Systems Thinking and Requirements Approaches for Innovative Solutions in Science and Engineering

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Imparting My Passion

- **Requirements approaches impact outcomes across disciplines**
- **Systems thinking and learning organizations foster innovation in a changing world**
- **Science and engineering benefit from “soft” skills for collaboration**

Agenda

- Cross-Discipline Analysis
- Systems Thinking and Patterns
- Applicability to Requirements Across Disciplines
- Healthcare Application Discussion
- Global Business Challenges and Innovation

Why Learn From Other Disciplines?

“In many ways, the greatest promise of the systems perspective is the unification of knowledge across all fields - for these same architypes recur... ”
The Fifth Discipline [Peter Senge, 1990]

“Many good ideas have been discovered because someone poked around in an outside industry or discipline, and applied what he found to his own field.”
A Kick in the Seat of the Pants, Using Your Explorer, Artist, Judge, & Warrior to Be More Creative [Roger von Oech, 1986]

- **Requirements engineering (RE), the capturing and managing requirements, can benefit from a cross-discipline approach vs. “reinventing the wheel” in computer based systems**

- **Alexanders’s (1977) concept of patterns (Object-oriented community application) can be extended to RE processes for applicability beyond a single discipline**

Systems Thinking (Wikipedia)

- *The Fifth Discipline: The Art and Practice of the Learning Organization* (Senge 1990) applies today
- Group problem solving using systems thinking method converts companies into learning organizations
- Core learning capabilities include fostering aspiration, developing reflective conversation, and understanding complexity

Five Disciplines for a Learning Organization (Wikipedia)

- Personal mastery
- Mental models
- Building shared vision with commitment and enrollment
- Team learning to suspend assumptions and think together
- Systems thinking as "The Fifth Discipline" integrating four

Patterns Concepts Evolution

- Patterns work by architect Christopher Alexander still cited (Alex Washburn, Stevens Industry Professor Design)

- Basis of patterns in object oriented community (Gamma et al, 1995)

- Concept applied to requirements processes (Gaska, 1999)

- Patterns and Systems Engineering blog (inaugural 2009) cites Christopher Alexander's work on "concept and value of patterns"

Pattern Concept Extension to Exploring Requirements Framework (Gause and Weinberg, 1989 and 1990*; Gause, 1998**)

- Keep **ambiguity reduction** as a goal; monitor with ongoing metrics
- Include **context free questions** which apply to any design domain
- Carefully use **naming** conventions in general, including selection of the project name
- Identify **users and clients** and plan participation
- Clarify and manage **expectations** to include features, functions, attributes (defining and differentiating variables), constraints, preferences, and assumptions
- Define project **scope**, including a clear statement of limitations and features
- Identify use **scenarios** and test cases up front
- Measure **satisfaction** throughout the process
- Define system **data** elements
- Assure **agreement** with client (sign off)

* Gause, D. and G. Weinberg, *Are Your Lights On? How to Know What the Problem Really Is,* 2nd ed. New York: Dorset House Publishing, 1990.

