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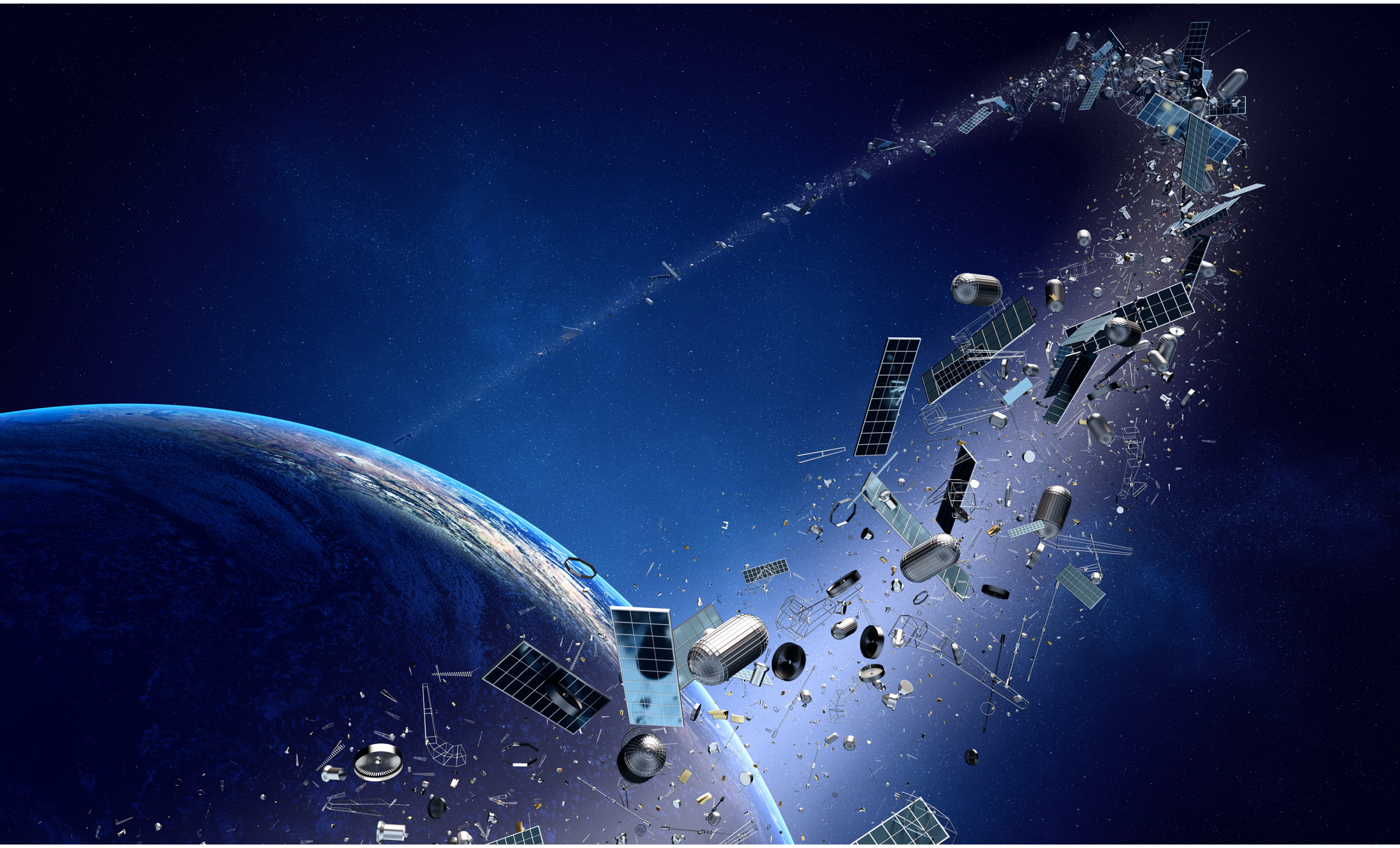
Orbital Debris: Policy Implications



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Orbital Debris: Policy Implications

IDA Ideas host Rhett Moeller spoke to Asha Balakrishnan, an Assistant Director at IDA's Science and Technology Policy Institute (STPI), about the challenges orbital debris poses and how to respond to them in the policy arena.

