
REPORTER'S TRANSCRIPT of COMMERCE SPECTRUM MANAGEMENT
ADVISORY COMMITTEE (CSMAC) MEETING at the
NATIONAL INSTITUTE OF STANDARDS and TECHNOLOGY,
BOULDER CAMPUS
325 BROADWAY STREET, BOULDER, COLORADO, 80305

Monday, August 1, 2016, beginning at 1:00 p.m. MDT

NOTE: The primary cause for the use of "(indiscernible)"
statements in this transcript is due to
participants not staying in close proximity
to the microphone or poor recording conditions.

1 UNIDENTIFIED MALE: All right. I think
2 we'll get going if everyone is ready. Welcome to this
3 edition of the CSMAC. I'm going to just turn it over
4 right to Glenn welcome us.

5 GLENN REYNOLDS: So I'll start off by
6 welcoming everybody to the Boulder labs. I think for
7 those of you who haven't been here before, hopefully,
8 you've had an opportunity to look around.

9 Obviously, this is a facility that is
10 jointly used by NIST, NOAA, and our ITS labs down at the
11 bottom of the hill in the parts that don't look nearly
12 this nice. And we'll just leave it at that.

13 Once again, I get the privilege of kind of
14 representing the assistant secretary at this meeting.
15 Larry had fully intended to be here today, both to kick
16 off this CSMAC meeting.

17 UNIDENTIFIED MALE ON TELEPHONE: Hello?
18 Hello?

19 UNIDENTIFIED FEMALE ON TELEPHONE: Hi,
20 there.

21 GLENN REYNOLDS: Folks, for those of you who
22 are on the line, can you please --

23 UNIDENTIFIED MALE ON TELEPHONE: Is this the
24 CSMAC meeting?

25 UNIDENTIFIED FEMALE ON TELEPHONE: This is

1 the CSMAC meeting, at least I think so.

2 GLENN REYNOLDS: This is the CSMAC meeting
3 and can everybody mute their phones, please.

4 UNIDENTIFIED MALE ON TELEPHONE: Because
5 it's started, but I don't hear it through the phone.

6 UNIDENTIFIED FEMALE ON TELEPHONE: Huh.

7 UNIDENTIFIED MALE ON TELEPHONE: I'm hearing
8 it online.

9 LARRY ALDER: Can you guys hear us? This is
10 the conference room.

11 UNIDENTIFIED FEMALE ON TELEPHONE: Uh, let's
12 see (indiscernible) --

13 (Background conversations from telephone
14 participants)

15 UNIDENTIFIED MALE: Okay. We'll see if we
16 can figure out the folks on the phone. Again, I don't
17 know if you -- I assume you can't hear us.

18 UNIDENTIFIED MALE ON TELEPHONE: There's
19 about -- there's a two-minute delay between the video
20 and the phone, and we cannot hear the meeting through
21 the phone.

22 UNIDENTIFIED MALE: We can hear you, David.

23 GLENN REYNOLDS: Yeah, that's why I'm a
24 lawyer. Guys, all I can say is we're going to try to
25 fix it on the phone as quickly as we can, but please

1 bear with us.

2 As I was about to say, Larry had fully
3 intended to be here with us to kick this off, kick off
4 this last meeting of the CSMAC, as well as to give
5 opening remarks tomorrow morning at the ISART meeting
6 down the road.

7 But, Larry is, as you all know, kind of
8 coming to the end of the administration. And Larry has
9 been trying to figure out what he wants to do next with
10 his life. And so he's decided to follow his real dream
11 and try to pitch for the White Sox.

12 And, as a result, the first step in that is
13 he had to get shoulder surgery last week. He says it's
14 a rotator cuff, but we're all kind of skeptical. I
15 think they're putting new muscle in there or something.
16 But anyway he, unfortunately, is on restricted travel
17 for three weeks. So he could not get out here.

18 So he sends his regards and he sends me here
19 not just with his welcoming, but with his appreciation
20 for all the hard work of this iteration of the CSMAC.
21 Looking back at this CSMAC -- we're still having some
22 issues I hear.

23 This CSMAC, when you look back at it, has
24 spanned a remarkably transformative period in this
25 industry, if you go back and look, starting with last

1 January with the record-breaking AWS-3 auction, which
2 closed and set all sorts of records for money for the
3 treasury and other things, but which also included rules
4 for proactive sharing that were developed through the
5 CSMAC process.

6 Then last April the FCC adopted truly
7 innovative tiered sharing arrangements for the 3.5
8 gigahertz band, placing new sharing technologies truly
9 in the mainstream of spectrum management. Ow, that
10 hurt. I don't know if that was me.

11 Then this year we're witnessing the first of
12 its kind incentive auction, an out-of-the-box effort to
13 create a win-win opportunity to repurpose spectrum for
14 brand new services.

15 But perhaps the most remarkable sort of
16 transition that we've seen over this CSMAC's lifetime is
17 watching the idea of 5G wireless go from something of a
18 vague concept to something really real, underscored by
19 the FCC's recent Spectrum Frontiers order, which gives
20 the U.S. a tremendous competitive advantage in the next
21 technology cycle by putting to use millimeter wave
22 spectrum for advanced wireless broadband, spectrum that
23 was barely on any of our radar screens when this CSMAC
24 convened.

25 So this last meeting of the current CSMAC is

1 a bit of a transitional milestone itself in that we're
2 looking both backwards and forwards. On the one hand,
3 we can take a brief moment to appreciate all of the hard
4 work that all of you have put into this, the committed,
5 forward-looking work that is reflected in the final
6 recommendations of the working groups that we heard at
7 the meeting two months ago, and then the work that's
8 reflected in the reports, in the papers that we're going
9 to be talking about today.

10 The work of the CSMAC has already made
11 important contributions to spectrum policy and will
12 continue to do so as we take on the next spectrum
13 management challenges. But after we take that breath to
14 appreciate the hard work of this group, we'll be right
15 back to the blank white board as we look forward and
16 finish this meeting up with the discussion, trying to
17 identify what issues we should be looking at next. As
18 the saying goes, no good deed goes unpunished.

19 In closing, I just wanted to first recognize
20 two special guests we have here today or at least one
21 that's here and one that hopefully will be here
22 momentarily. Julie Knapp is here from the FCC.

23 UNIDENTIFIED MALE: Got his own table and
24 everything.

25 GLENN REYNOLDS: Exactly. We had to stick

1 him in his own location. And then, hopefully,
2 momentarily we will be joined by Keith Gremban who is --
3 oh, Keith is here. Okay. Keith made it from our staff
4 meeting.

5 UNIDENTIFIED MALE: He doesn't even get a
6 table.

7 GLENN REYNOLDS: I know. Keith, you should
8 join Julie. Keith who is the head, has been the head
9 now for a little over a year of our Institute for
10 Telecommunication Sciences based here in Boulder.

11 So I just wanted to welcome everybody again,
12 express our tremendous appreciation for all of the hard
13 work, all the commitment, all the resources, and all of
14 the brain power that all of you guys have dedicated to
15 this effort.

16 I can assure you that we at NTIA appreciate
17 and recognize that you all have lots of demands on your
18 time, and it is our intent and our obligation, to make
19 sure that we try to make this effort both in this
20 meeting --

21 UNIDENTIFIED FEMALE ON TELEPHONE: Hey, can
22 you help me with this thing?

23 GLENN REYNOLDS: -- and all the efforts
24 going forward a valuable use of your time for all parts
25 of this wireless echo system. So with that, I'm going

1 to pass it back to Mark and Larry --

2 UNIDENTIFIED MALE ON TELEPHONE: Hi, Janice.
3 This is (indiscernible). I have the exact same problem.

4 MARK CROSBY (telephonically): This is Mark
5 Crosby, same thing.

6 LARRY ALDER: Okay. I think we're going to
7 just try to work through it. David, you're working the
8 -- okay. So I apologize to the folks on the phone, but
9 we're going to just keep plowing forward.

10 So, again, this is the final meeting for
11 this version of the CSMAC and I think Mark and myself
12 would like to echo Glenn and Larry Strickling's in-proxy
13 comments through Glenn to thank everyone for the
14 tremendous work that's been put together in these five
15 subcommittees.

16 There's really been some great work. I know
17 I've learned a lot from the reports. And I think these
18 are really outstanding work, and I appreciate all the
19 time. And I know Mark does as well. Mark worked harder
20 than anyone else, so great.

21 So for today, we've got kind of an
22 interesting agenda. We're going to hear from our
23 guests. So there'll be kind of the first hour we'll get
24 to do a lot of listening to our esteemed guests. And
25 then we're going to walk through the reports.

1 A lot of it was voted on and approved last
2 time. There's a few clean-up things that we want to
3 present, specifically around the 5G report and
4 recommendations. And then we're going to move into an
5 interesting and uncharted water for this group.

6 We're going to have a little brainstorming
7 session around future topics. So this is your chance
8 to, you know, open the doors pretty widely at a high
9 level, and we'll discuss potential future topics, you
10 know, real-time brainstorming, which will be input for
11 Paige and her process informing topics for next group.

12 So that's kind of what we have on the agenda
13 for today. So I thought what we'd do then is start with
14 our traditional roll call. So why don't we start down
15 there with Bob.

16 ROBERT PEPPER: Robert Pepper, The Aspen
17 Institute.

18 RICK REASER: Rick Reaser, Raytheon.

19 STEVE SHARKEY: Steve Sharkey, T-Mobile.

20 DENNIS ROBERSON: Dennis Roberson, Illinois
21 Institute of Technology and Roberson Associates.

22 PAUL KOLODZY: Paul Kolodzy, Kolodzy
23 Consulting.

24 AUDREY ALLISON: Audrey Allison, Boeing.

25 CHARLA RATH: Charla Rath, Verizon.

1 BRYAN TRAMONT: Bryan Tramont, Wilkinson
2 Barker.

3 PAIGE ATKINS: Paige Atkins, NTIA.

4 LARRY ALDER: Larry Alder with Google.

5 MARK GIBSON: Mark Gibson with Comsearch.

6 GLEN REYNOLDS: Glen Reynolds, NTIA.

7 MARIAM SOROND: Mariam Sorond, DISH Network.

8 ROBERT KUBIK: Robert Kubik, Samsung.

9 DALE HATFIELD: Dale Hatfield, University of
10 Colorado.

11 JENNIFER WARREN: Jennifer Warren, Lockheed
12 Martin.

13 JEFF REED: Jeff Reed, Virginia Tech.

14 KURT SCHAUBACH: Kurt Schaubach, Federated
15 Wireless.

16 MICHAEL CALABRESE: Michael Calabrese, Open
17 Technology Institute at New America.

18 CARL POVELITES: Carl Povelites, AT&T.

19 LARRY ALDER: And I dare not ask for the
20 phone, David, huh?

21 (inaudible response)

22 UNIDENTIFIED MALE: Well, we know Janice is
23 there.

24 LARRY ALDER: We know that Janice, Mark
25 Crosby, David Donovan, Mike Chartier, and Harold

1 Furchtgott-Roth, those are the people we know were
2 supposed to be on the phone. I'm going to wait for --

3 (dialing of phone and automated recording
4 playing)

5 LARRY ALDER: Okay. Can anyone on the phone
6 hear us? Anyone on the phone want to introduce
7 themselves? We're doing the roll call. I don't think
8 it's working so --

9 UNIDENTIFIED FEMALE ON TELEPHONE: Hi there.
10 Are we on the with Boulder now or just each other?

11 LARRY ALDER: This is Boulder.

12 UNIDENTIFIED FEMALE ON TELEPHONE: Okay.
13 Second time's a charm. Great. Thanks. I can see you,
14 but I couldn't hear -- you know -- we got cut off.
15 Anyway, thanks.

16 LARRY ALDER: So, Janice, why don't you
17 introduce yourself and then if anyone else is on the
18 call, we'll have you introduce yourself, and after you
19 introduce yourself, let's go ahead and use the mute
20 buttons to keep -- go ahead, Janice.

21 JANICE OBUCHOWSKI: Okay, it's Janice
22 Obuchowski, (indiscernible).

23 LARRY ALDER: Any other people on the phone?

24 JANICE OBUCHOWSKI: All right. It's Janice
25 Obuchowski from Washington, but I think we have a

1 two-minute delay. You'll hear me in two minutes.

2 LARRY ALDER: I heard Mark Crosby there.

3 MARK CROSBY: Yeah, Mark's on.

4 LARRY ALDER: Hi, Mark. Okay. I think
5 we're good. Let's continue on then with the agenda. So
6 I don't think there's -- Mark, do you have any other
7 introductory remarks? I think we've covered the
8 introductory remarks, and so we'll jump right in with
9 the spectrum update from Paige.

10 PAIGE ATKINS: Thank you -- a little bit of
11 feedback there. Well, welcome back to Boulder where we
12 are fortunate, again, to hold our CSMAC meeting
13 alongside the ISART conference, and the topic of this
14 year's conference spectrum forensics --

15 DAVID DONOVAN: Donovan is here.

16 PAIGE ATKINS: Who was that?

17 LARRY ALDER: David Donovan just joined.

18 PAIGE ATKINS: Okay. -- is timely as we
19 look to the next generation --

20 DAVID DONOVAN: Hello?

21 MARK CROSBY: David, there's a two-minute
22 delay so --

23 PAIGE ATKINS: -- of challenges and
24 opportunities associated with spectrum policy --

25 (indiscernible background conversations from

1 telephone participants.)

2 PAIGE ATKINS: -- in particular the
3 necessary technology capabilities and regulatory
4 frameworks that enable sharing while mitigating or
5 avoiding interference.

6 There is an impressive array of panelists
7 and discussions this week, so I hope all of you, if not,
8 some of you, can participate throughout the week, and it
9 is being sponsored by The Center for Advanced
10 Communications. So it's a great opportunity.

11 And the ISART agenda notes, paraphrasing
12 Robert Frost, that Spectrum Forensics will help build
13 and maintain good fences to make good neighbors. And
14 the ISART's sharing-centric theme of good fences and
15 good neighbors is very applicable to our discussions
16 here in CSMAC and our continuing discussions for the
17 next cycle.

18 We continue to live in exciting times in
19 spectrum management. I commend, as everyone has already
20 today, the CSMAC membership for answering the call and
21 in particular for the fast-paced assessments that we've
22 asked you to do the last few months and the expedited
23 timelines that we've put before you.

24 Since this is part of an extended membership
25 term, we appreciate that this is yeoman's work. These

1 are challenging issues at the cutting edge of new
2 technology and regulatory environments, and we do
3 appreciate the intellectual capital that you bring to
4 bear for us to answer the tough challenges and formulate
5 the right approach for the future.

6 As we close out this chapter of the
7 committee's current term, I look forward to your
8 insights and discussion today on what we need to focus
9 on for the future and the priorities. And that will
10 help us formulate the next set of questions for the next
11 membership term.

12 But for now, I'll turn to some of the
13 exciting things that have occurred since the last CSMAC
14 meeting in June. For a brief two months, a lot has
15 happened. And I will touch on some and others in this
16 room, Julie and Keith, will elaborate on many of these.

17 So a major step forward, as Glenn already
18 mentioned, was Spectrum Frontiers. This item made
19 available more spectrum for flexible-use wireless
20 broadband than ever before and lays the critical
21 groundwork for 5G services and applications and high
22 frequency, in particular millimeter wave spectrum.

23 The FCC's actions supported by NTIA and the
24 federal agencies offers exciting opportunities,
25 particularly for spectrum sharing and dual-use

1 technologies. And in particular, for spectrum sharing,
2 it was focused on the federal, non-federal sharing. It
3 provides some unique opportunities for us that we need
4 to exploit. And I'm sure Julie Knapp will talk about
5 that in much more detail in a few minutes.

6 Now, the advanced wireless research
7 initiative, if some of you heard the White House press,
8 we really need to put in place the building blocks of
9 research and technology development that will help make
10 Frontiers as well as 5G a reality.

11 And in July, the administration laid out
12 steps for U.S. leadership by launching a \$400,000,000
13 program to enable advanced wireless research over the
14 next decade. And that really builds on the Frontiers
15 policy framework that the FCC has put in place.

16 And through this initiative, which is run by
17 The National Science Foundation or NSF, there are more
18 than 20 technology companies and private sector
19 associations in conjunction with NSF that are investing
20 85 million in four city-scale public/private testing
21 platforms to support fundamental research on advanced
22 wireless technologies.

23 And the fundamental research supported on
24 these platforms will include the \$350,000,000 investment
25 by NSF for academic research over the next seven years

1 and will allow academics, entrepreneurs and industry to
2 mature advanced wireless technologies concepts, which
3 will translate into future innovations for next
4 generation 5G and other capabilities. So it's an
5 exciting opportunity for many.

6 Now, in a related announcement, NTIA's ITS,
7 the Institute for Telecommunication Sciences, this fall
8 will sponsor undergraduate and graduate student research
9 that will leverage the testbed it is developing with the
10 University of Colorado Boulder across the federal and
11 university campuses here in Boulder.

12 And the testbed will support research on
13 campus scale wireless networking, spectrum sharing, and
14 mobile applications and enable collaboration between
15 ITS, University of Colorado Boulder and the city of
16 Boulder. And so it's a very exciting opportunity for
17 all of us.

18 And you will hear more from our director of
19 ITS today, Dr. Keith Gremban, who will talk about their
20 strategic thrusts and related efforts to better inform
21 spectrum policy decisions and support development of new
22 telecommunications technologies.

23 Now, I wouldn't do justice to our efforts
24 without mentioning our continued progress on the 500
25 megahertz goal. Everyone's aware we're almost halfway

1 there, which we have been for a while now.

2 And, collectively, we continue to evaluate
3 the feasibility of increased sharing and multiple bands,
4 including with unlicensed devices in 5 gigahertz, and
5 many of you are participating in those efforts.

6 And since the last CSMAC meeting, the FCC's
7 comment period has closed on its public notice to
8 refresh the record in the proceeding on 5.9 gigahertz.
9 We also continue an intense schedule of analysis and
10 modeling for 5350 to 5470 megahertz and continue to work
11 with the agencies and industry on modeling approaches to
12 ensure we can ascertain whether sharing is technically
13 feasible in these bands.

14 The 5 gigahertz bands are a vital part of
15 our storyline related to meeting the 500 megahertz goal.
16 And we also continue to make progress on 3 dot 5
17 gigahertz and the incentive auction which, again, Julie
18 will talk to you in more detail in a few minutes.

19 And as Assistant Secretary Strickling has
20 mentioned before, we are optimistic that later this year
21 in conjunction with the FCC and the agencies, we will be
22 able to lay out a road map of how we will achieve that
23 500 megahertz by the year 2020.

24 Now, meanwhile, the Spectrum Pipeline Act,
25 which the president signed into law last fall as part of

1 a bipartisan budget act, sets out targets for
2 identifying an additional 130 megahertz for wireless
3 broadband as part of a series of deadlines in the 2022
4 to 2024 time frame. However, more significantly, the
5 Pipeline Act made important changes to the spectrum
6 relocation fund and the use of the spectrum auction
7 proceeds.

8 The Spectrum Pipeline Act allows federal
9 agencies to more flexibly apply those funds for advanced
10 spectrum planning and research and development that may
11 lead to more efficient spectrum use and repurposing of
12 spectrum for commercial applications, while ensuring we
13 maintain or enhance our federal critical capabilities.

14 This is a significant step forward and an
15 important component to creating a sustainable pipeline,
16 and we've moved quickly to implement this act, including
17 reconstituting the technical panel. And some will be
18 familiar with the technical panel's purpose in AWS-3.
19 This is a slightly different purpose and
20 responsibilities. And the agency's proposals are
21 subject to the technical panel review and approval under
22 the statute.

23 The intent is to help direct this additional
24 SRF funds to invest in high-payoff activities while
25 hopefully enabling sharing and relocation decisions.

1 And we are already working with several federal agencies
2 on pending proposals that they would like to bring
3 forward through this process. So we're very excited
4 about that.

5 Now I'm going to take a slightly different
6 turn. It's really amazing to look back 30-plus years
7 and see all the progress that we've made from a spectrum
8 policy perspective.

9 The effort to provide more spectrum access
10 for broadband wireless services really stands on the
11 shoulders of a federal spectrum policy that goes back to
12 about 1983 when FCC allocated the initial spectrum used
13 to begin the building blocks for the first cellular
14 networks.

15 And at least as far back as the
16 administration of President Bill Clinton, every
17 administration has acted to make spectrum available to
18 accommodate the need for commercial wireless services.

19 In 1993, Congress gave the commission
20 auction authority, recognizing it is a way to find the
21 most efficient way to get spectrum access into the most
22 productive hands and into the market. And, at that
23 time, Congress also directed NTIA to identify over 200
24 megahertz of federal government spectrum to repurpose
25 for the private sector.

1 And as the commercial wireless industry took
2 off, the U.S. government responded in a thoughtful,
3 strategic, and bipartisan approach to making additional
4 spectrum available while preserving the spectrum access
5 that government agencies and departments continue to
6 need to serve the public, and, in particular, in the
7 areas of homeland security, public safety, and other
8 critical mission areas.

9 Now, since 1994, the FCC has conducted
10 nearly a hundred spectrum auctions that have generated
11 billions of dollars for the U.S. Treasury, supporting
12 important public policy goals.

13 In 2003, fast forward, the president's
14 spectrum policy initiative under President George W.
15 Bush committed us to developing a comprehensive spectrum
16 policy for the 21st century. And this initiative, in
17 part, resulted in the formation of two key advisory
18 committees -- CSMAC as well as the PPSG, the Policy and
19 Plans Steering Group.

20 Since that time, we've had a series of
21 policy and legislative actions that have repurposed in
22 auction multiple bands, federal bands for commercial
23 broadband access, established the spectrum relocation
24 fund to help ease the transition of spectrum from
25 government to commercial use while preserving the

1 agencies' abilities to serve the public.

2 And we have progressively reformed the SRF
3 to more flexibly apply those funds for sharing advanced
4 planning and R & D. And as we all know, the Obama
5 administration brought continued emphasis on the need to
6 address accelerating growth of broadband services and
7 applications with two presidential memos, that we're all
8 very familiar with, in an effort to ensure that
9 sufficient spectrum will be available for broadband
10 expansion.

11 Now, July, last month now, was also the
12 four-year anniversary of a ground-breaking report on
13 spectrum sharing released by the President's Council of
14 Advisors on Science and Technology or PCAST. Though not
15 that long ago, much has changed in four years.

16 And to put a little perspective, the report
17 cited the internet of things as a novel wireless market.
18 And it is now a part of our common technology
19 vernacular. Similarly, 5G was not fully evolved as a
20 concept and didn't merit a mention in the report. So
21 how far we've come in four short years.

22 When it was released four years ago, the
23 PCAST report was a game changer in terms of articulating
24 a new paradigm based on using sharing to empower access
25 to federal spectrum without compromising important

1 federal agency missions.

2 And for this administration, the PCAST
3 report has been a cornerstone to an important policy
4 trifecta, again, starting with the president's 2010
5 memo, followed in 2013 by the second memo asking us to
6 accelerate our focus on spectrum sharing.

7 And we have made significant strides in
8 addressing the recommendations in the PCAST report in
9 some form or fashion including leveraging capabilities
10 in spectrum access systems and 3.5 gigahertz to enable
11 the kind of sharing that the PCAST report envisioned.

12 So, to be clear, as I've often said, we
13 still have a lot of work ahead of us, not only in the
14 technology, but also the policy, the process, the
15 framework within which we need to implement that
16 technology. But we have that foundation to build on and
17 to ensure we can prove out these new sharing techniques
18 and technologies.

19 So my intent is not to give you a history
20 lesson, because most of you know that history, but to
21 emphasize that it will continue to be a bipartisan
22 priority, regardless of which new administration takes
23 over in a few months, and our spectrum work and momentum
24 must continue.

25 However, what has worked in the past does

1 not guarantee success in the future, so the CSMAC is
2 going to remain a critical component, so we can better
3 think of things out of the box, look at things through
4 different lenses and continue to develop innovative
5 policy, regulatory and technology solutions to fully
6 exploit the spectrum opportunities now and in the
7 future.

8 So I look forward to wrapping up the final
9 recommendations for this membership today, and as Larry
10 and others have alluded to this brainstorming session in
11 terms of next steps, so we can consider those for the
12 next CSMAC cycle.

13 And we know being on a federal advisory
14 committee is not a very glamorous job, and we are
15 grateful for your time and invaluable insights. It's
16 the personal commitment that each of you make to
17 volunteer your time and expertise to help us do a better
18 job that is so important to us.

19 We sincerely appreciate your commitment and
20 the collective wisdom and advice that you've provided to
21 NTIA now over the last 30 months with that extension of
22 six months. So thank you very much. And I'm happy to
23 take any questions that folks may have.

24 MARK GIBSON: Just to make one comment, you
25 didn't mention the propagation tutorial that ITS has

1 been doing, which I'd like to just say thank you for. I
2 think Eric Nelson has put them together, and a lot of
3 his people have been doing them. And they are between
4 50 and 75 people on those calls so thank you very much
5 for that. That's awesome work. There's a lot of really
6 good information in that. So all of us that are
7 participating are getting a lot out of it, so thank you.

8 PAIGE ATKINS: Thanks, Mark.

9 DENNIS ROBERSON: Dennis Roberson here. You
10 talk very well about the past, and it is fun even for us
11 to hear it, even though we lived it. No, it really is
12 terrific. As we look forward, what is the game plan for
13 CSMAC? I know these are uncertain times as there's an
14 administration change in the (indiscernible) and so on.
15 But what does the next year look like for CSMAC and for
16 NTIA?

17 PAIGE ATKINS: Well, from my perspective,
18 and, obviously, I can't guarantee anything, but our plan
19 is to move forward as nothing will be changing. You
20 know, from our perspective, it is very important for us
21 to keep that momentum going.

22 We are in the process of vetting the new
23 membership through our normal activities, and we hope to
24 do that as expeditiously as possible and to get the next
25 round going. So we're very excited to move forward and

1 tee up that next cycle with important questions for us
2 to answer.

3 LARRY ALDER: Last call for questions for
4 Paige.

5 PAIGE ATKINS: Save all the hard ones for
6 Julie.

7 LARRY ALDER: For our brainstorming. So
8 without further ado then, we've got Julie from the
9 broadcaster's booth over there.

10 UNIDENTIFIED MALE: How's (indiscernible)
11 treating you over there, Julie?

12 (audio cut out)

13 JULIE KNAPP: -- collaboration. So thanks.
14 It's great to be here. Sometimes it feels like the only
15 time I get to go to these meetings is out here in
16 Boulder.

17 Just three terms initially come to mind.
18 One is that so many of the things that we have been
19 doing involve sharing of spectrum, perhaps more than any
20 time in the past.

21 Secondly, complexity -- thinking back to
22 those earlier days where it was generally identify a
23 particular band, have a debate over whether it was
24 lightly used or not and reallocate it, which worked
25 fine for the time, but there's a lot more operations in

1 the spectrum today, and we're trying to pack more and
2 more together. And that has meant that our ways of
3 recovering spectrum and our ways of sharing spectrum
4 have gotten more complex.

5 And then, thirdly, collaboration. We
6 couldn't have accomplished the things that were done,
7 such as with AWS-3 and many of the other things and all
8 of the challenges that we have in front of us without
9 the collaboration between NTIA and the federal agencies
10 and the industry and I think all of the people in this
11 room.

12 So I'm confident that we're going to meet
13 these challenges ahead, but it's going to take all of us
14 working together. So I'm just going to mirror a little
15 bit of what Paige said and perhaps add some commentary
16 to it from the broadcast booth.

17 Well, first of all, at least on our side,
18 we've done a lot of work to make the incentive auction
19 happen and that's in process, and, you know, it goes
20 back to the term complexity, because I don't think there
21 has been anything that we've had to deal with on our
22 side that was as complex as trying to figure out what
23 the chairman described as the Rubik's cube. And it's
24 been a monumental accomplishment just to get to the
25 point where the auction is actually going on.

1 The Spectrum Frontiers item, or what some
2 call the 5G item, almost 11 gigahertz of spectrum was
3 identified for mobile. The three bands that we talked
4 about generally -- the 28 gigahertz band, the 37
5 gigahertz band, 39 gigahertz band -- I'll spare you the
6 details. But every one of them had different sets of
7 incumbencies, different sets of challenges.

8 And I think one of the really interesting
9 things here that lies in the work ahead is in that band
10 at 37 where we identified 600 megahertz of sharing
11 basically for everybody, a portion of it with a priority
12 for the Department of Defense.

13 But it's not a separate spot for any one
14 service. It's a spot to find ways that we can maximize
15 use of the spectrum by essentially giving all of the
16 parties access to it. So I think that's going to be one
17 of the very challenging things that we have going ahead.

18 And if that wasn't enough, there's another
19 18 gigahertz of spectrum that we put in play in the
20 further notice. So for -- I think this is probably the
21 greatest boon for the FCBA and for the spectrum
22 engineers in terms of all the analytical work that lies
23 ahead.

24 And it's not only for the United States, but
25 what's going on internationally in trying to identify

1 the spectrum. So it was quite an accomplishment, I
2 think, for all of us to really lead the world in
3 identifying spectrum for the next generation of mobile
4 services and we went to keep up that momentum as we go
5 forward.

6 And the 3.5 gigahertz, the great news there,
7 first of all, has been all of the collaboration that has
8 gone among the industry and the stakeholders in the
9 WInnForum process. Getting everybody together in the
10 room to solve all of the details of how this is going to
11 work I think was probably one of the best things that we
12 as an agency could have done.

13 We set a basic framework and then set, you
14 know, all of the technology experts and the stakeholders
15 together in one place to try to figure out all of the
16 details, and there's been a lot of terrific work that
17 has been going on there.

18 We also had the applicants for the spectrum
19 access systems. And one of the things is as a regulatory
20 agency when you set these things up is you wonder, when
21 you send the invites out to the party, is anybody going
22 to show up. And it's always gratifying. You know,
23 we've had a number of parties that filed both to be
24 spectrum access service providers and environmental
25 sensing system providers.

1 So we're in the midst of the approval
2 process. It's going to take some time working through
3 all that and trying to figure out exactly how do we
4 ensure that these systems work the way we expected them
5 to work. But there's a lot of benefit out of it. I
6 think we're packing -- there's another example of where
7 we're packing more together in the spectrum in a dynamic
8 way to make the maximum use of it.

9 I would just also say that one of the
10 things, the way we think about things, it's not so much
11 about taking a particular model and trying to apply it
12 everywhere, but trying to figure out what is the best
13 model to maximize the use of the spectrum given the
14 conditions that there are in that space.

15 So SAS was the right approach there. It may
16 or may not be in other places, but the whole theme of
17 trying to find ways to make more use of the spectrum, I
18 think, is the challenge we have ahead.

19 A couple of other examples that Paige
20 mentioned but I'll say a little bit more about them.
21 What we've been talking about is the 5350 piece for
22 unlicensed. So there's two unlicensed bands that are
23 available now, and broadly -- 5150 to 5350 and 5470 to
24 5850. So you've got these two big chunks of spectrum
25 that are sitting there.

1 The IEEE 802.11 AC standard is designed to
2 work in those, but we could get more out of it, if we
3 can fill in the missing piece in the middle. So that's
4 why this is so important. But it is tough, because we
5 have got systems in there like earth exploration
6 satellite systems where the signals are really weak and
7 you're trying to figure out, well, I can't hear them, so
8 how do I share them? Do I predict where they are and
9 find periods of time where I turn off in that particular
10 piece of spectrum and I use it elsewhere?

11 So that piece has been a challenge. And
12 then there are multiple radar systems. We're already
13 sharing with radar systems in other parts of the 5
14 gigahertz spectrum, but these are different. They
15 include aeronautical systems. They include systems that
16 have extremely short response times.

17 So we've had a lot of people working very
18 hard trying to figure out how to do this, and I tip my
19 hat to Charles Glass who's really been in the middle of
20 it leading the effort. He's increased the level of work
21 that is going on there.

22 He's having meetings a couple times a week
23 trying to get everybody together to sort this out. So
24 there's a lot of dedication going into trying to figure
25 out how to gain access to that spectrum and make sharing

1 work.

2 And I shudder to talk about which piece is
3 more difficult or easier, but the other piece that we're
4 looking at is this piece that we call 5.9 gigahertz.
5 It's at 5850 to 5925 so it sits at the high end of the
6 unlicensed spectrum. It's been allocated for
7 intelligent transportation systems, what is often
8 referred to as DRSC -- dedicated short range
9 communications.

10 We issued, as Paige mentioned, a public
11 notice in early June to refresh the record and to
12 solicit prototypes. The good news is just last Friday
13 we received prototypes from Broadcom, KEA Technologies,
14 and CAV Technologies. And we extended the date.

15 They were all due to come in on the 30th of
16 July, but, as you know, when you're working with
17 prototypes, sometimes you've got to really put them
18 through their paces to make sure they're working before
19 you submit them in for testing.

20 So Qualcomm is submitting theirs by August
21 8th and Cisco by August 18th. There are three phases of
22 testing, first at the FCC lab; then DOT, Department of
23 Transportation, will be doing some basic field tests;
24 and then finally real-world testing.

