Draft Report to Congress on

NIST Activities in Support of the Energy Independence and Security Act (EISA) of 2007

December ??, 2008

Executive Summary

Introduction

Revitalizing the electric power grid has become one of our Nation's top priorities, promising to reduce our dependence on oil and to meet the anticipated 1.1% annual increase in demand for electricity[1]. In his New Energy for America plan, President-elect Obama calls for increased investment in the next generation power grid, referred to as the Smart Grid, to help reach the ambitious goals of ensuring that renewable sources provide 10% of our electricity by 2012 and

25% by 2025; and that 1 million Plug-In Hybrid cars are on the roads by 2015.

As the Nation's measurement and standards institute, NIST is making a unique contribution to the establishment of the Smart Grid. Recognizing the benefit of focusing NIST's technical expertise and industry-oriented mission on what is one of the Nation's most pressing issues, Congress called on NIST to take a leadership role in setting the standards to ensure an interoperable and open energy infrastructure. The **Energy Independence and Security Act (EISA) of 2007** states that NIST

> *"…shall have primary responsibility to coordinate development of a framework that includes protocols and model standards for information management to achieve interoperability of smart grid devices and systems…"*

Responding to this mandate, NIST has initiated a government/industry effort, in collaboration with the Department of Energy and organized by key Smart Grid domains, to establish an Interoperability Framework. This Framework will accelerate the development and adoption of Smart Grid products and practices through recommended consensus-based grid interoperability standards.

Definition of Smart Grid

The Department of Energy defines the Smart Grid as an automated, widely distributed energy delivery network characterized by a two-way flow of electricity and information, capable of monitoring and responding to changes in everything from power plants to customer preferences to individual appliances. By incorporating the benefits of distributed computing and communications, the Smart Grid will deliver real-time information and enable the near-instantaneous balance of supply and demand at the device level. This advanced network will make it possible to lower the high costs of meeting peak demand, and will support the incorporation of distributed and renewable energy sources.[2]

Full implementation of the Smart Grid will enable new opportunities and support innovations, including[3]:

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[1] Quote from DOE in http://www.barackobama.com/pdf/factsheet_energy_speech_080308.pdf .
[2] The Smart Grid: An Introduction, U.S. Department of Energy, http://www.oe.energy.gov/DocumentsandMedia/DOE_SG_Book_Single_Pages.pdf , (p. 13).
[3] Ibid. 15.

- Nationwide use of plug-in hybrid electric vehicles, including the ability to return stored energy to the grid
- Seamless integration of renewable energy sources like wind and solar
- A new era of consumer choice
- Integration of green building practices with the grid
- Large-scale energy storage

NIST Goals and Approach

The goal of the NIST Smart Grid effort is to accelerate the development and adoption of interoperable Smart Grid technologies through the use of recommended consensus-based standards. With additional resources and support from stakeholders, NIST plans to accomplish this goal by establishing a Smart Grid Interoperability Framework to orchestrate the creation of the common understandings, standards and tools needed to achieve interoperability. NIST defines the Interoperability Framework broadly to include:

> ***Concepts*** – consensus definitions, dictionaries, ontologies, and information models that support Smart Grid interoperability. Fortunately, the DOE GridWise program has laid a valuable foundation with the creation of the Interoperability Context-Setting Framework (http://www.gridwiseac.org/pdfs/interopframework_v1_1.pdf), which provides a conceptual model covering technical, business and regulatory policy information, and is being used to guide the NIST Work Plan.
>
> ***Processes*** – the business interactions and automated negotiations expected to characterize a fully implemented Smart Grid. NIST has already begun to work with the stakeholder community to document and prioritize their business objectives. The business processes which support those prioritized objectives will be further defined and "choreographed" as business "use cases". The transactions defined by the use cases will be mapped to standards, thereby illuminating where adequate standards exist and where further work is required. Southern California Edison has already made a significant contribution to this effort with their development of a library of use cases, which EPRI has translated into information models.
>
> ***Principles*** – the overall requirements, goals, tenets, and best practices that foster interoperable Smart Grid technologies. EISA provides a list of guiding principles for the Smart Grid upon which NIST will build, including:
>
> - Increase use of digital information and control technologies
> - Enable dynamic optimization of the grid
> - Integrate distributed resources including renewables
> - Incorporate demand response, demand-side resources, and energy efficiency
> - Deploy real-time, automated, interactive technologies for metering, communications, and distribution automation
> - Integrate electricity storage and peak shaving technologies including plug-in electric vehicles, and thermal storage air conditioning
> - Integrate smart appliances and consumer devices

- Provide timely information and control options to household, commercial and industrial consumers
- Develop standards for interoperability
- Lower barriers to interactions between Smart Grid technologies, practices, and services

Comment [ejb1]: This is the purpose/objective of the SmartGrid concept. I don't understand it as a principle.

Constructs – the tangible deliverables and services needed to make Smart Grid interoperability a reality. The constructs anticipated from this effort are expected to include: an interoperability assessment, a web-based knowledge base, recommended standards, conformance tests, interoperability testbeds, feasibility studies, pilots, and interoperable products. Many of the constructs, such as actual products, are not within the mission of NIST to deliver.

