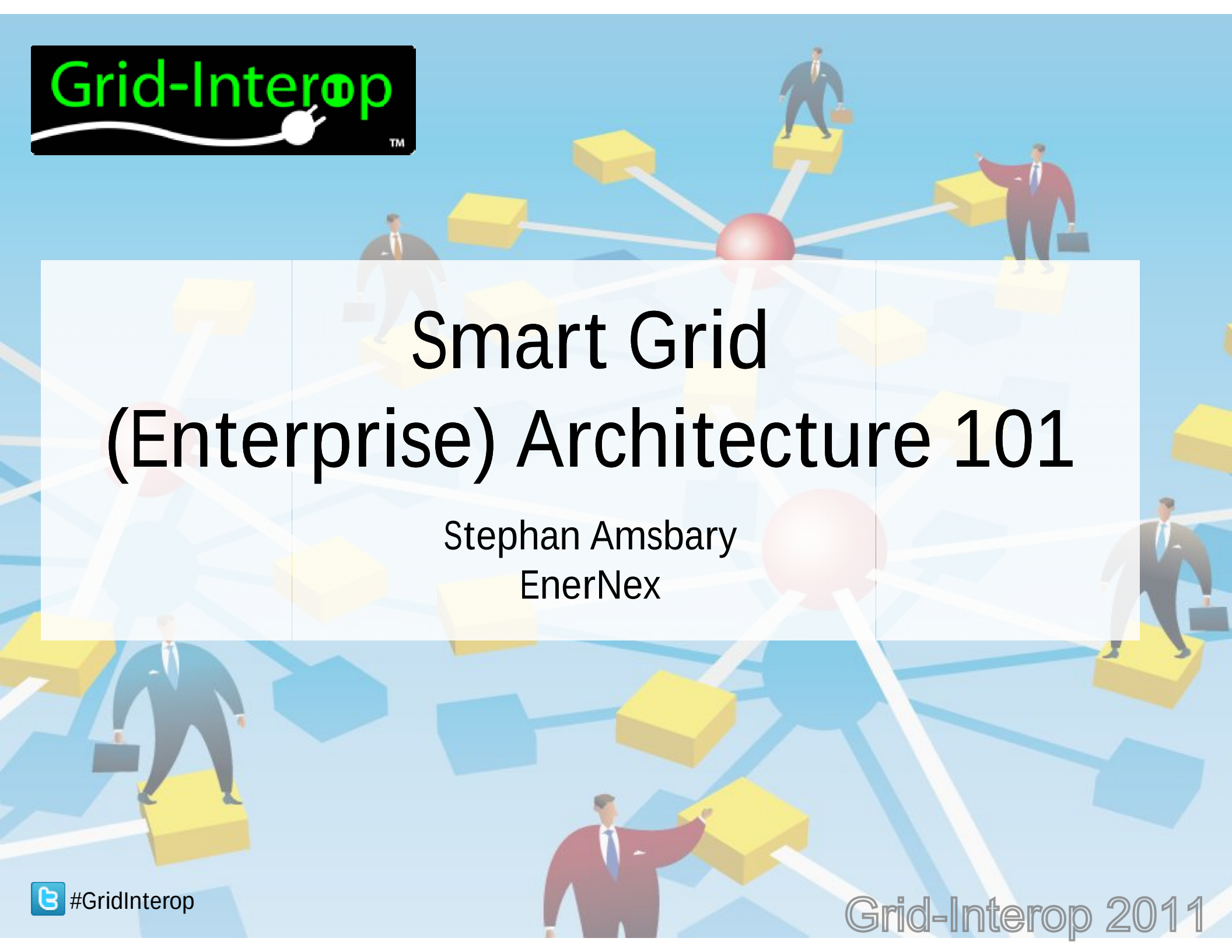


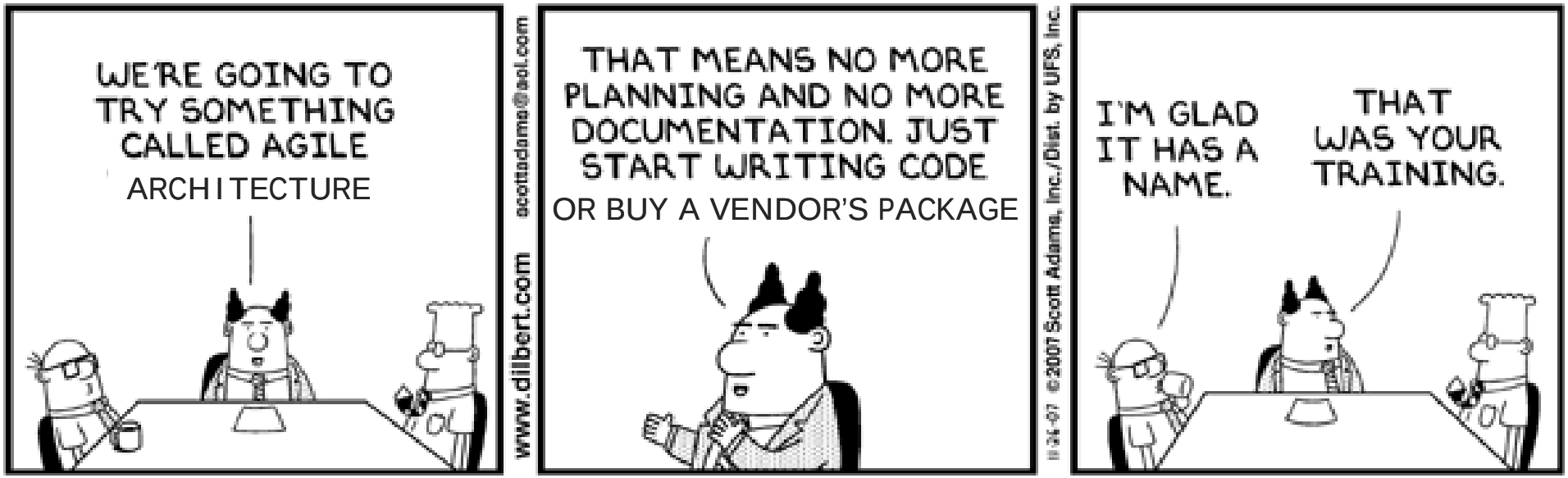
Smart Grid (Enterprise) Architecture 101

Stephan Amsbary
EnerNex

Agenda

- Architecture Overview
- SGAC Conceptual Architecture
- Semantics / Vocabulary
- Maturity Models
- Summary/Resources

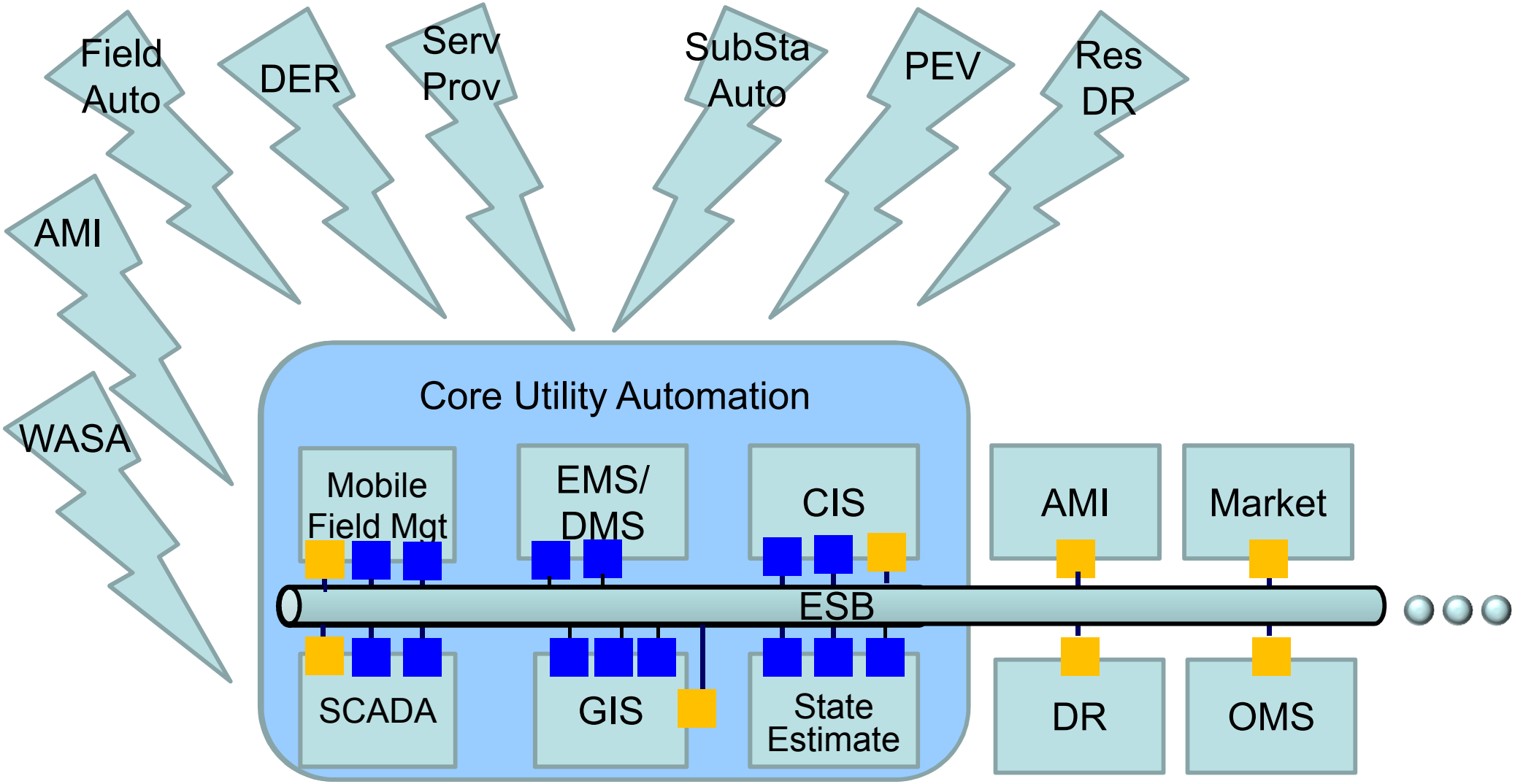
Architecture as usually practiced



(Apologies to Mr Adams and my fellow architects)

There is never enough time (or money) to do it right the first time
There is always enough time and money to fix it over and over again
-Anonymous

Siloed Implementation Approach



What is Architecture?

IEC 42010-2007: The formal organization of a system embodied in its components, their relationship to each other and the environment and the principles governing it's design and evolution

LEFT BRAIN – **Architectural process is a phased approach**. It documents with every increasing levels of granularity and specificity, the requirements, relationships, services and sequence necessary to realize those goals

RIGHT BRAIN – **Architectural art is intuition tempered by experience**; it usually takes practice to master. Artistry is needed to define the appropriate levels of component ontological abstraction for each phase

BOTH SIDES – **Enterprise Architecture** is the process of translating business vision and strategy into effective organizational change.

Why We Need Architecture

Logical – but … ?