25 So we've done a lot. We've still got a lot

1 left to do. These problems are hard. And, you know,
2 there's a lot of energy and, I think, intelligence going
3 into trying to figure out ways to make them work.

4 Thanks.

5 LARRY ALDER: Thanks, Julie. Do you folks
6 have questions for Julie? Michael.

7 MICHAEL CALABRESE: Yeah, Michael Calabrese.
8 Julie, you mentioned the 37 to 37.6, which will be, you
9 know, an intention to have that be a shared, a fairly
10 open shared band among many different types of users.

11 Are there issues that you've already
12 identified, these would be federal, federal use that
13 you -- whether you could -- I don't know. Are you ready
14 now to say that the CSMAC might, it might be productive
15 for the CSMAC to look at them, or just simply what are
16 your challenges when you think about sharing with
17 federal users in that band? Is it all very cut and
18 dried right now, or is it still a work in progress as
19 far as identifying the issues?

20 JULIE KNAPP: Thanks, Michael. Start with
21 the proposition that this was spectrum that was
22 allocated to the federal government. And so even if
23 there weren't systems deployed, this was spectrum that
24 for them, I think, from their point of view, was
25 potentially a place that they could deploy systems and

1 grow.

2 And I think one of the concerns from the
3 federal side was that they would still have the
4 opportunity to grow and use the spectrum in the future.
5 So what we tried to do was take this piece and, by the
6 way, most of the details we asked questions about in the
7 Further Notice of Proposed Rulemaking.

8 So the idea here was to provide some of it
9 where there was certainty that the federal government
10 would, and Department of Defense in particular, would
11 have access to it, so that we didn't create a model that
12 said we licensed it all nationwide, and now, although
13 you're co-primary, you have to get permission of an
14 incumbent licensee.

15 So the idea here was to provide some
16 certainty for Department of Defense access while still
17 allowing all of the other uses in the extended part of
18 the band, because we made this interoperable across the
19 entire spectrum so that the equipment would be able to
20 operate everywhere.

21 Our hope is that longer term this is a
22 win-win for everybody, that there are applications for
23 LTE that are potentially beneficial to the military as
24 well. So that entire market could help drive a system
25 that creates technology improvements that benefit

1 everybody.

2 So long answer for file comments, because we
3 opened these questions in the proceeding and whether --
4 you know, it's really up to NTIA to say whether this is
5 something they want to take a look at. But we have been
6 working with NTIA and Department of Defense through this
7 whole process and that's what led to where we came out.

8 MICHAEL CALABRESE: I guess a similar
9 question with respect to 5350 that you mentioned. So
10 there is ongoing technical work. Again, is that a very
11 defined technical problem at this point and it's just a
12 question of working through the process, or are there
13 issues in that band that need to be studied further or
14 developed?

15 Just wondering, again, if you would see the
16 CSMAC as potentially playing any kind of role there, or
17 is it just a question of working through very defined
18 technical issues at this point?

19 JULIE KNAPP: So we have a group that has
20 been open to anybody who wanted to participate from the
21 industry working together with the Department of Defense
22 and the other agencies. They've been at it for a while.

23 Whether an additional process on top of that
24 would help -- what I can tell you is they're on a pretty
25 fast timeline trying to get to an answer. They

1 understand what the technical characteristics are, and a
2 lot of it is the usual kind of analysis about how do you
3 determine, how do you model the deployments of what
4 might go in there and aggregate interference, all of the
5 usual things we'd go through before.

6 So I think the problem is pretty well
7 understood. The difficulty is trying to figure out, can
8 you come up with solutions that are viable for the
9 equipment and for the industry to deploy.

10 UNIDENTIFIED MALE: Thanks.

11 PAIGE ATKINS: So just to follow up quickly.
12 The subcommittee that was focused on the measurement and
13 sensing and in particular 5 gigahertz, the intent really
14 was, are we missing something? Are we missing something
15 that is innovative, that we're so focused on the
16 technical solution in this ongoing work that we've
17 missed something completely.

18 And I think there's been some good feedback
19 in that subcommittee. And I also think that just in
20 general as we look at, in particular, in the Frontiers
21 bands and reapply or looking at new techniques for a
22 much more dynamic sharing, that we will want to peel
23 back what should CSMAC perhaps be focused on or other
24 groups that may be collaborative in nature, be focused
25 on to come up with those innovative solutions in the

1 future.

2 LARRY ALDER: Go ahead, Rick.

3 RICK REASER: This is Rick Reaser. I was
4 wondering has there been any thought -- you know, most
5 of the sharing scenarios now sort of deal with new
6 people coming in, dealing with incumbents.

7 Has the commission looked at maybe starting
8 to establish technical rules that would be phased in
9 over time in the future for new systems, so that they
10 were built to share from the get-go, and has there been
11 much thought or work in that area, because you could
12 phase systems like that in over time and then maybe, you
13 know, 20 years from now have a different landscape.

14 JULIE KNAPP: Can I give this to Paige? No?
15 I think that sort of thinking is working into the
16 processes in different ways. Whether we think about it
17 in terms of -- we've been talking for a long time about
18 receiver characteristics and, you know, are you mindful
19 that it might be quiet next-door now, but it might not
20 be quiet later, and how do we weave that in without
21 jumping immediately to rules.

22 And I think there has been an increase in
23 awareness on that front, and some of the things that are
24 going on, I think, supported through, for example, the
25 spectrum research reallocation fund, looking at how we

1 can take incumbent systems longer to term and make them
2 more friendly for sharing. There's an awareness of that
3 and trying to build that in for the future as well.

4 LARRY ALDER: Other questions? Jennifer.

5 JENNIFER WARREN: Jennifer Warren. Julie,
6 just to follow up on Rick's question. Was your answer
7 just focused on the government systems, or is that also
8 on commercial? I wasn't quite sure.

9 JULIE KNAPP: I think it's across the board.
10 You know, as people have been looking -- we have a ways
11 to go yet, but I think people are -- you know, as we've
12 run into surprises along the way, and I'm not referring
13 to any one particular. People immediately think about
14 GPS, but we've struggled with this in other places as
15 well. I think we still have a lot of work to do going
16 forward to be, as people are designing systems to be
17 cognizant of trying to make them robust.

18 LARRY ALDER: Julie, I'll ask a question.

19 JULIE KNAPP: I've exceeded my limit here.

20 LARRY ALDER: Given that I don't know if
21 you'll be able to stick around for our brainstorming, I
22 wanted to see, do you have any thoughts on what are some
23 of the big, I mean you've mentioned a number, but what
24 are some of the issues, use cases that you think are
25 kind of emerging that need to really be looked at?

1 JULIE KNAPP: Use cases -- the reason I
2 pause at that is I think the technology is moving so
3 fast now, trying to figure out what it's going to look
4 like in the next year or two is a real challenge.

5 I think we have to be careful not to let the
6 perfect be the enemy of the good, because we often get
7 into discussions about what's the right interference
8 protection level; what are the right assumptions we make
9 going forward.

10 This came out of our TAC, as well as I'm
11 seeing it work its way into the analysis, too, of the
12 sharing with systems, and that's statistical analysis of
13 -- rather than, you know, historically we've looked at
14 things like worst case.

15 Well, you also need to evaluate, well, what
16 would happen if worst case occurred? Is it a dropped
17 call, which is not a good thing, obviously, but if that
18 were a rare event and the trade-off here is that we had
19 a multi-billion-dollar new service that was deployed --
20 I think that's the area where -- it's not very
21 glamorous, but it's an area where we often struggle as
22 to where's the right balance between protecting the
23 incumbents and providing for new services to be
24 deployed. .

25 LARRY ALDER: I guess we'll do one last

1 question from Paul. Oh, we've got two last questions.
2 We'll let Julie run over a little, because I know we
3 have some time on the agenda on the back end. Let's go
4 with Bryan and then Paul.

5 BRYAN TRAMONT: Thanks, Bryan Tramont from
6 Wilkinson. So, Julie -- and you actually caused me to
7 ask my question, so I blame the chair. My quick
8 question is we -- Charla co-chaired with Audrey our
9 committee looking at sharing of nonfederal bands by
10 federal users. And we've looked through some MOUs and
11 we have some different models.

12 From where you sit, how often does that
13 problem, how often has that problem come to you, that
14 is, a federal user looking to use a nonfederal band.
15 And is there anything -- and this is probably our fault
16 that we haven't interviewed you as part of our process
17 (indiscernible). We can now. Exactly. Under oath.

18 But is there anything that you would give us
19 as a to-do or as you've looked throughout your
20 experience, anything that you've picked up you think we
21 should be looking at that's a real barrier to that
22 process?

23 JULIE KNAPP: So I think in the past largely
24 that didn't happen. Largely, the federal systems were
25 designed for their specific bands, and we had this kind

1 of -- even though, even where we had shared spectrum. I
2 think the technology, first of all, could be used for
3 some of the federal applications that's coming out of
4 the commercial sector opens up new possibilities for
5 sharing.

6 And that could be all different kinds of
7 sharing. It could be shared systems, but I think going
8 forward, when we talked about sharing, and I shudder to
9 put words in the mouth of the federal side, but I think
10 where on the federal side, they say, well, I'm willing
11 to share, but how about the other direction?

12 And I think there's a sense that they are
13 able to share nonfederal in places that they would not
14 have an impact on the nonfederal users. And so I think
15 we have more work to do on that front going forward, in
16 part because there are places where even if there are
17 separate kinds of systems, we may able to share more
18 effectively.

19 BRYAN TRAMONT: And just a quick follow-up.
20 In your experience, when the federal users want access
21 to a non-federal band, are they traditionally
22 approaching the licensee, so they'll go to Carl or
23 Charla, or do they go to you and you help them find --
24 is there match-making component, or is it that you're
25 not necessarily involved per se at all?

1 JULIE KNAPP: I think part of it is
2 establishing what the ground rules are. Sometimes
3 there's an issue of consistent (indiscernible) with the
4 allocation table and how do we deal with that. And what
5 are the conditions that apply for the sharing.

6 I think there is a role for both the NTIA
7 and the FCC to play and make sure that framework for
8 sharing is going to work in a way that if there's
9 problems, we've already put everything in place to help
10 resolve them.

11 BRYAN TRAMONT: Thank you.

12 LARRY ALDER: Paul.

13 PAUL KOLODZY: This is Paul Kolodzy
14 (indiscernible). Hey, Julie. You made a comment, which
15 I think is interesting and I want to know what your
16 opinion is. For other people to do additional studies,
17 when we talk about going into the statistical analysis,
18 if you go to the next step and ask the question, we're
19 now living in a world now that where we're getting more
20 of systems of systems, where it isn't just a single band
21 doing a single job for a single user to provide a single
22 service, but generally a group of bands and a group of
23 systems and a group of technologies that are actually
24 combined together to provide redundancies and the like.

25 Does that actually play into your thoughts

1 in the sense of some analysis that needs to be done or
2 to be looked at when you're looking at sharing and how
3 you cross these systems and share across a multitude of
4 systems to systems?

5 JULIE KNAPP: It's a great point, Paul,
6 because, yes, I do think about it. We've gone from the
7 days where we started with a single system -- and if
8 your system got interference, you're out of luck. It
9 stopped working -- to systems that are much more dynamic
10 in their ability to share.

11 So if I get interference in one spot, the
12 service doesn't drop, it just adapts. But that said, if
13 you take enough hits, your investment in that service
14 comes into question. And I think we're still trying to
15 find our way on how do you take into account when the
16 protections for a technology or a service that might be
17 operating five, six, seven bands -- I mean, I expect
18 with the new spectrum that we're opening up, it's not
19 going to be one band is 5G. You know, they're going to
20 -- the services are going to evolve, so they're
21 operating across multiple bands. And so how do we take
22 that into account when we're doing our analysis?

23 LARRY ALDER: All right. I'd like to thank
24 Julie. I know we'd all like to thank Julie. It's
25 always a pleasure working with him and his organization,

1 and they've accomplished a great deal over the last few
2 years. So thanks, Julie. Let's give him a round of
3 applause.

4 JULIE KNAPP: Thanks.

5 LARRY ALDER: All right. We have Keith now.

6 (Audio cut out)

7 KEITH GREMBAN: -- broadcasting booth. I'm
8 suddenly concerned that the Broncos started their
9 training camp on Thursday. So Julie, Broncos started
10 their training camp on Thursday. What do you think of
11 their quarterback controversy?

12 JULIE KNAPP: I take the 5th.

13 KEITH GREMBAN: Okay. So thank you for
14 having me here. I want to talk to you a little bit
15 about how ITS works and tries to do the research to
16 inform spectrum policy. So I'll start out by giving
17 everybody a quick overview of ITS.

18 Many of you are familiar with what we do,
19 but there's probably quite a few people who aren't
20 really aware of some of the stuff that ITS does.
21 Sometimes I say we're one of the most capable
22 laboratories that nobody has ever heard of.

23 So moving on to Slide 2, I guess it's
24 numbered, the ITS history. It's actually interesting
25 that ITS has been around in one form or another for 100

1 years. It started originally as the National Bureau of
2 Standards Radio Section in 1916, and went through a
3 number of evolutions there.

4 It had a big growth area during
5 World War II, when it was the Inner Service Radio
6 Propagation Laboratory. And then finally it became just
7 ITS in 1967. And then recently in 2014, we also signed
8 a memorandum of understanding with NIST to form The
9 Center for Advanced Communications.

10 So over the course of that history, many of
11 the standard propagation models that are used by federal
12 agencies or commercial entities were developed at ITS.
13 And we continue our history of developing and upgrading
14 these models and performing the measurements to validate
15 them and continually improve them.

16 So next slide. We are the principal
17 telecommunications laboratory for the U.S. government.
18 And our mission is to inform policy, so we specifically
19 stay out of making any policy pronouncements. But our
20 job is to do the science and engineering that's needed
21 to inform the policy makers.

22 And the other thing we do as part of this,
23 is as we're developing the science and technology, we
24 solve a lot of the problems for other government
25 agencies. So we actually get over 50 percent of our

1 operating budget from other government agencies, doing
2 things like spectrum measurements, interference studies
3 and so on.

4 So the way we're running at ITS, we
5 reorganized last year and set up a policy where we
6 defined a number of strategic thrusts that are important
7 to inform policy, to take spectrum policy to the next
8 level. And we actually released an internal RFP to our
9 employees for ideas for research projects that would,
10 first of all, align with those thrusts and produce the
11 tools or understanding to, again, educate spectrum
12 policy.

13 So, in fact, we just released our RFP three
14 weeks ago. We start our first round of reviews next
15 week. And the senior staff get together and look at all
16 these proposals carefully and try to determine, okay,
17 are the really advancing the state of the art. Are they
18 going to produce the tool that we need to answer
19 questions for other agencies. Are they addressing some
20 of these fundamental problems that have been identified
21 by bodies like yours in spectrum policy.

22 On to Slide 4. So ITS at a glance, we
23 reorganized last year around four key technology
24 thrusts. So the first is radio propagation theory. And
25 Mike Cotton, who you'll be seeing at -- well, you've

1 seen all of them at ISART. Mike Cotton is the leader of
2 that group.

3 And that's the group that's really
4 responsible for advancing the theory, for advancing our
5 understanding and our use of propagation models,
6 aggregate propagation effects and electromagnetic
7 compatibility analysis.

8 Eric Nelson leads our RF measurement group,
9 and they're working on continually advancing the state
10 of the art in measurement both just to inform our
11 propagation models as well as to do interference
12 detection and mitigation.

13 We started a software engineering division
14 last year because nowadays, in the end, whatever we do
15 is embodied in a piece of software that either we're
16 going to use internally to apply to a problem or we're
17 making available publicly for other people to make use
18 of. And so as a result, it's critical to have the best
19 quality software we can possibly generate because we
20 can't release buggy code to the community.

21 And then, building on Paul's question and
22 Julie's answer here, we also identified the issue of
23 systems engineering evaluations being critical in moving
24 forward. And so we have a division that's devoted to
25 doing systems engineering, systems of systems analysis,

1 and evaluation of system performance, including what is
2 sometimes an overlooked area, what is the end-user
3 experience of the system as we evaluate it.

4 It's one thing to give a bit error rate or a
5 level of interference. It's another to say, what does
6 this do to the user on the other end? So we have got
7 some very advanced capabilities for solving that.

8 Flip over to the next slide on ITS assets.
9 We've actually got some very unique assets that a lot of
10 the community is unaware of. One of the most unique
11 assets is our Table Mountain facility which is a
12 flat-top mesa about 10 miles north of us. And it is one
13 of only two radio quiet zones in the United States,
14 federally mandated. The other one being the big radio
15 telescope in West Virginia.

16 And so this facility allows us to make
17 propagation experiments and emissions experiments in a
18 very controlled environment, because, by statute, we can
19 limit the amount interference we have from other systems
20 around us.

21 And we've got a number of facilities up
22 there to use including a turntable big enough to put a
23 city bus on. So we can do antenna analysis and rotate
24 it and so on, so it's a very robust facility.

25 Internally, well, not internally, we've got

1 a number of vehicles that are outfitted with antennas,
2 spectrum analyzers and computer systems that we
3 periodically just drive to various places around the
4 country to address interference problems or just do
5 propagation measurements. And you'll see one of those
6 vehicles if you attend ISART. It's part of our show
7 that we'll, part of demonstration we'll have out there.

8 And, of course, we've got laboratory
9 facilities ranging from Faraday cages and waveform
10 generators to actually do this user evaluation
11 experience, we have sound-proof isolated booths, so we
12 can exactly control the sound and the interference
13 that's caused and really determine how the user responds
14 to that.

15 And then, finally, we run our own over-
16 the-air LTE network to do, again, further
17 experimentation with. So we've got a lot of good
18 facilities to work with. Next line I'm just going to
19 skip over since we've already talked about spectrum
20 demand and Julie nicely set up the discussion of
21 spectrum sharing.

22 And on the next slide, what I want to do is
23 talk about the way we work. So we'll identify a problem
24 like spectrum sharing. And in this case, I would claim
25 there's three -- depending on how you slice it -- three

1 technology areas that are critical to being able to move
2 spectrum sharing forward and making it more efficient.

3 First, is just spectrum monitoring. You
4 need to understand what the spectrum occupancy is like,
5 what's available to share, what's not available to
6 share.

7 Second, you need to understand the
8 propagation characteristics. This involves propagation
9 measurements in various environments and upgrading and
10 utilizing propagation models, so you can understand how
11 much effect one system is having on another at a
12 distance.

13 And then, finally, you need to have good
14 quality electromagnetic compatibility analysis, because
15 just because one system is hitting another with a
16 certain power level, is that really interfering with the
17 system performance? We need to understand that.

18 And so we have major efforts going underway
19 in all three of those. And what I'll do next is walk
20 through some of those projects and show you what we're
21 doing in those domains so you get a feel for the way ITS
22 works.

23 So section heading, let's move on to some of
24 the project summaries. The first project I'll talk
25 about is spectrum monitoring. This is a joint effort

1 between ourselves, ITS, and our counterparts in the NIST
2 communications technology laboratory.

3 It's been a very successful collaboration
4 with most of the measurement sensing being worked on on
5 the ITS side and the software database issues being
6 worked on on the NIST side.

7 So we are working on developing general
8 technology and using our prototypes to understand the
9 challenges and the requirements and help influence the
10 standards as we move forward.

11 For example, you flip over to the next
12 slide, we have had four stations, spectrum monitoring
13 stations, running 24 hours a day, seven days a week for
14 a little over a year in several locations along the U.S.
15 coasts. The figure represents the data obtained for one
16 month along the West Coast in the 3.5 gigahertz band.

17 If you look at the top graph, the days of
18 the week are along the bottom axis and the vertical axis
19 is the particular band. And then the strength of the
20 signal in a particular band is shown by a color chart.

21 So you can see by looking at the top axis,
22 the top graph, it looks like in this band there's quite
23 a bit of opportunity for sharing. Now you kind of turn
24 a band, look at it sideways, and you can see the lower
25 graph which gives you the maximum, minimum, median, and

1 mean occupancy of that band over the days selected.

2 And it gives you a little more insight into
3 the opportunities and the difficulties with sharing. So
4 it looks like, if you just looked at the mean and
5 average, there is a lot of empty space in that band.

6 But, in fact, there are spurious signals
7 that pop up -- very, very high power -- that would
8 interfere with sharing uses. So we have to understand
9 this, and we're running these and doing the analysis and
10 developing more analytics to develop more insight on
11 spectrum sharing opportunities.

12 The next chart we go into a little our
13 propagation modeling and measurement. Again, it's
14 critical to understand the propagation characteristics
15 of the systems that are attempting to share.

16 Propagation, of course, is a complex
17 phenomenon, and it's very much affected by environmental
18 factors and especially physical factors like terrain,
19 structures, foliage and so on. The figure is an example
20 of one of the products that we provide, which is a
21 propagation modeling website, which allows users to log
22 on, pick a particular model, a particular frequency band
23 and run it across a terrain model.

24 So it's working well, but we can get better.
25 If you flip to the next slide, this is a case study of

1 the problem that we have with our current propagation
2 models. They do well in some circumstances, but there
3 are other instances in which the models just do not work
4 very well. And this is an example.

5 The top left figure is an overhead view of
6 Boulder. Down at the bottom left there's a little kind
7 of curlicue that ends where we place the transmitter,
8 and that's over there on a foothill, a couple miles to
9 the southwest. And the path on the top left shows you
10 the path of our measurement vehicle driving around the
11 city of Boulder. And the graph at the right shows three
12 things.

13 So, first, in black, is the propagation
14 power expected, the transmission gain expected using a
15 pure, flat free-space model. The red line is
16 propagation transmission gain expected using the
17 irregular terrain model, the Longley-Rice model. And
18 then the blue spots are the actual measured data.

19 And there's a significant discrepancy
20 between the measured data and the model. This is
21 something we've got to fix. I could pull out other
22 graphs of other urban areas in which the discrepancy is
23 very small. And we have to understand that.

24 And so we are continually working to do more
25 measurements and use them to upgrade our models so we

1 can get better and better agreement and develop a
2 process of measure, model, analyze, measure, model and
3 converge to a point where our answers are good for the
4 spectrum sharing community.

5 The next line is something that Julie
6 brought up, which is the effect of aggregates of
7 transmitters on the spectral environment. And this is a
8 problem as we put in more and more cellular devices and
9 user devices, how are these going to effect some of the
10 systems like weather radars, air traffic control radars
11 and so on.

12 So to understand that, we've got to get a
13 handle on how these aggregates behave. So we need to be
14 able to model the populations of aggregates, we need to
15 be able to model the way they transmit, and model the
16 aggregate transmission effects on the other end.

17 The figure at the bottom left here shows a
18 first order model of a population of end-user devices.
19 We obtained a map of cellular base stations from one of
20 the providers and then randomly dropped end-user devices
21 over this terrain and then associated the devices to
22 cell towers by picking, by running a propagation model,
23 and if there were two towers within five DB of each
24 other, we'd pick randomly an association.

25 And those associations are shown on the

1 figure -- you see these hub-and-spoke pieces, and those
2 are the end-user devices connected to the base station
3 hub. So that just drops them down. So now how do they
4 respond in terms of transmission and power?

5 Over to the next slide. This was a
6 measurement exercise that we did here in Boulder. We
7 took one of our measurement systems and put it at the
8 base of a cell tower and intercepted end-user
9 transmission to the tower and plotted the power of the
10 end user device.

11 And so your first naive thought is, well,
12 it's probably going to be Gaussian distributed, right?
13 The law of large numbers says that everything turns out
14 to be Gaussian in the end. But you look at the
15 histogram under the Gaussian, not too many of those
16 measurements turned out to be very Gaussian.

17 And a little more thought, that makes sense.
18 If you turn to the next slide, this was our simulation
19 of that. And what we did for the simulation was, again,
20 we've associated each of the end users with a base
21 station, and based on the distance from the base
22 station, that determined the power needed to reach the
23 base station.

24 And so if you step back and think about it,
25 is you have these increasing concentric circles of area

1 of transmitters. The farther out they are, the more
2 area those concentric circles cover, the more end-user
3 devices are in that area, so the more devices there are
4 farther away transmitting at high power.

5 So the graph, the simulation matches kind of
6 our intuition. It doesn't quite match yet the
7 distribution we're getting from the cell towers. So
8 we're doing a lot more work to try to equalize that and
9 get the right distribution for transmitters. So then we
10 can start computing the propagation effects at distances
11 from aggregates of devices.

12 Next slide is our introduction to what we're
13 doing in electromagnetic compatibility analysis. You
14 need to understand, again, we've got multiple systems of
15 systems interacting with each other. When do these
16 interaction become harmful?

17 The figure on the right shows the way these
18 studies are typically done, in particular, with the
19 radar. You have an operator sitting at the radar and
20 you apply more and more noise to the signal and ask the
21 operator questions.

22 How many targets can you find? How many
23 false targets are there and so on, to get an idea of
24 what this is doing to the operator. And that is
25 incredibly time-consuming. To get 200 data points from

1 an operator takes two days of effort, and you can't get
2 a good -- you can't get a good distribution that way.

3 So you turn over to the next slide. The
4 graph at left actually results from one of those
5 operator experiments. So the green is just the baseline
6 performance of the operator. There are two Gaussian
7 noise conditions, which are shown in kind of purple and
8 blue dots. You can see that as you raise the noise, the
9 operator's performance goes down.

10 I left in the continuous wave interference,
11 which looks like it performs really well, but that's
12 actually because we put the continuous wave in the wrong
13 spot. And that, again, highlights one of the problems
14 with using these human experiments.

15 You know, you set up something, and you get
16 to the end after spending two days with an operator, and
17 your results aren't even valid because you haven't done
18 the right thing. You need more control over your
19 experimentation.

20 So we've been putting a lot of effort,
21 jointly funded by Paige's office, on building a
22 simulation to be able to do this interference analysis.
23 And those are the results shown at the right. And in
24 the time it takes to do 200 trials with a human subject,
25 we can run 100,000 trials in the simulator.

1 And with the simulator, we've, in fact,
2 tracked down some of the difficulties and mistakes with
3 human trials, so that's maturing rapidly now, and we
4 think we're going to be able to make a lot of use of
5 that.

6 So that's kind of all I wanted to cover you
7 in the brief amount of time I had here. Let me just
8 leave you with a couple of thoughts. Just remember that
9 we've organized ITS around these four core technical
10 capabilities that we believe are the essential pieces
11 to move forward in advance spectrum policy. And that
12 is, propagation theory, propagation measurement, the
13 software engineering and the systems engineering
14 evaluation.

15 Our research portfolio, again, is reviewed
16 and updated annually. We have multi-year projects, but
17 every year they are reviewed. And if they're not making
18 progress or there is a higher priority, we drop that
19 project and move on to something else. We have to do
20 that. The state of the art is advancing so rapidly, we
21 can't keep doing the same old thing. We have to adapt
22 to things as we move out.

23 We're targeting challenges, obviously,
24 things that we have to have immediately to support the
25 current work that the FCC and OSM is doing, as well as

1 challenging the engineers to think 5 and 10 years out.
2 What are the things that we have to be working on now so
3 that we'll have the tools in place in five years.

4 And then we're focusing as much as we can on
5 foundational research and the development of these tools
6 that we can make use of in the future. So that's all I
7 wanted to cover. That was a lot. Questions?

8 LARRY ALDER: Yeah, thanks, Keith.
9 Questions? Dale.

10 DALE HATFIELD: Putting that TAC hat on just
11 for a moment -- oh, I'm sorry. One of the issues that
12 we're dealing with is not aggregate interference from
13 intentional sources, but unintentional radiation and
14 incidental radiation and so forth and the proliferation
15 of all these type of devices. I won't mention grow
16 lamps here in Boulder.

17 UNIDENTIFIED MALE: (indiscernible) more
18 interference, but people don't care.

19 DALE HATFIELD: ITS historically has done an
20 awful lot of work in the noise area, and the TAC
21 recently did something fairly innovative -- issued its
22 own notice of inquiry. It's not an FCC notice of
23 inquiry, but the TAC is asking for information on these
24 sources of noise.

25 And I'm just wondering what you're doing in

1 the sort of issues surrounding noise floor, and is
2 anything -- I'm going -- of course, it gets the
3 aggregate interference issue there, too. We had some
4 recent meetings with interference hunters, people that
5 do this professionally, and some of the things they're
6 turning up is where they have multiple interfering
7 digital devices that aggregate would cause interference.
8 I'm just curious if you're continuing that area of
9 research at ITS.

10 KEITH GREMBAN: Yes, we're continuing that
11 in a couple of forms. So first of all, that's one of
12 the end-user scenarios or end-user applications that
13 we're looking at in the spectrum monitoring domain, but
14 also in our Boulder testbed that we're working on.

15 That's going to give us the opportunity to
16 set up a lot of sensors over a significant geographic
17 area running 24 by 7, so we can gather good statistics
18 on noise floor and start running experiments on how do
19 we detect interferers of various types, what's the
20 density of sensors we need and how accurately can we
21 determine that.

22 DALE HATFIELD: Thank you.

23 LARRY ALDER: Go ahead, Jennifer.

24 JENNIFER WARREN: Jennifer Warren. And I'm
25 kind of going to build on what Dale's question was

1 because it's about interference as well. You, in the
2 beginning -- excuse me while my back's to you because of
3 the microphone (indiscernible) --

4 KEITH GREMBAN: Sure.

5 JENNIFER WARREN: You know, you indicated in
6 the beginning that one of the roles of ITS is to do the
7 hard technical work to inform policy making. And
8 aggregate interference is clearly one of those areas
9 there's a dearth, I guess, of technical expertise built
10 up for policy makers to make decisions in this area.

11 So what is your timing? Because there are a
12 lot of decisions that are being made and/or looking to
13 be made where this has been an issue and some real
14 concrete substance for the policymakers would be really
15 helpful.

16 KEITH GREMBAN: Wow, that's putting me on
17 the spot there. Yeah.

18 JENNIFER WARREN: (indiscernible).

19 KEITH GREMBAN: Obviously, as soon as
20 possible. As always with scientific research, it's a
21 little difficult to put a hard timeline on it. We've
22 been working the aggregate population problem over this
23 past year.

24 So next year, it's going to be applying that
25 and trying to attack and come up with models of

1 propagation so we can start answering some of those
2 questions. So, hopefully, over this next year, we'll
3 have the beginning of some answers for you.

4 LARRY ALDER: Steve and then Eric.

5 STEVE SHARKEY: So mine's maybe a little bit
6 different. So this is the first time -- I didn't
7 realize you had like the audio and visual user
8 experience evaluation capabilities here. And, you know,
9 you note the increasing demand for band width for things
10 like video.

11 Have you done any work on looking at how to
12 evaluate the efficiency of systems, where, help manage
13 the efficiency of systems by matching the data
14 transmission to the kind of capabilities of devices?
15 Like, so, for instance, a small device 1080p or as we go
16 to, you know, 4K video doesn't make a difference from a
17 user perspective, but use a lot of data.

18 So have you looked at evaluating user
19 perception that changes based on the size of the device
20 the impact that has on the amount of data required and
21 the potential, you know, difference that would have on,
22 you know, spectrum demand, demand for more capacity?

23 KEITH GREMBAN: So, yes, we have. There's a
24 couple of NTIA technical reports from last year and this
25 year addressing that issue of user perception for

1 different quality of display and size of display.

2 Additionally, we've got a project going now
3 in conjunction with the NIST PSCR laboratory on looking
4 at ways of evaluating the video, the raw video, and
5 determining how well it can be compressed to meet
6 certain user requirements.

7 LARRY ALDER: Mariam.

8 MARIAM SOROND: Thank you. This is Mariam
9 from DISH. I know that you do a lot of good work in the
10 propagation and all these areas, and one particular area
11 that we see is the standards work.

12 So I was wondering -- and from what I can
13 see right now in the standards (indiscernible) is mostly
14 related to public safety requirements. Did you have any
15 plans of increasing or expanding this into other topics
16 or other subjects besides just public safety?

17 KEITH GREMBAN: Thank you. So we have a
18 significant standards operation in public safety, but we
19 also have support, do a lot of work with the ITU on
20 standards with for RF propagation models, as well as, I
21 think this morning we're hosting an I triple E standards
22 meeting.

23 I'm sorry. I'm used to standing at the
24 front the and talking out. We are also hosting a
25 meeting of I triple E, what is it, 802, dot, 22, dot 3,

1 which is standards for spectrum monitoring.

2 MARIAM SOROND: Oh, sorry. Maybe I should
3 -- I was particularly talking about 3GPP. I should have
4 clarified that. I know you do a lot of good work
5 (indiscernible) --

6 UNIDENTIFIED MALE: Oh, (indiscernible.)

7 MARIAM SOROND: Well, because, you know, as
8 it relates to sharing and everything, there's perhaps
9 maybe opportunity there to comment (indiscernible) for
10 enabling technology sharing concepts (indiscernible) a
11 lot of things that you're working on.

