Pierre de Vries: Well, everybody, welcome to Silicon Flatiron's annual spectrum conference. This year, we're looking at 3D wireless, which is the promises and challenges of next generation, airborne and space wireless technologies. My name is Pierre de Vries. I'm co-director with Dale Hatfield of the Spectrum Policy Initiative here at Silicon Flatirons, and it's a real pleasure to welcome you here today.

I'd like to just start by briefly setting the scene for this conference. Why are we doing this? Spectrum policy used to be simple. And anybody in the audience who's ever done Spectrum policy, at this point, rolls their eyes and says, "Spectrum policy has never been simple." At least the geometry has been simple. Because, in the good old days, it used to be that licenses were points. There was an antenna, there was a transmitter at the point. Transmitter, for example, for TV. Or you had a geostationary satellite that was in orbital slot, that was a point. Then you got fixed point-to-point microwaves. So, you had points and lines. Then, there was the big innovation in the 80s, of cellular area licenses. So, then we went points, to lines, to areas.

What we're seeing now is a move to volumes. So, the geometry gets much more interesting. And so, to give you just a sense of what we're talking about, I have to use a prop. And so, this football, soccer ball, imagine this is the Earth, right? Diameter about 12,000 kilometers. So, to scale, a geostationary satellite is in orbit about two feet away from this ball. And, in fact, if I close this eye, this is the view that the geostationary satellite has of the Earth. You can see, it's about most of the Earth. And that orbit [00:02:00] is chosen, such that the satellite goes around the Earth in 24 hours.

And if it's on the equator, going the same direction as the Earth, seen from a fixed point on the Earth, it never moves, so it's stationary. That used to be it for satellites, mostly. Now, we're filling in a whole bunch of things. So, people talk about medium-Earth orbit satellites, they cover a range of altitudes. But, typically the kinds of things we'll be talking about today for broadband, it's about 8,000 kilometers up, so that's about six inches. Five-and-a-half, six inches.

And these things go around the Earth, two hours, ten hours, something like that. Then you get low-Earth orbit satellites. So, these, again, variety of altitudes, but typically, for the stuff we're talking about today, it's about 1,000 kilometers. That's three quarters of an inch. And these things go around the Earth, depending on altitude, about 100 minutes, to complete an orbit, which means, if you're on a particular spot on the Earth, you'll see one of these rising and setting in order of ten minutes.

So, these are the satellites that are now filling in the space between geostationary orbit, and low-Earth orbit. But, of course, that's not all. Oh, by the way, for scale, the moon is at the other end of the table, and this is the Earth. So, that's the scale.

One of the things you'll hear us talking about is high-altitude platforms stations. Things like, Lockheed Martin's high-altitude airship, Facebook's ocular drone, and so on. These things are at about 60,000 feet, and, to scale, that's about one one-hundredth of an inch above the soccer ball. But, to give you a sense of what 60,000 feet means, commercial aviation typically is 30,000 - 35,000, ceiling is about 42,000. So, these things are twice as high as most commercial planes get, and higher. Then, in commercial [00:04:00] airspace, we're seeing more and more, particularly in combat areas, unmanned aerial vehicles, drones.

Which can be quite big, flying at all these altitudes. And then, the big innovation over the last few years has been low-altitude drones. Mass deployment of drones, the new rules of the FAA, Federal Aviation Agency, they can fly no higher than 400 feet. So, that is the Washington Monument. That's 555. Or, for those who take a football rather than a soccer view of the world, it's half the height of the Eiffel Tower.

So, we're seeing things at all these altitudes, all of them use radios. They all use radios for command and control, and many of them use radios for payload. Payload meaning, for example, providing broadband internet service, or doing streaming video if you're doing surveillance.

And that takes us to this notion of 3D wireless. So, this is…this slide is, actually, up on the website, and let me just do a quick footnote, the primer that we had in the previous hour, this slide, Julie Knapp's keynote, and the conference brief are on the conference website. If you search for Silicon Flatiron 3D wireless, look in the right-hand margin, scroll down, all these things are there. So, this is just a small sliver of the broadcast allocation. You can't see it from the back of the room, but this is 18 to 32 gigahertz, the upper microwave. And you can see that we have a mixture of terrestrial services. Satellite services are different altitudes, and of course, satellite services typically have things on the ground as well. So, this is why we talk about 3D wireless. And the goal of the conversation today, is to look at the intersection between all these things. Aviation, new space, [00:06:00] and Spectrum.

And one of the things that struck me as I started to thinking about these things were collisions. And so, you'll be hearing about different kinds of collisions today, three kinds. For example, the first is the physical kind, where one piece of satellite's material bumps into another, perhaps creates a cascade, creates space debris. For most of us, a more worrying one would be if something bumps into a plane we're flying. So, those are physical collisions.

There are collisions of radio signals inside receivers, known as interference. And, because you have more and more of these systems, systems change dynamically, that interference becomes more challenging.

And, last, but not least, there are collisions between different institutions. There are, at the national level, different agencies with overlapping interests in all these areas. There are national and international agencies. And, on the other hand, you have collision between companies. There's a lot more competition. There are new companies entering the business.

And, to help think through, at least to a first approximation, what this area is about, we'll have three panels for you. One to look at innovation, one to look at some of the challenges, another to look at solutions. And then we'll wrap it up. We'll bring the moderators together for a short panel at the end to try and draw some conclusions.

To kick it off, I would like to introduce Professor Bobby Braun. He's the Dean of the College of Engineering in Applied Science. It's a great honor for us to have him here. He's a former chief technologist at NASA. He's used to placing bold bets. He's an entrepreneur, founded a company called Terminal Velocity Aerospace, that makes hypersonic flight products. University of Colorado, Boulder, is the national leader in aerospace research, aerospace teaching. [00:08:00]

And, Professor Braun is a new, energetic, leader here who's transforming engineering at CU. Ladies and gentlemen, Bobby Braun.

[Applause]

Bobby Braun: Thank you, Pierre. Good afternoon, and thank you all for allowing me to come here and speak to you. I'm genuinely excited to be here with you, and just thrilled about the topic of this conference, and of this session, which really is both cutting edge, and at the intersection of so many important topics.

So, just as a little bit of background, I'm an aerospace engineer. I have been in the aerospace field for, I don't like to admit it, but, for 30 years. Right? For 30 years now. And, I've seen a lot of things come and go in that time. And, what I believe, and what I can say, honestly, is I've never seen a more exciting time in the aerospace sector than right now. Not only do we have government programs that are going full bore, in both the civilian and the military sides of the house, but we have a very strong, and up and coming, continually growing industry presence in commercial space and aeronautics.

Frankly, like we used to talk about 20 years ago that we wanted, we've actually got that going on right now. And you can see that in the plethora of companies that are out creating an aerospace future for our society. Whether we're talking about SpaceX or Blue Origin and their rockets that they're generating, or OneWeb, or Planet, there's just a whole host of these companies springing up.

In fact, I read the trade press, space news, and the most interesting thing to me [00:10:00] was that the top news last week were about talks given by Lockheed Martin and SpaceX at a conference all the way over in Australia, talking about one day having humans on Mars. The headlines weren't about NASA administrator describes humans to Mars, it was about Lockheed Martin officials, by the way, from the state of Colorado, and SpaceX officials laying out their visions of the future.

Also in that meeting, you had officials from Planet talking about their constellation of small sats, that are going to provide continuous global coverage imagery of our world, and the rapidly changing effects of our world.

OneWeb was there talking about telecommunications. SpaceX gave other talks, talking about their telecommunications, visions of the future. And, so, it's just a remarkable time in the aerospace sector. And, by the way, it really is remarkable both in space, and also in aeronautics, where there are major undertakings happening, and major advances still occurring. In fact, the advances in space and the advances in aeronautics are somewhat synergistic because they all have to do with things getting small, and things being autonomous, right?

Those two advances, small and autonomous, lead to unmanned aerial systems, drones, or what have you. They lead to small sats, hundreds, thousands of them, doing what a big satellite used to do. So, I'm very bullish on the future of our space sector. And one of the reasons that I'm here today, is because I placed a bet and I moved to Colorado, right. And one of the reasons that I moved to Colorado was because of the strength of the aerospace industry in this state.

So, you probably know Colorado has the second highest number of jobs [00:12:00] in the aerospace sector in the United States. Per capita, it's the most. All the major space companies that I had been doing business with from the East Coast were here, so, why shouldn't I move, right? Why shouldn't I move to work more closely with Lockheed Martin, and Ball, and Sierra Nevada, and the hundreds of small businesses throughout the state of Colorado that are making a future for themselves in aeronautics and in space every day.

And so, what's at the epicenter of this Colorado aerospace ecosystem? It's the Department of Aerospace Engineering Sciences, right here at this University, at the University of Colorado, Boulder. This is the department that, frankly, I used to be envious of, and that I'm honored to be a member of today. This is a department that is leading the way in small spacecraft, in unmanned aerial systems, in autonomy, working with folks in computer science, moving into cyber security, this is a department you can be proud of.

It's a top 10 department nationally. It is the department that gets the largest number of applicants every year when we're filling out the freshman class, for our aerospace program. And it's a department that, I'm very happy to say, was recently approved by the Board of Regents to get a new building here on campus.

So, one of the things I wanted to mention, is that new building. Towards the end of this month, on October 26th, we're going to have a ground-breaking for the new aerospace engineering sciences building. It's going to be over on East campus. And that building will be up and fully operational, occupied, students, laboratories, faculty, industry, coming in and out of that building, by the fall of 2019. And, we're very excited about it, first of all, because of the potential [00:14:00] that that building offers the campus, but also because it's located on East campus, very close to LASP, the Laboratory for Atmospheric and Space Physics.

This is a laboratory that has built instruments, space-flight instruments, that have visited all the planets, whether Pluto's on your list of planets or not, they've got an instrument that's been there, right. And the synergies, I believe, between LASP and Aerospace Engineering Sciences, in fact, the whole college of engineering, including computer science, and electrical engineering, mechanical engineering, those synergies were just beginning to grow.

So, I'm very proud of that department, but I'm also equally proud of the college for what it offers the campus and the state of Colorado. We have the first, and still going strong, interdisciplinary telecom program, and you'll hear a little bit more about that from David Reed, during a session today. That interdisciplinary program is, kind of, is representative of the kind of interdisciplinary thinking that is happening across this campus now.

As another example of interdisciplinary thinking, between engineering and business, we're rapidly growing our entrepreneurship programs. And, we're doing that in connection with the greater, bolder entrepreneurial community. So, you're going to see a huge increase over, if you were to look five years ahead, you're going to see a very large increase in the number of student-led and student-active startup companies coming out of this campus, and going off in domains like we're discussing today. Not just in this domain, but certainly in this domain as well.

One of the other points I want to make about our college, is its strength and its ability to grow. So, this is a college that's growing very rapidly on campus. [00:16:00] It's growing both in size, in quality, and, actually, in diversity and access to students and people across the state and across the nation. In our freshman class, our freshman class that's here on campus today, we have 850 students in engineering. That includes computer science, by the way, for those of you not on campus. It's called Engineering and Applied Science.

In that class, 850 students, we have 38 percent female engineers. The average is 20 percent. Our freshman class is at 38 percent. 21 percent underrepresented minorities, 17 percent first-generation students in that same class. This is not only the strongest academic class we've ever had in the College of Engineering and Applied Science, but it's clearly the most diverse. And, it's really just a sign of where we're heading. Our college has announced the goal to be the first public engineering, educational organization at gender equity in our student population. Within five years, we hope to be 50 percent female, 50 percent male, like the world, right.

I mean, we're trying to prepare students to go into the world, right, so it kind of makes sense that while they're here practicing being in the world, they ought to be in an environment that is a good simulation of the world. So, this is something that we're also, that I and the college, are very proud of.

Turning my attention back to a little bit closer to the topic of this session, let me just say as a practicing aerospace engineer who has worked on flight systems that have traveled to Mars, and some come back, these systems are critically dependent on telecom. They're critically dependent on data, bandwidth, all of the topics, spectrum, all of the topics that you're going to be covering today. [00:18:00]

In fact, how would I know that the spacecraft that I built with my own hands, and helped launch to Mars, how would I know that that mission was actually successful, if it weren't for the data, the telecom that sends that back? The imagery, the science data, the health status information, all of that. And if you think about where we're headed with a more commercial space world, more and more activities in space, more and more activities monitored either from space, or from unmanned aerial systems, not just from the ground, from our ground assets.

Think about how all those things are going to play together. Not just in 3D, actually, but in 4D, if you include time. Time, I think, is a very important variable in this. I actually don't think there's going to be enough spectrum for all of the activities that we want to accomplish. And so, I imagine there'll be some sort of allocation sharing scheme in time across assets and across companies, governments, what have you.

So, I'm thrilled to have a number of representatives of the College of Engineering here in this session today. I think engineering can play a critical role in the discussions of this event, and in the activities going forward, but, this is an interdisciplinary topic that Silicon Flatirons is known for creating and having a space where people come around together. And this is a topic that, clearly, is bigger than engineering, right? There are all kinds of policy issues here. There are all kinds of communication issues here. There are issues that cross the government/industry divide, and so this is a really meaty topic. [00:20:00]

And I want to commend Pierre and his team for bringing you all together around this topic so we can put together, perhaps, a roadmap to move forward with. Not just as a college, or as a nation, but, frankly, a roadmap that's needed for our new world that we find ourselves in.

I also want to just give a brief thank you to my good friend, Phil Weiser, the Hatfield Professor of Law, who is also the founder of Silicon Flatirons. And I want to thank Phil because Phil, he may not know it, but Phil was actually instrumental in convincing me to come here. I moved out here about a year ago, it was just a little over a year ago, actually, and looking back on what I've been involved in this past year, and what we have planned ahead of us for the coming years, I'll tell you, I'm extremely happy with the decision to move here. Phil didn't have to twist my arm too hard once I saw the mountains, by the way. But, I am indebted to him for coaxing me out of my former, kind of, safe, existence, convincing me to take a risk. That risk has certainly been worth it as far as I'm concerned.

Anyway, I'm thrilled to be here with you as part of the discussion. I'm really looking forward to the conversation that we have around policy, technology, and all aspects of this discussion here today, and I want to thank you very much for allowing me to make some remarks. Thank you.

[Applause]

Pierre de Vries: Thank you very much, Professor Braun. Our Keynote speaker Julius Knapp is, you know, he's a national treasure. Sorry, Julie, I have to say this. He's a public servant par excellence, he became chief of the FCC lab back in 1994. For the FCC people here they don't think in terms of years, they think in terms of chairmanships. So that was Reed Hundt, he became chief of the office of engineering technology in 2006, Kevin Martin. So far, I think it's at four chairmen and counting...as chief, at least.

Julie has contributed his expertise and counsel on every major technology decision that the FCC has made, especially the spectrum ones. One of the things that Julie masterminds is the FCC's Technological Advisory Council, and in fact one of the working groups of that body on the implications of the mass adoption of aeronautical and space transmitters and receivers was the thing that prompted me to think about this area, and in fact we have the co-chairs of that working group Mike Tseytlin and Steve Lanning are both here today. So that was just one of the many things that Julie has done for us. Today, he's going to give us an introduction to the topic of 3D wireless. Ladies and gentlemen, Julie Knapp.

[Applause]

Julius Knapp: Did we lose the professor because I wanted to sign up some of the students. We need engineers. Oh, there you are. Send them our way. Yeah, before we get into it, just a couple of thoughts. Yeah, this is so much about the intersection of policy, engineering, [00:02:00] economics, and the services that they provide…provided.

