Collaborative Systems Thinking:

The role of culture and process in promoting higher-level systems thinking within aerospace teams

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Agenda

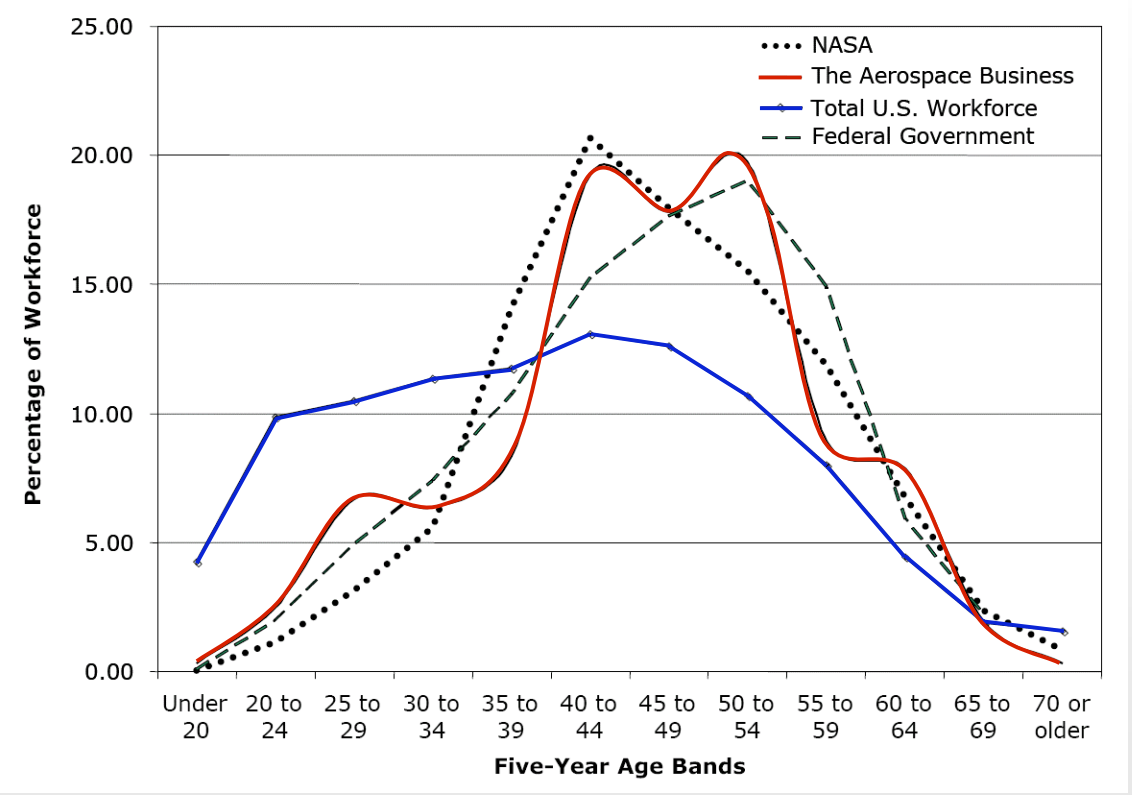
- Researcher Introduction
- Motivation
- Research Questions
- Expected Contributions to Industry
- How You Can Help
- Timeline for Completion

Researcher Introduction

- Caroline Twomey Lamb
  - S.B. Aeronautics and Astronautics, 2003
  - S.M. Aeronautics and Astronautics, 2005
- Research Interests
  - Propulsion
  - Systems engineering
  - Understanding how good design happens
  - Practical execution of engineering
- Experience
  - Composites manufacturing and testing
  - Fan design risk mitigation
  - Wind tunnel test design and execution
  - Numerical methods (e.g. Monte Carlo analysis, MISES)
- Industry Involvement
  - AIAA Student Liaison to Board of Directors
  - AIAA Public Policy Committee
  - AIAA Young Professional Committee
  - AIAA Diversity Taskforce

Aerospace Industry is Facing a Skills Crisis

- 25% of industry eligible for retirement within next 5 years
  (Gathering Storm 2005)
- Key competencies lost with each retirement
- Systems thinking skill shortage
  (Stephens 2003)



