Software Maintenance Data Collection and Estimating Challenges

SCEA 2012

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Abstract

Entering a period of fiscal austerity, it becomes more important than ever to estimate and consider operating and support (O&S) costs, which represent the lion’s share of life cycle cost (LCC) for most platforms, during acquisition. Given the ubiquity of software in today’s complex programs, a key component of O&S is software maintenance. This paper presents the results of a research study co-sponsored by the Air Force Cost Analysis Agency (AFCAA) and the Naval Center for Cost Analysis (NCCA) to collect software maintenance data from government support activities and development contractors to enable high-fidelity cost estimates for software maintenance.

Software maintenance cost estimates have often resorted to apocryphal rules of thumb or “black-box” off-the-shelf models. Rules of thumb might be in the form of “Annual software maintenance cost is such-and-such a percentage of software development cost” or “Each full-time staff person can maintain so many thousands of source lines of code (KSLOC).” Neither method is defensible if they are not readily traceable to the source data (if any) upon which they’re based. It is this acute need for data that prompted the study team to undertake our effort. We collected data from multiple maintenance organizations, both government and contractor, across various platform types, yielding scores of data points, each constituting a maintenance release. We focused on the key parameters needed for estimating, primarily sizing, schedule, effort, and quality data. Where available, we also collected cost, capability, and complexity. We endeavored to follow best practices by: (a) developing a flexible Data Collection Form in Excel, which could be filled in from scratch or easily linked to an existing source; (b) working to understand each organization’s process to provide context to the data; (c) visiting the organization when possible to speak directly with software managers, engineers, and estimators; and (d) documenting which activities were included in effort data.

The paper will present the summary metrics derived from the collected data and discusses important issues that arose, including (1) whether organizations focused on the base code being maintained or the code being changed with each release (more like a “mini-development”); (2) whether organizations focused on defects as a driver of maintenance effort or took a broader view of software trouble reports (STRs) as requested changes; and (3) how organizations accounted for infrastructure costs and sustaining engineering activities. It was evident that maintenance metrics were of increasing importance across all the organizations surveyed, and occasionally that meant that measurement systems themselves were in flux, often due to mergers or benchmarking against sister organizations. Finally, the paper will make recommendations as to the improvement of ongoing software maintenance data collection.
Outline

• Purpose of Presentation
• Background
• Identification of Data Sources
• Reasons for Participation
• Current SWMX Estimating Approach and Current Challenges
• Data Collection Study
  – Purpose
  – Joint Services Effort (MOA and ARDEC parallel study)
  – Study Objectives
  – Data Collection Approach
  – Data Protection
  – Desired Data
  – Data Collection Form
  – Data Assessment
• Study Challenges
• Results
• Road Ahead
Purpose of Presentation

• To present the current status of joint AFCAA/NCCA software maintenance data collection study
• To generate interest and solicit participation in the study
• To discuss challenges encountered and lessons learned on the study to date
  – To gather feedback from the community
• To present initial results from the study
  – Uncertain at “press time” how extensive these will be
• To complement the material being presented by Cheryl Jones (Army ARDEC)
  – The two study efforts are closely aligned, and some overlap is inevitable

Background

• With the emerging fiscal constraint in the DoD budget, there is more focus on the operating and support (O&S) costs, which represent the lion’s share of life cycle cost (LCC) for most platforms, during acquisition.

• One area of interest is the validity and defensibility of the estimates used to determine, allocate, and evaluate the value of software maintenance funds.

• Software maintenance cost estimates have often resorted to apocryphal rules of thumb or “black-box” off-the-shelf models. None of these methods are defensible if they are not readily traceable to the source data (if any) upon which they’re based.

• A research study co-sponsored by the Air Force Cost Analysis Agency (AFCAA) and the Naval Center for Cost Analysis (NCCA), with joint participation from Office of the Deputy Assistant Secretary of the Army for Cost and Economics (ODASA-CE), Armament Research, Development and Engineering Center (ARDEC), and the Air Force’s Electronic Systems Command (ESC), is collecting and analyzing software maintenance data from government support activities and development contractors to enable high-fidelity cost estimates for software maintenance.
ID of Data Sources – Government

• Data warehouses
  – Navy Visibility and Management of Operating and Support Costs (VAMOSC), Army VAMOSC Operating Support Management Information System (OSMIS), Air Force Total Ownership Cost (AFTOC)

• Data collectors
  – NAVAIR 4.1 Program Related Engineering (PRE)

• Cost estimators
  – NAVAIR 4.2, NAVSEA 05C, SPAWAR 1.6

• Maintainers
  – Air Logistics Centers (ALCs), Fleet Readiness Centers (FRCs)