So, I was so glad to hear you speak Professor Braun say, "Why aren't we doing this at the Engineering school." So, where are the students? Okay, so I'm going to do some things as I go through this that maybe a little overly simple for some because we have some folks in this room that know more about this subject material than I do, but I think sometimes we forget, for those of us who are involved, what the things are all about? Why do we have these different systems? What are there different characteristics? And the other point I wanted to make, I was just so happy to see the way this was structured with a session on innovation and challenges and solutions. I tried to get on the challenges section instead of solutions, I thought…that would be easier.

So, I'm going to run through some things here and right up at the front, I will tell you this is…a lot of this is plagiarism from the work of the TAC, but if you've got folks who have done something before you, better than you could possibly do it, steal it! So, how many of you have played chess? Most people in the room. How many have played 3D chess? Would have to be the department head. So, 2D, it's challenging. 3D, mind-boggling. So, now let's turn to wireless communications. So, for the most part we're often talking about terrestrial systems and how we can make them fit together and not interfere with [00:04:00] each other, whether it's cellular systems in reuse or land mobile systems or microwave systems.

We're usually thinking kind of 2D along the surface of the earth. Well, 3D isn't really something new. People will tell you right away, they've been aiming signals at satellites for years and years, but it's getting more complicated. What you heard before, there's a lot more things going up in the sky. And if we had the luxury of giving them all of their own separate bands maybe it wouldn't be so hard, but we don't have enough to do that so, so much of this is about doing the engineering, so that system's in some cases can share spectrum that they can aim their signals in such a way that they don't interfere with each other and so forth. So, what's new? All the satellites you heard about, in some cases systems with thousands of NGSO satellites. The high-altitude platforms, I threw 50,000 feet and I know folks will say that's not the right metric. They're not up in space. They're not as low to the ground as UAV's, and I think that's the important thing. And all of the unmanned aerial vehicles, the UAV's.

So, this is a 3D problem. So, at the Commission we said, "This sounds really hard, let's give it to the Technological Advisory Council." "We've got the world's leading experts here to advise us." And so, we had a working group that made recommendations just at the end of last year on what we call the implications for mass deployment of aeronautical slash space transmitters. And just to give you an idea of the folks that participated on it. You name the company or the area of expertise and almost all of them were in this, [00:06:00] and they reached out.

So, what we've been doing with this TAC—Technological Advisory Council—has been to tell them, "Well, don't just limit it to the members, let's include experts in the field." So, they reached out to all these folks, so the thing that I'm going to talk about are slides they put together and some of their recommendations on this subject. So, NGSO systems, so why… Yeah, non-geo-stationary satellite orbit systems. So, why, why? So, the Geo's because there are roughly 25,000 miles out in space to get to and back is roughly half a second. So, if you want to do real-time communications that becomes something you're going to have to deal with, not necessarily complete impediment. And for data communications sometimes that's not a problem at all. The whole idea of the NGSO's in most cases is to get world-wide coverage, to have lower orbits, so I can reduce the latency. And if you think about these things, they're almost like cellular systems inverted. There instead of having all of the base stations on the ground, now the base stations are in the air and handoff is happening between the satellites as they move.

So, the way we do things, and I am not an expert on satellite licensing, is there…are people here know more about it than I do. It's handled by our international bureau, but they're set up in terms of processing round. We put up a public notice, put out public notices, with everybody who's interested follow your application and we'll figure out how we can grant them. So, this is just a list of what got filed, quite a few different companies came forward to submit [00:08:00] applications in the filing window to establish satellite systems. And, in some cases, as you can see space X is over four thousand satellites.

So, here's an update. What have we done? We issued a public notice in May of 2017. We accepted applications for filing and it was just a few months ago, there was a cut-off established for additional NGSO-like satellite applications were partitions for operations in a number of bands. And there's the list of these applications that have been filed and got you the link on the bottom there if you want to go get more detail. And just last week the commission issued an order and a further NPRM to update the rules for NGSO satellite systems. So, what's so hard about this and why are we here at law school? So, if you had to put up a satellite system or a terrestrial system, you want to be sure that the investment that you're making…when you put it up there somebody isn't going to step all over your signals, that the system is going to work. And when we've got all of these moving pieces going on with multiple providers, it takes a lot of work in 3D to coordinate them. So, basically what the commission did is say, “Look, we’ve got a default, but we want you to all work together to try to figure out the details of how you can share.”

So, I’m going to move onto HAPS. So, what’s the difference relative to HAPS? What are they all about? Well, they’re not trying to achieve worldwide coverage like the NGSO systems. The beauty of HAPS is [00:10:00] get them low to the earth, so I don’t have the latency issue.

The power levels are higher, so I can get better penetration on the ground. I can use them to fill in areas that don’t have service. And in times of disaster, I can move them in place and get coverage to restore broadband. So, that’s kind of the real high-level difference about what HAPS is all about. And there’s lots of parts of the world that have no coverage at all, where if you had a population center where you might be able to use this as the most efficient way to provide service. There’s only one global allocation, perhaps, right now. So, you heard, I’m going to talk a little bit about these other bands you heard about 600 megahertz of [INAUDIBLE 00:10:57], 47, 48 gigahertz. But when you start getting that higher problems with re-invade. So, as long as you operate when it’s not raining you’re good. It’s really a problem too in the tropical zones.

The good news is that spectrum for use by HAPS was accepted for an agenda item for the World Radio conference to study and make recommendations for the 2019 conference. So, in part because the technology has advanced and the need to provide service to fill in these places, and it’s not just fill in, some folks out of ways that they intend to compete in providing broadband services. It’s all being studied right now. So, here are some of the bands. I won’t go through it all. 47, 49, 27, 31, et cetera. So, we’ll see what comes out of it. What you heard before too about, well, what about these other bands?

[00:12:00] The commission has got flexible rules. So, in many cases we’ll say, “Here’s the band, you can use it for service, you can provide it however you want.” Sometimes they’re not so clear about what happens when you put things in the air. I use the analogy of a light bulb, so take a transmitter, you put it on the ground, it illuminates the area around you, put it up in the air. Same thing with a light bulb. When I put the light bulb here it lights up the room, when I put it up higher it lights up a broader area. So, people are actually doing things using the unlicensed bands at 2.4 in five gigahertz, because this flexibility, there’s no restriction going up in the air. And some have said, “Yeah, but what’s that going to do to interference, to all those folks using [INAUDIBLE 00:12:47].” Well, so far at least nobody has identified a problem, but it’s in part the flexibility provides alternative ways to get services and then, of course, you can file for waivers or special temporary authority or an experiment and so forth. But the good news here is that there is work going on to identify more spectrum for HAPS, and you heard a little bit about…there is several companies that have got plans to deploy platforms. These are a few of them. Little bit more on HAPS, I’m going to move on, I think in the interest of time. So, we’ve moved… We didn’t really talk about GSOs – geo-stationaries. We talked about NGSOs, little lower. We talked about HAPS, little lower than that. We didn’t talk about cube SATS, which kind of ride along a free ride off an experimentation supported with unlicensed frequencies or supported by amateur frequencies, write on payloads with rockets they higher up.

But now we're down [00:14:00] to things kind of closer to the ground. The UAVs. And so, FAA has been working along with NASA and DoD, and we have been involved but we're not, I wouldn't say, the lead issue. First, they're trying to figure out how are going to make all these pieces fit together and not collide and manage them and so forth. So, NASA has been developing working with the FAA kind of drawing on the experience with air traffic control systems, a system to be able to manage the devices that are going to operate relatively close to the ground. And it's not going to involve air traffic controllers. It would be a set of rules, set of principles, and a set of information that would help people to determine what's the right flight path. Get information about what the weather conditions are and so forth.

So, there's a lot of work going on by NASA, FAA, and working with industry. There was an advisory committee we heard a little bit about before trying to figure out, how do we manage all of these things? Coming back to the innovation, they can do things that we couldn't do before that are terrific. Being able to go up and inspect the tower, for example. We certainly hear about the delivery of packages. Movie industry, lots of industries, the applications, the ability to do things that they couldn't do before using this technology.

So, the challenge here is. How do we make sure that can be done and meet those demands in a safe way? This is more on the NASA UTM project, you'll have the slides and you can look this up, there's plenty of information on it.

[00:16:00] Current uses divided, of course, between commercial and the recreational. A lot of the recreational. How many of you have got an unmanned aerial vehicle? All right, you're out. The thing that's, you know, quite a few people do this as a hobby, which is terrific. And most of the things that are operating below the 400-foot level are a line of sight and they're operating using those unlicensed frequencies, which always makes me a little bit nervous because there's no interference protection.

So, one highlight that I'd flag here, there the command and control and there's the payload, and they're two different things. So, the one is, I want spectrum that I can make sure I control where this goes. And the other is, okay, now I want HD video down from it, takes a lot more bandwidth. So, where's that going to come from? And I think there's been much more focus on the control part which is good. Not quite as much on the higher bandwidth, but that's where it also comes in with commercial wireless. So, commercial wireless has been looking at this as a potential solution, and they've been doing some test because it's that light bulb issue that I mentioned. You design a cellular system, free use and for re-use, and managing interference largely on the ground. And now what happens when you have part of your system that's up in the air? And how do you manage the interference in your system?

So, there's work going on that. And I think at least in some quarters they feel is a lot of promise both for the control [00:18:00] and the payload. So, the TAC recommendations. This was on part 107, which is the FAA rules. But I think it also kind of related to the FCC, was we should promote the use of existing communications infrastructure wherever possible. Commercial wireless networks present solutions for control tracking and payload communications for small low altitude UAS. One of the beauties of that is you already have a network that's widely deployed, so you don't have to build another network for access. You do have to ask…what happens when you get out of an area that's not covered? What does it do then?

Commission should act now to study if any rule changes or additions are required, in order to allow for airborne use of commercial wireless bands, and I think that kind of goes to the question of, does the agency need to do anything or hands off relative to making sure, as we don't have just a single licensee for commercial networks. There's not a single band. Some of these have got adjacencies and so forth. I'm going to make sure that everything still works together. And the commission's work can be done in parallel to the FAAs. We're still working with the FAA, but I think most of the focus has been on the things I talked about before — controlling the devices, and what are the rules of the road for how they operate? We should harmonize the 800 Megahertz began with other commercial mobile wireless bands. Anybody break the code there? Go ahead.

Audience Member: [INAUDIBLE 00:19:55]

Julius: Yeah, that's the only [00:20:00] band we had, a rule that says you can't operate onboard aircraft. And so, that's really what that was saying. [INAUDIBLE 00:20:11] consider collision avoidance spectrum, in other words radars, these things are all flying around, how do we help make sure that they don't fly into each other? Support use commercially available license in unlicensed bands wherever possible, support the use of ADSB technology which I think is still somewhat being debated. What did I skip? So, we had a continuation of the TAC workgroup on satellite communications. These are the folks that this is going on this year. They're due to get us recommendations by the end of the year. This just described what the charter of the group was.

Look, the recommendations for processes and communication solutions to support both start up and venture satellite operations, et cetera. Assess the challenges faced by these new satellite ventures. Some of the folks who are working on this are actually here. This is their work plan. To define use cases, satellite as a primary platform for access. IoT often, and I know satellite raises their hands were, "We're IoT too." So, what role do we play in IoT? Vehicle to space vehicle communications part of a network in the sky as generalization from bent pipe operations, you hear a little bit about that. And a white paper itself. I'm going to just touch on this last point which we can largely thank Pierre for, and this is risk-informed interference assessment. And I'm going to jump through some slides, it's probably not fair but hopefully I can capture the points.

[00:22:00] The goal is what? A frame of risk informed interference assessments. GSO and non-GSO co-existence, and why? I'm going to use a little bit different words. So, I started out talking about innovation. And often what happens is when we're doing interference analysis it gets what people would describe as worst case, worst case is often in the eyes of the beholder. And coming out of the TAC from work that was done two years ago, said we really ought to be looking at, well, what's the risk of interference? So, if my analysis says, "I might get interference for five minutes once a year." And the consequence of it is my bit rate goes down by 25 percent, and that's going to be the roadblock to an entire new service, where's the balance? And that we ought to be looking at the risk, obviously if it means there's a disaster you don't take that risk, but risk analysis is done in other areas all the time, whether it's the nuclear industry, the aeronautical industry and so forth. If you think risk is zero you're misleading yourself, you're trying make it really small, but it's usually never the zero. This is just the complexity of the co-existence. The 3D problem, and more on with space interference. That's it! So, thank you.

[Applause]

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]

Pierre de Vries: We now have our second panel on challenges, moderated by Anne Swanson, who's a partner at Wilkinson Barker Knauer. Thank you very much Anne. Take it away.

Anne Swanson: Thank you.

In this second panel we're going to pivot from innovation and we're going to begin to drill down on challenges in the 3D wireless world, and one of my panelists got real excited. He said, "Oh, great. That means all we get to do is complain. We can just complain about all the problems that we're having."

We'll continue to talk about spectrum, and communications regulatory issues, but we're also going to start to add an overlay of aviation, and aviation safety concerns a little more than we saw in the last panel. Two of our panelists are from the world of satellites, the two in the middle. And two are from the drone space. One high-altitude drone and one low-altitude drones. I'm going to keep my intros fairly short, as Pierre instructed.

Mike Tseytlin – immediately to my left is our first panelist. He's the director of engineering at Facebook, where he's worked for almost three years on Facebook's Aquila project, a high-altitude drone project. He's an expert. I've seen him in operation on melding technical concerns with policy issues. Prior to Facebook, Mike spent seven and a half years at LightSquared.

Joe Cramer, our next panelist, next to Mike, is a director of regulatory affairs at the Boeing Company, in D.C. Joe has spent 11 years at Boeing, and before that, he was with Lockheed Martin, and Rockwell Collins. Joe has both law and engineering degrees.

Brennan Price describes himself as a technically-minded attorney with spectrum and IP experience. Like Joe, he has both engineering and law degrees. He's currently the senior principle engineer and regulatory affairs at EchoStar in Germantown, Maryland, which, as many of you know, is right outside D.C.

And, finally, Skip Miller, our fourth [00:02:00] panelist, down on the end, is CEO and founder of UASUSA. He has a long history as an entrepreneur, and developer, and he's now plying those skills in the commercial drone space, particularly working with low-altitude drones, fixed-wing drones that weigh less than 55 pounds.

So, we're going to have each of our panelists address a few questions. We'll wrap up with a couple of short questions directed to all of them, and then we'll turn it over to the first student that dares to ask a question.

So, Mike, I'm very interested in Aquila. I think Aquila, in Greek, means eagle, is that right? And you've been working for several years on this high-altitude, broadband platform. What motivated Facebook to get into this? How did you all enter that market?

Mike: Thank you Anne. So, Facebook is a obviously high-tech, innovative company. And as a high-tech company, you get excited about 5G, and augmented reality, and virtual reality. But, I think we should not forget that while a lot of people are excited about technology, there's still four billion people, but not connected. Not enjoying connectivity, not enjoying the social benefits of that.

And so, the major issue for Facebook is how to get these people connected. What should be the technologies? What should be the policies that enable the connectivity for the unconnected people? Even from the remaining four billion people, about half of them under-connected, and they're counting their…they're counting every month what they spend. And so, the mission here is how to make the walk from the people who are accountant of their internet, to their abundance, that everyone can make as much, get as much internet as they needed, and can consume as much data as they possibly can. So, not a single technology can solve the connectivity problem and the digital divide is very real. In the wealthy world, people cannot afford connectivity, and they [00:04:00] people that can afford something are already covered .

So, that's one of the reasons that Facebook developed innovative technologies that may reduce costs of connectivity, and cost of connectivity is the major factor. You know, preventing people to get…

Anne: And one of the main technical challenges in launching this kind of activity.

