DRAFT

A High Performance Secure Platform for Smart Grid Research - A Project Plan to Lead to the Creation of Internet2 Smart Grid Testbeds

8 November 2015

The Internet2 Collaborative Innovation Initiative

Foreword

This project plan describes one of several exploratory activities currently in progress as part of the Internet2 Collaborative Innovation Initiative[1]. The overall initiative is led by Florence Hudson, Senior VP and Chief Innovation Officer for Internet2. This initiative incorporates many topics being explored by initiative participants, including end to end trust and security, distributed big data and analytics, and the Internet of Things. The Smart Grid concepts described in what follows include aspects of each of these areas.

In July, we began an exploratory activity to see how Internet2 might contribute to Smart Grid research and support researchers at Internet2 member institutions. We developed the white paper, including a one-page executive summary, provided here as Attachment A to this project plan. Since the reactions to this activity were very positive, we have now developed the following project plan for review and approval by Internet2.

For those not familiar with this activity, we suggest reading the attachment before reading the project plan. This white paper provides motivation for the plan.

This plan was developed by Robert Brammer, Senior Advisor to the Internet2 CEO, with inputs from initiative participants. It describes our current vision and approach.

For further information about the Internet2 Collaborative Innovation Initiative and this Smart Grid exploration contact:

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[1] http://meetings.internet2.edu/media/medialibrary/2015/04/29/20150429-Hudson-Collaborative_Innovation.pdf

A High Performance Secure Platform for Smart Grid Research - A Project Plan to Lead to the Creation of Internet2 Smart Grid Testbeds

8 November 2015

Project Background and Description

During the past few months, as part of the Internet2 Collaborative Innovation Initiative, we have been exploring concepts in which Internet2 could contribute to the development of the Smart Grid in the US. In particular, we have been assessing the potential of the Internet2 network to serve as a key part of the communications and networking plane for Smart Grid research and pilot demonstration projects. We have discussed this concept with several power industry executives and Smart Grid researchers from Internet2 member institutions and provided them with a whitepaper summarizing these ideas (Appendix A). We have received very positive responses to this concept. Internet2's Advanced Layers one and two services appear to be highly relevant to some Smart Grid research use cases. Additionally, the security and flexibility of the Internet2 network services as distinct from the public Internet are very attractive for Smart Grid research, testing, and demonstrations.

Many of our member institutions have researchers who are already engaged in Smart Grid research and operational activities. However, many of these current and potential Smart Grid researchers are not yet fully aware of Internet2's activities and resources in areas such as trust and security, software-defined networking, IPv6, federated identity, and others. Consequently, we believe that there are significant opportunities to extend Smart Grid research using Internet2 resources, notably in areas using Smart Grid testbeds, and our initial discussions have confirmed this potential. Consequently, Internet2 is planning to develop testbed environments for selected projects to help enable Smart Grid research, notably in areas of networked microgrids and institutional testbeds. This effort will increase the value of Internet2 membership to those institutions and enable significant developments in Smart Grid research. We plan to cover the costs of this initiative through membership dues from new industry members, consequent network connection fees, and some possible participation in aspects of the resulting research projects.

This plan describes the steps required to build awareness of Internet2 in this research community, to define relevant priority use cases, to aid in viable research proposals, and to create a unique and viable testbed to support Smart Grid research projects. Although the discussion here focuses on Smart Grid research, there is high relevance to Smart Cities research, as well. Many Smart Cities initiatives come from the same motivating factors as for the Smart Grid, as the cities want to reduce their costs and improve their environmental impacts with more efficient and flexible electric power.

Consistent with the exploratory nature of this initiative, this plan is in a continuing state of development. We will review the status of the project monthly and make appropriate modifications as required.

