

January 9, 2013 Presentation to INCOSE

Identifying Architectural Modularity in the Smart Grid

An Application of the Design Structure Matrix Methodology Architecture Track – Innovative Architectural Models Session

> Brad Rogers (Session Chair) & Erik Gilbert Navigant Consulting www.navigant.com

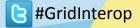
> > VIGANT





Simple Answer:

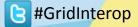
An **umbrella term** for the enhancement of the traditional electricity infrastructure that uses computer technology and **two-way digital communications** networking to improve and expand the capabilities of the grid.





Smart grid promises to transform the electric industry yielding many benefits, such as:

- A more stable and reliable electric supply
- Increased utilization of the immense investment in our electric infrastructure
- Increased capability to integrate **renewable** resources
- More **customer choice** and improved cost structures





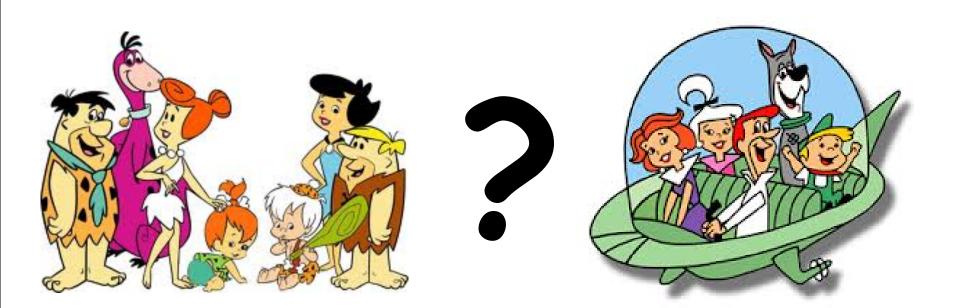
- But smart grid is currently a vision that can only be realized if the diverse elements of the grid can work together as a system.
- Interoperability is the lynchpin of smart grid success.

Interoperability refers to the ability of diverse systems and organizations to work together (inter-operate). In the context of the electric system, interoperability refers to the seamless, end-to-end connectivity of hardware and software from end-use devices through the T&D system to the power source, enhancing the coordination of energy flows with real-time information and analysis.

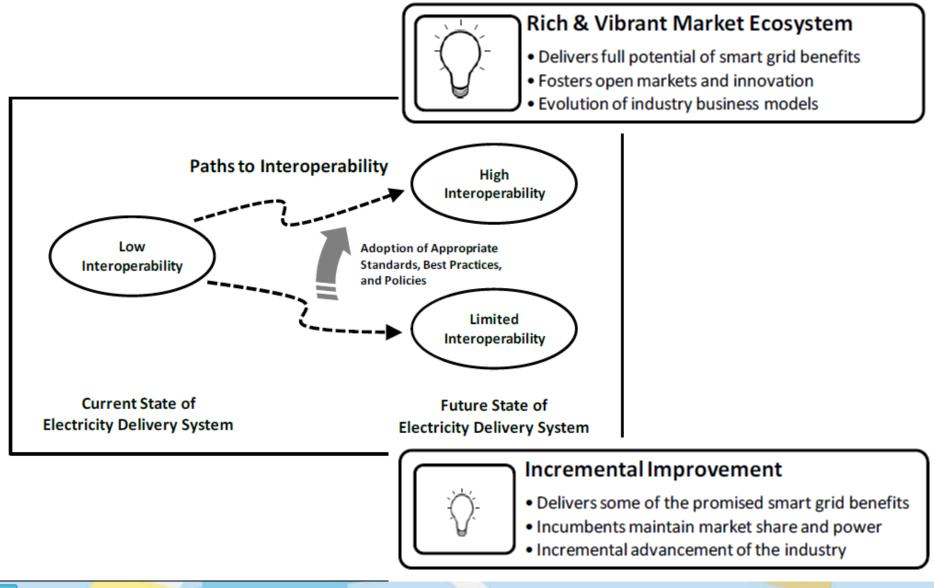




US 'smart' grid more Flintstones than Jetsons - Smart Grid Today Headline (8/8/2011)

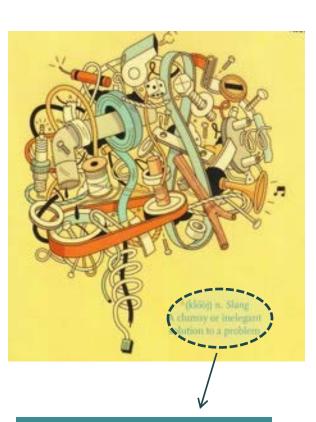


Grid-Interop Realizing the vision requires interoperability.



