Pierre de Vries: So, let's move right on to the first panel on innovation, and to lead the discussion, I'd like to hand it over to David Reed, who is the faculty director of the Interdisciplinary Telecommunications Program right here. David.

David Reed: What's our time?

Pierre: Go for an hour.

David: Okay. All right. [Laughs] Okay, thanks, Pierre. So, this is the innovation panel, and so, Pierre has given us the charge of to try to fill in a bit of the vision behind all these different developments that Julie just gave a great overview of. And what are the business models, technologies, driving factors, and new technologies that are emerging? So, we're going to try to address a lot of these different topics, so we can identify and fill in on innovation. Of course, if you have some questions on this, we will save some time for you to ask some questions. So, I want to introduce my panel members. Starting just straight down the line here, Larry Alder, who is the vice president product definition for OneWeb. Cory Dixon, who is the IRISS chief technologist, which IRISS stands for the Integrated Remote and In Situ Sensing for the University of Colorado Boulder. We have Steve Lanning, who is the director of advanced analytics at ViaSat. And Phil Larson, who is the assistant dean chief of staff at the College of Engineering and Applied Science at the University of Colorado Boulder. With those introductions, then, what we're going to be doing, there's four sections that we've kind of broken down into questions, and the first section here — if you're taking notes — are the new applications by high altitude platform or stratospheric solutions and the NGSO proposals. We're going to start with a question to Larry. OneWeb has received a lot of attention with regard to the NGSO proposal that was approved [00:02:00] by the FCC in June.

We'll delve into some of the technical issues in the second category that we'll be talking about with the panel, but first, if you could describe what services and applications will be provided to end users, both in terms of the replication of existing services and new services and features that's generated all this excitement.

Larry Alder: Sure, I've got get Pierre's ball here to do that.

[Laughter]

Larry: So, the first thing that… So, I've been involved in a couple of ventures with regard to satellite constellations that are non-geosynchronous. One of them was a MEO constellation. I work for… I was on the board and involved in the founding of the company O3b — that's now with SES — was a MEO constellation, and OneWeb is a LEO constellation. So, this being an innovation panel, what is the problem you're trying to solve? Why are you innovating? So, as Pierre said, the GEO constellations are about two feet away, I guess, in this scale, and they're very efficient. They see half the Earth. They're originally great because they were used for broadcast TV. They're still used for broadcast TV, and now, they're being used more and more for internet. And a lot of people… And so, with internet, you bounce the signal in the bent pipe we heard back and forth. There's two challenges, two innovations that we're looking to deal with to get with the service. So, the first is simply the latency. It takes a while to go there and back, and for many applications, latency is not a problem, video, it's not a problem. But there are some applications, where latency is an issue, and so, you want to bring your satellites closer to the Earth to solve or reduce the latency. So, that's the first thing. The second one — David talked about — is replicating existing applications. We talked about the limits of spectrum.

So, unfortunately, [00:04:00] if all your satellites are sitting in an equatorial band, and that's all you have, everything has to look to the equatorial band. And these systems look in very narrow beams. You can almost think they're a few degrees wide. So, imagine everything is looking out towards the equator. Well, I've got all my spectrum that I could reuse looking up or looking in a different angle. So, the other problem you're trying to solve — the reason for the innovation — is to unlock more spectrum, to simply unlock capacity. Instead of all being constrained to just one plane, you can now look in other directions. That presents challenges. It's not easy. There's a lot of issues with it. You have to protect the existing GEO arc because they were there first and have a long-established presence that needs to be protected. But that's really the two aspects of the innovation. From the services perspective, a lot of the services are the same. Internet, in these LEO and MEO constellations that I've been working with, these internets usually require a fixed, or a terminal, not a fixed terminal, but something that looks to the sky and points a narrow beam. They don't go to the handset. We're not doing that. That's where you get more towards the HAPS architectures that go directly to a handset. So, here, this is a pizza-box-sized thing, you put it on a roof, you put it on a plane, you put it on a boat. It can move around, but it does internet. That's the primary application. You're trying to do lower latencies. You're trying to access more spectrum.

David: So, one feature would be just on internet access presumably, location, and having a lot more flexibility on where you can access it.

Larry: Yeah, so, where you can access it. Obviously, it gets harder to access the GEO satellites the farther north you get. Depending on your orbit dynamics, you can cover north and south with different things so you can access…

David: [00:06:00] Pretty much anywhere, right?

Larry: Yeah, pretty much anywhere. It depends on what you do with your orbits, if they're MEO or LEO. And you can do all kinds of different orbits. So, that's basically…

David: Okay. All right.

Larry: Thanks for the ball, Pierre.

David: Phil, given your experience at SpaceX, how would you answer the same question, although you're not speaking, obviously, for [INAUDIBLE 00:06:22].