12 So the 3GPP, I think, is mostly focused on
13 public safety and I was wondering if your were planning
14 on expanding that one.

15 KEITH GREMBAN: So we are expanding a little
16 bit, in particular the internet of things is one of the
17 areas that we are getting involved in the 3GPP standards
18 body.

19 LARRY ALDER: Okay. Let's -- I think we're
20 running out of time, so we'll do Rick. Did you have
21 one? Okay, Dennis and then Paige had one last comment.

22 RICK REASER: This is Rick Reaser. So this
23 is a parallel to my question to Julie. I notice you had
24 talked about IPC, and that's sort of looking at the
25 interference protection criteria for existing systems.

1 Have you guys thought about creating standards for
2 future systems?

3 I know this gets into the receiver standards
4 world, but I just think that that's something that ought
5 to be looked at in terms of what kind of future
6 interference protection criteria ought to be out there
7 as new systems are being developed so that we build
8 systems that are a little more robust to interference
9 and other types of things like sharing. So I wonder if
10 you have thought about that at all.

11 KEITH GREMBAN: Actually, the issue of
12 determining, this is the standard, that, I would say, is
13 a policy issue and we would stay away from. What we
14 will do is develop the tools and the methods that can be
15 used for people to experiment with interference
16 protection criteria and determine the number that the
17 community agrees on.

18 LARRY ALDER: Dennis Roberson.

19 DENNIS ROBERSON: This is Dennis Roberson,
20 and I'm going to channel a question from the wizard
21 meeting this morning from Tom Taylor. Tom's concern was
22 that we're really running short of radio engineers and
23 with all of the things that are going on that Paige
24 talked about and that Julie talked about, that this is,
25 there's a significant amount of work to be done out

1 there.

2 But, in your instance, from National Academy
3 study we conducted earlier -- well, I'll let you
4 respond. Do you see the issue being lack of skills or
5 lack of money to be able to proceed to address all of
6 the challenges that we've been talking about this
7 afternoon? I said it was a loaded question.

8 KEITH GREMBAN: I look over to Glenn for --

9 DENNIS ROBERSON: And I'm going beyond --
10 I'm trying to get your perspective. I'm not really
11 addressing ITS per se. This is not a lobbying for more
12 for money for ITS, though I'd be happy to do that.

13 This is, in fact, more looking at the
14 generic issue in the context of what Julie and Paige
15 have talked about with the things that are going on and
16 all that new spectrum that Julie just made available to
17 the world and propagation models that we're still not
18 happy with and all of the things that you just talked
19 about, too.

20 KEITH GREMBAN: So we are unable to address
21 all the problems we think we should be addressing. We
22 have to prioritize. There just isn't a budget for it.
23 That said, we could do more with more resources, but
24 there is a problem in finding qualified personnel.

25 We've been putting out a lot of job reqs

1 this year. And it's not been easy finding good radio
2 engineers, and what's even harder, and I say this as an
3 embarrassed computer scientist, it's very hard to find
4 software people now with the mathematical and physics
5 background to be able to do the work we do. And so
6 there are interacting problems there, and we're having
7 to look very hard to find the right people

8 LARRY ALDER: All right. Let's everyone
9 thank Keith. I'm going to turn it over to Mark. He's
10 going to walk us through the next section of the agenda.

11 MARK GIBSON: Okay. So now we're at the fun
12 part where all the subcommittees will do outbriefs, but
13 since we did most of the outbriefs at the last meeting,
14 this is just really going to be checking in to see if
15 there's anything different from before.

16 So we'll start with bidirectional sharing.
17 I know you guys had a little bit of work you did, so is
18 there anything you wanted to update?

19 CHARLA RATH: The only update is the paper
20 that we did which was distributed to the full committee
21 a couple of weeks ago. We didn't get any comments back
22 on it. No changes to the recommendations that were
23 approved in June.

24 The only thing, the only couple of things I
25 wanted to mention was first to thank the subcommittee,

1 because there was an awful lot of work that was done.
2 And, you know, I always you feel a little bit of risk
3 when they call out particular names starting with my
4 subcommittee co-chair.

5 But I have to say that Bryan did the initial
6 drafting on the report so really appreciate that and
7 then Jennifer and Mark, Steve and probably Janice and a
8 couple of other people were really involved in getting
9 that paper done. So we do appreciate all the help and
10 everything that people did.

11 We will -- Janice actually provided the
12 whole group some of her thoughts, many of which came out
13 of this. I assume we'll talk about that later. The
14 other thing that we had talked about as a group was
15 just, you know, one of our recommendations was this
16 workshop.

17 And clearly, you know, a very obvious next
18 step for this group or some other version of this group
19 to take on would be to truly outline what a workshop
20 would look like. But that's it, and unless there are
21 any questions, I don't want to really take up anymore
22 time. Audrey, I don't know if you have anything.

23 MARK GIBSON: Okay. Thanks, Charla. Any
24 questions for Charla or Audrey or anyone else on the
25 subcommittee? Okay. Good. Thank you, guys. That was

1 good work. I monitored as much of it as I could, but
2 very good work.

3 CHARLA RATH: I should have said thanks,
4 too, to Mark Gibson, because you were on almost all of
5 the calls, and I know you were also on all the rest of
6 the subcommittee calls and I don't --

7 MARK GIBSON: My life is CSMAC.

8 CHARLA RATH: Yeah.

9 UNIDENTIFIED MALE: (indiscernible)

10 MARK GIBSON: At 3:00 in the morning. Yeah.
11 Sometimes they overlap. Then there's this thing that
12 Julie waved the flag on which was WINNForum. That's
13 kind of been taking some time, too.

14 So, anyhow, the next one is Agency and
15 Industry Collaboration. Steve, anything on that?

16 STEVE SHARKEY: I don't think so. I mean,
17 it was considered at the last meeting and approved, so I
18 don't think there's anything more to --

19 MARK GIBSON: There was a revisit of the
20 recommendation, but I think we tweaked that
21 appropriately, so I think it's pretty much all good and
22 all done, so, yeah.

23 STEVE SHARKEY: Right.

24 MARK GIBSON: Good. Measurement and
25 Sensing, Dennis and, um --

1 UNIDENTIFIED MALE: Paul.

2 MARK GIBSON: -- Paul. I was looking at
3 Steve and I couldn't remember --

4 UNIDENTIFIED MALE: It's tough getting old.

5 MARK GIBSON: It's what happens when you
6 spend all your time at CSMAC. Thanks, George.

7 DENNIS ROBERSON: Following in line with
8 Charla's lead on this, we'll do kudos do to the team and
9 to my counterpart, my co-chair, Paul, for all of the
10 really good work. I will highlight our liaison as being
11 really an extraordinarily valuable member of the team,
12 so Ed (indiscernible), you know, special kudos to you.

13 Ed has such a depth of expertise in this
14 area that often we found ourselves debating something
15 and then asking Ed to give us the answer. So it was a
16 very helpful contribution. But significant
17 contributions -- as many of you know, we were able to
18 create a catalog of the uses of the spectrum in the
19 5 gigahertz range.

20 And hats off to Rick and one of the members
21 of his team. They did a great job in sorting out some
22 of the items that Julie talked about, some of the uses
23 of that 5 gigahertz spectrum that are so difficult in
24 the lower, the 2B part of the U-NII band. And 5.9 has
25 its not only technical but political challenges as we

1 all know with the Intelligent Transportation System.

2 And then finally, the one-size-fits-all
3 commentary that we continue to beat the drums on with
4 the fact that there are many different measurement
5 systems. We often think about this as the measurement
6 system. Well, there isn't a measurement system. There
7 are many different architectures that are appropriate
8 for different environments. And you have to match the
9 measurement system with the thing that you are trying to
10 measure.

11 So those are some of the key observations,
12 and I'm going to pass it to Paul to talk about the
13 results of the actionable recommendations that we made.

14 PAUL KOLODZY: (indiscernible). So two
15 things that we did. One, is we actually -- I think Rick
16 actually put together a nice little tutorial -- not a
17 tutorial, but an outline on how to look at
18 recommendations and the prioritization of
19 recommendations. I'm not going to go into detail in the
20 meeting here, but it's in the final report, and I think
21 it actually gives you some of the things to worry about.

22 We have one issue that I think that we have
23 a recommendation that we discussed last meeting. We
24 didn't get really any feedback until this morning. We
25 had one call.

1 DENNIS ROBERSON: We had a good call.

2 PAUL KOLODZY: And so I think I'll leave it
3 up to the chairs as to -- we haven't vetted (microphone
4 feedback). We haven't vetted it -- anyway we haven't
5 vetted it with the committee, so I don't know how you
6 chairs want to actually address that issue. That was
7 with Recommendation No. 5, which is the detection
8 augmentation techniques. So we'll leave it up to the
9 chairs to determine what we should do there.

10 MARK GIBSON: Well, I'm looking at it right
11 now. I mean, you guys had a -- in realtime -- thank god
12 for cell phones -- I mean have you had any chance to
13 discuss it amongst yourselves? Okay. But you had a
14 call, right?

15 UNIDENTIFIED MALE: Oh, we talked a month
16 ago. One of us took it to do to write up based on the
17 call.

18 LARRY ALDER: Wouldn't it be appropriate
19 just to attach a note?

20 MARK GIBSON: Yeah, I think we're going to
21 do that. I mean, I'm looking at it -- it's not my
22 committee, so I'll let you guys deal with it.

23 DENNIS ROBERSON: The difficulty is we had
24 an approved recommendation.

25 MARK GIBSON: I realize that. The question

1 is does this significantly change it to the point where
2 it would need to be revoted? I'll leave it up to you
3 guys. I haven't had a chance to look at this because I
4 got it while we were in the Wizard meeting. So -- go
5 ahead, Larry.

6 LARRY ALDER: My read of it is it does not
7 look different. Attach a note -- I think that's the --

8 MARK GIBSON: Yeah.

9 UNIDENTIFIED MALE: Okay. Well, we'll
10 figure something out.

11 MARK GIBSON: We've done that in the past
12 where you attach a note and just refer to it that way.
13 But I want to go back and read it just to study it a
14 little bit.

15 BRYAN TRAMONT: (indiscernible)

16 MARK GIBSON: No. No. That's the other
17 thing.

18 UNIDENTIFIED MALE: It came in during
19 another meeting this morning.

20 BRYAN TRAMONT: No, I understood, I just
21 didn't (indiscernible) what you were talking about.

22 LARRY ALDER: And that's the other thing.
23 It was just sent to, yeah, four of us, so --

24 PAUL KOLODZY: Okay. And then we have some
25 recommendations about moving forward, but I don't know

1 if you want to do that in the other session --

2 MARK GIBSON: We'll do that in the next
3 session, yeah. Great, thanks

4 PAUL KOLODZY: -- (indiscernible) worry
5 about that.

6 MARK GIBSON: Great. Thanks, guys.
7 Spectrum Access System International Expansion -- I see
8 both Kurt and Jeff.

9 JEFF REED: Yeah, we wrapped up our report
10 and just made some minor tweaks to the recommendation
11 based upon the feedback that we got at the last meeting.
12 And I want to thank the committee members and my
13 co-chair here for their great work. Kurt, do you have
14 anything to add?

15 KURT SCHAUBACH: Yeah, I just would echo
16 Jeff's comments. Thanks to all for their contributions
17 and, yeah, I don't think there's anything else to really
18 add to the report. As Jeff said, we just tweaked some
19 of the language associated with the recommendations.
20 The recommendations themselves remained unchanged.

21 MARK GIBSON: Did that tweaked language go
22 out to the whole committee?

23 KURT SCHAUBACH: It did, yes.

24 MARK GIBSON: And so basically it was just
25 clarity?

1 KURT SCHAUBACH: Yes.

2 MARK GIBSON: Okay. I remember that from
3 the last meeting. Any questions? Okay. Good.
4 Finally, 5G, Mariam and Rob.

5 ROBERT KUBIK: Sure. I'll kick it off. As
6 others said, thanks to the committee for working in this
7 group. I think we had a relatively active group, good
8 contributions. I'd like to thank the liaisons, Rangam
9 and Bob. They did a great job of helping out and
10 keeping us on track.

11 Finally, I would like to thank Mariam. She
12 did a great job of providing a lot of the text and
13 editing and a lot of her input's within this document.
14 Since the last meeting, we had circulated the full
15 report that we had talked about. It's a 33-page report,
16 a lot of background material. I don't think we received
17 any comments or suggestions based on that report.

18 Also, at the last meeting, I think the key
19 comment that we had back is that we wanted to have some
20 more pointed direct recommendations on actions that we
21 could take to move forward. And I'll turn it over to
22 Mariam to address those changes.

23 MARIAM SOROND: Okay. Thank you. So we
24 actually, out of the six recommendations, I think there
25 were three of them that were voted yes, and three of

1 them we said we would revise. What happened is we ended
2 up revising all six of them just to make sure they're
3 more actionable.

4 And, essentially, a lot of, you know, these
5 discussions when we'd have the brainstorming, sessions
6 we would come back and look at it. But with support
7 again from Rangam and Bob and understanding exactly what
8 is actionable, we -- the recommendations now -- on the
9 first one, if you look at it, it's looking at, you know,
10 defining these three sort of -- well, prior to the
11 recommendations, we called out the 5G unique attributes.

12 And I know I've said this a couple times,
13 that this is so far what the commonalities that we can
14 find are. Obviously, 5G is evolving and as we move
15 forward, there will be a lot more unique attributes, and
16 if you get into the details and the weeds of things,
17 there will be further more attributes that you can find
18 that are unique.

19 But at least we know for these ones that
20 we've identified, they're not going to change at least,
21 while everything is changing, as they're defining the
22 waveform and other requirements for 5G. So, so far,
23 these attributes really helped with the recommendations.

24 And the first three recommendations, which
25 I'm going to group together, are really about just

1 specifically what the deployment scenarios and the
2 unique things about the technology are.

3 So the actionable stuff really at this point
4 is, we are recommending that the NTIA actually pursues
5 sort of an industry collaboration, an industry agency
6 collaboration to define these and move forward on it.
7 So I think that's where, you know, these collaborative
8 agreements, as we heard today, will help facilitate
9 these early sort of concepts that might help with
10 sharing.

11 And not so much, you know, as Julie and
12 everybody else talks about, is that we look at it after
13 it's defined, but really pre-definition, we take these,
14 the NTIA sort of takes these steps to, whether it's
15 through CSMAC or other areas but to create this
16 collaboration to be able to see how this will impact
17 sharing.

18 Now, we didn't, you know, identify any bands
19 over here, and as part of the next session, we could
20 look at the different bands. We could take the 37
21 gigahertz band, for example, as one of them or even an
22 already-existing band like 1695 to 1710, you know, also
23 is part of going forward and moving backward, like you
24 said earlier, to double-check if that process with 5G
25 should have any sort of considerations that fall under

1 these categories. So those are really the first three
2 recommendations.

3 The fourth recommendation is about exactly
4 this whole, you know, baseline assumptions that we've
5 been talking about, you know, on probability aspects,
6 that again was hit earlier today, on worst-case
7 probability aspects.

8 You know taking that and defining sort of a
9 new look at the baseline assumptions. Again, that does
10 fall into this multi-stakeholder collaboration process.
11 That is going to be the recurring theme of actionable at
12 this point.

13 Recommendation 5 is really this upgrades to
14 technology, both on the federal and the industry side.
15 So groups like -- you know, on the commercial side, 3GPP
16 is already defining these standards. So that is a place
17 where this sort of early intervention, so called, would
18 help.

19 Then on the agency side, there could be also
20 opportunities for these kinds of groups. But this time,
21 you know, in lieu of not being able to pick one
22 particular place, we really picked 3GPP and hence the
23 questions about how does this 3GPP membership work.

24 We know that the Department of Commerce has
25 a 3GPP membership. They're focused more on public

1 safety issues, but we're really calling out a
2 collaboration between the NTIA and the FCC for this, to
3 be able to move this forward as to, for example, as of
4 right now 5G waveform is still not defined. So there
5 could be hooks right now place in there that allow for
6 better sharing, a little better sort of technology
7 accommodation of sharing. So that's Recommendation 5.

8 And, finally, 6, I think, was the one that
9 was the least amount of change, and it was identified as
10 one that could happen. It is about propagation
11 modeling. It's really, you know, propagation modeling
12 of all the bands, and we are actually recommending that
13 immediate resources be allocated to this to move the
14 work forward. Because as we heard today, it takes time
15 to get the propagations. You don't want the train to
16 leave on a lot of these things and the propagation work
17 not being there. That's it. Thank you.

18 MARK GIBSON: Okay. Thanks, Mariam. Remind
19 me, which of these -- these were all approved last time,
20 though, right?

21 MARIAM SOROND: Three of them were.

22 MARK GIBSON: I forgot which ones.

23 LARRY ALDER: (indiscernible) she said
24 (indiscernible) all of them (indiscernible).

25 MARK GIBSON: We're just going to do the

1 whole thing, just do the whole thing again. Is that
2 okay with everybody, especially you guys? Okay. So
3 should we take them as a whole, all of them? Is there
4 any -- well, has anybody had a chance to read them?

5 UNIDENTIFIED MALE: They were circulated.

6 MARK GIBSON: They were circulated, yeah.
7 So are there any questions? All right. So is there a
8 motion to approve all of them as they stand? Second?
9 Any further discussion? All approve by saying Aye. All
10 disapprove by like sign. I got up at 3:30. Okay. And
11 any abstentions? Okay. That was easy. Okay. So
12 that's it. Thank you, guys. Yeah, right. I'm afraid
13 the people -- can the people on the phone hear?

14 UNIDENTIFIED MALE: Don't ask. No.

15 LARRY ALDER: Mark, I just wanted to make a
16 comment that I particularly found the report generated
17 by the 5G group very useful. It's something I'm sharing
18 with other people -- hey, this is something you can
19 really look at to see what's going on. So thank you.

20 MARK GIBSON: You should publish that bad
21 boy and --

22 CHARLA RATH: Yeah, just a quick comment. I
23 just sent it to the (indiscernible) on the same issue.

24 MARK GIBSON: I hear Janice. Go for it,
25 Janice -- two minutes from now. Janice, you're on. Go

1 ahead. Janice, are you listening?

2 JANICE OBUCHOWSKI: I am, but I don't have
3 anything to say. You were just asking --

4 MARK GIBSON: We thought you had a question.

5 JANICE OBUCHOWSKI: Oh, no, no, no. I'm --
6 for once, no, nothing.

7 MARK GIBSON: All right. Well, at least we
8 know you're there.

9 JANICE OBUCHOWSKI: I'm alive.

10 MARK GIBSON: All right. Thanks. I'm just
11 going to stay on this (indicating the hand-held
12 microphone). So that's it. It's approved. Rick?

13 RICK REASER: I just wanted to second. I
14 thought that report was excellent. I passed it around.
15 So that was a very good piece of work. I have one other
16 observation. Why is it that DISH and Samsung don't have
17 echo like Raytheon and T-Mobile do?

18 ROBERT KUBIK: We're better coordinated.

19 UNIDENTIFIED MALE: (indiscernible) in the
20 spectrum.

21 MARK GIBSON: All right. Let's move this
22 along. I think they turned the gain up on these so they
23 can hear them on the phone, but I'm going to use the
24 hand-held. Okay. So I think we're -- okay. Go ahead.
25 You want to use that?

1 (Mr. Gibson gave hand-held microphone to
2 Ms. Atkins).

3 PAIGE ATKINS: I just wanted to thank the 5G
4 subcommittee for continuing to tighten the
5 recommendations and create a great document, as others
6 have said, as well as helping us have something we can
7 take hold on and do something with as we look at our
8 response to the recommendations. So thank you.

9 MARK GIBSON: So I think we're done with the
10 committee outbriefs, so, yeah, unless anybody has any
11 other comments, anybody on the phone other than Janice?
12 Well, Janice, you can comment, too, if you've got one
13 since five minutes ago. Okay. So, Paige, you have --
14 you want to use this?

15 (Mr. Gibson gave hand-held microphone to
16 Ms. Atkins.)

17 PAIGE ATKINS: Okay. So we're going to
18 speed up here significantly as we head toward the
19 afternoon. That will give us more time to talk about
20 ideas for the next term of CSMAC and have that
21 brainstorming session that we talked about.

22 So the original intent of my session to give
23 you some preliminary views on the subcommittee
24 recommendations has changed a little bit. Last
25 December, I presented NTIA's initial response to and

1 planned actions to address the recommendations from the
2 last cycle.

3 And we have actually made some significant
4 progress in many of those actions, some which are
5 related to perhaps what we will want to look at on the
6 next cycle to include things like, from an enforcement
7 standpoint, what did we learn from the Terminal Doppler
8 Weather Radar (indiscernible) license interference
9 cases.

10 So we're going through that case study, as
11 we mentioned, as an action. So we will learn things
12 that we can also integrate as we think through what the
13 next set of questions will look like.

14 Now, due to the complexity and timing of
15 these recommendations, we really haven't had the kind of
16 time and due diligence to peel these recommendations
17 back and fully understand what we're going to do with
18 them. But we have started looking at them.

19 And as we've talked about with previous
20 recommendations, we really need to digest and decompose
21 them, so we can make the right decisions of where we
22 invest resources and the sequencing of those resources.

23 And I do want to thank folks for taking a
24 look at priorities within the subcommittees and also
25 that taxonomy, so to speak, of how we would define those

1 priorities. I'd like to look at that for potential
2 guidance into the next term, so we can shape how the
3 subcommittees look at their recommendations.

4 So, again, today the discussion around our
5 response will be very limited. We've started looking at
6 the recommendations to determine, first and foremost, do
7 we concur with each recommendation and how actionable it
8 is. What can we do with it. How they may be related to
9 prior CSMAC recommendations. Because there is some
10 interrelationship in many of those, and how those
11 interdependencies manifest themselves with prior
12 actions,

13 And then what actions NTIA would propose,
14 based not just on the recommendation, but how they align
15 with our strategic priorities within NTIA and
16 particularly from a spectrum standpoint. And then,
17 ultimately, we will identify, as we did last time, those
18 actions that we will move forward with, based on the
19 never-going-away caveat, resources of both money and
20 people, as well as evolving priorities.

21 Because as we've seen, as I mentioned with
22 the PCAST report four years ago, how much has changed.
23 You know, our landscape will change over time. So we'll
24 continue to revisit and reprioritize, if needed, as we
25 move forward to respond to the recommendations.

1 And so our challenge is to continue to
2 digest and decompose the recommendations and identifying
3 what we would all call the important trends,
4 interdependencies, and actions that can collectively
5 help us move forward to address some of the most
6 significant spectrum challenges, not just from a
7 technology standpoint, but, then again, that
8 intersection with technology or with policy process and
9 regulation, which is really key to making all of this
10 work and work well.

11 So our assessment will inform the future
12 topics. Unfortunately, we don't have that here today.
13 But we will certainly be listening to the discussion
14 this afternoon. I hope it's a robust discussion in
15 terms of your thoughts. And think of it as a
16 brainstorming session, as was mentioned earlier, and
17 somewhat open-ended, but remember we are being publicly
18 webcast.

19 And what I would ask as we have this
20 brainstorming session, is to think about potential
21 topics that we've talked about before for potential
22 collaboration with the FCC TAC, as an example. Other
23 topics may be, also, more appropriate for other forums.
24 They may not be CSMAC topics, but as we build this more
25 robust and expansive collaboration mechanism or things

1 like WinnForum, we may want to toss topics to other
2 activities.

3 And then, again, we will also be capturing
4 some lessons learned, like this taxonomy for
5 prioritization and how can we have used those lessons
6 learned from this cycle to better shape how we move
7 forward in the subcommittees.

8 And I will say, don't let perfect be the
9 enemy of the good, and we're looking for ideas. And I
10 will open it up to any questions you might have as we've
11 begun to look at these recommendations. But, as I said,
12 we're really just now still going through and peeling
13 back the recommendations and how we should best respond.

14 So we've got all this extra time for the
15 brainstorming session, so I'm looking forward to the
16 discussion.

17 LARRY ALDER: So I thought what we'd maybe
18 do is start off by going through recommendations for the
19 different subcommittees that wanted, that thought future
20 work was appropriate, because I know there was
21 definitely some around the sharing the federal and
22 nonfederal spectrum. So shall we do that to kind of
23 kick things off and then we'll go from there?

24 MARK GIBSON: Yeah.

25 LARRY ALDER: Charla, I'm looking at you.

1 CHARLA RATH: Yeah, and I've already
2 mentioned the one that we talked about as a group, which
3 was literally to map out the workshop that we had
4 recommended. And then Janice, who we all know is on the
5 phone, did actually send to everyone, but I wasn't sure
6 she wanted to just, you know -- but if she wants to
7 sort of talk about it or present it, it was not the
8 group's recommendation, but I'm sure that several of us
9 would agree with parts of it.

10 MARK GIBSON: Hers were multijurisdictional.

11 CHARLA RATH: Yes, well, that's true, too.

12 LARRY ALDER: Janice, would you like to walk
13 through your suggestions? Janice, are you there? I'm
14 waiting 10 seconds.

15 UNIDENTIFIED MALE: She sent it to all of
16 CSMAC.

17 CHARLA RATH: Yeah, she did. She sent it --

18 UNIDENTIFIED MALE: Yeah, but it was
19 yesterday --

20 UNIDENTIFIED MALE: Or three days ago.
21 Today's the 1st --

22 JANICE OBUCHOWSKI: Okay. So this is going
23 to be a little unusual. I'm going to turn off the
24 feedback, so you'll just hear me. I'm not sure, you
25 know, if we'll have this time lag here.

1 Sure. I'd be happy to. You know, I had two
2 generic ones, although they go to two-way sharing, you
3 know, importantly. One was on the topic of general
4 incentives. You know, sharing is the name of the game.
5 We'll be, I think, (indiscernible) increasingly going
6 forward given the plethora of demands for spectrum.

7 And, you know, a lot of the discussion
8 historically at CSMAC has been about financial
9 incentives for sharing. But as a general matter, I'd be
10 interested in hearing more across several topics of
11 potential other levers.

12 And some of these have come up already, but
13 in my view could use further amplification -- shared
14 access to technology perhaps. The ease of access to the
15 spectrum is another incentive at times for sharing, of
16 course.

17 The second sort of generic that I have which
18 pertains very importantly to federal commercial
19 spectrum, and it comes up -- I know it's controversial.
20 It came up in the Spectrum Frontiers proceeding. And
21 that is the issue of cyber security.

22 I'm not sort of ascribing -- I'm not
23 specifically talking about Spectrum Frontiers, but the
24 reality that is inescapable is that access to networks,
25 access to technology, in general, is -- you know, it is

1 increasingly a terror weapon; it's an economic weapon;
2 and we've heard it said to be a political weapon.

3 So, you know, that notion is not going away,
4 and it is inevitable in the sharing context. I don't
5 think we can escape it. We don't necessarily have to
6 resolve how we address the cyber issues, but they have
7 to be raised, and they have to be directed to someone.

8 Because I think it's irresponsible to talk
9 about sharing and the sorts of databases and sharing
10 technologies that we would support if we don't flag
11 cyber issues that need to be resolved simultaneously.
12 If you don't flag them, you do something that I think,
13 you know, I've seen at least the beginnings of at times.
14 It's sort of a runaway solution that doesn't flag a key
15 strategic problem.

16 And that, of course, comes up most readily
17 in shared commercial, federal. But it could be across
18 the board, or it is across the board. And then,
19 specifically, the bidirectional sharing -- I don't want
20 to belabor the various points that I raised in the memo.

21 I think, Charla, of course, raised the key
22 one, which is making sure that the workshop gets off the
23 ground, and that it's needy and that it's timely. It's
24 obvious, you know. Three years ago, nobody was talking
25 about commercial (indiscernible) wireless

1 (indiscernible) access to high band spectrum. And now
2 it's already, you know, well down the regulatory path.

3 So if we can't put this workshop together
4 quickly and in a needy fashion, it's going to be an
5 academic exercise. I was specifically concerned that it
6 wasn't -- you know, I had made a recommendation that
7 this not be a workshop, that it be perhaps an MOI or a
8 NTRM between the two agencies, federal and NTIA, that
9 wasn't ascribed to in the broader group, but I do think,
10 you know, time is of the essence.

11 A lot of bidirectional sharing is focused on
12 areas around military and other federal properties.
13 Going forward, this topic of geographic bounding has to
14 be revisited. That's critical for certain kinds of
15 testing. It's not going to be central to the
16 development of robust bidirectional sharing.

17 Sharing templates, I think we made a lot of
18 progress in our committee talking, for example, about
19 the model MOU that has been advanced. But I believe
20 that Julie, who is always intellectually honest, alluded
21 to the fact that, you know, in response to the question,
22 that now that sharing between federal and commercial is
23 more important, more necessary, given conflicting
24 spectrum demands, there is just not an easy way forward
25 for federal users to access commercial spectrum. And at

1 times vice versa.

2 It's encouraging that, you know, both the
3 NTIA head and Chairman Wheeler have raised this. But to
4 go from there to developing technologies and getting
5 them through the process where with the steps really
6 aren't easily understood or easily promoted are just
7 obviously not going to move the ball forward.

8 And then the last recommendation I had for
9 consideration going forward, and this is (indiscernible)
10 NTIA, but it would be at least equally applicable to the
11 FCC -- how to handle high-volume requests. Obviously,
12 you can't build a commercial network without getting a
13 license and that license entitles you to deploy in a
14 very robust fashion.

15 Well, in a sharing if you're operating in
16 onesy, twosy fashion, well, those are good for trials,
17 maybe good for testing. It's not good for development
18 of dynamic new technology. So that would be my sort of
19 fourth suggestion on bidirectional sharing.

20 So that covers the topics that I wanted to
21 raise and I appreciate you bearing with me, especially
22 given the call-in. And thanks for that.

23 LARRY ALDER: Thanks, Janice. I don't know
24 if you can hear our feedback, but we did hear your
25 presentation, and it was very helpful, and thank you.

1 And Mark is now trying to, going to
2 capture -- he is displaying stuff and he'll try and
3 capture some of this dialog. The next subcommittee that
4 I knew had suggestions -- oh. Go ahead. I don't know
5 if she's interactive or not.

6 PAIGE ATKINS: And so, Janice, you may or
7 may not be able to answer these, but just to clarify the
8 high-volume request, if I understood it, is really how
9 do you enable dynamic sharing between federal and
10 nonfederal users that would require a much higher volume
11 of interaction and coordination.

12 JANICE OBUCHOWSKI: Yeah, I think that's a
13 better statement of the situation.

14 PAIGE ATKINS: Okay. And then I just want
15 to highlight that what I would suggest as we think
16 through key areas that we need to focus on as we move
17 forward, again, remember CSMAC may or may not be the
18 best vehicle.

19 The last cycle we talked about this
20 multilayered collaboration framework that we are
21 fleshing out as we speak. And there may be good
22 strategies of how we address some particularly relevant
23 and important topics, just not through CSMAC.
24 Partially, quite frankly, maybe due to time lag or other
25 things where we want to be more responsive to the topic.

1 So I just want you to think about that as we talk about
2 these future issues.

3 JANICE OBUCHOWSKI: Paige, I think you're
4 absolutely right on the money there. And, you know, you
5 mentioned CSMAC-TAC cooperation going forward. Of
6 course, Dennis is on both and leads one of the groups.
7 I would certainly endorse that, because, you know, it's
8 been stated, I think it's inevitable that CSMAC is
9 delving deeper and deeper into technical issues.

10 You know, policy and technical are sort of
11 interwoven, because you're always talking about the art
12 of the possible when you're making policy. So I think
13 that dialog -- as somebody mentioned, there's a shortage
14 of -- there's a shortage of -- there's not a shortage of
15 experts, but there's a shortage of time and, you know,
16 breadth of expertise. And, you know, working on
17 parallel tracks is a good idea. Much more tight
18 collaboration I think would be terrific.

19 LARRY ALDER: So I see a number of tents up.
20 So what I want to do is avoid spending a lot of
21 discussion on particular topics. I want to make sure we
22 just flesh out the ideas. So real quick, are the tents
23 for ideas? Because what I wanted to do is I wanted to
24 walk through the different subcommittees first.

25 CHARLA RATH: Yeah, one thing I wanted to

1 add to this. I thought about it when Julie was saying
2 what are the reasons for bidirectional sharing, and I'm
3 wondering, I'm not quite sure what it is, but the idea
4 that there may be technologies where we need to be
5 thinking about jointly developing technologies to
6 actually to help implement sharing.

7 And we did that a fair amount. There was a
8 lot of that in AWS-3, but I'm wondering, and I'm not
9 quite -- you know, I just throw it out there. When he
10 mentioned it, I did think, you know, that that might be
11 a good topic for the next iteration, if there is one, of
12 bidirectional sharing. I'm not quite sure what it is
13 yet, but it just strikes me that there could be some
14 additional work.

