How Does NASA Estimate Software Cost? Summary Findings and Recommendations

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Background and History

Background

- The NASA software working group identified that software had a cost estimation problem.
- A team was formed to document the causes and possible solutions
  - The NASA Software Cost Improvement Task is a NASA wide task funded by the NASA Office of the Chief Engineer Software Working Group
  - Team is multi-center and multi-disciplined

The NASA OCE Software Working Group is taking steps to change the NASA software engineering culture from the grass roots level of the organization so that our engineering managers fully accept that cost estimation is a part of their job.

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Purpose

Purpose - Improve software cost estimation across the agency

1. Document current state of software cost estimation practices
   - Identify strengths and weaknesses
2. Provide recommendations to improve estimation practices
   - Make software cost estimates more defensible when negotiating over project budgets
   - Improve software cost estimation 'accuracy'
3. Enable and support implementation of recommendations both inside and external to the NASA software community

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Approach and Methodology Overview

Two step data collection approach

- On-line Survey (93 completed surveys)
  - Probes for basic activities primarily within the software community
    - Stratified across centers, roles and software
- In-depth Interviews (73 engineers were interviewed)
  - Document what happens to cost estimates as they move up and out through the organization
  - Population
    - Project Managers, Proposal Managers, Systems and Subsystem Managers, Center Cost Analysts, Line Managers, Software PDLs, Software Cost Analysts (SCA)
  - Collect detailed descriptions of key software estimation practices
    - Especially how PDLs and SCAs develop their BOE
    - Estimation of the appropriate level of software assurance
  - Detailed interviews completed at JSC, GSFC, GRC, MSFC and IPAO

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Current State of NASA Software Cost Estimation

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Software Cost Estimation Environment

- Requirements immaturity is a fact of life with most early estimates
  - Only 28% reported requirements were well defined most of the time
  - Even at PDR only 43% report that requirements are well defined most of the time

- The In-depth interviews revealed that Line Managers, PDL's and software cost estimators frequently negotiate a budget that they can accept, but with higher risk tolerance. The on-line survey results indicated that
  - Less than half reported they get their best estimate into the budget while the other half report the budget is set before the scope can be determined
  - 34% report there is frequently inappropriate pressure to alter estimate in some way.

- Requirements volatility is a key issue to address

  It's possible to plan and manage this volatility as a risk!

  Procedures and standards could make this easier and more routine.

On-line survey results shown are for responses indicating that the practice is performed at least "most of the time" (>75%)

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Key Findings

- Overall each software estimation and management Best Practice is being performed within at least one NASA Center and many are being performed at multiple Centers.
- However, these practices are not all being performed consistently at any one center.
- On average, the core set of best practices are only performed about 50% of the time. Software organizations that have designated staff performing a software cost analyst role reported performing these activities well above the NASA average.
- Best practices include:
  - Having a defined process
  - Generating more than 1 estimate
  - Estimating SW size and reuse
  - Producing supporting BOE documentation
  - Incorporating the impact of known risks into the estimate
  - Using a WBS
  - Recording actuals

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Software and Cost Community Interface

- **Center Cost Analysts**
  - Typically do not estimate software costs as they use a model like NAFCOM where software is 'just' included – focus is on system or project
  - When they do estimate software costs they need a software engineer or manager to assist with sizing
    - Issue is there is the potential for miss communication related to how the information will be used, counting method required, reuse rates, etc.
    - Also some software staff can provide insight other model inputs such as complexity
- **IPAO**
  - Primary concern is software development schedule as a software schedule slip can amplify through a project due to schedule dependencies and SW is a small percent of mission cost
    - This initially came as a bit of a surprise to the software engineers

We need to improve communication between the cost and software communities

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How We are Changing NASA Software Cost Estimation from the Bottom Up

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Key Recommendations for NASA Software Organizations

1. **All software organizations should have a documented process**
   - Process needs a standardized BOE Template with examples (standardization makes estimates more defensible and enables easier archiving and reuse of BOE information)
   - Software organizations should provide at least 2 estimates by PDR due to scope uncertainty
2. **All software organizations should use tools and historical data**
   - NASA Costing Office already provides free access to SEER and Price software cost models
   - All software organizations should establish and maintain a historical database
3. **Each Software intensive branch or division should have a specific person who fulfills the software cost analyst role, which may be a part time role**
   - This person also should also act as a bridge between the engineering and center costing organizations for best practices and access to tools and data (Infusion Agent)