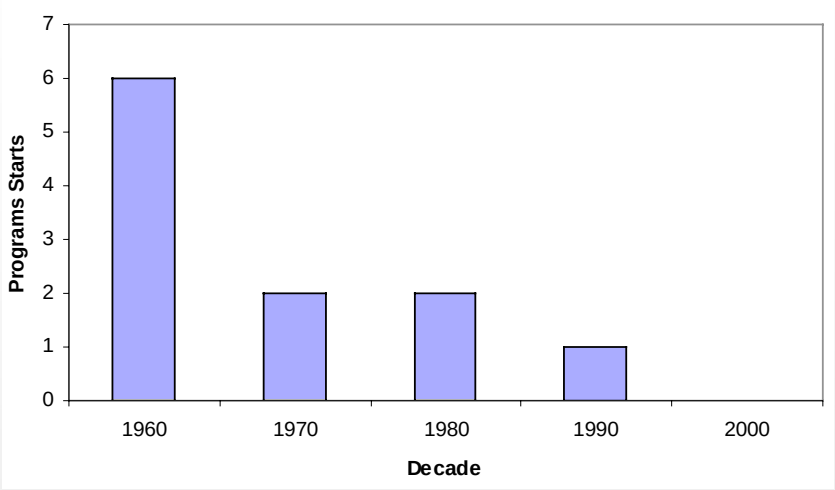
Engineering Demographics in the US
(Future US Space Workforce 2005)

N. Augustine and The Committee on Prospering in the Global Economy of the 21st Century. Rising Above the Gathering Storm. Technical report, National Academies, 2005.

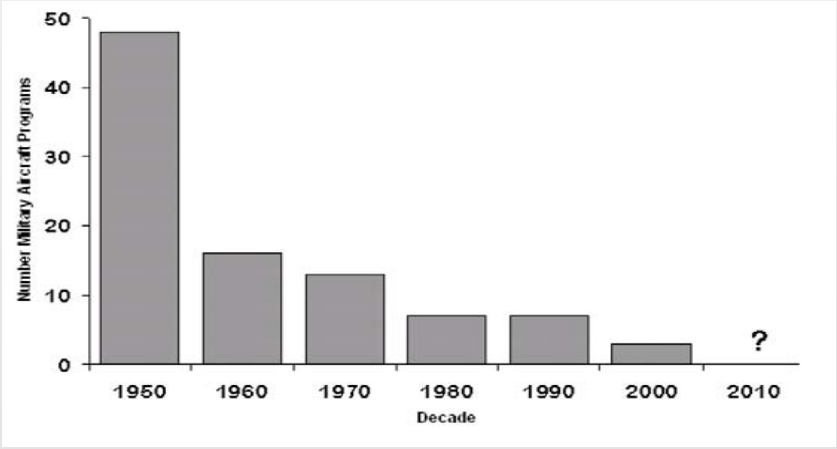
D. Black, D. Hastings, and the Committee on Meeting the Workforce Needs for the National Vision for Space Exploration. Issues Affecting the Future of the U.S. Space Science and Engineering Workforce: Interim report, 2006.

R. Stephens. Ensuring Aerospace Skills of the Future. In *Proc. AIAA/ICAS International Air and Space Symposium and Exposition: The Next 100 Years*, Dayton, OH, August 2003.

Fewer Opportunities for System-Level Skill Development



Manned Spacecraft Program Starts by Decade (Neal et al 1995)



Manned Fighter Program Starts by Decade (Murman et al 2002)

- Fewer program starts
  - Manned fighters
  - Commercial aircraft
  - Manned space vehicles
- Longer development times
  - Fewer programs experienced in career
  - Impact career development
- Reduction in R&D budgets
  - Defense
  - NASA aeronautics

E. Murman et.al. *Lean Enterprise Value: Insights from MIT's Lean Aerospace Initiative*. Palgrave, New York, NY, 2002.
V. Neal, C. Lewis, and F. Winter. *Spaceflight*. Macmillan, New York, NY, 1995.