IDA has supported nearly 20 years of sponsored and independent research into the effects of orbital debris, a concern which has intensified in recent years due to the phenomenal growth of satellite constellations in low Earth orbit (LEO), and the Defense Department's expected use of such constellations for national defense. Much of IDA's contributions over the years have centered on predicting the risks of spacecraft mission loss due to orbital debris impact, for both debris created promptly by satellite collisions or antisatellite tests, and over the longer term, as the background orbital debris population continues to grow. As discussed in the first *IDA Ideas* episode on orbital debris, this growth has led to what many researchers believe to be the beginning stages of a *Kessler Syndrome*, which is a self-sustaining growth of the orbital debris population wherein existing debris creates more debris when it hits operating and non-operating satellites. In the most recent episode of *IDA Ideas* on orbital debris, we talked about how the United States tracks Earth-orbiting objects and discuss IDA research published in *Journal of Spacecraft and Rockets*, "Improving Orbital Debris Environment Predictions through Examining Satellite Movement Data."

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Rhett Moeller: Hello listeners. I'm Rhett Moeller and I'm the host of *IDA Ideas*, a podcast hosted by the Institute for Defense Analyses. You can find out more about us at www.ida.org. Welcome to another episode of *IDA Ideas*. In this episode, we revisit a topic we've discussed in two previous episodes, orbital debris. It may seem like we're putting a lot of emphasis on this subject. But when we consider how important it is to the long-term safety of future space missions, especially as the number of operations increase. It's obvious that we need to take it seriously. And it's such a large problem that it's going to take time to work through. In those earlier podcasts, we spoke with idea researchers about the basics of orbital debris, concerns about kinetic anti-satellite technology and new ways to improve monitoring the orbital debris environment using the movements of our satellites. Today, we'll be discussing the challenges orbital debris poses and how we might respond to them in the policy arena. For this discussion, we are very glad to have with us, Asha Balakrishnan, Assistant Director at IDA's Science and Technology Policy Institute or STPI. Asha, thank you for being here. Can you take a moment to talk a bit about your background and your role with STPI?

Asha Balakrishnan: So I am an assistant director at STPI, as you mentioned earlier, I have a Ph.D. in mechanical engineering and I came to IDA over 15 years ago as a research staff member. I have worked on a number of issues since being at STPI—anything from STEM education to manufacturing policy—and more recently find myself doing a lot of work in space policy.

Rhett Moeller: Great. Well, welcome.

Asha Balakrishnan: Thank you.

Rhett Moeller: Well, Asha, as I mentioned, this is obviously a serious issue. It's a big one. Before we really get into our discussion, I think it'll be helpful to review the basics of the topic. Could you remind us what the basic challenge of orbital debris is and why it's of concern?

Asha Balakrishnan: So first, let's start with the definition of orbital debris. Orbital debris is any human-made space orbiting earth that no longer serves a useful purpose and has reached the end of its mission life. it's incapable of maneuvering or operating anymore. These are also objects that are orbiting Earth. And so we're not talking about deep space or anything in the moon's sphere. And orbital debris is important because it is commonly termed space junk. It's trash in space. It moves at a very fast speed because of the microgravity environment. And for example, at you know, 450 kilometers above earth, it's moving at something like 17,500 MPH. And so even a small speck of paint or a small piece of debris traveling at that speed has a lot of energy.

Rhett Moeller: Right.

Asha Balakrishnan: And so there's a lot of concern that if these objects collide with active satellites, there's two problems. One is they could actually end the mission right there.

Rhett Moeller: Right.

Asha Balakrishnan: The other thing is, once they collide with one another, they just create a lot more debris. So, it's two objects colliding with one another, creating hundreds of pieces of debris instead of just the one that was there prior.

Rhett Moeller: So, from what you've described then with smaller objects impacting and then potentially making more small objects than there were before, this is obviously a problem that's going to continue to grow, to spread, as more objects proliferate in space. Correct?

