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Size Matters … A lot!

Rick Collins

Nesma Conference, 25 November 2020

Agenda

- Setting the stage
- Recent GAO findings regarding U.S. defense programs
- U.S. defense program software size growth analysis
- Closing Remarks

The Big Picture

Credible, Defensible Cost Estimates

Avoid approving projects that can't be afforded

Realistic Budgets

Executable Contracts/Projects

Avoid awarding contracts that can't be executed

Successful Acquisition & Sustainment Outcomes

The 'right' cost analysis capability facilitates authoritative decision-maker knowledge that enables informed decision making

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Decision-makers Must Trust Our Work

- As analysts, we are asking decision-makers to place their trust/confidence in our analysis and resulting estimates

- Thus, the first requirement of an estimate is that it be credible/defensible

- The principal means to establish credibility/defensibility (and corresponding trust) is to explain in very specific terms the path from *data/facts* to *methods/models* to *estimates* (i.e., the evidentiary chain)
  - Clarity of this evidentiary chain is paramount
  - Clarity enables persuasion leading to trust

- Our work as analysts must be persuasive and even compelling
  - Many of the consumers of our estimates are exposed to an endless stream of advocates with agendas
  - So, when we tell these consumers “no, project x is going to cost 50% more than you expected”, we had better be prepared to sell/defend our position

Credibility --> Confidence --> Trust

Data Engenders Trust

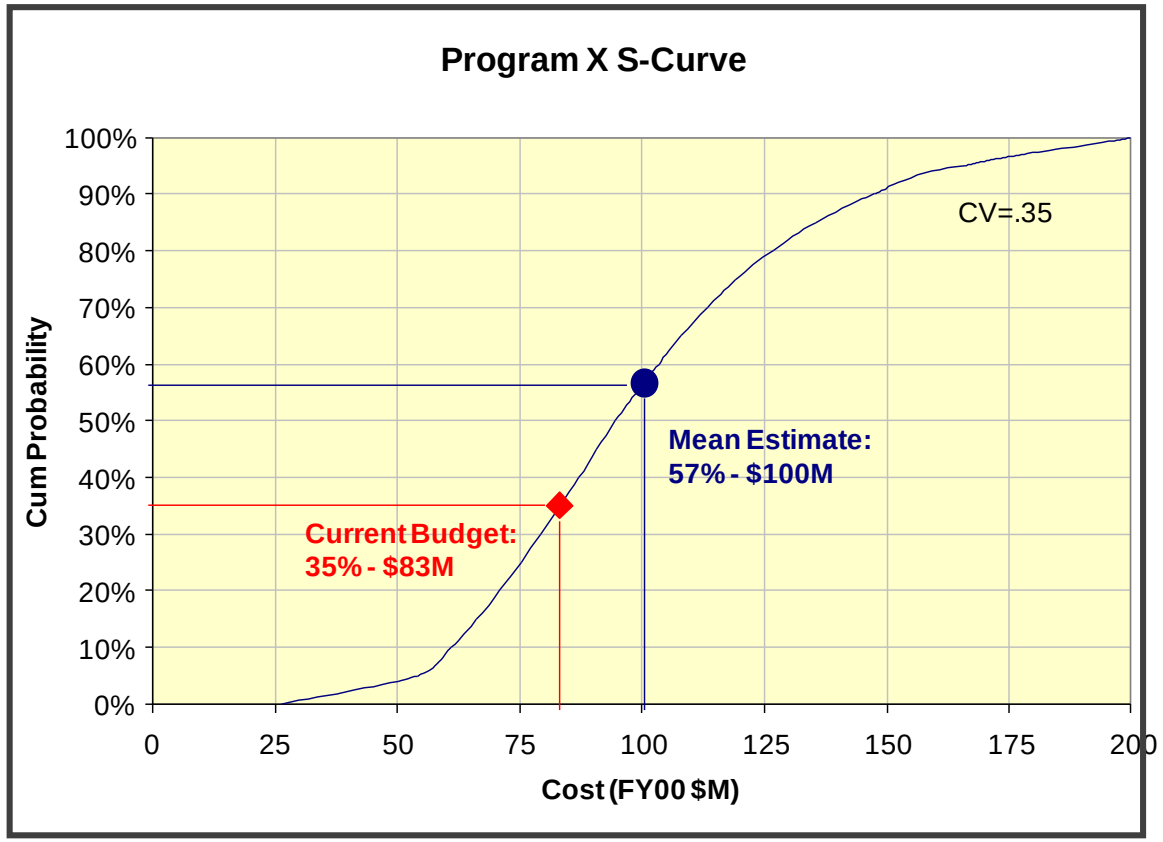
- Data is the foundation for estimate credibility and defensibility
  - An estimate not grounded in data can be viewed a guess or, at best, analyst opinion/judgement
  - An estimate is only as good as it’s underlying data

- Data collection and normalization must be a top priority of cost analysts
  - The equivalent of doing the all important prep work (scraping, sanding, priming) prior to painting the exterior of a house

Data is the lifeblood of cost analysts

But Always Bear in Mind

- Cost estimating is not about being right!
- Rather, it is about minimizing how wrong we are!
- The most credible, defensible cost estimates reflect data-driven evaluation of uncertainty & risk
  - Use Monte Carlo simulation to generate an "S-Curve depicting the potential range of cost outcomes for a project



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Can You Relate to This?

