Cost Overruns and Their Precursors:
An Empirical Examination of Major DoD Acquisition Programs

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The Persistence of the Problem

- Trends across the wider commodity list improved into the 1990's (Younssi)
- Aircraft remained relatively immune to improvement
- Graphic does not include outliers

“A million dollars here, and a million dollars there, and pretty soon, gentlemen, you’re talking about real money.” Attributed to Senator E. Dirksen

* From Younssi, et al, using a wider group of commodities

Cost overruns remain a serious problem
Previous Approaches to the Problem

- Cost and schedule overruns are not a new problem
- Previous work
  - Has tended to cast “cost overrun” as an amorphous lump, or
  - Investigators have dug deeper into the details of their specialties
- Previous papers and policy changes have failed to resolve the issue
  - RAND: Inadequate initial funding, Unexpected technical difficulties, Requirement changes, Estimating errors, Cost growth $\sim f (\text{quantity purchased})$ (Dews et al. 1979)
  - IDA added: Supply, labor shortages, Concurrency, Force majeur, Cost growth $\sim f (\text{median domain growth rates})$ (Asher and Maggelet 1984)
  - WSARA 2009, updates to DoD 5000 series, lower level directives (P.L. 111-23)

Previous approaches have addressed symptoms of the basic question

Technical Risk as a Precursor to Cost

- There are no truly independent variables:
  - Programmatic/Business $\rightarrow$ Contract Changes
  - Technical $\rightarrow$ Technical/Performance
  - Schedule $\rightarrow$ Schedule
  - Cost $\rightarrow$ Cost

“All roads lead to Rome”, and additional cost
Decisions, Decisions, Decisions...

Systems Engineering Technical Reviews

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<th>Technology Development</th>
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Work scope and costs are tied to Milestone decisions

The Cost Prediction Initialization Point

- It is important to note a significant normally unstated difference between the acquisition of ships and the acquisition of other customized purchases the Department of Defense makes
- We don’t build prototype ships
  - Outcomes occasionally notwithstanding, the intent is that every ship built for the U.S. Navy will become an operational asset.
  - This affects the definition of “baseline cost”, used later

Significant work scope and costs begin before MS B for ships
Knowing the Neighborhood

- Metaphorically speaking, the more interesting destinations sometimes pass through or near some bad neighborhoods – creating risks
  - Cox paper
  - Does not show confidence levels
  - “Grade inflation”
  - Cannot show performance to plan

Joint Confidence Level Scatterplot

Risk “Cube” (Matrix)

**How Bad Can it Get?**

- Like asking how low a particular stock price can go

- Sound decisions can only be made with sound information

Sound program and portfolio decisions require solid data, sound analysis
The Cost Risk Box Canyon

- Markowitz “portfolio effect”
  - Risk is minimized through diversification
  - Requires that assets be truly independent
  - Presumes investors are rational
- DoD 7000.14R: recommends budgeting to the most probable cost
- DAPA Report 2006: recommended an 80% confidence level
- DTM 09-027 (5)(e): requires justification if the recommended confidence level is less than 80%
- Possible maximum values associated with violating these “most probable costs” is not part of anyone’s spreadsheet.

Official policy is at odds with program behavior and decision patterns

Avoiding the Box Canyon

- Smart
  - Reminded us of the “flaw of averages”
  - Value at Risk: “the maximum loss not exceeded with a given probability”
  - Recommended lognormal v. normal distribution for lower risk
  - Conditional Tail Expectation
- “Conspiracy of hope” percentile funding is, unfortunately, built on faulty logic and does not work
- The way an aviator avoids becoming another “box canyon statistic” is by not flying into them

“Six months after winning a coveted $35 billion aerial tanker contract, Boeing Co. announced last year that the first planes would cost $1 billion more than promised during the contract’s competition.”

Avoiding box canyons requires adopting different decision inputs
 Unlike previous approaches

- We limit ourselves to a five year “crystal ball”
  - Not claiming to see too far into the future
  - Consistent with the needs of the Five Year Defense Plan
- Add two more factors
  - Difficulty of the task to be performed
  - Funding dedicated to risk mitigation
- Different points of reference
- Obviously different outcome spectra

\[
\text{Cost}_{\text{IOC}} = (\text{Median Cost Growth Factor})^y \cdot (\text{Cost})_0
\]

where

\[
y = \text{years between program approval and IOC}
\]

\[
0 = \text{Program approval point}
\]
Estimates for "modest" improvements are more accurate.
No penalty for under-estimating costs.
~1970 marks the availability of greater computing power:
- Engine design
- Reduced RCS

Aircraft were divided into three groups:
- Pre-1970
- Post 1970
- Derivatives & special cases

All data taken from open sources.
Computing power has made significant improvements possible.

~1970 marks the availability of greater computing power:
- Engine design
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Ships were divided into three groups:
- Pre-1970
- Post 1970
- Derivatives

Some progress was being made before significant computing improvement.
Intentionally avoided "cutting edge" performance in favor of greater reliability.

All data taken from open sources.
Results to Date: Aircraft

Combat Aircraft 5 yr Cost per 3-Variable Model

\[ R^2 = 99.12\% \]
\[ R^2 (adj) = 98.68\% \]
\[ S = 967.3 \]

\[ \text{Cost}_{5yr} = f(\text{domain tendencies, tech risk, } [\text{RDTE/Q-A Cost}]_3) \]

Results to Date: Ships

Combatant Ship 5 yr Cost per 3-Variable Model

\[ R^2 = 93.36\% \]
\[ R^2 (adj) = 83.40\% \]
\[ S = .8023 \]

- Not quite as good, but respectable
- Johnson transform required

\[ \text{Cost}_{5yr} = f(\text{domain tendencies, tech risk, } [\text{RDTE/Q-A Cost}]_3) \]
Using the Asher-Maggelet Approach: Aircraft

\[ \text{Cost}_{\text{IOC}} = (\text{Median Cost Growth Factor})^y \cdot \text{(Cost)}_0 \]

where \( y \) = years between program approval and IOC

0 = Program approval point

\[ \text{Cost}_{5 \text{yr}} = a_1 + (\text{Median Cost Growth Factor})^{a_2} \cdot \text{(Cost)}_0 \]

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\[ \text{Cost}_{5 \text{yr}} = a_1 + (\text{Median Cost Growth Factor})^{a_2} \cdot \text{(Cost)}_0 \]

P = 0.0000000

P = 0.0656
Contract Implications

- “There ain’t no such thing as a free lunch.” (TANSTAAFL)
  - Robert Heinlein

  - Risk doesn’t go away just because the contractor is forced to assume it
  - The contractor has to make a profit in order to stay in business
  - Contractor’s answer is to calculate the six-sigma probabilities and be very, very stubborn – especially when he is the only available supplier

- Can we use this new method to have more complete discussions about risk and the need to establish more accurate costs?

DoD’s Monopsic Status Skews Negotiations

Portfolio Implications

- Upper management needs to balance the entire portfolio, especially if future budgets are reduced as many people have postulated
- No one likes surprises
- DoD cannot afford egg on its face – every service and program will suffer
- Intended to augment, not replace current methods
- Portfolio and “Grand Portfolio” views of available budgets
  - Provides a higher level comparison to other programs in the same domain
  - Allows a head start on resolving problems

- Where next?
  - The two examples presented here were chosen because of the authors’ familiarity with the end products.
  - Similar relationships can be derived for other product lines

The Proposed Approach May Provide Lower Portfolio Risk
Thank You

Questions?

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