Phil Larson: Sure. I was at SpaceX the past two years. I just think… It's interesting just taking a step back 60 years ago today was the first telecom orbiter with Sputnik. And look how far we come, and how that drove investments in innovation in new applications. Obviously, government first but that led to a whole new array of commercial applications. And I think we're at that moment — in this industry — with the list Julie's had up there of all of these players driving towards a new application for billions of users and tens of billions of devices. And so, SpaceX has their reasons. You saw them with four thousand plus birds they want to put up there, which would more than double the amount of existing operational satellites right now. And so, it's obviously ambitious. It's obviously far reaching. I think all these plans are. And they see it as… Elon just gave a talk in Australia about SpaceX's goals for the future. They see it not just as, obviously, an application that will benefit humankind and users on Earth, but as a money-making operation for their larger goals, for going to Mars, for pushing humans to be multiplanetary. They see it as a gold mine, and that's why they're pursuing it in the fashion they are. [00:08:00]

They talk about thousands of satellites, and the only way to do that is to take what they've done in the launch market, which is helping to push innovations there — whether it's landing and reusing rockets, streamlining the production of our access to space so it's more like a Model T assembly line rather than a one-off Fabergé egg factory — and they're trying to do that with satellites now. And that's where they see making million-dollar satellites, hopefully, into the thousand-dollar satellites. And we can talk about the miniaturization of that technology later. But that's kind, I think, the piece SpaceX is trying for.

David: Again, it's kind of a focus on broadband access. That's what the LEO constellation will initially be delivering for the most part, in terms of both for commercial or residential.

Phil: Right, yes. So, it's broadband access LEO with low latency and ground terminals in localities, basically. And then, spread it out via fiber.

David: Okay. Steve, ViaSat, a little bit different with the GEO focus with ViaSat 1, 2, and 3. How would you characterize it?

Steve Lanning: So, first of all, ViaSat realizes that innovation in GEO is not done. It's not as though this is a, "Everything is finished, and there's no further innovation." In fact, if you look at the capacities that are being announced on successive GEOs, you see things on the order of 3x increases, generation over generation. Well, what does that do? That brings down the cost of capacity dramatically. And so, as you're able to bring down the cost of capacity, well, what happens? Your services become higher data rates. So, you see ViaSat out there today with a 25 megabit per second service [00:10:00] and having things with a 150 gig capacity.

And with the new satellite, we're going to be able to more widely provide services like that. Well, those compete everywhere. So, it becomes a… So, we do build the Fabergé eggs.

Phil: Which are useful.

Steve: And they're ever more capable. But we do benefit from any reduction in launch cost, and there are other innovations that are happening around… Actually, announcements of even upgrading GEOs. I think we heard in the other thing that GEOs can't be upgraded. Well, maybe they can be. So, even that is up for question. That's not even what is out there today. What ViaSat is doing is innovating by basically vertically integrating because rather than having to deal with it at arm's length with your entire ecosystem, it's sometimes easier to convince people when you're doing things that are new and different and increasing by multiples, to just have your own microelectronics group, have your own antennas group, have your own systems groups and think about how to build these things together. And that's really been the key to how ViaSat has been bringing down the cost and making it so that the internet services that can be provided are actually growing at a faster rate than what you see being provided on the ground. So, it becomes increasingly competitive and increasingly a better alternative for internet access.

David: And so, getting to 25 megabits per second [00:12:00] in 25-3 definition and meeting the FCC definition for broadband is obviously then, perhaps, one part of the service strategy in being able to provide those types of services that meet the definition for broadband via the satellite.

Steve: Quite frankly, I'm happy that that's the sort of thresholds that they chose because it happens to align well with where we're at.

David: Okay. All right. Good. Okay.

Steve: It wasn't a force fit at all.

David: Yeah, okay. [Laughs] Cory, you're our drone expert on the panel. And beyond the more well-understood examples for the HAP services that providing broadband access via Google Loon and the like. What other services or applications do you think might we see using drones?

Cory Dixon: Well, my first response is that that's a loaded question because they're ubiquitous. You can imagine the application area, and I'm sure we can find a way that a drone is meaningful to apply there. First and foremost, is toys. I think one of the benefits to bring up in toys is that it's opened the broader audience of what a drone is and bringing that perspective to the people of what capabilities drones can provide. Five years ago, when we talked about drones, everyone only envisioned the military assets. Ten years ago, when we talked about drones, we had to literally almost explain what that was, an unmanned aircraft. So, today we can just freely use the word drone and, "Oh, it's an aircraft that doesn't have a pilot in it." But the application areas are broad. Pseudolite is going to be my true first response. That's what the HAPS application really is, is to put a different type of vehicle up in the air that acts and looks like more like a satellite. There's benefits of cost, time, deployment strategies that are benefited from that, but really, in this world, in this domain here, is the pseudolite capability.