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What We are Doing

1. Develop NASA wide examples and templates to support center development of
   - Cost process, tools, BOE templates, WBS templates
2. Educate center software cost estimators and PDL's to use best practices
   - Already in process through the NASA Software Management Class and JPL SW Cost Estimation Class which rotates around the centers
   - Fund SEER-SEM Training
3. Develop a handbook and training for Costing Community on how experienced NASA SW engineering cost estimators set up their models for various classes of software
   1. Software Engineering Handbook can be reached
4. Work with the NASA Costing Office to improve NASA Cost Handbook, CADRe, Software Cost Model use and better integrate each others assets and procedures
   - Consider jointly developing a NASA SW Cost Model similar to NICM
5. Monitor and evaluate the effectiveness of the implementation of the study recommendations
   a) implementation and use of processes and templates
   b) cost and schedule growth across software tasks and projects

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What We are Doing

1. Developed a NASA software Cost Estimation Process (Guideline)
1. Educating center software cost estimators and PDL's to use best practices which rotate around the centers (3-5 times per year)
   - NASA Software Management Class
   - JPL SW Cost Estimation Class
   - Looking into supporting SEER-SEM Training
2. Developing NASA wide examples and templates to support center development of
   - Cost process, tools, BOE templates, WBS templates
3. Revise the NASA Software NPR 7150.2A to increase cost and risk related requirements
4. Expand the cost section in the NASA Software Engineering Electronic Handbook
   - https://swehb.nasa.gov/display/7150/Book+A.+Introduction
5. NsCIT Team will infusion the cost process throughout the centers by providing direct support
6. Monitor and evaluate the effectiveness of the implementation of the study recommendations
   a) implementation and use of processes and templates
   b) cost and schedule growth across software tasks and projects

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NASA Guideline
Software Cost Process

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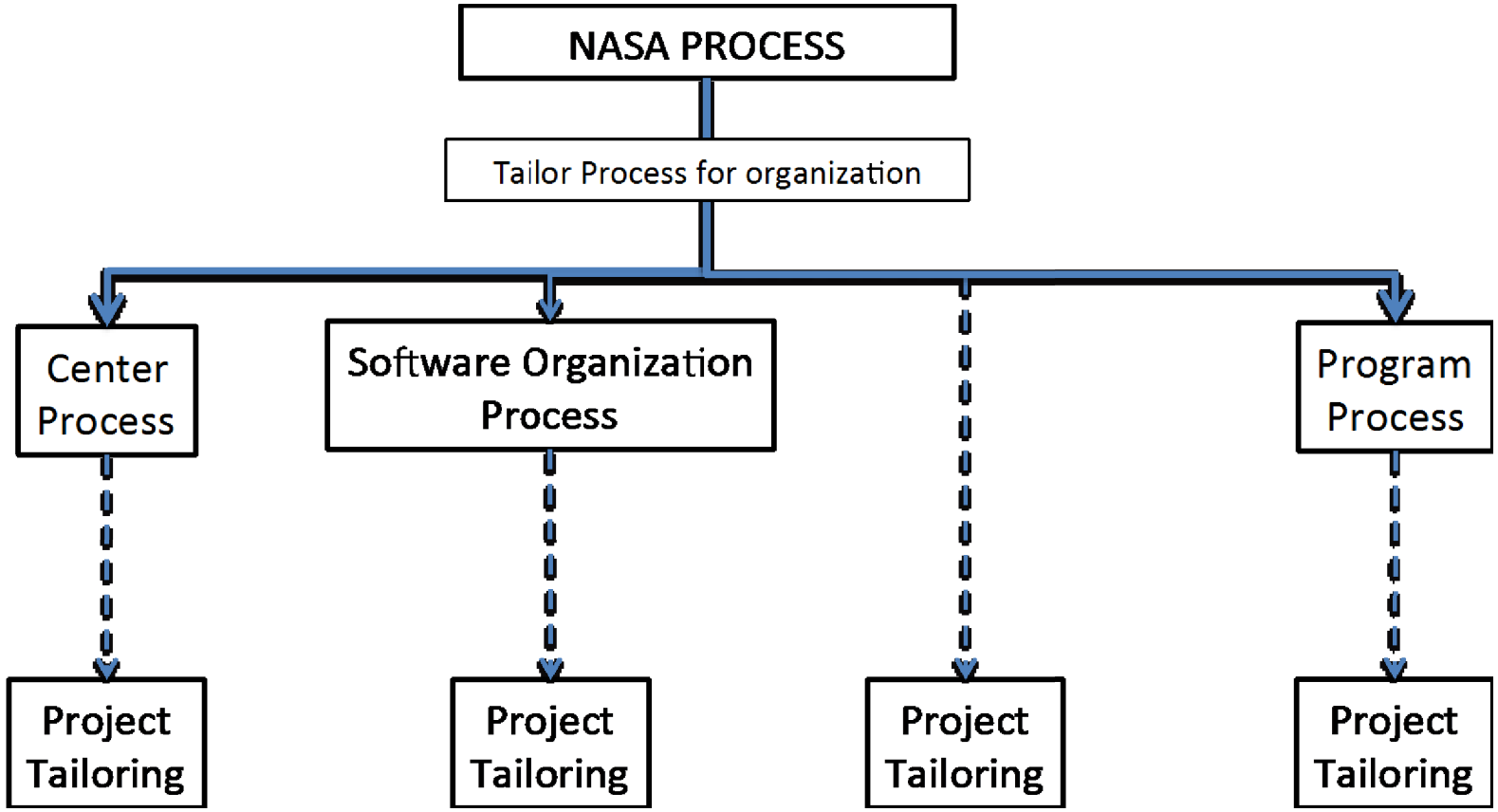
NASA SW Cost Process