An estimate not based on the size of a <u>completed (or nearly completed)</u> project is at best an educated guess

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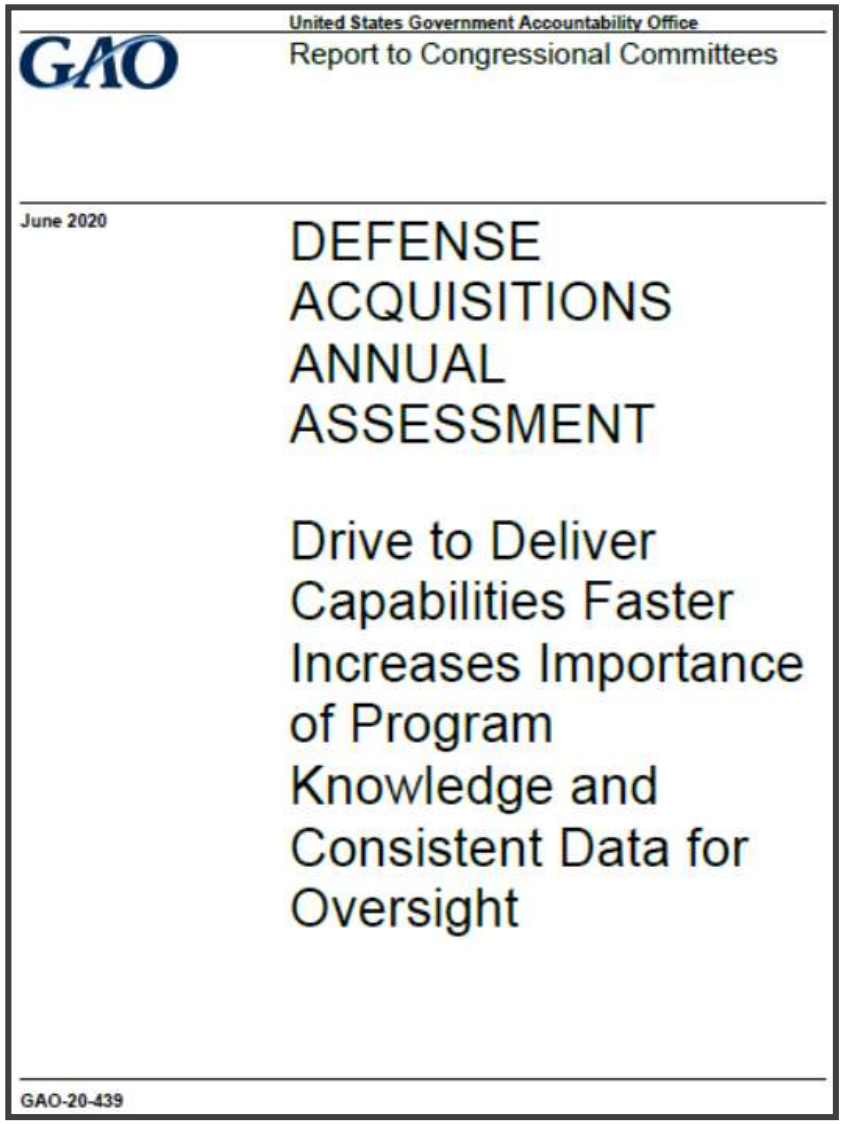
Cold Hard Facts

- Cost estimators cannot create estimates for a project that lacks definition
  - No definition = no estimate
- Ideally, project managers, engineers, etc. have enough understanding of the project to define it in terms that are useful to cost estimators
  - Professional cost estimators, particularly those with parametric estimating expertise, don't require much definition
- Size is not the only way to characterize the scope & complexity of a software development project, but it is arguably the key consideration for cost estimators

Recent “Real World” Findings re. U.S. Defense Programs


United States Government Accountability Office

GAO

Report to Congressional Committees

June 2020

DEFENSE ACQUISITIONS ANNUAL ASSESSMENT

Drive to Deliver Capabilities Faster Increases Importance of Program Knowledge and Consistent Data for Oversight

