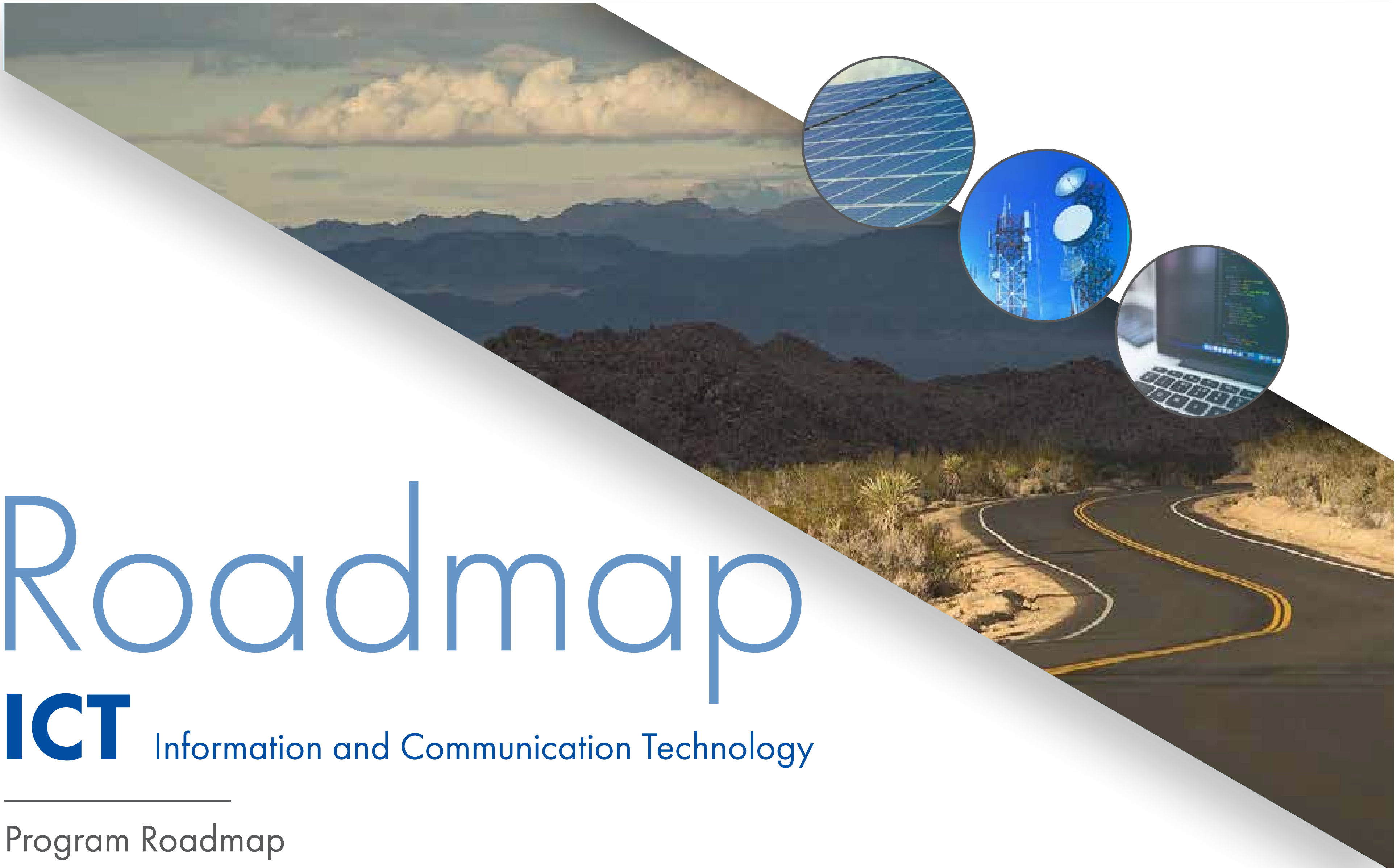
ELECTRIC POWER
RESEARCH INSTITUTE



Roadmap

ICT Information and Communication Technology

Program Roadmap

February 2021

ICT Vision and Mission:

Information and Communication Technology

The Vision of the ICT program:
An electricity infrastructure that is highly connected, highly interactive and highly interoperable.

The Mission of the ICT program:
Enable efficient data communications, grid integration and analytics through leadership, collaboration, and technology innovation.

Information and Communication Technologies (ICT) are foundational blocks to enable digital functions across the energy value chain from the transmission system, through the distribution system, distributed energy resources (DER), and customer interfaces. Through connectivity and information, the electric grid can better integrate digital functionality to become more flexible, resilient, and clean. Challenges to overcome include the sheer volume and meaning of data; proliferation of proprietary systems; varying life-cycle time scales between utility assets and new connected devices; and their effective integration into the power system. The overall roadmap development process is depicted below. It includes the development of aspired future states, a gap analysis between the future and current state, and action plans to address the identified gaps. EPRI's subject-matter experts (SMEs) collaborate with numerous industry stakeholders to identify over 20 future states, the associated gaps, and action plans over the next 3-5 years within the ICT research portfolio. Each subsequent year, EPRI reevaluates and updates the roadmap based on the research findings, state-of-the-art technologies, and innovation.

This program addresses electric industry challenges and advances the digital transformation by conducting value-based research in the following areas:

Grid Interoperability and Integration — accelerates the industry's migration toward integration by making interoperability-related technical contributions to DER data and communications, providing training to utilities, developing reference implementations and tools, organizing interoperability tests of developing standards, and collaborating with stakeholders to demonstrate emerging digital technologies. **Power Telecommunications Network** — provides leadership in communications standards development, provides tracking and analysis of communications technologies, develops the tools and techniques to effectively plan and design communications networks, and conducts laboratory and field tests to evaluate the performance of evolving and emerging technologies. **Enterprise Systems and Grid Architecture** — creates artifacts that help to improve the state of the art in enterprise architecture and develops guides to help utilities with standards-based systems integration. **Advanced Metering** — helps to lead an industry effort to develop open, interoperable, and advanced metering systems; it develops best practice guides for the operations and maintenance of advanced metering infrastructure (AMI) systems; and it investigates approaches for maximizing the value of AMI systems. **Geospatial Informatics** — focuses on the science and technology of acquiring, storing, cleaning, modeling, analyzing, producing, presenting, and disseminating geospatial data sets. Collaborative research projects in this program will enable utility geographic information system (GIS) professionals to master GIS data quality and data management challenges and deliver new geodata services for advanced planning and operations applications. **Distributed Energy Resource Connectivity** — advances DER technologies for utilities and customers toward a fully integrated and connected grid. The research develops tools and processes, harmonizes communication signaling systems, and develops the requirements for communications infrastructure, smart technologies, etc.

FUTURE STATE

- Technology performance and cost
- Technology implementation
- Integration and operational strategies

GAP ANALYSIS

- Determine gaps between the current and future states
- Gaps can be associated to technology performance, implementation issues, experience, etc.
- Prioritize the gaps

ACTION PLAN

- Sequencing and prioritization of recommended R&D activities
- Funding amounts
- Coordination and timing with other activities and programs
- Technical performance and cost targets for promising technologies
- Critical indicators of success

Mission, Drivers, and Future States

MISSION

ICT

Enable efficient data communications, integration and analysis through leadership, collaboration, standards and technology innovation.

DRIVERS

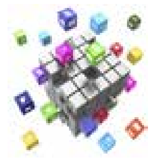
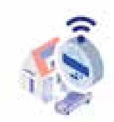
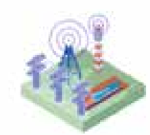
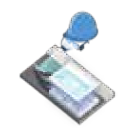
- Interoperability
- Data Management
- Pervasive communications and computing
- Integration of intelligent field equipment, edge devices, mobile workforce and consumer IoT devices with utility systems.

FUTURE STATES

FUTURE STATES	PROJECT SETS
DER Standards; End-to-End Interoperability; Optimized Practices for Connecting DER	Applied ICT for Distributed Energy Resources (DER) and Demand Response (DR)
Organizational Alignment; Portfolio Optimization; Information Availability; Enterprise Architecture (EA) Maturity	Enterprise Architecture and Integration
Open, Interoperable Advanced Metering Systems; Established and Proven Best Practices for AMI Systems O&M; Optimized AMI Systems Utilization and Value	Advanced Metering Infrastructure (AMI)
Interoperable and Reliable FAN; Optimal Use of Available Spectrum; WAN Using Packet Based Technology; Expansion of Reliable Fiber Backbone; Fully Integrated Network Management; Interoperability of Telecom Systems Through Standards	Telecommunications
Advanced Geospatial Data Management; Interoperable GIS and Extended Reality (XR); Complex Grid Modeling for Operations and Planning	Geospatial Informatics

ICT Roadmap

Information and Communication Technology (ICT)

Applied ICT for Distributed Energy Resources (DER) and Demand Response (DR)	Enterprise Architecture (EA) and Integration	Advanced Metering Infrastructure (AMI)	Telecommunications	Geospatial Informatics
				
161D	**161E**	**161F**	**161G**	**161H**
FUTURE STATES	**FUTURE STATES**	**FUTURE STATES**	**FUTURE STATES**	**FUTURE STATES**
1 Standards and Protocols for Interoperability and Interconnection for Grid and DER/DR Flexibility and Services **2** End-to-End Interoperability and Harmonization for DER/DR Devices and System **3** Field-Proven Practices and Applications for DER Communications, Architecture, and Knowledge Transfer	**1** Organizational Alignment **2** Portfolio Optimization **3** Information Availability **4** EA Maturity	**1** Open, Interoperable AMI Systems **2** Established and Proven Best-Practices for AMI System O&M **3** Optimized AMI System Utilization and Value	**1** Interoperable and Reliable Field Area Networks (FAN) **2** Optimal Use of Available Spectrum **3** Wide Area Networks (WAN) Using Packet Based Technology **4** Expansion of Reliable Fiber Backbone **5** Fully Integrated Network Management System **6** Interoperability of Telecom Systems Through Standards	**1** Advanced Geospatial Data Management **2** Interoperable GIS and XR **3** Complex Grid Modeling for Operations and Planning

PROGRAMS DEFINE ACTION PLANS

Project Definitions:

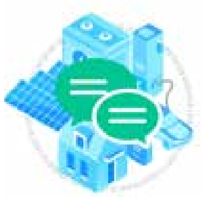
- What we need to do to bridge the gaps to achieve the Future States
- Actions are taken through a variety of different project types within EPRI, as described below

Annual Research Portfolio:
EPRI's offering of collaborative, membership funded research work for a given year. All annual research portfolio purchases are based on EPRI's research year (the calendar year). These offerings are made available each June for the subsequent research year.