😫 #GridInterop

Grid-Interop The grid has an 'Accidental Architecture'

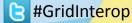


*(*klooj*) *n. Slang* A clumsy or inelegant solution An *accidental architecture*¹ is the organization of a system resulting from numerous **point-to-point** integrations between various applications to achieve **near-term** objectives.

Point-to-point integrations are **not scalable** and often create unintended *ripple effects* on downstream applications.

The result is a unique and customized system that becomes increasingly difficult to maintain and update.

1. Giroti, Tony. "Integration Roadmap for Smart Grid: From Accidental Architecture to Smart Grid Architecture." 2009.



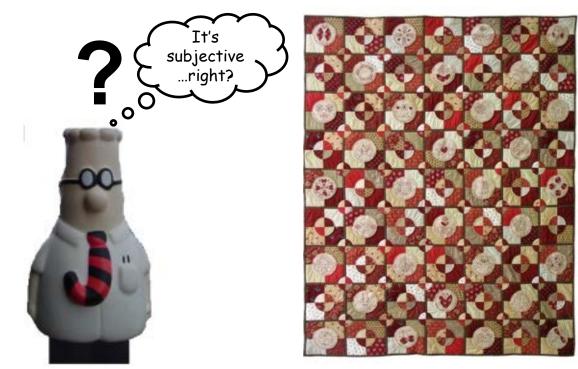


What's Architecture?

If the grid is a patchwork quilt, which quilt do we want?



Fiberfantasies.wordpress.com

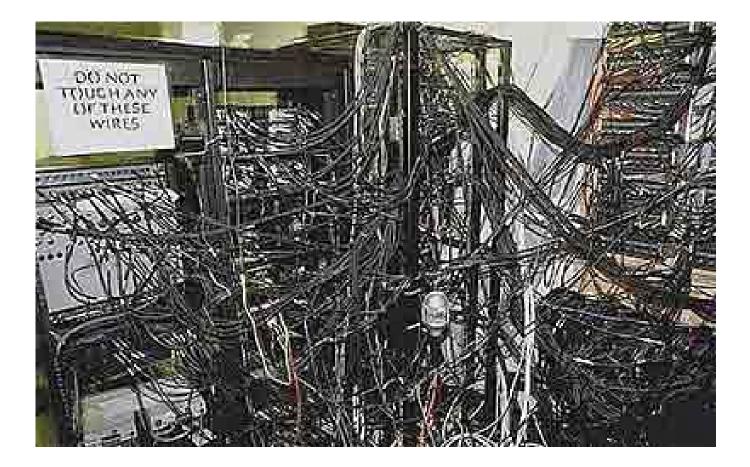


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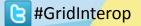


Why do we need architecture?

Well architected systems integrate easily, evolve flexibly, and operate simply and reliably.¹