Mike: That's exactly right. And so, we, as a Facebook…I won't say that…we are relatively agnostic. Probably from a lot of panelists here, we probably don't [INAUDIBLE 00:04:27] that do not advocate for any specific technology. Our mission is connectivity in itself, and any technology that connects people, obviously gets our support. We work with NGSO and NGSO satellites, we work closely with [INAUDIBLE 00:04:44]. But, what we determine that there is something missing in these different markets, and the [INAUDIBLE 00:04:52], could be that missing link. That can provide inexpensive capacity in a lot of developing world. So that…

Anne: How does this technology work?

Mike: So, basically, this is between the…where's the ball? The ball we cannot see that [Laughter] half an inch, somebody said that.

Anne: So, you're 60,000 feet up.

Mike: Yeah, so, it's basically 60,000 feet up. It's a good balance of a footprint, which is about 100 kilometers in diameter. The latency is comparable to the terrestrial services. So, there are two types of airplanes possible, lighter than air, and heavier than air, and between different companies that now pursuing that. Some pursuing heavier than air aircrafts, such as, actually, Aquila, that's what we do. But there are a number of proponents that develop dirigible types of aircraft, like [INAUDIBLE 00:05:48] is one example. But the idea here is that the, basically, the plane takes off in some way. It goes to the altitude of about FL 600, [00:06:00] in kilometers, and then it's assumes the position and provide some back-haul services.

So, Facebook's focus for these platforms is mainly on the back-haul service. But, obviously…

Anne: Wait, what?

Mike: Back-haul.

Anne: Back-haul.

Mike: Yeah, basically, what we are trying to do is to enable a back-hole connectivity, which we see it as the major issue for the terrestrial operators to deploy, and it's about in Africa rural connectivity expense about 50 percent, from the optics on the back-haul, basically, taking the connect back to the fiber. And so, that's the market that we are trying to address, basically, reduce the costs on the back-haul, but it's obviously possible to use [INAUDIBLE 00:06:41] planes as an access, basically sending it straight to the devices.

Anne: And give us a regulatory snapshot right now. What are the regulatory challenges, and are those countries specific, or are those cross-border? Which is dominant for you right now?

Mike: I think, similar that the previous panel that I very much enjoy, harmonized requirements for spectrum and aviation is the biggest challenge.

Anne: On aviation or on Spectrum?

Mike: For both, actually...but let's say Spectrum initially. So, on the Spectrum side, there is some small slices of Spectrum that were defined previously, but they are not harmonized as a few [INAUDIBLE 00:07:25] accepted them. And that was done for the 2G technology, HAPS. Basically, support voice. While our mission is actually provide the back-haul for 5G and 4G connectivity, and that requires 20 to 30, maybe 40 gigabits of capacity.

So, identifying that broad slice of Spectrum that can support broadband connectivity is a major challenge. And, we working now for last year to harmonize these requirements, and the work of this [INAUDIBLE 00:07:52] administrations to basically implement the recommendations, and adopt the recommendations, such as [00:08:00] Julie mentioned, as part of the talk.

But, that's a major challenge because spectrum's a contested resource. Now, truly, in the areas where we try to connect people, that resource is not very contested. An example of that, I was stationed in Madagascar, and…

Anne: Madagascar?

Mike: Yeah, Madagascar, and [INAUDIBLE 00:08:21] and you could put a spectrum analyzer and it would show a straight line, like, literally nothing. Yet, all the spectrum was gone. Nothing left. So, that is example obviously, of policies that prevent connectivity. Spectrum was a [INAUDIBLE 00:08:42] resource, and you've got NGSO, and NGSO should manage interference, and, obviously, interference ideas that undertaken right now at

ITU, is something that we're looking forward to prove, that, HAPS, can coexist with other technologies as well.

So, on Spectrum, harmonization is everything, and, particularly, because a lot of other countries in Africa, in Latin America, they don't have their strong, regulatory borders, so they very much relying on, ITU, to give them [INAUDIBLE 00:09:13]. In countries like United States, UK, and Europe, they have sufficient number of expertise to do this, studies in-house. Now, but, for the aviation piece, if you want to go there…

Anne: And in the aviation piece, I'm particularly interested in craft certification. When we move into aviation, we focus on the aircraft, and type certification, and special air-worthiness certificates. What have you all done in that field to design, produce, and get the relevant certificates?

Mike: Right, but I would like to even start before that, with a disconnect. So, there's two aviation under the UAN ITU, which is the International Telecommunications Union, and ICAO which is the…

Anne: ICAO.

Mike: Yes, similar aviation organization. And, for the upper [00:10:00] E- class which is HAPS belongs to, relations really not harmonized, and actually no uncommon terminology exist. HAPS is the ITU terminology.

Anne: Let's talk about what ICAO calls UAV's. They don't even call them UAV.

Mike: HALEs, for example. So, that is different, even terminology

Anne: They call them RPA's. I mean…

Mike: Well, yes, RPAs and UAS, and any other words. So, but, ultimately HAPS, lives the world of ITU. In the ICAO, it's called, HALE. HAPS that at the Spectrum, our definition starts at altitude between 20 to 50 kilometers.

Anne: So, how is Facebook approaching this? What do you do with all this tangled web?

Mike: Well, first, it's not the Facebook alone, because, even companies as Facebook cannot sort out that, be set up, upper air-space alliance, where we can actually…a lot of partners join in, and [INAUDIBLE 00:10:57] for example, a member of this upper-space alliance. So, we advocate through the ICAO, through the, obviously, FAA, EASA, and other [INAUDIBLE 00:11:09] harmonized approach to aviation. At the same time, they're try to advocate harmonized approached for Spectrum. But, even in the World Radio Conference of 2019 that is happening. They're still this disconnect…

Anne: Can you say that again for me?

Mike: World Radio Conference, 2019. That is going to take place in 2019. That disconnect still remains. HALEs, or upper-class E aviation under ICAO, 20 kilometers…

Anne: For folks who haven't worked in the -- talk about HALE. Some people didn't go to the first one.

Mike: HALE, so, on the aviation side, [INAUDIBLE 00:11:44] HAPS, it's all called HALEs, high altitude, low endurance platforms. And their specification is totally different from the spectrum. And so, that's a disconnect between spectrum and aviation, where the high-altitude endurance platform operate above class A, which is [00:12:00] upper-class E, 60,000 feet and above.

But the [INAUDIBLE 00:12:06] identification under ITU is, HAPS, which operate above 20 kilometers. And so, it's unclear what separating…

Anne: We see the challenge. You've had a challenge.

[Crosstalk]

Mike: 18 and 20, is anyone's guess. But, that's a lot of challenges here, yes.

Anne: Let's move on to air traffic management. I mean, that's something that, we talked about collision totally different in the last panel, but air traffic management as we move into the world of drones and aerospace, what do you all see as the role for regulation of air traffic management?

Mike: So, our traffic management is very important in this case. In upper-class E, until now, was just military planes, until recently. But, as you hear, there are actually a number of companies that now want to utilize altitude above 20 kilometers. Commercial aviation, jets, unmanned aviation, and so, for people who not only, basically, UTM [INAUDIBLE 00:13:02] ETM…

Anne: That's another acronym. Can you…that's actually an acronym within an acronym.

Mike: UAS Traffic Management, which itself stands for Unmanned Air-vehicle System Traffic Management, if you take all the words apart. Basically, in a nutshell, it is how to identify the different airplanes, how they don't bump in one another, how they can inform if emergency happens, so they can go…

Anne: Air traffic management, for drones.

Mike: So they can go down to the class A airspace, and if they account for the class airspace, how can they identify by the [INAUDIBLE 00:13:35] class E. So, this is actually very important subject that should be determined, and the activity is championed by NASA. In fact, they have a conference starting tomorrow, for the first time, to talk about ETM, which is upper E class traffic management system. So, it will take, probably, a few years while the setup, it might be two or three years while they set up the procedures [00:14:00] and define the UTM scope of work. Then it will be recommended to ICAO, and other aviation…

Anne: I think at the domestic level, it's going to be shunted partly from NASA, back to the FAA for…

[Crosstalk]

Mike: At the domestic level, NASA will sell to the FAA, and then the FAA, obviously, will work with [INAUDIBLE 00:14:22] for the standardization piece and with ICAO for the harmonization piece. So, that's how it's going to work.

Anne: But, I think the Holy Grail, ultimately, for you, is going to be autonomy, right? And right now, there are some rules that prevent you from doing that kind of the, one craft, one pilot rule. What are some of the challenges you see in reaching autonomy and fully autonomous operations?

Mike: So, autonomy, lot of times we misunderstood, because when we talk to…maybe here in the U.S. it's well understood, but when we talk to middle-eastern administrations, they think it's, like, artificial intelligence. The plane flies…

Anne: You think it's like what? I'm sorry.

Mike: Artificial intelligence. It's like the plane has a mind of its own, just flies where it's supposed to be. In reality, for the most part, we're talking about semi-autonomous operations, in that, most of the time, aircraft, when it's in service, can get autonomous, but it's monitored. And, if any emergency situation developed, if there is any anomaly is being developed, then control goes to pilot. And, then the pilot actually operates the plane. So, when they're saying, one, solve the issue of autonomous aircraft, one pilot monitors multiple airplanes, or airframes, but really, just during the station-keeping and normal operations. But, in emergency scenarios, an anomaly has developed, then it's going to be, actually, pilot, actually, controlling the situation and flying the plane.

Anne: When do you think you'll ultimately get to autonomy?

Mike: You know, I would think that's about two or three years. Optimistically speaking, but [00:16:00] good relations can happen, and it's mostly because there's a large number of the companies that are now interested in flying autonomous or semi-autonomous airplanes in that airspace. Obviously, Joe can have a different perception of that.

Anne: I think we need to bring in traditional satellite a little more at this point, and talk to you, Joe, about your perspective on what you think satellite can do in the broadband space. I mean, you know what Facebook is up to now, but give me your perspective on satellite, and broadband, and the challenges that you see for us from a technical standpoint.

Joe: Well, first think I should say is, anything I say cannot be held against my company, because I haven't said anything that they can review, you know that as a lawyer. But, as you know, from some of the slides before, Boeing is proposing an NGSO system to provide broadband and high-speed broadband services to fixed locations. Mostly, like, your house. You know, small antenna, about yay big, flat, sits on your RV, your car, or your house, and you can get high-speed broadband via an NGSO network.

And so, we already talked about NGSOs and all the nuances about that. So, that's our proposal. That's what we'd like to do. We have a lot of the same challenges as Michael at the ITU…

Anne: What are your top three technical challenges?

Joe: Well, designing the antennas, getting the regulatory approvals, which, I think, could be are just as difficult, if not more difficult than the technical challenges, and how about just those two. How about that? You know.

Anne: Okay.

Joe: And then getting people to buy it, right? That's always a minor technicality for most people, so, those three. But, internationally, the fun challenge that we're having, and you saw one, Julie Knapp's, one of his slides, he had agenda item 1.14, which is the HAPS agenda item, one of the frequency bands that Michael's looking at for HAPS, is the same frequency [00:18:00] band looked at by the terrestrial cellular providers for 5G, which is also the same frequency band looked at by Boeing for its NGSO system.

So, there's a minor regulatory, not challenge, but fight or something. We're all going to discuss it very cordially in Geneva over the next couple of years, and we'll see what the 2019 WRC does with respect to the satellites there.

Anne: How about the intersection of satellites with aviation in providing broadband to planes, and is that just a natural progression, or are there going to be new challenges there?

Joe: Tons of challenges, it's always fun. I have to admit I don't consider myself too much of a satellite person. I do Boeings, Boeing commercial aircraft, Boeing military aircraft systems, and regulatory spectrum stuff. So, I find the biggest challenge with respect to communications, and command and control, to be less with broadband. Because, right now, you can get broadband to your airplane. And, those of you who flew here, you might have flown on United, or Delta, or something, and you're getting decent broadband speeds to your commercial aircraft. And that started about 10 years ago, 15 years ago, with connection by Boeing to bring broadband to your commercial airplanes.

And, it's just evolved and gotten better over the years, and I think it'll only continue to get better. That's good and bad for the businessman, because that used to be the last place we could hide, is on the airplane, catch a few hours of sleep, but now you're doing work. Double-time.

Anne: And how about the current process of getting spectrum allocated for aviation in general and assigned for command and control?

Joe: So, again, in the slides before, it's great. If you were here earlier, you've already seen my answers. You need to get approval from more than one international, and, generally, [00:20:00] administration regulatory body, in order to be able to deploy something on an airplane that travels beyond a single country's borders.

You need, first, the international telecommunications union, the ITU, to give you and aeronautical, generally for command and control, a safety allocation, because, what we haven't talked about today yet, is safety is number one. The reliability required for a communications, or navigation, or surveillance system on a commercial airplane requires a reliability of, failure rates of one to a billion.

And, what people don't seem to realize with respect to UAVs and, maybe even, HAPS, because a HAPS, in my opinion, is a UAV below 60,000 feet in terms of the regulatory perspective. You need to provide the same levels of reliability in your command and control. Especially, the larger the aircraft gets, because, obviously, the damage and consequences change to a 737-size airplane falling on somebody's house is a lot greater than the consequences of your Best Buy or Brookstone UAV, that you fly around, landing.

So, the requirement, at least in my opinion, have to be greater in terms of the reliability for the command and control, sense and avoid, and avoiding the other aircraft. So, you talked about the regulatory problems. The FAA is one of the biggest players in this. As Boeing, we make unmanned underwater systems. We make unmanned aircraft. We make satellites. We make airplanes. We make -- you name it, we make it. So, we have found that the FAA is putting requirements on our medium sized UAVs [00:22:00], that, before, we only used to sell to DOD. Well, guess what?

Now we want to sell to state and local police and fire like everybody else, these services. They're not the Federal Government, and the regulatory regime is different when you're not selling it to the Federal Government. So, the FAA will say, "You need to put ADB-B," which is Automatic Dependence Surveillance Broadcast. Basically, it's a device that sends out a signal at 1030 megahertz. This is who I am, and this is kind of where I am.

Anne: And what's the cost of it?

Mike: Of ADB-B? Well, we're trying to figure that out for our small UAVs, because they don't exist yet, the devices. They have to be yay big. Every pound of avionics you put on an airplane is one less pound of payload or other stuff that you, fewer even, that you can put on that same small UAV. And the FAA requirements are impacting our ability to do things, such as, high-definition video, over a longer distance, on a medium-size or 55-pound UAV. We find, or, at least, I'm finding the FAA technical requirements are impacting the Spectrum by putting on more avionics requirements. And, obviously, the larger the aircraft the more avionics.

I envision the FAA saying to Michael and Aquila, of large aircraft, "You need to have the same avionics on that HAPS, because it flies through commercial airspace, in order to get to altitude as you have to put on a Boeing 737." So, the regulatory challenges and trying to find ways around, maybe [00:24:00] not having to do all of the requirements that might come from one or more government agencies? To be a huge challenge.

Anne: At reducing its manned aviation down to unmanned. I mean, it's just…

Mike: Fundamentally, they want to copy and paste the requirements. That's my perception. And that goes the same for ICAO, as well as the FAA and the U.S., and EurOK, the standard setting bodies. They're taking what they've done for manned aviation and just, kind of, putting it into unmanned.

Anne: But, that's what you and I do on a daily basis. We advocate for lessening or elimination of a lot of that, and it is a challenge, because they really are, you know, manned aviation and those regulations are their familiar. How about traffic management in the drone context?

Mike: Oi yoi yoi. Okay, so…

Anne: Do you agree with his challenges? Do you see different challenges?

