# ISART 2020:
# 5G SPECTRUM AND A ZERO-TRUST NETWORK

**ISART**

International Symposium on
Advanced Radio Technologies

**2020**

"There is no such thing as a secure system —
we can work to make things more secure,
be more mindful of vulnerabilities,
but ultimately, we must effectively use
networks in which we have 'zero trust.'"
Dr. Lisa Porter at Silicon Flatirons
"Saving Our Spectrum" Conference, October 10, 2019

## OVERVIEW

Future wireless systems (5G and beyond) will offer major economic benefit to countries and companies that can deploy those networks and services reliably, quickly, and securely. Spectrum—the foundation for much of 5G—presents unique security challenges, in addition to a multitude of technical, economic, regulatory, and political challenges. While spectrum security historically focused on jamming, spoofing, and interference, the time has come for governments, industry, and academia to re-examine what spectrum security means.

The 2020 International Symposium on Advanced Radio Technology (ISART) will focus on what a "zero-trust" network environment means from a 5G spectrum perspective. ISART 2020 will identify challenges for spectrum to be available, reliable, assured, and secure in a no-trust environment; explore potential technical solutions; and identify research areas that facilitate securing spectrum for rapid adoption of assured 5G networks. The symposium format will include panel discussions, presentations, tutorials, and demonstrations. ISART 2020 will feature speakers from the U.S. government, including DoD; international guests involved in 5G developments in their countries; academics; and industry participants including equipment manufacturers and service providers, providing a broad range of perspectives on 5G spectrum security, standards, and deployments.

The virtual agenda is designed to ensure that there is plenty of opportunity for the discussion and networking that has always been a hallmark of ISART, as well as the in-depth exploration of new and emerging technologies, the technical challenges they present, and the potential solutions that represent the future of radio technology.

## BACKGROUND

The International Symposium on Advanced Radio Technologies (ISART) is a U.S. government-sponsored conference that brings together government, academia, and industry leaders for the purpose of collaborating on groundbreaking developments and applications of advanced radio technologies.

ISART 2020 is co-hosted this year by the National Telecommunications and Information Administration's (NTIA) Institute for Telecommunications Sciences (ITS), the National Institute of Standards (NIST) and the University of Colorado Boulder (CU).

NTIA is the Executive Branch agency principally responsible for advising the President on telecommunications and information policies. In this role, NTIA frequently works with other Executive Branch agencies to develop and present the Administration's position on these issues. NTIA's programs and policymaking focus largely on expanding broadband Internet access and adoption in America, expanding shared use of spectrum by all users, and ensuring that the Internet remains an engine for continued innovation and economic growth. In addition to representing the Executive Branch in both domestic and international telecommunications and information policy activities, NTIA also manages the Federal use of spectrum. NTIA's Institute for
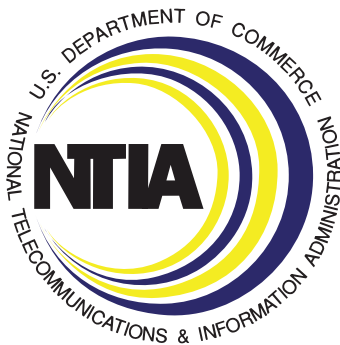
**ITS** Institute for Telecommunication Sciences

Boulder, Colorado

Telecommunication Sciences (ITS) is chartered as the nation's principal resource for the conduct of research and analysis of electromagnetic propagation, radio systems characteristics, and operating techniques affecting spectrum utilization. ITS conducts research and analysis in radio science and telecommunication to inform policy, advance spectrum sharing, and solve the telecommunication challenges of other Federal agencies, state and local Governments, industry, and international organizations.

NIST's mission is to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life. NIST has led in developing innovative, ground-breaking solutions for communication technologies since the early 1900s, creating the first-ever radio receiver that could run on alternating current electricity, and pioneering military applications such as radio triangulation used to find ships and coordinate counter battery fire during World War I. The NIST research portfolio in communication technologies in conjunction with standards and measurement science contributes directly to U.S. competitiveness and leadership in this technology sector, including enabling the infrastructure for 5G-and-beyond communications. In 2014, NIST formed the Communications Technology Laboratory (CTL) to unite its communications portfolio under one organizational structure. CTL priorities support the development and deployment of advanced communications technologies through the conduct of leading edge R&D, engineering, and standardization efforts in key technology areas including: public safety and first responder communications, wireless communications theory, channel and propagation modeling, interference analysis and characterization, modulation and coding, transmitter and receiver characterization, standards, antenna characterization, and spectrum access technologies.

# University of Colorado **Boulder**

As one of only 36 U.S. public research institutions in the Association of American Universities (AAU), the University of Colorado Boulder is all about realizing the positive impacts of new knowledge. From offering dozens of exciting programs in a range of academic fields, to serving as one of the world's most dynamic research and innovation hubs, to working closely through hundreds of public outreach efforts with communities across Colorado and the world, we take pride in helping our students, faculty, staff and partners turn new ideas into productive outcomes that change lives. The University of Colorado Boulder also hosts Silicon Flatirons, a center for innovation to serve students, entrepreneurs, policymakers, and professionals at the intersection of law, policy, and technology. We create productive collisions and spark tomorrow's thinking with intellectually honest programming and community engagement. Through papers, conferences, roundtables, and a series of other events, all of which provide valuable opportunities for students, we propel the future of technology policy, drive innovation, and develop the professionals ready to lead what's next.

## AGENDA

## Monday, August 10

### Morning Session: 9:00 AM - 11:30 AM

**Tutorials: Setting a Baseline** Tutorials on the current state of 5G are intended to set a common baseline for the discussions to follow. Live Q&A will follow.

• **Rebecca Dorch,** NTIA/ITS, Moderator

• **Jeffrey H. Reed and Nishith Tripathi,** Wireless @ Virginia Tech — 5G fundamentals and engineering considerations for use and deployment of 5G

• **Jeffrey Cichonski,** NIST — 5G standardization process and status, 5G Security enhancements within the 3GPP standards, and supporting infrastructure security considerations.

• **Monisha Ghosh,** FCC — 5G spectrum

• **Mohamed El-Moghazi,** NTRA — 5G spectrum allocations at the international, regional, and national level, particularly notable differences from the US allocations; ITU views on 5G

## AGENDA

## Monday, August 10

### *Afternoon Session: 1:00 PM - 3:00 PM*

**Welcome and Opening Remarks**

• **Sheryl Genco,** Director of NTIA/ITS

**Setting the Stage** Opening discussion among key leaders from the co-hosts—NTIA, NIST, and the University of Colorado—to set the stage for the panels and discussions that follow.

• **Doug Kinkoph,** Associate Administrator, Office of Telecommunications and Information Applications, performing the non-exclusive functions and duties of the Assistant Secretary of Commerce for Communications and Information, NTIA

• **Walt Copan,** Under Secretary of Commerce for Standards and Technology and Director, NIST

• **Terri Fiez,** Vice Chancellor for Research & Innovation, University of Colorado Boulder

**Keynote Address**

• **Joseph B. Evans,** Technical Director for 5G, Office of the Secretary of Defense

**Breakout Rooms**

*Attendees can join smaller groups in breakout rooms for further discussion.*

## AGENDA

## Tuesday, August 11

### Morning Session: 9:00 AM - 11:00 AM

### Opening Remarks, Logistics for the Day

- **ISART Co-chair Melissa Midzor,** NIST

### Opening Panel — Framing Zero-Trust Today

This panel dives deep into what zero-trust means within the spectrum world and the known risks that exist today at the intersection of 5G NR (New Radio) and zero-trust networks. Recognizing and naming the risks and vulnerabilities extant in the radio layer is crucial to identifying areas for research and developing solutions to better secure the spectrum relied upon for 5G services. Attendees can submit questions for panelists during the session.

- **Bryan Tramont,** Wilkinson Barker Knauer LLP, Moderator

- **Anna Gomez,** Wiley Rein LLP

- **Lisa Porter,** former Deputy Under Secretary of Defense for Research and Engineering

- **Charla Rath,** Commerce Spectrum Management Advisory Committee Co-chair

- **Henning Schulzrinne,** Columbia University

- **William Webb,** University of Cambridge

### Breakout Rooms

*Attendees can join smaller groups in breakout rooms for further discussion.*

# AGENDA

## Tuesday, August 11

*Networking Break: 11:00 AM - 12:00 PM*

*Afternoon Session: 1:00 PM - 3:00 PM*

### Technical Presentation: O-RAN

• **Brian Daly** of AT&T will offer a deep-dive into the current state of open radio access networks. Attendees can submit questions during the presentation.

### Panel 1: 5G Design — Resiliency at the Radio Layer

Panel 1 will look at design mechanisms and ideas, such as RF filtering, new antenna technologies, closed loop systems, and other ways to design the 5G radio layer for resilient services. Attendees can submit questions for panelists during the session.

