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Collaborative Requirements Scoring: An Innovative Approach for Sizing Software Projects
  Blaze Smallwood (Booz-Allen)

CADE Vision & Current Initiatives
  Bess Dopkeen (OSD CAPE)

Software Resources Data Reporting (SRDR): Development and Maintenance
  Mr. Richard Mabe (AFCAA)

Government-Wide CDRL: Agile SW Metric Data Collection
  Mr. William Plummer & Mr. Jeremiah Hayden (SPAWAR 1.6)

IT Cloud Services Cost Measures
  Mr. Matt Diacupua (VMWare)

COCOMO II: Workshop Overview
  Dr. Barry Boehm, Mr. Brad Clark

  Nicholas Lanham (NCCA)

TruePlanning Risk & Uncertainty Analysis: Best Practices
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NSA: Using Functional Size and Source Code to estimate ERP and Cloud Based Big Data Analytics
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NRO CAAG Software Development Agility Scale
  Ms. Michelle Jones (Booz-Allen)

Adventures in Collecting, Evaluating, and Analyzing Army System Data to Objectively Estimate Software Maintenance Costs
  Ms. Cheryl Jones (Army ARDEC)

COSYSMO 3: The “Expert” Model
  Mr. Jim Alstad and Dr. Barry Boehm
OVERVIEW

The Naval Center for Cost Analysis and the National Geospatial-Intelligence Agency presents the Software and Information Technology Cost Analysis Solutions Team (Software and IT CAST) meeting from August 22-24, 2016 at the Lockheed Martin Global Vision Center in Crystal City, Virginia. This meeting is organized with the support of US Army ARDEC, Lockheed Martin, and DOD cost agencies.

The Software and IT-CAST meeting is a venue to build coalitions with government and industry, to exchange cost data, share lessons learned, and establish best practices concerning software and information technology cost estimation. Topics of interest include:

- Software cost estimation
- Software schedule estimation
- Information Technology (IT) cost estimation
- Cost Data Collection and Analysis Best Practices
- Functional size measurements
- Early phase software and IT cost estimation
- IT Cost Measures and Benchmarks
- Measurements for agile or other developmental approaches
- Measurements for software maintenance and sustainment
- Measurements for cloud computing services - SaaS, PaaS, IaaS
- Measurements for IT help desk and support
- Measurements for data center and network consolidation

The program includes presentations, workshops, and contractor one-on-one discussions. Presentations and workshops are opened to all attendees. Contractor one-on-one discussions are restricted to federal employees who have registered.

COMMITTEE

Chair:
Wilson Rosa (NCCA)
Vjosa Dreshaj (NGA)

Coordination:
Corey Boone (NCCA)
Corrine Krause (NCCA)

Venue:
Gregory Nieman (Lockheed Martin)

Steering Committee:
Corinne Wallshein (NCCA)
Richard Mabe (AFCAA)
Andrew Murray (NGA)
## Monday, August 22, 2016 – Contractor Discussions (Restricted)

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<th>Presenter(s)</th>
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<tbody>
<tr>
<td>0800 – 0830</td>
<td>Registration</td>
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<tr>
<td>0830 – 1130</td>
<td>Oracle Enterprise One-on-One</td>
<td>Dr. Wilson Rosa (NCCA)</td>
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<td>Mr. Rizwan Jaka (Oracle)</td>
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<td>1130 – 1300</td>
<td>Lunch</td>
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<tr>
<td>1300 – 1445</td>
<td>SAP One-on-One</td>
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<td>Mr. Joe Duffy (SAP)</td>
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<tr>
<td>1445 – 1500</td>
<td>Break</td>
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<tr>
<td>1500 – 1700</td>
<td>General Dynamics One-on-One</td>
<td>Mr. Richard Mabe (AFCAA)</td>
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## Tuesday, August 23, 2016 – General Session (Open to All)

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<tr>
<td>0800 – 0810</td>
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<td>Dr. Wilson Rosa (NCCA)</td>
<td>Auditorium</td>
</tr>
<tr>
<td>0810 – 0840</td>
<td>Keynote Address</td>
<td>Honorable Dr. Jamie M. Morin (DCAPE)</td>
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<tr>
<td>0840 – 0910</td>
<td>Recognizing and Shaping Organizational Culture and Acquisition Strategy towards Optimal ERP Program Cost Profile</td>
<td>Mr. Mike Lennon (SAP)</td>
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<tr>
<td>0940 – 0950</td>
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<tr>
<td>0950 – 1020</td>
<td>Cost Assessment Data Enterprise (CADE) Initiatives</td>
<td>Ms. Bess Dopkeen (OSD CAPE)</td>
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<tr>
<td>1020 – 1050</td>
<td>Software Resource Data Reports: Development and Maintenance</td>
<td>Mr. Richard Mabe (AFCAA)</td>
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<tr>
<td>1050 – 1120</td>
<td>Government-Wide CDRL: Agile Software Metric Data Collection</td>
<td>Mr. William Plummer and Mr. Jeremiah Hayden (SPAWAR 1.6), Mr. Omar Mahmoud (Cask)</td>
<td>Auditorium</td>
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<tr>
<td>1120 – 1150</td>
<td>IT Cloud Services Cost Measures</td>
<td>Mr. Chris Harrell, Mr. Justin Snyder (VMware)</td>
<td>Auditorium</td>
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<tr>
<td>1150 – 1200</td>
<td>COCOMO III Workshop Overview</td>
<td>Dr. Barry Boehm and Dr. Brad Clark (USC)</td>
<td>Auditorium</td>
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<tr>
<td>1200 – 1300</td>
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<tr>
<td>1300 – 1630</td>
<td>COCOMO III Workshop</td>
<td>Dr. Barry Boehm and Dr. Brad Clark (USC)</td>
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</table>
# Software and IT-CAST Agenda

**22-24 August 2016**  
**Lockheed Martin Global Vision Center**  
2121 Crystal Drive  
Arlington, VA 22202

## 1300 – 1450  
**VMware One-on-One**  
Ms. Vjosa Dreshaj (NGA)  
Dr. Carol Traynor (VMware)  
Auditorium

## 1450 – 1500  
**Break**

## 1500 – 1650  
**Microsoft One-On-One**  
Ms. Haset Gebre-Mariam (NCCA)  
Mr. Robert Miller (Microsoft)  
Auditorium

### Wednesday, August 24, 2016 – General Session (Open to All)

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<th>Time</th>
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<tbody>
<tr>
<td>0800 – 0830</td>
<td>Networking</td>
<td>Ms. Jennifer Rose (NGA)</td>
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<td>0830 – 0840</td>
<td>Opening Remarks</td>
<td>Dr. Troy E. Meink (ODNI SRA)</td>
<td>Auditorium</td>
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<tr>
<td>0840 – 0910</td>
<td>Keynote Address</td>
<td>Mr. Nick Lanham, Dr. Corinne Wallshein (NCCA)</td>
<td>Auditorium</td>
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<tr>
<td>0910 – 0940</td>
<td>Exploring DoD Software Growth by Contract Type and CMMI Level</td>
<td>Ms. Arlene Minkiewicz (PRICE Systems)</td>
<td>Auditorium</td>
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<tr>
<td>1010 – 1020</td>
<td>Break</td>
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<td>Mr. David Seaver (NSA)</td>
<td>Auditorium</td>
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<tr>
<td>1050 – 1120</td>
<td>NRO CAAG Agile Software Development Practices</td>
<td>Ms. Michelle Jones (Booz-Allen)</td>
<td>Auditorium</td>
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<tr>
<td>1120 – 1150</td>
<td>Software Maintenance Cost Estimation</td>
<td>Ms. Cheryl Jones (Army ARDEC)</td>
<td>Auditorium</td>
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<td>COSYSMO 3 Workshop Overview</td>
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<tr>
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<td>Northrop Grumman Aerospace Systems One-on-One</td>
<td>Mr. Richard Mabe (AFCAA)</td>
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<td></td>
<td>Mr. Steve Huniu (Northrop Grumman)</td>
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<tr>
<td>1545 – 1600</td>
<td>Break</td>
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<tr>
<td>1600 – 1715</td>
<td>Lockheed Martin One-on-One</td>
<td>Dr. Wilson Rosa (NCCA)</td>
<td>Auditorium</td>
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<td>Mr. George Barbic (Lockheed Martin)</td>
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</table>
Opening Remarks and Keynote

Dr. Jamie M. Morin

Director

Office of the Secretary of Defense/Cost Assessment and Program Evaluation

Jamie Morin was confirmed by the Senate as the second Director of Cost Assessment and Program Evaluation for the Department of Defense on June 25, 2014. As director, he leads an organization responsible for analyzing and evaluating the Department’s plans, programs, and budgets in relation to U.S. defense objectives, projected threats, allied contributions, estimated costs, and resource constraints. The CAPE organization continues the heritage of the Systems Analysis office created by Secretary Robert McNamara and later renamed as Program Analysis and Evaluation. To support better defense decision making, CAPE develops analytical tools and methods for analyzing national security planning and the allocation of resources. The CAPE role in ensuring that the costs of defense programs are properly estimated and presented accurately was enhanced by the Weapons Systems Acquisition Reform Act of 2009.

Prior to joining CAPE, Morin served for five years as the Assistant Secretary of the Air Force for Financial Management and Comptroller. As the Air Force's chief financial officer, he was the principal advisor to the Secretary and Chief of Staff of the Air Force on financial matters, responsible for the financial and analytical services necessary for the effective and efficient use of Air Force resources. This included directing the development of the Air Force budget, overseeing the Air Force Cost Analysis Agency and conducting Air Force accounting and finance operations.

From July 3, 2012 until April 29, 2013, he was appointed by the President as Acting Under Secretary of the Air Force, during which time he served as the service’s chief management officer, senior energy official, chair of the Air Force Space Board, and acting Secretary of the Air Force during absences of the Secretary.

From 2003 until 2009, Morin was a member of the professional staff of the U.S. Senate Committee on the Budget, serving as the committee’s lead analyst for the defense, intelligence, and foreign affairs budgets, responsible for drafting relevant sections of the congressional budget resolution and advising the Senate on enforcement of budget rules.

