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Frontiers of Space Policy: Fireside Chat with Christopher Yoo

Scott Wallsten:

I'm Scott Wallsten, president of the Technology Policy Institute and for the very few of you who may not know Christopher, I'll quickly introduce him and we can get started. Christopher Yoo is the John H. Chestnut Professor of Law, Communication and Computer and Information Science and founding director of the Center for Technology Innovation and Competition at the University of Pennsylvania School of Law. He's among the most cited scholars in administrative and regulatory law as well as intellectual property. He's authored five books in over a hundred scholarly works and when you see a new area, policy area coming to the fore, having to do with technology, Christopher is going to be there leading the way. Christopher, really grateful for you joining us. Joining us today.

Christopher Yoo:

Thank you for having me, Scott.

Scott Wallsten:

So you led an effort to look at emerging issues in the commercial space age that culminated in a special issue of the Journal of Law and Innovation— Greg Rosston and I had an article there and I think I was solely responsible for holding it up at least six months. What were your key insights from the papers that you included?

Christopher Yoo:

Well, thank you very much and it wouldn't be a cutting-edge issue if you weren't involved as well, Scott. I mean, thank you for being part of that. But I guess the big motivation behind the project and some of the insights is that the rules that we created to govern space are obsolete. They were generated at a time when launches were relatively expensive. Satellites were relatively expensive and therefore relatively rare and, more importantly, were so expensive they were really only [owned] by nation states. And now we see a much larger involvement of commercial entities that increases the need for governance in very important ways, and we started to explore the ways that the existing law was no longer fit for purpose. For example, one of the odd things about space law is that debris falling from space is generally the responsibility

of a single nation state. There's an emerging ambiguity about whether the launch country, the owner, or the country that's the home of the company is ultimately responsible. There was a very well-publicized case where a corporate transaction transferred responsibility to a Dutch entity and the government of the Netherlands refused to take responsibility.

Christopher Yoo:

Basically, the existing rules made for nation states aren't fit for today's purposes. This is an area where academics haven't contributed a great deal. Existing scholarship tends to be very applied, very micro. And I think that there are a lot of different questions, particularly on emerging regimes for allocating scarce rights. We're talking about orbital slots, we're talking about spectrum, we're talking about problems that we just talked about in the Orbits Act with space debris where the regimes just haven't been very well developed. Interestingly, what we've seen is also some fascinating corporate law issues. For example, during the Covid era, three of the major satellite companies declared bankruptcy and there were large international bankruptcies with assets that really surpassed our traditional way of understanding them.

And we also see enormous promise, I think really epitomized by your article, which is that satellite broadband is contributing to solutions that didn't exist before. I think that for example, Australia, which has a large problem with very remote areas, wrote in its national broadband plan that the last few percent would be, served by satellite. Once upon a time that was intended to be a big concession because the satellite service had huge latencies because geostationary orbit is so high above the earth. And that's really changed. For example, I was recently talking with a friend of mine. He mentioned that when they were working with a team member who lives in the rural exurban DC/Northern Virginia area. And one day they noticed that their video link connection was much better and they revealed the reason was that they shifted to satellite, which is providing better service than what they were getting through terrestrial. And so we start to see some really neat opportunities that come through this and I think there's tremendous opportunity for academics to contribute to this conversation in ways that they haven't really yet done to the extent they can't.

Scott Wallsten:

I want to come back to that at the end to see whether academics have suggested any solutions that we haven't thought about along the way. Now you just said we haven't really heard about much: You pointed out that there were lots of bankruptcies in satellite over the last two years. That's really counter to the narrative that this is a new era in commercial space or maybe it's actually completely consistent with it. If the nature of commercial space and entrepreneurship is changing, how do these bankruptcies interact with the narrative of this new era?

Christopher Yoo:

Well, first, we have to bear in mind that many bankruptcies are about restructuring. They're companies that have large amounts of debt that essentially shed it. One of the realities of bankruptcy is the assets that were invested in don't disappear. They basically go through reorganization restructuring. And this is less about the failure of the asset and more about the corporate ownership and the financing structure about it now. But bear in mind, satellite businesses used to be the graveyard for entrepreneurs for the longest time. All I have to do is say the word Iridium and for all old hands like you and me, that elicits a knowing chuckle. And what we really need to understand is that there's different parts of the business that are actually saturated.