• **Tom Rondeau,** Defense Advanced Research Projects Agency (DARPA), Moderator

• **Kumar Balachandran,** Ericsson

• **Aleks Damnjanovic,** Qualcomm

• **Serge Leef,** DARPA

• **Andreas Molisch,** University of Southern California

• **Pam Patton,** John Hopkins University-Applied Physics Laboratory

### Breakout Rooms

*Attendees can join smaller groups in breakout rooms for further discussion.*

# ISART 2020: 5G SPECTRUM AND A ZERO-TRUST NETWORK

## AGENDA

## Wednesday, August 12

### Morning Session: 9:00 AM - 11:00 AM

**Opening Remarks, Logistics for the Day**

• **ISART Co-chair Andrew Thiessen,** NTIA/ITS,

**Technical Presentation: Supply Chain Protection and Verification Through EM Side-Channel Signature Analysis**

• **Alenka Zajic** of Georgia Tech will present a high-level overview of the supply chain verification problem and possible solutions offered by EM side-channels, including RF detection of malware. Attendees can submit questions during the presentation.

**Panel 2: 5G Deployment — Implementing Secure and Resilient Solutions**

Panel 2 will explore deployment challenges, including how to implement secure and resilient technical solutions in a rip and replace world within a zero-trust network environment. Attendees can submit questions for panelists during the session.

• **Drew Morin,** T-Mobile, Moderator

• **Carri Bennett,** Rural Wireless Association

• **Charles Mathias,** FCC

• **Michael Murphy,** Nokia

• **Anita Patankar-Stoll,** Verizon

• **Jaisha Wray,** NTIA

**Breakout Rooms**

*Attendees can join smaller groups in breakout rooms for further discussion.*

# AGENDA

## Wednesday, August 12

*Networking Break: 11:00 AM - 12:00 PM*

*Afternoon Session: 1:00 PM - 3:00 PM*

### Technical Presentation: Spectrum Monitoring

• **Doug Boulware** of NTIA-ITS, will give a technical presentation on spectrum monitoring. Attendees can submit questions during the presentation.

### Panel 3: 5G Monitoring and Data Collection — The Feedback Loop

Panel 3 will explore options for effective and efficient spectrum monitoring and obtaining usable data. Monitoring and data is the nexus of the feedback loop among design, deployment, and operations—and key to securing the 5G radio layer.

• **Ashley Zauderer,** NSF, Moderator

• **Jim Arnold,** DoT

• **Bob Baxley,** Bastille

• **Kaushik Chowdhury,** Northeastern University

• **Mark Gibson,** CommScope

• **Michael Schwab,** umlaut

### Breakout Rooms

*Attendees can join smaller groups in breakout rooms for further discussion.*

## AGENDA

## Thursday, August 13

### Morning Session: 9:00 AM - 11:00 AM

### Opening Remarks, Logistics for the Day

• **ISART Technical Advisory Committee member: Keith Gremban,** University of Colorado Boulder

### Technical Presentation: Spectrum Coliseum Competition

• **John Shea** from the University of Florida GatorWings team, winners of the recent DARPA Spectrum Coliseum Challenge competition, will give a technical presentation. Attendees can submit questions

### Panel 4: 5G Operations — Implementing Resilient Zero-Trust Networks

Panel 4 will examine operations and implementing resiliency within a network's operations. Attendees can submit questions for panelists during the session.

• **Paul Zablocky, DARPA,** Moderator

• **Tim Godfrey,** Electric Power Research Institute

• **Milo Medin,** Google

• **Wayne Phoel,** University of Maryland

• **Sanyogita Shamsunder,** Verizon

### Breakout Rooms

*Attendees can join smaller groups in breakout rooms for further discussion.*

## AGENDA

## Thursday, August 13

*Networking Break: 11:00 AM - 12:00 PM*

*Afternoon Session: 1:00 AM - 3:00 PM*

### Panel 5: Wrap-up — Bringing it All Together

The wrap-up panel brings together polymaths to help draw new insights and connections, identify potential new research areas, and hopefully add to the history of ISART by triggering important out-of-the-box thinking, innovative ideas, and novel solutions. Attendees can submit questions for panelists during the session.

- **Pierre de Vries,** Silicon Flatirons, Moderator

- **Paul Kolodzy,** Kolodzy Consulting

- **Blair Levin,** Brookings Institute

- **Doug Sicker,** University of Colorado Boulder

- **David Tennenhouse,** VMware

### Closing Remarks

- **Sheryl Genco,** Director of NTIA/ITS

### Breakout Rooms

*Attendees can join smaller groups in breakout rooms for further discussion.*

**James Arnold** has served as Senior Spectrum Manger and Spectrum Lead in the Office of Positioning, Navigation and Timing & Spectrum Management at the U.S. Department of Transportation since January 2014.

**Kumar Balachandran** is an expert in Wireless Communications Networks and has been with Ericsson Research since 1995. He has a BE (Hons) in Electronics and Communications Engineering from the Regional Engineering College, Tiruchirappalli, and holds an MS and PhD in Computer and Systems Engineering from Rensselaer Polytechnic Institute in Troy, NY. Dr. Balachandran has worked on a variety of areas in mobile communications spanning the physical layer, signal processing, radio resource management, spectrum sharing, protocol design, and systems engineering spanning all five generations of mobile cellular technologies. His recent contributions have been in the area of shared spectrum and he has been a prominent contributor to the specification of the Citizens Broadband Radio Service (CBRS) in the WInnForum and the CBRS Alliance. He is currently working on research problems pertaining to radio resilience and system reliability. He is active in working with Ericsson's technology strategy and takes an interest in competitive analysis of mobile technology. He has served as a technical expert on the FCC's Technological Advisory Council on spectrum topics, receiver performance, and 5G&IoT for several years. He has contributed to Ericsson's outreach to the FCC and the NTIA on several occasions with technical arguments favoring the release of spectrum for use by the mobile industry. He has served as panelist and invited speaker at several prominent conferences, is well published, has contributed to several books, and has been named on over 100 issued US patents as inventor.

**Bob Baxley** is a Co-Founder and the Chief Technology Officer of Bastille, the first cybersecurity company to detect and mitigate threats from the Internet of Things (IoT). Prior to starting Bastille, Dr. Baxley was the Director of the Software Defined Radio Lab at the Georgia Tech Research Institute where he led signal processing, machine learning, and radio frequency projects for various organizations including NSF, ONR, Army, DoD, and the Air Force. While there, he led GTRI's team in the DARPA Spectrum Challenge. The team took second place out of 90 international competitors. More recently, Dr. Baxley competed on the Zylinium Research DARPA Spectrum Collaboration Challenge (SC2) team which won $2.25M in prizes, finishing in the top three places each year of the three-year competition. Dr. Baxley is the inventor of 27 patents in areas including radio frequency, wireless signals, behavioral signatures, and machine-learning based threat detection and mitigation in IoT, among others. He has co-authored over 70 peer-reviewed papers and has spoken at dozens of

conferences globally on issues ranging from RF Threats in the IoT to Spatial Cognitive Electronic Warfare. Dr. Baxley earned PhD, MS, and BS degrees in Electrical Engineering from Georgia Tech. During his graduate work, he was recognized with the Sigma Xi Best Thesis award, the Georgia Tech Center for Signal and Image Processing PhD Research Award, and the National Science Foundation Graduate Research Fellowship Award. He is a Senior Member of the IEEE and a former Associate Editor of Signal Processing.
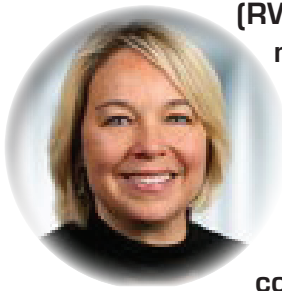
**Carri Bennet** is the General Counsel of the Rural Wireless Association (RWA), a non-profit member-led organization that represents rural wireless carriers who serve fewer than 100,000 subscribers. Ms. Bennet oversees regulatory matters and manages the legal affairs of the association. Since 1987, she has represented primarily rural wireless carriers, telephone companies, cellular carriers, PCS providers, and CLECs before the FCC, state regulatory agencies, the courts, and Congress. She is a nationally recognized expert on rural wireless issues and has been a key voice in ensuring that rural America doesn't lose critical wireless broadband services as a result of the ban of Huawei and ZTE equipment in the U.S. and the subsequent reimbursement program for rural wireless carriers. Ms. Bennet has also testified before the FCC, Congress, and the courts on rural wireless issues and speaks regularly at industry trade shows and legal seminars on cybersecurity, data privacy, spectrum policy, universal service funding reform and business development and strategy issues for communications and technology companies. In 2017, she was appointed by FCC Chairman Ajit Pai to serve on the FCC's BDAC Federal Siting Work Group and was tasked with making recommendations for improving the timing and processes associated with the siting and deployment of broadband infrastructure on federal lands and buildings. She is a member of the Federal Communications Bar Association and American Bar Association. Ms. Bennet is also an accomplished triathlete having competed in the Hawaiian Ironman in 2004.