Yes, it's a Kitchen/ Bathroom

First in first out/ Priority of the day

OR

Input

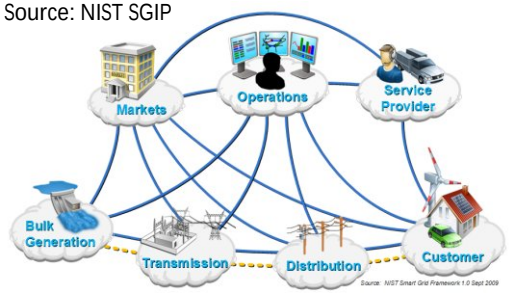
Architectural Process

Output

Different types of Architecture

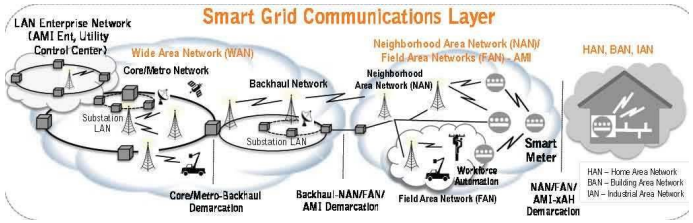
Conceptual – General landscape

Source: NIST SGIP



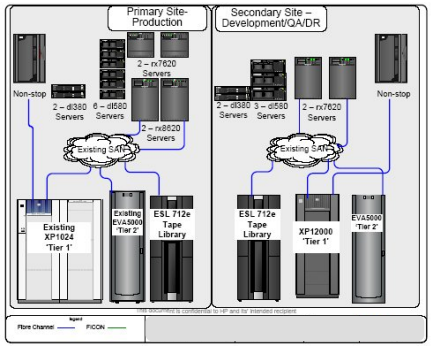
Network

Source: SIU



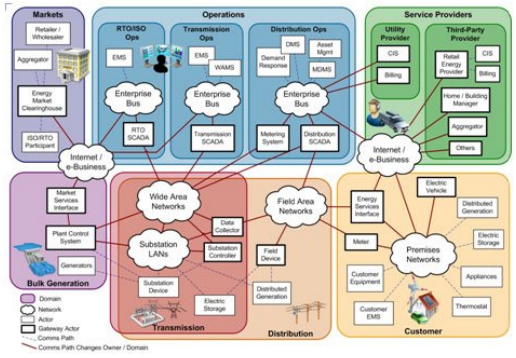
Physical – systems/solution inventory

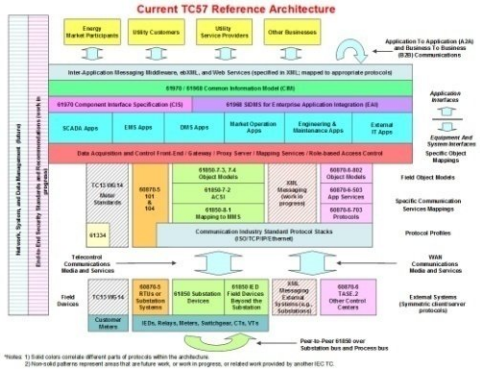
Source: Amsbary - client utility



Reference – Component (functions) make up

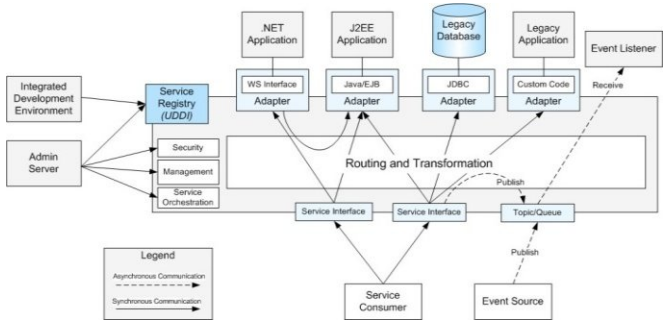
Source: NIST SGIP and IEC TC57





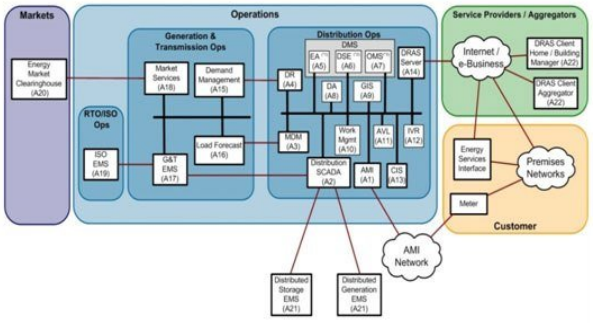
Infrastructure – exchanges/workflow

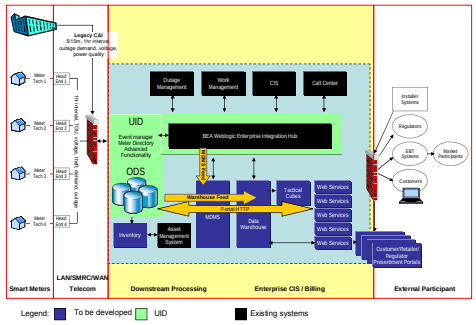
Source: Amsbary - client



Logical –functions relationship

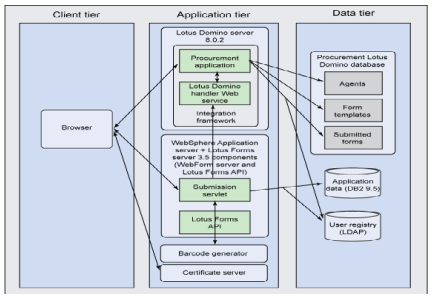
Source: Multispeak and Hydro One

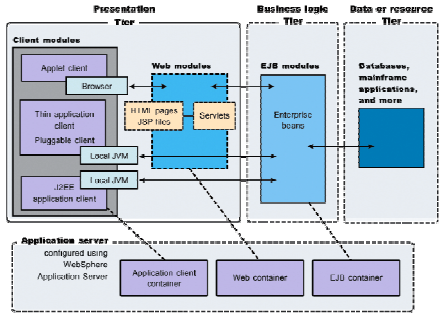




Application/Solution – Specifications

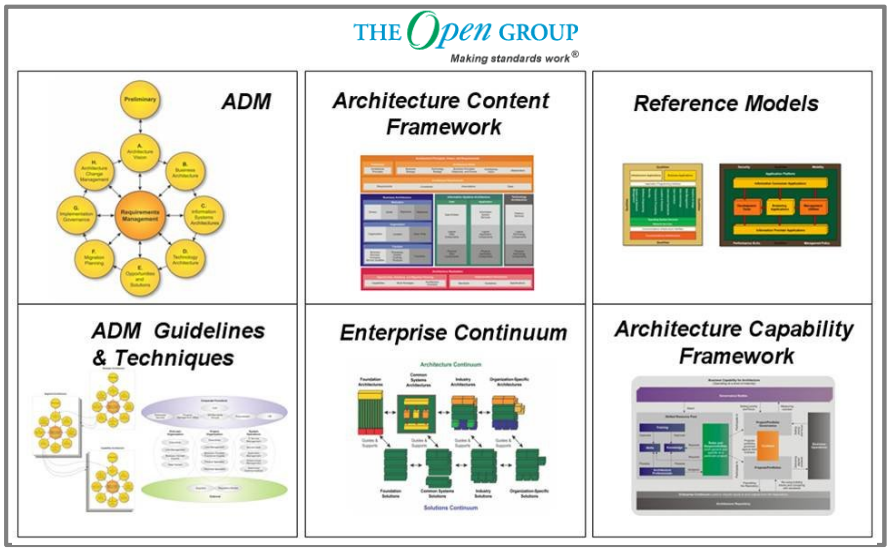
Source: Amsbary - client

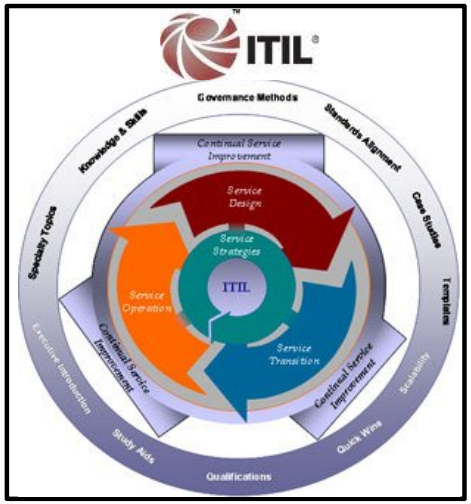


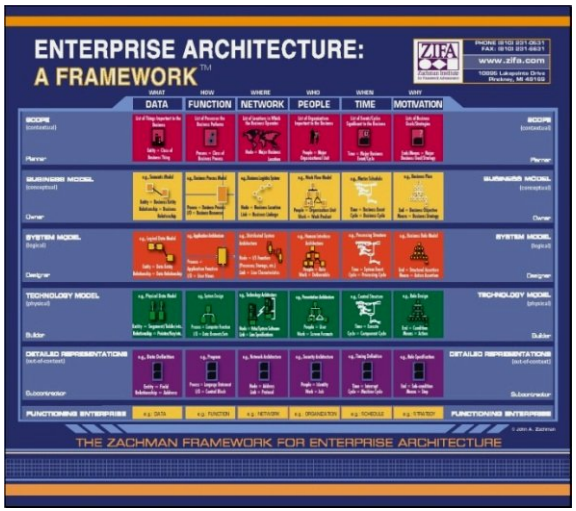


Architecture uses Frameworks

- Including TOGAF*, DoDAF, MoDAF, FEA, Zachman, &c
- They have their own Methodology, Techniques and Tools
- Incorporate Lifecycle maps for Project Management (PMO) and Systems Engineering lifecycles (ITIL)



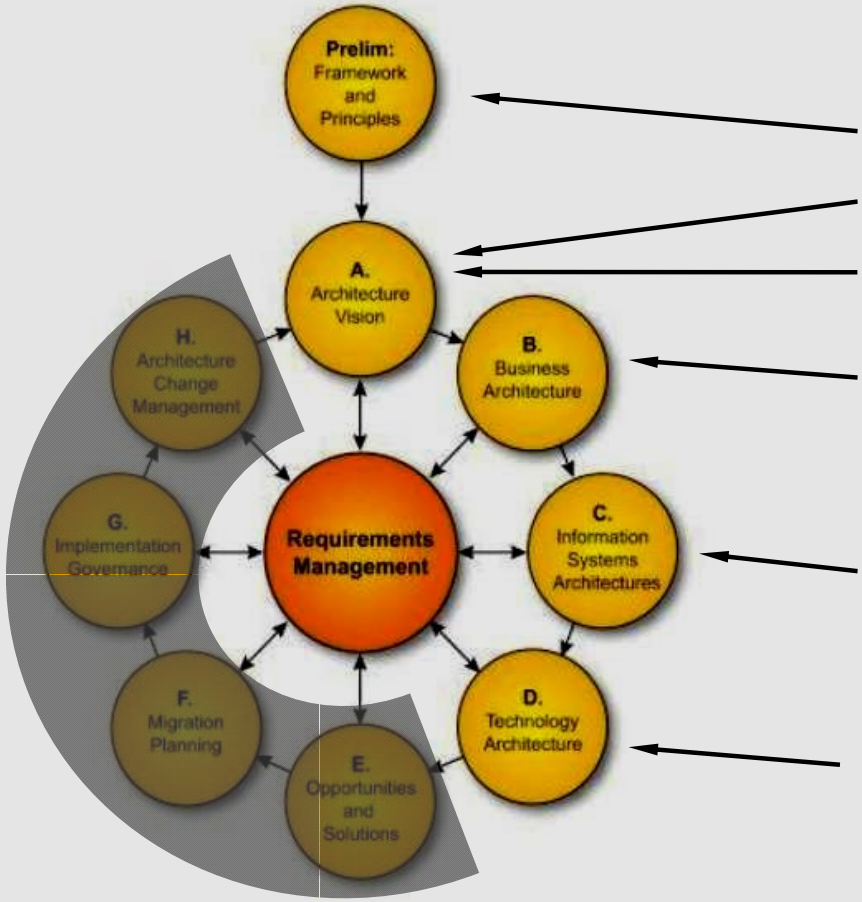




* The Open Group Architecture Framework

Architecture *Phases*

Rather then trying to “eat an elephant all at once”, architecture identifies goals and decomposes them into services that ultimately relate to the physical entities