A large number of entrepreneurial ventures are attempting to develop new launch technologies, which is an area where there's one that does essentially a slingshot where they put it in a vacuum and swing it around as fast as possible and then try to throw it into space. Frankly, you can see overinvestment from entrepreneurs where the chance of all of them surviving is low. The fact that some of them go bankrupt is not an indictment of the overall sector. It just may mean certain ones are saturated. I will say that during Covid some transitional issues came up, but I think there are some more structural ones, which is, for example, a dearth of launch vehicles. SpaceX is in the fortunate position of having its own launch apparatus and it can control whether it can send things into space.

They are the vendor that provides launch capabilities for many of the other providers as well. But I have no illusions that if they're selling the extra capacity they have, they're going to provision their [own cargo] first. Other countries and other platforms are looking to serve this market, as well. But we see a certain amount of difficulty in [becoming operational]. And also bottom line in the panel discussion that was discussed before, the licensing process for obtaining

spectrum has been so protracted that many of the original plans are behind schedule. And so you can get the financing, which you start paying cost of capital from the day you get it, and then it's a matter of a race to start generating revenue. And the longer it takes you to generate revenue, the bigger hole there is in your business model. You have this constant problem where delays cost money.

Scott Wallsten:

Let's go back to the issue that SpaceX represents a lot of launch capacity right now, [which means other companies are] possibly relying on a competitor to launch their satellites into space. Are the delays in other companies offering service primarily institutional ones in that they can't get permission or are they technological ones where they're just behind?

Christopher Yoo:

I think there's some combination at play. I have to confess, when you hear "new ventures," you and I have heard the bright shiny new object over and over again and people speak with great confidence... we remember when direct broadcast satellite to television probably languished a good 20 years before it started delivering real service.

In addition, it's not just the satellite capabilities of the CubeSats, which are a part of it. Investing in launch capability was an incredibly risky venture as we know from them blowing up. There's questions now about environmental impacts around their launch site, which are still being resolved and probably [were less serious when launch rates were lower]. We're trying to balance all these issues. But in addition to the technical side, I think that a part of it is business and part is regulatory. I don't mean to referee exactly which one is primarily responsible, but I think that on the other hand, other countries are trying to develop their launch capabilities, but the geopolitics that surrounds a great deal of this suggests that, for example, Russian launch facilities probably are not the best venue for US companies or western companies right now. And so a bunch of other factors are starting to matter as well.

Scott Wallsten:

What do you think about the adequacies or inadequacies of the current institutional frameworks for developing and managing space issues? A lot of it happens at the ITU and its conferences

like WRC, which you pointed out is a month-long and takes four years to organize, which to me sounds like the biggest nightmare in the world. But let's see how many enemies I can make here. The ITU has historically been a venue for protecting incumbents and for countries to veto things that they that don't want other countries to do. For example, 20 years ago or so, the US decided to stop playing the international settlements game where they had to send money to other countries [for completing phone calls from the US]. The ITU didn't like it, and the US finally said, enough is enough, and they cut those settlement rates. What is the ITU doing now and does the US have the stature to make big changes anymore?

Christopher Yoo:

So the ITU and particularly the WRC, they're very complicated entities. One is, so the ITU has traditionally privileged as you say, the incumbents. And in fact, there's an aspect of space allocations where it's sort first in time prevails. There have been a number of uproars in this, particularly with orbital positioning because obviously the developed countries got there first and can apply for them first. The most famous incident was in December 1976 when a series of equatorial countries issued what they called the Bogota Declaration that said, we're supposed to have rights to everything above us. The geostationary orbits are there and try to assert some sort of rights. They largely were rebuffed by the ITU, but the ITU did issue article 33 of its radio regulations requiring it to consider the special needs of developing countries. What that actually ends up meaning isn't entirely clear and it actually hasn't had the kind of contention yet.