Asha Balakrishnan: That's right. And right now, you know, a lot of people say space is big, space is large, you don't have to worry about it. It's a vast, it's vast. But at the same time, many satellite constellations and many satellite operations take place in pretty defined orbits. And countries, companies have recognized that there are particular orbits that give them the best data and these orbits are again, not yet crowded, but there is a concern that they will be in the future.

Rhett Moeller: Exactly.

Asha Balakrishnan: The problem is becoming more real and more concerning. For example, the International Space Station has been maneuvering more to avoid debris more recently. The other thing that's happening is, not only are we seeing more objects in orbit, but we are seeing a growth of just debris in itself. And that has come from really three major events in the last 15 years. The first was an anti-satellite test by the Chinese in 2007, which created thousands of pieces of debris in orbit. In 2009, there was an unintentional collision between a rocket body and an active satellite, which caused more debris on orbit. And then finally, more recently, there was a Russian anti-satellite test which caused a little bit more debris on orbit. Now, depending on where these activities occur, where these happen, the debris can either decay and burn up eventually in the atmosphere or they stay on orbit for hundreds of years. And so, the altitude at which these happen is a real concern. So, the reason the altitude matters is because the earth's atmosphere does still have a little bit of drag in it closer to the earth. So, for example, the International Space Station has to use some fuel on board to keep its altitude periodically because there is some atmospheric drag. So over 500-550 kilometers, a piece of debris might stay there for much longer than if it was at 250 kilometers, for example. So, the altitude does indeed matter, and a lot of operations are taking place in altitudes where, eventually, if the satellite does die or it loses operation, it will eventually burn up from atmospheric drag within 25 years. But that still remains to be seen.

Rhett Moeller: That all makes absolute sense. So you've described a pretty complex problem in space and we understand from the previous episodes that it's also equally challenging here on earth with so many interests in space related projects. Can you tell us a little bit more about the specific policy challenges associated with orbital debris and how they might affect that environment?

Asha Balakrishnan: So there are a number of challenges associated with orbital debris starting with, where did that debris originate. So, the Outer Space Treaty of 1967 was an attempt to have space faring nations come together and operate in space in a manner in which it allows the operations into space. But it doesn't give ownership to any one part of space to anybody.

Rhett Moeller: I see.

Asha Balakrishnan: As part of that, there is a rule that says that the registration of an object in space goes to the launching state. Any object that is launched from the US, irrespective of what country or company it comes from is assigned to the US. Now, they weren't really anticipating debris necessarily at that time. But the way it's been interpreted since is if there is a satellite breakup on orbit or if there is something that hits something else in orbit, those pieces that came off of the original piece also still belong to the launching state. The Department of Defense does track debris to about five centimeters and creates a public catalog for these objects and assigns a number to each one. We track who that piece of debris is owned by. Now, there is another piece of both the Outer Space Treaty and another convention that came in 1973 called the Liability Convention, which states that a country, or precisely, the launching state for that piece of object is liable should anything occur, if something happened to that object.

That sort of creates a policy challenge, in that first of all, we don't know and we cannot attribute all objects in space. There are about 47,000 objects tracked by the DOD as of this morning, five centimeters or larger, and of those about 27,000 have attribution to a country which means about 20,000 are not attributable. We wouldn't know who to attribute any damage to should damage occur with those debris. The other policy challenge, which is really a technology opportunity but also poses a policy challenge. There's new technology that's out there and it can help the environment, help the situation, but there's always policy ramifications from it. There are companies and countries looking to conduct what we call active debris removal missions, particularly on large debris. And it's almost like a lot of them call themselves the garbage sweepers or the trash collectors in space and because it is space junk and they're trying to collect this. So space can become more of a sustainable operating environment. These countries and companies seeking to remove debris, there's not a lot of policy around permissions to go and touch someone else's piece of debris or if a piece of debris is in the way of a satellite and a company is contracted to go touch it, move it, and get it out of the way, they need to get permission from the launching state or whoever owns that object in order to move it. And this is unprecedented, we really have not done it. And so, some policy solutions are out there to think about these things, but there are definitely a lot of challenges. I would say the last challenge is that there are many challenges, but I will add, there is one more challenge in that space offers a unique perspective and it's actually much cheaper to go into space now than it was before. So, you have a lot more countries and companies playing in space. They're not necessarily thinking about sustainability as their bottom line, they want to operate, they want to get data, they want to sell data, and sustainability and thinking about debris and debris mitigation and trying to avoid debris creation is an added cost to them. And so, the challenge on a policy side is to try and incentivize new actors, new companies, new countries in space to be more responsible actors in space so that it can become more sustainable. But it's book-ended by the fact that there's a real drive and excitement about going into space because it's actually somewhat of an unregulated territory at the moment.