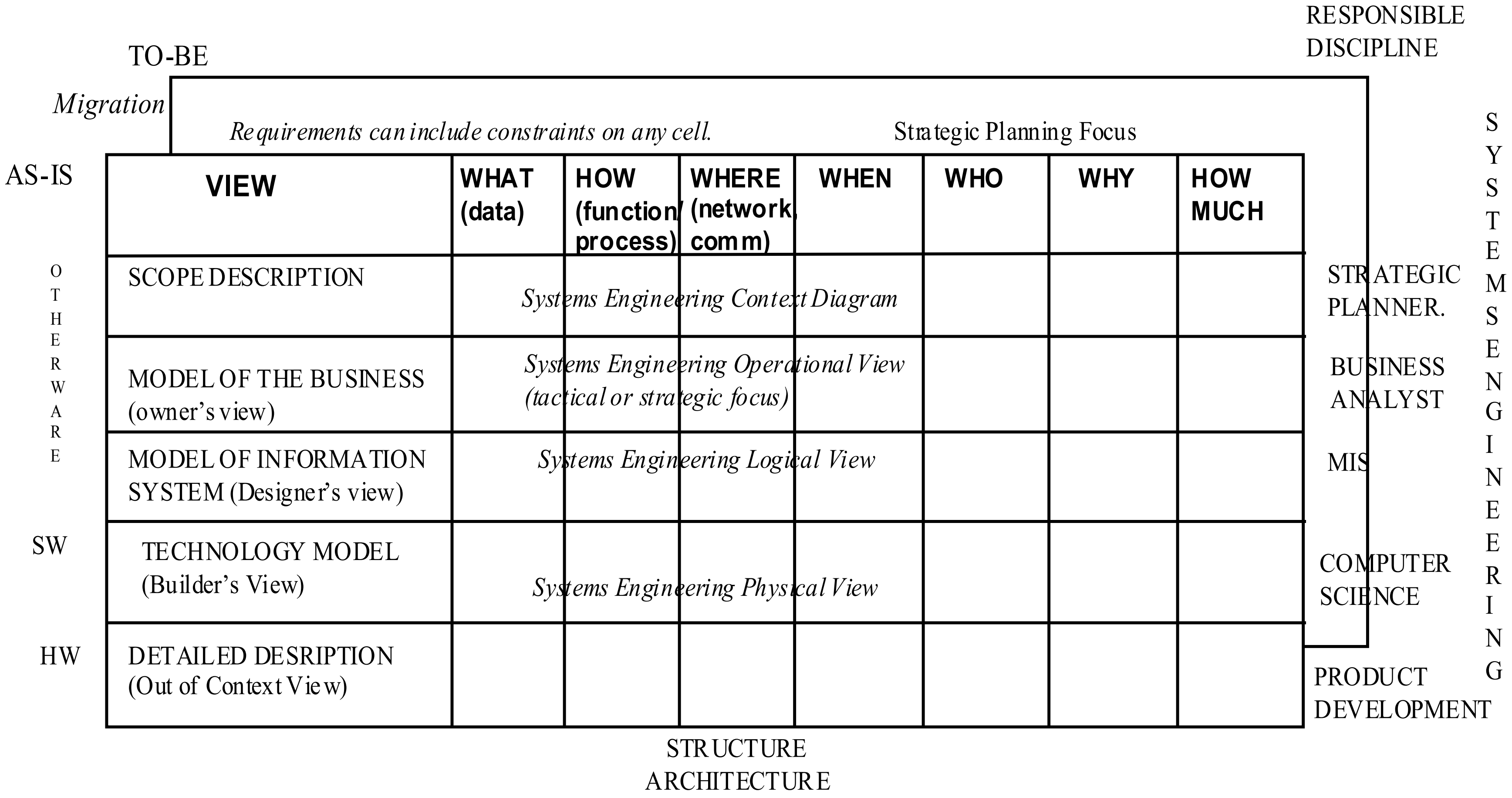
* Gause, D., and G. Weinberg, *Exploring Requirements: Quality Before Design*, New York: Dorset House Publishing, 1989.

** Gause, D., Personal communication, 1998.

Cross-Discipline Research Focus and Applicability

- Computer science
- Management information systems
- Product design and manufacturing
- Physical structure architecture
- Systems engineering

Mapping of Disciplines to Modified Zachman Framework (1987*)



TO-BE

Migration

AS-IS

Requirements can include constraints on any cell.