Mike: That, and more. How about that? So, who here has flown? I want to wake people up, because that's, you know. Who here has been on an airplane? Who flew here? Right. What you don't want to happen is a small UAV flying into your engine, right? It will take out the engine. Now, that's okay if it only takes out one engine, because we build airplanes that can fly on one engine. But, what if two do? Or a flock of them do, right? So, for me, the big regulatory challenge, and this goes to Julie and the FCC is, how do we mandate a technological level, the inability of a small UAV, small even, from flying in airspace used by the planes you fly on? Commercial aircraft. Now…

Anne: Well, you first need to identify it, so there's the aviation rule making committee going on on identification and authentication. Have you all been following that?

Mike: I'm sure we are, but I'm not. I only have so many hours in a day. I'm busy. They'll solve it for me, that's okay. And so, how do I do that? Now, the big challenge is, I saw on the board, multiple [00:26:00] times, cellphone systems. The cellular providers want to provide command and control of UAVs.

Well, guess what? I want to use my cell phone at an airport. Well, that's the same cell phone signal, theoretically, that's going to operate a UAV. So, if I'm the FCC, how do I prevent a UAV from flying at the airport, where my planes are flying, while still enabling at a technology level? The regulation can say, "Thou shalt not fly at an airport," but, realistically, how do we physically prevent that from happening?

And, really, we need to solve that. So, the engineers out there, here's a good project for you guys, for your grad school, and the law students, here's something to think about, the regulations that need to be put in place to do this. And I find that to be one of the big challenges. And it's the same with Wi-Fi, because unlicensed spectrum versus the cellular and other technologies.

The other aspect is the reliability. If you provide, if you have a UAV that has any kind of real size and weight, the FAA's going to require reliability in your command and control system, or, the smartness to, if you lose signal, to stop what you're doing, and fly back to your home base without hitting somebody else, or a building, or such-and-such. How do we do that? I find that to be a challenge that we still have yet to solve from the regulatory, and maybe, probably even, the technical.

Anne: Do you think international coordination going on, or not?

Joe Cramer: Only for flying in international airspace. But, it behooves the UAV, in my, the UAV manufactures…

Anne: Equipment manufacturers.

Joe: Because you want the economy to scale. You want the regulations to be the same, and fundamentally, if you're flying class A or E? I can't, the names, the certain airspace that commercial aircraft fly in, you're going to have to [00:28:00] follow a little bit of what ICAO says, International Civil Aviation Organization, and you're going to have to play in those regulatory bodies in order to get the standards and recommended practices, as well as the minimum operational performance standards, or MOPS, which are developed in the United States by RTCA, which is just an acronym, doesn't really have a thing for it anymore, and EUROCAE, which is the European equivalent of RTCA.

Anne: And what is RTCA, please?

Joe: Sorry?

Anne: RTCA, please?

Joe: It used to mean, Radio Technical Committee Aeronautics or Aviation. Now, they just got, they just say RTCA.

Anne: So, they're a standard setting body.

Joe: Yeah, you have to know what it means.

Anne: They're a shadow government entity that helps the FAA make rules, basically.

Joe: Fundamentally, yeah.

Anne: So, we've done challenges in high-altitude drones, we've done aerospace. Now we're going to return to traditional satellites and EchoStar, and Hughes. I guess you were talking about challenges with me, and one of the questions you wanted to cover was, how do NGSO constellations intersect with GSO operations, and are there sharing opportunities there, or do you see challenges?

Brennan Price: There are challenges, there are opportunities. We're optimistic that we'll be able to work through these things. But, just to add to the problem that Joe mentioned at the beginning of his presentation, the same band, of which Michael is interested for HAPS systems, and Joe is interested for Boeing's NGSO system, and the terrestrial wireless folks are interested in, is also a target of interest for a number of other NGSO applicants.

And, my company, the Hughes Network Systems subsidiary, which has applied to operate a geosynchronous satellite within the 47-48 gigahertz band.

So, the issue is complex and we continue the discussions over the next two years to [00:30:00] determine exactly what the sharing solution is going to look like. As far as the specific case of NGSOs, however, NGSO systems have been studied at the ITU in terms of compatibility with geosynchronous systems up to 30 kilohertz, pardon me, not kilohertz, good Lord, 30 gigahertz. What's six orders of magnitude among friends?

The agenda for WRC-19 is considering appropriate protection criteria and powerful [INAUDIBLE 00:30:37] limits for NGSO systems at the higher bands, the so-called Viet-cue [Phonetic] bands, going on up toward 50 gigahertz and above. The ITU limits on equivalent power flux density, essentially, how concentrated RF energy is, going up from Earth to a point on the geosynchronous arc, and vice versa, how concentrated energy is coming down from an NGSO constellation onto the surface of the Earth. Those ITU limits have been studied. We are gratified that the FCC adopted them in the recently completed NGSO rule-making. We view equivalent power flux density limits as important to our interests. In the bands that we're sharing, exists as far between GSOs and NGSOs we're optimistic…

Anne: Too many acronyms.

Brennan: Sorry about that, between geosynchronous satellites and non-geosynchronous systems. We're optimistic that coordination agreements can facilitate that call for reduction of power when necessary, can be reached. Determining when these reductions are necessary is easier in the GSO case, as opposed to the [00:32:00] NGSO versus NGSO case, because you have one target that's not moving, as opposed to two satellites that are moving at the same time.

Finally, as for opportunities for compatibility between NGSO, between non-geosynchronous and geosynchronous systems, we, obviously, the inter-satellite allocations do exist and provide opportunities for offloading of traffic from one web network to another. Within the fixed satellite applications, that actually does add a complication to the power flux density analysis. So, these are the problems that keep me up at night.

Anne: Let me get you to speak a little bit about the Space Data Alliance, because you guys are a member of that, and some of the specifics you're addressing there?

Brennan: All right. The Space Data Association, I thought it was, but it could be a…and their space data center, is a very great resource for evaluating collision potential and RF interference potential. I'm sure it will be part of the solution as to collision avoidance, as NGSO systems deploy. I'm hesitant to say that a private sector solution is the only solution in this case.

First, if you look at the list of members of Space Data, there's some very significant players that are absent. Second, the nature of satellite system co-existence involves the engagement of government and, frankly, multiple governments. And, finally, there's a significant amount of public sector operated space systems. So, I think it's important to all in our industry that governments continue to take active roles in both, in domestic regulatory bodies and through international organizations, ITU and the other appropriate organizations, so that these issues [00:34:00] can be addressed and mechanisms can be established.

With the amount of money that all of our companies are investing in next-generation satellite and aeronautical infrastructure, this is something that we really need the support of, not only ourselves, but…

Anne: Let's switch gears a little bit. How does the 5G bandwagon affect satellite? For instance, I'd love to have you talk about efforts to get satellite onto the 3GPP roadmap.

Brennan: We have been successful in getting satellite on the 3GPP roadmap. There is an open-study item in 3GPP on satellite networks and their contribution, pardon me. 3GPP is the 3rd Generation Partnership Project, is highly influential standards body in establishing protocols for various generations of telecommunications systems, and it has traditionally focused on the terrestrial, and we have been successful, along with other players in the satellite industry, in establishing a satellite item.

We view 5G as something that is not necessarily, that cannot be limited to terrestrial networks simply because terrestrial networks are not going to be able to reach every person on Earth. There are some difficulties in using millimeter wave bands for coverage in some parts of the country. The density that you have to, the density of base-stations that you have to have for a terrestrial 5G station to cover a particular area, is much greater than [00:36:00] what we would have at one of the lower bands at, say, three gigahertz, or six gigahertz or so forth, and the so-called mid-bands.

Our goal for 5G is to be an important player in the system, and to be a competitor within that environment. And we think, in order to do that, it's imperative for regulators to maintain technological neutrality, and to promote policies that allow the various platforms of GSO systems, NGSO systems, aerial systems, and terrestrial systems, to serve customers in the way that best fits the customer.

Anne: Hughes has been -- I grew up in the D.C. area -- Hughes has been a large government contractor for years. Can you expand that thought? I mean, how do you think new space is going to affect the space business ecosystem? I mean, that's got to be a challenge for your company.

Brennan: We think that GSO systems are going to continue to serve government and other users reliably and well. There is value in the wide-area coverage from a single spacecraft that is at a stationary point in the sky with reference to any given point on the Earth for government applications, and for other applications. Even in the case of Earth stations and motion, where we've done a lot of work with our government peers, where there's a station in motion, aboard an aircraft, a vessel or a vehicle, targeting a stationary point in the sky. Having a GSO system makes tracking very easy. So, we believe that GSOs will continue to function well in the new space environment.

That being said, we do acknowledge that new space [00:38:00] applications, such as NGSO constellations have great potential, particularly in applications where a shorter round-trip between Earth and platform, and Earth is critical for latency purposes. Hughes is among several investors in OneWeb, and we anticipate working with them to bring all aspects of their system to fruitions, though we do realize the landscape is changing. We believe we have a role to play as a GSO operator and NGSO partner.

Anne: Let's go from macro to micro. Skip, down on the end, is recently, fairly recently, entered the commercial drone service and operation business, and I think you've done it mainly with fixed-wing craft as opposed to rotor-craft. What are the challenges of operating fixed-wing drones, and how are those different than rotor-craft? Either small hobbyist craft or larger rotor-craft?

Skip: My company's name is UASUSA. That's Unmanned Aircraft Systems, and I designed with my partner, aircraft about seven or eight years ago for the University of Colorado, so I'm kind of proud to be here with the University of Colorado, to chase thunderstorms and tornados. And, I had a strong model aircraft background. I designed this aircraft, and the rest has, kind of, been history for us. At this point in time, I sell fixed-wing drones, fixed-wing aircraft. I don't think…

Anne: Why did you decide to do fixed-wing and not regular aircraft?

Skip: Well, I was going to go there right now. How many of you…I saw earlier, there was show of hands of how many flew out here. How many of you flew out here on a helicopter? Oh, there's one that flew out on a helicopter. I hope it wasn't too far away. A helicopter is a very, very inefficient object. It is very good for going up and down, and perching, and staring, etc. But, it has, really, no efficiency range. A fixed-wing aircraft is an aerodynamic object. It can go very far. For example, our Tempest [00:40:00] aircraft, on one battery, I can launch it out in the parking lot and fly a hundred miles from here, and look at whatever I want to look at.

So, I think, the big one is…the hobby grade people got involved. DJI is the big gorilla in the room that has promoted, basically, through the Phantom helicopter, the small one, very, very successful business story, but it's created its own little nightmare. And, I think the big difference is, when you deal with what I deal with, which is the future, which is, what can these vehicles really do? I am a strong believer in efficiency, and distance, and duration.

On the earlier panel, there was a discussion, briefly, about agriculture. Agriculture's really strong, and can be really strong for multi-rotors and for fixed-wings in the future. But, infrastructure, all the power lines, all the roadways, all of the infrastructure that we operate on needs to be inspected at all times. And, with a vehicle that's a fixed-wing, and the efficiency that you have, it can cover that ground every easily.

You actually are required today to do that with full-size aircraft. Unfortunately, youngsters coming up don't want to sit in the back of a Cessna with special glasses, looking at insulators on power lines. It's just not that sexy environment. You can do this all with the drone safely and carefully.

So, I think, the big one is the multi-rotor's excellent for, if you just want to pop up and look for 15 or 20 minutes, but if you have to get into some distance or duration of survey, that's where the fixed-wing comes in.

Anne: What are the fuel challenges with fixed-wing?

Skip: Well, we fly electric airplanes. So, our airplane flies anywhere from an hour and a half, to, a version of our aircraft that University of Colorado's flying right now, is flying for three hours on one charge, and it's a fairly small battery, comparatively speaking. Again, this aircraft, our aircraft, was designed to be efficient. I come out of the sailplane competition world, and I've been competing for a long time in that arena. [00:42:00] And sailplanes were the most efficient aircraft.

Certainly, what Michael's trying to develop, the high-level, about 60,000 feet area, that's a whole other beast right there. That's a very lightweight, another level of elegance of flight. But, at any rate, for our aircraft, the sailplane side has always been the thing that made it most efficient. You can do fuel aircraft, and a lot of the military drones that you know, are fuel oriented. And, they have long durations, four, six, eight, ten, hours. Bigger aircraft, need a crew to operated it and stuff. Our, basically, our aircraft takes two people to operate, a computer operator and a safety pilot, and you can fly for an hour and a half. But it can go anywhere you want.

Anne: But, I don't see commercial drones, certainly fixed-wing drones, out and about in the world every day. What are the things that the governments, specifically the FAA need to do to facilitate the growth of that industry? And I'm going to limit you to just a minute or two there. I know the list is long.

Skip: Okay, so the FAA is an interesting organization, and I'm sure there's some full-size pilots in the room, and the FAA, it's always interesting how they approach a problem. They've come a long way with the 107. It used to be you could only fly with a 333. University of Colorado has more colors of 333…

Anne: And with the 333 you had to get something before you could take off. Now, with 107, if you comply with those rules, you don't need advance authorization to fly.

Skip: Right. You don't need an advance authorization and it made all those hobbyists, they can actually fly a drone. But, here's the interesting thing, I think everybody in the room probably has a driver's license, right? How many of you went, studied, took the driver's test, without ever driving a car? That's what the 107 does right now. You can actually go get this test. You can be legal to fly the drone. So, the FAA is not quite moving with the speed. It's great that you can do this, but then, if you come up to me and say, "You have a 107. I have to ask you to show me how you fly."

Anne: So, there are pilot training issues. I think there are also going beyond visual line of sight issues, they're [00:44:00] flying at night, they're flying over people. There are just a whole number of issues, but I think if we could solve, we can, hopefully, get away down the road, right now, we can get waivers, but not for all of those, particularly not for package delivery.

Skip: The 107, it's a step, it's the best step the FAA has made for the commercial drone operation. Also, 400 feet and below is not a place where you want a 747, except on a take-off and landing. Why some of these idiotic people fly into airports with a multi-rotor, I have no idea. I really, really, I don't even understand it. But, really, the only place where you're in jeopardy, is a person that's out of control out there, and just said, "I don't give a about rules and regulations. I'm just going to fly the drone."

But, as far as 400 feet and below, if you just give me 400 feet and below, and tell me to stay away from five miles from any airport, I'm a happy guy. But, it's all, once again, time will tell on this one for sure.

Anne: And we're going to need to start teeing up solutions here. I guess I'd like to go down the line, really quickly, and have each of you give me two solutions that you'd like the next panel to solve. And then we'll open it up for Q and A. So, what are the two solutions you want the next panel to solve?

Mike: [INAUDIBLE 00:45:08] Spectrum…

Anne: Can you be a little more granular than that?

Mike: There is not enough granularity on that, but obviously harmonization of spectrum and was the best way to achieve it between so many competing services, right? So, you have 5G, and satellite, and NGSO, and GSO, and HAPS, and…

Anne: So, you're talking spectrum coordination…

Mike: Spectrum coordination, whatever the rules that needs to apply to spectrum of the future. That definitely could be an interesting challenge.

Anne: Joe?

Joe: Spectrum. Well, that was a tough one, because I didn't think about that one ahead of time. I think finding a way to realize that safety has to be number one, in terms of UAV's flying in the airspace. And, I think they can do that. So, I'll let them come up with the answer.

Anne: Brennan?

Brennan: I'm going to say spectrum and spectrum, and split it into two parts. Terrestrial spectrum, [00:46:00] both geostationary and non-geostationary satellite networks really need to have a slight degree of flexibility and the ability to sight the Earth's portion of their networks, and also some certainty early in the design process, so that the satellite can work with the network as established on the ground. The initial efforts to establish terrestrial wireless rules for 5G, in my view, do not provide the necessary amount of certainty for satellite operators. And, we, very much, would like to see that in other bands.

