Performing Software Feasibility Analysis on Major Defense Acquisition Programs

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13th Annual NDIA Systems Engineering Conference
San Diego, CA | October 27, 2010

Mission Context

Director, Systems Engineering
Steve Welby

Systems Analysis

"Weapon Systems Acquisition Reform Act of 2009"

S.454-10; d.(1): The development and tracking of detailed measurable performance criteria as part of the systems engineering master plans…

S.454-10; d.(3): A system for storing and tracking information relating to the achievement of the performance criteria and objectives specified…

S.454-12; SEC. 103.b.(4): Evaluating the utility of performance metrics used to measure the cost, schedule, and performance of [MDAPS], and making such recommendations …to improve such metrics.

Major Program Support
James Thompson

- Program Support Reviews
- Systems Engineering Plans
- Program Technical Auditing
- OIPT/DAB Support
- DAES Database Analysis and Support
- Performance Measurement
- Systemic Root Cause Analysis

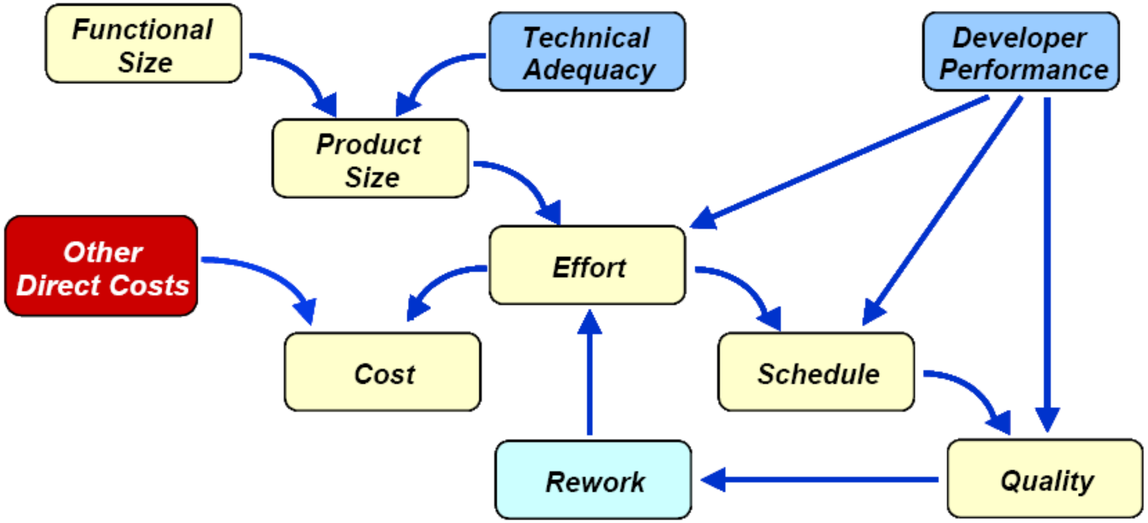
Mission Assurance

Software Performance Measurement and Analysis

- DAPS 4.5 Software
- Data Collection based on Best Practices
- Parametric analysis used to assess program feasibility and establish benchmarks

Initial Metrics Data Call

- **Metric**
  - Sizing (for each build, broken down by new/modified/reused, in SLOC)
- **Numerical Context (for each build)**
  1. Peak staffing
  2. Effort hours
  3. Duration (start and end dates, both planned and actual)
  4. Software reliability target (Mean Time to Defect, MTTD) or actual defects discovered



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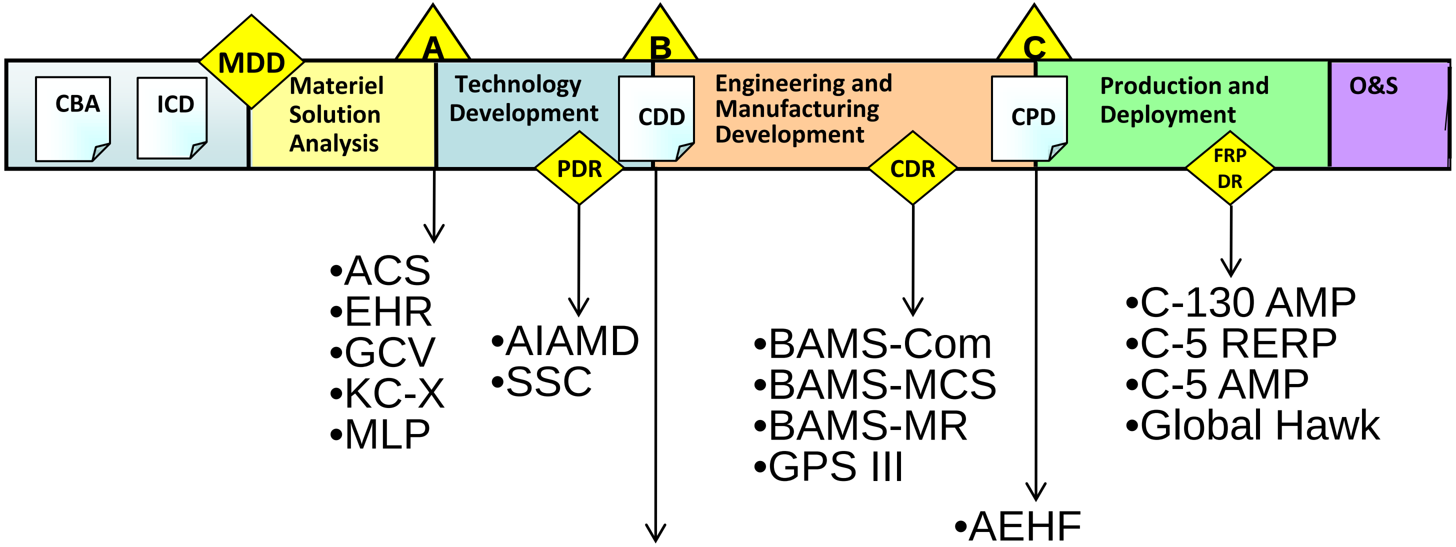
Initial Metrics Data Call

- **Descriptive Context (Background)**
  - System type (business, scientific, real time (e.g., avionics))
  - Program briefs that explain the software effort and any discussion of functionality included in each build or release (and which builds are customer releases vs. engineer builds), as well as Software Development Plan (explains their metrics collection plan).
  - Any metrics from previously completed builds/releases
  - Listing of the key PSR event dates (e.g., initial review dates, final brief, etc.)
- **Expected Sources**
  - CARD and Software Resources Data Report (SRDR) appendixes (2630-1 or 2630-2, 2630-3)
  - Software Development Plan (SDP)
  - Contract Deliverables (CDRLs) that contain monthly software performance data
  - Integrated Master Schedule (IMS) if software is shown
  - Integrated Master Plan (IMP)

40 Software Program Analyses Completed/Ongoing (2008-2010)



MDD
A
B
C
CBA
ICD
Materiel Solution Analysis
Technology Development
CDD
Engineering and Manufacturing Development
CPD
Production and Deployment
O&S
PDR
CDR
FRP DR