The NIST Work Plan

The NIST Work Plan outlines the steps needed to establish recommended suites of standards to enable interoperability among the full range of Smart Grid devices. The Plan presented is aggressive, and assumes not only a sufficient budget for NIST but that the stakeholder community contribute to many of the tasks and produce several of the deliverables.

While the task of recommending standards may appear deceptively simple, it is ambitious and requires significant effort to ensure that the needed standards exist, are tailored to the industry they are meant to serve, and have sufficient vendor support to encourage a market of compatible products. Standards can only have impact if they are broadly adopted, and will enjoy broad adoption only if they represent a true consensus among the entire stakeholder community. To achieve their goals, standards must be accessible, easy to understand and implement, flexible to varying business models, maintained and adapted to changing needs, and cost effective to implement. For a suite of standards for something as complex as the power grid to be used in concert, they must be orchestrated to meet well-defined business use cases among the relevant business partners. In short, it requires the entire stakeholder community to define, recommend, develop, maintain, test and support the suite of standards that will be needed to provide a secure, robust and reliable infrastructure upon which to build tomorrow's energy grid.

NIST has begun to focus the Smart Grid community on a common framework for interoperability. As a non-regulatory agency, NIST is accustomed to serving as a neutral mediator to build consensus towards common standards. In the months following the EISA authorization, NIST has proactively taken steps to engage the community of stakeholders, and to develop a roadmap of activities towards the goal of achieving interoperability among Smart Grid devices. The following are key elements of the NIST Work Plan:

- **Engage the community of Smart Grid stakeholders** through public meetings and a network of working groups focused on the common goal of interoperability;
- **Prioritize business interoperability objectives**, develop or collect business use case scenarios relevant to the top-priority objectives, and define these scenarios in enough detail to enable their implementation with standardized, automated transactions;
- **Conduct a thorough assessment** of the current state of Smart Grid standards and infrastructure, identifying gaps and overlaps, and existing standards that can be used or adapted to meet Smart Grid specific interoperability requirements;

- **Partner with standards development organizations and consortia** to ensure that the highest priority Smart Grid standards and protocols are developed, maintained and coordinated;
- **Create a web-accessible "Interoperability Knowledge Base"** to provide users a customized snapshot of the Smart Grid interoperability infrastructure;
- **Create a living Roadmap** of the steps required to achieve Smart Grid interoperability, and recommendations for suites of standards that enable Smart Grid interoperability in the identified business scenarios.
- **Develop a conformance testing strategy** to ensure that the recommended standards are supported by test suites, services and pilots.

Engaging the Stakeholder Community

NIST has embarked on an ambitious effort to engage in the Smart Grid stakeholder community, and to coordinate work within that community to begin to build consensus towards a common framework for interoperability. To date, NIST has focused its outreach work in two areas: *communication and domain-level coordination*. NIST has advanced these objectives by organizing two public meetings—one in August focused on establishing domain expert working groups (DEWGs), and a workshop in November aimed at gathering input from a wider stakeholder base, including standards organizations, vendors and customers. The timeline for 2008 is shown below:

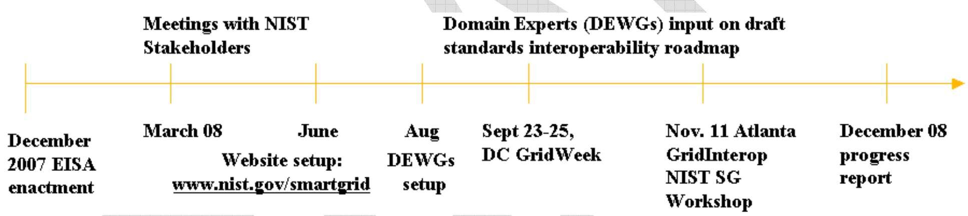

Figure 1 NIST Smart Grid project 2008 timeline.

Communication

NIST began meeting with the primary stakeholders called out in EISA, as well as several other interested parties, beginning in March 2008. The following are examples of specific communication outreach activities conducted to date:

- NIST serves on the Smart Grid Task Force, and NIST staff have held numerous individual meetings with various Task Force members and guiding stakeholders including: DOE, FERC, IEEE, NEMA, EPRI, and EEI.
- NIST has regular communications and coordinates closely with the GridWise Architecture Council (GWAC). The Council has contributed significantly to the NIST Smart Grid interoperability Work Plan, and Council members serve as co-chairs of the Domain Expert Working Groups described below.
- NIST staff have made several invited presentations at conferences and other public forums. Key talks were given at Gridweek in Washington, DC in September 2008, and at GridInterop in Atlanta in November 2008.

- NIST coordinated a workshop as a key element of the GridInterop conference in Atlanta. This facilitated public workshop allowed NIST to gather critical objectives and challenges from the Smart Grid stakeholder community to help NIST refine its plans for the Smart Grid Interoperability Framework.
- NIST has established a public website at http://www.nist.gov/smartgrid.

Domain-Level Coordination

Domain-level coordination activities have focused on forming and fostering the Domain Expert Working Groups (DEWGs), which currently serve as the main vehicle for harnessing the expertise of the many stakeholders in the Smart Grid community. The DEWG members are subject matter experts representing a range of stakeholders including utilities, vendors, academia, industry and trade organizations, standards groups, and federal agencies.