With respect to spectrum on space stations, the NGSO, of EPFD limits, are on V band, are something that will be of primary importance to GSO interests and we'd like to see that resolved. So, those two big issues.

Anne: Skip, one challenge for the next panel?

Skip: Okay, one challenge. I think the big one for me is, how do we solve teaching people what fully autonomous means. And, it's not just fully autonomous in pushing a button. It's fully autonomous with responsibility. And, how do we gain that responsibility so that we have no accidents?

Anne: Thank you. Who's the brave student who wants to identify himself or herself?

Jordan: So…

Anne: Hold on, the mic is coming.

Skip: Mic coming.

Jordan: Thank you. My name is Jordan. I'm a 1L here at the law school. Michael, I don't want to call you out, but you were asked about the Holy Grail of autonomy, and I feel like you gave a political answer about having a person always there, able to respond. Is that actually the case, or, and I want to open it up to the rest of you [00:48:00] guys, because, full autonomy, Skip, I'm glad you transitioned into that, is really the Holy Grail, right?

We don't want to have people to have to respond to these things, when we can have autonomy, full autonomy, action and control, in a safe environment, know how to respond to those emergency situations.

Anne: I think that's for you.

Mike: Yeah, so, ultimately it is going to happen.

Anne: I think you were referring to some regulatory constraints first, right?

Mike: For full autonomy? Full autonomy, you know, as anything today, there is, really, everything ruled by exceptions except for the part 107. There is not even the rules exist. It's all exception-based rules, so, waiver-based rules. But, as experienced company and the new statistics come in, then it's become a rule. And so, ultimately, I believe that full autonomy will be implemented. Maybe together with artificial intelligence, and, you know, another Holy Grail today. Everyone talks about it. But, before that happens, I think, certainly not for a long time, we should see self-driving cars first, that can drive people. And then, when that works, then we may have self-driving planes with, they have the mission determined. But, I don't think that we are…it will happen, but it's not near-term, I would say, many years.

Joe: Can I throw in that now? So, my prediction for autonomy is 10 to 20 years, all right? Autonomy is really…

Anne: That's from takeoff to landing.

Joe: I could do that today, but the regulatory and political…

The public perception will depend on Tesla's self-driving vehicle, and, as I get older, me being able to go to the grocery store with somebody else driving the car. When the generations, when we get older, we will want people to drive for us. When people are comfortable in their cars being driven for them, they will be comfortable having no pilot [00:50:00] in the commercial airplane.

But, to get there, the technology's there to do that today. I can back up the airplane from the gate. I can drive on the airport. I can take off. I can fly. I can land. I can go back to the gate, today. But, the regulatory restrictions don't allow it, and the public perception doesn't really, fundamentally, allow it. Autonomy is really, if this happens, then you go through a checklist of responses. It's that, and it's software programming. I mean, come on guys, you know, start working on it. You can do it.

Brennan: I think fail safes are important in considering autonomy objectives. In the satellite context, we have standards for the operation of Earth station's motion, where they have to remain pointed to a fixed point in the sky, and intervention is required if something gets out of kilter. Things are, generally, very well automated, but, when things fail problems can be caused, and I think, certainly, when I'm in a vehicle or on a plane, if an automated system failed, I'd like for there to be a backup, including a human backup, in case of this.

Mike: And even today, the satellite NOC, network operations center, which is…

Anne: I'm sorry, what?

Mike: Network operations center. If you go to any company, there's still humans actually monitoring. And that was 40 years, about 40 years that satellite launched. So, over these 40 years, with all the safety check, there's still person monitoring the number of satellites. So, that [INAUDIBLE 00:51:44] in a perspective for the autonomous, full autonomous aviation.

Anne: I think Dale had a question.

Dale Hatfield: Thank you. People who know me, will probably anticipate the question, but the sort of reliabilities that you're [00:52:00] talking about, and so forth, sort of looks at interference. For example, something that happens inadvertently, it's not somebody really intentionally. But, what bothers me is when people are intentionally trying to jam things or spoof, and they're hitting these control channels, which, we've all said, are so critical to the command and control channels. And, are we doing enough to look at the intentional? This is the really bad guy who wants to do something really bad. Are we looking at, because, when I hear numbers, like, one out of some billion, that, you know, it only takes one kook, right? I'm worried about it. Do you think enough has been done in terms of intentional interference in jamming?

Anne: Go ahead.

Dale: Spoofing?

Joe: I can speak for Boeing, and we are working on that now, with respect to, not just spoofing and jamming in the comm sense, but also hacking into the actual aircraft itself, you know, by anybody, whether it be wireless or not. And, we're working with government agencies and, no sense getting into details.

Dale: I see a lot of the work being done on the external electronics. What I don't see as much of is when the signals are coming in from outside the plane which you can't prevent. You can't shut off the communications. So, anyway, I'm worried about it, especially the externally generated intentional jamming.

Mike: But, I think, just to answer, we're obviously very careful about spoofing of the launch airframe that we are flying. But, I think that goes to show, the communication links help, so it's hard to spoof if you have a number of communications, terrestrial, satellite, line-of-sight, beyond line-of-sight. So, that, coupled with the better technologists, better relation techniques, [00:54:00] basically makes the plane certifiable from the safety perspective including spoofing.

Anne: Are type certifications looking at that kind of issue as your craft are getting certified?

Mike: So, that certification does not look at the jamming, for example, of the signals. It makes it certifiable to fly safe, the plane, but not if it's maliciously spoofed or tried to be intercepted by others. At least, not presently.

Anne: Right. I saw another hand up.

[Silence]

Anne: Any other questions? Join me in thanking this panel.

Pierre de Vries: But we turn now to our solutions panel. So, these are the folks, this is the standard joke, right, you will tell us how to solve all the problems we've heard about, or else you'll tell us what the problems are as well. So, our last panel, and after this panel, the moderators will come up and try and help all of us make sense of what happened this afternoon. Before we get to that, solutions panel moderated by Anna Gomez, a partner at Wiley Rein and a wonderful supporter of the program. Anna.

Anna Gomez: I am delighted to have this great… Oh, I wasn't on, was I? I am on now. Thank you again. I'm delighted to have this really excellent panel to talk about how we're going to solve all the challenges that have been raised so far. It's been an interesting day going from innovation to challenges to now talk about the potential solutions. What I've identified is two general areas that I thought we would talk about today. The first is preventing collisions and then, also spectrum. How to handle the proliferation of systems and the need for spectrum, which Julius already told us this morning, we can't have dedicated spectrum for every single one of them. Thank you, Julie. We have a wonderful set of panelists, like I said. We did not intentionally segregate the men and the women.

[Laughter]

Anna: They are set up by alphabetical order.

[Laughter]

Anna: But I'm going to start by introducing the gentleman to my left. That's my left, right? Tom Hazlett, Tom is the H.H. Macaulay Endowed Chair of Economics at Clemson, and he's also a prior FCC Chief Economist.

[00:02:00] He also directs the Information Economy Project and will give us our very needed economic perspective on the issues that we are discussing today. Next to Tom is someone that needs no introduction because he's already been introduced.

[Laughter]

Anna: And I believe he was introduced as a national treasure. So, [Laughs] part of my job, by the way, is to harass our panelists because it's the end of the day, so I will be doing that. So, Julie, thank you for joining us.

Julius Knapp: Thank you.

Anna: Next to Julius is Jennifer Richter. Jennifer is a partner at Akin Gump. She is a very established attorney in telecommunications and spectrum, in particular, and unmanned aircraft systems, so she will be providing her perspective on unmanned aircraft systems and anything else she wants to provide her perspective on. And then, finally, Jennifer Warren. Jennifer is the Vice President of Technology Policy and Regulation at Lockheed Martin. Jennifer can talk about everything we discuss today. She can talk about drones, she can talk about high altitude platforms, she can even talk about satellites and stratospheric communication systems which has not been raised today, but she will be able to discuss that. And Jennifer has an illustrious history in communications, so I'm excited to have her here. I'm hoping that we will be able to run today's panel as more of a conversation, so, please, speak up, break in, be rude to each other, but avoid acronyms.

Jennifer Richter: Good luck.

[Laughter]

Jennifer Warren: That's what those charts say.

[Laughter]

Anna: We will also look forward to our questions and answers period, so please start thinking up something really challenging to ask us.

Even though I said I want to start this off as a conversation, [00:04:00] I did want to ask the two Jennifers to give us a little bit of a baseline with Jennifer Warren starting us out on while we talk about possible solutions to the issues that we discuss, it would be very helpful to have a review of the international regulatory regime for satellites in particular. So, if I can kick that off to you to start us that would be [INAUDIBLE 00:04:27]

Jennifer W.: Okay, if we can get rid of that interference. So, yeah. So, I'm going to try and build on the very good primer that Smitty did at lunch today on international treaty requirements. So, there's really two main treaty documents that apply and impact satellite or space more broadly, and one is the Outer Space Treaty. And the reason I raise that is because it requires under Article VI of the Outer Space Treaty that each state party have an entity designated to authorize and supervise any non-governmental or private activity in space. So, while we've talked a lot about coms here, there's a lot of other new ideas from commercial satellite servicing which addresses some of the orbital debris and longevity in space issues to asteroid mining to Mars missions, etc. So, keep that in mind that there's that, and that without the US and every other state party having designated an agency to have that role for some of the really cool technologies that are coming forward, we cannot be compliant with that treaty, so that is a challenge. The second is the International Telecommunications Union which you've heard several times, so I'm going to use the ITU with all deliberation. So, the ITU is a treaty organization UN affiliated that is 150 plus years old, so it predates the UN.

[00:06:00] And it has, as a treaty requirement, regulations and processes for satellite networks. How to register your satellite, how to coordinate your satellite, and how to notify your satellite. This is very unique. No other technology has this requirement imposed on it at an international level which is again, in addition to any national regulatory requirement. So, again, that's unique. The purpose of it is good. The purpose of it is to ensure that a space system is actually protected in space from interference and is recognized internationally. It has treaty status. So, good goals but it's a very burdensome process, particularly as space becomes increasingly congested. So, the more and more space-faring nations you have, with more and more robust industrial space programs and commercial programs, the more congested it becomes, and so, the concept of coordination between and among satellite systems is increasingly complicated. And there are rules for how NGSO and NGSO systems coordinate in certain spectrum bands. There's rules, as we've heard, for how NGSO has to protect GSO systems in certain spectrum bands. And then, there's some kind of wild west rules as well. But all of this coordination has to keep in mind that every satellite filing request at the ITU has a seven-year window within to bring the satellite into use. Otherwise, that satellite filing gets cancelled. So, all the work, all the investment, all the planning that has been done by any entity is for naught without a treaty decision to extend the life of that filing. That's 194 countries having to agree that your satellite filing should be extended for reasons that had nothing to do with your fault.

So, [00:08:00] again, this is all very different from any other technology deployment environment that we're in today. And one last overlay to bring to your attention is another element of the ITU. In the Constitution, there's a provision called article 44, and article 44 requires the concept of equitable access to orbital resources. So, every country is intended to try and minimize its use of just what it needs for orbital access and the use of resources, so that every country has the ability to access space. And in particular, or with particular attention to developing countries, and then, those with unique geographic interests, so keep in mind small island nations whether you're an Indonesia or a Fiji those aren't as well served. Their global connectivity is really best served to date by satellites. So, those are some of just kind of the pressure points that are very unique to deploying a satellite system and keeping it operational compliant with national regulations and then, this international overlay which I think is, again, something we haven't really talked about.

Anna: Yeah, so, basically, as we consider solutions on how these different systems are going to interplay, we have to also consider the treaty obligations that we have is basically what you're saying, and we'll hear more about that, I'm sure, as we move forward. Jennifer, on the drone side, what I was hoping you would talk about, we've heard a little bit about it from other panels, but in terms of collision avoidance, there are some activities that are going on right now, both at the FAA, at NASA, and even in some of the security agencies, so what are some of the activities that are taking place right now on drone operation and collisions?

Jennifer R.: Yeah, so, building off of what Jennifer was just talking about [00:10:00] before I get to some of our domestic activities, one of our frustrations over the last four and a half years is that we've been focused on low-altitude traffic management for small UAS, so drones that are 50 pounds and lighter and operations ground to 400 feet, so it's a very sort of specific environment. There hasn't been an international body that's been thinking about what the spectrum solution should be for those drones, for control links, and payload communications, and collision avoidance, and remote ID and tracking. The ITU has been really focused on UAS at higher altitudes and using aviation protected spectrum that is coordinated worldwide, and they talked earlier today about the spectrum for HAPS where there's a study item that's coming up in 2019 to make more spectrum available. But we haven't had that same kind of international coordination for low-altitude. Something really exciting happened at ICAO at their Drone Enable couple of days at the end of the conference just a couple of weeks ago in Montreal. We were there talking about international systems for low-altitude traffic management for drones because they don't really exist, and there are no standards. ICAO had let out an

RFI asking for people to submit proposals for what those systems would look like. Oh, sorry.

Anna: RFI.

Pierre: ICAO.

Anna: And ICAO.

Jennifer R.: ICAO, International Civil Aviation Organization.

Thomas: Busted.

Jennifer R.: Sorry. That really threw me. [Laughs]

Anna: Montreal, ICAO.

Thomas: Like a drinking game.

Anna: Yeah.

[Laughter]

Jennifer R.: Yeah, right. So, we were all there to talk through. I think 50 or more proposals were made and 17 were chosen to present at this conference, very exciting.

But the most [00:12:00] exciting thing for people in this room and for me, in particular, because I've been working on this issue for so long, is that a member of the ITU came and did a presentation, and his presentation was about spectrum for low-altitude drones which they've never spoken about before. And he validated that using the LTE networks really is the most logical solution for doing this which we've been saying for years, but it was really wonderful to hear a regulator say it. I swear to God he'd hacked my presentations for the last four years because he said everything I've been saying about the differences between unlicensed bands and licensed bands, the LTE bands, and the aviation protected spectrum, and each of them has a place for drones at different altitudes, but some are better than others for certain applications, so that was really exciting. I think what we're going to see is ICAO trying to develop a blueprint for regulators worldwide around low-altitude traffic management and what those systems should include. And so, that's really exciting, and I'll talk about that a little bit more later. But back to domestic activities, so there has been a remote tracking, an ID ARC, Aviation Rulemaking Committee that the FAA started this summer. The purpose is to take a look at technologies that can be recommended for remote ID and tracking of drones. This is a really important concept because last year the Department of Homeland Security stepped in and wouldn't allow the FAA to move forward with flight over people rulemaking related to drones, low-altitude drones until this ID and tracking had been solved. So, we were tasked — I'm a voting member on the ARC, well, I guess I still am, it's not over yet but close — we were tasked with studying solutions.

So, over 50 solutions were [00:14:00] submitted, and we bucketed them and thought there were roughly eight that made sense to us, and we've made a report, and we're making recommendations to the FAA administrator about it. That ID and tracking technology also relates, then, to this UTM concept that we've been talking about here today, so the UTM is the Unmanned Aerial Systems Traffic Management, and I'm just going to refer to that generically as low-altitude traffic management because I think it just makes more sense. The ID and tracking of drones will be fed into this low-altitude traffic management system which will be a dashboard. It will be just like what they have for high-altitude navigable airspace traffic management providing situational awareness of all aircraft in the air both manned and unmanned. And so, the ID and tracking is necessary because you need to be able to identify the drones that are out there. If a drone did not have ID and tracking, that might suggest to law enforcement that there is a nefarious intent. There may or may not be, but we hope that these requirements will be applied in a manner that's widespread enough that law enforcement will have an easy job of determining whether it needs to be concerned about any particular drones. And the UTM project is a NASA project. It's been going on for a number of years, so they're in their third phase of testing right now, and collision avoidance is one of the items that they're studying, all different methods of collision avoidance. This is all part of real field simulations and trials that they're doing. The ID and tracking and the UTM together provide an external way of providing collision avoidance.