Government Project:
A project that EPRI has been awarded through a government entity such as the U.S. Department of Energy (DOE)., California Energy Commission (CEC) or the New York State Energy Research and Development Authority (NYSERDA) are typically made by these organizations through an open, competitive solicitation process.

Supplemental Project:
Some research projects are not part of the annual research portfolio, they are executed as supplemental projects. These supplemental projects are done more as one-off projects; they can be single or multiple funded projects.

Technology Innovation Project (TI):
Technology Innovation allows members to leverage their long-term investment (10+ years) in collaborative research that may create entirely new markets, products and services, increase the public benefits of efficient, clean affordable energy and ensure the competitiveness of the energy enterprise.



Applied ICT for Distributed Energy Resources and Demand Response (161D)

Utilities are embracing the flexible operations from distributed energy resources (DER) and demand response (DR) technologies to play a key role in a sustainable, optimized, and integrated electric grid. These DERs — both in-front and behind - the-meter, solar photovoltaics, energy storage, electric vehicles, and demand-responsive loads — support the grid reliability and resiliency by providing utilities and their customers with multiple options to balance supply and demand and integrate renewables.

The goal of this research is to provide tools, technologies, and strategies to enable flexibility, as a most cost-effective option and enhances their value to enable future states, such as microgrids, renewable energy (RE) targets, and new grid services. The technologies for communications, information exchange, optimization, and advanced analytics from DER/DR are key enablers for of the research goal and grid modernization plans. As a result, the project-set research focuses on ever-changing data and communication technologies, system architecture and integration solutions, and approaches.

This project set adds value to the utility DER/DR goals and roadmaps by performing research that can help utilities at any stage of DER/DR planning, deployment, and integration. This includes industry leaders targeting full end-to-integration for monitoring and control of DERs devices and systems. The research outcomes add value to utilities and grid operators by reducing costs and improving the efficiency of existing operations, such as the monitoring and operation of DERs and DR programs. The project set has activities that support both the immediate needs (existing plans) and long-term (strategic vision) value streams.

Research Drivers

- A need for a flexible grid operations from deployment of DER/DR and renewable energy.
- An industry need for guidelines, specifications, standards, and connected criteria for a common set of information exchanged with any DER/DR application or device.
- New value streams from DER interoperability, streamlined data and system integration, and support for modularity and options for DER/DR systems.
- Grid operators' interest in communications systems to manage and aggregate DER/DR.
- Diversity and propriety of customer and third-party owned DER/DR devices and systems.
- Practices to evaluate communication standards and protocols technology and integration framework for DERs through studies, laboratory and field testing.
- Evaluation of communication standards for DERs through studies, lab testing, and demonstrations.

Value

- Increase the cost effectiveness and long-term efficacy of grid modernization plans.
- Awareness of standards and protocols, issues, and solutions to streamline integration of DER/DR and reduce costs for operation and maintenance (O&M) over the asset lifetime.
- Understand architectural, technical, and business decisions of others to inform interoperable and interconnected practices.
- Access to tools, technologies, and strategies to help utilities integrate and support investments in new transformative digital technologies in DR/DR.

Project Set Lead: Rish Ghatikar, gghatikar@epri.com

161D Applied ICT for DER and DR – Future State 1: Standards and Protocols for Interoperability and Interconnection for Grid and DER/DR Flexibility and Services

Future State 1: a) field-proven and industry-recognized interoperability and interconnection standards with native communications capabilities in DER/DR products; b) conformance and certified open standards and data models; and c) default interoperability in field deployments.

This Future State incorporates the following characteristics:

- Open, interoperable standards applied in the field to meet the needs of utilities, aggregators, customers, and other grid-operator use-cases.
- Clear, industry-accepted examples of how open standards reduce the cost and effort for initial integration of DER and O&M over the life of the system.
- Data models are well understood and harmonized across relevant standards and protocols.
- Robust certification processes exist for validating standards implementations in DER/DR devices and systems.

Gaps Addressed:

- Lack of interoperability certification for DER/DR standards to cover grid applications.
- Missing coordination among and between DER/DR interoperability and interconnection standards.
- Lack of approaches to accommodate customer-, utility-, or third-party-owned technologies with Internet of Things (IoT) and DER/DR devices and systems.
- Missing vision for standards that embrace next generation requirements (e.g. transactive energy, group management, and harmonization for integrated grid objectives).

Major Past Accomplishments	2021	Future
ACTION PLAN ANNUAL RESEARCH PORTFOLIO		
• DER Protocol Reference Guidebook – 4th Edition; 3002018544 (2020), 3rd Edition 3002016140 (2019) • Residential Battery Energy Storage: Demand Response Opportunities with OpenADR 2.0b—Field Deployments and Performance Analysis; 3002017985 (2020) • DER Integration Testbed and Toolkit: An Overview of EPRI Test Tools for DER Integration 3002016138 (2019)	• DER Protocol Reference Guidebook – 5th Edition. • Maintenance and Support to Apply EPRI DER/DR Integration Toolkit. • Tools for testing efficacy of communications for field deployments	• Evaluate the Effectiveness and Cost of Conformance Testing Programs for widespread Interoperability. • Tools and Repository of Relevant Standards & Protocols to Achieve Grid Interoperability • ICT and Approaches to manage variable DER (solar PV, energy storage, and EVs)
ACTION PLAN SUPPLEMENTAL PROJECTS		
• Functional Specifications and Use Cases for Communicating DER • Information Exchange and Certification for CTA-2045	• Open-Source Tools for DER Standards (e.g., CTA-2045, DNP3, IEC-2030.5, OpenADR) • Digital Technologies and Strategies for Grid	• Design & Modeling of Centralized & Distributed DER/DR Communication & Control Architectures • Demonstrate Transactive Pricing Signals for Flexible DER/DR Services • Standards Assessment Tools for Utility DER/DR Planning & Operations
ACTION PLAN GOVERNMENT PROJECTS		
• Grid Resiliency by Managing Communicating Loads, Energy Storage and Solar Systems 3002016335 (2019-20) • DER Integration Toolkit 3002016138 (2019)	• Grid Interoperability and Deployment of Flexible DER • Grid-Flexibility Using Price-Based Transactive Signals: Findings and Recommendation.	• Support Demonstrations & Field Deployments Across DER Types and Market Domains • Develop ICT for DER Digital Strategies for T&D Infrastructure, and Grid Operations and Planning

VALUE

- Stay updated on the state of technologies and industry through insights on existing and emerging grid standards and protocols, and compliance to grid codes.
- Research insights on communication technologies, standards, etc., to support operations, ease of data and systems integration, long-term access to DER/DR systems, support modularity, and identify options for DER/DR components and management systems.
- Accelerate deployment of interoperable, interconnected, and harmonized DER/DR devices and systems through use cases, test tools, and open-source applications.

ARP PROJECT

P161.049: Enabling Open, Interoperable DER – Standards, Testability, and Embracing DER/DR Abilities

TIES TO OTHER PROGRAMS

The work in this project set is coordinated with related EPRI programs. Specifically, among them are, but not limited to, the following: Electric Transportation (P18), Energy Storage and Distributed Generation (P94), Customer Technologies (P170), DER Integration (P174), Understanding Electric Utility Customers (P182), Distribution Operations and Planning (P200), Cybersecurity for Power Delivery and Utilization (P183), and Advanced Buildings (P204).

161D Applied ICT for DER and DR – Future State 2: End-to-End Interoperability and Harmonization for DER/DR Devices and Systems

Future State 2: Grid stakeholders (utilities, manufacturers, third-parties, etc.) have access to guidelines, specifications, and tools that describe how to automate process and respond to information exchanged with any application or device through a communication interface that is specified in an open standard. Communication integration occurs end-to-end – i.e., from the head-end to a system, device, or a component.

Description: Interoperability is the ability of two or more systems to exchange and understand information and to process and respond. Harmonization is a process where one or more standards to interoperate with a diversity of grid standards and protocols to meet integrated grid objective(s). In this context, end-to-end refers to "plug-and-play" capabilities of DER/DR that integrate with related devices, and IT and OT systems.

This Future State incorporates the following characteristics:

- Connected DER/DR devices and data standards with industry adoption and market-facing products.
- Guidebooks and specifications for a diversity of DER/DR communication technologies to meet the functional requirements of digital grid transformation and grid codes.
- Use-cases and functional requirements for end-to-end integration and automation of DER/DR, (solar PV, energy storage, flexible loads, and EVs).

Gaps Addressed:

- Lack of cohesive ICT features and interoperability for DER/DR systems for monitoring and control.
- Limited understanding of communication technologies and associated data models for end-to-end DER/DR interoperability.
- Lack of access to open-source and digital tools for utility grid planners and operational programs.