[00:14:00] Of course, we all know about drone delivery, the last mile delivery. There's a same application from that from Amazon side of doing delivery of packages. There is the same last mile concept in communication networks, over the hill, over the horizon type of extensions using UAVs as communication relays. This is probably one of the more academic research areas right now. Specifically, here locally we have NIST, the National

Institute for Standards and Technology has the public safety communications radio group, our division. Their whole sole focus is how do we deploy mobile networks for first responders. So, this is immediate application area of how we utilize drones for disaster response, Hurricane Irma down in Texas or Florida, and the FAA has actually allowed a lot of authorizations and waivers for companies to go down and literally just test and try their different solutions. So, the FAA rapidly responded to these disasters with the attitude of, "We don't know what's gonna happen, but let's open the doors and let's get the feedback." So, when we issued these waivers their only response was, "Report back to us of what you did, what happened, what you provided, and if you had any incidents." But really it is the first responder's communications and using these aircraft, whether they're at the 400-foot level, the 10,000-foot level, or the high-altitude platforms that are providing that over-the-horizon communication and enabling on-demand communication for those first responders. In demand in space and time, get them where they need them. If you're over here in Colorado and you're in the mountains, it's hard to have LTE coverage. On top of that, I might want it tomorrow, so the UAVs really bring the ability to deploy in space and time on demand.

David: Okay. How many of you mentioned that you owned a drone at home? How many of you have used it in the last three months?

[Laughter]

David: Yeah, yeah. So, for me, it kind of went into the closet, and I don't really have daily applications for it, so I wonder how often [Laughs] they get used. I [00:16:00] have seen fisherman who rigged it up so it can take the lure out into the middle of the lake and drop it.

[Laughter]

David: That seems like cheating to me. [Laughs]

Cory: And I would add to that. It's really that low-cost consumer drone level that people… It used to be a couple of thousand dollars to buy it. Now, we're talking about 200 dollars, and you can have a nice eye in the sky. That's a fun toy to play with and not this expensive asset. But there comes complications with it. Now, instead of talking about tens of thousands, we're talking about millions of vehicles that can bein the air and coordinating with those.

David: Okay. Okay, Larry, so, that's kind of the application space. If you have some more questions on applications, we'll take them later. Now, going to the second category which is looking at the new capabilities that we're seeing in the drones and the satellites, and what are these innovations and the capabilities that are creating this innovative space right now. Larry, I'm going to start with you with a couple of questions on the OneWeb system. If you could describe or briefly explain what are the unique aspects for the OneWeb Ku-band proposal. It's raised 1.7 billion at this point in time, so it's obviously been commercially successful in attracting investment. And it consists of these 720 LEO satellites.

Larry: Yeah, so, we're not allowed to have slides at this presentation, so I'm going to get the ball back. So, people that don't know, again, the GEO arc is out here. The OneWeb system is proposing what's essentially polar orbits, and so, the satellites are circulating around the Earth. And for those of you who don't know, it would be really nice to put a low E arth orbit satellite and just have it stay at a thousand kilometers and sit there. That would be a really nice thing, but the physics don't make that work. So, the challenges with all these low Earth orbit satellites is they're moving, right, so they're moving around. And I wanted to take this section of the… So, that's the configuration of OneWeb, [00:18:00] so the satellites are passing over very quickly.

So, the challenge is you have to have a terminal on the ground that can track them. And so, we talked about what some of the innovations are. You got to make… Since you're going to need many satellites — they're only a few inches over the ball, we talked about 700 here — you're going to need cheap satellites. You can't make a 500 million-dollar satellite and launch 600 of them. You have to get your satellite cost and launch cost down, so you're talking about a million, a couple of million dollars a satellite. That's really where you have to be to have anything that's kind of close to viable.

So, launch is important. OneWeb is not building launch vehicles. We're riding on the industry. There's lots of innovations. But we are working on the shrinking and mass production of the satellites. So, traditionally, the satellites are produced one-off, hand done, highly customizable process. We're going to be producing 600 satellites in much more of a manufacturing process. So, I was involved in another project which I'm actually quite proud of. Which was O3b and we launched 12 satellites, so that's kind of a compromise. You're not just building one, you're building 12, but it still wasn't really a production line. The satellites aren't going into iPhone quantity, it's not going to be a million a day kind of quantity. It's going to be 600 in a year or two. But that's a big area of innovation, getting that production going, miniaturization, launch, costs, terminal. Those are kind of the key innovation areas and components towards making it work. From a regulatory perspective, the key innovation is to be able to use the spectrum without interfering, and so, to have regulatory access to the spectrum. And that's actually an innovative thing. For the students and so forth, the licensing [00:20:00] and access to spectrum.

Licensing is even the wrong word, the access to spectrum for non-geosynchronous satellites is a very interesting topic. It's controlled first by the ITU because these satellites are moving all around the globe. So, the ITU coordinates this all. And there was a very interesting proceeding in the 90s… Oh, ITU. Okay.

Pierre: For the students in the room.