**Doug Boulware** joined ITS in 2017 and currently serves as the project leader and senior software developer for the Propagation Modeling Website (PMW) and senior software developer for the Spectrum Characterization Occupancy Sensing (SCOS) spectrum monitoring system. Prior to joining ITS, Mr. Boulware conducted research and developed software for 15 years in support of the DOD as both a private contractor and government employee. Mr. Boulware holds a B.A. in Computer Science from Hamilton College and an M.S. in Computer Science from Syracuse University.

**Kaushik Chowdhury** is a Professor in the Electrical and Computer Engineering Department at Northeastern University, Associate Director of the Institute for the Wireless Internet of Things, and Faculty Fellow of the College of Engineering. He received his PhD from the Georgia Institute of Technology in August 2009 and M.S. from the University of Cincinnati in 2006. Dr. Chowdhury is the winner of the U.S. Presidential Early Career Award for Scientists and Engineers (PECASE) in 2017, the Defense Advanced Research Projects Agency Young Faculty Award in 2017, the Office of Naval Research Director of Research Early Career Award in 2016, and the National Science Foundation (NSF) CAREER award in 2015. He is the recipient of best paper awards at IEEE GLOBECOM'19, DySPAN'19, INFOCOM'17, ICC'13,'12,'09, and ICNC'13. He serves as area editor for IEEE Trans. on Mobile Computing, Elsevier Computer Networks Journal, IEEE Trans. on Network Science and Engineering, and IEEE Trans. on Wireless Communications. He is Sr. Member of the IEEE, co-directs the operations of Colosseum RF/network emulator, as well as the Platforms for Advanced Wireless Research project office, a joint $100 million public-private partnership between the NSF and wireless industry consortium to create city-scale testing platforms. His current research interests include deep learning for wireless sensing and spectrum access, networked robotics, wireless RF energy harvesting/transfer and IoT applications for intra/on-body communication.

**Jeff Cichonski** is an Information Technology Specialist working with a broad array of technologies at the National Institute of Standards and Technology, working in the Applied Cybersecurity Division of the Information Technology Laboratory. He is an active member of 3GPP's SA3 working group, the standards group responsible for specifying cellular security architectures and has been engaged in the development of 5G security. He is leading the National Cybersecurity Center of Excellence's project on 5G Cybersecurity. Mr. Cichonski also performs applied cybersecurity research focusing on cybersecurity for industrial control systems, next generation credentials, and LTE network security, with a specific interest in security for public safety cellular Implementations. He has a BS in Information Science and Technology from the Pennsylvania State University.

# SPEAKERS, PRESENTERS AND ORGANIZERS

**Walter G. Copan** was confirmed by Congress as Under Secretary of Commerce for Standards and Technology and NIST Director on October 5, 2017. Dr. Copan formerly served as president and CEO of the IP Engineering Group Corporation, providing services in intellectual property, strategy and innovation. He was founding CEO and chairman of Impact Engineered Wood Corporation, an advanced materials technology company, and founding board member of Rocky Mountain Innovation Partners, fostering entrepreneurship in the Rocky Mountain West. From 2010–2013, Dr. Copan served as managing director of Technology Commercialization and Partnerships at DOE's Brookhaven National Laboratory (BNL). From 2005–2010, Dr. Copan was executive vice president and chief technology officer at Clean Diesel Technologies, Inc. Prior to joining CDTI, Dr. Copan had served at the DOE's National Renewable Energy Laboratory (NREL) as Principal Licensing Executive, Technology Transfer. He also served with the National Advisory Council to the Federal Laboratory Consortium. After earning dual BS/BA degrees in Chemistry and Music from Case Western Reserve University in 1975, Dr. Copan began his 28 year career with the Lubrizol Corporation. He earned a PhD in Physical Chemistry from Case Western in 1982. He has contributed to the U.S. National Academy of Sciences, the Council on Competitiveness, the World Intellectual Property Organization and the United Nations on innovation, technology and economic development matters.

**Brian Daly** is Assistant Vice President for Standards & Industry Alliances for AT&T, overseeing AT&T's strategy and leadership in global industry standards. As a technology visionary and thought leader, his focus is on emerging technologies for 5G and beyond; open source; public safety initiatives including mission critical services for FirstNet, earthquake early warning, and wireless emergency alerts; IoT including C-V2X, Smart Cities, UAS/UAVs; Cybersecurity and national security/emergency preparedness/critical infrastructure protection. Mr. Daly is an appointed member of the FCC's Technological Advisory Council (TAC) and Communications Reliability, Security, and Interoperability Council (CSRIC), and is a member of the FBI's Infragard partnership. He is a Board member representing ATIS on the National Public Safety Communications Council (NPSTC), and a Board Director on the IEEE International Standards and Technology Organization (IEEE-ISTO). Mr. Daly's industry leadership roles include Co-chair of the

FCC TAC 5G/IoT Working Group, Chair of the GSM Association's North American Fraud Forum and Security Group, Chair of the SAE's Cellular V2X Advanced Applications Technical Committee, co-chair of the O-RAN Alliance Standards Development Focus Group, and co-chair of the ANSI Unmanned Aircraft Systems Standardization Collaborative Critical Infrastructure & Environment working group. He received his BS and MS degrees in Electrical Engineering from Arizona State University with a focus on communication systems and electromagnetic engineering. Mr. Daly is the AT&T coordinator for the Department of Homeland Security SHAred RESources (SHARES) High Frequency (HF) Radio Program.

**Aleksandar D. Damnjanovic** received a Doctor of Science degree in Electrical Engineering from the George Washington University in 2000. He joined Ericsson Wireless Communications Inc. in San Diego in 2000, where he worked on cdma2000 base station controller development. In 2003, he joined Qualcomm Inc., San Diego, where he worked on 3G, 4G and 5G cellular standards, prototyping of 3GPP Long Term Evolution (LTE) network where he led MAC system design efforts, and most recently 5G NR-U. He is a co-author of the book The cdma2000 System for Mobile Communications. His research interests include interference management, medium access, shared spectrum, network MIMO, and relay networks.

**Jean Pierre de Vries** is Co-Director of the Spectrum Policy Initiative at the Silicon Flatirons Center at the University of Colorado Boulder. He is a Visiting Senior Scientist at the Institute for Networked Systems of RWTH Aachen University. He has worked on maximizing the value of radio operation by modeling and managing inter-system interference, and is currently exploring the intersection of technology, mythology, and public policy. He has been a Technology Advisor to Harris Wiltshire & Grannis LLP, Washington DC (2007–2010), and Senior Fellow at the Annenberg Center for Communication of the University of Southern California (2006–2007). Prior to this he held various positions at Microsoft Corp. in Redmond, WA, including Chief of Incubation, Senior Director of Advanced Technology and Policy, and Director of User Experience Design (1993–2005). He started his career at Korda & Co, a London-based seed capital company and technology consultancy (1987–1993). De Vries holds a B.Sc. (Honours) from Stellenbosch University, and a PhD in Theoretical Physics from the University of Oxford.

**Rebecca Dorch** serves as Senior Spectrum Policy Analyst at ITS, focusing on spectrum sharing. She recently managed ITS's conformance testing program for the Spectrum Access System and Environmental Sensing Capability components of the 3.5 GHz Citizens Broadband Radio Service. In 2019, she served on the planning committee for the DOC Space Commerce Workshop. In 2018 she served as Vice-Chair of the International Symposium on Advanced Radio Technologies. Prior to joining NTIA in March of 2016, Ms. Dorch served for thirteen years as the Western Region Director of the Federal Communications Commission's Enforcement Bureau, overseeing resolution of harmful interference affecting communications infrastructure. Ms. Dorch was previously involved in policy and rulemaking matters as Deputy Chief of the FCC Office of Engineering and Technology, and in legal and competition matters as Deputy Chief of the Competition Division of the FCC's Office of General Counsel. Ms. Dorch began her career in private law practice with the firms of Bryan Cave, and Wilner and Scheiner. She earned her JD at the Washington University School of Law in St. Louis, Missouri, and her BA (Phi Beta Kappa) at the University of Illinois.