Rhett Moeller: So, you've described problems in space. You've described policy problems here on earth as we're trying to work through all these things. How is STPI working to help investigate all this? What is your organization doing to help make sense of all this?

Asha Balakrishnan: So, STPI has been involved in understanding the policy challenges, some of the technical challenges, for about three or four years now. And we did a study first on really what is the problem? Right? What problem are we trying to solve? Now orbital debris, we know in and of itself is a problem. But what are the real challenges that this and, and threats that this this creates? Some people say space is really big, Yes, we're going to have junk in there, but it's really not that big of a problem. So, the first thing we did was we did a study and we looked at what are the major challenges and we created a framework for these challenges and we put them into three buckets. What are the challenges when it comes to debris prevention? So, this is not a new construct that's used in environmental studies as well. How can you prevent creating the debris in the first place? And that's kind of the cheapest place to start. The second bucket is, once the debris is there, how can you better understand its behavior? Track and characterize it. We're using telescopes and radar to watch these debris. It's not like we're communicating with them. Right? They, they don't have, they're not active debris, they're actually very passive. And then the third bucket is, OK, we didn't prevent it. We know where it is. We know it's there. How do we remove it if we need to? And so, those are kind of the three buckets we put in place to try and make sense of this as a problem. On the debris prevention side, some of the challenges are that there really aren't standards and best practices for satellite manufacturers or launch vehicles to say, these are the ways we're going to make sure that we prevent debris. Or, the end of life approach. So a piece of debris, remember it's not operating system, it doesn't have to just be a piece of paint or a rocket body that's hanging out there. It could also be a satellite that's not functioning anymore because it lost communication or something happened on board. There are some best practices for end of life, right? How do you appropriately dispose of your satellite before it becomes a piece of junk? Some of the other challenges, with respect to tracking and characterization, is that we don't have enough data really to track and predict where these objects are going to be in the future. We are not staring at the skies or in space and watching every single moment where everything is. We don't have ubiquitous tracking of debris. We predict where it's going to be, we use a radar, maybe a few days later to say, OK, I predicted it was going to be here. Is it where it is? And then we reassign its position. So it's sort of an on off. and then there's an uncertainty kind of an error in which we don't exactly know when the telescope or the radar sees the piece of the debris. Is it exactly where we thought it was or is there an error to the measurement? And that error, when you predict where it's going to be later, just gets propagated, so that error becomes a lot larger. So, unless you know, the uncertainties on your measurement, you're really not going to know where it is later. And challenges with respect to remediation are actually more policy challenges than they are technical challenges. Who's going to pay for debris removal? Maybe it's a good idea, but who pays for your trash pickup? Right? The taxpayers do. And so I think that that is a challenge that, you know, what are the incentives to get companies and countries to think about debris removal? And then again, there's been some research done on if we were to remove certain pieces of debris from orbits that would reduce the risk of collisions because these pieces of debris are either really large or they're in really crowded orbits. But there, the community hasn't come to a consensus in terms of which pieces of debris to remove. So even if we have the technology to remove it, we haven't really come to a consensus on which ones to remove it where. And finally, there are really large pieces of debris. And you can imagine that these large pieces of debris are easier to see. You might be able to go and grab them, move them out of the way or tug them to a different orbit. But the smaller piece of the debris is much harder to both track and they can still cause mission ending catastrophes on orbit. And so removal, remediation and removal, of small debris is very hard and it's barely a drop in the bucket. If you came up with some removal technology, you've got, like I said earlier, we're tracking 47,000 pieces of debris that are five centimeters or larger, but there are some data to show. And the European Space Agency does this. NASA does this, somewhere between 500,000 to 2 million small pieces of millimeter sized debris are out there and we really just wouldn't even know because we can't track them. That's on the challenge side.