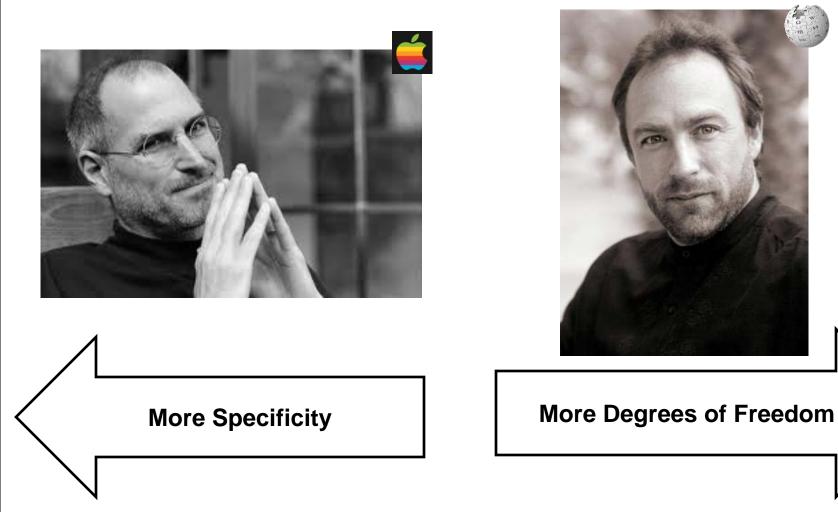


1. Massachusetts Institute of Technology © Ed Crawley 2007



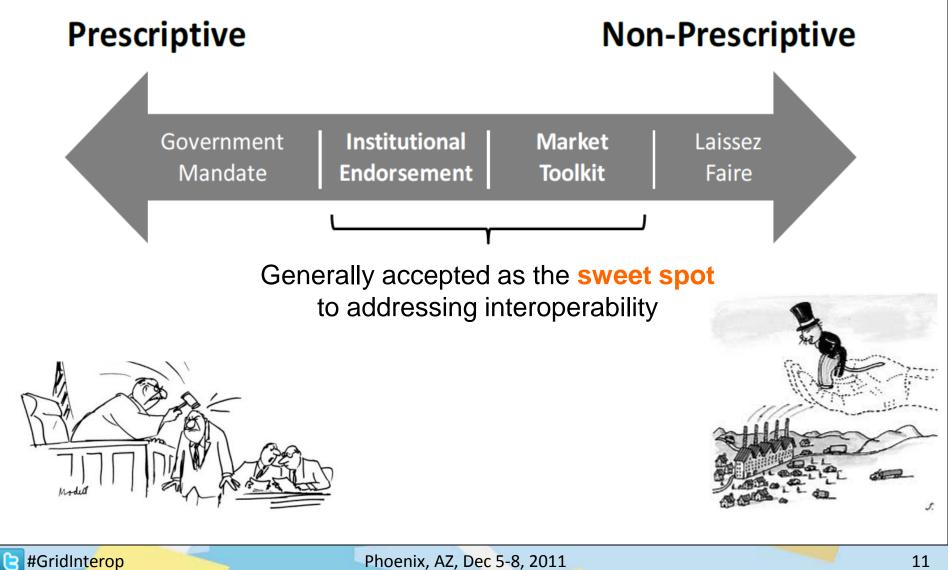


How to approach architecture?





How do we get interoperability?





In the Energy Independence and Security Act of 2007 (EISA), the U.S. Congress established the development of a "smart" electric power grid as a national policy goal.



Essential components of the Smart Grid, as conceived in the EISA legislation, include:

- standards
- an information architecture
- a cyber-security strategy
- a framework for testing and certification

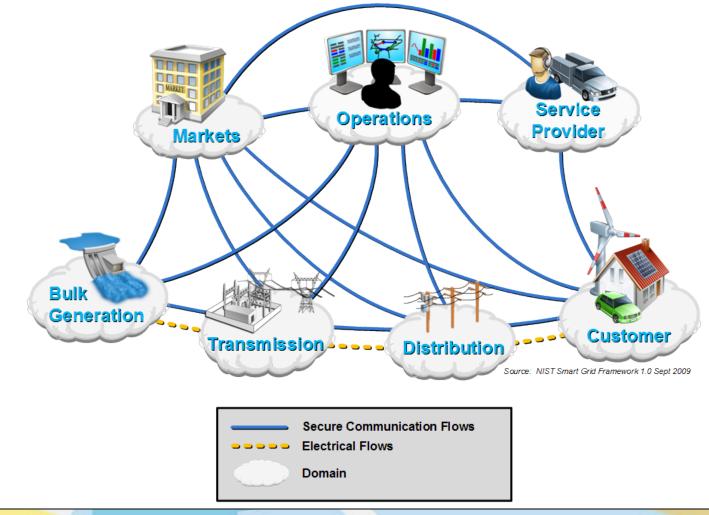
Initiated by the National Institute of Standards and Technology (NIST), the Smart Grid Interoperability Panel (SGIP) plays a leadership role in facilitating and developing these components and in realizing the national policy for the transformation of the power system to the Smart Grid. National Institute of Standards and Technology U.S. Department of Commerce