But you see countries like India as a condition to providing service are starting to put pressure on providers to reallocate orbital rights to them by using their control over the licensing of communications technologies not so much through the ITU process, but outside. The ITU is kind of an odd process in the sense that not every member votes because the ones that aren't current on their dues don't get to vote. And so you see some of that, but more importantly, you've seen the ITU take certain actions that were enforced by say roughly half the countries. I'm thinking really the WCIT [World Congress on International Telecommunications] from, I think, 2012. And for some of these agreements, the fact that half the world doesn't agree with them essentially renders them dead letters, which is the fact the body of the ITU can declare something to be policy, but if people don't comply, we have a problem.

For example, the launch registry maintained by the ITU is maintained very sporadically. Many launches are registered quite late, many of them are not registered at all. And the ability to mandate compliance with that is minimal in the sense that there's no really coercive power of the ITU. So the fact that it's sort of in the best interest of multiple countries to have some degree of coordinating function has not been historically enough to get all countries to comply. I think the ITU is useful, and it's useful to aspire to coordinate, but in the international realm, as long as it's in an individual country's interest not to cooperate, there'll always be a certain gap between what the ITU hopes can happen and what will actually happen.

Scott Wallsten:

I'm hearing a few things. I think one is that the ITU processes really are complicated. There are different ways that countries can interact in good and bad ways. We need some way for different countries to express their preferences. It probably, it's not great, it might be better than an alternative, but also these sorts of complications can be used as ways to prevent things like bringing market-based mechanisms into play. How do we work through all those?

Christopher Yoo:

Well, a couple things. One is that I didn't answer one thing you asked me about the US's role in the World Radio Conference (WRC). Also, when US industry does not coordinate its response, it sort of paralyzes the US negotiating position in the WRC, and when you see competing interests that can be a problem. In particular in the 6 GHz band in the most recent WRC, there was a negotiation about how to allocate that spectrum, particularly between licensed and unlicensed uses. And basically the US didn't have a strong position on this because different parts of the industry failed to coordinate. Going to your more specific question, David Goldman was alluding to this and to pick up on something he's saying and he sort of politely tiptoed around it, but I'm an academic, I don't have to do that quite so much, it's important to take the interests of existing right holders into account.

On the other hand, you and I both know from broadcast spectrum policy that giving too much emphasis to existing customers can allow them to maintain technologies that have become obsolete. Analog technologies were much less efficient in terms of using spectrum to send standard definition, but with a new digital world, we could send [the same information] in one

sixth to one-eighth the amount of spectrum. And that's not the fault of the people who deployed in analog in the day, that's all we had. That was the right thing to do. But at some point, when you give a consistent privilege to existing deployments and then you have an analog broadcaster who'd have to invest in new equipment and a whole different setup, which would cause real cost to them, they would say, that's not fair. We invested in the existing regime. There's real weight to that.

But at some point the importance of the shift to digital technology says we should make the shift and think about ways of making the [analog incumbents] whole by using the "digital dividend," which we did, and giving them those rights. And so we see in this world a hierarchy now of geostationary orbit satellites, which take privilege over all the low earth orbit satellites. And then in the bidding rounds, the earlier bidders getting privileges over the later bidders, you need to create some incentives to make sure to reward them for their insights and their investments. But one of the things David said is having a sunset on them at some point to say they don't always get that privilege probably makes sense because we have a problem when we have expanding uses for certain spectrum. We have to clear new spectrum. We have to create high-powered incentives for people to relinquish that spectrum. And I would say in the satellite realm, that's kind of been slower to come around.

Scott Wallsten:

And what should the role of the FCC's new Space Bureau be in that, and how do you think it should be set up? I mean, some things like having someone like Whitney Lohmeyer who has deep industry experience and a PhD in aeronautics and astronautics seems like exactly the right kind of person you want there. And so do they need to build out more along those lines? Should they start bringing in people who focus more on markets? I mean, I assume they're still trying to figure out their direction, although I shouldn't speak for anybody, but where would you want to see them going?