Project Scope

As described above, we need to do the following

- **Build awareness of Internet2 in the Smart Grid research community**. We have developed a white paper that we have discussed with some researchers at Internet2 member institutions, with some research sponsors[2] at NSF, DHS, DARPA, NIST, and DOE, and with some power industry executives and NERC and

[2] We have sent copies of the white paper (Appendix A) to Kevin Thompson at NSF, Doug Maughan at DHS, John Everett at DARPA, Chris Greer at NIST, and James Cale at DOE. We would like recommendations for other potential sponsors.

the New York ISO. We have also sent the white paper to some Internet2 members and to the Power Systems Engineering Research Center[3] (http://pserc.wisc.edu). It was a topic of discussion at the recent TechExchange Conference, and the white paper has been posted on the Internet2 CINO website. We will continue to find ways to build awareness among the Smart Grid research community.

- **Define relevant priority use cases**. The possible use of the Internet2 network to exchange large files of synchrophasor data to aid in maintaining a high degree of grid situational awareness appears to be an important use case for research. Our white paper cites relevant reports describing power grid situational awareness as a national priority that has received Presidential attention. Other possible use cases include using the network services to configure secure networks of microgrids and to conduct high resolution multi-point video conferences for grid operations and emergency response. We will work with researchers and sponsors to define a variety of other use cases that can be the subjects of significant research projects.

- **Aid in developing viable research project proposals**. While Internet2 staff members will not be doing the Smart Grid research, they can make important contributions to successful proposals and projects. For example, we will work with various regional network connectors and member CIOs to ensure optimum connectivity to support project operations. We can establish procedures for measuring network performance and enabling required quality of service. We can also assist with the implementation of appropriate identity management and other security measures. Additionally, we can work with researchers to help attract industry partners to be part of their research teams. Some of these industry organizations may already be Intenet2 members. If not, we can explain the benefits of membership, including this research area, as well as the many other benefits of Internet2 membership.

- **Create unique and viable testbeds for Smart Grid research.** Beyond necessary network connectivity, there will be other characteristics of Smart Grid research testbeds that we should implement in order to aid in the acceleration of research results to operations. The power industry is highly regulated in many aspects. Accordingly, Internet2 has begun a discussion with the North American Electric Reliability Corporation (NERC) about jointly developing the needed guidelines for realistic environments for Smart Grid research. Consistent with the Internet2 mission, work on our network will be for research and education, including advanced concept development and feasibility tests where no large-scale operational risks arise. However, we want to do this research and education in a realistic environment. We will work with the appropriate organizations to ensure that our testbeds can help to support credible research.

Deliverables

There will be a variety of deliverables associated with this project. We will update the white paper as we receive further feedback and continue to use the whitepaper to build more awareness about the potential value of Internet2 in Smart Grid research. We will also have agreements and testbed designs with organizations with

[3] We have sent the white paper to Vijay Vittal, Director of the PSERC. This is a university-industry consortium with 50+ members focused on power systems research. Many of these members are also Internet2 members.

which we will be developing research project proposals. We may also have a few professional publications, as this project evolves.

Internet2 Project Team

The project will be led by Robert Brammer, Senior Advisor to the Internet2 CEO. He will work on this project on a two-day per week basis and be responsible for leading the awareness building and use case development activities. Since this effort is part of the Collaborative Innovation Initiative led by Florence Hudson, Senior VP and Chief Innovation Officer, he will receive support from the CINO staff.

As described above, we will likely collaborate with some regional networks to establish necessary connectivity for researchers when we have enough specific definition of project use cases. Accordingly, we will then need assistance from George Loftus, AVP for Business and Relationship Management in our Network Services Division, to help with the development of arrangements with the regional networks. The nature and level of this support will be defined as the use cases develop.

We will also have involvement from current and prospective new Internet2 industry members. Accordingly, we will need the involvement of Ann O'Beay, Senior Director of Industry Relations and Community Engagement in our Community Outreach Division, to help with initiative communications with current members and to bring in prospective new members (e.g., electric utilities interested in participating in these research projects). The nature and level of this support will be defined as the use cases develop.

We will also need support from John Moore, AVP for Network Planning and Architecture in our Network Services Division, since we will need to define the best ways to establish connectivity at various industry and university research facilities for the various research projects that we will be supporting. The nature and level of this support will be defined as the use cases develop.