Organized roughly by Smart Grid domains, the current DEWGs are:

- Transmission & Distribution (T&D)
- Building to Grid (B2G)
- Industry to Grid (I2G)
- Home to Grid (H2G)
- Business & Policy (B&P)
- Cyber Security (CS)

The first four domain working groups align with those previously initiated at the 2007 GridInterop meeting to address the electric grid (T&D) and the interface to customer classes (B2G, I2G, H2G). The remaining two working groups have been formed in recent months to address cross-cutting issues related to business policy and the regulatory environment (B&P), and security concerns (CS). In order to thoroughly address other cross-cutting issues, such as Demand-Response, it may be necessary to further adjust or add to the structure of the working groups.

The DEWG objectives are to:

- Identify business objectives and guide use case development
- Develop interaction requirements
- Identify relevant standards (that feed into the Interoperability Knowledge Base)
- Help develop the NIST interoperability Roadmap
- Interact directly with standards organizations on implementing the Roadmap and harmonizing standards where needed

NIST has provided a number of collaboration tools to assist with DEWG operations. In addition to regular teleconferences and email distribution lists, the DEWGs share a TWiki website. The TWiki serves as a collaboration site for discussion, idea generation, work organization, and as an intermediate repository for documents in progress. A key element of the NIST Work Plan, contingent on funding, is the development of the Smart Grid Interoperability Knowledge Base, to be built with the input of domain experts and used as a resource for identifying standards gaps and overlaps.

Prioritizing Business Interoperability Objectives

In order to focus the community's resources where they can best advance interoperability, NIST tasked the DEWGs with identifying and prioritizing the business objectives that require Smart Grid functions. Over eighty business objectives and seventy-seven barriers to achieving them were identified and prioritized per domain during GridInterop, where NIST conducted five sessions in six parallel breakout groups. Although the final conference proceedings have not yet been published, highlights of the data collected is provided in Appendix 2. The prioritized business objectives will be used to select and develop business use cases, a process described below.

NIST Smart Grid Interoperability Assessment

Before one can set a course to move forward, one must establish their current location. NIST considers an assessment of the current state of Smart Grid interoperability a necessary and important step before laying out a roadmap. This process requires review of existing standards and technology as well as discussion with stakeholders to determine their current and planned activities in this area. This process is underway.

If fully funded, this Assessment will present a Smart Grid domain-level view of the existing and emerging standards and their relevance to the Smart Grid business applications. The Assessment will indicate which existing standards could be applied as is, which standards might be readily adapted to specific SmartGrid business needs, and where there are interoperability requirements for which no useful standards currently exist.

The use case development approach proposed for the Assessment provides a powerful tool to expose communications requirements among utilities, customers, market entities and other actors in the Smart Grid. The use case exposes who is communicating what specific information in what order with which requirements for security, timing and other properties of the interactions. Together this provides requirements for standards and protocols all the way from the basic connectivity layer (wired or wireless signal transmission, grouping signals into messages, e.g., Ethernet) up through the network interoperability layer (delivery of the message to the intended recipient, e.g., TCP/IP) to syntactic and semantic layers (the specific form and contents of the messages, e.g., IEC 61850), and beyond that to standards of practice for common business processes and even requirements for regulation and regulatory policy.

A visual picture of this "layer" concept can be seen in the figure below which presents a standards reference model developed by the GridWise Architecture Council. In this figure we can see a progression from technical layers at the bottom (that govern how messages are packaged and moved across networks) up to the middle informational layers where message content is defined and put into business context, and then to the higher organizational layers where business objectives and regulatory policy drive the lower layers.

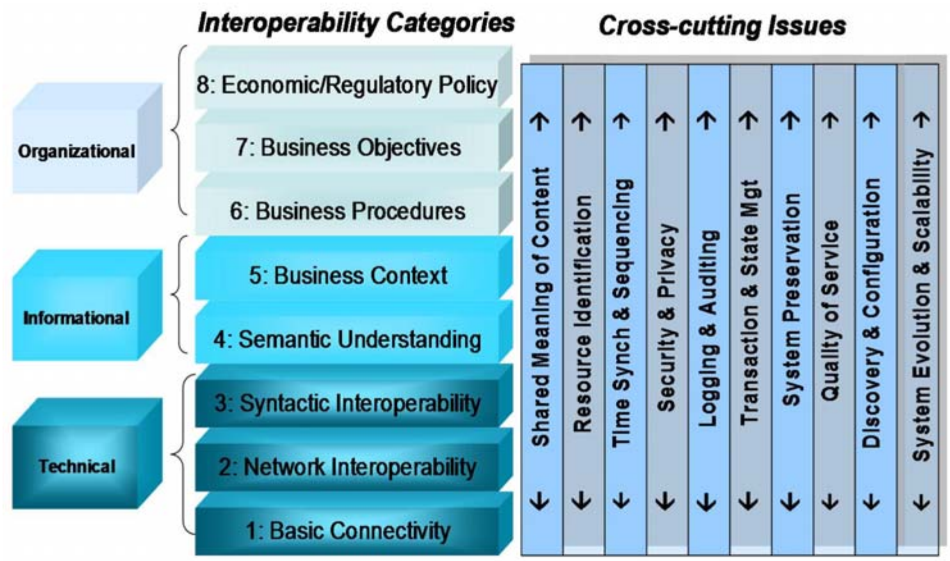

Figure 2 GridWise Architecture Council Standards Reference Model, Shown with Cross-Cutting Issues