Major Past Accomplishments	2021	Future
ACTION PLAN ANNUAL RESEARCH PORTFOLIO		
• Interoperability in DR Technologies; 3002018543 (2020), 3002016141 (2019) • Enhancing Grid Resiliency Through Improving Capabilities to Manage Communicating Energy Storage and Solar Systems: Developing Tools to Enable DNP3 for Energy Storage; 3002016335 (2019-20).	• Repository of Interoperability Technologies and Barriers in DER/DR • Market Study on Penetration of DER/DR Interoperability Guidelines, Specifications, Standards, and Grid Codes	• Solutions and Performance Evaluation of Grid Network Interfaces in DER/DR systems & Smart Inverters • Evaluate Effectiveness of ICT for Integrated Grid Reliability & Resiliency • Develop & Demonstrate Harmonized Use of Solar, Storage, EVs, and Smart Loads for Grid-Services
ACTION PLAN SUPPLEMENTAL PROJECTS		
• DER Communication Standards and Protocols Harmonization, and Interest Group (DER-SIG); 3002020093 • Laboratory and Field Evaluation of DERMS Interoperability; 3002016662 (2019) • Understanding the Uses and Value of Utility DER Gateways; 3002017116 (2019)	• Technical and Implementation Guide for Harmonization of DER Standards and Protocols. • Integrated DER/DR Communications & Data for Grid Services • Develop and Demonstrate Capabilities of DER Network Gateways for Control Integration	• Reference Design and Prototype for DER Gateway for Cost-Effective & Secure Network Integration • Evaluation and Use Cases of Digital Strategies for Grid Operators • Use of Digital Voice Assistants for Integrated and Interoperable Operational Efficiency.
ACTION PLAN GOVERNMENT PROJECTS		
• Evaluating Transactive (Price-Based) Load Management Signals; 3002012290 (2018-20) • Evaluation of Standards-Based DER/DR Capabilities to Support Grid Needs 3002016335 (2019)	• Smart-Inverter Use Cases and Communications for Grid Services in New York State • Increasing Solar Hosting Capacity Using Decentralized Architecture for Smart Loads & Inverter-based DERs	• Demonstrate Flexible and Integrated Resource Management for Grid Systems & End Uses • Prototype open-source software and tools for grid signaling and services • Collaborative Projects for RD&D of ICT solutions for Grid Applications

VALUE

- Develop awareness of technologies, issues, and solutions that can streamline the end-to-end integration of DER/DR and reduce costs for operation and maintenance.
- Stay updated on results from interoperability testing to understand how to develop robust RFP documents, interconnection and harmonization requirements, and program design.
- Access to tools and guidance to help utilities integrate new transformative communication technologies in DER/DR and support the investment in of these resources into associated control systems and their integration into the grid.
- Support members in looking at the bigger picture to prepare for the various technical, organizations, and business changes needed to embrace end-to-end integration of DER/DRs.

ARP PROJECT

P161.052: Bigger Picture — Preparing for End-to-End Integration of DERs

TIES TO OTHER PROGRAMS

Electric Transportation (P18), Energy Storage and Distributed Generation (P94), Customer Technologies (P170), DER Integration (P174), Understanding Electric Utility Customers (P182), Distribution Operations and Planning (P200), Cybersecurity for Power Delivery and Utilization (P183), and Advanced Buildings (P204).

161D Applied ICT for DER and DR – Future State 3: Field-Proven Practices and Applications for DER Communications, Architecture, and Knowledge Transfer

Future State 3: Develop and document applications and practices for ICT-centric DER/DR solutions in a communications and architecture that are mature with multiple, well documented case studies conducted in collaboration with other EPRI programs, and transfer knowledge.

Description: ICT regulate how some aspects of the communications and DER system/device architecture are developed. However, the decisions made without solid application of research findings can have unintended large business and technical impacts for scaled grid deployments.

This Future State incorporates the following characteristics:

- Well-documented DER/DR applications and best practices, and case studies for adoption impacts.
- Field-tested communications metrics (e.g., payloads, bandwidth, latency), choice of communication technologies.
- DER monitoring, control, and interconnection practices that understands and transfers the industry business and technical impacts.

Gaps Addressed:

- The infancy and transformation in the state-of-the art practices for DER communications and architectural practices.
- Lack of data-centric approaches to accelerate DER deployments through field studies and support to grid modernization roadmaps.
- Approaches to manage and utilize DER devices and/or systems for business services are not explored by the electric grid stakeholders.

Major Past Accomplishments	2021	Future
ACTION PLAN ANNUAL RESEARCH PORTFOLIO		
• Communications & Architecture Requirements for Smart Inverter Use Cases – 2nd Edition; 3002019357 (2020); 3002016143 (2019) • Federated Architecture for DER Integration • ICT for DER Case Studies – Business Justifications for DER Communications 3002017103 (2019) • Evaluation of Translation Capabilities in DERMS; 3002016142 (2019) • Semi-Annual Task Force Meetings for Technology Transfer	• Study of Challenges and Opportunities in • Utility Deployments of DER/DR Digital Technologies • Technology Transfer Webcasts and Utility Engagement Showcasing the State-of-the-Art Practices in DER/DR Deployment • Industry Updates and Webcasts on Guidelines & Specifications to Achieve Interoperability • Semi-Annual Task Force Meetings for Technology Transfer	• Utility Data and Metrics to Document Cost-Benefits of Interoperability • Evaluate Impact of Communications Decisions in Field Demonstrations • Review Grid codes, case studies, and RFP language for scalable deployments of DER/DR • Develop Use-Cases on Performance and Grid-Flexibility Benefits of Next-Generation Utility Platforms (DERMS,Data Management)
ACTION PLAN SUPPLEMENTAL PROJECTS		
• DER Resource Center, Repository of DERMS RFP Language	• Document Approaches for DER/DR Monitoring and Control Architectures • Programmatic Guidance to Develop Grid Services to Embrace Interoperability	• Develop digital strategies and conduct training to use and automate DER/DR operations • Develop Collaborative Research for Grid Operations & Planning and T&D Infrastructure • Engage Advisors and Task Force Members for Research Prioritization & Engagement.
ACTION PLAN GOVERNMENT PROJECTS		
• Increased Inverter-Based DER and Flexible Load Adoption. • Developed and Delivered Training to Monitor, Manage, and Configure DER/DR • Enhanced Value with Findings from Collaborative Projects and Review Applications with Advisors and Task Forces	• Software or Hardware in-the loop Testing on DER Architectures • Training Curriculum for ICT to Monitor, Manage, and Configure of DER/DR • Review ICT research and applications for inverter-based DERs	• Identify Best Practices and State-of-Art Technology Adoption from Projects • Identify Government Projects for Next-Generation Digital DER Communications • Review Technologies & Strategies for Next Generation Utility Workforce Development

VALUE

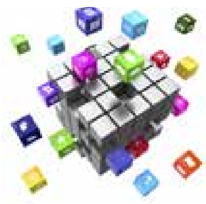
- Inform decision making and understand how different approaches impact business and technical considerations.
- Field-tested practices will help better understand real-world scenarios and avoid negative impacts from economics and timeliness.
- Receive updates on key lessons learned from utility field demonstrations and pilots and enhanced value from collaborative and government projects.

ARP PROJECT

P161.051: Utility Case Studies in DER Architecture – Experiences, Best Practices, and Barriers

TIES TO OTHER PROGRAMS

The work in this project set is coordinated with related EPRI programs. Specifically, among them are, but not limited to, the following: Electric Transportation (P18), Energy Storage and Distributed Generation (P94), Customer Technologies (P170), DER Integration (P174), Understanding Electric Utility Customers (P182), Distribution Operations and Planning (P200), Cybersecurity for Power Delivery and Utilization (P183), and Advanced Buildings (P204).



Enterprise Architecture and Integration (161E)

The utility industry is being transformed by customer and regulatory expectations while facing the combined threats of reduced demand and new energy sources. Efficient operation through organization alignment and application portfolio optimization has never been more important. Efficient operation frees up resources to focus on the new capabilities required to create agile, data driven organizations that can succeed in a rapidly evolving environment.

Enterprise Architecture and Integration provides methods, tools, frameworks to increase alignment and reduce support costs while increasing agility and the availability of actionable information. It utilizes a holistic and integrated view of all four architecture domains; business, application, data and technology.

Value

- Roadmap development (Grid Modernization, Digital Transformation etc.) is enabled by a utility business capability model
- Strategic application adoption is supported by industry reference architectures
- Strategic alignment visualization is enabled through Enterprise Architecture tools and models
- The elimination of organizational silos and duplicate business functions is supported by architecture reference models and community building techniques.
- Increased application data quality is foundational for developing new capabilities
- Enterprise Architecture maturity development is accelerated by principles, governance models, team organization and skillset
- New or enhanced applications are enabled by a robust web service eco-system
- Business Intelligence (BI) and Analytics is enabled by a holistic framework for the required skills, tools and data curation

Research Drivers

- Strategic roadmap development is a key activity for most utilities.
- The widespread, strategic adoption of grid management and analytics applications.
- Enterprise Architecture maturity varies greatly across the industry.
- More extensive use of business architecture for IT alignment
- New Enterprise Architecture roles and team structure pose new governance and management challenges.
- New demands for Customer and OT data for analytics and operational insight.
- Large scale application suite replacement cannot respond at the speed required.
- Data quality is a barrier to new capability development.
- Application integration challenges multiply implementation time and cost.
- Best practices for enterprise architecture and integration.
- Advancement of standards-based systems integration capabilities.
- Digital transformation – providing business efficiency by aligning Operations and Information Technology (IT).

Value

- Roadmap development
- Strategic application adoption
- Strategic alignment visualization
- Enterprise Architecture maturity development
- Business Intelligence (BI) and Analytics

Project Set Lead: Sean Crimmins, scrimmins@epri.com

Enterprise Architecture and Integration – Future State 1: Organizational Alignment

Future State 1: The organization focuses its resources on executing the strategic vision.

Description: Successful organizations ensure that investments align with strategic objectives and that the capabilities required to implement the future vision are identified and assessed. A business capability model is a foundational element in a framework for organizational alignment. It enables enterprise wide conversations around strategy, road mapping, maturity and new business models within a framework that focuses on outcomes. This approach enables strategic planning, gap analysis, measurement and prioritization. Focusing on outcomes first, instead of technology, allows for more innovative solutions to develop.

