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Comparison of CES-21 efforts and programs and projects currently conducted through

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Comparison of CES-21 efforts and programs and projects currently conducted through

Academia

University of California Berkeley * University of Illinois, Urbana-Champaign * Stanford

National Laboratories

National Renewable Energy Laboratory * Oak Ridge National Laboratory *
Pacific Northwest National Laboratory * Sandia National Laboratory

Federal

Advanced Research Projects Agency–Energy (ARPA-E)

Industry

Electric Power Research Institute (EPRI)

State of California

Energy Commission

California Energy Systems for the 21st Century (CES-21) is a collaborative effort of the California Public Utilities Commission (CPUC) and state investor-owned utilities (IOUs)— Southern California Edison (SCE), Pacific Gas and Electric Company (PG&E), San Diego Gas and Electric (SDG&E)—with Lawrence Livermore National Laboratory (LLNL) to improve the information decision makers need to guide policy and investment in the state of California's multi-billion dollar energy infrastructure. This document is part of a series of summaries on how the results

expected from CES-21 efforts compare with programs and projects currently conducted throughout the United States.

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University Programs / Projects related to CES-21 Goals

University of California, Berkeley	
<p>University of California Energy Institute: California Institute for Energy and Environment (CIEE)</p> <p>CES-21 Related Area: Operations</p>	<p>The CIEE focuses on electrical engineering of the power grid and recently received a three-year grant from the DOE to study grid stability. The goal of this grant is to develop microsynchronphasor hardware.</p> <p>No duplication. While the data from an array of such sensors might be useful to the simulation and control tools developed by CES-21, this research does not overlap with any of the CES-21 business cases. CES-21 is not proposing to develop hardware.</p>
<p>Renewable and Appropriate Energy Laboratory: SWITCH</p> <p>CES-21 Related Area: Planning</p>	<p>The SWITCH (which stands for solar, wind, hydro, and conventional generators and transmission) grid-planning model explores generation, transmission, and storage options for the future electricity grid. The model, which uses time-synchronized load and renewable generation data, identifies cost-effective investment decisions for meeting future electricity demand. Model optimization is formulated as a deterministic mixed integer program, which is solved by standard commercial software.</p> <p>No duplication. Task 2 of the CES-21 Planning Engine Business Case will develop a higher resolution, higher fidelity model of the transmission system than is currently used in the SWITCH model. The CES-21 equations and constraints will be developed with the Plexos modeling platform. These could be transferred to the SWITCH development team and used in their model. The CA IOUs require a higher fidelity model to understand how to co-optimize transmission system plans and generation plans.</p>



University of California, Berkeley

Department of Electrical Engineering and Computer Sciences—Energy Research Area

CES-21 Related Area:
Operations

Energy research in the EECS department at Berkeley spans the entire spectrum from microscopic to macroscopic aspects of energy and power generation, distribution, and management. Collaborations with faculty in related departments, such as Physics, Bioengineering, and Mechanical Engineering are active. Research areas include the creation of new devices for harvesting energy, on-device energy management, system-wide algorithmics for energy management, and large-scale policy issues. Many of EECS's grid-related projects focus on microgrids and specific device integration into grid information networks. No duplication exists between CES-21 research and EECS projects. CES-21 is not proposing any microgrid projects or focusing on specific devices. The CA IOUs are in need of tools that address the state-wide grid and they need to evaluate all their technology/device options.

University of Illinois, Urbana-Champaign

A Game Theoretic Intrusion Response and Recovery Engine

CES-21 Related Area:
Cyber Security

This research aims to provide security and automated response on advanced metering infrastructure (AMI) networks. No duplication. CES-21 Cyber ATAC proposes to build detection and response algorithms aimed at the ICS networks as a whole (not just AMI networks), focusing on the entire system.

Assessment and Forensics for Large-Scale Smart Grid Networks

CES-21 Related Area:
Cyber Security

This trustworthy cyber infrastructure for the power grid (TCIPG) project built (1) a network monitoring system that evaluates how well power systems comply with policies and (2) a tool for forensically evaluating memory, which focused on general-purpose computing systems and not grid-connected devices. No duplication. CES-21 Cyber ATAC proposes to build a network monitoring and aggregation system that evaluates security of the power systems themselves and does not focus on compliance to any particular policy. Cyber ATAC proposes to evaluate the firmware running on these devices offline and does not intend to look at device memory in a powered-on state. CA IOUs are focused on understanding and improving security posture state-wide, above and beyond compliance requirements.



University of Illinois, Urbana-Champaign

Specification-based IDS for the DNP3 Protocol

CES-21 Related Area:
Cyber Security

This project developed a DNP3 protocol parser for the Bro intrusion-detection system (IDS), developed at LBNL.

No duplication. The CES-21 Cyber ATAC project proposes to build a situational awareness system based on monitoring many points of the IOU networks, including an IDS. Cyber ATAC proposers are talking with the authors of Bro at LBNL to learn more about using this open-source software within CES-21.

Usable Management Tools for the Smarter Grid's Data Avalanche

CES-21 Related Area:
Cyber Security

The goal of this project is to create a situational awareness environment for grid networks focusing on security compliance with the NERC CIP rules.

No duplication. CES-21 Cyber ATAC is focused more on threat awareness and mitigation than compliance. It proposes to build a situational awareness environment that aggregates more data than a compliance tool requires. Also, Cyber ATAC intends to find advanced persistent threat (APT) compromises and traditional cybersecurity vulnerabilities and compromises. CA IOUs are focused on understanding and improving security posture state-wide, above and beyond compliance requirements.

Cyber Modeling and Analysis for a Smart Grid (ARPA-E)

CES-21 Related Area:
Cyber Security

This project will develop grid electrical infrastructure modeling and monitoring and analysis tools to examine the impact of failures and malicious threat on grid infrastructure. The goal is to increase the resiliency and reliability of the grid during cyber attacks. e.g. at the level of anti-virus and SSH on a computer.

No duplication. While the Stanford project focuses on currently deployed cyber security infrastructure and techniques applied to individual grid hardware components, CES-21 Cyber: Mod-Sim focuses on malware propagation and intervention dynamics, DDoS, and other network effects at scale for future systems. CA IOUs are looking to CES-21 to help formulate design and security strategies for their future systems.



Stanford

Global Climate and Energy Project

Stanford's Global Climate and Energy Project is funding research at UT-Knoxville, UIUC, Northeastern and RPI to develop a flattened and autonomous control structure for the electric grid. This program seeks to re-architect the entire structure of the electrical grid control system, giving far more authority to local autonomous units. This project also envisions a substantial role for energy storage in the form of vehicle-to-grid technology.

CES-21 Related Area: Operations

No duplication. CES-21 projects in Grid Operations do not envision this depth of re-architecting. Rather CES-21 seeks to analyze and optimize the utilization of existing infrastructure and emerging technologies and their evolution. CA IOUs, though they must evolve their infrastructure, are not looking to re-architect the entire system, as this would not be cost effective.



TomKat Center

CES-21 Related Area:
Operations / Planning

Stanford's TomKat Center for Sustainable Energy Solutions is funding four projects in grid simulation and control. One of these projects is focused on autonomous control at the distribution level.

No duplication. None of CES-21's projects are focused only on distribution system control.

TomKat's wind forecasting project is based on statistical modeling.

No duplication. Statistical techniques are complementary to the multi-physics forecasting which will be developed by CES-21 Planning: Weather Forecasting. CA IOUs are keenly interested in LLNL physics-models as they can capture uncertainty and address CA unique conditions with high geographic fidelity. There is no duplication in approach, though the projects have similar goals. However, initial research at LLNL demonstrates that ensemble-physics-based forecasting will provide superior results for the sub-18-hour-ahead timeframe, which is important to CA IOUs and CAISO.

