum, which examined over 400,000 conjunction data messages or CDMs, issued by LeoLabs during the last half of 2020. These CDMs included all objects against all objects. The search was not limited to the riskiest conjunctions for the largest objects only. We let the data select the worst offenders.

The probability of each conjunction is multiplied by the total mass of the objects included. This serves as a surrogate for consequences if a collision happened to occur. There's total mass involved in each close approach and was used to obtain a risk value. For this analysis of all objects in the space catalog, the top four items were, again, SL-16 rocket bodies.

Further, the analysis clearly showed what had been hypothesized in the past from previous analyses. The greatest risk of future debris growth is from potential collisions between massive derelicts abandoned decades ago, not the small, agile newly deployed smallsats populating constellations.

Further, there are two altitude regimes that continue to rise up in all analyses as potential hotspots for future debris growth and therefore targets for ADR. These two regions are centered around 840 kilometers and 975 kilometers.

While active debris removal, or ADR, as a remediation option is rapid and permanent, there are some benefits to consider the general category of remediate-in-orbit to work cooperatively with ADR.

This may be even more relevant for the most massive objects, such as the SL-16s, as their removal would definitely require controlled reentry to assure limiting the probability of ground casualty to below the threshold of 1 in 10,000.

Just-in-time collision avoidance, or JCA, and nano-tugs are examples of remediate-in-orbit options. JCA calls for the use of either laser impulse or interaction with a ballistically launched cloud to nudge one of the two derelict objects from an imminent collision.

If a JCA solution could be developed that was much less expensive and response than ADR, in conjunction dynamics, accurately improved, this solution might become a valuable complement to ADR for the most massive of derelict objects.

Similarly, a nano-tug is simply a small, probably a 6U cubesat, system that could be attached to an abandoned derelict object. The nano-tug comprises accelerometers, electric thrusters, GPS receiver to in essence bring the derelict object back to life by providing the capability to perform collision avoidance maneuvers as necessary.

We are decades beyond the point of urgency of cleaning up mass deposited in LEO decades ago whose collision churning may adversely affect commercial and national security space systems for decades to come. This is especially true for constellations of satellites whose collective exposed area will make them uniquely susceptible to lethal non-trackable debris.

As the popular press and regulators seem to be fixated on constellations as the catalyst for reduced space safety, I propose that the constellations will end up being the victims of decades of complacency in debris remediation and debris mitigation policy and regulation. Thank you for your time.

[pause]

Ian Christensen: "We recognize the growing hazard of space debris and increasing congestion in Earth's orbit. We welcome all efforts, public and commercial, in debris removal and on-orbit servicing activities and undertake to encourage further institutional or industrial research and development of these services."

My name is Ian Christensen, Director of Private Sector Programs for Secure World Foundation. Those were not my words but rather are quotes from a joint statement issued by the leaders of the G7 countries after their summit in England earlier this month.

The spotlight talk we just heard from Darren McKnight gives us an idea of part of the reasons why the G7 countries might have made this statement. The urgency of the need to address the orbital debris challenge is indeed increasing.

Following through on policy statements will require sustained attention to implementation. Technical research and development will surely be needed, but it will also require understanding whether there is economic and business rationale or reason to tackle space debris.

In the next 55 minutes, this panel on Activating Active Debris Removal plans to dive into these topics. What can we do to spur government and industry alike to get serious about removing orbital debris? We have a panel of experts well-placed to look at this from multiple angles, economics, business, and policy.

You can find their full bios on the summit website, but I do want to briefly introduce each of them.

Asha Balakrishnan is a Research Staff Member at the Science and Technology Policy Institute, a federally funded research and development center that provides analysis of science and technology policy issues for the White House Office of Science and Technology Policy. Recently, she has collaborated with colleagues on a number of reports on space situational awareness, orbital debris issues, space traffic management, and small satellite technologies. Asha holds a PhD degree in mechanical engineering from the Massachusetts Institute of Technology.

Clelia Iacomino is a Research Fellow at the SEE Lab, the Space Economy Evolution Lab, of SDA Bocconi School of Management in Milan. She is currently a PhD candidate in management and innovation at the Catholic University of Milan. Her research interests include technology transfer regarding on-orbit servicing, economics to be applied to space debris, and the role of [industry and the public sector in the sustainability of low Earth orbit.

Ian: Luc Piguet is the CEO and Co-founder of ClearSpace, a Lausanne, Switzerland-based startup aiming to clear up space debris and build up in-orbit servicing for sustainable space operations. Luc studied at the EPFL Space Center with a Master's Degree in Electrical Engineering.

