

PATH LOST: NAVIGATING PROPAGATION CHALLENGES FOR ULTRA- DENSE WIRELESS SYSTEMS



International Symposium on
Advanced Radio Technologies

JULY 24-26, 2018
Broomfield, Colorado

ISART 2018

ISART 2018 is jointly sponsored by the National Telecommunications and Information Administration's (NTIA) Institute for Telecommunication Sciences (ITS) and the National Institute of Standards and Technology's Communications Technology Laboratory (NIST/CTL).

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. ITS, NTIA's telecommunications research laboratory, performs cutting-edge telecommunications research and engineering. This research informs spectrum policy and management activities and is also applied to resolving technical telecommunications issues for other Federal government agencies.

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. CTL was formed in 2014 to promote 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.

NAVIGATING PROPAGATION CHALLENGES FOR ULTRA-DENSE WIRELESS SYSTEMS

Network densification in response to the explosion in demand for wireless data presents technical, economic, and regulatory challenges. In the scramble to meet the demand for wireless data, alternatives and adjuncts to fixed frequency assignment and infrastructure-based networks, such as coexistence, spectrum sharing, and infrastructureless communications are being introduced. Network operators are looking to ultra-dense networks and ever-shrinking cell sizes to build capacity, but existing propagation models have an inadequate level of fidelity to represent these environments. Detailed knowledge of radio frequency propagation in these ultra-dense network environments is key to not only building capacity but also regulating in ways that ensure minimal interference and offer appropriate economic incentives. Accurate, reliable, validated, and trusted propagation models that can predict signal strength across a wide variety of environments and conditions are key to navigating the challenges of deploying ultra-dense wireless systems in shared radio spectrum. ISART 2018 will bring together leading experts from government, academia, and industry to explore the current state of the art and map the path forward to the next generation of foundational propagation models.

GENERAL CHAIR

Chris R. Anderson, NTIA/ITS
303-497-3414

VICE-CHAIR

Rebecca Dorch, NTIA/ITS
303-497-5221

TECHNICAL COMMITTEE

Geoff Sanders, NTIA/ITS
303-497-6736

Billy Kozma, NTIA/ITS
303-497-6082

Doug Boulware, NTIA/ITS
303-497-4417

CONFERENCE COORDINATORS

Christine Carson, NIST/CTL
303-497-3831

Gladys Arrisueno, NIST/PAO
301-975-5220

Jointly sponsored by the
National Telecommunications and Information Administration
Institute for Telecommunication Sciences
and the
National Institute of Standards and Technology
Communications Technology Laboratory



ITS

Institute for Telecommunication Sciences
Boulder, Colorado

NIST
National Institute of
Standards and Technology
United States Department of Commerce



ISART SYMPOSIUM



July 24-26, 2018

Registration Desk open

8:00 A.M. TO 5:00 P.M.

Product Demos

8:00 A.M. TO 5:30 P.M.

Poster Session

8:00 A.M. TO 5:30 P.M.

9:00 A.M.

MORNING EVENTS

- **Commerce Spectrum Management Advisory Committee (CSMAC) Meeting**
- **Demos from the ITS Labs**

12:00 P.M.

BREAK/POSTER SESSION

1:00 P.M.

WELCOME AND OPENING REMARKS

Keith Gremban, Director, Institute for Telecommunication Sciences, NTIA

1:20 P.M.

OPENING KEYNOTE ADDRESS

- **It's Getting Crowded in Here! Understanding the Spectrum Implications of IoT and 5G**
David J. Redl, Assistant Secretary for Communications and Information and Administrator, NTIA

1:50 P.M.

PLENARY ADDRESS

- **Ultra-dense Networks**
Scott Townley, Technology Fellow, Verizon Network Technology Strategy

2:30 P.M.

BREAK/POSTER SESSION

3:00 P.M.

PANEL

- **Mapping a Path Forward: Economics, Applications, and Policy Implications**
Moderator: Giulia McHenry, NTIA Chief Economist

Ongoing research into propagation modeling supported by academic, industry, and federal spectrum research funds and industry-government collaborations have set the stage for marked improvements in modeling. A forward looking approach requires preliminary analyses of future rulemakings to determine use case scenarios and propagation morphologies and a research effort that leads—not lags—upcoming rulemakings. This session will explore policy implications of improved propagation modeling, discuss economic valuations of improved models, and explore means of coordinating research at the national and international level.

Panelists:

- Julius P. Knapp, FCC, Office of Engineering and Technology
- Marc Levesque, Communications Research Centre Canada
- Peter Tenhula, NTIA, Office of Spectrum Management
- Bryan N. Tramont, Wilkinson Barker Knauer, LLP
- Scott Wallsten, Technology Policy Institute

**TUESDAY
JULY 24TH**

8:30 A.M.

KEYNOTE ADDRESS

Heidi King, Deputy Administrator, National Highway Traffic Safety Administration, U.S. Department of Transportation

9:00 A.M.

TECHNICAL TALK

- **Considerations for Mobile Urban Applications**

Keith Gremban, Director, Institute for Telecommunication Sciences, NTIA

9:10 A.M.

TECHNICAL TALK

- **Data and More Data: Inputs to Modern Propagation Prediction Tools**

Roger Skidmore, CEO, EDX Technologies, Inc.

9:30 A.M.

BREAK/POSTER SESSION

10:00 A.M.

PANEL

- **Preparing the Road: Recent Advances in Modeling Infrastructure**

Moderator: William Kozma, NTIA/ITS

Vast improvements in terrain databases, computational power, and measurement data repositories have fostered a renaissance in propagation model development. Increased collaboration has led to improved measurement methods using narrowband and broadband channel sounders, more extensive measurement data sets, applications of common, high resolution terrain databases, precision geolocation, etc. However, more data does not necessarily mean better data or better results, thus the panel will also look at how to make sense of what tools are available and how to utilize those new tools. The overall purpose of this panel is to promote a shared awareness of these new resources and their potential applications and value to different stakeholders.

