GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

# GRID MODERNIZATION INITIATIVE PEER REVIEW

# GMLC 1.2.5 – Sensing & Measurement Strategy Project

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# Sensing & Measurement Strategy

## High-Level Project Summary

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***Project Description***

- A cohesive strategy to develop and deploy sensing & measurement technologies for the modern grid is lacking.
- Project focuses on such a strategy to define measurement parameters, devices for making measurements, communications to transfer data, and data analytics to manage data and turn it into actionable information.

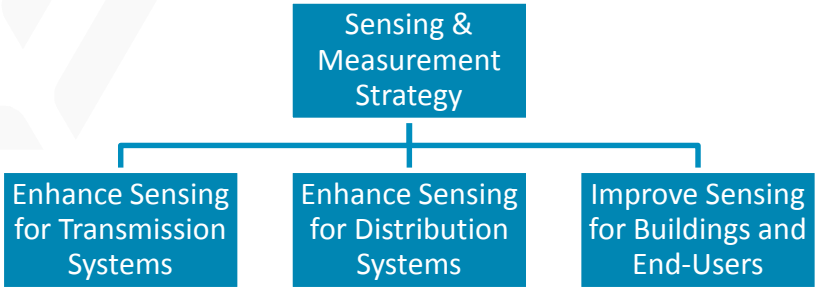
***Value Proposition***

- ✓ Grid is undergoing a major transformation (integration of new devices, major shift in generation mix, aging infrastructure, added risk of extreme system events (both manmade and climate).
- ✓ A need exists to characterize the state of the grid at much higher fidelity/resolution to maintain system reliability and security.

***Project Objectives***

- ✓ Create extended grid state model.
- ✓ Develop a sensor technology roadmap.
- ✓ Develop a sensor placement optimization tool (SPOT).
- ✓ Outreach to technical & standard groups.

**Sensing & Measurement Technologies are foundational needs of the GMI MYPP.**



# Sensing & Measurement Strategy

## Relationship to Grid Modernization MYPP

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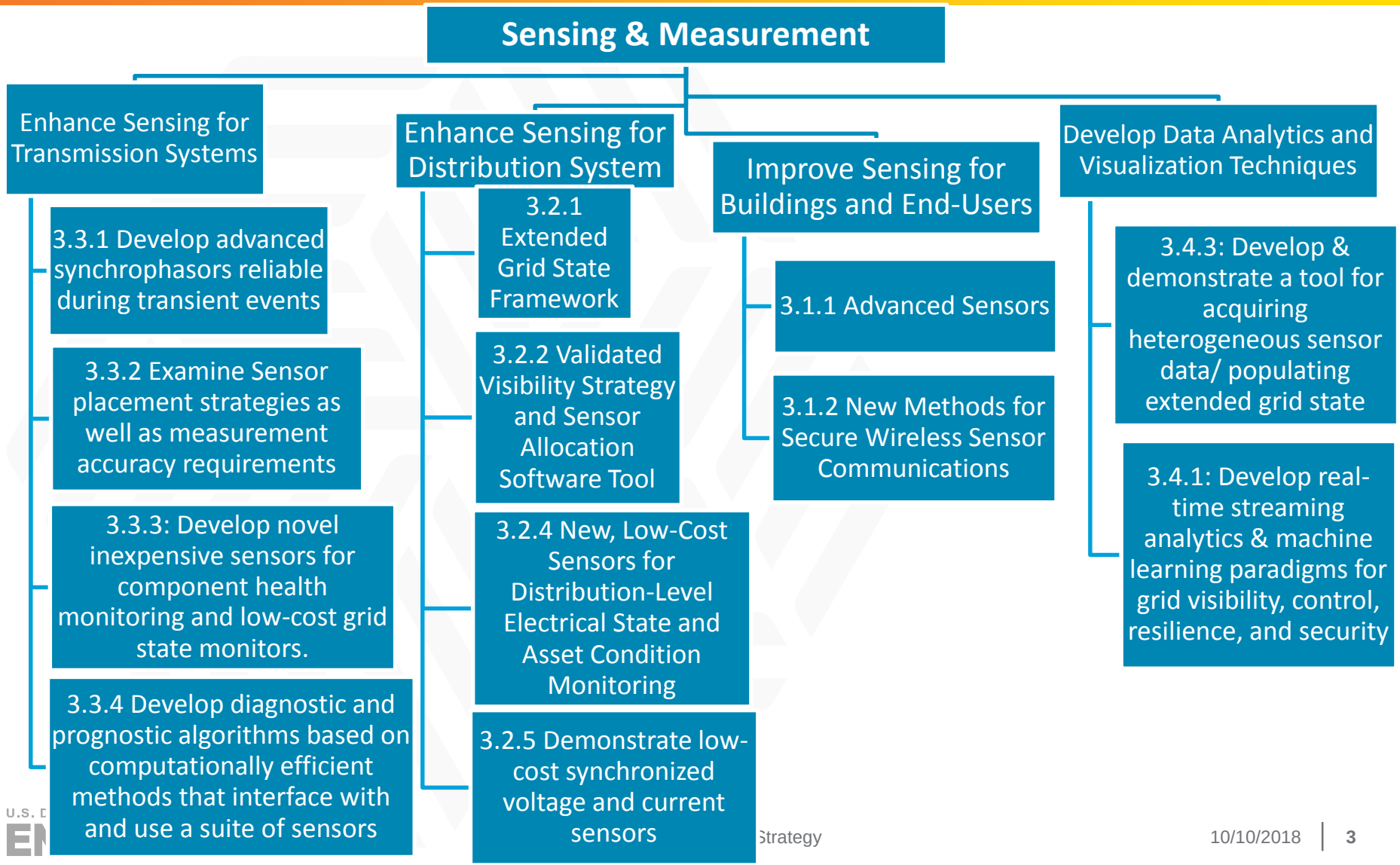