Importance of Teams and Systems Thinking

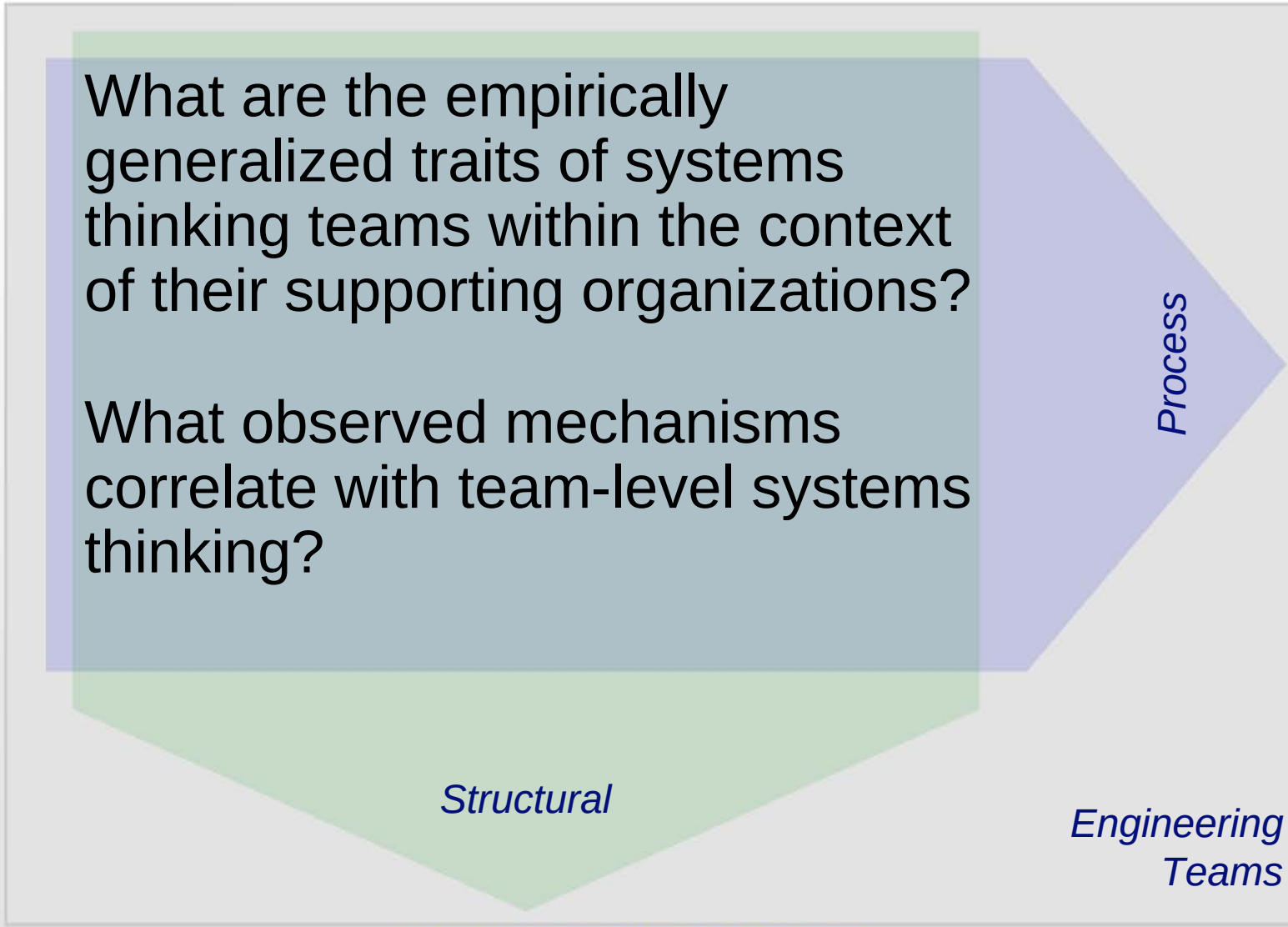
- Engineering is socio-technical activity
- Design occurs at team level
  - Technical, policy and demographic pressures to use teams
  - Multidisciplinary teams now common early in design
- Understanding systems thinking at the team level becomes important

Logistical Complexity	Physical Complexity	Design Space Complexity
– Systems as hierarchy of components – Maintaining awareness of 'whole' – Complex interfaces – Opportunities at interfaces – Complexity in inter- and intra- team interactions	– Large number of components – Static complexity: pieces fitting together – Dynamic complexity: Interactions, emergent behavior	– Exploration of design space – Requirements negotiation – Identification of 'sweet spots' within design space

Research Questions

I. What are the empirically generalized traits of systems thinking teams within the context of their supporting organizations?

