New Army Software Sustainment Cost Estimating Results

DASA-CE

Presented to

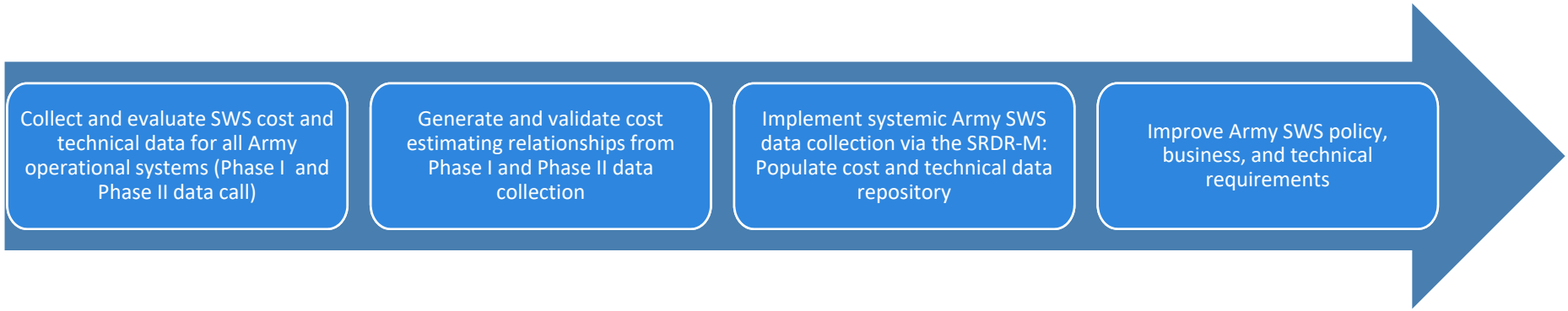
ICEAA

May 2019

SWS Initiative Objective and Strategy

Accurately estimate Army system Software Sustainment (SWS) costs to:

- Effectively project and justify software and system life cycle costs
- Objectively evaluate Army system software sustainment execution costs
- Inform and optimize the allocation of available sustainment resources across the Army



Effective software sustainment cost estimation is the basis for Army system software life cycle cost management

Executive Summary - Accomplishments

- Established Software Sustainment Data Collection Mechanisms
  - Army Software Data Collection Questionnaire
  - SRDR for Maintenance
  - Software Sustainment WBS Used to Collect Sustainment Costs
- Created Comprehensive Software Sustainment Data Repository
  - 192 Systems
  - 700 Capability Releases
  - 300 IAVA Releases
  - 3,200 records on software license data
- Established Robust Foundation for Software Sustainment Fact-Based Decisions
  - Allocations of Costs by WBS Elements
  - Cost & Schedule Estimating Relationships
  - Benchmarks
- Data and Analysis Results provided to DoD Community

Presentation Overview

- Overview
- Data Characterization
- Capability Release Analysis
  - Cost Estimation Relationships (CER)
  - Software Estimating Relationships (SER)
- IAVA Release Analysis
- Benchmarks
- Cost Impact of Software Baselines
- Lessons Learned
- Future Efforts

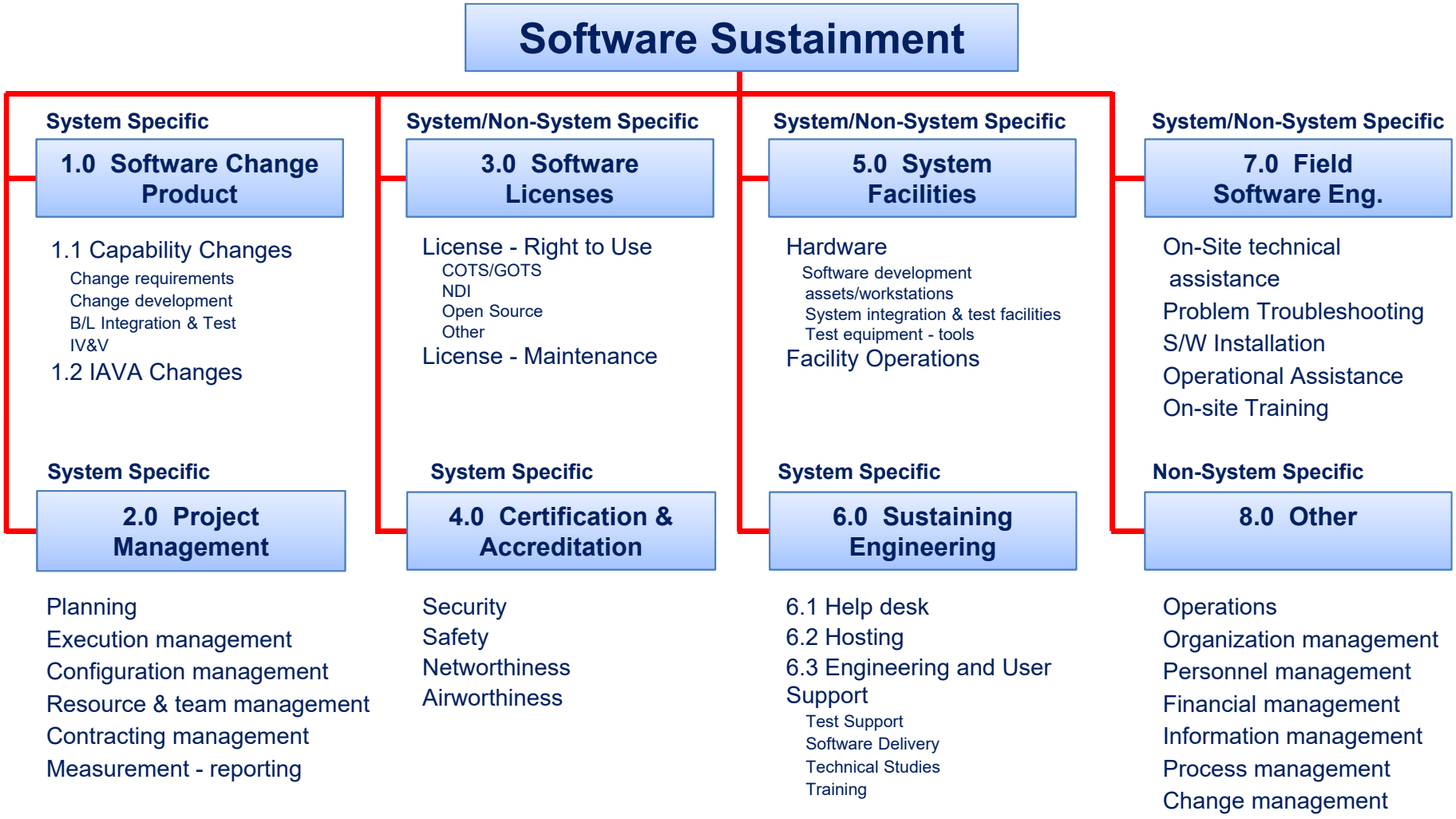
Decision Information

- Decision information must objectively tie investment costs to software product mission capability

- Program-level management must decide
  - Which baseline change requirements to implement
  - Prioritization of capability, maintenance, and security changes
  - Delivery strategy for incremental software releases

- Enterprise-level management must decide
  - Prioritization of resources across the operational system portfolio
  - Tradeoffs between funding and associated mission capability

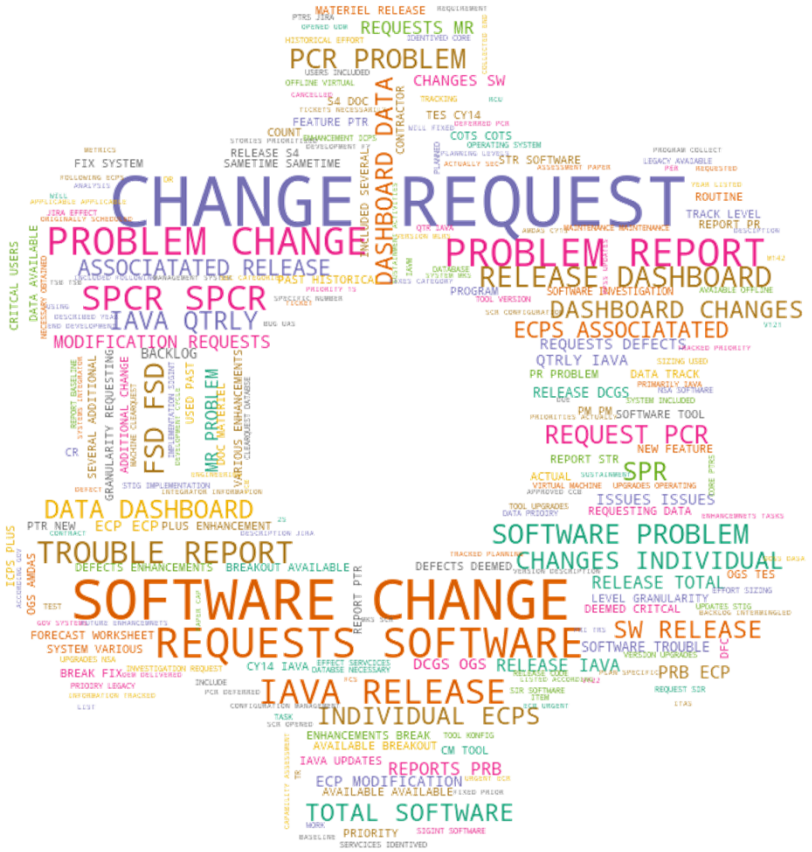
DASA-CE SWS WBS



Version 5.0

Software Change Definition Variability

- Within WBS 1.0, the effort associated with software releases is captured
- A software release can be sized using the count of the number of software changes
- A software change describes a change where source code/script is altered whether it be added, deleted or modified
- Respondents defined a software change as:
  - Enhancements
    - New capability: ECPs, new requirements
    - Redesign / rewrite: 100% new code, new architecture
  - Maintenance
    - Defect repair: bug fixes, PTR fixes
    - Reconfiguration: threat loads, EW parameters
    - Rehost: migration from Windows to Linux
    - Testing: interoperability testing
    - Update: weapon tables, switch configurations, Operating System
    - Update, Defect repair (see above)
    - Upgrade: upgrade the v “n” to v “n+1”, upgrading applications
  - Cyber
    - Vulnerabilities: enhance security posture not resolved



Since there was significant variability across the programs in the definition of a software change, a more in-depth analysis was conducted to understand the costs of different types of software changes

Army Software Sustainment Definition

- Software sustainment (SWS) includes all software change activities and products associated with modifying a software system after a software release has been provided to an external party
- The release is the primary SWS change product - a composite of one or more changes - it can be either a formal release or an engineering release
- SWS includes software enhancements, software maintenance, and cybersecurity updates
- Software maintenance includes defect repair, rehosting, adaptations, updates, and reconfiguration
- SWS may be funded by multiple funding sources
- Costs include both Fixed and Variable costs accrued at both the system and organizational levels
- Costs include both organic (government) and contractor resources

