# Standardized Process as a Tool for Higher Level Systems Thinking

**Presenting Author:**
Caroline Twomey Lamb
Doctoral Research Assistant
Massachusetts Institute
of Technology
cmtwomey@mit.edu

**Research Advisor:**
Donna H. Rhodes
Senior Lecturer
Massachusetts Institute
of Technology
rhodes@mit.edu

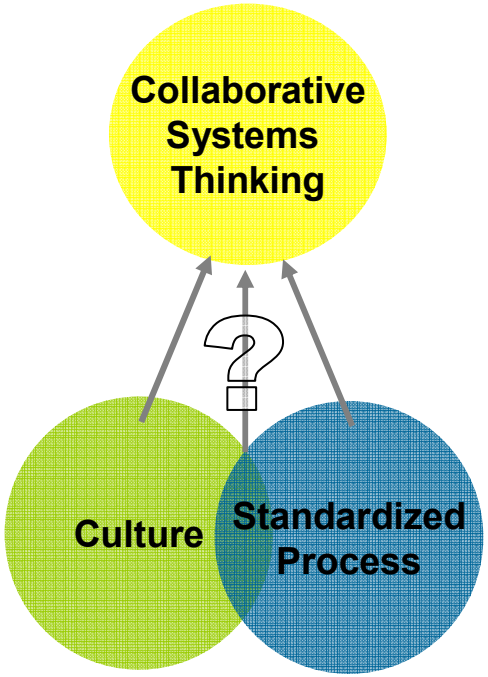
INCOSE 2007
Systems Engineering: Key to Intelligent Enterprises
June 27, 2007
Caroline Twomey Lamb ©

# Agenda

- Research Question
- Motivation
- Objectives
- Prior Art
- Constructs and Methods
- Pilot Interview Results
- Moving Forward

# Research Question

How do standard processes and culture support the development of systems thinking with engineering teams?



# Why process and culture?

- People, process and technology are the three components to be addressed when improving SE practices. (Jansma and Jones, 2006)
- Culture, structure and standard process are important factors in team performance. (Lee, et.al., 2003)
- Recent emphasis on process maturity.
- Using well-documented and successful processes does not guarantee success. (Spear and Bowen, 1999; Dougherty, 1990)
- Address two of identified contributors to development of systems thinking in individual engineers (Davidz, 2006)
  - Specific individual traits
  - Supportive environment
  - Experiential learning

*We can lick gravity, but the paperwork's a bit tougher.*

**-Werhner von Braun**

# Motivation

- Aging demographics within engineering
  - Average age of engineer within US = 45 (NA Report, 2006)
  - Average age of engineer at NASA = 49 (Lemos, 2006)
- Increasing system complexity and development time
  - 48 military aircraft program starts in 1950's; only 7 in 1990's (Murman et.al., 2002)
  - Similar trends in commercial airframes, manned spaceflight programs and planetary probes.
- Systems thinking an identified skill shortage within aerospace industry

- Prior systems thinking research at level of individual engineer (Davidz, 2006; Frank, 2000)
- Research on team-based design thinking focuses on undergraduate engineering students
- Literature likening people and process as social and technical components of the design system (Pajerek, 2000)

# Research Objectives

- Operationalize the construct of collaborative systems thinking
  - Pilot interviews with experts
  - Literature on systems thinking
  - Literature on design thinking in teams
- Identify enablers and barriers to collaborative systems thinking
  - Focus on culture and process
- Contribute to practice by relating “best practices” to cultural contexts