Charity Weeden is Vice President of Global Space Policy at Astroscale US, coordinating and synchronizing Astroscale's global policy efforts towards spaceflight safety and long-term space sustainability. Charity also serves as the chair of the US Commercial Space Transportation Advisory Committee or COMSTAC. She holds a Master's Degree in Space Science from the University of North Dakota

I'm excited to get to the discussion with our panelists on the virtual stage.

[audio glitch]

Ian: For audience questions, please submit your questions via the Mentimeter website. Our first question today is going to go to Clelia.

Clelia, in our first panel at the conference this morning we discussed space's role in addressing climate change, SEE Lab has looked at the parallels of space debris to the challenges of climate change. After listening to Darren's introductory talk, how would you describe the environmental challenges that space debris represents?

Clelia Iacomino: Thank you. Thank you, Ian. Thank you for inviting me to this interesting event. As SEE Lab, we started to study this space debris programs, and we started. When we started to analyze this program, we compared the space debris program ecosystem with the climate change.

We started to analyze in particular what was something in the climate change, so the comparison with the biosphere degradation of tropical forest loss, so the cumulative problems, and the cumulative effects regarding the natural ecosystem with the parallel with the orbit ecosystem.

Let me read a quote that was very important for us when we started to compare the orbital, the debris problems with the climate change. The quote is of the Professor Alfred Kahn that was an American professor and expert in regulation.

He developed a theory, the tyranny of the small decision. He said that the tyranny of the small decision is “a situation in which a series of small, individually rational decisions, cumulatively result in a larger and significant outcome which is neither optimal nor desired and can negatively change the context of subsequent choices, even to the point where desired alternatives are irreversibly destroyed."

This is what is happening with the space debris, and the challenges, and the comparison that we did with the natural ecosystem and the orbit ecosystem?

Ian: Thank you, Clelia. I understand there's some problems with my connection. Hopefully, folks can hear me. It sounds like it's better. We'll try this. If my Internet goes bad again, we'll have to see if my colleagues step in. My apologies here.

Charity, Luc, the next question is going to be basically the same question for both of you. Maybe if I have Charity go first and then Luc once Charity finishes. The question is, "What is your company doing to respond to the challenges that Darren and Clelia have just talked about?"

What near term mission milestones can we look for from your company? Charity first, and then to Luc. Thank you.

Charity Weeden: Can you hear me, Ian? Can you hear me?

Ian: I can hear you, yes.

Charity: OK, great. I just wanted to check. Thank you, it's a pleasure to be here. I appreciate the invitation.

Space sustainability is a growing market and an essential element in a robust space economy. Astroscale is on the leading of an emerging on-orbit services market. We're developing technologies, the business models, and driving the policy discussions globally.

We support the management of the space environment via life extension, in-situ space situational awareness, end-of-life, which is disposal of prepared objects, and active debris removal, which is disposal of unprepared objects.

Key to these missions, what many on-orbit services have in common, are rendezvous and proximity operations, docking and capture, automation, and ground support command and control. This is why our first in-orbit demo for end-of-life services will naturally advance efforts across all these business lines.

Our very own ELSA-d, End-of-Life Services by Astroscale demo, is the first commercial mission to demonstrate end-to-end debris docking and removal. It launched in March of this year and will be testing a series of progressively difficult maneuvers to capture a prepared satellite, one equipped with a lightweight docking plate that was stacked with our servicer.

ELSA-d has since passed its major operational checkups. We will begin the demonstrations later on this summer. You can track ELSA-d on our website. We are sharing ephemeris, covariance, and maneuver plans with both ESA and the 18th [Space Control Squadron]. Notably, this demonstration is entirely self-funded. ELSA-d is exciting because it's the first demonstration of an end-to-end debris docking and removal.

We see all debris as a threat to space commerce, exploration, national security, critical services, and our way of life. While small debris is clearly problematic, it's also important to prevent large debris from becoming smaller pieces of debris by remediating those objects that pose the greatest threat.

Last year, Astroscale was selected as the commercial partner for JAXA's Commercial Removal of Debris Demonstration Phase I, which is the inspection of an upper-stage rocket body expected to launch by 2023.

Finally, let's not forget space sustainability also involves economic sustainability in orbit. Last year, Astroscale announced its entry into the satellite life-extension market, which adds value and ensures effective use of the limited natural resources that is GEO. I'll just pause there and hand it over to Luc.

Luc Piguet: Thank you for having me on this panel. ClearSpace is a spinoff from the EPFL in Lausanne. Initially, it's a team of engineers EPFL that's been working since 2010 to find a solution to remove space debris from orbit.

The project was initiated after launching a cubesat straight into the field of debris of the Cosmos-Iridium collision, which generated a lot of conjunction notifications and brought our team to start thinking, "What can be done and what should be done to address the growing problem of space debris?"