**Mohamed El-Moghazi** is the Spectrum Management Research and Studies Director at the National Telecommunications Regulatory Authority (NTRA) of Egypt. He is currently Egypt and ASMG coordinator for several WRC-23 Agenda Items mainly focusing on broadband and mobile issues. He is also the founder of the Global Telecom Policy Research Network (GTPRN). www.gtprn.org, an initiative for scholars in telecom policy, and the Vice Chairman of CPM-23. Dr. El-Moghazi was part of the NTRA team that achieved a successful $2 billion 4G auction, and has published numerous papers in prestigious conferences and journals including TPRC, ITS Europe, CPR Asia, DySPAN, Intermedia, Info, and Telecommunication Policy. He has also supervised several Master and PhD thesis on spectrum pricing and international spectrum management related issues. Dr. El-Moghazi was awarded the British Chevening Scholarship from the Foreign and Commonwealth Office (FCO) to join the Master of Communications Management (MCM) program in Strathclyde University in 2007, was selected as one of the three finalists for the 2018 Study UK Alumni - Professional Achievement Award in 2018, and was honored by the UK Ambassador in Egypt. He was also one of the winners of Young Scholar Award from the Pacific Telecommunication Council in 2017.

**Joseph B. Evans** is the inaugural Technical Director for 5G, reporting directly to the Under Secretary of Defense for Research and Engineering within the Office of the Secretary of Defense. Dr. Evans is responsible for coordinating 5G efforts across the Department of Defense, oversees and directs the Department's "5G to Next G" research and development portfolio, and advises the Under Secretary of Defense for Research and Engineering on 5G-related topics. He served as a Program Manager in the DARPA Strategic Technology Office from 2015 to 2019. While there, he started the SHARE (Secure Handhelds on Assured Resilient networks at the tactical Edge) and GCA (Geospatial Cloud Analytics) programs, and managed the Mobile Hotspots, RadioMap, SSPARC (Shared Spectrum Access for Radar and Communications), CommEx (Communications Under Extreme RF Spectrum Conditions), WND (Wireless Network Defense), and DyNAMO (Dynamic Network Adaptation for Mission Optimization) programs. From 1989 to 2019, Dr. Evans was the Deane E. Ackers Distinguished Professor of Electrical Engineering & Computer Science at the University of Kansas. Dr. Evans served as a Program Director in the Division of Computer and Network Systems, Directorate of Computer & Information Science & Engineering (CISE) at the National Science Foundation (NSF) from 2003 to 2005. At NSF, he was responsible for multi-organizational networking research efforts in wireless networking, cybersecurity, optical networking, and scientific applications. Dr. Evans was a co-founder and member of the Board of Directors of NetGames USA, Inc. Dr. Evans was a partner and Chief Scientist at Ascend Intelligence, LLC, which developed the Tactical Ground Reporting System (TIGR) for DARPA and the US Army. He served as a Council member for the Computing Community Consortium Council from 2012 to 2015, and as a Member-at-Large on the IEEE Communications Society Board of Governors from 2009 to 2011. Dr. Evans received the BSEE from Lafayette College, and his MSE, MA, and PhD from Princeton University. He is an IEEE Fellow.

**Terri Fiez** is the Vice Chancellor for Research for the University of Colorado Boulder. In this capacity, Dr. Fiez leads the campus research enterprise, positioning CU-Boulder as a leader in global innovation by facilitating the creation and dissemination of new knowledge through research, scholarship and creative works. Before joining CU-Boulder in 2015, Dr. Fiez spent more than fifteen years at Oregon State University (OSU) as the head of the Department of Electrical and Computer Engineering, the Research Agenda Strategy Consultant to the Vice President for Research, and head of the School of Electrical Engineering and Computer Science. A former

National Science Foundation Young Investigator awardee with over 150 publications and 80 graduate students, Dr. Fiez's scholarly interests focus on analog and mixed-signal integrated circuits and approaches to innovative education. In addition to her extensive research and track record of collaboration with industry, Dr. Fiez received the 2006 Institute of Electrical and Electronics Engineers (IEEE) Educational Activities Board's Innovative Education Award and the 2016 IEEE Undergraduate Teaching Award. She received her BS and MS in Electrical Engineering from the University of Idaho and PhD in Electrical and Computer Engineering from Oregon State University.

**Sheryl M. Genco** joined NTIA in May 2020 as Director of the Institute for Telecommunication Sciences. Dr. Genco has more than 30 years of experience in engineering and management, having held technical and management positions at a wide range of organizations including Honeywell Corporation, IBM, Ball Aerospace, and the National Institute of Standards and Technology (NIST). Her career has focused on the development of new technologies and moving research into operation. Dr. Genco was most recently the Senior Research and Development Manager for Engineering at Honeywell Quantum Solutions, where she led an organization developing systems for quantum computing based on trapped ions. At NIST, she led the National Advanced Spectrum and Communications Test Network, managing programs in the areas of LTE-3.5GHz, GPS, AWS-3, and Fifth Generation Advanced Training Waveform. Dr. Genco co-founded an engineering R&D company that developed synthetic nanomaterials. The precise nanomaterials were produced in large volumes for lunar simulants for NASA, glass fiber manufacturing processes, microsphere production and other applications with Fortune 500 companies. Dr. Genco also founded a STEM focused K-8 public school that has won multiple awards, including the prestigious John Irwin School of Excellence award. The school has educated more than 13,000 students in its decade and a half of continuous operation. Dr. Genco received a PhD in Electrical Engineering from the University of Colorado's Center of Excellence in Optoelectronic Systems, and she holds B.S. and M.S. degrees in Electrical Engineering.

**Monisha Ghosh** has been serving as the Chief Technology Officer (CTO) of the Federal Communications Commission (FCC) since Jan. 13, 2020. Prior to this, she was at the National Science Foundation as a rotating Program Director in the Computer and Network System (CNS) division within the Directorate of Computer & Information Science and Engineering (CISE), where she managed wireless networking research within the Networking Technologies and Systems (NeTS) program. Dr. Ghosh is also a Research Professor at the University of Chicago, with a joint appointment at the Argonne National Laboratories, where she conducts research on wireless technologies for the IoT, 5G cellular, next generation Wi-Fi systems, and spectrum coexistence. Prior to joining the University of Chicago in 2015, she worked at Interdigital, Philips Research and Bell Laboratories, on various wireless systems such as the HDTV broadcast standard, cable standardization and on cognitive radio for the TV White Spaces. Dr. Ghosh has been an active contributor to many industry standards and was recognized with a Certificate of Appreciation for her outstanding contributions to IEEE 802.22. She is a Fellow of the IEEE. Dr. Ghosh received her Ph.D. in Electrical Engineering from the University of Southern California in 1991, and her B. Tech from the Indian Institute of Technology, Kharagpur (India) in 1986.

**Mark Gibson** is responsible for developing domestic and international business opportunities for CommScope. He has over 36 years of spectrum management experience. In addition to leading technical and business development efforts for numerous wireless and spectrum-related products and services, he has led efforts to address spectrum sharing between Federal government and commercial users. He leads CommScope's CBRS efforts on the Spectrum Access System/Environmental Sensing Capability. He is a board member of the CBRS Alliance and an officer on the board of the Wireless Innovation Forum. He is a member of the Commerce Spectrum Management Advisory Committee, where he has also co-chaired working groups related to spectrum sharing and data exchange issues. He has led spectrum management efforts including the development of the SAS and ESC, TV White Space, spectrum sharing analysis protocols and sharing criteria, as well as development of Comsearch's engineering services and software products. He has led efforts in working with the American Hospital Association as their technical partner for WMTS frequency coordination. He has authored several papers on spectrum sharing and relocation and has advised numerous wireless participants in their system design. He is a Life Member of IEEE. He has an amateur radio license and is an instrument-rated commercial pilot.

# SPEAKERS, PRESENTERS AND ORGANIZERS

**Tim Godfrey** is a Technical Executive with the Electric Power Research Institute. He manages the Telecommunications research in the Information and Communication Technology program, addressing the key challenges utilities face as they enhance their telecommunications infrastructure to enable grid modernization. He holds a BSEE from the University of Kansas and has worked in the area of wireless networking and communications for 30 years. He is the Chair of the IEEE 802.24 Smart Grid Technical Advisory Group and the IEEE 802.15.16t Task Group.

**Anna Gomez**, a former National Telecommunications and Information Administration (NTIA) Deputy Administrator, specializes in a wide range of spectrum licensing issues and regulatory, policy, and transactional matters related to domestic and international telecommunications and unmanned aircraft systems at the Wiley law firm. Dr. Gomez also served for twelve years in various positions at the FCC, including Deputy Chief of the International Bureau, where she developed and implemented Commission policy on international telecommunications and satellite spectrum, and Senior Legal Advisor to then-Chairman William E. Kennard. Dr. Gomez is co-chair of Wiley's Unmanned Aircraft Systems practice.