Additionally, since we will be reaching out to researchers among various Internet2 member institutions, we will need the assistance of Rick McMullen, Senior Director, Research Engagement & Development, in our Community Outreach Division, to assist with communications with the Smart Grid researchers. The nature and level of this support will be defined as the use cases develop.

Finally, we will create a focus group of Smart Grid researchers who will advise us on testbed requirements. While these researchers may regard one another as competitors for funding, some of them will recognize common testbed requirements. We have received help thus far from researchers at Cornell, Clemson, Washington State, and IBM and will look for additional participation in this initiative.

Partner Organizations

We have identified a few potential partner organizations. They have all shown interest in this initiative and made some contributions to our white paper. These include Cornell University (Ken Birman), Clemson University (GK Venayagamoorthy), the University of Pittsburgh (Brian Stengel), IBM (Jeff Katz), Washington State University (Anjan Bose), and NYSERnet (Tim Lance).

Additionally, we have been contributing to a proposal concept paper for "A Grid of Microgrids" led by Brett Murphy at RTI with participation from NIST, DOE/NREL, and the Green Energy Corporation. This has been sent to Stuart Laval at Duke Energy, Kostas Tolios at DTE Energy, and Andy Paylan at Southern California Edison for review and possible sponsorship. This activity came from an initiative within the Industrial Internet Consortium. We will establish a dialog and some form of partnership with them.

We have also received advice on our work from Bob Cummings, Director of Engineering and Reliability at NERC and from Edgardo Luzcano, Director of Regulatory Compliance, at the New York Independent System Operator (NYISO). We will continue to communicate with these industry organizations to ensure that research concepts are important and realistic.

Expanding this list is an early priority for this initiative. Candidates include Indiana University (Rob Lowden), the University of Illinois, and the New England ISO.

High-Level Schedule and Milestones

- **December 2015** – This plan must be reviewed and approved by Internet2 since it has budget implications and staff resource requirements. We will have internal discussions with Internet2 staff to include them in planning and action items. We will also have additional outreach steps to Internet2 members and potential sponsors. We will also have some communication with the PSERC meeting in early December.
- **January and February 2016** – Broaden our partner list and create a Smart Grid research focus group to help with testbed requirements. Conduct conference calls to refine and expand the above list of potential research project concepts with use cases for the Internet2 network and associated services. Identify potential funding sources from above federal agencies or possibly industry sponsors, notably electric utilities and the Electric Power Research Institute (EPRI). These latter organizations may be candidate Internet2 members if we can establish significant interest in Internet2 across the power industry.
- **March through June 2016** – Help to organized proposal teams. Help to develop initial research proposals including Internet2 network and associated services. These will form the basis of our Smart Grid testbeds.

Concluding Remarks

As stated earlier, this plan is a work in progress as part of the overall Internet2 Initiative. We will review the status of this project monthly and revise the plan as we learn more about how to address the Smart Grid research community. We invite your feedback.

Appendix A

A High Performance Secure Platform for Smart Grid Research - the Internet2 Network

10 October 2015

The Internet2 Collaborative Innovation Initiative

Foreword

This paper describes one of several exploratory activities currently in progress as part of the Internet2 Collaborative Innovation Initiative[4]. The overall initiative is led by Florence Hudson, Senior VP and Chief Innovation Officer for Internet2. This initiative incorporates many topics being explored by initiative participants, including end to end trust and security, distributed big data and analytics, and the Internet of Things. The Smart Grid concepts described in what follows include aspects of each of these areas.

This Smart Grid exploration is a work in progress. This document was developed by Robert Brammer, Senior Advisor to the Internet2 CEO, with inputs from initiative participants. It describes our current vision and approach. However, it is likely that there will be changes for the remainder of this year while the Internet2 management and membership decides how to proceed with this and other possible new initiatives.