Panelists:

- Daniel J. Breton, U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory (CRREL)
- Ben Hilburn, DeepSig, Inc.
- Katherine Mulreany, Naval Surface Warfare Center
- Frank Rotondo, Institute for Defense Analyses
- Roger Skidmore, EDX Technologies, Inc.

**WEDNESDAY
JULY 25TH**

12:00 P.M.

LUNCH BREAK

1:30 P.M.

ROADSIDE CHAT

- **Visions of the Road Ahead**

Moderator: Mark Gibson, Director, Business Development, CommScope

Massive reductions in uncertainty and dramatic increases in modeling precision have transformational possibilities. Our distinguished guests will share and debate their visions of what could lie beyond next-generation wireless if technology, policy, and economics can be aligned.

- Paul Kolodzy, Kolodzy Consulting
- Preston Marshall, Engineering Director and Principal Wireless Architect, Google LLC Communications

2:30 P.M.

TECHNICAL TALK

- **Link Budget Uncertainty**

Thomas Schwengler, principal architect, wireless strategy and developments, CenturyLink, and adjunct faculty at the University of Colorado, Boulder

3:00 P.M.

BREAK/POSTER SESSION

3:30 P.M.

PANEL

- **Driving Forward: Advances in Propagation Modeling**

Moderator: Kevin Sowerby, University of Auckland

The availability of higher fidelity datasets and the desire for increased precision in modeling results has led to a re-visiting of how to handle modeling the radio environment. Features such as vegetation, building clutter, and 3D geometries had traditionally been either ignored by existing models or incorporated after-the-fact as a form of endpoint correction. This panel will look at ongoing research that strives to implicitly incorporate such features directly into the propagation model.

Panelists:

- Evelyn Dohme, University of New Mexico
- Katsuyuki Haneda, Aalto University
- David W. Matolak, University of South Carolina
- Paul McKenna, NTIA/ITS



WEDNESDAY
JULY 25TH

8:30 A.M.

TECHNICAL TALK

- **Current DoD Propagation Challenges**

Howard McDonald, Defense Spectrum Organization, Defense Information Systems Agency

9:00 A.M.

TECHNICAL TALK

- **Modeling Interference Risk: Propagation and other Uncertainties**

Pierre de Vries, Silicon Flatirons Center

9:30 A.M.

TECHNICAL TALK

- **Overview of 5G Channel Models in 3GPP**

Jean-Aicard Fabien, NTIA/ITS

10:00 A.M.

BREAK/POSTER SESSION

10:20 A.M.

PANEL

- **Tuning for Precision: Best Practices for Measurements and Models**

Moderator: Lorne Liechty, CEO, EDX Wireless

Once models have been developed they need to be verified and validated. Verification is the process of establishing the truth, accuracy, or soundness of something. Validation, on the other hand, demonstrates that a product or product component fulfills its intended use when placed in its intended environment. This panel will discuss techniques for accomplishing this and address typical timelines, roadblocks, risks, and challenges.

Panelists:

- Chriss Hammerschmidt, NTIA/ITS
- James Linehan, Alion Science and Technology
- Mark Poletti, CableLabs
- Jeanne Quimby, NIST/CTL

12:05 P.M.

ENDNOTE

Keith Gremban, Director, Institute for Telecommunication Sciences, NTIA

**THURSDAY
JULY 26TH**

12:25 P.M.

LUNCH BREAK

1:40 P.M.

