# The Value of Test Engineering's Early Involvement in the Systems Engineering Process

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# A Problem

**From March 2008, *Defense Acquisitions: Assessments of Selected Weapon Programs* (GAO, 2008).**

- "Of the **72 programs** GAO assessed this year, **none of them** had proceeded through system development **meeting the best practices** standards for mature technologies, stable design, or mature production processes by critical junctures of the program, each of which are essential for achieving planned cost, schedule, and performance outcomes.
- The **absence** of wide-spread adoption of **knowledge-based acquisition** processes by DOD continues to be **a major contributor** to this lack of maturity. Aside from these knowledge-based issues, GAO this year gathered data on four additional factors that have the potential to influence DOD's ability to manage programs and improve outcomes—**performance requirements changes**, program manager tenure, reliance on nongovernmental personnel to help perform program office roles, and software management.
- GAO found that **63 percent of the programs had changed requirements once system development began, and also experienced significant program cost increases…"**

# Presentation Overview
# or
# BLUF

- Before ~1990, systems developed using design teams
  - Included testers in final phases
  - Specialty engineers limited
- Mid 1990s, many developments used IPTs
  - Tester, specialty engineers throughout
- Since then…back to design team concepts…but retained IPT name
- Successful programs meet performance, schedule & budget
  - **Success improves with authentic IPTs.**
  - **Authentic IPTs have early involvement of testers** (and specialty eng.)
- Two case studies illustrate successful and unsuccessful developments.

# Pre1990s - Design Teams…

- Included electrical, mechanical, software and token systems engineers
- Rarely contained specialty engineers (maintainability and reliability)
  - When elements of the system fail, reliability engineers called
- Testers held at arm's length for most of the development program
  - Design engineers ran tests; many problems go unnoticed or are put on hold.
  - Testers arrive near the end of the program
  - Tests were planned and executed from poorly written requirements
  - With little time/money remaining, testers rushed to determine system compliance
- The original team was disappointed when problems found…testers resented for finding them
- Testers frustrated by poor requirements, lack of support and time restraints
- Whole program suffered…redesigns and retests

# Mid 1990s - Authentic IPTs

- IPTs = Design + systems + specialty + test engineers
- Here's how it works…
  - Each member has the RAA to represent his discipline
  - All disciplines participate in requirements definition, preliminary design, detailed design, building and fielding
    - Every step of the process has the benefit of the perspective of all the engineering disciplines
    - Issues are resolved through consensus.
  - Magnitude of the effort for any specific discipline is tailored
  - Testers participate during
    - Requirements development
    - Program planning and source selection
    - Test execution and evaluation

# During Requirements Development

- When creating a new product, getting the requirements right is an essential–but **pothole** filled–road
  - Wrong or non-existent requirements yield something with no user or market
  - Can desired product be built within a reasonable time and cost?
  - Will the target market or user readily benefit…i.e. no buyer's remorse
  - Pushing state-of-the-art
    - Program Offices hear from potential contractors that X can be done—even though in reality no one knows
    - POs and marketing organizations are hoping for a small push to the state-of-art ….But…
    - Hope is not an engineering strategy

# Potholes Are Avoided When Testers Are Involved

- Testers are accustomed to and experienced at challenging and questioning …Working together as a team, the group can sort out truth from fiction
- Requirements must be stated in a verifiable way…negative surprises after delivery are death on future business
  - It's in tester's enlightened self interest to assure the requirements are verifiable, …ultimately verification is his responsibility
  - **Can we readily imagine a verification* technique for this requirement?**
    - If no…rewrite or discard
    - Assuring **verifiability** creates requirements that are well written, understandable and **unambiguous.**

*Verification methods are test, demonstration, inspection or analysis (includes M&S)

# Requirements Development Example

- Consider “shall be capable of”…How can it be verified?
- It’s ambiguous
  - Can be satisfied hundreds of ways…only one is correct
  - If it survives, an interpretation will be made so that design and building can occur.
  - Later, it’s found that the item is not what was intended…correction is costly
- From a verifiable requirement flows a verifiable specification
  - Verifiable specifications are readily understood…not susceptible to misinterpretation during flow-down process.

