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Software Cost Metrics Manual

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MOTIVATION

- DOD desires more credible estimates
  - Provide for more realistic Program Element budgets
  - Permit better assessment of Contractor proposed costs
  - Reduce bad press and the perception that it is wasteful of taxpayer dollars
- To achieve this goal, DOD needs
  - Benchmarks that can be used to assess reasonableness of budget submissions and Contractor proposals
  - Consistent ways of addressing the many different size and cost parameters used in preparing estimates and cost-to-complete exercises
  - Hard data that is statistically solid that justifies findings
- With this data, improvements can be made in processes used for planning, budgeting and control

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Data Quality Challenges

- DoD has many software cost data repositories
  - DCARC, NRO, AFCAA, ODASA-CE, NCCA, NSA, Aerospace, …
- Despite increased interest in data, it is surprising that so little effort has been committed reconciling inconsistencies within and across data repositories…
  1. No reporting of Equivalent Size Inputs – CM, DM, IM, SU, UNFM, Type
  2. No common SLOC reporting – logical, physical, etc.
  3. No standard definitions – Application Domain, Build, Increment, Spiral,…
  4. No common effort reporting – analysis, design, code, test, CM, QA,…
  5. Product size only reported in lines of code
  6. No reporting of quality measures – defect density, defect containment, etc.
- The data needs to be statistically sound and defendable
- A good opportunity to communicate and work towards standardization is the current MIL-STD 881 efforts

The key to standardization is encouraging broader participation among these groups

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Limited Research within DoD

1. Other contributors to Productivity besides effort and size, are being ignored by most analysts
   - Operating Environment, Application Domain, and Product Complexity
   - Personnel Capability
   - Required Reliability
   - Quality – Defect Density, Defect Containment
   - Integrating code from previous deliveries – Builds, Spirals, Increments, etc.
   - Requirements Volatility
2. Converting to Equivalent SLOC
   - Categories like Modified, Reused, Adopted, Managed, and Used add no value unless they translate into single or unique narrow ranges of DM, CM, and IM parameter values. We have seen no empirical evidence that they do
   - Other categories like COTS, Converted, Generated and Rehosted are handled differently and there is no consistency when they're used

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Model Calibration Challenges

- Most program offices and support contractors rely heavily on software cost models for their estimates
- May have not been calibrated with most recent DoD data
- Calibration with recent data (2002-Present) will help increase program office estimating accuracy

SEER®

SLIM-Estimate™

TruePlanning® by PRICE Systems

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Consequence: Significant Cost Growth (%)

Statistics	*Total System	**Software Only
Minimum	-64%	-80%
Mean	45%	37%
Maximum	471%	623%
Standard Deviation	71%	107%
Milestone Phase	Development	Development
Sample Size	137	111
Year of Data	1993-2003	2002-2008

Source : *John McCrillis, 36th DOD Cost Analysis Symposium (2003)
**Defense Automated Cost Information System (DACIMS)

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PROPOSED SOLUTION

AFCAA in conjunction with USC and other DOD Cost Agencies, will publish a Manual to help analysts develop more credible estimates based on empirical data in a timely and consistent manner

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Special Features

- **Augment NCCA/AFCAA Software Cost Handbook:**
  - Empirical Productivity Benchmarks by Operating Environment, Application Domain, and Software Size
  - Default Equivalent SLOC Inputs (DM, CM, IM, SU, UNFM); Requirements Volatility derived from empirical data
  - Empirical Code, Effort, and Schedule Growth Measures derived from SRDRs
  - Guidelines and Knowledge Base that capture best practice
  - Empirical Cost Risk and Uncertainty Analysis Metrics
  - Calibrated SLIM-Estimate™ using most recent DoD data
  - Mapping between COCOMO, SEER, True S cost drivers
  - Empirical Dataset for COCOMO, True S, and SEER Calibration
  - Software Maintenance Cost Model

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Table of Contents

Completed by Sep 09

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Our Plan of Attack

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Step 1: Data Definition Approach

1. Review literature/ past research results	Lots of really good work already done by variety of sources
2. Update USC's cost model comparisons	Model comparisons done for NASA last year
3. Synthesize Overall Framework	Develop framework that builds on past to achieve goals established for effort
4. Identify Candidate Application Domains	Estimate accuracy have been shown to be better when they are domain-specific
5. Define Counting Rules and Standards	Use framework as basis to relate counting rules and standards
6. Validate Framework Via Trial Use	Make sure it works with real data; else, change it.