• System Commands and Warfare Centers
  – MARCORSYSCOM, NSWC Dahlgren

• Program Offices
  – ISPAN, JSF, DDG 1000
ID of Data Sources – Contractor

• Focus on Tier 1 defense contractors
  – Tend to have more and larger programs

• Grass roots aka “bottom-up”
  – Contacts from industry symposia, “kindred souls”
  – Heavily reliant on study sponsors
  – Self-motivated to participate, even if “guerilla” effort required

• “Top-down” via corporate leads
  – Overhead effort already committed, or at least authority to do so

• “Side-door” via established government-industry forum
  – Aviation Cost Integrated Product Team (CIPT), establishment of Software sub-group TBD
  – Process for information exchange already established
Reasons for Participation

• Improved Estimating
  – Participants will receive non-proprietary version of metrics
  – More defensible analysis for BOEs, insourcing studies, etc.
  – Data support better estimates, which in turn defend budgets and support better management

• Benchmarking
  – Learn where your organization’s performance stands relative to industry averages
  – Insight into criteria for government evaluation of proposals

• Perception as Industry Leader
  – DoD-wide reputation as key contributor to elevation of the software cost estimating community
  – Access to the study group (Air Force, Army, Navy) as a Government Partner

All contribute to improved ability to manage and win business!
Current SWMX Estimating Approach and Challenges

• Level of Effort (LOE) or SLOC/FTE
  – Equivalent to analogy with SLOC scaling
  – Annual Change Traffic (ACT) effort
• Cost Factor or % of Development
• Defects and Productivity (hours/item, by severity)
• Cost or Effort Estimating Relationships (CERs / EERs)
• Time-Phasing
  – “Aging” of code (New to Modified to Carryover)
  – Ramp-down over time as you “work out the bugs”

• Current estimates too often rely on apocryphal Rules of Thumb

Need to improve methods drives the research study
Purpose of Study

• To collect actual data to improve software maintenance cost estimating
  – Sizing, schedule, effort, quality, etc.

• To develop appropriate cost estimating methodologies and cost estimating relationships (CERs) for use in future software maintenance cost estimating efforts
  – Plan to update maintenance chapter in AFCAA’s Software Cost Estimation Metrics Manual

• Plan to share normalized data and insights with participants
  – Sanitized results will be segregated by commodity but with no identifying parameters
  – Mutual benefit to contractor and government organizations
Joint Services Effort

• This effort presents the results to date of a research study co-sponsored AFCAA and NCCA, with joint participation from the Army’s ODASA-CE and the Air Force’s ESC, to collect and analyze software maintenance data from government support activities and development contractors to enable high-fidelity cost estimates for software maintenance.

• Another complementary effort is run by ODASA-CE and ARDEC that focuses more on developing improved software maintenance estimation processes, cost relationships, associated models, and establishing better policies.

• The two efforts are collaborative; site visits and data collection trips are jointly supported.
  – Recurring Software Maintenance Summit meetings between the three services, kicked off at DoDCAS 2012.

• All three services signed a Memorandum of Agreement to share data and analyses.
<table>
<thead>
<tr>
<th>Sponsor</th>
<th>MOA Signatory</th>
<th>Title</th>
<th>Study POC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Force Cost Analysis Agency (AFCAA)</td>
<td>John G. Georges</td>
<td>Division Director</td>
<td>Dr. Wilson Rosa</td>
</tr>
<tr>
<td>Naval Center for Cost Analysis (NCCA)</td>
<td>Justin E. Moul</td>
<td>Division Director</td>
<td>Dr. Corinne Wallshein</td>
</tr>
<tr>
<td>Office of the Deputy Assistant Secretary of the Army for Cost and Economics (ODASA-CE)</td>
<td>James Judy</td>
<td>Division Chief</td>
<td>Jeramia Poland</td>
</tr>
<tr>
<td>Air Force Materiel Command (AFMC) Electronic Systems Center (ESC), Hanscom AFB</td>
<td>David A. Morana</td>
<td>Chief, Cost Estimating Division</td>
<td>Brian Fersch</td>
</tr>
</tbody>
</table>
MEMORANDUM OF AGREEMENT


1. This Memorandum of Agreement (MOA) establishes roles, responsibilities, and deliverables amongst Air Force Cost Analysis Agency (AFCAA), the Naval Center for Cost Analysis (NCCA), the Office of the Deputy Assistant Secretary of the Army for Cost and Economics (ODASA-CE), and the Air Force Materiel Command (AFMC) Electronic Systems Center (ESC) in a joint study of Software Maintenance Data Collection of weapon system platform software.