Gaps Addressed:

- Understanding business capability models and their use
- Metrics to measure capability maturity
- Poor linkage between projects and strategy
- Poor linkage between technology and business risk
- Understanding alignment via collaboration and community building
- Use of tools to democratize EA

Major Past Accomplishments	2021	Future
ACTION PLAN ANNUAL RESEARCH PORTFOLIO		
• Digital Transformation: Aligning Information Technology and Operations, 3rd Edition, 3002018638 • The Business Capability Model Builder, 3002016064	• Digital Transformation: Aligning Information Technology and Operations, 4th Edition	• Develop strategy, road mapping and maturity frameworks around the EPRI Utility Business Capability Model • Demonstrate effective enterprise wide use of EA tools to collaborate on and communicate results of the frameworks • Jointly develop maturity models for strategic capabilities • Publish cases studies of the impact of alignment efforts lead by collaboration and community building
ACTION PLAN SUPPLEMENTAL PROJECTS		
	EPRI Utility Business Capability Model	Expand the capability model framework to strategic planning, application rationalization, application health and business value

VALUE

- Strategy development, road mapping and maturity
- Business language for IT-Business conversations
- Industry wide frameworks

ARP PROJECT

P161.041: Enterprise System Integration

TIES TO OTHER PROGRAMS

Cyber Security for Power Delivery and Utilization (P183), Distribution Operations and Planning (P200)

161E Enterprise Architecture and Integration – Future State 2: Portfolio Optimization

Future State 2: The systems necessary to run the business are optimized for performance and cost

Description: An optimized application portfolio provides significantly more business value than it costs in licensing and support. It can meet its business function/s (as determined by its users) and can quickly met evolving needs in those areas. All applications, cloud service providers and third parties are interoperable and extensible via configuration, not code releases. New technologies and innovative solutions are constantly reviewed for impact or addition to the portfolio. Application rationalization, while still important to control costs, is no longer enough to meet the higher expectations of a utility.

Gaps Addressed:
- Data quality metrics
- Application health and value metrics
- Application and data reference architectures
- Method to select technology to be investigated

Major Past Accomplishments	2021	Future
ACTION PLAN ANNUAL RESEARCH PORTFOLIO		
Architectural Impacts of Disruptive Technologies, 2nd Edition 3002018640	• Architectural Impacts of Disruptive Technologies: Methodology to select technologies • AMI Reference Architecture • A framework for interoperable open source applications	• Utilize reference architectures to enable interoperable open source applications • A methodology to determine technology maturity and applicability
ACTION PLAN SUPPLEMENTAL PROJECTS		
Network Model Data Management: Transmission and Distribution	• OT Reference Architecture: Data and the functions that create and consume it • Network Model Data Management: Transmission and Distribution	Build and apply functional additional industry reference architectures

VALUE
- Application rationalization
- Application interoperability
- Faster application/service implementation
- Objectively measure of quality and health
- Identify all potential uses of AMI

ARP PROJECT
P161

TIES TO OTHER PROGRAMS
Advanced Metering Infrastructure (P161F),
Distribution Operations and Planning (P200)
Transmission Operations and Planning (P39/40)

161E Enterprise Architecture and Integration – Future State 3: Information Availability

Future State 3: All participants in the enterprise have access to the information and toolsets necessary.

Description: Business Intelligence, analytics, Artificial Intelligence and machine learning are only possible with the secure widespread availability of high-quality data, the tools necessary to access, process and understand it. The application portfolio, cloud service providers and business partners can provide high quality data to downstream applications and users.

Gaps Addressed:
- Cloud integration
- Semantic models for analytics
- Semantic model-based integration
- Data Reference Architectures

Major Past Accomplishments	2021	Future
ACTION PLAN ANNUAL RESEARCH PORTFOLIO		
• The CIM Primer 6th Edition, 3002018634 • Cloud Integration Guidebook, 5th Edition, 3002018639 • Utilizing a Framework for Measuring Application Data Quality, 3002018699 Program on • Technology Innovation: Web Services Robustness, An Agile Integration Ecosystem 3002018641	• The CIM Primer: Model-based enterprise integration • Cloud Integration Guidebook: Blueprints for managed services	• Develop sets of APIs and associated user communities for utility domains e.g. generation, transmission, distribution • Develop industry specific application quality and health metrics • Domain driven information availability
ACTION PLAN SUPPLEMENTAL PROJECTS		
	Customer data reference architecture	Additional data reference architectures

VALUE
- Faster application integration
- Accelerate cloud adoption
- Enable analytics and AI
- Agile web services

ARP PROJECT
P161

TIES TO OTHER PROGRAMS
Cyber Security for Power Delivery and Utilization (P183), Nuclear plant modernization program, Artificial Intelligence (AI) Initiative

161E Enterprise Architecture and Integration – Future State 4: EA Maturity

Future States 4: Disruptive technologies are "competence destroy. The EA practice is an integral part of the business from strategy development to technology evolution.

Description: The EA practice encompasses all four architecture domains; business, data, application and technology. The practice utilizes all necessary team structures; centralized, distributed, matrixed as well as informal communities and centers of excellence to fully understand and the implement the business strategy. The EA practice principles, tools and metrics are widely known and shared.

Gaps Addressed:

- EA as strategy
- Business-IT relationship
- Business Architecture
- Use of EA Tools

Major Past Accomplishments	2021	Future
ACTION PLAN ANNUAL RESEARCH PORTFOLIO		
• Utility Enterprise Architecture Guidebook, 5th Edition, 3002018635 • Library of Enterprise Architecture Patterns 2nd Edition, 3002018636 • EA Annual Survey and benchmark 3002018637	• Utility Enterprise Architecture Guidebook: Community building • EA Annual Survey • LEAPWorx: Cyber Security	• Community building case studies • Managing a matrixed team • Expand the pattern library
ACTION PLAN SUPPLEMENTAL PROJECTS		
	EA Capability Maturity Assessments	EA and Cyber Security

VALUE

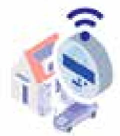
- EA Governance options
- Practice Structure options
- Skillsets and career path
- EA Repository for communication
- Maturity Assessments
- EA Modeling accelerators

ARP PROJECT

P161

TIES TO OTHER PROGRAMS

None



Advanced Metering Infrastructure (161F)

Advanced metering infrastructure (AMI) is being deployed by utilities worldwide. System performance, reliability, and consumer trust in them are crucial to the utility business, and many challenges must be addressed. Both metering and communication technologies used in AMI are evolving rapidly, and the methods for optimizing their utilization and value are still developing. Investments in AMI are among the largest being made by utilities, resulting in a need for high-quality asset management throughout the system life cycle. Because many current systems are largely custom-designed or proprietary rather than standards-based, the consequences are vendor lock-in, heightened risk of obsolescence, and poor interoperability.

This project set consists of the whole of EPRI research in metering and advanced metering systems, bringing together communications and meter-specific research previously conducted in separate programs. This project set aids utilities in optimizing existing system utilization and in discovering the full value of AMI-collected data; accelerates and guides the development of emerging standards and architectures to enhance interoperability, innovation, and marketplace competition; and identifies best practices for the support of system operations and monitoring of systems. Finally, the project set will investigate AMI meters with regard to accuracy, reliability, standards compliance, and tamper resistance.

Research Drivers

Infrastructure (AMI) pose challenges and opportunities:

- Large investments in Advanced Metering
- Needs to avoid vendor lock-in
- Emerging O&M best practices – improving
- operational efficiency
- Exploiting full value from systems and data
- Advance interoperability through accelerating standards:
- Assess advanced meter performance
- Discover uses that optimize existing system value
- Identify industry best practices for AMI management

Value

- Realize a greater return on AMI investments
- Conduct high quality asset management through system life cycle
- Reducing business risks of obsolescence and product performance

Project Set Lead: Ed Beroset, eberoset@epri.com

161F ICT for Advanced Metering Infrastructure – Future State 1: Open, Interoperable AMI Systems

Future State1: Enable utilities and other system integrators to build-out AMI systems from best-in-class sources of supply. This includes using meters, routers, and access points from multiple sources of supply, enhancing competition, and improving quality. Open, Interoperable AMI systems include the following:

- Products being open platforms such that applications can be independently developed and deployed
- Headend systems that can be compatible with multiple network types and provided by any company
- Ability to seamlessly leverage, to the extent for a desirable, existing communication infrastructure
- Availability of an unbiased, vendor-neutral implementation of the communication stacks that accelerates availability of products

Gaps Addressed: Existing AMI networks (both RF and PLC) are proprietary due to lack of implementation of standards at both the lower (Phy/MAC) and application layers:

- Existing standards are competing and there is lack of consensus regarding their use
- Supporting multiple NAN technologies: Lack of standards for system backhaul
- Enabling intelligence at the edge: Standards for meters to have consistent functionality and applications
- Methods and architectures for leveraging other communication infrastructures (e.g. internet) are not developed

Major Past Accomplishments	2021	Future
ACTION PLAN ANNUAL RESEARCH PORTFOLIO		
• Metering and the Common Information Model (CIM): A Practical Approach, 3002015770 (2020) • Reference Implementation of DLMS/COSEM Access Point, 3002018619 (2020) • PRE-SW: DLMS/COSEM (Device Language Message Specification/Companion Specification for Energy Metering) to International Electrotechnical Commission (IEC) 61968-9 Mapping, 3002015769 (2019) • Wi-SUN Meter Test Tool WISUND), version 1.0 3002010501 (2018)	• ANSI Meter Standards Utilization	• Reference AMI headend – enabling Application integration testing • "Open backhaul" methods and messages

VALUE

Availability of AMI-related products in the marketplace that are interoperable and interchangeable

ARP PROJECT

P161.032: Open, Interoperable Advanced Metering Systems

TIES TO OTHER PROGRAMS

Power Quality (P1), Grid Support Functions and Connectivity (P174B), Technologies Evaluation and Assessment (P180G), and Customer Insights (P182)

161F ICT for Advanced Metering Infrastructure – Future State 2: Established and Proven Best-Practices for AMI System O&M

Future State 2: A comprehensive collection of AMI best-practices, each being broadly applied by utilities and iteratively improved. Best-practices for key O&M processes are precisely documented and widely utilized by utilities including the following:

- Requirements development, RFP, and selection
- System deployment
- Performance monitoring and management
- Prognostics and health management
- Revenue protection

Gaps Addressed:

- No documented best-practices for AMI operation and management
- Duplication of efforts to define and document practices
- No forum, resource or entity to document, compile, manage, and disseminate AMI-related practices
- Vendor feedback regarding utility O&M needs

ACTION PLAN ANNUAL RESEARCH PORTFOLIO

Major Past Accomplishments	2021	Future
• AMI Wireless Access Point Requirements 3002018620 (Feb 2021) • Revenue Protection Guidebook, 2nd Edition: Utilizing Advanced Metering Infrastructure 3002018630 (Feb 2021), 1st Edition: 3002008943 (2016) • Guidebook for AMI Data Management, First Edition 3002013399 (2018) • Guidebook for AMI system disaster management and restoration 3002010502 (2017)	Guidebook for Using AMI in Outage Management	Guidebook for AMI system RFP and deployment processes, including evolving, hybrid networks