- ACS
- EHR
- GCV
- KC-X
- MLP

- AIAMD
- SSC

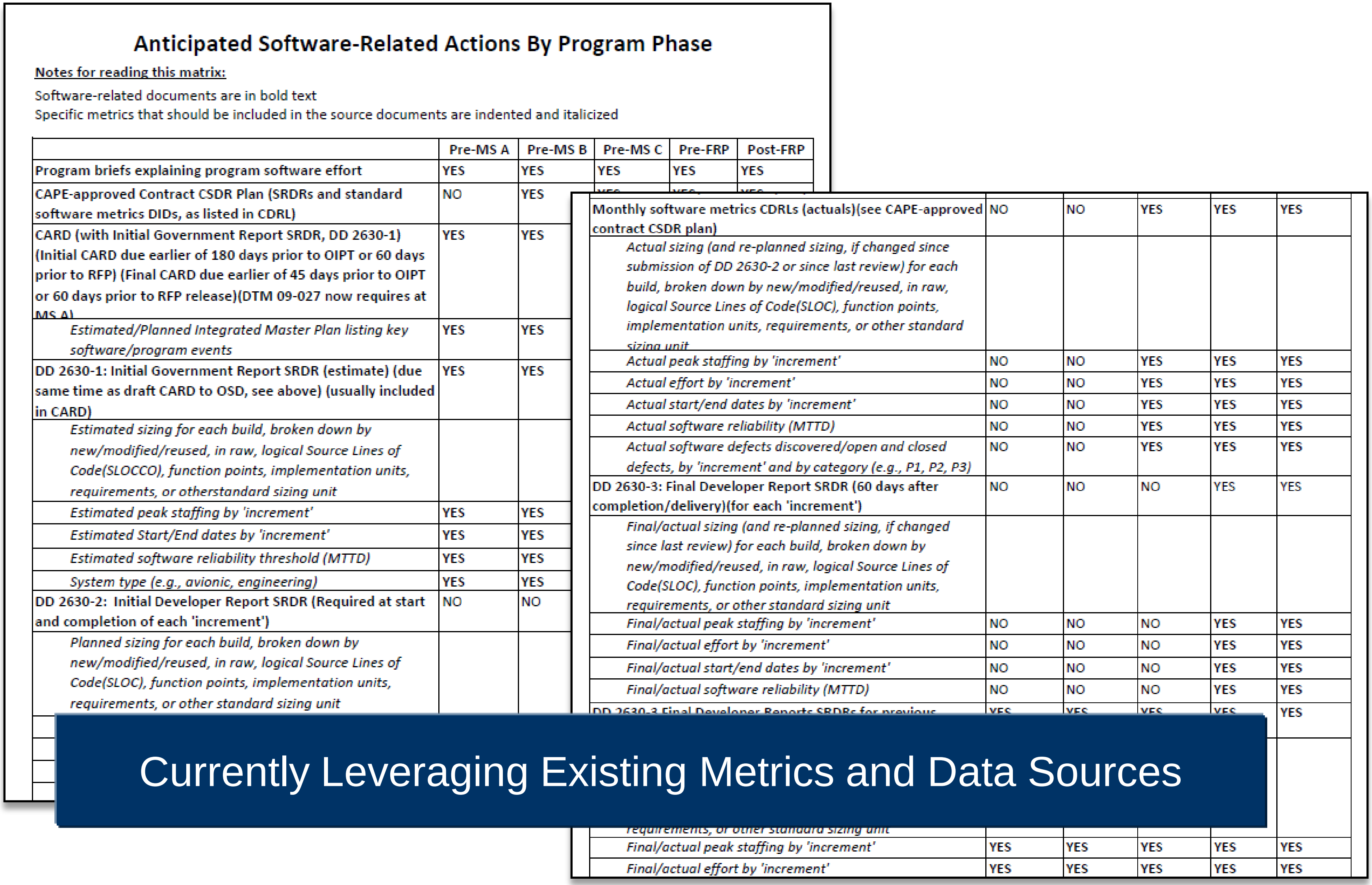
- BAMS-Com
- BAMS-MCS
- BAMS-MR
- GPS III

- C-130 AMP
- C-5 RERP
- C-5 AMP
- Global Hawk

- AIAMD (Initial CARD)
- AIAMD (After De-Scope)
- AOC WS
- ARH-70A
- CH-53K
- DDG 1000
- LCS
- SIAP

- AEHF
- Apache Block 3
- BCS
- EA-18G
- E-2D
- ER/MP
- Excalibur
- FCS
- ISPAN
- JSF
- MPS
- P-8A
- VA Class (MS III)

Existing Lifecycle Metric Sources



Anticipated Software-Related Actions By Program Phase

Notes for reading this matrix:

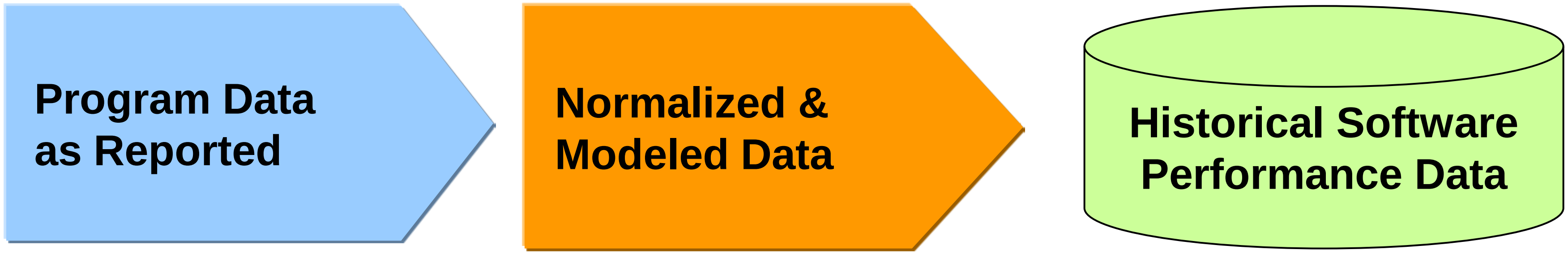
Software-related documents are in bold text
Specific metrics that should be included in the source documents are indented and italicized