ClearSpace has been spun off in 2018. We signed a contract with European Space Agency to lead the first debris removal mission where we have as the objective to go pick up a piece of debris that belongs to the European Space Agency in orbit and remove it by the end of 2025.

This mission, called ClearSpace-1, is the first mission to execute a complete value chain of removing a piece of debris from orbit, addressing all the different dimensions, whether legal challenges, liability challenges but also technical challenges and how to pick up a non-cooperative object in orbit.

Today, ClearSpace has about 40 employees. We work with an extensive industrial team across Europe, and we're in the first phases of the development of our mission.

Ian: Thank you, Charity. Thank you, Luc. We'll have time to come back to some of these activities in the subsequent discussions. I'm already seeing some questions in the chat that have to do with the specifics of the Astroscale and ClearSpace missions. We'll get to those towards the end of the panel as well today here.

I want to turn now to Asha. I referenced the G7 statement at the beginning of this panel. We've also seen in the US National Space Policy a goal to evaluate and pursue active debris removal. In January of this year, we saw that the NASA Office of the Inspector General issued a report that argues that mitigation alone is not sufficient, and that we need more strategic remediation activities to address space debris. Can you tell us about the current state of US government activities regarding active debris removal?

Asha Balakrishnan: Sure. Thank you for inviting me on to talk about this topic. In addition, in January, not just the OIG from NASA issued a report but the OSTP, the Office of Science Technology Policy, the White House, also issued a National Orbital Debris Research and Development Plan, which laid out some of the research priorities for all areas with respect to debris.

There are three major thrusts in that. One was debris mitigation. One was tracking and characterization of debris, which is very related to SSA and STM. The third one, for the first time in a national-level document like this, they addressed remediation of debris as a core element or core area.

They then further described three particular research and development efforts that agencies should move forward with.

These were to develop remediation/repurposing technologies and techniques for large debris objects, as well as the same type of thing but not repurposing technologies but remediation technologies and techniques for small debris objects. Similar to what Darren was talking about, there are many ways to go about this.

That paper of 50 derelict objects, there are very large ones that one could try and remove for the purposes of removing risks long term, but then there's also a lot of discussion with respect to lethal non-trackable debris. It could be mission-ending. They identified two areas.

Then the third one, which I think is a really important area, and it's one that I think a lot of the people on this panel have talked about is developing models for risk and cost benefit analysis. Everybody feels like there are models out there.

They may touch on some aspects of risk or some aspects of a certain type of debris, but we really haven't seen a holistic model looking at all of the tradeoffs between the impacts of the probabilities, as well as the different orbits, the regimes, and then the numbers of satellites are going up in that area, and not just technical risk but also economic risk as well.

I would say that the last thing is we do need better data. That tracking and characterization piece that is part of the R&D plan is a really important piece, because the models are only as good as the data that we have.

I fear that for the large debris, we have better data, and there's more work going on with C2, SSA, and some improvements in Space Fence, coming online and those kinds of things. On the small debris scale, we don't have as much good data that has good accuracy to it to understand the environment enough.

I would say, lastly, on the ADR technology and where the US government is, this is a long-term thing. There is no one agency that has the mission nor the funding to do this. That's where we're stuck. We're stuck with that when it comes to space traffic management. [laughs] We're stuck with that when it comes to ADR as well. I feel like there needs to be a little bit of unsticking in the government realm. [laughs]

Ian: Indeed. The who and what agency in that question is one that is coming up in several different areas of US space policy right now and seems to be...

[crosstalk]

Ian: That might again be another one that we come back to here as we go because it certainly relates to the previous panel with the space traffic management question, and that relates to this as well.

Speaking of the previous panel, in that previous panel we just had a good discussion of some of the challenges that the policy and regulatory structure for these large constellations pose. The topic of debris certainly came up in that discussion as well.

Darren in his talk suggested that these large constellation operators might potentially be a victim of some of this regulatory tension in that the existing risk from the large objects is where some of the real challenge is as these constellations are operating in that environment.

I want to pose a question to you, Charity. Your company has worked with one of these large constellation operators in some technology development programs along with the European Space Agency. What is the role of the large constellation community in addressing the debris challenge on orbit?

Charity: Great to point out that Astroscale did announce a partnership with OneWeb in May to develop an ELSA that can conduct multiple end-of-life disposals.

Per your comment on Darren, he always does make good points. Derelict debris, approximately 8,000 tons of it, is a real threat to operators in orbit. However, as we increase the use of orbit, we need to prevent additions to this derelict population.