→ **Software Cost Handbook**

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Operating Environments:

Operating Environments
1. Avionics
2. Business
3. Unmanned Ground
4. Manned Space
5. Manned Ground
6. Military Mobile
7. Missile and Unmanned Airborne
8. Shipboard
9. Telecommunications
10. Unmanned Space
11. Web

Comparing results from an Avionics development with that of a business project makes no sense what-so-ever

All comparison need to take software quality into consideration to be meaningful (threshold in terms of defects/KSLOC when delivered)

Application Domains:

Application Domains	
1. Bus	12. Platform
2. Command & Control	13. Process Control
3. Communications	14. Radar
4. Controls & Displays	15. Signal Processing
5. Database	16. Simulation & Modeling
6. Executive	17. Situation Awareness
7. Information Assurance	18. Sonar
8. Maintenance & Diagnostics	19. Test & Evaluation
9. Mission Management	20. Tool and Tool Systems
10. Mission Planning	21. Training
11. Payload	22. Weapons Delivery

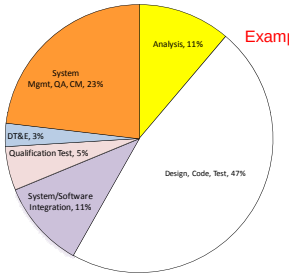
Software Sizing: Counting Rules & Standards

- **Define software size measures used as input to cost estimation models, and provide guidelines for counting and normalizing software size.**
  - Provide rules and guidelines to convert size inputs between models so projects can be represented in all models in a consistent manner
  - Logical source statements consisting of data declarations executables
  - Rules for considering statement type, how produced, origin, build, etc.
  - Providing automated code counting tools adhering to definition , including initial modified-code counting
  - Providing conversion guidelines for physical statements

Software Effort by Activity: Counting Rules & Standards

•Guidelines to adjust effort inputs so projects can be represented in a consistent manner

Example – Not Endorsed



Source: Defense Automated Cost Information System (DACIMS), Proprietary Sources

Equivalent SLOC: Stutzke's Counting Rules

- **For adapted software, apply the parameters:**
  - DM: % of design modified
  - CM: % of code modified
  - IM: % of integration required compared to integrating new code
  - Normal Adaptation Adjustment Factor AAF = 0.4*DM + 0.3*CM + 0.3*IM
- **Reused software has DM = CM = 0.**
  - IM is not applied to the size of the reused software (e.g., 70M SLOC of Windows Vista) but to the size of the other software directly interacting with it (frequently estimated using a %)
- **Modified software has CM > 0. Since data indicates that the AAF factor tends to underestimate modification effort due to added software understanding effects, two other factors are used:**
  - Software Understandability (SU): How understandable is the software to be modified?
  - Unfamiliarity (UNFM): How unfamiliar with the software to be modified is the person modifying it?

Step 2: Indentify Candidate Sources

Commodity	Source	Format	Records
Space, Ground, Air	Defense Cost Analysis Resource Center	DD Form 2630	340
Space	AEHF, MILSTAR, GPS	SEER	~100
Air	F-22 Increment II	DD Form 2630	13
Space	FAB-T	DD-Form 2630	24
Space	NPOESS	SEER	67
Space, Air, Ground	Northrop Grumman, Raytheon	COCOMO, SEER	81
Air, Ship, Ground	Naval Center for Cost Analysis	DD Form 2630	68
Air	Lockheed Martin	COCOMO	10
Air	Army Cost and Economics Analysis Center	DD Form 2630	16
Space	**NRO CAIG**	**SEER**	**40-60**
Space	**Aerospace, Space & Missile System Center**	**SEER**	**TBD**
Space	**NASA JPL**	**NASA**	**TBD**
Space, Air, Ground	**USC Affiliates**	**COCOMO**	**TBD**