It's sort of a [00:16:00] management function as opposed to the drone itself having vehicle-to-vehicle technology that will allow it to avoid another drone or another object, this system is an external fail-safe, so you kind of want to have both. You want the drone to be very smart, and then, you want a system that's there as a fail-safe. So, that's how all this stuff works together.

Thomas: Can I just ask her a question?

Anna: Ask away.

Thomas: Well, just on the ITU saying LTE spectrum would be appropriate for the very low drone space.

Jennifer R.: Yes. Yep.

Thomas: How would that accessed? Through the licensees, the LTE operators, or…?

Jennifer R.: Yeah.

Thomas: Through an unlicensed or a shared sponsorship or something?

Jennifer R.: Yeah. These communications functions will take place through the LTE networks as they exist today. And so, I represent a working group, the CTIA working group that includes Amazon, AT&T, T-Mobile — Sorry, you're losing me — T-Mobile, Qualcomm, Intel, Ericsson, Nokia, everybody that's sort of involved in that ecosystem, and they're all very much on board with having these systems used to support drone communications.

Thomas: Thank you.

Jennifer R.: Yeah.

Anna: And as I recall when AUVSI did its call for papers, since I'm sure you can't talk about what the remote ID ARC is recommending yet, but when they did their call for papers, there were those that said that the same technology could be used for some of the remote tracking, correct?

Jennifer R.: Yes. Yep, yep. Tracking and ID.

Anna: Well, thank you for that. So, today, we've talked about domestic regulatory regimes, international regulatory regime, and then, earlier in, I forget which panel, we also talked about the parties, individual industries getting together to put together systems for managing traffic and avoiding collisions as well as RF interference.

One of the things we wanted to talk about [00:18:00] is what is the right mix of government and private party action and also who are the right parties? You just mentioned ICAO, the International Civil Aviation… God, it's so… When all you do is talk in acronyms, you forget what they mean. Organization talking about having its own processes and recommendations for regulatory bodies. Is that going to become a treaty-based organization that all of the sudden tries to regulate drone flights and drone registrations and so on and so forth. So, what is the right mix? Anybody want to jump in, in particular? Jennifer.

Jennifer W.: Okay, I'll jump in.

Anna: You breathed.

Jennifer W.: Well, I think it's more than just a question of what one body because what we're really talking here about is a lot of different sectors of industry that are all playing a role. So, we haven't talked about launch corridors, so you've got launch sites, state space boards, the Cape, Vandenberg for launching satellites, so they've got to have… They're part of the collision discussion. You've got the manned aircraft, the unmanned, you've got the cube sats, you've got things being launched from space, not just from the ground, so you've got maiden space launching small satellites from the space station. There is all sorts of different players that need to come together to talk because it's only that integrated dialogue that's actually going to kind of get to a safe environment. And what I'm happy about is I'm happy about seeing, for example, the FAA, which we all know through… We think about from the drone side, the UAS side, but they obviously, manned aircraft, but they also are the launch authorization, and they also have responsibility right now for mission authorization for a lot of kind of the new applications [00:20:00] in space.

So, right there, you got a dialogue among three or four parts of an agency that has jurisdiction over a lot of space and airspace related activity. To me, that's a starting point. And the fact that on the Drone Advisory Committee we have manufacturers of manned and unmanned aircraft, we have pilots, we have state and local governments which we can't forget, aside from federal interests. Having those type of fora are really important. I don't know where the end of the discussion is going to get, but having everybody engaged is really important because there are a lot of moving parts just to transit the airspace, to get to a stratospheric level, or anywhere in between.

Jennifer R.: I agree with that completely, and I think if you look at the whole landscape of what's happening with UAS today, there are a number of working groups that include both government and industry together, so the DAC is one that Jennifer just mentioned, the Drone Advisory Committee, but there are many others. There are probably a dozen, and I have a presentation if anybody wants to see it, I'll give you the slides. But there are probably a dozen that are working on these issues. It is a joint responsibility because the technology has moved so fast, and the regulatory environment just has not been ready for it. And so, it's incumbent upon industry to build the safety cases, to figure out what the collision avoidance technology is going to be, to help NASA with the low-altitude traffic management system. It really is incumbent on industry to help drive the solutions, and the FAA is really looking for that kind of input.

Anna: And presumably there is incentives for those that would prefer not to have regulation imposed on them to actually come up with the solutions, and maybe that becomes the regulations, but it's at least it's an industry led solution.

Jennifer R.: You bet.

Julius: Me?

Anna: Yes, you. You don't have to answer that question.

[Laughter]

Julius: [00:22:00] Just a few things. We're focused right now on UAVs, so I think there's a lot of tremendous work going on in the private sector. And before we start running ahead and saying, "Hey, we need to adopt rules…" I don't even know what the rules would be. I think there's a lot of this that can be addressed through the private sector. I see a very collaborative process with government that's going on. We heard about a lot of different issues here, about things like the spectrum for the command and control, and the spectrum for the payloads, and can you use a commercial wireless network, and I know that there is good work going on out there to make sure that, "Hey, yeah, that can work," or, "What the problems are? And how you solve them?" So, I think the thing to do is to just keep going. Let the process play out. And I think what we've been trying to do is keep our finger on the pulse and participating in the places that have made sense. Some of these issues are not what we think of as FCC issues. Like the collision avoidance, that seems to be more in domain of FAA and things like the identification and so forth. It certainly seems to be more in the FAA domain.

Jennifer W.: Julie?

Julius: Yes.

Jennifer W.: Can I challenge on that?

Julius: No.

Jennifer W.: Just a little bit? Okay.

[Laughter]

Julius: You wanted controversy.

Jennifer W.: She said to interrupt.

[Laughter]

Julius: Go ahead.

Jennifer W.: Okay, I wasn't sure. But I think everything you've said is correct for the small UAVs, but I and many other in aerospace and defense look at larger than small UAVs.

And to use Michael's term, HALE, High Altitude Long Endurance, those [00:24:00] will require a different approach than the low-altitude traffic management, and so, dedicated spectrum for at least command and control is going to be something that you're going to see a different case being made for. But I think the challenge here is which comes first because the FAA has to set out performance objectives, we have to be able to meet those performance objectives with the spectrum that the FCC will make available for command and control, so it's going to be an interesting timing scenario. And the one has to be informed by the other, then the other has to be satisfied that the performance objectives can actually be met through the way the FCC has made that spectrum available. So, I just wanted to say there's a little bit of a collaboration that we're hoping for between the FCC and the FAA when we get beyond the small UAS.

Julius: I disagree we don't disagree. One of the problems is we get so many things lumped together in the discussion. And so, for example, we actually did allocate the 5030 to 5091 earlier this year for command and control, and I think the idea there was — because it's federal and non-federal — that it would be licensed somehow, and we said, "Well, we'll deal with the rules that deal with the…for the services…" You're absolutely right. There's so many different kinds of UAVs in use by both non-federal and federal, and I'm not suggesting that we put them all on one bucket. So, I think that that's certainly a valid point. Just to touch on some of the other things from the prior panels because I was glad to hear that nobody said one of the problems was spectrum.

[Laughter]

Julius: What I think is interesting is that had you asked each one, they probably would've had a different answer for the spectrum because they think each one of these things presents a different [00:26:00] set of issues whether we're talking about UAVs and the multiple kinds of UAVs…

Jennifer R.: Different altitudes.

Julius: Yeah. I was certainly not suggesting that we would have UAVs that are operated large by the federal government that would be in the unlicensed band. I don't think they would ever accept that. [Laughs]

Jennifer R.: Yeah, exactly.

Jennifer W.: Commercial.

Julius: On each one of these things and I'm going to come back to flexibility last. So, when we talk about HAPS, we've got the work going on in the International Telecommunications Union. And I think it's important to see how that plays out. There's also those systems are largely being trialed, so in trying to understand how they may go forward, so that will play out. The questions of the satellite allocations certainly… We've moved forward on satellite allocations. There are issues of sharing between terrestrial systems and satellite systems and GEOs, geostationary orbits [Laughs] systems, so forgive me, GEOs and NGSOs and so forth. And you heard about the different kinds of altitude systems. So, we're working through those. Some of them are in an outstanding proceeding, and I think, one way or another, they will get settled. And then, there's the UAVs we talked about a minute ago. So, I think there's progress being made on each one of these. There's just a couple of other things that I would say about spectrum generally, and maybe, Tom, you have some things to add. Because I've been at this a long time and I still remember when somebody came in and he says, "I did my job. I came up [00:28:00] with the innovative idea. Your job is to give me spectrum." [Laughs]

And it's just not that simple. Most of the spectrum is spoken for in one way or another. You may debate whether you think it's valuable or you think it's heavily used, but it generally comes down to there's something there, and either you're going to share without modifying it or it's got to be moved or something. That usually costs money which means funding, and so, "Woah, I didn't want to have to pay for something." [Laughs] And so, a lot of what we're trying to do, we'd love to clear some spectrum, and I think that's something we still look for those opportunities, auctions will still be in the future, there's no doubt in my mind. And then, there's cases where, and a lot of this is what's going on in the ITU, can this share with some existing system? And we've got a lot more tools on the engineering side to enable this. [00:29:00] You heard about the focused beams, and the ability through technologies like MIMO and so forth. I still think we haven't fully tapped into artificial intelligence for…we call that a different term, for dynamic techniques to squeeze more out of what we have. So, you're going to see a mix of this, I think. Hopefully you understand the agency is fully committee to open up more bands not only for terrestrial, but I think for other services as well. But, it seems like each next thing we're doing is harder than the last, because there's more things there.

Anna: So I just read about an Intelsat proposal, which I thought was interesting and Tom may want to…I don't know if you've read about this proposal where they would do market-based mechanisms, enter into agreement with terrestrial providers in more urban markets for use of their spectrum. That also insured protection of their systems. I just read this, so I'm paraphrasing very highly. Have you read about that and do you have thoughts on that mechanism? Is this an answer to the concern that the FCC is going to move forward with reallocating or forcing sharing of spectrum anyway, so let's take control of our agenda here. Do we have any lessons in history for some mechanism like that?

Thomas Hazlett: Yeah, thank you and thanks to the University of Colorado for inviting me out to beautiful Boulder. You mean the part where it says, "Advances the public interest without the risk and delay associated with the sharing framework by regulatory fiat?" That filing? Yeah.

Anna: We did not coordinate this.

Thomas: We are in a chaotic state, so the fact that we merged on that is…that's how dangerous collisions in [00:31:00] space are. So, it can happen that fast. Let me just say something about collisions in space. Hearing the challenges and the challenges are profound and it's 3D, so we've got this extra dimension to worry about. The fact is this is how rules develop. This is just a very standard property rights conflict. We got radio spectrum out of laboratory experiments that sort of sat around for a while and then all of a sudden in the 1920's there was a business model that forced conflict. So, even people talk about land being simple, land rights are simple. Well, when planes start flying over land, you have to figure out what the relationship to the landowner and the plane is. So, we have a 1926 act of the United States that says, "Well, the planes get to fly. They don't actually have to contract with every landowner down below." The traditional rule from Blackstone from the center of the Earth to the Heavens above, those were supposed to be the rights of the property owner. Well, that kind of gets set aside. We discover these useful pools of oil underneath the surface and it just turns out if surface owners stick a straw down and start sucking out oil, well, that really screws things up. There's a race to dissipate the resource. So, now all of a sudden, what they ended up with is, in most cases, unitization. That's kind of a common pool resource owned by all the property owners. You work these rules out, so now we've got these tremendous opportunities for just great efficiencies. The laboratory science is fairly well developed by now and so for the immediate future, the main beneficiary of the technology will be the travel and leisure business because of all the conferences.

[Laughter]

Thomas: Hotel and planes are going to do well on these. Part of it is, that's just the way the world works. [00:33:00] We have to figure out what…there does need to be a traffic cop. I can say that I don't think people are going to put up drones and be oblivious to the collision problem because they own the drones and they want the drones to stay afloat and do something productive. On the other hand, there are liability issues and so, fly by night drones…get it? Fly by night drones…

Anna: Which is prohibited today.

Thomas: I'm not talking about scheduling. "Wake up! It's four what?" Fly by night drones are an issue. You have to have liability fixed and you don't want accidents to be more expensive than people can pay. Things like cheap registration systems, they really do make a lot of sense. Expensive sensing devices, maybe they don't make so much sense. We don't want to kill the technology because people in Geneva got sold something nice and it's now being mandated. So, I hope that as we go forward here, there are some new institutional structures including consortium and non-profit organizations that may take over a lot of the central planning and directioning on this that we have learned, that there are some regulatory rigidities that we'd like to avoid, even as we want some of these rules to go forward. We want a lot of flexibility. We do want stakeholders out there. Even as I smile to myself as you talk about the FAA, yeah, let's privatize the FAA. Oops, sorry. Didn't mean to…

Anna: Ooh, that's another panel.

Thomas: Extend the conference. But, the FAA, there's no reason it should be a government organization when it comes to air traffic safety and it should be rolled out into, like the Canadians and others have done, into a non-profit organization. Perhaps there is some innovation that can be done there. That's an analogy. [00:35:00] I'm not trying to argue for that. So, in the intel/Intelsat joint comment you're talk…just filed and I did happen to get a copy, just by coincidence and was looking at this. This is, to my way of thinking, a wonderful idea where you have incumbents and they're specifically here talking about 3.7 to 4.2 gigahertz. Can I say gigahertz? Is that an acronym?

Pierre: You can say gigahertz.

Thomas: Hertz? This [INAUDIBLE 00:35:31] hertz times how many?

Anna: It's an acronym in your head, but it's actually a word.

Pierre: It's a word.

Thomas: It's a word? Okay, it's a word now.

Anna: One of my lessons from today, just so you know.

Thomas: So, they're talking about incumbent licensees, including especially satellite licensees being allowed to make commercial deals with terrestrial, in particular, but it could be other application providers. This would be a situation where incumbents currently using the band are protected, but new users have an opportunity to come in and make business deals, to make bargains, to move resources around with money, changing hands. They specifically do make the argument, I think it's nice. I didn't consult on this, but it's a little jarring to be so peripheral to the process that you think you know something about. But, they say it just right. There are rigidities in the system that can be overcome by allowing the rights to go into the marketplace that allow bargains to be made. Then you have, in a decentralized way, you do have the players going and saying, "What are the opportunity costs of making moves and what technology can be developed so that there can be accommodations made to the incumbents?" You don't have to make, Julie, who has enough to worry about at night, have to make these [00:37:00] tradeoffs about all kinds of things that are completely unknowable like, is a band better used for autonomous vehicles or Wi-Fi delivery of cab videos? I can frame that anyway, but he doesn't know the answer to that and, of course, neither do I.

Anna: Joe Cramer would say that it's better used for dedicated use to protect aircraft and cat videos should be watched on the airplanes, on their Wi-Fi systems, right? Sorry, that was another panel.

Thomas: Yeah, so I've got nothing against cats, but we want the opportunity cost to be visible, transparent. We want users to make rational calculations and we don't want resources to go to low valued uses when there's something much better. So, getting markets to deliver these answers, everybody agrees at a high level. I mean, there's certainly a consensus on that. Liberalization has gone forward and has intellectually become quite a compelling paradigm. But, how you move out of the marketplace, well, I'm happy to see filings like this at the FCC. By the way, I will say, in reading the FCC's rulemaking on this and I'm sure nobody on the panel had anything to do with this, but in the 3.7 to 4.2 when the, I don't know if it's a notice of inquiry or the proposed rulemaking when out, but whatever's the open docket now, I saw that good and the bad of FCC spectrum allocation. In some language it says to the marketplace, "Please tell us exactly what the costs and benefits of the new technologies are." That's…well, I'm looking here looking at Washington lawyers. You should love that language, okay. Your kids have to pay for tuition. [00:39:00] I understand that, but that's just an open-ended debate about things that, again, we can't decide.