Any additions pose a threat to creating those lethal non-trackables that Asha was talking about but also interrupt critical services in commerce by requiring more collision avoidance maneuvers. Even if they deorbit within the international norm of 25 years, they're still creating a perturbation, [laughs] if you will, on the normal operations in orbit.

Large constellations are exciting, and they bring a wealth of benefits just here on Earth. I personally know people in communities who are benefiting from the proliferation of access to space, but we can't add to the population of debris in space now. We need to be responsive to new hazards and congestion.

This means one of two things for constellation providers, and all operators in space. Either ensure high reliability of satellites, which might be rather expensive, or have a plan for controlled disposal at end of mission. Regulators under Article VI of the Outer Space Treaty need to make sure one of these two options happen. There's no middle ground here in terms of space safety.

What does this mean and how do we get from here? That's the major question at hand. I feel the first step is to measure accurately what that risk of a system is, meaning the entire system's risk needs to be measured for probability of collision. Next, we need to cap that risk. No one wants excessive or unlimited risk in this business. It would simply drive investors away.

Third, proper monitoring is needed of this risk profile that constellations are imposing on the space environment. Right now, there are educated guesses at best of how a constellation may impact the environment. How about a near real-time update as the system is deployed?

Finally, there is no use making limits if regulators aren't going to enforce said limits. Sure, customer access to the benefit of a constellation should be a natural economic driver to limit debris. What if it's not? Then governments are ultimately liable for private operator activity.

There should be financial carrots and sticks, as Asha mentioned, the economic drivers here that drive responsible behaviors in space and limit debris.

Just foot-stomping, we're all in this together. Operational satellites that can maneuver are good things. Transparency and information sharing among operators to understand who's doing what is a good thing. Space situational awareness is a good thing. Space traffic coordination and management is a good thing.

Inactive satellites without collision avoidance raining down through operational orbits and human spaceflight is not a good thing. I don't care if that takes 2, 5, or 25 years to deorbit. I count current large debris objects among the items that are not conducive to a successful space environment or a space economy.

Ian: Thank you, Charity. I'm seeing a lot of questions coming in from the audience here. This is good. I've got a couple more I want to ask that we discussed in advance. We're going to get to those audience questions. Keep them coming.

Clelia, this next one, I'm going to turn to you. Both Asha and Charity now have mentioned the need to create economic incentives and possibly the consequences and enforcement penalties that might come along with that.

From your standpoint, does the rise of large constellations pose or offer any sort of solution or relationship to the economic challenge of addressing space debris? Does it change the way that we think about the economics of the space debris challenge?

Clelia: This was the point that helped us, as a research center, when we started our research. In particular, the question that guided us was is it the market that can solve the problem of the space debris or we need the government intervention in order to solve this problem? I did before the parallel with the change that was a useful example to understand the role of the public and also the private sector.

For sure, this question, is it the market that can solve this problem? We tried to answer this question through a simulation of different scenarios. We tried to understand, first of all, the risk. If the risk of collision is in the short term, in the middle term, or in the long term. This changed the position of the private sector in order to invest in such technologies.

We started, first of all, to understand which kind of technologies the private sector can use and have the economic incentive to use in order to avoid and to solve the problem of space debris. We analyzed the mitigation of, for example, post mission disposal or collision avoidance technologies, active debris removal technologies.

We saw that this technology in effect mitigated risk of collision. In particular, the post mission disposal solution was, in our point of view, a good solution to solve, to mitigate, the collision because we saw the curve of the risk lower than the curve of the risk of collision.

This was then, in our conclusion, cheap solution for the private sector in order to have economic incentive to invest and to use the post mission disposal for sure if the risk is in the short term. If the risk is in other scenarios, in the long term, I don't think that the private sector would use this kind of solution, to use their fuel in order to de-obrit the satellites and so on. In the long-term scenario, we saw...I think that the private sector decides to leave their satellites to fail to deorbit.

In this case, the active debris removal is needed for the dead satellite in this case. Also for the active debris removal, it's a question that I ask for myself but also when I talk with my colleagues, is there the market for the active debris removal?

Ian: You're hitting on, I think, a number of themes that are right. One, we've talked a lot already in this panel about the need to have a good understanding or characterization of the technical and economic risk and being able to communicate that across actors.

You're also talking about active debris removal as part of an overall scope of responses that operators need to think about here, including simply post-mission disposal. Compliance is important, and operating to a business plan.

Luc, turning to you now. Clelia talked about whether if there is or there's not a private market for active debris removal. Your company is trying to find that market. That is what both you and part of Astroscale's business as well. Outside of technology, what factors do we need to have further development in to enable the commercial debris removal market?

Luc: To reflect on what has been said until now, I agree with Darren that large objects are a major issue and have to be addressed. I agree with Charity that we have to build up a solution that is sustainable for the future.