VALUE

- Number of best practice guidebooks developed
- Breadth of utility use/ application of the practices
- Ongoing efforts to refine and improve

ARP PROJECT

P161.043: Advanced Metering Systems Operations and Management

TIES TO OTHER PROGRAMS

Distribution (P180)

161F ICT for Advanced Metering Infrastructure – Future State 3: Optimized AMI System Utilization and Value

Future State 3: Optimized AMI System Utilization and Value

Description: Utilities will have a clear understanding of the range of uses and applications that can be effectively supported by their AMI systems and AMI data. Specific guidance on how to employ these uses will be available. Optimized system utilization and value will be achieved through:

- Up-to-date data on global AMI deployments and uses
- Comprehensive development and documentation of methods and algorithms for metering-related applications
- Field evaluation of new/emerging uses
- Improved AMI integration with internet, cellular and other utility systems for optimized overall utilization

Gaps Addressed:

- Lack of understanding of what applications the present generation of AMI can support
- Inaccurate GIS data regarding metering assets and connectivity
- Lack of knowledge of what AMI system and data uses are in practice and on what AMI technologies
- Lack of algorithms and data analytics for optimizing the use of AMI-derived data
- Lack of methods for effectively integrating AMI with distribution operations

Major Past Accomplishments	2021	Future
ACTION PLAN ANNUAL RESEARCH PORTFOLIO		
• AMI Data Analytics Survey, 3002018631 (March 2021) • Next Generation AMI System Design and Utilization – Case Studies in Utility Innovation Expanded AMI Use Case Database 3002013401 (2019) • Advanced Metering Infrastructure Resource Center (AMI Status DB), version 3.0 —An Online AMI RFP Language Repository, 3002010503 (2017)	AMI Sensor Integration — Developing and field testing new AMI system uses and data analyticst	AMI analytic algorithms repository

VALUE

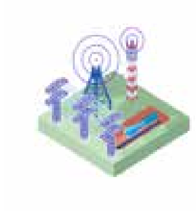
- Quantity of documented application use cases
- Guidance on what system types are suitable for each

ARP PROJECT

P161.044: Optimizing Advanced Metering System and Management

TIES TO OTHER PROGRAMS

Power Quality (P1), Customer Insights (P182), and Distribution (P180)



Telecommunications (161G)

Telecommunication is essential to utilities and has an increasingly critical role in the operation of the integrated grid. In grid modernization, telecom supports higher penetration of distributed energy resources (DER) and a greater reliance on sensors to provide situational awareness. No single technology can meet all the widely varying requirements, resulting in complex and heterogeneous telecom networks that are challenging to manage.

The project set addresses challenges that utilities face with respect to telecommunications:

- Planning a scalable, multi-service network that meets current and future needs
- Leveraging technologies and best practices from commercial telecom operators (both wireline and wireless)
- Resolving barriers to complete the transition of the wide area network (WAN) to packet technologies
- Evaluating new business models and partnerships to make fiber deployment in more locations economically viable
- Addressing industry challenges with potential interference to licensed microwave links
- Enabling wider use of wireless networks by identifying suitable licensed wireless spectrums
- Identifying the optimal wireless technologies and spectrum choices for field area networks (FAN)
- Stewarding the standards to enable interoperability and interchangeability
- Identifying the best roles for commercial wireless and shared networks and navigating the transition to 5G networks
- Developing approaches to maximize the performance of wireless technologies in unlicensed spectrums and developing strategies for alternatives when unlicensed bands can no longer support desired utility applications
- Developing a scalable IT architecture to support work environment disruptions and a remote workforce
- Developing best-in-class telecom network management, visualization, and control systems that take advantage of advances (such as software-defined networking [SDN] and, SD-WAN], and network functions virtualization [NFV]) while maintaining reliability, resilience, and cyber security

Research Drivers

The need to develop strategic assets, so utilities can maintain and achieve future outcomes:

- Design reliable, resilient, flexible, and secure telecom networks to support advanced grids
- Tools to manage complex, mission critical telecom networks
- Migrate from today's networks and legacy equipment to future telecom network
- Development of telecommunication strategic architecture and roadmap decision tree for utilities

Value

- Collaborative with multiple utilities to gain perspectives based on practical experiences
- Cost savings and risk avoidance resulting from strategic network planning, adoption of standards, convergence of IT/OT, leveraging best practices from the industry
- Ability to scale and expand the telecom network to meet business requirements and new opportunities
- Improved knowledge and capability to plan and deploy advanced networks, creating and preparing for economic and business opportunities of the modernized grid

Project Set Lead: Tim Godfrey, tgodfrey@epri.com

Telecommunications – Future State 1: Interoperable and Reliable Field Area Networks (FAN)

Future State 1: A ubiquitous, interoperable field area network that has the necessary reliability to support multiple applications and can adapt to network impairments. **This Future State incorporates the following topic(s):**

- FAN Testing and Evaluation
- FAN Commercial Cellular
- FAN Technology
- FAN Use Cases
- FAN Resilience
- FAN Connectivity at the Grid Edge

Gaps Addressed:

- Lack of interoperability for specific wireless technologies for certain bands and applications
- Lack of mechanisms to incorporate multiple wireless technologies for improving reliability and resilience
- Lack of effective prioritization sufficient to enable operation in impaired state while meeting application requirements

Major Past Accomplishments	2021	Future
ACTION PLAN ANNUAL RESEARCH PORTFOLIO		
• FAN Capacity Offload – selective use of higher-band spectrum, 3002018510 (2020) • Evaluate private and commercial NB-IoT, 3002018511 (2020) • Additional FAN Performance Testing 3002015944 (2019) • Design and deployment of Private LTE 3002015943 (2019) • Communications network requirements for DER applications Phase 1 3002016143 (2019) • FAN Technology Performance Evaluation 3002013393 (2018)	• Evaluate 5G Ultra-reliable low-latency communication (URLLC) networks for DTT • LTE Inter-network Operation Leveraging LTE interoperability for Private/ public roaming, mutual aid, and examine UE compatibility, failover and handover design practices for reliability. Evaluate 5G Dual Connectivity for higher performance	• Evaluate commercial 5G URLLC networks for Direct Transfer Trip (F1c-M1) • Evaluate integration and migration of LMR and voice to private LTE (F1b-M2) • Lifecycle and lifespan of Cat-M evolution to 5G NRLite (F1c-M3) • Failover of Private LTE cores between utilities or operators (F1c-L2) • Develop database of FAN use cases with parameterizable traffic models (building on prior work in OpenSG) (F1a-L2) • Evaluate commercial 5G eMBB for AR/VR and "Digital worker" in the field (F1c-M2) • Supporting drones for NLOS flight with the FAN for damage assessment and telecom inspection and maintenance (F1a-M1) • Evaluation of new Wi-Fi standards – 802.11ah and 802.11ax (Wi-Fi 6). New use cases enabled? What testing and demonstration is needed? (F1d-M1) • Develop application specific profiles for QoS parameters (F1b-M4) • Mobile worker, mobile workforce – adapting the FAN for support for very high bandwidth, low latency use case (e.g. tele-control/ robotics) (F1a-L1) • Extend multi-mode FAN to interoperate with AMI, private FAN, and customer broadband (F1d-L1)

VALUE

- Increased communications resilience
- Reduced risk when migrating to new technologies
- Understanding technology options
- Multi-services capabilities

ARP PROJECT

P161.054: Field/ Neighborhood Area Networks

TIES TO OTHER PROGRAMS

Substations (P37), Distribution Systems (P180), End-Use, Energy Efficiency, and Demand Response (P170), Integration of Distributed Energy Resources (P174), Electric Transportation (P18), Energy Storage and Distributed Generation (P94)

Future State 2: Optimal Use of Available Spectrum

This Future State incorporates the following topic(s):
- FAN Spectrum
- FAN Testing and Evaluation
- FAN Resilience

Description: The network can make optimal use of available spectrum including licensed, unlicensed and shared.

Gaps Addressed:
- Crowding and interference in unlicensed spectrum results in lack of reliability and inadequate performance
- Lack of adequate channel bandwidth in licensed spectrum limits data capacity and thus servable applications
- Lack of understanding of operational constraints resulting from spectrum sharing mechanisms such as database-controlled Spectrum Access Systems
- Lack of understanding of actual FAN Performance in various spectrum types and deployment scenarios.
- Lack of FAN technologies ability to adapt to constrained spectrum, interference, failures, damage, and other network impairments, while ensuring critical traffic is prioritized.

Major Past Accomplishments	2021	Future
ACTION PLAN ANNUAL RESEARCH PORTFOLIO		
• Evaluation of "mid band" shared spectrum for aggregation • Explore License Assisted Access (LAA) approach of licensed control channel, and unlicensed broadband private utility FAN • Develop parameters for shared operation in 406-420 MHz spectrum • Optimizing Wireless Spectrum: Operation and Coexistence in Sub 1GHz • Unlicensed Spectrum, 3002013392 (2018) • IEEE 802.16S Overview, 3002011195 (2017) • Optimizing Wireless Spectrum 3002013392 (2018) • Wireless Taxonomy and • Architecture 3002009786 (2017) • Assessment of Licensed Spectrum 3002005851 (2015)	• Frequency planning an interference managementfor licensed spectrum FANs • LTE Flexible Frequency Use and Spectrum Sharing. Technical solution for utility requirements in a shared spectrum environment. Is Dynamic frequency assignment, opportunistic sharing, etc necessarily incompatible with high reliability, high availability, 100% predictable utility telecom? Field testing of SAS based FAN operating in 3.6 GHz CBRS band	• Pilot Deployment of private LTE in 406-420 MHz (F2a-M2) • Develop, simulate, and test dynamic network reconfiguration due to damage or impairment (F2c-M2) • Simulation and possible prototype of 700 MHz Upper A block + 4.9/5.8 GHz FAN. Analysis of existing systems and techniques for split band operation (F2b-M1) • Develop approaches for multi-mode FAN nodes, with adaptive path selection and failover, support for band pairs (F1b-L3) • Wi-Fi Broadband Mesh: Are standards-based solutions viable and available for outdoor Wi-Fi mesh systems? (F2b-L1) • Interference adaptation and mitigation in unlicensed spectrum (F2b-L2) • Identify and evaluate uses of TV White Space spectrum (F2a-L2) • Develop a next generation SDR platform for spectrum monitoring (lower cost, more precision) (F2a-L1)

VALUE
- Determining the best match between requirements and wireless technologies
- Increased communications resilience
- Understanding technology options to reduce risk when migrating and deploying networks
- Improved FAN interoperability, longer lifecycle for installed FAN network equipment, reduced vendor lock-in

ARP PROJECT

P161.054: Field/Neighborhood Area Networks

TIES TO OTHER PROGRAMS

Substations (P37), Distribution Systems (P180), End-Use, Energy Efficiency, and Demand Response (P170), Integration of Distributed Energy Resources (P174), Electric Transportation (P18), Energy Storage and Distributed Generation (P94)

Telecommunications – Future State 3: Wide Area Networks (WAN) Using Packet Based Technology

Future State 3: Wide Area Networks (WAN) Using Packet Based Technology

This Future State incorporates the following topic(s):

- Packet WAN
- Leased Circuits in the WAN
- Other WAN Technologies

Description: Wide area networks will use the latest packet-based technology and deliver reliability and latency performance to meet present and future requirements.

