The Shape of Uncertainty in Systems Engineering Peer Reviews: Requirements Versus Design Activities

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Uncertainty in Organization Theory

- Neoclassical Economics
  - No uncertainty, optimal decision-making
  - All options identified
  - Utility maximization
- Organizational Economics (Coase, 1930s)
  - Why are transactions organized in hierarchies rather than markets?
  - Role of uncertainty and efficiency of "administration by fiat" for certain kinds of transactions
- March & Simon (1950s)
  - Costs of resolving uncertainties too high
  - Bounded rationality, satisficing
- Institutional Economics (1970s)
  - Transaction Cost Economics (TCE) – markets, contracts, hierarchies
    - Opportunism, uncertainty, asset specificity
  - Agency Theory
    - Adverse selection (observability of beliefs)
    - Moral hazard (observability of behaviors)

Uncertainty in Organization Theory (cont.)

- Stinchcombe (1980s)
  - Uncertainty X importance –> unique organizational structures
- New Institutionalism
  - Legitimacy
  - Stakeholders rely on proxies for organization's status
- Organizational Culture
  - Strong cultures – reduces uncertainty from top-down
  - Negative effects (politics, ambiguity, anxiety)

Uncertainty in System Design

- System Development Lifecycle (SDLC)
  - What (requirements)
  - How (design)
  - Uncertainties expected to be resolved prior to next step
- Agile
  - Explicit acknowledgment that uncertainties may not be adequately resolved prior to next step
  - Iterative approach adding more detail at each iteration
- "Cone of uncertainty"
  - Market, technology, project (scope, budget)
  - Uncertainty attenuates through time
- Quality Control
  - CMMI, Six Sigma apply Statistical Process Control (SPC) principles to monitor variation in <u>design processes</u>

Original Research Question

- What uncertainties are represented in the systems engineering design activities as reflected in engineering peer review artifacts?

Data Set

- Defense Contracting Company in New England
  - Trident fire control systems, D5 missile guidance systems
- ~1200 employees, mostly systems engineers
- 21 peer reviews
- Approximately 157 comments per review on average
- Applicable data fields
  - Comment
  - Resolution
- Access data base
- Comments phrased as <u>questions</u>

Method

- Qualitative (ethnographic)
- “coding” in database
- Allows patterns to emerge from data

Analysis

- <u>Objects</u> of uncertainty?
- Emergent codes (in order of volume)
  - *Document*
    - Template/rules
  - *Ontology*
    - legacy and future system (requirements/design)
  - *Language*
    - grammar, acronyms, labels, words
  - *Linking*
    - tracing/allocating between documents

Analysis (cont.)

- Discussion
  - Complexity of the documentation process
  - Ontology – what the future system needs to be
    - Philosophy of technology only deals with existing systems
  - Language
    - Localized language that is in flux
      - Wittgenstein ("Linguistic Turn" in social sciences)
        - Tracticus (single objective building-blocks)
        - Philosophical Investigations (contextual, understanding)
        - Language games, family resemblances

Subsequent Analysis: Requirements versus Design

- Expectation was that the uncertainty over the ontology (future system) would separate cleanly into
  - What? For requirements specifictions
  - How? For design documents
- Surprised that these kinds of uncertainties were found in roughly equal volume for both requirements and design

Ontology of a future system

- Extremely complex system
  - Elephant analogy
- As expected, some uncertainties are tied to requirements or design
- However much of the uncertainty revolves whether reviewing requirements or design tend to center on the same things
  - What *is* the system given what has been documented or agreed upon by the customer, technical authorities, and subject-matter experts?
- Documentation intends to capture the baseline system, but a great deal of it exists in shared political and social understandings

Discussion

- Professionals draw from an abstract body of knowledge to diagnose and treat/solve problems
- Engineers learn various methods for requirements definition and design/architecture
- But for highly complex systems, it is knowledge of the uniqueness of the system that is most valuable and imposes the greatest uncertainty
- Systems engineering as a unique kind of profession
  - Both *create* and need to *understand* highly unique complex systems

Discussion (cont.)

- Systems engineering as a unique kind of profession

Uniqueness		low Complexity	high Complexity
	high	• HW engineering • SW engineering	• Systems engineering • Some sciences
	low	• Non-professional occupations • E.g., trades	• Law • Medicine • Natural Science

Questions?