	Pre-MS A	Pre-MS B	Pre-MS C	Pre-FRP	Post-FRP
Program briefs explaining program software effort	YES	YES	YES	YES	YES
CAPE-approved Contract CSDR Plan (SRDRs and standard software metrics DIDs, as listed in CDRL)	NO	YES			
CARD (with Initial Government Report SRDR, DD 2630-1) (Initial CARD due earlier of 180 days prior to OIPT or 60 days prior to RFP) (Final CARD due earlier of 45 days prior to OIPT or 60 days prior to RFP release)(DTM 09-027 now requires at MS A)	YES	YES			
Estimated/Planned Integrated Master Plan listing key software/program events	YES	YES			
DD 2630-1: Initial Government Report SRDR (estimate) (due same time as draft CARD to OSD, see above) (usually included in CARD)	YES	YES			
Estimated sizing for each build, broken down by new/modified/reused, in raw, logical Source Lines of Code(SLOCCO), function points, implementation units, requirements, or otherstandard sizing unit					
Estimated peak staffing by 'increment'	YES	YES			
Estimated Start/End dates by 'increment'	YES	YES			
Estimated software reliability threshold (MTTD)	YES	YES			
System type (e.g., avionic, engineering)	YES	YES			
DD 2630-2: Initial Developer Report SRDR (Required at start and completion of each 'increment')	NO	NO			
Planned sizing for each build, broken down by new/modified/reused, in raw, logical Source Lines of Code(SLOC), function points, implementation units, requirements, or other standard sizing unit					

Monthly software metrics CDRLs (actuals)(see CAPE-approved contract CSDR plan)	NO	NO	YES	YES	YES
Actual sizing (and re-planned sizing, if changed since submission of DD 2630-2 or since last review) for each build, broken down by new/modified/reused, in raw, logical Source Lines of Code(SLOC), function points, implementation units, requirements, or other standard sizing unit					
Actual peak staffing by 'increment'	NO	NO	YES	YES	YES
Actual effort by 'increment'	NO	NO	YES	YES	YES
Actual start/end dates by 'increment'	NO	NO	YES	YES	YES
Actual software reliability (MTTD)	NO	NO	YES	YES	YES
Actual software defects discovered/open and closed defects, by 'increment' and by category (e.g., P1, P2, P3)	NO	NO	YES	YES	YES
DD 2630-3: Final Developer Report SRDR (60 days after completion/delivery)(for each 'increment')	NO	NO	NO	YES	YES
Final/actual sizing (and re-planned sizing, if changed since last review) for each build, broken down by new/modified/reused, in raw, logical Source Lines of Code(SLOC), function points, implementation units, requirements, or other standard sizing unit					
Final/actual peak staffing by 'increment'	NO	NO	NO	YES	YES
Final/actual effort by 'increment'	NO	NO	NO	YES	YES
Final/actual start/end dates by 'increment'	NO	NO	NO	YES	YES
Final/actual software reliability (MTTD)	NO	NO	NO	YES	YES
DD 2630-3 Final Developer Reports SRDRs for previous	YES	YES	YES	YES	YES
requirements, or other standard sizing unit					
Final/actual peak staffing by 'increment'	YES	YES	YES	YES	YES
Final/actual effort by 'increment'	YES	YES	YES	YES	YES

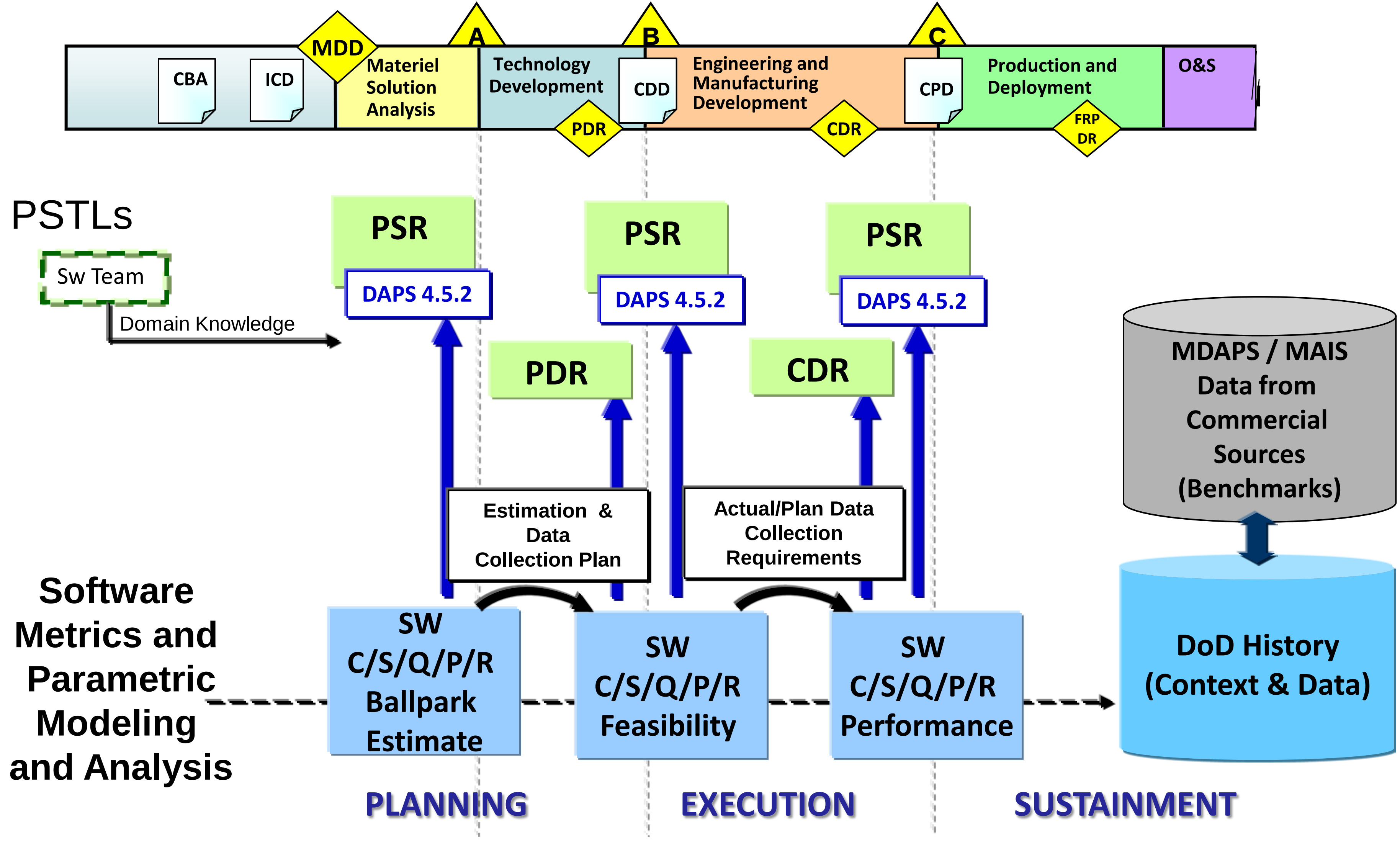
Currently Leveraging Existing Metrics and Data Sources

Sample Metrics Collected, Normalized, and Modeled


Program Data as Reported
Normalized & Modeled Data
Historical Software Performance Data

- **Metrics are captured as reported by the Program (as Program Artifacts)**
  - Identify internal inconsistencies within Program metrics
  - Identify data gaps, and omissions
  - Data validation is necessary to conduct analysis
- **Metrics are normalized to enable parametric modeling and benchmark analyses**
  - Normalization provides ability use parametric models to assess feasibility
  - Software development effort assessed based on probability of success
- **Data compiled into historical repository to support benchmark analyses**
  - Normalized data allows for benchmarking
  - Unified data set provides ability to assess software performance across portfolios of programs