**Keith Gremban** is a Senior Fellow at the Silicon Flatirons Center and a Research Professor at the University of Colorado Boulder. Dr. Gremban has over 30 years of experience in systems engineering and advanced technology development. His research interests are in spectrum science and security, wireless communications, and the Internet of Things. Prior to joining the University of Colorado, Dr. Gremban was the Director of the Institute for Telecommunication Sciences (ITS), which is the research and engineering laboratory for the National Telecommunications and Information Administration (NTIA). He was also a Program Manager at the U.S. Defense Advanced Research Projects Agency (DARPA). Dr. Gremban received his PhD and MS in Computer Science from Carnegie Mellon University, and his MS in Applied Mathematics and BS in Mathematics from Michigan State University. He is currently the Editor-in-Chief of the IEEE Internet of Things Magazine.

**Dale N. Hatfield** is currently a Senior Fellow at the Silicon Flatirons Center for Law, Technology, and Entrepreneurship and an Adjunct Professor at the University of Colorado at Boulder. Prior to joining the University of Colorado, Mr. Hatfield was Chief of the Office of Engineering and Technology at the Federal Communications Commission (FCC) and, immediately before that, he was Chief Technologist at the Agency. He retired from the FCC and government service in December 2000. Before joining the FCC in December 1997, he was Chief Executive Officer of Hatfield Associates, Inc., a Boulder, Colorado based multidisciplinary telecommunications consulting firm. Before founding the consulting firm in 1982, Mr. Hatfield was Acting Assistant Secretary of Commerce for Communications and Information and Acting Administrator of the National Telecommunications and Information Administration (NTIA). Before moving to NTIA, Mr. Hatfield was Chief of the Office of Plans and Policy at the FCC. He holds a BS in Electrical Engineering from Case Institute of Technology and an MS in Industrial Management from Purdue University. In May 2008, Mr. Hatfield was awarded an Honorary Doctor of Science degree by the University of Colorado for, inter alia, his commitment to the development of interdisciplinary telecommunications studies. Until recently, Mr. Hatfield was the Executive Director of the Broadband Internet Technical Advisory Group (BITAG). He is currently serving on the FCC's Technology Advisory Council (TAC) and on the Commerce Department's Spectrum Management Advisory Committee (CSMAC) and has served as an independent Director of Crown Castle International Corp. since July 2001.

**Doug Kinkoph** is Associate Administrator of NTIA's Office of Telecommunications and Information Applications, performing the non-exclusive functions and duties of the Assistant Secretary of Commerce for Communications and Information. Mr. Kinkoph joined the Department of Commerce in 2010 and has served in a number of roles, most recently as Acting Deputy Assistant Secretary where he worked on issues including spectrum management, broadband, and public safety communications. While serving as head of the Office of Telecommunications and Applications, Mr. Kinkoph created the agency's BroadbandUSA program, which works to promote broadband deployment and adoption nationwide. He also oversaw a $4 billion broadband grant program that funded the deployment of broadband infrastructure, public computer centers, sustainable adoption of broadband service, and statewide broadband planning.

**Paul Kolodzy** is an independent telecommunications consultant to government and commercial clients. His areas of expertise include the development of advanced component, device, and system technology; advanced architectures; interference analysis; and spectrum policy, regulation and acquisition. He has been active in broadcast; cellular including 700 MHz, AWS-1, AWS-3, and AWS4; and public safety spectrum policy and regulation. Prior to his work as an independent consultant, Dr. Kolodzy was the Director of the Wireless Network Security Center at the Stevens Institute of Technology. He also served as the Senior Spectrum Policy Advisor and the Director of the Spectrum Policy Task Force at the Federal Communications Commission. He also has worked as a program manager and a subject matter expert at the Defense Advanced Projects Agency and was the Director of Signal Processing and Strategic Initiatives at Lockheed Martin Sanders (now BAE). He began his career as a Group Leader and Staff Member at MIT's Lincoln Laboratory. Dr. Kolodzy is also a member of the National Research Council Panel on Active Sensing. He founded the IEEE Dynamic Spectrum Access Network Symposium and served as the first general chair and co-chaired the steering committee for over a decade. Dr. Kolodzy has served as a member of NTIA's Commerce Spectrum Management Advisory Committee since 2014. He holds a PhD degree in Chemical Engineering from Case Western Reserve University and a BS in Chemical Engineering from Purdue University.

**Serge Leef** joined DARPA in August 2018 as a program manager in the Microsystems Technology Office (MTO). His research interests include computer architecture, simulation, synthesis, semiconductor intellectual property, cyber-physical modeling, distributed systems, secure design flows, and supply chain management. He is also interested in the facilitation of startup ecosystems and business aspects of technology. Leef came to DARPA from Mentor, a Siemens Business where from 2010 until 2018 he was a Vice President of New Ventures, responsible for identifying and developing technology and business opportunities in systems-oriented markets. Additionally, from 1999 to 2018, he served as a division General Manager, responsible for defining strategies and building successful businesses around design automation products in the areas of hardware/software co-design, multi-physics simulation, IP integration, SoC optimization, design data management, automotive/aerospace networking, cloud-based electronic design, Internet of Things (IoT) infrastructure, and hardware cybersecurity. Prior to joining Mentor, he was responsible for design automation at Silicon Graphics, where he and his team created

revolutionary, high-speed simulation tools to enable the design of high-speed 3D graphics chips, which defined the state-of-the-art in visualization, imaging, gaming, and special effects for a decade. Prior to that, he managed a CAE/CAD organization at Microchip and developed functional and physical design and verification tools for major 8- and 16-bit microcontroller and microprocessor programs at Intel. Leef received his BS in Electrical Engineering and MS in Computer Science from Arizona State University. He has served on corporate, state, and academic advisory boards, delivered numerous speeches, and holds two patents.

**Blair Levin** has worked for the past 25 years at a high-level at the intersection of broadband policy and capital markets. From 1993-1997 Levin served as Chief of Staff to FCC Chairman Reed Hundt. In 2009 he co-lead the technology transition team for President-elect Obama and returned to government service from 2009-2010, to oversee the development of the National Broadband Plan for the United States. He then founded and oversaw Gig.U, a consortium of three dozen university communities working to accelerate the deployment of next generation broadband networks. FCC Chairman Tom Wheeler has praised Mr. Levin's work, noting "no one's done more to advance broadband expansion and competition through the vision of the National Broadband Plan and Gig.U." In 2018-19, working with the World Bank and UNHCR, he led a team that produced a Global Broadband Plan for Refugees. Between his stints working for the FCC, Mr. Levin worked as an equity analyst at Legg Mason and Stifel Nicolaus. He now does similar work for New Street Research. He has also served as a consultant to numerous communications enterprises, and to a number of local, state, and national governments on broadband policy. In addition, he is a non-resident Senior Fellow of the Metropolitan Policy Project of the Brookings Institution and previously was with the Aspen Institute Communications and Society Program. He is a graduate of Yale College and Yale Law School.

**Charles Mathias** is the Associate Bureau Chief in the Wireless Telecommunications Bureau at the Federal Communications Commission. He serves as the Bureau lead for Commission initiatives related to cybersecurity and public safety that have a wireless component. Mr. Mathias advises Commissioners and the Bureau Chief on a broad range of policy, regulatory and legal issues, including spectrum transactions, spectrum use, re-purposing spectrum, spectrum sharing and mobile device safety and integrity. Previously, he served as Special Counsel to Chairman Julius Genachowski. His areas of responsibility included public safety and homeland security, including cybersecurity, and a variety of spectrum-

related issues. Prior to working with Chairman Genachowski, Mr. Mathias was Associate Bureau Chief in the Wireless Bureau where he coordinated certain Bureau merger review activities and oversaw development of the Bureau's report on mobile privacy. Before working in the Wireless Bureau, Mr. Mathias was Senior Legal Advisor to Commissioner Meredith Atwell Baker. Prior to joining Commissioner Baker, he was Associate Bureau Chief, and before that Special Counsel, in the Wireless Telecommunications Bureau, where he worked on a variety of spectrum and wireless policy issues. He also served as Special Counsel in the Wireline Competition Bureau. Before joining the FCC, Mr. Mathias provided legal, regulatory affairs, government relations and business development guidance and support at Lucent, Bechtel, and in private practice to companies and individuals in the information and communications technologies sector, and especially to companies interested in expanding their business internationally. He began my career as a corporate lawyer at Ropes & Gray in Boston.