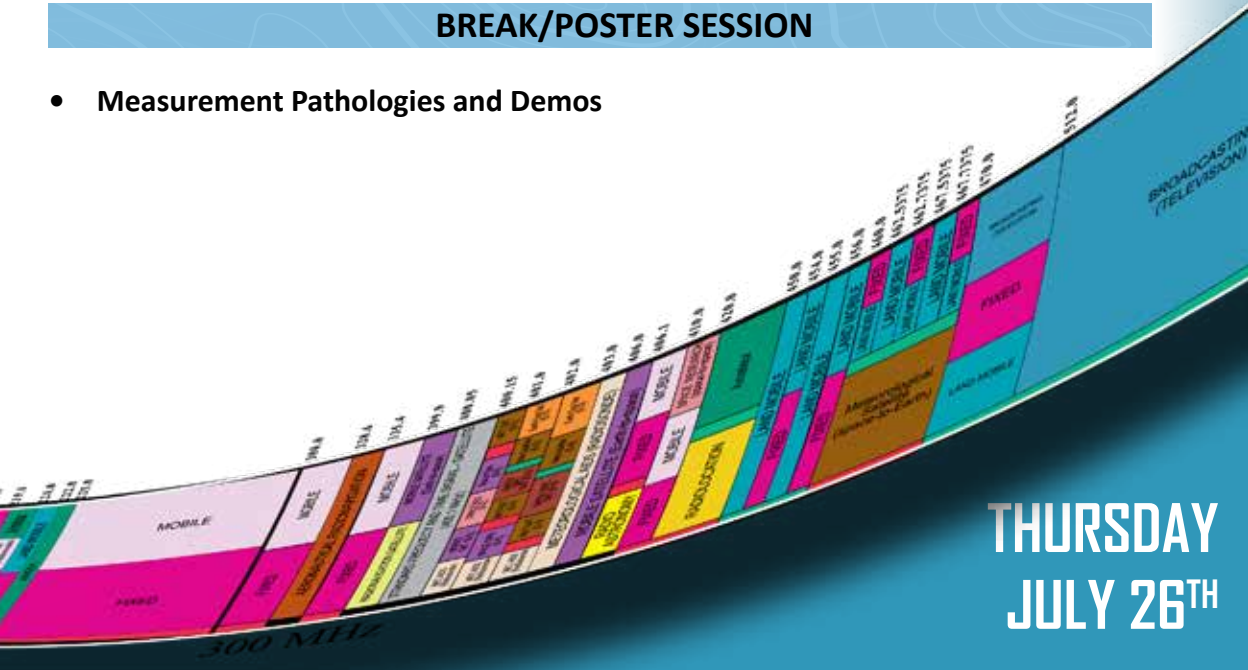
HANDS-ON WORKSHOP AND DEMO SESSION

Highly accurate propagation measurements are key to both model development and model validation. This two-part workshop will focus on precision propagation measurements and best practices. The first part will include a series of talks on precision propagation measurement systems, best practices for doing accurate propagation measurements, and ways to assess measurement uncertainty of a measurement system. The second part of this session will consist of live demos with actual propagation measurement systems. Experts will demonstrate best measurement practices with these systems, what is needed to get the best out of a propagation measurement system, and problems that can occur if best practices are not followed.

- **Benchmarking Measurements and Modeling**
 - **Introduction & Overview**
 - Robert Johnk, NTIA/ITS
 - **Three Propagation Measurement Systems**
 - Erik Hill, NTIA/ITS
 - Robert Johnk, NTIA/ITS
 - Jeanne Quimby, NIST/CTL
 - **Best Measurement Practices**
 - Chriss Hammerschmidt, NTIA/ITS
 - Anna Paulson, NTIA/ITS
 - **Channel Sounder Intercomparisons**
 - Jeanne Quimby, NIST/CTL
 - **Screening Experiments in Mobile Channel Measurements**
 - Mark McFarland, NTIA/ITS

BREAK/POSTER SESSION

- **Measurement Pathologies and Demos**



THURSDAY
JULY 26TH

Daniel J. Breton is a Research Geophysicist with the Signature Physics Branch at the Cold Regions Research and Engineering Laboratory (CRREL), a part of the Engineer Research and Development Center, the research arm of the U.S. Army Corps of Engineers. Prior to joining CRREL, he was a U.S. Navy submarine officer aboard the USS Parche (SSN 683), obtained his PhD in Physics from the University of Maine, and completed his post-doctoral work at Dartmouth. His current research includes measurement and estimation of the ground-to-ground radio channel used by ground-based military and first-responder operations in geospatially complex terrain (mountains, urban, etc.) where opportunities for line-of-sight and/or radio infrastructure are limited.

Pierre de Vries is an Executive Fellow of the Silicon Flatirons Center at the University of Colorado, Boulder, and Co-Director of its Spectrum Policy Initiative. He is a Visiting Senior Scientist at the Institute for Networked Systems of RWTH Aachen University, and serves on the FCC Technology Advisory Council. His current work focuses on maximizing the value of radio operation by modeling and managing inter-system interference. 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 D.Phil. in theoretical physics from the University of Oxford.

Evelyn Dohme is currently a PhD graduate student at Applied Electromagnetic Group, University of New Mexico (UNM), where she received her masters of engineering (2018). She received her bachelors of art and science from Xavier University in theoretical physics (2008). She was a Program Coordinator and Assistant Program Officer at The Air Force Office of Scientific Research (AFOSR) (2011-2016), where she had been selected as AFOSR Team of Quarter Award Recipient (2015, 2014, 2013, 2012) and Team of the Year Award Recipient (2011). She currently works with Prof. Zhen Peng at UNM, focusing on wireless communications, antenna efficiency, and wave scattering in congested and contested environments.

Jean-Aicard Fabien was born in Haiti and moved to New York in 1972 where he studied electronics engineering technology at the RCA Institutes. He holds a BS in electronics engineering technology from the Capitol Institute of Technology and an MSEE with a focus on communications and networks from George Washington University. Fabien started his career in hardware design and systems integration and test for industrial applications, paging systems, and satellite communications systems. He was involved in system design, planning, and deployment of a wideband satellite TDMA system (SBS) and in the trial deployment of the Personal Earth Station hub network with Hughes Network Systems. He was a member of the system design group for an air to ground system (Claircom) and for a geostationary mobile system (Thuraya). Fabien joined Motorola in 1998, initially working in Iridium system design and later in standards development and research for WCDMA, HSPA, and LTE. After briefly serving as a patent examiner at the USPTO, Fabien moved to NTIA/ITS, where he is participating in several spectrum sharing projects. Fabien has co-authored 10 issued patents, mostly in physical and MAC layer signaling, and continues to participate in and monitor standardization of radio technology at 3GPP.

Mark Gibson has served as a member of NTIA's Commerce Spectrum Management Advisory Committee since 2011 and is currently a Co-Chair. Gibson has more than 30 years of spectrum management experience and is responsible for developing domestic and international business opportunities for Comsearch. He has led Comsearch's spectrum management efforts including the development of spectrum sharing analysis protocols and sharing criteria, as well as development of Comsearch's engineering services and software products. Gibson 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 and received his BSEE from the University of Maryland.

Keith Gremban is the Director of the Institute for Telecommunication Sciences (ITS), which is the research and engineering laboratory for the National Telecommunications and Information Administration (NTIA). Gremban has been involved in systems engineering and advanced technology development for over thirty years. Prior to arriving at ITS, Gremban was a Program Manager at the Defense Advanced Research Projects Agency (DARPA) where he managed a portfolio of programs in the areas of wireless communications and electronic warfare. Prior to DARPA, Gremban worked at a variety of companies and research institutes, managing and leading research and systems engineering projects, including a diverse collection of unmanned systems and command-and-control applications. Gremban received his Ph.D. and M.S. in Computer Science from Carnegie Mellon University, and his M.S. in Applied Mathematics and B.S. in Mathematics from Michigan State University.