This breaks-down into:

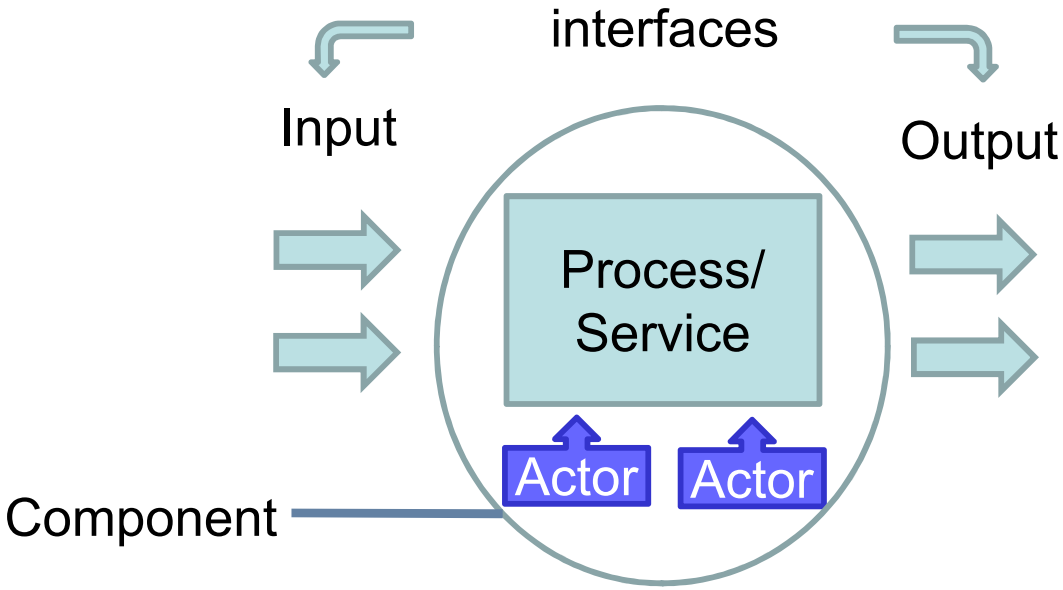
- **Preliminary**, What do you have
- **Vision**, what goals you trying to achieve
- **Requirements**, what needs do the goals impose
- **Business Services**, what *abstracted* services are needed to support a requirement
- **Information (or Application) Services**, what *sort* of applications are needed to support the abstracted service
- **Technical Service**, what is actually performing the service

Don’t worry we’ll cover phases E ⇒ H later

Architecture *Semantic Vocabulary*

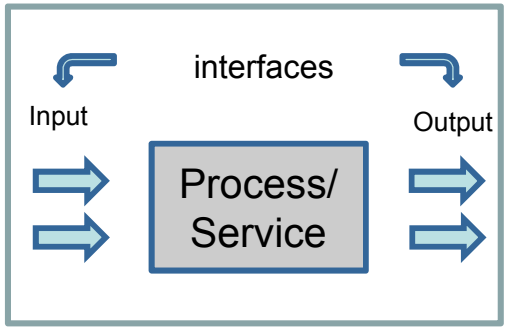
Vocabularies define the concepts and relationships used to describe and represent an area of concern. Vocabularies are used to classify a particular application, characterize relationships, and define constraints.

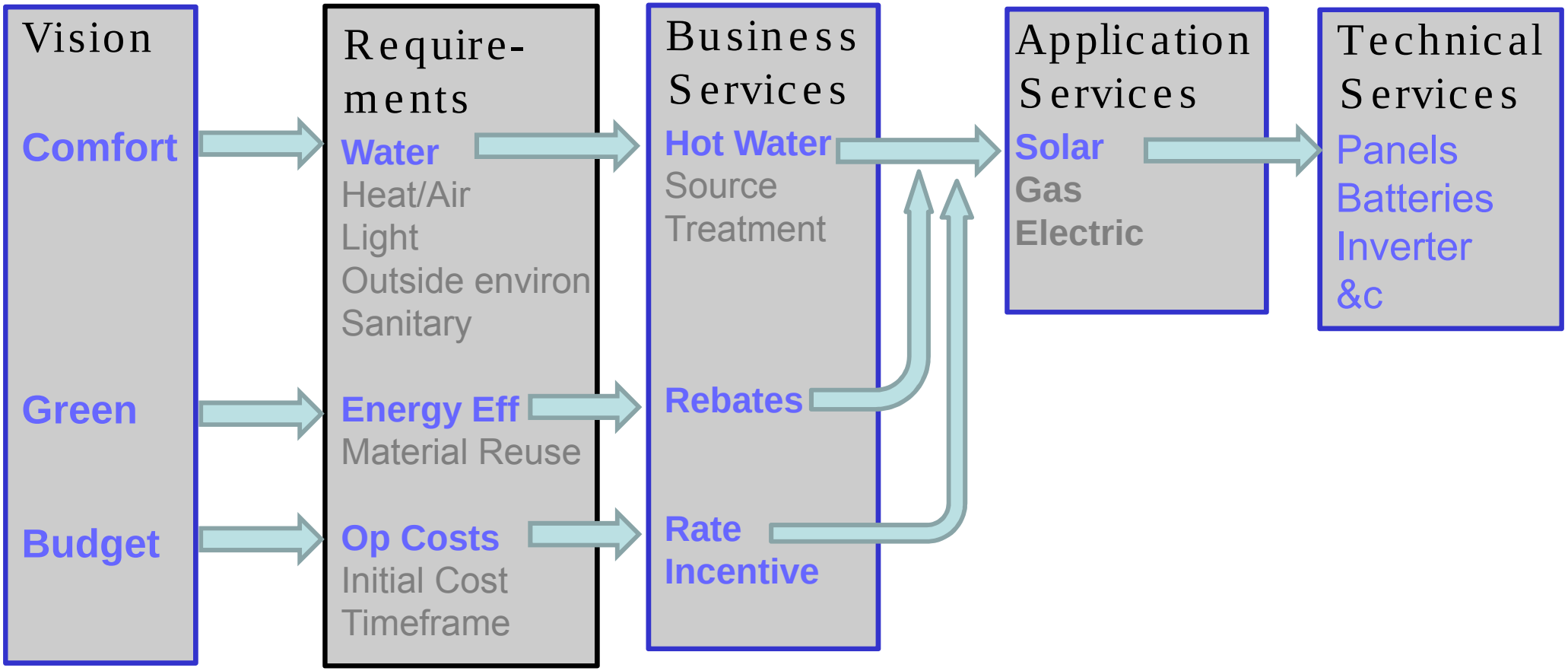
By extension *in Computer Science*, vocabulary is a domain model used to identify components/**services** and their relationships to each other (their **interfaces**)



Simple Building Architecture Example

Magic in this case is the ability to infer the options





Why we need sequence

Sequence ensures the right thing is done in the right order & illuminates alternatives
It's not as easy as it sounds

Impact of no sequence

Sequence changes based on the Situation

Simple restaurant* example

Business Requirement	Business Service
A. Sit-down Restaurant	1. Order 2. Eat 3. Pay
B. Fast Food Chain	1. Order 2. Pay 3. Eat
C. Buffet	1. Pay 2. Order 3. Eat

* Courtesy of Doug Houseman

Smart Grid Architecture Produces

- Strategic Plans
- Technical Road Maps
- Use Cases
- Reference Models
- Recommends standards
- Migration Plans
- Change Management
- Security and Governance

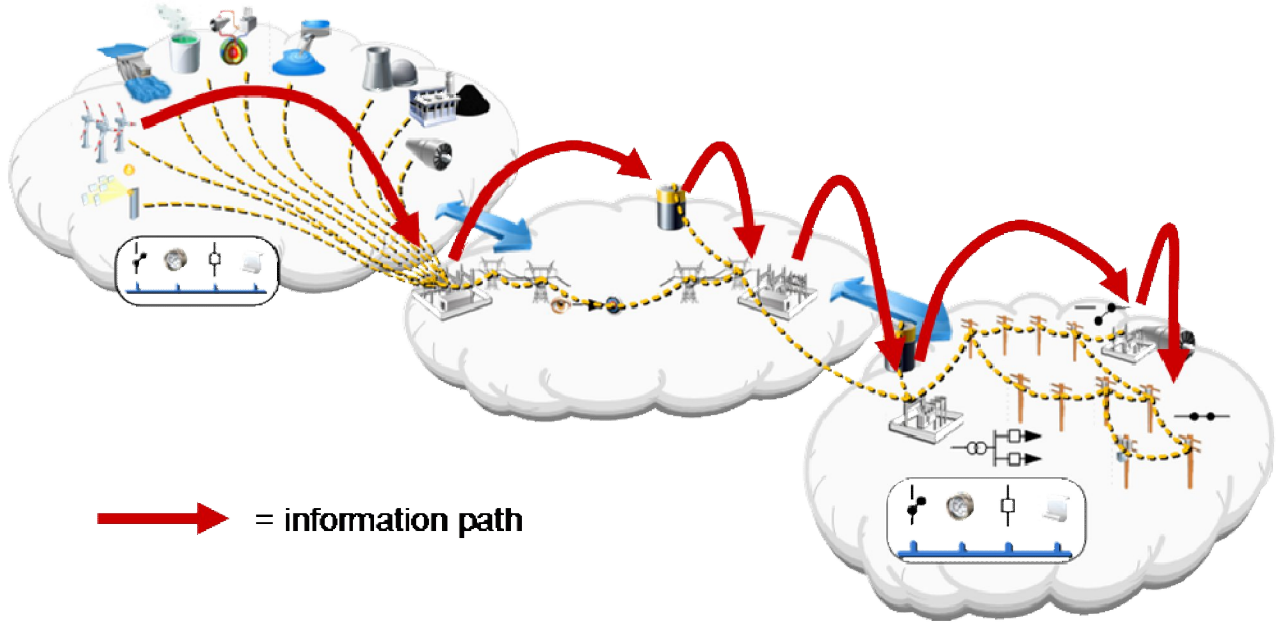
In short what is required to move from today's state to the stakeholder's goal

Use Cases

Clarifies how a Smart Grid requirement is envisioned to work – provides:

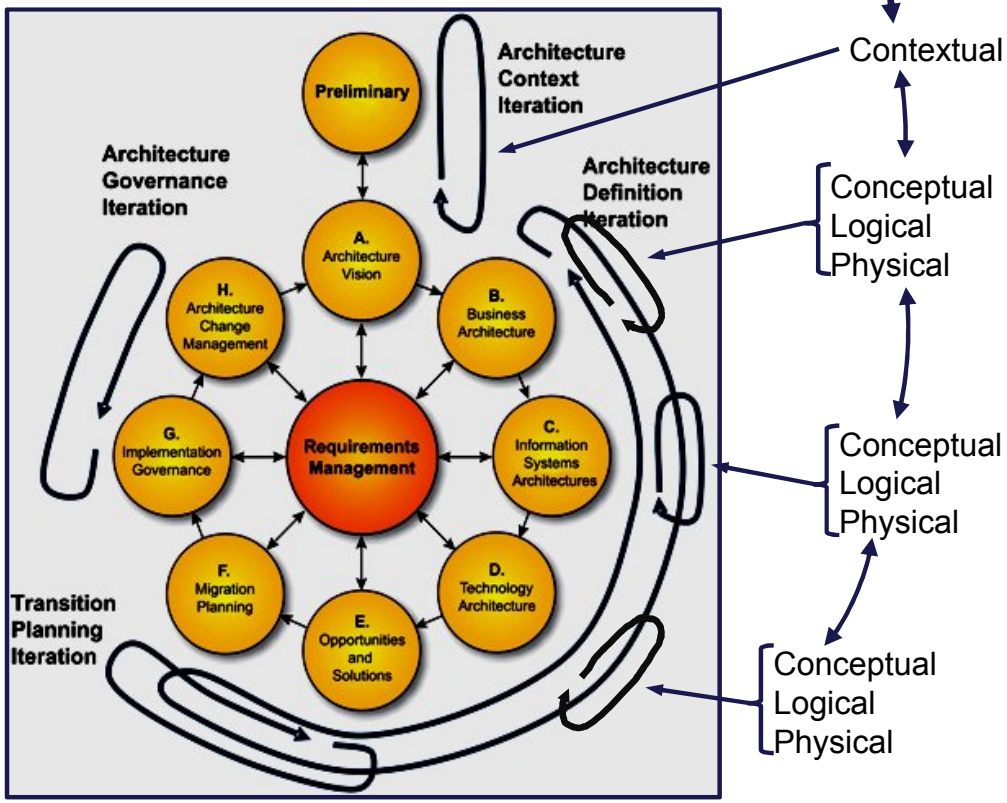
- Functional requirements
- Non-Functional requirements
- Interfaces
- Sequence
- Actors