It is in the context of the GridWise Reference Model that NIST sees the value of business objectives prioritization and use case development to guide technical standards development. That is, there are hundreds of standards that govern communications at different layers in the stack, but which ones are most important? Which ones best meet requirements? Use cases help establish the answers. This stack also helps explain why a single use case may require multiple standards (a suite of standards) to satisfy requirements—because different standards are focused at different layers of the stack. To be complete, the NIST Interoperability Assessment will need to examine standards for all of the layers relevant to each use case, and to develop a standards framework that covers the whole model.

The prioritized business objectives and interoperability barriers identified by the DEWGs at GridInterop 2008 represent an important contribution to this Assessment, and will be useful in distilling existing Smart Grid use cases and pinpointing standards requirements. NIST has also identified significant prior work that will aid the assessment task. Most notably, EPRI conducted a project in 2003-2004, the Integrated Energy and Communication Systems Architecture (IECSA) Project (now referred to as "Intelligrid"), to develop an open systems based industry-level architecture for advanced energy industry automation and consumer communications. In addition to identifying industry technical requirements in use case form, IECSA provides a large body of work that identifies standards and technologies to meet Smart Grid needs, although it is now several years old. In addition to the IECSA resource, some other work has been done that may be useful, including the GridWise Knowledge Base (available at: http://gwac.pnl.gov/cocoon/morf/gridwise). Contingent upon funding, relevant knowledge from these resources will be ported into a NIST Interoperability Knowledge Base.

Comment [ejb2]: When will this assessment be available? 2009? 2010? How much will it take in resources? In money?
What will it really cover? What "use cases" are being studied?
What are we doing that Intelligrid and GridWise aren't doing?
This is what the real reader wants to know. The rest is yet another architecture -- SOS.

Cyber Security

Of particular importance and specifically called out in the EISA authorization is the issue of cyber security. The NIST Assessment must identify specific risks and vulnerabilities to enable mitigation strategies to be implemented to ensure the secure operation of the Smart Grid.

NIST has identified three overall goals related to cyber security for Smart Grid interoperability:

- Make the North American electricity system less vulnerable to disruptions because of intentional, accidental, or natural (e.g., floods, hurricanes, earthquakes) acts against the system. The Smart Grid will enhance situational awareness for easier detection of deviations and decreased time to distinguish attacks/events and reduce outage propagation (self-healing characteristics).
- Restore the North American electricity system integrity subsequent to disruptions (i.e. event management). The Smart Grid will allow compartmentalization of disturbances, facilitate informed decision making and response, and enable faster response time responding to multiple events.
- Facilitate nationwide, interoperable emergency communications and control during local, regional, and national emergencies. The Smart Grid will permit better information sharing across systems and provide for rapid identification and response to significant events.

The limited cyber security controls currently implemented leaves the energy grid vulnerable, allowing an attacker to potentially:

- Alter and change load conditions to destabilize the grid in unpredictable ways; and/or
- Network into the overall architecture and attack one or more critical infrastructures.

With limited cyber security controls, even unintentional errors could result in destabilization of the grid.

In addition to risk assessments in the specific domain areas, there are several program-level risks that need to be examined:

- Increasing complexity that could introduce vulnerabilities and increase exposure to potential attackers;
- Linked networks can introduce common vulnerabilities;
- Increasing vulnerability to communication and software disruptions that could result in denial of service and/or software/system integrity compromise;
- Intelligence gathering tool for adversaries; and
- Potential for breach of customer privacy.

Each domain will have domain-specific vulnerabilities and risks and there will be vulnerabilities that are common to all the domains. The cyber security strategy must examine both domain-specific and common risks when developing the mitigation strategy to ensure interoperability of solutions across the domains. Following is a preliminary list of the cross-cutting security requirements that need to be considered for the Smart Grid:

- *Identification and authentication* to provide unambiguous reference to system entities.
- *Access control* to protect critical information.
- *Integrity* to ensure that the modification of data and/or commands is detected.

- *Confidentiality* to protect sensitive information, including personally identifiable information (PII) and business identifiable information (BII).
- *Availability* to ensure that intentional attacks, unintentional events, and natural disasters do not disrupt the entire Smart Grid or result in cascading effects.
- *Security architecture* to ensure that there is no single point of failure.
- *Certification* for Smart Grid devices (conformance testing) and certification criteria for the personnel and processes.
- *Strategies for isolating* and repairing compromised components of the Smart Grid.
- *Auditing* to monitor changes to the Smart Grid.
- *Supply chain* to ensure that products and services are not compromised at any point in the life cycle. (This is a defense-in-breadth strategy.)

NIST has assembled an initial list of about a dozen national and international security standards that may be relevant to the Smart Grid. These and others will be considered in the Assessment.