GAO-20-439

- The U.S. Government Accountability Office (GAO) produces a Congressionally-mandated annual assessment of the Defense Department’s largest acquisition programs
- The most recent report (June 2020) addresses 121 defense programs
  - 106 weapons programs ($1,853B)
  - 15 IT programs ($15B)
- The report highlights software development risk/challenges/growth for 42 of the 121 programs

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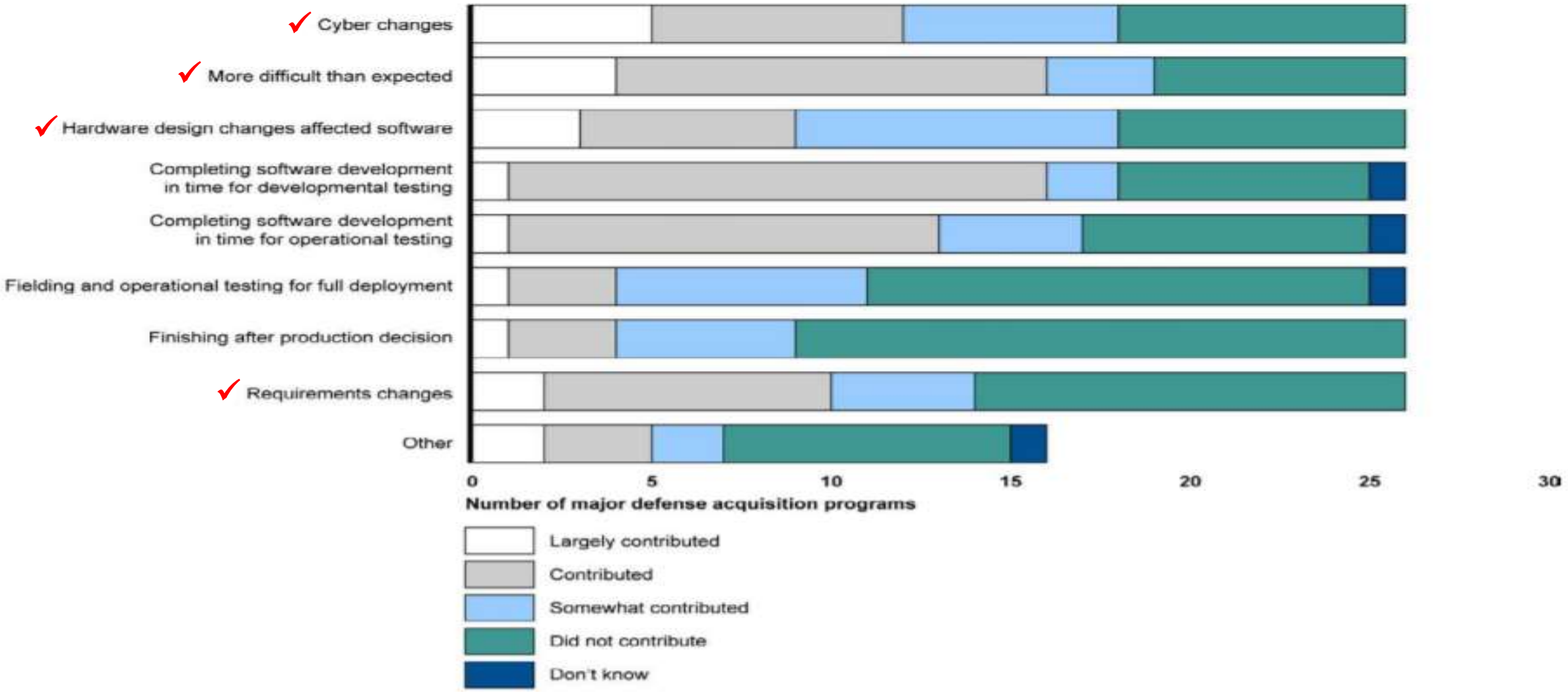
U.S. Defense Program Software Development Risk Factors

Figure 6: Factors That Contributed to the 26 Selected Major Defense Acquisition Programs That Identified Software Development as a Program Risk

