switching costs a little bit more which is a variant on that idea. And why I like that better is I think it explains a little better why incumbents and I think the FCC are terrified about the implications of software-defined radio for spectrum policy because of the impact on switching costs. The last thing an incumbent wants is to make it very easy for, I think, consumers to comparison shop and shift around and SDR offers that in heretofore inconceivable way and also as to specificity, it's always been associated with telecommunications and spectrum policy where assets are closely tied to spectrum and SDR disentangles the two with I think really revolutionary consequences for thinking about spectrum policy.

So my first question to you is really what are the implications of SDR for spectrum policy? I certainly don't think the FCC has remotely grappled with those implications.

And secondly, what is the political analysis of SDR? Why does there seem to be such resistance to thinking through the implications? Is this just because it's a novel technology or it's economics are not -- poorly understood? Or is there some political dynamic that mitigates against

it, efficient use of technology to eliminate scarcity.

DR. KOLODZY: Okay, does anybody want to take those on? I think the second question I want to push back a little bit, it's a political question and I don't know if that's a bunch of technologists that we have here and being an technology oriented panel, we might not be able to address that, but I think the first question is a darn good one. Does anybody want to address that?

I'm looking at Bruce.

DR. FETTE: Actually, I'd like to take on the second question a little bit.

DR. KOLODZY: Okay.

DR. FETTE: The service provision of cellular telephony, for example, requires a tremendous infrastructure that hides behind the cell phone. We all see the device that fits in the shirt pocket or hangs on the belt clip as a very small device and yes, it's true that when you have a software-defined handset, it's possible to provide that handset with a wide variety of functionality and provisions, but the infrastructure behind that is really what the customer is paying for when he pays the monthly

bills. And it's very easy to forget that the investment associated with the infrastructure behind the cell phone is truly a remarkable investment and while our cellular providers have rolled that out rather quickly, the fact is that they expect a return on that investment and sometimes that return on investment takes a very long time and because it takes a very long time and the technology evolves during that time, an SDR is actually a way that the infrastructure can keep up with what people are expecting to get in the way of service provision at their handset. So I would like to share that idea with you.

The more sticky problem of how the FCC grapples with the implications is -- back to you, Paul.

MR. SHARKEY: You know, I guess, your point on companies being afraid of this new thing is a competitive aspect. I haven't heard that when -- in discussions on SDR and I think one of the -- it seems like it's been more of an implementation issue on technical interference which obviously can also be used to to mask competitive reasons, but I think the reality is SDR technology, there are many levels of it and while radios are developed and are

here, I don't think consumers are going to be to the store and making a choice between SDR and the cell phone any time soon. The costs are very different for an SDR radio right now and you're not going to put it in your shirt pocket. I think that there are very different expectations from what a consumer wants from a cell phone and driving the costs down, getting it out to as many people as possible and deployed as widely as possible, then you would get from an SDR, at least in the near future.

MR. SNYDER: If I could just interject. When I use SDR, I'm talking about something much more ambitious than I think you have in mind. I'm thinking of Vanu Bose's zero to 2.5 gigahertz system. And when you think about some of the oppositions, just think of number portability. You're in the cell phone business and the resistance of the cell phone companies to number portability. People have been talking about it for decades. The last thing Sprint or Verizon or anybody else wants is for you to easily be able to switch from one cell phone company to another so there's this infinite resistance and this is a trivial element of switching costs. We're talking

about a complete revolution where you could go up and down the dial and buy the cheapest bit. I mean no incumbent is going to, I think, want that type of scheme because it would make it so much more efficient and they'd lose their market power.

MR. SHARKEY: And I don't think that that technology is ready to be deployed in that way either.

MR. PITSCH: Could I jump in?

(Laughter.)

I want to answer the second question to. Intel is a great fan of SDR. I don't know if Mike Shardier is here. There he is. He's on the forum as well with Bruce.

MR. SHARKEY: Motorola is a big fan of SDR too.

MR. PITSCH: Okay. And I think we need, what the Commission needs to do is come up with mechanisms. As I said commons and rights approaches will actually, could enable SDR and other technologies much more quickly than we have in the current environment. But to respond to your second point, that goes to the practicality question because can curse the darkness or we can light a candle. Okay? I mean people have rights.