Gaps Addressed: Utilities are challenged to transition from TDM networks to packet technology.

Major Past Accomplishments	2021	Future
ACTION PLAN ANNUAL RESEARCH PORTFOLIO		
• Teleprotection Over Packet Guidebook 3002018509 (2020), 3002015941 (2019) • Telecom data isolation techniques and NERC CIP requirements 3002015939 (2019) • Strategic Fiber Guidebook 3002015940 (2019) • Evaluation of SDN in Utility Operational Networks 3002013403 (2018)	Integrating and orchestrating WAN services	• Develop requirements and test scenarios of SDN and SD-WAN for OT. Leverage more of Internet for remote locations. (W3a-M1) • Define best-practices on SD-WAN. Reliability, business continuity, and resilience of backbone during crisis events (in contrast to public Internet) (W3a-M2) • Interoperability/Interfacing between private MPLS and commercial MPLS (W3b-M2) • Testing of commercial 4G and 5G services as part of the WAN (W3b-M1) (W3b-L1) • Evaluation and testing of TSN standards-compliant devices for latency management and time synchronization on the WAN (W3a-L2) • Timing Synchronization and distribution in packet WAN, timing security, availability, resilience (backup for GPS vulns) (W3a-M3) • Develop virtual SDN testbed and reference architecture for OT networks (W3a-L1)

VALUE

- Increased communications resilience, reliability, and lower cost for WANs and teleprotection circuits, enabling more advanced protection schemes
- Cost savings and risk avoidance resulting from strategic network planning, adoption of standards, convergence of IT/OT, leveraging best practices from the industry
- Understanding technology options—ability to more rapidly scale and expand the telecom network to meet business requirements and new opportunities

ARP PROJECT

P161.053: Wide Area Networks

TIES TO OTHER PROGRAMS

Substations (P37), Distribution (P180), End-Use, Energy Efficiency and Distributed Resources (P170), Integration of Distributed Energy Resources (P174), Electric Transportation (P18), Energy Storage and Distributed Generation (P94)

Future State 4: A reliable backbone built with fiber and other technologies

This Future State incorporates the following topic:
Strategic Fiber in the WAN

Description: Expansion of the reach of the fiber backbone to support the backhaul requirements of rapidly growing FAN bandwidth, and in some cases, fiber is deployed as an alternative to a wireless FAN.

Gaps Addressed: Challenges making economic and business case for broader fiber deployment.

Major Past Accomplishments	2021	Future
ACTION PLAN ANNUAL RESEARCH PORTFOLIO		
• Evaluation of interference potential for 6 GHz Microwave Links 3002018508 (2020) • Unlicensed Use of the 6 GHz Band, 3002019705 (2020) • Unlicensed Use in the 6 GHz Band: Field Interference Test Results, 3002019712 (2020) • TI — Fiber Optic Primary Power Cable Feasibility Analysis, Literature Survey and Analysis, 3002017834 (2020) • Strategic Fiber Handbook/ Fiber Survey 3002015940 (2019) • Strategic Fiber in the WAN - Synergistic Fiber Deployment for Utility and 5G 3002013389 (2018) • Strategic Fiber Handbook Phase 1, 3002009793 (2017) • Strategic Fiber Handbook Phase 2 — Innovative Business Models Case Studies, 3002009797 (2017)	• "Reliable operation of 6 GHz microwave links: Understand potential impact of 6 GHz unlicensed operation on existing links, Identify links that are most "at risk", design mitigation plans • Update of the Strategic Fiber Guidebook to include: » Rural Broadband Opportunities – Look into opportunities and implications for build-out » Cost benefit study of fiber monitoring systems (e.g. Ntest FiberWatch). Look at lifecycle, and physical line characteristics too » Underground Fiber – economics and best practices » Hybrid wireless/ fiber architecture for high capacity - Fiber infrastructure backbone and "last mile" wireless for FAN » Coordinating fiber projects with microwave transition	• Evaluate and document fiber deployment architectures over the range of points of access from single point-to-point to PON. (W4a-L1) • Evaluate the reliability factors of Fiber? Storm damage, physical damage, malicious attacks, compared to wireless interference/ jamming (W4a-L3) • Develop detailed use cases for hybrid primary power/ fiber optic cables (O/H and U/G) to include splicing/ termination methods and procedures. Work with cable manufacturer(s) to develop prototypes of hybrid primary power/ fiber optic cable types. (W4a-M1) • Evaluate new and emerging satellite technologies as WAN extension for challenging locations (e.g SpaceX Starlink broadband constellation (W4b-L1) • Evaluation of improvements in fiber cable make-up and configurations. (W4a-M2) • Evaluate relative impact of solar flares and other activity, and EMP on the fiber plant (W4a-L4) • Produce a comparison study of conventional OSP (field splicing) versus a preterminated OSP system, to include cost and schedule impacts. (W4a-M3)

VALUE

Utility fiber networks perform an essential role as the backbone of the telecom network. Increased fiber is needed, but installation costs are high. The concern over the future of 6 GHz microwave links increases the urgency of fiber deployment. The strategic focus of this research provide valuable insights into how partnerships and new business models can improve the economics of building fiber networks.

ARP PROJECT

P161.055: Telecommunications Planning and Management Systems

TIES TO OTHER PROGRAMS

Overhead Transmission [P35], Substations (P37), Distribution Systems (P180), Integration of Distributed Energy Resources (P174)

161G Telecommunications – Future State 5: Fully Integrated Network Management System

Future State 5: Fully Integrated Network Management System

This Future State incorporates the following topic(s):

- Network Management
- Planning Framework
- Provisioning and Device Management

Description: A fully integrated network management system incorporating best practices from commercial carriers provides detailed, relevant and actionable metrics to support network planning and operation.

Gaps Addressed:

- Independent, non-integrated network management systems for each network technology provide a disjointed view of operational status
- Lack of information and network metrics needed to inform telecom planning
- Inability to understand telecom requirements resulting from increasing density of communicating devices on the system

Major Past Accomplishments	2021	Future
ACTION PLAN ANNUAL RESEARCH PORTFOLIO		
• Telecom Network Management Systems: NMS and MoM Metrics, and Opportunities for Interconnections, 3002018513 (2020) • Multi-technology Provisioning Architecture, 3002018512 (2020) • IP Network Planning and Architecture for IPv4 and IPv6, 3002018515 (2020) • Optimizing provisioning and device management 3002015946 (2019) • Integration of GIS Visualization in Telecom Network Management 3002013394 (2018) • Zero-Touch Provisioning White Paper 3002013395 (2018) • Manager of Manager Survey Results 3002009800 (2017) • Creating Telecommunications Metrics for the Electric Sector 3002009803 (2017) • Framework for Migrating Telecom Services to Software Defined Networking, and Network Function Virtualization 3002009802 (2017)	• Approaches for islanded telecom operation: » Design and planning of a scalable IT network. » Design and application of Multi-tier networks » Develop approaches for traffic segmentation and management on multitier FAN) » Integration of the telecom NMS with GIS data for operation, management, and planning	• Continue research into zero-touch device provisioning. Implement GSMA reference architecture on non-3GPP networks. Prototype management of devices settings (possible joint work with Distribution programs) (N5b-M1) • Investigate methods to achieve better visibility into the commercial cellular NMS? (N5a-M2) • Improve automation of alert handling (N5a-M1) • Evaluate potential uses of AR and VR in the Telecom NOC, for simplification and automation (N5a-L2) • Extensions to the telecom planning framework, including evolution of traffic modeling (N5c-M2) • Study (qualitative and quantitative) of reliability and resilience benefits of multi-technology redundant networks (N5c-L2) • Refine requirements for network metrics to v2.0. Evaluate potential for standardization (N5a-M3) • Framework for intelligence at the edge – a reference architecture approach for embedded virtual machines in modems and edge devices, including their remote installation, provisioning, and management (N5b-M2)

VALUE

- For telecom, reduction of outages through better situational awareness, and higher availability of telecom networks
- Improved ability to plan and deploy advanced networks, creating new economic and business opportunities, understanding technology options
- Improved internal customer satisfaction by providing high reliability telecom services, with performance and reliability that meet application requirements now, and anticipate future business opportunities

ARP PROJECT

P161.055: Telecommunications Planning and Management Systems

TIES TO OTHER PROGRAMS

Substations (P37), Distribution Systems (P180), End-Use, Energy Efficiency, and Demand Response (P170), Integration of Distributed Energy Resources (P174), Electric Transportation (P18), Energy Storage and Distributed Generation (P94)

161G Telecommunications – Future State 6: Interoperability of Telecommunications Systems Through Standards

Future State 6: Interoperable Telecommunications Systems

This Future State incorporates the following topic(s):
Telecommunication Standards

Description: Standards based telecom solutions are available for all aspects from WAN to FAN to network management. Interoperability between technologies is enabled by a standardize architecture based on multiservices networking.