The GridSpice project aims to build an entirely new end-to-end simulation framework for the electrical grid, based on the Gridlab-D core, in a cloud-computing environment.

No duplication. CES-21 is not proposing to build an entirely new simulation tool, rather, the Planning and Grid Operations portfolios will rely on extensions to, and combinations of existing modeling frameworks on secure, high performance computing platforms. Scaling and coupling models is of key interest to the CA IOUs as they seek to perform statewide impact analysis (scale) and system-wide impact analysis (coupling.) The CES-21 approach should result in more cost-effective and more quickly and easily operationalized solutions for the CA IOUs because the starting points are models that the IOUs currently use and understand. Furthermore, starting with HPC enables sensitivity analysis so that future cloud or small-cluster-based products that are deployed to IOUs will be based on the factors most relevant to the solutions of interest.

TomKat's final program is related to regulatory barriers. CES-21 is not proposing to do research on regulatory barriers.



National Renewable Energy Laboratory

Programs / Projects related to CES-21 Goals

Operations / Planning / Workforce	
<p>Maui Integration Study</p> <p>CES-21 Related Area: Planning</p>	<p>This study investigates strategies utilizing energy storage resources to reduce anticipated wind curtailment and mitigate any increases in production costs. The integration of different energy storage resources into an hourly production cost model of the Maui Electric Company power system allows for a load balance and economic analysis to evaluate the efficacy of energy storage deployment.</p> <p>No duplication. The Maui grid, although under significantly more severe constraints than California (no interstate trade is available) is much smaller and less computationally costly to model. CES-21 will leverage LLNL’s computational resources in a way that is not required for utility planning on Maui. Furthermore, the Maui Integration Study was heavily focused on the value and efficacy of energy storage. The goals of CES-21’s planning engine project will go far beyond evaluating the merits of energy storage strategies for California.</p>
<p>Western Wind and Solar Integration Study – Phase 2</p> <p>CES-21 Related Area: Planning</p>	<p>This analysis is examining the impacts of increased penetrations of wind and solar energy on the cycling and ramping of conventional coal and gas generators in the West. Data on measured emissions from each plant and wear-and-tear costs of conventional generators are being incorporated to more fully investigate the operational impacts of wind and solar energy.</p> <p>No duplication. The primary result of this multi-year coarse-grained simulation of all generation on grid will be a report and a set of recommendations, rather than a set of models or operational tools. CA IOUs are in need of tools suites (in addition to reports) that they can utilize long term to evaluate numerous scenarios of interest. CES-21 anticipates that useful conclusions will come out of the flexibility portion of this study which will be incorporated into CES-21 Flexibility Metrics project.</p>



Operations / Planning / Workforce

<p>Distributed PV on Arizona Public Services</p> <p>CES-21 Related Area: Operations</p>	<p>NREL is studying the effects of large amounts of distributed PV on Arizona Public Services' utility feeder and its associated customers. Activities include:</p> <ul style="list-style-type: none"> • Creating and validating models to describe the interactions between weather, PV, and utility feeder equipment and operations • Identifying technical and operational modifications that could be deployed in future feeder designs. Arizona Specific. <p>No duplication. The fundamental difference is that the CES-21 Distribution Modeling and Optimization project is working to scale the model across CA and analyze the interactions among emerging technologies (not limited to PV) to determine optimization opportunities and identify impacts to CA's grid.</p>
<p>Hawaii Solar and Wind Grid Integration Study</p> <p>CES-21 Related Area: Planning</p>	<p>This study examines the integration of renewable energy as part of the Hawaii Clean Energy Initiative's Energy Agreement.</p> <p>No duplication. Hawaii is an interesting case study in generation/load balancing, but it is small scale compared to California and the WECC. CA IOUs need models and tools that scale to the size of CA's grid. CES-21 Planning projects are all aimed at just that.</p>
<p>The Eastern Renewable Generation Integration Study (ERGIS)</p> <p>CES-21 Related Area: Planning</p>	<p>This study concerns how to plan and operate the Eastern Interconnection in the face of generation and transmission uncertainty. This is a multi-year coarse-grained simulation of all generation in the Eastern Interconnect.</p> <p>No duplication. This is very different from CES-21 projects. CES-21 is focused on CA's grid challenges in renewable integration and involves high fidelity models. ERGIS' primary result will be a report and recommendations rather than CES-21's tools and models.</p>
<p>Energy Imbalance Market</p> <p>CES-21 Related Area: Planning</p>	<p>NREL is working with the Western Interconnection to obtain deeper insights into the potential benefit of an energy imbalance market using a detailed electricity production simulation model. The goal is a new market mechanism, and the results will be shared with utility commissioners and other stakeholders to inform future decision-making for Western Interconnection operations.</p> <p>No duplication. This study shares tools and geography with CES-21, so we are interested in seeing if this new market mechanism should be included in tools and models developed by or used by CES-21. CES-21 is not proposing to develop or study market</p>



Operations / Planning / Workforce

mechanisms directly. This effort is still ongoing but LLNL will follow its progress.

Grid Engineering for Accelerated Renewable Energy Deployment (GEARED)

CES-21 Related Area:
Workforce Preparedness

The objective of this DOE-sponsored work is to support the increase in power systems research, development, and analytical capacity while simultaneously growing the expertise and preparedness of current and incoming electric utility sector professionals for high penetrations of solar and other distributed energy technologies. The goal is to build a national consortium of workforce preparation activities.

No duplication. CES-21 may join this consortium as it gets underway, but CES-21 will focus on the workforce needs of the CA IOUs, and will not be a national program itself.

The Solar Utility Networks

CES-21 Related Area:
Planning / Workforce Preparedness

The goal of Replicable Innovations in Solar Energy (SUNRISE) is to enable utilities to develop long-term strategic plans that integrate high levels of renewable energy generation and ensure reliable real-time power systems 24 operations under high renewable penetration and provide technical assistance for capacity-building activities regarding utility-scale photovoltaic planning and installation.

No duplication. SUNRISE is focused primarily on solar, while CES-21 focuses on both wind and solar. SUNRISE provides assistance directly to utilities to support their strategic planning activities and provides funding for utilities to install and train on new models, but does not seek to develop new models or tools, as does CES-21.



Oak Ridge National Laboratory

Programs / Projects related to CES-21 Goals

Electric Grid Wide-Area Modeling & Analysis	
<p>Eastern Interconnect Dynamic Modeling & Analysis</p> <p>CES-21 Related Area: Planning</p>	<p>Models are being developed for the Eastern Interconnect (EI). The work includes the reliability impacts of shutting down large numbers of existing plants within the Eastern Interconnect.</p> <p>No duplication. CES-21 is focused on CA grid in its Planning projects.</p> <p>A variety of scenarios are considered, including replacing existing plants with renewables.</p>
<p>Improved Cost and Operational Analysis of EIPC Study</p> <p>CES-21 Related Area: Planning</p>	<p>Three main scenarios (with five subcases) for the future EI grid are being studied. They represent various levels of new grid infrastructure and wind penetration in the year 2030: a high wind penetration with large grid development; a high wind penetration with little grid development; and a business-as-usual case.</p> <p>No duplication. CES-21 is focused on CA grid in its Planning projects. The modeling and simulation platforms proposed will support numerous scenarios—including but not limited to wind penetration.</p>
<p>Green Energy-Based Dynamic Response for Grid Control</p> <p>CES-21 Related Area: Planning</p>	<p>Design control algorithms that enable green energy sources—initially wind—to contribute to keeping the grid stable.</p> <p>No duplication. CES-21 projects do not seek to design control algorithms with the exception of informing controls through advanced analytics of PMU data.</p>
<p>Dynamic Protection Planning Simulation</p> <p>CES-21 Related Area: Operations</p>	<p>Demonstrating the consolidated planning and system protection modeling for assessing high penetration of renewable generation and impact on protective relaying schemes during power system disturbances.</p> <p>No duplication: CES-21 is not proposing any projects focused on protection schemes.</p>
<p>MOVARTI</p> <p>CES-21 Related Area: Operations</p>	<p>This work determines the proper placement, management, and optimization of reactive power (or VAR) resources in the Eastern Interconnect (EI) under the new paradigm of a high penetration of renewable sources and future transmission infrastructure.</p> <p>No duplication: CES-21 is not proposing any reactive power management projects.</p>