Software Sustainment Data Characterization

Data Demographics

Overview

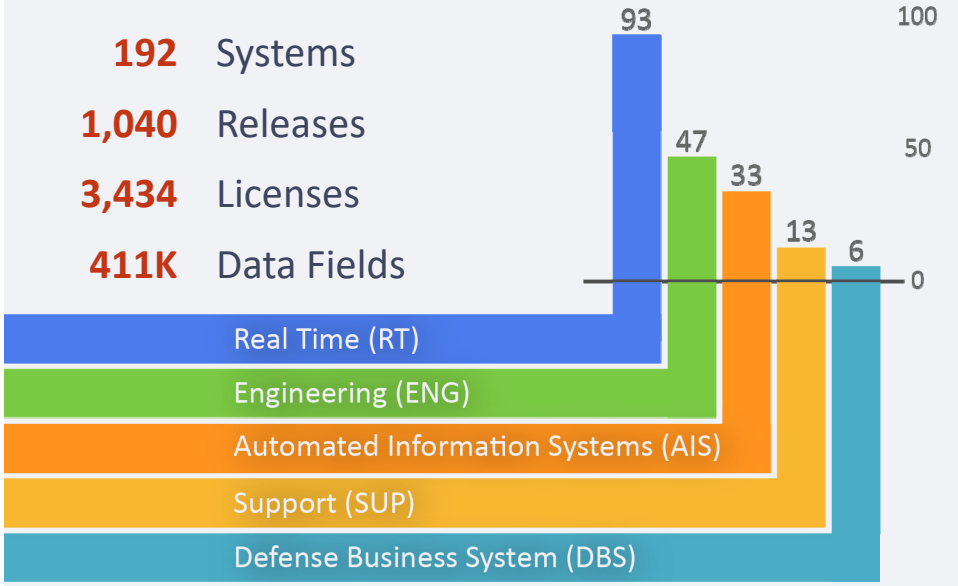
192 Systems

1,040 Releases

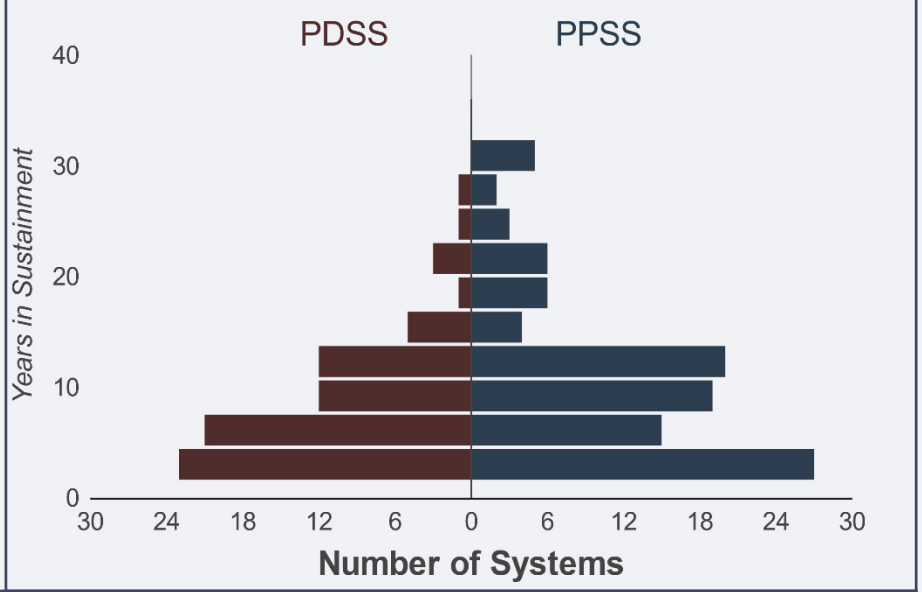
3,434 Licenses

411K Data Fields

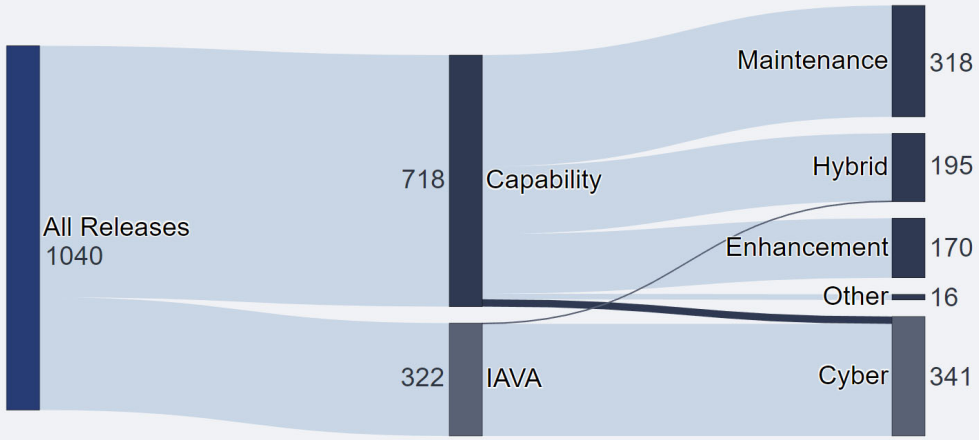
Systems by Super Domain



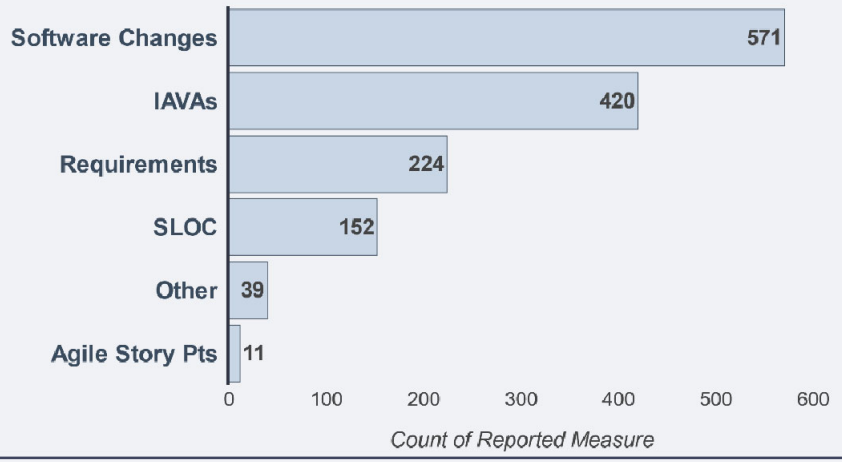
Distribution of System Age



Releases by Change Type

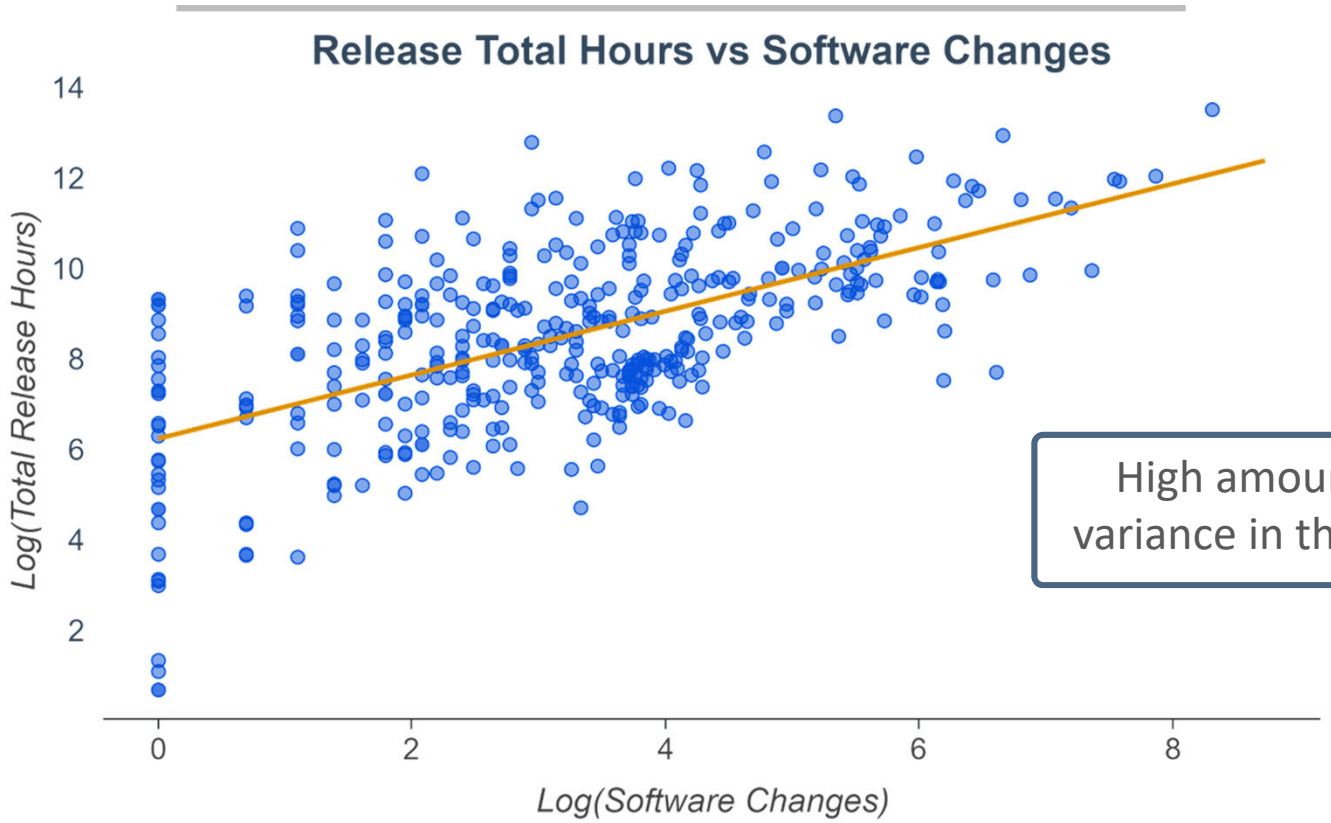


Releases by Size Measure



Cost and Schedule Estimating Relationships (CER/SER) Capability Releases

All Data CER



High amount of variance in the Data

Equation
$\log(Hours) = 0.703 \log SC + 6.2438$

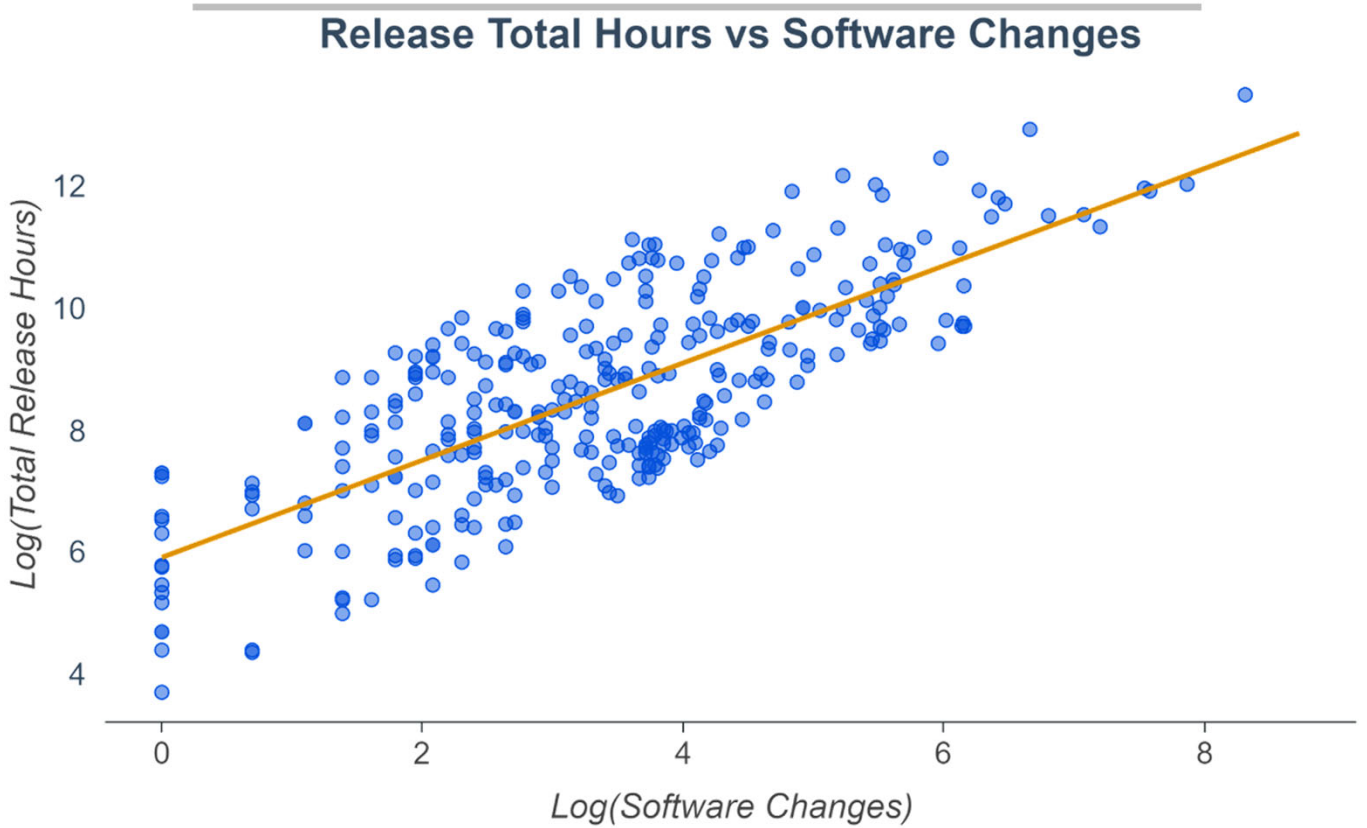
R-Squared	36.0%
Adj. R-Squared	35.8%
Observations	397

Variable	Coef.	Std Err	T-Value	P-Value
Constant	6.2438	0.172	36.231	0.000
Log(SC)	0.0730	0.047	14.900	0.000

CER Analysis Approaches

- In an effort to reduce variability, the data was exhaustively "cleaned"
  - All measures were normalized to a common measurement unit, format & terminology
  - Outliers were identified by comparing labor cost per hour to the reported annual burdened labor cost and annual hours per person-year
  - Equivalent SLOC was derived using formulas that combined new, modified, reused, and autogenerated code counts
  - Release data was divided into Capability Releases and IAVA-only Releases
- The data was then segmented into categories or groups to tighten variability
  1. The upper and lower 10% of the data was trimmed from the dataset - Trimming was based on unit cost (total release hours / #software changes)
  2. Meta-data was used to derive 15 categories each of which was analyzed for CERs using trimmed and untrimmed data
  3. Unit cost was divided into quintiles resulting in strong CERs but the challenge was finding common characteristics for each quintile

Strategy 1: Trimmed Data CER*



Equation
$\log(Hours) = 0.7981 \log SC + 5.905$

R-Squared	57.2%
Adj. R-Squared	57.1%
Observations	317

Variable	Coef.	Std Err	T-Value	P-Value
Constant	5.9052	0.145	40.618	0.000
Log(SC)	0.7981	0.039	20.532	0.000

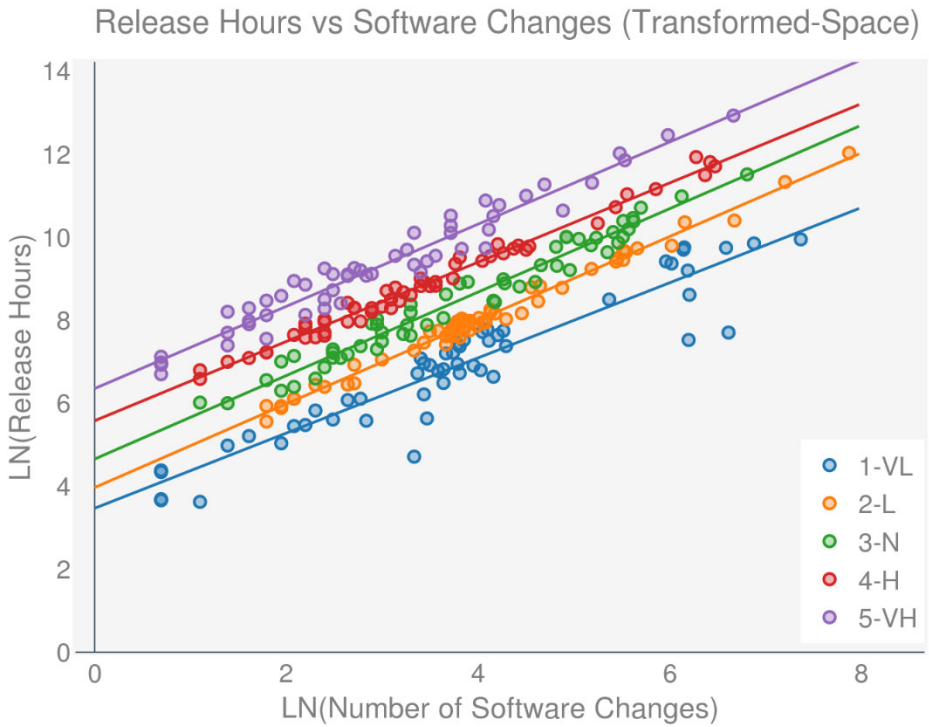
* Data records trimmed by 10%

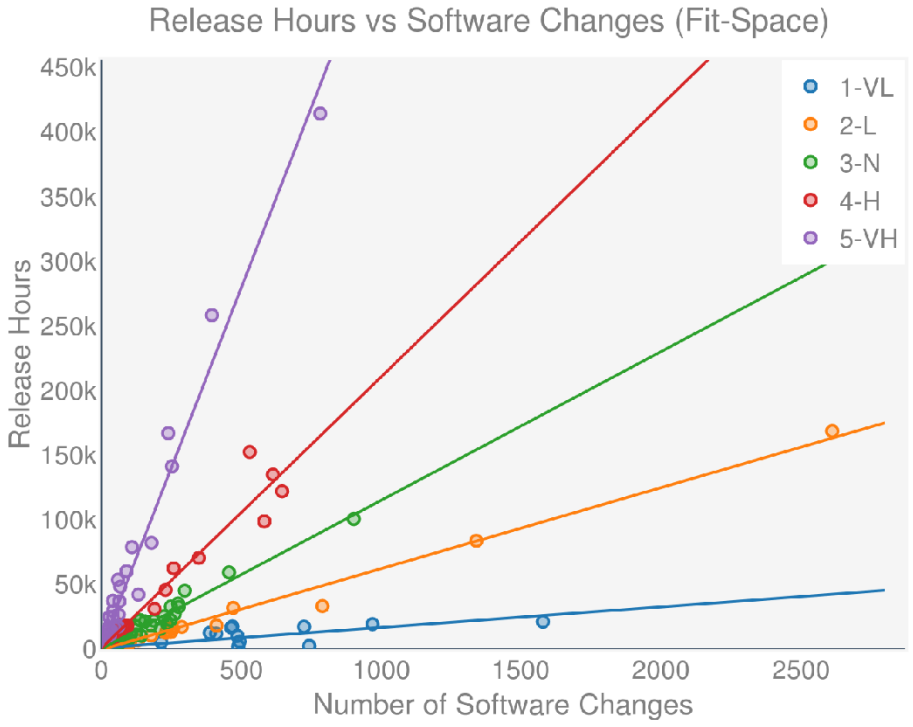
Strategy 2: Meta-Data

- ✓ Unit Cost (Hours per Software Change)
- ✓ Commodities (10)
- ✓ Change types (Enhanced, Maintenance, Cybersecurity)
- ✓ Number of Inter-Services Partners
- ✓ ACAT Level
- Super Domains (RT, ENG, SUP, AIS)
- Sustainment Organization (17)
- Business models (Government, Contractor, Integrated)
- Location of Sustainment Organization (11)
- Sustainment Phase (MS-C LRP, MS-C FRP, O&S)/Time in Phase
- Number of Software variants
- Number of Platform variants
- Number of Users
- Number of Licenses
- Release/Total Cost

A number of characteristics were examined for significance

Strategy 3: Unit Cost Grouping Levels: Hrs/SC





Release Hrs per Software Change	1-VL (Count: 49)	2-L (Count: 46)	3-N (Count: 41)	4-H (Count: 48)	5-VH (Count: 39)
Mean	26.8	60.8	138.3	413.4	2,725.2
Median	28.6	60.8	129.5	403.3	1,437.9
Min Value	2.0	46.9	78.2	212.1	718.0
Max Value	46.2	78.0	211.3	699.9	11,136.0

Commodities

Release Unit Cost Level count % by **Commodity**						
Commodity	**Cnt**	**1-VL**	**2-L**	**3-N**	**4-H**	**5-VH**
Business	36	**27.8%**	**11.1%**	**33.3%**	19.4%	8.3%
C5ISR	131	**22.9%**	**28.2%**	**14.5%**	16.8%	17.6%
ChemBio	1			**100.0%**		
Missiles	7			**57.1%**	**14.3%**	28.6%
Fire	12	33.3%	16.7%	**16.7%**	**33.3%**	
Aviation	13		7.7%	15.4%	**23.1%**	**53.8%**
Space	12		8.3%	25.0%	**25.0%**	**41.7%**
Test	6	16.7%			**50.0%**	**33.3%**
Vehicles	6			33.3%	**33.3%**	**33.3%**

Observations

- *(Bus & C5ISR) < ChemBio < (MS & Fire) < (Avn & Space) < (Test & Vehl) Hrs/SC*
- *Test Hrs/SC is not what we expected*

Release Hrs per Software Change	**1-VL** (Count: 49)	**2-L** (Count: 46)	**3-N** (Count: 41)	**4-H** (Count: 48)	**5-VH** (Count: 39)
Mean	**26.8**	**60.8**	**138.3**	**413.4**	**2,725.2**