**Testers assure unambiguous and verifiable requirements and specifications!**

# During Program Planning and Source Selection

- Test-related scheduling, budgeting, infrastructure and personnel must be a part of a program's master planning documents, the RFP, the proposal and the proposal evaluation
  - Both customer and contractor testers are prepared to develop these documents having participated in the requirement and specification development process
  - With early involvement, contractor testers have the knowledge to prepare a proposal with "right-sized" testing
  - Proposal evaluation team testers assure that there is test realism (feasibility, cost, schedule) in the proposal and/or the negotiated test program

# During Program Planning and Source Selection

- Testers can improve budget and schedule planning by answering… "How much and what type of data need to be collected?"
  - Depends on factors like statistical confidence and the ability to access and record data
  - If certain data are essential but not readily accessible in the preliminary design…huge savings result from early redesign
  - Planning the number of test trials—somewhat an art since the data are not always cooperative—is best handled by testers using their past experience
- Without early tester involvement one has inappropriate or poorly utilized test-related resourcing
- BTW—looking ahead to the "end-game" when final testing is ongoing—these same testers are in the ideal position to determine when testing is complete

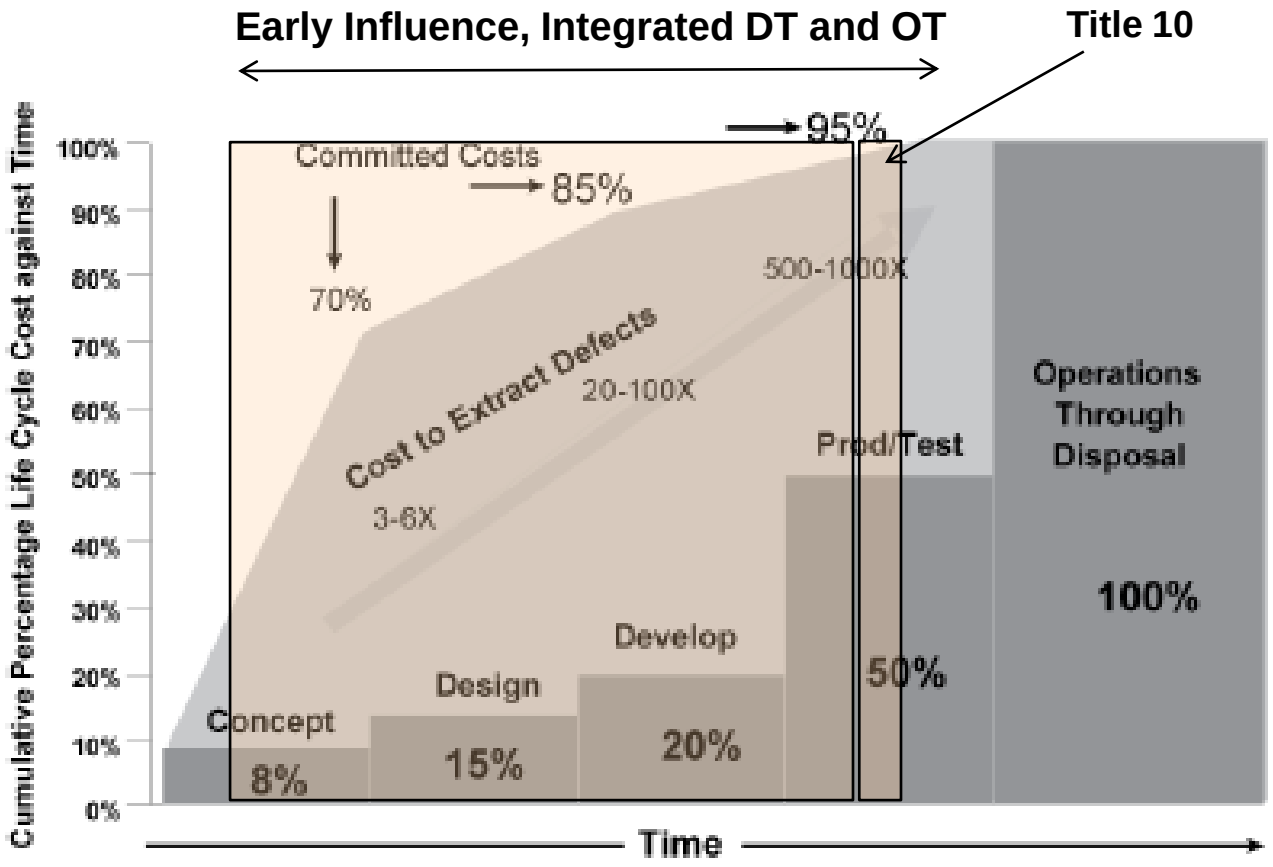
**Testers assure "right sized" test programs for contractors and customers**