Assessment Status

A thorough assessment is an ambitious goal, given the number of potentially relevant standards and the fact that their level of development and adoption is a moving target. For optimum impact, an Assessment would need to cover the breadth of the Smart Grid domains and consider the full range of security vulnerabilities. NIST has taken some modest first steps towards an Assessment, but at the current level of funding, will be forced to focus on a few of the highest priority use cases, and may further restrict the focus to only select layers of the standards reference model.

Partnering with Standards Development Organizations

While NIST can be effective in identifying, prioritizing and recommending standards, and in calling attention to unmet standardization needs, the task of developing and maintaining standards requires a dedicated organization. This role could be played by one or more of the dozens of relevant Standards Development Organizations (SDOs), or may be assumed by an industry consortium that acts as a standards setting organization. It will be important for NIST and its collaborators to identify organizations willing to play the long-term role of shepherding specifications through the standardization process, in order to provide the stakeholder with standards they can rely on to meet their current needs and revisions that meet their changing needs over time. Since SDOs and consortia have different policies governing participation in the standards development process and the accessibility of published standards, establishing effective partnerships will require a thoughtful analysis.

NIST and the stakeholder community will also need to be engaged in the development of standards to fill identified gaps. Effective and robust standards require the participation of subject matter experts throughout the development process. With sufficient resources, NIST would contribute expertise to several Smart Grid standards committees to encourage the development of harmonized standards.

Standards Development Status

NIST has begun to engage standards development groups in the Smart Grid interoperability dialogue. Several such organizations participated in the GridInterop 2008 conference, including:

- The OPC Foundation, which creates and maintains open specifications for interoperability among production devices, control systems, and instrumentation.
- National Electrical Manufacturers Association (NEMA), an electronics manufacturing trade association which is an ANSI-accredited standards developer.
- Organization for the Advancement of Structured Information Standards (OASIS), a not-for-profit consortium that develops open standards for web services, security, and e-business.
- IEEE, a professional society with 38 societies and 7 technical councils which is also an ANSI-accredited standards developer.

As standards and gaps are identified, NIST will consider the priorities reflected in the business objectives and use cases, and the level of funding available, to determine where best to contribute. At current funding levels, NIST staff will selectively engage in those standards activities that have spill-over benefits to other NIST programs.

NIST Smart Grid Interoperability Knowledge Base

Working with the DoE, Smart Grid stakeholders, and other interested parties, NIST plans to create an Interoperability Knowledge Base (IKB) whose primary purpose will be to enable effective communication and collaboration within the large and diverse community of Smart Grid stakeholders. As a cornerstone of NIST's planned interoperability framework, the IKB will be the national clearinghouse for information supporting the development of a fully interoperable Smart Grid. Key to this database is interoperability requirements that draw from the large body of work already done by EPRI, electric utilities, vendors, consumer groups, and others. An important feature of the IKB is rigorous application of semantically consistent terms and definitions throughout the IKB to promote shared understanding and uniform use of semantics within the Smart Grid community.

NIST and its collaborators are now determining the appropriate scope and taxonomy for the IKB's content. It is expected that the IKB will encompass the following types of information relevant to grid interoperability:

- Entities (people, organizations, systems, devices...)
- Technologies (standards, protocols, processes, practices...)
- Applications and their respective domains (industrial, commercial, residential, transportation…)
- Interactions and their respective requirements
  - intra-domain / inter-domain
  - intra-application / inter-application
- Information objects (measurements, events, commands, settings, requests, prices, commitments, identification, authorizations...)
- Policies & regulations (security, privacy, financial, environmental, safety, reliability…)
- Smart Grid and related interoperability development activities

- The relationships between all of the above

Initially, NIST plans to identify, import, and normalize existing sets of relevant information from a variety of sources including industry consortia (EPRI, GridWise Architecture Council, EEI, …) and standards development organizations (IEC, IEEE, NEMA, OASIS, …). User interfaces that will enable the large community of industry experts to efficiently contribute and edit IKB information content will be implemented. It is expected that a suite of online forms and UML (Unified Modeling Language) modeling tools would be incorporated that will support text-based information entry and file imports. It is envisioned that the modeling tools will give contributing experts a standard way to visually portray all of the technical details needed to fully characterize any type of Smart Grid process and its associated interaction(s). Both the forms and the modeling tools are intended to guide contributors toward the use of common methods and semantics. .

NIST also plans to develop interfaces for IKB users to explore, interpret, and acquire Knowledge Base content by providing a graphical visualization tool. Users seeking a detailed technical understanding of Smart Grid processes and/or interactions would be supported by one or more tools that enable them to fully access, view, and download any UML model data. IKB users will also be provided with form-based interfaces for running queries and reports against the data in the IKB. When fully implemented, NIST foresees using the IKB and its user interfaces as key resources for developing, retaining, and presenting the evolving interoperability landscape and the recommended roadmap for achieving greater interoperability. A diagram portraying the IKB is shown below.