Gaps Addressed: Proprietary communications technologies implemented individual for each application:

- Multiple incompatible technologies implemented across the utility performing the same function
- Stranded assets due to early obsolescence of nonstandard systems

Major Past Accomplishments	2021	Future
ACTION PLAN ANNUAL RESEARCH PORTFOLIO		
• Telecom Standards Guidebook, A high-level description of telecom and communications standards, their roadmap, utility applications, and interrelationships, updated annually, 3002018516 (2020) 3002015951 (2019) • TI - Communications Connectivity Technology Newsletter, January 3002017359 (2020) • TI - Fiber Optic Primary Power Cable Feasibility Analysis, Literature Survey and Analysis, 3002017834 (2020) • Comms Intelligencer Newsletters 3002018519, 3002018517 (2020) • The 5G Technology Roadmap for the Utility FAN: Staying Ahead of the Technology Adoption Curve 3002016411 (2019) • Business Case for Telecommunications 3002016412 (2019) • Com Intelligencer newsletter complete listing 3002020175 (2020)	• Comms Intelligencer newsletters • Telecom Standards Guidebook Update • Lead TG16t standard for FAN operation in licensed spectrum for channel widths below 100 KHz. (licensed narrowband)	• Investigate options for engaging with 3GPP to represent grid requirements for ongoing 5G evolution (S6a-M1) • Additional engagement with PES Power Systems Relaying & Control (PSRC) and Power System Communications and Cybersecurity (PSCC) committees (S6a-M2) • Emerging LPWAN technologies 802.15.4w and others. (S6a-M3) • Evaluate need and opportunity for further standardization of "mid-bandwidth" P-MP FAN • Technologies (S6a-L1) • Evaluate potential and value • of engagement with IETF in areas related to utility telecom and IoT (S6a-L2) • Additional engagement in CIGRE D2 (S6a-L3) • Engage with ITU Standards for buildings and facilities (S6a-L4)

VALUE

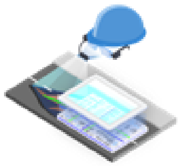
- Improved awareness of standards in development and their potential impact
- Improved interoperability of telecom systems, resulting from development and deployment of relevant standards

ARP PROJECT

P161.056: Telecommunication Standards Tracking and Analysis

TIES TO OTHER PROGRAMS

Substations (P37), Distribution Systems (P180), End-Use, Energy Efficiency, and Demand Response (P170), Integration of Distributed Energy Resources (P174), Electric Transportation (P18), Energy Storage and Distributed Generation (P94)



Geospatial Informatics (161H)

EPRI has been conducting research in electric utility geographic information systems (GIS) since 2012. Geospatial applications are now expanding well beyond traditional utility GIS because of new capabilities:

- New aerial, space-based, and ground-based image-capture capabilities are rapidly expanding the amount and types of available geospatial data.
- Advanced applications are being enabled with GIS data, such as augmented, virtual, and mixed reality (AR/VR/MR) technologies. These are now collectively referred to as extended reality (XR). Digital field workers are interacting with physical assets in new ways.
- Geospatial technologies are increasingly embedded in all consumer systems, driven by new autonomous systems (unmanned aerial vehicles, self-driving cars, robotics), and they are often connected with Internet of Things platforms and sensor networks.
- Fast analytics can now be performed on extremely large geodata sets, paving the way for the application of machine learning and AI techniques for data quality improvements.
- Artificial Intelligence (AI) software development platforms have become increasingly capable and the cost to add AI functionality to GIS data analytics has fallen dramatically. Code and algorithms can now be easily embedded within the computing environments on field devices.

The Geospatial Informatics project set focuses on the science and technology of acquiring, storing, cleaning, modeling, analyzing, producing, presenting, and disseminating geospatial data sets. Collaborative research projects in this project set will enable utility GIS professionals to:

- Understand the expanding role of GIS and geospatial platforms at electric utilities
- Prepare for rapidly growing data volumes delivered by new imaging and data collection systems
- Master GIS data quality and data management challenges
- Develop geospatial standards to support expanding XR applications
- Deliver new geodata services for advanced planning and operations applications

GIS professionals at EPRI funding utilities must continue to optimize the cartographic role of GIS while exploring the impacts of these trends, which can be disruptive. The Geospatial Informatics project set focuses on helping funders develop maturity in delivering geospatial data services. Project set funders will learn more about acquiring, storing, cleaning, modeling, analyzing, producing, presenting, and disseminating geospatial data via maps and applications to their customers, both within and outside of the utility enterprise.

Research Drivers

- Improve GIS data quality
- Enable the workforce of the future
- Leverage geospatial resources across the enterprise
- Identify best practices for acquiring, indexing, organizing and curating geospatial data
- Demonstrate potential applications of AI [machine learning, neural networks, advanced algorithms] for improving GIS data quality
- Develop geospatial services to support expanding XR applications
- Enhance network model data management and exchange to support more advanced analytics in planning and operations

Value

- Increased workforce safety and operational efficiencies
- Reduced errors via improved data accuracy
- Identify and mitigate gaps in GIS standards
- Reduced integration and operational costs through standards enhancement and utilization

Project Set Lead: Randy Rhodes, rrhodes@epri.com

161H Geospatial Informatics – Future State 1: Advanced Geospatial Data Management

Future State 1: Electric utility GIS professionals are skilled in managing the rapidly growing volume and diversity of geospatial data.

Description: The long-held GIS role of mapping electric utility networks is changing. Computing power and network bandwidth is expanding, driving more use of mobile devices by field workers. The range of sensing devices are also expanding, offering new, increasingly precise methods for field "reality capture." Yet, most utilities struggle with the timeliness, accuracy and precision of their data. This project will focus on identifying best practices for geospatial data management at electric utilities.

Gaps Addressed:

- Immature data, incomplete system models, and insufficiently accurate modeling
- Inability to visualize and evaluate dataset quality
- Duplicate data and incomplete metadata
- Difficulty with quickly and accurately on-boarding precise asset data and closing work orders

Major Past Accomplishments	2021	Future
ACTION PLAN ANNUAL RESEARCH PORTFOLIO		
• Geospatial Informatics Guidebook, 3002019291 (2020)	• Geospatial Informatics Guidebook Update • Next-Generation GIS - A fully digital and interactive deliverable for educating electric utility GIS professionals and their internal customers on the expanding role of GIS. • GIS Data Management Maturity Model — • Applications of AI algorithms to GIS data quality challenges for AI and machine learning; fast analytics on extremely large geodata sets • Standards development for 3D and 4D data management	• Guidebook Updates • Standards development • Advanced AR and analytics-based field corrections for automatic redlining • Maintaining geospatial data integrity beyond GIS systems • Development of fully automated workflow for field surveying, design, engineering and work order closure
ACTION PLAN SUPPLEMENTAL PROJECTS - ASSESSING GIS DATA QUALITY IMPROVEMENT OPTIONS 3002017823		
	• Investigate utility case studies in GIS data quality improvement • Benchmark improvement methods with geospatial analytics (text/graph; spatio-temporal; fusion/conflation; machine learning/neural networks) • Investigate opportunities to standardize GIS data quality metrics • Evaluate costs and benefits for different approaches	• Investigate advanced platform-agnostic asset identification • Leverage EPRI.AI data sets for algorithm improvement

VALUE

- Accurate models suitable for consuming applications
- Procedures for ensuring the integrity of the data supply chain and QA/QC processes
- Delivering the right data at the right time in the right location for engineers, planners, and digital field workers

ARP PROJECT

161.059:Geospatial Information Systems (GIS) Data Practices

TIES TO OTHER PROGRAMS

Substations (P37), Distribution Systems (P180), Distribution Operations & Planning (P200)

161H Geospatial Informatics – Future State 2: Interoperable GIS and XR

Future State 2: Mobile and XR applications supporting 3D interaction with utility infrastructure are seamlessly integrated with utility GIS systems and geospatial platforms.

Description: Extraordinarily rich application functionality will be available soon for digital field workers. Extended Reality (XR) solutions will allow them to see and utilize visually rich, context-sensitive, streaming geo data, 3D objects, imagery and more. Utility GIS professionals must prepare to support the geospatial data needs of these applications. Geo-related (locational "where") information is necessary for placing and orienting XR content correctly – formatted for rendering and coordinate-referenced in 3D space to surrounding features. In this project augmented reality research specialists may more clearly define GIS contributions to augmented reality, virtual reality, and mixed reality applications. The project will research how current standards efforts (such as the World Wide Web Consortium's Immersive Web standard) can be harmonized with existing electric utility environments and needs. The research is centered around questions related to interoperability of geospatially-referenced data capture, management, search, delivery and presentation with emerging 3D XR solutions.

Gaps Addressed:

- Lack of consensus between experienced, utility-focused GIS vendors and emerging XR vendors regarding application architecture and interoperability requirements
- De facto standards in an emerging XR industry are not yet harmonized with proven standards already used in electric utility operations and planning, limiting interoperability with legacy utility systems

Major Past Accomplishments	2021	Future
ACTION PLAN ANNUAL RESEARCH PORTFOLIO		
• Geospatial Data Integration in Augmented Reality Solutions for Electric Utilities, 3002016147 (2019) • Using Virtual Reality to Train Utility Workers to Assess Storm Damage 3002014695 (2019) • Extended Reality Guidebook - Digital Transformation for Training and Telemetry 3002017159 (2019) • Identify future requirements for utility GIS systems in augmented reality, mixed reality, and virtual reality applications • Develop guidelines for governance and integration standards for mobile and XR apps portfolio	• Geospatial Requirements for XR Applications 3002019292 (2021) • Define functional requirements in more detail for GIS and AR Cloud integration • Partner with cybersecurity team to define guidelines for cloud GIS deployment • Develop guidelines for GIS integration with virtual positioning systems • Case studies: BIM and 3D integration with GIS • Coordinate with and support 161G on telecom GIS requirements for coverage analysis	Analyze impacts of 5G availability on AR Cloud performance

VALUE

The industry collaboration resulting from this project will enable electric utility GIS, Computer Aided Design (CAD) and Building Information Modeling (BIM) systems to have a migration path from restricted 2D digital displays into systems that can support immersive 3D environments. This will support not only the needs of utility field workers and control center operators, but also the needs of external groups such as incident managers, public safety officials, and fire and rescue teams.