The United States is a country of laws and people have a constitutional right to come in and tell the Commission you can't allow this new service and they can raise lots of legitimate interference questions and guess what? They can be secretly in the dark of their heart motivated by fear of competition reasons, right? Okay. But how do we solve that problem? I mean we can blithely say well, oh let's just impose a noninterfering easement over all the spectrum or we could blithely say let's propertize, if that's a word, everything. But those things aren't going to happen easily and in the near term. So let's be practical, okay? In the next five years, let's look rigorously and practically at creating some easements, creating more common spectrum, getting more five gigahertz on license spectrum and let's also look at creating a simultaneous exchange where we can create flexibility, define property rights, use voluntary mechanisms which guess what, are going to be politically easier to do than simply going in and taking things away from people. Let's look at both.

DR. FARBER: Yes. I was spittering and spattering. All my instincts say that if you

create the marketplace, you'll find a software-defined radio in my pocket within a very small amount of time. Right now the marketplace isn't there to really push it and that's something the FCC by changing its rules can encourage.

There may be actually, a little aside, one of the big problems that a lot of us see is that a lot of the spectrum is controlled by our friends over across the river in the Pentagon and that spectrum is a very valuable space for them. On the other hand, they hardly ever use it, especially in the continental U.S. Their problem is when they want to use it, they don't have to have to negotiate with anybody to use it and that seems like, in fact, an ideal place for innovation for software-defined radios, for agile radios who can get, who can use space, but get out of the way when the owners need it. And it's probably an area where, in fact, one could do some meaningful research and meaningful application as opposed to challenging say a TV company whose main value is the alleged value of the spectrum quite often.

One other thing and I'll shush. No, I won't --

(Laughter.)

I've mentioned the word research. One of the big problems I see coming down the road is that we have very few places to do advance research now in this area. The economic situation, the decline of almost every major research laboratory in the United States is going to have a big impact on our ability to move. As a sidebar, I point out that, in fact, a broad -- some research labs are growing fast. Ours are declining. Somehow we have to respark the research that got us largely where we are and that's a nontrivial job.

DR. KOLODZY: I'll just make one comment. Actually, one of the things that you mentioned there about the technology with the defense world is that actually there's some projects going on at DARPA right now that people can look into and actually try to address some of those questions.

Dave, you had one quick question or comment?

DR. REED: Yes, just a quick comment on software-defined radio in the cellular space which you raised. It's very clear that software-defined radios that can support at least the agility among all the different types of cellular technology and

all possible bands that we might bring into use in the future are there today at the infrastructure level and what's interesting is the argument that Bruce made that what seems to be the economic barrier there is just the spectrum. In fact, we could have a lot more competition for the same handsets and so forth technologically just by allowing an operator to operate a software-defined bay station network that could handle all kinds of things and then capital investment of the operators could be much lower. And I think that type of thing would benefit, would immediately benefit everybody if the regulations enabled that and they do block it in many ways today.

DR. KOLODZY: Okay, now we have lots of questions coming up there. Ed?

MR. THOMAS: Yes, I have a question for anybody in the audience or the panel, vis-a-vis software-defined radios. Is there anything in our rules right now that are inhibiting to their development, especially when you look at the flexibility that's in the unlicensed rules and a couple of a years ago we did, in fact, authorize software-defined radios? So is there any big obstacles in our rules right now that inhibits the

development?

DR. REED: The main thing is licensing by use that Commissioner Powell referred to which is the tying of specific uses to licenses.

MR. THOMAS: Okay.

MR. STEVENSON: Carl Stevenson, Ager Systems and I had a question for Mr. Rittenhouse. Did I hear you or mis-hear you when I thought I heard you make the comment that Wi-Fi was spectrally inefficient?

DR. RITTENHOUSE: It's spectrally inefficient compared to the shared channels that you find in 3G systems.

MR. STEVENSON: Okay, I think my colleagues 802 would probably draw and quarter me if I went home without refuting that. We've constantly improved our spectral efficiency and our data rates. We've gone from 1 megabit to 11 megabits to 54 megabits in the same spectral mass. The spectral efficiency also comes into play because of the low power and the very, very small cell sizes which allow an incredible amount of frequency use, so I would disagree vehemently with your contention that Wi-Fi is spectrally inefficient.