Process is designed to be tailored in various ways



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NASA SW Cost Process
Identifies Cost Infrastructure Needs

A. Institutional Pre-Requisite - Establish and maintain a software cost infrastructure

A.1 Develop and maintain a documented estimation process

A.2 Establish tailorable standard software work breakdown structure

A.3 Develop and maintain a historical repository that captures cost and supporting metrics.

A.4 Develop and maintain cost models that are regularly tuned and validated against actuals

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NASA SW Cost Process
Identifies all necessary tasks

ESTIMATION TASKS:

1. Prepare for software cost estimation
2. Produce estimate of software size, effort, and cost
3. Document and configuration manage the estimate
4. Review, negotiate, and maintain the final estimate

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TASK 2: PRODUCE ESTIMATE OF SOFTWARE SIZE, EFFORT, AND COST

2.1 Estimate software size

Estimate the software product size for each WBS element that corresponds to a software subsystem or CSCI. Size is often measured in Source Lines Of Code (SLOC) which is generally a required input for cost models. Other ways to measure size include, counting function points, number of modules, or number of interfaces. For maintenance tasks, size is usually measured in number of change requests or anomaly reports.

Notes:

Required Activity:

- NPR 7150.2A, Section 2.2.3 (SWE-015) requires that the software estimate is based on project attributes. Size is listed as an example project attribute.
- NPR 7150.2A (SWE-102.e) includes software size as a required component of the WBS.

Tailoring Guidance:

- Supports CMMI practices:
  - Establish Estimates of Work Product and Task Attributes (SP 1.2) for Project Planning - Class A and B Software

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TASK 2: PRODUCE ESTIMATE OF SOFTWARE SIZE, EFFORT, AND COST

2.1 Estimate software size

Implementation:

- Cost estimates that explicitly use software size are usually more accurate and defensible.
- The size may be estimated based on the measured sizes for analogous software when they exist.
- For consistency, identify a software code counting tool to use and stick to it. There are many different ways to count lines of code (e.g. logical, physical, "wc -l"). For more information, refer to the SLiC User Guide in the NASA PAL.
- When using a parametric model, the preferred way to size is logical SLOC.
- A key characteristic of software size is how much of the software is a new development, reengineered, or reused.
- Compute the total estimated size and its uncertainty. To handle uncertainty, it is recommended to use "best-case", "most-likely", and "worst-case" values to determine a sizing range.
- Size can be used to generate both top-down and bottom-up estimates.

Work-aids and Resources Notes:

- Source Lines Counter (SLiC) tool (available on the NASA PAL)

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A Good BOE Should Contain …

- Statement of Work and Scope
- High Level product decomposition (If it exists)
- WBS with dictionary (work breakdown structure)
- Planning Parameters or supporting lower level estimates
  - E.g. Software Size Estimates
- Significant Cost and Risk drivers
- Effort Estimates with supporting assumptions and detailed BOE
- Supporting Model Estimates and Analogies
- Schedule
- Procurements
- Acquisition Approach (If applicable)
- Cost estimates
- Risk List/Issues/Known Liens

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What You Can Do for Us

- Contact a member of the NsCIT team
  - if problems have arisen in the past when estimating software cost and what you have seen here does not address them
  - On the rare occasions you estimate software cost for flight or ground in the future and problems arise
  - If you would like a copy of our report or any of our products (Available late September or early October)
- Current Center Contacts
  - Jairus Hihn (JPL) - jhihn@jpl.nasa.gov
  - Lisa Van der Aar (GRC) - lvanderaar@nasa.gov
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What You Can Do for Us

- Last but not least there are 2 recommendations that we will be discussing with you in FY14 (My OCE bosses office is right around the corner from the CAD)
  - Work with the NASA Costing Office to improve NASA Cost Handbook, CADRe, Software Cost Model use and better integrate each others assets and procedures
  - Consider jointly developing a NASA SW Cost Model similar to NICM

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