Larry: International Telecommunications Union. So, the ITU had a very interesting proceeding in the 90s where they looked at, "Well, how do we coordinate between these geosynchronous satellites and the non-geosynchronous satellites?" As Julie said, the first claim of any incumbent, and I'm not picking on the GEO guys, it's true of any incumbent anywhere is to say any interference is unacceptably bad. We will not allow it. We will fight tooth and nail in the regulatory process to avoid it. But what happened in the 90s was there was a regulatory process led by Teledesic where they actually created rules that are pretty good. It was a pretty good regulatory effort where they said, "All right, let's look at statistics. Let's model this thing." And if you Google "ITU Article 22," they actually came up with rules about how much power you can transmit in different directions, and it's a function of time. There's a worst-case power. It's a cumulative distribution function. And so, that is the basis for a lot of the coordination that goes on today. We operate within these rules of Article 22 that allows us to transmit. But we can't transmit to the GEOs, so a lot of innovation goes on in how you transmit and get access to the spectrum. Sorry, that was a long answer, but I thought it's a very interesting topic, and I encourage people to look at that regulatory process.

Phil: And if I say one thing to stick up for the Fabergé eggs, the GEO birds out there [00:22:00] two feet from the soccer ball. We've all been on a plane recently, we're on our Gogo Wi-Fi, I did a quick calculation before. If every plane was not Gogo but ViaSat enabled, we'd all be getting 12 megabits per second to our seat. We wouldn't have that you can't stream video, but 300 of your best friends and you could all be watching Airplane while on an airplane using a ViaSat bird. So, I think it's all of the above there's spots for.

David: So, Larry, as one follow-up, you mentioned MEOs and in fact, OneWeb then came in March with a proposal for adding MEO constellations to the LEOs, right?

Larry: Yeah.

David: 1280. Explain some of the thinking behind that proposal.

Larry: Well, as we said, the LEOs are pretty close. We were talking two inches, Pierre. So, these are pretty close to the Earth, and the MEOs are a little bit higher. They have a little bit higher latency, and they have different characteristics. You're so close with the LEO, you don't have a lot of degrees of freedoms. If my LEO is here two inches above, it's pretty hard for me to cover this spot here. I'm pretty much covering where the LEO is covering. But once I go to a MEO, I can have choices of where to put my capacity. The MEO system we worked on at O3b, they have articulating dishes, so you can say, "You know what? I don't need to cover everywhere. I just wanna cover here." So, it gives you some flexibility in terms of capacity. So, you can use MEOs to inject capacity where you want and to have some flexibility, and so, they're very complimentary. So, we actually see all of it very complementary. GEOs are extremely efficient, very good for certain things. MEOs have a place and LEOs have a place. And my personal view, not speaking for OneWeb, that I think it all fits together very nicely. Of course, the key to that is your terrestrial technology to pull all the systems together.

David: Okay. [00:24:00] Steve, so you want to talk about some of the interference issues from a GEO perspective?

Steve: Well, the challenge with being two feet out is that you are a distance out, so somebody interfering can cause a significant decrease in your throughput. And so, after you've been investing billions in the technology and launching, you're going to be wanting to protect that position, especially when you're planning on launching more. Which we are working on this, production of that has been announced. So, the focus is, as I said earlier, to really drive costs down per bit. So, there's many… One is how do you make sure the design of the GEOs, we see those as not interfering. But the question always comes as like, "Okay, there's thousands of these things, and are they always working exactly as they're supposed to? Is everything going…" And when they don't, they've been designed so that they won't interfere, but if the timing's off a little, well, they're probably going to start interfering and it doesn't take too much interference to have significant decreases in throughput and which could have a material impact because we are going to try to sell to fill these things up. And so, if you're sitting in there saying, "Okay, we're close to where we want to be, and we're trying to maintain certain service level agreements," and now, all of the sudden somebody starts interfering with you, then, so you're taking a 10% hit on capacity. Well, that [00:26:00] 10% hit on capacity is going to translate to potentially much larger decreases in, say, measured throughput.

So, suddenly you're going to show up in some Measure Broadband America report with half the data rate that you advertised. Well, we don't want that. That's bad for business in many ways. It's not like we have a spare sitting there ready to launch up there and provide capacity. Now, we have been thinking about how to make things more flexible and other innovations in the system, so that maybe we can make some modifications. But at the end of the day, you're still talking about needing to get serious about detecting the interferer and being able to say, "Hey, man, bad things are happening here, and let's see about going to fixing them."

David: Do you see that as a challenge now, or do you think there's some good rules in place that can be built upon, that can make that workable?

Steve: The technical challenge is just in identifying and being able to know who your interferer is. I think once you know that, there aren't that many total organizations out there, and most of these guys will respond to you in a positive way, if you can say, "Hey, here's the data. Look. You did it here, you did it here, you did it here. Now, let's stop." That feeds into other areas of innovation around spectrum sharing, timing, and everything else.

David: So, Cory, can you talk a little bit about how with drone technologies, the capabilities have expanded their driving, all these new innovations?