Strategic Planning Focus

	VIEW	WHAT (data)	HOW (function/ process)	WHERE (network, comm)	WHEN	WHO	WHY	HOW MUCH	RESPONSIBLE DISCIPLINE
OTHERWARE	SCOPE DESCRIPTION	*Systems Engineering Context Diagram*							STRATEGIC PLANNER.
	MODEL OF THE BUSINESS (owner's view)	*Systems Engineering Operational View (tactical or strategic focus)*							BUSINESS ANALYST
	MODEL OF INFORMATION SYSTEM (Designer's view)	*Systems Engineering Logical View*							MIS
SW	TECHNOLOGY MODEL (Builder's View)	*Systems Engineering Physical View*							COMPUTER SCIENCE
HW	DETAILED DESRIPTION (Out of Context View)								PRODUCT DEVELOPMENT

SYSTEMS ENGINEERING

STRUCTURE ARCHITECTURE

*** Zachman, J. "A Framework for Information Systems Architecture," IBM Systems Journal, 1987, pp. 276-292**

Lessons Learned Approach

- Selected successes and failures
- Documented in independent case studies
- Process patterns identified applicable to any problem
- Patterns applied to additional case study as validation

Why Study Past Successes and Failures?

"In the normal pursuit of a goal over time, successes and failures lead to patterned ways to do things."
Exploiting Chaos [Dave Olson, 1993]

"Case histories of failures and strategies for failure avoidance provide an invaluable source of information about design that has generally not been exploited in more than an ad hoc way." *Design Paradigms: Case Histories of Error and Judgment in Engineering* [Henry Petroski, 1994]

- **Case study approaches can be applied to provide lessons learned and evidence of association of RE process pattern recommendations with an increase in probability of success.**

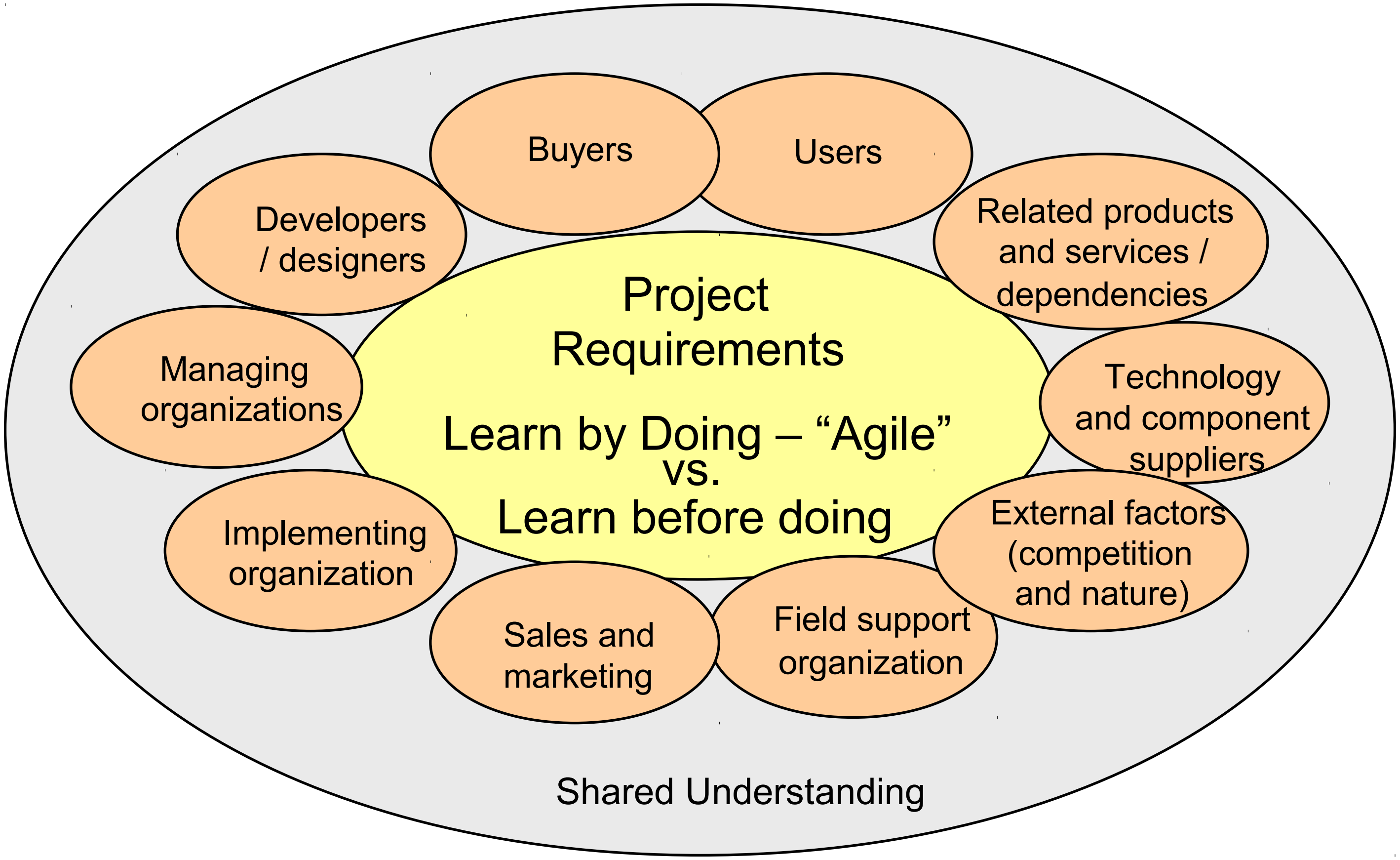
Best Practices for Exploring Requirements