Chriss Hammerschmidt joined NTIA/ITS in 2010. She is currently involved with spectrum surveys, propagation measurements, and soil permittivity and conductivity material measurements. Prior to joining ITS, she was with NIST from 1990 to 2010. During her time at NIST she worked in the area of material measurements using stripline cavities, coaxial airlines, Fabry-Perot resonators, and free-field, time-domain systems. She has also worked in the noise temperature project assembling and running measurement systems. She then moved to the Time-Domain project where she worked on measuring the shielding effectiveness of aircraft, including the orbiter Endeavour. Hammerschmidt received a bronze medal for her work on the Endeavour project. Hammerschmidt has a B.A. degree in physics and an M.S. degree in electrical engineering, both from the University of Colorado Boulder.

Katsuyuki Haneda received the Doctor of Engineering from the Tokyo Institute of Technology, Tokyo, Japan, in 2007. Haneda is presently an associate professor in the Aalto University School of Electrical Engineering. He is the recipient of the best paper award of the antennas and propagation track in the IEEE 77th Vehicular Technology Conference (VTC2013-Spring), Dresden, Germany, and of the best propagation paper award in the 7th European Conference on Antennas and Propagation (EuCAP2013), Gothenburg, Sweden. Haneda served as an associate editor for the IEEE Transactions on Antennas and Propagation for 2012-2016 and has been an editor of the IEEE Transactions on Wireless Communications since 2013. He has also been an active member of a number of European COST Actions, e.g., as a co-chair of Working Group on Radio Channels in CA15104 "Inclusive Radio Communication Networks for 5G and beyond (IRACON)." His current research activity focuses on high-frequency radios such as millimeter-wave and beyond, wireless for medical and post-disaster scenarios, radio wave propagation modeling, and in-band full-duplex radio technologies.

Ben Hilburn is the Director of Engineering at DeepSig Inc., which is commercializing the fundamental research behind deep learning applied to wireless communications and signal processing. He also runs GNU Radio, the most widely used open-source signal processing toolkit in the world, serving as Project Lead and President of The GNU Radio Foundation. He received his B.S. and M.S. degrees from Virginia Tech in Computer Engineering, with minors in Mathematics and Computer Science, and went on to become the first Hume Fellow at the Hume Center for National Security and Technology. He works heavily in the open-source community, across government, industry, and academia.

SPEAKER BIOGRAPHIES

Erik Hill received a B.S. in Engineering Physics with a minor in Computational and Applied Mathematics in 2010 from the Colorado School of Mines and an M.S. in Physics in 2012 from the University of Florida, where he specialized in quantum field theory and computational physics. Hill has been a researcher at the Institute for Telecommunication Sciences in Boulder, Colorado since 2016 where he has worked on developing and using a pseudorandom noise sliding correlator channel sounder to perform path loss and other channel properties measurements. Hill is the United States delegate to the United Nations ITU-R Study Group 3 Working Party on Electromagnetic Propagation Fundamentals. Prior to joining the Institute, Hill worked for the United States Air Force as an analyst for experimental weapon systems.

Robert Johnk received his Ph.D. in Electrical Engineering at the University of Colorado in 1990, where he specialized in electromagnetics, propagation, and antennas. Johnk is currently an electronics engineer at the Institute for Telecommunication Sciences (NTIA/ITS) where he is engaged in public safety radio and mobile radio propagation research. Prior to joining NTIA/ITS in 2007, he was with the National Institute of Standards and Technology (NIST) in Boulder, Colorado, for 17 years where he was the leader of the time-domain fields project. Johnk has received best paper awards from the IEEE EMC Society, NIST, and NTIA. In 2011, Johnk received a technical achievement award from the IEEE EMC Society in 2011 for his work “in the development of free-space time-domain measurement techniques.”

Heidi King is the Deputy Administrator of the National Highway Traffic Safety Administration. She comes to NHTSA with extensive experience in public safety, innovation, risk management, evidence-based decision-making and law enforcement. An economist and research scientist by training, King parlayed degrees from California Institute of Technology and University of California, Irvine, and her early experience as a California State Park Ranger into a distinguished career in both government and the private sector. Her work at Telcordia Technologies, a research and development company established after the 1982 breakup of Bell Laboratories, fueled a life-long passion for research innovation and the ability to anticipate and foster technological progress. Areas of particular interest to her in this context include cybersecurity and the development of automated driving systems. King served as a Regulatory Policy Analyst in the White House’s Office of Management and Budget (OMB) from 1998 to 2000 and 2007 to 2011, and two years as Chief Economist on the House Committee on Energy and Commerce. Having worked as Senior Manager of Management Science at Pfizer Inc. from 2002 to 2006, and as Global Director of Environmental Risk at General Electric (GE) from 2013 to 2016, she is well-versed in the private sector and the market-forces that challenge manufacturers.

Julius Knapp has been with the FCC for 44 years and has served as the Chief of the FCC’s Office of Engineering and Technology (OET) since 2006. OET is the Commission’s primary resource for engineering expertise and provides technical support to the Chairman, Commissioners and FCC Bureaus and Offices. He received the FCC’s Silver and Gold Medal Awards for distinguished service at the Commission as well as the Presidential Distinguished Rank Award for exceptional achievement in the career Senior Executive Service. Knapp has been the recipient of the Eugene C. Bowler award for exceptional professionalism and dedication to public service; the Federal Communications Bar Association Excellence in Government Service Award; the WCAI Government Leadership award; the National Spectrum Management Association Fellow Award; the Association of Federal Communications Consulting Engineers E. Noel Luddy Award; the Satellite Industry Association Satellite Leadership in Government Award; and, the Dynamic Spectrum Alliance Lifetime Achievement Award. Knapp is a Life Member of the IEEE. He received a Bachelor’s degree in electrical engineering from the City College of New York in 1974.