Provides for and is used throughout the architectural process



TOGAF Iteration & Architecture layers

TOGAF cycle and corresponding Artifact level of detail



Contextual/Vision

- What are the Goals
- What is the current state

Conceptual

- What it shall accomplish
- What services are required

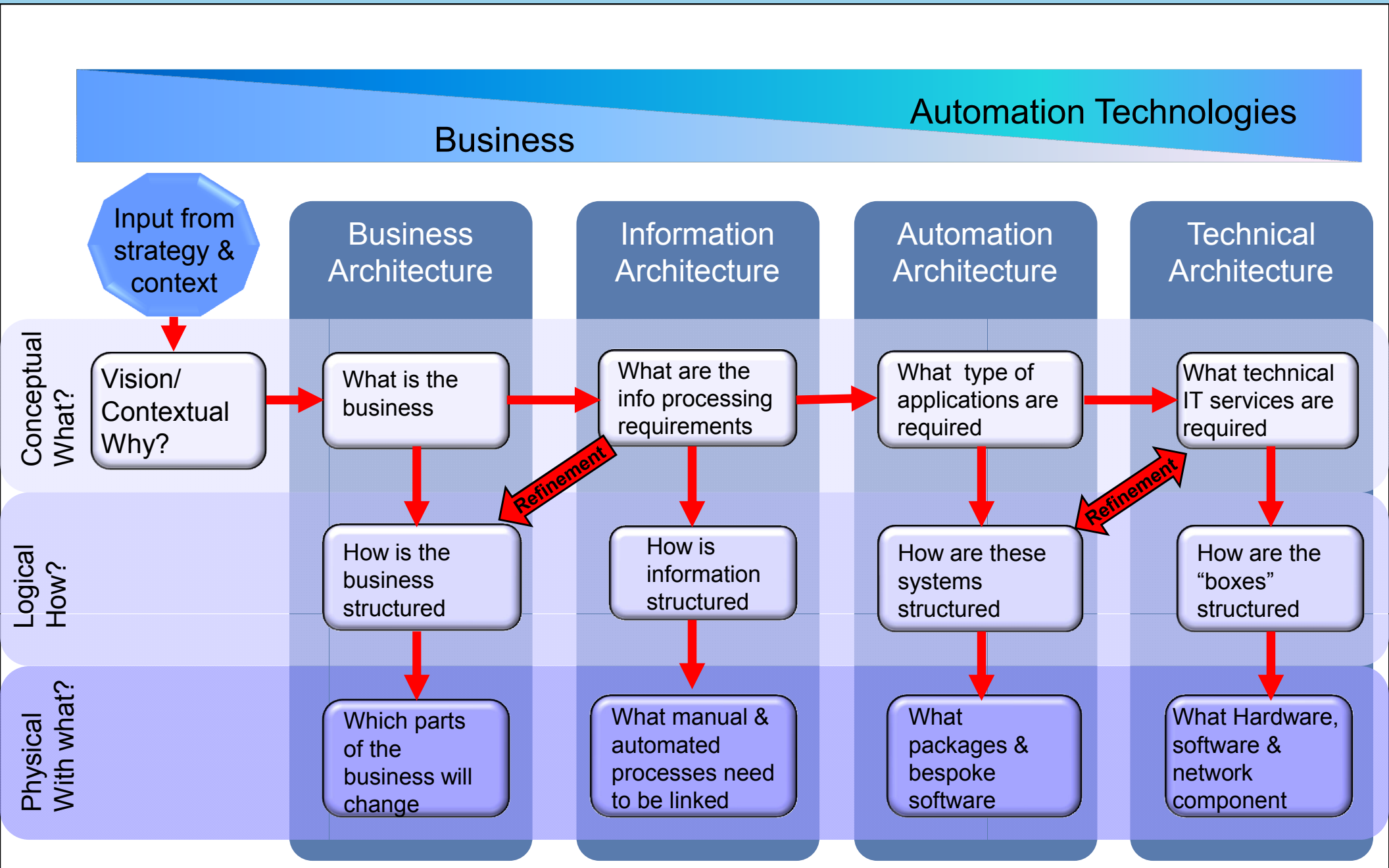
Logical

- How it shall be accomplished
- How is the architecture structured

Physical

- What resources shall be required

Architecture roadmap



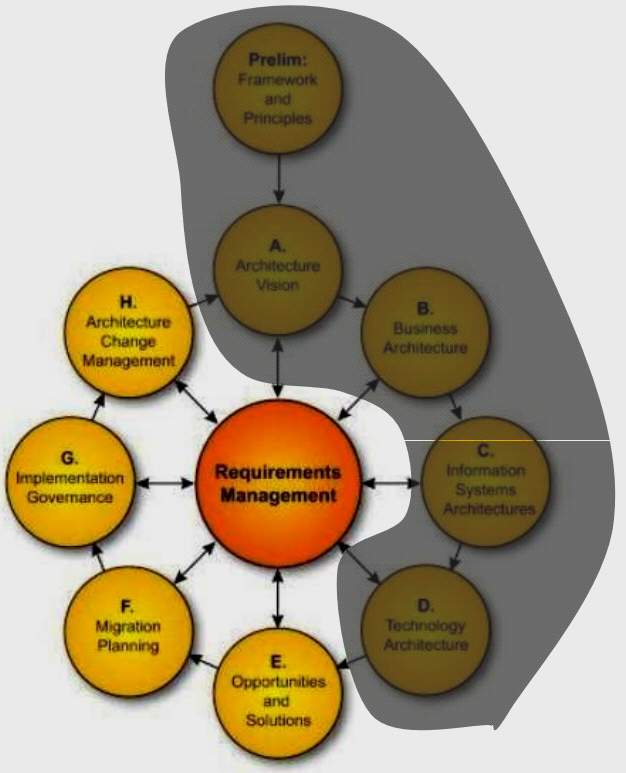
The Rest of the Story

Ok, now we understand what it takes to design a Smart Grid. ***Now*** we have to implement it, migrate legacy procedures/systems, operate it, handle changes and ensure governance

- **Yikes** …. Remember the other half of the cycle?

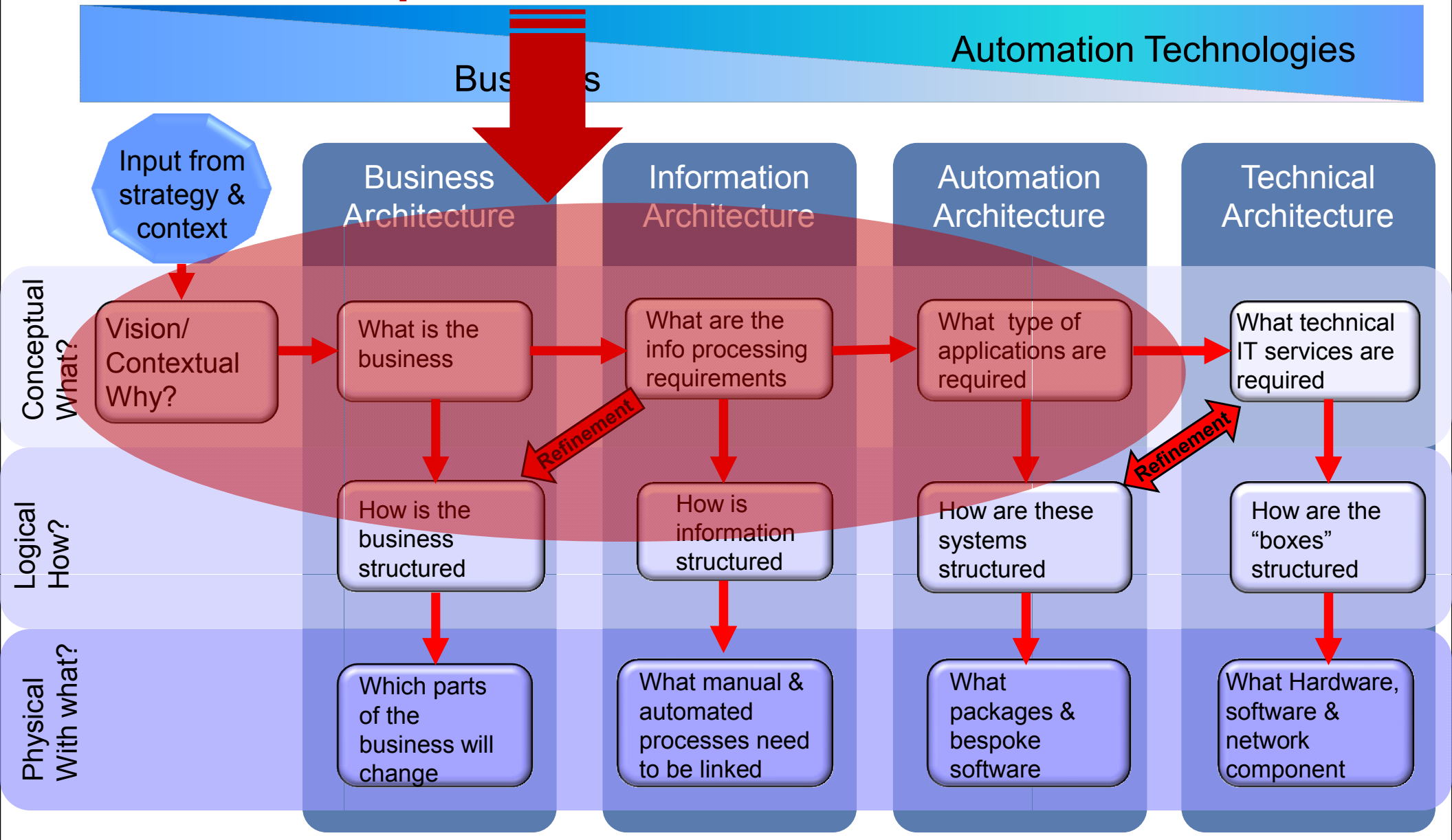
  That's where those areas are handled

- This ensures the architecture stays viable instead of stale
  - Think of this as your "honey-do" list