Analysis Across the Acquisition Lifecycle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FRP DR
PSTLs
Sw Team
Domain Knowledge
PSR
DAPS 4.5.2
PSR
DAPS 4.5.2
PSR
DAPS 4.5.2
PDR
CDR
MDAPS / MAIS Data from Commercial Sources (Benchmarks)
Estimation & Data Collection Plan
Actual/Plan Data Collection Requirements
Software Metrics and Parametric Modeling and Analysis
SW C/S/Q/P/R Ballpark Estimate
SW C/S/Q/P/R Feasibility
SW C/S/Q/P/R Performance
DoD History (Context & Data)
PLANNING
EXECUTION
SUSTAINMENT

C/S/Q/P/R – cost, schedule, quality, performance, & risk

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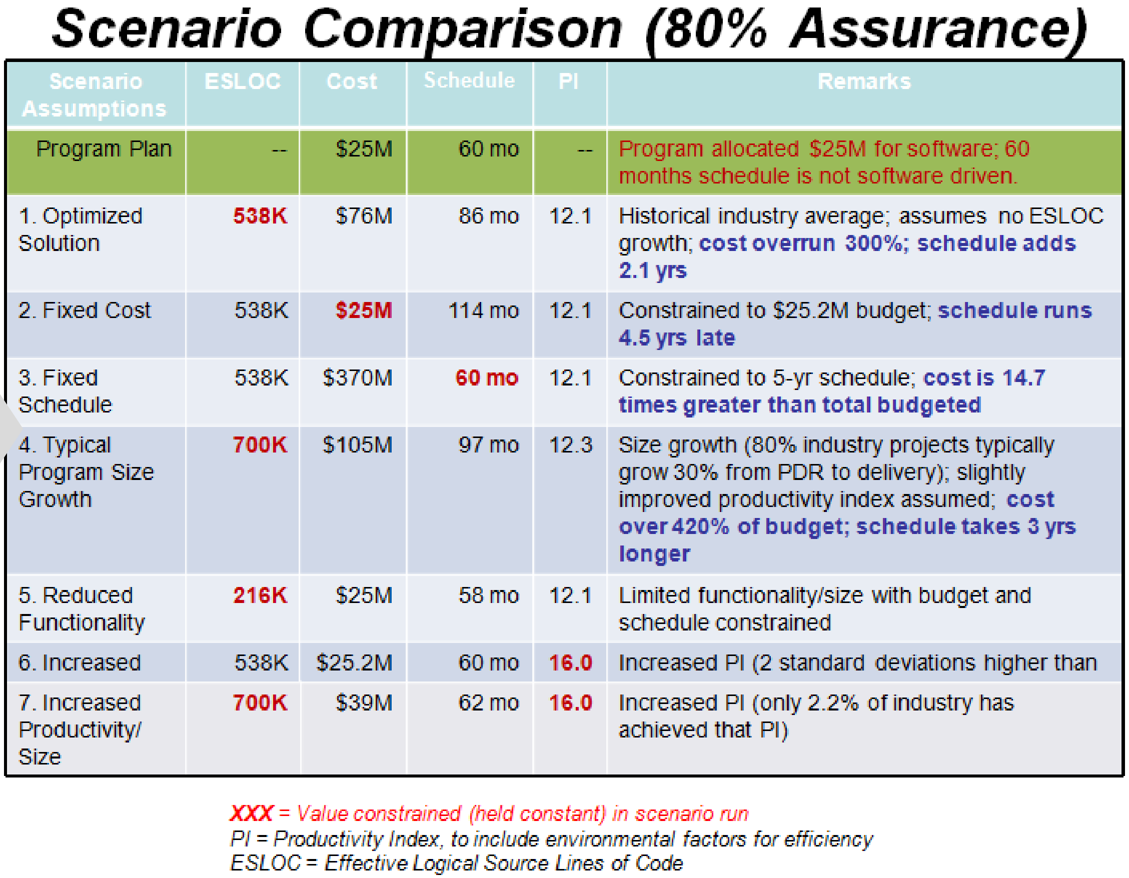
Software Analysis and Insight

- **MS A: Ballpark Estimate / Feasibility analysis**
  - Is the program's plan to estimate the software adequate? Is the Acquisition strategy adequately accounting for the software development aspects?
  - What information (granularity) is missing or inadequate at this point in the program? Has the program identified the software metrics/data reporting requirements for the TD & EMD?
- **MS B: Independent Estimate / Plan Feasibility Analysis**
  - Are the software planning artifacts mature enough to support an estimate? What is the probability of meeting the delivery date?
  - How does their software plan compare to similar programs WRT size, complexity, schedule, staffing, & effort/cost?
  - Has the program adequately incorporated data collection & metrics reporting into the RFP and contract deliverables to support OSD program performance assessments?
- **MS C: Benchmark / Software Reliability Assessment**
  - Based on the performance data to date, what is the probability the program will deliver on time and on schedule?
  - What is the software defect density? And how does it compare to other similar programs? Does the data indicate a software quality issue?
- **Nunn-McCurdy/Special Emphasis:**
  - Is the Program's performance typical? (i.e., was the breach due to inadequate funding/planning or is the breach due to poor performance)?

Example A/Pre-MS B: “Trade Space”

Program Office received trade space analysis

Enabled the program office to select initial planning options in the feasible trade space



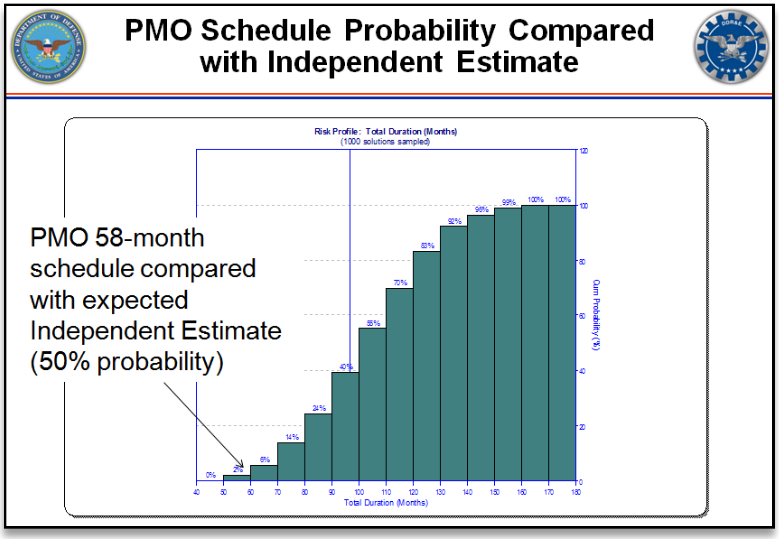
Scenario Comparison (80% Assurance)