DR. RITTENHOUSE: Yes. Those peak data rates certainly do go up, no doubt about it, but just the multiple access schemes tend to be very inefficient with respect to a shared channel scheduler, for example. So the average throughput is -- would be the more appropriate, not the peak data rate.

DR. KOLODZY: Questions?

MS. ARBAGAST: Rebecca Arbagast with Legg Mason. Now as I've been listening to the comments this morning, I've been struck oftentimes by tensions or at least potential tensions between various goals and objectives that people seem to have and that's not a criticism. I think my experience at the FCC was that that's just a fact of life that makes the job much more difficult.

One of the tensions that I'm wondering if people could speak to is the desire on the one hand to have more precise definitions of rights and on the other hand having a regime, a regulatory regime that allows for greater flexibility and the ability to evolve across time. In my experience in trying to draft rules that was to me the hardest thing that we grappled with. And I guess I have a two-part question. The first is when folks are

saying that they would like to see greater precision and certainty in definitions of rights which I think we would all agree is a goal and now in my job trying to persuade investors that there's a place to invest in this industry, I think one question I have is what else are you talking about besides a definition of harmful interference? Are there other aspects of that property right definition that are important to you all?

The second question is if you're talking about definitions of freedom from interference and an acceptable ability to give off interference, is there a way to do that without, in effect, curbing the range of uses that a particular spectrum can be put to. Those are my questions.

MR. SIDDALL: Rebecca, I guess to try to answer that, let me first of all back into it by answering Ed's question on software-defined radio. Let me use the example of personal communication service. There is no technical standard. You can put anything in that band and provide PCS. I'm not the -- I'm a lawyer for this purpose. I'm not sure what the technical aspects would be, but at least 15 or 30 megahertz you can aggregate by buying your neighbor's as shortly the spectrum cap comes off or

will come off. So in rural areas you can do that. So I'm not too sure that your rules are inhibited that way. PCS specifically was not defined by the service provided, nor did it adopt any technical standards.

Rebecca, with regard to the flexibility property rights thing, I guess I would see the Commission would be beneficial to move to something that I call the constitutional model and that is in the U.S. Constitution there are many provisions written by our forefathers 250 years ago. Around the edges we're still arguing about what some of that language means.

(Laughter.)

I guess every day down in the Supreme Court, but you can define areas so people understand without getting so specific as to constrain future options and allow things to move in the natural way and to the extent the Commission can define spectrum rights in a way that can be interpreted and flexible, not to specific, but not so amorphous that nobody knows what the heck you're talking about, I think that's the model that should be followed and would resolve some of these issues because it would have meaning today, but there's

the flexibility that it would still have meaning through some interpretation in the future.

MS. RATH: Do you have an example in mind?

MR. SIDDALL: With regard to?

MS. RATH: I'd like to actually understand that piece a little bit better and I don't want to jump ahead to the solution sections of our questions, but that's -- it's a really wonderful thing to say, but then to give an example of how you would actually do that, I think that's the challenge to the Commission.

You could do it, if anybody could.

MR. SIDDALL: Well, in fact, I tried to do it 10 years ago which is why I used the PCS. If you look at the PCS rules and I think this is an example that already exists. You have certain limitations with regard to the power that you put out. That actually defines what the interference rights are, assuming that the spectrum owner of the spectrum licensee has exclusive use of that spectrum. Now with that information, you have a geographic area. You have a right to emit up to certain powers. They're limited at the boundaries of that geographic area. That's what I would call

a constitutional solution, to be honest. You can put in any technology, including software-defined radios with or without repeaters. Do it any way you want. So it has the possibility of evolving with technology. And yet everyone knows what that is today. It can be something very different 20 years from now.

MR. PITSCH: I would build on David's points. They're excellent points and PCS is the model and you only need to contrast it to the early days with cellular, where the Commission got so many things wrong and in PCS they got so many things right.

This is an excellent question. If we're going to be serious about this, we do need to define rights. I give all the credit here to Evan Kwerel and John Williams and people before me who worked on this, these ideas. But there is an opportunity to identify a swath of spectrum and the Commission would have to go in first on the interference questions and focus on outputs as Professor Krattenmaker said which means emission set boundaries, geographical and spectrum and PCS took that approach.