Change Types

Release Unit Cost Level count % by **Change Type**						
Change Type	**Cnt**	**1-VL**	**2-L**	**3-N**	**4-H**	**5-VH**
Maintenance	120	**26.7%**	**30.0%**	11.7%	15.0%	16.7%
Cyber	12		25.0%	**50.0%**	25.0%	
Enh / Maint	30	6.7%	6.7%	**40.0%**	**23.3%**	23.3%
Enhancement	34	5.9%	5.9%	29.4%	**20.6%**	**38.2%**
Other	9	11.1%		22.2%	**55.6%**	11.1%
Enh / Other	3					**100.0%**

Observations

- *Maintenance < Cyber < Enhancement < Other Hrs/SC*

Release Hrs per Software Change	**1-VL** (Count: 49)	**2-L** (Count: 46)	**3-N** (Count: 41)	**4-H** (Count: 48)	**5-VH** (Count: 39)
Mean	**26.8**	**60.8**	**138.3**	**413.4**	**2,725.2**

Inter-Service Number of Partners

Release Unit Cost Level count % by **Inter-Service Partners**						
Inter-Serv	**Cnt**	**1-VL**	**2-L**	**3-N**	**4-H**	**5-VH**
Army Only (1)	165	**24.8%**	**23.0%**	**19.4%**	18.2%	14.5%
2	11	**9.1%**	**36.4%**	**9.1%**	27.3%	18.2%
3	7			**42.9%**	**14.3%**	42.9%
4	7	14.3%		14.3%	**28.6%**	**42.9%**
5	33	6.1%	6.1%	24.2%	**27.3%**	**36.4%**

Inter-Service Partners: Air Force, Navy, Marines, Others

Observations

- *More partners = Higher Unit Cost*

Release Hrs per Software Change	**1-VL** (Count: 49)	**2-L** (Count: 46)	**3-N** (Count: 41)	**4-H** (Count: 48)	**5-VH** (Count: 39)
Mean	**26.8**	**60.8**	**138.3**	**413.4**	**2,725.2**

ACAT Level

Release Unit Cost Level count % by **ACAT**						
ACAT	**Cnt**	**1-VL**	**2-L**	**3-N**	**4-H**	**5-VH**
ACAT I	38	5.3%	15.8%	26.3%	**18.4%**	**34.2%**
ACAT II	41	31.7%	4.9%	9.8%	**24.4%**	**29.3%**
ACAT III	101	**24.8%**	**31.7%**	16.8%	13.9%	12.9%
Non PoR	2			100.0%		

Observations

- *ACAT III < (ACAT I & ACAT II) Hrs/SC*

Release Hrs per Software Change	**1-VL (Count: 49)**	**2-L (Count: 46)**	**3-N (Count: 41)**	**4-H (Count: 48)**	**5-VH (Count: 39)**
Mean	**26.8**	**60.8**	**138.3**	**413.4**	**2,725.2**

Cost Estimating Relationships (CER)

Assumptions

- Removed records with:
  - Defense Business Systems (DBS) super domain
  - Hour data outliers or missing data
  - Records with no dependent variable, e.g., SW Change (SC) counts
  - Upper & lower 10% of records based on unit cost
- Both Dependent and Independent variables were transformed using $\log_{10}$
  - Zeros were represented with 0.1
- All categorical variables were represented as dummy variables (0,1)
- Adjusted R^2 was used for model performance comparisons

Total Hours vs SW Changes -1

Model		Conditions	Obs	Adj R^2	SEE (Hrs)	PRED(30)
$THrs = 463 * (TSC)^{0.69}$		All data	329	0.36	48,385	17.3%
$THrs = 341 * (TSC)^{0.79}$		10% trimmed data	263	0.57	44,842	23.6%
AIS ENG RT SUP	$THr = 242 * (TSC)^{0.73}$ $THr = 386 * (TSC)^{0.73}$ $THr = 736 * (TSC)^{0.73}$ $THr = 698 * (TSC)^{0.73}$	10% trimmed & Super Domains (Categorical)	263	0.62	39,330	20.2%
Aviation Business C5ISR ChemBio Fire Missiles Simulation Space Test Vehicles	$THrs = 1,452 * TSC^{0.66}$ $THrs = 301 * TSC^{0.66}$ $THrs = 364 * TSC^{0.66}$ $THrs = 182 * TSC^{0.66}$ $THrs = 1,531 * TSC^{0.66}$ $THrs = 1,114 * TSC^{0.66}$ $THrs = 577 * TSC^{0.66}$ $THrs = 1,005 * TSC^{0.66}$ $THrs = 1,742 * TSC^{0.66}$ $THrs = 425 * TSC^{0.66}$	10% trimmed & Commodities (Categorical)	263	0.68*	40,886	23.2%
$THrs = 608 * (TSC)^{0.98} / (TReqts)^{0.21}$		10% trimmed	32	0.84	32,228	25.0%
$THrs = 330 * (TSC)^{0.97} / (TReqts\_Imp)^{0.11}$		10% trimmed	65	0.74	63,904	23.1%

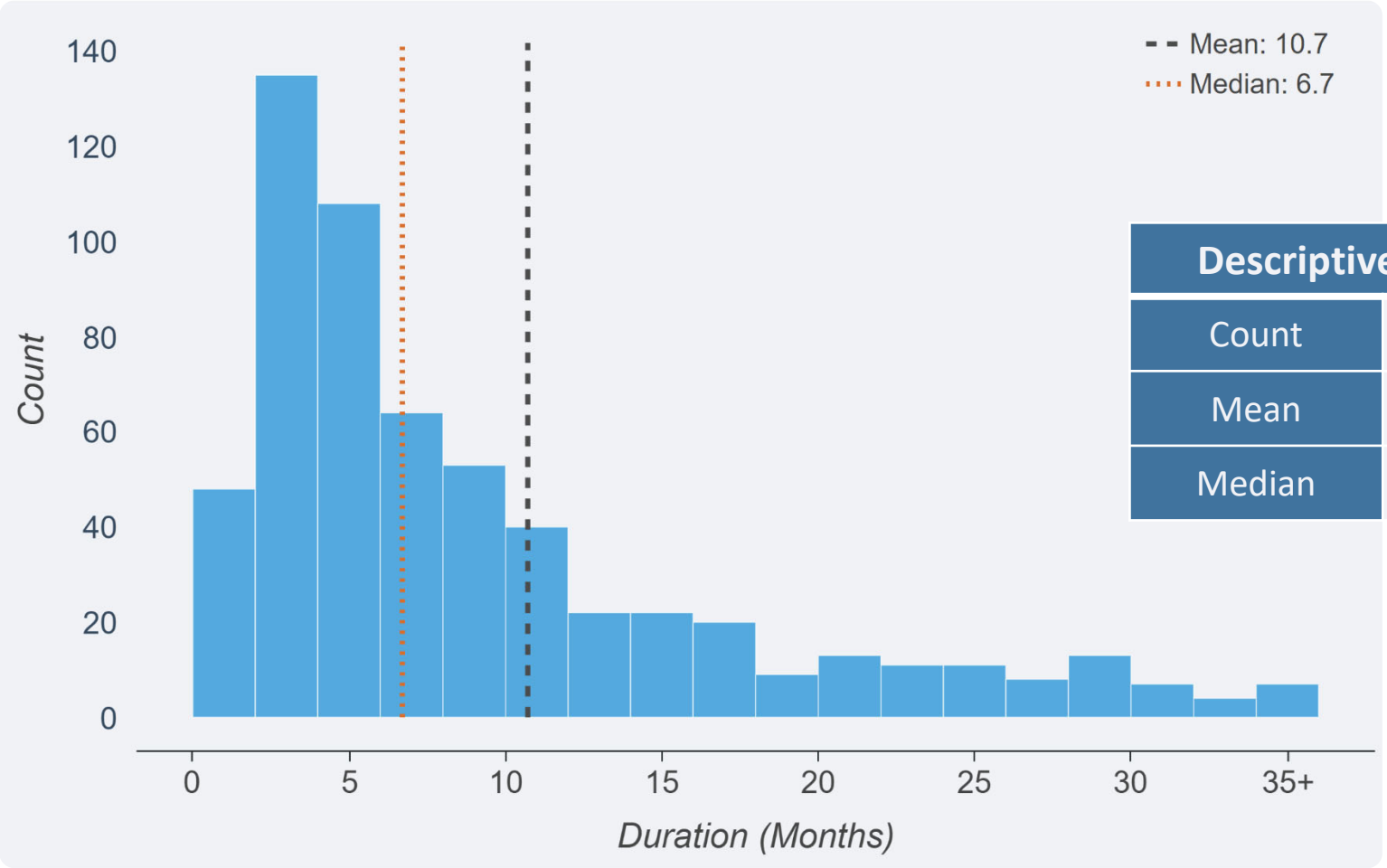
* High P-Values for one or more coefficients

Total Hours vs SW Changes -2

Model		Conditions	Obs	Adj R^2	SEE (Hrs)	PRED(30)
$THrs = 296 * (TSC)^{0.94} / (EI\_Mod)^{0.11}$		10% trimmed	41	0.74*	47,326	22.0%
$THrs = 1,219 * (TSC)^{0.75} / (SWBase)^{0.04}$		10% trimmed	69	0.61*	36,567	26.1%
$THrs = 757 * (TSC)^{1.02} / (BL)^{0.36}$		10% trimmed	45	0.74	81,719	15.6%
Cyber Enhance Hybrid Maint Other	$THrs = 332 * TSC^{0.79}$ $THrs = 531 * TSC^{0.79}$ $THrs = 382 * TSC^{0.79}$ $THrs = 281 * TSC^{0.79}$ $THrs = 284 * TSC^{0.79}$	10% trimmed & Change Type (Categorical)	263	0.59*	39,573	21.3%
$THrs = 338 * TSC^{0.77} * Enh\%^{0.10} * Maint\%^{0.02} * Cyber\%^{0.03} * Other\%^{0.01}$		10% trimmed & percentages of Change Types	263	0.60*	26,494	6.8%

Schedule Estimating Relationships (SERs)

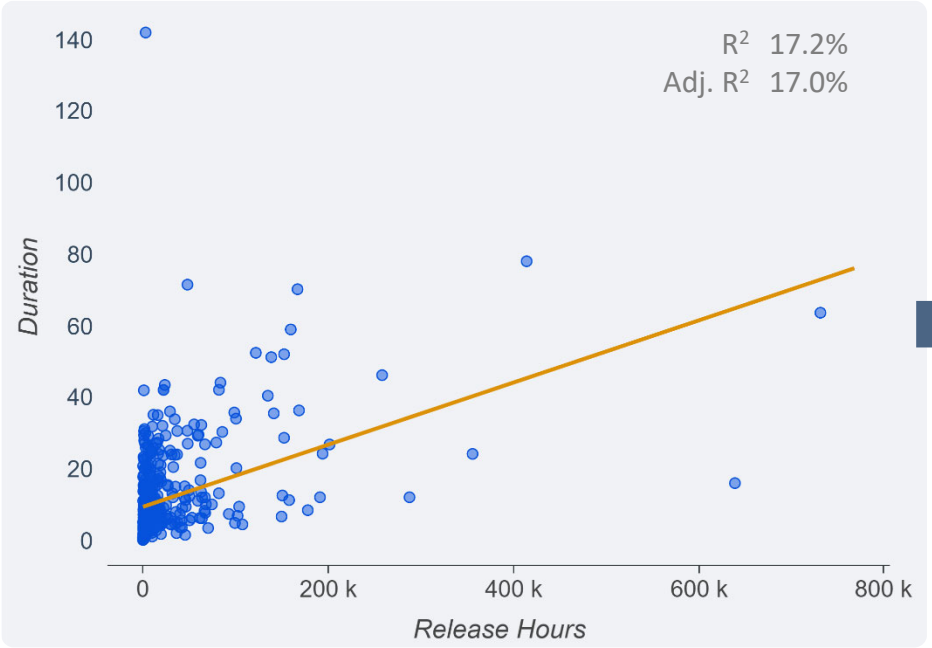
Release Duration Distribution



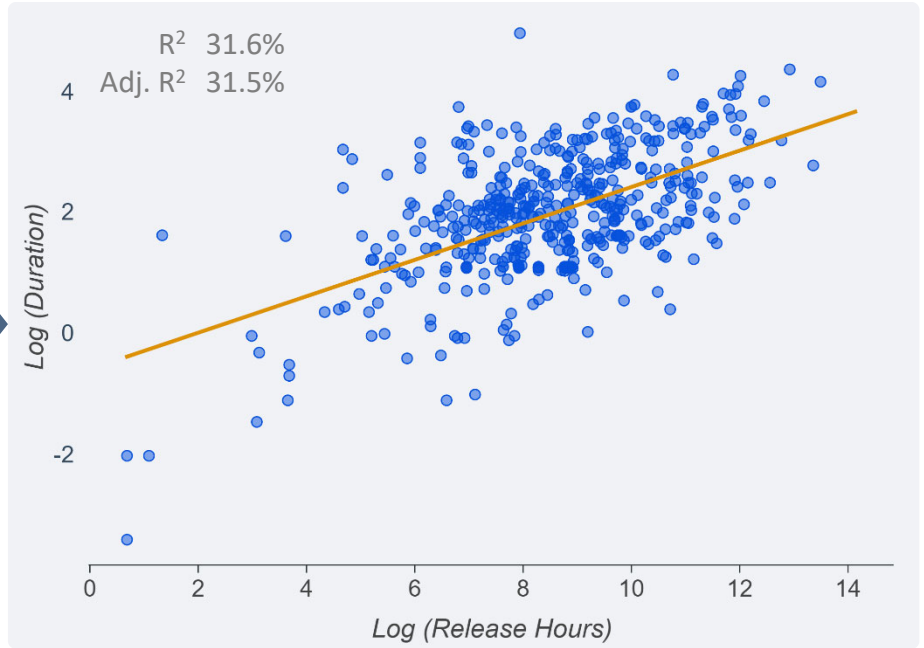
Descriptive Statistics	
Count	614
Mean	10.713
Median	6.702

$Duration(Months) = 0.55*(THrs)^{0.30}$

Unit Space



Log Space



COCOMO II Schedule Equation

$$TDEV(Months) = 3.67 \times (PM)^{0.32}$$

Equation

$$\log(Duration) = 0.301 \times \log(Release\ Hours) - 0.5997$$

R-Squared	31.6%
Adj. R-Squared	31.5%
Observations	490

Variable	Coef.	Std Err	T-Value	P-Value
Constant	-0.5997	0.175	-3.429	0.001
Log(SC)	0.3010	0.020	15.025	0.000

SER Results with All & Trimmed Data

Model	Data	Obs	R^2
Duration(Months) = $0.55*(THrs)^{0.3}$	All	491	31.4%
Duration(Months) = $0.15*(THrs)^{0.45}$	10% Trimmed	393	44.6%
Duration(Months) = $0.45 * (THrs)^{0.31} * (TSC)^{0.05}$	All	382	40.7%*
Duration(Months) = $0.15 * (THrs)^{0.44} * (TSC)^{0.03}$	10% Trimmed	309	49.7%*

* The coefficient for TSC had a P-value > 0.1

Segmentation Strategy

- The best segmentation strategy we could find to improve SERs was based on release duration categories:
  - Cyclic
    - Fixed rate, generally every three or four months
    - Usually level-of-effort
    - Easy to estimate effort and schedule
    - Programs adjust SCs within schedule and effort constraints
  - Sequential
    - Variable duration release
    - Next release commences near the end of previous release
    - Effort does not always correlate to duration
    - SER contains both effort and SCs
  - Concurrent
    - Multiple releases in development of variable duration
    - Effort sometimes correlates to duration but not always
    - SC's appear to have an influence
    - SER contains both effort and SCs