Scenario Assumptions	ESLOC	Cost	Schedule	PI	Remarks
Program Plan	--	$25M	60 mo	--	Program allocated $25M for software; 60 months schedule is not software driven.
1. Optimized Solution	**538K**	$76M	86 mo	12.1	Historical industry average; assumes no ESLOC growth; **cost overrun 300%; schedule adds 2.1 yrs**
2. Fixed Cost	538K	**$25M**	114 mo	12.1	Constrained to $25.2M budget; **schedule runs 4.5 yrs late**
3. Fixed Schedule	538K	$370M	**60 mo**	12.1	Constrained to 5-yr schedule; **cost is 14.7 times greater than total budgeted**
4. Typical Program Size Growth	**700K**	$105M	97 mo	12.3	Size growth (80% industry projects typically grow 30% from PDR to delivery); slightly improved productivity index assumed; **cost over 420% of budget; schedule takes 3 yrs longer**
5. Reduced Functionality	**216K**	$25M	58 mo	12.1	Limited functionality/size with budget and schedule constrained
6. Increased	538K	$25.2M	60 mo	**16.0**	Increased PI (2 standard deviations higher than
7. Increased Productivity/ Size	**700K**	$39M	62 mo	**16.0**	Increased PI (only 2.2% of industry has achieved that PI)

XXX = Value constrained (held constant) in scenario run
PI = Productivity Index, to include environmental factors for efficiency
ESLOC = Effective Logical Source Lines of Code

Interrelationships among size, effort, staffing, duration, and productivity allow decision-makers to see the impact of existing program constraints

Example A/Pre-MS B: Feasibility



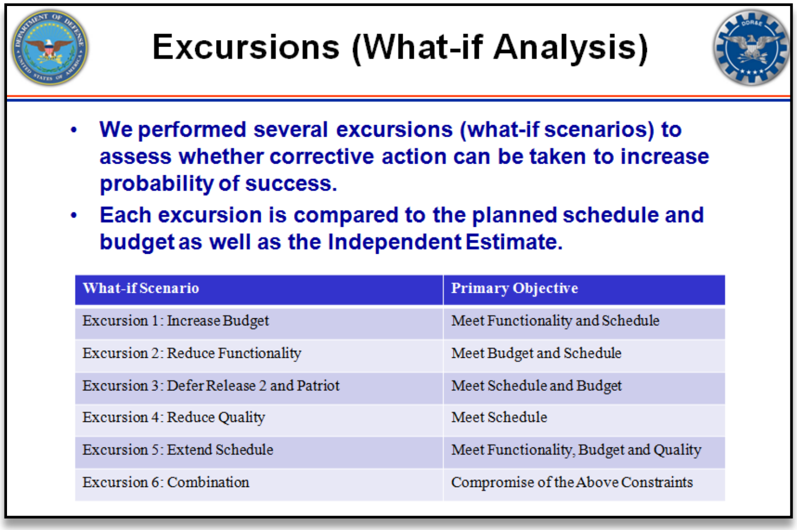
PMO Schedule Probability Compared with Independent Estimate

PMO 58-month schedule compared with expected Independent Estimate (50% probability)

- Feasibility analysis of the proposed Government estimate/plan indicated a 7% probability of meeting schedule

- Excursion analysis showed Program Office feasible options

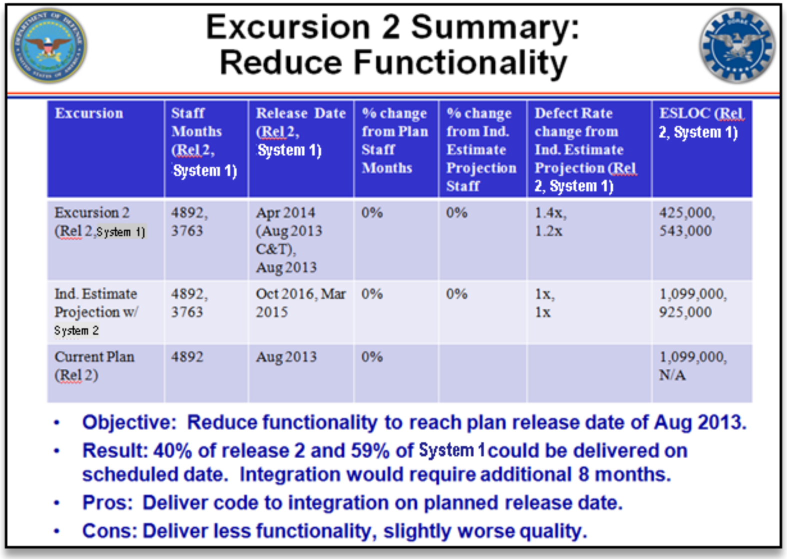
- Program Office “de-scoped’ and revised plan was assessed near 50% probability of meeting schedule; reducing overall cost & schedule risk to the program



Excursions (What-if Analysis)

- We performed several excursions (what-if scenarios) to assess whether corrective action can be taken to increase probability of success.
- Each excursion is compared to the planned schedule and budget as well as the Independent Estimate.

What-if Scenario	Primary Objective
Excursion 1: Increase Budget	Meet Functionality and Schedule
Excursion 2: Reduce Functionality	Meet Budget and Schedule
Excursion 3: Defer Release 2 and Patriot	Meet Schedule and Budget
Excursion 4: Reduce Quality	Meet Schedule
Excursion 5: Extend Schedule	Meet Functionality, Budget and Quality
Excursion 6: Combination	Compromise of the Above Constraints



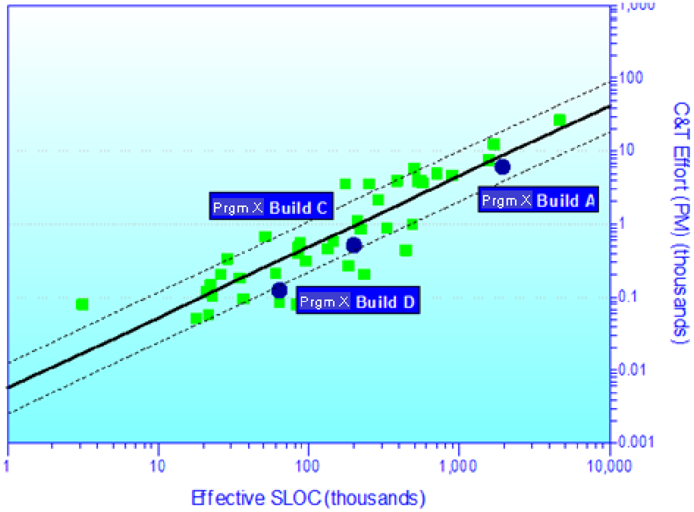
Excursion 2 Summary: Reduce Functionality

Excursion	Staff Months (Rel 2, System 1)	Release Date (Rel 2, System 1)	% change from Plan Staff Months	% change from Ind. Estimate Projection Staff	Defect Rate change from Ind. Estimate Projection (Rel 2, System 1)	ESLOC (Rel 2, System 1)
Excursion 2 (Rel 2, System 1)	4892, 3763	Apr 2014 (Aug 2013 C&T), Aug 2013	0%	0%	1.4x, 1.2x	425,000, 543,000
Ind. Estimate Projection w/ System 2	4892, 3763	Oct 2016, Mar 2015	0%	0%	1x, 1x	1,099,000, 925,000
Current Plan (Rel 2)	4892	Aug 2013	0%			1,099,000, N/A

- Objective: Reduce functionality to reach plan release date of Aug 2013.
- Result: 40% of release 2 and 59% of System 1 could be delivered on scheduled date. Integration would require additional 8 months.
- Pros: Deliver code to integration on planned release date.
- Cons: Deliver less functionality, slightly worse quality.