# Sensing & Measurement Strategy

## Relationship to Grid Modernization MYPP

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- **Project focuses on a strategy for sensing & measurement technologies to:**
  - ✓ Meet the challenges of integrating new technologies, such as renewable sources and storage, and new types of loads (EV, responsive loads).
  - ✓ Provide the visibility needed to operate the modern grid to deliver resilient, reliable, flexible, secure and sustainable electricity.
  - ✓ Identify sensor R&D needs, priorities, and sensor allocation.
- **Project is a crosscutting effort of the three thrusts of the GMI MYPP including**:
  - ✓ Technology – identifies grid states that need measurements, roadmap of sensor R&D needs, and how to allocate sensors in the system.
  - ✓ Modeling and analysis – identifies communications and data analytics requirements for sensing and measurement technologies.
  - ✓ Institutional and business – working with industry to identify needs and priorities and with technical and standards organizations to identify enhancements and new standards needed.

# Sensing & Measurement Strategy

## Project Effort, Period, and Team

**Three Year (April 2016 to 2019) and $3M project**

**Project Participants and Roles**

*Ten National Laboratories make up the project team:*

- ✓ ORNL, PI and Task 3 & 4 Leads
- ✓ NETL , Plus One and Task 2 Lead
- ✓ PNNL, Task 1 Lead
- ✓ Total of ten labs involved in Task 1-4
- ✓ Multiple Labs served as working group leads to the sensor R&D roadmap development
- ✓ Others include: NREL, SNL, ANL, LBNL, LLNL, LANL, INL

*Industry partners include*:

- Entergy, EPRI
- Southern Co.
- EPB
- OSIsoft, Dominion
- TVA
- ComEd
- NASPI

*Industry Stakeholders* include multiple organizations from industry (utilities, vendors, contractors), academia, and other relevant government organizations.

# Sensing & Measurement Strategy

## Project Integration and Collaboration (Industry Outreach)

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**Utility Industry, EPRI, & NASPI**

- ✓ Three industry meetings hosted by EPB, ComEd and Southern Co. Most recent was held at Georgia Power HQ in Atlanta.
- ✓ EPB and Duke Energy provided data for SPOT use cases
- ✓ EPRI – provided update on their current sensor activities
- ✓ NASPI Synchrophasor Task Teams: Performance, Standards & Verification and Distribution Systems