- Define the problem
- Understand goals/strategies/objectives
- Define scope
- Define solution context
- Identify critical stakeholders
- Identify assumptions

Best Practices for Exploring Requirements, Cont.

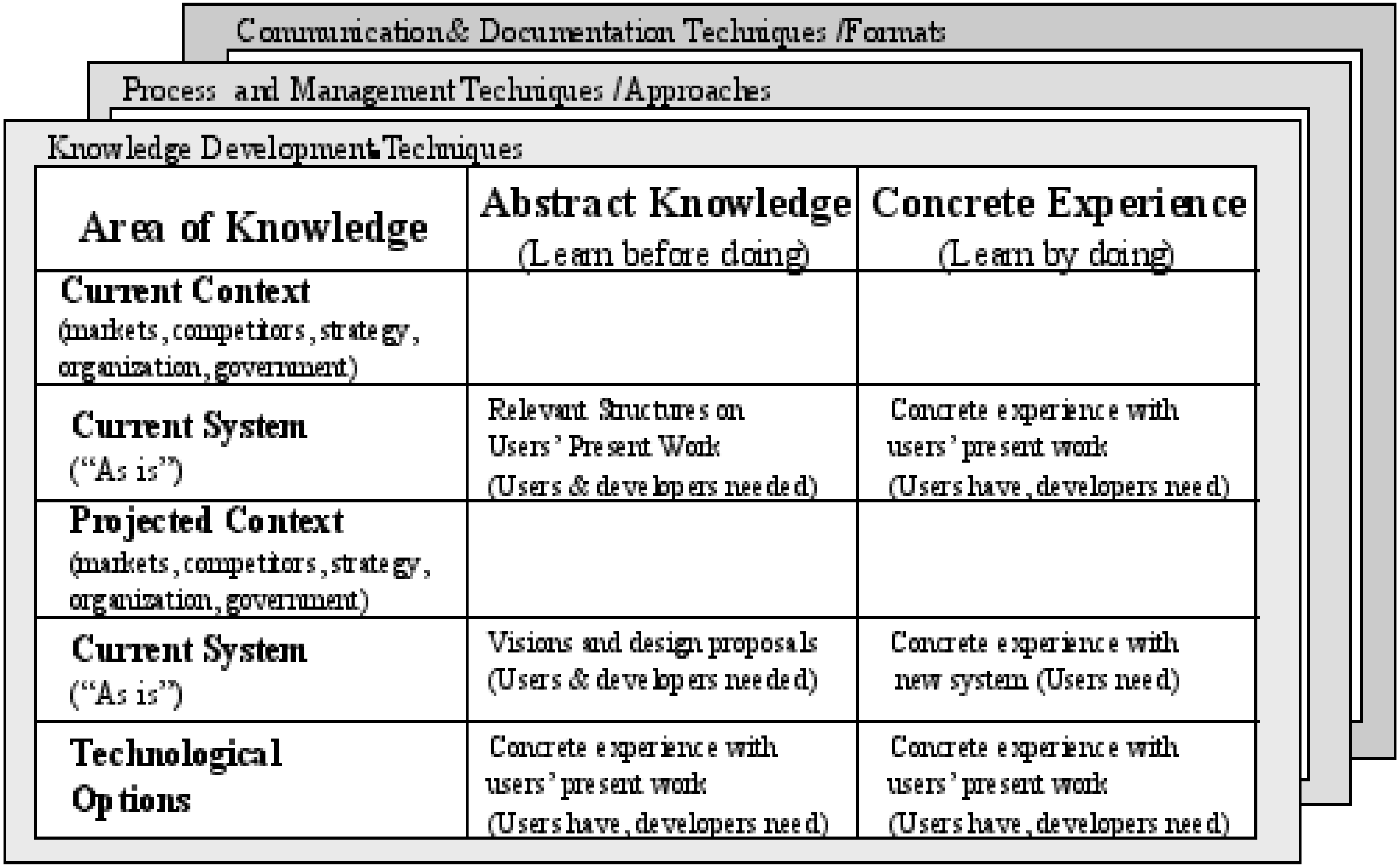
- Ask context-free questions
- Determine evolution and change requirements
- Execute explicit user inclusion strategy and plan
- Manage key stakeholder expectations and assumptions
- Observe users with product / system
- Obtain agreement with client