SGIP created the Conceptual Model

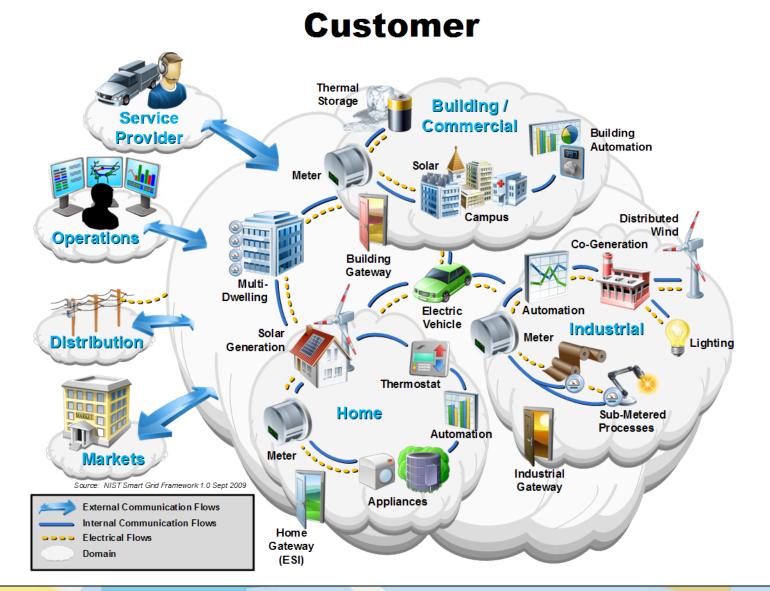
Conceptual Model





🔁 #GridInterop

...and added some detail.

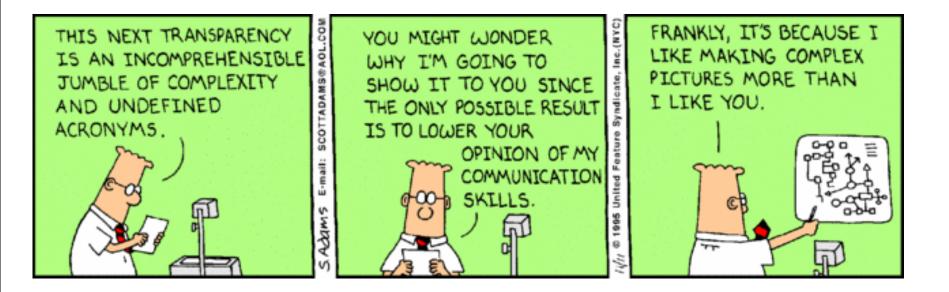


Phoenix, AZ, Dec 5-8, 2011

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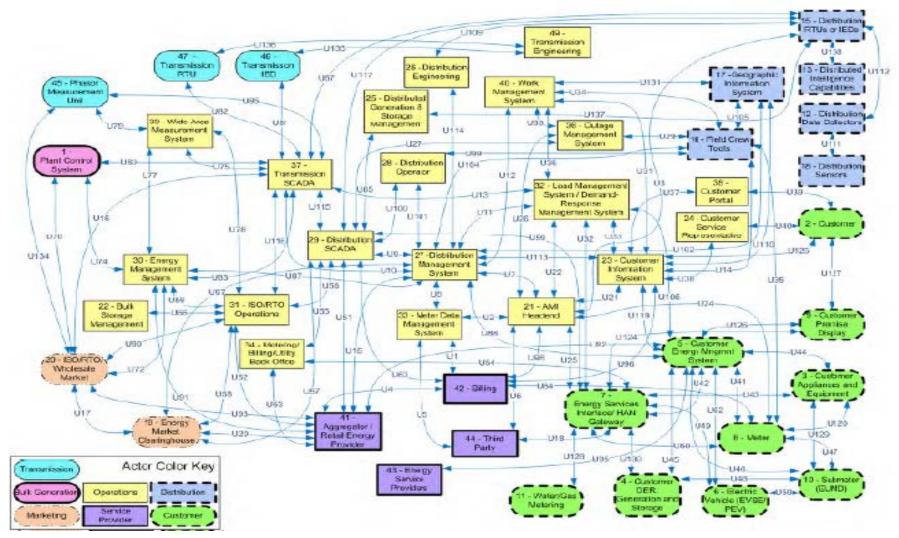


A Brief Moment of Zen.





NISTIR Logical Reference Model¹



1. NISTIR 7628. "Guidelines for Smart Grid Cyber Security." v1.0, Volume 1, p. 17. Aug 2010.



What is modularity?