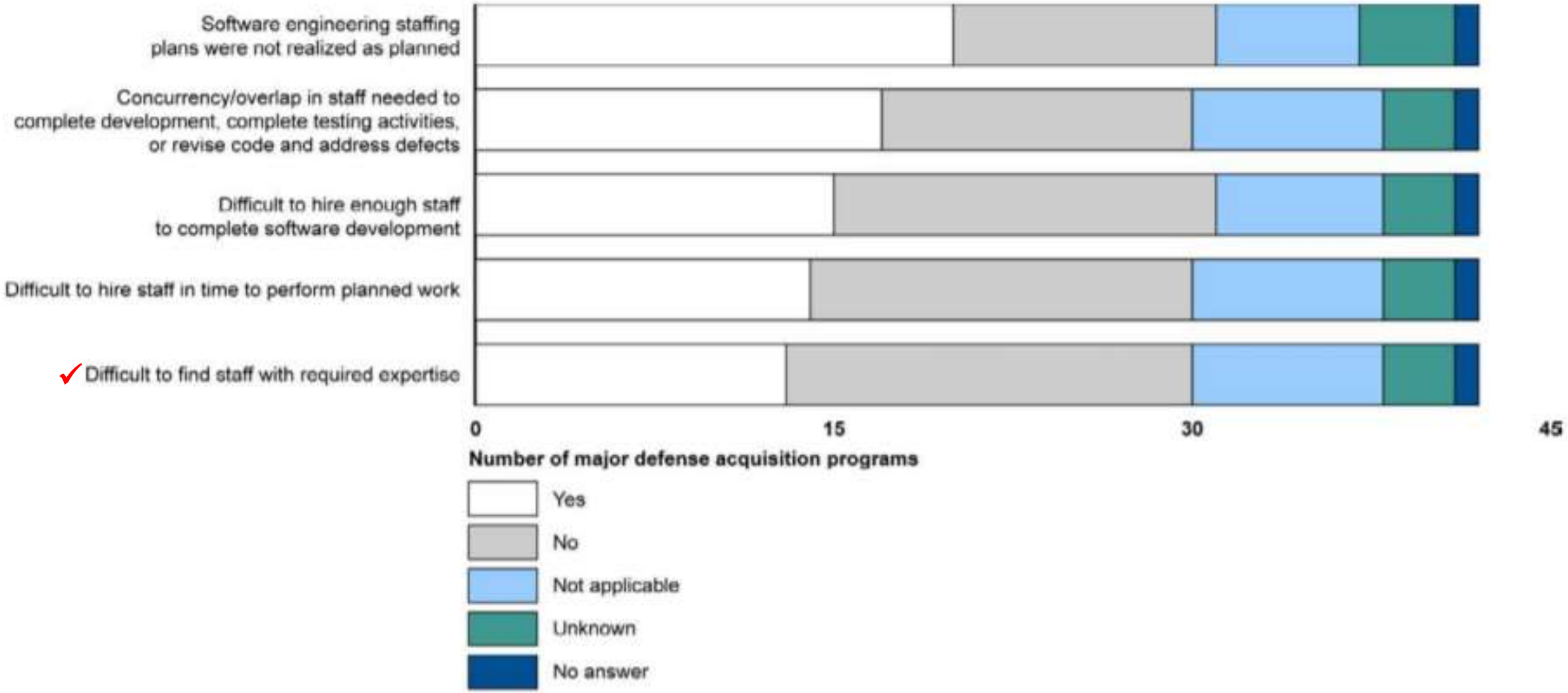


Source: GAO analysis of programs' questionnaire responses. | GAO-20-439

Note: Examples of "Other" factors that programs identified in their questionnaire responses included late delivery of hardware that compressed integration schedules, system integration difficulties that required additional development, or changes to meet anti-tamper requirements.