On the other hand, they did have some very nice language that invited a comment about how rights could be construed so that marketplace decentralized decision-making can happen. In essence, invited the comment, in fact they used the word in some places, for overlays. So new rights in the marketplace that are subordinate to the existing transmission rights that can allow the owners, presumably the new winners, by auction of those rights, to make bargains with incumbents and transition or reconfigure markets such that you can have new technologies, new services, and new business models deployed. That's what those FCC proceedings should be when they look out at the marketplace and say, "Help us. Give us some good ideas." Yeah, the marketplace is going to have the diversity of thought out there is something that Julie, quite honestly says, "I want you to tell me. I want a lot of coordination and collaboration."

The FCC as an agency, predates anything in our lives. It has always said, "We want the interested parties to hammer things out and to make a deal and come to us and then tell us what's in the public interest. Then, we'll decide." That means that there's a lot of stuff. There's a lot of information out there that has to…it is distributed, there's no question. The whole rule making process, by the way, where this is always set up to ask the people who have that specific information, to reveal it to the regulator. The regulator wants to know what these folks know. So, yeah, those are great ideas, but it's good to tee that up in a way that it's not an argument. What's the example? This is my most vicious example at the moment. It's not an argument of how many work crews there are to change out TV station signals. [00:41:00] The argument being whether or not there are 14 work crews in America or 50 work crews in America. That's not a made-up example. You know what I'm talking about? You know the answer.

Anna: Television transitions.

Thomas: Yeah, there used to be physical scarcity for airwaves. Now there's physical scarcity for work crews. By the way, that's a very funny line to an economist.

[Laughter]

Thomas: I don't know why you people aren't laughing. The idea that there's a physical number of work crews in the United States. But, that's what you get when you tee up the wrong answer. You just get these debates that can be endless because the answers are unknowable. If you do invite people, as has been done, to do an Intelsat has done in that filing, talk about ways to devise rights for the agency to configure that can give us forward progress and introduce that innovation that essentially all of us want and still mitigate the costs to society, to the incumbents, to all the other users out there. That's what the agency should focus on. I'm glad to see that there is that language.

Anna: So, going back to the whole topic of today is this proliferation of systems, and they're at every level. So, what are the challenges of implementing something like the Intelsat proposal where all of a sudden, we have different systems operating in the same spectrum that can affect other incumbents at different levels? What are the challenges of implementing something like what Intelsat has done? Jennifer, I don't know, Julie.

Julius: I can't touch it.

[Laughter]

Julius: I'll just say a couple of words. So, this was a notice of inquiry and I think it also reflects the challenges in trying to find access to more spectrum. We asked a lot of questions in there as an agency. I do want to stress that we don't go into it with, "We think this is what's going to work," [00:43:01] and so forth or that there's a one-size-fits-all. We're going to take dynamic access and we're going to put it here. So, we just asked a lot of questions about it. I think, before I left, because they were still coming in, there was something like 80 plus comments. There may be more when you get into the record. They're kind of all over the map.

But, just as a side bar, if you look at what we did in the spectrum frontiers proceeding, which was a little bit different, which we said, "Okay, you're a licensee. We tied your hands and said all you can do is fix. We're going to give you a right to do mobile and let the market figure out what the service is going to be." Even that, we had constraints to try to protect the incumbents. There's still debate going on there. In each spot, I think what we try to do is come at this as, how can we get more out of this? How do we protect the incumbents? What's the right solution here? Jennifer was mentioning to me about flexibility because sometimes we've got flexibilities in the allocations. We've got flexibility in the licenses. But, there's usually conditions that go hand and hand with it, to make sure that we don't have chaos reigning.

Jennifer W.: I think one of the interesting things here is, what I've understood from the Intelsat proposal is basically the urban, non-urban split, right? Typically, at least in my experience, and Julie can tell me that my memory is completely faulty, that there's been a reluctance to do that kind of geographic partitioning among services in quite that way, because this was explored at Ka-band and rejected because the view was wireless, 5G wireless, or mobile wireless needed to have the entire nation, and it would deploy across the entire nation. You read a lot today and it seems like it's going to be much more urban-centered and maybe suburban. It's very unclear what the trajectory is for covering [00:45:00] the non-urban areas. So, in effect, this kind of proposal reflects, it seems to me, again, this is personal, not Lockheed, seems to me to reflect kind of a reflection of what some see the mobile wireless industry doing, which is needing capacity, urban. Not needing it anywhere else and finding a way to maintain space operations, satellite operations outside of urban corridors and finding a way for additional capacity.

I don't know how the FCC policy approach is to that. I think it will be very interesting to see the discussion at the policy level among the government policy makers. It requires, in some ways, an acceptance that there may be some natural partitioning, if you like. I don't mean that in a spectrum sense, but some natural partitioning. I think it's going to be a really interesting dialogue to see how that moves forward and what that portends for future spectrum discussions, because one of the things I don't see is enough incentives. I think that's part of the solution, too. I think every single panelist said spectrum on the prior challenge. Incentives have to be incentives that are perceived that nobody will get what they want unless you come up with a solution that works for everybody. That's rarely the situation in a spectrum proceeding at the FCC. There's always an industry or a player that's perceived to have the upper hand, irrespective of how balanced individuals are. It's just that perception. So, how do you create regulatory incentives? Or maybe they're not that. Maybe it's an XPRIZE for RF spectrum sharing, which results in ten megahertz of spectrum nationwide to whoever really comes up with something?

Julius: Only ten?

Jennifer W.: Yeah, I know ten is…500. [00:47:00] That comes up with actual spectrum sharing technology that doesn't constrain the incumbent and allows growth on both. Sharing, typically, and this is our challenge that all the other guys were talking about, means somebody gets constrained. How do you come up with a sharing regime that doesn't constrain? That may be bringing in more autonomy, but you've got to have the incentive for development of that. That may not be the DARPA role, right? That really may need to be others. So, just throw that out there. Tom, XPRIZE?

Thomas: Well, yeah, XPRIZEs are great, but the normal way you give people incentives is you pay them. The actual way that sharing is most often accomplished is pay them to go away. Then, they're sharing, I mean, they have rights to use some radio spectrum and a new user comes in and says, "Hey, have some money." They're sharing in the new…the value of the new use. That's the way you do it. In fact, that's extremely important. The FCC understands there's many proceedings and it just…I mean, even in the 600 auction, it was interesting in the assignment round how the FCC algorithm automatically tried to put everybody together to eliminate borders. It's just the way you see it happen in the marketplace, just to get this done. You were doing it without money. Part of this, and then you use money to, for the rest of the assignment around to just settle. The tie goes to the money.

But, so, to take something that happened 2004, 2005 on the 3650 band. We had these, I think they were government radar systems on the coast. There was this dispute and there was a debate about whether or not it should be licensed, unlicensed. The problem with doing an unlicensed, which is the FCC's decision. The band hasn't turned out the way it was [00:49:00] described in the order that it was going to have fixed wireless broadband. It was going to compete with cable modems and DSL and fiber and all that. As soon as you decide to have fragmented rights, which in this case are unlicensed, you don't have anybody who can buy out or substitute or do the real sharing, which is to figure out how to get rid of the government use.

Now, if they're private licensees, probably it's a little easier, but we've seen that even these overlay rights can put incentives in the marketplace, where private companies now can go to markets. They can borrow capital. They can generate new technologies. They can upgrade existing government technology. They can actually, in many cases, make deals to move out those…to change the spectrum allocation. There's just no way to do that, given the way the FCC took 3650, beautiful 50 megahertz band, but said it was going to be all unlicensed. Then there were all these rules that you had to have listen before talk. You had to have these kinds of restrictions on where the government radar was and so forth. I could go into white spaces with TV white spaces, exactly the same problem. As soon as you decide not to do an overlay, you've got nobody to negotiate with the TV stations to move them out. At that point, you've just sunk the whole proceeding. This has gone for 15 years now. It really is onerous to tell the white space devices, you've got to have all this listen before talk. You've got to be in the database. You can't really have rules for mobility because fixed is easier right now. We'll give you a chance to do mobility later, maybe.

Anna: So, I'm glad you're raising that. I apologize for interrupting, but we are running out of time and I need to give the standard question and answer period for the students. But, just want to give the thought of how do we enable innovation while imposing requirements? [00:51:00] We talked about it with the FAA earlier, imposing avionics requirement that actually have spectrum consequences. There can be cost issues. We're seeing issues with collision avoidance if we don't have propulsion mechanisms, we don't have adequate fuel. How do we allow these innovative services to come in without regulating them out of business, but still ensuring we have safety? I'm not going to let you answer the question because I have to go to the audience.

Julius: We have 30 seconds for questions.

Anna: Does anybody have a five…a student have a five second question? No, I'm kidding. Anybody have a…It could be a student.

Pierre: [INAUDIBLE 00:51:44] do you want to pick a student? Yes, Gabrielle. We'll try and go to people who haven't asked questions before.

Student: So, I was reading an article before coming to this panel that was discussing the fact that with all of the new space industry growth that we're seeing, particularly in the private sector, that it might be time to establish some sort of regulatory body for that. So, I've heard several different suggestions for how we might think about both encouraging and regulating innovation. If anybody on the panel has a reaction to that, I'd appreciate it.

Anna: I had a similar question to that. Do we need to have some type of division, bureau, separate body? Really, I wanted to be cheeky just to add a little controversy. But, thank you for adding it now.

Thomas: And the portfolio would be?

Anna: Well, I had actually thought whether we needed some kind of regulatory regime for the…we have space and we have terrestrial. We don't really have [00:53:00] more, sort of, a high altitude platforms. But this sounds like it's almost an entire coordinating body that takes all of the various bodies that we've talked about, domestic and international and puts them in one place to regulate all the different segments or the different matters around this shared use of the airspace and of space.

Jennifer W.: There is an advisory committee called Comstock, which is the committee on space transportation. It is a committee that makes recommendations to FAA Office of Commercial Space Transportation. The recommendation there was that basically the FAA AST, which is what that office is called, be responsible for all space authorizations with the exception of the commercial satellite jurisdiction that the FCC has for spectrum. So, excepting that, the recommendation there was that it would be appropriate to give the FAA AST office all of that authority. Now, current discussions in DC are looking at whether or not it should be there, whether it should be at commerce department, whether actually it should be elevated to another mode of the Department of Transportation, which has its pluses and minuses too, all for debate. But, that was the industry advisory committee's recommendation.

Thomas: I would say the only other time in my life I've been in this room was to celebrate the birthday of Fred Kahn. Professor Weiser brought him here.

Male: Best conference we ever had.

Anna: Except for today, of course.

Thomas: But I have a hard time saying there should be another regulatory agency, thinking [00:55:00] of the late Fred Kahn. He had turned 90 and I think it was 2009 you had that wonderful conference for him. I don't know if I can say, sitting where Fred sat, that there should be another regulatory agency. It is a good question, would that coordinate…

Jennifer W.: One, it's a consolidation.

Thomas: Exactly. Okay.

Anna: Whenever we have hard policy issues, we do tend to look at reorganization.

Thomas: I'm not…I just can't do it, out of deference to Fred.

Julie: We have another question up there.

Anna: That's right. You were first.

Julie: That's not a student back there.

Anna: Oh, sorry, microphone right here. How many minutes do I have? Two minutes?

Audience member: I was very excited about some of the issues that Tom brought up and I wanted to ask if that might be a principle that might be extended further. Let's assume you have an incumbent use and some band, some new innovative use, whether it be some of the ones you talked about or others comes along and says, "I'd like to make a deal with that. Here's new dollars for you as the incumbent." Could the FCC, instead of going to auction or consider that here's a market recommendation of a higher use and actually do a rule change to allow that?

Thomas: What a wonderful question and it is discussed in a new book from Yale University Press called The Political Spectrum.

Julius: All I get to hold up is the CFR, Code of Federal Regulations.

Thomas: Marketing. Okay, what was it? You want Euros or do you want dollars? Thank you for that. Yes, now there should be a liberal system where that can happen and that should be generalized. That's part of the [00:57:00] liberalization of the rights, the flexibility that I think we've heard about and in some cases, you do need extra rights coming into the market because there's unallocated channels or bands. Secondary rights are important to rationalize a whole bunch of spectrum, a whole bunch of frequency space. So, that's where the overlays come in.

Jennifer R.: And in all seriousness, the TBRS, which build off of some of the 3.5 spectrum that Tom was discussing earlier. You know, the commission expanded that from 50 megahertz to 150 megahertz. The notion there is, they're going to protect incumbents in the band which include the naval radars off the coast and other incumbents. Utilities that are using that spectrum already. But then, making it available to others and there's a technology called the spectrum access system, a SAS that will be used to manage all of these uses. It's not really…it doesn't have to only be applied in the 3.5 band. I think that technology, those spectrum access systems can be applied very broadly in order to make more spectrum resource available for more different uses.

Pierre de Vries: Conversation about what happened. What were your key take aways? What were the messages in your panel? I'll go down the table one at a time. Not only what you thought you heard that was most interesting, but what you didn't hear. What did we miss? So, David, you want to start?

David Reed: Okay. I have to note that I've never heard of CU parking tickets ever being waived, so, you have truly…

Pierre: Maybe we have the sponsors to thank for paying them, I don't know.

David: Okay.

[Laughter]

David: You're setting a precedent that's hard to match. Well, so, what one reaction, and maybe this is something that was discussed but wasn't, in the sense that, broadband, so, I do a lot of research in broadband access and the economics of different broadband solutions, and looking comparatively at the capital costs associated with the deployment of those systems. And, it's clear that for a lot of the NGSO systems, that they're being deployed as, for, broadband access, right? For providing that connectivity. They're differentiating based upon speed, latency, location. And that's a primary driver. It's not necessarily an application vision, that of a new thing beyond better speed, latency, a better broadband in different places.

And, that's interesting. Having looked at, so, I think there's still an opening here, some research that needs to be done in understanding comparatively, what are the advantages for these new systems, whether it's with LEOs, or MEOs and with the GEOs being more understood, but with high-throughput satellites changing the economics some. So, we really don't quite have a clear description of what the coverage gap is, so to speak, these systems are going to provide. And, so, there's some risk [00:02:00] associated with that.

Having done some research a little bit on comparing, in rural areas, some of the terrestrial wireless systems, such as LTE and wi-fi, wi-max, with high-altitude platform, in this case Google Loon, and looking at how those costs look. An early look at those economics do indicate that high-altitude platform, if they deliver on their promises, do, in fact, provide, what I call, a broadband onramp, in that there's not a lot of infrastructure that's required as compared to a terrestrial broadband system. And so, you can get broadband to some of these more rural areas, and emerging or developed countries, that the broadband isn't there, at a lower cost initially, in the earlier years. But then you want to transition over to terrestrial wireless systems as the speeds go above, say, two, four, six, eight, megabits per second. You need the terrestrial systems to deliver more broadband.

Pierre: That's still broadband. And so, one of the things that struck me, we heard this in the course of a day, which is, "General use is good, but I need spectrum for x."

[Crosstalk]

Pierre: When we, are we unnecessarily fixating on broadband, that we're going to end up with rules and allocations that are good for broadband, maybe flexible use for broadband, but not anything else?

David: Right. So, it's interesting. There were calls for spectrum, right?

Pierre: Right.