I think the first thing is that we have to overall generally, whether if it's agencies or commercial operation, recognize the complete cost of space operation. The complete cost of space operation means the complete cost of a sustainable space operation. In this cost, removal of debris has to be included.

You cannot consider that you looked at the complete missions, "OK, now it flies. We paid for it. We operated this platform with a satellite for a while. Everything's OK, whether it's failed or not in orbit."

Often, what has been done in the past is that when you look at the overall cost of a space mission, you would go all the way up to the point where the satellite fails in orbit or it's deorbited if it has been deorbited.

This is not the complete cost. The complete cost should include also the deorbiting. Specifically, if you follow the logic of Darren, specifically for the most dangerous and problematic objects in orbit to start with.

This means that the first thing that has to happen is that agencies have to start looking at the object they have in orbit and say, "What kind of budget can we put in place to make sure that we don't produce a situation which will affect everyone in the future?"

Beyond that, this has to be also integrated in the business case for commercial operators. The question then is what is the financial dynamics that makes the payment of that kind of service a natural step of a complete business case? This dimension is important. We have a lot of regulation today that are in place already. There's a lot of things that are just not applied.

The other part that is happening right now that we can see happening much faster than we expected when we created ClearSpace is the conscious of the problem. I remember for years before we created ClearSpace, people would tell us, "Nobody will ever pay for that. Nobody will ever pay for deorbiting mission."

Why would anybody pay for that? It doesn't make any sense. You're just removing a piece of debris to make space for the others. It's the tragedy of the comets. There's no reason why somebody should ever pay for that.

When we created ClearSpace, when we founded the company at the beginning, we thought it's going to be hard to find investors, so we should find sponsors to make a demonstration. We were surprised to see how quickly everything evolved. We see that the timing is right to effect change today.

What has to be done is first that agencies start thinking about the objects in orbit. What's interesting in the list of the 50 more dangerous objects in orbit is that there's not a single American one. [indecipherable 200:09] is just one.

There should be more transparency about what's up there. There should be a conscience in the agencies in thinking, "How do we put in place a budget that makes sure that we increase the space of operational orbit?"

There are some orbits where constellations already cannot operate today, which are there are some orbits where you can already see Kessler syndrome appearing. You see that happening already today. It's a very slow evolving problem, but it's already there.

The first step for me is, I agree with Darren that those lists of 50 objects have to be addressed. I agree with Charity. We have to build up the constellations in a way that takes in account all the different outcomes of an end-of-mission and addresses them in a consistent and logical way.

Ian: Thank you, Luc. You've teed up the question that I want to start with from the audience. Almost like we planned this, but it just worked out this way.

You were talking at the end of that remark about how to communicate the value and the need to start working on the top 50 objects and to start working on integrating this into the business case of the large constellations and designing those to operate safely and sustainably.

The question I'm going to put up on the screen here shortly, I'm going to ask Asha to start and then the other panelists to come in. Asha, as we try to communicate the need to address debris, to remove the large objects, to figure out how to field the active debris removal services, how should we as a community be communicating that to lawmakers and to policymakers?

Is there anything you've seen in your experience where messaging has worked well or perhaps has not? Then I'll let the other panelists come in as they think here.

Asha: I haven't seen much in my experience in terms of moving this forward to get...as we see in SSA and STM, we're still waiting on that. [laughs] With respect to ADR though, one thing that might we work if we...Not we. I'm not an advocate here..., but if one was to pull a story together about the cost now versus the cost later.

You have to think about it might seem expensive now with lots of dollar signs or euros, but if you waited and it created a much more untenable situation down the line, then the cost to remove millions of pieces of debris, if things ended up colliding...

That comes back to the data. That comes back to the model. We need to be able to have robust models with good data, not data that we took in Shuttle windows in 2011 or 2009 for predicting what the debris environment is.

We need good data, on the small debris side as well as the large one, to feed into these models so we can convince ourselves of understanding what does it look like down the line. If we did this now, yes, it's going to cost money, but it's going to cost a lot less than if we did it later.

Ian: Thank you for that. Charity?

Charity: Asha reminds me of a great quote from Darren. "Pay me now or pay me more later" is essentially what he says. There's a good paper at IAC on that. I recommend everyone read that.

Just to quickly add on, this comes down to domestic priorities, those policy priorities. Clearly, Europe and Japan have made it a priority to invest in research and development for debris removal. Therefore, there are programs.

I feel that ADR and just generically on-orbit services writ-large check a lot of domestic priority boxes for the United States in particular. International collaboration, technology development, growing the industry, national security, application to exploration, and just simple leadership.