Cory: Well, Dean Braun said it best when it was it's the autonomy aspect of the drone. [00:28:00] You don't require a large footprint to be able to operate this system anymore. It used to be that was the case. To put up a military drone up in the air 10 years ago required a ground crew of 60 persons. That was much higher than the F-22. These days one operator can put an aircraft in the air because of autonomy, because of the systems are able to do a lot more of health and safety monitoring of their own systems, be able to position themselves on demand. So, it's the autonomy part. In regards to communication link for back to the first responders' applications, it's ability for that firefighter or that first responder to put that vehicle in the air and then forget about it, and he's not devoting his asset and his time to do a different task. He can go back to being a firefighter. The aircraft, then, through autonomy can measure the environment. It can react to a dynamic environment, both in the environment itself and the noise in the environment interference, as well as the quality of service. So, if you have a group of firefighters or first responders in a certain area, the UAVs can measure the quality of service that's delivered to them and adjust its position, to be able to go deploy into the area and augment that service field, if you will.

So, the autonomy is really what has driven the application. Of course, there's a lot of other innovation that's across the board has enabled this which is the miniaturization of technologies, both on the autopilot side and on the communications side. These days we're talking about putting cell on wheels up in the air, so mobile LTE networks that, still require a backhaul, a backbone, but now instead of having a cell on wheels, it's going to be a cell in the air and provide that capability. So, again, the miniaturization of that. Technologies in RF, conformal antennas, making antennas part of the vehicle is an enabling innovation as well, and how do we handle the large bandwidth and large frequencies relative to these small size of vehicles, especially in the lower altitude ones. How do you really do the RF density problem on these small aircraft? There's other innovations that are coming into play. And of course, FAA policy of commercialization is a big innovation that changed to allow commercial [00:30:00] ventures to start looking at these opportunities as well.

Steve: I would interject that with some of the more exciting stuff that strikes me around drones has been around agriculture and around sensing the need to water, the need to apply pesticides, and that there's massive reductions in pesticide application that are enabled by these things. And the application of water. So, as water becomes more scarce, that becomes important. And having tons of fertilizer being washed into the streams can be massively reduced. To get the same yields and to improve yields. So, that sort of innovation in terms of applications of drones, I think, is a huge potential benefit. I don't think we know enough to quantify what that is worth, but I just think it makes just common sense that if you can apply less water and less pesticide, that is going to be a good thing for the environment and for productivity of food production.

Cory: And I appreciate the follow up, and I was trying to stay more towards the wireless content, wireless focus, but my group name is the Integrated Remote and In Situ Sensing Program, so our job is to help develop capabilities to deploy systems to do remote and in situ sensing. One of the aspects too — to follow on that — we developed an L-band radiometer here at the University of Colorado to measure soil moisture. So, there are other application areas. Again, they're tremendous in how… From delivery precision, to ag, infrastructure inspection, commerce, communications. Again, you can almost think of almost any market application area and apply that. But remote sensing is a big one where spectrum is of interest to us and the ability to use that spectrum as well. Both for active sensing and passive sensing is an innovation that will expand [00:32:00] the capability of drones.

Larry: Just to add, I couldn't help but think over the last couple of weeks that we needed some drones over Puerto Rico. It's an obvious thing to have a drone because the capability is completely there to generate a cell signal from a drone. The backhaul is available through GEOs, MEOs, all kinds of things. It's just something that needs to be built because it's… I think the challenge is making a commercial model of it, but from a disaster relief perspective, it's a very obvious solution, and from a 3D wireless spectrum perspective, I'm sure the carriers in Puerto Rico would lend out their spectrum for the emergency situation. So, you can coordinate in the time dimension. But it's a really obvious application for disaster relief.

David: And to be fair, I think, Google Loon did that in Peru during some floods for some backhaul for exact… Good observation.

Larry: And it's an easier problem than having to give it… You can afford to keep it there for a limited time which is less difficult than keeping it there for five years.

Cory: And I'm going to jump ahead. I'm just going to finish it up. The challenge to this is the training of those commercial people to be in the field in a disaster scenario. So, again, in Houston, the FAA decided to go ahead and just open up the door to allow that experience to start happening. Right now, though, I can say there's very few entities in the US that are trained and should be allowed in disaster response. Next year, hopefully, it will be a different picture.

David: Okay. Good follow-ons. All right, so now, we're going to the third category which is the issues and challenges for managing the innovation that we've just talked about. I wanted to start with a question to Phil. How the policy makers done here and Julie will accept any comments here that anyone… But how are they doing in managing this innovation space? And are there some gaps or some suggestions or some things that are happening that…? Fill the audience in on it.

Phil: There's definitely [00:34:00] gaps, and it wouldn't be a surprise to say government's role in these types of things is not to take risks, especially in operational domains, but have some surgical interventions, have some walled-off areas for innovation. It was 2004 when then President Bush said we need universal cost-effective access to broadband by 2007, and we still have 34 million Americans without that access. And so, obviously, there's some policy challenges. We're talking about some of them. There's a diverse array of applications as well as providers. But that's part of the government's job. And so, in 2010, one of the things we did in the Obama administration was working together with the FCC, was working to start the process of freeing up spectrum, 500 megahertz of spectrum by 2020. Reallocating government use, reverse auctions, sharing arrangements, and so, that I think is part of the answer. It's not the whole answer. One thing, I'm a space guy. I'm a rocket and going-to-Mars type of guy, but one of the fun things about a panel like this and the conversation that's happening now probably for many years is combining the space community with the telecom community. And I think we're still seeing an outgrowth of that and opportunities and challenges both with NASA and the DOD, which uses 80% commercial sats for their coms. Working with these commercial providers to help spur innovation and help drive that conversation. So, [00:36:00] the current administration, I know is looking at this.