Earlier in his career, Morin served in the Office of the Under Secretary of Defense for Policy and as an economic development strategist with the firm J.E. Austin Associates. His academic research focused on U.S. national security policy, particularly the role of Congress in defense budgeting and policy making. He held fellowships at the University of Virginia’s Miller Center for Public Affairs and at the Center for Strategic and Budgetary Assessments, where he conducted research for the Pentagon’s Office of Net Assessment. He also served as a policy advisor on President Obama’s defense transition team.
Dr. Troy E. Meink

Assistant Director

National Intelligence for Systems and Resource Analyses (ADNI/SRA)

Prior to his ODNI appointment, Dr. Meink was the Deputy Under Secretary of the Air Force for Space and the Director, Executive Agent for Space Staff, Washington, D.C. He provided the principal support to the Under Secretary's role as the Headquarters U.S. Air Force focal point for space matters and in coordinating activities across the Air Force space enterprise.

Dr. Meink is from Lemmon, S.D., and entered the Air Force in 1988 through the ROTC program at South Dakota State University. His assignments have included operations and training, systems engineering, research and development, and program management of major defense acquisition programs. Dr. Meink began his career as an Air Force Navigator and then a lead test engineer for the design and evaluation of ballistic missile test vehicles for the Missile Defense Agency resulting in two successful launch campaigns. As a rated officer, he completed 100 sorties including eight combat and 29 combat support missions in support of operations Desert Shield, Desert Storm, and Provide Comfort.

As an Air Force civilian, Dr. Meink managed multiple next generation joint research and development programs transitioning global space capabilities, optical sensors, and advanced structures into DoD operations. He subsequently led multiple communications organizations within the Air Force and the Office of the Assistant Secretary of Defense, Networks and Information Integration. Prior to his assignment as the Deputy Under Secretary of the Air Force for Space and the Director, Executive Agent for Space Staff, he was the Director, Signals Intelligence Systems Acquisition at National Reconnaissance Office.

Dr. Meink has authored 20 articles in professional journals and conference publications, has been awarded three patents, and designed, built, and flown two experimental aircraft.
IT CAST Conference

Systems and Resource Analyses
Independent Cost Estimates By Type

ODNI is performing ICEs on an increasing number of IT and Software programs
IT and SW programs are a focus area to collect more data and improve our estimating capabilities

ICE Deltas: All versus IT/SW/Other

ICE Average = 3.8%
ICE Std. Dev. = 15.5%

IT/SW Average = -5.9%
IT/SW Std. Dev. = 17.4%

ICE Average = 5.9%
ICE Std. Dev. = 14.0%

IT/SW Average = -10.6%
IT/SW Std. Dev. = 17.7%
Code Baselines for IC Programs and Other Software

Key
- = Variety of Software
= IC Program Actuals
= Recent ICES

Design and Development Cost Comparison

<table>
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<th>Cost (16$M)</th>
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<tr>
<td>ANGRY BIRDS</td>
<td>$0.1</td>
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<tr>
<td>ENTER THE MATRIX</td>
<td>$25.5</td>
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<tr>
<td>THIS IS VEGAS</td>
<td>$49.6</td>
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<tr>
<td>FINAL FANTASY IX</td>
<td>$52.8</td>
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<tr>
<td>RIFT</td>
<td>$53.7</td>
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<tr>
<td>L.A. NOIRE</td>
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<tr>
<td>CALL OF DUTY: MODERN WARFARE 2</td>
<td>$55.2</td>
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<tr>
<td>HALO: REACH</td>
<td>$60.2</td>
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<tr>
<td>FINAL FANTASY VII</td>
<td>$61.1</td>
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<td>FINAL FANTASY XII</td>
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<tr>
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<td>EXTIMATE X</td>
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<td>STAR CITIZEN</td>
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<td>ESTIMATE Y</td>
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<td>GRAND THEFT AUTO V</td>
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<td>DESTINY</td>
<td>$143.2</td>
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<tr>
<td>STAR WARS: THE OLD REPUBLIC</td>
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Key:
- **Blue** = Video Games
- **Orange** = Recent IC Estimates

Multiple sources; available upon request
Final Thoughts

- We understand space systems costs very well
- We need the same understanding for software & IT
- Increased data collection and sharing is critical!

The IT CAST forum is a great opportunity to discuss IT and software issues, exchange best practices, and create ideas to drive innovative IT and software analyses.
Recognizing and Shaping Organizational Culture and Acquisition Strategies toward an Optimal ERP Program Cost Profile

An SAP Perspective
Agenda / Story Flow

Benefits of an Educated Workforce
1. What do we spend on?
2. “Things that are inherently governmental”
3. Best Practices for ERP Implementations

Beginning with the End in Mind
4. Plan and Execute Iteratively
5. Align Acquisition Strategy to Support Overall Plan
6. The Role of the Software Provider

What about the Cloud?
7. Why the Cloud?
8. Aligning the Dream of Cloud with the Realities of DoD
Federal IT Spend Software and IT Services

2016 Spend By Market and Federal Segment ($M)

- Fed Civilian: 61.7 (Structured Data), 285.9 (Supply Chain), 448.4 (CRM), 187.8 (Operations and Manufacturing), 568.1 (Data Access, Analysis, and Delivery), 152.0 (ERM), 371.5 (IT Services)
- A&D: 59.3 (Structured Data), 193.5 (Supply Chain), 440.9 (CRM), 425.1 (Operations and Manufacturing), 126.1 (Data Access, Analysis, and Delivery), 525.1 (ERM), 212.7 (IT Services)
- US DoD: 63.6 (Structured Data), 58.6 (Supply Chain), 371.5 (CRM), 152.0 (Operations and Manufacturing), 525.1 (Data Access, Analysis, and Delivery), 63.6 (ERM), 212.7 (IT Services)

“Per Employee” IT Spending is four times the industry average”
- IDC August 17, 2016

Source: IDC April 2016
Most government agencies have a desire to invest in commercial-off-the-shelf (COTS) software

Most find that they need to customize their solutions anyway
- Connections to legacy systems
- Workflow management
- Application compatibilities

CAD excludes customization of COTS
- Additional large opportunity for customization of COTS which is significant in Federal

Standardization across agencies (and states) is having an impact on COTS for gov solutions. They are getting better

Template based solutions allow more flexibility, and customization sometimes can be handled via configuration settings vs. full custom coding

Government has a need for quick customization because of changing laws, reporting requirements, etc.

Source: IDC April 2016
"An educated consumer is our best customer" – Sy Syms, Syms Corp.
Forrester states the following:
“...in a situation where a large enterprise licenses and implements a single vendor solution consisting of an ERP package supplemented by one or more functional suites...If one of the functional suites is bought from a third party, the ... costs will be significantly higher. The most significant cost difference will be the integration cost, which can be little or nothing when a suite is purchased, but can be substantial when a third party tool must be integrated.”
Best Practices for ERP Implementations

Adoption of Best Practices Varies at Each Stage

Over 100 organizations took the survey. The study found that those that had a high maturity:

- Obtained 40% more value of their expected IT project value
- Had 64% lower project duration delays
- Had 71% lower project overruns
Plan and Execute Iteratively

Roadmap –alignment with PoM

Waterfall vs. “Agile” Methodology

Phasing/’flow’ of personnel during lifecycle

Jump-start project with pre-assembled solution

Prototype, Build and Run solution leveraging Support Centers

Identify and validate delta requirements and gaps

Build customer solution in short, time-boxed sprints

If I have 8 hrs to chop down a tree, I’d spend 6 sharpening my axe
Align Acquisition Strategy to Support Overall Plan

Preplanned Product Improvement (P³I)

Current Approach

Recommended Approach

Increment-1

Increment-2

Increment-3

Procurement

Research

Operations & Maintenance
The Role of the Software Provider

- “Directional guidance” i.e. HANA/Cloud
- Access to the company/partners/providers and ‘birds of a feather’
- Events like Sapphire and TechEd
- Functional/Technical Architecture Services
- Share Industry Best Practices and Insight
- User Forums like DEIG and/or ASUG
- Help with Product Capabilities, and Implementation Best Practices
SAP Digital Strategy

Characteristics of the Digital Transformation journey

1. **Customers and employees** are hyper-connected, always on, with **seamless access anywhere and anytime**

2. **Cloud and hybrid cloud environments** have become the norm challenging traditional “protect the 4 walls” security approaches

3. **Digitally connected supply chains** are based on high trust and availability of all parties

4. The Internet of Things and Big Data bring **unprecedented data streams and volumes**

5. **Confidentiality, integrity and availability** of data is the basis for secure operations and trusted relationships
Public Cloud in Federal is a small portion of the software market in 2016 but fast growing at 22% CAGR

Source: IDC
About 8.5% of all federal IT spend is for “cloud” as termed by the government

About 8.5% of the federal government’s IT spending, or $6.7 billion, in fiscal 2016 will go to cloud technologies – a marked increase from the 5% of IT spending that the government put toward cloud in fiscal 2015.

A further blurring of “cloud” may happen as more agencies obtain servers for their data centers which are remotely managed and updated by cloud providers, effectively blurring the lines between what is hosted and what is pure cloud.

US Federal Government classifies some types of shared services as “cloud” though it does not meet IDC’s cloud definition. Such shared services could be private cloud for SaaS, PaaS or IaaS.

Greater opportunity for IaaS vs SaaS in Federal due to overall lack of off the shelf packaged apps.

“Shared Services Cloud” adds about 5 percentage points to Software Public Cloud proportions, which are ~7-8% share.

Clearly, lower price points for cloud services and the changing nature of cloud are helping to drive federal cloud consumption into new directions, resulting in substantial growth in some consumption patterns.

Source: IDC
Why Organizations are Investing in the Cloud?

**Cost and Consolidation**
Bottleneck in adapting to changes in business needs and requirements

**Improve Time of Delivery to Production**
An ever increasing need for faster time to value while simplifying the IT landscape

**Improve Project Success Rates**
Pressure on IT and Business to reduce costs while still achieving business goals

**Difficult Provisioning Innovation**
Long lead times required for innovation

Pressure to ensure secure resources protecting your information
Cloud Adoption – Strategy for Success

Application

Information

Infrastructure

Managed Services

Updates

Deployments

Security

Innovation

Support

Benefits of an Educated Workforce

Beginning with the End in Mind

What about Cloud?
Recommended Reading

2. Every Dollar Counts – Memorandum dated April 15, 2016 – Secretary of the Army, Washington, DC.
3. ASUG Implementation Services – Best Practices Survey- 2011
4. Article on ASC.ARMY.MIL COL Harry Culclasure, AESIP project manager and Mr. Thomas Neff (CHESS project leader). Topic: Acquisition strategy of six Army programs selecting a single enterprise resource planning solution…. (URL: http://asc.army.mil/web/news-better-to-best/)
6. “Per Employee” IT Spending: Federal Government is Nearly Four Times the Industry Average”, IDC August 17, 2016

Please write to Mr. Mike Lennon (Mike.Lennon@sap.com) if you want to receive electronic copies of documents per #1-3 above
Collaborative Requirements Scoring: An Innovative Approach for Sizing Software Projects

Blaze Smallwood
Software and IT-CAST 2016
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- Problem Description

- Collaborative Requirements Scoring Process
  - Identify Appropriate Requirements to Size
  - Plan/Structure Scoring Session
  - Execute Scoring Session
  - Estimate Using the Results

- Benefits and Challenges

- Summary
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  - Benefits and Challenges
  - Summary
Existing software cost estimating techniques present various challenges, particularly when applying to modern systems with limited analogs and custom application requirements

- Estimating size using physical/functional measures is often non-intuitive to program engineers, particularly when estimating newer, lower-level requirements.