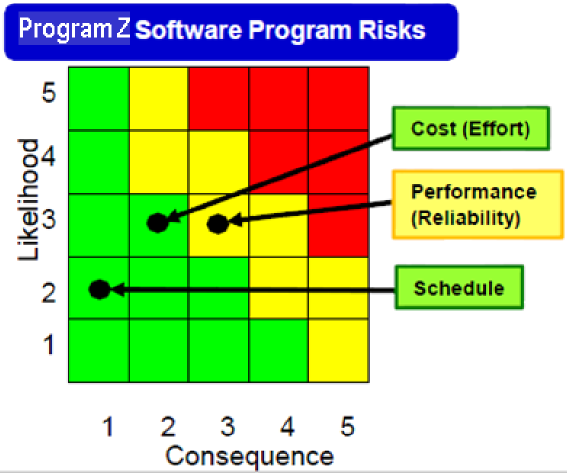
Example MS B: Plan Feasibility

- Similar AT&L projects shown in green
- **Program X Builds in blue**
- Plot provides solid center line of AT&L project and 1 standard deviation dotted line
- View all four views concurrently to gain insight:
  - Size vs Effort
  - Size vs Staffing
  - Size vs Productivity parameter
  - Size vs Schedule



Scatter plot shows feasibility of planned builds compared to other similar AT&L programs

Risk areas identified based on statistical distance from historical program performance



Although consistent with AT&L projects, potential risk due to large size and increased defects, impacting reliability and, to lesser degree, schedule (fixing instead of coding).

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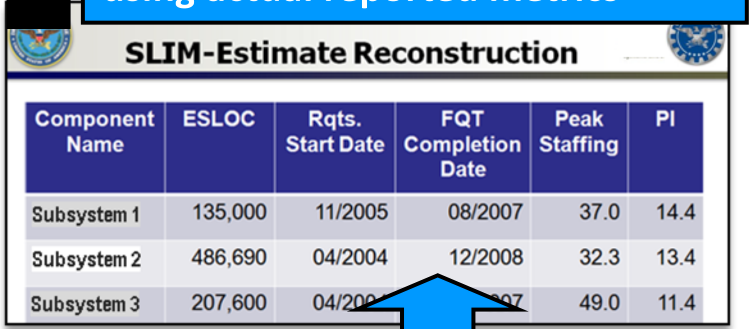
Example MS C: Software Reliability Modeling

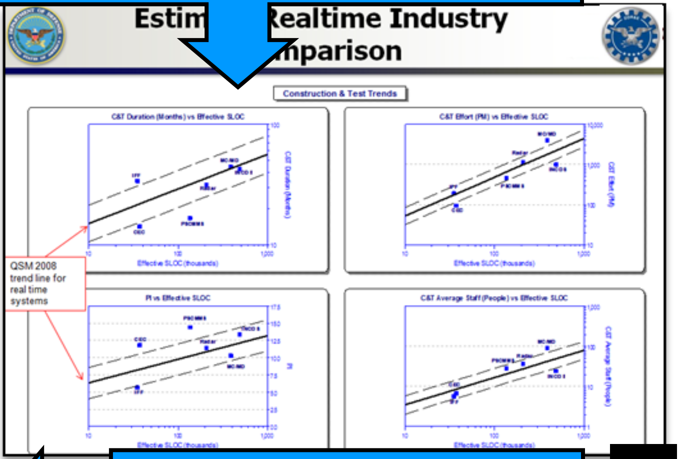
1 Reconstruct current/adjusted plan using actual reported metrics



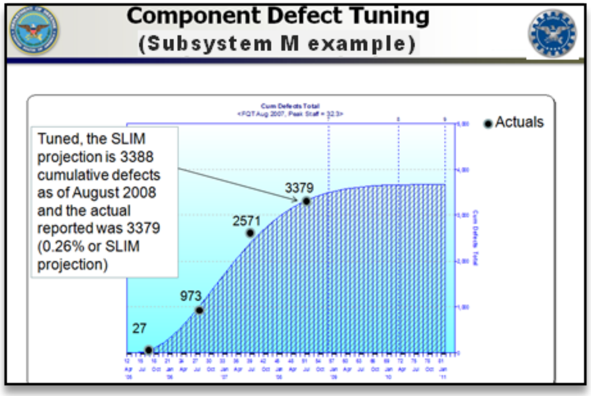
SLIM-Estimate Reconstruction

Component Name	ESLOC	Rqts. Start Date	FQT Completion Date	Peak Staffing	PI
Subsystem 1	135,000	11/2005	08/2007	37.0	14.4
Subsystem 2	486,690	04/2004	12/2008	32.3	13.4
Subsystem 3	207,600	04/200	007	49.0	11.4

2 Compare and quantify performance to date with similar programs



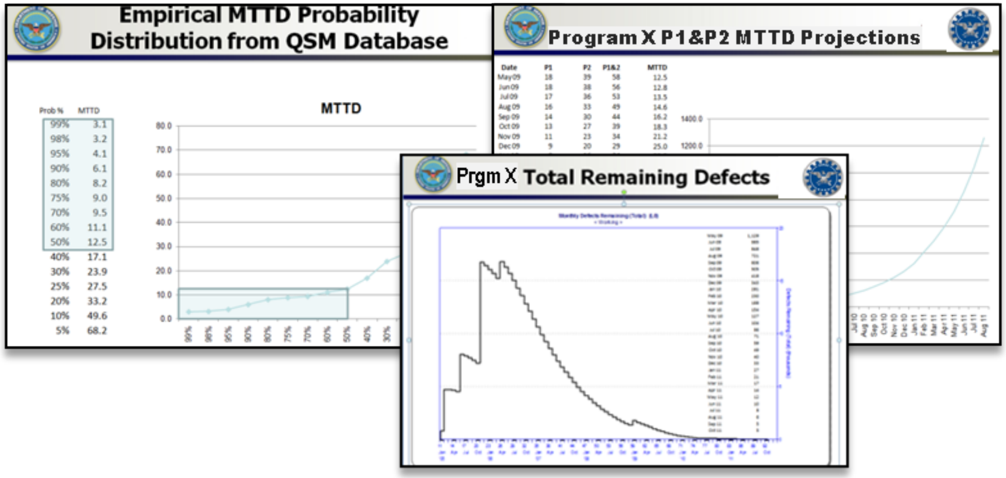
3 Using reported defects, calibrate model



