GRID MODERNIZATION INITIATIVE PEER REVIEW
1.2.1 Grid Architecture

JEFFREY D. TAFT, PHD (PNNL)

April 18-20, 2017

Sheraton Pentagon City – Arlington, VA

Grid Architecture
High Level Summary

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Project Description

Grid architecture is the application of system architecture, network theory, and related disciplines to the whole electric grid. The purpose of this project is to re-shape the grid, remove essential barriers to modernization, redefine key grid structures, and identify securable interfaces and platforms.

Value Proposition

- ✓ Relieve essential constraints that impede grid modernization
- ✓ Enable new grid value streams by identifying platforms and structures that provide secure interoperability and system integration,
- ✓ Manage grid complexity so as to assure successful investment in grid modernization across the industry

Project Objectives

- ✓ Build stakeholder consensus around a DOE-convened vision of grid modernization, expressed as a new set of grid reference architectures
- ✓ Enable superior stakeholder decision-making to reduce risk of poor functionality and stranded investments
- ✓ Provide a used and useful framework for GMLC projects
- ✓ Establish and win industry acceptance for the use of Grid Architecture work products and methodologies
- ✓ Supply a common basis for roadmaps, investments, technology and platform developments, and new services and products for the modernized grid.

Grid Architecture
Project Team

Labs shown in table.
Lab members have various roles on the Grid Architecture team, including SMEs, validators, architects, and researchers.

External Partners:

- SGIP
- EPRI
- GWU Law
- Alstom-GE
- Omnetric Group
- CA ISO
- MISO
- Ameren
- SMUD
- GridWise Alliance
- Paul De Martini, Wade Malcolm (Industry SMEs)

PROJECT FUNDING				
Lab		FY16 $	FY17$	FY18 $
PNNL	*	500,000	500,000	500,000
ORNL	Arjun Shankar (+1)	100,000	125,000	100,000
LANL	Anatoly Zlotnick	100,000	50,000	50,000
ANL	Jianhui Wang	50,000	75,000	50,000
LBNL	Bruce Nordman	100,000	100,000	100,000
LLNL	Brian Kelley	50,000	50,000	50,000
NREL	Maurice Martin	50,000	50,000	50,000
SNL	Ross Guttromson	50,000	50,000	100,000

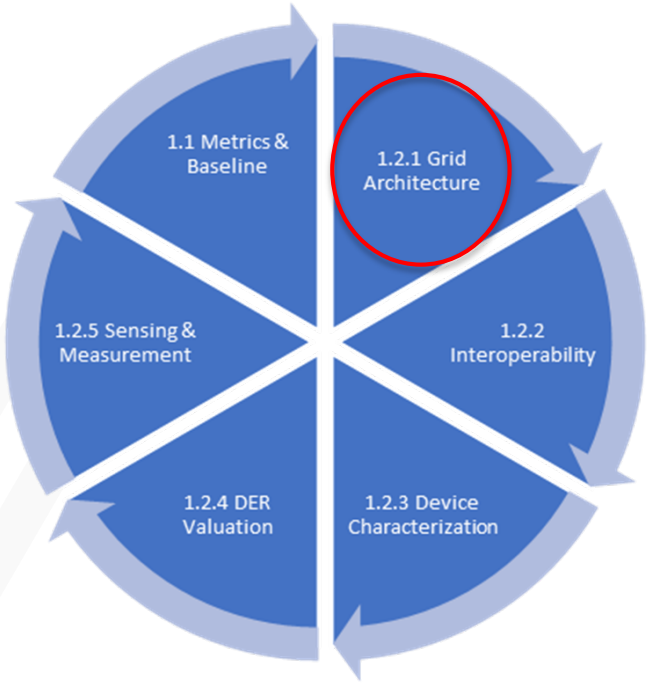
* Ron Melton, Steve Widergren, Olga Kuchar, Renke Wang, Jeff Taft

Grid Architecture
Relationship to Grid Modernization MYPP

Grid Architecture is fundamental to all aspects of grid modernization since it defines the basic structures of the grid and thus determines overall capability limits, removes legacy constraints, and manages the complexity of the modernization process. It provides the structures within which grid planning, grid operations, and markets operate, and therefore includes or impacts sensing and measurement, control, communications, interface and interoperability, and even industry structure.

Grid Architecture addresses electric infrastructure, industry structure, ICT, control structure, convergence with other networks (gas, transportation, etc.), regulatory and market structure (not rules), and most importantly, coordination framework.

Grid Architecture is a cross-cutting fundamental project that influences all six MYPP Technical Areas.