Cyclic Duration Example

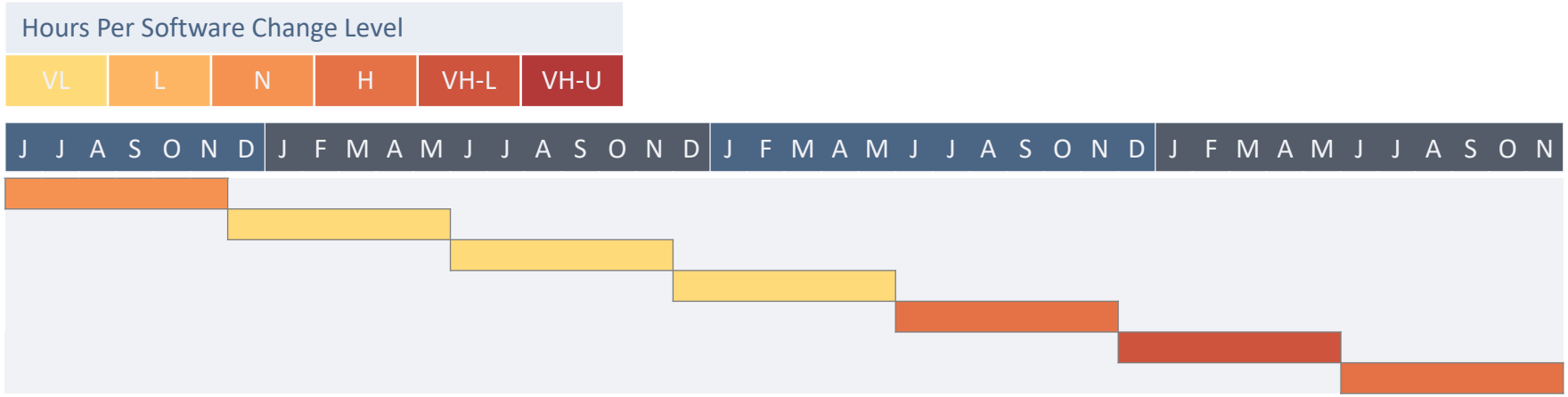
- Cycles are 5 months, fixed
- Effort varies
- Amount of effort influences software changes

Regression Equation

$$Software\ Changes = 0.34 \times THrs^{0.64}$$

R-Squared	93.69%
Adj. R-Squared	92.99%
SEE	0.2351
Observations	11

Variable	Coef.	Std Err	T-Value	P-Value
Constant	-0.469	0.195	-2.41	0.04
Log(THrs)	0.6402	0.055	11.56	0.000



Sequential Release Example

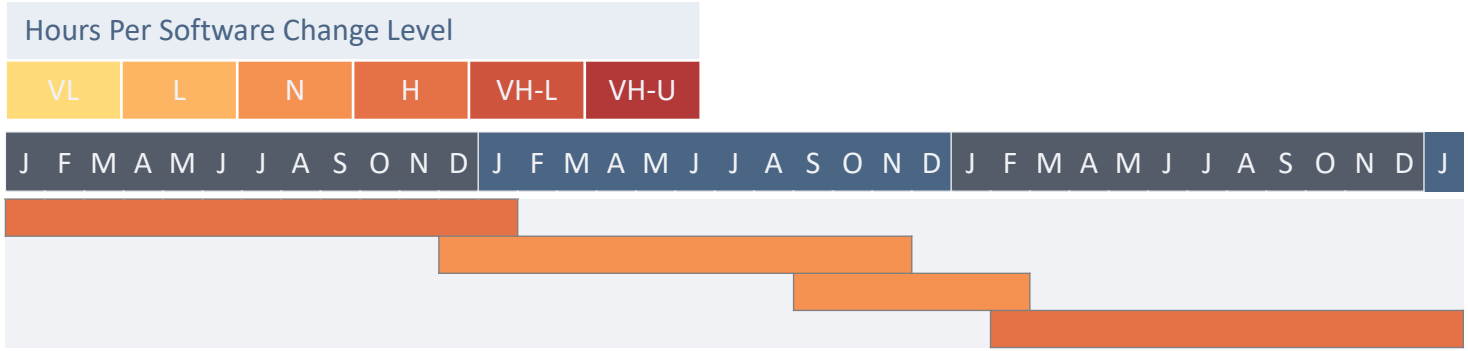
- Releases occur sequentially with a little overlap
- Duration varies
- Effort and number of software changes influence duration

Regression Equation

$$Duration = 0.05 \times (Hrs)^{-0.16} \times (SC)^{2.04}$$

R-Squared	99.07%
Adj. R-Squared	97.22%
SEE	0.0431
Observations	4

Variable	Coef.	Std Err	T-Value	P-Value
Constant	-1.300	0.492	-2.64	0.231
Log(Hrs)	-0.157	0.256	-0.61	0.650
Log(SC)	2.036	0.411	4.96	0.127



Concurrent Release Example

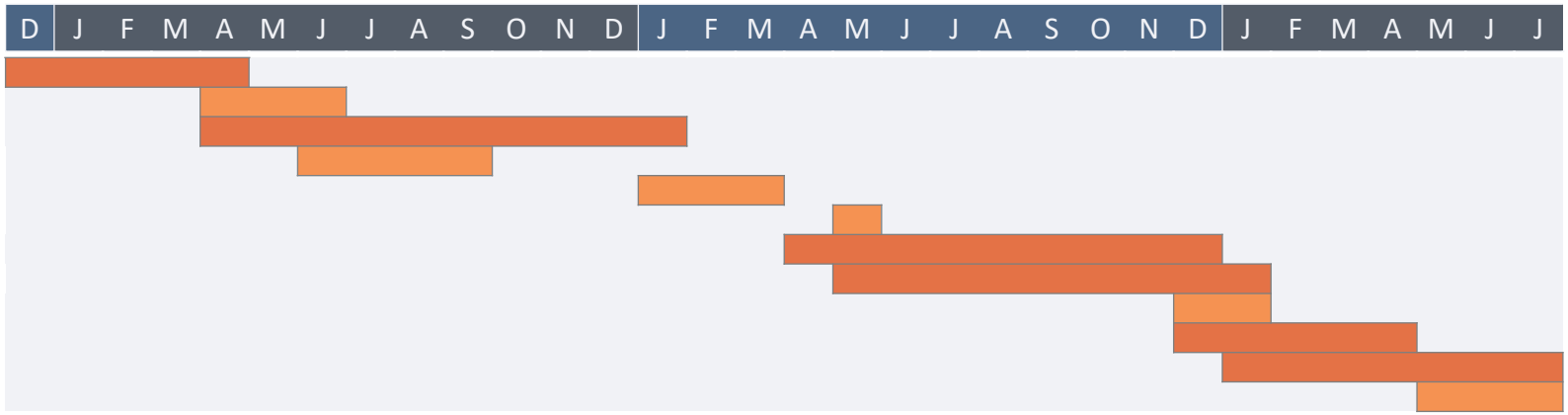
- Multiple concurrent releases
- Durations vary
- Effort and number of software changes influence duration

Regression Equation

$$Duration = 0.0004 \times (Hrs)^{1.0} \times (SC)^{0.03}$$

R-Squared	98.35%
Adj. R-Squared	98.14%
SEE	0.0511
Observations	14

Variable	Coef.	Std Err	T-Value	P-Value
Constant	-3.437	0.137	-25.06	0.000
Log(Hrs)	0.9962	0.0395	25.22	0.000
Log(SC)	0.0332	0.0201	1.65	0.119

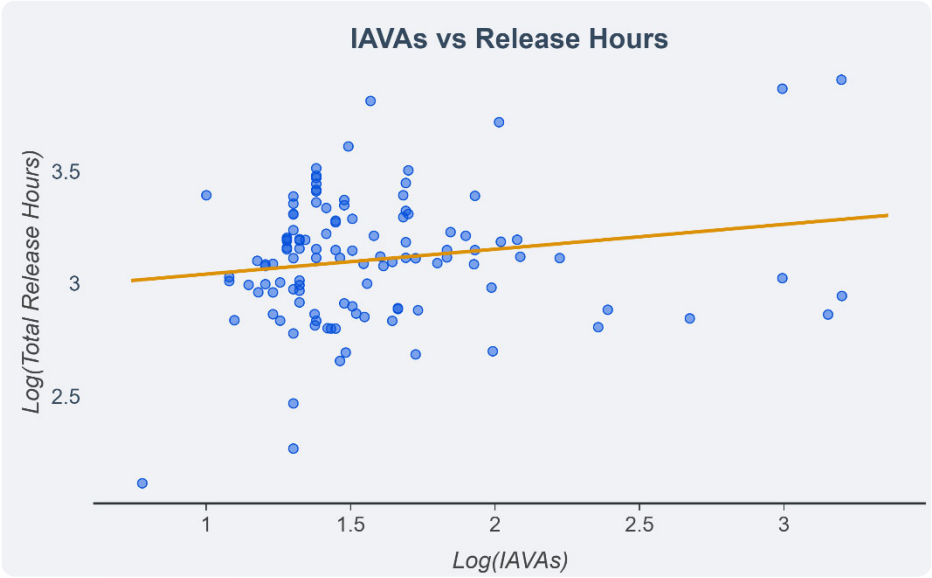


Future CER/SER Research

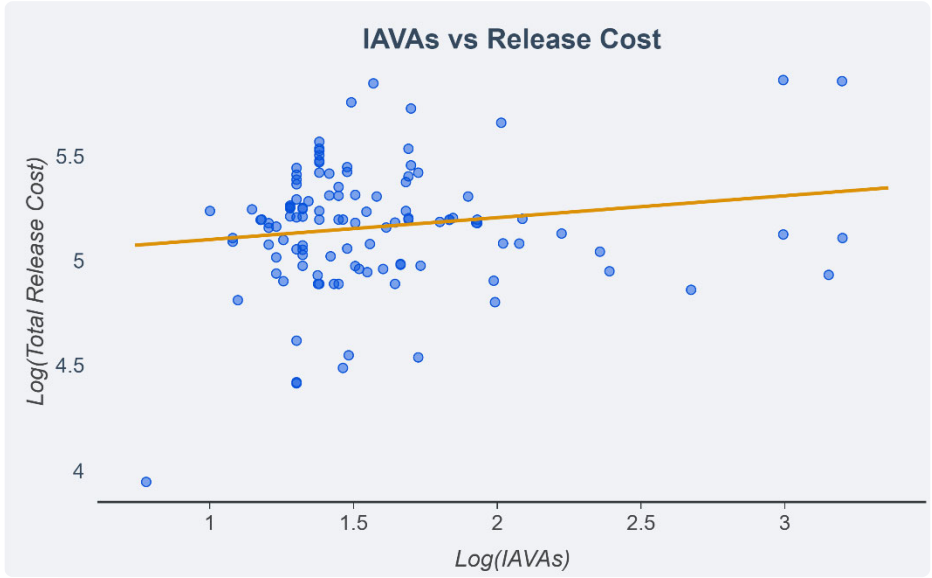
- Additional analysis of data, including:
  - Cost impact of cybersecurity framework (DIACAP vs RMF)
  - Cost of Cybersecurity
  - Analysis of annualized release data
- Expand SER analysis to include all systems in each release duration category (Cyclic, Sequential, Concurrent)
- Additional license analysis
  - Does higher license costs correlate to higher sustainment costs?
  - Does using COTS software save money in sustainment?
- Impact of budget reductions on fixed-cost versus variable-cost funding
- Iterative/Agile versus traditional development is being explored for differences
- New FY18 PPSS data being collected

IAVA Release Analysis

All IAVA Data



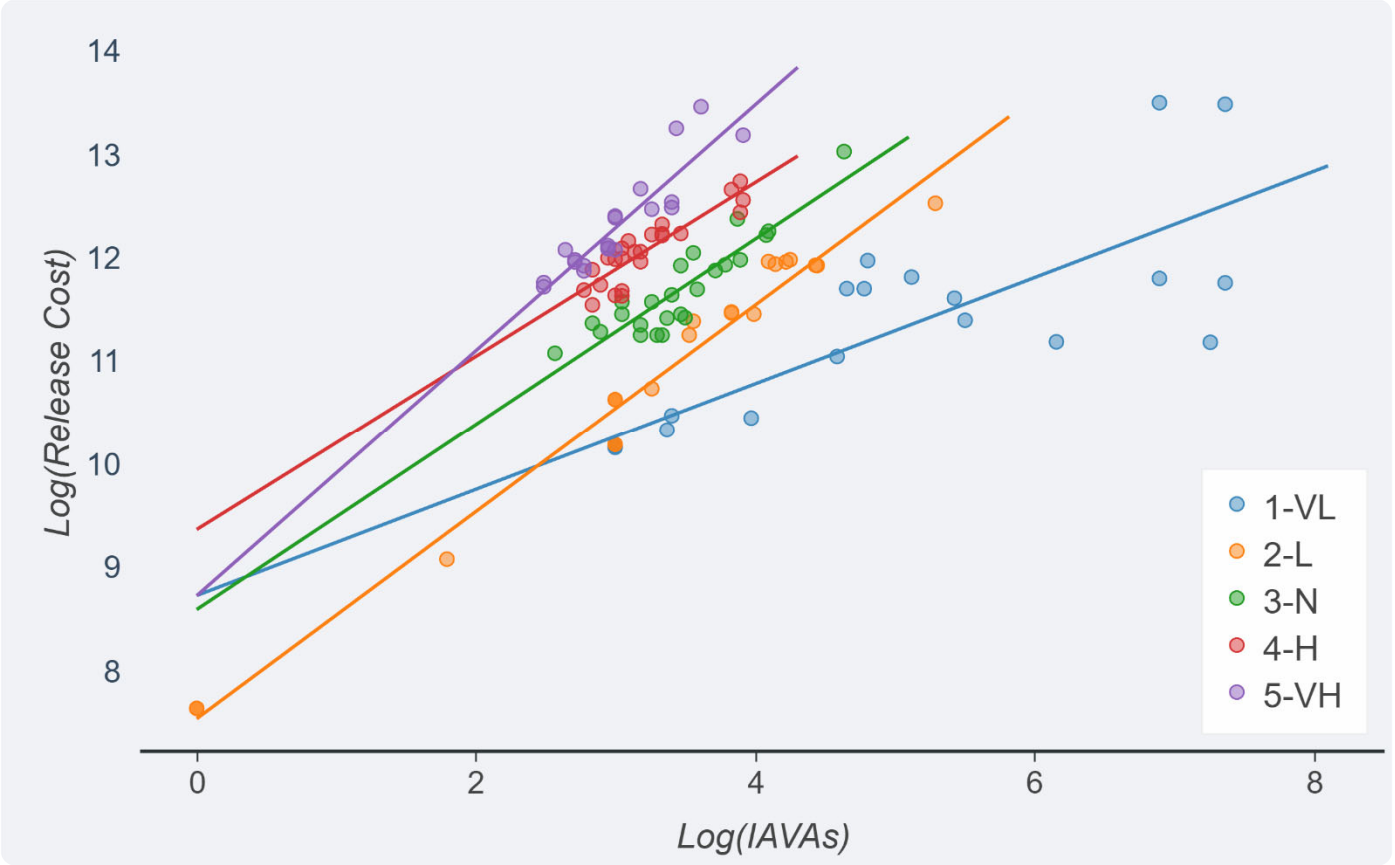
Records =115
R^2 = 11.7%



Records =115
R^2 = 11.7%

IAVA data is often level-of-effort, so CERs are not significant: Is the number of licenses a better indicator of cost?