What are the Benefits?
Shared understanding across the RE Chain


Buyers
Users
Developers / designers
Related products and services / dependencies
Project Requirements
Learn by Doing – "Agile"
vs.
Learn before doing
Managing organizations
Technology and component suppliers
Implementing organization
External factors (competition and nature)
Sales and marketing
Field support organization
Shared Understanding

Shared Understanding through RE Framework Enables Cross-Discipline Collaboration

RE Process Patterns and Knowledge and Understanding Areas



Communication & Documentation Techniques /Formats

Process and Management Techniques /Approaches

Knowledge Development Techniques

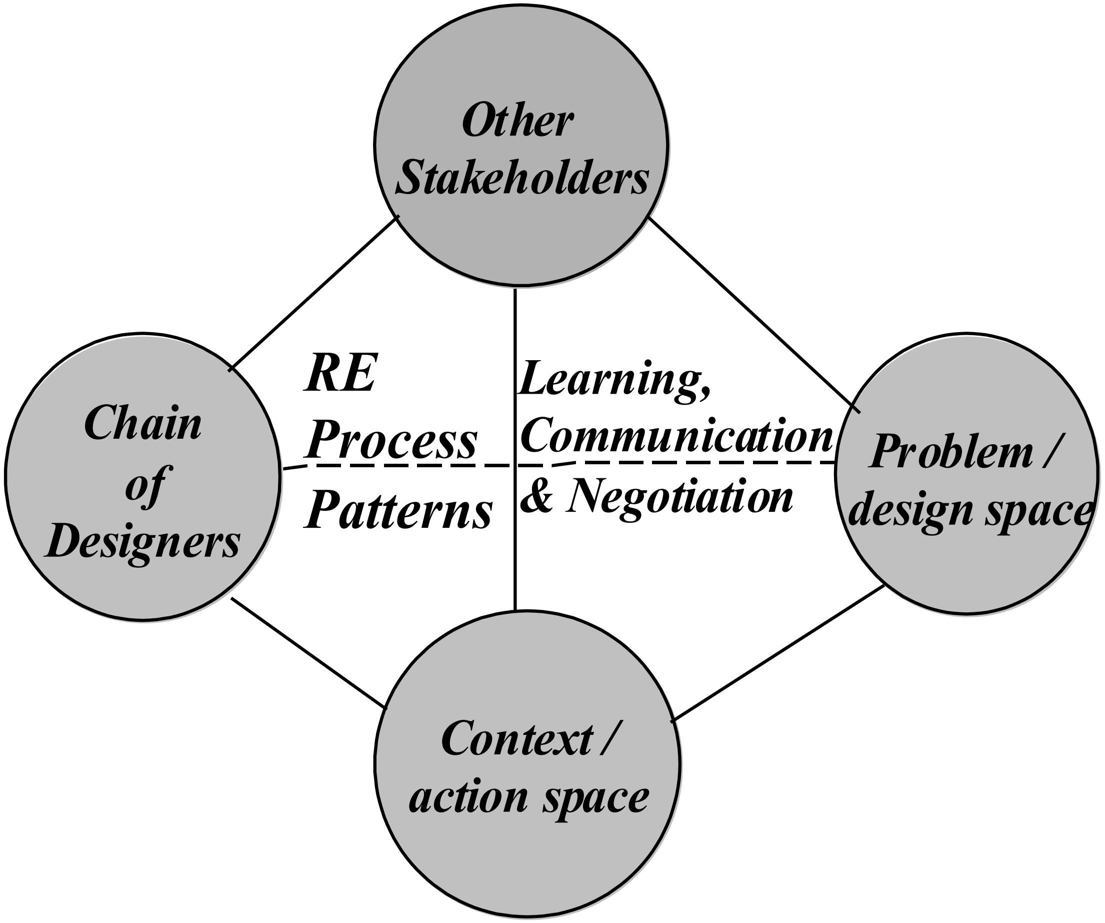
Area of Knowledge	Abstract Knowledge (Learn before doing)	Concrete Experience (Learn by doing)
Current Context (markets, competitors, strategy, organization, government)		
Current System ("As is")	Relevant Structures on Users' Present Work (Users & developers needed)	Concrete experience with users' present work (Users have, developers need)
Projected Context (markets, competitors, strategy, organization, government)		
Current System ("As is")	Visions and design proposals (Users & developers needed)	Concrete experience with new system (Users need)
Technological Options	Concrete experience with users' present work (Users have, developers need)	Concrete experience with users' present work (Users have, developers need)

Expansion of Macaulay, 1996, adaptation of Kensing and Munk-Madsen

Agile Evolution

- "Agile software development is a group of software development methods in which requirements and solutions evolve through collaboration between self-organizing, cross-functional teams" (Wikipedia)
- Incorporates learn by doing approach
- Joe Justice, ScrumInc, as one agile approach