# Prior Art

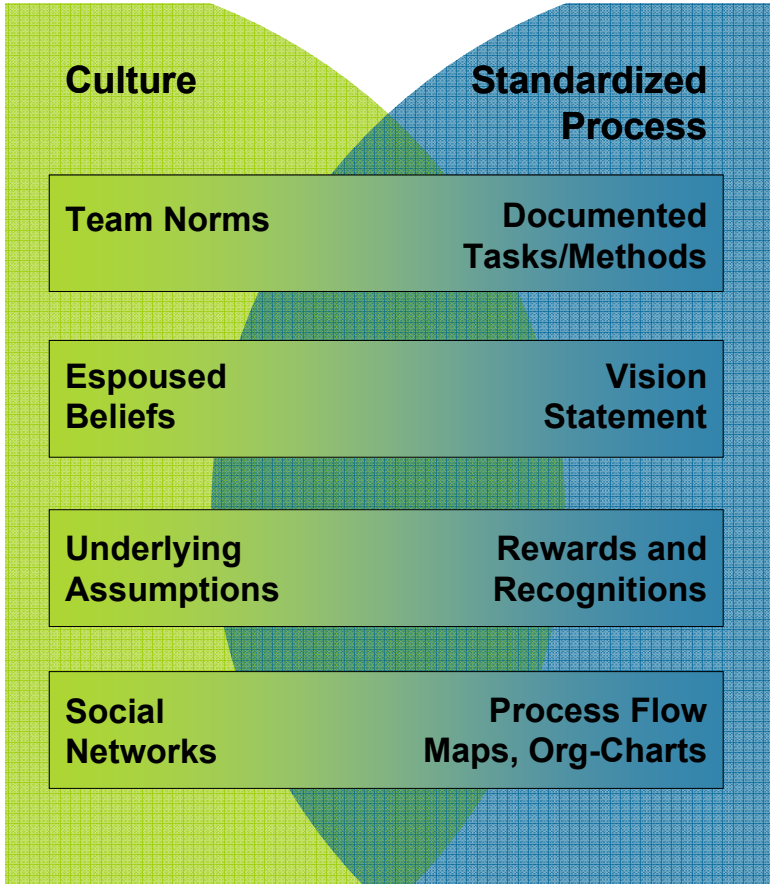
- Systems Thinking as the *Fifth Discipline* (Senge, 2006; Ackoff, 2004)
  - Emphasis on holistic thinking as way to elucidate patterns
  - Based on field of systems dynamics
- Systems Thinking within Engineering
  - Framework for seeing patterns and interrelationships; for seeing the whole (Frank, 1999)
  - The "analysis, synthesis, and understanding of interconnections, interactions, and interdependencies" (Davidz, 2006)
- Design Thinking (Dym, et.al., 2005)
  - Design is a social process
  - Successful teams cycle between divergent and convergent stages
- SE Process (Sheard, 2000; Pajerek, 2000)
  - Should reflect the way an organization works
  - Focus on interactions among individuals and teams
  - Should not be developed without considering the individual and team users

# Research Constructs

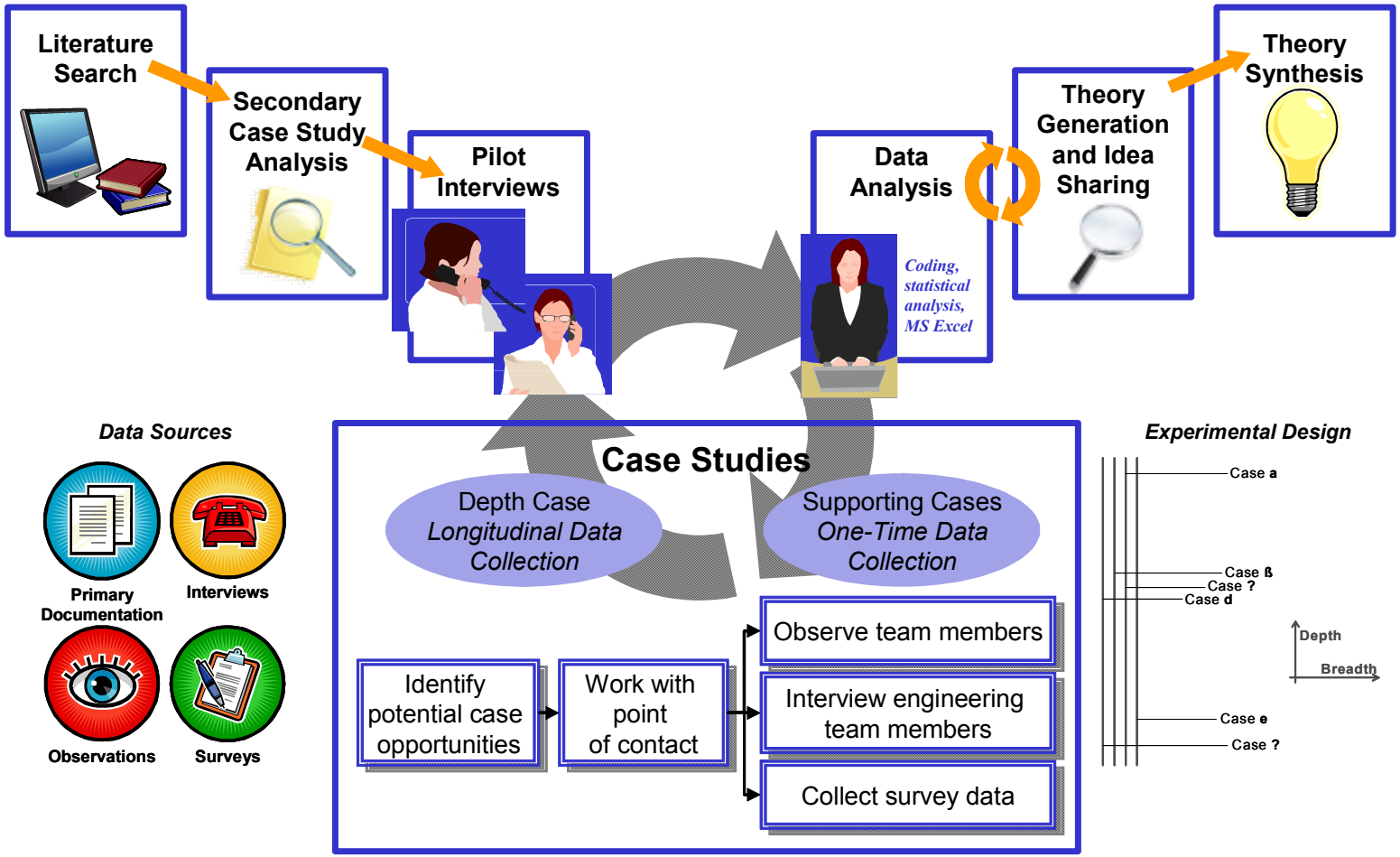
- Team-Based Systems Thinking
  - Emphasis on interconnections, interactions and interdependences within technical, social and temporal spheres (Davidz, 2006)
  - Tendency to communicate in abstractions, using intuition to assign meaning rather than relying solely on sensory inputs (O'Brien, et.al. 1998)
  - Concept of cycling between divergent and convergent thinking (Dym, et.al., 2005)
  - Ability to leverage the various "languages of design" (Dym, et.al., 2005)
  - Termed ***Collaborative Systems Thinking*** to address discriminant validity
- Culture
  - Behavioral norms, espoused beliefs, underlying assumptions (Schien, 2004)
  - Social structure
- Standard Process
  - Documented sequences of tasks executed during engineering design
  - Interested in design stage of lifecycle
- Teams (Hackman, 2002)
  - Common goals
  - Collective action
  - Clear membership