Log(IAVA) vs Log(Cost) by Unit Cost Level



Grouping by Unit Cost did not work for IAVA-only capability release data

IAVA Analysis

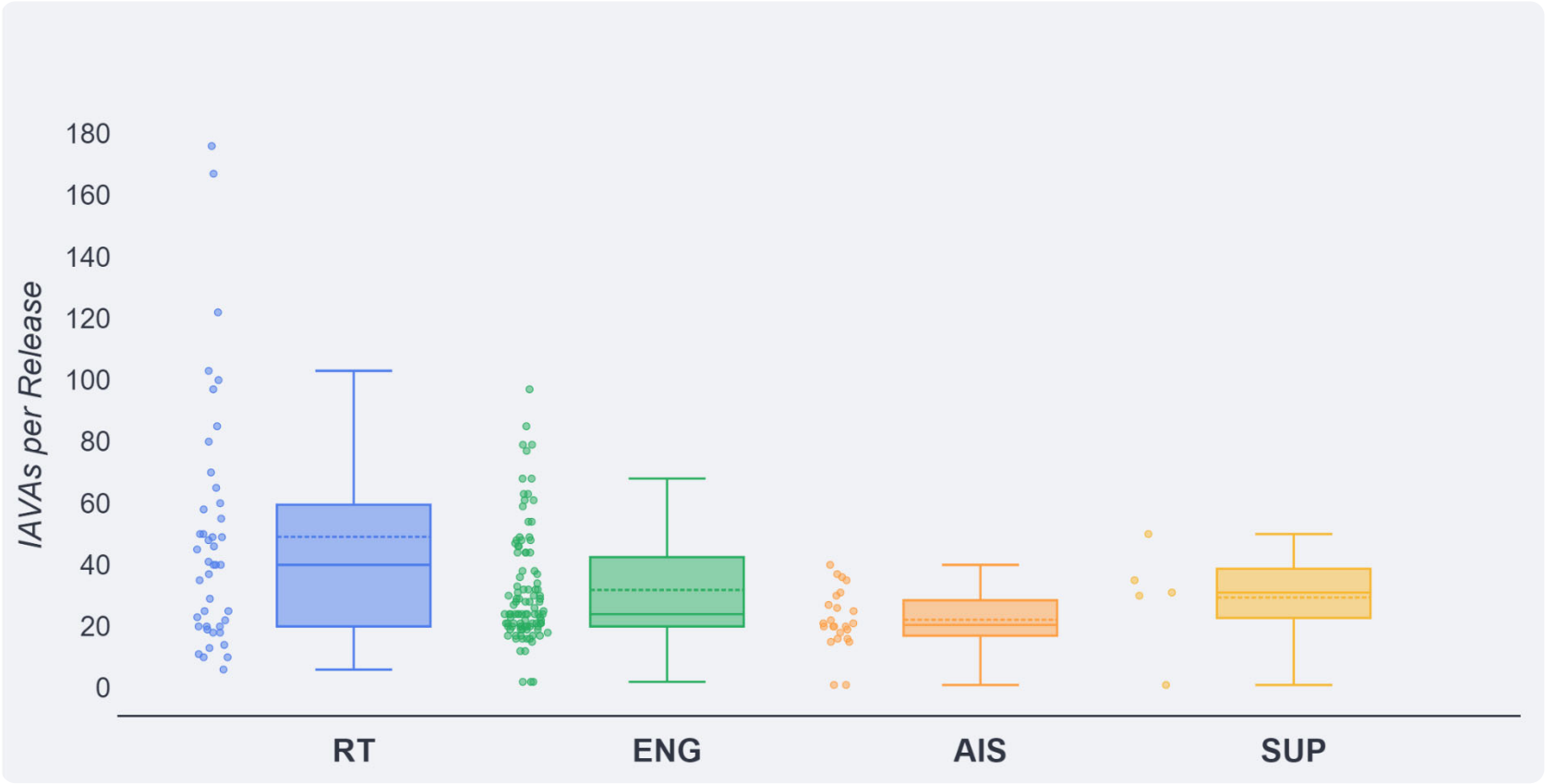
Group	Mean	Median
MaintOrg	243.7	24.2
System	164.0	25.6
Commodity	28.1	30.1
Super Domain	38.0	36.5

There is a central tendency across segmentation groups using the Median

IAVA data is better estimated using descriptive statistics i.e. average cost (hours per IAVA) as compared to regression

IAVAs per Release

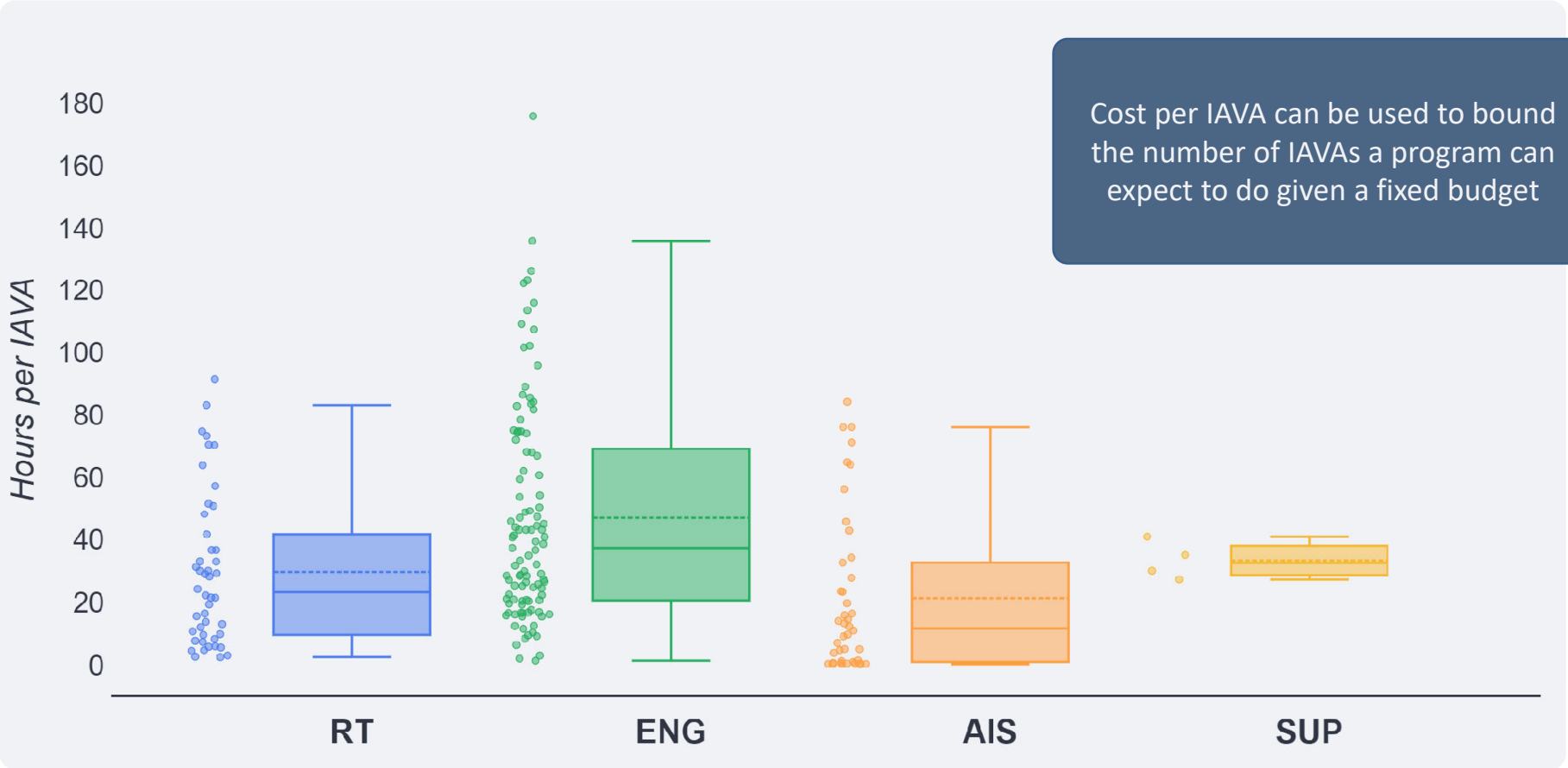
IAVA Releases



Super Domain	Count	Mean	Median
RT	48	45.875	40
ENG	112	30.875	24
AIS	39	21.744	20
SUP	7	21.286	30

Hours per IAVA

IAVA Releases



Super Domain	Count	Mean	Median
RT	50	64.72	40.5
ENG	113	42.478	25
AIS	56	497.839	30
SUP	6	19.667	15.5

Benchmarks for Capability Releases

Average WBS Cost

WBS 1.0
Software Changes
26%
$369.8M

WBS 2.0
Project Management
10%
$136.5M

WBS 3.0
Licenses
10%
$144.5M
License Management
0.005%
$5.7M

WBS 4.0
Cert. and Accreditation
4%
$60.0M

WBS 5.0
System Facilities
3%
$42.0M
System Facilities ODC
3%
$36.3M

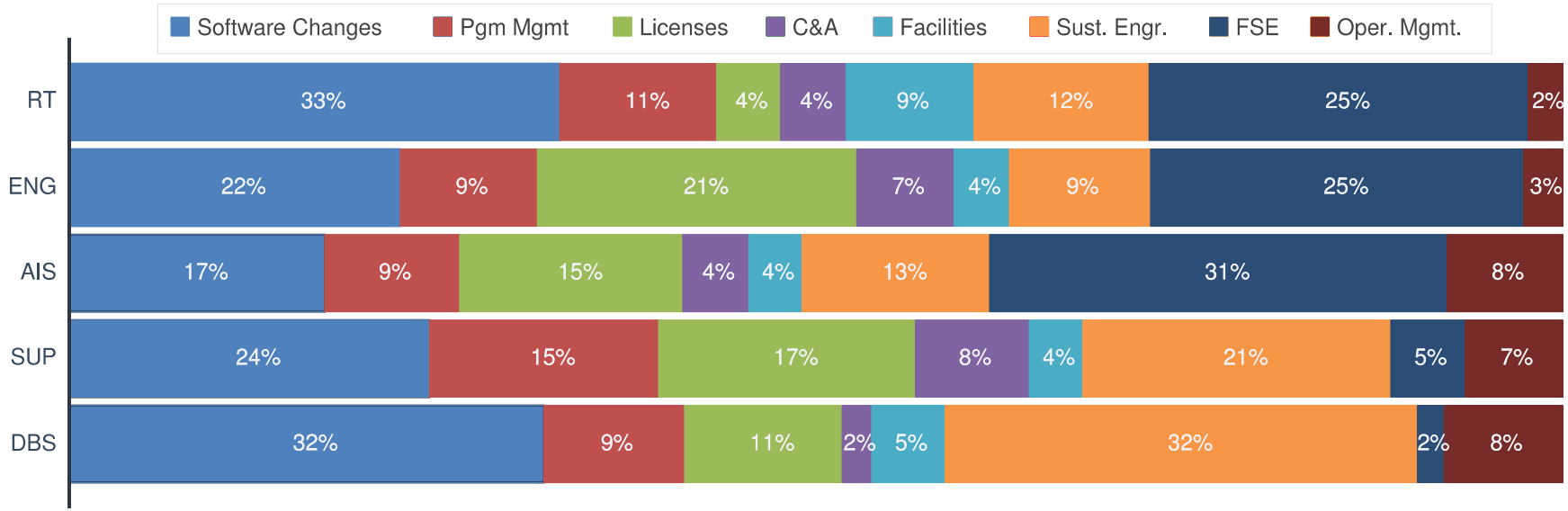
WBS 6.0
Sustaining Engineering
18%
$248.7M

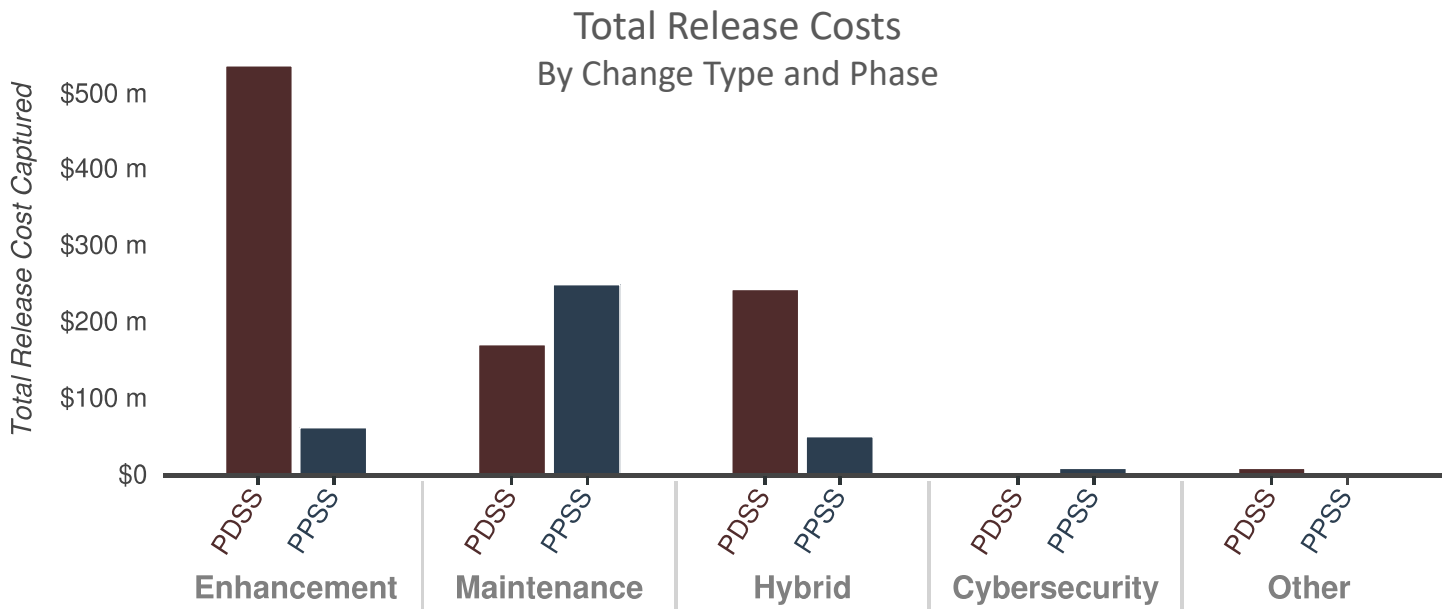
WBS 7.0
FSEs
20%
$291.4M

WBS 8.0
Operations Management
5%
$74.0M

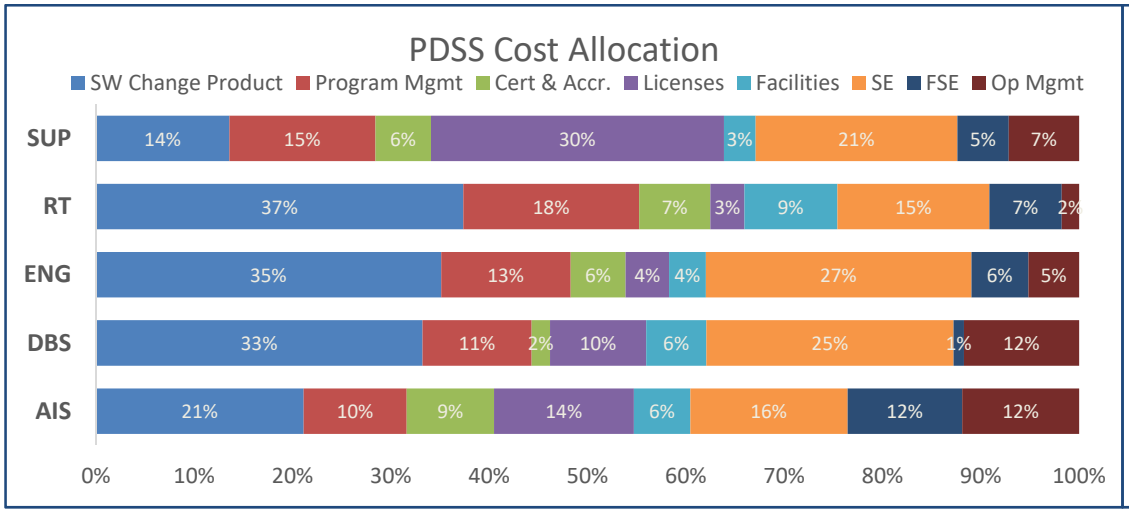
All Programs
Average Annual Cost
$1.41B (BY18)