Electric Grid Wide-Area Modeling & Analysis

<p>FIDVR analysis</p> <p>CES-21 Related Area: Operations</p>	<p>This new methodology for voltage stability tracking uses synchronized phasor measurements to directly calculate the margins to the point of voltage collapse or any other desired threshold voltage.</p> <p>No duplication: CES-21 is not proposing any Fault-Induced Delayed Voltage Recovery projects.</p>
<p>Predictive Modeling and Look Ahead Simulation</p> <p>CES-21 Related Area: Operations</p>	<p>This suite of GPU-accelerated codes and supercomputers makes predictions based on the precursor event that the power grid was in at the onset of a disruption while accounting for dynamic effects, contingency factors, distributed parameter descriptions, stochastic dimensions in uncertainty parameters, and complex load behaviors.</p> <p>No duplication. CES-21 Monitoring and Control has a similar which is to create predictive algorithms to identify system stress and determine notifications/alarms to transmission and system operators. But, there is a fundamental difference. The project under the CES-21 focuses on using data mining and pattern recognition approach to make predictions and the ORNL's project uses modeling and simulation approach to make predictions. CES-21 will inform CA IOUs how to leverage their PMU data sources to be effect. This is not a focus of the ORNL project.</p>
<p>Renewable Energy Siting and Costs Study</p> <p>CES-21 Related Area: Planning</p>	<p>In this ongoing study with an industrial partner, a renewable energy siting and cost methodology is being developed by creating a common spatial canvas that brings together resource availability, system reliability, cost incentives, and development costs to support system optimization.</p> <p>No duplication. CES-21 is not proposing any siting studies.</p>
<p>SGIG Benefits Analysis</p> <p>CES-21 Related Area: Operations</p>	<p>Evaluates the benefits of electricity delivery technologies, systems, and programs for DOE/OE. Currently developing and implementing an analytical framework and modeling approach to estimate the benefits and costs of projects funded under the Smart Grid Investment Grant and Smart Grid Demonstration Programs.</p> <p>No duplication. CES-21, is not proposing to evaluate projects. Analysis and models in CES-21 are geared towards evaluating technology, design, and incentive options for CA IOUs.</p>



Electric Grid Wide-Area Modeling & Analysis

Data Sharing and Management for the 2020 Power Grid

CES-21 Related Area:
Operations

The objective of this work is to continue to support an advanced grid modeling enterprise, while organizing, collecting, and widely sharing information in compliance with proprietary concerns, freedom of information, and national security requirements.

No duplication. CES-21 is not proposing a generic data-sharing/management activity. CES-21 Cyber ATAC is proposing controlled data sharing but limited to the CA IOUs and cyber-related data sets. The data will also be significantly processed prior to dissemination.

North American SynchroPhasor Initiative (NASPI)

CES-21 Related Area:
Operations

Technical support was provided to the NASPI working group to improve power system reliability through wide-area time-synchronized measurements, monitoring, and control based on PMUs.

The CES-21 team acknowledges that because of significant investments as part of the American Recovery and Reinvestment Act (ARRA) in synchrophasor technology, there are many organizations interested in leveraging synchrophasor data to provide meaningful improvements in grid operations, reliability, integration of renewable generation as well as compensatory technologies such as reactive power injection and energy storage. Much of this work is coordinated among California IOUs and CAISO that have significant involvement and collaboration in system operations and data sharing.

No duplication. CES-21 Monitoring and Control project intends to exploit existing and forthcoming PMU data streams from the major utilities in the State and create useful correlation algorithms and mitigation strategies. By using these data and enhanced computational tools (long term dynamics and intermittency) the project seeks to deliver meaningful control algorithms, which have broad applicability to the participating California utilities. The growing synchrophasor data pool is already large and the complexities of the correlation and mitigation strategies are significant across the asset base owned by the CA IOUs. The project seeks to deliver solutions, which build on existing assets, as well as identify methods for effectively integrating promising new technologies.



Electric Grid Wide-Area Modeling & Analysis

Ultrascale Computing for Power Systems

CES-21 Related Area:
Operations

ORNL is funding an internal effort to develop the capability to simulate electric power systems at a geographic scale and with a sufficient scope of electrical, mechanical, control, and communication components to explore monitoring, control, and cyber-security issues in the Smart Grid.

This is an early stage internally-funded research program and will likely take many years before results are proven and available to a broad audience. CES-21 will certainly track this program, and coordinate with ORNL. But the CA IOUs need applied research conducted now and that is focused on their highest priority CA-specific challenges.

Other Areas of Related Research

ORNL/University of Tennessee Engineering Research Center

CES-21 Related Area:
Operations

The center is researching technologies to utilize advancements in power grid wide-area measurement and redesign the control and information structure. It will draw on high performance computing to realize large-scale and faster-than-real-time dynamic simulation for predictive control (and fast response) to ensure secure and reliable operation. It will include high-speed power electronics based controllers, advanced power electronic interfaces with wind and solar farms, and bulk energy storage and associated controls

No duplication. This is a 10 year NSF/DOE co-funded engineering research center which is early stage and fundamental research program and will likely take more than 10 years before results are proven and available to a broad audience. CES-21 will certainly track this program, and coordinate with ORNL. But the CA IOUs need applied research conducted now and that is focused on their highest priority CA-specific challenges.

Operational Reliability: Integrated Electric and Information Grid Analysis

CES-21 Related Area:
Operations

This is a multi-faceted program and includes topics such as: petascale real time dynamic modeling, outage data set development, agent-based response mechanisms, and contingency analysis.

No duplication. While the work being done is similar in that much of it relies on advanced computing capabilities, none of the projects share objectives with any CES-12 proposed projects. Furthermore, the ORNL work is not focused on the CA grid. CES-21 is also focused on delivering tools that can be operationalized for use by CA IOUs and CAISO, rather than proof of concept studies or academic publications.



Cyber Security

Distributed Enterprise-Level cyber-PHysical Intelligence (DELPHI)

CES-21 Related Area:
Cyber Security

ORNL is developing a reference architecture for distributed enterprise-level cyber-physical intelligence (DELPHI) enabling secure, resilient operation of all aspects of the -DELPHI will provide persistent enterprise level situational awareness of the grid, detecting and identifying attacks as they occur, autonomously implementing response/recovery protocols to ensure resilient operation. This technology may not be implemented beyond the reference architecture.

No duplication. This work is in early stages (reference architecture) and will be a potential area for collaboration in with CES-21 Cyber ATAC. However, it is too soon to make that evaluation but LLNL will stay coordinated with ORNL. LLNL has already completed a strategic initiative to develop a prototype distributed-agent-based cyber situational awareness framework, so LLNL's architecture is farther along and more appropriate for CES-21 ATAC adoption.

