Cost Overruns and Cost Growth: A Three Decade Old Cost Performance Issue within DoD's Acquisition Environment

Leone Young

Stevens Institute of Technology

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Self Introduction

- Professional Experience
  - IBM
  - Accenture
  - KPMG
- Academic Background
  - PhD Candidate – Stevens Institute of Technology
  - MS – George Washington University
  - BS – Purdue University
- Research Areas
  - Cost Estimating
  - Project Management and Agile Project Management
  - Systems Engineering and Systems Integration
  - Higher Education

Agenda

I. Introduction

II. Life Cycle Cost Estimation of Complex Systems

III. Principal Influential Factors that Cause Cost Performance Issues

IV. Potential Methods, Processes and Techniques May Improve Current Cost Performance

V. Conclusion

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Introduction

- The cost performance of Department of Defense (DoD) has been seen as unsatisfactory and problematic by the congressional committees during its defense budgetary and monitory meetings.
- Since the 1970’s, the Government Accountability Office (GAO) has reported that considerable cost growth and overruns continue occurring within many development programs
- DOD acquisition management has long recognized the reform effort needed to correct such cost performance issues and has taken numerous initiatives to revise its acquisition policy and process in hope to improve acquisition outcomes since 1971, but despite these efforts, defense acquisition programs in the past three decades continue to routinely experience cost overruns, schedule delays and performance shortfalls.