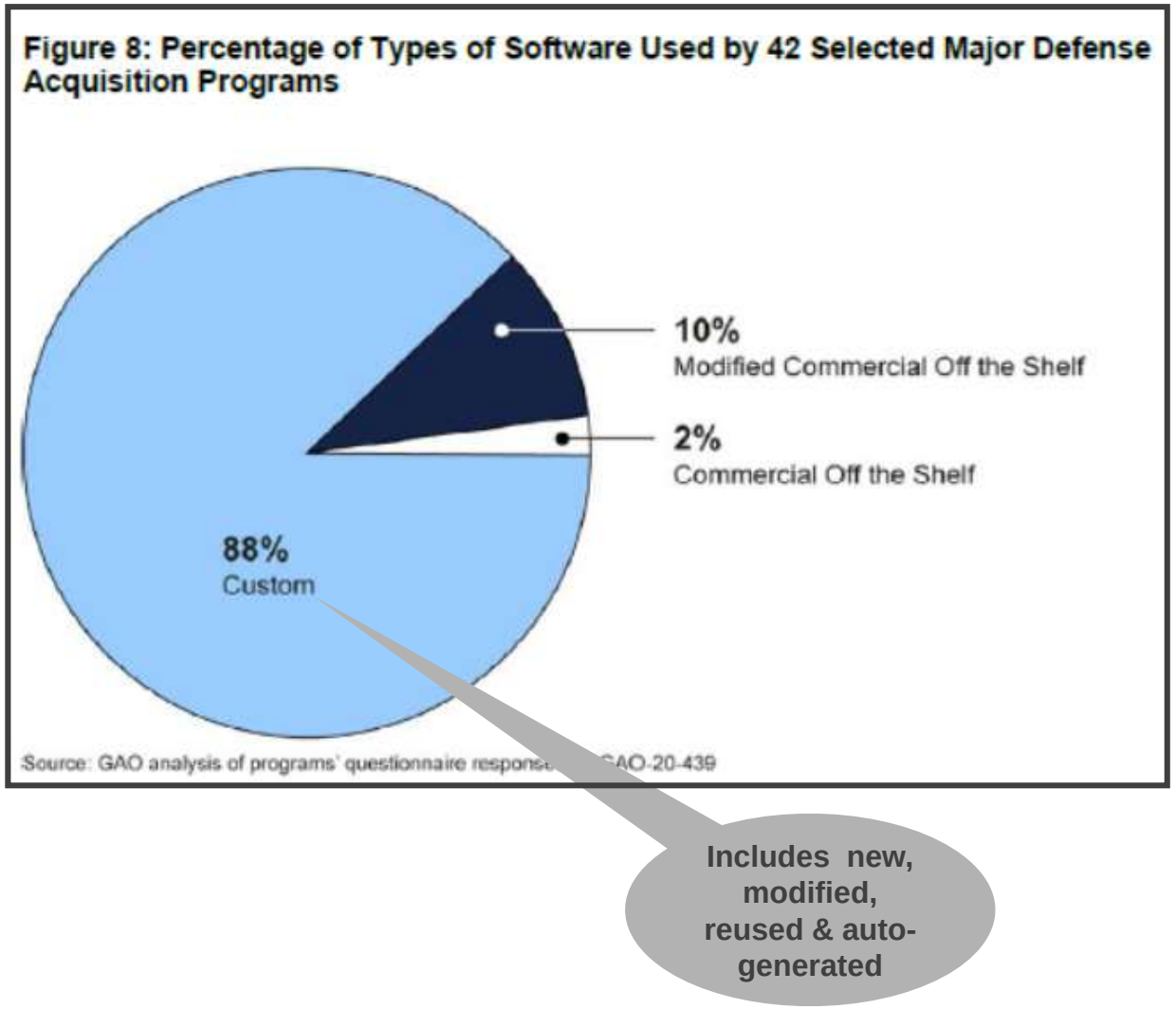
U.S. Defense Program Software Development Staffing Risks

Figure 7: Challenges Associated with Government and Contractor Software Development Staff among 42 Selected Major Defense Acquisition Programs



Source: GAO analysis of programs' questionnaire responses. | GAO-20-439

U.S. Defense Program Software Development Characteristics



Includes new, modified, reused & auto-generated

- Unique nature of weapon systems necessitates custom-created software
- Custom created code is relatively expensive
- If custom code grows, then growth is by definition more expensive
  - Strong evidence that estimated new code count will grow
  - Strong evidence that estimated reused code count will be unrealistically/optimistically high & be replaced with more costly new code
  - Strong evidence that estimated COTS & modified COTS count will be unrealistically high & be replaced with more costly new code