**Vendors**

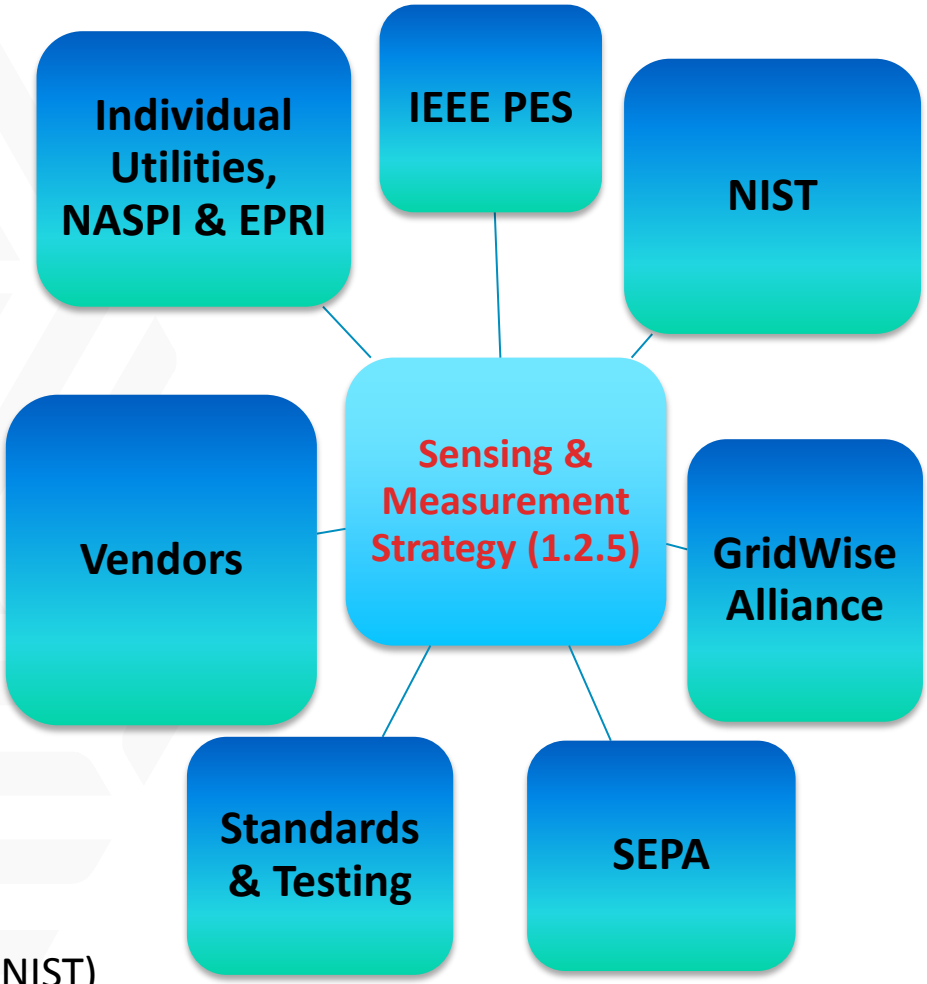
- ✓ EATON, Alstom, OSIsoft, Quanta, GE

**IEEE PES**

- ✓ IEEE Smart Distribution Working Group

**Standards & Testing Organizations**

- ✓ GridWise Alliance
- ✓ Smart Electric Power Alliance
- ✓ National Institute of Standards and Technology (NIST)



# Sensing & Measurement Strategy

## Project Integration and Collaboration (within GMLC)

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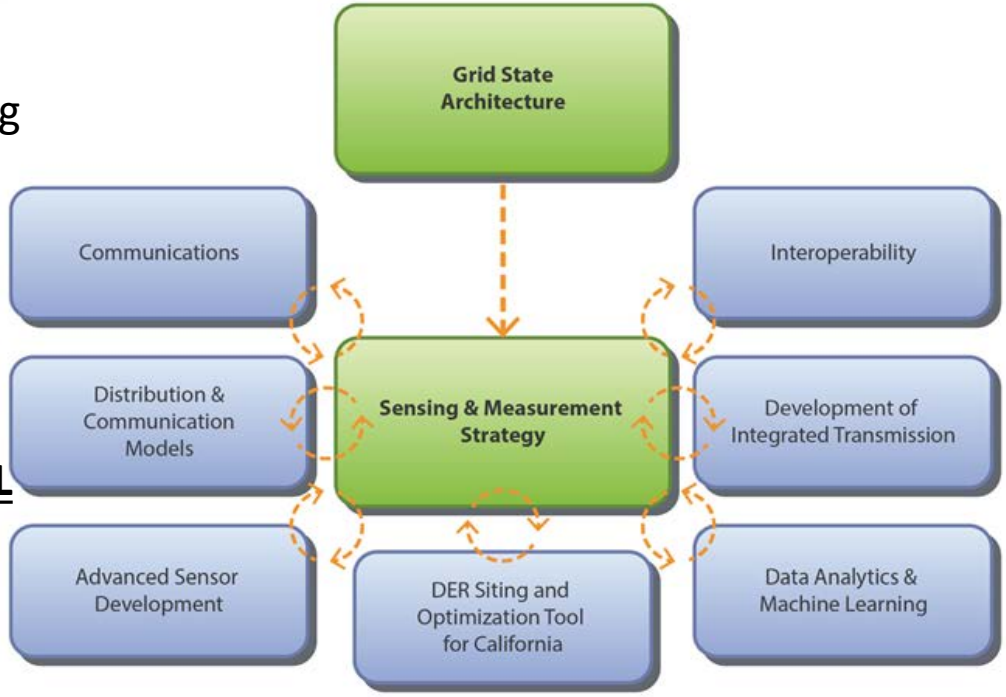
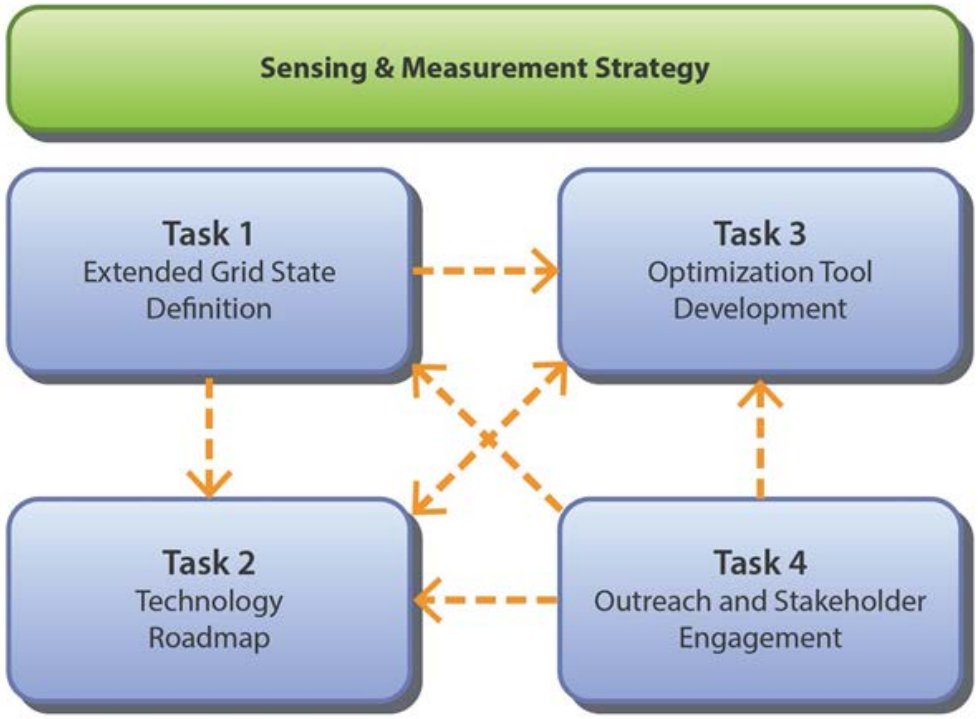
- **Grid Architecture (1.2.1) –** What needs to be incorporated into EGS development?
- **Interoperability (1.2.2) –** Determine sensing & measurement interoperability needs.
- **DER Siting and Optimization Tool for CA (1.3.5) –** Approaches, methods or lessons learned that may be helpful to accelerate optimization tool development.
- **Advanced Sensor Development (1.4.4) –** New functionality of advanced sensors.
- **Data Analytics and Machine Learning (1.4.9) –** Data analytics needed for sensing and measurement.
- **Development of Integrated T&D and Communication Models (1.4.15) –** Communication models needed for sensing and measurement.
- **Communications Roadmap Project by INL –** INL completed draft report and participates in team meetings.