15 LARRY ALDER: Let Mark capture it here.
16 What would he --

17 CHARLA RATH: Yeah, you can capture it,
18 Mark.

19 MARK GIBSON: (indiscernible)

20 CHARLA RATH: Not good for the person taking
21 notes. Yeah, let me see if I can do it more succinctly.
22 Julie brought up the idea that one of the reasons that
23 the federal government is particularly interested in
24 bidirectional sharing is the ability to sort of use the
25 technology development that's going on in the commercial

1 sector to develop, you know, more services in the
2 federal government that can actually use the same sorts
3 of technologies.

4 But I've always had a question about what
5 does that really mean, because, you know, you've got
6 different missions, you have different -- you know, how
7 applicable is that? And I'm just wondering if there is
8 something for us to be talking about along those lines.

9 LARRY ALDER: So it's kind of a technology
10 question around federal and non-federal --

11 CHARLA RATH: Around federal sharing and how
12 real is that. I mean, that is something that we talk
13 about a lot and how real is that, and is that something
14 that CSMAC can make recommendations on for NTIA to take
15 action on.

16 PAIGE ATKINS: So I would -- actually, I
17 would -- how I think of it is how do we leverage dual
18 use technologies to enable federal and nonfederal
19 sharing.

20 CHARLA RATH: Is it leveraging dual use,
21 because we're not even sure yet whether -- you know,
22 it's almost exploring whether --

23 PAIGE ATKINS: Well, I'm thinking you have
24 to explore it to understand how to leverage it.

25 CHARLA RATH: Yeah, true.

1 PAIGE ATKINS: I think as we look at
2 Frontiers, many of these topics are directly relevant to
3 Frontiers, so I think as we look at the topics, we may
4 want to tie it to something like Frontiers that allows
5 us to focus it in the process.

6 LARRY ALDER: All right. I'm going to --

7 MARIAM SOROND: Can I make just one comment?
8 About the -- that's what we were trying to do in the 5G
9 just to clarify, that's actually the recommendation
10 (indiscernible)

11 LARRY ALDER: I'm going to move to Michael
12 because he's had --

13 MARK GIBSON: Charla and Paige are saying
14 the same thing more or less so (indiscernible) --

15 LARRY ALDER: Yeah. I don't think we really
16 (indiscernible) wordsmiths here. It's broad concepts at
17 this point. Michael.

18 MICHAEL CALABRESE: Yeah, and I just wanted
19 to add on to -- I hope this is an add-on to support for
20 what Janice said, rather than have to bring it up again,
21 you know, separately, later.

22 So Janice mentioned, I thought it was when
23 she was talking about the high volume requests and the
24 need to, you know, signal to agencies that this is
25 possible and to reduce the friction in federal users and

1 NTIA getting access, and that is that it might be very
2 useful as a continuation of bidirectional sharing to
3 look at whether there isn't a framework for at least
4 temporary and nonharmful access to any band for federal
5 agencies.

6 And what would be the framework for that,
7 what would be the mechanism? Is it a geolocation
8 database or a leveraging of one of the existing ones
9 such as the SAFS, because the PCAST report essentially
10 said that that should be the case, that federal agencies
11 should also be able to do that.

12 And I think we haven't really addressed --
13 we keep sidestepping, kind of, the direct question of,
14 at least in this sort of, in this kind of easier case of
15 temporary and nonharmful sharing, is there a workable
16 framework for doing that, which would, I think, get at
17 some of the high-volume, reducing-the-friction kind of
18 ideas.

19 LARRY ALDER: (indiscernible) for any band --
20 I'd put that. You're up, Jennifer.

21 JENNIFER WARREN: Jennifer Warren. Just to
22 follow up on that -- I'm going to save my new ideas for
23 later. The question, though, if folks want to do what
24 Michael was suggesting, I think is looking at least what
25 we did two CSMACs ago in the first iteration of the

1 bidirectional sharing group, which was kind of looking
2 at short-term, nonharmful and what were the criteria,
3 and it's almost you're talking about, I think,
4 implementation of the prior report, is kind of how I'm
5 interpreting what you're saying, Michael.

6 MICHAEL CALABRESE: (indiscernible)

7 JENNIFER WARREN: That's what I mean, yeah.
8 So just to throw that out there.

9 LARRY ALDER: Got that? Okay. One of the
10 other subcommittees that had, I know had a suggestion
11 for future work was the sensing subcommittee, and it's
12 great Dennis is just walking back in.

13 (indiscernible comments)

14 PAUL KOLODZY: Okay. No feedback. There
15 are three basic recommendations or actually suggestions,
16 actually, I think would be. One was from the entire
17 committee that wanted to continue on the effort of the
18 subcommittee in the sense of picking either a few new
19 bands or looking at another broader area in the sense of
20 looking at the architectures, the measurement
21 architectures for spectrum sharing.

22 And because we were just starting to get
23 into the details as to where you want to go in certain
24 of these places, we picked another couple bands that you
25 have an interest in, they might be very good, even going

1 up into the 6 gigahertz and 7 gigahertz might be a very
2 big help there, we think, to the community as well as
3 you have a lot of enthusiasm by the group to actually
4 continue on the subcommittee.

5 Now, there's two other recommendations that
6 weren't the subcommittee's, that were mine, but we had
7 discussed within the subcommittee, and I put them in the
8 report -- not the report, the presentation. One of them
9 is looking at something completely different.

10 Right now, you have a distinct change going
11 on in the nation, if not the world, in a sense the
12 development of counter UAV systems. And this is going
13 to cause a lot of stress both in the federal and
14 nonfederal areas as to how to do development and testing
15 and actually implementing.

16 Because some of the counter measures that
17 are being looked at will be very different, very harsh,
18 in a sense, with respect to what kind of sensing systems
19 they're going to try to put on the counter systems,
20 countering the sensing systems that are being put on the
21 actual UAS's that are being put out there. What are the
22 counter measures in a sense of trying to bring them down
23 or overtake them. What kind of technology might be
24 used. How are you going to test those --

25 LARRY ALDER: Go easy on Mark, here. He's

1 trying to --

2 PAUL KOLODZY: Right. I've got them all
3 written down here for you, Mark.

4 MARK GIBSON: (indiscernible)

5 PAUL KOLODZY: So it is a -- really it
6 crosses the boundaries between the spectrum management
7 and non-spectrum management, and it has a huge impact on
8 commerce. And so thinking this is the time that you may
9 want to take a look at this prior to something major
10 occurs and you're trying to be reactive. This might be
11 more pro-active. Though we're right now getting close
12 to the reactive stage because of what is going on. That
13 is Problem 2.

14 Problem 3 is something that -- I have not
15 talked with the committee, but it's been put forward a
16 lot lately. And this is something even further afield
17 from what we've generally talked about with spectrum
18 sharing. And that is, given that the technology -- I'm
19 involved with a lot of the communities now that are
20 developing technologies for distributed antenna systems
21 (indiscernible) distributed transmitters and the like.

22 It changes the fundamental aspects of what
23 is EIRP now. What is transmission quality? And also,
24 it also changes what is interference, because now you're
25 looking at coherence at a particular point. And so,

1 therefore, sharing now changes dramatically when you
2 start looking at distributed antenna systems.

3 And I think that this community with getting
4 both the policy folks to understand what the policy
5 ramifications would be with the technical folks being
6 able to discuss some of those issues might actually take
7 you down a very different path.

8 And it's a path that we're all going to have
9 to address, because these systems are going to be
10 deployed probably within the next five, definitely
11 within the next 10, and probably within the next five
12 years.

13 LARRY ALDER: Paul, are you talking about
14 distributed transmitter or distributed sensors or both?
15 I was --

16 PAUL KOLODZY: Actually, I'm looking at
17 distributed transmitters, though it could also be
18 distributed sensing as well. But this was more
19 transmitters, because EIRP doesn't make sense then, out
20 of band emission don't make sense. A lot of things
21 don't make sense at that point.

22 MARK GIBSON: That was in your
23 (indiscernible) --

24 PAUL KOLODZY: That was not. I'll provide
25 that.

1 LARRY ALDER: Anything else from sensing?
2 Dennis? Did that cover it?

3 DENNIS ROBERSON: There was more to the
4 bullet that Mark put up there. I think that's the
5 point. Some of this relates to the -- well, most of it
6 is in the thing there. But Paul has brought up the
7 point on the studying the architectures.

8 One of the comments that we've made is that
9 the new structures, MIMO, massive MIMO and so on, that
10 that does not lend itself to any of the measurement or
11 sensing techniques that we've historically utilized. So
12 it's a very significant problem to be dealt with.

13 LARRY ALDER: And a topic that I'd throw out
14 that's related to sensing is I'm definitely seeing, you
15 know, this move towards with the 3.5 gigahertz, where
16 you're having it distributed to permanently deployed
17 sensing networks, and how would some of those
18 permanently deployed sensing networks yield spectrum
19 sharing help, open up more bands, should be there be
20 defined APIs or something.

21 There could be a whole broad range of
22 questions and topics around distributed sensing. I
23 don't know if that's best handled in another forum, but
24 I think it's an interesting extension of the sensing
25 work that you guys did.

1 PAIGE ATKINS: So I would extend that
2 description as federated sensing and then exposing,
3 being able to expose data in a federated sense. Some
4 may or may not be exposed, and some of the work that ITS
5 is doing is related in that area, that ITS is doing in
6 conjunction with NIST, so there might be some synergy
7 there.

8 DENNIS ROBERSON: I would just note that one
9 of our members strongly supports the use of federated
10 (indiscernible).

11 LARRY ALDER: Okay. Let's move on to the
12 other groups to see if there was suggestion for future
13 work. Steve, I don't think there was out of the
14 collaboration --

15 UNIDENTIFIED MALE: Keep it going.

16 STEVE SHARKEY: Yeah. There wasn't -- you
17 know, I think we've been through this group a couple of
18 times, and, really, I think the work is subsumed, you
19 know, under the other group looking at bidirectional
20 sharing as kind of a subset of that.

21 LARRY ALDER: Perfect. And then the next
22 group is 5G. You guys had some suggestions for future
23 activities formally or --

24 MARIAM SOROND: (indiscernible)

25 STEVE SHARKEY: I'll bring you the mike.

1 MARIAM SOROND: Thanks, Steve. I think
2 we've outlined already most of our recommendations.
3 Five out of six are actually future work, but beyond
4 that, just personally, I wanted to also bring up, and
5 maybe Julie touched upon this earlier, but receiver
6 performance.

7 I think that it's really important, because
8 sharing, I think, is 99 percent about receiver
9 performance and 1 percent about transmitter. And we
10 have relied heavily on transmitter specifications. And
11 so I think it's important, and maybe this could be part
12 of the joint work with the TAC as well, but I think
13 receiver standards both from the commercial industry and
14 the government, federal government side, so equally
15 applied to both sides, are what will enable much better
16 or different sharing.

17 So I think we really do need to look. Now,
18 if you want to look up receiver performance standards, I
19 think it's probably more suitable to look at future
20 technologies, because existing technologies have already
21 been deployed and are out there, and they are what they
22 are.

23 So right now, 5G is an opportunity for us to
24 revisit receiver -- and when I say 5G, I'm calling the
25 federal side, also. They're going to go through a 5G

1 evolution kind of like the industry side, under that
2 assumption, if we look at the receiver performance.

3 LARRY ALDER: Mark, you got that
4 (indiscernible) receiver performance.

5 (indiscernible comments)

6 MARIAM SOROND: And then that also -- then
7 therefore maybe a second (indiscernible) would be
8 related to this is the baseline of sharing, so defining
9 the baseline. I think baseline assumptions moving
10 forward, which then leads to the technology
11 collaboration and technology evolutions and things like
12 that.

13 And then one particular one was I was going
14 to suggest that, you know, CSMAC did a lot of good work
15 on the AWS-3 spectrum. I think I was going to suggest
16 that we, not revisit because there was something wrong
17 with it, but just go back and apply 5G, because a lot of
18 the work that was done at that time was for LTE and not
19 5G.

20 So I would say, specifically, I was going to
21 propose 1695 to 1710, but it could also be 1755 to 1780,
22 no particular preference. But essentially taking those
23 assumptions and looking at 5G and how that changes it,
24 and if any would be useful. It's an existing piece of
25 spectrum. A lot of the learnings over there would also

1 help the other spectrum.

2 I think a lot of the -- for a while -- some
3 people still think of 5G as a millimeter wave and that's
4 really not the case. I mean, it is a centimeter wave, a
5 millimeter wave, and the existing spectrum is definitely
6 a part of it. And it's going to evolve into that. So
7 even the current sort of technologies today in these
8 bands are going to evolve to 5G.

9 So if we don't go back and take at least one
10 of them that is still fresh sort of and like does not
11 have millions of users on it -- it would be a good
12 opportunity to do this at this point.

13 And also you could take another band --
14 again just throwing out 37 gigahertz just because it
15 came up earlier today, but you know -- so that is the
16 alternative. So the lower band. One of the AWS-3 ones
17 and then a higher one like 37 gigahertz.

18 MARK GIBSON: When you say the higher band,
19 you started off by saying go back and look at AWS-3
20 considerations. I got that. Are you saying apply the
21 same considerations to the higher --

22 MARIAM SOROND: No. No, it would be
23 different. Yeah, just higher band under like -- just
24 specifically -- different topic, whatever. Higher bands
25 as applicable to the 5G.

1 LARRY ALDER: Thanks, Mariam. Any comment
2 on that?

3 DALE HATFIELD: Just quickly. I'm really a
4 strong fan of the harms claim threshold thing. I'm
5 getting very -- I get very concerned about government
6 getting in and actually designing receivers and things
7 like that. I think the harms claim threshold is a much
8 better approach, and I would urge us to continue to
9 think along the harms claim threshold line. Of course,
10 a lot of that work is being done, a lot of work on that
11 is being done in the TAC.

12 UNIDENTIFIED MALE: That wouldn't
13 necessarily be a 5G. That would be sort of be on its
14 own, don't you think?

15 UNIDENTIFIED MALE: (indiscernible).

16 LARRY ALDER: Carl.

17 CARL POVELITES: Carl Povelites. Going to
18 Mariam's --

19 LARRY ALDER: Hold on a second, Carl. Can
20 you run the mike over --

21 MARK GIBSON: Here, I've got it. I'll be
22 the mike runner. Here you go.

23 CARL POVELITES: Going to Mariam's, one of
24 her recommendations, and also going back to Paige's
25 start of her presentation earlier where we've now

1 reached about halfway through the president's target for
2 500 megahertz. I'm not sure what necessarily going back
3 to AWS-3 for 5G necessarily, what that whole process
4 would do, particularly when it's already been auctioned.
5 But there are other lower bands that, you know, it was
6 on the 6th report and all that. We may want to go back,
7 and we may want to go into like 1300 to 1390 or some
8 other band to do a similar study that we did with the
9 AWS-3 band.

10 LARRY ALDER: Okay. Give Mark a chance to
11 catch up here. And I think Carl's point is just looking
12 at some non-AWS-3 lower bands might also be an idea.

13 CARL POVELITES: (indiscernible) report that
14 NTIA is currently studying and seems like it might have
15 an opportunity in the future.

16 LARRY ALDER: Okay. Michael, since you're
17 right next to the mike.

18 MICHAEL CALABRESE: Yeah, I'd like to add on
19 to the 5G. Again, kind of building on what Julie
20 mentioned earlier, specifically with respect to 37 to
21 37.6. Julie mentioned that the federal users would like
22 to optimize, I guess, their flexibility for perhaps
23 introducing or altering uses in the future that they may
24 not even know about yet.

25 So it may be worthwhile to, right at this

1 point, if we do it quickly, to look at, to explore
2 mechanisms for sharing that particular 600 megahertz
3 that will speak to those federal agency needs; in other
4 words, particular sharing mechanisms look at, you know,
5 whatever they are. I mean, I realize there will
6 probably be comments on that coming this fall as well,
7 but it may be worth kind of drilling into that as a
8 group.

9 LARRY ALDER: Okay. Thanks, Michael.
10 Bryan.

11 BRYAN TRAMONT: Are we using both or just
12 this one? All right. Anyway. So I feel very strongly
13 about this ill-informed idea or ill-formed idea. That's
14 why I have both mikes to make sure you really capture
15 how ill-formed this is.

16 So I feel as if we have at times, and I
17 think this is somewhat based on my own regulatory
18 experience, too, that in developing policy, sometimes we
19 focus a lot on figuring out something that is capable of
20 working, but we don't always go back to figure out if it
21 actually did work.

22 So I'm wondering if by the time we reconvene
23 with the new group, what have you, if it isn't time to
24 go back and look at particular dynamic sharing
25 experiences. White spaces springs to mind, but we may

1 have stuff developed to 3.5. We may have other -- AWS-3
2 there may be lessons. And trying to figure out what did
3 and didn't work and why.

4 I had occasion recently to go back and look
5 at the original white spaces decisions in 2004, I think,
6 when we did the original. You know, it's now 12 years
7 ago, and we've learned a lot along that (indiscernible),
8 but we still don't have a widely deployed white spaces
9 infrastructure, and I suspect there might be things we
10 can learn from that experience.

11 I just want to make sure we're not creating
12 regulatory regimes for sharing that don't have any
13 public interest benefits to both sides, either because
14 the federal government can't use the spectrum the way we
15 had envisioned or because there is no commercial demand
16 for it, so people aren't putting the investment dollars
17 into it.

18 So my ill-formed idea is that we would
19 figure out what the lessons learned are and then perhaps
20 think about what the public policy test is for whether
21 sharing has been a success and when we call that
22 question.

23 Because I think there are a lot of ideas out
24 there, and I think we are trying to experiment with a
25 lot of the different ideas, but we need to -- I think

1 because there's such increasing demands so quickly, we
2 need to focus on what ideas are working as early in the
3 process as possible so that we thin out the herd a
4 little bit.

5 LARRY ALDER: Mark's got that.

6 UNIDENTIFIED MALE: (indiscernible)

7 LARRY ALDER: He's got the general category.

8 BRYAN TRAMONT: (indiscernible) sharing.

9 MARIAM SOROND: (indiscernible)

10 BRYAN TRAMONT: I don't think we should
11 limit it to federal and non-federal because we have some
12 examples that are commercial on commercial and some
13 federal on federal. I took out Jennifer's tent on the
14 way.

15 LARRY ALDER: Hold on, hold on. I've got a
16 few questions. Going to hit these questions and I just
17 wanted to check before I do these questions, did the
18 International SAS, did you guys have follow-up for
19 future work?

20 KURT SCHAUBACH: We didn't really have
21 specific recommendations related to the international
22 extension, but maybe a related topic might be to -- this
23 was something that came up in the recent wizard workshop
24 on enforcement was metrics or measures of, for example,
25 spectrum access systems or other sharing technologies on

1 their way to the market.

2 How would you measure the effectiveness of
3 them? Are they performing sort of roles or functions
4 that they're supposed to? So sort of beyond the measure
5 of initial certification, I think there's this notion of
6 perhaps like a monitoring facility, you know, or even
7 like a network operations center that, you know, could
8 be looked at for sharing technologies.

9 MARK GIBSON: (indiscernible)

10 KURT SCHAUBACH: Yeah, and perhaps the
11 feasibility of that and what role NTIA could or should
12 play in that.

13 JENNIFER WARREN: (indiscernible)

14 KURT SCHAUBACH: No, I think this is a
15 little more technical in nature, Jennifer, so this is --

16 UNIDENTIFIED MALE: (indiscernible)

17 KURT SCHAUBACH: Exactly. And this is also
18 sort of more focused on the systems themselves versus
19 the policy, perhaps.

20 LARRY ALDER: Okay. At least we've gotten
21 through the groups. Your questions just went down.

22 (indiscernible comments)

23 UNIDENTIFIED MALE: Just to clarify,
24 wireless (indiscernible) --

25 DENNIS ROBERSON: My comment goes with the

1 earlier comment I made about LSA, inserting it into the,
2 going back and looking at success. LSA is not that.
3 LSA really is the looking forward. So it would fit
4 under that one.

5 But I think it is important that we look at
6 this point that Kurt's made around metrics and
7 efficiency, look at this on a global basis, using LSA as
8 the example. LSA there's a lot of pursuit -- Mark, I'd
9 put that on the next one, not on the go back.

10 Because LSA isn't something that we've
11 really embraced here in the U.S., Qualcomm
12 notwithstanding, where Europe seems to be on a path to
13 move that way. So looking at and checking on the
14 efficacy, as you've described it, of other systems
15 around the world -- I think that is an important one for
16 us.

17 LARRY ALDER: Okay. Thanks, Dennis. Okay.
18 I think we've covered all of the subcommittees.
19 Michael, do you still have a question or is that just a
20 leftover?

21 MICHAEL CALABRESE: No (indiscernible) --

22 LARRY ALDER: What?

23 UNIDENTIFIED MALE: (indiscernible) open --

24 LARRY ALDER: Yeah, we're going to open up
25 for just -- I think we've covered the subcommittees, so

1 right now it's just free form, whatever the ideas are.
2 Dale, it sounds like you have one.

3 DALE HATFIELD: It relates a little bit to
4 bidirectional sharing, but one of the key things here I
5 think is if you're, when you have an incumbent, let's
6 say the feds, and they do entrance on the commercial
7 side, one of the things you need to know is the
8 waveforms or you would like to have as much information
9 on the waveforms as you can to be able to avoid causing
10 interference, at least with certain forms of dynamic
11 sharing.

12 In the same way, when the incumbent's
13 commercial, you have the same issues, needing waveforms.
14 And I realize the sensitivity to the waveforms from the
15 federal government side, but when you're out there
16 looking for these waveforms, especially at the lower
17 frequency, there's going to be an awful lot of other
18 signals in that band, and they can be harmonics, all
19 kinds of interfering signals.

20 So I'm coming back, I always do, to
21 interference issues. But if -- what we need, I think,
22 is a catalog of not only the signals you expect to see
23 in this band, but a catalog of signals that are
24 interfering signals like switching power supplies in
25 grow lamps in Boulder. I thought I'd get a laugh.

1 No, to be serious, you know, these different
2 types of devices have different signatures, and what we
3 need is a catalog of interfering signals that we don't
4 expect to get in there. I mean, when we're looking for
5 the signal that we want to see, to be able to avoid, for
6 example, we're also going to be picking up others. And
7 that leads me to two comments.

8 One, it would be interesting to share that
9 information among different people so we have this
10 catalog of these waveforms. The other thing, it could
11 lead you to automatic, some sort of automatic
12 interference enforcement thing.

13 In other words, you're seeing a signal that
14 they shouldn't be in there, even though you're looking
15 for the other guy. I'm not saying this very clearly.
16 But if you see it, then, of course, it could trigger --
17 then there needs to be some sort of an enforcement
18 action, because this is a harmonic, 7th harmonic of an
19 FM radio station or something like that, and you would
20 want to take action to mitigate against it or to
21 actually start enforcement actions. Maybe somebody else
22 can say that a little clearer.

23 LARRY ALDER: I think we -- I think Mark
24 summarized it kind of briefly there. Pass the mike
25 to -- go ahead, Jennifer.

1 JENNIFER WARREN: Jennifer Warren. So I'd
2 like to suggest -- it goes back to, again, the
3 presentation that Dr. Gremban did, which is one of his
4 areas of work, is kind of the technology side of
5 aggregate interference.

6 And I wanted to look at the companion side
7 of that, which is the regulatory mechanisms to actually
8 then implement a decision on aggregate interference.
9 What are the policy challenges? What are methods and
10 options that a regulator may have, or maybe there's only
11 one conclusion, on how to implement -- I don't want to
12 use the word enforcement -- but enforcement of an
13 aggregate interference level.

14 Internationally, it's been a challenge.
15 Domestically, you know, hands have been thrown up.
16 Maybe this is a question that we could look at. The
17 only example of that internationally that I know of is
18 in the ITU with a group called Resolution 609. But I do
19 think that that is an area that we could perhaps bring
20 some effort. Thank you.

21 LARRY ALDER: Jeff.

22 JEFF REED: Okay. Jeff Reed. I have three
23 suggestions. The first one is very similar to what
24 Janice said. Does NTIA have a role to play in
25 communications security? If so, what? Just a very

1 broad look at that, a very philosophical issue.

2 The second suggestion is, how might NTIA be
3 able to best leverage the new research programs that are
4 coming. With the advanced wireless technology, that's
5 \$400,000,000 worth of research that's coming out of the
6 NSF, and there are a number of darker programs as well.
7 How might NTIA be able to best harvest the research that
8 comes from those programs.

9 And then the third one -- the third one is a
10 bit different, and I suppose it's -- in some ways, it's
11 a different sort of study or role for CSMAC. And that
12 is doing some external reviewing of some key reports
13 that come out of NTIA.

14 For instance, one of the issues that is
15 being looked at now is 1.3 gigahertz spectrum sharing.
16 And there's a lot of smart people in this room who could
17 do some sanity check on what comes out of those reports.
18 So those are my suggestions.

19 LARRY ALDER: Thanks, Jeff. Those sound
20 very well thought out. Michael.

21 MICHAEL CALABRESE: Okay. I think there's a
22 couple more I'll throw out there. The first one, you
23 know, NTIA would have to judge whether they have had
24 enough of this or not, but the idea of --

25 (indiscernible comments)

1 MICHAEL CALABRESE: No, it's not that
2 painful. But, actually, you know, when we -- eventually
3 we'll get through, hopefully, some of these bands we're
4 working on like 5 gigahertz. The notion of, you know,
5 developing more explicit criteria for identifying the
6 next band or set of federal bands that are best suited
7 for sharing, and you know, how do we -- so how do we
8 decide that, you know, it's much better to target this
9 here rather than that over there?

10 And, you know, I think when (indiscernible)
11 would say it's always easier when there's fixed, the
12 federal uses fixed rather than mobile, for example. So
13 we've heard rules of thumb. I'm not sure we have a set
14 of criteria that are very well developed for that, and
15 it might help point to some future bands with a long
16 lead time.

17 The other is, I don't think there has been
18 enough attention to beaconing as a potential mechanism
19 for sharing. You know, we've been able to bring,
20 obviously, geolocation databases and now sensing with
21 3.5 band into the mix, and there's some obvious
22 potential downsides with beaconing, depending on the
23 service, But I think maybe exploring the pros and cons
24 of that for federal users and different types of federal
25 users, some of which want to be identified and some

1 don't or some who could obscure even while beaconing or
2 not.

3 So it's a good tool, I think. It could be
4 very useful and built in ahead of time. But I'm not
5 sure we understand its implications completely.

6 LARRY ALDER: Thanks, Michael. I think
7 we've got about five more minutes left in our
8 brainstorming. You want to add some --

9 PAIGE ATKINS: I think we covered, I think,
10 most of the general areas I was thinking about. I would
11 ask on -- we talked about counter UAS as a focus. There
12 is quite a bit of activity going on in the area. So it
13 might be not right for CSMAC, specifically, but what
14 about the broader category of UAS, not counter UAS, but
15 UAS in a general sense.

16 PAUL KOLODZY: Yeah, I think that UAS has
17 (indiscernible) of problems we're talking about that
18 Julie was looking at and the TAC -- is it on? It's on.
19 Yeah, so I think the FCC TAC has been trying to look at
20 that, so trying to do some parallel efforts and ask the
21 question is also useful.

22 I will counter you a little bit on the
23 counter UAS. In a sense, there's a lot of effort going
24 on, a lot a swirl as to what they should be doing. But
25 what people have not been asking the question, which I

1 think is a very hard question is, what spectrum and how
2 do we test in these areas, especially if people are
3 doing -- make modifications to classic commercial UAS's
4 and you're going to have to somehow develop systems both
5 for your federal and non-federal users to counter those.
6 But, again, that's your choice.

7 LARRY ALDER: Other topic areas that people
8 want to bring up and put on the radar? Dennis?

9 UNIDENTIFIED MALE: Pass the (indiscernible)
10 again.

11 DENNIS ROBERSON: It's the Olympics. We've
12 got to be prepared. Michael, I didn't tell you about
13 our role in one of the teams, but anyway.

14 One of the areas and some of you, many of
15 you would know why this is on my mind, but it's a much
16 broader topic than what has been occupying some amount
17 of my time, and that's the whole area of navigation.
18 We've become very dependent -- I got here this morning
19 using my GPS system. And that is a normal and standard
20 part of a what we do.

21 But we're also in a place where we're
22 navigating using Wi-Fi, we're navigating using our
23 cellular, the combination of those things. In the U.S.,
24 it is still the law of the land that you use GPS,
25 whereas there seem to be a lot more satellites up there

1 that people, some of them -- Rick can tell you -- can't
2 get away from the satellites.

3 But this whole notion of geolocation and
4 navigation and so on, even time for that matter, since
5 we're in this facility, the future of that, particularly
6 as it applies to the needs within the government
7 systems, the government environment, this is a big
8 topic. Maybe it's too big for the CSMAC to take on.

9 But it's becoming a really significant topic
10 in how to get from here to there, how you establish the
11 time where you are, and so on and what the alternatives
12 are and where this should be steered as we go forward.

13 PAUL KOLODZY: I just want to -- that's a
14 great topic area. That comes back to something that I
15 was mentioning to Julie, which was a systems of systems,
16 meaning if you're doing PNT (indiscernible) it's not
17 just GPS. It's so many other things and so many other
18 satellites and components, that we don't really look at
19 our, an analytical tool set of how to actually start
20 addressing the service -- not the service, meaning the
21 radio service, but the service that is trying to be
22 provided.

23 LARRY ALDER: Yeah, I mean, if you want to
24 go extreme, coming from Google, you'd say, you know,
25 machine learning solves all known problems. So how to,

1 in this new world, with all these devices out there, how
2 can you apply some of these techniques. You even have a
3 question, what emerging technologies -- that the Smart
4 phones enable the power of machine learning, cloud.

5 It would be a very open-ended, broad
6 question, but how would all those topics maybe
7 facilitate spectrum sharing in unusual ways. You have
8 mapping, you have satellites, you have phones. So just
9 that would be a broad technology question.

10 DENNIS ROBERSON: And even gyros -- I mean,
11 even, you know, embedded gyros, so when you lose all the
12 other signals, you still have ways of getting --

13 LARRY ALDER: Okay. I'm seeing two tents.
14 I'm going to go with Rick because he has the mike near
15 him and then we'll bring it over to Dennis.

16 RICK REASER: Okay. This is Rick Reaser,
17 Raytheon. I wanted to mention, it was mentioned last
18 meeting, and this is a totally different tack, but I
19 think that given all the things we're throwing on NTIA's
20 plate, the question I would wonder is if NTIA would be
21 interested in having someone take a look at ways that
22 they could, you know, with their limited staff, other
23 ways they could augment what they need to do by other
24 strategies.

25 Because right now, you have a limited number

1 of folks, and you might need some help in terms of
2 figuring out how to -- you know, what other mechanisms
3 are out there for you to do your job rather than just
4 with your existing staff. Whether that's through a
5 bunch of -- there's lots of strategies out there.

6 But I think that -- I mean, look at this
7 list of things. This is just more work for NTIA with
8 staff they don't have. Because once we get done making
9 all these recommendations, then what? So there's some
10 strategies that they can use. They're not going to get
11 an influx of new people and money, in my opinion. So
12 are there ways we can help?

13 LARRY ALDER: That sounds like an
14 interesting idea, Rick. Thanks for suggesting that.
15 Dale.

16 DALE HATFIELD: Yeah, just real quickly.
17 One of the things that we had, one of the sessions that
18 really sort of interested me was this notion of going
19 from open loop interference to closed loop. For
20 example, when you have ducting, for example, you could
21 be operating at high power most of the time, but if you
22 have ducting, then you get feedback and you reduce your
23 power. We tend not to do that.

24 The aggregate interference issue is the same
25 way. You've got a whole bunch of transmitters turned

1 on, so you turn off half of them and gain
2 (indiscernible) or whatever, whatever the number is. So
3 this notion of closing the interference loop is not
4 original with me, but it did catch my eye in one of the
5 sessions we had as something that might be useful to
6 look at.

7 LARRY ALDER: Thanks, Dale. I think we're
8 about ready to wrap up this brainstorming session. Any
9 final comments? I assume that's an old tent, Rick.

10 PAIGE ATKINS: Just a quick comment to
11 follow up on the navigation topic. Like we discussed
12 with the FCC TAC, there are other advisory committees
13 like the PNT Advisory Board, so we might want to think
14 about looking at other committees, other advisory
15 committees that exist, and if there are opportunities to
16 either partner with them or at least understand what
17 they're doing and potentially influence their topics as
18 well.

19 UNIDENTIFIED MALE: Is there one for
20 (indiscernible)?

21 PAIGE ATKINS: There are different ones that
22 are related.

23 (indiscernible comments)

24 LARRY ALDER: So thanks everyone for the
25 brainstorming session. We talked to Paige beforehand.

1 You know, clearly, this ends this CSMAC and this idea
2 and these charts will feed into Paige, and when the new
3 CSMAC forms, there will be some kind of process around
4 figuring out the questions and that will evolve.

5 I think this will be helpful, just some of
6 the ideas from this membership, and it was good to
7 collect it as we come to the end of this CSMAC term.
8 So, Mark, thanks, also, for capturing all that.

9 So I think this is the time in the agenda
10 where we have the opportunity for public comment. Is
11 there anyone in the room who is a member of the public
12 that would like to comment?