- Accounting for non/cross-functional and/or derived requirements can be challenging.

- Explaining to PMs how estimates are derived based on physical/functional sizing can be difficult.

- Estimates are typically difficult to break out at lower levels of detail, hindering trade space analysis.

- When estimates are wrong, hard to diagnose why.

*Traditional methods work well for many programs, but not all; some could use an alternative approach based on current software practices*
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- Summary
Identifying appropriate requirements source and level of detail is essential to any sizing estimate

- Foundation would be functional/architectural requirements in program requirements document (e.g. Capability Definition Document (CDD) or Requirements Definition Package (RDP))
  - If non-functional/cross-functional requirements (architectural, usability, reliability, etc) are not captured in requirements document, they can be identified and estimated during the sizing process

- Requirements from CDDs or RDPs are often captured in a Requirements Traceability Matrix (RTM)

- Ideally, RTM would be used to map functional requirements to components in the intended architecture
  - Much more intuitive for SW engineers to estimate building components in an architecture
Best Practices for Requirements Identification

- Get agreement from estimate stakeholders (program manager, cost analyst, engineers) what requirements will be estimated and at what level
  - Need to identify the level of detail in requirements that fit time allocated to sizing and the appropriate units of measure (points, person-days, person-months)

- If documented requirements are all functional, work with engineers to identify non/cross-functional requirements/constraints before estimating session

- Identify trade space requirements up-front to inform later CAIV analysis

- Get Excel formats of requirements lists or matrices to help in building estimating template
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Scoring sessions require upfront planning and coordination to be successful

- Identifying appropriate participants is key
  - “Scorers”: Software engineering SMEs that will be providing estimates
    - A panel of four or five is ideal; minimum of three
    - Should be a mix of SMEs; at least a couple with experience in systems similar to the one being estimated, but independent SMEs add value, as well
  - Facilitator(s): Person who runs the meeting, records scores and assumptions, facilitates discussions, takes care of admin items
    - Ideally, two people – can be a lot for one person to handle
  - Other support SMEs: People knowledgeable about the program that can help scorers better understand requirements and constraints
    - Requirements analysts, test engineers, cyber experts, past users of similar system

- Coordinate schedules for participants and facilities early
Developing scoring materials and thinking through scoring process in advance will help the actual session go more smoothly.

- Develop scoring template based on requirements to be estimated.

<table>
<thead>
<tr>
<th>Req #</th>
<th>Req. Description</th>
<th>Exp.</th>
<th>Low</th>
<th>High</th>
<th>Exp.</th>
<th>Low</th>
<th>High</th>
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<th>Low</th>
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</table>

- Coordinate systems or materials needed to conduct scoring; session requires scorers to provide estimates anonymously and simultaneously:
  - Decision analysis system, like Expert Choice
  - Agile Planning Poker app
  - Real-time collaboration tools, like Google Docs or Real Time Board
  - Screen sharing, like WebEx or Defense Collaboration Services (DCS)
  - White boards
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- Benefits and Challenges

- Summary
Scoring process helps objectify subjective inputs and documents assumptions for each estimate

**Process Highlights**

- Employs disciplined Delphi method with participation from software SMEs (“Scorers”) and key PMO SMEs
  - Like Agile “Planning Poker”, scorers simultaneously provide estimates to avoid influencing each other
  - Estimates capture developer effort (i.e. coding effort), in person-months or days; can also use points
    - Other development effort (SEPM, QA, CM, etc) is accounted for separately using factors or LOE estimates
- All scorers provide low, expected, and high estimates to inform uncertainty analysis
Best Practices for Executing Scoring Session

- Baseline all participants upfront on ground rules and assumptions
  - Ensure everyone is operating off of the same overarching technical assumptions
  - Agree on the scope of estimates to be provided; typically, developer effort from design to code unit test
  - Discussion before scores should be limited to technical assumptions only
    - No value statements -> “This is easy, should be minimal effort”
  - Second round is needed when one or more outlier scores

- Ensure everyone is clear on time constraints to stay on schedule
  - Calculate benchmark requirements to measure progress against time plan

- Capture all assumptions for each requirement in scoring spreadsheet; capture any other thoughts on white boards or smartboards & take pictures

- Use white board to capture “parking lot” items; could inform additional items to score, like cross-functional or derived requirements
Outputs of a successful scoring session

- Fully populated scoring template with all scores and documentation comments

<table>
<thead>
<tr>
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<td>5</td>
<td>10</td>
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<tr>
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<td>The system shall enable the user to ...</td>
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<td>4</td>
<td>8</td>
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<tr>
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<td>The system shall enable the user to ...</td>
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<td>3</td>
<td>5</td>
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<tr>
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<td>The system shall enable the user to ...</td>
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<td>5</td>
<td>9</td>
</tr>
<tr>
<td>1.2.3</td>
<td>The system shall enable the user to ...</td>
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<td>1</td>
<td>3</td>
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<tr>
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<td>2</td>
<td>4</td>
</tr>
<tr>
<td>2.1.3</td>
<td>The system shall enable the user to ...</td>
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<td>2</td>
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</tr>
<tr>
<td>2.2.1</td>
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<td>3</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>2.3.1</td>
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<tr>
<td>XXX</td>
<td>The system shall enable the user to ...</td>
<td>9</td>
<td>6</td>
<td>12</td>
</tr>
</tbody>
</table>

- Additional information captured in the room during the session, such as sketches or assumptions on a white board or smart board captures
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- Summary
Other costs must be added to the scoring outputs to derive full software development cost estimate

**Software Development Costs**

**Implementation (Coding) Costs**
- **Scoring effort** (Implement capabilities: Design -> Unit Test)
- **Non-capability development effort** (Defects, HSI, etc.)

**Development Support (Non-Coding) Costs**
- PM, QA, CM, System-Level IAT, Documentation/CDRLs, etc.

- Estimated based on scoring session outputs; provides foundation for the rest of the SW development estimate
- ~25-50% of scoring effort
- ~80% of implementation costs
- Can be estimated using a factor like this or using a LOE build-up
Ranges provided during scoring analysis provide solid inputs for robust uncertainty analysis

- Ranges provided by multiple scorers provide many possibilities for uncertainty bounds
  - Average of Expected
  - Min of Low, Max of High
  - Average of High as Expected

- Uncertainty can be applied at whatever level in requirements desired
Uncertainty adjusted developer estimates can be used to build up total estimate using multiple methodologies

- Variable schedule/CAIV driven methodology based on annual budget constraints
  - Annual budget determines team size and number of developers
  - # of developers coupled with scoring session effort estimates determine total estimated schedule
  - Non-coding effort can be added along that schedule using factors or LOE

- Fixed schedule driven methodology based on schedule constraints
  - Targeted schedule determines how developer effort gets spread and required # of developers
  - Non-coding effort can be added using factors or LOE
  - Requires sanity check on required development team size for reasonableness
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Utilizing this process to estimate size of a software project has various benefits and a few challenges

**Benefits**

- More intuitive scope sizing methodology
- Sizing explicitly relates complexity to effort
- Systematic scoring process
- Scoring ranges inform robust uncertainty
- Allows for trade-off analysis at requirement level

**Challenges**

- Subjective sizing inputs; limited analogous data
- New type of cost model required
- Sizable effort/coordination to run scoring session

*For many projects, the benefits outweigh the challenges, and challenges can be mitigated*

\[
PM = A \times \text{Size}^E \times \prod_{i=1}^{n} EM_i
\]
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- Problem Description

- Proposed Process to Baseline an Agile Project
  - Define and Prioritize Scope
  - Derive Baseline Project Cost/Schedule based on Scope Definition and Annual Budget Assumptions
  - Conduct Uncertainty Analysis
  - Revisit Assumptions to Finalize Cost/Schedule Baseline
  - Solidify Release Plan based on Schedule Baseline / Scope Definition
  - Track/Manage Progress

- Benefits and Challenges

- Summary
Collaborative requirements estimating is a viable new methodology for informing cost estimates for software projects

- While traditional methodologies are still viable for various types of software projects, this new methodology is viable for newer projects with limited analogs and new requirements
  - Scoring methodology is intuitive to software engineers and aligns with how software teams estimate, plan, and execute work
  - Disciplined scoring process attempts to add objectivity and documentation to subjective inputs
  - Scoring ranges enable detailed uncertainty analysis
  - Estimates at low requirement levels enable detailed scope trade-off analysis
  - Easy to explain to decision makers and diagnose estimating error
Questions?
For further information . . .