Christopher Yoo:

Well, first I think that the Chair's emphasis on this is very welcome. I think creating the new Space Bureau is a tremendous innovation. It's traditionally been handled by the International Bureau, which has not historically had the same sort of spectrum licensing responsibilities and

that sort of ability to resolve disputes. And so a big question to me is how are they going to staff the Space Bureau? Are they going to do more personnel who've been in the past or are they going to bring in some of the expertise, say from the wireless bureau who have been used to really managing these kinds of disputes better or some combination of the two? I think that staffing question is critical. The interesting question about the example of Whitney's presence and the Space Bureau is really interesting to me because I think about how engineering issues have been handled in the broader FCC.

We have a chief technologist who's typically someone from academia on a short-term leave. And we've had longer-term officials in the Office of Engineering and Technology or OET. And we know OET has traditionally been spectrum engineers, but there's been a weakness or an omission in network engineering in the basic functions of it because in the era of the AT&T monopoly we largely relied on a commercial entity to provide that expertise for the better part in the first half century or more of the FCC's existence. And what we see is typically the chief technologist is someone that can address the networking side, but because they tend to be there on shorter term stints as opposed to a longer term expertise, they tend to be at the beck and call of the chair for whatever issues they expect to do. And it's much harder for them to get engaged in longer-term development of issues.

And so I think there's a real staffing question, which isn't to say that having people like Whitney and the chief technologists of the overall FCC aren't valuable, but they may not be sufficient. You may need to develop your own expertise within the commission to try to address some of these issues on a more operational basis. Because my friends who've taken those positions, I've often asked them why they get involved in the issues they do because let's just say they didn't always necessarily have, they weren't always the most important issues, I think in the bigger picture. And then we say it takes you about six months to find your issues and then after you find them, it's teed up for decision during your tenure. And those are the things you can affect. And when you're on a short-term basis, you can't pick and choose what to influence because the regulatory vehicle may not just be there.

And so I think there's a huge amount of question about whether we may need more technological expertise in the space bureaus themselves. Frankly, it's kind of interesting. The FCC has become the regulator almost by default in the sense that they're involved in ITU negotiations about orbital slots. And we often look to NASA to do it. NASA is not a regulatory agency, it just

doesn't have that capability. But educating the FCC about orbital debris is a stretch of their capabilities. And yes, it tangentially affects spectrum and therefore service. We can do this sort of ancillary jurisdiction, which they have and stretch it farther and farther, but it is requiring them to develop expertise that gets farther and farther afield from the core competencies for which the agency was created. And that's an interesting stress that's going to happen on the agency as well.

Scott Wallsten:

That is, I mean, what agency do you think should have that authority? Where should the expertise be built? I mean, NTIA gets more things all the time, so do we want to put something else on their plate? What are the alternatives?

Christopher Yoo:

Well, NTIA is part of Commerce and is also historically not classically a regulatory agency. We know that, for example, they're given tremendous grant-making responsibilities initially under the ARRA and now under the BEAD program, which they've had to expand their capabilities. That's not something that they're used to doing. And even that giving grants is different from regulation. I mean, regulation requires ongoing oversight expertise. The economists, the engineers, to actually evaluate competing claims from different actors who are advocating their interests. And you need people in the middle to try to determine policy. At the risk of sounding like, I think it's Winston Churchill who said democracy is the worst form of government except for all the others, I don't really have a candidate to replace the FCC in mind. You could create an entirely new agency, which seems unlikely or ill-advised more importantly. And so it could be that the Space Bureau is going to be the bridge to create that kind of expertise, but it's going to require a fundamentally different type of organizational culture and staffing than they've had in the past.

Scott Wallsten:

Not to push you too much on it, but what direction should they be building?

Christopher Yoo:

They need to bear in mind that this is still an entrepreneurial world in the sense that we talked about launch capabilities. This is not the right time for any government entity to determine, oh, this is going to be the winner or the loser. I mean, it's a very difficult position. And we should also bear in mind that regulatory bodies don't deal as well with areas where the technology is changing rapidly and still requires huge investment incentives. When you think about traditional utility regulation, it's ground zero is water, natural gas, electric power, these things where in many cases the distribution networks are fully amortized and the technology for moving stuff around really hasn't changed in decades. That's the antithesis of this, where you have rules that will have tremendous unintended impacts on new technologies which can't be foreseen.