**Milo Medin** has been part of the Internet development community for more than 25 years. He is currently the vice president of wireless services at Google. Prior to joining Google in 2010, he was founder and CTO of M2Z Networks, a company that sought to deploy a national broadband wireless network system, and before then he was cofounder and the Chief Technology Officer of Excite@Home, where he led the development of the company's national infrastructure, and helped deliver the first large scale residential broadband access service in partnership with major cable operators, including the development of the DOCSIS cable modem standard. Earlier, Milo worked at NASA's Ames Research Center, where he developed the first peering point between backbone networks, and managed primary west coast interconnect for the Internet, and architected and managed the global NASA Science Internet, including the deployment of the first Internet connections to a number of countries around the world. Milo majored in computer science at UC Berkeley. He has participated in a number of public policy forums, including two National Academy of Sciences panels, given testimony in Congress and before the Federal Communications Commission on Broadband technology policy, and served on the PCAST working group on Spectrum Sharing. He holds several patents in the field of network access technology, and sits on the FCC's Technical Advisory Committee.

**Melissa Midzor** is the Program Manager for the National Advanced Spectrum and Communications Test Network. She leads a multi-agency group, hosted at NIST, focusing on wireless communication spectrum sharing between commercial and federal systems. Prior to NIST, Dr. Midzor supported the Navy for 15 years in Electronic Warfare (EW) and Spectrum compatibility across the joint services. She served as Director for EW Integrated Laboratories at NAWCWD and a rotation at the OSD Electronic Warfare and Countermeasures Office, developing EW Threat environments and tools to evaluate current and future RF technologies. She was appointed the first Senior Scientific Technology Manager (SSTM) of S&T EW at NAVAIR. Dr. Midzor earned her PhD in Physics from Caltech in Nanotechnology, and a BA in Physics and Sociology from the University of Colorado, Boulder.

**Andy Molisch** received his PhD and Habilitation degrees from the Technical University Vienna, Austria. He spent the next 10 years in industry, at FTW, AT&T (Bell) Laboratories, and Mitsubishi Electric Research Labs, where he rose to Chief Wireless Standards Architect. In 2009 he joined the University of Southern California (USC) in Los Angeles, CA, where he is now the Solomon Golomb – Andrew and Erna Viterbi Chair. His research interests revolve around wireless propagation channels, wireless systems design, and their interaction. Recently, his main interests have been wireless channel measurement and modeling for 5G and beyond 5G systems, wireless video distribution, hybrid beamforming, UWB/TOA based localization, caching at the wireless edge, and novel modulation/multiple access methods. Overall, he has published 4 books, 21 book chapters, 260 journal papers, and 360 conference papers. He is also the inventor of 60 granted (and more than 20 pending) patents, and co-author of some 70 standards contributions. Dr. Molisch has been Chairman of various international standardization groups. He is a Fellow of the National Academy of Inventors, Fellow of the AAAS, Fellow of the IEEE, Fellow of the IET, an IEEE Distinguished Lecturer, and a member of the Austrian Academy of Sciences. He has received numerous awards, among them the IET Achievement Medal, the Technical Achievement Awards of IEEE Vehicular Technology Society (Jose Avant-Garde Award) and the IEEE Communications Society (Edwin Howard Armstrong Award), and the Technical Field Award of the IEEE for Communications, the Eric Sumner Award.

**Drew Morin** currently serves as the Director, Federal Cyber Security Technology and Engineering Programs for T-Mobile. He is responsible for identifying emerging cyber security trends and regulatory policies to improve information security programs. He serves on several industry and Federal workgroups and councils focused on resilience, cybersecurity, and risk mitigation. He is currently the chairperson for the CTIA IOT Cybersecurity Working Group, the co-chair for two of the working groups supporting the DHS Supply Chain Risk Management Task Force, the Treasurer and a member of the Executive Committee on the Communication Sector Coordinating Council, a co-chair for the ATIS/DoD 5G Supply Chain Risk Management working group and serves on the Secure Telephone Identity Technical Committee focused on mitigating robocalling. Mr. Morin has over 35 years of experience in communications technology and cyber security. Prior to T-Mobile, he co-founded TeleCommunication Systems, serving as Senior Vice President and Chief Technology Officer. Mr. Morin holds a BS degree in Systems Engineering from the University of Virginia and a MS degree in Systems Engineering from George Mason University.

**Mike Murphy** is CTO for Nokia, North and South America. He is responsible for aligning Nokia's product roadmap with the needs of customers in the United States, Canada and Latin America. Mr. Murphy was formerly head of R&D for Nortel. He began his tenure with Nokia in 2006 as Japan country manager, assumed the role of CTO for Asia Pacific in 2007, then moved to the U.S. in 2013. Mike has a Master's degree in Mathematics from the University of Waterloo, in Canada, has a black belt in Tae Kwon Do, and is a semi-professional photographer. He lived in eight countries to date, is fluent in English, French, and basic Thai. He is based in Irving, Texas.

**Anita Patankar-Stoll** serves as Public Sector Counsel in Verizon Business Group, Public Policy, Law & Security. Ms. Patankar-Stoll supports public sector compliance in various areas, including supply chain risk management, cybersecurity, and Universal Service Fund program implementation. She also supports policy coordination and the federal bid and proposal process. She previously served as Director for Critical Infrastructure Cybersecurity, at the National Security Council, Executive Office of the President, White House. In that capacity, she oversaw implementation of the National Cyber Strategy for critical infrastructure sectors, including

the communications, information technology, energy, healthcare, and finance sectors. She led Executive Branch cyber response and review of vulnerabilities in information and communications technology. Prior to the NSC, Ms. Patankar-Stoll served in multiple roles at the Federal Communications Commission (FCC). She also served as Special Counsel to the FCC Managing Director and Chief Financial Officer, legal advisor on Universal Service Fund programs in the Wireline Competition Bureau, and legal advisor on media and wireless regulatory violations in the Enforcement Bureau. Before joining the FCC, Ms. Patankar-Stoll served in the Office of General Counsel at the District of Columbia Public Service Commission (PSC) supporting energy and telecommunication regulatory issues and consumer complaint adjudication. She received her BA, magna cum laude, in English and Political Science from Case Western Reserve University and her JD, cum laude, from American University, Washington College of Law.

**Pamela Patton** is a Senior Communications Engineer at the Johns Hopkins University Applied Physics Lab (APL). She received her BS in Electrical Engineering from Virginia Tech and an MS in Telecommunications and Computers from George Washington University. As a technical lead for the 5G Wireless Communications Lab, she is standing up a 5G security research environment utilizing Nokia and SDR RAN equipment to support non-standalone and future standalone network architectures connected to a virtualized core network utilizing NFV and SDN technologies. The lab builds on existing 4G/LTE infrastructure that she has utilized for various tactical use case studies, security architecture and vulnerability analysis, and performance assessments of secure VoIP in a contested RF and network environment. Prior to joining APL in 2012, she took on various wireless communications engineering roles within the Department of Defense and with defense contractors over the past twenty five years. Her focus has been primarily on protocols on the RAN side of the network from 2G/GSM through the generations up to 5G.

**Wayne Phoel** is currently a Visiting Research Engineer at the University of Maryland Institute for Systems Research and the owner of a small eponymous research and development company. His work includes assessing 5G components and system architecture for use in defense applications as well as developing technologies to create robust networks. Previously, Dr. Phoel served as a program manager in the Defense Advanced Research Projects Agency (DARPA) Strategic Technology Office where he initiated and cultivated research efforts on wireless systems, novel techniques for protecting from

attacks, and adaptability for operation in complex environments. Prior to DARPA, Dr. Phoel was a Senior Member of the Technical Staff at MIT Lincoln Laboratory where he guided research and development in protected wireless communications, including anti-jam techniques and analysis, interference cancellation, and wireless networking protocol attacks. Dr. Phoel is a recipient of the Office of the Secretary of Defense Medal for Exceptional Public Service and a member of the Commerce Spectrum Management Advisory Committee.

**Lisa J. Porter** is the Co-Founder and Co-President of LogiQ, Inc., a company providing high-end management, scientific, and technical consulting services. Dr. Porter was previously the Deputy Under Secretary of Defense for Research and Engineering, and in that role, she shared responsibility with the Under Secretary for the research, development, and prototyping activities across the Department of Defense. In prior roles she served as Executive Vice President of In-Q-Tel (IQT) and Director of IQT Labs, the President of Teledyne Scientific & Imaging, the first Director of the Intelligence Advanced Research Projects Activity (IARPA) in the Office of the Director of National Intelligence (ODNI), the Associate Administrator for the Aeronautics Research Mission Directorate at NASA, and as a program manager and senior scientist at the Defense Advanced Research Projects Agency (DARPA). She holds a bachelor's degree in nuclear engineering from the Massachusetts Institute of Technology and a doctorate in applied physics from Stanford University. Dr. Porter received the Office of the Secretary of Defense Medal for Exceptional Public Service, the NASA Outstanding Leadership Medal, the National Intelligence Distinguished Service Medal, the Presidential Meritorious Rank Award, and the Department of Defense Distinguished Public Service Medal.