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 also has contributed in counter-UAS, underwater acoustic signal processing, laser measurement systems, and advanced signal analysis technologies. Kolodzy has served on multiple National Research Council studies on spectrum management and a counter-UAS study. He is a member of the Commerce Spectrum Management Advisory Committee (CSMAC). His career has spanned both public and private sectors (MIT/LL, Sanders, Stevens Institute, DARPA, FCC).

William (“Billy”) Kozma, Jr is a Computer Engineer at the Institute for Telecommunication Sciences. He works in the Telecommunications Theory Division in the area of propagation modeling, with recent work focused on air-to-ground modeling. Kozma specializes in applying propagation theory to software techniques to assist in solving relevant spectrum problems. He is also active in the ITU-R Study Group 3 as both a contributor and the U.S. Head of Delegation. Prior to arriving at ITS, Kozma worked as software developer and system architect at the Space and Naval Warfare Systems Command (SPAWAR) and a software development and test engineer at Microsoft. Kozma received his M.S. degree from the University of Arizona in Electrical and Computer Engineering.

Marc Levesque is Vice-President of the Communications Research Centre Canada’s Wireless Technologies branch. He joined the CRC in 2015, with over 20 years of experience spanning engineering, technical sales, business development and management. Levesque joined the CRC from Altera Corporation, where he served as a Global Account Manager, leading an international team focusing on telecommunications customers. Earlier in his career, he worked in various engineering capacities—including hardware design, software development, system verification and field support—for companies supplying telecommunications equipment, such as Nortel. This experience in research and development (R&D) formed the engineering base that propelled him into technical sales, business development and senior management. It also provided him with an in-depth understanding of guiding scientific principles that he applies in R&D team leadership today. Levesque also brings to the CRC a strong track record interfacing with stakeholders, from internal experts tackling technical issues and team members managing business functions, to external collaborators and global clients. Levesque has a BSc in Electrical Engineering from the University of New Brunswick and a Master’s Degree in Engineering Management from the University of Ottawa. He is a Professional Engineer with the Association of Professional Engineers of Ontario.

Lorne Liechty started his career in RF theory and wireless network design with a lead role in the design and development of indoor and outdoor wireless design products at Motorola, where he combined theory with practice to enable customer success. Later, Liechty expanded his role in technology management at Motorola Solutions and Bypass Mobile, managing applications across desktop, mobile, web, and cloud platforms. Liechty joined EDX Wireless in 2018 to return to the wireless domain with the wealth of experience he brings in technology company growth and operations. Liechty is an Electrical Engineering alum of Texas A&M University and received his M.S. degree in Electrical and Computer Engineering from the Georgia Institute of Technology.

James (Jim) Linehan has 42 years of experience in the electrical/electronic engineering field and currently serves as a Senior Principal RF Engineer at Alion Science and Technology. He has performed in a variety of roles related to the inception, planning, execution, analysis, and documentation of radio-frequency (RF) and electromagnetic compatibility (EMC) measurements, including bench and field measurements in support of model development and validation. Experience includes measurement of transmitter and receiver characteristics; propagation loss; system-level performance of RF systems; non-linear effects; antenna characteristics; and electromagnetic environmental (EME) surveys. Linehan is knowledgeable in RF system engineering related to terrestrial RF systems and satellite earth stations and associated subsystems, and presently leads the technical development and fielding of an automated spectrum monitoring system designed to detect radio-frequency energy and potential interference and jamming activity.

SPEAKER BIOGRAPHIES

Preston F. Marshall is an Engineering Director, and Principal Wireless Architect for Google LLC Communications, responsible for spectrum access technology, with a focus on the creation of a vibrant ecosystem of equipment, users, and standards in the newly shared 3.5 GHz Citizen's Broadband Radio Service (CBRS) band. He is chair of the Wireless Innovation Forum Spectrum Sharing Subcommittee, co-chair of the Steering Group developing the standards base for 3.5 GHz spectrum sharing, and vice chair of the CBRS Alliance, developing coexistence and neutral host technology for the 3.5 GHz band. He has a new book on this subject, "Three Tier Shared Spectrum, Shared Infrastructure, and a Path to 5G", just released by Cambridge University Press, as well as two prior books on Cognitive Radio. He has been heavily involved in wireless technology and policy, including: Deputy Director of the Information Sciences Institute (ISI) of University of Southern California, a Research Professor at USC's Electrical Engineering Department, and before that, Program Manager for many of the Defense Advanced Research Projects Agency (DARPA) wireless and spectrum programs.

David W. Matolak has over 20 years' experience in communication system research, development, design, and deployment, with private companies, government institutions, and academia, including AT&T Bell Labs, L3 Communication Systems, MITRE, and Lockheed Martin. He has over 200 publications, eight patents, and expertise in wireless channel characterization, spread spectrum, ad hoc networking, and their application in civil and military terrestrial, aeronautical, and satellite communication systems. He has been a visiting professor at several institutions in the U.S. and Europe, has worked on multiple NASA aviation projects, and serves on the ITU Radio Propagation Study Group. He was with Ohio University from 1999-2012, and is now a professor at the University of South Carolina. His research interests are radio channel modeling and communication techniques for non-stationary fading channels, multicarrier transmission, aviation communications, and mobile ad hoc networks. Matolak is a member of Eta Kappa Nu, Sigma Xi, Tau Beta Pi, URSI, ASEE, AIAA, and a senior member of IEEE

Howard McDonald joined the Defense Information Systems Agency (DISA) Defense Spectrum Organization (DSO) in December 2008 after a 23 year career in private industry addressing a wide variety of challenges associated with DoD spectrum operations. He has successfully guided multidisciplinary teams to perform electromagnetic environmental effects and spectrum management related activities at all phases of the equipment life cycle. He is currently the Branch Chief for DSO's Advanced Access Initiatives Branch, leading DSO's efforts to address the impacts of emerging technologies, including Dynamic Spectrum Access and Policy-Based Spectrum Management, on DoD spectrum operations. McDonald is also responsible for the DoD 1755-1780 MHz Spectrum Sharing Test and Demonstration Program and the development of the DoD 1755-1780 MHz Coordination Portal.