Extreme Cyber Testbed

CES-21 Related Area:
Cyber Security

This work involves the capability to test power grid components' behavior under cyber threat and place the results within a virtual interconnection scale simulation platform to examine threats and consequences.

No duplication. This project emphasizes high-fidelity representation of the grid though does so at a scale smaller than CES-21 Cyber Mod/Sim will provide. The CA IOUs require a state-wide model so they can understand the true impact of threats and mitigations.

Grid SQuARe

CES-21 Related Area:
Cyber Security

This project is developing technologies based on Quantum Key Distribution (QKD) to better protect communications between devices on the grid.

No duplication. CES-21 has no similar proposed work.

Beholder

CES-21 Related Area:
Cyber Security

ORNL is developing, in partnership with GE Research, technology that exploits fine-grained timing data collected from remote SCADA and network devices to reveal the presence of software and network intrusions.

No duplication. CES-21 is not proposing this method (timing data). It is proposing a suite of methods to identify anomalous network activity. CES-21 ATAC is not limited to SCADA devices and is proposing a broader suite of detection tools to get a comprehensive awareness of the networks' behaviors. ORNL's tool may be appropriate for integration at some point.



Cyber Security

Detection of Embedded Vulnerabilities Prior to Deployment

CES-21 Related Area:
Cyber Security

ORNL's Hyperion (renamed SEI FX) system creates a "behavior catalog" that can be coupled with other analysis techniques to reveal the specific conditions for an event of interest such as disconnecting power or computing usage in order to assure that a system will perform correctly and be free of exploitable vulnerabilities when delivered to the field. This work is done as part of a private partnership.

No duplication: Function Extraction (FX) is a tool that was open sourced by SEI, who developed it over a period of about 10 years and is currently being developed at ORNL and extensions are not open source. It is currently not available (proprietary). It is targeting some specific forms of analysis to communicate the behavior of binary executables. It is a specific tool rather than an infrastructure for building tools. CES-21 Cyber: ATAC is proposing to use its open source (not proprietary) system for evaluating vulnerabilities in device firmware. This capability can be transitioned to the IOUs or an ISV as needed. This is part of a larger situational awareness project; the firmware analysis is integrated into the broader picture of security posture through the proposed ATAC infrastructure.

Cyber Sciences Laboratory (CSL)

CES-21 Related Area:
Cyber Security

This cyber initiative is designed to further develop DOE/NNSA cyber defenses by leveraging the extensive research capabilities of eight National Laboratories together with the unique testing capabilities resident at the Nevada National Security Site. Three general areas of research have been established with goals to protect the grid among other potential targets but specific projects have not yet been launched.

No duplication assessed at this time. This effort is very early stage and broad in scope. LLNL, as an NNSA Lab, will be able to track progress and coordinate with CES-21.



Pacific Northwest Laboratory

Programs / Projects related to CES-21 Goals

Planning / Operations	
<p>GridLAB-D</p> <p>CES-21 Related Area: Operations</p>	<p>GridLAB-D examines the power system, end use loads, building characteristics, and market structures in a single environment so that simulation and analysis properly account for interactions between these coupled systems. It enables utilities and regulators to run simultaneous assessments of costs and benefits related to investing in new distribution system technologies.</p> <p>No duplication. LLNL acknowledge DOE/PNNL's GridLAB-D work, and PNNL has been considered as a potential partner for CES-21 because of its GridLAB-D work. No CES-21 project seeks to duplicate this work.</p>
<p>Distribution System Operation and Analysis</p> <p>CES-21 Related Area: Operations</p>	<p>This project currently includes work associated with micro grids, advanced controls in high PV penetration areas, and the operational impacts of changing loads, which PNNL addresses through a focusing on grid-ready appliances, home energy management systems, and electric vehicles. The previous PNNL research work focused on a specific emerging technology.</p> <p>No duplication. The fundamental difference in research approaches between the PNNL work and the CES-21 project Distribution Modeling and Optimization Research is that the CES-21 project scales the model across the state and analyzes the interactions among such emerging technologies, including but not limited to PV. The CES-21 joint utilities acknowledge DOE/PNNL's previous work on distribution system operations and analysis, and we will leverage this and other existing work as needed.</p>



Planning / Operations

Transmission Reliability

CES-21 Related Area:
Operations

New analytic methods are being developed to capitalize on PMU data and other system measurements to provide new tools giving operators previously unavailable information about the bulk transmission system. This includes development of methods to measure oscillatory behavior, degree of damping of wide area oscillations, assessment of frequency response, and other comparable signals.

No duplication. The fundamental difference in research approaches is that the CES-21 project Monitoring and Control takes existing data for CA IOUs and creates correlation algorithms and mitigation strategies using the data and enhanced computational tools. The results will go well beyond aggregation on PMU data, but will reveal new information. The data set is very large and the complexity of the correlation and mitigation strategies would be significant across the asset based owned by the CA IOUs.

Renewable Integration

CES-21 Related Area:
Planning / Operations

This work involves new strategies for incorporating large-scale wind generation into the western grid. Topics include stochastic power operations, reliability metrics and markets, and enhanced grid flexibility.

No duplication. In CES-21, the focus is on developing very high fidelity modeling and simulation frameworks that can be used to evaluate numerous scenarios of interest to CA IOUs. The specific foci of the PNNL work are different. No CES-21 project is proposing work in reliability metrics/markets, CES-21 Flexibility Metrics project is focused on economics, not operations, and CES-21—though it is proposing stochastic planning work, is not proposing stochastic operations work.

Grid Modeling and Analysis

CES-21 Related Area:
Planning / Operations

This multi-year research and development program focuses on four aspects: (1) developing end-to-end grid models across generation, transmission, distribution, and end-uses; (2) improving computational efficiency in grid simulation; (3) bringing dynamics into real-time power grid operation using advanced sensor data such as phasor measurement; and (4) developing and enhancing optimization techniques for power market operations and management. This is an early stage internally funded research program and will likely take many years before results are proven and available to a broad audience.

No duplication. CES-21 will track this program and coordinate with PNNL, but the CES-21 project consists of needed applied research focused on the highest priority CA-specific challenges.



Planning / Operations

Pacific Northwest Smart Grid Demonstration Project (ARRA)

CES-21 Related Area:
Operations

This project tests transactive control technology that allows the PNW-SGDP to predict electricity load and price of delivery for up to 72 hours in advance. Allowing responsive assets and load to communicate reduces any discrepancies between supply and demand, thus balancing the grid. This project is a demonstration project, not a research program.

No duplication. CES-21 differs in that it will be advancing the state of the art in preparation for the next generation of deployment and demonstration efforts that are needed to achieve the goals of the CA IOUs (such as 33% RPS). Additionally, CES-21 does not focus on transactive control. Several PNNL research initiatives in this area have been acknowledged by the CES-21 team and will be leveraged to incorporate their findings into the broader view of the impacts to emerging distribution technology within the California regulatory structure.

AEP Ohio GridSMART (ARRA)

CES-21 Related Area:
Planning / Operations

This project tests voltage reduction controls, energy storage, small renewables, and electric vehicle charging, while conducting several demand response experiments.

No duplication. This is a demonstration project and is examining some grid planning scenarios, similar to those in CES-21. However, this project is Ohio-based and is looking at hundreds of customers while CES-21 is taking a modeling and simulation approach to examining the whole state of CA, running numerous scenarios to find optimal solutions.