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Associate

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Mobile 619.850.6123
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CADE Objectives/KPPs

Provide decision makers with relevant, high quality, timely and actionable analyses for better acquisition strategies and execution

- Move from reactive to proactive
- Insight equates to trust and facilitates faster and more knowledgeable decision making
- Facilitate telling the program’s “story”, holistic analysis

Improve Analyst Productivity (at all levels: OSD, Services, PMOs)

- Increase output per unit time, without degrading confidence in results
- Provide near real-time access to data, more data, and less burden on the analyst to retrieve and process
- Reduce time for analyst to climb the program familiarization learning curve

Comprehensiveness

- Having all DoD’s relevant data at analysts’ fingertips for comprehensive assessments, regardless of analysis type

Community Knowledge Sharing

- Gain insight from previous and fellow analysts and data stakeholders

Quality and Transparency of Source Data

- Where it comes from, what we know about it – consistency
- Enterprise data stewardship – Enterprise agreement and accountability for what data means and how it’s used
- Reporting Compliance Improvement

Properly Secured
Comprehensiveness and Our Vision

Comprehensive Data Availability:
All information at the analyst’s fingertips – centralized virtual library with everything in it

- **Cost Data (CCDRs/1921s)**: Contains all an analyst needs to build an estimate
  - **FlexFiles**: New generation of cost data collection
- **Cost Analysis Requirements Description (CARD) / Technical Data ("1921-T")**: Programmatic and technical descriptions analysts need to build estimates
- **Software Resource Data Report (SRDR)**: Software effort, size, and schedule estimating approaches including analogy, parametric and commercial models
- **Institutional Knowledge**: What analysts need to know about the data
- **Policy Improvements**
- **Community Support**

Our Vision for CADE:
Cost analysts will have all of this data and institutional knowledge at their fingertips. It will be the exception – not the rule – to go back to industry to do our estimates
CADE Coalition:
The Cost Community, AT&L & Industry

Cost
FlexFile: Daron Fullwood, CAPE
CSDR/EVM Co-Plan, WBS Alignment: John McGregor, AT&L PARCA/EVM
1921-3: Mike Biver and Carol Moore, CAPE
Sustainment: Tom Henry, CAPE; Lisa Mably, AFCAA

Technical
SRDR: Ranae Woods, AFCAA
CARD: Curt Khol, CAPE
Tech Data WG: Greg Hogan, AFCAA
MAIS WG: Richard Mabe, AFCAA

Commodity Study Joint Effort
Aircraft, UAV  Missiles  Radar, C2 Center, C4I  ICBM  O&S  Ships  Space  WTV  MAIS

Office Collaboration
Army
JIAI, ACDB/WTV prototype, WTV CIPT, TACOM, Historical Data Migration

MDA
MDA-DCARC alignment, CCRG

AT&L
EVM-CR, CSDR/EVM Co-Plans, DAVE (DAMIR, AIR, Kaleidoscope) DDR&E/SE tech data; Big Data initiative, LM&R CARD input, DCMA, DPAP, DAU

Industry
CSDR Focus Group, Joint Training, NDIA, FlexFile Pilot Leads: LMCO, Boeing, NGC, BAE, GDLS, HII, Ball Aerospace CIPTs: Aviation, JSCC, O&S, Software and IT, WTV

Service Cost Agency Leads
DASA-CE
David Henningsen
Sean Vessey

NCCA
Duncan Thomas
John Fitch

AFCAA
Ranae Woods
Greg Hogan
FlexFiles
The Future of Cost Analysis
FlexFiles: Objectives
A Win-Win Government and Industry Partnership

Today’s Shortcomings

CCDR Data
• Time consuming to industry
• No details below the CCDR functional labor categories
• Allocations are not transparent
• Limited Data sampling over time
• Allows for human error

Ad-Hoc Data Calls
• Time consuming to industry
• Requires burdensome site visits
• Limited Access to Data
• Allows for human error

The FlexFile Solution

Increase Efficiency:
• Collect data according to the contractor’s management structure
• Removal of legacy 1921 forms
• Reduce ad hoc/supplemental government data collection efforts
• Much easier and less time consuming for Industry – allows them to reduce back end support
• Automation: data flows directly from contractor systems into ours

Improving Data Quality:
• Eliminate Human Error/Subjectivity
• Collect raw data, and use technology to eliminate arbitrary allocations and errors
• Consistent application of Mil-STD-881C to both EV and CSDR data – data Alignment
• Review and mapping pre-contract award

Ensure Completeness:
• Provides much more insight and analysis flexibility
• Annual submissions
• Receive data over time
• Include cost and supporting technical data
History of the FlexFile Effort

Traditional CCDR data collection. Evolving from handwritten documents to XML submissions.

1966

Jun. 2014 – LM Space and Aero discussion with cost community FlexFile beginning

2014

Dec. 2014 – LM Prototype discussion (F-35, PAC-3, SBIRs)

2015

Apr. 2015 – BAE site visit and FlexFile initial discussion (PIM)

Jul. 2015 – BAE, GDLS FlexFile discussion

Oct. 2015 – SMC FlexFile discussion/Boeing FlexFile Pilot initiation (WGS)

Jan. 2016 – LM Space FlexFile follow-up discussion

Feb. 2016 – LM visit on the FlexFile (recreating the 1921 series)

Apr. 2016 – BAE FlexFile Pilot initiation (Bradley ECP)

Oct. 2015 – CADE Focus Group

Nov. 2015 – BAE FlexFile Pilot initiation (Bradley ECP)


Jun. 2014 – CADE Focus Group and FlexFile Kickoff


Aug. 2015 – First Draft of the FlexFile DID completed

Jun. 2015 – Boeing Defense FlexFile brief to CFO and Head of Space System

Aug. 2015 – CADE Focus Group

Feb. 2016 – 2nd FlexFile DID Draft completed

Jan. 2015 – EV community involvement w/ the FlexFile

Apr. 2015 – CADE Focus Group w/ LM presenting FlexFile implementation

Apr. 2016 – BAE FlexFile follow-up

Oct. 2015 – CADE Focus Group

May 2016 – GDLS Lima, OH site visit

Apr. 2016 – LM Space FlexFile follow-up discussion

May 2016 – 3rd FlexFile DID Draft completed

Jun. 2016 – Huntington Ingalls FlexFile Review

May 2016 – CADE Focus Group

May 2016 – F-35 Cost Summit /FlexFile discussion (FlexFile on Contract)

May 2016 – Huntington Ingalls FlexFile Review


Jun. 2014 – CADE Focus Group


Aug. 2015 – First Draft of the FlexFile DID completed

Jun. 2015 – Boeing Defense FlexFile brief to CFO and Head of Space System

Aug. 2015 – CADE Focus Group

Feb. 2016 – 2nd FlexFile DID Draft completed

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May 2016 – 3rd FlexFile DID Draft completed

Jun. 2016 – Huntington Ingalls FlexFile Review

May 2016 – Huntington Ingalls FlexFile follow-up discussion

National Defense Industrial Association
1/2014, 8/2015

Joint Space Cost Council

Aviation CIPT

SMC CIPT
6/2016

Wheeled and Tracked Vehicle IPT
7/2015, 5/2016

SW & IT CIPT
8/2016

8
1921, 1921-1 formatted CCDRs today require an average of 533 hours per contract, assuming set-up and 4 reports. This is how we have collected contractor cost data for nearly 50 years.

Efficiencies Realized from the FlexFile:
- Contractor A:
  - Complex program requiring post-extraction allocations
  - FlexFiles covers 1921 & 1921-1
  - Provided enough detail to replace 1921-2

- Contractor B:
  - Did not require post-extraction allocations
  - Provided manufacturing floor hours report
  - Had automated CCDR reporting with scripts

Today's Burdensome CCDR Process:
- Estimated Resources for Preparing Contractor Cost Data Reports:
  - Mean Time (w/o 1921-2)
  - Median Time (w/o 1921-2)
FlexFile Draft DID (May/August 2016)

A. WBS Dictionary & Remarks
- WBS Index
- Definitions by WBS
- Cost Content
- Work Content
- Supplier & GFE elements
- Contractor Remarks, Comments by WBS Element
- Direct-Reporting Subs

B. Metadata
- Program Name
- Contract #
- Approved Co-Plan #
- Contractor Name, Location, POC
- As of Date
- Submission Event Name
- Phase
- Report Type

C. Contractor Cost Data Report
- Unallocated Actual Costs & Hours
- WBS, Control Account, Work Package Data by Month
- CLIN & Lot
- Functional Rate (Gov & Internal)

D. Contractor Cost Data Field Dictionary
- Contractor Internal Accounting Data Field Descriptions

E. Allocation Methodology
- Contractor’s Distribution of Unallocated Actual Costs
- Unit/Lot Level Allocation

As required by Co-Plan

F. Estimates at Completion
- Estimates at Complete (EAC) by WBS Element (as required by Co-Plan)

G. Supplemental Information
- MRP Floor Hours Report
CRAWL

June 2016 – December 2016

- Tailored FlexFile DID
- XLS FlexFile submission
- Recreate 1921, -1; Consistent w/-2

Immediate change that can easily be executed

WALK

January 2017 – June 2017

- Approved FlexFile DID
- Define FlexFile XML schema

Near-term change that can be executed once processes are streamlined

RUN

July 2017 - Future

- XML FlexFile submission
- 1921-T submission

Long-term change executed by a mature organization
March 18, 2016: CAPE & PARCA signed CSDR/EVM Co-Plan Pilot Memo

MEMORANDUM FOR: SEE DISTRIBUTION

REFERENCE: Contractor Cost and Software Data Reporting (CSDR) and Earned Value Management (EVM) Co-Plan

As required by Tables 7 and 8 of DoD Instruction 5000.02, “Operation of the Defense Acquisition System,” CSDR and EVM reports must be submitted for a variety of contracts issued by the Department. In order to increase efficiency, improve data quality, and foster efficient and consistent cost reporting, the Office of the Secretary of Defense, Cost Assessment and Program Evaluation (CAPE), and Office of the Secretary of Defense, Technology and Logistics (AT&L) Performance Assessment (PARCA) organizations are proposing a CSDR/EVM Co-Plan for reporting. All contracts requiring CSDR and EVM reporting must use the CSDR/EVM Co-Plan (using Directives Division (DD) Form 1140) for cost planning.
Standard Co-Planning Benefits

**STANDARD CO-PLAN**

- One Voice, One Direction
- Integrated Post Award Meeting
- Support needs of both Cost & EV communities
- Less allocations caused by CCDR and CPR misalignment
- Aligned with SRDR, Tech data & IPMR goals

**Work Products:**

- Standard CSDR Plans for each commodity area
  - Rooted in analytical requirements
  - Based on assessment of contemporary plans

- Extensions to 881C appendices
  - Added detailed child elements to give granularity into high-interest topics
  - Removed extraneous elements; clarified content or improved their location

- Implemented as starting point for DCARC and PARCA CSDR/EVM Co-Planning
  - Better communication of expectations to Industry
  - Serve as a starting point for a new program CWIPT’s initial plan
  - Serve as a reporting ideal for on-going program’s tailoring of new contract plans
CSDR/EVM Co-Plan Format

The table and diagram below provide a structured format for reporting cost and software data, including key elements such as WBS codes, names, and level of consistency. This format helps in aligning with EVM and IPMR reporting requirements, ensuring accurate and consistent data collection.