And where it's very difficult to look at the current state and the particular winners and losers. And we have to bear in mind what matters is the steady state at maturity. We can look at who's ahead and who's behind now, but if we're at the early stages of the adoption curve, it reminds me of when we were deploying radio and the adoption of the radio was in the single digit percentages, certainly well below 20 percent. There was a question about whether we should increase the standards on receiver design to allow them to be tuned more finely, which would allow us to put the channels closer together. And at the time they said, but we would strand the new adopters who've actually purchased equipment because that new technology wouldn't be compatible with them. And the historical criticism is that when when 90 percent of the people haven't adopted, you're putting too much weight on the 10 percent.

We're kind of in that world in satellite where is a moving target. A lot of things that seemed like huge problems have been solved relatively easily. For example, there was a complaint about these moving satellites interfering with astronomical observations. As it turns out, a minimal amount of visual shielding on the satellites was able to accommodate this relatively quickly. And so what we thought might've been a big problem demanding regulatory intervention was handled in a much less intrusive way that allowed the industry to continue to innovate and be flexible. And so it's a new task for an agency like the SEC to shepherd really, they've had experience shepherding innovative technologies through, but this is at a different order of magnitude.

Scott Wallsten:

It seems like one that's ripe for error because it's about predicting the future, which obviously we never know. And it's hard to know what the different opportunity costs are yet. Right?

Christopher Yoo:

And in a sense, when you mentioned markets, when you don't know that, that's a perfect example to let risk capital take its shot, and you lose most of the time, but on the few times where you hit and you hit big is the whole reason that expected value calculation works out. The people who are willing to take the entrepreneurial risks and end up actually solving the technical problems that no one else can solve and make or identify a business model that other people didn't think was going to succeed end up doing very well. And so in essence, it's very natural for us to think, oh, that's a problem. When in fact it's not, it's actually a feature. And in fact it's an essential feature of a system that depends on entrepreneurial investments to drive it forward. Yes, I mean I think that this is the problem. I don't think regulators are very good at this. We know, going back, all the tools we get, price cap and incentive regulation was supposed to unleash these sorts of things. And then we discovered regulators once they see things that turn out successful just can't resist going back in and penalizing them, which defeats the entire purpose of why we struck an incentive regulation the way we did.

Scott Wallsten:

Let me pose an impossible question to you. In the first panel, there was some disagreement, a little bit indirect, between David Goldman at SpaceX and Brennan Price at Viasat, but it was over a technical issue. Part of the question is how does a regulator deal with something like that? They're going to be presented with competing studies because that's the way you have to educate the regulator. We don't want a new entrant to be able to put the incumbent out of business through interference or something like that. But if they have a better business model, they can put them out of business that way. What is the right kind of mechanism we can put into place so that competition happens the way we want to see it happen rather than just by competing technical reports?

Christopher Yoo:

This is where I think academics can contribute a great deal. I would say part of it is an entitlement design that is the design of spectrum rights and part of it's an entitlement allocation. For example, this is something that actually the geostationary people would've worked in their favor had it been structured differently. Geostationary orbits share spectrum, but the problem in the C-band initiative was that they wanted to have the authority to resell that spectrum and redeploy it for terrestrial uses because in the new world, it's quite likely I think that in fact an old use of low, very high latency technology has been replaced by some new uses, which are probably more valuable. And it certainly, the C-band initiative is premised on a recognition by the geostationary industry that they saw that opportunity and wanted to oversee its reallocation. Five of the six existing geostationary satellite operators played along, one did not. And, in the process, defeated the entire initiative. An academic, like me, would call this an anti-commons problem, which is when you have too many owners of the same property, each of whom can destroy the entire value for all the others, it takes an economic form of the game of chicken, which is not the missing win-win of the prisoner's dilemma. It's a win-lose opportunity and it creates unstable outcomes. And that is a very bad entitlement design. We see this and we see tragedy via commons. The person from Viasat noted that millimeter wave is very bad for national coverage. That's absolutely correct. But that's not allocation, that's entitlement design, which is how big do you make the rights?