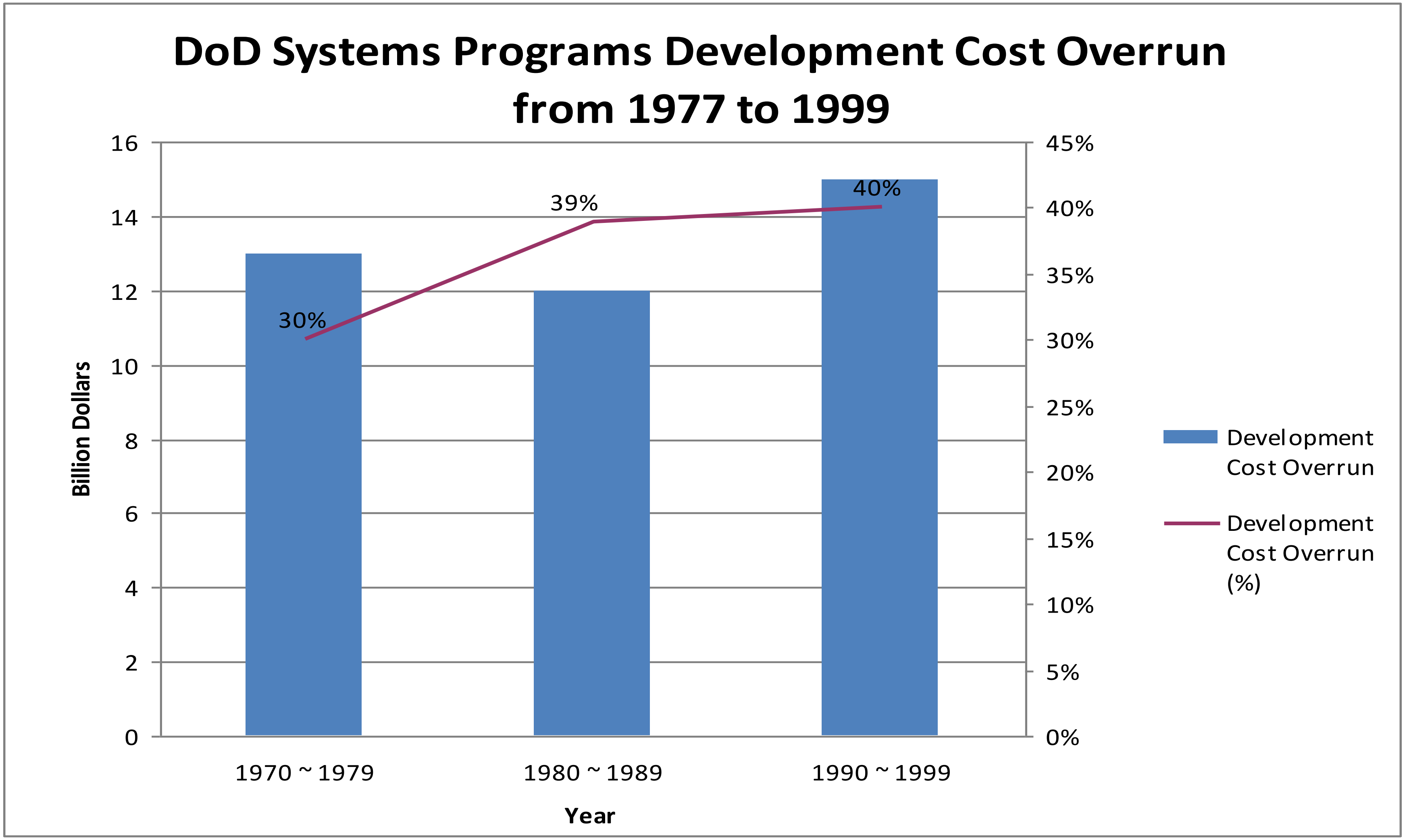
Introduction

Development Cost Overruns by Decade [in FY2005 Dollars] and Key Reform Efforts

1970 - 1979	1980 - 1989	1990 - 1999
Development cost overrun: **$13 billion** (30%)	Development cost overrun: **$12 billion** (39%)	Development cost overrun: **$15 billion** (40%)
Key Studies and Initiatives Impacting the Defense Acquisition Process		
• **1970** Fitzhugh Commission • **1972** Commission on Government Procurement	• **1981** Carlucci Initiatives • **1982** Grace Commission **1986** Packard Commission	• **1994** Federal Acquisition Streamlining Act • **1996** Clinger-Cohen Act
DOD Acquisition Policy Changes		
• **1971** DOD 5000 policy established • **1975** Policy revised • **1977** Policy revised	• **1980** Policy revised • **1982** Policy revised • **1985** Policy revised • **1986** Policy revised • **1987** Policy revised	• **1991** Policy revised • **1996** Policy revised

GAO-06-368

Introduction



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Introduction

The executive branch and legislation initiatives & actions

- The US Congress amended the “Nunn-McCurdy” provision in the Department of Defense Authorization Act of 1982 as a cost monitoring mechanism
  - Requires of the Secretary of Defense to notify the Congress should the additional funding is requested due to the unit cost growth of a major acquisition program is **at least 15%,** and if the unit cost growth had reached at **least 25%,** it further requires of the secretary to include a written certification statement as whether:
    1. Such system is essential to the national security
    2. No alternatives to such system will provide equal or greater capability at less cost
    3. The new estimates of the total program acquisition unit costs or procurement unit costs are reasonable
    4. The management structure is adequate to manage and control acquisition unit costs or procurement unit costs

Introduction

The executive branch and legislation initiatives & actions (cont'd)

- The Department of Defense Authorization Act of 1996
  - Requires of DoD to provide analysis of alternatives to the Congress when the cost growth of a system program has reached by **15%**, and such analysis must include explanations on costs of both with and without changes to the systems designs, requirements and alternatives.
  - Furthermore, this amended law prohibits DoD programs that have reached **25% or more on cost growth** to re-baseline cost estimates until programs have breached the 25% inflation threshold or significantly reduced the scopes of the programs.

Introduction

Example - GAO Assessment

- Assessment on DoD’s defense acquisition programs portfolio of 72 major weapon programs
- Concluded that the 2007 portfolio was experiencing greater cost growth and schedule delays than programs in fiscal years 2000 and 2005
- Since the year of 2000, DoD has roughly doubled its planned investments in new systems from $790 billion to $1.6 trillion in 2007, but the acquisition outcomes in terms of cost and schedule have not improved.

(GAO-08-674T, GAO-08-467SP)

Introduction

Fiscal year 2008 dollars			
	Fiscal year		
	2000 portfolio	2005 portfolio	2007 portfolio
Portfolio size			
Number of programs	75	91	95
Total planned commitments	$790 Billion	$1.5 Trillion	$1.6 Trillion
Commitments outstanding	$380 Billion	$887 Billion	$858 Billion
Portfolio performance			
Change to total RDT&E costs from first estimate	27 percent	33 percent	40 percent
Change in total acquisition cost from first estimate	6 percent	18 percent	26 percent
Estimated total acquisition cost growth	$42 Billion	$202 Billion	$295 Billion
Share of programs with 25 percent or more increase in program acquisition unit cost	37 percent	44 percent	44 percent
Average schedule delay in delivering initial capabilities	16 months	17 months	21 months

- The total acquisition costs for 2007 programs increased 26% from first estimates, whereas program in fiscal year 2000 had increased by 6%.
- Total Research Development Test & Evaluation (RDT&E) costs for programs in 2007 increased by 40% from first estimates, compared to 27% for programs in 2000.
- The total cost growth steadily enlarged and more programs have experienced unit cost growth.
- The cost estimations projected by DoD were afar from the vicinity of reliability and reasonableness and do not represent the reality of true systems programs costs.