Being involved and making sure that the United States is involved in ensuring the norms and leading the rules, the norms, and behavior on this activity as well. The stars are aligned. It just needs action, like other domestic priorities do.

Ian: I think we could certainly interpret the G7 statement as recognition of wanting to take that leadership that you're talking about there, Charity. It's a good statement. Let's work on the follow-through and providing that story and implementation that needs to be provided.

We are fully into the audience Q&A portion here. We're going to jump around to some different subjects here as we go. I'm sure some commonality and threads will come up.

The next one goes towards spurring action and some of the tools that we might or might not use. Clelia, I'm going to put you on the spot to answer this first, and then other panelists might come in, because there's a little bit of economic theory behind this.

Would a prize model or a bounty model provide an effective incentive to remove some of these hazardous objects that we're talking about?

Clelia: Yes. It was mentioned before, so I think that, if we demonstrate that the risk is now -- so it's not in the long term, but it's in the short term -- I think that is an important point to change the government attitude to fund the technologies or to fund the private sector in order to take the action to mitigate the space debris.

This is the point that I want to stress about, to understand and to demonstrate the risk because this is the one point that can convince the governments to take an action. It was happening with the environment on Earth.

Before, you mentioned that, if we pay now, invest now in the future, we will have less costs about to invest to technologies. This is true. If we invest now to the technologies and to help the private sector in order to avoid and to mitigate the risk, also, there are several options that the government can do, is to fund the technologies.

Or through the public-private partnership is a good solution in order to invest in the technologies such as active debris removal, because we know that the active debris removal is a costly solution, if we compare these technologies with other technologies.

This was the logic that we did when we started our research. To understand, and to compare the cost of the different solution, and we know that the active debris removal is a costly technology, and there is the need of the government to co-fund these kind of solution. The public-private partnership would be an option in order to help the private sector.

Ian: That's an interesting suggestion, that use of the PPP model, which we've seen for other areas of government and commercial cooperation on space system development with success might be something that we look at here.

I think there are elements of public-private partnership in both some of the, both the ClearSpace mission and some of the Astroscale partnerships as well. I think that is something that the governments are looking at.

The next round of questions is going to be a lightning round for our Astroscale and ClearSpace colleagues. We have a lot of questions in the chat about where you guys are going, what your missions look like, and how you interact with each other.

Asha and Clelia, you can chime in, if you have anything to add here, but it might be a brief break for you. Putting a question up, the first question, just to get started here, ClearSpace and Astroscale, are you guys competitors, and are there others in your market space, if you are?

Luc and Charity, I don't know who wants to take that one on, but go for it.

Luc: I think to be a competitor, it should be in the market already, probably. We have regular interactions, and we obviously see each other, because we are trying to produce the same change in the industry, maybe with a different approach in different regions.

At the end, what we see is that the market, when it activates to actually address all that, requires more than both of our companies to actually address the complete problem. There is plenty of room to do a lot of work.

Right now, what we can see is that we are active. Well, in Europe, we're active together. Astroscale is active in the UK. Otherwise, we are on European mission. Astroscale's on a Japanese mission. The question is how far can international collaboration work?

That's one of the questions that will at some point come up, mostly also because, for many, ADR technologies, are considered as dual-use. There can be limitations and strategic interest from different countries around that.

I think at the end, we might likely end up competing on some markets and collaborating in some others.

Charity: I'll just echo some of what Luc said. Maybe less competitors and more pioneers -- aren't we, Luc? -- in this space. Really, this industry needs to be collaborative at this very moment. We need to get together to build those policy and best practices to conduct these operations safely.

A small difference between our companies, I feel Astroscale is looking at a whole suite of on-orbit services in a number of orbits. ADR is just one of those missions. If you can rendezvous with another object in order, you can provide in-situ SSA, life extension, maintenance, etc., etc.

Just a shoutout to those industry associations and industry groups that are driving best practices and making sure this is a sustainable and safe market. One of those is The Consortium for Execution of Rendezvous and Servicing Operations (CONFERS).

Of course, there's other ad hoc groups, like the Space Safety Coalition. I know that probably Luc's company and Astroscale, we're part of many, many discussions with our industry colleagues, so it needs to be collaborative.

Ian: Thank you. We had a question there you both have already spoken to about whether you're doing the same thing or are there definitive differences. It's a little bit of both. Charity, I like the phrasing "pioneers, not competitors." As Luc said, make the market, and then compete for the market.

Luc, you've already teed up the next question very nicely. You keep doing that for me, so thank you. There's a question from the audience. Luc, you mentioned there's some potential dual-use implementations of some of this technology for ADR or for servicing.