The other kinds of definitional things

that have to be cleared up have to do with not having exhaustively assigned spectrum. UHF is a great example. The Commission has on a demand basis allocated and assigned a lot of spectrum to areas, so if you look at the spectrum today, you have holes. The Commission has to assign the swiss cheese part, right?

And the point here is by doing that, creating those rights and defining them better, you allow for efficient transactions to occur. Because if you don't have good output restrictions, if you don't exhaustively assign a spectrum, then you're not going to enable voluntary efficient transactions to occur where they should occur. And just to lay out and complete the idea where which I'll want to discuss some more in the solution section is the Commission could do this under current law, an awful lot of this. I'm not today going to say what 300 megahertz the Commission ought to identify, but it could do that. It could say we are going to create a simultaneous exchange. We are going to give people on this 300 megahertz flexibility. You can voluntarily participate or not. And if it were to do that, there would be many benefits. The most important

would be it would dramatically reduce the scarcity of the spectrum and I would argue it's that what would drive SDR. That's what's holding SDR in new technologies.

MR. TAWIL: No. What I'm hearing from Peter is reasonable in the sense that you need to use the spectrum more efficiently, but one issue here is once you define the property rights and interference rights, especially the interference mitigation rights, I think you could do a lot.

The key is you have to make sure that you keep enforcing the interference rights and that's what's been happening in the past. In the broadcast band, we had interservice sharing rules in the 478512, the interference boundary was defined. Both services are working more or less, but the problem right now is people are relaxing those interference rights. But interservice sharing, once you to define the property, both services have flourished. And the key is to define them and enforce them. Enforcement is a very important part.

DR. KOLODZY: Any other questions?

MR. LEWIS: I had one, Paul, which is for the whole panel. I heard Jim Lewis of CSIS.

People talk about commons and of course from a historical point of view, the problem with the problems is it guaranteed inefficient use of resources. And so the issue is how do you transition to a better use of the resource or a more productive use of the resource? And that sort of is issue 1.

Issue 2 would be you've talked about a system designed for AM radio and that's bad because the technology has changed. Yet, we seem to be focusing on an SDR so the question I've had is you take those two things, the problem with the commons is how do you transition to more efficient use? The question I'd ask is how do you not only transition to SDR, but how do you have a process that will let you transition out of SDR when it's time to do that?

DR. REED: I'd like to just comment, a couple things. One is the commons model is actually, although popular, is kind of a misnomer because the traditional definition of a commons is a fixed resource that needs to be shared and in fact, the capacity of the spectrum appears to have no particular limits, if proper understood Shannon's law -- Shannon's work and what's built on

top of it in multi-user information theory indicates that it's at least feasible and looks like the developments are at our doorstep to make a situation where the commons is such where the sheep bring their own grass, as we mentioned in an earlier session. That is, the more sharers in a region of spectrum, the more capacity if they organize their activities right. And that's quite different. That means that manufacturing spectrum is possible by end user investment or intermediaries that they pay. Manufacturing capacity. They can't manufacture spectrum. So the commons model is basically applying the idea of everyone sharing to a resource that is not limited as the commons so we probably should call it something different.

The second thing that relates to that is how do you make a transition. I think there is a danger in the transition and this is something I tried to emphasize even though I strongly think we should make the transition that the first -- it's sort of the potential for what I might call carpetbaggers invading the truly unlicensed space who decide that they're going to use old, badly designed radio system architectures, transmit at

infinite power and act, in general, badly. In the long run, those kinds of things won't be a problem, technologically, because in fact, there are ways to isolate even bad actors as long as they don't form the majority of users, but that relies on technology advances we haven't seen yet and we need to sort of ease the transition into that space and I think the kind of ease of transition that's important is some kind of certification of software-defined radio, a certification of network protocols that is lightly imposed, not used as a tool of competitive economic challenge, but such that it continues to allow that process to pass.

MR. TAWIL: The reason I've been quiet is I haven't figured out how to get myself to define radio and broadcasting. We use our spectrum. We transmit on the spectrum. We probably transmit it with a very high powered transmitter and we transmit all the time on all that spectrum. We don't have holes.