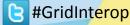
Lego Einstein



Modularity is a general systems concept, typically defined as a continuum describing the degree to which a system's components may be separated and recombined.¹ It refers to both the tightness of **coupling** between components, and the degree to which the "rules" of the system architecture enable the **mixing and matching** of components.

- Wikipedia article on modularity 12/5/2011

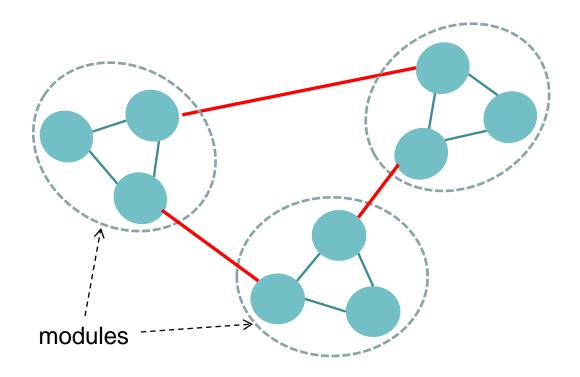
1. Schilling, M.A. 2000. Towards a general modular systems theory and its application to inter-firm product modularity. Academy of Management Review, Vol 25:312–334.





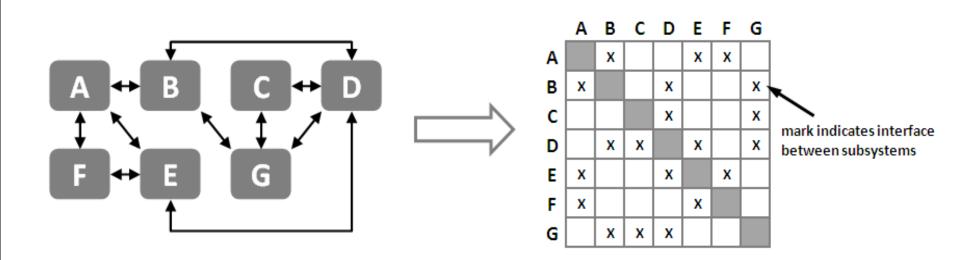
What is modularity?

Modularity in systems architecture is the degree to which elements of a system can be **grouped** with minimal dependency across groups.





What is Design Structure Matrix?

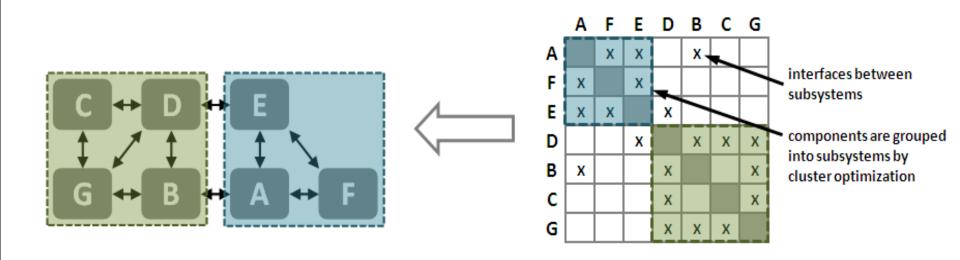


The **design structure matrix** (DSM) is a modeling tool that represents the relationships and dependencies between components of a system, product, or process. The DSM captures **coupling and dependency** relationships between the components of a system in a graphical matrix.

¹ Steward, Donald V., "Systems Analysis and Management: Structure, Strategy and Design," Petrocelli Books, Princeton, NJ, 1981.



Clustering is a process applied to a DSM by which elements of a system are arranged and grouped in order to **minimize interdependency** across groups.

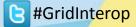




"Technical skill is mastery of complexity, while creativity is mastery of simplicity."