For further information about the Internet2 Collaborative Innovation Initiative and this Smart Grid exploration contact:

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[4] http://meetings.internet2.edu/media/medialibrary/2015/04/29/20150429-Hudson-Collaborative_Innovation.pdf

A High Performance Secure Platform for Smart Grid Research -- The Internet2 Network
10 October 2015

Executive Summary

This paper addresses researchers interested in the Smart Grid. In particular, we address researchers at Internet2 member institutions who may not yet be aware of the potential resources in the Internet2 community that can aid in the development of large-scale multi-institutional collaborative research with significant advantages in performance, functionality, security, and cost-effectiveness.

The Smart Grid markets have grown rapidly and will continue do so during the next decade, driven by needs for decreased costs, reduced carbon emissions, increased grid security and reliability, and more electric power. Realizing the benefits of the Smart Grid requires significant advances in information technology and systems to collect, secure, manage, analyze, and act on massive volumes of information. These advances will help to meet these needs and will enable significant advances in grid intelligence. There is a high requirement for reliability of the grid and associated information flows, as well as increasing needs to mitigate risks from physical and cyber-attacks on the grid. Many reports address such requirements. For example, last year the Center for the Study of the Presidency and the Congress developed a report for the President entitled, "Securing the U.S. Electrical Grid." Furthermore, research in distributed operations are important. For example, NIST organized a workshop focused on Smart Grid testbeds. The resulting NIST report devotes considerable discussion to the benefits and challenges associated with networked testbeds.

Internet2 has a unique position in the Research and Education (R&E) community with a history of facilitating unique and innovative member-led initiatives. Internet2 has created the world's most powerful research network with current optical capacity of 8.8 terabits per second (soon to double) across the US. This network connects members of the US research and education community with unmatched capabilities for high performance and minimal latency. Of particular interest to Smart Grid researchers are the Advanced Layers 1 and 2 services. These services enable researchers to create custom high performance networks with the flexibility, security, and privacy to meet their needs. Internet2's Advanced Layer 1 Service enables researchers to create a state-of-the-art network isolated from the public Internet with more access points than any other national R&E network. Internet2's Advanced Layer 2 Service provides effective and efficient wide area 100 gigabit Ethernet technology. This service is used today by researchers needing big data and secure network services. This service enables balancing long-term or short-term global big data science collaborations and production services, as well as research on network capabilities. Additionally, Internet2 has begun a discussion with NERC about jointly developing the needed guidelines for realistic environments for Smart Grid research. Consistent with the Internet2 mission, work on our network will be for research and education, including advanced concept development and feasibility tests where no large-scale operational risks arise. However, we want to do this research and education in a realistic environment.

Many of our member institutions have researchers who are already engaged in Smart Grid research and operational activities. However, some of these current and potential Smart Grid researchers may not be fully aware of Internet2's activities and resources in areas such as trust and security, software-defined networking, IPv6, federated identity, and others. Consequently, we believe that there are significant opportunities to extend Smart Grid research using Internet2 resources, notably in areas using Smart Grid testbeds. Consequently, Internet2 is planning to develop a testbed environment to help enable Smart Grid research, notably in areas of networked microgrids and institutional testbeds.

These ideas are discussed further in this paper with footnotes providing references to provide further information for research. In particular, we provide further information about Internet2. We invite your inquiry.

Introduction

As stated in the Executive Summary, our focus is on communicating the potential of Internet2[5] resources to Smart Grid[6] researchers so that they can extend the depth and breadth of their research[7]. The ideas described here are part of a Collaborative Innovation Initiative at Internet2 and to an Internet2 outreach effort to a broader population of researchers whose work can leverage and benefit from new developments in advanced networking, high performance computing (HPC), big data, end to end trust and security, and other priorities in this community.

Smart Grid Background

Driven by needs for decreased costs, reduced carbon emissions, increased grid security and reliability, and more electric power, the global markets for Smart Grid systems and technology has grown rapidly and will continue to do so during the next decade[8]. New types of loads from distributed operations and DC devices are challenging the current AC grid architecture. Furthermore, new types of generation (e.g., wind, solar) on large scales offer advantages for environmental compliance, but their variability may present reliability risks.[9] Necessary changes to meet new operating and regulatory requirements will require significant investment. For example, the Edison Electric Institute estimates that "By 2030, the electric utility industry will need to make a total infrastructure investment of $1.5 trillion to $2.0 trillion."[10] This figure includes additional intelligence and direct electrical infrastructure upgrades and replacements.