# Research Framework

- Grounded theory research
  - Data collection using surveys, interviews, and primary documentation
  - Validation addressed in research design-5 types of validity (Valerdi and Davidz, 2007)
- Levels of Analysis
  - Teams of engineers
  - Individual team members
- Variables of interest
  - Team maturity
  - Stage in design process
  - Team composition
- Research tool goals
  - Team norms
  - Level of process compliance
  - Some amount of interaction data
  - Measure systems thinking characteristics present in team interactions



# Research Methods



# Pilot Interview Results

- Collaborative systems thinking needs product orientation
  - Teams produce products
  - Product, not process is end-goal
- Divergent opinions on team composition
  - Teams of systems thinkers
  - Teams led by systems thinkers
  - Team of non-systems thinkers expressing systems thinking properties through interactions
- Agreement that culture and process present both enablers and barriers to collaborative systems thinking

# Pilot Interview Results, cont

Team culture considerations

- Enablers
  - Willingness to ask and answer questions
  - Ability to engage in divergent and convergent thinking
  - Identifying with product
- Barriers
  - Team polarization
  - Misalignment between team goals and individual reward systems
  - Identifying with discipline
  - Failure to consider social dimensions when forming teams
  - Resistance to change

# Moving Forward

- Finalize case study design
  - Finalize case study tools
  - Conceptualizing ways to analyze and communicate results
- Identify cases
  - This is where your help is appreciated
  - Collect and analyze data
- Return next year with results

# Selected References


- Davidz, Heidi, Enabling Systems Thinking to Accelerate the Development of Senior Systems Engineers, Doctor of Philosophy in Engineering, Massachusetts Institute of Technology, Cambridge, MA, 2006.
- Dougherty, Deborah, "Understanding New Markets for New Products", *Strategic Management Journal*, 11, 1990, pp 59-78.
- Dym, C., et.al., "Engineering Design Thinking, Teaching, and Learning", *Journal of Engineering Education*, 94:1, 2005, pp 103-120
- Frank, M., "Engineering Systems Thinking and Systems Thinking", *Systems Engineering*, 3:3, 2000, pp 163-168
- Jansma, P.A. and Jones, R.M., *Advancing the Practice of Systems Engineering at JPL*, Proceeding of Aerospace 2006, March 2006.
- Lee, M., et.al., The Conceptual Framework of Factors Affecting Shared Mental Models
- Lemos, Robert, "NASA Fights Premature Graying", *Wired News*, http://www.wired.com/news/technology/space/0,71822-0.html, (Accessed December, 2006).
- Murman, E., et.al., *Lean Enterprise Value*. Palgrave, New York, NY, 2002.
- National Academies' Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future, 2005.
- Pajerek, L., "Process and Organizations as Systems: When the Processors are People, Not Pentiums", *Systems Engineering*, 3:2, pp 103-111
- Sheard, S., et.al., Overcoming Barriers to Systems Engineering Process Improvements, Systems Engieering, 3:2, 2000, pp 59-67
- Spear, S. and Bowen, H.K., "Decoding the DNA of the Toyota Production System", *Harvard Business Review*, Sept-Oct, 1999, pp 96-106.