Component Defect Tuning (Subsystem M example)

Tuned, the SLIM projection is 3388 cumulative defects as of August 2008 and the actual reported was 3379 (0.26% or SLIM projection)

4 Forecast if acceptable software reliability will be achieved by release date compared to similar programs



Empirical MTTD Probability Distribution from QSM Database

Prob %	MTTD
99%	3.1
98%	3.2
95%	4.1
90%	6.1
80%	8.2
75%	9.0
70%	9.5
60%	11.1
50%	12.5
40%	17.1
30%	23.9
25%	27.5
20%	33.2
10%	49.6
5%	68.2

Program X P1&P2 MTTD Projections

Date	P1	P2	P1&2	MTTD
May 09	18	39	58	12.5
Jun 09	18	38	56	12.8
Jul 09	17	36	53	13.5
Aug 09	16	33	49	14.6
Sep 09	14	30	44	16.2
Oct 09	13	27	39	18.3
Nov 09	11	23	34	21.2
Dec 09	9	20	29	25.0

Prgm X Total Remaining Defects

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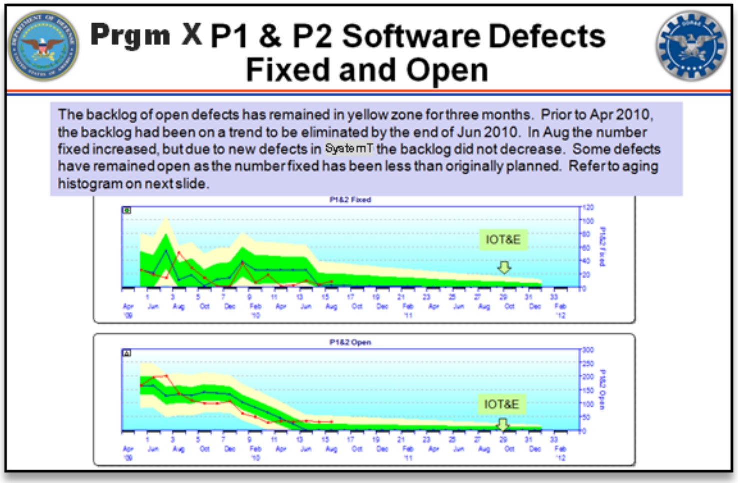
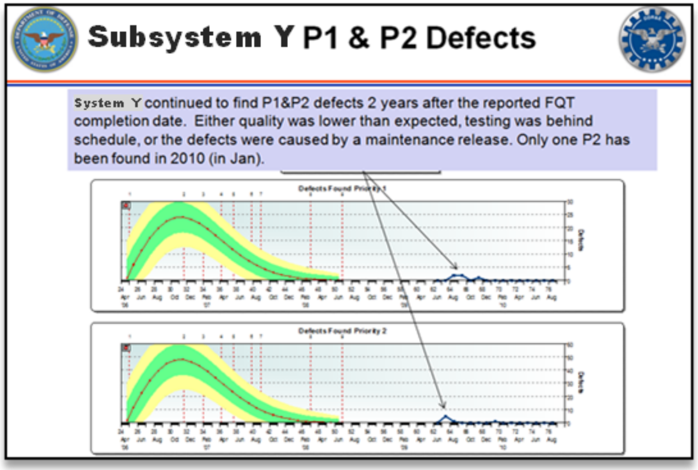
Example Continuous Defect Monitoring



Prgm X P1 & P2 Software Defects Fixed and Open

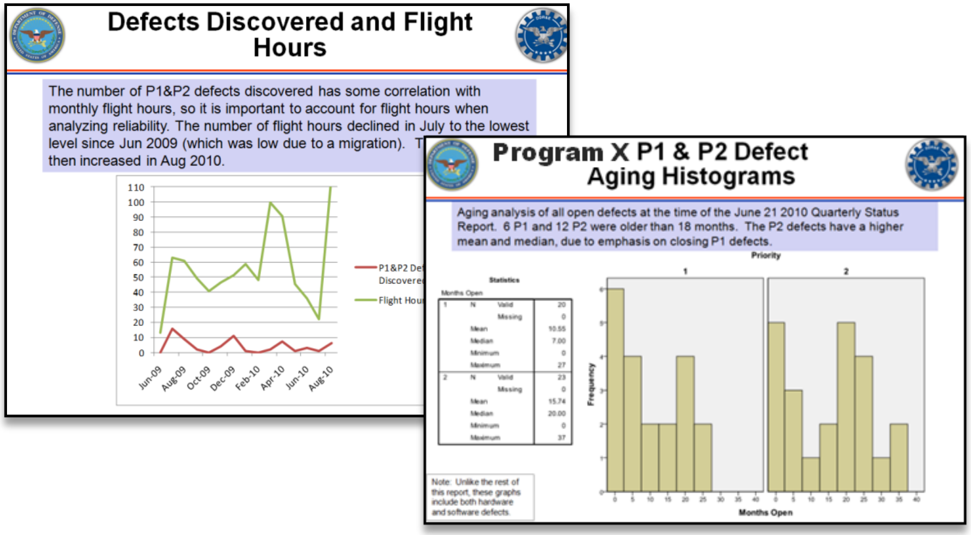
The backlog of open defects has remained in yellow zone for three months. Prior to Apr 2010, the backlog had been on a trend to be eliminated by the end of Jun 2010. In Aug the number fixed increased, but due to new defects in SystemT the backlog did not decrease. Some defects have remained open as the number fixed has been less than originally planned. Refer to aging histogram on next slide.



Subsystem Y P1 & P2 Defects

System Y continued to find P1&P2 defects 2 years after the reported FQT completion date. Either quality was lower than expected, testing was behind schedule, or the defects were caused by a maintenance release. Only one P2 has been found in 2010 (in Jan).

Continuous monthly monitoring provides detailed insight into projected reliability, highlighting any unusual backlog or defect discovery, down to subcomponent level



Defects Discovered and Flight Hours

The number of P1&P2 defects discovered has some correlation with monthly flight hours, so it is important to account for flight hours when analyzing reliability. The number of flight hours declined in July to the lowest level since Jun 2009 (which was low due to a migration). T then increased in Aug 2010.

Program X P1 & P2 Defect Aging Histograms

Aging analysis of all open defects at the time of the June 21 2010 Quarterly Status Report. 6 P1 and 12 P2 were older than 18 months. The P2 defects have a higher mean and median, due to emphasis on closing P1 defects.

Statistics

Months Open

1	N	Valid	20
		Missing	0
	Mean		10.55
	Median		7.00
	Minimum		0
	Maximum		27
2	N	Valid	23
		Missing	0
	Mean		15.74
	Median		20.00
	Minimum		0
	Maximum		37

Note: Unlike the rest of this report, these graphs include both hardware and software defects.