David: Turns out that you don't need new spectrum in the sense, you can use LTE. And so, you can talk, particularly in rural areas, for example, LTE, spectrum, emerging country is not being used very intensively, so you might have 40 or 80 megahertz there, that, if you partner with the mobile broadband provider, [00:04:00] you might be able to have that spectrum available.

And so, that, kind of, eliminates the need for the call for spectrum, and, by the way, it lowers the transition cost, because you're deploying LTE receivers, a termination devices, then you can transition to a traditional LTE system at lower cost.

Pierre: So, what I hear you saying is, to some extent, spectrum isn't a challenge. And, what I heard a lot on Anne's panel was that that's the big challenge.

David: Again, where's Tom? I don't know, yeah, so, the process itself. So, what complicates this discussion is the allocation, spectrum allocation process. That is, kind of, if you build something then others try to participate, and get some ownership rights. I didn't read the Intelsat filing. I assume it's associating some property rights that maybe they can trade, and get associated with, being part of the conversation. So, the spectrum piece, it's kind of a land rush, right? Gold rush that you want to be at the table in order to do that. But, for example, Google has been with the project Loon, and they've been talking about partnering with the local telephone companies, or whoever it is, and working with their backbones and system, and their spectrum, right? So, that's an example of them being able to deploy that. I think that's an interesting correlation that, certainly, if you had spectrum, it could be easier, but the LTE spectrum is typically lower. And what they're asking for is higher, and so, that might impact some of the economics. I've been look at that.

Pierre: So, let's move on to Anne, and we'll circle back if people have more [INAUDIBLE 00:05:53]

Anne Swanson: And my take-away is, such a much more general take-away, and I started in the FCC area, but, in the last 10 years or so, I really have [00:06:00] segued over to aviation safety, and the FAA, and DOT and, I've found in that field, just as in the communications field, and I'm not sure why I'm echoing, the tech is just so far out in front of regulations. I mean, it's just, you can't help it, and I've benefited, and I started in the avionics context when I crossed over to the FAA, I've benefited from watching some of the different ways they approach solving the problem.

And, in some ways, this has made it a little more cumbersome, but I think they've gotten to technical solutions, sometimes in a way that has had a more practical and beneficial effect through, what I mockingly called shadow government a little bit ago. But the RTCA process, which is a multi-stakeholder process, and I think your panels supports multi-stakeholder in a couple of different ways, but it's a multi-stakeholder process involving the technical folks, who are leading the innovative charge, and not necessarily the lawyers in this room, or even, I'm sorry, Tom, the economists. It's the guys who understand and the women who understand the technology, and working sometimes with groups like MITRE or others, the process is corralled and they come up with recommendations for the FAA, and these are highly specific technical recommendations.

But, it does seem to get them to a solution. I thought initially, it was terribly bureaucratic, but I think it gets them to a solution that works quicker, sometimes, than having the lawyers and the economists try to figure it out.

Pierre: So, are there any things that we, in the spectrum space can learn, so when you think about, FAA does this, how would one do that in the FCC context?

Anne: They've done that in the application of some of their psectrum real estate in avionics, and it's putting Julie's folks a little more in charge than I think they've been in the past. OET does a great job, but it's called in on an ancillary basis, usually to advise. And, I just see at the FAA side, and on the DOT side, and the technical spheres, it really is not an agency or department of lawyers as much. In the FAA, the Chief Counsel's office is over [00:08:00] on the side.

The lawyers aren't integrated into all the different substantive bureaus, the substantive offices. It's just a different approach to solving technically driven regulatory problems.

Anna Gomez: I know this isn't about my panel, but, if I could just add on to that? One thing that the FAA does very differently is it runs very quick processes through the aviation rule-making committee.

Anne: Which are another multi-stakeholder kind of thing.

Anna: Which is another stakeholder driven body to provide recommendations to the FAA. I think both Jennifers have, Jennifer Richter and Jennifer Warren, sorry, participated in the Drone Advisory Committee, and the remote identification and tracking advisory committee. But where we have seen the FAA do, is they convene these bodies. They give them very short deadlines. They tell them, "This is what we're trying to solve." Not, "We're looking to establish rules that do x. It's a goal that we're trying to resolve, and come back with recommendations." They've turned that into rule-makings, and they've turned that around. I think that that is a very quick process. It's not something the FAA -- FCC has done.

I've always, kind of, wondered about the APA implications of these advisory rule-making committees. [Laughs] Which is part of the reason why I think the FCC does do it.

Pierre: Could you just explain, briefly, what you mean by that?

Anna: What the APA is? The APA is the Administrative Proced…just kidding. It's the Administrative Procedures Act, but there's a question of how much notice and due process you are giving if you are limiting participation and developing rules to a particular body of stakeholders. I have not answered the question of why the FAA gets away with these aviation rule-making committees. They do, eventually, put the recommendations out for public notice, and create notices of proposed rule-making, unless, of course, they're doing interim roles as they did with the registration requirement. That's a different story.

But, nevertheless, that is one way that the FAA does tend to do things more quickly. I don't think [00:10:00] the RTCA, the Radio…

Anne: Technical.

Pierre: Committee.

Anna: Advisory.

Pierre: Aeronautical.

Anna: Yeah.

Pierre: Shadow government.

Anna: Yeah, I actually don't think that is the most efficient body either. It's a standards process that tends to go on for a very long time, so much so, that the FAA has declined to use the RTCA to develop lower-risk recommendations. So, for the low-altitude flight, they're not going to the RTCA to ask for particular standards or requirements that they should…

[Crosstalk]

Anne: Technically, they don't need them I think, that's what's [INAUDIBLE 00:10:34]

Anna: For the, you know, protecting us when we're on airplanes, that's a very different story. That's where we really want those standards to be very well developed. But, in any event, I'm going on and on and that's not [INAUDIBLE 00:10:44] my panel.

Pierre: You've got comments on your panel, but let me just pick up this theme and I think it goes back to something Anne should be interested to hear, you as well David. For me, one of the themes of the afternoon has been autonomy. Dean Braun started off saying what's driving this size and autonomy. The systems are getting more autonomous, and then, as the day wore on, reality started setting in saying, "Well, we need autonomy to do all these wonderful things, but, boy, it's going to take 10 years. It's going to take 20 years." So, to what extent is the technology ahead of regulation? Is regulation pre-regulating autonomy before we know what it is?

Anne: Which panelist said autonomy is more a political problem? Was that you, Joe? I mean, I tend to agree with that. I don't think autonomy is a regulatory problem. I think it's a political problem.

Pierre: So, a political problem in terms of perception?

Anne: In terms of perception.

Pierre: Right.

Anna: Anyway, I think that that's right. It's interesting, watching autonomous vehicles progress, because they seem to be progressing with less of the public blow-back that, say, unmanned aircraft have. I mean, there's obviously concerns, and you hear about the guy in the Tesla who should not have been watching a movie, and died while he was allowing the car [00:12:00] to navigate.

But, that segment of the industry seems to be on a much quicker path to getting fully autonomous vehicles than we are with regard to the airspace. Now, what has really held up the airspace as, I think, both the first and the second panel discussed, was the security concerns, and that is, really, the lay of the FAA taking action. And the FAA is working on a continuum. Julie showed it on his slide during his remarks, which go from low risk to high risk. And so, if we do it step-by-step, then you're seeing a lengthy process before we get to full autonomy.

David: Yeah, so I think the question is the definition of autonomy. And, when we're dealing with these highly complex systems, autonomy can be defined in a number of different ways, for a number of different components. And, for example, when you talk about autonomous spectrum management, there are some systems that work that way, like wi-fi and the like, but there's a particular cost associated with the unlicensed band, and that there's potentially some issues associated with the quality of the service. So, I think, and we are seeing how autonomous comes across, and it sounds like it will work really well, and we're just reminded, today, on some of the so-called fake news associated…

[Mic issues]

David: Yeah, some of the fake news, say, associated with on Facebook and Google, on current news events, right? That's there's algorithms that just do things that miss the context. And, we will get the same thing associated as, Pierre, as you've gone through. You know all the different complexities, for example, [00:14:00] associated with the spectrum interference question, and how can we make that fully autonomous? I think…I'm not sure technology folks have solved that issue yet.

Anne: But I think Dale's question was a good question, and I think that really needs to be balanced into any discussion of how we go forward with autonomy, because, at some point we do need human intervention when we have bad actors. And you could do a whole other conference. I mean, the one thing we didn't hear about today, too much, was drone security and counter-drones, and only now in the military context are you seeing those kind of operations and that kind of roll-out. And I think, local government is at its wits end trying to figure out how to control drones, and I think we'd love to employ systems which the Feds just won't let them use at all today.

Pierre: Anna, do you have any more thoughts about take-aways from your panel? I know it's…you're still processing with Live.

Anna: Right. No, I have a few thoughts. Here are what I thought were the, sort of, top level things I came away with from our discussion. First of all, I thought our panelists were fabulous. I had this roadmap in mind, that we were going to talk about one thing, and then the next, and the next, and it just, sort of, went off on its own. But I still think, I feel like we touched on all of our subjects.

So, first of all, lots going on already. So, we're talking about solutions. There are a lot of things going on already, a lot of multi-stakeholder processes. But, participation by all parties is important, and, at this point, it's not clear the incentives are in place to have everybody come forward with solutions. Hence, the discussion of the XPRIZE, and other ways to bring forward the parties.

Second, we need more flexibility, to allow innovation, but, we must continue to consider our overarching goals. So, that's, sort of, a traditional balancing act. Spectrum use and allocation is getting more and more complicated, due to the proliferation of uses and systems. But, we should consider using market mechanisms to solve problems, even the sharing of spectrum. Finally, gigahertz is a word [00:16:00] and Faberge satellites are a thing.

[Laughter]

Pierre: Very good. Faberge eggs are a thing. You know, one of the things that intrigues me is, this question of flexibility versus the overarching goals. And, I suppose, you pre-answered my question by saying, "It's the traditional balancing act." But, isn't that saying, "I want to eat ice cream and not get fat." I mean, how do we think about that?

Anna: Yeah, I think, this is where being Julie is so hard, because once you have a system, once you've spent money, and you're operating, you don't want to be touched or affected. You don't even want the possibility of being affected by something new. But, innovation brings in something new. Now, say we're talking about cube sats, we're talking about the possibility of thousands and thousands of disposable satellites. That's all well and good until you've got somebody that wants to launch their satellites, or you're concerned about the space debris, and what's going to happen.

But, the rules aren't allowing that, quite yet, although the FCC, of course, has started to relax some of its rules, and the NGSO rulemaking is a good example of how they're trying to permit these new uses. It's just instinctual that if you were the one that has invested in your system, you don't want it touched, and I think that it's important for the FCC to keep that in mind, while, at the same time, making the case for new entry and innovation. It's just tough.

Pierre: And, it's also tough, I think, because people who are in the process of making investments, but have not yet launched deployed systems, use that as part of their pitch to the FCC. It's interesting, wave Tom's book [00:18:00], we've got wonderful history of a hundred years of mistakes. We're talking about new allocations. We heard about a number of them today, and I'm sitting there thinking, it sounds like the same old story, we're asking the FCC to make decisions about, you know, should this be for system a, b, c, or d, or, all three? I'm not hearing people saying, "Let's assign flexible use. Let's forget about overlays." Overlays is a fix for a problem that you already have. So, do market solutions help? Why aren't we using them?

David: Tom was arguing for flexible use.

Pierre: Yeah, I know, right. So, the question is…

David: But that's the legacy, right? I mean, that's the legacy from the ITU rules that are splashing over in this space, like with HAPS. Get spectrum if you can, because the process allows for that in a particular way.

Anna: I was going to say, it's one thing to talk about more flexible technical rules. It's another thing to talk about flexible allocations, when you're talking about satellites and space systems, because, then you've got the complication of the ITU. How do we meet our treaty obligations and our international systems while allowing more flexible allocations?

Pierre: So, does that mean that satellite systems are a special reserve, untouched by market forces in the way that Tom is [INAUDIBLE 00:19:28]?

Anna: That's what they would argue every time. [Laughs] Yes and no. I mean, there's the domestic implications. The question is, are you going to affect the international allocation in our obligations to other countries, and including, operators that are not U.S. operators that may also be operating in the same internationally harmonized spectrum? We heard a lot about harmonized spectrum today, and there's a great benefit to it, but it comes with this additional layer of complications.

Pierre: So, let's just go down the table one last time. If there are any last thoughts or, if not, we can go and have drinks. [00:20:00]

David: Well, I think one notion is that the application space is to be thinking that a lot of application platforms, so to speak, are now being formed by a deployment on these NGSO systems, right? And so, there is…it was raised, for example, Planet, and what they're doing with imaging. There are a lot of different ways that's being used. And, I think we're just starting to scratch the surface, I hope, for that. And so, that you will see a lot of these systems being used in ways that we hadn't seen before. It's hard to, kind of, state that up front and if anybody's got a good idea, they're not going to say, be ready to go public yet, but I think it established the way the internet, early on, with setting up a platform allowed for a lot of cloud-based services. We're establishing, maybe, some interesting new boundaries associated with space that could do the same thing.

Anne: And, I'm going to come at this from an entirely different perspective again, but I did hear risk-based rulemaking and decision-making pop up a little bit, and I, now that I'm more in the aviation world I find that risk-based decision making isn't quite the same option in aviation safety, that it may be in spectrum decisions. The FAA certainly has embraced the concept of risk-based decision making, but on adopting some basic rules, I think they don't necessarily use that as their test, but, then, when it comes time to waive those rules, I see risk-based decision making coming in. But, risk-based decision making, I would posit, is something that should be considered different in the communications and the aviation safety context.

Pierre: Because of safety of life?

Anne: Because of safety of life, yeah.

Anna: Yeah, I agree with that. One of the things we talked about today is the FAA rules that permit small, small unmanned aircraft flights that are part 107. There's a waiver process that permits longer flights…

Anne: And that's the risk-based process I was referring to.

Anna: Right, whereas before, the [00:22:00] way that you could get commercial authorization to operate a drone, it was through what was called an exemption process, or 333. Once the FAA got comfortable that certain types of flights were less risky, they basically started rubber-stamping every one of those applications. They're not doing that now, with systems that don't meet the exact requirements of unmanned aircraft. So, if you want to fly long-distance with multiple pilots, at night, you're going to have to make a showing specific to your system, specific to your aircraft. And, they're not going to say, "Oh, wait, we let this party do it." They're going to say, "You show me exactly how you're going to guarantee safety [INAUDIBLE 00:22:45]."

Anne: And, they won't yet waive that for package delivery, because there's a whole other economic permitting process involving DOT that we didn't even talk about today. That was one of the dogs that didn't bark, was that one. But, yeah, I wrote the first templates for those original exemptions, and it was amazing how I saw my typos duplicated down the road in what people were filing, and I was embarrassed I'd had typos, but they kept popping up over and over again.

Anna: But, that reminds me of a point that we didn't really discuss today, and that is the traditional satellite licensing regime is very system specific, in that, we would start with proposals for certain constellations, and we would build the rules around that. What the new challenge is, is to redirect our thinking toward, how do we allow these multiple entities to coexist with sufficient protections to mitigate problems, but without having to have complete carbon copies of proposed constellations.

Anne: Air traffic management has the same integration issue.

Anna: Yeah.

Pierre: One more sentence that has been too cryptic for me, is that air traffic management [INAUDIBLE 00:23:52]

Anne: Has the same kind of integration problem in a different regulatory context that she's raising for satellites, yeah.

Pierre: Very good. David, you get the last word if you want it. [00:24:00]

David: Nope.

Pierre: Well, we've come to the end of the day. Thank you very much, to the moderators. Thank you to all of you for being here. The lectures are going to be up on the website, [INAUDIBLE 00:24:14]. Thank you very much for coming.