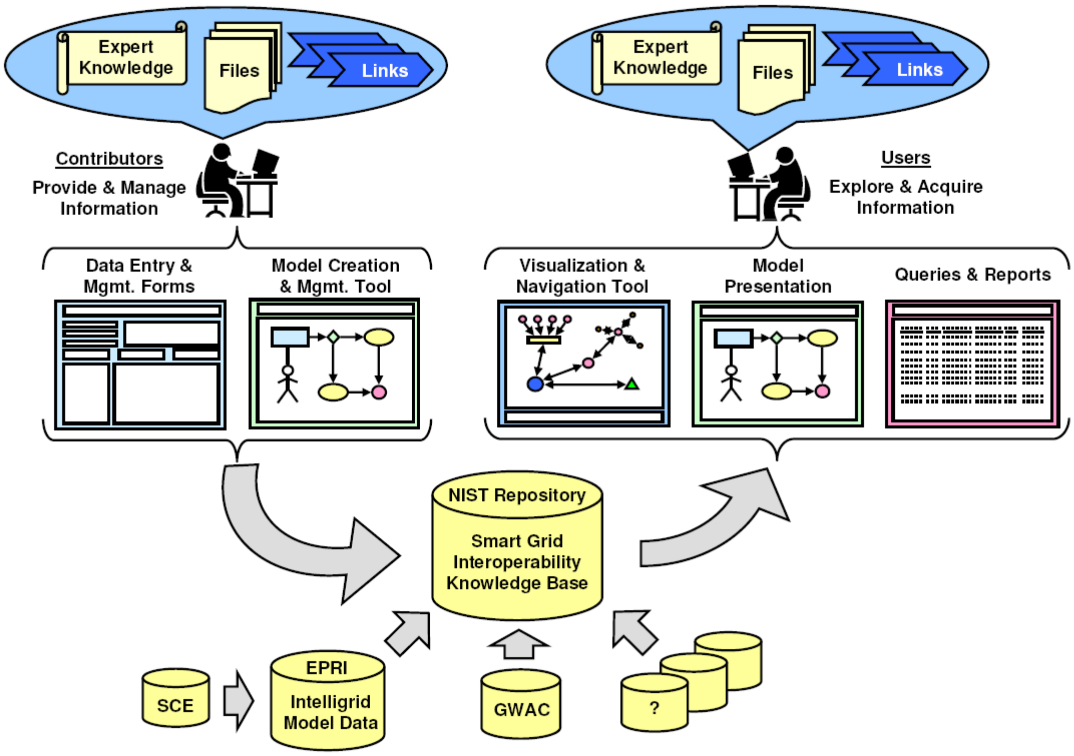

Figure 3 NIST Smart Grid Interoperability Knowledge Base

Interoperability Knowledge Base Status

The Knowledge Base is one of the key deliverables of the NIST Smart Grid effort, providing a web-based information portal for the entire stakeholder community. At current funding levels, NIST will be able to plan but neither implement nor maintain a Knowledge Base.

Smart Grid Interoperability Roadmap

The Interoperability Roadmap will capture the decisions made throughout the Interoperability Framework process, and will plot a recommended course towards a highly interoperable grid. In the context of the prioritized business objectives and use cases, the Roadmap will recommend standards, practices and policies to foster automated negotiation and plug-and-play interoperability of Smart Grid devices. The Roadmap will identify barriers to interoperability and will recommend and prioritize strategies for addressing them. The Roadmap will place these recommendations along a suggested timeline.

The Roadmap, if fully implemented, will include a cross-cutting cyber security strategy so that security can be designed into the Smart Grid rather than retrofitted afterwards. To balance the need for security with resources and cost, policy guidance will be required concerning the level of risk that the Smart Grid will be expected to assume. The strategy will include a phased implementation approach, and will include recommended standards for the various levels of the grid: the domains, components, and the overall network.

Interoperability Roadmap Status

Since the Interoperability Roadmap reflects conclusions drawn from all of the NIST Smart Grid activities, a Roadmap reflective of the level of effort will be produced at current funding levels. The scope and depth of the Roadmap will depend upon the level of funding appropriated, and the extent of the NIST Work Plan it supports.

Develop a Conformance and Interoperability Testing Strategy

Conformance and interoperability testing provide consumer confidence in vendor claims of compatibility, and provide vendors confidence in the standards they need to support. Conformance testing allows a vendor to be sure that their product complies with a given standard and works in an interoperable manner during the development process. Equally important are interoperability pilots and testbeds that demonstrate whether multi-vendor solutions can plug and play in a production-like environment. An interoperability testbed would allow vendors to perfect their standard implementations in a neutral environment.

Conformance and Interoperability Testing Status

A rigorous conformance test program would require a multi-year dedicated effort, and would be a significant undertaking, especially in light of the number of standards needed for Smart Grid interoperability. Research into planning a testing strategy could be initiated within the coming year, but any implementation would be contingent upon the selection of recommended standards. NIST does not typically implement testing programs, but could facilitate and help plan the establishment of such programs for key Smart Grid standards.

Conclusions and Next Steps

NIST has initiated a Smart Grid interoperability program that, if resourced for success, will yield tremendous benefits. Since beginning the work in January, 2008 in response to the EISA 2007 mandate, NIST has been meeting with industry stakeholders to gather input on how best to coordinate an interoperability framework for the emerging Smart Grid, which will identify standards, gaps, and overlaps. It is clear that the scope of the NIST Interoperability Framework is daunting, covering the entire electricity network from generation through the power grid–the "most sophisticated machine" ever built.