Mark McFarland is a Board certified electrical engineer and statistician. His research has been published in national and international peer-reviewed journals, and he has addressed national and international audiences at technical conferences over his 20+ year career. He earned a BSEE from Lehigh University, and two Master of Engineering (ME) degrees in Telecommunications and Engineering Management from the University of Colorado. McFarland also holds a Six Sigma Master Black Belt certification from the University of Colorado. His practice areas include electrical engineering, data mining, inference and prediction, and quality improvement and control.

Giulia McHenry joined the National Telecommunications and Information Administration (NTIA) as the Chief Economist in November 2015. She is an expert in the economics of the Internet, telecommunications, and media. She advises and has written reports on a range of issues including broadband policy, adoption, and access; the digital economy; and the economics of spectrum and spectrum management. She is particularly focused on incentives to improve spectrum efficiency and effectiveness of federal agencies, methods for defining and measuring the digital economy, and digital adoption and connectivity. Prior to joining NTIA, McHenry was a Senior Associate at The Brattle Group, where she focused on telecommunication matters, prepared expert reports and coauthored papers related to spectrum management and valuation, broadband deployment, regulatory proceedings, Universal Service Fund, and competition policy. McHenry received her Ph.D. in economics from the University of Maryland in 2009. She specialized in microeconomics, both applied and empirical methods. In particular, she focused on network theory and industrial organization. Her dissertation addressed issues related to social networking and successful entrepreneurship.

Paul McKenna has been with NTIA's Institute for Telecommunication Sciences (ITS) as an Electronics Engineer since 1998. Prior to that, he was Staff Scientist with Electro Magnetic Applications, Inc. McKenna received an M.S. (Astro-Geophysics) from the University of Colorado Boulder in 1983 and an A.B. (Astronomy, m.c.l.) from Harvard University in 1974. From 1974 to 1977, McKenna taught A- and O-level Physics and Mathematics at Nyeri High School in Nyeri, Kenya, as a U.S. Peace Corps volunteer. McKenna is a Member of the IEEE and currently serves as International Chairman of the ITU-R Working Party 3K (Point-to-Area Propagation). McKenna's work at ITS is generally concerned with the development and application of electromagnetic wave propagation predictive models, including both empirical and deterministic models such as the Okumura-Hata, the FCC-Carey Curves, the Irregular Terrain Model (ITM), the Terrain Integrated Rough Earth Model (TIREM), ITU-R Recommendations P.452 and P.1546, the Millimeter (Wave) Propagation Model (MPM), and the ITS-FAA-1977 (IF-77) model. McKenna's work also includes research and development on other computational electromagnetics models and methods, including Fresnel-Kirchhoff, Parabolic Equation, Finite Difference Time Domain (FDTD), Ray Tracing, and hybrid Integral Equation methods, as applied to a range of wave propagation, scattering, and coupling problems.

Katherine Mulreany received a B.S. in Meteorology from North Carolina State University in 2006. She is currently working on her M.S. in Atmospheric Science from Texas Tech University. Mulreany is currently a Lead Scientist at the Naval Surface Warfare Center in Dahlgren, Virginia in the Electromagnetic and Sensor Systems Department. She performs research in numerical weather prediction and electromagnetic propagation and supports research, development, test, and evaluation of Navy electromagnetic systems.

Anna Paulson began her career in Telecommunications as a Multichannel Transmission Systems Operator (31R) in the 10th Signal Battalion of the U.S. Army's 10th Mountain Division. After leaving the Army, she worked as a Network Technician for Broadwing Communications (a high capacity network provider) while completing her Bachelor of Science in Electrical Engineering at the University of Colorado at Denver. Paulson has spent the majority of her time at ITS as an Electronics Engineer as part of the Public Safety Communications Research group conducting research on priority mobile (LTE) communications, communications protocol analysis, and call modeling/simulation on behalf of the U.S. Department of Homeland Security's Office of Emergency Communication. She is currently the project lead for the Precision Geolocation project in the Spectrum and Propagation Measurements Division at ITS. Paulson is a graduate of the U.S. Department of Commerce's Aspiring Leaders Development Program.

SPEAKER BIOGRAPHIES

Mark Poletti is the Director of wireless technologies at CableLabs; a non-profit R&D organization that is dedicated to creating and driving technologies and innovations critical to the cable industry's technology roadmap. In this role, Poletti is responsible for wireless R&D activities across fixed, mobile and emerging wireless technologies. Prior to CableLabs, Poletti has built, managed and operated 3G (CDMA) and 4G (WiMax) networks for US WEST and Clearwire, respectively. He has also been addressing mobile operator design, operations and performance issues of 2G, 3G, 4G, and satellite networks for over 20 years with such companies as ViaSat, Clearwire, ATECS/Centerline, U S WEST/Qwest, and General Electric. Poletti holds a M.S in Telecommunications from University of Colorado and has multiple issued and pending patents.

Jeanne T. Quimby is a Researcher in the Metrology for Wireless Systems Group in the Communication Technology Laboratory (CTL) at NIST, Boulder. She received a B.S. degree from the University of California of San Diego and her M. S. and Ph.D. degrees from The Ohio State University. Her thesis involved an efficient representation of phased array and dish antennas using spherical harmonics as an input into a ray tracing technique. She served as a research scientist for the U.S. Navy working in military communications before joining CTL. She has authored and co-authored numerous papers for conferences, journals and patents. She is a contributor to the NIST 5G mmWave Channel Modeling Alliance. Her current research interests are channel sounder measurements in multiple environments including manufacturing facilities, channel sounder hardware verification for 5G applications, and channel sounder uncertainty. Quimby is a member of IEEE.