2. AFCAA will be the lead service for the study with active participation and support from NCCA, ODASA-CE, and ESC.

3. AFCAA will develop final data collection sheets; provide documentation on participation, status, data, and data analysis; manage Non-Disclosure Agreement (NDA) or Proprietary Information Agreement (PIA) forms, as appropriate; provide resources; and share raw and normalized software maintenance data with NCCA, ODASA-CE, and ESC.

4. NCCA, ODASA-CE, and ESC will provide program participants' points of contact (POCs) to AFCAA, share in-houes software maintenance data and corresponding documentation, provide resources, and review data collection sheets and documentation.

5. All organizations agree that it is essential to the success of this task that our efforts be open and transparent, and all data and information be shared to the maximum extent possible. In cases where it may not be possible to share data used in the study, each organization agrees to notify the others regarding data restrictions.

6. AFCAA will lead in sharing and presenting results of this study to organizations outside this MOA. All organizations will concur on release of this data to other government organizations not participating in this data collection study.

7. Deliverables include a final list of participants with their contact and organizational information; spreadsheets of raw and normalized data (per above); a description of normalization rules and procedures; collected source metadata; normalized source metadata; written descriptions of the overall scope, data analysis techniques used, and data analysis; a summary briefing and report; and a list of potential future software maintenance research where appropriate.

8. Participants providing software maintenance data will receive a normalized data set, a description of normalization rules and procedures, normalized source metadata, and a summary briefing and report.

9. Each organization is responsible for its respective contract management and overall data management.

10. This MOA will become effective upon signature of all parties. The MOA will remain effective after its effective date unless earlier revoked in writing by any party.

JOHN G. GEORGES
Division Director, Air Force Cost Analysis Agency
1 Mar 2011
(Date)

JUSTIN E. MOUL
Division Director, Naval Center for Cost Analysis
2 Mar 2011
(Date)

JAMES J. FYDY
Division Chief, Office of the Deputy Assistant Secretary of the Army for Cost and Economics
2 Mar 2011
(Date)

DAVID A. MÖRANA
Chief, Cost Estimating Division
Air Force Electronic Systems Center
17 Mar 2011
(Date)
Study Objectives

• Provide summary metrics derived from collected data
  – Base code being maintained vs. the code being changed with each release
  – Defects as a driver of maintenance effort vs. software trouble reports
  – Infrastructure costs and sustaining engineering activities

• Make collected data useful to oversight and management entities
  – Provide guidance on how to condition data to address challenges
  – Segment data into different Application Domains and Operating Environments
  – Analyze data for simple Cost Estimating Relationships (CER) and Benchmarks within each domain
  – Develop rules of thumb for missing data
Data Collection Approach

• Collect data in as unobtrusive a manner as possible
  – Make use of the data collected in the course of business, in the form in which it is collected
  – Take advantage of data deliveries in support of milestone decisions (e.g., for follow-on programs) or other customer events
  – Remote collaboration where possible, site visit where appropriate

• Initial survey
  – Instrumentation in the form of Excel workbook with front-end form and back-end data table for AFCAA/NCCA
    • Enhancement of data collection form to accommodate data challenges and complement the Army’s questionnaire
  – Ease of entry, ease of analysis
  – Link to existing data workbooks

• Follow-up interview for clarification and data validation
Data Protection

• Protection of the source data is of utmost concern to the study group
  – Our ability to estimate depends on data
  – Our ability to obtain data is only as good as our reputation for safeguarding it

• All data delivered directly to the government

• All personnel will sign Non-Disclosure Agreement (NDA) or Proprietary Information Agreement (PIA) as appropriate

• Sanitized results will be segregated by commodity but with no identifying parameters
  – Best practices from USC/CSE (COCOMO), ACE Libraries (ACDB)

We safeguard the data as if it were our own
Desired Data

• Focus on key parameters needed for estimating:
  – Project Context and Maintenance Process
  – Sizing Data
    • Code (Base, New, Adapted, Auto, etc.)
    • Change traffic
  – Schedule Data
  – Effort Data
  – Quality Data
  – Capability Data
  – Complexity Data

• Multiple projects, multiple releases (or annual snapshots)

Make the most of the opportunity - collect only what’s needed
Data Collection Form – General

• A modified version of an earlier questionnaire

• Data Priorities
  – High Priority fields show key parameters needed for estimating
    • Identifying Information
    • Sizing – Source Lines of Code
    • Schedule
    • Effort
    • Quality
    • Capability*
  – Lower Priority fields good to have for additional analysis and benchmarking
    • Cost
    • Requirements*  
    • Earned Value
    • Test Effort
    • Model Information (COCOMO)

• Features for ease of use and/or data integrity
  – MS Excel as data form
  – Drop-down menus
  – Hyperlinks to data dictionary (on ReadMe tab)*

* Later reprioritized based on study group discussions
System, Program, Project, Version, Release, etc.