# Sensing & Measurement Strategy

## Approach

- **The project created an overall sensing and measurement strategy to:**
  - ✓ Bring together various stakeholders to define the “extended grid state”.
  - ✓ Create technical a roadmap for sensors and measurement technology, including communications requirements, data management and analytics requirements.
  - ✓ At the same time considering MYPP goals (i.e., reliability, security, etc.).



# Sensing & Measurement Strategy

## Approach

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- **Tasks are:**

1. **Extended Grid State (EGS)** – define the EGS reference model, drive extensions in standards, support development of strategy frameworks, and enhance interoperability.
2. **Technology Roadmap** – identify technical objectives, sensor functionality, measurement requirements, and associated data management/analytics and communication requirements.
3. **Optimization Tool** – provide/develop a tool for sensor allocation and placement and to enable creation of individual strategies by utility stakeholders.
4. **Outreach to Technical and Standards Organizations**
   - Work/coordinate with them and industry to incorporate ESG framework/definitions and sensing/measurement requirements in domestic and international standards.
   - Identify roadmap gaps and prioritize roadmap R&D objectives and ensure the usefulness of both of these and the optimization tool for industry.

# Sensing & Measurement Strategy

## Accomplishments to Date

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### Webinars & Working Groups

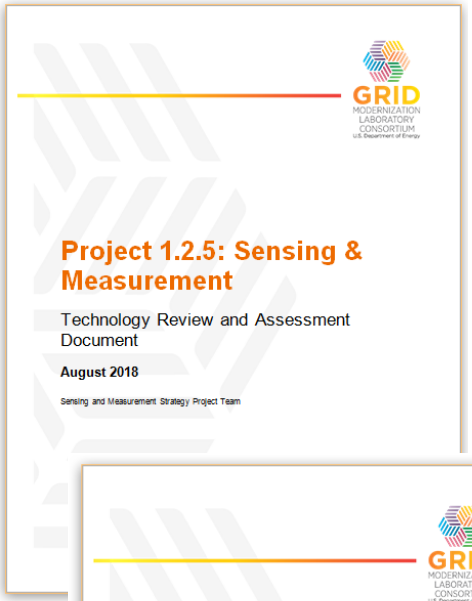
- ✓ Well attended webinars held in 2016-2018 to share the EGS and Roadmap with industry and to get their input/feedback.
- ✓ Direct participation by industry partners/stakeholders on roadmap WGs led by the Labs.

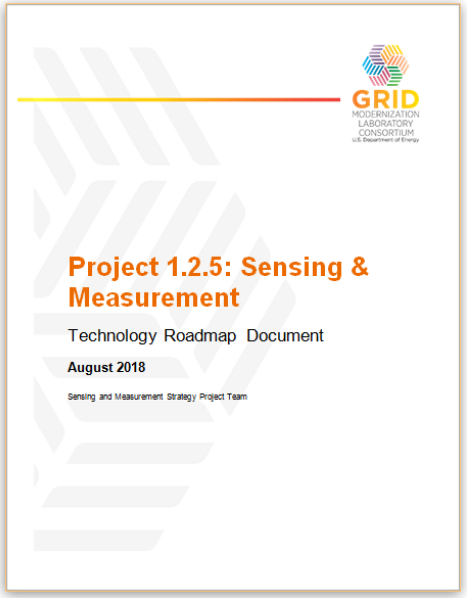
### Industry Meetings

- ✓ Held at EPB in 2016, at ComEd in 2017, Southern Co. in 2018.
- ✓ EGS, Roadmap and SPOT status/progress and drafts were shared with industry at these meetings.