They've stood up a National Space Council for the first time since the '90s, which I think this will be one of the things on their docket. Their first meeting is tomorrow in DC. And so, I think we're lagging behind, but the tools and the pillars are set up for success. And I think that's what we need to see in the coming years.

David: So, are you saying with the National Space Council, that a lot of what's been reported there, they're focusing on is exploration strategy.

Phil: That's the headline grabbing thing, right? That we're going to free up 100 megahertz of spectrum.

David: But you think in the details it will help?

Phil: I think so. I think it'll be an avenue. We did that in the Obama administration. We used OSTP, the Office of Science and Technology Policy with Office of Management and Budget, OMB, which is the administration's budget and regulatory arm. Phil Weiser was part of that team. And so, they're looking, I think, at their mechanisms for doing that. They have different things in different offices stood up that could help coordinate that across the agencies in the government.

David: Okay. All right, question for Steve and Larry. Pierre raised orbital debris, I think, didn't you? Discussion… Can innovation help at all in that space or are just doomed to watch it slowly fill up with debris?

Steve: Well, I would hope that the innovation would be around fewer collisions and leaving stuff up. I know that the… It's always asked what your plan for bringing this thing down at the end of life, and clearly, there's room for improvement in terms of how to stop adding. There's the physics of the whole thing has it so that a lot of stuff is just going to fall to Earth [00:38:00] and burn up.

But clearly, there's a lot of things up there that haven't had that happen. That are moving at just the right speed to stay in nasty places and cause problems. It creates a problem for even the GEO guys because this stuff comes zipping on through, and you are literally flying even a GEO satellite. Because you can see the thing, you know that this stuff is coming, and you need to move, so that you don't take a big hole in your solar panel, something flying through it or worse. So, the innovation, I think, really is in figuring out how to stop putting stuff up that isn't going to come down. And then, of course, it's collision avoidance because you can create a lot of debris through a collision or some nasty act by somebody blowing up your satellite.

David: You started saying you had some concerns that if there were some requirements on, for example, the timing of when it came down, though?

Steve: You can bring it almost to accountability. It's like, "Okay, you put this thing up." If this entity goes out of business, who's accountable at the end for getting this thing back down? Because, like I said earlier, if you're flying these things, there are actions you could take to decommission it and bring things down safely, so that it's not going to fall in the middle of some populated area.

David: So, you're saying accountability is a good thing in that sense?

Steve: Yes.

David: Yeah, yeah.

Larry: Well, I'm going to first of all start by saying I'm not a space debris expert. It's not my [00:40:00] field of expertise.

But it is real. It was kind of the story that we had with O3b is you get a call from NASA. They're tracking, they say you're 20 minutes away from a potential collision. Here's what we know the accuracy and they said take evasive maneuvers if you can. So, this is a company that at time that had 12 satellites, 100 million dollar kind of class of cost if you take this satellite out. And the guys are looking and go, "Okay, what move do we make?" And in this particular case, they decided the best move was to hold tight and hope it missed.

[Laughter]

Larry: It did. So, it's a real problem. And I think a couple of things on innovation. I think first of all, it's a real problem that has to be considered. We can't pollute space for the future, so we got to take this problem very seriously. I think that's my first point. I'm not an expert, so I'm not going to have all the answers. It does tend to become more of a problem the closer you get to Earth. You saw the slide that Pierre… The last we want is a problem where you can't launch through because there's so much debris. So, areas for innovation are being able to take evasive maneuvers, making sure your equipment does treat space respectfully, burns itself up. You got to make sure that when you burn yourself up that you don't have a piece of glass that comes flying down to the Earth because some of this stuff doesn't actually burn up. Especially, when you're talking about laser glass and things like that. So, there is areas for innovation there. People have talked about let's get a space garbage truck and go fly around — I don't know viable that is — and collect the garbage. But I know at OneWeb it's something that were taking very seriously. We look at really how the ability to make sure these things deorbit under all scenarios, triple fail safe, that these things [00:42:00] are going to deorbit and burn up, that they're not going to have shrapnel that's coming to the Earth.

So, it's something we look at really seriously, but it is a topic that I think the regulators need to be cautious because there is points of no return. There's points of no return if gets too bad.

David: Sounds like you might have hit on a new movie or TV series.

[Laughter]

[Crosstalk]

Larry: Well, I think that people are looking… That's not infeasible.

David: No, no, no. Exactly.