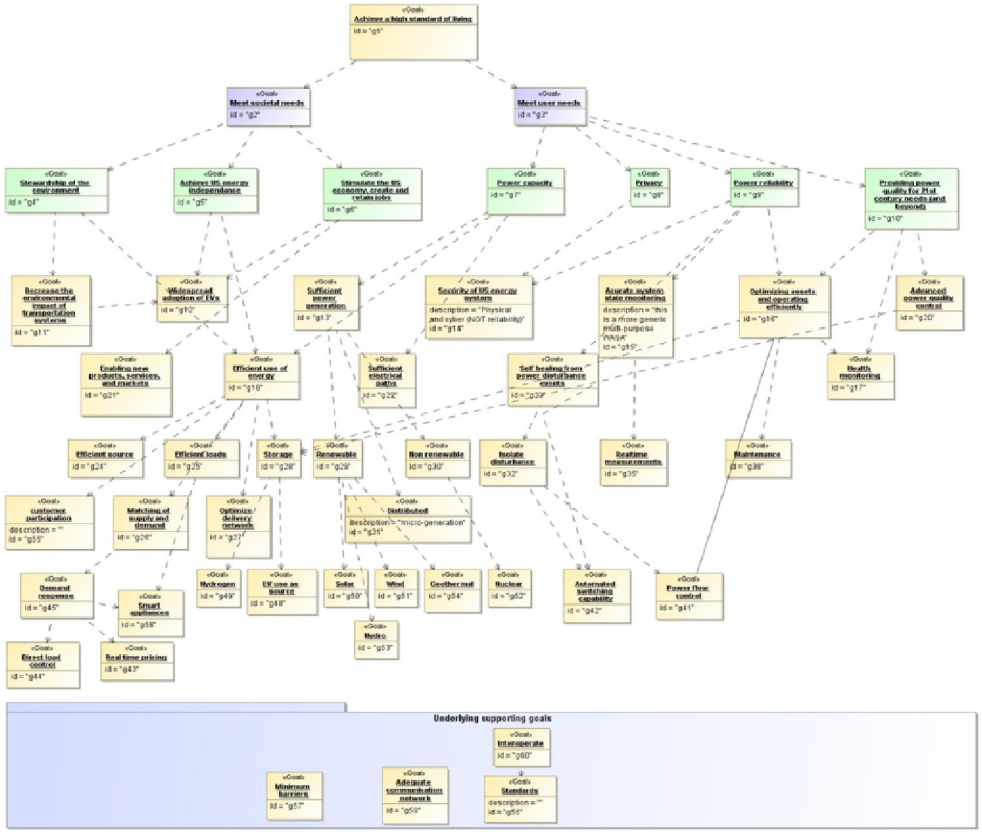
NIST - Architecture roadmap

NIST Conceptual Architecture



Goal Analysis/Goal Decomposition

- Goal Analysis
  - Reviewed all legislation and other government documents for stated smart grid goals
  - Goals include pointer to original document
  - Reviewed and harmonized for overlap and redundancy
- Goals Decomposed
  - Organized goals and add relationships (dependencies and conflicts)
  - Bottom level links processes/use case
- Reference ids created for backward compatibility for subsequent steps)



Requirements

- There is not a one-to-one relationship between goals, requirements and services - All Services are traceable to one (or more goals)

- The EPRI Use Case Requirements Database used a basis
- Subsequent requirements were created to support each goal

Domain	Ref	Req No	HL ID	Requirement	Business Services	Business Service Definition	Improve United States energy security.	meet future demand growth	Stimulate the economy &create and retain jobs.	Meet User Needs	The grid must be more reliable.	Grid will provide the level of power quality desired by 21st century users.	Privacy
Customer	7EPRCPT	7EPRCPT009	c1	Service Level data shall be collected in order to ensure that service level agreements are met	Service Level Agreement Compliance	Manage compliance with Service Level Agreements (SLAs) using service performance data.	x	x		x	x	x	x

Requirement Source &id

Business Requirement

Business Service

Top Level National Goals

Services

- There is not a one-to-one relationship between goals, requirements and services - All Services are traceable backward to one (or more goals)

- Business Services were created to support each requirement
- High-level Automation (information) Services were identified necessary to support each Business Service

Domain	Referenc	Req No	HL ID	Requirement	Business Services	Business Service Definition	Automation Service	Automation Service Definition
Bulk Generation	1IECGEA	1IECGEA161	G14	shall support minimum cost real time scheduling of generation units	Least cost dispatch	Provide a mechanism to allow for the lowest cost units to be called on first for providing energy	economic dispatch support service	provides a set of analytics that determine which units offer the lowest total cost for the energy delivered to the required locations

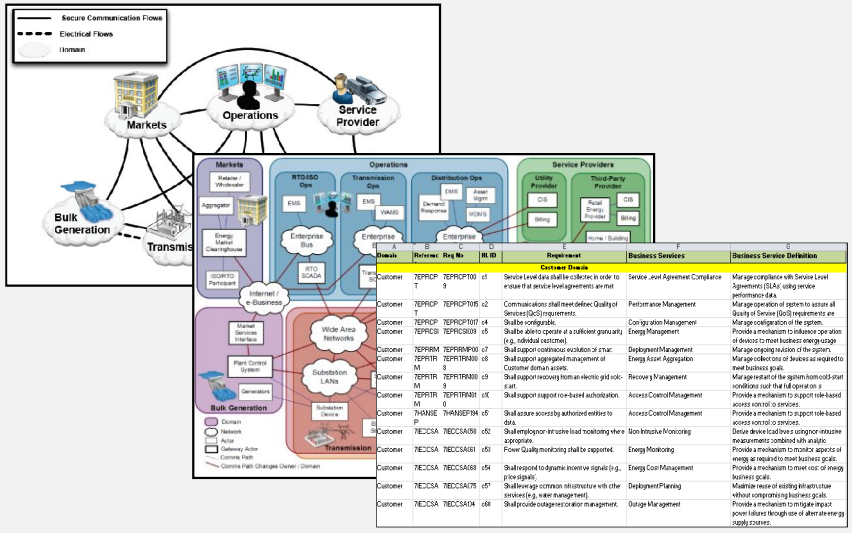
Original document

Besiness Requirement

Business Service(s)

Automation Service(s)

NIST Smart Grid Goal: To support Business Specific Solutions

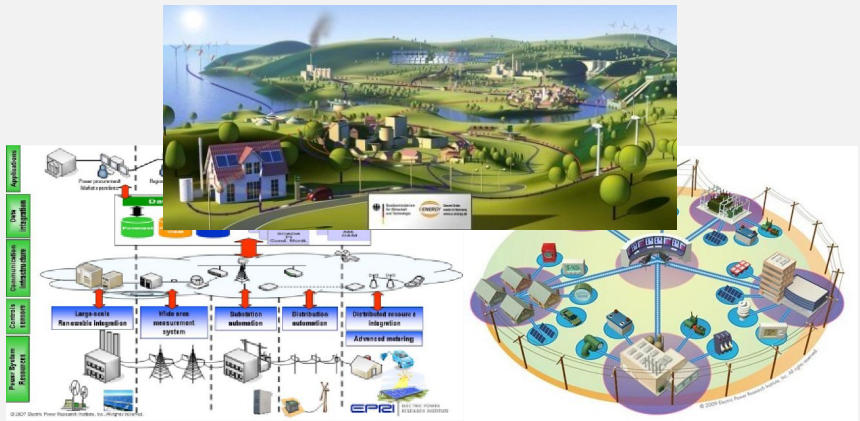


Domain	Reference	Req No	RI ID	Requirement	Business Services	Business Service Definition
Customer Domain						
Customer	7EPRCPT	7EPRCPT00 9	c1	Service Level data shall be collected in order to ensure that service level agreements are met	Service ,evel Agreement Compliance	Manage compliance with Service Level Agreements (SLAs) using service performance data.
Customer	7EPRCPT	7EPRCPT015	c2	Communications shall meet definec Quality of Services (QoS) requirements.	Performance Management	Manage operation of system to assure all Quality of Service (QoS) requirements are
Customer	7EPRCPT	7EPRCPT017	c4	Shall be configurable.	Configuration Management	Manage configuration of the system.
Customer	7EPRCSI	7EPRCSI009	c5	Shall be able to operate at a sufficient granularity (e.g., individual customer).	Energy Management	Provide a mechanism to influence operation of devices to meet business energy usage
Customer	7EPRRM	7EPRRMP00	c7	Shall support continuous evolution of smar.	Deployment Management	Manage ongoing evolution of the system.
Customer	7EPRTRM	7EPRTRN00 9	c8	Shall support aggregated management of Customer domain assets.	Energy Asset Aggregation	Manage collections of devices as required to meet business goals.
Customer	7EPRTRM	7EPRTRN00 9	c9	Shall support recovery from an electric grid sole-start.	Recovery Management	Management of the system from cold-start conditions such that full operation s
Customer	7EPRTRM	7EPRTRN00 0	c9(	Shall support support role-based authorization.	Access Control Management	Provide a mechanism to support role-based access control to services.
Customer	7HANSEP	7HANSEP04	c6	Shall assure access by authorized entities to data.	Access Control Management	Provide a mechanism to support role-based access control to services.
Customer	7ECCSA	7ECCSA(50	c52	Shall employ non-intrusive load monitoring where appropriate.	Non-Intrusive Monitoring	Derive device load from a single non-intrusive measurements combined with analytic
Customer	7ECCSA	7ECCSA(61	c53	Power Quality monitoring shall be supported.	Energy Monitoring	Provide a mechanism to monitor aspects of energy, as required to meet business goals.
Customer	7ECCSA	7ECCSA(68	c54	Shall respond to dynamic incentive signals (e.g., price signals).	Energy Cost Management	Provide a mechanism to meet cost of energy business goals.
Customer	7ECCSA	7ECCSA(75	c57	Shall leverage common infrastructure with other services (e.g., water management).	Deployment Planning	Maximize reuse of existing infrastructure without compromising business goals.
Customer	7ECCSA	7ECCSA04	c68	Shall provide outage/restoration management.	Outage Management	Provide a mechanism to mitigate impact power failures through use of alternate energy supply sources.

Conceptual Architecture

Community-Serving Conceptual Architecture Deliverables

- Concepts
- Requirements
- Business and Automation Services
- Domain Interactions
- Use-Cases
- Semantics/Vocabulary, Terminology



Logical & Physical Architecture

Business-Focused Solution Architecture

- Business specific requirements
- Business specific processes
- Logical component and model design
- Physical interface and schema design
- Solution specifications and development
- Project validation & testing
- Deployment & Architecture Governance