Cyber Security

Cybersecurity for Energy Delivery Systems (CEDS)

CES-21 Related Area:
Cyber Security

CEDS is a DOE/OE-funded Program that PNNL is a part of. The work focuses on performing analyses and providing timely technical assessments related to threats to computer systems and analytic processes.

No duplication. CES-21 focuses on coupling mod-sim of cyber-physical systems to understand impacts of threats and mitigations, as well prototyping and collaboratively deploying ICS traffic and device analytic tools into the CA IOUs operations. CES-21 will enable statewide awareness of threats to the grid.



Cyber Security

Field Device Management CES-21 Related Area: Cyber Security	<p>This project aims to build a virtualized framework for better management of network-connected ICS devices. The overarching goal is to provide a governance framework in order to meet increasingly tight security requirements.</p> <p>No duplication. These goals differ significantly from the CES-21 goals of (1) coupling mod-sim of cyber-physical systems to understand impacts of threats and mitigations and (2) building a cyber-security situational awareness system for use by the California IOUs.</p>
Secure Coding for Energy Control Systems CES-21 Related Area: Cyber Security	<p>This project is attempting to address the issue of insecurely written code running on ICS devices. Workshops are being held for software developers in the ICS industry to make them aware of the problem and educate them on secure coding techniques.</p> <p>No duplication. While the CES-21 Cyber ATAC project has a component aimed at evaluating software on ICS devices, it will focus on evaluation of firmware binaries for potential flaws. Secure coding is not a goal of the CES-21 project.</p>



Sandia National Laboratory

Programs / Projects related to CES-21 Goals

Operations / Planning / Workforce	
<p>Maui Integration Study</p> <p>CES-21 Related Area: Planning</p>	<p>This study investigates strategies utilizing energy storage resources to reduce anticipated wind curtailment and mitigate any increases in production costs. The integration of different energy storage resources into an hourly production cost model of the Maui Electric Company power system allows for a load balance and economic analysis to value the efficacy of energy storage deployment.</p> <p>No duplication. The Maui grid, although under significantly more severe constraints than California (no interstate trade is available) is much smaller and less computationally costly to model. CES-21 will leverage LLNL’s computational resources in a way that is not required for utility planning on Maui. Furthermore, the Maui Integration Study was heavily focused on the value and efficacy of energy storage. The goals of CES-21’s Planning Engine project will go far beyond evaluating the merits of energy storage strategies for California.</p>
<p>Determining Greatest Impact for a Given Adversary-RICA</p> <p>CES-21 Related Area Cyber</p>	<p>This project analyzes grid impact (load not served) and resulting revenue loss associated with cyber incidents and security technologies themselves.</p> <p>No duplication. The CES-21 Cyber: Mod-Sim project is (1) focused on the CA grid, (2) focused on grid impact in general-- not just revenue loss, and (3) a general enough simulation platform to enable a variety of what-if scenarios to be evaluated.</p>
<p>Supply Chain Threat</p> <p>CES-21 Related Area: Cyber</p>	<p>This project is developing a decision-making framework to help government agencies make informed decisions about procurements and potential threats to the supply chain of those procurements. Goals include sharing the developed process with the energy sector in order to mitigate cyber risks to their infrastructure.</p> <p>No duplication. CES-21 Cyber ATAC includes tasking that addresses supply chain issues as well. CES-21 Cyber-ATAC will focus on evaluating binary firmware of ICS devices for flaws. The CES-21 work provides one technical solution that could be recommended or included in the framework being developed by Sandia. The CES-21 project will analyze specific devices that are fielded or planned for the CA grid.</p>



Operations / Planning / Workforce

<p>Nevada Energy Integration Study</p> <p>CES-21 Related Area: Planning</p>	<p>This study will determine the value of energy storage for deployment in the NV Energy Balancing Area to meet operating reserve requirements and to defer T&D asset capital improvement needs in the face of renewable integration. The study uses production cost modeling to evaluate system operation at a high resolution time step.</p> <p>No duplication. The CES-21 Planning Engine project is not limited to storage deployment and is focused on (1) CA grid investments and (2) a general platform to evaluate numerous scenarios.</p>
<p>Threat Characterization</p> <p>CES-21 Related Area: Cyber</p>	<p>This work provides utilities with open-source cyber threat information.</p> <p>No duplication. The CES-21 Cyber: ATAC project will be doing this as well as a multitude of other tasks, including network mapping, situational awareness, and device vulnerability analysis. The open source information in ATAC will be focused on CA IOU security needs and challenges.</p>
<p>Renewable Source Controls for Grid Stability</p> <p>CES-21 Related Area: Operations</p>	<p>The goal of this SNL's project is to identify renewable source control algorithms to improve grid stability. The project will also characterize the expected degradation in performance with increased renewable penetration.</p> <p>No duplication. CES-21 is not proposing any renewable source control research projects.</p>
<p>Improved Power systems Operations Using Stochastic Optimization</p> <p>CES-21 Related Area: Operations / Planning</p>	<p>This ARPA-E GENI project seeks to develop a market management system based on a stochastic implementation of an existing unit commitment model. None of the projects in the CES-21 Planning or Grid Operations portfolios seek to construct a stochastic unit commitment model for operationalized use. Each project in the Grid Operations portfolio seeks to extend the modeling and simulation on which utility operations are based by adding detail, incorporating new data streams, or combining transmission and distribution. None of them seek to add probabilistics and/or uncertainty.</p> <p>No duplication. The projects in the CES-21 Planning area will run enhanced models for the purpose of simulating future grid topologies, and not for immediate market integration. In the future, a stochastic operationalized unit commitment model such as that under development by SNL may be suited to interface with the information generated by the results of the CES-21 Ensemble Weather Forecasting project. We will assess the compatibility of these potentially complementary technologies as the results from their development are reported.</p>



Operations / Planning / Workforce

Modeling and Simulation of High PV deployment scenarios CES-21 Related Area: Operations	<p>This distribution model is specific to high penetration PV.</p> <p>No duplication. The CES-21 Operations: Distribution Modeling and Optimization project is designed to evaluate several emerging technologies and is not limited to PV.</p>
MANY Planning Studies focused on Storage CES-21 Related Area: Planning	<p>This work consists of numerous projects in different regions.</p> <p>No duplication. The CES-21 Planning Engine project is similar in approach but is a more general platform that enables a variety of scenarios to be evaluated; it is not limited to storage. SNL's work is primarily not CA specific. Southern Company Integration Study is an illustrative example of SNL's work, and is not focused on the unique RPS, weather conditions, and customer choices that CA IOUs face.</p>
Power Electronics Performance and Reliability CES-21 Related Area: Operations	<p>This work consists of development of dynamic electrical models to gain a better understanding of the degradation of power conversion system and its internal components.</p> <p>No duplication. CES-21 Operations projects are not proposing anything in power system degradation.</p>