Phil: I think it is getting the attention it belatedly deserves. Senator Cory Booker just announced yesterday an effort on mitigating space debris. It's getting looked at from

DoD, DARPA, unique possibilities like you're talking about, Larry. But it is affecting operations right now. If we're going to increase the amount of satellites in space, we need more launches and, right now, launch windows because you have to put these birds in the exact right slot in orbit. Launch windows are being affected by debris and conjunction, potentially hitting each other. I think there's some solutions being looked at in the commercial sector that can help. I think it's have a more accurate and specific space traffic control. Right now, it's run by DoD. And these two-line elements that give you a sense for what might be coming into your sphere of concern, but I think there's better ways of doing that, and I think the commercial sector has some applications there.

Cory: If I may real quick, another innovation that's related here at UC of Boulder is going to be the space weather aspect. To be able to accurately predict these deorbit maneuvers. So, there's tremendous amount of research here within the aerospace department and other departments. What is our upper atmosphere look like? What is those near space environment, so we can do accurate deorbital maneuvers and bring down small [00:44:00] sats.

Larry: Yes, so they've even considered standardizing on small sats a grapple fixture, so that every sat has a common fixture, so that if you had something that could go up, it would have a common interface that the satellite could be grabbed and robotically deorbited or something.

David: Okay, interesting. For time, let's go to the key disruptive technology developments and trends category, last one. Steve and Larry, just HTS, the High Throughput Satellites, can we expect speeds to continue in the GEO?

Larry: Ask Steve.

David: But do we also consider LEOs at HTS at some point in time? Or are they going to…? How does that play out?

Steve: I think that things are going to be looked at from an economic point of view. So, I do think that there's scope for reducing costs. We have announced that we're putting up ViaSat-3 class satellites more than just one Fabergé egg which does have the potential to spread some cost out and help keep things cheap. But we continue to innovate in order to use basically all the technological tricks to continue to improve things. We continue to go beyond what… It reminds me very much of conferences I used to go to when I was at Bell Labs where we would talk about how many transistors could you get on a chip and when are we going to reach that limit. And you would have PhD physicists and engineers up there talking about getting to certain scales, and we'd all walk out of there going, "Oh, wow, well, that's three years from now." And then, we'd come back three years [00:46:00] from now, and it's still going.

The clever people keep coming up with new ways to push things forward. And clearly, we're in that business and continuing to push and other people are really starting to… I think that the high-throughput satellite business is… Unfortunately, we're not alone. We would love to be the only player here, and everybody had to buy from us, but that's not quite the case. And so, we will continue to have competition and push each other in that.

David: It's safe to say the economics are such that the speed, the throughput for satellites are going to kind of increase with the distance of the orbit and the size of the bird.

Larry: Let's first define what high-throughput satellite is for the audience. And again, we said, and I got to get the ball out. In the beginning of time, there was GEO satellites, and they illuminated a third of the Earth. And so, if you had one unit of spectrum, all that spectrum was spread across that third of the Earth. And if you had a user that wanted to consume one unit of spectrum, you could have support one user on a third of the Earth. If it was broadcast, it was different, but if you're talking about data… And so, what high throughput is is dividing that into more and more spots on the Earth, more and more spectrum per spot, more and more power per spot. So, it's kind of like cellular division. You start it with the macro cell, you divide into smaller and smaller cells which really increases the total capacity. And so, I think that is just a natural evolution of all these systems. They're going to self-split to drive capacity at power all the other innovations. But that's what a high throughput concept is. It's really splitting spectrum and splitting into smaller spots. And as you go up in spectrum, your spots [00:48:00] naturally get smaller.

It's easier to make them smaller. You use a big antenna. If you have low-frequency spectrum, you need a gargantuan antenna to get a small spot, but if you go up in spectrum to some of these bands like 40 gigahertz, you can do it with smaller antennas. You got to worry about the rain. But I think it's going to be a natural evolution for all the systems to squeeze capacity out.

David: Okay. Phil, any other comments just about what's going on with launch technologies. You've talked about it a little bit already.

Phil: Yeah, I think that's obviously a huge piece here, and we need to enable more of what we're seeing in the commercial launch industry. The rocket launches, the landings, the new players from SpaceX to Blue Origin, to the smaller providers, that has the ability to help dramatically lower the cost of access to space. That's what the holy grail is for enabling a new economy in space which is what we're talking about. And getting out of Earth's gravity well is the long pole in the tent there. And so, as strategic as they… enter these discussions in the new administration in DC, how do we help enable that commercial market which Ronald Reagan put into NASA's charter in the '80s by having government act as a VC for launch providers which will, then, help enable commercial providers to benefit.

David: So, I'm going to ask one quick question here, but then, we'll open it up to the audience for questions, and students will start. I recognize a couple of ITP students, but if there's some law students as well here, start thinking of your question while I answer this one question. Dean Braun talked about a couple of the articles that came out. One of which had the title [00:50:00] from Buzzfeed, "The Trump administration is about to enter the space race. Everyone wants to know how they'll deal with the billionaires building their own rockets."

So, is this going to continue to be a billionaire space for investment? Or is that just that clickbait, in terms of getting folks to read the article? Or is this reflecting just very high fixed costs and high risk and they're the only ones who are…?

Phil: BuzzFeed doing clickbait?