II. What observed mechanisms correlate with team-level systems thinking?



Systems Thinking within Engineering Teams

What is systems thinking?

Systems thinking is utilizing modal elements to consider the componential, relational, contextual, and dynamic elements of the system of interest (Davidz, 2006)

What is collaborative systems thinking?

Collaborative systems thinking is an emergent behavior of teams resulting from the interactions of team members and utilizing a variety of thinking styles, design processes, tools, and languages to consider systems attributes, interrelationships, context and dynamics towards executing systems design. (Lamb, 2008)

H. Davidz. *Enabling Systems Thinking to Accelerate the Development of Senior Systems Engineers*. PhD thesis, Massachusetts Institute of Technology, Cambridge, Massachusetts, 2006.
C. Lamb Systems Thinking as an Emergent Team Property: Ongoing research into the enablers and barriers of team-level systems thinking. IEEE Systems Conference, Toronto, Canada, April 2008 (forthcoming)

Research Framework

- Four constructs to frame inquiry
  - Team
  - Standard Technical Process
  - Culture
    - Organizational culture
    - Engineering culture
    - Team norms and behavior
  - Collaborative systems thinking

Map to enablers from past research on systems thinking

- Individual Characteristics
- Experiential Learning
- Supportive Environment
- Systems thinking

- Use of Mixed Qualitative/Quantitative Research Methods
  - Techniques and tools borrowed from social science
  - Similar to past LAI, Aero-Astro, and ESD theses
  - Uses qualitative and quantitative data types to describe systems thinking within teams

Expected Contribution to Field

1. An operational definition characterizing team-level systems thinking
   - New term: *Collaborative Systems Thinking (CST)*
   - New way for conceptualizing systems thinking
   - Implications for training/workforce development and skill deployment
2. A set of heuristics for enabling CST
   - Context framed effective practices
   - Grounded in observations of aerospace teams, linked to current industry practices
3. Descriptive theory explaining influence of organizational culture and standard technical processes in enabling CST
   - Explanatory theory based on observations
   - Links team context to CST
   - Identify future areas of research towards forming prescriptive theory
4. Research outcomes may influence:
   - Workforce development
   - Design procedures for fielding large-scale complex systems
   - Enterprise architecture

Summary of Pilot Interviews

Summary of key point from six structured interviews and dozens of unstructured conversations

- Effective communication is necessary
  - Good communication uses the multiple language of design (sketches, equations, models, simulations, etc)
  - Evidence supports role of information sketching in improving early communication and improving final design
- Use of multiple thinking styles: convergent and divergent
  - As problem solvers, engineers excel at convergent thinking
  - Divergent thinking predicated on culture that promotes early critical discussion without fear of criticism
- Product orientation solidifies team objectives
  - Clear goals enable better communication and teamwork
  - Exciting, motivating goals, get people to think and act outside of the box
- Engineering culture is its own worst enemy
  - Engineering archetypes affirm individuals, technology considerations over social, and procrastination
  - Norms limit communication and result in schedule pressure
- Culture and process are important elements in CST: Validation of research direction

How You Can 'Help Me Help You'

- Case-based research
- Require 15-20 cases to explore phenomena of collaborative systems thinking
- Deadline of July/August for completion of case work

Case Requirements

- Aerospace teams
- Multiple disciplines
  - E.g. structures, systems, electrical, mechanical, aerodynamic
- Design stage
  - Conceptual design
  - Detail design
- Espoused systems thinking capability
- Industry Sector
  - Commercial
  - Space
  - Military
  - General Aviation
- Systems level

Case Execution

- Individual Case Timeline
- Day 1
  - Introduce myself and research
  - Brief presentation/Q&A session
  - Team survey
- Day 2
  - Interviews with team members
- Day 3
  - Complete team interviews
  - Manager/supervisor interviews
- Maximum 2 hour time commitment/individual
- Multiple cases in one week if at same organization and location
- Follow up at later date to share results

Questions\Comments?