Analysis of DOD Major Defense Acquisition Program Portfolios in FY 2008 dollars [GAO-08-674T]

Introduction

In the world of systems environments, systems engineers and technology practitioners of related systems development professionals integrate hardware, software, people, and interfaces and to produce economically viable and innovative systems while ensuring that all elements of the enterprise are functionally serving its purpose.

No systems are immune from cost, performance, schedule, and risks, and even though extensive array of economic techniques and tools are available helping us to predict and monitor costs, but yet, overruns are commonplace and in general are the rule and not the exception, especially for software enabled systems.

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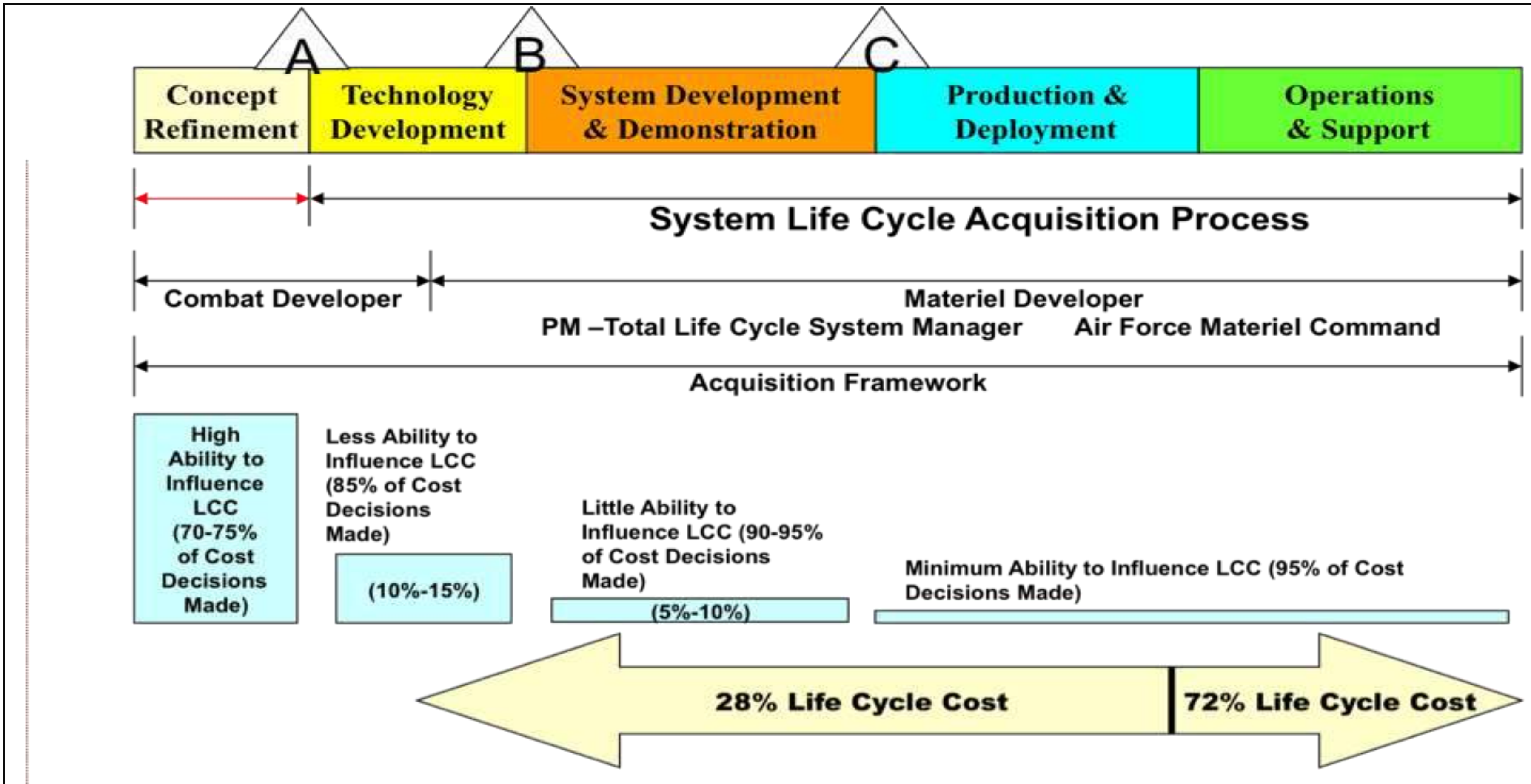
Life Cycle Cost Estimation of Complex Systems