- Project Identification, which may have to be purposely obscured later anyway!
- Identification of multiple (preferably sequential) releases of the same software
  - Important for temporal analysis

**System Type and Application Domain**

- To date, we have *not* pursued AIS programs
- Application domain (software type), or even “super-domain”
  - Application domain can be collapsed into 3 “Super Domain” types depending on the number of data points based on Cheryl Jones DoDCAS brief

**Platform**

- Straightforward, but remains to be seen whether it drives differences in benchmarks (analogy vs. parametric thought process)
- In conjunction with Application Domain, or independently
### Sizing

- Breakout of SLOC at these various levels is usually not provided
- Type of SLOC need to be specified with conversion factors assumption provided for normalization
### Data Collection Form – Schedule

#### Schedule

- Breakout of schedule by CSCI and phases is usually not provided
- Top level schedule by each release is preferable to overall project schedule
Data Collection Form – Effort

Effort

- Estimated and actual staff hours by software maintenance and sustaining engineering activities at the total and/or CSCI level
  - Option for identifying activities or providing expert-based percentages if breakdown of hours is not available
  - Usually only available at total level
- Total staffing level by labor category
  - Remains to be seen whether it drives differences in benchmarks
**Data Collection Form – Quality**

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<tr>
<th>A</th>
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<tr>
<td><strong>SOFTWARE MAINTENANCE FORM</strong></td>
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**Form instructions**

- **Point of Contact Identifying Information (Mandatory)**
- **Project Identifying Information (Mandatory)**
- **Rating (Mandatory)**
- **Schedule (Mandatory)**
- **Effort (Mandatory)**
- **Quality (Mandatory)**

**Defect count dates are linked to overall schedule but can overwrite if needed. If tracking quality metrics other than the defects listed in table below, or if available per site, please provide in a supporting file and insert at upper right.**

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<th>#</th>
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<tr>
<td>210</td>
<td><strong>Quality (Mandatory)</strong></td>
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<td>211</td>
<td><strong>Prior Defect Count Date</strong></td>
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<td>212</td>
<td><strong>Most Recent Defect Count Date</strong></td>
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**Defect Category (Number of Defects)**

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<td><strong>Known Defects (new existing prior to release)</strong></td>
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<td><strong>Known Defects planned to be fixed as part of this release</strong></td>
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<tr>
<td><strong>Known Defects actually fixed as part of this release</strong></td>
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<td><strong>New Defects found during work on this release</strong></td>
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<tr>
<td><strong>New Defects fixed as part of this release</strong></td>
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<td><strong>Total number of known defects fixed by category</strong></td>
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<tr>
<td><strong>Total number of known defects remaining by category</strong></td>
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</table>

**Quality**

- List of defect information by severity level but can possibly be reported via a different metric, e.g. STRs.
- Many organizations track defects within release throughout the process (peer reviews, etc.)
Data Collection Form – Capability

- Currently a mandatory field but can be optional
- List company maturity and accreditation rating
- Identifies experience levels and program languages used in the project
- This was often tracked at the organization level but not at the project level
Data Collection Form – Requirements

- Currently an optional field but should be mandatory especially if used as a sizing method
- Identifies the number of requirements by types
- May include non-defect STRs
SWMX Data Assessment

• During the SWMX Summit on 12 March, the group agreed on a process to identify the quality of data received from various sources

• Color-coding shows the usability of data for the SWMX study
  - **Red**: Missing data*, unusable data
  - **Orange**: Incomplete data, can make assumptions to use data in analysis
  - **Green**: Usable data for analysis, reliable values for key parameters
  - **Blue**: Eminently usable, more robust or more detailed data

• Data categories agreed upon at the summit are:
  - **Identifying Information (ID)**: program name, organization, domain
  - **Sizing (SLOC)**: base code and New/Modified/Reuse for release
  - **Requirements/Functionality (REQ)**: number of items to be addressed
  - **Schedule (SKED)**: total duration (preferably with begin and end dates)
  - **Effort (EFF)**: labor hours or dollars or (preferably) both
  - **Quality (QUAL)**: defect information
  - **Backlog (BACK)**: requirements/defects remaining after release