Realizing the benefits of the Smart Grid will require significant advances in relevant information technology and systems to collect, secure, manage, analyze, and act on the massive volumes of relevant information. These advances will help to meet the above needs and will enable significant advances in relevant grid intelligence.[11] For example, some early research suggests that smart grid data may be comparable in size to that of the multi-petascale social networks and also has aspects that require high speed transmission with synchronization and minimal latency.[12] Accordingly, Smart Grid data management is a growing distributed big data problem with critical timing and security requirements that will require many new developments to realize practical and timely benefits.

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[5] www.internet2.edu

[6] In this paper, we use the somewhat colloquial term "Smart Grid" as a short version of the very broad term "21st Century Grid Technologies." Our intent with this concise term is to capture the potential for significant integration of information and communication technologies into the future power grid.

[7] While we do mention some research sponsors, this is not a guide to Smart Grid research funding programs. We believe that researchers are familiar with these sponsors and have other information sources about their programs.

[8] Bennet A. and Fike, V., US Department of Commerce, "The Global Grid-Smart Grid Growth in International Markets, US Government Support for Exporters," Electric Light & Power, 16 January 2015

[9] Cauley, G. W., NERC, "Testimony Before the Subcommittee on Energy and Power of the House Energy and Commerce Committee on Energy Security and Reliability," 19 May 2015

[10] The Edison Electric Institute, "Transforming Americas Power Industry," http://www.eei.org

[11] Venayagamoorthy GK, "Dynamic, Stochastic, Computational and Scalable Technologies for Smart Grid", *IEEE Computational Intelligence Magazine* (*Special Issue on Smart Grid*), Vol. 6, No. 3, August 2011, pp. 22-35.

[12] Aiello, A., and Pagani, G., "The Smart Grid's Data Generating Potentials," Proceedings of the 2014 Federated Conference on Computer Science and Information Systems pp. 9–16

Moreover, since there is a high requirement for reliability of the grid itself and associated information flows, more diverse grid interfaces, increased consumer participation, as well as an increasing need to mitigate risks from physical and cyber-attacks on the grid[13], there is a growing need for grid modernization. In particular, there is a strongly growing need for regional and national situational awareness of grid status.[14] For example, last year the Center for the Study of the Presidency and the Congress developed a report for the President entitled, "Securing the U.S. Electrical Grid."[15] This reports notes that the President has directed the Executive Branch to "Develop a situational awareness capability that addresses both physical and cyber aspects of how infrastructure is functioning in near-real time."[16] The report presents a dozen recommendations, including the following

> *"Unresolved questions about the implementation of Smart Grid, microgrid, and the shift to renewable generation require further examination with an eye towards grid security and reliability."*

In addition to federal attention to the need for improved situational awareness for the power grid, there is considerable industry interest. Many power industry analysts are discussing the integration of information technology and operational technology (IT/OT)[17]. This integration in the power grid (e.g., integrating IP and SCADA networks) is a prime example and leads to new requirements for situational awareness. For example, the presentation[18] on grid real-time monitoring and analysis given in a June 2015 North American Electric Reliability Corporation (NERC) Technical Conference provides considerable data on the motivation and requirements for creating additional grid situational awareness. An informal group, the North American Synchrophasor Initiative, is doing related work.[19] Many utilities have related developments within their operating areas.[20]

The Internet2 Consortium

The Internet2 Consortium is a highly innovative community with unique resources that could be used to help to develop regional and national-level Smart Grid situational awareness capabilities and to enable examination of advanced technologies that may be proposed for use in such developments. The Internet2 membership of nearly 500 institutions includes all of the leading US research universities, many leading corporations developing relevant technologies and systems, regional and state education networks across the US, and many engaged federal agencies (including the DOE laboratories, NIST, and NSF). Additionally, we have partnerships with research and education networks in more than 100 countries. Consequently, there is considerable opportunity for multi-institutional collaboration facilitated by the Internet2 Consortium and a nearly 20 year history of such collaboration.