Costs incurred and committed during our systems life cycle acquisition process



modified from Andrews, 2003

Life Cycle Cost Estimation of Complex Systems

Cost estimation techniques throughout the life cycle

	Concept Refinement	Technology Development	System Development & Demonstration	Production & Deployment	Operations & Support
Parametric Cost Estimation	●	●	◒	○	◒
Analogy	●	◒	◒	○	◒
Detailed Engineering Build Up	◒	◒	●	●	◒

● Primary Technique ◒ Some Applicability ○ Little or No Utility

modified from NASA, 2004 and Farr, 2011

Life Cycle Cost Estimation of Complex Systems

Summary of Life Cycle Cost Estimating Methods

Method	Description	Advantages	Disadvantages
Actual Costs	Use costs experienced during prototyping, hardware engineering development models and early production items to project future costs for the same system	• Could provide detailed estimate • Reliance on actual development data	• Development data may not reflect cost correctly • Higher uncertainty • Often mistakenly use contract prices to substitute for actual cost • Various levels of detail involvement • Require existing actual production data
Analogy/Comparative Method	Extrapolate available data from similar completed projects and adjust estimates for the proposed project	• Reliance on historical data • Less Complex than other methods • Save time	• Subjective/bias may be involved • Limited to mature technologies • Reliance on single data point • Hard to identify appropriate analog • Software and hardware often do not scale linearly
Cost Accounting	Formulate based on the expenditures of reliability, maintainability, and decomposed component cost characteristics	• Reliance on detailed data collection	• Accounting Ethics (i.e. Cook the Book) • Post-production phase strongly preferred • Requires of large and complex data collections • Labor Intensive
Detailed Engineering Builds/Bottom-Up	Estimate directly at the decomposed component level leading to a total combined estimate	• Most detailed at the component level through work breakdown structures • Systemic oriented • Highly accurate • High Visibility of Cost Drivers	• Resource-intensive (time and labor) • May overlook system integration costs • Reliance on stable systems architectures and technical knowledge

Life Cycle Cost Estimation of Complex Systems

Summary of Life Cycle Cost Estimating Methods (cont'd)

Method	Description	Advantages	Disadvantages
Expert Judgment/Delphi Method	Produce by human experts' knowledge and experience via iterative processes and feedbacks	• Available when there are insufficient data, parametric cost relationships, or unstable system architectures	• Subjective/Bias • Detail cost influence/driver may not be identified • Programs complexities can make estimates less reliable • Human experience and knowledge required
Parametric/Statistical Algorithm	Use mathematical expressions and historical data to create cost relationships models via regression analysis	• Statistical predictors provide information on expected value and confidence of prediction • Less reliance on systems architectures • Less subjective	• Heavy reliance on historical data • Attributes within data may be too complex to understand • Resource intensive (time and labor) • Difficult to collect data and generate correct cost relationships • Limited by data and independent variables
Top-Down	Based on the overall project characteristics and derive by decomposing into lower level components and life cycle phases. into the lower level components and life	• Fast and easy deployment • Minimal project detail required • Systemic oriented	• Less accurate than others • Tend to overlook lower level component details or major cost drivers • Limited detail for justification

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- Background & History
- Research Motivation