David J. Redl serves as Assistant Secretary for Communications and Information at the Department of Commerce and Administrator of the National Telecommunications and Information Administration (NTIA), the Executive Branch agency that is principally responsible for advising the President on telecommunications and information policy. Redl is a lawyer and communications policy expert with more than a decade of experience in government and the private sector. He was previously the chief counsel at the U.S. House of Representatives Committee on Energy and Commerce. In that role, he served as principal legal advisor to the chairman and members of the Energy and Commerce majority on communications and technology matters. Prior to his time with the committee, Redl was director of regulatory affairs at CTIA, a trade association that represents the U.S. wireless communications industry. Redl earned his J.D. from the Catholic University of America with a certificate from the Institute for Communications Law Studies, and he is a graduate of Pennsylvania State University with degrees in journalism and political science.

Frank Rotondo is a researcher in the Science and Technology Division of the Institute for Defense Analyses, where he has focused on the development of RF, communications, and radiation detector technologies, as well as the assessment of energy & power systems. He previously worked at Lockheed Martin Corp., where his research centered on RF and CBRNE sensor development, and technologies for the clean energy sector. Rotondo earned his Ph.D. in Physics at Yale University and B.S. in Applied Physics at Columbia University's School of Engineering and Applied Science.

Thomas Schwengler is principal architect and chief wireless architect at CenturyLink, where he researches and analyses a broad range of wireless systems and services. He held positions as director of RF engineering at Qwest wireless, senior staff engineer at US WEST Advanced Technologies, and research engineer at France Telecom R&D. His areas of work are RF engineering applied to wireless voice and broadband communications. Current areas of interest include propagation and performance modeling and measurements, lab and field trials, especially focus on Wi-Fi and LTE.

Roger Skidmore is a 20+ year veteran of the wireless industry, with much of that time focused on the design and simulation of wireless networks. He was co-founder of Wireless Valley Communications, a leading edge inbuilding wireless network design and simulation company, which he led to successful acquisition by Motorola. He went on to serve as Director of Emerging Technologies in Motorola's enterprise network design and management group, and later as Principal Architect of ATT's small cells group. Until just recently, he was CEO of EDX Wireless, a leading wireless network design software company. He is currently CEO of EDX Technologies, an augmented reality software startup. He received both his MS and PhD in wireless communications at Virginia Tech.

Kevin W. Sowerby received the B.E. and Ph.D. degrees in Electrical and Electronic Engineering from the University of Auckland in 1986 and 1989, respectively. During 1989 and 1990, he was a Leverhulme Visiting Fellow at the University of Liverpool (UK). In 1990, he returned to the University of Auckland to take up an academic post in the Department of Electrical and Computer Engineering, where he is now a Professor and Head of the Department. Since the first generation of cellular telephony, Sowerby's research has focused on planning high capacity radio networks, with a particular interest in radio propagation measurement and modeling. Wireless-friendly building design, network reliability and security, and spectrum management are also subjects of his research activity. Sowerby has spent extended periods of research leave at Virginia Tech, Simon Fraser University, Motorola Research Labs, Georgia Tech, TNO (The Netherlands), and Hong Kong University of Science and Technology. Within the IEEE he was the founding Chair of New Zealand's first Communications Society Chapter and he has served as Chair of the New Zealand North Section and the New Zealand Council. He currently serves as the Past-Chair of the award committee for the IEEE Daniel E. Noble Award for Emerging Technologies.