The question is are your companies doing anything to make sure that ADR operations don't create security concerns? What is the relationship between civil ADR technology that we're talking about in this panel and some of the national security implications that that might have?

Luc: I think to do a mission that has national security implication, you have to be placed in the right orbit. You have to get an authorization to launch. This means that you would have authorization by a launching state that actually knows what you're planning to do.

You have to provide a lot of content, a lot of detail about what you're going to do in orbit, especially if you're in-orbit servicing. This is already quite a deterrent. The other aspect is that we look at it, for us, it's quite obvious that the solution we are building is a sustainability solution.

That's what we're after. That's what we try to build, and I'm certain Astroscale as well. We want to address a fundamental problem. In our perspective, there's a lot of dimensions that can make...If you want to debilitate or break a satellite or military satellite. You don't necessarily need to capture it. You need to collide with it.

You need to do other stuff, and there's probably ways that are much more cost-effective to do that than to actually do the complete exercises that we do. In addition to that, I think that it's a little like an ambulance. We don't use an ambulance for warfare. Mostly because you know that if you start to do that, the cost-benefits in terms of your complete exercise makes it illogical.

You have more to lose than to win if you start using it this way. That's the way we look at it. Maybe it's a little naïve when it comes to military application. For us, the approach is very clearly and has to remain a sustainability solution that we are building here.

Nevertheless, it's a solution that is dual use and will be classified as dual use. What we export and how we address it, because the question obviously came in from the Swiss government. [laughs] When we started working on the first mission for ESA, the question came up, and it comes up on a regular basis. What we export is a service and not the spacecraft or the technology itself.

Charity: I'll just add that Astroscale categorically is against the deliberate creation of debris in orbit. That is incredibly important. That is our ethos and reason why we stood up as a company.

Beyond that, the government, point fingers here, can be the worst offender of debris generation in orbit, especially the last six decades. We feel that government should be customers of our services to prevent debris incidents from occurring.

Echoing Luc, private operators are regulated by domestic nations. Therefore, we have to adhere to space safety standards. We also are pushing norms and behavior, best practices in this market as well. As I said, we're regulated and want to develop solutions, not create problems. That's all I'll say about that.

Ian: Thank you. Important point that both of you are talking about is one that we discussed earlier: transparency and sharing of information. It's going to be a civil commercial mission. It's going to be an emphasis on transparency and information sharing. We hope that helps to distinguish those sorts of activities from something that might be more national security in nature.

Thank you, Charity and Luc, for the ClearSpace and Astroscale portion of these questions. I'm going to try and open up to a broader question now.

There's a number of questions in the chat about removing spent rocket bodies. We know the majority of those bodies are Russian and some Chinese ones as well, from the top 50 list. There's a legal and policy question here around permissions to remove those objects, responsibility to remove those objects, and liability associated with that.

A broad question about what legal and policy tools can we think about to address nations that do not consent to the removal of their derelict objects, or to encourage those nations to start participating in removal of those objects. Open to anyone on the panel who wants to try to take that thorny issue on. Did that not come through?

Asha: We did hear you. It's a little better now though. I'm not going to be able to answer that question. That's a really, really hard question. I think we're all silent because we don't know. This

is an international cooperation diplomacy issue. This cannot be solved by technology development.

When we helped support the orbital debris R&D plan, we looked at what are the big challenges in orbital debris. Irrespective of R&D, what are the major challenges? What Can R&D solve? R&Ds can solve some of the challenges, but they cannot solve the liability challenge. [laughs]

They cannot solve post-mission disposal, people complying with the 25-year rule. They cannot solve the registration challenge. These are things that have to happen on the diplomatic efforts. I'm now going to step back and saying that although I'm a policy analyst, I'm an engineer. [laughs] I'm not a diplomat.

Charity: I'll add, Ian, that when we say we look to leadership of this sort of issue, this is what we're talking about. We'd like to see nations get together and discuss what is that pathway forward before technology catches up [laughs] to that eventuality. Technology will run fast here. We hope that nations will be able to have an open dialogue and come to some sort of solution.

Luc: If I can also add to it. There are some good news in the situation. There have been collaboration where objects from different countries, including Russia and US, docked in orbit. This happened in the past. This kind of collaboration was possible in the past.

This is a field where governments have to put aside competition on the military scale to look into collaborating to address a common problem. If it has been possible for the ISS, it has to be possible for debris removal. Because we all coexist in the same environment, we all benefit from the same environment, this cannot be treated in a usual competitive way. It's not possible.

Ian: We are unfortunately almost coming to the end of our time already. There are well too many questions in the chat that I'm not going to be able to get to, but I do want to go one round around the table here with a wrap-up question and give everybody a minute-and-a-half to try to wrap up all of the great thoughts in a very brief time.