### Co-Plan Metadata
- **WBS Element Codes & Names**
- **CSDR Reporting Requirements**
- **EAC Level Identification**
- **EVM Reporting & IPMR Reporting Level of Consistency**

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<th>WBS Element Code</th>
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<th>Contract/Subcontract</th>
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</table>

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The table above outlines the structured format for detailed data reporting. Each row and column represents specific parameters for data collection, such as WBS element codes, names, and level of consistency. This structured approach ensures that all required information is captured accurately and consistently, facilitating effective EVM and IPMR reporting.
STANDARD Co-PLANS

*Includes an AIS Sustainment WBS
Tech Data Streamlining
Lessening Burden and Improving Data

Current State:
- Current data collection methods are ad-hoc, inefficient and scattered across the department
- Result: We re-construct technical analogies for nearly every estimate

Commodity
Unique Templates
- Estimating Requirements
- Comprehensive data source

MIL-STD 881C WBS (Oct ’11)

CARD
- Interim Policy (Jun ’15)
- Updated Format
- Annual Delivery
- Historical Record

Tech Data Report 1921-T
- SWaP parameters
- Complement to cost and software
- Completes the CARD

CADE
- Authoritative data source
- One stop shop for analysis
- Visual Analytics

Air Force
Army
Navy

FY15
FY16
FY17
Interim CARD Draft 1921-T
Final CARD Final 1921-T
Train and Transition
CADE Path Forward
CADE Planned Accomplishments – Next 12 months

**Policy:**
- CARD Guidance Policy Memo
- SRDR DID Policy Memo
- Draft Tech Data DID
- Co-Plan Pilots
- FlexFiles – FlexFile Prototype Instruction and Prototypes (Next Draft DID Update)

**Business Process:**
- Co-Plan (DD Form 2794)
- CSDR Plan Standards
- CARD Submission
- ICE Submission

**IT Development 5.0 to 5.5:**
- Cross Program Query Follow-on
- 1921-3 Data Availability
- MARs Data Availability
- FlexFile IT Development
- 1921-Q IT Development
CADE Closing: Why It’s Important

Improved Acquisition Outcomes:
- **Authoritative Quality Data**: Cooperative planning and compliance lead to better data and improved program management
- **Cost Realism**: Provide real-time cost data for analysis and facilitating quicker contract negotiations
- **Full view of Weapons Systems Program Performance**: Visual analytics, trend analysis and technical data to improve cost realism and make informed decisions

Efficient and Effective Analysis (at all levels: OSD, Services, PMOs):
- Improved Analytical Rigor and Productivity
- More time for analysis and execution; Less time collecting and feeding data
- More comprehensive assessments and reduced burden on industry

Cost Community Coordination:
- Revolutionizing cost data collection
- Cost community ownership of leadership, training and estimating responsibility
- Improving terminology and practices across Departments

Let’s continue to become more efficient together
Software Resources Data Reporting (SRDR)

Updates and Revisions:
Development SRDR
Maintenance SRDR
ERP Development SRDR

SW and IT CAST

Presented By:
Mr. Richard Mabe, AFCAA

23 August 2016
Purpose

- Provide an overview of the new SRDR DID (DI-MGMT-8035) and reporting formats:
  - Format 1- Development (DD Form 3026-1)
  - Format 2- Maintenance (DD Form 3026-2)

- Now available on the DCARC public website

- Example CDRLs also available

- Introduce an ERP Development SRDR
  - Addendum to DI-MGMT-8035
  - Format 3- DD Form 3026-3
History

- Software (SW) development/support cost is significant
- Quality data underpins quality SW cost estimate
- Data collection via SRDRs began in 2004
  - Size and Effort focus, but collect over 170 data fields
  - Inconsistent/non-standard data and formats
  - SRDRs available from DCARC but manually input in various “databases” (e.g. NAVAIR Excel spreadsheet)
- Data widely used by cost community but in need of more standardization and quality improvement
  - ~ 40% of data to-date is “good” for primary cost analysis use
  - ~ 20% of data is good for growth analysis (i.e. initial & final)

SRDRs – A success story ready for its next chapter…
### Recommendation

1. **Revised SRDR Data Item Description (DID) for Development**

2. **New SRDR Maintenance Format included in DID**


4. **CADE Software Database Design and Implementation**

### Benefit

1. Reduces inconsistency, lack of visibility, complexity, and subjectivity in reporting

2. Aligned w/ dev. but w/ unique data/metrics for maintenance phase

3. Higher quality, less duplication; joint team & guide gives early, consistent feedback to contractors

4. Avoids duplication, variations - ONE central vs many distributed; Based on surveyed best practices and user expectations
Formats

SRDR Initial & Final (Old)

- Software size, effort, and schedule
- Data dictionary (Descriptions)
- Initial Developer Report- Due at beginning of project increment (estimates)
- Final Developer Report- Due at completion of project increment (actuals)

SRDR Development (New)

- Part 1: Software size, technical parameters, descriptions, and schedule
- Part 2: Effort -actuals, EACs, and time phased (tie to 1921-1)
- Specific Release Level and CSCI Level Reporting
- Initial (estimates), Interim (actuals to-date/estimates), and Final (actuals, monthly) Reporting

SRDR Maintenance (New)

- Part 1: Software size, technical parameters, descriptions, and schedule
- Part 2: Effort (actuals) (tie to 1921-5)
- Release Level Reporting
- Annual (actuals) Reporting
Process

SUBMISSION

- Phase 1 - SURF manually enters raw data into existing SRDR MS Excel DB
- Phase 2 - Automated XML, manual entry for some SURF Tags

SRDR Raw Forms Submitted (Phase 1 is non-standard; Phase 2 - XML)

Data uploaded to DCARC CADE Portal for Review

DCARC review via CADE

Pass

SURF* Pre-Accept Review via CADE

Pass

SRDR acceptance

DATABASE

Raw SRDR Database

With Tags

- Revised SRDR Database available via DCARC portal
- SURF SRDR Database for V&V purposes; USERS do not see

CADE

- SRDR data storage/management
- Data access/query
- Visual Analysis Tools (VATs)

SECONDARY ANOMALY RESOLUTION THROUGH DCARC

SURF Final Review & Documentation in Database

Raw SRDR Database

With Tags

Secondary Anomaly resolution through DCARC

*DSD CADE
V&V Process

- **SURF Team:**
  - **DCARC Analyst:**
    - CAPE: William Raines
    - Navy: Corrine Wallshein
    - Marine Corps: Noel Bishop
    - Air Force: Ethan Henry, Ron Cipressi
    - Army: Jim Judy, Jenna Meyers, James Doswell
    - SPAWAR: Jeremiah Hayden
    - MDA: Dan Strickland
  - **SURF Primary:**
    - Various
    - Scott Washel, Dane Cooper, Stephen Palmer, Philip Draheim
    - John Bryant
    - Janet Wentworth, Chinson Yew, Eric Sommer
    - Michael Smith, Michael Duarte
    - Min-Jung Gantt
  - **SURF Secondary:**
    - Various

- Performs pre and post SRDR acceptance V&V w/ DCARC
- Uses a detailed first-ever published **joint** V&V guide
  - Training guide and used to determine SRDR quality tags for database
- Submits distributed amongst SURF members to balance workload
Software Development Report
SRDR Implementation Process

- The Program Office (PO) will use cPet to insert the commodity-based standard WBS or O&S CRS and tailor accordingly
- Elements with software data will be identified
- CDRL for SRDR will reference approved Plan (CSDR or Flexfiles)

- Post Award Contract Meeting between contractor and CWIPT will further define the software data requirements
- Plan revision possible with CSDR Supplement

- Revise Page 3 of the CSDR Plan as Release dates, Release Names, and CSCIs are defined

- Contractor will submit 3026-1 and/or 3026-2 according to the requirements in the approved Plan
  - Part 1 will be submitted in XML to the Submit-Review
  - Part 2 (if required) will be submitted in MS Excel to the Submit-Review
  - Validated according to requirements within approved Plan

- Cost and software data parsed and viewed together within CADE for analysis
- Requires that software data submissions align with cost submissions

Approved Data Available in CADE
Human Readable Format*

The public reporting burden for this collection of information is estimated to average 16 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Executive Services Directorate, Directives Division, 4800 Mark Center Drive, East Tower, Suite 02G09, Alexandria, VA 22350-3100 (0704-0188). Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR COMPLETED FORM TO THE ABOVE ORGANIZATION.

SOFTWARE RESOURCES DATA REPORTING: Metadata SECTION 3.2.1

PHASE/MILESTONE: SECTION 3.2.1.2

PERFORMING ORGANIZATION SECTION 3.2.1.5

APPROVED PLAN NUMBER SECTION 3.2.1.6

TYPE ACTION SECTION 3.2.1.8


PERIOD OF PERFORMANCE SECTION 3.2.1.9

APPROPRIATION SECTION 3.2.1.10

REPORT TYPE SECTION 3.2.1.11

SUBMISSION NUMBER SECTION 3.2.1.12

RESUBMISSION NUMBER SECTION 3.2.1.13

DATE PREPARED (YYYYMMDD) SECTION 3.2.1.14

TELEPHONE (Include Area Code) SECTION 3.2.1.15

EMAIL ADDRESS

REMARKS SECTION 3.2.1.16

SECTION 3.1.3 UNCLASSIFIED

DD Form 3026-1, MAY 2016

*Double Click Object to see Complete Worksheet
Software Maintenance Report
### Section 3.2.1: Software Resources Data Reporting: Metadata

#### Section 3.2.1.1
**Prime Mission Product**

#### Section 3.2.1.2
**Phase/Milestone:**
- Pre-A
- B
- C - FRP

#### Section 3.2.1.3
**Reporting Organization Type**
- Prime/Associate Contractor
- Direct-Reporting Subcontractor
- Government

#### Section 3.2.1.4
**Performing Organization**

#### Section 3.2.1.5
**Approved Plan Number**

#### Section 3.2.1.6
**Division**

#### Section 3.2.1.7
**Customer**

#### Section 3.2.1.8
**Type Action**
- Contract No.
- Modification No.
- Solicitation No.
- Task Order/Delivery Order/Lot No.