Software Observations

- **Summary findings from our parametric analyses of software intensive programs at OSD AT&L:**
  - Lack of software reliability requirement
  - Missing core metrics needed for monthly tracking / forecasting
  - Inadequate program level estimation and probability assessment
  - Too much schedule compression (high staffing and risk of poor quality)

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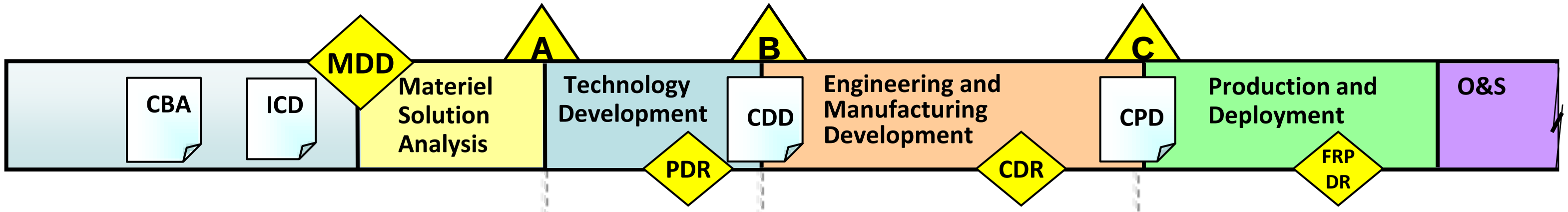
Path Forward

- **Leveraging existing metrics and data sources**
  - From many potential metrics; initial data call is limited to 5 fundamental metrics which should naturally exist based on existing acquisition policy and guidance.
  - Normalized and validated metrics provide a basis to model the software development effort and provide insight into overall software development feasibility
- **Extending and maturing metric-based oversight**
  - Time Sensitive
    - Measures collected during program interactions (e.g., PSRs)
    - Metrics collected to support specific decisions (e.g., Program's 'readiness to proceed')
  - Milestone Driven
    - Metrics collected based on a Milestone or Technical Review
    - Metrics provide a static or 'snapshot' of program as of a specific date/time
  - Periodic Data Collection
    - Metrics collected to show trends or 'movement'
    - Frequency
      - Monthly (e.g., defect modeling)
      - Quarterly (e.g., requirements stability)
      - Annually (e.g., inputs to congressional report)

Summary of Software Data, Analysis, & Lifecycle Decision Support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Technology Development
CDD
Engineering and Manufacturing Development
CPD
Production and Deployment
O&S
PDR
CDR
FRP DR

Program Artifacts	CARD ConOps SRDR-1	Sys Spec SDP SRDR-2	Monthly Status Test Plan SRDR-3
SW Data/ Metrics	**Domain (Context)** Ballpark Size, Constraints • Schedule, • Budget, etc.	Planned: • Size • Schedule • Staffing/Effort • ***SW Reliability***	Actual: • Size • Schedule • Staffing/Effort • Defects • Test Points
Parametric Analysis Objectives	Feasible Trade Space? Alternatives?	Realistic plan? Assumptions - Productivity - Amount of Reuse - Existence of SW Reliability Rqmt	Program health check: • Actual vs. Plan • Forecast to Complete • SW Reliability Modeling

For Additional Information

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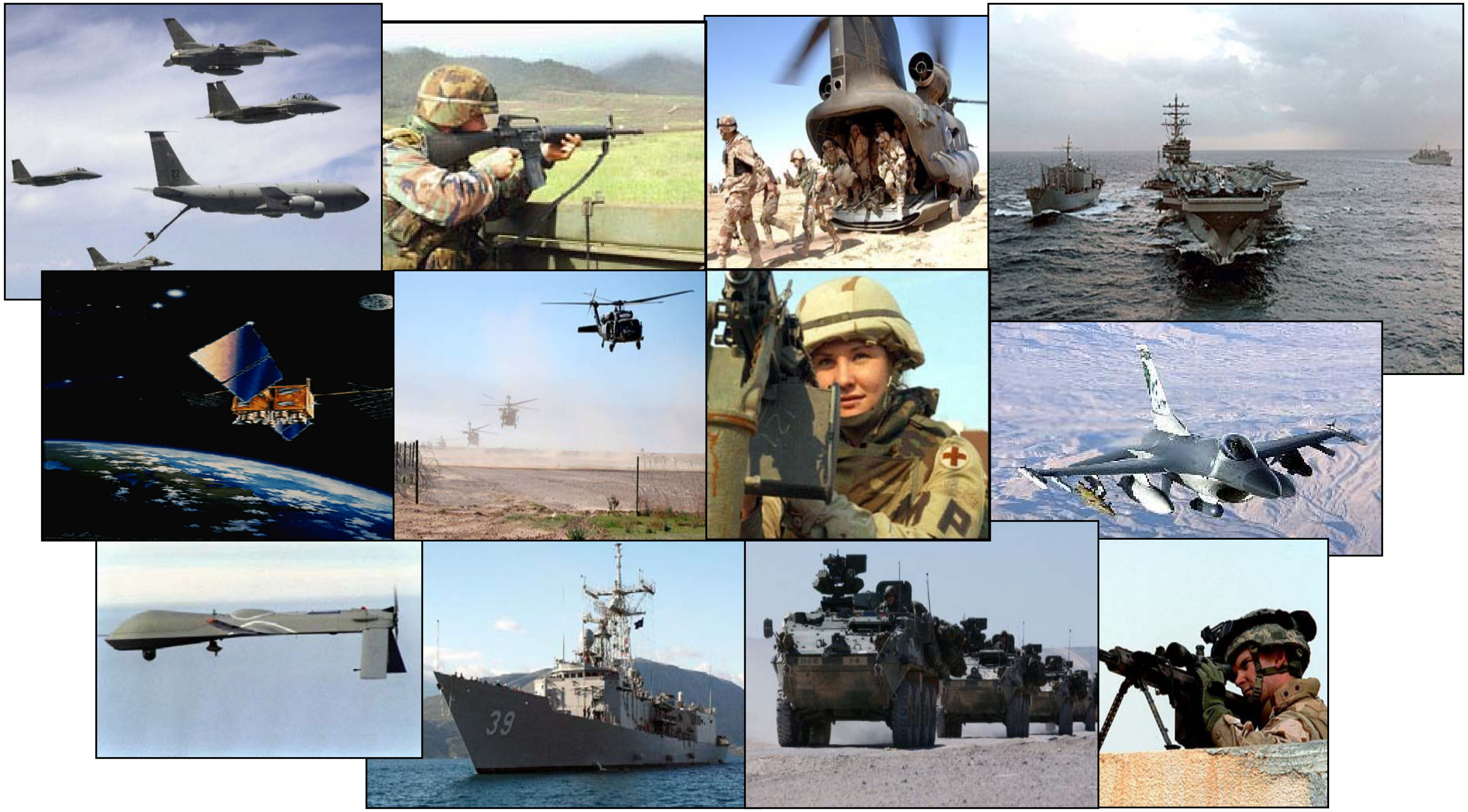
Systems Engineering: Critical to Program Success



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