By establishing the DEWGs, NIST has created a foundation to support identification and prioritization of key business objectives, and to identify the use cases that support these key objectives. Many use cases for the Smart Grid have been developed already by EPRI in the IECSA ("Intelligrid") work and by utilities. The use cases describe the communication requirements to support those objectives, and the requirements, in turn, help to identify the necessary standards. Other groups have separately determined requirements for Smart Grid devices and systems, such as for Home Area Networks (HANs)[4]. Once the key requirements are

[4] Utility AMI Home Area Network System Requirements Specifications

established, with the input of the DEWGs, an interoperability assessment can be performed. The degree to which existing standards support the key requirements can be assessed, and gaps and overlaps identified. With the assessment performed, NIST can then seek consensus of the stakeholders and make recommendations that specify suites/profiles of standards that enable interoperable communications between the systems engaged in each of the business processes identified.

To perform a comprehensive assessment of the requirements, standards, and protocols will take considerable resources and time. The implementation of the Smart Grid in pilot programs has already begun and is progressing rapidly. Smart Grid devices and systems deployed throughout the North American power grid are almost *guaranteed not to be interoperable* without the appropriate standards in place. To accelerate the framework development for the most important applications, the DEWGs will focus on the use cases, requirements, and standards for the top priority business objectives in the near term. NIST will use the existing body of use cases from the IECSA work and other sources. Cybersecurity requirements will also be included to ensure that the requirements are met up front, and not added later. NIST will begin by addressing the standards that enable semantic and syntactic interoperability in these cases. Existing standards will be assessed first for their applicability, and recommendations will be made as appropriate.

If fully funded, NIST and the DEWGs will work to complete the Smart Grid Interoperability Assessment of key applications in the next year, and that will serve as the starting point for the Smart Grid Interoperability Roadmap. The Roadmap will identify the path forward to interoperability, suites of recommended standards, and the relevant standards bodies that need to be engaged. NIST would work with the relevant standards bodies to develop, extend and harmonize the standards as indicated by the Assessment and the Roadmap. NIST will target the end of 2009 for a subsequent progress report and appropriate recommendations.

In parallel and with funding available, NIST will continue the longer-range goal of the development of the interoperability knowledge base as a national clearinghouse for Smart Grid interoperability information and in particularly, as a repository for Smart Grid use cases. NIST will incorporate the existing body of use cases and other information as available, but will rigorously apply a set of semantically consistent terms and definitions. The IKB is intended to enable effective communication and collaboration within the large community of Smart Grid stakeholders.

With the initial assessment and interoperability roadmap completed, the most pressing Smart Grid interoperability standards issues will be addressed, and critical standards will be in place. Smart Grid deployments can be made with fairly good assurance of interoperability. In the longer run, the assessment, roadmap, and IKB will be expanded to include the entire Smart Grid and will evolve with it.

Appendix 1 – Domain Expert Working Group Membership

Advanced Control Systems/Efacec
AHAM/Whirlpool
AHAM/Invensys
AKUACOM
American Electric Power
AOL
APC
Argonne National Laboratory
Bucciero Consulting, LLC
California ISO

CCET
Cimetrics
Cisco Systems
Citizens Utility Board
Clasma Events
Climetrics
Comverge
Constellation
Cornice Engineering
Cox Software Architects
CSIRO Energy Technology
Dayton Power and Light
Drummond Group
Edison Electric Institute
Endeavor Engineering
Energetics Incorporated
Energy Central
Energy Control
Enernex
EnerVision Incorporated
Entergy Corporation
EPRI
Factory IQ
Florida Power and Light
GE Appliances
Georgia Power
Gridlogix
Gridpoint, Inc.
GSA
GWAC/Gridplex
GWAC/IBM
Hypertek
Idaho National Laboratory
Invensys Controls
ISO NE
ITRON
JL Cub
Kansas City Power and Light
Landis+Gyr
Lawrence Berkeley National Laboratory
Litos Ad
Lockheed Martin
Lonmark International
NEMA
NIST
NovusEdge
NRECA
Oak Ridge National Laboratory
OATI
oBix Server Project
OI Ventures
Oncor Electric Delivery
OPC Foundation
OSIsoft
PG&E
PJM
Plexus Research
Pacific Northwest National Laboratory
Quanta Technologies
Reliant Energy
RLtec
SAP
SCE
Sempra Energy
Siemens
Software Engineering Institute - CMU
South California Edison
Southern California Edison
Southern Company
Spirae
Tendril
Tennessee Valley Authority
The Structure Group
Tridium
Tucker Engineering
TVA
UISOL
University of North Carolina
US EPA
Utilimetrics

Utilities Telecom Council
Utility Integration Solutions
Verizon
Wattstopper
WilliamsPyro
Xanthus
Zigbee

Appendix 2 – Prioritized Business Objectives and Barriers Gathered at GridInterop 2008 (Atlanta, November 11-13)