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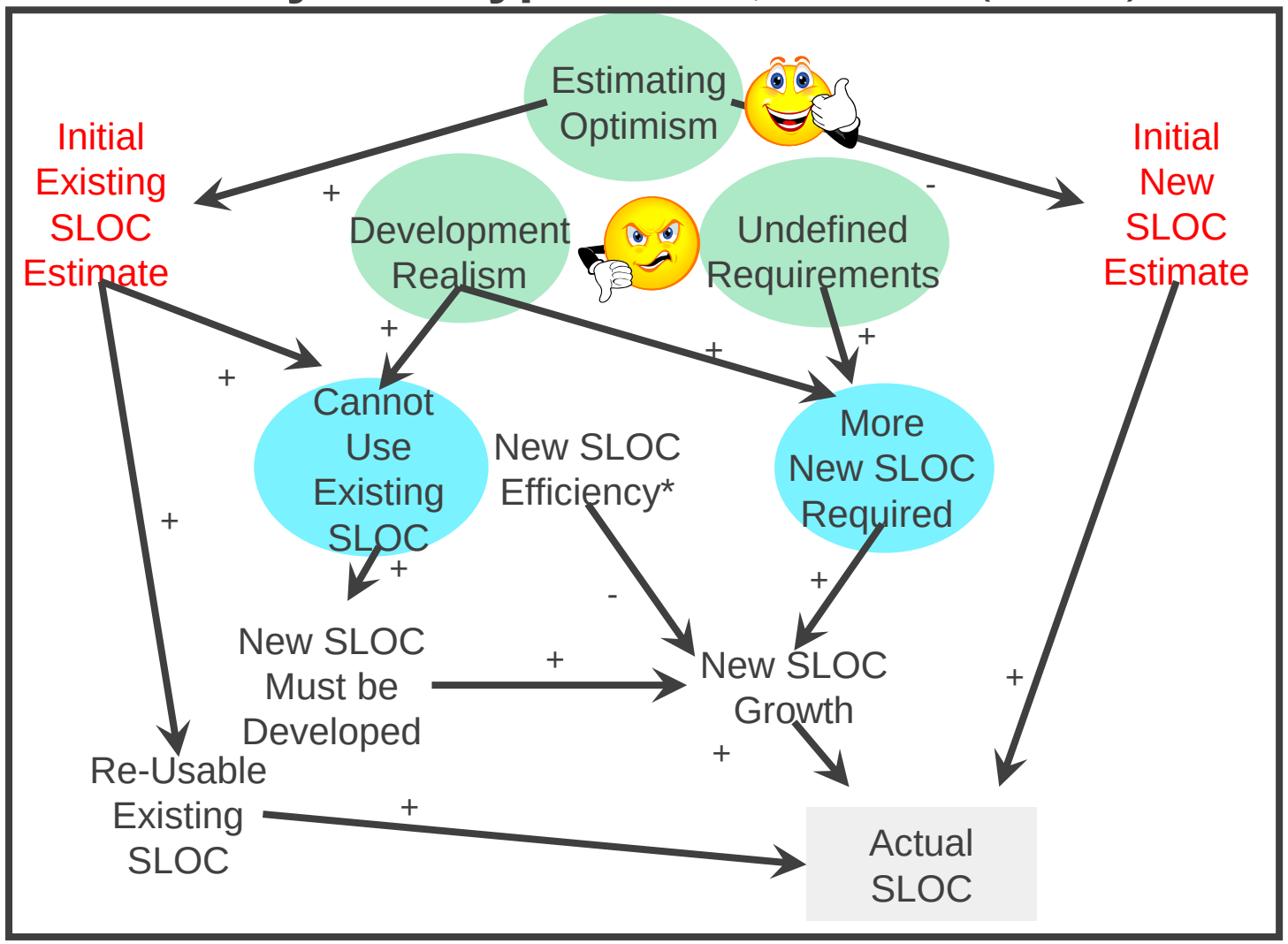
U.S. Defense Program Software Size Growth (2007 Study*)

"Analytical Hypothesis, 1 of 2" (slide 5)



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* "*Software Code Growth: A New Approach Based on Historical Analysis of Actuals*," Technomics, Inc. (Hardin & Jones), 2007 ISPA-SCEA Conference, June 2007

U.S. Defense Program Software Size Growth (2007 Study)

Ratio of Actual Final to Estimated SLOC by Composition & Complexity				
	Complexity			
Composition	Simple	Routine	Moderate	Difficult
100% new	1.15	1.29	1.44	1.58
75% new/25% modified	1.09	1.20	1.31	1.42
50% new/25% modified/25% unmodified	1.04	1.12	1.19	1.26

- Results based on analysis of actual vs. estimated sizing data for ***50 defense programs***
  - ~75% of the 50 represent real-time software
  - 30% of the 50 are waterfall, 24% incremental, 16% incremental & 30% unspecified
  - 4% of the 50 are simple efforts, 20% routine, 28% moderate & 48% difficult

- Constrained optimization (i.e., residual minimization) analysis using MS Excel Solver indicates
  - Magnitude of growth depends on composition & complexity
  - New SLOC growth = growth of new SLOC + replacement of “existing” SLOC with new SLOC
    - Replacement because existing SLOC reusability is 20% less than expected
  - Non-reusable existing SLOC is replaced by new SLOC using 30% fewer lines of code