Processes Facilitate Understanding



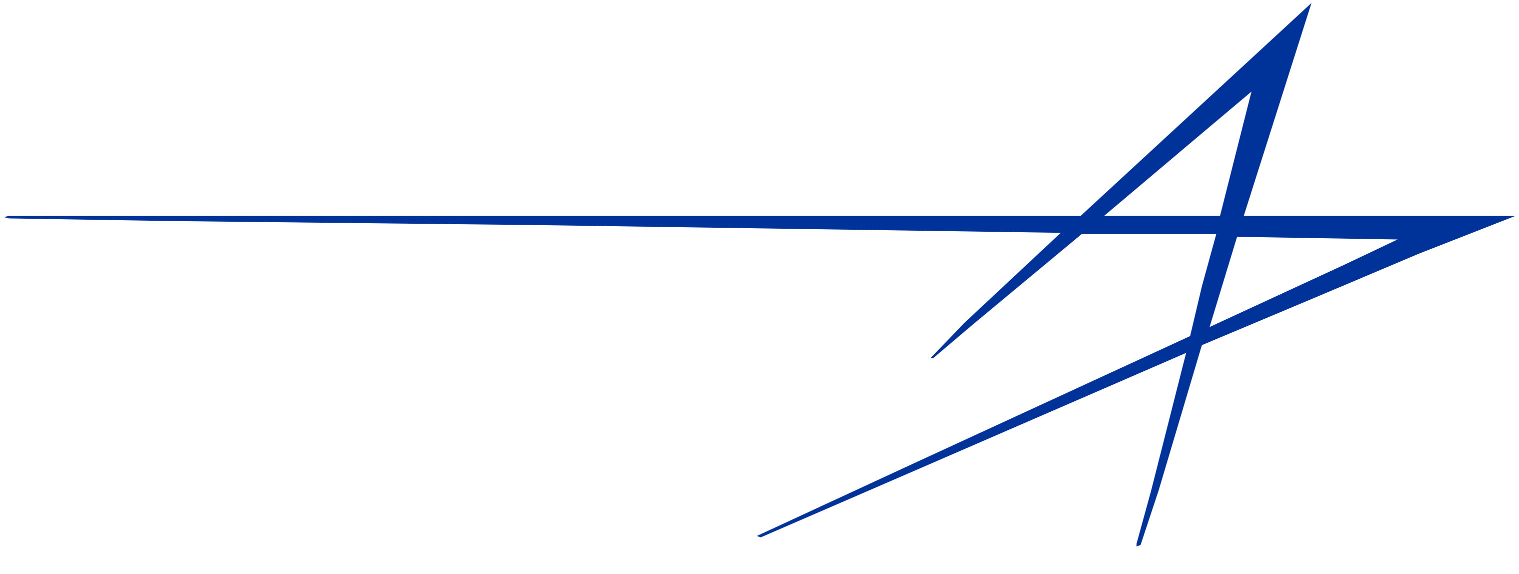
Processes Facilitate Learning, Communication, and Negotiation about and among Nodes of Tetrahedron

Healthcare Application Discussion

- Cross-domain example with enterprise cost reduction objectives
- Application of performance based logistics concepts
- Parallels between product sustainment incentives and people sustainment challenges
- Optimal supply chain mix and personnel
- Part of a healthcare reforms for a sustainable future

Global Business Challenges Application

- Challenge domain mental models and assumptions
- Apply cross-discipline perspectives for innovation
- Adapt requirements process patterns to address challenges



Best Practices for Exploring Requirements (1-6)

- ***Define the problem***

- ***Understand goals/strategies/objectives***

- ***Define scope***

- **Carefully use naming conventions throughout**
- **Iterate through each orthogonal concept**
- **Define domain or class of problem and approach**

Best Practices for Exploring Requirements (7-12)

- ***Define solution context***
- ***Identify critical stakeholders***
- ***Identify assumptions***
- **Identify interfaces / interoperability requirements**
- **Identify use scenarios**
- **Identify failure modes and test cases**

Best Practices for Exploring Requirements (13-17)

- ***Ask context-free questions***
- ***Determine evolution and change requirements***
- ***Execute an explicit user inclusion strategy and plan***
- **Analyze and prioritize need in terms of key features, functions, objects, and attributes**
- **Identify non-functional requirements**

Best Practices for Exploring Requirements (18-22)

- ***Manage key stakeholder expectations and assumptions***
- **Develop visualization / prototype / model**
- **Do early performance modeling on concept**
- **Document specification of problem to be solved**
- **Manage requirements baseline**

Best Practices for Exploring Requirements (23-27)

- ***Observe users with product / system***
- **Maintain traceability from requirements to solution**
- **Document and manage implementation constraints and preferences**
- **Review design history**
- **Develop / select reusable component requirements (product patterns)**

Best Practices for Exploring Requirements 28-32

- ***Obtain agreement with client***
- **Identify project management approach (management patterns)**
- **Document standard RE processes for discipline (process patterns)**
- **Use metrics to monitor satisfaction and ambiguity**
- **Train professionals in requirements engineering**