### Reports Produced

- ✓ Produced EGS framework and definitions document which has been shared with NIST, NASPI, IEEE and IEC.
- ✓ Technology Review and Roadmap reports will be published as GMLC reports (Oct. 2018).



# Sensing & Measurement Strategy

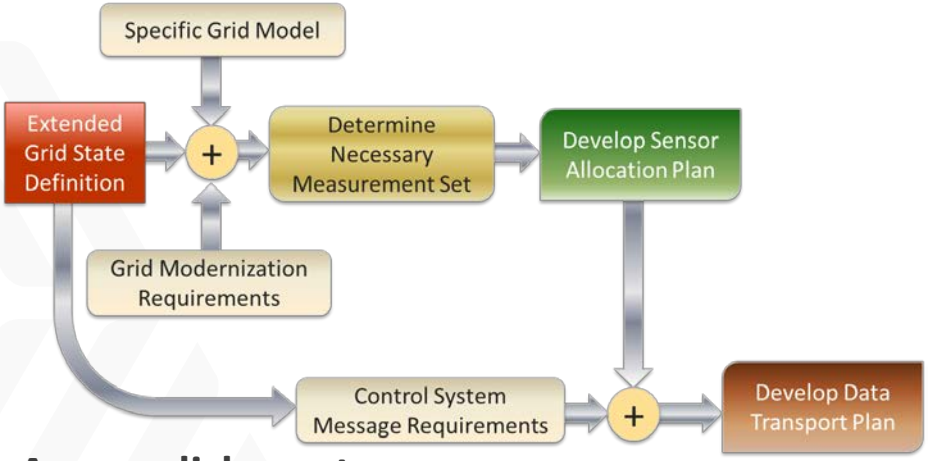
## Extended Grid State Framework

**YR 1: Define and Validate Extended Grid State Definition**

- ✓ V0: proposal as starting point
- ✓ V1: developed by the team; get initial input from industry experts via meetings
- ✓ V2: updated V1 with inputs from external reviews
- ✓ Engaged key SDOs to work out alignment and harmonization
- ✓ V3: Update V2 with input from key Standards Development Organizations (SDOs)