Cross-Cutting Projects

Grid Architecture
Approach

Project tasks:

- Architecture development
  - Develop an ensemble of architectures covering a range of scenarios and industry segments, using the discipline of Grid Architecture (see below)
- Stakeholder engagement
  - Three stage process; continual engagement
- GMLC Inter-project collaboration
  - Interaction with many other GMLC projects
- Grid Architecture tools development
  - Browser-based diagram tools
  - Comparative analysis
  - Evaluation and optimization

- Key issues: Bulk System/DSO interaction, structural securability, silo-to-layer conversion, and distributed coordination for distribution grid control, transactive energy, and DER integration. These are all primary grid modernization issues.

- Uniqueness: Grid Architecture is a combination of system architecture, software engineering, network theory, and control engineering applied to the grid. It focuses primarily on structure(s) and employs a range of new paradigms, including the grid as a network of structures concept.

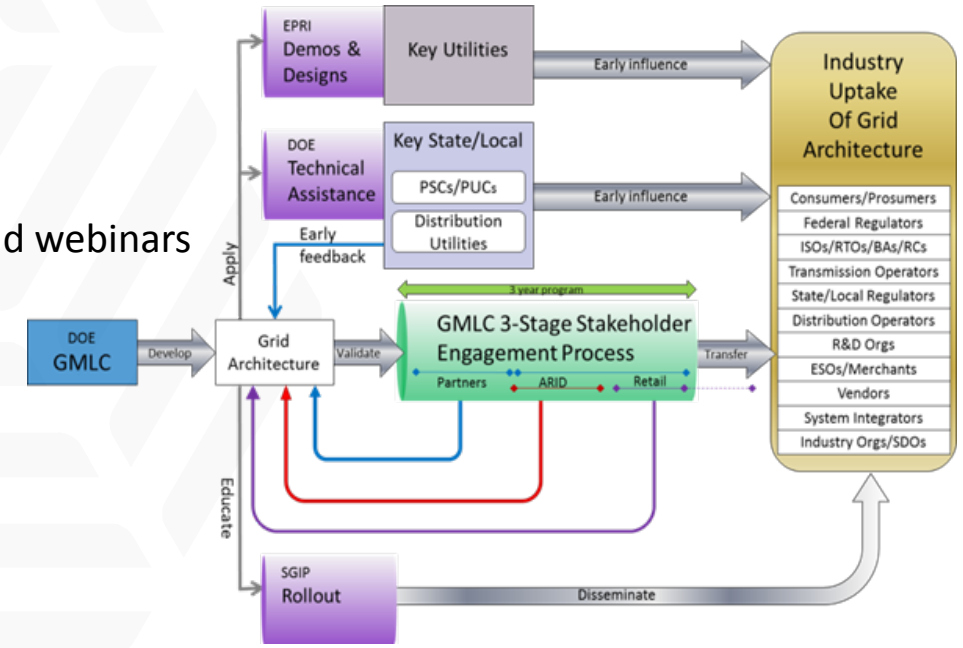
Grid Architecture
Key Project Milestones

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Milestone (FY16-FY18)	Status	Due Date
1.1 Initialization	• Quality/property list and initial mapping complete • Architecture glossary complete • Emerging trends and systemic issues lists complete • Architectural views list generated, priorities received from external partners • Initial collaboration with 11 other GMLC programs established; architecture package delivered to 1.4.10	10/1/2016
1.2 Reference model development	Reference models for high DER grids, structure diagrams for market-control systems in high, medium, and low DER grids, and industry structure models for ISO/RTO industry segment completed	10/1/2016
1.3 Component/interface model development	Six models complete; interaction with 1.2.2 underway	4/1/17
1.4 Architecture development	One package completed for 1.4.10; others underway	10/1/17
1.5 Architecture validation	Simulation of distribution storage circuit models and wide area closed loop control with SDN underway	4/1/18
1.6 Architecture completion	Development underway	10/1/18

Grid Architecture
Accomplishments to Date

- Early Technical Insights
  - Use of sensor/comms layer networks and DSO structure to improve cyber security; structural securability
  - Use of layered decomposition to perform comparative architecture analysis; framework for distributed TE; impact on Grid Codes for DER
  - Grid services taxonomy & list development
- Stakeholder engagement
  - Extensive public and private presentations and webinars
  - DSPx project; CSIRO project
  - External partner engagement as per plan
- Early Stakeholder Adoption
  - NY PSC Order Adopting Distribution System Implementation Plan Guidance (Grid Arch.)
  - HPUC Order 34281 (Grid Arch., Sensor Nets)