13 (indiscernible comments)

14 LARRY ALDER: Fair enough. Oh, we do have
15 -- we have two people who would like to comment. Please
16 state your name so we know you are.

17 ALLAN BERLINSKY: Okay. I'm Allan
18 Berlinsky. And I'm with LGS Innovations. Janice's
19 comment of cyber, I think is actually more important
20 than or it should be a certain high priority.

21 And you have to look at, really, spectrum
22 sharing as being an overall control system. And being a
23 control system, it has to be secure. Now, with spectrum
24 sharing, though, there could be lots of different ways
25 to be able to maybe sabotage the system or to make it do

1 things that it shouldn't be doing, both on the sides of
2 the commercial and on the government side.

3 On the government side, they probably would
4 call it maybe EW warfare, okay? But on the commercial
5 side, there can be ways that you might say of getting
6 into, you know, a commercial service provider's system
7 and basically hijacking the entire, hijacking the system
8 so that it's not operating in the appropriate manner.

9 That can be, I think, at a lot of different
10 levels from not only with regard to his operations and
11 management types of systems to be able to handle this
12 problem, but it also could be at other echo system type
13 of levels, of how being able to control that
14 transmitter, okay, or to be able to control that
15 receiver so it's able to combat the problem and to
16 actually being able to mitigate it.

17 You know, if an overall system is being
18 attacked in a certain way, there could be probably ways
19 that you may not be able to even control the power of
20 that base station, okay, or even to take it offline.
21 And other mechanisms could be working there that are
22 stopping him from being able to do that, that someone
23 actually got into the power grid to be able to do this.

24 So it can touch a number of different areas,
25 but basically an overall control system, if you look at

1 it from that perspective, has to be secure.

2 LARRY ALDER: All right. Thank you. You
3 can pass the mike to the gentleman in front of you. n

4 DANIEL: Thank you. Daniel (indiscernible)
5 and I'm from the Idaho National Lab. I had two
6 thoughts. One was, I believe, a comment made by
7 Mr. Calabrese. My old boss, Don Cox, used to say,
8 Wireless gets reinvented every 20 years.

9 And the idea of beaconing, in fact, was well
10 known and discussed. In fact, there's a patent of which
11 I have one, but it's more than 20 years ago so it's
12 expired. But the idea of beaconing is a very
13 significant one, and, in fact, there's an I triple E
14 paper on that as well, which I'd be happy to send you.

15 The next (indiscernible) was related. I
16 think there was subsequently a follow-up thought that
17 came from, I think, Mr. Hatfield, and which I have
18 always talked about as a spectrum (indiscernible)
19 incumbent systems. Because today we have incumbents and
20 all the spectrum people are trying to dance around it.
21 Wouldn't it be nice if, as future systems get built, as
22 incumbents, that they can, in fact, give feedback,
23 saying, I'm beginning to hurt.

24 So it's not quite bidirectional sharing, but
25 it's really more a question of feedback to close the

1 interference loop (indiscernible) so that you have
2 better ideas as to how to do that.

3 So those are two thoughts that I'd like to
4 suggest to you for your future consideration. Thank
5 you.

6 LARRY ALDER: All right. Thank you very
7 much. I'll also ask if there's any public comment on
8 the phone. I know it's risky to even ask that given the
9 phone situation, but public comment from the phone?

10 All right. Hearing none, I think we are
11 wrapping up. Mark, do you have any closing comments
12 that you would like to make?

13 MARK GIBSON: No.

14 (indiscernible comments)

15 LARRY ALDER: I have a few closing comments.
16 First of all, as we come to the end of this term of the
17 CSMAC, it's been a pleasure working with everyone, as we
18 said before. It's been a particular pleasure working
19 with Paige in her first -- this is your first full
20 CSMAC, am I correct?

21 So it's been a particular pleasure working
22 with Paige and I would like to thank her for her
23 leadership in guiding all this. And to all the NTIA
24 liaisons, it's been mentioned once, but it's been very,
25 very helpful to all of us to have your input and

1 guidance. So we thank everyone for that. I don't think
2 I have anything else.

3 PAIGE ATKINS: Just to close, we, NTIA, do
4 owe you a debt of gratitude, and we're very appreciative
5 for all your insights and, again, your wisdom to help us
6 do a better job. And I know Larry Strickling would also
7 echo his gratitude for all the work that you've done
8 over the last 30 months. So thank you very much.

9 LARRY ALDER: And then one final thank you
10 to all the co-chairs who I know put in the double extra
11 work being a co-chair. Having done that, it's been much
12 easier -- except for Mark -- for me being a co-chair of
13 the whole committee than being a co-chair of a
14 subcommittee -- I know it's a tremendous amount of work.
15 So thank you subcommittee co-chairs for all you do.

16 And I think with that, we're adjourned.

17 (End of meeting)

18

19

20

21

22

23

24

25

1 STATE OF COLORADO)

2) ss. REPORTER'S CERTIFICATE

3 COUNTY OF DENVER)

4 I, MARY L. HENDERSON, do hereby certify
5 that I am a Certified Shorthand Reporter and Notary
6 Public within the State of Colorado.

7 I further certify that the foregoing is a
8 correct transcription from the digital recording of the
9 proceedings in the above-entitled matter.

10 I further certify that I am not related
11 to, employed by, nor of counsel for any of the parties
12 or attorneys herein, nor otherwise interested in the
13 result of the within action.

14 In witness whereof, I have affixed my
15 signature and seal this 18th day of August, 2016.

16 My commission expires September 4, 2017.

17
18
19
20
21
22
23
24
25

Mary L. Henderson
216-16th Street, Suite 600
Denver, Colorado 80202

WORD INDEX

< \$ >

\$350,000,000 15:24
\$400,000,000
 15:12 116:5

< 1 >

1 1:1 103:9
1.3 116:15
1:00 1:1
10 47:12 58:1
 86:14 100:11
100 43:25
100,000 56:25
1080p 61:15
11 27:2
12 109:6
130 18:2
1300 107:7
1390 107:7
1695 76:22 104:21
1710 76:22 104:21
1755 104:21
1780 104:21
18 27:19
18th 31:21 129:15
1916 44:2
1967 44:7
1983 19:12
1993 19:19
1994 20:9
1st 86:21

< 2 >

2 43:23 99:13
20 15:18 36:13
 126:8, 11
200 19:23 55:25
 56:24
2003 20:13
2004 109:5
2010 22:4
2013 22:5
2014 44:7
2016 1:1 129:15
2017 129:16
2020 17:23
2022 18:3
2024 18:4
216-16th 129:21
21st 20:16
22 62:25
24 50:13 59:17
28 27:4
2B 69:24

< 3 >

3 17:16 62:25
 99:14
3.5 5:7 22:10
 28:6 50:16 101:15
 109:1 117:21
3:00 68:10
3:30 79:10
30 23:21 128:8
30-plus 19:6
30th 31:15
325 1:1
33-page 74:15
37 27:4, 10 32:8
 76:20 105:14, 17
 107:20
37.6 32:8 107:21
39 27:5
3GPP 63:3, 12, 17
 77:15, 22, 23, 25

< 4 >

4 45:22 129:16
4K 61:16

< 5 >

5 17:4, 14, 16
 30:13 35:13 58:1
 69:19, 23 71:7
 77:13 78:7 117:4
5.9 17:8 31:4
 69:24

50 24:4 44:25
500 16:24 17:15,
 23 107:2
5150 29:23
5350 17:10 29:21,
 23 34:9
5470 17:10 29:23
5850 29:24 31:5
5925 31:5
5G 5:17 9:3
 14:21 15:10 16:4
 21:19 27:2 42:19
 74:4 75:11, 14, 22
 76:24 78:4 79:17
 81:3 95:8 102:22
 103:23, 24, 25
 104:17, 19, 23
 105:3, 8, 25 106:13
 107:3, 19
5th 43:12

< 6 >

6 78:8 98:1
600 27:10 108:2
 129:21
609 115:18
6th 107:6

< 7 >

7 59:17 98:1
75 24:4
7th 114:18

< 8 >

802 62:25
802.11 30:1
80202 129:22
80305 1:1
85 15:20
8th 31:21

< 9 >

99 103:8

< A >

abilities 21:1
ability 42:10 93:24
able 17:22 33:19
 37:21 40:13, 17
 49:1 53:14, 15
 56:22 57:4 65:5
 66:5 69:17 76:16
 77:21 78:3 91:7
 96:11 100:6 102:3
 113:9 114:5 116:3,
 7 117:19 124:25
 125:11, 13, 14, 15,
 16, 19, 22, 23
above-entitled
 129:9
absolutely 92:4
abstentions 79:11
AC 30:1
academic 15:25
 89:5
academics 16:1
Academy 65:2
accelerate 22:6
accelerating 21:6
access 19:9, 21
 20:4, 23 21:24
 22:10 27:16 28:19,
 24 30:25 33:11, 16
 40:20 73:7 87:14,
 14, 24, 25 89:1, 25
 96:1, 4 110:25
accommodate 19:18
accommodation
 78:7
accomplished 26:6
 43:1
accomplishment
 26:24 28:1
account 42:15, 22
accurately 59:20
achieve 17:22

Act 17:24 18:1, 5,
 8, 16
acted 19:17
action 82:11
 94:15 114:18, 20
 129:13
actionable 70:13
 75:3, 8 76:3 77:11
 83:7
actions 14:23
 20:21 74:20 82:1,
 4 83:12, 13, 18
 84:4 114:21
active 74:7
activities 18:24
 24:23 85:2 102:23
activity 118:12
actual 52:18 98:21
adapt 57:21
adapts 42:12
add 26:15 73:14,
 18 93:1 95:19
 107:18 118:8
additional 18:2, 23
 20:3 34:23 41:16
 93:14
Additionally 62:2
add-on 95:19
address 21:6 48:4
 65:5, 20 71:6
 74:22 82:1 84:5
 88:6 91:22 100:9
addressed 96:12
addressing 22:8
 45:19 61:25 65:11,
 21 120:20
adjourned 128:16
administration 4:8
 15:11 19:16, 17
 21:5 22:2, 22
 24:14
ado 25:8
adopted 5:6
advance 57:11
advanced 5:22
 13:9 15:6, 13, 21
 16:2 18:9 21:3
 44:9 47:7 89:19
 116:4
advancing 45:17
 46:4, 4, 9 57:20
advantage 5:20
advice 23:20
Advisors 21:14
ADVISORY 1:1
 20:17 23:13
 123:12, 13, 14
aeronautical 30:15

affixed 129:14	111:20 112:17, 22, 24 114:23 115:21 116:19 118:6 119:7 120:23 121:13 122:13 123:7, 24 124:14 126:2 127:6, 15 128:9	anybody 28:21 34:20 79:4 81:10, 11 anymore 67:21 anyway 4:16 11:15 71:4 108:12 119:13 APIs 101:20 apologize 8:8 applause 43:3 applicable 13:15 90:10 94:7 105:25 applicants 28:18 applications 14:21 16:14 18:12 21:7 33:22 40:3 59:12 applied 103:15 applies 120:6 apply 18:9 21:3 29:11 41:5 46:16 55:20 104:17 105:20 121:2 applying 60:24 appreciate 6:3, 14 7:16 8:18 13:25 14:3 23:19 67:6, 9 90:21 appreciation 4:19 7:12 appreciative 128:4 approach 14:5 20:3 29:15 106:8 approaches 17:11 approaching 40:22 appropriate 70:7 71:18 84:23 85:20 125:8 appropriately 68:21 approval 18:21 29:1 approve 79:8, 9 approved 9:1 66:23 68:17 71:24 78:19 80:12 April 5:6 architectures 70:7 97:20, 21 101:7 area 36:11 38:20, 21 44:4 47:2 54:25 55:2, 3 58:20 59:8, 17 60:10 62:10 69:14 97:19 102:5 115:19 118:12 119:17 120:14 areas 20:7, 8 49:1 52:22 60:8 62:10 63:17 76:15 89:12 91:16 98:14 115:4	118:10 119:2, 7, 14 125:24 arrangements 5:7 array 13:6 art 45:17 46:10 57:20 92:11 articulating 21:23 ascertain 17:12 ascribed 89:9 ascribing 87:22 asked 13:22 33:6 asking 22:5 58:23 69:15 80:3 118:25 aspects 77:5, 7 99:22 Aspen 9:16 assessment 84:11 assessments 13:21 assets 47:8, 9, 11 assistant 2:14 17:19 associated 12:24 53:21 54:20 73:19 Associates 9:21 association 53:24 associations 15:19 53:25 assume 3:17 67:13 123:9 assumption 104:2 assumptions 38:8 77:4, 9 104:9, 23 assure 7:16 ATKINS 10:3, 3 12:10, 16, 18, 23 13:2 24:8, 17 25:5 35:11 81:2, 3, 16, 17 91:6, 14 94:16, 23 95:1 102:1 118:9 123:10, 21 128:3 attach 71:19 72:7, 12 attack 60:25 attacked 125:18 attempting 51:15 attend 48:6 attention 117:18 attorneys 129:12 attributes 75:11, 15, 17, 23 auction 5:1, 12 17:17 18:6 19:20 20:22 26:18, 25 auctioned 107:4 auctions 20:10 audio 25:12 43:6 61:7
align 45:10 83:14 alive 80:9 Allan 124:17, 17 ALLISON 9:24, 24 allocated 19:12 31:6 32:22 78:13 allocation 41:4 allow 16:1 78:5 allowing 33:17 allows 18:8 47:16 51:21 95:4 alluded 23:10 89:20 alongside 12:13 already-existing 76:22 altering 107:23 alternative 105:16 alternatives 120:11 amazing 19:6 America 10:17 amount 47:19 57:7 61:20 64:25 78:9 93:7 119:16 128:14 amplification 87:13 analysis 17:9 35:2 38:11, 12 41:17 42:1, 22 46:7, 25 47:23 49:14 51:9 55:13 56:22 analytical 27:22 120:19 analytics 51:10 analyze 53:2 analyzers 48:2 anniversary 21:12 announcement 16:6 annually 57:16 answer 14:4 25:2 34:2, 25 37:6 45:18 46:22 69:15 91:7 answering 13:20 61:1 answers 53:3 61:3 antenna 47:23 99:20 100:2 antennas 48:1			

AUDREY 9:24, 24
39:8 67:22, 24
augment 121:23
augmentation 71:8
August 1:1 31:20,
21 129:15
authority 19:20
automated 11:3
automatic 114:11,
11
available 14:19
19:17 20:4 21:9
29:23 46:17 49:5,
5 65:16
average 51:5
avoid 92:20 113:9
114:5
avoiding 13:5
aware 16:25 43:20
awareness 36:23
37:2
awesome 24:5
awful 58:20 67:1
113:17
AWS-3 5:1 18:18
26:7 93:8 104:15
105:16, 19 107:3, 9
109:1
axis 50:18, 18, 21
Aye 79:9

< B >

back 4:21, 23, 25
6:15 8:1 12:11
19:6, 11, 15 25:21
26:20 35:23 39:3
54:24 66:21 72:13
74:19 75:6 82:17
85:13 97:12
104:17 105:9, 19
106:24 107:2, 6
108:20, 24 109:4
112:2, 9 113:20
115:2 120:14
Background 3:13
12:25 66:5 74:16
back's 60:2
backward 76:23
backwards 6:2
bad 79:20
balance 38:22
ball 90:7
band 5:8 25:23
27:4, 5, 5, 9 32:10,
17 33:18 34:13
39:14 40:21 41:20
42:19 50:16, 19, 20,
22, 24 51:1, 5, 22
61:9 69:24 76:21,

22 89:1 96:4, 19
100:20 105:13, 16,
18, 23 107:8, 9
113:18, 23 117:6,
21
bands 17:3, 13, 14
20:22, 22 27:3
29:22 35:21 39:9,
25 41:22 42:17, 21
76:18, 20 78:12
97:19, 24 101:19
105:8, 24 107:5, 12
117:3, 6, 15
barely 5:23
Barker 10:2
barrier 39:21
base 53:19 54:2, 8,
20, 21, 23 125:20
based 7:10 21:24
54:21 61:19 71:16
73:11 74:17 83:14,
18 108:17
baseline 56:5 77:4,
9 104:8, 9, 9
basic 28:13 31:23
97:15
basically 27:11
73:24 125:7, 25
basis 112:7
beaconing 117:18,
22 118:1 126:9, 12
bear 4:1 14:4
bearing 90:21
beat 70:3
becoming 120:9
beginning 1:1
60:2, 6 61:3
126:23
beginnings 88:13
begun 85:11
behave 53:13
belabor 88:20
believe 57:10
89:19 126:6
beneficial 33:23
benefit 29:5 33:25
benefits 109:13
BERLINSKY 124:17,
18
best 28:11 29:12
46:18 85:13 91:18
101:23 116:3, 7
117:6
better 16:20 23:2,
17 51:24 53:1, 1
78:6, 6 80:18 85:6
91:13 103:15
106:8 117:8 127:2
128:6

beyond 65:9
103:3 111:4
bidirectional 66:16
88:19 89:11, 16
90:19 93:2, 12, 24
96:2 97:1 102:19
113:4 126:24
big 29:24 37:23
44:4 47:14, 22
98:2 120:7, 8
Bill 19:16
billions 20:11
bipartisan 18:1
20:3 22:21
bit 6:1 12:10
26:15 29:20 43:14
47:4 50:23 61:5
63:16 66:17 67:2
72:14 81:24 110:4
113:3 116:10
118:12, 22
black 52:13
blame 39:7
blank 6:15
blocks 15:8 19:13
blue 52:18 56:8
board 6:15 37:9
88:18, 18 123:13
Bob 9:15 74:9
75:7
bodies 45:21
body 63:18
Boeing 9:24
boon 27:21
booth 25:9 26:16
43:7
booths 48:11
boss 126:7
bottom 2:11 50:18
52:6 53:17
BOULDER 1:1, 1
2:6 7:10 11:10, 11
12:11 16:10, 11, 15,
16 25:16 52:6, 11
54:6 58:16 59:14
113:25
boundaries 99:6
bounding 89:13
box 23:3
boy 79:21
brain 7:14
brainstorming 9:6,
10 23:10 25:7
37:21 75:5 81:21
84:16, 20 85:15
118:8 123:8, 25
brand 5:14
breadth 92:16
breath 6:13

brief 6:3 14:14
57:7
briefly 114:24
bring 14:3 19:2
95:20 98:22
102:25 103:4
115:19 117:19
119:8 121:15
broad 95:16
101:21 116:1
121:5, 9
broadband 5:22
14:20 18:3 19:10
20:23 21:6, 9
broadcast 26:16
broadcaster's 25:9
broadcasting 43:7
Broadcom 31:13
broader 89:9
97:19 118:14
119:16
broadly 29:23
BROADWAY 1:1
Broncos 43:8, 9
brought 21:5 53:6
93:22 101:6
BRYAN 10:1, 1
39:4, 5, 5 40:19
41:11 67:5 72:15,
20 108:10, 11
110:8, 10
budget 18:1 45:1
65:22
buggy 46:20
build 13:12 22:16
37:3 59:25 64:7
84:24 90:12
building 15:8
19:13 46:21 56:21
107:19
builds 15:14
built 36:10 60:9
118:4 126:21
bullet 101:4
bunch 122:5, 25
Bureau 44:1
bus 47:23
Bush 20:15
buttons 11:20

< C >

cages 48:9
Calabrese 10:16,
16 32:7, 7 34:8
95:18 97:6 107:18
112:21 116:21
117:1 126:7
call 9:14 11:7, 18
13:20 25:3 27:2

31:4 38:17 67:3
 70:25 71:1, 14, 17
 84:3 109:21 125:4
called 75:11 77:17
 115:18
call-in 90:22
calling 78:1 103:24
calls 24:4 68:5, 6
camp 43:9, 10
CAMPUS 1:1 16:13
campuses 16:11
capabilities 13:3
 16:4 18:13 22:9
 47:7 57:10 61:8,
 14
capable 43:21
 108:19
capacity 61:22
capital 14:3
capture 91:2, 3
 93:15, 17 108:14
capturing 85:3
 124:8
care 58:18
careful 38:5
carefully 45:16
Carl 10:18, 18
 40:22 106:16, 17,
 17, 19, 23 107:13
Carl's 107:11
case 38:14, 16
 48:24 51:25 82:10
 96:10, 14 105:4
cases 37:24 38:1
 82:9
catalog 69:18
 113:22, 23 114:3,
 10
catch 107:11 123:4
categories 77:1
category 110:7
 118:14
cause 1:1 59:7
 98:13
caused 39:6 48:13
causing 113:9
CAV 31:14
caveat 83:19
cell 53:22 54:8
 55:7 71:12
cellular 19:13
 53:8, 19 119:23
Center 13:9 44:9
 111:7
centimeter 105:4
central 89:15
century 20:16
certain 49:16 62:6
 89:14 97:23

113:10 124:20
 125:18
certainly 84:13
 92:7
certainty 33:9, 16
CERTIFICATE 129:2
certification 111:5
Certified 129:5
certify 129:4, 7, 10
chair 39:7
chairman 26:23
 90:3
chairs 71:3, 6, 9
challenge 29:18
 30:11 38:4 84:1
 115:14
challenges 6:13
 12:23 14:4 26:8,
 13 27:7 32:16
 50:9 57:23 65:6
 69:25 84:6 115:9
challenging 14:1
 27:17 58:1
chance 9:7 71:12
 72:3 79:4 107:10
change 24:14 72:1
 75:20 78:9 83:23
 98:10
changed 21:15
 81:24 83:22
changer 21:23
changes 18:5
 61:19 66:22 74:22
 99:22, 24 100:1
 104:23
changing 24:19
 75:21
channel 64:20
chapter 14:6
characteristics
 35:1 36:18 49:8
 51:14
CHARLA 9:25, 25
 39:8 40:23 66:19
 67:23, 24 68:3, 8
 79:22 85:25 86:1,
 11, 17 88:21 92:25
 93:17, 20 94:11, 20,
 25 95:13
Charla's 69:8
Charles 30:19
charm 11:13
chart 50:20 51:12
Chartier 10:25
charts 124:2
check 110:17
 116:17
checking 66:14

112:13
choice 119:6
chunks 29:24
circles 54:25 55:2
circulated 74:14
 79:5, 6
circumstances 52:2
Cisco 31:21
cited 21:17
city 16:15 47:23
 52:11
city-scale 15:20
claim 48:24 106:4,
 7, 9
clarified 63:4
clarify 91:7 95:9
 111:23
clarity 73:25
classic 119:3
clean-up 9:2
clear 22:12
clearer 114:22
clearly 60:8 67:17
 114:15 124:1
Clinton 19:16
close 1:1 14:6
 99:11 126:25
 128:3
closed 5:2 17:7
 122:19
closing 6:19 123:3
 127:11, 15
cloud 121:4
Coast 50:16
coasts 50:15
co-chair 67:4 69:9
 73:13 128:11, 12,
 13
co-chaired 39:8
co-chairs 128:10, 15
code 46:20
cognizant 37:17
coherence 99:25
collaboration 16:14
 25:13 26:5, 9 28:7
 50:3 68:15 76:5,
 6, 16 77:10 78:2
 84:22, 25 91:20
 92:18 102:14
 104:11
collaborative 35:24
 76:7
collect 124:7
collective 23:20
collectively 17:2
 84:4
color 50:20

COLORADO 1:1
 10:10 16:10, 15
 129:1, 6, 22
combat 125:15
combination 119:23
combined 41:24
come 21:21 25:17
 31:15 35:8, 25
 39:13 60:25 75:6
 87:12 116:13
 124:7 127:16
comes 42:14
 87:19 88:16 116:8,
 17 120:14
coming 4:8 36:6
 40:3 108:6 113:20
 116:4, 5 120:24
commend 13:19
comment 17:7
 23:24 41:14 63:9,
 21 74:19 79:16, 22
 81:12 95:7 106:1
 111:25 112:1
 123:10 124:10, 12,
 15, 19 126:6 127:7,
 9
commentary 26:15
 70:3
comments 8:13
 34:2 66:21 73:16
 74:17 81:11 97:13
 101:8 104:5 108:6
 111:22 114:7
 116:25 123:9, 23
 124:13 127:11, 14,
 15
COMMERCE 1:1
 77:24 99:8
commercial 18:12
 19:18 20:1, 22, 25
 37:8 40:4 44:12
 77:15 87:18 88:17,
 25 89:22, 25 90:12
 93:25 103:13
 109:15 110:12, 12
 113:6, 13 119:3
 125:2, 4, 6
commission 19:19
 36:7 129:16
commitment 7:13
 23:16, 19
committed 6:4
 20:15
COMMITTEE 1:1
 23:14 39:9 66:20
 71:5, 22 73:12, 22
 74:6 81:10 89:18
 97:17 99:15
 128:13

committees 20:18
 123:12, 14, 15
committee's 14:7
common 21:18
commonalities
 75:13
Communications
 13:10 31:9 44:9
 50:2 115:25
communities 99:19
community 46:20
 47:10 53:4 64:17
 98:2 100:3
companies 15:18
companion 115:6
compatibility 46:7
 49:14 55:13
competitive 5:20
completely 35:17
 98:9 118:5
complex 26:4, 22
 51:16
complexity 25:21
 26:20 82:14
component 18:15
 23:2 40:24
components 120:18
comprehensive
 20:15
compressed 62:5
compromising
 21:25
computer 48:2
 66:3
computing 55:10
Comsearch 10:5
concentric 54:25
 55:2
concept 5:18 21:20
concepts 16:2
 63:10 76:9 95:16
concern 64:21
concerned 43:8
 89:5 106:5
concerns 33:2
conclusion 115:11
concrete 60:14
concur 83:7
conditions 1:1
 29:14 41:5 56:7
conducted 20:9
 65:3
conference 3:10
 12:13, 14
confident 26:12
conflicting 89:23
Congress 19:19, 23
conjunction 15:19

17:21 62:3 102:6
connected 54:2
cons 117:23
consider 23:11
consideration 90:9
 127:4
considerations
 76:25 105:20, 21
considered 68:17
consistent 41:3
Consulting 9:23
context 65:14 88:4
continually 44:15
 46:9 52:24
continuation 96:2
continue 6:12
 12:5 13:18 17:2,
 9, 10, 16 20:5
 22:21, 24 23:4
 44:13 70:3 83:24
 84:1 97:17 98:4
 106:8
continued 16:24
 21:5
continuing 13:16
 59:8, 10 81:4
continuous 56:10,
 12
contribution 69:16
contributions 6:11
 69:17 73:16 74:8
control 48:12
 53:10 56:18
 124:22, 23 125:13,
 14, 19, 25
controlled 47:18
controversial 87:19
controversy 43:11
convened 5:24
converge 53:3
conversations 3:13
 12:25
cooperation 92:5
coordinated 80:18
coordination 91:11
co-primary 33:13
core 57:9
cornerstone 22:3
correct 127:20
 129:8
Cotton 45:25 46:1
Council 21:13
counsel 129:11
counter 98:12, 16,
 19, 22 118:11, 14,
 22, 23 119:5
countering 98:20
counterpart 69:9

counterparts 50:1
country 48:4
COUNTY 129:3
couple 29:19
 30:22 52:8 57:8
 59:11 61:24 66:21,
 24 67:8 75:12
 97:24 102:17
 116:22
course 44:10 48:8
 51:16 59:2 87:16
 88:16, 21 92:6
 106:9 114:16
cover 55:2 57:6
 58:7 101:2
covered 12:7
 112:18, 25 118:9
covers 90:20
Cox 126:7
create 5:13 33:11
 69:18 76:15 81:5
creates 33:25
creating 18:15
 64:1 109:11
criteria 63:25 64:6,
 16 97:2 117:5, 14
critical 14:20
 18:13 20:8 23:2
 46:18, 23 49:1
 51:14 89:14
CROSBY 8:4, 5
 10:25 12:2, 3, 21
cross 42:3
crosses 99:6
CSMAC 1:1 2:3, 16,
 24 3:1, 2 4:4, 20,
 21, 23 5:5, 23, 25
 6:10 8:11 12:12
 13:16, 20 14:13
 17:6 20:18 23:1,
 12 24:13, 15 32:14,
 15 34:16 35:23
 68:7 69:6 76:15
 81:20 83:9 84:24
 86:16 87:8 91:17,
 23 92:8 94:14
 104:14 116:11
 118:13 120:8
 124:1, 3, 7 127:17,
 20
CSMACs 96:25
CSMAC's 5:16
CSMAC-TAC 92:5
cube 26:23
cuff 4:14
curious 59:8
curlicue 52:7
current 5:25 14:7

52:1 57:25 105:7
currently 107:14
cut 11:14 25:12
 32:17 43:6
cutting 14:1
cyber 87:21 88:6,
 11 124:19
cycle 5:21 13:17
 23:12 25:1 82:2, 6
 85:6 91:19

< D >
Dale 10:9, 9 58:9,
 10, 19 59:22 106:3
 113:2, 3 122:15, 16
 123:7
Dale's 59:25
dance 126:20
DANIEL 126:4, 4
dare 10:19
darker 116:6
data 50:15 52:18,
 20 55:25 61:13, 17,
 20 102:3
database 50:5
 96:8
databases 88:9
 117:20
date 31:14
David 3:22 8:7
 10:20, 25 12:15, 17,
 20, 21
day 50:13 129:15
days 25:22 42:7
 50:13, 17 51:1
 56:1, 16 86:20
DB 53:23
deadlines 18:3
deal 26:21 36:5
 41:4 43:1 71:22
dealing 36:6 58:12
dealt 101:12
dearth 60:9
debate 25:23
debating 69:14
debt 128:4
decade 15:14
December 81:25
decide 117:8
decided 4:10
decision 115:8
decisions 16:21
 18:25 60:10, 12
 82:21 109:5
decompose 82:20
 84:2
dedicated 7:14
 31:8

dedication 30:24	details 27:6 28:10, 16 33:6 75:16 97:23	digest 82:20 84:2	12:15, 15, 17, 20
deed 6:18	detect 59:19	digital 59:7 129:8	doors 9:8
deeper 92:9, 9	detection 46:12 71:7	diligence 82:16	Doppler 82:7
Defense 27:12 33:10, 16 34:6, 21	determine 35:3 45:16 48:13 59:21 64:16 71:9 83:6	direct 18:23 74:20 96:13	dot 17:16 31:22 62:25, 25
define 76:6 82:25	determining 62:5 64:12	directed 19:23 88:7	dots 56:8
defined 34:11, 17 45:6 76:13 78:4 101:20	develop 23:4 51:10 53:1 64:14 94:1 119:4	direction 40:11	double 128:10
defining 75:10, 21 77:8, 16 104:8	developed 5:4 34:14 44:12 64:7 109:1 117:14	directly 95:2	double-check 76:24
definitely 85:21 100:10 101:14 105:5	developing 16:9 20:15 44:13, 23 50:7 51:10 90:4 93:5 99:20 108:18 117:5	director 16:18	downsides 117:22
delay 3:19 12:1, 22	development 15:9 16:21 18:10 58:5 89:16 90:17 93:25 98:12, 14	disapprove 79:10	Dr 16:19 115:3
delving 92:9	device 54:10 61:15, 19	discrepancy 52:19, 22	drafting 67:6
demand 48:20 61:9, 22, 22 109:15	devices 17:4 53:8, 9, 18, 20, 21 54:2 55:3, 3, 11 58:15 59:7 61:14 114:2 121:1	discuss 9:9 71:13 100:6	dramatically 100:1
demands 7:17 87:6 89:24 110:1	devoted 46:24	discussed 70:23 98:7 123:11 126:10	dream 4:10
demonstration 48:7	dialing 11:3	discussion 6:16 14:8 48:20 79:9 83:4 84:13, 14 85:16 87:7 92:21	dried 32:18
Dennis 9:20, 20 24:9, 9 63:21 64:18, 19, 19 65:9 68:25 69:7 71:1, 23 92:6 97:12 101:2, 3 102:8 111:25 112:17 119:8, 11 121:10, 15	dialog 91:3 92:13	discussions 13:7, 15, 16 38:7 75:5	drilling 108:7
density 59:20	difference 61:16, 21	DISH 10:7 62:9 80:16	drive 33:24 48:3
DENVER 129:3, 22	different 18:19 19:5 23:4 27:6, 7 30:14 32:10 36:13, 16 39:11 40:6 61:6 62:1 66:15 70:4, 7, 8 72:7 76:20 85:19 92:24 94:6, 6 98:9, 17 100:7 103:16 105:23, 24 109:25 114:1, 2, 9 116:10, 11 117:24 121:18 123:21 124:24 125:9, 24	display 62:1, 1	drop 42:12 57:18
Department 27:12 31:22 33:10, 16 34:6, 21 77:24	difficult 31:3 60:21 69:23	displaying 91:2	dropped 38:16 53:20
departments 20:5	difficulties 51:3 57:2	distance 49:12 54:21	drops 54:3
dependent 119:18	difficulty 35:7 71:23	distances 55:10	DRSC 31:8
depending 48:25 117:22		distinct 98:10	drums 70:3
deploy 32:25 35:9 90:13		distributed 54:12 66:20 99:20, 21 100:2, 14, 14, 17, 18 101:16, 22	dual 94:17, 20
deployed 32:23 38:19, 24 100:10 101:16, 18 103:21 109:8		distribution 55:7, 9 56:2	dual-use 14:25
deployment 76:1		division 46:13, 24	ducting 122:20, 22
deployments 35:3		document 74:13 81:5	due 1:1 31:15 82:14, 16 91:24
depth 69:13		doing 11:7 24:1, 3 25:19 31:23 41:21 42:22 45:1 46:25 49:21 51:9 55:8, 13, 24 57:21, 25 58:25 96:16 102:5, 5 116:12 118:24 119:3 120:16 123:17 125:1	dynamic 29:7 35:22 42:9 90:18 91:9 108:24 113:10
described 26:23 112:14		dollars 20:11 109:16	< E >
description 102:2		domain 59:13	earlier 25:22 65:3 76:24 77:6 84:16 103:5 105:15 106:25 107:20 112:1
designed 30:1 39:25		domains 49:21	early 31:11 76:9 77:17 110:2
designing 37:16 106:6		Domestically 115:15	earth 30:5
detail 15:5 17:18 70:19		Don 126:7	ease 20:24 87:14
		Donovan 10:25	easier 31:3 96:14 117:11 128:12
			easily 90:6, 6
			easy 66:1 79:11 89:24 98:25
			echo 7:25 8:12 73:15 80:17 125:12 128:7
			economic 88:1
			Ed 69:12, 13, 15
			edge 14:1
			editing 74:13
			edition 2:3
			educate 45:11
			effect 49:11 53:6,