**YR 2: Test, Validate, Standards**

- ✓ Perform analyses and work with SDOs

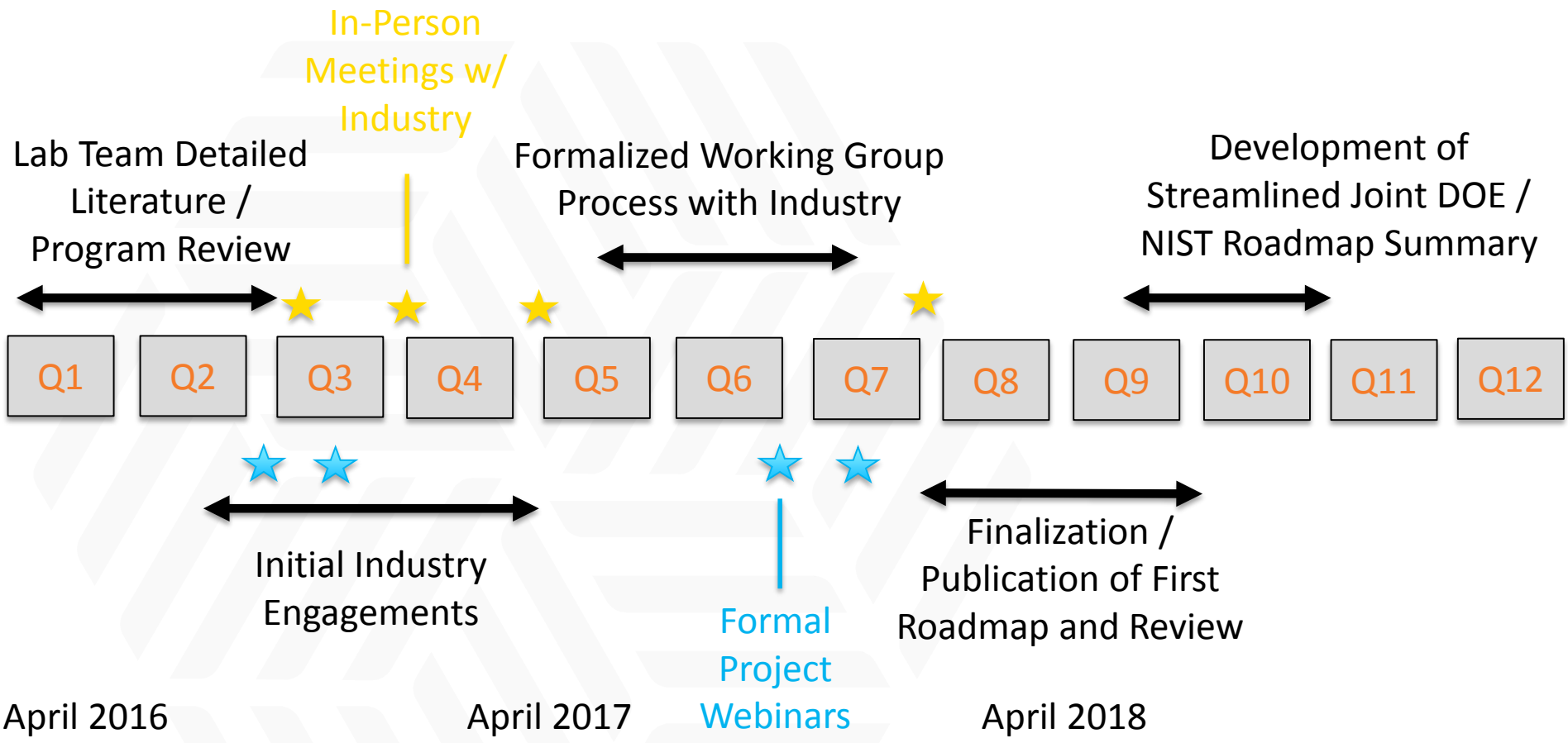



**Key Accomplishments**

- ✓ EGS includes more than just traditional power states. (e.g. asset health and stress accumulation, thermal and other environmental states, and the states of grid connected assets)
- ✓ Document has been reviewed and received well by numerous utilities looking to define their sensing and measurement "needs"
- ✓ Follow-on is extension to new projects outside of GMLC in cyber-physical measurement space

# Sensing & Measurement Strategy

## Technology Roadmap Development




- **Process and timeline for development of the technology roadmap**

# Sensing & Measurement Strategy

## Accomplishments to Date - Roadmap: Example & Structure

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**Suggested Focus Area with Description**

**Grid Asset Health Performance Monitoring – R&D Thrusts**

Monitoring for determining the heath condition of assets can be applied to all those within the electrical power system. Benefits derived from improved visibility of their condition and health include increased reliability and resilience through prevention of catastrophic failures of critical assets and implementation of condition-based maintenance programs as a substitute for run-to-failure or time-based applications. It is desirable, with the movement toward a modern electric power system, to develop improved sensor device technologies at sufficiently low cost to monitor assets' health and performance in greater quantity with higher visibility. In regards to electrical parameters measurements, please refer to the the Novel sensors area on R&D thrusts.

**Direct Links to GMI MYPP / EGS**

**Attributes:** Reliability, Resiliency, Security

**EGS Level:** Component State, Convergent Network State

**Scope of Activity:** Conduct sensor device technology development at laboratory scale, followed by pilot-scale deployment and testing, and ultimately technology transition to industry.

**Individual Research Thrusts with Key Parameters and Quantitative Metrics**

**#2: Grid Asset Internal Temperature**

Internal temperature is a key parameter which serves as an early indicator of fault conditions in essentially all electrical grid assets, including centralized thermal generators. Temperature measurements tend to provide insights into natural degradation and failures of electrical grid assets including aging, arcing, etc. Lower-cost temperature probes that can be deployed internal to electrical grid assets need to be developed including multi-point sensor technologies. High-temperature, harsh-environment sensor technologies also need to be developed for centralized thermal generator applications.

*High-Grade/Transmission Level*:
Cost: Fully Installed Cost < $2,000
Performance:
- Temperature (Ambient to ~100°C)

Geospatial: Multi-point, > 10 Individual Nodes

*Low-Grade/Distribution Level:*
Cost: Fully Installed Cost < $100
Performance:
- Temperature (Ambient to ~150°C)

Geospatial: Single Point

*High-Grade/Centralized Thermal Generator:*
Cost: Fully Installed Cost < $10,000
Performance:
- Temperature (Ambient to as High as 1500°C)

Geospatial: Multi-point, > 10 Individual Nodes

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# Sensing & Measurement Strategy