NIST SGAC* Conceptual Architecture

"Conceptualization" of Smart Grid's overarching business and system operations

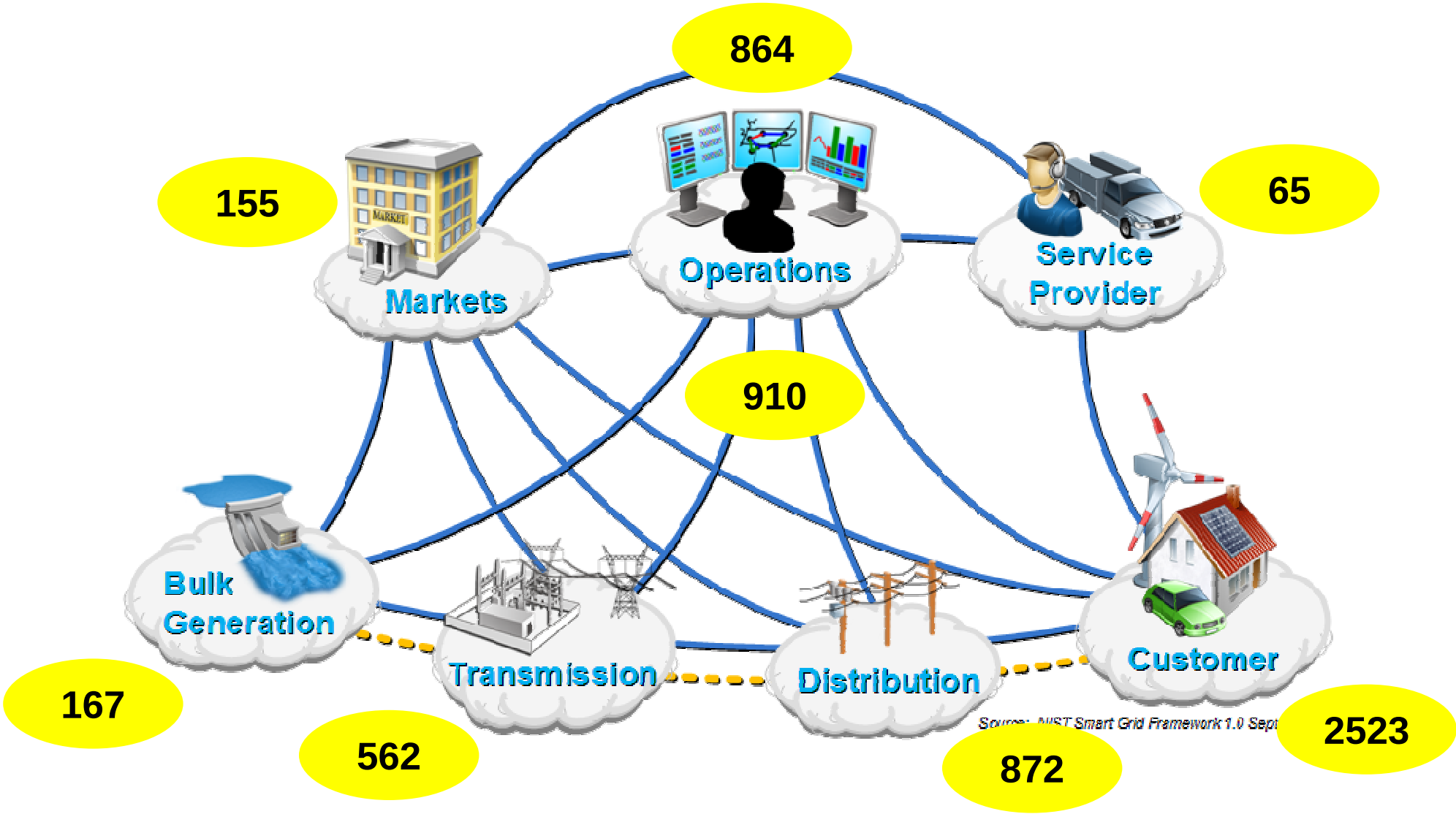
- Recognizes many strategic initiatives fail because new technologies are viewed in isolation
  - Addresses a holistic view of the power system and business domains
- Provides context allowing business stakeholders to prioritize and justify often conflicting technology decisions based on a robust conceptual model
- Facilitates common vocabulary and re-use of system level constructs across all Smart Grid business domains
- Rich knowledge base of national-level goal decomposition, business requirements, services and actionable vocabulary

* SGAC - Smart Grid Architecture Committee

NIST Conceptual Architecture Effort

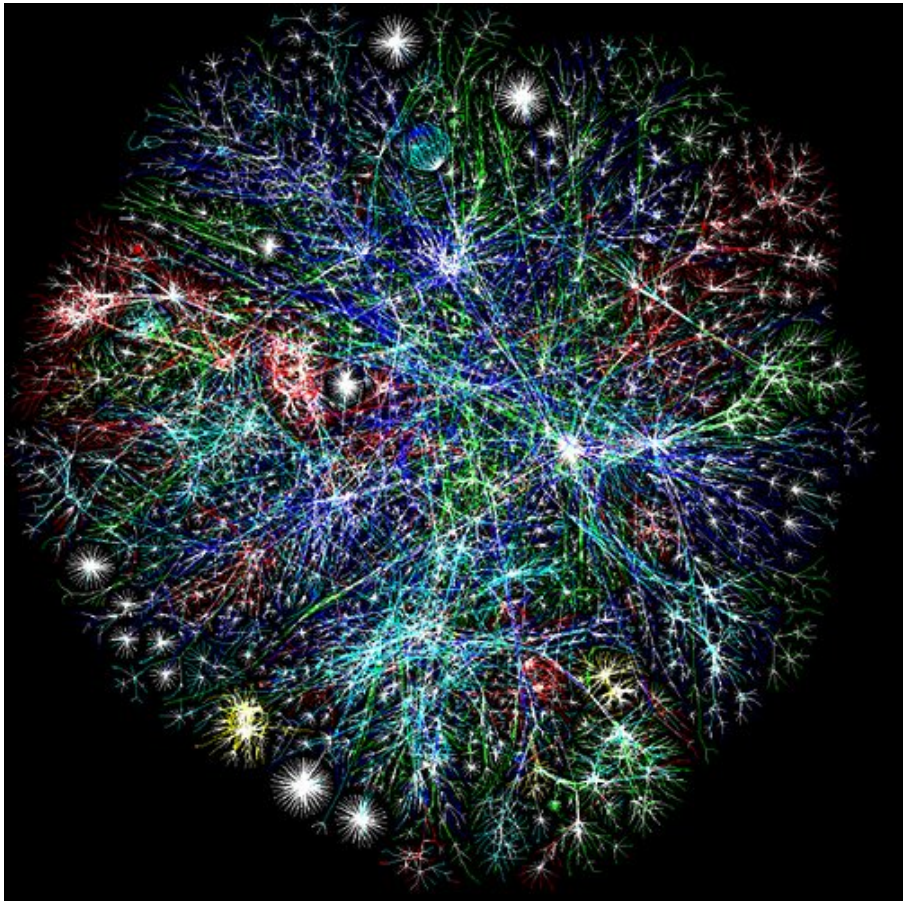
- ~9500 pages of national laws
  - 400 National Goals – 20 high level families
- ~700 Use Cases, 20 System Requirement Documents, 33 originators
  - 7900+ Requirements
- 450+ high level families of requirements
- 450+ business requirements
- 500+ technical requirements

Number of *new* business requirements



Need for a Semantic Vocabulary

- Natural Language is Ambiguous
  - One Reality, Multiple Views of It
  - Meaning is *Relative* to a Perception
  - Perception is Contextualization
- Ambiguity can be eliminated with Contextualization
- Contextualization can be defined through Relations



Vocabulary and Semantics

Information Challenges

- Ambiguous Semantics
  - Inter-domain communications
- Multiple Technologies
  - Consistency
- Partially Known Value-Chain
  - Cross Business-Unit Operational implications
- Low Data Quality
  - Decisions/Trust-Risk
- Poor Data Specification
  - Expectations

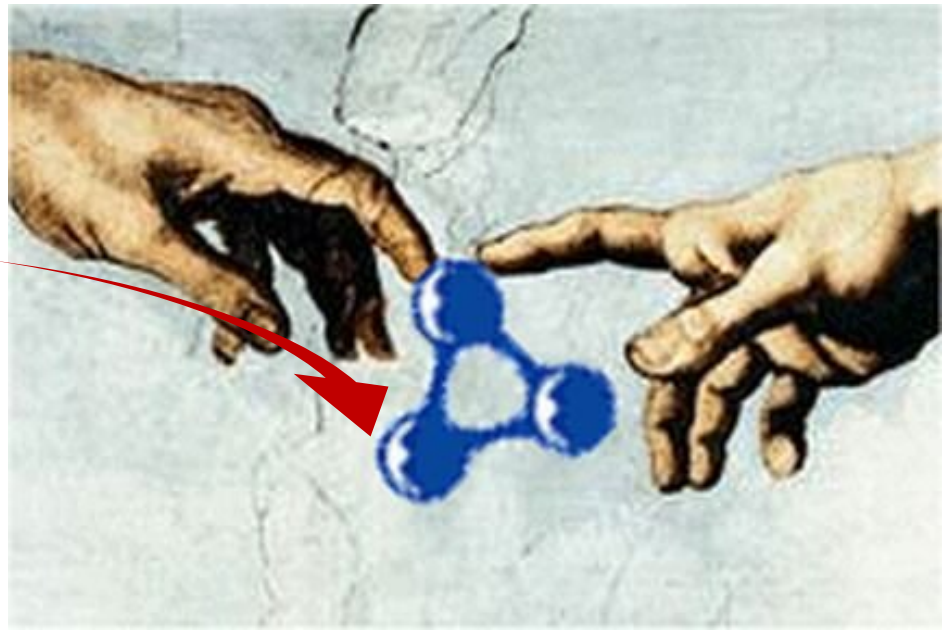
Success Factors

- Well defined vocabulary and semantics
- Eliminate technology dependencies/disparities
- Precise Relations
- Clear Expectations

Semantic Modeling Language

Need for *actionable* vocabulary beyond model languages such as Universal Modeling Language (UML)

- Open Source managed by WW3C a non-propriety file format
- Ontology Web Language (OWL) is more expressive than UML

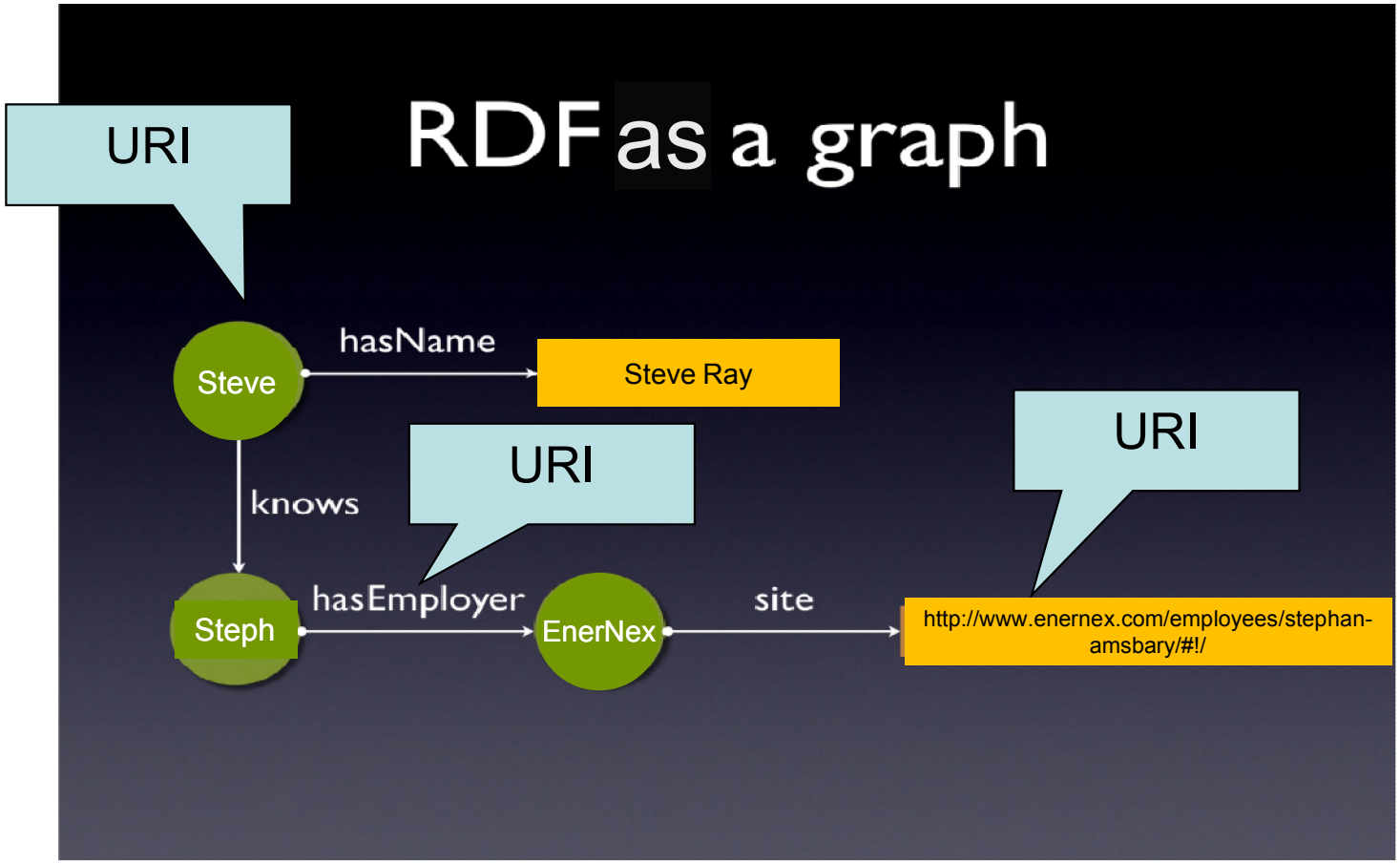


Actionable

- Simple Structure
  - Subject, Verb, Object (triple) which is stored in a Resource Description Framework (RDF) for access
  - Triplets can be transparently merged across data sources
- Provides formal verification across diverse vocabularies
- If it's Web addressable, its available for use
- Analysis/query (SPARQL)