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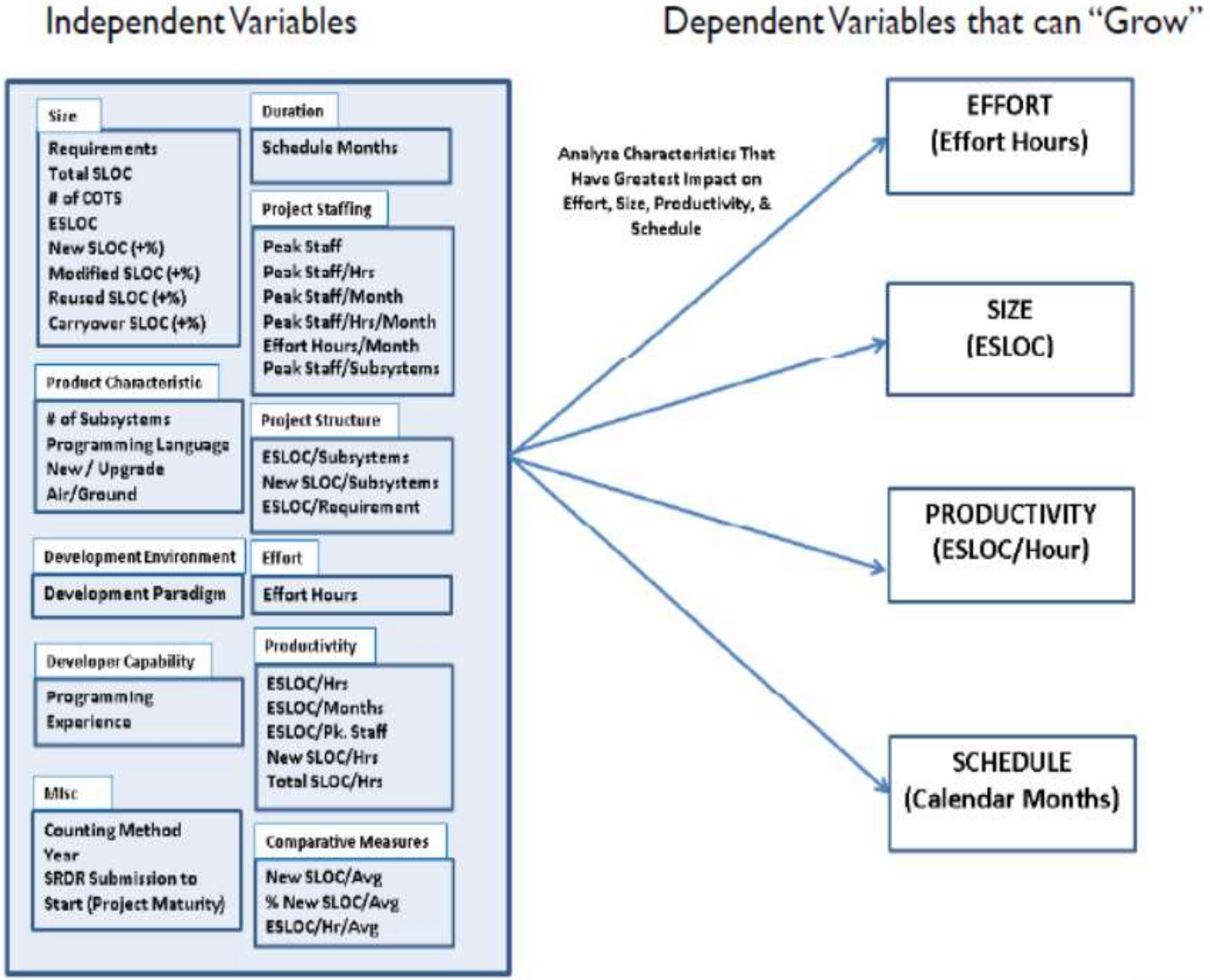
U.S. Defense Program Software Size Growth (2013 Study*)



- Results based on analysis of actual vs. estimated data for ***17 defense programs***
  - Software development efforts started/completed in 2001-2009
  - Original data set = 127 programs; data for 110 did not meet stringent inclusion criteria
- Linear, log-linear & non-linear regression analysis using the coefficient of variation (CV) as the principal statistical "measure of merit"
  - Each dependent variable was regressed on all possible combinations of four & five independent variables (> 1.5 million combinations!)
  - Developed seven "best" statistical relationships
  - Relationship specific to size growth reflects 19-61% size growth; this is consistent with 2007 study results