ARPA-E GENI-supported Programs / Projects related to CES-21 Goals

Demand Response and Efficiency	
<p>Texas Engineering—Automated Grid Disruption Response System</p> <p>CES-21 Related Area: Operations</p>	<p>The Robust Adaptive Technology Control (RATC) research team is using topology control to improve system operations and manage disruptions within the electric grid, including cascading faults caused by extreme operating conditions, malicious external attacks, and intermittent electricity generation from renewable energy sources. The RATC system detects, classifies, and responds to grid disturbances by reconfiguring the grid’s topology to maintain economically efficient operations while guaranteeing reliability.</p> <p>No duplication. CES-21 has no research areas related to topology control. LLNL is part of the Texas Engineering team and provides high-performance computing expertise.</p>
<p>Georgia Tech Research Corporation—Autonomous, Decentralized Grid Architecture</p> <p>CES-21 Related Area: Operations</p>	<p>Georgia Tech is developing a decentralized, autonomous, internet-like control architecture and control software system for the electric power grid. This new architecture is based on the emerging concept of electricity prosumers—economically motivated actors that can produce, consume, or store electricity. This is in marked contrast to the current one-way, centralized control paradigm.</p> <p>No duplication. CES-21 has no research efforts related to decentralized and internet-like control.</p>
<p>Cornell University—Cloud Computing for the Grid</p> <p>CES-21 Related Area: Operations</p>	<p>Cornell is creating a new software platform for grid operators called GridControl, which uses cloud computing to more efficiently control the grid by minimizing hardware and software demands on users. Cornell's GridControl focuses on four elements: delivering the state of the grid to users quickly and reliably; building networked, scalable grid-control software; tailoring services to emerging smart grid uses; and simulating smart grid behavior under various conditions.</p> <p>No duplication. CES-21 has no research efforts related to cloud computing. Furthermore, CES-21 proposes to utilize computing resources and expertise not currently available from cloud providers. The CA IOUs need these initial high-fidelity simulations and analysis to inform their future computing strategies (which may include cloud solutions) and to develop “reduced” models that capture the most impactful and salient features.</p>



Demand Response and Efficiency

Boston University (BU) - Decision-Support Software for Grid Operators

CES-21 Related Area:
Operations

The BU team is developing control technology to help grid operators more actively manage power flows and integrate renewables by optimally turning on and off entire power lines in coordination with traditional control of generation and load resources. The new control technology, based on fast optimization algorithms and their software implementation, would provide grid operators with tools to help manage transmission congestion by identifying the facilities whose on/off status must change to lower generation costs, increase utilization of renewable resources, and improve system reliability.

No duplication. CES-21 has no research efforts related to fast optimization algorithms for the near-to-real-time changes in the on/off status transmission line.

AutoGrid Systems— Integration of Renewables via Demand Management

CES-21 Related Area:
Operations

AutoGrid, in conjunction with Lawrence Berkeley National Laboratory and Columbia University, will design and demonstrate automated control software that helps manage real-time demand for energy across the electric power grid. Known as the Demand Response Optimization and Management System – Real Time (DROMS-RT), the software will enable personalized price signals to be sent to millions of customers in extremely short timeframes—allowing them to alter their electricity use in response to grid conditions. AutoGrid will help grid operators better manage unpredictable demand and supply fluctuations in short time scales, making the power-generation process more efficient and cost effective for both suppliers and consumers.

No duplication. The DROMS-RT project and the CES-21 Electric Operations Distribution Modeling and Optimization projects are fundamentally different. Unlike DROMS-RT, which focuses on demand response, CES-21 will develop a model and optimization platform that incorporates emerging technology options and demand response to help the Joint Utilities evaluate the statewide impact of these options to improve planning for the distribution system of the future.



Demand Response and Efficiency

Sandia National Laboratories - Probability-Based Software for Grid Optimization

CES-21 Related Area:
Operations

Sandia National Laboratories is working with several commercial and university partners to develop software for market management systems (MMSs) that enable greater use of renewable energy sources throughout the grid. MMSs securely and optimally determine which energy resources should be used to service energy demand across the country. By incorporating a new, probability-based formulation to account for these uncertainties in real time, Sandia's software can reduce the risk of inefficient electricity transmission, save ratepayers money, conserve power, and support the future use of renewable energy.

No duplication. Sandia's project concerns electricity transmission while the CES-21 Distribution Modeling and Optimization project is focused on the distribution system. There is no wholesale energy market research proposed in any CES-21 projects. The planning engine project does focus on the transmission system but proposes to investigate stochastic unit commitment not energy markets.

University of Washington (UW) - Renewable Energy Positioning System

CES-21 Related Area:
Operations

UW and the University of Michigan are developing an integrated system to match energy storage facilities with precise control technologies to more easily include energy from renewable power sources in the grid and save consumers money. This project will position renewable energy storage facilities in locations that optimize their ability to provide and transmit electricity where and when it is needed most.

No duplication. This ARPA-E project focuses on well-positioned energy storage facilities with precise control technologies. The CES-21 Electric Operations: Distribution Modeling and Optimization project, is working to build a statewide model of the distribution system and analyze the interactions among emerging technologies, including but not limited to storage.



Demand Response and Efficiency

California Institute of Technology (Caltech)— Scalable Distributed Automation System

CES-21 Related Area:
Operations

Caltech is developing a distributed automation system that allows millions of distributed generators—solar panels, wind farms, thermal co-generation systems—to effectively manage their own power through local sensing, computation, and communication. An automated, grid-wide power-control system could ease the integration of renewable energy sources like solar power into the grid by quickly transmitting power when it is created, eliminating the energy loss associated with the lack of renewable energy storage capacity of the grid.

No duplication. One of the Joint Utilities, SCE, is working with Caltech on this ARPA-E project, which focuses on specific emerging technology components—distributed generators. CES-21 Electric Operations: Distribution Modeling and Optimization project could eventually benefit from incorporating the optimization algorithms that will be developed through this Caltech ARPA-E project, and Caltech is a potential partner.



Electric Program Investment Charge (EPIC) Programs / Projects related to CES-21 Goals

Pacific Gas and Electric	
<p>Demonstrate Energy Storage End Uses</p> <p>CES-21 Related Area: Operations</p>	<p>This project uses an established, commercially-available energy storage technology to test end-use applications and minimizes start-up challenges so the focus can be on the applications. It develops and demonstrates automated controls via PG&E’s existing SCADA system. The goal of this project is to understand how storage could be used more broadly and efficiently (via controls).</p> <p>The CES-21 Planning Engine project will, among other things, provide a platform that could evaluate the economics associated with various storage deployment and performance scenarios, but does not deploy the storage or evaluate the performance. These projects are not duplicative, and are potentially complementary in assessing the viability of and roles for storage in the evolving grid.</p> <p>The CES-21 Distribution Modeling project will, among other things, provide a platform that could evaluate the engineering (reliability) feasibility and value of various storage deployment and performance scenarios, but does not deploy the storage or evaluate the performance. These projects are not duplicative, and are potentially complementary in assessing the viability of and roles for storage in the evolving grid.</p>
<p>Demonstrate New Resource Forecast Methods to Better Predict Variable Resource Output</p> <p>CES-21 Related Area: Operations</p>	<p>This project type would develop, deploy, and operate a mesoscale meteorological modeling system that would improve the accuracy of wind and solar forecasts for forward energy markets (hour-ahead, day-ahead, and earlier). This is a demonstration project, focused on improved data assimilation as a way to improve forecasts. The CES-21 Weather Forecasting project is an R&D effort to improve physics-based forecasting algorithms and reduce renewable generation forecast uncertainty. Results from this project could improve this or similar demonstration modeling systems in the future.</p>



Pacific Gas and Electric

Demonstrate Communication Systems Allowing the CAISO to Utilize Available Renewable Generation Flexibility

CES-21 Related Area:
Operations

This project would demonstrate the use of accepted communications protocols to allow the CAISO to send an operating signal to reduce output under specified conditions in order to resolve potential reliability issues and avoid payments related to over-generation occurrences. The CES-21 Flexibility Metrics project, while addressing the value of flexibility, does not seek to make suggestions about how to realize flexibility. Furthermore, the CES-21 Operations modeling efforts focus on evaluating options (like “turndown”) from an engineering perspective, they do not propose to deploy those options. These projects may potentially be complementary to exchange data and/or validate models.