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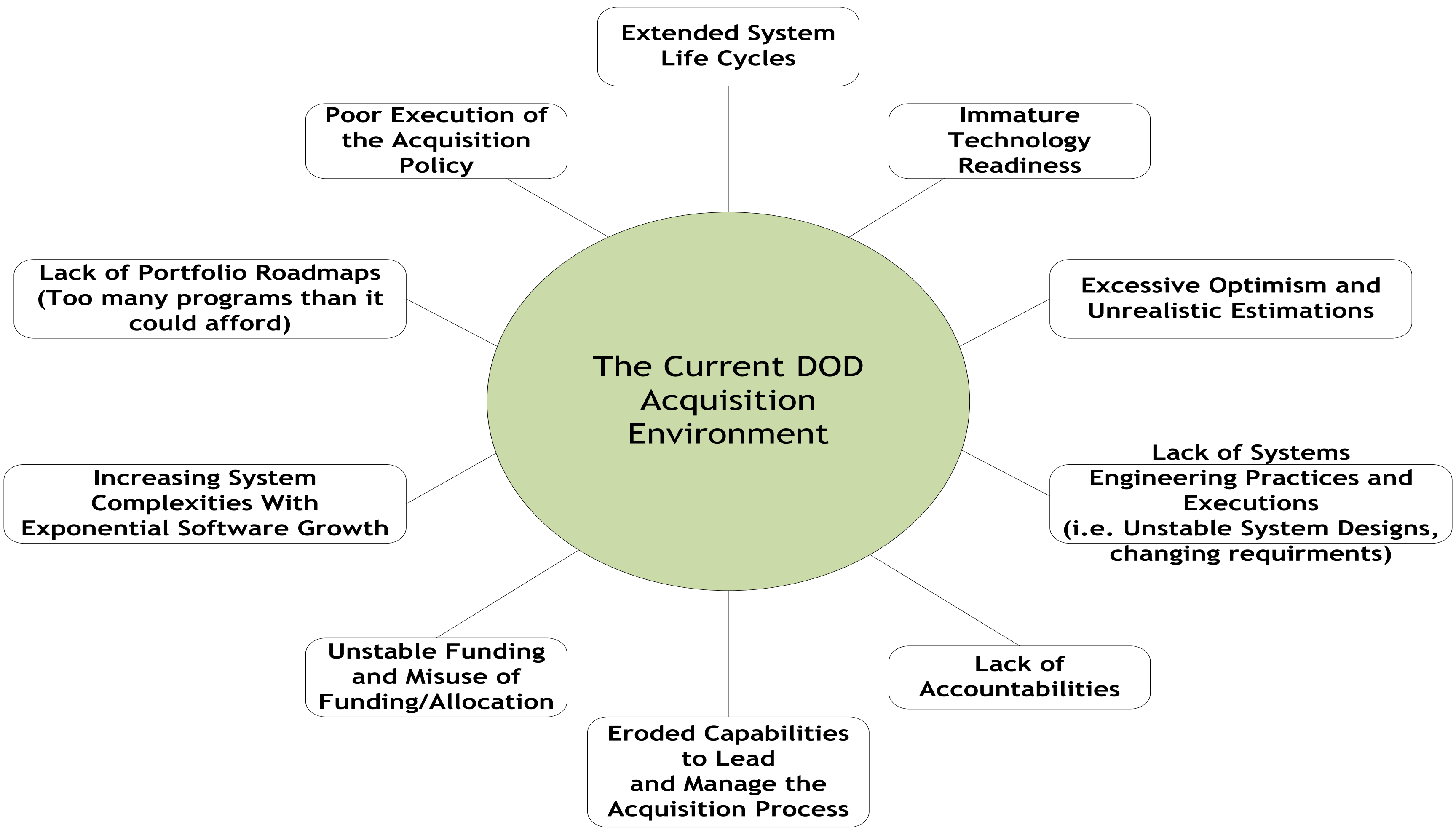
Principal Influential Factors that Cause Cost Performance Issues

- After an intensive examination on multiple reports and studies, we have consolidated the findings and conclusion of each report and summarized those principal factors leading to DoD's continuing cost performance issues

Principal Influential Factors that Cause Cost Performance Issues

Leading Causes



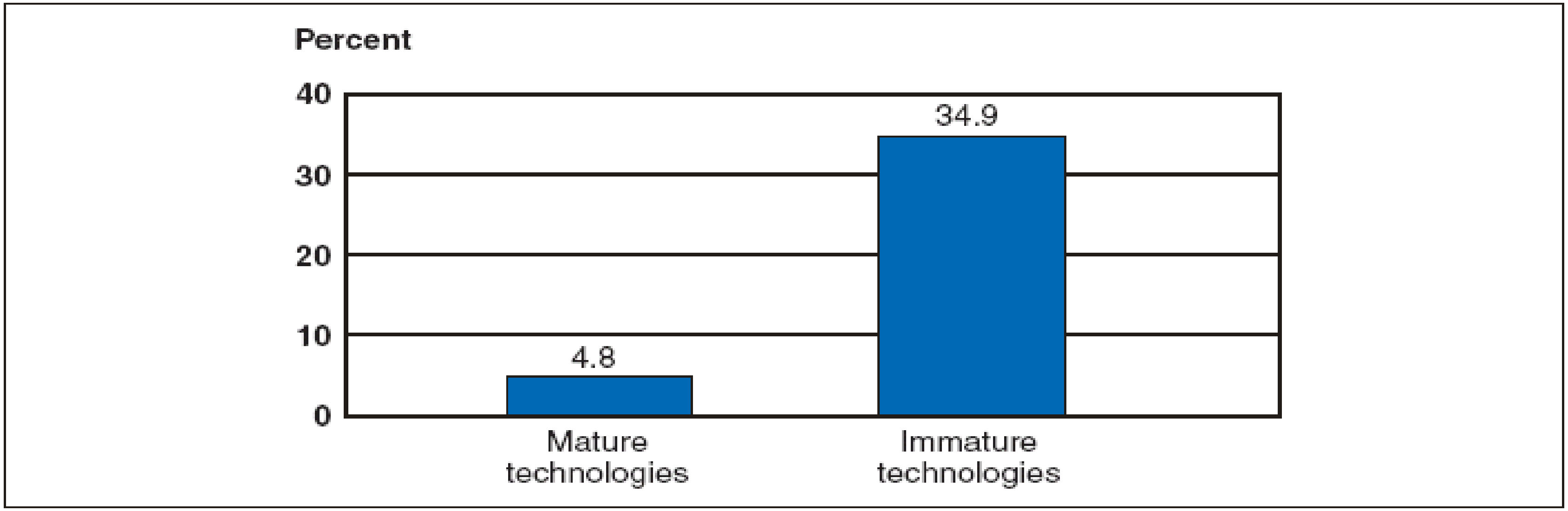
Principal Influential Factors that Cause Cost Performance Issues