DR. REED: Actually, maybe I should comment on broadcast because there's an assumption that broadcast needs to be high power. We do broadcasting on the internet today with internet broadcasting through a network architecture

approach where there are repeaters distributed through the network and so forth and in fact, experimentation has happened in the past with what was called single frequency networks which allow spectral re-use, even though the content is literally broadcast to the end points and that single-frequency network uses a lot lower power and so forth. You can do the same thing with ad hoc mesh networks in the long run where, in fact, the bits of the broadcast are constantly being made available to the end users without transmitting all that energy and interfering with other users.

So in the long term, I'd like to see us evolve away from these legacy architectures that were great when radios were really expensive, but are pretty inefficient, given the state of the art.

If we were to try to build a broadcast network today for typical commercial television content, we wouldn't build it the way we do.

MR. TAWIL: I don't disagree with you on that, but the fact it has been built, it was built for 50 years and the question is you need to transition it. That transition will take time.

Obviously, flexibility in the way you assign that spectrum for that broadcasting would be

able to transition to that. But you have to realize one of our biggest problems is we have a legacy issue. We have a 250 million sets out there that have the legacy issue and sometimes we always are very much interested in moving, but we have the problem that you've got to build the receiver end of it. You have got to worry about the receiver end of it because you don't own that portion of it.

DR. REED: Right. That is analogous to the PC world, for example, where we have natural evolution of the architecture. We don't still use DOS machines used 30 years ago to do our work and the customer expects that. I think a combination of changing customer expectation around the value of their legacy sets and realizing that even if we were to pay off every owner of a television set $100 to switch to something new, that's a tiny fraction of the kind of cost we're talking about imposing on the future, on our children in terms of innovation costs. So that's worth thinking about, if not definitive an answer.

MR. TAWIL: Again, I do not disagree with you, but you have to realize it's a very, very mammoth effort here.

DR. FARBER: You also don't -- we're

talking about technology, guys. You don't have to, even though it would be pleasant to throw everything up in the air at the same time, I think it's reasonable to not do so in practice here in broadcasting because of the large number of legacy. It's going to take time to wiggle its way into the future. That doesn't mean that one should use as an excuse for doing nothing, with the rest of the space.

MR. TAWIL: I have to disagree with you on doing nothing. I think the broadcast industry and -- we have done a lot. I mean we have done a lot. If you look at the history of spectrum and 50 years ago, we actually operated on 500 megahertz of spectrum. Today, in the next 5 to 7 years, we'll be operating on 280 megahertz of spectrum. We did a 40 percent reduction. We're moving from analog to digital and we're doing it.

DR. FARBER: I just can't resist. You should come and visit me some time and watch the terrible interference that my receivers get from stations that just dramatically interfere with each other.

MR. TAWIL: I'm sorry, could I go on more?

You have to understand this is an open system, broadcast to transmit, and it's an issue of who built the receiver. And if the receiver doesn't have the proper immunity, you've got some problem. So let's make sure when we put the blame on here is we -- broadcasting is an open system. We control one part of that system. The second part of it is not controlled.

Receiver standards are important. I think there's a lesson, historical lesson here. We have for the past 50 years, probably developed building a receiver out there and guess what, they don't perform any better than the first receiver that was built in 1952. It's too late now, but I think there's a lesson to be learned here. You can't only look at the transmitting end and forget about the receiving or the collector end of it. That's how we're going to deal with interference.

DR. KOLODZY: Questions?

AUDIENCE MEMBER: Listening to the course of the conversation, it becomes easy for me as a nerd to accept the fact that the technology is such that the frequencies space is largely unused and not very limited. Now that I'm a self-admitted nerd, attempting to think like a wonk for a second

here, I examine why there might be inertia to giving up portions of allocated frequency space. First of all, I will admit that I'm not familiar with how long these allocations are in effect or whether there's a fixed cut off date or how someone can lose that space other than through direct FCC decree, but it seems to me that one of the economic reasons for that inertia may not be so much -- certainly there's a possibility of the unwillingness to accept competition, but it seems to me that some previous statements that were made about the costs associated with existing infrastructure provide a viable service now even with a company that's a good player is a factor here. The question I have is is there any type of in conjunction with defining what is a inappropriate interference or incorrect interference, purely from a technical point of view should there be some type of economic set of models with respect to those infrastructure costs that are also taken into account in the equation when you make that type of decision that might be played into the rules for allocating frequency spectrum in the future.

MR. PITSCH: Actually, you raised a