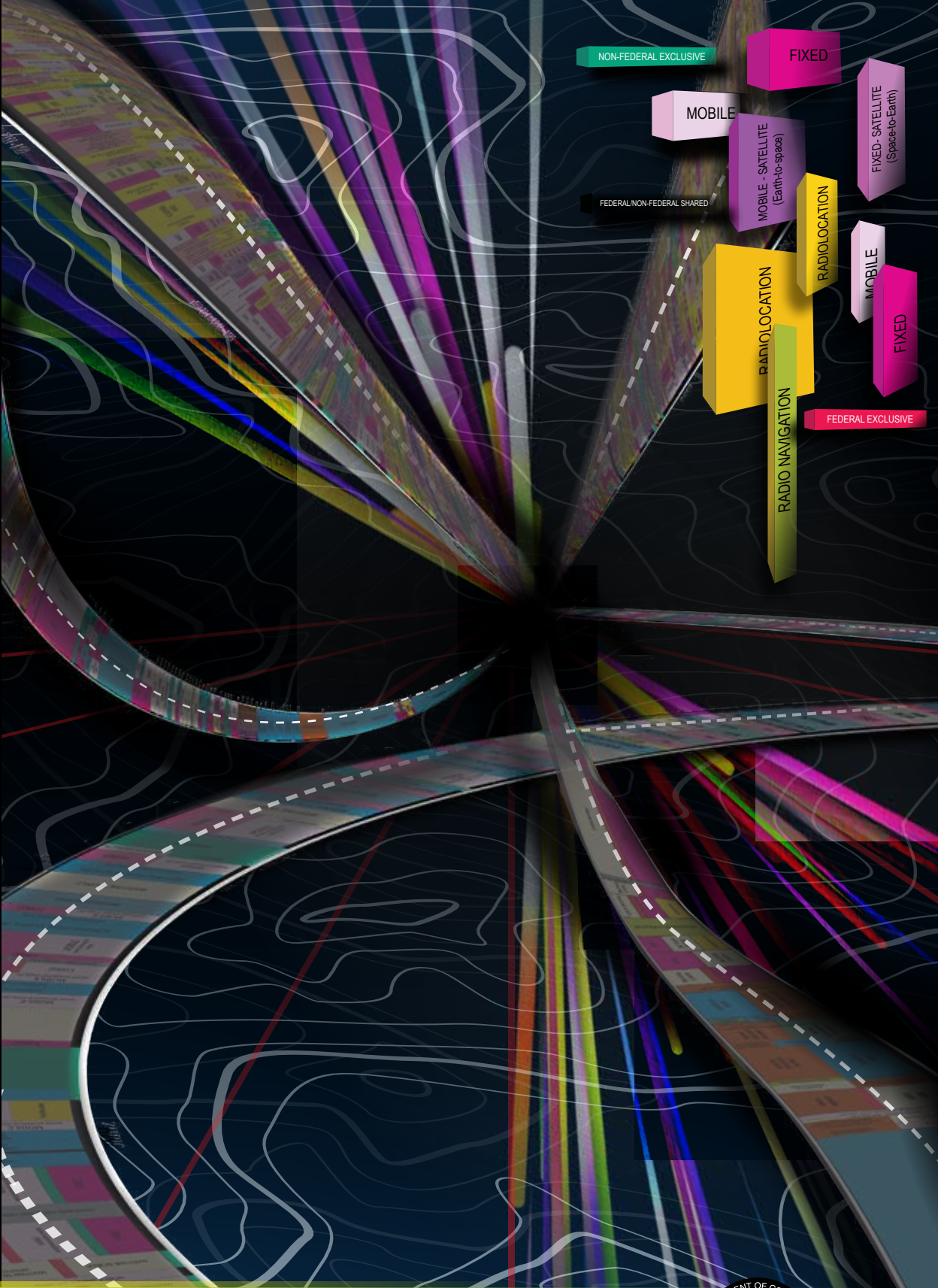
Peter Tenhula is the Deputy Associate Administrator for Spectrum Management in the Office of Spectrum Management (OSM) at the National Telecommunications and Information Administration (NTIA). In that role, he oversees complex initiatives to facilitate effective and efficient management of the Federal Government's use of radio frequency spectrum. He also serves as the Chair of the Interdepartment Radio Advisory Committee. Prior to joining OSM in October 2014, he was a Senior Advisor in NTIA's Office of the Assistant Secretary where he advised the Assistant Secretary of Commerce for Communications and Information on spectrum policy matters. Before joining NTIA in 2012, Mr. Tenhula worked at Shared Spectrum Company, serving as Vice President and General Counsel. From 1990 to 2006, Mr. Tenhula served at the Federal Communications Commission where he held several positions including Acting Deputy Chief of the Wireless Telecommunications Bureau, Director of the Spectrum Policy Task Force, Senior Legal Advisor to the FCC Chairman, Special Counsel to the General Counsel, and staff attorney in the Office of General Counsel and the Mass Media Bureau. Tenhula received his undergraduate degree in telecommunications from Indiana University, Bloomington, and earned a law degree from Washington University in St. Louis, Missouri.

Scott Townley is a Technology Fellow with Verizon Network Technology Strategy and has been with the company since 1994. Mr. Townley provides guidance to the Verizon network field and planning organizations regarding link budgets, spectrum management, and radio network capacity and coverage planning. Prior to Verizon, he was employed in the defense sector as an antenna design engineer. Townley holds a BSEE from the University of Colorado and an MSEE from Arizona State University, with emphases in antennas and electromagnetics. He has been awarded 17 patents and holds Radiotelegraph, General Radiotelephone, and Amateur Radio licenses.

SPEAKER BIOGRAPHIES

Bryan Tramont offers strategic counsel to Fortune 100 companies and trade associations, as well as small and mid-sized telecommunications and media companies, on all aspects of communications law and regulation. He regularly advises companies as they develop and evaluate new business opportunities in the technology, media, and telecommunications sectors. Before joining WBK, Tramont served as Chief of Staff of the Federal Communications Commission under Chairman Michael Powell. Prior to that he served variously as Senior Legal Advisor to Chairman Powell, and to Commissioners Kathleen Abernathy and Harold Furchtgott-Roth. He is an adjunct law professor in Catholic University of America's Communications Law Institute and at the University of Colorado, Boulder. In 2017 Tramont was named to the inaugural Legal 500 Hall of Fame List. He has been awarded The Best Lawyers in America © 2017 "Lawyer of the Year" for Media Law and "Lawyer of the Year" in Communications Law in 2016. Tramont serves on the Commerce Department Spectrum Management Advisory Committee and previously co-chaired the Committee for three years. He is on the Board of Trustees at William Woods University and has served in numerous leadership positions for the Federal Communications Bar Association, including President for 2010-2011.

Scott Wallsten is President and Senior Fellow at the Technology Policy Institute and also a senior fellow at the Georgetown Center for Business and Public Policy. He is an economist with expertise in industrial organization and public policy, and his research focuses on competition, regulation, telecommunications, the economics of digitization, and technology policy. He was the economics director for the FCC's National Broadband Plan and has been a lecturer in Stanford University's public policy program, director of communications policy studies and senior fellow at the Progress & Freedom Foundation, a senior fellow at the AEI – Brookings Joint Center for Regulatory Studies and a resident scholar at the American Enterprise Institute, an economist at The World Bank, a scholar at the Stanford Institute for Economic Policy Research, and a staff economist at the U.S. President's Council of Economic Advisers. He holds a PhD in economics from Stanford University.



NON-FEDERAL EXCLUSIVE

FIXED

MOBILE

MOBILE - SATELLITE
(Earth-to-space)

FIXED - SATELLITE
(Space-to-Earth)

FEDERAL/NON-FEDERAL SHARED

RADIOLOCATION

RADIOLOCATION

MOBILE

FIXED

RADIO NAVIGATION

FEDERAL EXCLUSIVE

www.its.bldrdoc.gov/isart