RDF Example

Three triplets



Web Semantic Mash-up Example

With no programming – just a RFS definition

Each project has dissimilar
- Location information
- Labels
- Project details

Google recognizes as such
- Maps each project location
- Labels each by it's type (AMI, CS, DS, &c.)
- Links to project details

DoE Smart Grid Clearinghouse

http://www.sgiclearinghouse.org/?q=node/13

Maturity Models are strategic frameworks to identify opportunities for improvement

- They create a roadmap identifying activities, best practices and investments leading to the desired state
- Provides maturity characteristics expected for each stage of maturity
- Provide an assessment of the current state and help bridge the gaps to the future state
- Observable indicators of progress – measurable outcomes that improve with each stage of maturity

SEI* Smart Grid Maturity Model

Smart Grid Maturity Model – Levels, Descriptions and Results

Level 5: *Innovating – Next wave of improvements*		New business, operational, environmental and societal opportunities present themselves, and the capability exists to take advantage of them.	***Perpetual Innovation*** *Self-healing operations* *Autonomic business* ***Innovators***
Level 4: *Optimizing – Enterprise Wide*		Smart Grid functionality and benefits realized. Management and operational systems rely on and take full advantage of observability and integrated control across and between enterprise functions.	***Transformation*** *Real time corrections* *Broad reuse* ***Victors***
Level 3: *Integrating – Cross Functional*		Smart Grid spreads. Operational linkages established between two or more functional areas. Management ensures decisions span functional interests, resulting in cross functional benefits.	***Systemization*** *Repeatable practices* *Shared information* ***Cross LOB Champions***
Level 2: *Functional investing*		Making decisions, at least at functional level. Business cases in place, investments being made. One or more functional deployments under way with value being realized. Strategy in place.	***Strategy*** *Proof of Concepts* ***Missionaries***
Level 1: *Exploring and Initiating*		Contemplating Smart Grid transformation. May have vision, but no strategy yet. Exploring options. Evaluating business cases, technologies. Might have elements already deployed.	***Vision*** *Experiments* ***Prophets, Heroes***

Eight Smart Grid Domains and Important Elements

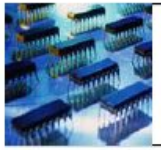
People and Technology Domains

Strategy, Management and Regulatory 1

Vision, planning, decision making, strategy execution and discipline, regulatory, investment process

Organization 2

Communications, culture, structure



Technology 3

Information, engineering, integration of information and operational technology, standards, and business analytics tools

Societal and Environmental 4

Conservation and green initiatives, sustainability, economics and ability to integrate alternative and distributed energy

Process Domains

Grid Operations 5

Advanced grid observability & advanced grid control, quality and reliability

Work and Asset Management 6

Optimizing the assets and resources (people and equipment)

Customer Management and Experience 7

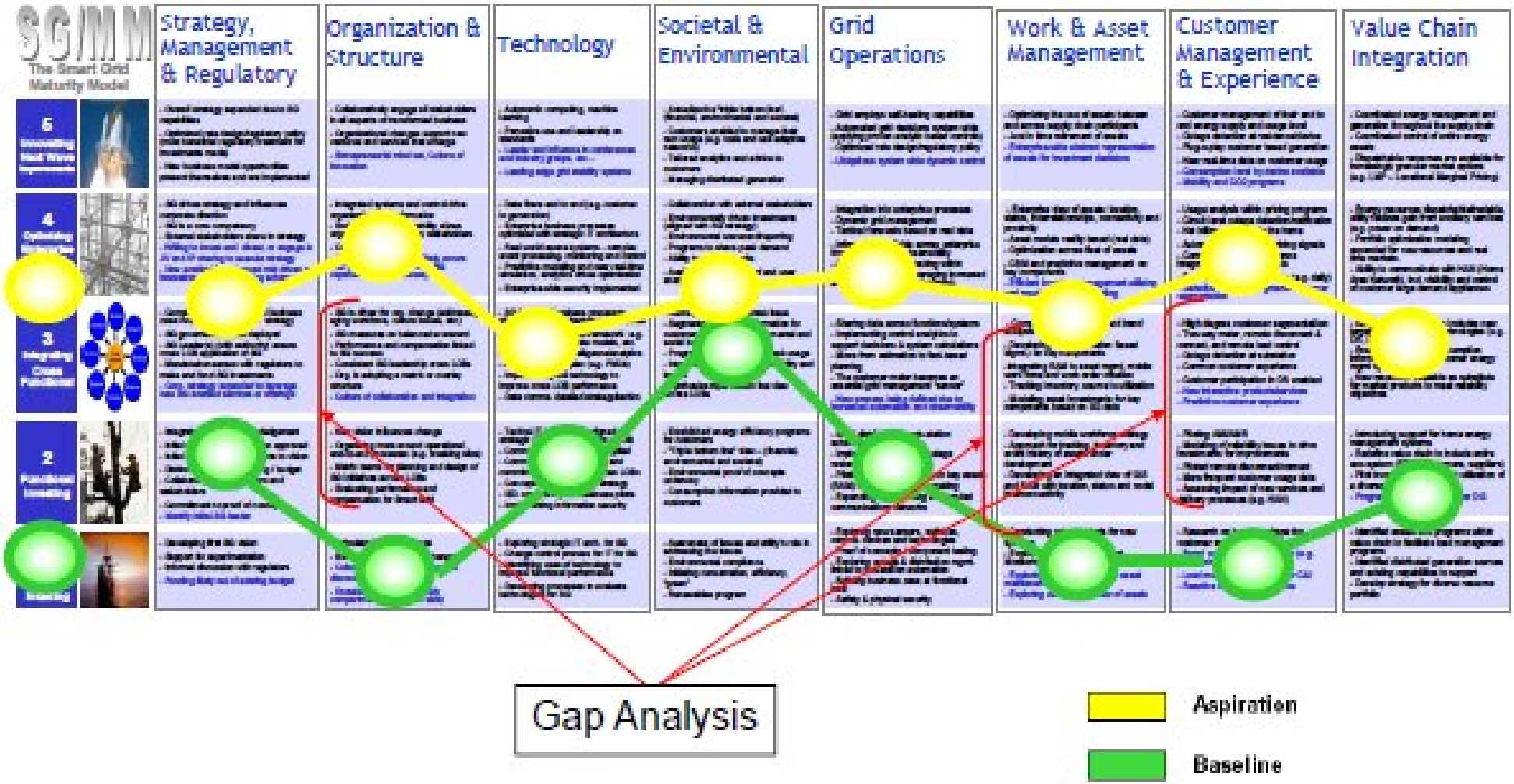
Retail, customer care, pricing options and control, advanced services and visibility into utilization quality, and performance

Value Chain Integration 8

Enabling demand and supply management, distributed generation, load management, leveraging market opportunities

* SEI - Carnegie Mellon Software Engineering Institute

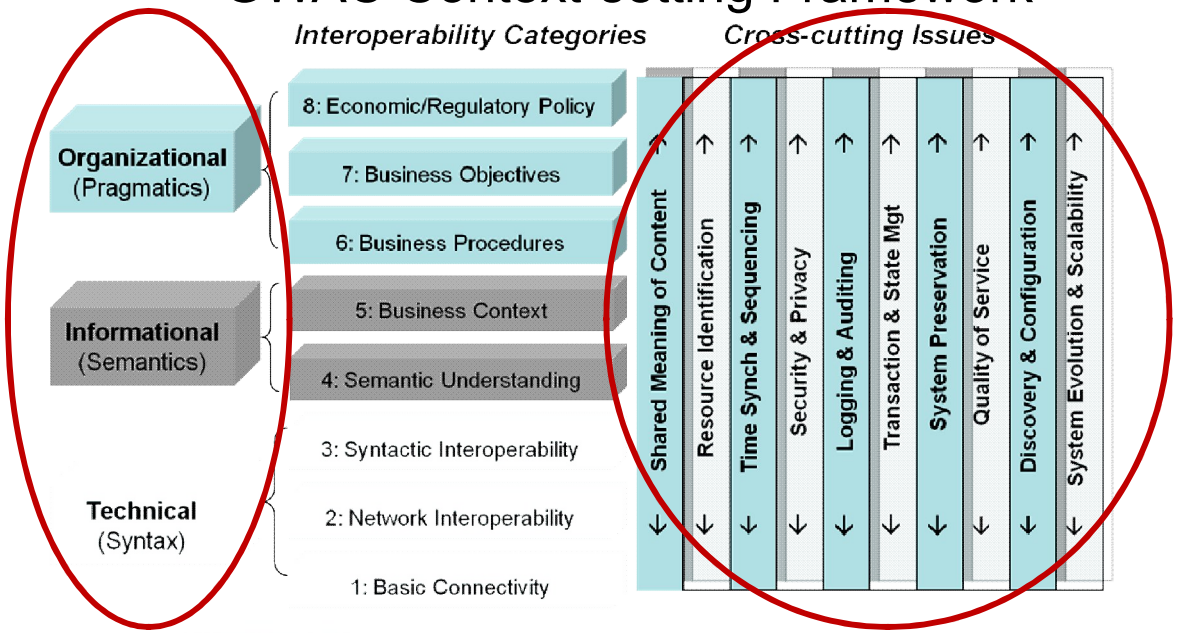
SEI Smart Grid Maturity Model



GWAC* Smart Grid Interoperability Maturity Model (IMM)

Work In Progress

GWAC Context-setting Framework



NEHTA Interoperability Maturity Model

http://www.nehta.gov.au/connecting-australia/ehealth-interoperability

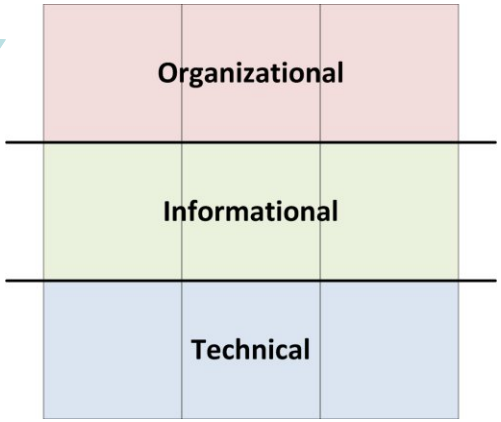
SEI Smart Grid Maturity Model

Level	Title
5	***Optimizing***
4	***Quantitatively Managed***
3	***Defined***
2	***Managed***
1	***Initial***