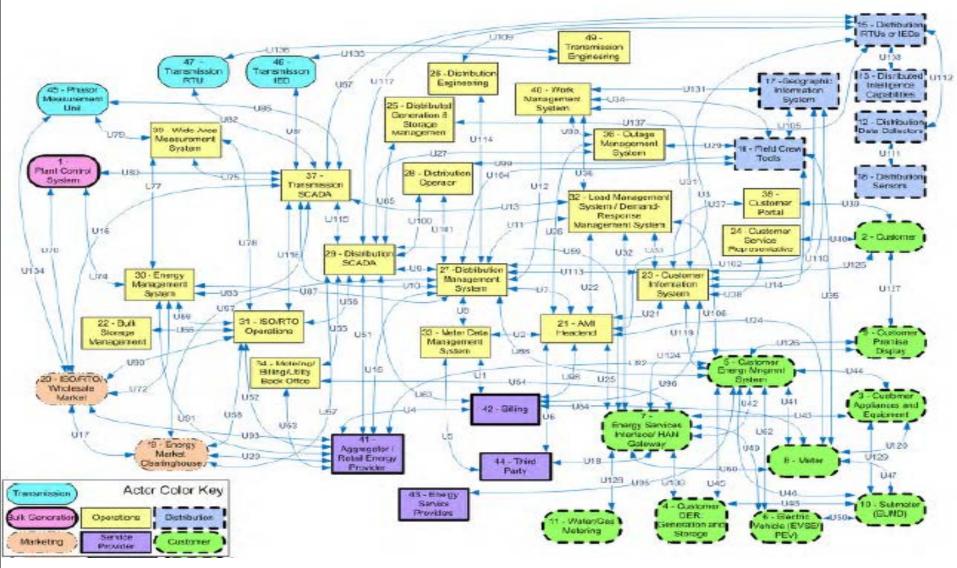
- Sir Erik Christopher Zeeman, Mathematician





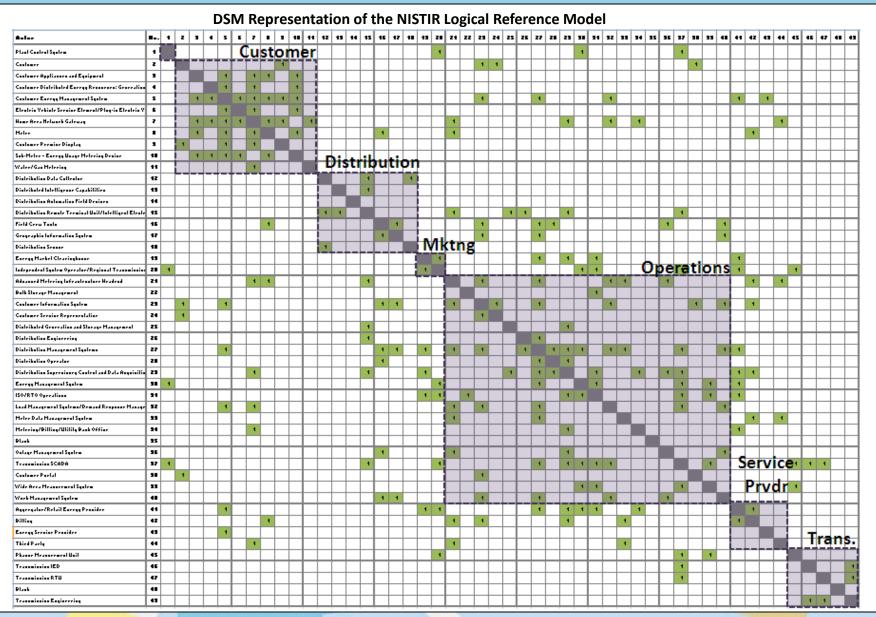


Let's take the NISTIR Logical Reference Model



1. NISTIR 7628. "Guidelines for Smart Grid Cyber Security." v1.0, Volume 1, p. 17. Aug 2010.

Grid-Interop Translate dependencies into a DSM matrix



🕒 #GridInterop

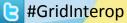


How to find modularity?

Clustering can be more an art than a science.

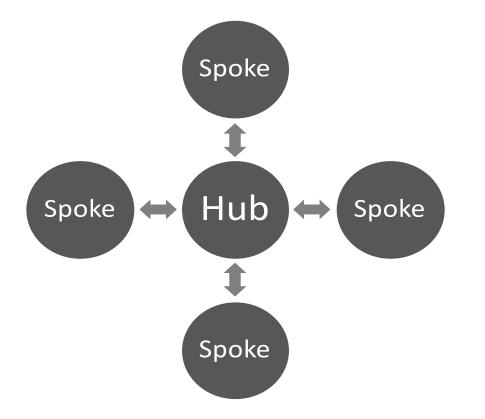
A clustering algorithm can give a good starting point, but "manual" organization is typically needed.

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Clustering complex systems frequently results in a Hub & Spoke configuration



Identifying the appropriate hub elements allows for the creation of **modular spokes**.

