Presentation Outline

- Motivation
- Key questions
- Research design
- Findings
Motivation

• **Goal:** Guidelines for reducing defense aerospace product cost & development cycle time

• **Literature:** Engineering Changes lead to increased cost & cycle time
  – How do these results apply in defense aerospace product development?

• **Context:** Defense aerospace
  – Different communities

Note: Diagram adopted from Ellis & Ludwig’s *Systems Philosophy*, & Blanchard’s *System Engineering Management.*
Class I Engineering Changes: Development & Production Phases

- Impacts on product form, fit, or function
- Functionalities or physical config different before/after engineering change
- Visible to all communities
- Significant effort to process an engineering change
Key Questions

- What are the major causes and impacts of engineering changes?
- What are practices that would help reduce undesirable engineering changes?
- What might the customer do to help reduce undesirable engineering changes?
Research Design

- **Method**
  - Case studies focusing on 3 major defense aerospace programs

- **Database**
  - Studied 118 engineering changes
    - Engineering Change Proposal (ECP) contractor submittals
    - Program A: 60, Program B: 31, Program C: 27
    - Each set comprehensive for each program until 11/17/1997
    - Supporting documents & written background information
  - Conducted formal & informal interviews
    - Personnel interviewed
      - Government (24)
      - Contractors (29)
    - Purpose of interviews
      - Obtain perspectives on programs & engineering changes
Overview of Case Studies

- **Program A** - Major aircraft subsystems upgrade
  - Modification program to integrate 4 electronics mission subsystems
  - Single prime contractor
  - No IPTs during development

- **Program B** - Major electronics subsystem upgrade
  - Modification program - technology upgrade
  - Somewhat dependent on Program A
  - Two primes during development, customer as integrator
  - No IPTs during development

- **Program C** - Major aircraft development & production program
  - New program, single prime contractor
  - Integrate Program A basic electronics mission subsystems into aircraft
  - Incorporate some newer technology
  - IPTs during development
Primary Causes of Engineering Changes

Across 3 programs, based on all engineering change data (118)

<table>
<thead>
<tr>
<th>Causes</th>
<th>% of Engineering Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reqmts definition issues</td>
<td>19.5%</td>
</tr>
<tr>
<td>Changes in needs</td>
<td>14.4%</td>
</tr>
<tr>
<td>Fix deficiencies</td>
<td>18.6%</td>
</tr>
<tr>
<td>Govt-prime interactn</td>
<td>11.0%</td>
</tr>
<tr>
<td>Program-to-program interactn</td>
<td>7.6%</td>
</tr>
<tr>
<td>Technology change</td>
<td>19.5%</td>
</tr>
<tr>
<td>Documentation changes</td>
<td>9.3%</td>
</tr>
</tbody>
</table>

- Comprehensive data set identified 3 dominant causes
- Added two more based on data normalizations
Across 3 programs, based on all engineering change data (118)

- Combinations of dominant causes are different across programs
- Conventional wisdom would predict major program schedule delay in Program C. Is the prediction correct?
Program A Dominant Causes

Program Key Characteristics
- Dominated by complex, modified OTS system integration
- Supplier of OTS system involved in development early
- Many redesigns on OTS system
- Recent producibility & reliability problems
- Other mission systems evolved by introducing newer technology

Total Program A engineering changes: 60
Program B Dominant Causes

Program Key Characteristics

- Subsystems suppliers involved early in design
- Two primes during development
  - Reqmts-related questions remained despite frequent contacts
  - 2 engineering changes per ECP issue
- Program baseline shifted due to changes in Program A

Total Program B engineering changes: 31
Program C Dominant Causes

Program Key Characteristics

- Program schedule a priority
- Clarified reqmts early
- Opportunities for fast customer learning
  - Accommodate newly definitized needs
  - Add newer, low risk technology
- Documentation changes mostly due to program newness

Total Program C engineering changes: 27
Use of IPTs helped clarify design assumptions/capabilities as much as possible early in Program C, thereby reducing engineering changes due to “Requirements definition issues”.

Changes in Needs

Due to few “Reqmts definition issues”, Program C quickly accommodated evolving customer needs as customer learned more about its needs.
- Program C also had opportunity to quickly incorporate newer technology
- The newer technology involved tended to be low risk
Impacts of Engineering Changes on Program Schedule

- Program C schedule priority ensured no program schedule delay
- Programs A & B engrg change-related schedule delays due primarily to “Reqmts definition issues” & “Fix deficiencies”
- Not all program schedule delays are due to engrg changes: other mechanisms exist to allow schedule delay
• Use of IPT helped prime of Program C clarify reqmts early, & have less “Rework” than primes in Programs A & B
• Engineering changes infrequently provide relief from reqmts for primes
• Use of IPTs including key suppliers may have helped clarify key suppliers’ capabilities to the primes early in Programs A & B, thereby avoiding some “Rework”
• Engineering changes infrequently provide relief from reqmts for suppliers
• Majority of engrg changes do not result in surprises to be dealt with using additional engrg changes
• Impact of engineering changes well-understood on change-by-change basis.
Summary of Findings

- Five dominant causes of engineering changes identified
- Combination of dominant causes in each program driven by characteristics & practices in each program
- Use of IPTs enabled reduction of engineering changes due primarily to "Requirements definition issues"
- Lessons on supplier integration into product development
  - Early involvement not always sufficient to reduce undesirable engineering changes
  - Reduction of undesirable engineering changes requires understanding of key suppliers’ capabilities by primes, IPT environment would help
- Frequent changes in needs and insertion of newer technology can be done without PD cycle time increases
- Few engineering changes provide relief from requirements for primes & their suppliers
- Impacts of individual change well understood, a tribute to capabilities of all parties