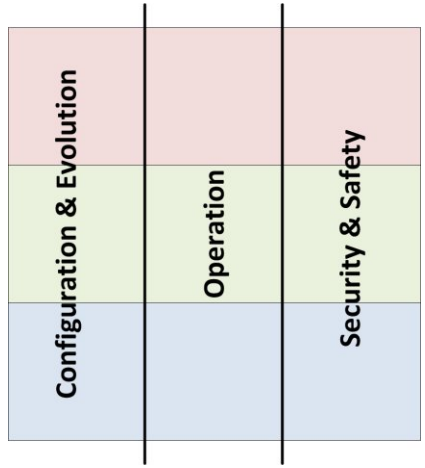
* GWAC – DoE GridWise Architecture Council

The GWAC IMM Stack

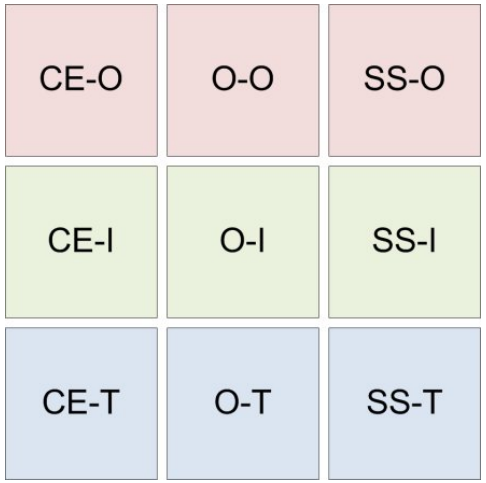
- 1 Framework (GWAC Stack)
  - 8 interoperability categories consolidated into 3 layers



- 10 Cross -Cutting issues – 3 layers



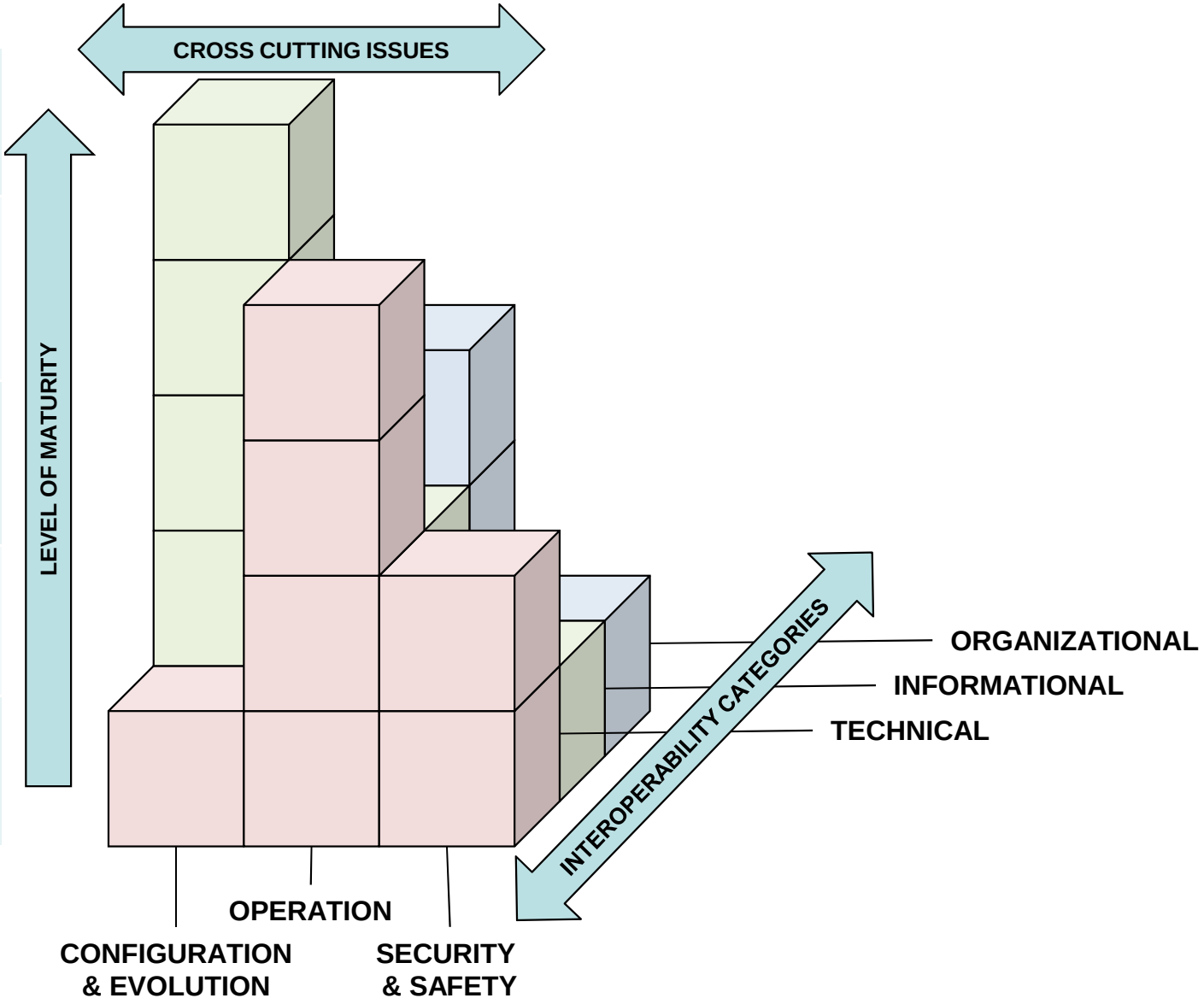
- 9 Interoperability Areas
  - Combining the interoperability and cross cutting categories provides a two dimensional matrix that helps simplify the conceptual landscape



Slide courtesy of Mark Knight

Level 5 IMM Maturity Example

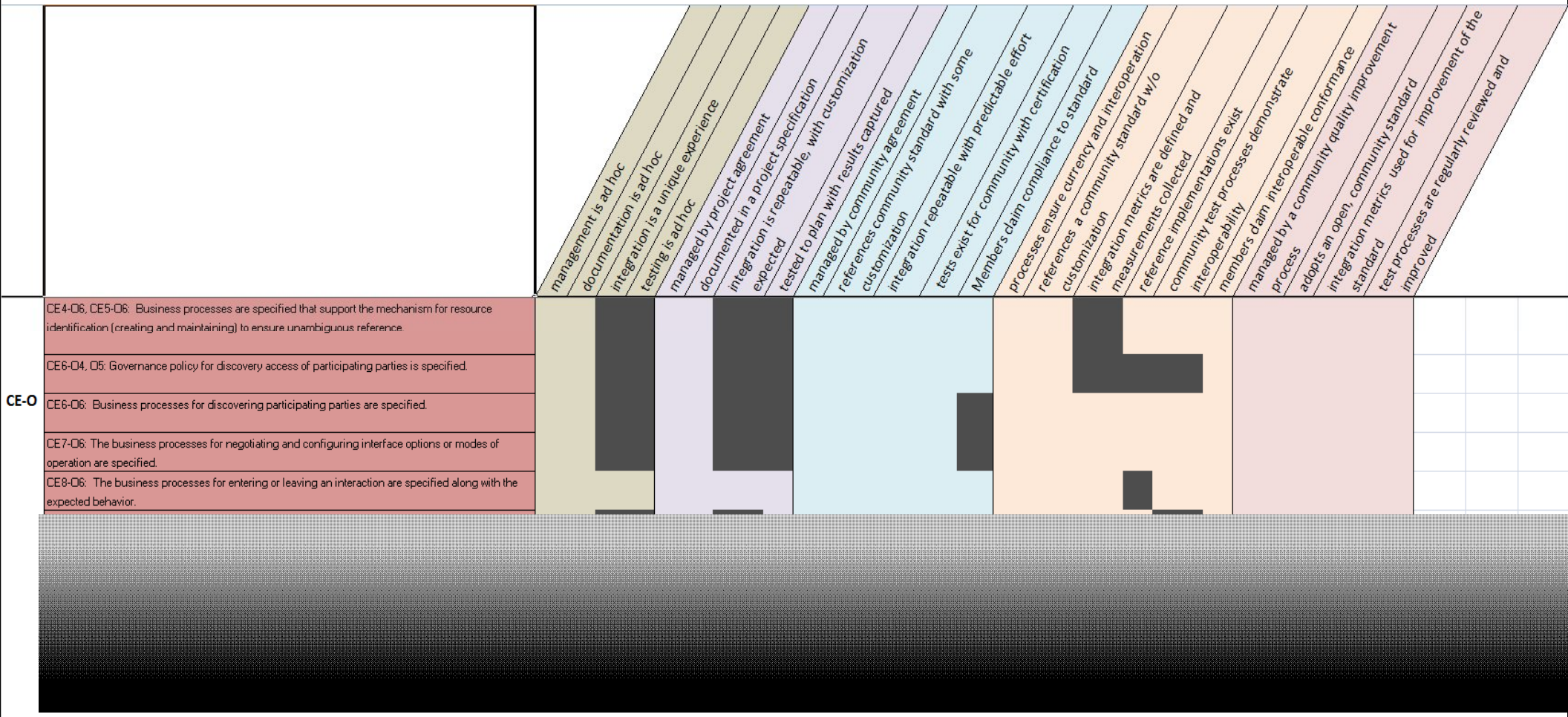
5	*Optimizing*
4	*Quantitatively Managed*
3	*Defined*
2	*Managed*
1	*Initial*



GWAC SG IMM Evaluation Matrix

Interoperability Areas

Maturity level Metrics (questions)



Smart Grid Architecture Summary

- Affects the entire organization, not just computer techies
- A process that minimizes risk and gives insight into how the business operates today and what changes are needed to achieve the business' grid modernization objectives
- A means to:
  - Gain operational efficiencies
  - Maximize assets and personnel
  - Bring order to IT delivery - aligning Business Services with the underlying automation Services-Oriented (SOA) foundation
- SGAC efforts are performing the heavy lifting to define Smart Grid's foundation
- Several Utilities are using EA (and TOGAF)

Notable examples:

Southern California Edison
Consumers Electric
Duke Energy
Florida Power and Light
National Grid
Pacific Gas & Electric
Most Smart Grid software vendors

Want to know more

- SGAC Conceptual Architecture Session
  - Wednesday at 1:30 – 5:00PM – room 164
- Semantic Working Group Session
  - Tuesday at 3:30-5:00PM - Room 161 (*CHANGED*)
- Foundational Session - Interoperability Maturity
  - Wednesday at 10:30-12:00AM – South Ballroom
- Smart Grid Interoperability Maturity Model and GWAC
  - Wednesday at 1:30-3:00PM – room 163

References

National Use-case repository:
http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/IKBUseCases

NIST SGIP SGAC:
http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/SmartGridArchitectureCommittee

EPRI IntelliGrid
http://intelligrid.epri.com/

GridWise AC:
www.gridwiseac.org

UCA International (OpenSG):
http://osgug.ucaiug.org

Software Engineering Institute Smart Grid Maturity Model
http://www.sei.cmu.edu/smartgrid/

The Open Group (TOGAF):
http://www.opengroup.org/togaf/

Questions ?

How does this work?

EnerNex
Electric Research, Engineering, and Consulting

Stephan Amsbary
Director, Utility Enterprise Architecture

Stephan@EnerNex.com
Phone: +1.828.559.1110
FAX: 865.218.8999
1993 Grants Mountain Rd, Marion, NC, 28752-9513

EnerNex
Electric Research, Engineering, and Consulting

Doug Houseman
Vice President, Innovation and Technology

Doug@EnerNex.com
Phone: +1.865.218.4600
FAX: +1.865.218.8999
Suite 300, 620 Mabry Hood Rd, Knoxville, TN, 37932