#### Section 3.2.1.9
**Report Type**

#### Section 3.2.1.10
**Period of Performance**
- Start Date (YYYYMMDD)
- End Date (YYYYMMDD)

#### Section 3.2.1.11
**Approportion**
- RDT&E
- Procurement
- O&M

#### Section 3.2.1.12
**Submission Number**

#### Section 3.2.1.13
**Resubmission Number**

#### Section 3.2.1.14
**POC Name** (Last, First, Middle Initial)

#### Section 3.2.1.15
**Remarks**

#### Section 3.2.1.16
**Date Prepared (YYYYMMDD)**

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*Double Click Object to See Complete Worksheet*
History

- July 2015: compared the draft Development and Maintenance SRDR forms and revised DID to a proposed ERP version developed in 2012 by Dr Wilson Rosa
  - Determined as a WG that the edits to add ERP specific data fields to the new SRDR formats were significant enough to warrant a separate form for ERP Development
  - But: the format and content for the Maintenance SRDR were adequate for ERP programs
- Initial draft form and DID for ERP presented on 2 November to the WG
- Multiple iterations followed through March 2016
- Current version is a Final WG version (as of 1 May 2016):
  - Reviewed by service cost agencies, ERP integrators, service ERP program cost chiefs, others in DOD
  - Form in Excel
  - DID in Word
Way Ahead

• **Review and process through OSD and Services**
  – To be reviewed by CADE team to ensure can be processed same as SRDR
  – Review and approve at Service Cost Chief level (Deputy Assistant Secretaries for Cost and Economic Analysis)

• **Submit as addendum to SRDR documents**
  – Same format as SW Development SRDR Form and DID
  – Cut and paste identical data fields from the SRDR
  – Share DID paragraphs 1.0 through 3.2
  – ERP SRDR unique instructions in DID Format 3 (paragraph 3.3 and 3.4)

• **Beginning work on V&V approach**

• **Will test with real-world program**
Software Resource Data Reports (SRDRs)

ERP SRDR
Development Only (In Work)

Part 1: Software size, technical parameters, implementation

Part 2: Effort - actuals, EACs, and time phased (tie to 1921-1)

Specific Release Level Reporting

Initial (estimates), Interim (actuals to-date/estimates), and Final (actuals, monthly) Reporting
**Enterprise Resource Planning (ERP) Software Development Report**

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<th>Section 3.2.1.1</th>
<th>MAJOR PROGRAM NAME:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase/Milestone:</td>
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<tr>
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<td>SECTION 3.2.1.6</td>
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<tr>
<td>PERFORMING ORGANIZATION:</td>
<td>SECTION 3.2.1.5</td>
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<tr>
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<td>SECTION 3.2.1.11</td>
</tr>
</tbody>
</table>

*Double Click Object to see Complete Worksheet*
Back-Up Slides
Software Reporting
Frequency
SRDR DID/Forms

Development Reporting Paradigm
SRDR DID/Forms

Maintenance Reporting Paradigm

- Cumulative to Date Reporting on Part 2 Effort
- Completed Release, Part 1 & 2
- No change from previous submission

Cost Assessment Data Enterprise

OSD CAPE

Maintenance

UNCLASSIFIED
Government-Wide CDRL Agile SW Metric Data Collection

Agile Project Management Controls and a central repository of Agile SW Metric Data for Government Use, Evaluation, and Analysis

William Plummer (SPAWAR 1.6)
Jeremiah Hayden (SPAWAR 1.6)
Omar Mahmoud (Cask)
August 23, 2016
Agenda

- Agile Software Metric Data Collection
- Metric Collection Team
- Data Analysis Benefactors
- Suggested SRDR Addendum
- Agile Metric Data Collection CDRL
  - Visualization and Trending Charts
- Case Study
  - Initial Baseline Estimates (Database Utilization)
  - Measuring In-Progress Performance
  - Caution of Agile Metric Usage
- CDRL Key Takeaway
- Get Involved
- Wrap Up/Questions
Agenda

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Agile SW Metric Data Collection

- **Purpose:** Development of an Agile Metric Database by utilizing Agile SW CDRL that aligns with PARCA’s guide to Agile and EVM System compliance

- **Goal:** Standardize metric reporting to inform cost estimation of Agile software development project costs across various application domains and government agencies

- **Benefits:** Initial project baseline cost estimates, in-progress metric analysis and projections, feature estimation, technical debt analysis, earned value estimation, CER development, and much more...

- **What We Need:** Government agencies to utilize Agile Metric CDRL and include the SPAWAR 1.6 cost organization as a recipient of the data (NDA to be signed)
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- **Metric Collection Team**
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<table>
<thead>
<tr>
<th>Agile SW Metric Data Gathering Team Composition</th>
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<tbody>
<tr>
<td>William Plummer and Jeremiah Hayden</td>
</tr>
<tr>
<td>Omar Mahmoud</td>
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<tr>
<td>Dan Strickland</td>
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<td>Richard Mabe</td>
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<td>James Doswell</td>
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<tr>
<td>Kelly Hazel</td>
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<td>Mary Anne Scully</td>
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Agenda

- Agile Software Metric Data Collection
- Metric Collection Team
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Data Analysis Benefactors

The following organizations can benefit from this and future data collection efforts:

- Army, Navy, Air Force, Marine Corp, and other Non-DOD Government Agencies and Analysts
- Cost Component Agencies (CAPE, NCCA, AFCAA, DASN CE, MDA, others)
- Program Office Estimates
- Contract Evaluation
- Possible SRDR Addendum for Agile Metric Collection
Agenda

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## Suggested SRDR Addendum

### SRDR Addendum for Estimating SW Dev Costs on Agile Projects

- Agile Product Roadmap
  - Establishes the PMB
- Features Completed per Sprint
  - Earned Value
- Total Issues in Backlog per Sprint
  - Scope Creep
- Monthly Cost Expenditures (EAC)
  - Estimates for Future Conditions
- Sprint Length (weeks)
  - Schedule Estimate Time-box
- Non-Story Related Issues
  - Technical Debt Ratio
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How can YOU assist???
Agile Metric Data Collection CDRL

Quantitative Analysis

Qualitative Assessment/Baseline

Utilize the CDRL and provide results to SPAWAR 1.6 for database development and metric consolidation.
Visualization and Trending Charts

**Efficiency and Velocity**
- Complexity Points Completed
- Avg. Velocity
- Hours per Sprint
- Avg. Hours per Sprint

**Productivity and Velocity**
- SK per Complexity Point
- Avg. SK per Complexity Point
- Complexity Points Completed
- Avg. Velocity

**Feature/Req. Tracker**
- Points per Feature/Req. (Cum. Avg.)
- SK per Feature/Req. (Cum. Avg.)
- Hours per Feature/Req. (Cum. Avg.)

**Feature/Req. Burndown**
- Actual Feature/Req. Burndown
- Linear Feature/Req. Burndown (Expected)
Visualization and Trending Charts (cont’d)

**Issue Sand Chart**

**Comparison of Stories to Technical Debt**

**Feature/Req. Tracker**
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How can YOU benefit from the Agile Database and CDRL Template???
Case Study – Initial Baseline Estimates
(Database Dashboard Utility)

Formulate Initial Baseline Estimates
Total Project Cost: $5,000,000
Schedule: 20 Sprints (2 weeks/Sprint)
Anticipated Technical Debt: 35%

Input: Development Environment
Output: Database Metric Range for Initial Baseline Estimates
Case Study – Measuring In-Progress Performance

Project A:
Background: Agile SW project issued to ACME Contracting with 3 years of experience working in an Agile environment.
SCRUM Master recently received certification from an 8 hour online Agile webinar.

- Command and Control Project developed for the Air Force
- ACAT III on a CPIF Contract
- CMMI Level 3

Project B:
Background: Agile SW project issued to Prestine Developers with over 10 years of experience working in an Agile environment.
SCRUM Master has 15 years of experience leading organized teams.

- Radar Project for the NAVY
- ACAT II on a CPAF Contract
- CMMI Level 4

How do these projects measure up and what information can you glean from their metrics?
Project A:

Feature Burndown

Ahead in completed features, but notice technical debt growth

Cumulative Defect Trendline

Completed Issue Tracking

Technical Debt reflects 65% of the total effort

Project B:

Feature Burndown

Better balance of overall project quality

Cumulative Defect Trendline

Completed Issue Tracking

Technical Debt reflects 31% of the total effort
Case Study - *Caution when Using Agile Metrics*

- Caution should be used when using Agile related metrics to baseline or estimate other projects
  - Story points are subjective and relative
    - Defined by each development team
    - Particular to teams history and skillset
  - Sprint timelines may vary across organizations

- Considerations:
  - Velocity is fairly stable after 3 sprints
    - Agile teams experience “storming and norming” productivity
  - Project Performance should be estimated by Hours and/or Cost expended per Completed Feature
  - Story points estimates can be used if the point definitions, scope of effort, and development team are analogous
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Key Takeaway of the CDRL Template

- Monthly EVM reporting and various trending and estimates on a Sprint by Sprint basis
- More robust government database to be shared across government organizations
- Allows for key factors that can be used in future estimating analysis:
  - $/hr, $/feature, $/sprint, % of Requirements vs. Technical Debt, and Buffering for unplanned effort
- Broad dataset will provide insight into a large array of programs
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Get Involved

To participate in the database development or for a copy of the Agile Metric CDRL

Reach out to:
Jeremiah Hayden (jeremiah.hayden@navy.mil)
William Plummer (william.s.plummer@navy.mil)
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Wrap up Questions
Back up
Terms Used in Presentation

- **Buffering**: Planning effort for unplanned events due to changes in requirements, scope creep, defects, or usability assessments and feedback.

- **Human Systems Integration (HSI)**: Describes possible usability issues with the software.

- **Issue/Artifact**: Detailed description of a feature of the software that needs to be developed, tested, integrated, QA’ed, etc.

- **Product Backlog/Backlog**: Database or list that records all Issues or Artifacts the software team will work on. Categories include: Planned Sprint, Story Points, Resource, Issue type, Status, etc.

- **Sprint**: Fixed-time box in which SW dev activity occurs (typical ranges are 2 or 4 weeks).

- **Story Points/Points**: Quantitative-subjective measure of the requirement to fully plan, develop, test, and integrate a feature into the overall software development deliverable.

- **Technical Debt**: Refers to other non-requirement related activities that are incurred on the project as a result of requirements development (e.g., Defects, Enhancements, HSI, etc.).