**Charla Rath** is co-chair of the Commerce Spectrum Management Advisory Committee (CSMAC), which advises the National Telecommunications and Information Administration (NTIA) on a broad range of spectrum policy issues. Ms. Rath has an MA in Science, Technology, and Public Policy from The George Washington University and a BSFS (Foreign Service) in international economics and finance from Georgetown University. Previously, Ms. Rath was Verizon's Vice President – Wireless Policy Development, responsible for developing and managing the company's public policy initiatives related to spectrum management. She was particularly focused on alternative spectrum auction mechanisms and finding sources of spectrum for next generation wireless networks, including 5G. At Verizon Wireless, alongside the company's business development and

network planning groups, Ms. Rath identified and addressed the key policy and regulatory issues that enabled Verizon Wireless to secure a nationwide spectrum footprint. Prior to joining Verizon Wireless, she was Vice President – Strategic Affiliations, of NextWave Telecom Inc. and Vice President of Freedom Technologies, Inc., a Washington, DC-based telecommunications consulting firm. She also served in the public sector as advisor to FCC Chairman Alfred C. Sikes on common carrier and radio spectrum issues and as a primary specialist in spectrum and internet policy at NTIA.

**Jeffrey H. Reed** is the founder of Wireless @ Virginia Tech, and served as its Director until 2014. He is the Founding Faculty member of the Ted and Karyn Hume Center for National Security and Technology and served as its interim Director when it was founded in 2010. He has co-founded several companies in wireless communications and cybersecurity areas. Dr. Reed recently served as the interim Director of the Commonwealth Cyber Initiative, a statewide research, teaching, and innovations center for Virginia. Dr. Reed is a Fellow of the IEEE.

**Tom Rondeau** is a DARPA program manager with a focus on adaptive and reconfigurable radios, improving the development cycle for new signal-processing techniques, and exploring new approaches and applications with the electromagnetic spectrum. Prior to joining DARPA, Mr. Rondeau was the maintainer and lead developer of the GNU Radio project, a visiting researcher with the University of Pennsylvania, and an Adjunct with the IDA Center for Communications Research in Princeton, NJ.

**Henning Schulzrinne,** Levi Professor of Computer Science at Columbia University, received his PhD from the University of Massachusetts in Amherst, Massachusetts. He was an MTS at AT&T Bell Laboratories and an associate department head at GMD-Fokus (Berlin), before joining the Computer Science and Electrical Engineering departments at Columbia University. He served as chair of the Department of Computer Science from 2004 to 2009, as Engineering Fellow, Technology Advisor and Chief Technology Officer at the US Federal Communications Commission (FCC) from 2010 to 2017. In 2019-2020, he worked as a Technology Fellow in the US Senate. He has published more than 250 journal and conference papers, and more than 70 Internet RFCs. Protocols co-developed by him, such as

RTP, RTSP and SIP, are used by almost all Internet telephony and multimedia applications. He is a Fellow of the ACM and IEEE, has received the New York City Mayor's Award for Excellence in Science and Technology, the VON Pioneer Award, TCCC service award, IEEE Internet Award, IEEE Region 1 William Terry Award for Lifetime Distinguished Service to IEEE, the UMass Computer Science Outstanding Alumni recognition, and is a member of the Internet Hall of Fame.

**Sanyogita Shamsunder** is the Vice President of Technology Development and 5G Labs at Verizon. Previously, she was Director of Advanced Wireless and Mobile Technology Planning, and has led the 5G network planning and Device Technologies teams at Verizon. She has directed and managed teams in all areas of the wireless business, including silicon, and network technology development, marketing, planning and strategy. Dr. Shamsunder received an MBA from The Wharton School, and a PhD in Electrical Engineering and Math from The University of Virginia.

**John M. Shea** is a Professor in the Department of Electrical and Computer Engineering at the University of Florida, where he has been on the faculty since 1999. His research is in the areas of wireless communications and networking, with emphasis on military communications, software-defined radio, networked autonomous systems, and security and privacy in communications. He was co-leader of Team GatorWings, the overall winner of the DARPA Spectrum Collaboration Challenge (DARPA's fifth grand challenge), in which the teams used software-defined radios to implement intelligent radio networks for collaborative spectrum sharing. He received the Lifetime Achievement Award for Technical Achievement from the IEEE Military Communications Conference (MILCOM) and is the only two-time winner of the Ellersick Award from the IEEE Communications Society for the Best Paper in the Unclassified Program of MILCOM. Dr. Shea was selected as a Finalist for the 2004 Eta Kappa Nu Outstanding Young Electrical Engineer Award. He has been an editor for IEEE Transactions on Wireless Communications, IEEE Wireless Communications magazine, and IEEE Transactions on Vehicular Technology. He is the author of more than 130 refereed journal and conference papers, as well as six book chapters.

**Douglas Sicker** is a Professor of Computer Science and Senior Associate Dean of Computing at the University of Colorado, Denver. Prof. Sicker is also the Executive Director of BITAG and co-Director of the IRLE (Institute for Regulatory Law and Economics). Previously, he served as the Lord Endowed Chair in Engineering, Department Head, interim Director of CyLab, and Professor of Computer Science at Carnegie Mellon University. He was a founder and continues on the Board of CMMB Vision, a high power L-band satellite company. Previously, Prof. Sicker was the DBC Endowed Professor in the Department of Computer Science at the University of Colorado at Boulder with a joint appointment in, and Director of, the Interdisciplinary Telecommunications Program. He recently served as the Chief Technology Officer and Senior Advisor for Spectrum at the National Telecommunications and Information Administration (NTIA). He also served as the CTO of the Federal Communications Commission (FCC) and prior to this he served as a senior advisor on the FCC National Broadband Plan. Earlier he was Director of Global Architecture at Level 3 Communications, Inc. In the late 1990s, he served as Chief of the Network Technology Division at the FCC. Prof. Sicker has published extensively in the fields of networking, wireless systems and network security.

**David Tennenhouse** is VMware's Chief Research Officer. Dr. Tennenhouse holds a BASc and MASc in Electrical Engineering from the University of Toronto and obtained his PhD at the University of Cambridge. He leads the research & innovation activities that are accelerating and extending VMware's technology leadership. These include: formation of a new VMware research group focused on networks and distributed systems; a portfolio of incubation activities; and the VMware academic program of engagements with university researchers. Dr. Tennenhouse has a track record of driving innovation, both in academia and industry. He joined VMware from Microsoft, where he was a Corporate Vice President and led their Technology Policy group. Dr. Tennenhouse was previously a Partner at New Venture Partners, where he focused on the creation of spin-outs from corporate R&D teams. Prior to that, he was Vice President of Platform Strategy at Amazon and CEO of its A9.com subsidiary. Before Amazon/A9, he was Vice President and Director of Research at Intel Corporation where he pioneered an "open collaborative" approach to corporate research. At DARPA and Intel, Dr. Tennenhouse was involved in the strategic planning and execution of programs related to a wide range of technologies, including distributed/cloud computing, networking, computer architecture, storage, wireless communications, machine learning, search/data mining, image

processing, robotics, MEMs, healthcare, and nano/bio-technology. As faculty at MIT, he led research on high-speed networking, active networks, software radio and telecommunications policy. He is a member of the ACM, a Fellow of the IEEE, and a member of the FCC's Technology Advisory Council.

**Andrew Boedigheimer-Thiessen** is the Division Chief for the Telecommunications and Information Planning Division of NTIA's Institute for Telecommunication Sciences. Mr. Thiessen's Division is responsible for functional areas that include 5G & beyond standardization, Public Safety and National Security/Emergency Preparedness, commercial mobile broadband test and evaluation, and Quality of Experience assessment for audio and video communications. Mr. Thiessen leads for NTIA on 5G standards and research & development. Prior to beginning work at ITS, he was the principal engineer at a startup (Integral Focus) focused on developing cloud based medical office management software. Prior to working at Integral Focus, he was a senior systems engineer for Sun Microsystems and MITRE, along with several successful starts ups including MessageMedia (purchased by DoubleClick), where he managed the integration of acquisitions into the business and managed the system architecture upon the successful integration. Mr. Thiessen started his career with the National Security Agency out of undergraduate school, working in varied areas. He did his undergraduate academic work at Worcester Polytechnic Institute, where he earned a BS in both Electrical Engineering and English. He received his MS in Electrical Engineering from Stanford University, and his MBA from Duke University. Mr. Thiessen is the recipient of Department of Commerce Gold, Silver, and Bronze medals for his work. He is also the recipient of the DJ Atkinson Technical Award from NPSTC.