Immature Technologies

- Contain high levels of risks and uncertainties due to its complex technical issues that are not yet known, which could cause integration complications as well as decrease the overall systems readiness as a whole
- Increases the chances of cost overruns and schedule delays in systems development which describes the chronic symptoms of DoD's unfavorable cost and schedule outcomes.
  - Systems embedded with immature critical technologies can impossibly offer substantiated basis for cost estimations to be realistic, reasonable due many unknown factors within the elements of critical technologies under discovery (GAO-07-96)
  - 10 times the saving can be achieved if technology problems are identified and resolved before systems development phase compare to correct such problems after launch, and would be even more costly when such corrections are made in the production stage. (GAO-99-162)
- Technology Readiness Levels (TRLs) – good, bad, and ugly

Principal Influential Factors that Cause Cost Performance Issues

Research Development, Test and Evaluation Cost Growth from First Full Estimate



GAO's assessments on 52 selected major weapons systems programs found programs began with immature technologies experienced average RDT&E cost growth of 34.9 percent where systems programs began with mature technologies only experienced cost growth of 4.8 percent.

Principal Influential Factors that Cause Cost Performance Issues

Excessive Optimism & Unrealistic Estimations

- Optimistic “can do” attitude & culture
- Realistic cost estimates are often overlooked due to funding competitions among programs
- Hence, producing unrealistic life cycle cost estimates
- Lack of provisions for management reserve can seriously distort management decisions
- Intensively reliance on contractors & subcontractors – low buy in & bids

Principal Influential Factors that Cause Cost Performance Issues

Lack of Systems Engineering Practice & Execution

- 72 weapons programs - 63% had requirement changes after system development and encountered 72% of cost growth, while programs that did not change requirements had only 11% of cost growth (GAO-08-467SP)
- Many systems programs enter into contracts with contractors before requirements were analyzed, and programs continue past design review with immature systems designs
- Do not conduct SE in a timely fashion to support critical investment juncture and often omit key SE activities
- Developing systems with unstable designs is extremely risky & changes made to the designs require different sets of requirements and raise uncertainties
- A rigid systems design before system demonstration phase allows requirements to be firm & reduces the risk of costly design in the production phase
  - More than a third of the programs that had entered the production phase still had not released 90% of the system designs which is the minimum percentage of being matured design (GAO-08-467SP, GAO-06-368)
- The original systems cost estimates become unreliable and inaccurate
    - Systems life cycle cost estimations are highly sensitive to requirement changes
    - Requirements changes or "requirements creep" during and after the development phase can alter the basis of a LCC and impact significantly on systems development effort

Principal Influential Factors that Cause Cost Performance Issues

Lack of Accountability

- High frequency of program manager turnover rate during system development
  - 39 major program started from March 2001 (GAO-08-62R)
    - Average development time = 37 months
    - Average program manager tenure time ~ 17.2 months
    - DoD policy provides for program managers to serve as close to 4 year tenures as practicable, but many serve for only 2 years
- Program decision makers are rarely held accountable for the cost estimate
- Not clearly specified who is accountable for what or even required program leaders to stay until the job is done
- Program mangers often are:
  - Not empowered to make go or no-go decisions
  - Have little control over funding
  - Cannot veto new requirements
  - Have little authority over staffing