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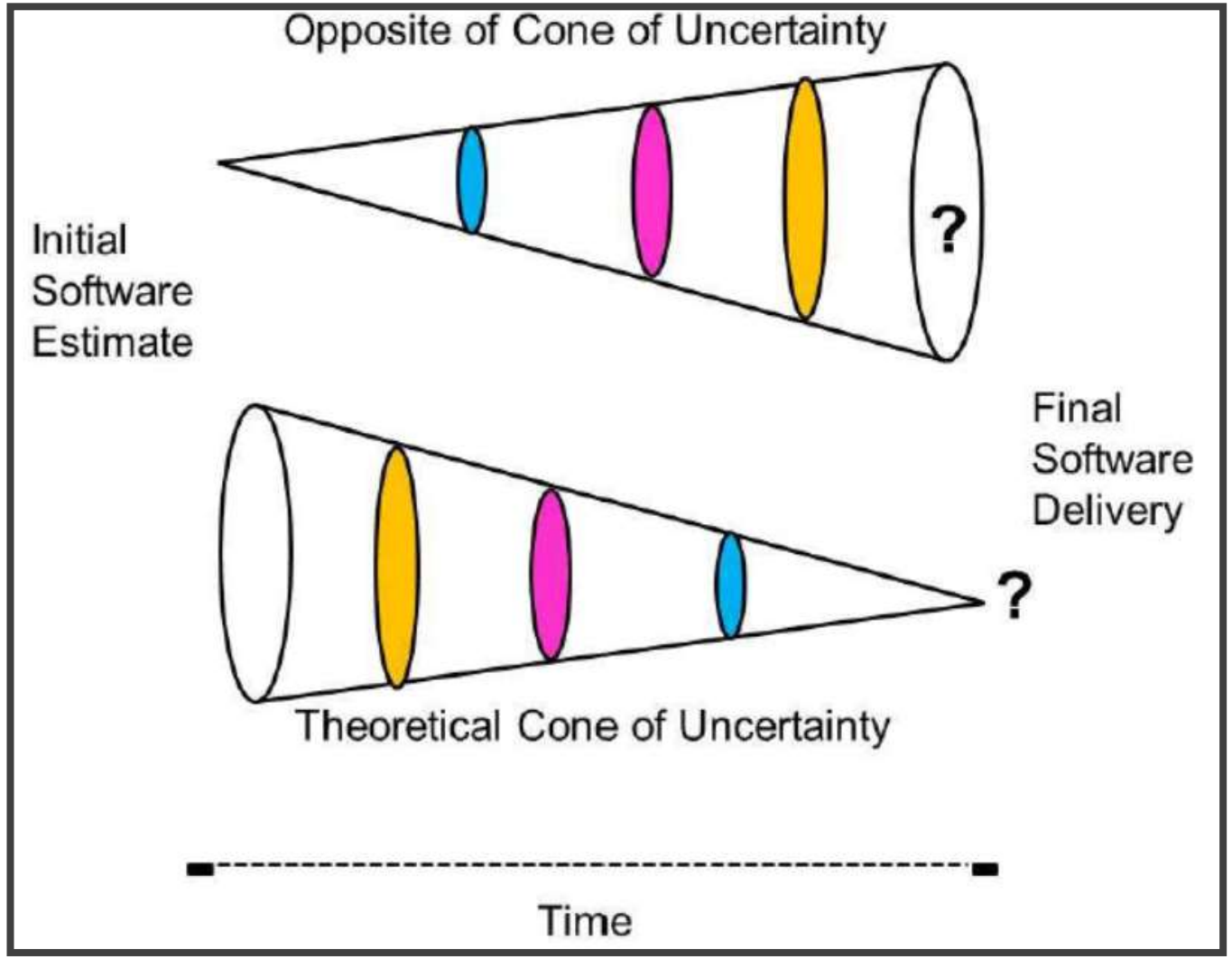
* "ODASA-CE *Software Growth Research,"* Technomics, Inc. (Arnold, Cincotta, Lofgren & Nolte), 2013 ICEAA Workshop, June 2013

U.S. Defense Program Software Size Growth (2015 Study*)

"Does software size grow or shrink?" (slide 5)



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* "*Software Growth Analysis,*" Naval Center for Cost Analysis (Brown, Lanham, Rosa, Staley & Wallshein), 2015 Annual ICEAA Workshop, June 2015

U.S. Defense Program Software Size Growth (2015 Study*)

	Ratio of Final Delivered SLOC to Initially Estimated SLOC					
	Mean	Median	CV	Count	Percent < 1	Percent ≥ 1
DEVELOPMENT PROCESS						
Waterfall	1.41	1.04	0.71	62	32%	68%
Spiral (*prototype program removed*)	1.45	1.26	0.70	63	34%	64%
Incremental	1.29	0.98	0.94	50	50%	50%
Iterative	1.67	1.02	1.19	25	40%	60%

- Results based on analysis of actual vs. estimated sizing data for 200 computer software configuration items (CSCI) for a variety of defense programs
  - ~75% of the data points represent real-time software
- Mean growth factors reflect 29-67% size growth (consistent with other study findings)
  - Coefficient of variation (CV) reflects significant variability
  - 32-50% of the CSCIs did not grow, but 50-68% did

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* "*Software Growth Analysis,*" Naval Center for Cost Analysis (Brown, Lanham, Rosa, Staley & Wallshein), 2015 Annual ICEAA Workshop, June 2015

In closing

- Size is an objective measure of software development complexity that is essential to credible, defensible cost estimates
- Regardless of the sizing technique employed by those responsible for defining the project in enough detail to facilitate cost estimation, the most credible sizing estimates are based on actual sizing data for completed or nearly completed projects
- Regardless of the sizing technique employed and best intentions of all parties responsible for delivering a software product, size growth is an unfortunate fact of life
  - In case of SLOC, three studies of U.S. defense program software data indicate ~20-60% code growth
- Budgets established for future software projects should reflect historical size growth relevant to the type/complexity of the future projects
  - Requires data and rigorous analysis of the type reflected in the three studies

Beware of hallucinated assumptions and 'experts' who don't come to the table with data!

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Thanks for attending today!

Noted software growth presentations at https://www.iceaaonline.com/archives/

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