## Accomplishments to Date - Roadmap: Example & Structure

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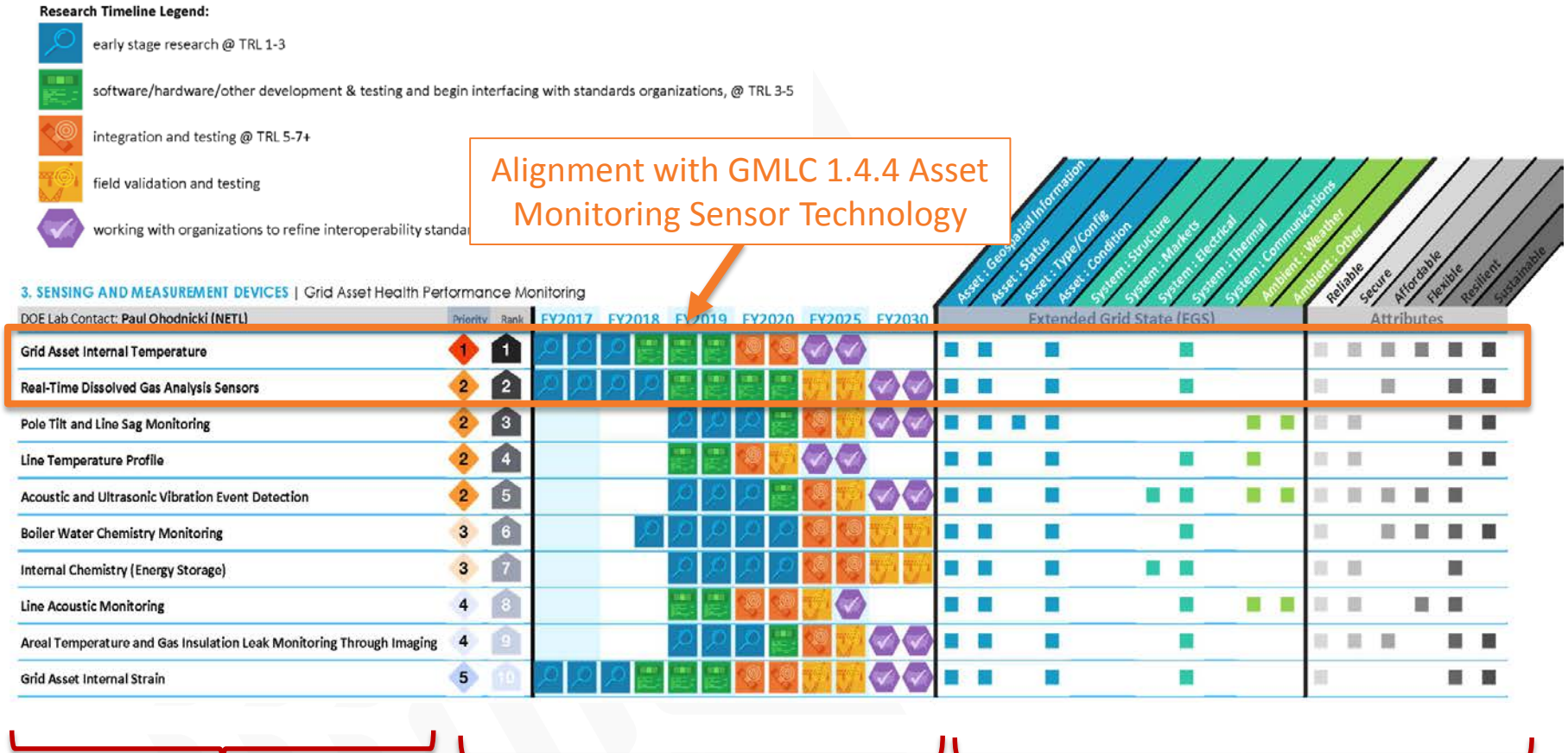

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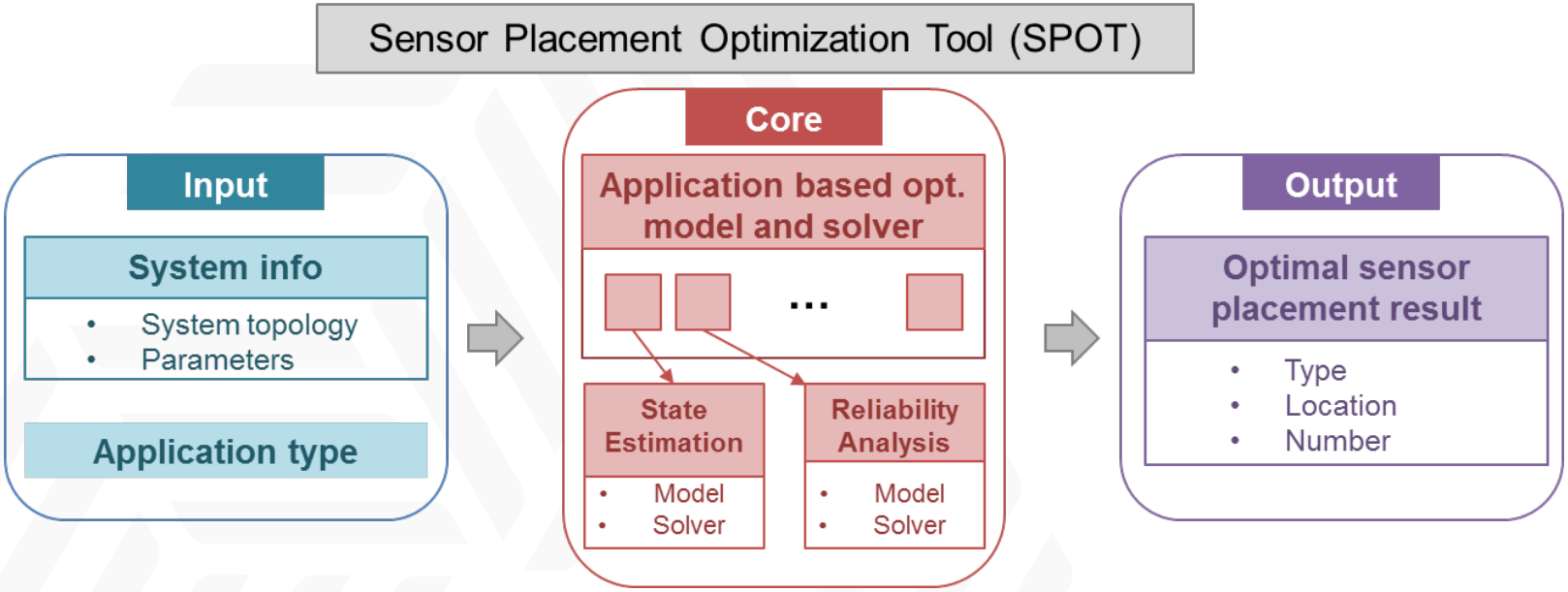
## Accomplishments to Date – Tool Developed