Principal Influential Factors that Cause Cost Performance Issues

Increasing System Complexities with Software Growth

- Technologies advance = systems complexities and uncertainties increase
- Systems Development Effort and Cost Management
  - System designs and requirements increase in difficulty, the number of related interactive items to be considered increases at some greater rate, thus intensifying the difficulty in developing a good and sound estimate (Handcock, 1982)
  - Advancement of complex systems management practices has been enigmatical to systems programs management. (Sauser *et al.* 2008)
  - Producing accurate and reliable systems life cycle cost estimates become challenging
    - High volumes of new and complex technologies integrated within systems
    - Require extended time, adequate and sufficient resources and extensive effort needed to develop the systems
    - Thorough understanding of systems complexities, sufficient SE knowledge and life cycle cost management

Extended Systems Life Cycles

- Takes 10 to 15 years, sometimes even longer, to design and develop a weapon system and to produce and deploy initial operationally capable units (GAO/NSIAD-93-I5)
- Highly correlated with systems complexities
  - SE may help shorten the development time

Principal Influential Factors that Cause Cost Performance Issues

Poor Execution of Acquisition Policy

- Mainly not following knowledge based, and evolutionary model
  - Although stated as preferred, it should be encouraged
  - Bottom line is still systems engineering not followed
    - Generate cost estimates
      - Realistic and accurate
    - Bid process and contract management

Unstable Funding & Misuse of Funding Allocation

- Not commit full funding to develop major systems when they are initiated
  - Make unplanned and inefficient funding adjustments
  - Moving budget from one program to another
  - Deferring costs into the future
  - Reducing procurement quantities