Internet2 has created the world's most powerful research network with current optical capacity of 8.8 terabits per second (soon to double) across the US. This network connects members of the US research and education community with unmatched capabilities for high performance and minimal latency. The network offers many services, including wide area petascale file transfer and a selection of distributed collaboration services,

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[13] The Department of Energy has begun to adapt the NIST Cybersecurity Framework to Smart Grid requirements. See the DOE report, "Energy Sector Cybersecurity Framework Implementation Guidance", January 2015

[14] Beasley C, Zhong X, Deng J, Brooks R, Venayagamoorthy GK, "A Survey of Electric Power Synchrophasor Network Cyber Security", *IEEE PES Innovative Smart Grid Technologies Conference*, Istanbul, Turkey, October 12-15, 2014.

[15] McLarty III, T. and Ridge, T., "Securing the U.S. Electrical Grid," The Center for the Study of the Presidency and Congress, Washington DC, July 2014

[16] Presidential Policy Directive 21, "Critical Infrastructure Security and Resilience," February 2013

[17] Steenstrup, K. and Iyengar, P., "2016 Strategic Roadmap for IT/OT Alignment," Gartner, Inc. G00277331, June 2015

[18] NERC, "Project 2009-02, Real-Time Monitoring and Analysis Capabilities," Technical Conference, 4 June 2015

[19] www.naspi.org

[20] Rahman, T., et al, "Real time Situational Awareness of WAMS at San Diego Gas and Electric," 16 March 2014

including video conferencing and telepresence. Furthermore, since Internet2 is a leader in software defined networking, the network has the flexibility to adapt segment architectures to meet a variety of requirements.[21] It is exactly the platform for the "High-bandwidth, low-latency, cost-effective, interoperable communications systems will that will overlay the future grid"[22] called for in many Smart Grid planning reports. While the network-related focus here is on the use of the Internet2 network, we emphasize the close working relationships with the Energy Sciences Network[23] (ESnet) connecting the US DOE labs, and the various regional and state educational networks. They may be interested in some form of collaboration here and will be included in future discussion.

Of particular interest to Smart Grid researchers are the Internet2 Advanced Layer 1 and 2 services[24]. These services enable researchers to create custom high performance networks with the flexibility, security, and privacy to meet their needs. Internet2's Advanced Layer 1 Service enables researchers to create a state-of-the-art network isolated from the public Internet with more access points than any other national R&E network, including paths through regions never served previously. Internet2's national fiber network, optical system and network operations center (NOC) provide a set of leading edge resources and capabilities that offers the most reliable, high-capacity network solution. While Internet2 continues to implement advanced security features (e.g., custom tools for monitoring networks at these high performance bandwidths), the high degree of reliability and security in this flexible research platform can be augmented by further research projects to address the particular requirements of the Smart Grid. Internet2's Advanced Layer 2 Service provides effective and efficient wide area 100 gigabit Ethernet technology. This service is being used today by researchers needing big data capabilities (e.g., particle physics data from the Large Hadron Collider) and secure network services (e.g., genomic and other biomedical data). The flexibility of this service enables balancing long-term or short-term global big data science collaborations and production services, as well as research on network capabilities (e.g., researchers on the GENI program).

Internet2 has a unique position in the Research and Education (R&E) community[25] with a history of facilitating unique and innovative member-led initiatives in advanced networking, federated identity management, and cloud services. The Internet2 network, the InCommon Federation, and the NET+ Program and other Internet2 member developments show the benefits to the broader R&E community from collaboration facilitated by Internet2.