*Could also use gray for data that were not captured (by the source) and hence will never be available.
## Data Assessment Category Definitions

<table>
<thead>
<tr>
<th>DATA CATEGORIES</th>
<th>No program information provided</th>
<th>Partial program information provided</th>
<th>Program information available in super-domain break-out from Cheryl Jones’ brief</th>
<th>Detailed program information provided such as domain, platform, etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identifying Information (ID)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Sizing (SLOC)</td>
<td>No SLOC data</td>
<td>Partial SLOC data with no breakout</td>
<td>Total SLOC with break-out of Base, New, Re-use, Modify</td>
<td>SLOC with breakouts by CSCI</td>
</tr>
<tr>
<td>Requirements/Functionality (REQ) can be enhancements but not defects</td>
<td>No requirements or functionality data provided</td>
<td>Partial requirements data provided</td>
<td>Identifies other counting points</td>
<td>Provides breakdown of data for other counting points</td>
</tr>
<tr>
<td>Schedule (SKED) ties to EFF</td>
<td>PoP not available (e.g., end date but no start date)</td>
<td>PoP is only available for top level program</td>
<td>PoP available for all releases</td>
<td>PoP available at CSCI level</td>
</tr>
<tr>
<td>Effort (EFF) ties to SKED</td>
<td>No indication of activities included</td>
<td>Includes core SWMX activities; dollars but no hours</td>
<td>Hours broken out across a wide range of activities</td>
<td>Includes all activities/phases of SWMX and hours for the program or release</td>
</tr>
<tr>
<td>Quality (QUAL)</td>
<td>No quality data provided</td>
<td>Quality metric is not defined but with priority level</td>
<td>Quality metric is defined with priority level</td>
<td>Quality metric is defined with priority level and identified for System Test and Operations phases</td>
</tr>
<tr>
<td>Backlog (BACK) could trace back to REQ and QUAL</td>
<td>No backlog information provided</td>
<td>Does not define Backlog but has tracking methods</td>
<td>Defines Backlog and tracking methods</td>
<td>Defines the Backlog definition and tracking methods with priority levels</td>
</tr>
</tbody>
</table>
Currently over 200 data points in repository
General Study Challenges

• Data Scarcity
  – Desired data not commonly collected across organizations

• Data Consistency
  – Collection methods differ between organizations
  – Metrics measurement systems occasionally in flux, often due to mergers or benchmarking against sister organizations

• Study resistance
  – Lack of sufficient upper management support
  – Lack of resources
  – Data proprietary restrictions
Government Source Challenges

• Resources for study participation
  – Working Capital Fund (WCF) organizations need to maximize “direct-charge” work just like contractors!

• Granularity of data
  – Effort may not be tracked to individual maintenance release if there are multiple concurrent releases
  – Government timecard systems have the same implementation issues as those of contractor organizations

• Data Scarcity
  – Data collection driven by policy, often not in centralized database

• Data Consistency
  – Collection methods differ between organizations
  – Metrics measurement systems occasionally in flux, often due to benchmarking against sister organizations
Contractor Source Challenges

• Data access
  – Proprietary information agreements (PIAs)

• Resources for study participation
  – Limited ability to charge overhead, especially if not well-aligned with organizational objective
  – Drove study team to focus on “as-collected” data sources

• Data Scarcity
  – Data only collected if government deliverable or internal initiative

• Data Consistency
  – Collection methods differ between organizations
  – Metrics measurement systems occasionally in flux, often due to mergers
Results

• ~ 240 data points collected (at “press time”)
  – Comparable number of Government and Contractor data source
  – Former tend to have many more data points

• Initial Data Analysis
  – Computation of benchmarks (e.g., SLOC/FTE)
  – Exploration of cost drivers (e.g., scatterplot effort vs. STRs)
  – Testing for populations (e.g., Ground vs. Air)
  – Including reduced # of data points

• Initial Findings
  – TBD

• Data Repository Status
  – Air Force
    • Program, Organic and Contractor Software Support
  – Army
    • Organic and Contractor Software Support
  – Navy
    • Program, Data Warehouse, and Data Collectors

• Desired Metrics
  – TBD
Road Ahead

• Focusing or “streamlining” data collection instrument
  – Content: Focus on key data elements

• Additional data collection
  – Previous and new sources
  – Are you interested?

• Database enhancement to include raw and normalize data collected

• Develop guidance and recommendations
  – Cost estimating methodologies and relationships
  – Update maintenance chapter in AFCAA’s Software Cost Estimation Metrics Manual

• Institutionalize data collection via policies/CDRLs
  – SRDR for Software Maintenance, DD Form 1921-4