GAO-08-619, GAO-07-566, GAO-07-415, GAO-07-388

Principal Influential Factors that Cause Cost Performance Issues

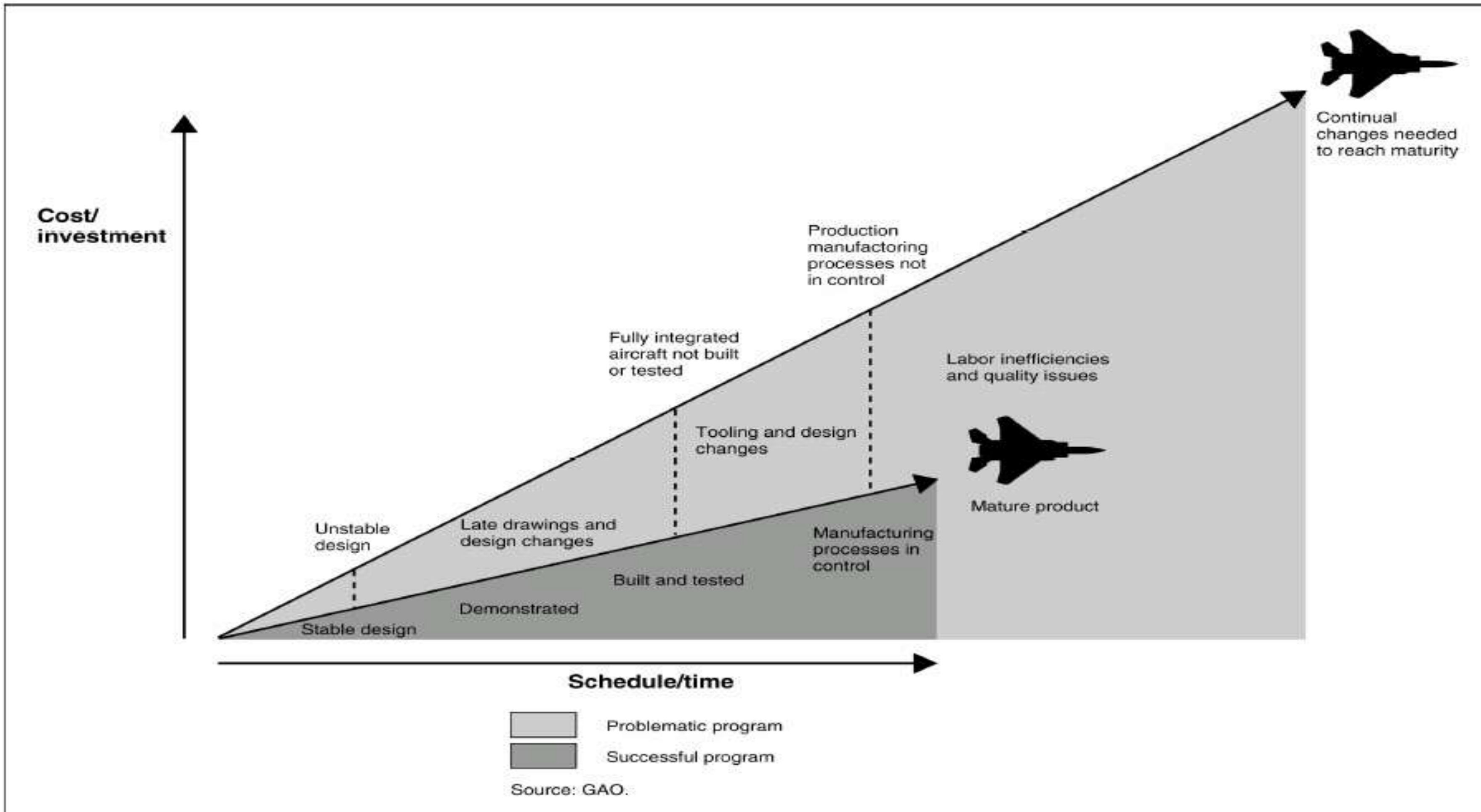


Illustration of Cascading Negative Effect of Failing a Knowledge Based Acquisition Approach

GAO-07-566

Principal Influential Factors that Cause Cost Performance Issues

Eroded Management Capabilities & Lack of Portfolio Roadmap

- Lack of strategy planning
  - Related with optimism
  - Affordability
  - Invest/spend more than it could afford,
  - More costs if harbor all
- Lack of trade off and portfolio planning and management
- Lack of tradeoff analysis or alternative considerations
- Lack of human resource management – why employees leave
  - Inexperienced hires
  - Job satisfaction
  - Career planning
  - Skills development, etc

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Potential Methods, Processes and Techniques May Improve Current Cost Performance

Other organizations encountering similar difficulties

- Air Force, Navy, Army, etc
- DOE, EPA, NASA

Their current effort ***trying*** to resolve these similar issues

- NASA
  - Multiple guidebooks – SEH, CEH, etc
  - Streamline practice – SE centers, CE centers
  - Knowledge Management Implementation & Integration CE
  - Human Resource – specific guidelines printed in words
- Air Force & Rand
  - SE/PM work and F22/18 Lesson Learned
  - Engineering Build estimation further upstream
  - Must be able to do engineering build sooner to get a handle on costs during concept exploration
  - Knowledge based development

Potential Methods, Processes and Techniques May Improve Current Cost Performance

- Must be able to do engineering build sooner to get a handle on costs
  - Bring down +/- 40 to 60% during concept exploration
- Mix of CE methods
  - Analogies, engineering build, dephi, etc
- Iterative/Incremental Development
  - Speed up integration and minimize incompatibility between technologies integration
- Implement advance knowledge management, knowledge engineering
- Implement advance requirement management, requirement engineering, and change management
  - Especially for organizations adapting CMM model and where its position is at CMM level 2 and beyond
- Adapt NASA's CRL concept – similar to TRL, perhaps develop Requirement Readiness Level (RRL)

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Conclusion

Controllable Factors

- Growth in requirements
- Unstable Funding
- Over Optimistic Culture – Can Do culture
- Systems Engineering Practices
- Accountabilities
- Requirements Change/Creep
- Misuse of Fund Allocation
- Unstable Baselines
- Portfolio Roadmaps
- Poor Execution of Acquisition Policy

Uncontrollable Issues

- Stability of Funding
- Immature Technologies
- Longer Acquisition Development Time
- Increasing Technology Complexity & Integration Effort
- Growth in SW Reliance – Integration Effort
- Extended System Life Cycles

Other organization encountering similar difficulties

- NASA, DOE, EPA, Commercial sectors, etc

Conclusion

- CE techniques and methods is not the root problem
  - Top-down as early as possible, but bottom-up as soon as possible
    - Ideally, use bottom-up estimates and scale based upon experience (e.g. analogy or expert judgment) to identify potential cost drivers
    - Provide advance opportunities for programs stakeholders to perform program tradeoff for systems requirements (e.g. cost and schedule goals vs. estimated risks, cost, schedule and resources needed)
    - Disciplined SE practices are required
    - However, due to its interrelationships and interdependencies, performing cost estimations early in advance may not reduce the uncertainties
- SE practices and its key activities are desideratum and crucial
  - Preliminary design, functional and operational designs
  - Requirement and knowledge managements
- Enforce rigid SE practices throughout its organization at every level
  - Programs success may be one step closer as SE discipline matures

Questions?