Demonstrate Systems to Ramp Existing Gas-fired Generation More Quickly to Adapt to Changes in Variable Energy Resources Output

CES-21 Related Area:
Operations

This project would demonstrate the use of a specific product to improve ramping rates of gas turbines. The goal is to resolve potential reliability issues due to the intermittency of renewables (and lack of ability to augment during ramp down events). The CES-21 Flexibility Metrics project, while addressing the value of flexibility, does not seek to make suggestions about how to realize flexibility, nor does it evaluate a specific product. Furthermore, CES-21 Operations Modeling efforts focus on evaluating options (like ramp rate) from an engineering perspective, they do not propose to deploy those options. These projects may potentially be complementary to exchange data and/or validate models.

Demonstrate New Technologies and Strategies that Support Integrated "Customer-to-Market-to-Grid" Operations of the Future

CES-21 Related Area:
Operations

PG&E will develop and demonstrate initial versions of new, integrated operator’s consoles that incorporate and consolidate more data about the system state. Uses cases include distributed generation, load monitoring, and other grid operations. The CES-21 Monitoring and Control project addresses data about the system (PMU data about the transmission system specifically) but it is focused on novel, big-data analytics that will inform new control system designs and sensor design/deployment. This EPIC project consolidates new data sources in an operator-friendly environment/interface, but does not seek to perform advanced analytics on the data itself.

Demonstrate Electric Vehicles as a Resource to Improve Grid power quality and Reduce Customer Outages

CES-21 Related Area:
Operations

This project looks at electric vehicles from the perspective of using the energy storage capabilities to improve utility-grid operations by reducing outage occurrence and duration. No CES-21 project focuses on PEV as a mobile storage solution.



Southern California Edison

Distribution Market Demonstration and Analysis

CES-21 Related Area:
Operations

This demonstration project will leverage ongoing work with the California Institute of Technology as part of an Advanced Projects Research Agency – Energy (ARPA-E) effort to develop a distributed volt/VAR control. The project would extend this interconnected and optimized network of devices to include an active distribution grid market that enables supply and demand balancing within a geographic area. The CES-21 Distribution Modeling project seeks to model the distribution system for the purpose of evaluating the efficacy of several emerging technologies, including those involved in this EPIC demonstration project. While the demonstration will obtain localized, “ground truth” information about such a system, the CES-21 effort will provide information about the system’s impact to the state-wide grid and enable optimization of this option with several others. The efforts are not reliant on each other, but could be highly complementary.

Advanced Voltage and VAR Control of SCE’s Transmission System

CES-21 Related Area:
Operations

This project will demonstrate that automation of switching operations will improve grid reliability by basing switching automation on optimal reactive power flow formulation. CES-21 Electric Operations projects seek to improve the modeling of this aspect of grid operations. However, this EPIC demonstration project will involve the Devers substation only. While providing localized “ground truth” the demonstration will not address the scale-wide grid impacts of this new switching automation scheme. The CES-21 efforts will. The efforts are not reliant on each other, but could be highly complementary.



**Modeling and Simulation
for Mitigating DER
Variability with Distributed
Energy Storage (DES)**

CES-21 Related Area:
Operations

This project seeks to help evaluate the use and optimization of energy storage devices in distribution circuits where penetration of Distributed Energy Resources (DER) is high. This will be accomplished by testing an actual controller with many simulated units in aggregation using the RTDS. The goal is to evaluate storage as a solution to renewable intermittency.

The CES-21 Planning Engine project will, among other things, provide a platform that could evaluate the economics associated with various storage deployment and performance scenarios, but does not evaluate performance. These projects are not duplicative, and are potentially complementary in assessing the viability of and roles for storage in the evolving grid.

The CES-21 Electric Operations projects will, among other things, provide platforms that could evaluate the engineering (reliability) feasibility and value of various storage deployment and performance scenarios. While RTDS provides detailed simulation of actual hardware, the scale is limited. The CES-21 Hybrid Simulator project will extend the capabilities of RTDS by coupling it with supercomputers to enable analysis of the CA-wide grid. These projects are not duplicative, and are potentially complementary.

**Application of Advanced
Early Warning System with
Adaptive Protection
Assessment**

CES-21 Related Area:
Operations

The project selects two specific applications for large-scale demonstration of PMU utilization: 1) adapt the operation of protection systems and 2) monitor and alarm for distance relays. In addition to the above protection applications, a protection information tool (PIT) will be developed to assist operators in the interpretation of PMU data. The CES-21 Monitoring and Control project is also focused on novel uses for PMU data. While the EPIC demonstration focuses on two specific use cases for PMU data, CES-21 will apply new big data analytic algorithms to identify more uses for PMU data and inform efficient PMU placement and data utilization. The projects are not duplicative, though they both seek to make optimal use of PMUs for grid operation automation.



San Diego Gas and Electric

Distributed Control for Smart Grids Program

CES-21 Related Area:
Operations

This program will pilot and evaluate a distributed control system that achieves the needed capabilities to support further advancement of the smart grid. The focus of this research will initially be on the management of resources at or below the individual feeder level and their integration into an overall distribution management system. CES-21 projects do not seek to pilot any control systems. Rather, CES-21 efforts seek to provide simulation platforms that could be used to evaluate control systems within the context of their operational environment. This program and CES-21 may potentially be complementary to exchange data and/or validate models.

Demonstration of Grid Support Functions of Distributed Energy Resources

CES-21 Related Area:
Operations

This program seeks to understand function and performance of DER by executing prototype demonstrations of particular DER functions in specific application situations. The results of these demonstrations will help determine the situations, if any, these grid-support functions are technically and economically viable. In addition, the results will help guide new standards, rules and regulations concerning the grid support DER functions. The CES-21 Distribution Modeling project has similar goals though it is not limited to DER, but models many other aspects of the distribution system. The CES-21 project also models the entire state's system and assesses state-wide impact, and is not limited to a localized demonstration/deployment region. This program and CES-21 may potentially be complementary for model validation with "ground-truth" deployment data.

Visualization and Situational Awareness Demonstrations Program

CES-21 Related Area:
Operations

The objective of this demonstration program is to explore how data collected from sensors and devices can be processed, combined, and presented to system operators in a way that enhances grid monitoring and situational awareness. In particular, this program will look at how data currently unexploited and separately processed can be integrated and visually presented for strategic use by system operators.

No duplication. Though several CES-21 projects have a visualization component, these are focused on the data and usage goals specific to each project, and are primarily intended as prototype tools or for demonstration purposes. No CES-21 project focuses solely on data visualization. As this EPIC program evolves, LLNL will coordinate with SDG&E to ensure leverage opportunities are explored.



Smart Distribution Circuit Demonstrations Program

CES-21 Related Area:
Operations

The objective of this program is to perform pilot demonstrations of smart distribution circuit features and associated simulation work to identify best practices for integrating new and existing distribution equipment in these circuits. Simulations will take advantage of hardware-in-loop technology not currently available at SDG&E. Using simulations to optimize one particular circuit; desired features will be tested in that circuit to assess their suitability for widespread commercial adoption.

No duplication. The CES-21 Electric Operations projects: Distribution Modeling and Optimization and Hybrid Simulator have potential synergies with this program, but are not duplicative. CES-21 Distribution Modeling will develop a detailed model of the distribution network to evaluate a wide variety of emerging technologies and will be optimizing, not one circuit, but the entire state-wide distribution system, which is a major goal for CA IOUs. Hybrid Simulator also involves RTDS, but is looking at ways to scale RTDS capabilities by coupling it with supercomputers. Initial focus will be on the transmission system.