Rhett Moeller: That's some good insight, Asha. Thank you. And obviously, you've described quite a few interesting challenges with challenges come opportunities though and I know, you've mentioned some previously in your comments so far, but are there any particularly strong areas where research and development can be of particular use?

Asha Balakrishnan: So, you're right that we identified these challenges first, both technical S&T and policy challenges. And now, we next went to the R&D [*research and development*] space, we said, OK, well, we know we're not going to solve this problem wholesale, but what R&D is needed to address some of these issues? And we did go a little bit beyond R&D to say, OK, what policies need to be investigated more in order to address some of the policy challenges? So on the R&D side, there are a number of things we can do in each of the buckets. I'll just give you a few examples. On debris prevention, there is some R&D that could improve, let's say, minimizing debris at launch. And we're starting to see that. If you've ever watched the launch of Space X or ULA, you'll see that there's like stuff flying off, right? At launch. And even once it's somewhat in orbit, it's not to say that we can prevent this wholesale, but there are some designs that you can put in to say, OK, these tension rods are not going to come off in the same way we're going to try and design them with something that actually disintegrates better. Another example is improving onboard propulsion systems. What I mean by that is if you imagine a debris, impending debris collision, you have two pieces of debris that potentially could collide, there's nothing you can do there. You have two active satellites that could potentially collide. Well, it's just like two cars. If you maneuver around each other, you can get away from it. And that's what we call space traffic management or space traffic coordination. And then if you have a piece of debris and you have an active satellite, the only option is that the active satellite has to move. And so, having onboard propulsion and kind of knowing where you are real time and what you might need to do and how to maneuver is also another area for both R&D and potential implementation. In the tracking and characterization piece, it's really about reducing those uncertainties I talked about earlier. It is about developing potential new technologies or fusing existing what we call phenomenonology. So, taking radar data, with optical data with RF sensing and putting them all together to see if you can do a better job understanding your space environment. So, there is a lot of R&D to be done in tracking and characterization. And then on the remediation side, we really haven't demonstrated active debris removal. We really haven't demonstrated ways in which, the best ways to go and grab an object and move it out of the way. A lot of people are thinking about recycling in space. This is probably among the most far-out-there basic research topics is people say, well, why are we going to just move it and have it burn up in the atmosphere or put it into what we call a graveyard orbit? Why don't we recycle it and repurpose it on orbit?

Especially as we move towards new technologies such as in-space servicing assembly and manufacturing where we're no longer launching things wholesale into space, but we're building things in space. So why keep going against earth's gravity and taking things down and up versus, you know, keeping things up there and repurposing them? But this is very, very basic research and would need to be looked into further.

Rhett Moeller: Well, thanks for all that information, Asha. it sounds like STPI is really, really working on many aspects of this problem. I understand another area where STPI is working is in policy issues around orbital debris, especially with the R&D interagency working group. Can you tell us a little bit more about that body and its work?

Asha Balakrishnan: Sure. So, after STPI conducted this study on looking at orbital debris challenges and R&D solutions, we began supporting an inter-agency working group which is run under the National Science and Technology Council, which is part of the Office of Science and Technology Policy [*OSTP*] sitting in the White House. So, STPI is an FFRDC [*Federally Funded Research and Development Center*] that was chartered and stood up to support the office of Science and Technology Policy. So that is our main sponsor, and a lot of the work that we do there is helping support OSTP as they bring the interagency together to tackle these issues. An inter-agency working group was stood up to look at this topic. Luckily, STPI had completed the report on orbital debris challenges and R&D opportunities or solutions and were able to present that work to the group. That work went into and was kind of fed into a number of discussions and deliberations as the group prepared the National Orbital Debris Research and development plan. Much of the work that we had done in the STPI task was then corroborated, massage, fixed, supported by the interagency members. The reason you need the interagency in this case is that this is a topic where a number of agencies touch. When it comes to, let's say, the United Nations, State Department is responsible for representing the U.S. in discussions at the United Nations. And so, when we talk about who's liable and registration and liability convention, that is State Department, when we talk about R&D and understanding the debris environment, both NASA as well as the DOD have done a lot of work historically on this. When we talk about who's tracking these objects, well, I just said earlier, the DOD historically has maintained a catalog of space objects, that authority is now going to be transferred, at least on the civil side, to the Department of Commerce. And so that is a big handoff that we're in the midst of right now. It was put into an NDAA, a National Defense Authorization Act, I believe in 2017. And that transfer's supposed to happen by 2024. So, the Department of Commerce will then become the storefront for collecting the information from commercial entities and creating a way in which the public can engage with the data and look and see where the objects are. So, the Department of Commerce is involved. The FAA has launch authority. These are all examples of agencies who have equities in this and need to work together because of either their regulatory space or their expertise on these issues. And so, STPI was there to support the writing teams and the development of the R&D plan. Following that, STPI supported another kind of follow on task to the R&D plan, which was a National Orbital