**Bryan Tramont** is widely recognized as one of the nation's top media and communications lawyers. A relentless advocate, he is sought after by clients ranging from Fortune 50 companies to innovative startups for his exceptional understanding of spectrum management, transactions and strategic advocacy before multiple regulatory agencies. His commitment to excellence brings both loyal clients and leading industry honors. Mr. Tramont's years as Chief of Staff at the Federal Communications Commission under Chairman Michael Powell, along with his earlier work at the agency and beyond, give him a profound understanding of the often complex legal, political and regulatory environments where his clients operate. His keen

instincts for achieving results have been honed at the center of the industry. In addition to his role as Managing Partner of Wilkinson Barker Knauer LLP (WBK), Mr. Tramont also leads the strategy and implementation of WBK's award-winning communications, media and technology team, and directs client management and development. Mr. Tramont lives by the pay it forward ethos, a philosophy he has helped to infuse throughout WBK. He gives generously of his time and talents to support the community. Whether as a speaker, educator or thought-leader, he is always focused on helping others succeed and encouraging the next generation to thrive.

**Nishith Tripathi** is doing research on advanced wireless technologies beyond 5G at Samsung Research America. Dr. Tripathi is also an adjunct faculty member at Virginia Tech, where he teaches cellular communications and guides students in their research projects. He has co-authored the cellular industry's first-ever multimedia book on 5G as well as a textbook on Cellular Communications that is used at leading universities worldwide. As the 5G Technical Lead at Award Solutions, Dr. Tripathi led 5G training initiatives on content development and content delivery for comprehensive, in-depth, and practical technology courses. At Award Solutions, Dr. Tripathi developed content on 3G, 4G, and 5G cellular technologies and trained thousands of engineers and executives in the areas such as 5G, LTE-Advanced Pro (LTE-M/Cat-M, NB-IoT, LAA, and D2D/ProSe), LTE-Advanced, LTE, VoLTE, Radio and Core Networks, IMS, and RF Engineering. Dr. Tripathi designed and analyzed high-performance radio resource management (RRM) algorithms at telecom equipment manufacturers. His pioneering research on the applications of Artificial Intelligence (AI) in cellular networks has been published as a monograph and as part of a book on neuro-fuzzy applications. As an industry expert, he has contributed to FCC, CTIA, GSMA, Scientific American, EE Times University, and CNN Business.

**William Webb** is a consultant providing technical and strategic advice across the wireless communications space. His activities include advising CEOs, Government Ministers, regulatory bodies and acting as an Expert Witness. He was President of the IET – Europe's largest Professional Engineering body during 14/15. He was one of the founding directors of Neul, a company developing machine-to-machine technologies and networks, which was formed at the start of 2011 and subsequently sold to Huawei in 2014 for $25m. He then became CEO of the Weightless SIG, the standards body developing a new global M2M technology, a position he held until 2019. Prior to this, Dr. Webb was a Director at Ofcom where he managed a

team providing technical advice and performing research across all areas of Ofcom's regulatory remit. He also led some of the major reviews conducted by Ofcom including the Spectrum Framework Review, the development of Spectrum Usage Rights, and most recently cognitive or white space policy. Previously, Dr. Webb worked for a range of communications consultancies in the UK in the fields of hardware design, computer simulation, propagation modelling, spectrum management and strategy development. Dr. Webb also spent three years providing strategic management across Motorola's entire communications portfolio, based in Chicago. Dr. Webb has published 17 books, over 100 papers, and 18 patents. He is a Visiting Professor at Southampton University, a Fellow of the Royal Academy of Engineering, the IEEE and the IET and a non-executive director at Motability.

**Jaisha Wray** is the Associate Administrator for International Affairs at the Department of Commerce's National Telecommunications and Information Administration (NTIA). In this role, she formulates telecommunications and information policies and promotes these policies in international fora. Previously, she was the Director for International Cyber Policy in the Cybersecurity Directorate of the National Security Council where she was responsible for drafting and implementing the U.S. strategy on 5G technology as well as enhancing international cybersecurity cooperation with a wide range of partners and allies. She was also the Acting Deputy Director of the State Department's Office of Emerging Security Challenges where she contributed to the formulation of outer space and cyber stability policies and diplomatic strategies. At the State Department, she served as a Political Officer at U.S. Embassy London and as a Foreign Affairs Officer in the Office of Missile Defense and Space Policy. She began her government career as a Presidential Management Fellow where she completed rotations in the Space and Cyber Policy Directorate of the Office of the Secretary of Defense and in the National Reconnaissance Office. Ms. Wray holds a BA in Political Science from the University of California at Los Angeles as well as a MA in International Relations and a Master of Public Administration from the Maxwell School at Syracuse University. She has completed the International Space University Space Studies Program and the Harvard Kennedy School's Executive Education course on cybersecurity.

**Paul G. Zablocky** serves as a program manager in the Strategic Technology Office (STO) of the Defense Advanced Research Project Agency (DARPA). His programs focus on enabling joint operations, robust communications, wide area surveillance of small unmanned aircraft systems, airspace operations, and low cost seekers for weapons all in highly contested environments. Prior to that he served as the Office of Naval Research (ONR) Chief Scientist (Acting) and the Associate Research and Development Portfolio Director for Artificial Intelligence. In these roles he managed ONR's basic and early applied research portfolio and all aspects of ONR's Artificial Intelligence portfolio. Dr. Zablocky served as the Division Director in ONR's Expeditionary Maneuver Warfare Department where he was responsible for leading science and technology efforts in support of the United States Marine Corps (USMC). Prior to joining ONR, Dr. Zablocky served as the Director of the US Army Communications Electronics Research Development and Engineering Center (CERDEC) Intelligence and Information Warfare Directorate (I2WD) and the Director of CERDEC Space and Terrestrial Communications Directorate (S&TCD). In these positions he provided leadership and guidance in the execution of S&T programs, development of prototypes, and systems engineering support for Army programs. Dr. Zablocky received a Professional MBA from the University of Massachusetts, a PhD in Electrical Engineering from the University of Pennsylvania, an MS in Electrical Engineering from the University of Central Florida and BS in both Electrical Engineering and Physics from Fairleigh Dickinson University.

**Alenka Zajic** is currently an Associate Professor in the School of Electrical and Computer Engineering at the Georgia Institute of Technology. She received BS and MS degrees from the University of Belgrade, Serbia, and her PhD degree in Electrical and Computer Engineering from the Georgia Institute of Technology, Atlanta. Before joining Georgia Tech as an assistant professor, Dr. Zajic was a post-doctoral fellow in the Naval Research Laboratory and visiting faculty in the School of Computer Science at the Georgia Institute of Technology. Her research interests span electromagnetics, wireless communications, and computer engineering. Dr. Zajic is the recipient of the IEEE Atlanta Section Outstanding Engineer Award (2019), The Best Poster Award at the IEEE International Conference on RFID (2018), NSF CAREER Award (2017), Best Paper Award at the 49th Annual IEEE/ACM International Symposium on Microarchitecture (2016), the Best Student Paper Award at the IEEE International Conference

on Communications and Electronics (2014), Neal Shepherd Memorial Best Propagation Paper Award (2012), the Best Paper Award at the International Conference on Telecommunications (2008), the Best Student Paper Award at the Wireless Communications and Networking Conference (2007), IEEE Outstanding Chapter Award as a Chair of the Atlanta Chapter of the AP/MTT Societies (2016), LexisNexis Dean's Excellence Award (2016), and Richard M. Bass/Eta Kappa Nu Outstanding Teacher Award (2016). She was an editor for IEEE Transactions on Wireless Communications 2012-2017 and an executive editor for Wiley Transactions on Emerging Telecommunications Technologies 2011-2016.

**Ashley Zauderer** is a Program Director in the Division of Astronomical Sciences within the Directorate for Mathematical and Physical Sciences at the National Science Foundation. Her primary responsibility is Electromagnetic Spectrum Management, where she works to represent the scientific interests for protection and use of the electromagnetic spectrum both within the United States and internationally. In this role, she is the U.S. Head of Delegation to the Radio astronomy Working Party (7D) of the International Telecommunication Union and served as a spokesperson on the U.S. delegation for three agenda items at the 2019 World Radio Conference. Dr. Zauderer helps to lead NSF's Spectrum Innovation Initiative, a program designed to facilitate innovation and security in advanced wireless research, spectrum management, and passive uses of the spectrum. At the National Science Foundation, she also serves as the Program Officer overseeing the Arecibo Observatory. Dr. Zauderer completed her MS and PhD in Astronomy at the University of Maryland, College Park and her Bachelor's in Astrophysics at Agnes Scott College, working as a research intern for the California Institute of Technology and Cornell University before and during graduate school. Upon completion of her PhD, she was a Research Fellow and an NSF Astronomy & Astrophysics Postdoctoral Fellow in the Berger Time Domain Group at Harvard University. Her research specialization is observational radio astronomy applied to some of the most explosive astrophysical transients in the Universe including supernovae, gamma-ray bursts, and tidal disruption events of stars around supermassive black holes.

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