Step 3: Collect Data

- **USC will interview program offices and developers to obtain additional information or resolve data anomalies**
  1. SLOC reporting – logical, physical, NCSS, etc.
  2. Requirements Volatility and Adaptation
     - Modified or Reused using DM, CM, IM; SU, UNFM as appropriate
  3. Size Type – Modified, Generated, New, Re-host, COTS, etc.
  4. Effort reporting – phase and activity
  5. Quality measures – defect density, defect containment, etc.
  6. Source – in-house, third party, Prior Build, Prior Spiral, etc.
  7. Requirements Volatility -- % of ESLOC reworked or deleted due to requirements volatility
  8. Programming Languages
  9. Cost Model Parameters – True S, SEER, COCOMO

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Step 4: Organizational Taxonomy

Operating Environment
- Similar systems
- Similar products
- Similar operating characteristics
- Similar requirements

→ **Application Domains**
- Environment independent
- Application-oriented
- Technology driven
- Characterized differently using model cost drivers

→ **Productivity Groups**
- 0-25 KSLOC
- 26-50 KSLOC
- 51-100 KSLOC
- 100+ KSLOC

→ **Meaningful Comparisons**

USC Research Results
Productivity comparisons/benchmarks show best results achieved when similar **application domains** in similar **operating environments** are compared using actual data that is consistent and defendable

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Productivity Benchmarks (Example 1 – Not Endorsed)

Operating Environment	Application Domain	No. Projects	Size Range (EKSLOC)		ESLOC / SM		
					LOW	AVE	HIGH
Avionics	Command & Control	2	8	506	67	74	82
	Communications	4	26	125	145	302	399
	Controls & Displays	3	733	746	183	241	312
	Maintenance & Diagnostic	3	6	205	259	283	329
	Mission Management	18	1	1,581	38	155	585
	Mission Planning	4	43	542	43	376	542
	Radar	11	6	268	33	111	418
	Signal Processing	6	13	444	98	213	429
	Simulation & Modeling	6	32	560	188	683	1552
	Test & Evaluation	1	21	21	34	34	34
	Weapons Delivery	2	29	32	88	90	93

Source: Defense Automated Cost Information System (DACIMS), Proprietary Sources

USC Research Results
Productivity comparisons/benchmarks show best results achieved when similar **application domains** in similar **operating environments** are compared using actual data that is consistent and defendable

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Productivity Benchmarks (Example 2 – Not Endorsed)

Operating Environment	Application Domain	No. Projects	Size Range (EKSLOC)		ESLOC / SM		
					LOW	AVE	HIGH
Manned Ground	Command & Control	32	20	2486	22	296	831
	Controls & Displays	5	8	353	110	314	419
	Executive	2	71	424	78	264	450
	Logistics	1	231	231	290	290	290
	Mission Planning	11	44	2395	75	519	1766
	Platform	4	276	1517	88	129	161
	Process Control	3	39	172	215	352	485
	Signal Processing	1	286	286	358	358	358
	Simulation & Modeling	1	81	81	98	98	98
	Situational Awareness	2	20	1453	140	218	297
	Test & Evaluation	7	1	16	33	59	81

Source: Defense Automated Cost Information System (DACIMS), Proprietary Sources

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Productivity Benchmarks (Example 3 – Not Endorsed)

Operating Environment	Application Domain	No. Projects	Size Range (EKSLOC)		ESLOC / SM		
					LOW	AVE	HIGH
Shipboard	Command & Control	33	1	91	46	128	304
	Communications	8	0	159	8	171	808
	Controls & Displays	7	3	41	33	60	78
	Database	2	5	5	83	129	176
	Executive	4	12	77	48	85	159
	Maintenance & Diagnostic	7	0	144	13	444	1026
	Mission Planning	7	5	88	32	104	203
	Platform	15	2	80	31	134	590
	Radar	17	1	46	4	66	265
	Simulation & Modeling	14	1	81	17	78	244
	Sonar	1	2	2	193	193	193
	Test & Evaluation	1	56	56	69	69	69
	Training	6	35	46	55	98	217
	Weapons Delivery	9	4	369	83	243	527