Home to Grid – Key Barriers to Interoperability by Business Objective

Interoperable and open communication from utility to home devices

- Need to standardize HAN protocols/device interfaces
- Critical Barrier – Most responsive devices cannot be manufactured for dissimilar regional DR programs. (Appliances are made for all U.S. or world)
- Too many proprietary solutions being implemented without regard to interoperability

Retail Distribution model with Plug and Play interoperability for H2G

- Converge various standards to provide simple integration and certification
- Ease of use (plug-in, reconfigure, forget, add value)
- Consumer does not have a value-proposition today

Interface of utility communications platform to HAN to storage or EV metering

- Roaming utilities are large, costly; Robust infrastructure is needed to support (e.g., DBs) Barrier: utilities will have challenge of sharing data as all phone providers manage their "mins" for billing
- On-board metering: EV manufacturers do not want to embed meters on vehicles

Information, diesaggregation, and controls that modify residential energy use, provide demand response, conservation, and grid stability

- Consumer education and acceptance
- Standard message set
- Timely delivery of useful information for H2G

Integrated common interoperable systems strategy for HAN across the U.S. and internationally

- Lack of awareness of NIST as a nationally-endorsed clearinghouse, lack of leveraging existing utility-led standards efforts
- Policy issues: complexity of rates makes value proposition difficult to understand and quantify for vendors and consumers

Well-understood consumer experiences as they relate to smart appliances, which are coordinated with DG-DR-RTP

- Barrier: cost of equipment to respond to energy management
- Barrier: consumer ignorance and utility obfuscation
- Barrier: Utility parameters are complex (kWh – Therms); Need simple to understand metrics
- Barrier: ease of use impact on daily activities

Building to Grid – Key Barriers to Interoperability by Business Objective

Automated DR

- Lack of standards for services and data models and lack of standards for moving information
- No standards for DR program design nationwide, and uneven distribution of DR programs.
- Inconsistent regulatory structure state to state.
- Lack of building control infrastructure and standard DR strategies to enable automated DR.

Dynamic Pricing

- There are a variety of uncoordinated programs that pass price information. Organizations have created their own price formats without knowledge of other organizations' work.
- There has been no national body to bring these efforts together to achieve consensus of requirements and best approach.
- The implications of "real-time pricing" are not well understood by customers, and the term is not well-defined. There is fear of paying higher prices on peak. Benefits need to balance and be communicated.

Distributed Generation (DG)

- Currently, because of complexity of building systems and because of differences in utility programs, each DG installation requires custom implementation.
- The mixed regulatory environment inserts arguably un-needed barriers to innovation.

Facility Management (internal to building)

- Proprietary approach of building control system vendors—many existing buildings do not implement BACnet, or only some control sub-systems use BACnet communications. This requires integration efforts to tie systems together for effective energy management.
- Construction industry is not structured to achieve integration (e.g., multiple sub-contractors, no unified planning for energy management)

Industry to Grid – Key Barriers to Interoperability by Business Objective

Transform the relationship between customer and utility into one of collaboration.

- Education of both customer and utilities to understand each other's needs
- Need real-time meter data for utilities and customer
- Customers are often not motivated to conserve energy
- Rate structures can be too complicated
- Conflicting objectives between utilities and customers related to current pricing structure

Bi-directional communication of dynamic pricing information.

- Lack of an economic business model
- Needs to be enabled through regulatory policy
- Lack of interoperability for pricing transactions

Market for industrial distributed energy sources including sustainable and renewable generation, energy storage and CHP (Combined Heat and Power)

- Capital investment needed by utilities and customers
- Need standards for interfacing remote generators to the grid
- Both utilities and industry perceive increased risk due to sharing an important resource that has requirements for security and reliability
- Not a common operational model for utilities or industry

Maintain a high level of electrical power reliability and quality

- Reduced utility feeder and substation reliability based on aging substation equipment with high operational costs
- Aging equipment at point of interconnection
- Need feedback from industrial customers.
- Lack of automation results in manual operation and potential security problems

Demand Response in regulated and unregulated markets for reduced cost to industrial customer

- Lack of customer access to demand response events and pricing information
- Lack of demand response communication standards
- Lack of customer access to metering data

Transmission and Distribution – Key Barriers to Interoperability by Business Objective

Improved Grid Reliability
- Lack of adequate sensors/controls to identify/correct grid problems
- lack of knowledge of transimission line ground clearances
- lack redundancy at control center for grid monitoring; need system engineering approach
- need better real time feedback about grid condition

Demand Response
- lack cooperation between stakeholders
- lack standards/tools for measurement and validation of DR events

Grid Automation and Control
- Application isolation
- Lack of adequate data standards
- Multiple vendor control systems that each have their own syntax in doing automation and control
- Lack of accepted value proposition

Communication
- Lack of application level standards
- Multiple protocols—protocols non-interoperable
- Lack of a common standard to acquire/process RT field data
- CI not defined or used by DA
- Lack of real time communication between systems

Renewables Integration
- Coordination command and control
- Limited flexibility of current grid architecture
- Knowing capacity of existing transmission assets
- Lack of operational experience
- No accepted standard for communicating needed information
- Distribution system design can limit application of DG to grid
- Lack of real time power flow information

Better Asset Utilization
- Market inefficiencies
- Improved available data on asset status in real time
- Capability of the existing equipment