ARP PROJECT

161.060 Geospatial Information (GIS) Applications

TIES TO OTHER PROGRAMS

Substations (P37), Distribution Systems (P180), Distribution Operations & Planning (P200)

161H Geospatial Informatics – Future State 3: Complex Grid Modeling for Operations and Planning

Future State 3: GIS systems are optimally configured to model the most important aspects of the transmission and distribution networks, substations, and customer-owned DER.

Description: GIS systems at electric utilities support many applications by providing an accurate network model and detailed facility information useful for grid planning studies and operations. Further research on the GIS contribution to accurate models is needed now because higher fidelity of components within the model (including DER penetration) is required for more sophisticated grid studies at most utilities. Timely and sufficiently accurate network and DER representation is a new and significant challenge. Most system planners, and the GIS professionals that support them, do not have a mutual, shared understanding of these changing modeling requirements, nor a methodology for assessing the GIS contribution to model fidelity and accuracy. This research will enable both parties to adopt a recommended practice and avoid problems before they occur.

Gaps Addressed:

- Highly customized mapping and modeling practices that vary significantly among utilities, making it difficult to learn best practices
- Most utilities are uncertain about what data is needed, and what should be stored in the GIS
- Geoprocessing frameworks that manage data received from facility design and asset management applications often do not support end-user information and analytics needs (e.g. distribution system assessments - static load-flow, quasi-static load-flow, fault analysis, harmonics, dynamic, electromagnetic transient, and reliability)

Major Past Accomplishments	2021	Future
ACTION PLAN ANNUAL RESEARCH PORTFOLIO		
• Enhanced Grid Modeling for Advanced Planning Analytics report 3002018992 (2020) (joint deliverable with P200E) • Distribution Planning Guidebook for the Modern Grid: 2020 Edition 3002018813 • Distribution Modeling Guidelines: DER Modeling Recommendations for Distribution System Assessments 3002007976 (2016)	• Enhanced Grid Modeling for Advanced Planning Analytics Workshop • Extend research to cover areas not addressed in 2021, such as fault studies and harmonics • Evaluate changing needs considering the trend toward T&D model fusion • Collaborate with GMDM project on GIS implementation of functional requirements for grid model management.	Incorporate requirements into CIM standards and model exchange interoperability testing
ACTION PLAN SUPPLEMENTAL – DISTRIBUTION GEOGRAPHIC INFORMATION SYSTEM AND GRID MODEL DATA MANAGEMENT (GMDM) 3002009807		
• Develop a network model data management architecture for the electric distribution industry • Provide the data foundation for improved grid simulations and analytics • Define functional requirements for grid model • management software tools	• Utility and vendor demonstrations • Continued sharing of project results at industry events • Exploration of data management architecture support for mobile and extended reality (XR) applications	Socialize GMDM data management architecture Expanded standards definition for network model exchange with field applications
ACTION PLAN SUPPLEMENTAL – GRID MODEL DATA MANAGEMENT (GMDM) VENDOR FORUM 3002017776		
• Tech Transfer Outreach to Vendor Community • Improve of the GMDM architecture via vendor feedback • Accelerate CIM standards development	• Demonstration of multi-vendor interoperability using the GMDM architecture • Improved CIM support for distribution network model data exchange	Deeper harmonization of CIM with OGC standards

VALUE

Practical insight into the requirements imposed by various advanced distribution planning analytics on the GIS and related applications; awareness of methodologies working well at other utilities; recommendations that can be incorporated into distribution planning investment roadmaps.

ARP PROJECT

P161.061: Geospatial Information (GIS) Analytics and Visualization

TIES TO OTHER PROGRAMS

Distribution Operations and Planning (P200), and Customer Insights (P182) Programs

Glossary and Acronym Definitions

A

AI: Artificial Intelligence
AMI: Advanced Metering Infrastructure
API: What is an API architecture? API architecture refers to the process of developing a software interface that exposes backend data and application functionality for use in new applications. With an API-first architecture, you can create ecosystems of applications that are modular and reusable — which is ideal for microservices
AR: Augmented Reality

B

BI: A **business intelligence** architecture is the framework for the various technologies an organization deploys to run business intelligence and analytics applications.
BIM: Building Information Modeling

C

CAD: Computer Aided Design
CBRS: Citizens Broadband Radio Service, is a 150MHz broadcast band of the 3.5 GHz band (3550MHz to 3700MHz) historically used by the United States government for radar systems
CEC: California Energy Commission
CIM: Common Information Model
CIP: Critical Infrastructure Protection

D

DER: Distributed Energy Resources
DERMS: Distributed Energy Resource Management System
DLMS: Device Language Message Specification
DLMS/COSEM: IEC series of standards specifying electricity meter data exchange
DOE: Department of Energy
DR: Demand Response
DTTV or DTT: Digital terrestrial television, sometimes also abbreviated

E

EA: Enterprise Architecture
EPRI: Electric Power Research Institute

F

FAN: Field Area Network

G

GIS: Geospatial Information System
GMDM: Grid Model Data Management

I

ICT: Information and Communications Technology

IoT: Internet of Things
IT: Information Technology

L

LAA: License Assisted Access
LTE: Long-Term Evolution

M

MOM: Message-oriented middleware
MPLS: Multi-Protocol Label Switching
MR: mixed reality

N

NAN: Neighborhood Area Network
NB-IoT: Narrowband Internet of Things
NFV: Network Functions Virtualization
NYSERDA: New York State Energy Research and Development Authority

O

O/H: Overhead
O&M: Operation and Maintenance
OT: Operational Technology

Q

QA/QC: is the combination of quality assurance, the process or set of processes used to measure and assure the quality of a product, and quality control, the process of ensuring products and services meet consumer expectations.

R

R&D: Research and Development
RE: Renewable Energy
RFP: Request for Proposal
RF: Radio Frequency includes frequencies from 3 KHz to 300 GHz
RF Mesh: A globally recognized wireless network model, the consists of flexible radio nodes that operate in a self-guided, resilient manner.

S

SDN: Software-defined Networking
SME: Subject Matter Expert

U

U/G: Underground
URLLC: Ultra-reliable low-latency communication

V

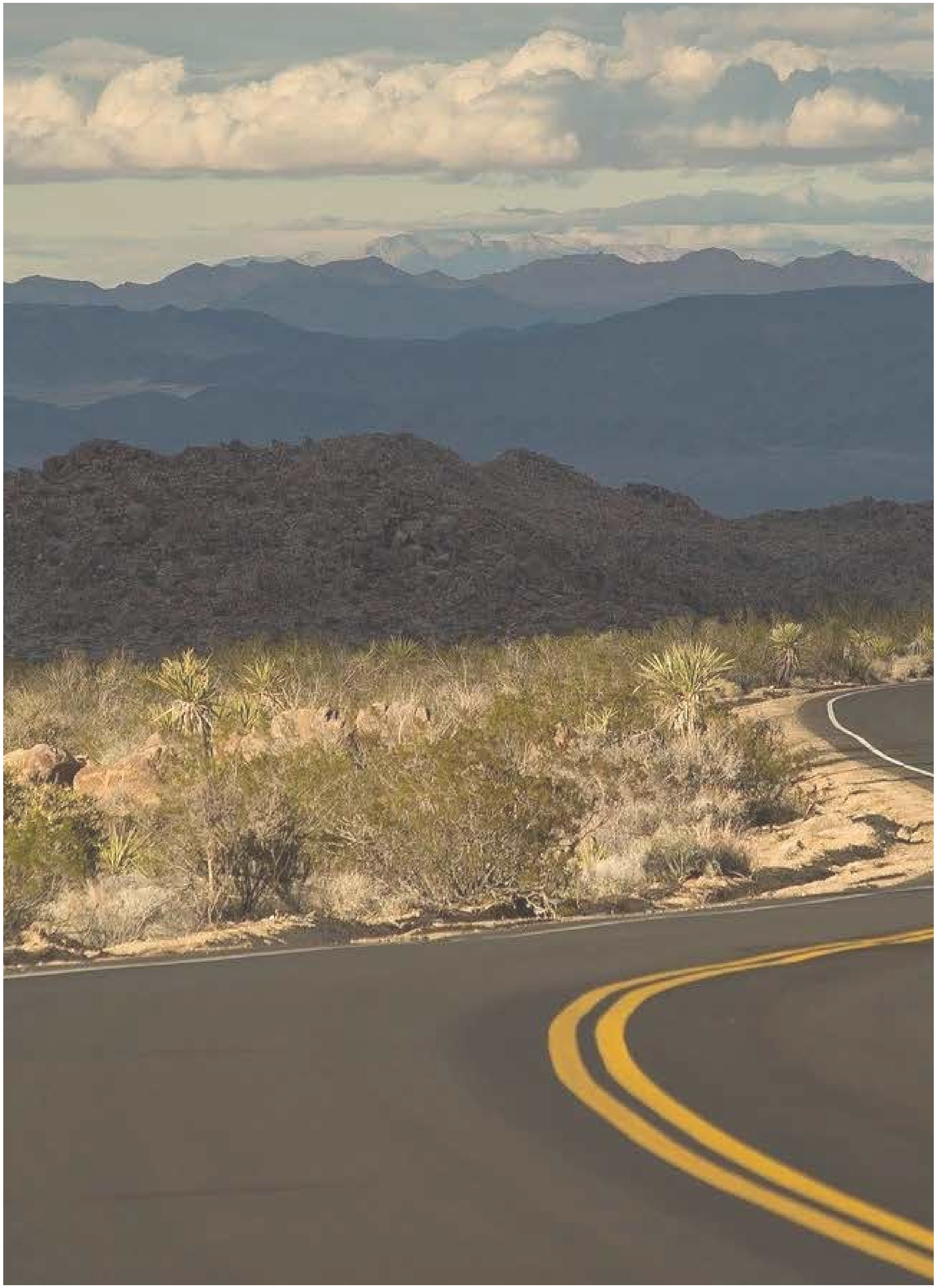
VR: Virtual Reality

W

WAN: Wide Area Network

X

XR: Extended Reality



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EPRI's principal offices and laboratories are located in Palo Alto, Calif.; Charlotte, N.C.; Knoxville, Tenn.; Dallas, Texas; Lenox, Mass.; and Washington, D.C.

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