# During Test Execution

- Plan and execute integrated developmental and operational tests
  - Testers involved from the beginning notice that some of the DT&E data are also relevant to operational considerations.
  - Testers can cause operationally related data to be gathered or made available that are virtually free
  - Program has early look at operational issues that are traditionally addressed in OT&E…related to effectiveness and suitability.
- For example, reliability growth tests occur during early phases.
  - Unit under test will occasionally break and need repair.
  - Measure and record time and skill to repair… provides data for making early maintainability assessments…a glimpse of potential problems.
  - Early changes can be made in the maintenance approach or in the design relatively inexpensively rather than years later and very expensively

**Test once…evaluate multiple times/ways**

# Find Issues Early

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# Now - IPTs in Name Only

- Once again test and specialty engineers are being minimalized, left out and ignored
- The result…more than 60% of Major Defense Acquisition Programs are deemed not effective or suitable by DOT&E
  - The financial, program and war-fighter impact of this is tremendous

The following case studies serve as illustration of my early tester, value-added, assertions.

# Case Study 1

- Concerns huge banking-system development at a major, well-known firm in the early 1990s
- Their systems engineering and testing process...
  - Sales force promises potential customers whatever they think the customer will buy.
    - The customers are financial institutions…this system would be their interface with the public for on-line banking and on-line bill paying
    - SE step…Determine the need or problem to be solved
  - Sales force reports to the “systems engineers” what the customer wants.
    - SE step…Develop and document the requirements
  - Systems engineers change the requirements without consulting anyone
    - SE step…Trade studies
  - Systems engineers select from the company’s portfolio of existing banking software programs for use in the new system.
    - SE step…Preliminary design
  - Systems engineers cobble together this collection with some additional (“glue”) code.
    - SE step…Final design

# Case Study 1

- Senior management insists the new system be turned over to company testers who were not involved in the design.
  - SE Step…OT&E
  - With no written requirements testers used emails and interviews for requirements
  - Based on these self-created, after-the-fact requirements, testers built and executed the tests
  - Problems were found and reported to the developers (aka SEs)…the testers were blasted!
  - Later, the SEs admitted there were problems
- Because this approach to systems engineering and testing was typical
  - The product never made it to market
  - The company of about 80 thousand people commenced massive layoffs
  - The publicly traded stock fell in value by 75% in a relatively short period of time
  - This company is no longer in business

**A bogus requirement and product development process could have been avoided with tester early involvement**

# Case Study 2

- Involves a large, complex and expensive military system
  - Built a complete system to demonstrate that newly discovered phenomena could be exploited for military purposes **by** military people
  - Produced as a mixture of engineering development and production model approaches
- The abbreviated systems engineering process, emphasizing the testers role…
  - IPTs that included testers were formed from the beginning
    - One IPT for each subsystem
    - Overarching IPT for the whole system.
  - Integrated contractor and government testers determined
    - The cost (in man years),
    - The test resources
    - The schedule for the T&E effort
  - Testers were major participants in writing both
    - Top level requirements
    - System specification…with over 5000 “shalls!”

# Case Study 2

- Testers assured the specs were verifiable
  - If one can't readily imagine a verification technique, rewrite or eliminate
  - Caused significant spec rewriting or elimination
- Testers were major reviewers at all system and subsystem design reviews
  - Assured maintainability was achievable through appropriate BIT
  - Grew the reliability using Test Analyze and Fix techniques
- Testers brought the system together in a SIL
- After the SIL over 500 system-level test events using six test sites were executed

# Case Study 2

- Direct, early, full-time involvement of testers—concept through operational use—resulted in these specific outcomes:
  - Successful completion of the original program months ahead of schedule and 20% below budget for integration, test and T&E
  - Sufficient contract time and budget remained to successfully complete an extra 6-month demonstration
  - Even with the extra demonstration, the whole program was within 10% of budget and within weeks of the originally scheduled completion date—5 years after the start!
  - Full scale development followed, and systems based on this effort are now operational
  - The program was awarded the Defense Superior Management Award.

**This phenomenal success was due to early tester involvement and authentic IPTs**

# Conclusion

- Program offices or engineering businesses need to make use of all the insights they can get to make the right requirement and design decisions early
- In terms of performance, cost and schedule, good program management and good results depend on knowledge
- Testing and testers provide much of that necessary knowledge

**Increase the tester's impact substantially… have them participate from the beginning.**

# In Summary

**Again, from GAO March 2008, *Defense Acquisitions: Assessments of Selected Weapon Programs***

- The big three issues…
  - Faulty requirements definition
  - The lack of a rigorously followed systems engineering discipline
  - The lack of knowledge concerning potential technical issues, especially by the beginning of full scale development.

Authentic IPTs, with testers involved early, are well positioned to solve all three of these problems.

# The Value of Test Engineering's Early Involvement in the Systems Engineering Process

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