Source: Defense Automated Cost Information System (DACIMS), Proprietary Sources

- A similar table will be provided for the other 8 operating environments
- Descriptive statistics and project descriptions will follow each table

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Default ESLOC Factors (Example 4 – Not Endorsed)

Size Type	Description	No. Projects	ESLOC Factor Low	AVE	High
Reused	Pre-existing code that is not changed with the adaption parameter settings: •Design Modification % (DM) = 0% •Code Modification % (CM) = 0%	60	0%	9%	40%
Modified (High)	Pre-existing code that is changed with the adaption parameter setting: •Code Modification % (CM) > 25%	21	22%	51%	100%
Modified (Low)	Pre-existing code that is changed with the adaption parameter setting: •Code Modification % (CM) < 25%	38	3%	16%	34%
Generated	Software created with automated source code generators using different technologies. It may consist of the generator statements directly produced by the programmer or the 3GL generated statements from automated tools.	40	0%	6%	50%
Re-Host	Rehosting software from one target environment to a similar environment. Assumes no major operating system changes. Development tools may be different between the platforms.	6	10%	16%	25%
COTS	Pre-built commercially available software components whereby the source code is not available to application developers. It is not included for equivalent size. Other unmodified software not included in equivalent size are Government Furnished Software (GFS), libraries, operating systems and utilities.	1	1%	1%	1%

ESLOC Factor = Adaptation Adjustment Factor = 0.4 x DM + 0.3 x CM + 0.3 x IM

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Raw Datasets (Example 5 – Not Endorsed)

IOC YR	Record	Operating Environment	CSCI	Application Domain	Productivity (ESLOC/MM)	Total Size (SLOC)	Effective Size (ESLOC)	Effort (Person-Months)	Effort (Peak-Staff)	Schedule (Months)
1999	1	Airborne	Signal Processing	Avionics	60	90000	90000	1000	69	71
2008	2	Unmanned Space	Spot Antenna Control	Payload	39	78000	5000	2000	95	69
2008	3	Unmanned Space	Bootstrap	Bus	44	35000	31000	800	70	60
2007	4	Manned Ground	Data Handling	C2	250	25000	21000	100	40	32
2007	5	Military Mobile	Display and Control	Radar	100	10000	9000	100	30	30
----	6	Unmanned Space	Classified	Payload	46	36000	29000	807	71	63

- In case you want to challenge or refine the benchmarks and metrics provided in the manual, the raw datasets (Non Proprietary Version) will be included in the appendix

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Current Status

- **Already collected a significant amount of data**
  - 345 projects --Defense Cost Analysis Resource Center
  - 240 projects – Raytheon, Lockheed, Northrop Grumman, etc.
  - Expecting space software projects from National Reconnaissance Office, NASA, and Military Prime Contractors (>100 projects)
- **Analyzing over 200 projects**
- **Common Data Definitions and Standards**
  - Initial Review (May 2009)
  - Interim Review (International COCOMO Forum, Oct 2009)

Framework and definitions are done as is the initial data analysis – detailed data analysis is in process as is adding guidelines

- **Manual Publication**
  - Initial Release (Sep 2009)
  - Subsequent Releases (Sep 2010, Sep 2011, Sep 2012)

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Concluding Remarks

- **Goal is to publish a manual to help analysts develop quick software estimates using empirical metrics from recent programs**
- **Additional information is crucial for improving data quality across DoD**
- **We want your input on Productivity Domains and Data Definitions**
- **Looking for collaborators**
- **Looking for peer-reviewers**
- **Need more data**
- **Need even more data**

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Questions or Comments?

- Any questions
- Any pointers
- Any feedback

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