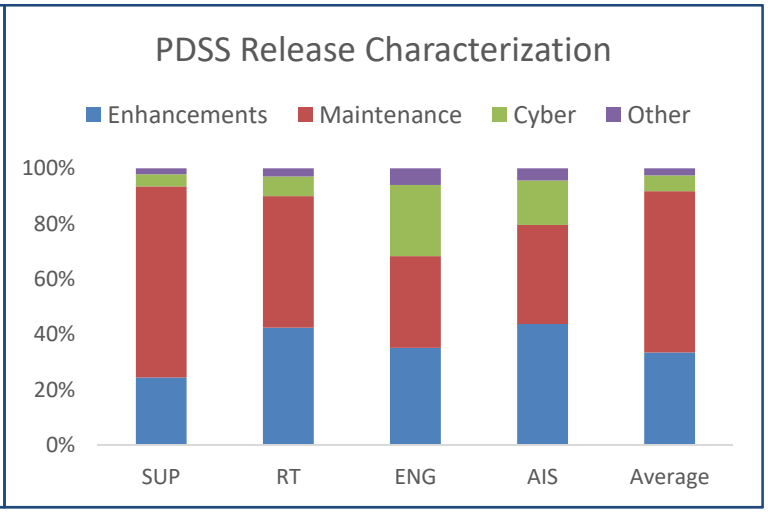
SWS Cost Allocation by WBS

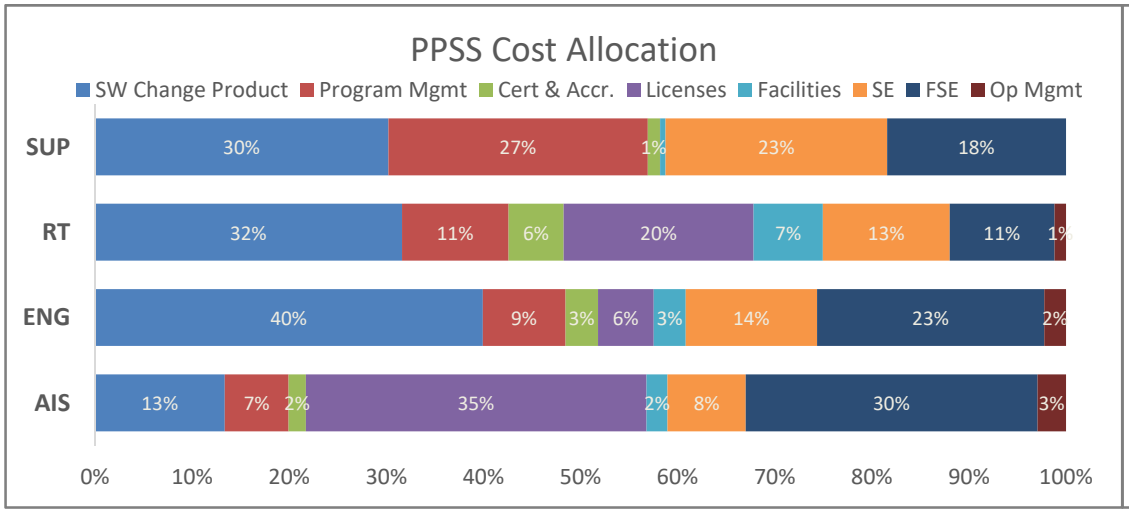


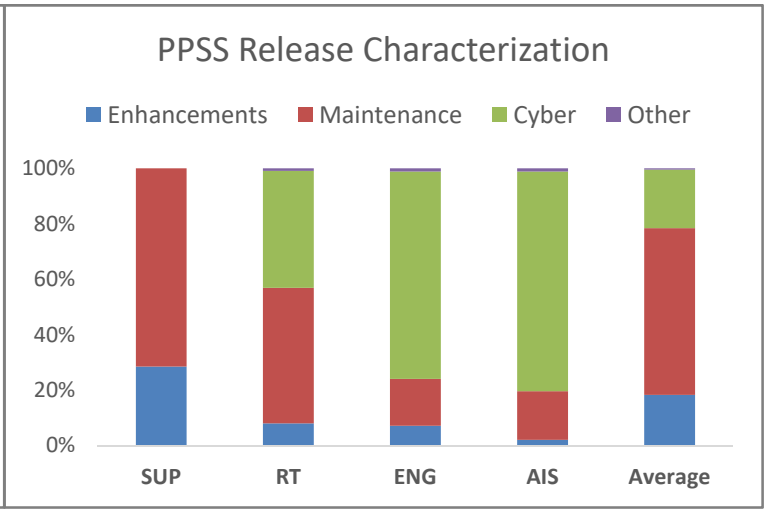


PDSS vs PPSS Cost Drivers





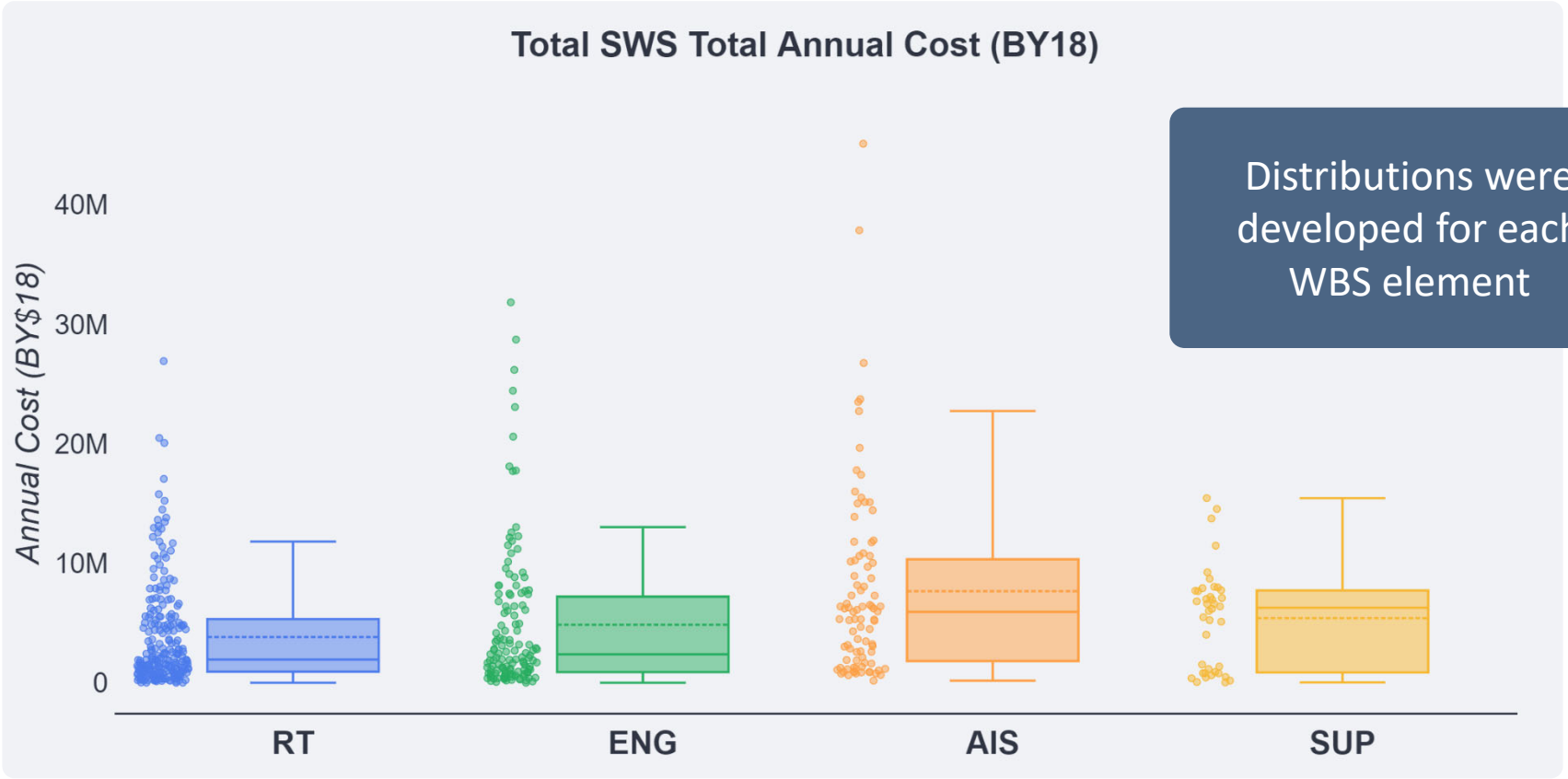




While the cost drivers do not change dramatically from PDSS to PPSS, the software release characterization shifts from maintenance and enhancements to maintenance and cybersecurity

Total Annual Cost Distribution

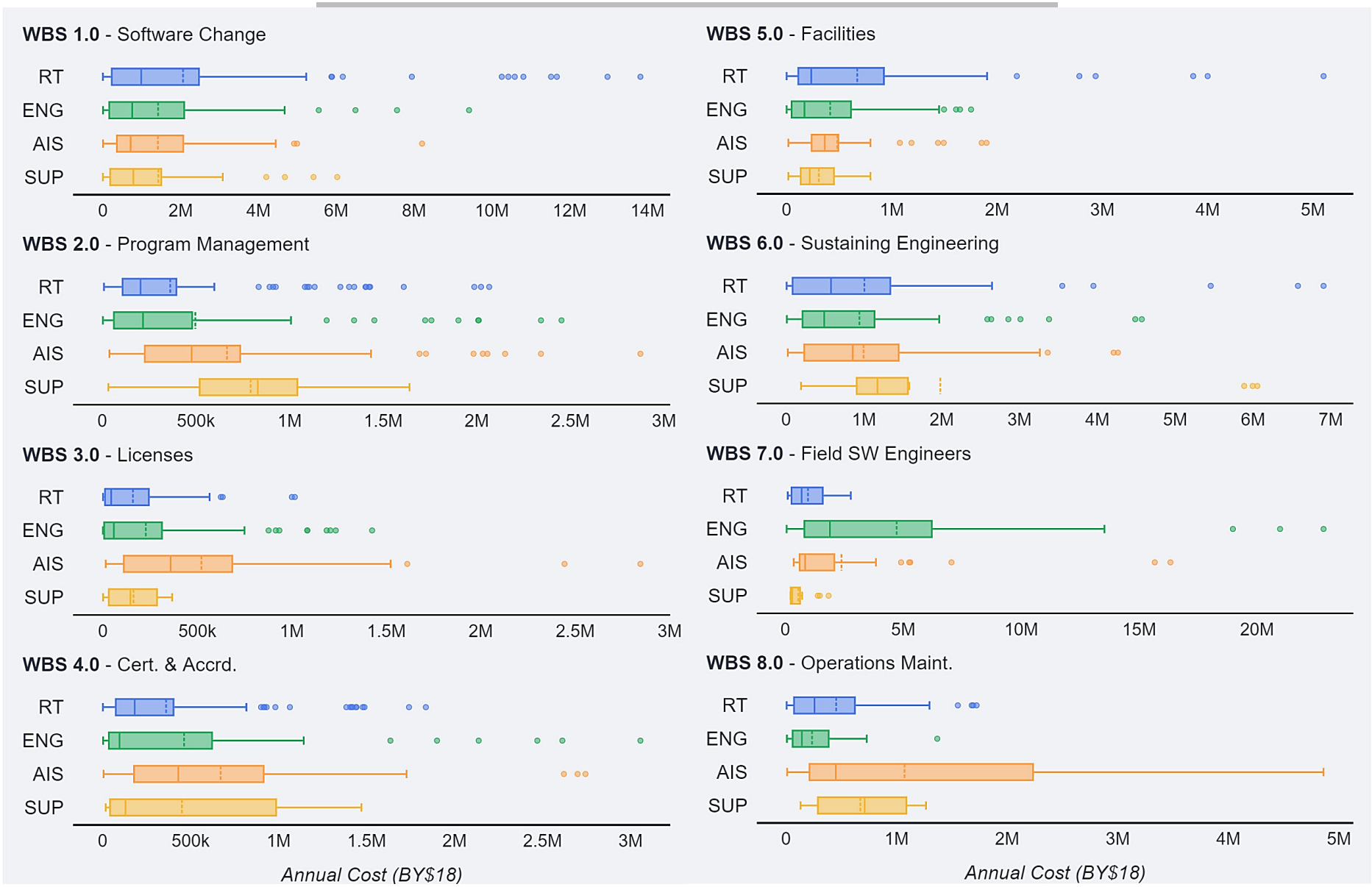
By Super Domain (BY18)



Super Domain	Count*	Mean	Median
RT	227	$3,826,739	$1,939,343
ENG	130	$4,830,487	$2,333,787
AIS	89	$7,666,135	$5,938,701
SUP	40	$5,411,627	$6,285,354

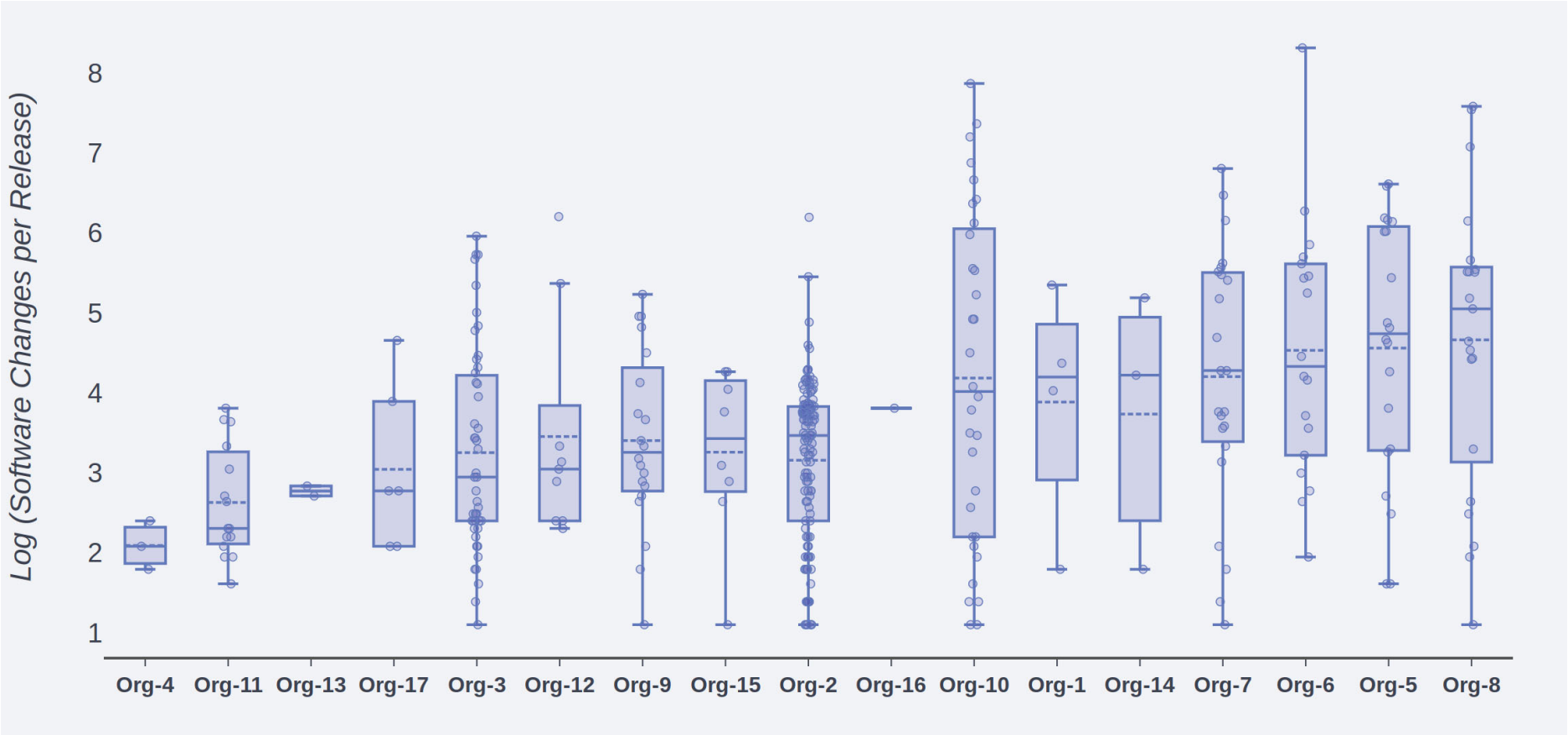
* Up to 3 FYs per system

Annual Cost by WBS
(BY18)