[Laughter]

Phil: I think the billionaires get the headlines, and it's an easy headline to write, but there's been more venture capitalism from small to billionaires in the last 15 years than in all previous years combined. And you're seeing it at all levels. There's a thousand innovative new space companies across all 50 states. You hear about the obviously the two, three, four big ones that are making waves. But that's what we are trying to unleash with some of the policies we did last eight years, as well as what I hope is being discussed in DC is we had the computer revolution based off the miniaturization of transistors on chips, and that led to obviously a trillion dollars of economic growth in over a decade combined with the internet. And that was all terrestrial. So, how do we take that type of thinking and investment in to this new, I think, frontiers is a key question.

David: Okay. Anybody else wants [INAUDIBLE 00:51:33]?

Steve: To me, what's going on seems a lot like… When you look at technological revolutions and things replacing… You saw when telephones came out, there were nasty pictures of phone lines everywhere, nothing organized. Then, when… Here comes railroads and investments all over the place, big names investing all over the place, [00:52:00] and lots of these things turn into bad investments and things had to get rolled up into things that were sustainable and made economic sense.

Earlier in my own career, I wrote about Silicon economics and how fiber everywhere made certain amount of sense. And then, as I started looking at it more, I said, "Well, maybe not." Obviously, became convinced enough that I joined ViaSat to go and pursue things from space. And do I think it's the whole solution? No, but do I think that there's a place for it and that it's an important thing to take us from notions of universal service to ubiquity and service everywhere? I think it's extremely important.

David: Okay. Okay, student. Come on. Don't be bashful. I'm waiting for a student to pick one. Oh, there is one behind… Okay. You got one? Oh, great.

Jonathan Bair: So, Jonathan Bair, 3L at the law school. So, Pierre kind of stole my thunder with the question on space debris, but to my knowledge there is no space law of salvage, so the satellites that people are putting up into space, even if they are in junk orbit or partially destroyed, it's still their property. Is there movement towards getting some kind of international space law of salvage so that we can clear up the space? Or is it something that we might expect companies to want to reuse this material that they've now put into space in the future that they've moved to the junk orbit or have just [00:54:00] left up there?

Phil: I think both approaches are being discussed. The second one first, there's some basic research being done at DARPA, at NASA on how to do we… It's basically a fuel issue, usually. How do we refuel billion dollar satellites if all they need is station keeping fuel. So, how do we dock with it? Create a system for elongating their lifespan is one approach. The '67 space treaty, United Nations, focuses on these issues internationally. Obviously, there's no borders. Something can come down anywhere. And so, right now, they talk… In the '67 space treaty, the launching state is responsible if and when it comes down. So, that's when it's a problem. If it does some damage on the ground, it's up to the government of which it launched from physically. But in terms of stuff that's just floating up there right now, there is not much of regime for that kind of enforcement, at least. But the '67 space treaty is a little outdated and we'll get, I think, we'll have to require the private sector to lead on a number of fronts from… If Elon really wants to go to Mars, what does that look like in terms of international treaties, a private company leading. I think it's going to obviously take a village to go. But it's those types of endeavors that push bodies like the US government, like the United Nations Committee on the Peaceful Uses of Outer Space to tackle these issues. Property rights on asteroids and Peter Diamandis says the first trillionaire is going to be made in space mining asteroids. And so, right now, those property rights are not covered in that treaty, and so, it will take the technology to push the policy there.

David: Okay. We had a question. Does this solve your question? Yeah, wait. Mic's [00:56:00] coming here.

Audience: I wondered…Larry and Steve, I presume your small satellites are solar powered. Is that correct? And so, you need enough energy to keep them panels aligned, antennas alignment to the ground and maintain orbit. Is that practical to get enough solar that way?

Larry: Yeah, so that the main constraint is not actually powering the satellite from a station-keeping perspective. It's to power the payload. The payload is the dominant consumer of energy on a satellite. The other thing is… So, we need solar cells to power the payload and to do your electronics onboard. You also bring some propulsion with you, and there's a variety of forms of propulsion. So, one of the problems for… Steve can speak. But in the GEO hit, if your propulsion runs out, you can no longer effectively station-keep, and that's why I talk about the refueling. So, you need the solar cells as kind of your day-to-day power your payload. Propulsion is being used slowly over the lifetime, and at some point, it runs out. So, in the propulsion scenarios for the LEOs, you're required to, before your propulsion runs out, deorbit, burn up, get yourself… You cannot be in a state where you just run out. GEOs, right now, they just run out. They don't deorbit.

David: Good question. I have been asked to wrap up for the session here, so if you have any questions, please come down. The panelists would love to answer your question. And I guess we're going to a break now, or do you want to wrap up?

Pierre: Yes, we're going to a break. Before we thank the panel, just let everybody know we will start at three o'clock. So, I know the breaks are the best part of the conference. This one will be 10 minutes, not 15 minutes as planned, but please, try and be back at three. And so, with that, [00:58:00] thank you to David and the whole of the panel. Thank you very much.

[Applause]