Electric Power Research Institute (EPRI) Programs / Projects related to CES-21 Goals

Grid Operations	
<p>Situational Awareness Using Comprehensive Information</p> <p>CES-21 Related Area: Operations</p>	<p>This multi-year project will help improve system operators' situational awareness by integrating comprehensive information, such as operating boundary/margin information and asset-related information into control centers.</p> <p>There is no duplication with CES-21. No research efforts included under the CES-21 are related to incorporating asset-related information into control centers.</p>
<p>System Voltage and Reactive Power Management</p> <p>CES-21 Related Area: Operations</p>	<p>The goal of this project is to develop advanced study techniques, mitigation measures, and decision-support tools for grid operators and planners to address potential voltage stability problems.</p> <p>No duplication. There are no research efforts under the CES-21 that are related to voltage management and controls.</p>
<p>Application of New Computing Technologies and Solution Methodologies in Grid Operations</p> <p>CES-21 Related Area: Operations</p>	<p>This project is expected to investigate, identify, and develop advanced data processing and computing technologies for control centers to improve online simulation performance in speed, accuracy, robustness, and the depth of information presented.</p> <p>There is no duplication with CES-21. CES-21 is not proposing to develop any control center tools. CES-21 will, however, inform the development of such tools, in the Monitoring and Control project. In particular, how to effectively utilize PMU data to improve automated control systems. The CES-21 project is focused on the PMU analytics, not the end-user tools.</p>



Grid Operations

Decision Support Tools for System Emergency and Restoration

This project will investigate critical system operation functions and develop tools to help system operators with decision support in mitigating extreme disturbance events, especially natural disasters, and in restoring power systems.

CES-21 Related Area: **Operations**

LLNL is aware of this EPRI project. The EPRI project investigates critical system operation functions and develops tools to help system operators with decision support in mitigating extreme disturbance events. The goal of the CES 21 project is to develop the integrated transmission and distribution model in the power industry and use the integrated T&D model developed under phases 1 and 2 to investigate black-start strategy options to establish backbone transmission paths in San Francisco area. The CES-21 project may benefit from the restoration research work undertaken at EPRI, and EPRI is therefore considered a potential partner for the Integrated T&D model project. These two projects are not duplicative. The CES-21 project is not dependent on, but could benefit from, the EPRI restoration work.

Synchrophasor Applications

This project aims to develop practical systems and computational techniques to effectively apply synchrophasor data in an online monitoring and control environment to improve operators' situational awareness and control capability against major stability issues.

EPRI's Synchrophasor Applications research utilizes power engineering approaches to answer the questions: (1) What dynamic trajectories/waveforms need to be continuously monitored by PMUs? (2) How can an adaptive equivalent model of the original system from be built from its PMU data at different locations? (3) What control actions can be suggested using that model if fed with PMU data on major events?

There is a fundamental difference between the CES-21 Electric System Monitoring and Control project and this EPRI project; they are not duplicative. The CES-21 project utilizes a data-driven approach to exploit existing and forthcoming data streams from the state's major utilities and create useful correlation algorithms and mitigation strategies. By using these data and enhanced computational tools (long-term dynamics and intermittency) the project seeks to deliver meaningful control algorithms that have broad applicability to the participating California utilities. The data mining and pattern recognition algorithm to be used for this project is unique.



Planning	
<p>Plexos-related projects</p> <p>CES-21 Related Area: Planning</p>	<p>EPRI is engaged in a suite of activities related to electricity system planning. In several of their projects, EPRI uses high-fidelity models in the PLEXOS simulation framework.</p> <p>No duplication. EPRI is challenged to achieve sufficient levels of model performance on commodity simulation platforms. CES-21's Planning Engine project specifically targets the application of high performance computing resources to achieve a level of performance for extended PLEXOS models. In this sense, CES-21 addresses a singular need that EPRI's programs cannot fill.</p>
<p>Flexibility Project</p> <p>CES-21 Related Area: Planning</p>	<p>EPRI is currently investigating options for flexibility metric such as Ramp Percentile Deficit and Insufficient Ramping Resource Expectation.</p> <p>No duplication. CES-21's Flexibility Metrics project will evaluate these metrics and compare them against other proposed metrics. CES-21 will also operationalize these and other metrics for long-term planning purposes in models that have been extended specifically to incorporate them. In this sense, CES-21 may incorporate the results of EPRI's work, and does not duplicate it.</p>
<p>Solar Forecasting in Transmission and Distribution Applications</p> <p>CES-21 Related Area: Planning</p>	<p>The Solar Forecasting project is focused on solar energy only, and not on a combined wind-and-solar forecast. It is not intended to develop multi-physics and/or multi-analysis methods, but may leverage those methods when they become available through demonstration of existing and new forecasting techniques. Essentially this project will serve to inter-compare emerging forecasting techniques via a set of case studies.</p> <p>No duplication. This is not the goal of the CES-21 Ensemble Weather Forecasting project, rather, the CES-21 forecasting project seeks to operationalize a well-understood, but highly computationally intensive forecasting methodology.</p>
<p>Improved Methods for Variable Generation Forecasting and Integration into Operations</p> <p>CES-21 Related Area: Planning</p>	<p>The Variable Generation Forecasting project will focus on technology watch, best practices, targeted research areas, and advanced techniques. This project is not intended to develop a specific forecasting methodology; rather it is designed to provide information to utilities and other stakeholders on the merits of emerging forecasting technology.</p> <p>Although there is no duplication between the Ensemble Weather Forecasting project and this project, the results of EPRI's project will serve as an important benchmark on the relative value of the results of the CES-21 project.</p>



Cyber Security

Managing Cyber Security Incidents for T&D Systems

CES-21 Related Area:

Cyber Security

This project has the following objectives: (1) Create an event correlation test bed for testing Intrusion Detection Systems and Security information and event management solutions in EPRI's Cyber Security Research Lab, (2). Develop guidelines to build an Integrated Security Operations Center, and (3) Develop methodologies to perform event correlation across distributed power systems and conduct initial tests in EPRI's laboratories.

No duplication. This project differs from CES-21 Cyber: ATAC in that the EPRI effort is focused on development of guidelines and reports to assist utilities in developing integrated security operating centers for EPRI stakeholders, while CES-21 will be focused on developing highly scalable "big data" analytic tools to detect advanced persistent threat class attacks, fusing IT, SCADA alerts, and network traffic with electric grid data (e.g., voltage frequency) for the California IOUs. The CES-21 contribution is unique in that proposed CES-21 tools are not available to the California utilities for effectively analyzing cyber data across these three domains.

Modeling the Impact of Cyber Incidents on Electric System Reliability

CES-21 Related Area:

Cyber Security

The primary objective of this work is to mitigate the potential risks to reliability of introducing IT "smart" technologies on the electric power grid. This is achieved through modeling and simulation of the interactions between IT and electric systems to improve decision making regarding adequate architectures and procedures. The level of detail of the model should be consistent with the use case considered and the expected outcome.

No duplication. The major difference between this project and CES-21 Cyber: Mod-Sim is in their intended use. The EPRI effort is focused on providing models and tools that an individual utility can use to understand high-level trade-offs in the Information and Communication Technology architecture and reliability. The CES-21 project is intended to enable very detailed understanding of how malware could propagate through the California power grid and the effectiveness of proposed mitigation strategies. The EPRI tools are for rapid analysis and quick turn-around estimates, while the CES-21 tools are for very detailed simulations that utilize large scale computing. The CES-21 contribution is unique in that there are no tools available that enable detailed design and analysis of a communications / grid network at the scale of the entire state.