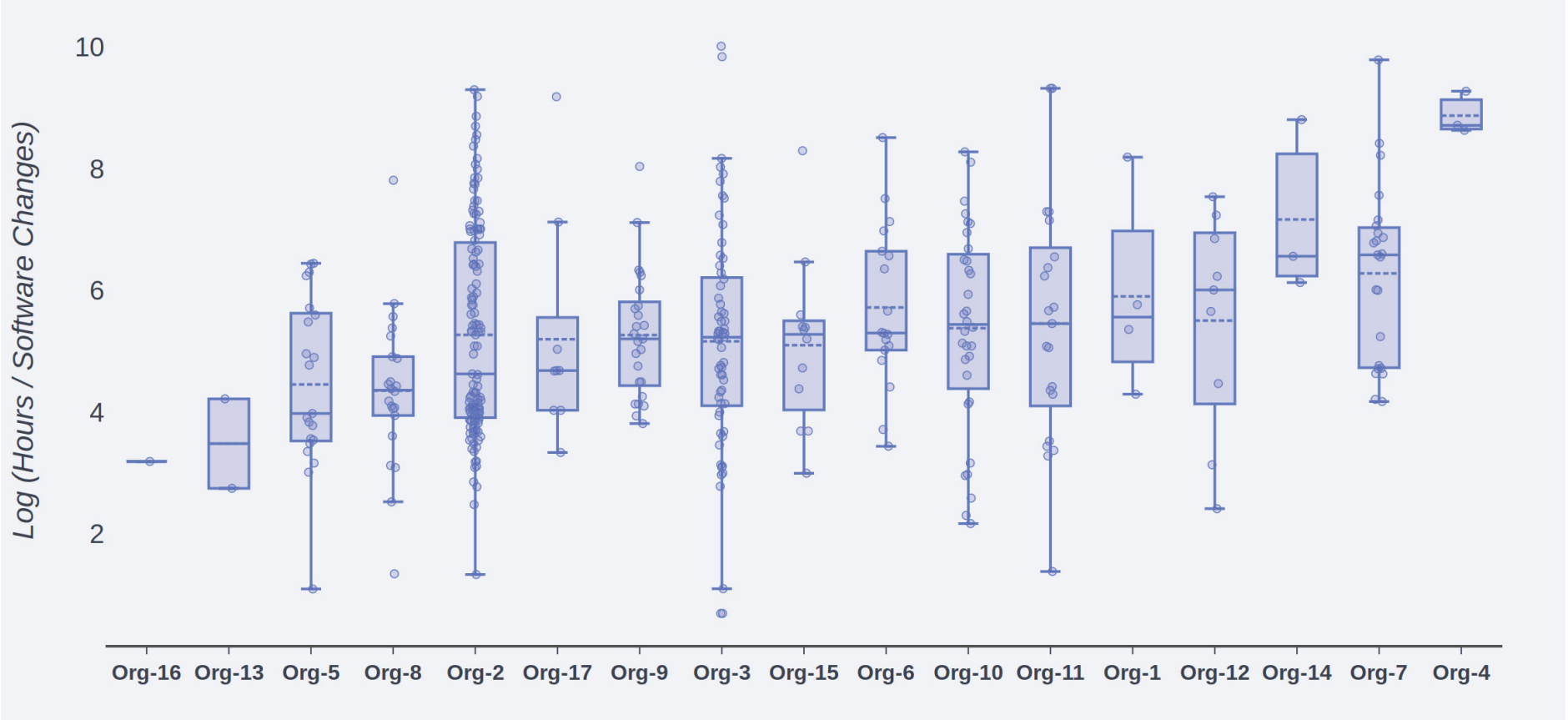
Software Changes per Release

By Sustaining Organization



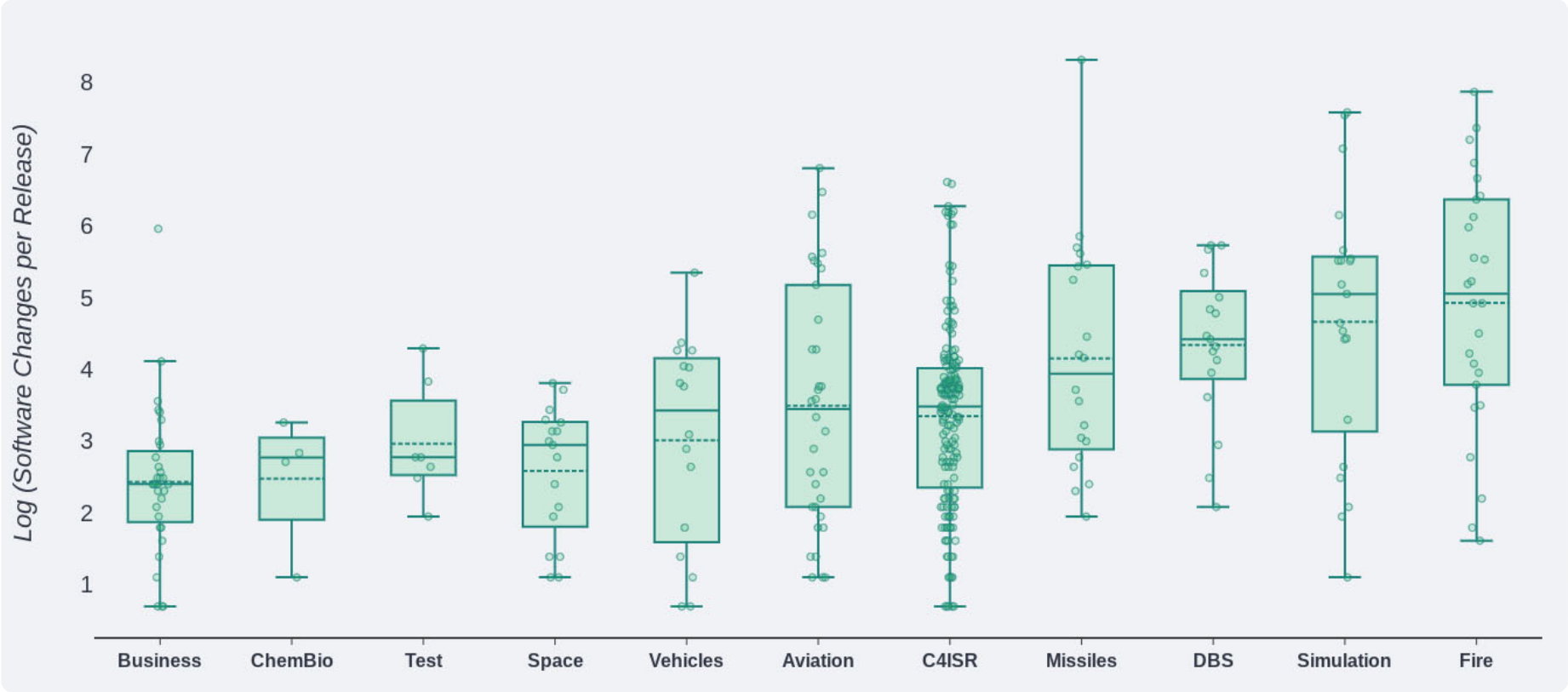
	Org-4	Org-11	Org-13	Org-17	Org-3	Org-12	Org-9	Org-15	Org-2	Org-16	Org-10	Org-1	Org-14	Org-7	Org-6	Org-5	Org-8
Count	1	2	21	22	131	9	25	61	12	18	32	21	4	9	3	23	3
Mean	3.19	3.483	4.454	4.352	5.268	5.197	5.266	5.163	5.099	5.719	5.378	5.456	5.901	5.503	7.164	6.279	8.87
St Dev	N/A	1.039	1.399	1.281	1.712	1.823	1.037	1.88	1.402	1.327	1.675	1.995	1.646	1.802	1.438	1.474	0.349
Median	3.19	3.483	3.978	4.361	4.626	4.682	5.202	5.231	5.278	5.3	5.439	5.454	5.56	6.007	6.559	6.582	8.712

Hours per Software Change
By Sustaining Organization



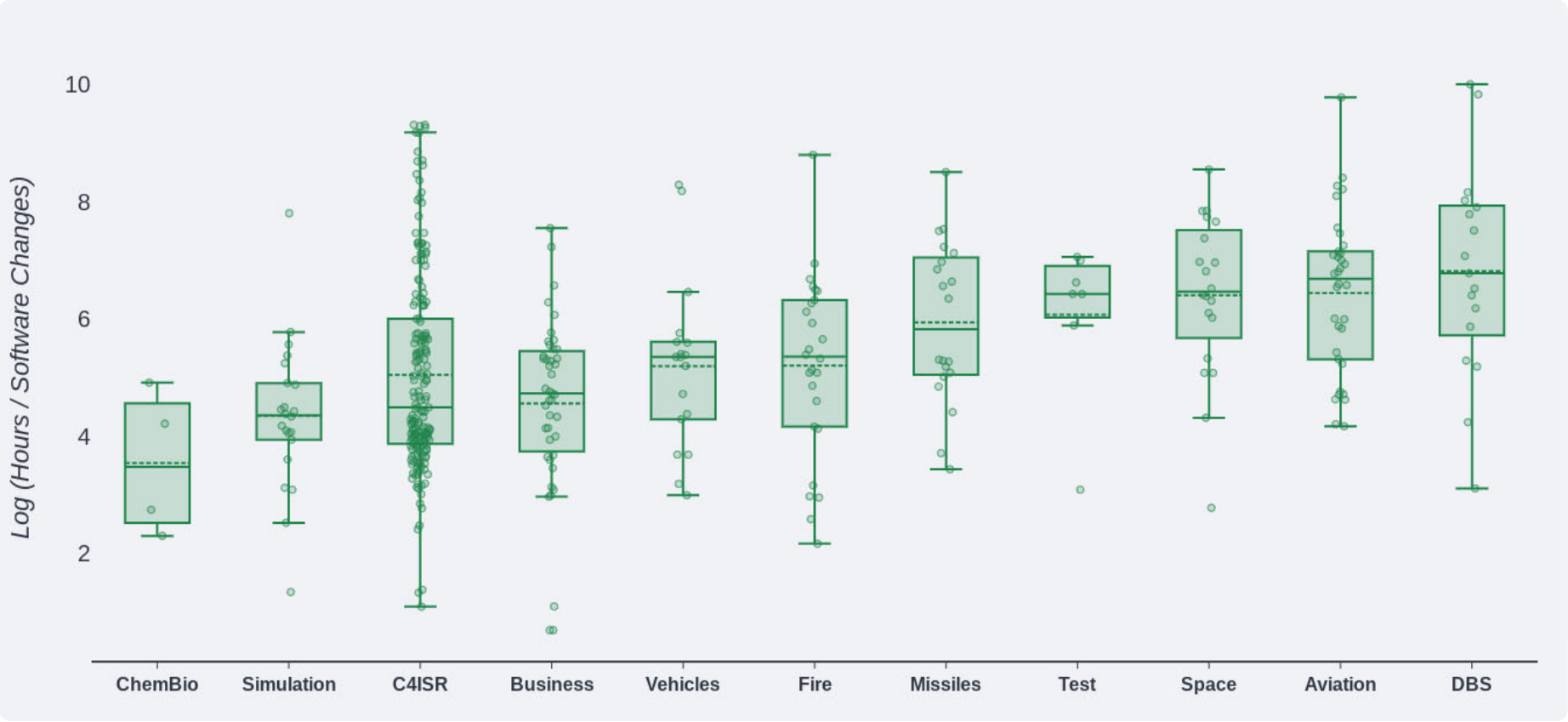
	Org-16	Org-13	Org-5	Org-8	Org-2	Org-17	Org-9	Org-3	Org-15	Org-6	Org-10	Org-11	Org-1	Org-12	Org-14	Org-7	Org-4
Count	1	2	21	22	131	9	25	61	12	18	32	21	4	9	3	23	3
Mean	3.19	3.483	4.454	4.352	5.268	5.197	5.266	5.163	5.099	5.719	5.378	5.456	5.901	5.503	7.164	6.279	8.87
St Dev	N/A	1.039	1.399	1.281	1.712	1.823	1.037	1.88	1.402	1.327	1.675	1.995	1.646	1.802	1.438	1.474	0.349
Median	3.19	3.483	3.978	4.361	4.626	4.682	5.202	5.231	5.278	5.3	5.439	5.454	5.56	6.007	6.559	6.582	8.712

Software Changes per Release
by Commodity



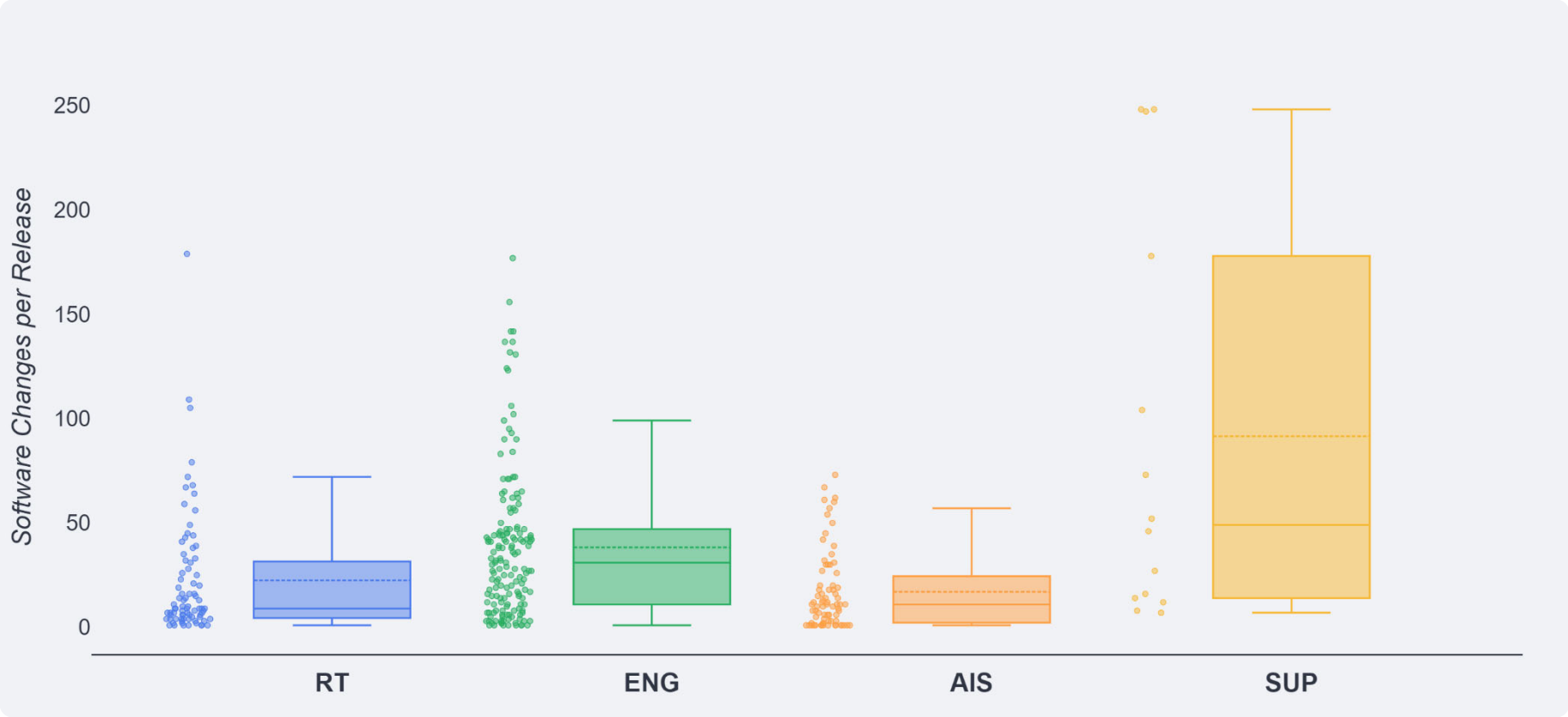
	Business	ChemBio	Test	Space	Vehicles	Aviation	C5ISR	Missiles	DBS	Simulation	Fire
Count	32	4	7	17	16	34	172	20	17	21	26
Mean	2.43	2.47	2.96	2.58	3.01	3.49	3.35	4.15	4.34	4.66	4.93
St Dev	1.05	0.95	0.81	0.91	1.47	1.71	1.28	1.60	1.08	1.83	1.73
Median	2.40	2.77	2.77	2.94	3.43	3.44	3.48	3.94	4.42	5.05	5.05

Hours per Software Change
by Commodity



	ChemBio	Simulation	C5ISR	Business	Vehicles	Fire	Missiles	Space	Test	Aviation	DBS
Count	4	22	198	48	19	26	20	21	7	34	17
Mean	3.55	4.35	4.99	4.79	5.31	5.21	5.95	6.37	6.08	6.45	6.82
St Dev	1.23	1.28	1.70	1.56	1.49	1.56	1.37	1.36	1.38	1.35	1.81
Median	3.48	4.36	4.44	4.94	5.36	5.36	5.83	6.42	6.43	6.69	6.79