Smart Grid Research

Many of our member institutions have researchers who are already engaged in Smart Grid research and operational activities. For example, nearly all of the Smart Grid research projects listed by the National Renewable Energy Laboratory for their Climate-Neutral Campus Program[26] are funded at Internet2 member institutions. Furthermore, some of our university members have significant campus projects. For example, Cornell University and Washington State University have a joint project called GridControl[27] for grid monitoring and control. Clemson University's situational intelligence (SI) laboratory is able to collect, analyze and predict

[21] Ramel, D., "Internet2 Achieves SDN-Enabled Milestone: Virtualization Review", November 2014
[22] Grid Wise Alliance, "The Future of the Grid," National Summit, 26 June 2014, p7
[23] https://www.es.net/
[24] For further information on these services -- http://www.internet2.edu/products-services/advanced-networking/
[25] The term "R&E community" as used here includes higher education institutions, corporate R&D organizations, and government agencies with strong interest in advanced information and communications technology.
[26] http://www.nrel.gov/tech_deployment/climate_neutral/smart_grid.html
[27] http://www.cs.cornell.edu/projects/gridcontrol/

synchrophasor data/information[28]. Additionally, the University of Pittsburgh's Center for Energy manages the DC-AMPS Program (Direct Current Architecture for Modern Power Systems) for DC-based power electronics technologies. This team will be building a High-Voltage/High-Power Lab at the Pittsburgh Energy Innovation Center and is working with Internet2 to explore options for campus-I2 connectivity.

Personnel from Internet2 industry member institutions have participated in some larger Smart Grid projects, including the Pacific Northwest Smart Grid Demonstration Project and the European Union Smart Grid Demonstration Project. Additionally, Internet2 members (e.g., IBM, GE) are also working with several major utilities on Smart Grid projects.

However, all of these current and potential Smart Grid researchers may not be fully aware of Internet2's activities and resources in areas such as trust and security, software-defined networking, IPv6, federated identity, and others. Consequently, we believe that there are significant opportunities to extend Smart Grid research using Internet2 resources, notably in areas using Smart Grid Testbeds.

Smart Grid Testbeds

In December 2014, NIST published a report on a workshop focused on Smart Grid testbeds.[29] The report devotes considerable discussion to the benefits and challenges associated with networked testbeds. In particular, one of the key findings of the workshop is the following

> *"Significant measurement, characterization, performance, and other challenges remain that will benefit greatly from testbed analysis and demonstration. A range of testbed scenarios are needed, including 1) targeted testbeds for unique problems; 2) modular/composable testbeds; and 3) interconnected testbeds – across domains, with multiple interconnected smart grid technologies, and those that connect the different capabilities of R&D laboratories or organizations." (Emphasis added.)*

The report also provides a set of interconnected testbed priorities which the Internet2 services could help to address. Appendix A in that report lists more than 30 Smart Grid testbeds, and more than half of them are operated by Internet2 member institutions. Consequently, there is a considerable facilities base to leverage, and the use of the Internet2 network could help to address some challenges noted in the report about shared infrastructure. However, the report does not mention "grid situational awareness" or "the Internet2 network," so some of the ideas described here will complement the developments described in that report.

We have reviewed these projects and many others and believe that we can extend Smart Grid research with the advanced networking capabilities of the Internet2 network. What could be created beyond current activities are pilot distributed situational awareness projects that could demonstrate advanced concepts and technologies for the Smart Grid in distributed multi-institutional collaborations. These projects, enabled by the unique capabilities of the Internet2 network, could show results scaling above current demonstrations. For example, they could show how the integration of such diverse data types as grid phasor measurement unit (PMU) data[30], weather information[31], cyber threat information[32], and power grid generation and load demand data[33] could be used to enhance decision making and emergency response to significant grid incidents. Issues that could

[28] "Real-Time Power and Intelligent Systems Laboratory" – http://rtpis.org.