- ✓ SPOT provides sensor placement strategy for distribution systems.
- ✓ Two distribution system applications (DSE and recloser placement for feeder reconfiguration) and optimization algorithms have been developed.
- ✓ SPOT has been tested against three different IEEE test feeders.
- ✓ Two utility (EPB and Duke) use cases have been conducted. In discussion with Southern Co. for another use case.
- ✓ The tool leverages the CYME tools of EATON.

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## Accomplishments to Date – Tool Case Study Example

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**Case Study**

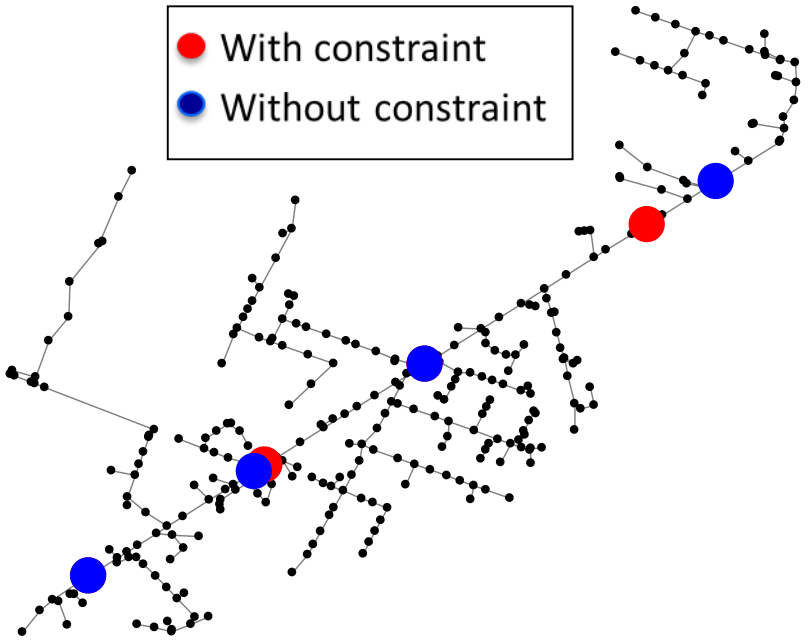
- ✓ Optimize recloser locations to improve the system reliability indices, e.g., System Average Interruption Frequency Index (SAIFI), System Average Interruption Duration Index (SAIDI).

**Practical constraint implementation**

- ✓ Length constraint along the main trunk, 3000 ft
- ✓ Power constraint in each zone, 750 kW
- ✓ Customer constraint in each zone, 150 customers

**Value assessment for improving reliability**

- ✓ ICE calculator – An LBNL tool designed for estimating interruption costs/benefits associated with reliability improvements.
- ✓ **Input**: states/locations; number of customers; SAIFI; SAIDI.
- ✓ **Output**: Total benefit; without improvement (baseline); with improvement; benefit of each customer category.




| Metric | Without Constraint | Constrained |
|---|---|---|
| SAIFI | 1.3769 | 1.4172 |

# Sensing & Measurement Strategy

## Next Steps and Possible Future Work

- **Extended Grid State**
  - Gather feedback on EGS draft version from the IEEE/IEC (2018/2019)
  - Incorporate feedback into the EGS reference model and definitions (Future Plan, 2018 to 2019)
  - Conduct modeling of the EGS based on the final document (Future Plan, 2019)
- **Technology Roadmap**
  - Create streamlined version of the roadmap for DOE (Dec. 2018)
  - Share the findings and recommendations of the roadmap with technical and standards organizations including the IEEE and IEC (Future Plan, 2018/2019)
- **Optimization Tool**
  - Complete the technical report and user guide for the tool (Dec. 2018)
  - Complete case study with Duke Energy (2018/2019)
  - Conduct a case study with Southern Co. (Future Plan, 2019)
  - Work with vendors to transition the tool to industry (Future Plan, 2019)
- **Outreach**
  - Identify vendors that can support SPOT beyond the project period (2019)
  - Develop a PAR with the IEEE/IEC to develop/enhance technical standards to lay the groundwork for sensor technology developments (Future Plan, 2019)

# Sensing & Measurement Strategy