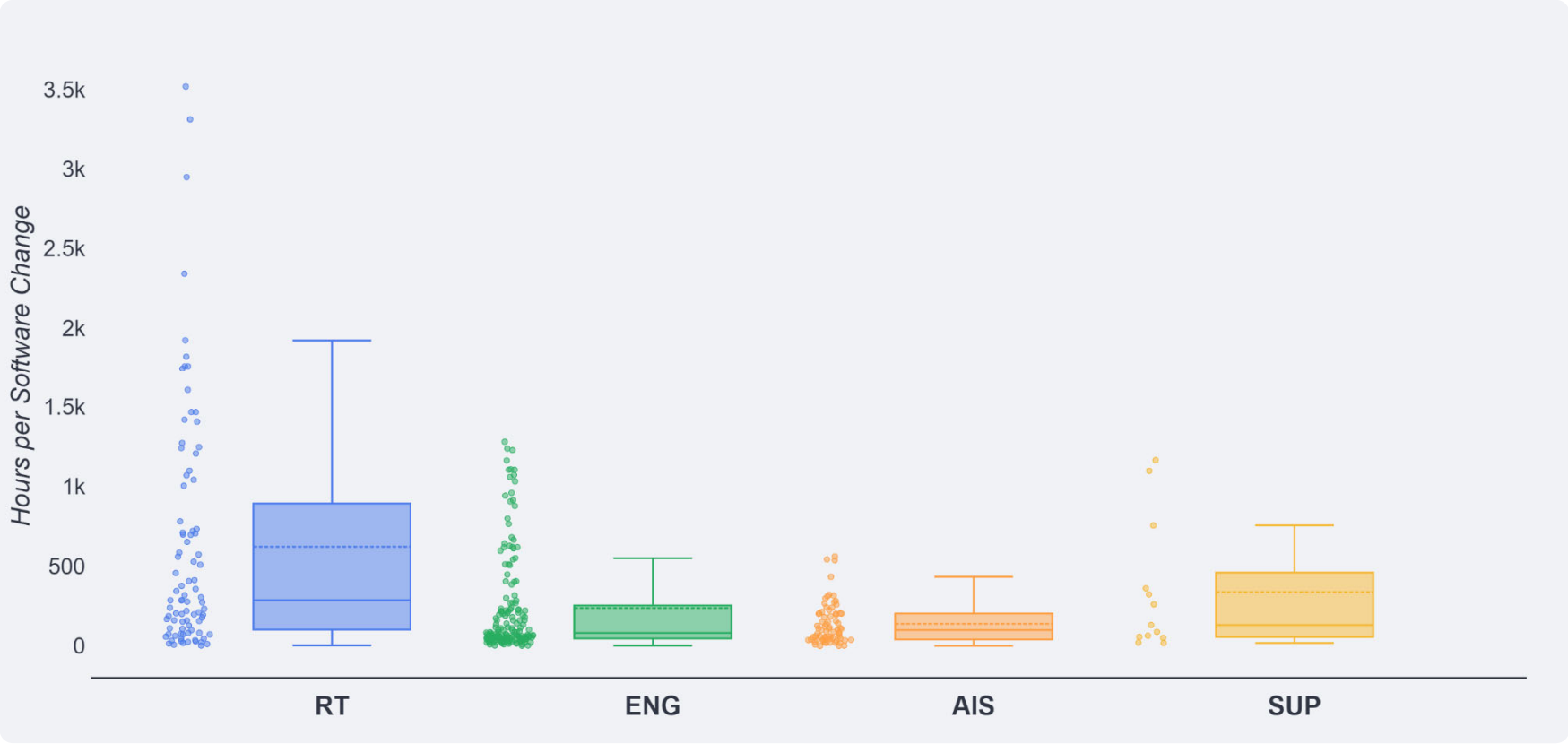
Number of Software Changes per Release
By Super Domain



Super Domain	Count	Mean	Median
RT	80	22.5	9.0
ENG	161	38.3	31.0
AIS	75	17.0	11.0
SUP	14	91.4	49.0

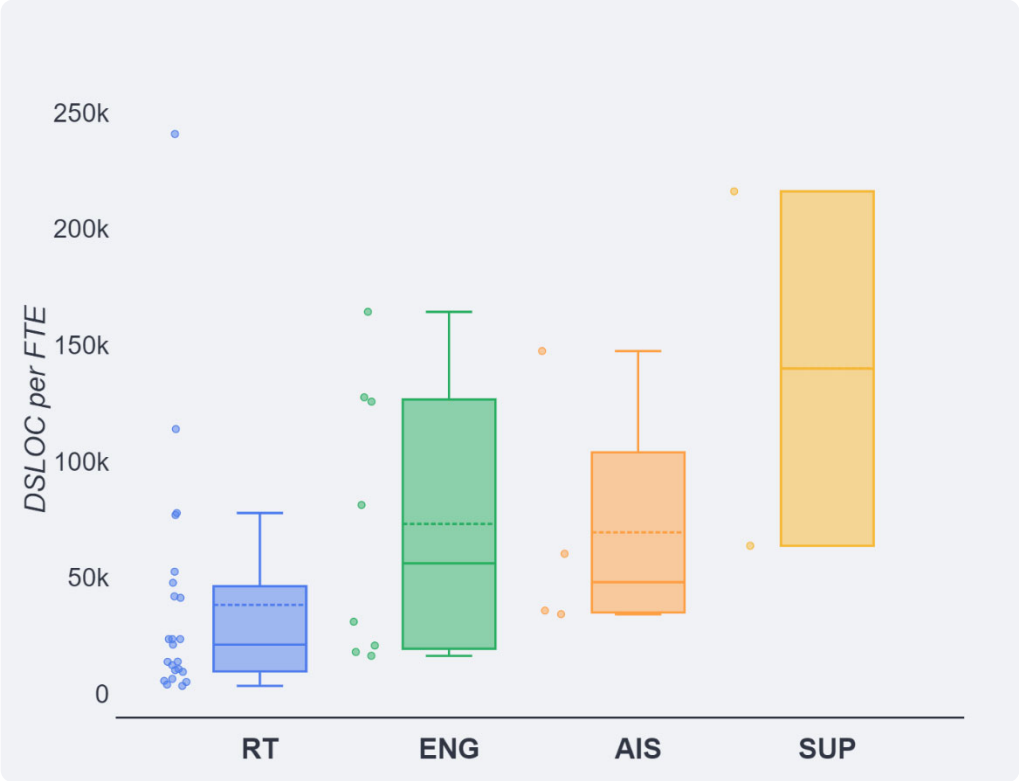
Number of SW Changes/Release can be used to size future releases when program specific data is unknown - The resulting size can be used with the associated cost benchmark or put into a CER

Hours per Software Change
By Super Domain



Super Domain	Count	Mean	Median
RT	101	1481.6	407.4
ENG	186	629.8	102.5
AIS	79	244.9	111.5
SUP	14	490.7	197.0

DSLOC per FTE
By Super Domain



Super Domain	AIS	ENG	RT	SUP
Count	4	8	23	2
Mean	69,492	73,166	38,306	139,953
Min	34,307	16,424	3,496	63,754
1Q	35,486	20,138	9,892	101,853
Median	48,094	56,181	21,221	139,953
3Q	82,099	126,185	44,916	178,052
Max	147,473	164,340	240,813	216,151

For a 100,000 DSLOC baseline, the estimated FTEs are RT=4.7, ENG=1.8, AIS=2.1 & SUP=NA

- DSLOC represents Delivered Source Lines of Code which counts all code equally
- The earliest baseline size reported was used to represent DSLOC
- Full Time Equivalent (FTE) counts were derived by including the following WBS Elements: SW Change Product (1.0), Program Management (2.0), Certification and Accreditation (4.0), and Sustaining Engineering (5.0)
- FTEs were derived by using labor hours per man-year and labor rate reported for each program

Baseline Impact Analysis

Cost Impact of Multiple SW Baselines

Background

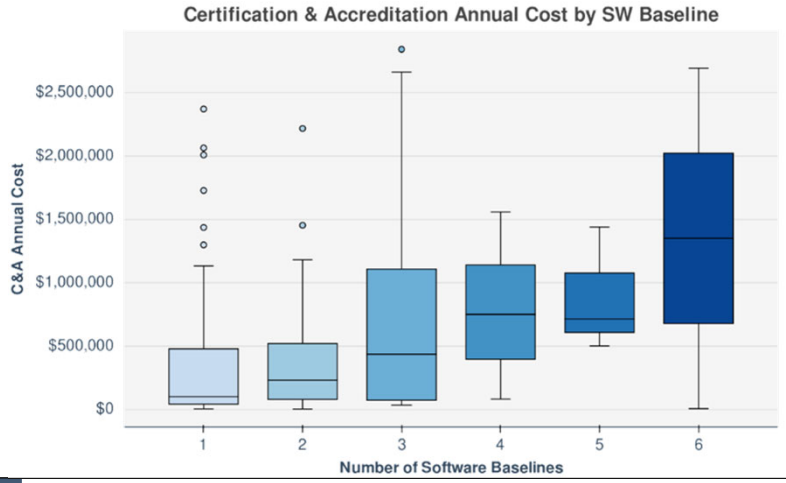
- Fielded systems often have multiple software baselines that must be maintained by the SEC
- Investigate the cost impact of multiple software baselines

Approach

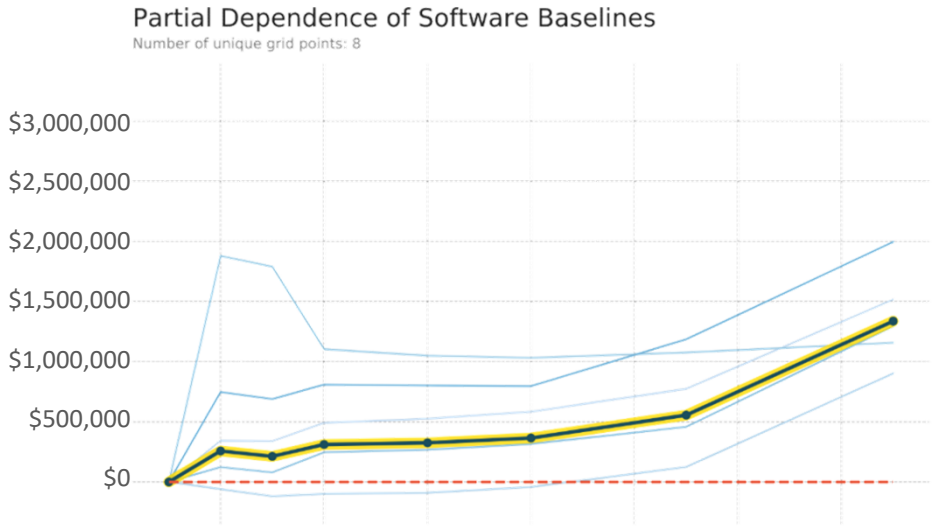
- Analyze relationship between number of software baselines and annual Certification and Accreditation costs using 1) cost distribution 2) partial dependence
- While there is variation within the dataset, there is an increasing trend in costs as the number of fielded baselines increases

Interpretation

- Yellow line represents the average of the predicted cost for each record when changing the number of baselines
- Blue lines represent 5 quantiles of the predictions, meaning there are some data points that are more affected than others by having multiple baselines. Below 0 does not imply a negative cost, it means that the record's predicted cost was less than the average cost at that number of baselines



# of Baselines	1	2	3	4	5	6
Count	50	34	16	10	5	4
Median	$104,942	$234,411	$438,457	$752,890	$716,197	$1,353,313



Lessons Learned

Software Sustainment Estimating Framework

1.0 Software Change Product	
Activities	IAVAs, SW Changes (defects/enhancements)
Performing Org.	Contractor
Challenges	Use of inconsistent size measures; effort not generally tracked by release

2.0 Project Management	
Activities	CM, Execution, Project/Engineering Leads
Performing Org.	Government/Contractor
Challenges	Roles/Responsibilities spread throughout WBS; contractor generally paid by overhead

3.0 Software Licenses	
Activities	License Cost
Performing Org.	Government/Contractor/Outside Organization (enterprise licenses)
Challenges	Paid for by multiple sources; licenses generally underreported; not always tracked

4.0 Certification and Accreditation	
Activities	DIACAP/RMF, STIGs
Performing Org.	Government/Outside Organization
Challenges	Differs between types of C&A's, Difficult to track preparation vs certification vs fixes post certification

5.0 System Facilities	
Activities	Lab infrastructure, Mgmt
Performing Org.	Government/Contractor/Outside Organization
Challenges	Facilities paid by various sources; inheriting hardware from other sources

6.0 Sustaining Engineering	
Activities	Hosting, Help Desk, Delivery/Test Support
Performing Org.	Government/Contractor/Outside Organization
Challenges	Inconsistent/varying activities reported; category generally misunderstood

7.0 Field Software Engineers	
Activities	Field Maintenance, Installation, Troubleshooting
Performing Org.	Government/Contractor/Outside Organization
Challenges	Difficult to estimate required support; shared between multiple programs

8.0 Operational Management	
Activities	Enterprise Management, Business Management
Performing Org.	Government/PEO/Contractor
Challenges	Generally treated as overhead, spread across programs

Lessons Learned From Analysis

- It often takes multiple iterations with the data provider to clean up the data provided – this may be caused by a misunderstanding of what data is being requested or a lack of complete data
  - It is worth the effort to clean up the submitted data
- Data for some of the WBS elements was reported "unavailable" because the work was funded by different organizations, because costs were applicable to multiple systems, or because data was not tracked at lower WBS levels
- Release data was collected for a full release – yet it is tracked annually
  - Future analysis will evaluate annual release data and aggregate release data that spans multiple fiscal years
- Inner program CERs and SERs show significantly better statistics
  - Project leads at LCMC's can use same methodology to develop estimates for program funding

Conclusion & Next Steps

Importance of Data Collection

- Consistent and accurate technical/cost data allows for more meaningful CERs that are relevant to the changing environment of software sustainment
- Software sustainment data can be used to better inform design decisions and cost analysis
  - DASA-CE and the Army cost community are now able to develop cost products that use analogous program data and technical output to estimate software sustainment
  - This facilitates major milestone estimates, O&S cost targets, Operation Sustainment Reviews, and yearly POM reviews
  - Dataset is hosted on CADE under “Library”

Next Steps

- Annual data collection
  - Collection of FY18 PPSS actual execution data by Army G4
  - Development of Army OSMIS data repository for data collection and storage
  - The Software Resources Data Reporting for Maintenance (SRDR-M*) closely aligns to the DASA-CE SWS WBS and data requirements
    - Moving forward, the SRDR-M will be utilized to collect SWS data from Army programs and perform analysis

*See http://cade.osd.mil/policy/dids for more information

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Acronyms -1

ACAT	Acquisition Category
AIS	Automated Information System super domain
BL	Software Change Backlog
BY	Base Year
C&A	Certification and Accreditation
C5ISR	Command, Control, Communications, Computers, Cyber, Intelligence, Surveillance, and Reconnaissance
CADE	Cost Assessment Data Enterprise
CER	Cost Estimating Relationship
COTS	Commercial Off The Shelf
CRED	Uncertainty Estimation Determination
CSCI	Computer Software Configuration Item
Cyber%	Percent of the release that is Cybersecurity updates
DASA-CE	Deputy Assistant to the Secretary of the Army for Cost and Economics
DBS	Defense Business System commodity
DIACAP	DoD Information Assurance Certification and Accreditation Process
DISA	Defense Information Systems Agency
DoD	US Department of Defense
DSLOC	Delivered Source Lines of Code
ECP	Engineering Change Proposal
El_Mod	External Interfaces Modified
ENG	Engineering super domain
Enh%	Percent of the release that is Enhancements to the system
EW	Electronic Warfare

Acronyms -2

FSE	Field Software Engineering
FTE	Full Time Equivalent
IAVA	Information Assurance Vulnerability Alert
IAVM	Information Assurance Vulnerability Management
ICEAA	International Cost Estimating and Analysis Association
Maint%	Percent of the release that is Maintenance changes
NVD	National Vulnerability Database
O&S	Operations and Sustainment
ODC	Other than Direct Costs
OMA	Operations and Maintenance Army funding
OPA	Other Program Army funding
OSMIS	Operation/Sustainment Management Information System
PDSS	Post-Deployment Software Support
PEO	Program Executive Office
POM	Program Objective Memorandum
PPSS	Post-Production Software Support
PTR	Problem Trouble Report

Acronyms - 3

RDT&E	Research, Development, Testing, and Evaluation
RMF	Risk Management Framework
RT	Real-Time super domain
SC	Software Changes
SEC	Software Engineering Center
SER	Schedule Estimating Relationship
SLOC	Source Lines of Code
SRDR	Software Resources Data Report
SRDR-M	Software Resources Data Report for Maintenance
STIG	Security Technical Implementation Guides
SUP	Mission Support super domain
SW	Software
SWBase	Software Baseline SLOC
SWS	Software Sustainment
TDEV	Time to Develop
THrs	Total release hours
TReqts	Total Requirements in a system
TReqts_Imp	Total Requirements Implemented in a release
TSC	Total Software Changes for a release
WBS	Work Breakdown Structure