Without indentifying and grouping the most central, cross-cutting elements...high levels of dependency would exist across the spokes, and little modularization can be achieved.



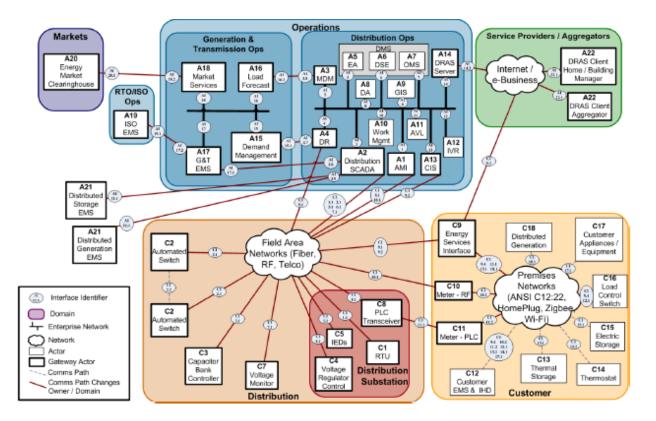
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Grid-Interop DSM can be applied for specific implementations.

This is the planned architecture for a federally funded smart grid demonstration project.

NRECA's Demonstration Architecture: Physical and Logical Architecture for Enterprise Application Integration¹



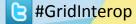
1. "Interoperability and Cyber Security Plan, NRECA CRN Smart Grid Regional Demonstration." May 2010.

Grid-Interop DSM can be applied for specific implementations.

High densities of dependencies and of whitespace generally indicate a more modular organization.

DSM Representation of NRECA's Demonstration Architecture

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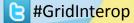




But you never know what might emerge...such as two independent hubs in this case.

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Or a daisy chain of dependency in an alternate configuration.

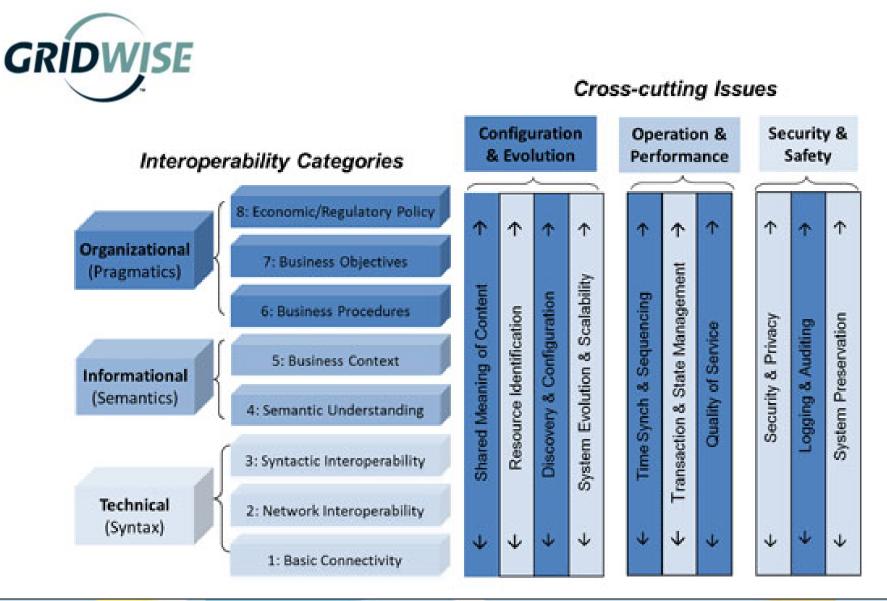
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- Modularization can help combat accidental architectures by isolating groups of dependency allowing them to be treated as an independent sub-system. Modular systems can evolve more elegantly because modular organization is more easily respected.
- Hubs identify the most cross-cutting elements of a system.
 Prioritizing these elements and acknowledging their centricity will reduce the complexity of the system.
- DSM is a useful approach to visualizing and structuring complex systems, such as those in a smart grid.





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B

If you work with complex systems, products, processes, or other giant hairballs... ...this is a MUST READ!

Design Structure Matrix Methods and **Applications** Steven D. Eppinger and Tyson R. Browning

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For more DSM resources, see: **DSMweb.org**

For DSM training, see: **executive.mit.edu** Managing Complex Product Development Projects