Grid Architecture

Response to December 2016 Program Review

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

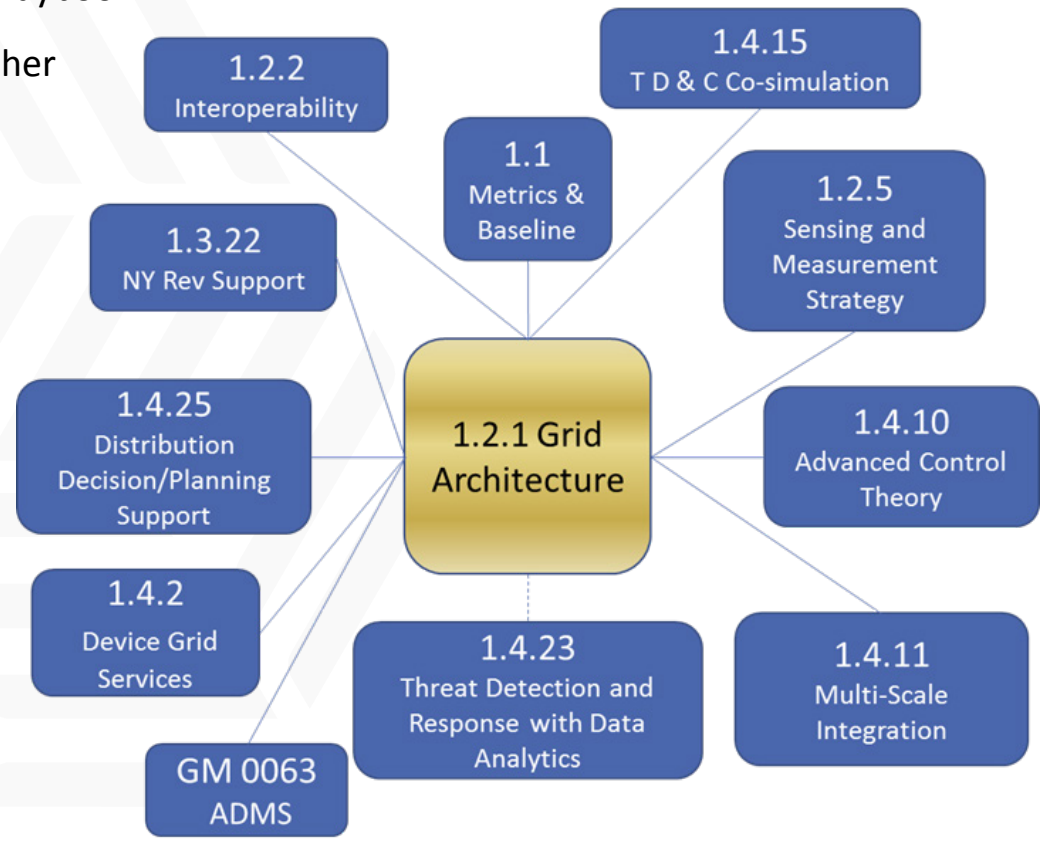
Recommendation	Response
• Excellent outreach with IEEE (1,100 registrants on webinar!) and close interaction with SGIP and EPRI.	Will continue the process.
• Close interaction with other projects is excellent (1.4.10, 1.2.2).	Will continue the process.
• Please work with Sensing and Measurement Strategy (1.2.5) and Interoperability (1.2.2) to develop a webinar(s) that will support their understanding of grid architecture so they can incorporate it into their programs.	Have planned a webinar with 1.2.5; working with 1.2.2 on application of Grid Architecture to interface and grid services definition.
• Given the level of resources, the team needs to better prioritize their efforts around grid architecture. Please identify how this effort is unique compared to other similar efforts underway in grid architecture.	Have prioritized the 63 proposed views into five scenarios with a plan to maximize use of common elements; this effort has broader scope and uses methods not available to IT-based efforts; 1.2.1 is focused mainly on structures, whereas most other efforts focus on components (mainly IT components).

Grid Architecture
Project Integration and Collaboration

Grid Architecture provides the structural framework for the modernized grid and as such provides the playbook for the GMLC PIs and project managers. Grid Architecture is actively collaborating with 11 other GMLC projects.

Communications include:

- Incorporated into DSPx project
- Incorporated into CSIRO project
- IEEE Smart Grid Webinar
- EPRI Grid Architecture webinar
- CA ISO webinar
- GWU Regulatory Conference
- NERC meeting
- UTC Annual Meeting
- 2016 TE Systems Conference
- ISGT 2016
- EBA Conference
- SGIP Architect training
- GRID Management Group Meeting
- EPRI Sector Meeting



Grid Architecture
Next Steps and Future Plans

Both the Grid Architecture work products and the Grid Architecture discipline will be rolled out to the electric utility industry. This will have the impact of providing rigorous means for managing grid modernization complexity and enabling superior decision making about grid modernization investments, platform developments, and designs at all stakeholder levels.

Future projects will include applying Grid Architecture at all scales in the industry to assist utilities and others to adopt and adapt reference architectures and associated tools for meet specific regional, industry segment, and technology integration needs.