In the spotlight talk, Darren told us or suggested that we are decades beyond urgency in addressing the orbital debris challenge. In a minute-and-a-half or so, what is the immediate next step that we must take to start addressing that urgency and to start solving that gap? Just go around. I will pick on Charity to start. I see her at the bottom of my screen.

Charity: Lucky me. [laughs] I think that's a great approach. A lot of folks are thinking of active debris removal of, "Oh, it's decades away. We have time," or, "We don't have time." What can we do right now? Then what do we build on to get ready? I think domestic national priority on space environment management, active debris removal, whatever you want to call it.

Make it a priority, make it a statement, and have that drive, the discussions of who owns it, how are we going to fund the R&D aspects to it, how are we going to develop the PPP and the economic models, how are we going to do the international pieces? It all starts with laying down a policy.

Ian: Get the policy right. Luc?

Luc: There's not much to add to what Charity just said. For us, we see it exactly the same way. Governments have to lead the first efforts. In Europe, it's already the case. ESA demonstrates that. Today, there's more European agencies that are starting to look into that. This is moving in Japan as well. This should be a global effort.

There's another dimension. This dimension of building up international collaboration to address those problems. That's something that has to be driven probably with a very similar model that has been done for the ISS.

Ian: Clelia, you're next on my screen.

Clelia: I'm a researcher. My job is to understand the different solutions that we have on the table. We discussed the different solutions about PPP solution. If we go through this way, we have to think about if there is a market to sustain this PPP model and to understand how the business model of active debris removal is based on.

It's based on to give profit to private sector or to save the profits. This is a distinction that is important to understand how to develop a sustainable business model of the active debris removal. This is the first thing that I wanted to share with you.

The second thing is that if it's not sustainable, if the PPP model is not sustainable to think about if the market can have the economic incentive to solve this problem alone. For sure, then we need the intervention of legislation and to think about if we need binding legislative intervention or if we need other solution. For example, to pay a fee. Each satellite operator to pay a fee in order to invest in this kind of technical solution.

It depends on the risk, as I said before, if the risk is now or if the risk is long-term. Then to position the intervention on the public and private sector in different way along with this timeline.

Ian: Asha, last word.

[laughter]

Asha: I'm going to give two, since I have the last word. One is I really do think we have to develop these risk and cost benefit models that Clelia is talking about and develop them in a holistic way that's transparent and people buy into. We need the evidence behind whatever next steps we're going to take.

I would say secondly...I do not speak on behalf of anybody. I speak on behalf of myself and representing the Science and Technology Policy Institute. I do not represent the US government here.

I do think that the US is losing an opportunity to get in in terms of technology development in ADR technology and to help to both look at their own missions as an example of a customer to use these technologies down the line but also to buy down risk and try and better understand

some of the challenges that we have on the policy side, some of the concerns we have on the legal and policy side, and work that out.

We can't admire the problem so much more unless we go forward and do it. In order to do it, we need action from, at least in the US, we do need some direction on which agency is going to take the lead in doing it and who's going to be funded to do it.

Ian: Thank you, all. To activate active debris removal, we need to know that governments must act. We need to get space environmental management policy in place. International cooperation is essential. We have some models that we can consider for that. The ISS cooperation, public-private partnerships.

Then we need to understand what the technical and cost/benefit risks and analyses are in sustainable active debris removal businesses models, and the overall risk portfolio in orbit. We have to look for opportunities for leadership. We need a US government champion to step up and take this responsibility.

Very simple, straightforward steps that we need to do [laughs], but I'm sure that we have ample opportunity to continue this conversation and we've identified some good work to go forward.

Thank you to the panelists. I wish we could keep talking. Thank you to the audience for the number of questions that were submitted. Again, I wish we could get to them all, but we certainly had a good discussion.

I want to welcome my colleague, Krystal, back up on stage, our conference chair here, to take us out for the day. Thank you.

Krystal: Thank you, Ian. Thank you again to all of our panelists from all three of our sessions today. I couldn't be happier with what we've been able to bring you with the discussions that we've had and with the opportunities for follow-up that this gives us.

Just to let you all know, this is Day 1. We're concluding now. Starting tomorrow, we're going to have another day of packed content for you. Two panels, one on the space race, or what we really should call it, the second on the space force, and what it should be focusing on, what should be its prime directive.

I'm also incredibly pleased to offer you two keynotes. One is an interview-style keynote with Tory Bruno from ULA, and one is Bhavya Lal, a senior advisor at NASA, to hear a little bit about the Biden administration's priorities on space sustainability.

Join us tomorrow. If you know anyone else you'd like to invite, please have them register. We are excited for our event to continue. Thank you so much.

[music]

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