9	engineers 27:22 58:1 64:22 66:2	evolutions 44:3 104:11	92:15
effectively 40:18	enhance 18:13	evolve 42:20 105:6, 8 124:4	expired 126:12
effectiveness 111:2	ensure 17:12 21:8 22:17 29:4	evolved 21:19	expires 129:16
effects 46:6 53:16 55:10	ensuring 18:12	evolving 75:14 83:20	explicit 117:5
efficacy 112:14	enthusiasm 98:3	EW 125:4	exploit 15:4 23:6
efficiency 61:12, 13 112:7	entire 33:19, 24 97:16 125:7	exact 8:3	exploration 30:5
efficient 18:11 19:21 49:2	entities 44:12	Exactly 6:25 29:3 39:17 48:12 75:7 77:3 111:17	explore 94:24 108:1
effort 5:12 7:15, 19 19:9 21:8 30:20 49:25 56:1, 20 97:17 115:20 118:23	entitles 90:13	example 29:6 36:24 50:11 51:19 52:4 76:21 78:3 84:22 89:18 110:24 112:8 114:6 115:17 117:12 122:20, 20	exploring 94:22 117:23
efforts 7:23 16:20, 23 17:5 49:18 118:20	entrance 113:6	examples 29:19 110:12	expose 102:3
EIRP 99:23 100:19	entrepreneurs 16:1	exceeded 37:19	exposed 102:4
either 46:15 97:18 109:13 123:16	environment 47:18 53:7 120:7	excellent 80:14	exposing 102:2
elaborate 14:16	environmental 28:24 51:17	excited 19:3 24:25 14:13, 24 16:5, 16	express 7:12
electromagnetic 46:6 49:14 55:13	environmets 14:2 49:9 70:8	excuse 60:2	extend 102:1
embarrassed 66:3	envisioned 22:11 109:15	exercise 54:6 89:5	extended 13:24 31:14 33:17
embedded 121:11	equalize 55:8	exist 123:15	extension 23:21 101:24 110:22
embodied 46:15	equally 90:10 103:14	existing 63:25 96:8 103:20 104:24 105:5 122:4	external 116:12
embraced 112:11	equipment 33:19 35:9	expanding 62:15 63:14, 15	extra 85:14 128:10
emerging 37:25 121:3	Eric 24:2 46:8 61:4	expansion 21:10 73:7	extraordinarily 69:11
emission 100:20	error 47:4	expansive 84:25	extreme 120:24
emissions 47:17	escape 88:5	expect 42:17 113:22 114:4	extremely 30:16
emphasis 21:5	especially 51:18 79:2 90:21 113:16 119:2	expected 29:4 52:14, 14, 16	eye 123:4
emphasize 22:21	essence 89:10	expedited 13:22	< F >
employed 129:11	essential 57:10	experience 39:20 40:20 47:3 48:11 61:8 108:18 109:10	facilitate 76:8 121:7
employees 45:9	essentially 27:15 75:4 96:9 104:22	expeditiously 24:24	facilities 47:21 48:9, 18
empower 21:24	establish 36:8 120:10	experiment 64:15 109:24	facility 2:9 47:11, 16, 24 111:6 120:5
empty 51:5	established 20:23	experimentation 48:17 56:19	fact 45:13 51:6 57:1 65:13 70:4 89:21 126:9, 10, 13, 22
enable 13:4 15:13 16:14 22:10 91:9 94:18 103:15 121:4	establishing 41:2	experiences 108:25	factor 51:18, 18
enabling 18:25 63:10	esteemed 8:24	experiment 64:15 109:24	fair 93:7 124:14
encouraging 90:2	Europe 112:12	expertise 23:17 60:9 69:13 92:16	fairly 32:9 58:21
ended 75:1	evaluate 17:2 38:15 47:3 61:12	experts 28:14	fall 16:7 17:25 76:25 77:10 108:6
endorse 92:7	evaluating 61:18 62:4		false 55:23
ends 52:7 124:1	evaluation 47:1 48:10 57:14 61:8		familiar 18:18 21:8 43:18
end-user 47:2 53:18, 20 54:2, 8 55:2 59:12, 12	evaluations 46:23		fan 106:4
enemy 38:6 85:9	event 38:18		far 19:15 21:21 32:19 75:13, 22
energy 32:2	eventually 117:2		Faraday 48:9
enforcement 82:6 110:24 114:12, 17, 21 115:12, 12	everybody 2:6 3:3 7:11 27:11 28:9 30:23 33:22 34:1 43:17 76:12 79:2		farther 55:1, 4
engineering 44:20 46:13, 23, 25 57:13, 13	Everyone's 16:25		fashion 22:9 89:4 90:14, 16

FCC 5:6 6:22
15:15 17:21 19:12
20:9 31:22 41:7
57:25 58:22 78:2
84:22 90:11
118:19 123:12
FCC's 5:19 14:23
17:6
feasibility 17:3
111:11
feasible 17:13
federal 14:24 15:2
16:10 18:8, 13
19:1, 11, 24 20:22
21:25 22:1 23:13
26:9 32:12, 12, 17,
22 33:3, 9 39:10,
14, 24 40:3, 9, 10,
20 44:11 77:14
85:21 87:18 88:17
89:8, 12, 22, 25
91:9 93:23 94:2,
10, 11, 18 95:25
96:4, 10 98:13
103:14, 25 107:21
108:3 109:14
110:11, 13, 13
113:15 117:6, 12,
24, 24 119:5
federally 47:14
Federated 10:14
102:2, 3, 9
feds 113:6
feed 124:2
feedback 12:11
35:18 70:24 71:4
73:11 86:24 90:24
97:14 122:22
126:22, 25
feel 49:21 67:2
108:12, 16
feels 25:14
FEMALE 2:19, 25
3:6, 11 7:21 11:9,
12
fences 13:13, 14
field 31:23
figure 3:16 4:9
26:22 28:15 29:3,
12 30:7, 18, 24
32:3 35:7 38:3
50:15 51:19 52:5
53:17 54:1 55:17
72:10 108:20
109:2, 19
figuring 108:19
122:2 124:4
file 34:2

filed 28:23
fill 30:3
final 6:5 8:10
23:8 70:20 123:9
128:9
finally 31:24 44:6
48:15 49:13 70:2
74:4, 11 78:8
financial 87:8
find 19:20 27:14
29:17 30:9 40:23
42:15 55:22 66:3,
7 75:14, 17
finding 65:24 66:1
fine 25:25
finish 6:16
first 4:12 5:11
6:19 8:23 19:13
26:17 28:7 31:22
40:2 45:10, 14, 24
49:3, 24 52:13
53:18 54:11 59:11
61:6 66:25 75:9,
24 77:1 83:6
92:24 96:25
115:23 116:22
127:16, 19, 19
fit 112:3
five 8:14 42:17
53:23 58:3 81:13
100:10, 11 103:3
118:7
fix 3:25 52:21
fixed 117:11, 12
flag 68:12 88:10,
12, 14
flat 52:15
flat-top 47:12
flesh 92:22
fleshing 91:21
flexibility 107:22
flexible-use 14:19
flexibly 18:9 21:3
Flip 47:8 50:11
51:25
floor 59:1, 18
FM 114:19
focus 14:8 22:6
91:16 95:5 108:19
110:2 118:11
focused 15:2
35:12, 15, 23, 24
37:7 63:12 77:25
89:11 111:18
focusing 58:4
foliage 51:19
Folks 2:21 3:16
8:8 23:23 32:5

82:23 96:23 100:4,
5 122:1
follow 4:10 35:11
37:6 96:22 123:11
followed 22:5
Following 69:7
follow-up 40:19
110:18 126:16
foothill 52:8
foregoing 129:7
foremost 83:6
forensics 12:14
13:12
forgot 78:22
form 22:9 43:25
44:8 113:1
formally 102:23
formation 20:17
forms 59:11
113:10 124:3
formulate 14:4, 10
forth 58:14
fortunate 12:12
forum 101:23
forums 84:23
forward 6:15 7:24
8:9 14:7, 17 18:14
19:3 20:13 23:8
24:12, 19, 25 28:5
37:16 38:9 40:8,
15 46:24 49:2
50:10 57:11 72:25
74:21 75:15 76:6,
23 78:3, 14 83:18,
25 84:5 85:7, 15
87:6 89:13, 24
90:7, 9 91:17 92:5
99:15 104:10
112:3 120:12
forward-looking 6:5
forwards 6:2
found 69:14 79:16
Foundation 15:17
22:16
foundational 58:5
four 15:20 21:15,
21, 22 45:23 50:12
57:9 72:23 83:22
fourth 77:3 90:19
four-year 21:12
frame 18:4
framework 15:15
22:15 28:13 41:7
91:20 96:3, 6, 16
frameworks 13:4
frankly 91:24
free 113:1
free-space 52:15

frequency 14:22
51:22 113:17
fresh 105:10
friction 95:25
Friday 31:12
friendly 37:2
front 26:8 36:23
40:15 62:24 126:3
Frontiers 5:19
14:18 15:10, 14
27:1 35:20 87:20,
23 95:2, 3, 4
Frost 13:12
full 66:20 74:14
127:19
fully 2:15 4:2
21:19 23:5 82:17
fun 24:10 66:11
functions 111:3
fund 18:6 20:24
36:25
fundamental 15:21,
23 45:20 99:22
funded 56:21
funds 18:9, 24
21:3
Furchtgott-Roth
11:1
further 25:8 27:20
33:7 34:13 48:16
75:17 79:9 87:13
99:16 129:7, 10
future 9:7, 9 14:5,
9 16:3 23:1, 7
33:4 36:1, 9 37:3
58:6 64:2, 5 84:11
85:19 92:2 97:11
102:12, 22 103:3,
19 107:15, 23
110:19 117:15
120:5 126:21
127:4

< G >
gain 30:25 52:14,
16 80:22 123:1
game 21:23 24:12
87:4
gather 59:17
Gaussian 54:12, 14,
15, 16 56:6
general 35:20
50:7 87:3, 9, 25
110:7 118:10, 15
generally 25:22
27:4 41:22 99:17
generate 46:19
generated 20:10
79:16

generation 12:19
16:4 28:3
generators 48:10
generic 65:14
87:2, 17
gentleman 126:3
geographic 59:16
89:13
geolocation 96:7
117:20 120:3
George 20:14 69:6
get-go 36:10
getting 24:7 28:9
41:19 55:7 63:17
67:8 69:4 90:4, 12
96:1 99:11 100:3
106:5, 6 121:12
125:5
GIBSON 10:5, 5
23:24 66:11 67:23
68:4, 7, 10, 19, 24
69:2, 5 71:10, 20,
25 72:8, 11, 16
73:2, 6, 21, 24 74:2
78:18, 22, 25 79:6,
20, 24 80:4, 7, 10,
21 81:1, 9, 15
85:24 86:10 93:19
95:13 99:4 100:22
105:18 106:21
111:9 127:13
gigahertz 5:8 17:4,
8, 14, 17 22:10
27:2, 4, 5, 5, 19
28:6 30:14 31:4
35:13 50:16 69:19,
23 76:21 98:1, 1
101:15 105:14, 17
116:15 117:4
give 4:4 22:19
36:14 39:18 43:2
47:4 59:15 69:15
81:19, 22 107:10
126:22
given 29:13 37:20
87:6 89:23 90:22
99:18 121:19
127:8
gives 5:19 50:25
51:2 70:21
giving 27:15 43:16
glamorous 23:14
38:21
glance 45:22
Glass 30:19
GLEN 10:6, 6
Glenn 2:4, 5, 21
3:2, 23 6:25 7:7,

23 8:12, 13 14:17
65:8
global 112:7
go 4:25 5:17
11:19, 20 25:15
28:4 35:4, 5 36:2
37:11 39:3 40:22,
23 41:18 51:12
59:23 61:15 70:19
72:4, 13 73:21
79:24, 25 80:24
85:23 87:2 90:4
91:4 97:23 98:25
103:25 104:17
105:9, 19 106:22
107:6, 7 108:20, 24
109:4 112:9
114:25 120:12, 24
121:14
goal 16:25 17:15
goals 20:12
god 71:11
goes 6:18, 18
19:11 26:19 56:9
111:25 115:2
going 2:2, 3 3:24
6:8 7:24, 25 8:6,
9, 22, 25 9:4, 6
11:2 19:5 23:2
24:21, 25 26:12, 13,
14, 25 27:16, 17, 25
28:10, 17, 21 29:2
30:21, 24 32:2
36:24 37:15 38:3,
9 40:7, 15 41:8, 17
42:19, 19, 20 45:18
46:16 48:18 49:18
53:9 54:12 57:4
59:2, 15, 25 60:24
62:2 64:20, 23
65:9, 15 66:9, 10,
14 70:12, 19 71:20
75:20, 25 76:23
77:11 78:25 79:19
80:11, 23 81:17
82:10, 17 85:12, 18
86:22, 23 87:5
88:3 89:4, 13, 15
90:7, 9 91:1 92:5
93:25 95:6, 11
96:22 97:25 98:10,
12, 19, 24 99:12
100:8, 9 102:15
103:25 104:13, 15,
20 105:6, 8 106:17,
23, 24 107:2
110:16 112:2, 24
113:17 114:6

118:12, 23 119:4
121:14 122:10, 18
good 6:18 12:5
13:13, 13, 14, 15
24:6 31:12 35:18
38:6, 17 48:17
49:13 53:3 56:2, 2
59:17 62:9 63:4
66:1 67:25 68:1,
2, 21, 24 69:10
71:1 74:3, 7 80:15
85:9 90:16, 17, 17
91:21 92:17 93:11,
20 97:25 104:14
105:11 118:3
124:6
Google 10:4
120:24
gotten 26:4 111:20
government 19:24
20:2, 5, 25 32:22
33:9 37:7 44:17,
24 45:1 93:23
94:2 103:14, 14
106:5 109:14
113:15 120:6, 7
125:2, 3
GPS 37:14 119:19,
24 120:17
graduate 16:8
graph 50:17, 22, 25
52:11 55:5 56:4
graphs 52:22
grateful 23:15
gratifying 28:22
gratitude 128:4, 7
great 8:16, 20
11:13 13:10 25:14
28:6 42:5 43:1
69:21 73:3, 6, 13
74:9, 12 81:5
97:12 120:14
greatest 27:21
green 56:5
Gremban 7:2
16:19 43:7, 13
59:10 60:4, 16, 19
61:23 62:17 63:15
64:11 65:8, 20
115:3
grid 125:23
ground 41:2 88:23
ground-breaking
21:12
groundwork 14:21
group 6:14 9:5, 11
20:19 34:19 41:22,
22, 23 46:2, 3, 8
67:12, 14, 18, 18

74:7, 7 75:25
79:17 86:2 89:9
97:1 98:3 102:17,
19, 22 108:8, 23
115:18
groups 6:6 35:24
77:15, 20 92:6
102:12 111:21
group's 86:8
grow 33:1, 4
58:15 113:25
growth 21:6 44:4
guarantee 23:1
24:18
guess 34:8 38:25
43:23 60:9 107:22
guests 6:20 8:23,
24
guidance 83:2
128:1
guiding 127:23
guy 114:15
guys 3:9, 24 7:14
64:1 66:17 67:25
71:11, 22 72:3
73:6 79:2, 12
101:25 102:22
110:18
gyros 121:10, 11

< H >
half 123:1
halfway 16:25
107:1
hand 6:2
hand-held 80:11,
24 81:1, 15
handle 53:13
90:11 125:11
handled 101:23
hands 19:22
115:15
happen 26:19
38:16 39:24 78:10
happened 14:15
75:1
happens 69:5
happy 23:22
65:12, 18 87:1
126:14
hard 4:20 6:3, 14
7:12 25:5 30:18
32:1 60:7, 21
66:3, 7 119:1
harder 8:19 66:2
harmful 55:16
harmonic 114:18,
18

harmonics 113:18
harms 106:4, 7, 9
Harold 10:25
harsh 98:17
harvest 116:7
hat 30:19 58:10
HATFIELD 10:9, 9
 58:10, 19 59:22
 106:3 113:3
 122:16 126:17
hats 69:20
head 7:8, 8 81:18
 90:3
heading 49:23
hear 3:5, 9, 17, 20,
 22 4:22 8:22 11:6,
 14 12:1 16:18
 24:11 30:7 79:13,
 24 80:23 86:24
 90:24, 24
heard 6:6 12:2
 15:7 43:22 76:8
 78:14 88:2 117:13
hearing 3:7 87:10
 127:10
heavily 103:10
he'll 91:2
Hello 2:17, 18
 12:20
help 7:22 13:12
 14:10 15:9 18:23
 20:24 23:17 33:24
 34:24 40:23 41:9
 50:9 61:12 67:9
 76:8, 9 77:18 84:5
 93:6 98:2 101:19
 105:1 117:15
 122:1, 12 128:5
helped 75:23
helpful 60:15
 69:16 90:25 124:5
 127:25
helping 74:9 81:6
HENDERSON 129:4,
 21
herd 110:3
Hey 7:21 41:14
 79:18
Hi 2:19 8:2 11:9
 12:4
high 9:8 14:21
 31:5 51:7 55:4
 89:1 95:23 122:21
 124:20
higher 57:18
 91:10 105:17, 18,
 21, 23, 24
highlight 69:10

91:15
highlights 56:13
high-payoff 18:24
high-volume 90:11
 91:8 96:17
hijacking 125:7, 7
hill 2:11
histogram 54:15
historically 38:13
 58:19 87:8 101:11
history 22:19, 20
 43:24 44:10, 13
hit 77:6 110:16
hits 42:13
hitting 49:15
hold 12:12 81:7
 106:19 110:15, 15
homeland 20:7
honest 89:20
hooks 78:5
hope 13:7 24:23
 33:21 84:14 95:19
hopefully 2:7 6:21
 7:1 18:25 61:2
 117:3
hosting 62:21, 24
hour 8:23
hours 50:13
House 15:7
How's 25:10
hub 54:3
hub-and-spoke 54:1
huge 99:7
Huh 3:6 10:20
human 56:14, 24
 57:3
hundred 20:10
hunters 59:4
hurt 5:10 126:23

< I >
Idaho 126:5
idea 5:17 33:8, 15
 55:23 92:17 93:3,
 22 107:12 108:13,
 13 109:18 116:24
 122:14 124:1
 126:9, 12
ideas 45:9 81:20
 85:9 92:22, 23
 96:18, 22 109:23,
 25 110:2 113:1
 124:6 127:2
identified 27:3, 10
 32:12 45:20 46:22
 75:20 78:9 117:25
identify 6:17
 19:23 25:22 27:25
 48:23 76:18 83:17

identifying 18:2
 28:3 32:19 84:2
 117:5
IEEE 30:1
II 44:5
ill-formed 108:13,
 15 109:18
ill-informed 108:13
Illinois 9:20
immediate 78:13
immediately 36:21
 37:13 57:24
impact 40:14
 61:20 76:16 99:7
implement 18:16
 22:15 93:6 115:8,
 11
implementation
 97:4
implementing 98:15
implications 118:5
important 6:11
 18:5, 15 20:12
 21:25 22:3 23:18
 24:20 25:1 30:4
 45:6 84:3 89:23
 91:23 103:7, 11
 112:5, 15 124:19
importantly 87:3,
 18
impressive 13:6
improve 44:15
improvements
 33:25
inaudible 10:21
incentive 5:12
 17:17 26:18 87:15
incentives 87:4, 9
incidental 58:14
include 15:24
 30:15, 15 82:6
included 5:3
including 17:4
 18:16 22:9 47:1,
 22
increase 36:22
increased 17:3
 30:20
increasing 54:25
 61:9 62:15 110:1
increasingly 87:5
 88:1
incredibly 55:25
incumbencies 27:7
incumbent 33:14
 37:1 113:5 126:19
incumbents 36:6
 38:23 126:19, 22

incumbent's 113:12
indicated 60:5
indicating 80:11
indiscernible 1:1
 3:12 8:3 11:22
 12:25 24:14 25:10
 39:17 41:3, 14
 58:17 60:3, 18
 62:13 63:5, 6, 9, 10
 68:9 69:12 70:14
 72:15, 21 73:4
 78:23, 24, 24 79:23
 80:19 82:8 87:5
 88:25 89:1 90:9
 93:19 95:10, 14, 16
 96:19 97:6, 13
 99:4, 21 100:23
 102:10, 24 104:4, 5,
 7 106:15 107:13
 109:7 110:6, 8, 9
 111:9, 13, 16, 22, 24
 112:21, 23 116:25
 117:10 118:17
 119:9 120:16
 123:2, 20, 23
 124:13 126:4, 15,
 18 127:1, 14
industry 4:25 16:1
 17:11 20:1 26:10
 28:8 34:21 35:9
 68:15 76:5, 5
 77:14 103:13
 104:1
inescapable 87:24
inevitable 88:4
 92:8
influence 50:9
 123:17
influx 122:11
inform 16:20
 43:16 44:18, 21
 45:7 46:10 60:7
 84:11
information 24:6
 58:23 113:8 114:9
informing 9:11
infrastructure 109:9
initial 19:12 67:5
 81:25 111:5
initially 25:17
initiative 15:7, 16
 20:14, 16
Inner 44:5
innovations 16:3
 124:18
innovative 5:7
 23:4 35:15, 25
 58:21

in-proxy 8:12
input 9:10 127:25
input's 74:13
inquiry 58:22, 23
inserting 112:1
insight 51:2, 10
insights 14:8
 23:15 128:5
instance 61:15
 65:2 116:14
instances 52:3
INSTITUTE 1:1
 7:9 9:17, 21 10:17
 16:7
integrate 82:12
intellectual 14:3
intellectually 89:20
intelligence 32:2
intelligent 31:7
 70:1
intended 2:15 4:3
intense 17:9
intent 7:18 18:23
 22:19 35:13 81:22
intention 32:9
intentional 58:13
interacting 55:15
 66:6
interaction 55:16
 91:11
interactive 91:5
intercepted 54:8
interdependencies
 83:11 84:4
interest 97:25
 109:13
interested 87:10
 93:23 121:21
 122:18 129:12
interesting 8:22
 9:5 27:8 41:15
 43:24 101:24
 114:8 122:14
interfere 51:8
interference 13:5
 35:4 38:7 42:8, 11
 45:2 46:11 47:5,
 19 48:4, 12 56:10,
 22 58:12, 18 59:3,
 4, 7 60:1, 8 63:25
 64:6, 8, 15 82:8
 99:24 113:10, 21
 114:12 115:5, 8, 13
 122:19, 24 123:3
 127:1
interferers 59:19
interfering 49:16
 59:6 113:19, 24

114:3
internal 45:8
internally 46:16
 47:25, 25
International 73:7
 110:18, 21
internationally
 27:25 115:14, 17
internet 21:17
 63:16
interoperable 33:18
interpreting 97:5
interrelationship
 83:10
intersection 84:8
intervention 77:17
interviewed 39:16
interwoven 92:11
introduce 11:6, 17,
 18, 19
introducing 107:23
introduction 55:12
introductory 12:7, 8
intuition 55:6
invaluable 23:15
invest 18:24 82:22
investing 15:19
investment 15:24
 42:13 109:16
invites 28:21
involve 25:19
involved 40:25
 63:17 67:8 99:19
involves 49:8
IPC 63:24
irregular 52:17
irresponsible 88:8
ISART 4:5 12:13
 13:11 46:1 48:6
ISART's 13:14
isolated 48:11
issue 41:3 46:22
 59:3 60:13 61:25
 64:11, 13 65:4, 14
 70:22 71:6 79:23
 87:21 116:1
 122:24
issued 31:10 58:21
issues 4:22 6:17
 14:1 32:11, 19
 34:13, 18 37:24
 50:5 58:11 59:1
 78:1 88:6, 11
 92:2, 9 100:6
 113:13, 21 116:14
item 14:18 27:1, 2
items 69:22
iteration 4:20
 93:11 96:25

ITS 2:10 5:12
 16:6, 15, 19 17:7
 23:25 38:11 43:15,
 17, 20, 24, 25 44:7,
 12 45:4, 22 47:8
 49:21 50:1, 5 57:9
 58:19, 21 59:9
 60:6 65:11, 12
 69:25 102:4, 5
 106:13 118:5
ITU 62:19 115:18

< J >
Janice 8:2 10:22,
 24 11:16, 20, 21, 21,
 24, 24 67:7, 11
 79:24, 25, 25 80:1,
 2, 5, 9 81:11, 12
 86:4, 12, 13, 22
 90:23 91:6, 12
 92:3 95:20, 22
 115:24
Janice's 124:18
January 5:1
Jeff 10:13, 13 73:8,
 9, 18 115:21, 22, 22
 116:19
Jeff's 73:16
Jennifer 10:11, 11
 37:4, 5, 5 59:23, 24,
 24 60:5, 18 67:7
 96:20, 21, 21 97:7
 111:13, 15 114:25
 115:1, 1
Jennifer's 110:13
job 23:14, 18
 41:21 44:20 65:25
 69:21 74:9, 12
 122:3 128:6
join 7:8
joined 7:2 12:17
joint 49:25 103:12
jointly 2:10 56:21
 93:5
judge 116:23
Julie 6:22 7:8
 14:16 15:4 17:17
 25:6, 8, 11, 13 32:5,
 6, 8, 20 34:19
 36:14 37:5, 9, 18,
 19 38:1 39:2, 6, 23
 41:1, 14 42:5, 24,
 24 43:2, 4, 9, 12
 48:20 53:5 63:23
 64:24 65:14, 16
 68:12 69:22 76:11
 89:20 93:1, 22
 103:5 107:19, 21

118:18 120:15
Julie's 46:22
July 15:11 21:11
 31:16
jump 12:8
jumping 36:21
June 14:14 31:11
 66:23
justice 16:23

< K >
KEA 31:13
keep 8:9 11:20
 24:21 28:4 57:21
 96:13 102:15
keeping 74:10
Keith 7:2, 3, 3, 7, 8
 14:16 16:19 43:5,
 7, 13 58:8 59:10
 60:4, 16, 19 61:23
 62:17 63:15 64:11
 65:8, 20 66:9
key 20:17 45:23
 70:11 74:18 84:9
 88:14, 21 91:16
 113:4 116:12
kick 2:15 4:3, 3
 74:5 85:23
kind 2:13 4:7, 14
 5:12 8:21, 23 9:12
 22:11 34:16 35:2
 37:25 39:25 50:23
 52:6 55:5 56:7
 57:6 59:25 61:14
 64:5 68:13 82:15
 85:22 94:9 96:13,
 14, 17 97:1, 4
 98:18, 23 102:20
 104:1 107:19
 108:7 114:24
 115:4 124:3
kinds 40:6, 17
 77:20 89:14
 113:19
Knapp 6:22 15:4
 25:13 32:20 34:19
 36:14 37:9, 19
 38:1 39:23 41:1
 42:5 43:4, 12
knew 91:4
know 3:17 4:7
 5:10 7:7 8:16, 19
 9:8, 10 10:22, 24
 11:1, 14 21:4
 22:20 23:13 24:13,
 20 26:19 28:14, 22
 31:16 32:1, 9, 13
 34:4 36:4, 13, 18
 37:10, 11, 20 38:13

39:2 41:15 42:19,
24 56:15 60:5
61:8, 16, 21, 22
62:9 63:4, 7 64:3
66:17 67:2, 15, 17,
22 68:5 69:12, 17
70:1 71:5 72:25
75:4, 9, 12, 19 76:7,
11, 18, 22 77:4, 5, 8,
15, 21, 24 78:11
80:8 83:23 85:20
86:4, 6, 25 87:1, 3,
4, 7, 19, 25 88:3, 13,
24 89:2, 6, 10, 21
90:2, 23 91:4
92:4, 7, 10, 15, 16
93:9, 10 94:1, 5, 6,
21 95:21, 24 97:10
101:15, 23 102:17,
19 104:14 105:15
107:5, 24 108:4
109:6 111:6, 7
113:7 114:1
115:15, 17 116:23
117:2, 4, 7, 8, 10, 19
119:15 120:24
121:11, 22 122:2
124:1, 16 125:6, 17
127:8 128:6, 10, 14
known 120:25
126:10
Kolodzy 9:22, 22,
22 41:13, 13 70:14
71:2 72:24 73:4
97:14 99:2, 5
100:16, 24 118:16
120:13
KUBIK 10:8, 8
74:5 80:18
kudos 69:8, 12
Kurt 10:14, 14
73:8, 13, 15, 23
74:1 110:20
111:10, 14, 17
Kurt's 112:6

< L >
lab 31:22 126:5
laboratories 43:22
Laboratory 44:6,
17 48:8 50:2 62:3
labs 2:6, 10
lack 65:4, 5
lag 86:25 91:24
laid 15:11
lamps 58:16
113:25
land 119:24

landscape 36:13
83:23
language 73:19, 21
large 54:13
largely 39:23, 24
Larry 2:15 3:9
4:2, 7, 8 8:1, 6, 12
10:4, 4, 19, 24 11:5,
11, 16, 23 12:2, 4,
17 23:9 25:3, 7
32:5 36:2 37:4,
18, 20 38:25 41:12
42:23 43:5 58:8
59:23 61:4 62:7
63:19 64:18 66:8
71:18 72:5, 6, 22
78:23 79:15 85:17,
25 86:12 90:23
92:19 93:15 94:9
95:6, 11, 15 96:19
97:9 98:25 100:13
101:1, 13 102:11,
21 104:3 106:1, 16,
19 107:10, 16
108:9 110:5, 7, 15
111:20 112:17, 22,
24 114:23 115:21
116:19 118:6
119:7 120:23
121:13 122:13
123:7, 24 124:14
126:2 127:6, 15
128:6, 9
lately 99:16
laugh 113:25
launching 15:12
law 17:25 54:13
119:24
lawyer 3:24
lay 17:22
lays 14:20
lead 18:11 28:2
69:8 114:11
117:16
leader 46:1
leadership 15:12
127:23
leading 30:20
leads 46:8 92:6
104:10 114:7
learn 82:7, 11
109:10
learned 8:17 85:4,
6 109:7, 19
learning 120:25
121:4
learnings 104:25
leave 2:12 57:8