It would be a mistake to create a national license for millimeter wave. It just doesn't make a lot of sense. It doesn't accord with its propagation characteristics. So part of it's the propagation characteristics, part of it's the economics, which is we discovered when we put out these small cellular licenses, there was demand for national licenses and people had to run around and assemble them, which created holdout behavior and all these other basic problems that we can study better and do design. After you design the rights properly we then have to allocate them. And the answer there to me is Coase, and Coase isn't just about auctions. This is also about challenging the notion that the first-in-time user always the best user. And that in fact, it's about reciprocal causation.

It's not just the new user who's coming in and causing the problem. It's the two users who want inconsistent uses. And one of the designs was not just auctioning, but to try to find ways to reallocate spectrum across inconsistent uses so that we can enhance market techniques to do it. And what we're seeing now is the existing regime, which sort of prioritizes existing users over

new users, and then takes sort of a split-the-baby approach, is (A) actually inefficient, and (B), inviting games because if the regulator is going to simply split the baby, there is a huge incentive to, for example, make more and more extreme requests because then you're moving the half of the split farther and farther to one side. An interesting alternative might be what we call baseball arbitration, where both sides present one side and you pick one or the other, which has a tendency to moderate demands.

There's a lot of dispute resolution mechanisms we can discuss, but the ones that we have right now are not designed to create high-powered incentives to encourage agreement and to create more about can you encourage claiming behavior? It can reward and it creates a bad mechanism for reallocating uses that were once justified in their day to higher uses now. And so in some ways, we are experimenting with the incentive auction to try to do this with broadcast spectrum. And I would look to newer mechanisms and other forms of incentives to try to reallocate spectrum because this problem is only going to grow.

Scott Wallsten:

You started off by saying that the government has a particular role in defining X. And then from there we have market mechanisms. The point being that there's no such thing as an absolutely pure market mechanism because somebody sets the rules. Can you say again, in this world, what is the government's role? What should government set up, and then where should we push on market forces?

Christopher Yoo:

The government clearly has to represent the interests of United States companies in organizations such as the ITU for global satellite allotments and spectrum allotments. In addition, once those have been allotted, I think they have a role in advocating for standardization. Spectrum allocation and service authorization remains a matter of national law. And we are a leader here. One of the frustrations from the companies attempting to deploy satellite broadband is the one-off negotiations they have to have with every single country about the terms under which they can enter and getting spectrum allocated to them and the likes of that. And in some ways, I think having talked to some of the developing countries, they actually are open to some degree of

standardization. They don't know what proper terms are. They're deathly afraid of being taken in the negotiations.

And if there was a broader sense of better information about what a reasonable settlement was and what seems to be effective, I think it would speed deployment, which would benefit the service providers, the citizens of these countries. And assuming it creates a fair division or allocation of the benefits across the countries and the companies, I think that would potentially be liberating once it's been assigned to the countries. Even in the most market-oriented economy, the government defines and enforces property rights. And that's an essential irreducible element here that I think that the government has to serve. And mediate disputes. That's something we probably haven't made as much progress on since, if you will, the sixties and seventies.

If you look at the debates about how we handle those sorts of disputes, we're really not much farther past than where we were then and maybe incrementally, but the terms of the debate remain largely the same. My colleague, Rakesh Vohra, has this wonderful article about even licensed uses where pricing doesn't work very well because transmitters at the edge of the service area can interfere with each other because they are designed to reach the base station, not each other. He said, you can never get perfect pricing because it's going to be dynamic. On the other hand, he's experimenting with second best pricing, which does a reasonable approximation. We're going to end up with having those sorts of rules take over in all of these areas because as of right now, anytime a LEO goes below a GEO, I think under an 18-degree arc below it, it has to shut off. And so then all LEOs have to come at an angle to serve, and it causes, in my opinion, extreme inefficiencies. And there's got to be a way that we could refocus this in terms that would allow this to be used much more efficiently.

Scott Wallsten:

Are there any analogs outside of space and satellites, maybe even something that deals with a smaller number of dimensions, but does deal with the international component that has been successful in bringing market mechanisms to bear, maybe pollution trading credits? I don't know. Is there something we can learn from?