Debris Implementation plan, which is taking kind of the strategic vision set out by the research and development plan and saying, OK, what are the tangible specific things that the agencies can do? Not the public, not the commercial sector, not other countries, but what can the agencies take on to address this issue? And so, we were there to support the interagency working groups, we actually separated them out into subgroups which was: one was debris prevention; one was tracking and characterization; one was debris remediation, and they all came up with actions on things their agencies could possibly do some, things with existing funds, and some things might require new funds, but at least they came together in a way that was holistic and whole of government to identify these. And that implementation plan was published last year.

Rhett Moeller: I really appreciate your insights, Asha, and obviously with so much interaction and so much cross team working and everything. You're trying to establish a community that works together. You're trying to create policies or help form policies that help bring all these different expertise levels together, and that's commendable. Speaking of working together and collaboration, especially within IDA, you also hosted a space forum in 2022, and that was focused on norms in space. Did this topic come up there?

Asha Balakrishnan: So orbital debris came up in the norms of behavior and space insofar as countries and entities and stakeholders in space do have an opportunity to identify best practices, which is often termed as a norm or even some rules of the road of how you might deal with debris. So, it wasn't the only thing that came up, but it was a piece of this, right, orbital debris, like I said earlier, is kind of the problem of everybody. It transcends national borders though there is sort of a registration launching state, and we need to learn how to establish guidelines and best practices on what we can do about debris. So even things like, for example, putting a magnet or a tug as part of a satellite constellation, every satellite has kind of a grappling hook at the end of it, is a potential R&D solution that if everybody agreed to this standardized grappling hook that they would all put on their satellite, it would cost them something because mass on a satellite costs you money in space. But maybe it would allow for a common way to remove that piece of that satellite in the event it malfunctioned and didn't operate anymore. So, coming to agreements on these things is part of the discussion of norms of behavior in space. So insofar as that is concerned, yes, it did come up. The first space forum that IDA did was on orbital debris and it was a little bit fortuitous because we had done some work internally between STPI and IDA SAC on orbital debris. And we said let's have a forum and it was virtual and that was great. Last year's 2022 forum was on norms of behavior and it has now become an annual forum. And so, this year in early May, we will be having our next forum in space. This is going to be about the government utilization of commercial capabilities in government missions. So how is the government leveraging and utilizing commercial capabilities to conduct their own missions? And what are the challenges and possible solutions that the government needs to be thinking about to better leverage those capabilities.

Rhett Moeller: Great. Well, thank you very much for sharing all that with us, Asha. We have covered a lot in a short amount of time and I appreciate you taking the time to chat with us today and for sharing STPI's work and the extra dimension that you've provided about the seriousness of this problem. Thank you for joining us.

Asha Balakrishnan: Thank you. It was wonderful to be here.

Rhett Moeller: It's been most illuminating. Listeners, as always. If you want more information on IDA and its ongoing work, please check us out at ida.org. The show is hosted by the Institute for Defense Analyses, a nonprofit organization based in the Washington, D.C., area. Once more, you can find out more about us and the work we do at ida.org. Thanks for tuning in and we hope you'll join us again next time as we discuss another big idea here at *IDA Ideas*.