[29] NIST, "Measurement Challenges and Opportunities for Developing Smart Grid Testbeds," December 2014

[30] https://www.naspi.org See also the EPRI Research Program that Includes NASPI sponsorship. www.epri.com

[31] http://www.weather.gov The National Weather Service provides ready access to large volumes of data

[32] There are several commercial cyber threat information services, as well as industry ISACs creating relevant data

[33] Data from regional Independent System Operators (ISOs) can be made available with proper arrangements

be addressed include the management of PMU data from 1000's of units[34], prediction of grid vulnerabilities during extreme weather conditions[35], response of the grid and management centers to simulated cyber-attacks[36], and the factors necessary to facilitate distributed collaboration[37] among diverse governing organizations involved in grid decision-making in critical situations. On-demand HPC to do forecasting of grid state during an emergency would also be possible with the aforementioned facilities.

Through successful research based on ideas described here, the government could develop a national view of the real-time transmission system, similar to what the FAA has for the National Airspace System, fed from the regional independent system operators (ISOs). This could provide the timely detection and decision making that was not possible, for example, during the August 2003 US northeast blackout and could address the national objectives stated above for real-time situational awareness and decision making for the grid during emergencies.

Unique Security and Operational Policy Challenges

As stated earlier, NERC[38] is responsible for publishing guidelines laying out the security expectations that power system operators must follow. Called the NERC Critical Infrastructure Protection guidelines, NERC CIP[39] (currently at version 5.0) dictates the specific rules concerning physical infrastructure protection, vetting employees who would have physical access, logical security policies and monitoring obligations, and data encryption standards that should be used. The NERC CIP rules were conceived when utilities typically operated their own dedicated communications infrastructures. Thus, there are significant legal obstacles to simply using the NERC CIP rules in applications that might use Internet links supplied by third parties. This stands as a non-trivial barrier to adoption of the standard Internet model by major smart grid operators, who would face stiff penalties for violating the NERC CIP even in unintentional ways.

As a part of this Smart Grid initiative, Internet2 has begun a discussion with the NERC about jointly developing the needed guidelines and regulatory frameworks. Consistent with the Internet2 mission, work on our network will be for research and education, including advanced concept development and feasibility tests where no operational risks arise. However, we want to do this research and education in a realistic environment. Hence participation by the Internet2 community in creating NERC guidelines aimed at leased private network structures, similar to the Internet2 network, would be important in accelerating the research results into operations. Such steps would advance a national cause in many ways. We can help to further the transformation of the US power grid so as to achieve the benefits discussed earlier. We can do this in ways that are secure against tampering, that minimize vulnerability to third-party errors such as network configuration mistakes, and also that are unbiased with respect to particular characteristics of major smart grid participants. Research in these aspects would also be important to accelerate the development of the Smart Grid.

Concluding Remarks and Next Steps

Initial pilot projects focused on research related to grid situational awareness on a large regional or national scale could build on our existing network infrastructure and member capabilities to minimize cost and time to show significant results. While this paper has focused on Smart Grid applications and the implications of the regulatory environment, notably large-scale situational awareness, it is clear that the Internet2 assets

[34] NASPI, "Synchrophasor Technology Fact Sheet, 2014
[35] Abi-Samra, et al, "Managing Extreme Weather Events Affecting Electrical Power Grids," IEEE Power and Energy Society, September 2014
[36] McLarty op cit,
[37] Cisco, "Collaboration Case Studies," www.cisco.com
[38] http://www.nerc.com/Pages/default.aspx
[39] http://www.nerc.com/pa/Stand/Pages/CIPStandards.aspx

described above could be applied more generally to other areas including other aspects of Smarter Cities and Smarter Campus initiatives.

We are reaching out to many diverse stakeholders to determine how best to proceed with these ideas. Specifically, we will be discussing these ideas further in the Internet2 Collaborative Innovation Initiative meetings and at the Technology Exchange meeting in October 2015.[40] If there is sufficient interest, we may organize a workshop to develop these ideas further. If all of this is successful in attracting and organizing a critical mass of qualified and interested researchers, our vision is to obtain the resources to develop a national-level program and platform for Smart Grid research with emphasis on the essential grid situational awareness capabilities envisioned by the President's direction. We invite your feedback at CINO@internet2.edu

[40] https://meetings.internet2.edu/2015-technology-exchange/