- **Velocity**: Schedule productivity typically described as “completed points per sprint”
Agenda

Overview
The Challenge Today

- Siloed teams relying on disconnected data
- Point in time, manual data to make decisions
- Fragmented views of cost, performance and forecast of services
- No mapping of the relationships between asset, service, labor and performance info
- Many, disparate data sources

- Not Real-time
- No Collaboration
- No Analytics
- No Reporting

- No Utilization Model
- No Quality Model
- No Activity-based Costing

- Labor
- Tickets
- Servers
- Apps
### Common IT Business Management Problems

<table>
<thead>
<tr>
<th>Decisions Made by Gut Feel</th>
<th>Treated Like Free, Unlimited Resource</th>
<th>Difficult to Explain IT Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private or Public</td>
<td>IT Consumption</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IT Costs</td>
<td></td>
</tr>
</tbody>
</table>

- Decisions Made by Gut Feel: Treated Like Free, Unlimited Resource can lead to Difficult to Explain IT Costs.
- IT Consumption and IT Costs increase when decisions are made impulsively.
- Public or Private cloud services can contribute to these issues.

*Image source: vmware*
AND WARREN HERE IS IN CHARGE OF OUR GUT FEELINGS
IT Business Management Solutions

- Reporting
- Cost Modeling
- Data Management
Communicating Across The Organization
vRealize Business Approach

Crawl Phase
- Private Cloud Infrastructure
- Private Cloud Metering

Walk Phase
- Showback Reporting
- Role-Based Dashboard Targeted w/ Personas - CIO, CFO, Business Owners
- Cost of Wastage and Savings from Reclamation

Run Phase
- Flexible and Intuitive cost modeling
- General Ledger integration
- Chargeback Reports
- Service Level Management

Cloud Business Management
Cloud Reporting and Analytics
IT Business Management
vRealize Business Primary Use Cases

- Private Cloud Costing
- Cloud Business Management
- Enterprise IT Business Management

- CRAWL: vRealize Business for Cloud Standard
- WALK: vRealize Business for Cloud Advanced
- RUN: vRealize Business Enterprise
Cost Overview on a Single Pane of Glass

Total cost of Cloud infrastructure

Cloud Consumption

EXPENSES

$90,229
November 2015: Projected Cost

OPERATIONS

529 VMs
November 2015

CONSUMPTION

$19,543
November 2015: Projected Charge
Showback by LOB/Customer

- **Projection**
  - Month to Date Charge: $78,500
  - Projected Monthly Charge: $142,300
  - Monthly Budget: $70,000

- **Trend**
  - Private Cloud Reclamation: $7,350

- **Breakdown by App or Service**

[Image of a dashboard showing financial projections and breakdowns by application or service]
Bill of IT for the Full Portfolio of IT Services

Consumer visualizes what's driving cost

LOB Specific View

Consumer understands consumption and price

Costs by Service
Complete Visibility into All of IT Cost

Leverage OOTB Dashboards Targeting a Broad Range of Stakeholders

Observation Engine Highlights Key Cost Changes

Actuals vs. Budget Tracking

Cost of IT Services Delivered (Apps, Projects, HW, SW, Labor)

OOTB Views are Easily Configurable
Software Cost Estimation Meets Software Diversity
COCOMO III

Barry Boehm, Brad Clark
Software and IT-CAST Meeting
August 23, 2016
Estimation Meets Diversity

• Sources of Software Diversity
  – A Short History of Software Estimation Accuracy
  – Process, Product, Property, and People Drivers

• Options for Software Cost Estimation
  – Expert Judgment/Consensus; Size-Based; Productivity-Based; Component-Based; Process-Based; Composites

• Best Fits of Estimation-Types to Diversity-Types
  – Extensions of ICSM Common Cases

• Charting Your Path to Improved Estimates
  – Current COCOMO III Strategy Overview
COCOMO III Project

The purpose of the COCOMO® III project is to develop a software cost estimation model for modern software development.

• Address the scope of modern software projects
  – Subset of the estimation diversity challenges
• Improve the accuracy and realism of estimates
• Estimate software cost that is complementary with a COSYSMO system engineering cost estimate
• Improve the value of COCOMO® in decision-making
• Create a strategy for maintaining past COCOMO® models
COCOMO III Use Cases

1. Top-level estimate
2. Multiple component estimate
3. Analysis of alternatives
4. Analysis with Size-Effort-Schedule as independent variables
5. Estimation for different processes
6. Lifecycle cost estimates
7. Legacy system transformation
8. Estimate using COCOMO® III and COSYSMO together
9. Alternative size measures
10. Local calibration
COCOMO III Software Cost Estimation

• COCOMO is the most widely used software cost estimation model in the world
  – Registered Trademark for protect the intellectual property
  – Model is open and free for anyone to use
  – Has been commercialized

• It has been 16 years since the model has been updated and calibrated to new Software Engineering data

• What we are looking for:
  – Your ideas on how the new model should be used and new input parameters to estimate software engineering development costs
  – Your chance to influence the new COCOMO III model

• Why you should consider participating:
  – Review of COCOMO III model
  – If you contribute data for model calibration, you will receive:
    • An advanced copy of the new model
    • Comparison of your data with respect to other data points used to calibrate the model
PLEASE JOIN US AT THE WORKSHOP

August 2016

Presenter: Nicholas Lanham
Authors: Corinne Wallshein, Nicholas Lanham, and Wilson Rosa
Naval Center for Cost Analysis
nicholas.lanham@navy.mil
corinne.wallshein@navy.mil
wilson.rosa@navy.mil
Outline

• Introduction
• Experimental Design
• Data Analysis
• Descriptive Statistics
• Effort Models
• Conclusion
Frequently Used Terms

- **CPAF**: Cost Plus Award Fee (type of contract)
- **CPIF**: Cost Plus Incentive Fee (type of contract)
- **CPFF**: Cost Plus Fixed Fee (type of contract)
- **Development Process**: The process used to develop software (e.g., Waterfall, Incremental, Iterative, Agile, etc.)
Introduction
Study Design

• Highlight elements of project size from paired initial-final Computer Software Configuration Item (CSCI) records to estimate using new categories

• Perform statistical analysis on sizing parameters such as
  – Estimated requirement counts
  – Estimated source lines of code (SLOC)
  – Estimated effort
  – Estimated duration
  – Estimated peak staffing
Problem Statement

• Software effort estimates should take into account requirement, process, and tool evolution

  – Cost-plus contract types recommended for exploratory studies, demonstrations, and development

  – Development processes also recommended for exploratory studies, demonstrations, and development
Research Questions

1) By using process-oriented categories, will data available at the initial project stage help predict effort hours?

2) Do growth rates change differently in process-oriented categories?

3) Are estimated effort hours useful to predict actual effort hours?
Effort Estimation Challenges

• Old paradigm estimates based on:
  – Completed project data
  – Source Lines of Code (SLOC)
  – Subject Matter Experts

• Old paradigm estimates impacted by:
  – Inconsistent SLOC conversions
  – Lack of relevant historical data
  – Lack of quality historical data
  – Lack of subcategory trend analysis
Estimating Paradigm Shift

• This paper attempts to describe an alternate software development effort estimating paradigm
  – Based on actual DoD software development efforts
  – Based on completed development efforts

• Initial analysis indicates very strong relationships between actual and estimated values
  – From analyzing the relationships between initial and final software report submissions
  – From comparing initial (e.g., estimated) variable values to final effort values (e.g., actual)
Model Subcategories

- Model Flexibility Supports New Hypotheses for existing and created subsets
  - New vs. Upgrade
  - Primary Language
  - CMMI Level
  - Contractor
  - Development Process
  - Application Domain
  - Super Domain
  - Operating Environment
  - Contract Type
  - Program Type (NCCA tag?)

Software Estimating: New Paradigm

Univariate:
- Distributions for Uncertainty
- Factors
- Parametric CERs
- Percent Change Analysis

Multi-variable:
- Parametric CERs
- Factors

Subset CER/Factor Comparisons

Increased Estimating Flexibility

Focusing on Deriving Relationships Less Dependent on SLOC Inputs
Experimental Design
Quantitative Method

- Non-random sample of secondary data

- Projects reported at the CSCI level for early program phases, beginning to elaborate system requirements

- To minimize threats to validity, the analysis framework focused on estimated inputs rather than final inputs
Instrumentation

• Questionnaire:
  – Software Resource Data Report (SRDR) (DD-Form 2630)

• Content:
  – Allows for the collection of project context, responsible company or government information, certified maturity level, requirements, product size, effort, and schedule

• Source:
  – Cost Assessment Data Enterprise (CADE) website:
    http://cade.osd.mil/Files/Policy/Initial_Developer_Report.xlsx
    http://cade.osd.mil/Files/Policy/Final_Developer_Report.xlsx
Sample and Population

• Empirical data from 408 recent records
  – 204 paired initial and final records

Each program submitted:
SRDR Initial Developer Report (Estimates)
&
SRDR Final Developer Report (Actuals)
2624 Total CSCI Records
911 Completed Program / Build CSCI Records
403 Completed CSCIs with IEEE 12207 break-outs
219 Paired CSCI Records
204 analyzed

Since last ICEAA (2015)
15 outliers were excluded, accompanied by documented rationales
# Contract Type

<table>
<thead>
<tr>
<th>Contract Types</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost Plus Award Fee</td>
<td>CPAF</td>
<td>The contract level of effort is uncertain and it is not feasible or effective to negotiate an adjustment formula. The likelihood of meeting objectives can be enhanced by a clear subjective fee plan.</td>
</tr>
<tr>
<td>Cost Plus Fixed Fee</td>
<td>CPFF</td>
<td>Cost uncertainty is so great that establishment of predetermined targets and incentive sharing arrangements could result in a final fee out of line with the actual work</td>
</tr>
<tr>
<td>Cost Plus Incentive Fee</td>
<td>CPIF</td>
<td>Cost uncertainties are so great that any fixed-price contract would force the contractor to accept an unreasonable risk, but reasonable targets and formulas for sharing costs may be negotiated</td>
</tr>
</tbody>
</table>
Contract Type

- Firm Fixed Price (FFP): 2
- Indefinite Delivery - Indefinite Quantity (IDIQ): 6
- Fixed Price Fee (FPIF): 8
- In-house and/or To Be Determined (TBD): 17
- Cost Plus Incentive Fee (CPIF): 43
- Cost Plus Fee (CPFF): 44
- Cost Plus Award Fee (CPAF): 84
# Development Process