71:2, 8 72:2 78:16
led 34:7
left 32:1 52:5, 6, 9
53:17 56:4, 10
118:7
leftover 112:20
legislative 20:21
lend 101:10
lenses 23:4
lesson 22:20
lessons 85:4, 5
109:2, 19
level 9:9 30:20
38:8 45:8 47:5
49:16 115:13
levels 125:10, 13
leverage 16:9
94:17, 24 116:3
leveraging 22:9
94:20 96:8
levers 87:11
LGS 124:18
liaison 69:10
liaisons 74:8
127:24
license 82:8 90:13,
13
licensed 33:12
licensee 33:14
40:22
lies 27:9, 22
lieu 77:21
life 4:10 68:7
lifetime 5:16
lightly 25:24
limit 37:19 47:19
110:11
limited 83:5
121:22, 25
line 2:22 48:18
52:15 53:5 69:7
106:9
lines 94:8
list 122:7
listening 8:24
80:1 84:13
literally 86:3
little 7:9 9:6
12:10 21:16 26:14
29:20 39:2 43:14
50:14 51:2, 12
52:6 54:17 60:21
61:5 63:15 64:8
66:17 67:2 70:16
72:14 78:6 81:24
86:23 110:4
111:15 113:3
114:22 118:22

live 13:18
lived 24:11
living 41:19
loaded 65:7
lobbying 65:11
location 7:1
locations 50:14
Lockheed 10:11
log 51:21
long 21:15 34:2
36:17 117:15
longer 33:21 37:1
Longley-Rice 52:17
look 2:8, 11 4:23,
25 6:15 12:19
14:7 19:6 23:3, 8
24:12, 15 32:15
34:5 35:20 38:3
45:15 50:17, 24
54:14 65:8 66:7
67:20 70:17 72:3,
7 75:6, 9 76:12, 20
77:9 79:19 81:7
82:5, 13, 24 83:1, 3
85:11 95:1, 3 96:3
99:9 103:17, 18, 19
104:2 105:19
108:1, 4, 24 109:4
112:5, 7 115:6, 16
116:1 118:19
120:18 121:21
122:6 123:6
124:21 125:25
looked 36:7 37:25
38:13 39:10, 19
42:2 51:4 61:18
64:5 98:17 111:8
116:15
Looking 4:21 6:2,
17 31:4 35:21
36:25 37:10 39:9,
14, 21 42:2 50:21
59:13 60:12 61:11
62:3 63:24 65:13
69:2 71:10, 21
75:9 82:18 83:5
85:9, 15, 25 96:24
97:1, 19, 20 98:9
99:25 100:2, 16
102:19 104:23
107:11 112:2, 3, 13
113:16 114:4, 14
118:18 123:14
looks 50:22 51:4
56:11
loop 122:19, 19
123:3 127:1
lose 121:11

lot 8:17, 24 9:1
14:14 22:13 24:2,
5, 7 25:25 26:18
28:16 29:5 30:17,
24 31:25, 25 32:2
35:2 37:15 44:24
47:9 48:17 51:5
55:8 56:20 57:4
58:7, 20 59:16
60:12 61:17 62:9,
19 63:4, 11 65:25
67:1 74:12, 13, 16
75:4, 15 78:16
87:7 89:11, 17
92:20 93:8 94:13
98:3, 13 99:16, 19
100:20 104:14, 17,
25 105:2 106:10,
10 108:19 109:7,
23, 25 112:8
113:17 116:16
118:23, 24 119:25
125:9
lots 7:17 122:5
124:24
lower 50:24 69:24
105:16 107:5, 12
113:16
LSA 112:1, 2, 3, 7,
8, 10
LTE 33:23 48:16
104:18
luck 42:8

< M >

machine 120:25
121:4
mainstream 5:9
maintain 13:13
18:13
major 14:17 49:18
99:9
makers 44:21
60:10
making 20:3
44:19 46:17 49:2
57:17 60:7 84:9
88:22 92:12 122:8
MALE 2:1, 17, 23
3:4, 7, 15, 18, 22
6:23 7:5 8:2
10:22 25:10 35:10
58:17 63:6 68:9
69:1, 4 71:15
72:9, 18 79:5, 14
80:19 86:15, 18, 20
102:15 106:12, 15
110:6 111:16, 23

112:23 119:9
123:19
manage 61:12
MANAGEMENT 1:1
5:9 6:13 13:19
99:6, 7 125:11
mandated 47:14
manifest 83:11
manner 125:8
map 17:22 53:19
86:3
mapping 121:8
MARIAM 10:7, 7
62:7, 8, 8 63:2, 7
74:4, 11, 22, 23
78:18, 21 95:7
102:24 103:1
104:6 105:22
106:1 110:9
Mariam's 106:18, 23
Mark 8:1, 4, 4, 11,
19, 19 10:5, 5, 24
12:2, 3, 4, 6, 21
23:24 24:8 66:9,
11 67:7, 23 68:4, 7,
10, 19, 24 69:2, 5
71:10, 20, 25 72:8,
11, 16 73:2, 6, 21,
24 74:2 78:18, 22,
25 79:6, 15, 20, 24
80:4, 7, 10, 21 81:9
85:24 86:10 91:1
93:15, 18, 19 95:13
98:25 99:3, 4
100:22 101:4
104:3 105:18
106:21 107:10
111:9 112:8
114:23 124:8
127:11, 13 128:12
market 19:22
21:17 33:24 111:1
Mark's 12:3 110:5
Martin 10:12
MARY 129:4, 21
massive 101:9
match 55:6 70:8
matches 55:5
matching 61:13
match-making
40:24
material 74:16
mathematical 66:4
matter 87:9 120:4
129:9
mature 16:2
maturing 57:3
maximize 27:14
29:13

maximum 29:8
50:25
MDT 1:1
mean 37:23 42:17
51:1, 4 68:16
71:11, 12, 21 94:5,
12 97:7 105:4
108:5 114:4
120:23 121:10
122:6
meaning 120:16, 20
meant 26:2
measure 53:2, 2
70:10 111:2, 4
measured 52:18, 20
measurement
35:12 46:8, 10
50:4 51:13 52:10
54:6, 7 57:12
68:24 70:4, 5, 6, 9
97:20 101:10
measurements
44:14 45:2 48:5
49:9 52:25 54:16
measures 98:16, 22
110:24
mechanism 84:25
96:7 117:18
mechanisms 108:2,
4 115:7 122:2
125:21
median 50:25
meet 26:12 62:5
MEETING 1:1 2:14,
16, 24 3:1, 2, 20
4:4, 5 5:25 6:7,
16 7:4, 20 8:10
12:12 14:14 17:6,
15 62:22, 25 64:21
66:13 68:17 70:20,
23 72:4, 19 73:11
74:3, 14, 18 121:18
128:17
meetings 25:15
30:22 59:4
megahertz 16:25
17:10, 15, 23 18:2
19:24 27:10 107:2
108:2
member 69:11
124:11
members 69:20
73:12 102:9
membership 13:20,
24 14:11 23:9
24:23 77:23, 25
124:6
memo 22:5, 5

88:20
memorandum 44:8
memos 21:7
mention 21:20
23:25 58:15 66:25
121:17
mentioned 14:18
17:20 29:20 31:10
32:8 34:9 37:23
82:11 83:21 84:16
86:2 92:5, 13
93:10 95:22
107:20, 21 121:17
127:24
mentioning 16:24
120:15
merit 21:20
mesa 47:12
methods 64:14
115:9
metrics 110:24
112:6
Michael 10:16, 16
32:6, 7, 7, 20 34:8
95:11, 17, 18 96:24
97:5, 6 107:16, 18
108:9 112:19, 21
116:20, 21 117:1
118:6 119:12
microphone 1:1
60:3 71:3 80:12
81:1, 15
middle 30:3, 19
midst 29:1
Mike 10:25 45:25
46:1 102:25
106:20, 22 107:17
114:24 121:14
126:3
mikes 108:14
miles 47:12 52:8
milestone 6:1
military 33:23
89:12
millimeter 5:21
14:22 105:3, 5
million 15:20
millions 105:11
MIMO 101:9, 9
mind 25:17
108:25 119:15
mindful 36:18
mine 98:6
mine's 61:5
minimum 50:25
minor 73:10
minutes 12:1 15:5
17:18 79:25 81:13

- 118:7
mirror 26:14
missed 35:17
missing 30:3
 35:14, 14
mission 20:8 44:18
missions 22:1 94:6
mistakes 57:2
mitigate 114:20
 125:16
mitigating 13:4
mitigation 46:12
mix 117:21
mobile 16:14 27:3
 28:3 117:12
model 29:11, 13
 33:11 35:3 51:22,
 23 52:15, 17, 17, 20
 53:2, 2, 14, 15, 15,
 18, 22 89:19
modeling 17:10, 11
 51:13, 21 78:11, 11
models 39:11
 44:11, 14 46:5, 11
 49:10 52:2, 3, 25
 60:25 62:20 65:17
modifications 119:3
MOI 89:7
moment 6:3 58:11
momentarily 6:22
 7:2
momentum 22:23
 24:21 28:4
Monday 1:1
money 5:2 65:5,
 12 83:19 92:4
 122:11
monitored 68:1
monitoring 49:3,
 25 50:12 59:13
 63:1 111:6
month 21:11
 50:16 71:15
months 6:7 13:22
 14:14 22:23 23:21,
 22 128:8
monumental 26:24
morning 4:5 62:21
 64:21 68:10 70:24
 72:19 119:18
motion 79:8
MOU 89:19
Mountain 47:11
MOUs 39:10
mouth 40:9
move 9:4 24:19,
 25 49:1, 23 50:10
 57:11, 19, 22 74:21
 75:14 76:6 78:3,
 13 80:21 83:18, 25
 84:5 85:6 90:7
 91:16 95:11
 101:15 102:11
 112:13
moved 18:16
moving 38:2
 43:23 46:23 72:25
 76:23 104:9
multi-billion-dollar
 38:19
multijurisdictional
 86:10
multilayered 91:20
multiple 17:3
 20:22 30:12 42:21
 55:14 59:6
multi-stakeholder
 77:10
multitude 42:3
multi-year 57:16
muscle 4:15
mute 3:3 11:19
- < N >
naive 54:11
name 87:4 124:16
names 67:3
nation 98:11
NATIONAL 1:1
 15:17 44:1 65:2
 126:5
nationwide 33:12
nature 35:24
 111:15
navigating 119:22,
 22
navigation 119:17
 120:4 123:11
near 121:14
nearly 2:11 20:10
necessarily 40:25
 88:5 106:13 107:2,
 3
necessary 13:3
 89:23
need 14:8 15:3, 8
 19:18 20:6 21:5
 22:15 34:13 37:25
 38:15 45:18 49:4,
 7, 13, 17 53:13, 14
 55:14 56:18 59:20
 72:2 82:20 88:11
 91:16 93:4 95:24
 103:17 109:25
 110:2 113:7, 21
 114:3 121:23
 122:1
- needed** 44:20
 54:22 83:24
needing 113:13
needs 42:1 108:3
 114:17 120:6
needy 88:23 89:4
neighbors 13:13, 15
Nelson 24:2 46:8
Network 10:7
 48:16 90:12 111:7
networking 16:13
networks 19:14
 87:24 101:17, 18
never-going-away
 83:19
new 4:15 5:8, 14
 10:17 14:1 16:21
 21:24 22:17, 22
 24:22 35:21 36:5,
 9 38:19, 23 40:4
 42:18 64:7 65:16
 77:9 90:18 96:22
 97:18 101:9
 108:23 116:3
 121:1 122:11
 124:2
news 28:6 31:12
next-door 36:19
nice 2:12 70:16
 126:21
nicely 48:20
NIST 2:10 44:8
 50:1, 6 62:3 102:6
NOAA 2:10
noise 55:20 56:7,
 8 58:20, 24 59:1,
 18
non-AWS-3 107:12
nonfederal 39:9, 14
 40:13, 14 85:22
 91:10 94:18 98:14
non-federal 15:2
 40:21 94:10
 110:11 119:5
nonharmful 96:4,
 15 97:2
non-spectrum 99:7
normal 24:23
 119:19
north 47:12
Notary 129:5
NOTE 1:1 61:9
 71:19 72:7, 12
 102:8
notes 13:11 93:21
notice 17:7 27:20
 31:11 33:7 58:22,
 22 63:23
- notion** 88:3 111:5
 117:4 120:3
 122:18 123:3
notwithstanding
 112:12
novel 21:17
nowadays 46:14
NSF 15:17, 19, 25
 116:6
NTIA 7:16 10:3, 6
 14:23 19:23 23:21
 24:16 26:9 34:4, 6
 41:6 61:24 76:4,
 14 78:2 83:13, 15
 89:8 90:3, 10
 94:14 96:1 107:14
 111:11 115:24
 116:2, 7, 13, 23
 121:20 122:7
 127:23 128:3
NTIA's 16:6 81:25
 121:19
NTRM 89:8
number 28:23
 37:23 44:3 45:6
 47:21 48:1 64:16
 92:19 116:6
 121:25 123:2
 125:24
numbered 43:24
numbers 54:13
- < O >
oath 39:17
Obama 21:4
obligation 7:18
obscure 118:1
observation 80:16
observations 70:11
obtained 50:15
 53:19
OBUCHOWSKI
 11:21, 22, 24, 25
 80:2, 5, 9 86:22
 91:12 92:3
obvious 67:17
 88:24 117:21
Obviously 2:9
 24:18 38:17 57:23
 60:19 75:14 90:7,
 11 117:20
occasion 109:4
occupancy 49:4
 51:1
occupying 119:16
occurred 14:13
 38:16
occurs 99:10

- offers** 14:24
office 56:21
offline 125:20
oh 7:3 39:1
 58:11 63:2, 6
 71:15 80:5 91:4
 124:14
Okay 3:15 7:3
 8:6, 8 11:5, 12, 21
 12:4, 18 43:13
 45:16 63:19, 21
 66:11 67:23, 25
 71:13 72:9, 24
 74:2, 3, 23 78:18
 79:2, 2, 10, 11, 11
 80:24, 24 81:13, 17
 86:22 91:14 97:9,
 14 102:11 107:10,
 16 108:9 111:20
 112:17, 17 115:22
 116:21 121:13, 16
 124:17 125:4, 14,
 20
old 57:21 69:4
 123:9 126:7
Olympics 119:11
Once 2:13 80:6
 122:8 127:24
ones 25:5 75:19
 78:22 87:2 96:8
 105:16 123:21
one-size-fits-all
 70:2
onesy 90:16
ongoing 34:10
 35:16
online 3:8
open 9:8 10:16
 32:10 34:20 85:10
 101:19 112:23, 24
 122:19
opened 34:3
open-ended 84:17
 121:5
opening 4:5 42:18
opens 40:4
operate 33:20
operating 42:17, 21
 45:1 90:15 122:21
 125:8
operation 62:18
operations 25:25
 111:7 125:10
operator 55:19, 21,
 24 56:1, 5, 6, 16
operator's 56:9
opinion 41:16
 122:11
- opportunities**
 12:24 14:24 15:3
 23:6 51:3, 11
 77:20 123:15
opportunity 2:8
 5:13 13:10 16:5,
 16 33:4 50:23
 59:15 63:9 103:23
 105:12 107:15
 124:10
optimistic 17:20
optimize 107:22
options 115:10
order 5:19 53:18
organization 42:25
organized 57:9
original 81:22
 109:5, 6 123:4
originally 44:1
OSM 57:25
ought 64:4, 6
outbriefs 66:12, 13
 81:10
outfitted 48:1
outline 67:19
 70:17
outlined 103:2
out-of-the-box 5:12
outstanding 8:18
overall 124:22
 125:17, 25
overhead 52:5
overlap 68:11
overlooked 47:2
overtake 98:23
overview 43:17
Ow 5:9
owe 128:4
- < P >**
p.m 1:1
paces 31:18
pack 26:1
packing 29:6, 7
Paige 9:11 10:3, 3
 12:9, 10, 16, 18, 23
 13:2 24:8, 17
 25:4, 5 26:15
 29:19 31:10 35:11
 36:14 63:21 64:23
 65:14 81:3, 13, 17
 91:6, 14 92:3
 94:16, 23 95:1, 13
 102:1 118:9
 123:10, 21, 25
 124:2 127:19, 22
 128:3
Paige's 56:21
- 106:24
painful 117:2
panel 18:17, 21
panelists 13:6
panel's 18:18
paper 66:19 67:9
 126:14
papers 6:8
paradigm 21:24
parallel 63:23
 92:17 118:20
paraphrasing 13:11
part 13:24 17:14,
 25 18:3 20:17
 21:18 33:17 39:16
 40:16 41:1 44:22
 48:6, 7 66:12
 69:24 76:19, 23
 103:11 105:6
 119:20
Partially 91:24
participants 1:1
 3:14 13:1
participate 13:8
 34:20
participating 17:5
 24:7
particular 13:2, 21
 14:22 15:1 20:6
 25:23 29:11 30:9
 33:10 35:13, 20
 37:13 50:19, 20
 51:22, 22 55:18
 62:10 63:16 67:3
 77:22 92:21 99:25
 104:13, 22 108:2, 4,
 24 127:18, 21
particularly 14:25
 63:3 79:16 83:16
 91:22 93:23 107:4
 120:5
parties 27:16
 28:23 129:11
partner 123:16
parts 2:11 7:24
 30:13 86:9
party 28:21
pass 8:1 70:12
 114:24 119:9
 126:3
passed 80:14
patent 126:10
path 52:9, 10 89:2
 100:7, 8 112:12
Paul 9:22, 22 39:1,
 4 41:12, 13, 13
 42:5 69:1, 2, 9
 70:12, 14 71:2
 72:24 73:4 97:14
- 99:2, 5 100:13, 16,
 24 101:6 118:16
 120:13
Paul's 46:21
pause 38:2
PCAST 21:14, 23
 22:2, 8, 11 83:22
 96:9
peel 35:22 82:16
peeling 85:12
pending 19:2
people 11:1, 23
 24:3, 4 26:10
 30:17 36:6 37:10,
 11, 13, 16 41:16
 43:19 46:17 58:18
 59:4 64:15 66:4, 7
 67:8, 10 79:13, 13,
 18 83:20 105:3
 109:16 114:9
 116:16 118:25
 119:2, 7 120:1
 122:11 124:15
 126:20
Pepper 9:16, 16
percent 44:25
 103:8, 9
perception 61:19,
 25
perfect 38:6 85:8
 102:21
performance 47:1
 49:17 56:6, 9
 103:6, 9, 18 104:2,
 4
performing 44:14
 111:3
performs 56:11
period 4:24 17:7
periodically 48:3
periods 30:9
permanently
 101:16, 18
permission 33:13
person 93:20
personal 23:16
personally 103:4
personnel 65:24
perspective 19:8
 21:16 24:17, 20
 61:17 65:10 126:1
pertains 87:18
phase 36:12
phased 36:8
phases 31:21
phenomenon 51:17
philosophical 116:1
phone 3:5, 16, 20,
 21, 25 8:8 10:20

11:2, 3, 5, 6, 23
 79:13 80:23 81:11
 86:5 127:8, 9, 9
phones 3:3 71:12
 121:4, 8
physical 51:18
physics 66:4
pick 51:22 53:24
 77:21
picked 39:20
 77:22 97:24
picking 53:22
 97:18 114:6
piece 29:21 30:3,
 10, 11 31:2, 3, 4
 33:5 46:15 80:15
 104:24
pieces 54:1 57:10
Pipeline 17:24
 18:5, 8, 15
pitch 4:11
place 15:8, 15
 28:15 32:25 41:9
 52:7 58:3 77:16,
 22 78:5 119:21
places 29:16
 37:14 40:13, 16
 48:3 97:24
placing 5:8
plan 24:12, 18
planned 82:1
planning 18:10
 21:4 63:13
Plans 20:19 62:15
plate 121:20
platforms 15:21, 24
play 27:19 41:7,
 25 111:12 115:24
playing 11:4 34:16
please 2:22 3:3,
 25 124:15
pleasure 42:25
 127:17, 18, 21
plethora 87:6
plotted 54:9
plowing 8:9
PNT 120:16 123:13
point 26:25 32:24
 34:11, 18 42:5
 53:3 72:1 76:3
 77:12 95:17 99:25
 100:21 101:5, 7
 105:12 107:11
 108:1 112:6
 117:15
pointed 74:20
points 55:25 88:20
policy 6:11 12:24
 15:15 16:21 19:8,

11 20:12, 14, 16, 18,
 21 22:3, 14 23:5
 43:16 44:18, 19, 21
 45:5, 7, 7, 12, 21
 57:11 60:7, 10
 64:13 84:8 92:10,
 12 100:4, 4 108:18
 109:20 111:19
 115:9
policymakers 60:14
political 69:25
 88:2
poor 1:1
pop 51:7
population 53:18
 60:22
populations 53:14
portfolio 57:15
portion 27:11
possibilities 40:4
possible 24:24
 60:20 92:12 95:25
 110:3
possibly 46:19
potential 9:9
 61:21 83:1 84:20,
 21 87:11 117:18,
 22
potentially 32:25
 33:23 34:16
 123:17
Povelites 10:18, 18
 106:17, 17, 23
 107:13
power 7:14 49:16
 51:7 52:14 54:4,
 9, 22 55:4 113:24
 121:4 122:21, 23
 125:19, 23
PPSG 20:18
pre-definition 76:13
predict 30:8
preference 104:22
preliminary 81:23
prepared 119:12
present 9:3 86:7
presentation 90:25
 98:8 106:25 115:3
presented 81:25
preserving 20:4, 25
president 17:25
 19:16 20:14
presidential 21:7
president's 20:13
 21:13 22:4 107:1
press 15:7
pretty 9:8 34:24
 35:6 68:21

previous 82:19
primary 1:1
principal 44:16
prior 75:10 83:9,
 11 97:4 99:9
priorities 14:9
 82:24 83:1, 15, 20
prioritization 70:18
 85:5
prioritize 65:22
priority 22:22
 27:11 57:18
 124:20
private 15:18, 20
 19:25
privilege 2:13
proactive 5:4
pro-active 99:11
probability 77:5, 7
probably 27:20
 28:11 39:15 43:19
 54:12 67:7 100:10,
 11 103:19 108:6
 125:3, 18
problem 8:3 34:11
 35:6 39:13, 13
 46:16 48:23 52:1
 53:8 60:22 65:24
 88:15 99:13, 14
 101:12 125:12, 15
problems 32:1
 41:9 44:24 45:20
 48:4 56:13 65:21
 66:6 118:17
 120:25
proceed 65:5
proceeding 17:8
 34:3 87:20
proceedings 129:9
proceeds 18:7
process 5:5 9:11
 19:3 22:14 24:22
 26:19 28:9 29:2
 34:7, 12, 23 39:16,
 22 53:2 76:24
 77:10 84:8 90:5
 95:5 107:3 110:3
 124:3
processes 36:16
produce 45:10, 18
productive 19:22
 32:14
products 51:20
professionally 59:5
program 15:13
programs 116:3, 6,
 8

progress 16:24
 17:16 19:7 32:18
 57:18 82:4 89:18
progressively 21:2
project 49:24, 24
 57:19 62:2
projects 45:9
 49:20 57:16
proliferation 58:14
promoted 90:6
pronouncements
 44:19
propagation 23:25
 44:6, 11 45:24
 46:5, 6, 11 47:17
 48:5 49:8, 8, 10
 51:13, 14, 16, 21
 52:1, 13, 16 53:22
 55:10 57:12, 12
 61:1 62:10, 20
 65:17 78:10, 11, 16
propagations 78:15
properties 89:12
proposals 18:20
 19:2 45:16
propose 83:13
 104:21
Proposed 33:7
proposition 32:21
pros 117:23
protecting 38:22
protection 38:8
 63:25 64:6, 16
protections 42:16
prototypes 31:12,
 13, 17 50:8
prove 22:17
provide 19:9 33:8,
 15 41:21, 24 51:20
 100:24
provided 23:20
 67:11 120:22
providers 28:24, 25
 53:20
provider's 125:6
provides 15:3
providing 38:23
 74:12
proximity 1:1
PSCR 62:3
public 15:20 17:7
 20:6, 7, 12 21:1
 31:10 62:14, 16, 18
 63:13 77:25
 109:13, 20 124:10,
 11 127:7, 9 129:6
publicly 46:17
 84:17

publish 79:20
pull 52:21
pure 52:15
purple 56:7
purpose 18:18, 19
pursues 76:4
pursuit 112:8
put 6:4 8:14
 13:23 15:8, 15
 21:16 24:2 27:19
 31:17 40:9 41:9
 47:22 53:8 54:7
 56:12 60:21 70:16
 89:3 96:20 98:7,
 19, 20, 21 99:15
 101:4 112:9 119:8
 128:10
putting 4:15 5:21
 56:20 58:10 60:16
 65:25 109:16

< Q >

Qualcomm 31:20
 112:11
qualified 65:24
quality 46:19
 49:14 62:1 99:23
quarterback 43:11
question 34:9, 12,
 17 37:6, 18 39:1, 7,
 8 41:18 42:14
 46:21 59:25 63:23
 64:20 65:7 71:25
 80:4 89:21 94:4,
 10 96:13, 23
 109:22 112:19
 115:16 118:21, 25
 119:1 121:3, 6, 9,
 20 126:25
questions 14:10
 23:23 25:1, 3 32:6
 33:6 34:3 37:4
 39:1 45:19 55:21
 58:7, 9 61:2
 67:21, 24 74:3
 77:23 79:7 82:13
 85:10 101:22
 110:16, 16, 17
 111:21 124:4
quick 39:7 40:19
 43:17 79:22 92:22
 123:10
quickly 3:25 18:16
 35:11 89:4 106:3
 108:1 110:1
 122:16
quiet 36:19, 20
 47:13

quite 28:1 37:8
 43:19 50:22 55:6
 91:24 93:3, 9, 12
 118:12 126:24

< R >

radar 5:23 30:12,
 13 55:19, 19 82:8
 119:8
radars 53:10, 10
radiation 58:13, 14
Radio 44:2, 5
 45:24 47:13, 14
 64:22 66:1 114:19
 120:21
raise 56:8 90:21
raised 88:7, 20, 21
 90:3
ramifications 100:5
randomly 53:20, 24
Rangam 74:8 75:7
range 31:8 69:19
 101:21
ranging 48:9
rapidly 57:3, 20
rare 38:18
rate 47:4
Rath 9:25, 25
 66:19 68:3, 8
 79:22 86:1, 11, 17
 92:25 93:17, 20
 94:11, 20, 25
raw 62:4
Raytheon 9:18
 80:17 121:17
reach 54:22
reached 107:1
reactive 99:10, 12
read 72:6, 13 79:4
readily 88:16
ready 2:2 32:13
 123:8
real 4:10 5:18
 38:4 39:21 60:13
 92:22 94:12, 13
 122:16
reality 15:10 87:24
realize 61:7 71:25
 108:5 113:14
reallocate 25:24
reallocation 36:25
really 5:18 8:16,
 18 15:8, 14 19:6,
 10 24:5, 11 27:8
 28:2 30:6, 19
 31:17 34:4 35:13
 37:25 43:20 45:17
 46:3 48:13 49:16
 56:11 60:14 64:22
 65:10 66:14 67:6,
 8, 21 69:10, 11
 70:24 73:17 75:23,
 25 76:3, 13 77:1,
 13, 22 78:1, 11
 79:19 82:15, 20
 84:9 85:12 90:5
 91:8 94:5 95:15
 96:12 99:5 102:18
 103:7, 17 105:4
 106:3 108:14
 110:20 112:3, 11
 120:9, 18 122:18
 124:21 126:25
realtime 71:11
real-time 9:10
real-world 31:24
reapply 35:21
Reaser 9:18, 18
 36:3, 3 63:22, 22
 80:13 121:16, 16
reason 38:1
reasons 93:2, 22
received 31:13
 74:16
receiver 36:18
 64:3 103:5, 8, 13,
 18, 24 104:2, 4
 125:15
receivers 106:6
recognize 6:19
 7:17
recognizing 19:20
recommendation
 68:20 70:23 71:7,
 24 73:10 77:3, 13
 78:7 83:7, 14 86:8
 89:6 90:8 95:9
recommendations
 6:6 9:4 22:8
 23:9 66:22 67:15
 70:13, 18, 19 72:25
 73:19, 20 74:20, 24
 75:8, 11, 23, 24
 77:2 81:5, 8, 24
 82:1, 15, 16, 20
 83:3, 6, 9, 25 84:2
 85:11, 13, 18 94:14
 97:15 98:5 103:2
 106:24 110:21
 122:9
recommended 86:4
recommending
 76:4 78:12
reconstituting
 18:17
reconvene 108:22
record 17:8 31:11
record-breaking 5:1

recording 1:1
 11:3 129:8
records 5:2
recovering 26:3
recurring 77:11
red 52:15
reduce 95:25
 122:22
reducing-the-friction
 96:17
redundancies 41:24
Reed 10:13, 13
 73:9 115:22, 22
refer 72:12
referred 31:8
referring 37:12
reflected 6:5, 8
reformed 21:2
refresh 17:8 31:11
regard 125:10
regardless 22:22
regards 4:18
regimes 109:12
regulation 84:9
regulator 115:10
regulatory 13:3
 14:2 23:5 28:19
 89:2 108:17
 109:12 115:7
reinvented 126:8
related 16:6, 20
 17:15 62:14 82:5
 83:8 101:14 102:5
 104:8 110:21, 22
 123:22 126:15
 129:10
relates 63:8 101:5
 113:3
relatively 74:7
release 46:20
released 21:13, 22
 45:8, 13
relevant 91:22
 95:2
relied 103:10
relocation 18:6, 25
 20:23
remain 23:2
remained 73:20
remarkable 5:15
remarkably 4:24
remarks 4:5 12:7,
 8
remember 57:8
 69:3 74:2 84:17
 91:17
Remind 78:18

reorganized 45:5, 23
report 9:3 21:12, 16, 20, 23 22:3, 8, 11 67:6 70:20 73:9, 18 74:15, 15, 17 79:16 80:14 83:22 96:9 97:4 98:8, 8 107:6, 13
Reporter 129:5
REPORTER'S 1:1 129:2
reports 6:8 8:17, 25 61:24 116:12, 17
representing 2:14
represents 50:15
reprioritize 83:24
repurpose 5:13 19:24
repurposed 20:21
repurposing 18:11
reqs 65:25
request 91:8
requests 90:11 95:23
require 91:10
required 61:20
requirements 50:9 62:6, 14 75:22
research 15:6, 9, 13, 21, 23, 25 16:8, 12 18:10 36:25 43:15 45:9 57:15 58:5 59:9 60:20 116:3, 5, 7
Resolution 115:18
resolve 41:10 88:6
resolved 88:11
resources 7:13 65:23 78:13 82:22, 22 83:19
respect 34:9 98:18 107:20
respond 54:4 65:4 83:25 85:13
responded 20:2
responds 48:13
response 10:21 30:16 81:8, 25 83:5 89:21
responsibilities 18:20
responsible 46:4
responsive 91:25
rest 68:5
restricted 4:16
result 4:12 46:18

129:13
resulted 20:17
results 56:4, 17, 23 70:13
review 18:21
reviewed 57:15, 17
reviewing 116:12
reviews 45:14
revise 75:1
revising 75:2
revisit 68:19 83:24 103:24 104:16
revisited 89:14
revoted 72:2
REYNOLDS 2:5, 21 3:2, 23 6:25 7:7, 23 10:6, 6
RF 46:8 62:20
RFP 45:8, 13
RICK 9:18, 18 36:2, 3, 3 63:20, 22, 22 69:20 70:15 80:12, 13 120:1 121:14, 16, 16 122:14 123:9
Rick's 37:6
right 2:1, 4 6:14 11:24 12:8 14:5 29:15 32:18 38:7, 8, 22 42:23 43:5 52:11 54:12 55:9, 17 56:18, 23 62:13 66:7, 8 68:23 71:10, 14 78:4, 5, 20 79:7, 12 80:7, 10, 21 82:21 92:4 95:6 98:10 99:2, 11 103:23 107:17, 25 108:12 113:1 118:13 121:25 126:2 127:6, 10
risk 67:2
risky 127:8
road 4:6 17:22
Rob 74:4
ROBERSON 9:20, 20, 21 24:9, 9 64:18, 19, 19 65:9 69:7 71:1, 23 101:3 102:8 111:25 119:11 121:10
ROBERT 9:16, 16 10:8, 8 13:12 74:5 80:18
robust 37:17 47:24 64:8 84:14, 25 89:16 90:14

role 34:16 41:6 111:11 115:24 116:11 119:13
roles 60:6 111:3
roll 9:14 11:7
room 3:10 14:16 26:11 28:10 116:16 124:11
rotate 47:23
rotator 4:14
round 24:25 43:2 45:14
Rubik's 26:23
Rulemaking 33:7
rules 5:3 36:8, 21 41:2 117:13
run 15:16 37:12 39:2 48:15 51:23 56:25 106:20
runaway 88:14
runner 106:22
running 45:4 50:13 51:9 53:22 59:17, 18 63:20 64:22
< S >
sabotage 124:25
safety 20:7 62:14, 16, 18 63:13 78:1
SAFS 96:9
Samsung 10:8 80:16
sanity 116:17
SAS 29:15 110:18
satellite 30:6
satellites 119:25 120:2, 18 121:8
Save 25:5 96:22
saying 6:18 79:9 93:1 95:13 97:5 105:19, 20 114:15 126:23
says 4:13 54:13
scale 16:13
scenarios 36:5 59:12 76:1
SCHAUBACH 10:14, 14 73:15, 23 74:1 110:20 111:10, 14, 17
schedule 17:9
Science 15:17 21:14 44:20, 23
Sciences 7:10 16:7
scientific 60:20
scientist 66:3
screens 5:23

se 40:25 65:11
seal 129:15
Second 11:13 22:5 49:7 79:8 80:13 87:17 104:7 106:19 116:2
Secondly 25:21
seconds 86:14
secretary 2:14 17:19
Section 44:2 49:23 66:10
sector 15:18 19:25 40:4 94:1
secure 124:23 126:1
security 20:7 87:21 115:25
see 3:12, 15 11:13 19:7 34:15 37:22 48:5 50:21, 24 54:1 56:8 62:11, 13 65:4 66:14 73:7 76:16 79:19 92:19 93:21 102:12 113:22 114:5, 16
seeing 38:11 45:25 101:14 114:13 121:13
seen 5:16 46:1 83:21 88:13
selected 51:1
send 28:21 86:5 126:14
sends 4:18, 18
senior 45:15
sense 40:12 42:1 54:17 97:18, 19 98:11, 18, 22 100:19, 20, 21 102:3 118:15, 23
sensing 28:25 35:13 50:4 68:25 97:11 98:18, 20 100:18 101:1, 11, 14, 17, 18, 22, 24 102:2 117:20
sensitivity 113:14
sensors 59:16, 20 100:14
sent 72:23 79:23 86:15, 17
separate 27:13 40:17
separately 95:21
September 129:16
sequencing 82:22