Christopher Yoo:

Well, I guess if you want to, I'm going to take your suggestion not to move away from spectrum, but move from satellites. We always have to remember that receiver technology is an alternative to spectrum policy. And one of the great frustrations, we saw this with the altimeter dispute about when the companies tried to turn on 5G. I hadn't realized it until a couple of weeks ago, the fix was 30 bucks. And it's quite shocking. I'm pretty convinced that if we had, if you had created the option for the phone companies, they would've written that check willingly in that it was apparently among others, Boeing, who was very much in the way. And we've learned over the last several months, sadly, that Boeing doesn't always make the best engineering decisions here. We saw this with receiver technologies, with radios and the like.

The funny thing I keep thinking is creating the incentives for doing those sorts of things would be helpful. The beautiful thing about satellites is they create opportunities for both simultaneous terrestrial use and space-based use to an extent that wasn't possible before. And it's interesting that we may see experiments of using side loading through different forms of terrestrial uses as well as satellite uses that could augment things in ways that I think would bring opportunities as well as costs. And we've become better and better at discerning the sources of signals in different ways through MEO technologies and the like to actually try to detect better and better how things are working. And I think that there's a tremendous amount of opportunity – who knew that antenna design would be such a hot potential topic in space and communications? But now it absolutely is in a way that wasn't on our radar for a very long time.

Scott Wallsten:

We're running out of time, but five years from now, how will we know whether our current approach to space has been successful or held us back? I mean obviously, there's never any way to really know the counterfactual, but we've talked about all kinds of problems that exist, and yet we've now got LEOs doing all kinds of things. Kuiper is going to be joining Starlink soon and the EU might launch something. So maybe it's not as bad as we're saying, right? I mean, good things have happened. How will we know if we're on the right track or not?

Christopher Yoo:

How do we know now? I would say that I keep thinking about a short article by Shane Greenstein in I think what is now the call Colorado Journal of Law and Technology, I think may have been the Journal of Technology and Telecommunication in high tech law. Called "Glimmers and Signs of Innovative Health in the Commercial Internet." And he asked the question, what does a healthy innovation environment look like and how do we promote it? One of the things he talked about was obviously investment - people who are putting skin in the game to try to deploy things, I think is a sign of a healthy environment. He thinks standards competition was sign of a healthy environment where people are buying with each other, which is often interpreted as through an anti-competitive lens.

But I found that really interesting. Increased usership is a great barometer for us to see the potential of these. And I think those are all very encouraging. But what I would say is someone had mentioned direct-to-phone, and this is really a very exciting prospect because first it radically potentially lowers the cost of deployment. But to go outside the economics where we largely focused, one of the problems, I always teach my class, Bill Clinton famously said, trying to regulate the internet is trying to nail jello to the wall. And I always say, well, Bill Clinton hadn't known about China yet. And what we've learned is that as long as there's a terrestrial facility, whether it's a cell tower or a telephone central office or a cable headend that's necessary for distribution, governments can control them. I mean, it's just the way it is. Direct to phone satellite eliminates that possibility.

And even satellite, you have a satellite dish out, it's relatively small, it's distributed, but it has to be visible to the sky. And over time people can find them. Enforcement officials, highly motivated enforcement officials can close that link. Direct to phone is pretty exciting. And the other thing is then they're forced with perhaps jamming spectrum, which is expensive but possible. And they're now talking about laser-based links, direct to phone, which is visible spectrum. And then suddenly you start to see a dynamic environment that's pretty stunning and that I would be excited to see possibilities. They're already using lasers for what they call inner satellite links because as the constellations go across one satellite zooms out of range, they can now use lasers to backload information to the trailing satellite to make sure that you maintain connection and service. There's a lot of different things like this. This is all fantastic, very, very exciting to me. Very, they're all dual-use technologies. We have to take the negatives into account in a very serious way, but I would be very worried about, it's easy to conjure up that would lead

us to cut off certain directions of innovation. And the danger is there's as real a danger that we use too little of it in the future as we do too much and it's causing problems.

Scott Wallsten:

So that is, well, I'm mostly optimistic place to leave it. Christopher, thank you very much for talking with me today. It's really interesting. Really appreciate your time.

Christopher Yoo:

My pleasure.