- series** 18:3 20:20
serious 114:1
serve 20:6 21:1
service 27:14
 28:24 38:19 41:22
 42:12, 13, 16 44:5
 117:23 120:20, 20,
 21, 21 125:6
services 5:14
 14:21 19:10, 18
 21:6 28:4 38:23
 42:20 94:1
session 9:7 23:10
 73:1, 3 76:19
 81:21, 22 84:16, 20
 85:15 123:8, 25
sessions 75:5
 122:17 123:5
set 5:2 14:10
 28:13, 13, 20 45:5
 48:20 56:15 59:16
 82:13 117:6, 13
 120:19
sets 18:1 27:6, 7
seven 15:25 42:17
 50:13
shape 83:2 85:6
share 30:8 36:10
 40:11, 13, 17 42:3,
 10 49:5, 6 51:15
 114:8
shared 32:9, 10
 40:1, 7 87:13
 88:17
sharing 5:4, 7, 8
 13:4 14:25 15:1, 2
 16:13 17:3, 12
 18:25 21:3, 13, 24
 22:6, 11, 17 25:19
 26:3 27:10 30:13,
 25 32:16 35:22
 36:5 37:2 38:12
 39:9 40:5, 7, 8
 41:5, 8 42:2
 48:21, 24 49:2
 50:23 51:3, 8, 11
 53:4 63:8, 10 64:9
 66:16 76:10, 17
 78:6, 7 79:17
 85:21 87:2, 4, 9, 15
 88:4, 9, 9, 19 89:11,
 16, 17, 22 90:15, 19
 91:9 93:2, 6, 12, 24
 94:11, 19 96:2, 15
 97:1, 21 99:18
 100:1 101:19
 102:20 103:8, 16
 104:8 108:2, 4, 24
 109:12, 21 110:8,
- 25 111:8 113:4, 11
 116:15 117:7, 19
 121:7 124:22, 24
 126:24
sharing-centric
 13:14
SHARKEY 9:19, 19
 61:5 68:16, 23
 102:16, 25
short 21:21 30:16
 31:8 64:22
shortage 92:13, 14,
 14, 15
Shorthand 129:5
short-term 97:2
shoulder 4:13
shoulders 19:11
show 28:22 48:6
 49:20
shown 50:20
 53:25 56:7, 23
shows 52:9, 11
 53:17 55:17
shudder 31:2 40:8
side 26:17, 22
 33:3 40:9, 10
 50:5, 6 77:14, 15,
 19 103:14, 25
 104:1 113:7, 15
 115:4, 6 125:2, 3, 5
sides 103:15
 109:13 125:1
sidestepping 96:13
sideways 50:24
sign 79:10
signal 50:20 55:20
 95:24 114:5, 13
signals 30:6 51:6
 113:18, 19, 22, 23,
 24 114:3 121:12
signature 129:15
signatures 114:2
signed 17:25 44:7
significant 18:14
 22:7 52:19 59:16
 62:18 64:25 69:16
 82:3 84:6 101:12
 120:9 126:13
significantly 18:4
 72:1 81:18
similar 34:8 107:8
 115:23
Similarly 21:19
simply 32:15
simulation 54:18,
 19 55:5 56:22
simulator 56:25
 57:1
- simultaneously**
 88:11
sincerely 23:19
single 41:20, 21, 21,
 21 42:7
sit 39:12
sits 31:5
sitting 29:25 55:19
situation 91:13
 127:9
six 23:22 42:17
 74:24 75:2 103:3
size 61:19 62:1
skeptical 4:14
skills 65:4
skip 48:19
slice 48:25
Slide 43:23 44:16
 45:22 47:8 48:22
 50:12 51:25 54:5,
 18 55:12 56:3
slightly 18:19 19:5
small 52:23 61:15
smart 116:16
 121:3
software 46:13, 15,
 19 50:5 57:13
 66:4
solicit 31:12
solution 35:16
 88:14
solutions 23:5
 35:8, 25
solve 28:10 44:24
solves 120:25
solving 47:7
somebody 92:13
 114:21
somewhat 84:17
 108:17
soon 60:19
Sorond 10:7, 7
 62:8 63:2, 7 74:23
 78:21 95:7 102:24
 103:1 104:6
 105:22 110:9
sorry 58:11 62:23
 63:2
sort 5:15 30:23
 36:5, 15 59:1
 63:24 75:10 76:5,
 9, 14, 25 77:8, 17
 78:6 86:7 87:17,
 22 88:14 90:18
 92:10 93:24 96:14
 105:7, 10 106:13
 111:3, 4, 18 114:11,
 17 116:11 122:18
sorting 69:21
- sorts** 5:2 88:9
 94:2
sound 48:12
 116:19
sound-proof 48:11
sounds 113:2
 122:13
sources 58:13, 24
southwest 52:9
Sox 4:11
space 29:14 51:5
spaces 108:25
 109:5, 8
spanned 4:24
spare 27:5
speak 82:25 91:21
 108:3
special 6:20 69:12
specific 39:25
 110:21
specifically 9:3
 44:18 76:1 87:23
 88:19 89:5 104:20
 105:24 107:20
 118:13
specifications
 103:10
spectral 53:7
SPECTRUM 1:1
 5:9, 13, 19, 22, 22
 6:11, 12 12:9, 14,
 24 13:12, 19 14:18,
 19, 22, 25 15:1
 16:13, 21 17:24
 18:5, 6, 8, 10, 11, 12
 19:7, 9, 11, 12, 17,
 21, 24 20:4, 4, 10,
 14, 15, 23, 24 21:9,
 13, 25 22:6, 10, 23
 23:6 25:19 26:1,
 3, 3 27:1, 2, 15, 19,
 21 28:1, 3, 18, 24
 29:7, 13, 17, 24
 30:10, 14, 25 31:6
 32:21, 23 33:4, 19
 36:25 40:1 42:18
 43:16 45:2, 7, 11,
 21 48:2, 19, 21, 24
 49:2, 3, 4, 25 50:12
 51:11 53:4 57:11
 59:13 61:22 63:1
 65:16 69:18, 23
 73:7 80:20 83:16
 84:6 85:22 87:6,
 15, 19, 20, 23 89:1,
 24, 25 97:21 99:6,
 17 101:18 104:15,
 25 105:1, 5 109:14
 110:25 116:15

119:1 121:7
 124:21, 23 126:18, 20
speed 81:18
spend 69:6
spending 56:16
 92:20
sponsor 16:8
sponsored 13:9
spot 27:13, 14
 42:11 56:13 60:17
spots 52:18
springs 108:25
spurious 51:6
SRF 18:24 21:2
ss 129:2
staff 7:3 45:15
 121:22 122:4, 8
stage 99:12
stakeholders 28:8, 14
stand 79:8
standard 30:1
 44:11 64:12
 119:19
STANDARDS 1:1
 44:2 50:10 62:11, 13, 18, 20, 21 63:1, 17 64:1, 3 77:16
 103:13, 18
standing 62:23
standpoint 82:7
 83:16 84:7
stands 19:10
start 2:5 9:13, 14
 32:20 43:16 45:14
 55:10 59:18 61:1
 66:16 85:18 100:2
 106:25 114:21
 120:19
started 3:5 42:7
 43:8, 9 44:1 46:13
 82:18 83:5 105:19
starting 4:25 22:4
 36:7 67:3 97:22
state 45:17 46:9
 57:20 124:16
 129:1, 6
stated 92:8
statement 91:13
statements 1:1
States 27:24 47:13
station 54:2, 21, 22, 23 114:19 125:20
stations 50:12, 13
 53:19
statistical 38:12
 41:17
statistics 59:17

statute 18:22
 47:18
stay 44:19 64:13
 80:11
staying 1:1
steered 120:12
Steering 20:19
step 4:12 14:17
 18:14 41:18 54:24
 67:18
steps 15:12 23:11
 76:14 90:5
STEVE 9:19, 19
 61:4, 5 67:7
 68:15, 16, 23 69:3
 102:13, 16, 25
 103:1
stick 6:25 37:21
stopped 42:9
stopping 125:22
storyline 17:15
strategic 16:20
 20:3 45:6 83:15
 88:15
strategies 91:22
 121:24 122:5, 10
STREET 1:1 129:21
strength 50:19
stress 98:13
Strickling 17:19
 128:6
Strickling's 8:12
strides 22:7
strikes 93:13
strong 106:4
strongly 102:9
 108:12
structures 51:19
 101:9
struggle 38:21
struggled 37:14
student 16:8
studied 34:13
studies 41:16 45:2
 55:18
study 51:25 65:3
 72:13 82:10 107:8
 116:11
studying 101:7
 107:14
stuff 43:20 76:3
 91:2 109:1
subcommittee
 35:12, 19 66:25
 67:4, 25 68:6
 81:4, 23 91:3
 97:11, 18 98:4, 7
 128:14, 15

subcommittees
 8:15 66:12 82:24
 83:3 85:7, 19
 92:24 97:10
 112:18, 25
subcommittee's
 98:6
subject 18:21
 56:24
subjects 62:16
submit 31:19
submitting 31:20
subsequently
 126:16
subset 102:20
substance 60:14
subsumed 102:18
success 23:1
 109:21 112:2
successful 50:3
succinctly 93:21
suddenly 43:8
sufficient 21:9
suggest 91:15
 104:14, 15 115:2
 127:4
suggesting 96:24
 122:14
suggestion 90:19
 97:10 102:12
 116:2
suggestions 74:17
 86:13 91:4 97:15
 102:22 115:23
 116:18
suitable 103:19
Suite 129:21
suited 117:6
summaries 49:24
summarized 114:24
supplies 113:24
support 15:21
 16:12, 21 57:24
 62:19 75:6 88:10
 95:19
supported 14:23
 15:23 36:24
supporting 20:11
supports 102:9
suppose 116:10
supposed 11:2
 111:4
sure 7:19 15:4
 31:18 37:8 41:7
 60:4 74:5 75:2
 86:5, 8, 24 87:1
 88:22 92:21 93:3,
 12 94:21 107:2

108:14 109:11
 117:13 118:5
surgery 4:13
surprises 37:12
surrounding 59:1
suspect 109:9
sustainable 18:15
swirl 118:24
switching 113:24
synergy 102:6
system 7:25 28:25
 33:24 42:7, 8
 47:1, 3 49:11, 15,
 17 70:1, 6, 6, 9
 73:7 119:19
 124:22, 23, 25
 125:6, 7, 12, 17, 25
systems 22:10
 28:19 29:4 30:5,
 6, 12, 13, 15, 15
 31:7 32:23, 25
 36:9, 12 37:1, 7, 16
 38:12 39:24 40:7,
 17 41:20, 20, 23
 42:3, 4, 4, 9 46:23,
 25, 25, 25 47:19
 48:2 51:15 53:10
 54:7 55:14, 15
 57:13 61:12, 13
 63:25 64:2, 7, 8
 70:5 98:12, 18, 19,
 20 99:20 100:2, 9
 110:25 111:18
 112:14 119:4
 120:7, 15, 15
 125:11 126:19, 21

< T >
table 6:23 7:6
 41:4 47:11
TAC 38:10 58:10,
 20, 23 84:22
 103:12 106:11
 118:18, 19 123:12
tack 121:18
take 6:3, 12, 13
 19:5 23:23 26:13
 29:2 33:5 34:5
 37:1 42:13, 15, 21
 43:12 45:7 67:19,
 21 74:21 76:13, 20
 79:3 81:7 94:14
 99:9 100:6 105:9,
 13 114:20 120:8
 121:21 125:20
takes 22:22 56:1,
 24 76:14 78:14
talk 15:4 16:19
 17:18 24:10 31:2

- 41:17 43:14 48:23
49:24 67:13 70:12
81:19 86:7 88:8
92:1 94:12
talked 27:3 40:8
48:19 63:24 64:24,
24 65:15, 18 67:14
69:22 71:15 74:15
81:21 82:19 84:21
86:2 91:19 99:15,
17 118:11 123:25
126:18
talking 6:9 29:21
36:17 62:24 63:3
65:6 72:21 77:5
87:23 88:24 89:18
92:11 94:8 95:23
97:3 100:13
118:17
talks 76:12
target 107:1 117:8
targeting 57:23
targets 18:1 55:22,
23
taxonomy 82:25
85:4
Taylor 64:21
team 69:8, 11, 21
teams 119:13
Tech 10:13
technical 18:17, 18,
21 34:10, 11, 18
35:1, 16 36:8 57:9
60:7, 9 61:24
69:25 92:9, 10
100:5 111:15
technically 17:12
techniques 22:17
35:21 71:8 101:11
121:2
technologies 5:8
15:1, 22 16:2, 22
22:18 31:13, 14
41:23 88:10 90:4
93:4, 5 94:3, 18
99:20 103:20, 20
105:7 110:25
111:8 121:3
TECHNOLOGY 1:1
5:21 9:21 10:17
13:3 14:2 15:9, 18
21:14, 18 22:14, 16
23:5 28:14 33:25
38:2 40:2 42:16
44:23 45:23 49:1
50:2, 8 63:10 76:2
77:14 78:6 84:7, 8
87:14, 25 90:18
93:25 94:9 98:23
99:18 104:10, 11
115:4 116:4 121:9
tee 25:1
Telecommunication
7:10 16:7
telecommunications
16:22 44:17
TELEPHONE 2:17,
19, 23, 25 3:4, 6, 7,
11, 13, 18 7:21 8:2
11:9, 12 13:1
telephonically 8:4
telescope 47:15
tell 34:24 119:12
120:1
templates 89:17
temporary 96:4, 15
tend 122:23
tent 110:13 123:9
tents 92:19, 22
121:13
term 13:25 14:7,
11 26:20 33:21
37:1 81:20 83:2
124:7 127:16
Terminal 82:7
terms 21:23 23:11
25:17 27:22 36:17
54:4 64:5 84:15
122:1
terrain 51:18, 23
52:17 53:21
terrific 24:12
28:16 92:18
terror 88:1
test 98:24 109:20
119:2
testbed 16:9, 12
59:14
testing 15:20
31:19, 22, 24 89:15
90:17 98:14
tests 31:23
text 74:12
thank 8:13 12:10
23:22 24:1, 4, 7
41:11 42:23, 24
43:13 59:22 62:8,
17 66:9, 25 67:25
71:11 73:12 74:8,
11, 23 78:17 79:12,
19 81:3, 8 82:23
90:25 115:20
126:2, 4 127:4, 6,
22 128:1, 8, 9, 15
Thanks 11:13, 15
24:8 25:13 32:4,
5, 20 35:10 39:5
43:2, 4 58:8 67:23
68:3 69:6 73:3, 6,
16 74:6 78:18
80:10 90:22, 23
103:1 106:1 108:9
112:17 116:19
118:6 122:14
123:7, 24 124:8
the-air 48:16
theirs 31:20
theme 13:14
29:16 77:11
theory 45:24 46:4
57:12
thin 110:3
thing 7:22 8:5
38:17 44:22 47:4
56:18 57:21 66:24
67:14 68:11 70:9
72:17, 22 79:1, 1
92:25 95:14 101:6
106:4 114:10, 12
things 5:3 9:2
14:13 21:17 23:3,
3 25:18 26:6, 7
27:9, 17 28:11, 19,
20 29:10, 10 35:5
36:23 38:14 45:2
52:12 57:22, 24
58:2 59:5 61:9
63:11, 16 64:9, 23
65:15, 18 66:24
70:15, 21 75:16
76:2 78:16 82:6,
11 84:25 85:23
91:25 100:20
104:11 106:6
109:9 113:4, 7
119:23 120:17
121:19 122:7, 17
125:1
think 2:1, 6 3:1
4:15 8:6, 11, 17
11:7, 25 12:4, 6, 7
23:3 24:2 26:10,
20 27:8, 16, 20
28:2, 11 29:6, 10,
18 32:2, 16, 24
33:2 35:6, 18, 19
36:15, 16, 22, 24
37:9, 11, 13, 15, 24
38:2, 5, 20 39:20,
23 40:2, 7, 9, 12, 14
41:1, 6, 15 42:6, 14
43:10 54:24 57:4
58:1 62:21 63:12,
19 64:4 65:21
68:16, 18, 20, 21
70:5, 15, 20, 22
71:2, 20 72:7
73:17 74:7, 16, 18,
24 76:7 78:8
80:22, 24 81:9
82:12 84:15, 20
87:5 88:5, 8, 12, 21
89:9, 17 91:12, 15
92:1, 3, 8, 12, 18
93:10 94:17 95:1,
3, 15 96:12, 16, 24
97:3, 16 98:2
100:3 101:4, 24
102:13, 17, 18
103:1, 7, 8, 11, 12,
17, 19 104:9, 15
105:2, 3 106:7, 9,
14 107:11 108:17
109:5, 20, 23, 24, 25
110:10 111:5, 14
112:5, 15, 18, 25
113:5, 21 114:23,
23 115:19 116:21
117:10, 17, 23
118:3, 6, 9, 9, 16, 19
119:1 121:19
122:6 123:7, 13
124:5, 9, 19 125:9
126:16, 17 127:10
128:1, 16
thinking 25:21
36:15 93:5 94:23
99:8 118:10
third 116:9, 9
thirdly 26:5
thought 9:13 36:4,
11 54:11, 17 64:1,
10 80:4, 14 85:17,
19 93:1 95:22
113:25 116:20
126:16
thoughtful 20:2
thoughts 37:22
41:25 57:8 67:12
84:15 126:6 127:3
three 4:17 25:17
27:3 31:21 45:13
48:25, 25 49:19
52:11 74:25, 25
75:10, 24 77:1
78:21 86:20 88:24
97:15 115:22
threshold 106:4, 7,
9
throw 93:9 97:8
101:13 116:22
throwing 105:14
121:19
thrown 115:15
thrusts 16:20 45:6,

10, 24
thumb 117:13
Thursday 43:9, 10
tie 95:4
tiered 5:7
tight 92:17
tighten 81:4
time 7:18, 24 8:19
 9:2 18:4 19:23
 20:20 23:15, 17
 25:15, 20, 25 29:2
 30:9 36:9, 12, 17
 39:3 56:24 57:7
 61:6 63:20 67:22
 68:13 69:6 77:20
 78:14, 19 81:19
 82:16 83:17, 23
 85:14 86:25 89:10
 91:24 92:15 99:8
 104:18 108:22, 23
 117:16 118:4
 119:17 120:4, 11
 122:21 124:9
time-consuming
 55:25
timelime 60:21
timeline 34:25
timelines 13:23
timely 12:18 88:23
times 13:18 24:13
 30:16, 22 75:12
 87:15 88:13 90:1
 102:18 108:16
time's 11:13
timing 60:11 82:14
tip 30:18
T-Mobile 9:19
 80:17
today 2:15 6:9, 20
 8:21 9:13 13:20
 14:8 16:19 23:9
 26:1 76:8 77:6
 78:14 83:4 84:12
 105:7, 15 126:19
Today's 86:21
to-do 39:19
Tom 64:21
tomorrow 4:5
Tom's 64:21
tool 45:18 118:3
 120:19
tools 45:11 58:3,
 5 64:14
top 34:23 50:17,
 21, 22 52:5, 9
topic 12:13 87:3
 89:13 91:25 93:11
 101:13 105:24

110:22 119:7, 16
 120:8, 9, 14 123:11
topics 9:7, 9, 11
 62:15 84:12, 21, 23,
 24 85:1 87:10
 90:20 91:23 92:21
 95:2, 3 101:22
 121:6 123:17
toss 85:1
totally 121:18
touch 14:15 125:24
touched 103:5
tough 14:4 30:4
 69:4
tower 54:8, 9
towers 53:22, 23
 55:7
track 74:10
tracked 57:2
tracks 92:17
trade-off 38:18
traditional 9:14
traditionally 40:21
traffic 53:10
train 78:15
training 43:9, 10
Tramont 10:1, 1
 39:5, 5 40:19
 41:11 72:15, 20
 108:11 110:8, 10
transcript 1:1, 1
transcription 129:8
transformative 4:24
transition 5:16
 20:24
transitional 6:1
translate 16:3
transmission 52:14,
 16 53:16 54:4, 9
 61:14 99:23
transmit 53:15
transmitter 52:7
 100:14 103:9, 10
 125:14
transmitters 53:7
 55:1, 9 99:21
 100:17, 19 122:25
transmitting 55:4
transportation
 31:7, 23 70:1
travel 4:16
treasury 5:3 20:11
treating 25:11
tremendous 5:20
 7:12 8:14 128:14
trends 84:3
trials 56:24, 25
 57:3 90:16

tried 33:5
tries 43:15
trifecta 22:4
trigger 114:16
triple 62:21, 25
 126:13
true 86:11 94:25
truly 5:6, 8 67:19
try 3:24 4:11
 7:19 8:7 28:15
 45:16 55:8 91:2
 98:19
trying 4:9 6:16
 26:1, 22 27:25
 29:3, 11, 12, 17
 30:7, 18, 23, 24
 32:3 34:25 35:7
 37:3, 17 38:3
 42:14 60:25 65:10
 70:9 91:1 95:8
 98:22 99:1, 10
 109:2, 24 118:19,
 20 120:21 126:20
turn 2:3 14:12
 19:6 30:9 50:23
 54:18 56:3 66:9
 74:21 86:23 123:1
turned 54:16
 80:22 122:25
turning 59:6
turns 54:13
turntable 47:22
tutorial 23:25
 70:16, 17
tweaked 68:20
 73:18, 21
tweaks 73:10
two 6:7, 20 12:1
 14:14 20:17 21:7
 29:22, 24 38:4
 39:1 47:13 53:23
 56:1, 6, 16 70:14
 79:25 87:1 89:8
 96:25 98:5 114:7
 121:13 124:15
 126:5 127:3
two-minute 3:19
 12:1, 21
twosy 90:16
two-way 87:2
type 58:15 125:12
types 32:10 59:19
 64:9 114:2 117:24
 125:11
typically 55:18

< U >
U.S 5:20 15:12
 20:2, 11 44:17

50:14 112:11
 119:23
UAS 118:11, 14, 14,
 15, 16, 23
UAS's 98:21 119:3
UAV 98:12
Uh 3:11
ultimately 83:17
um 68:25
unable 65:20
unaware 47:10
uncertain 24:13
unchanged 73:20
uncharted 9:5
undergraduate 16:8
underscored 5:18
understand 35:1
 49:4, 7, 10, 17 50:8
 51:8, 14 52:23
 53:12 55:14 82:17
 94:24 100:4 118:5
 123:16
understanding
 44:8 45:11 46:5
 75:7
understood 35:7
 72:20 90:6 91:8
underway 49:18
unfortunately 4:16
 84:12
UNIDENTIFIED 2:1,
 17, 19, 23, 25 3:4, 6,
 7, 11, 15, 18, 22
 6:23 7:5, 21 8:2
 10:22 11:9, 12
 25:10 35:10 58:17
 63:6 68:9 69:1, 4
 71:15 72:9, 18
 79:5, 14 80:19
 86:15, 18, 20
 102:15 106:12, 15
 110:6 111:16, 23
 112:23 119:9
 123:19
U-NII 69:24
unintentional 58:13
unique 15:3 47:9,
 10 75:11, 15, 18
 76:2
United 27:24 47:13
University 10:9
 16:10, 11, 15
unlicensed 17:4
 29:22, 22 31:6
unpunished 6:18
unusual 86:23
 121:7
update 12:9 66:18,

19
updated 57:16
upgrade 52:25
upgrades 77:13
upgrading 44:13
 49:9
urban 52:22
urge 106:8
use 1:1 5:21
 7:24 11:19 18:6,
 11 20:25 27:15
 29:8, 13, 17 30:10
 32:12 33:4 37:24
 38:1 39:14 46:5,
 16, 17 47:22 52:25
 57:4 58:6 61:17
 80:23, 25 81:14
 87:13 93:24 94:2,
 18, 20 102:9
 109:14 115:12
 119:24 122:10
useful 79:17 96:2
 104:24 118:4, 21
 123:5
user 39:14 41:21
 47:6 48:10, 13
 53:9 54:10 61:7,
 17, 18, 25 62:6
users 32:10, 17
 39:10 40:14, 20
 51:21 54:20 89:25
 91:10 95:25
 105:11 107:21
 117:24, 25 119:5
uses 33:17 51:8
 69:18, 22 107:23
 117:12
usual 35:2, 5
utilized 101:11
utilizing 49:10

< V >

vague 5:18
valid 56:17
validate 44:14
valuable 7:24
 69:11
various 48:3 49:9
 59:19 88:20
vehicle 52:10
 91:18
vehicles 48:1, 6
Verizon 9:25
vernacular 21:19
versa 90:1
version 8:11 67:18
versus 111:18
vertical 50:18

vetted 71:3, 4, 5
vetting 24:22
viable 35:8
vice 90:1
video 3:19 61:10,
 16 62:4, 4
view 32:24 52:5
 87:13
views 81:23
Virginia 10:13
 47:15
visual 61:7
vital 17:14
volume 91:10
 95:23
volunteer 23:17
voted 9:1 74:25

< W >

wait 11:2
waiting 86:14
walk 8:25 49:19
 66:10 86:12 92:24
walking 97:12
want 9:2 11:6
 34:5 35:22 40:20
 41:15 43:14 48:22
 67:21 71:6 72:13
 73:1, 12 78:15
 80:25 81:14 82:5,
 23 85:1 88:19
 91:14, 25 92:1, 20,
 21 95:4 96:23
 97:23 99:9 103:18
 107:6, 7 109:11
 114:5, 20 115:11
 117:25 118:8
 119:8 120:13, 23
 123:13
wanted 6:19 7:11
 34:20 37:22 57:6
 58:7 66:18, 25
 74:19 79:15 80:13
 81:3 85:19 86:6
 90:20 92:23, 23, 25
 95:18 97:17 103:4
 110:17 115:6
 121:17
wants 4:9 86:6
War 44:5
warfare 125:4
Warren 10:11, 11
 37:5, 5 59:24, 24
 60:5, 18 96:21, 21
 97:7 111:13 115:1,
 1
Washington 11:25
watching 5:17
water 9:5

wave 5:21 14:22
 56:10, 12 105:3, 4,
 5
waved 68:12
waveform 48:9
 75:22 78:4
waveforms 113:8,
 9, 13, 14, 16 114:10
way 19:20, 21
 29:4, 8, 10 33:6
 37:12 38:11 41:8
 42:15 45:4 48:23
 49:21 53:15 55:17
 56:2 72:12 89:24
 109:14 110:14
 111:1 112:13
 113:12 122:25
 125:18
ways 26:2, 3
 27:14 29:17 32:3
 36:16 37:10 62:4
 116:10 121:7, 12,
 21, 23 122:12
 124:24 125:5, 18
weak 30:6
weapon 88:1, 1, 2
weather 53:10
 82:8
weave 36:20
webcast 84:18
website 51:21
weeds 75:16
week 4:13 13:7, 8
 30:22 45:15 50:13,
 18
weeks 4:17 45:14
 66:21
Welcome 2:2, 4
 7:11 12:11
welcoming 2:6
 4:19
well 4:4 8:19
 10:22 12:11 15:10
 20:18 24:10, 17
 26:17 30:7 33:24
 35:6 37:3, 15
 38:10, 15, 15 40:10
 45:25 46:11 47:25
 51:24 52:2, 4
 54:11 56:11 57:25
 60:1 62:5, 20 63:7
 65:3 70:6 71:10
 72:9 75:10 79:4
 80:7 81:6, 12
 83:20 84:10 86:11
 89:2 90:15, 16
 94:23 98:2 100:18
 101:5 103:12
 108:6 116:6, 20

117:14 123:18
 126:9, 14
went 28:4 44:2
 111:21
we're 3:24 4:14,
 21 5:11 6:1, 8
 8:6, 9, 22, 25 9:4, 6
 11:7 12:5 16:25
 19:3 21:7 24:25
 26:1, 12 29:1, 6, 7
 30:12 31:3 35:15
 41:18, 19 42:14, 18,
 22 43:21 44:23
 45:4 46:15, 16
 49:20 51:9 55:7,
 8, 12 57:4, 23 58:4,
 12 59:10, 13, 14
 62:21 63:19 64:22
 65:17 66:6, 11
 71:20 78:1, 25
 80:18, 24 81:9, 17
 82:10, 17 85:9, 12
 94:21 99:11 100:8
 109:11 112:24
 114:4, 6 117:3
 118:17 119:21, 21,
 22 120:5 121:19
 123:7 128:4, 16
West 47:15 50:16
we've 5:16 8:21
 12:7 13:21, 23
 18:16 19:7 20:20
 21:21 25:8 26:18,
 21 28:23 29:21
 30:17 31:25, 25
 35:16 36:17 37:11,
 14 38:13 39:1, 10
 41:9 42:6 47:9,
 21, 25 48:8, 17, 19
 52:21 53:12 54:20
 55:14 56:20 57:1,
 9 60:21 62:2 65:6,
 25 72:11 75:20
 77:4 82:19 83:5,
 21 84:21 85:10, 14
 88:2 99:17 101:8,
 11 102:17 103:2
 106:25 109:7
 111:20 112:10, 18,
 25 117:13, 19
 118:7 119:11, 18
Wheeler 90:3
whereof 129:14
White 4:11 6:15
 15:7 108:25 109:5,
 8
widely 9:8 109:8
width 61:9
Wi-Fi 119:22

Wilkinson 10:1
 39:6
willing 40:10
WInnForum 28:9
 68:12 85:1
win-win 5:13
 33:22
wireless 5:17, 22
 7:25 10:15 14:19
 15:6, 13, 22 16:2,
 13 18:2 19:10, 18
 20:1 21:17 88:25
 111:24 116:4
 126:8
wisdom 23:20
 128:5
witness 129:14
witnessing 5:11
wizard 64:20 72:4
 110:23
wonder 28:20
 64:9 121:20
wondering 34:15
 36:4 58:25 62:12
 63:13 93:3, 8 94:7
 108:22
word 115:12
words 40:9 108:4
 114:13
wordsmiths 95:16
work 4:20 6:4, 5,
 7, 10, 14 7:13 8:7,
 14, 16, 18 13:25
 17:10 22:13, 23
 24:5 26:18 27:9,
 22 28:11, 16 29:4,
 5 30:2, 20 31:1
 32:3, 18 34:10
 35:16 36:11 37:15
 38:11 40:15 41:8
 48:18, 23 52:3
 55:8 57:25 58:20
 60:7 61:11 62:9,
 11, 19 63:4 64:25
 66:5, 17 67:1
 68:1, 2 69:10
 73:13 77:23 78:14,
 16 80:15 84:10, 10
 85:20 93:14 97:11
 101:25 102:4, 13,
 18 103:3, 12
 104:14, 18 106:10,
 10 108:21 109:3
 110:19 115:4
 122:7 128:7, 11, 14
workable 96:15
worked 8:19
 22:25 25:24 50:4,
 6

working 6:6 8:7
 11:8 19:1 26:14
 29:2 30:17 31:16,
 18 34:6, 12, 17, 21
 36:15 42:9, 25
 46:9 50:7 51:24
 52:24 58:2 59:14
 60:22 63:11 74:6
 92:16 108:20
 110:2 117:4
 125:21 127:17, 18,
 21
works 43:15 49:22
workshop 67:16,
 19 86:3 88:22
 89:3, 7 110:23
world 28:2 41:19
 44:5 64:4 65:17
 98:11 112:15
 121:1
worry 70:21 73:4
worst 38:14, 16
worst-case 77:6
worth 108:7 116:5
worthwhile 107:25
Wow 60:16
wrap 123:8
wrapped 73:9
wrapping 23:8
 127:11
write 71:16
written 99:3
wrong 56:12
 104:16

< Y >

Yeah 3:23 12:3
 32:7 58:8 60:17
 68:8, 10, 22 71:20
 72:8, 23 73:3, 9, 15,
 17 79:6, 12, 22
 81:10 85:24 86:1,
 17, 18 91:12 92:25
 93:17, 21 94:25
 95:15, 18 97:7
 102:16 105:23
 107:18 111:10
 112:24 118:16, 19
 120:23 122:16
year 5:11 7:9
 17:20, 23 24:15
 38:4 45:5, 23
 46:14 50:14 57:17
 60:23, 24 61:2, 24,
 25 66:1
years 15:25 19:6
 21:15, 21, 22 36:13
 43:2 44:1 58:1, 3
 83:22 88:24

100:12 109:6
 126:8, 11
year's 12:14
yeoman's 13:25
yesterday 86:19
yield 101:18

< Z >

zones 47:13