<table>
<thead>
<tr>
<th>Contract Types</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waterfall</td>
<td>Wat</td>
<td>Sequential (non-iterative) design process</td>
</tr>
<tr>
<td>Incremental</td>
<td>Incr</td>
<td>Total development effort divided into smaller builds that are designed, coded, and tested in sequence before moving to the next build</td>
</tr>
<tr>
<td>Iterative</td>
<td>Iter</td>
<td>Gradual addition of features that are designed, coded, and tested in repeated cycles</td>
</tr>
<tr>
<td>Spiral</td>
<td>Spi</td>
<td>Similar to incremental model with increased emphasis on risk analysis</td>
</tr>
<tr>
<td>Agile</td>
<td>Agi</td>
<td>Developed in small, rapid cycles with each release building upon the prior build</td>
</tr>
</tbody>
</table>
# Measures of Model Reliability and Validity

<table>
<thead>
<tr>
<th>Measure</th>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Records</td>
<td>n</td>
<td>The number of records used in the model</td>
</tr>
<tr>
<td>Coefficient of Variation</td>
<td>CV</td>
<td>Percentage expression of the standard error compared to the mean of the dependent variable. This is a relative measure allowing direct comparison among models.</td>
</tr>
<tr>
<td>P-value</td>
<td>α</td>
<td>Level of statistical significance established through the coefficient alpha (p ≤ α)</td>
</tr>
<tr>
<td>Coefficient of Determination</td>
<td>$R^2$</td>
<td>The Coefficient of Determination shows how much variation in the dependent variable is explained by the regression equation.</td>
</tr>
<tr>
<td>t-test</td>
<td>t-stat</td>
<td>Provides a measure of the significance of the predictor variables in the regression model. The variable is significant when the t-stat is greater than the two-tailed value, given the degrees of freedom and coefficient alpha (α = 0.05)</td>
</tr>
<tr>
<td>Mean Magnitude of Relative Error</td>
<td>MMRE</td>
<td>Mean Magnitude of Relative Error (MRE) measures differences between actual and predicted values relative to the actual value. The mean is computed using every observation.</td>
</tr>
<tr>
<td>Prediction Accuracy</td>
<td>PRED(30)</td>
<td>Prediction accuracy is rated as a percentage of the number of records below an individual MRE ≤ 0.30</td>
</tr>
</tbody>
</table>
Data Analysis
Pairwise Correlation Analysis

- Variable selection based on Pairwise Correlation
  - Pairwise correlation chosen over structural equation modeling as the number of observations by subset was below the minimum observations (i.e. 200) needed

<table>
<thead>
<tr>
<th>From Final Report</th>
<th>From Initial Report</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Effort</td>
<td>Estimated CSCI Requirement Counts</td>
</tr>
<tr>
<td>Actual Duration</td>
<td>Estimated Peak Staff</td>
</tr>
<tr>
<td></td>
<td>Estimated Total SLOC in Logical Statements (LS)</td>
</tr>
<tr>
<td></td>
<td>Estimated New Code in LS</td>
</tr>
<tr>
<td></td>
<td>Estimated Effort</td>
</tr>
<tr>
<td></td>
<td>Estimated Duration</td>
</tr>
</tbody>
</table>
Contract Type Correlation Analysis

- Actual Effort Hours
  - For all cost plus contracts, Actual Effort Hours are correlated to Estimated Effort Hours
  - CPAF is correlated to PS, New, and SLOC
  - CPFF is correlated to New
  - CPIF is correlated to PS

- Actual Duration
  - For all cost plus contracts, Actual Duration is correlated to Estimated Duration (in months)
  - CPAF is correlated to REQ
  - CPIF is correlated to New and SLOC
Development Process Correlation Analysis

- **Actual Effort Hours**
  - For all development processes, Actual Effort Hours are correlated to Estimated Effort Hours
  - Spiral is correlated to New and Mod
  - Waterfall and Iterative are correlated to PS and New
  - Incremental is correlated to PS, New, and REQ

- **Actual Duration**
  - For Iterative and Spiral development processes, Actual Durations are correlated to Estimated Durations (in months)
  - Waterfall and Incremental do not show strong duration correlations for this dataset

---

8/17/2016

24
New Paradigm
Hours and Requirement Count Estimating Concept
# Effort Model Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Type</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Effort</td>
<td>Dependent</td>
<td>Actual software engineering effort (in hours)</td>
</tr>
<tr>
<td>Estimated New, Mod, Reuse, and Auto SLOC</td>
<td>Independent</td>
<td>Total Source Lines of Code (SLOC) categorized as New, Modified, Reuse, or Auto</td>
</tr>
<tr>
<td>Estimated Total Requirements</td>
<td>Independent</td>
<td>Total Requirements captured in the Software Requirements Specification (SRS). These are the estimated total requirements at contract award.</td>
</tr>
<tr>
<td>Estimated Peak Staff</td>
<td>Independent</td>
<td>Actual peak team size, measured in full-time equivalent staff. Only include direct labor.</td>
</tr>
<tr>
<td>Estimated Effort</td>
<td>Independent</td>
<td>Estimated software engineering effort (in hours)</td>
</tr>
<tr>
<td>Estimated Duration</td>
<td>Independent</td>
<td>Estimated software engineering duration (in months)</td>
</tr>
</tbody>
</table>
Entire Dataset: Predicting Actual Hours with All Estimated Variables

- Multivariate analysis of all “Initial” variables indicates summary level fit

- Several independent variables were not significant (Prob > |t| above .05)
  - Initial New
  - Initial Mod
  - Initial Reuse

- Several independent variables were significant (Prob > |t| below .05)
  - Initial Hours
  - Initial Requirement counts
  - Initial Peak Staff counts
  - Initial Duration (in months)

| Term         | Estimate | Std Error | t Ratio | Prob>|t| | VIF  |
|--------------|----------|-----------|---------|----------|------|
| Intercept    | -3,233.87| 3,954.495 | -0.82   | 0.4145   | .    |
| Initial-New  | 0.0715735| 0.039668  | 1.80    | 0.0728   | 1.7278008 |
| Initial-Mod  | 0.0516804| 0.050073  | 1.03    | 0.3033   | 1.7583416 |
| Initial-Reuse| 0.005661 | 0.006708  | 0.84    | 0.3997   | 1.1211566 |
| Initial-Auto | 0.1391352| 0.03714   | 3.75    | 0.0002*  | 1.0483384 |
| Initial-Hours| 0.8101929| 0.0569    | 14.24   | <.0001*  | 2.3353118 |
| Initial-Req  | 7.134068 | 2.124851  | 3.36    | 0.0009*  | 1.7140274 |
| Initial-Peak-Staff | 318.95122 | 146.3109  | 2.18    | 0.0305*  | 2.0139019 |
| Initial-Month| 264.23516| 107.6958  | 2.45    | 0.0150*  | 1.3089695 |
Entire Dataset: Predicting Actual Hours with Selected Estimated Variables

- Analysis indicates good fit with the statistically significant independent variables below:
  - Initial Hours
  - Initial Requirements Count
- Cost analysts may generate software estimates without explicit SLOC/ESLOC counts or productivity-based metrics
- Based on April 2014 paired initial and final SRDR data points, excluding four records with multiple missing initial values

| Term          | Estimate  | Std Err  | t Ratio | Prob>|t| | VIF |
|---------------|-----------|----------|---------|-------|-----|
| Intercept     | 5870.9039 | 2550.668 | 2.30    | 0.0224* | .   |
| Initial Hours | 0.9915144 | 0.040649 | 24.39   | <.0001* | 1.055324 |
| Initial Req. Count | 9.0827304 | 1.771865 | 5.13    | <.0001* | 1.055324 |

RSquare 0.784236
RSquare Adj 0.782045
Root Mean Square Error 26113.47
Mean of Response 52380.44
Observations (or Sum Wgts) 200
New Paradigm
Univariate Statistics
Percent Change by Contract Type
Entire Dataset: Percent Change (PC) Analysis

• Compares percent growth in effort hours from initial to final reporting events
Contract Type:
Percent Change (PC) Analysis

- Contract types result in similar distribution shapes
- Higher variance for CPAF
- When contract type is known, PC effort hour uncertainty may be explicitly modeled, based on empirical data

<table>
<thead>
<tr>
<th>Contract Type</th>
<th>Level</th>
<th>Number</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Std Err</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPAF</td>
<td>76</td>
<td>0.522</td>
<td>0.814</td>
<td>0.093</td>
<td></td>
</tr>
<tr>
<td>CPFF</td>
<td>43</td>
<td>0.332</td>
<td>0.659</td>
<td>0.101</td>
<td></td>
</tr>
<tr>
<td>CPIF</td>
<td>40</td>
<td>0.324</td>
<td>0.665</td>
<td>0.105</td>
<td></td>
</tr>
</tbody>
</table>

Filter: Contract Type, less than +300%
## Effort Models

### By Contract Type

<table>
<thead>
<tr>
<th>Subset</th>
<th>Records</th>
<th>Equation</th>
<th>R2 in Fit Space</th>
<th>R2 in Unit Space</th>
<th>SE</th>
<th>RMS of % Errors</th>
<th>MAD</th>
<th>CV (MAD Res/Avg Act)</th>
<th>MMRE</th>
<th>PRED(30)</th>
<th>Minimum Value</th>
<th>Maximum Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPAF</td>
<td>74</td>
<td>aEH = 8.53 * eEH ^ 0.82</td>
<td>0.79</td>
<td>0.64</td>
<td>28741.6</td>
<td>0.78</td>
<td>0.51</td>
<td>0.35</td>
<td>0.51</td>
<td>0.46</td>
<td>575</td>
<td>169583</td>
</tr>
<tr>
<td>CPFF</td>
<td>40</td>
<td>aEH = 1.27 * eEH ^ 0.99</td>
<td>0.71</td>
<td>0.78</td>
<td>15281.0</td>
<td>1.11</td>
<td>0.58</td>
<td>0.31</td>
<td>0.58</td>
<td>0.50</td>
<td>1896</td>
<td>101665</td>
</tr>
<tr>
<td>CPIF</td>
<td>43</td>
<td>aEH = 18.8 * eEH ^ 0.75</td>
<td>0.66</td>
<td>0.70</td>
<td>35749.2</td>
<td>0.84</td>
<td>0.49</td>
<td>0.28</td>
<td>0.49</td>
<td>0.60</td>
<td>2235</td>
<td>191013</td>
</tr>
</tbody>
</table>

Legend:
- **R2**: Coefficient of determination
- **SE**: Standard error
- **MAD**: Mean absolute deviation
- **MMRE**: Maximum absolute relative error
- **PRED(30)**: Predicted value for the 30th percentile
Conclusion

• New paradigm subset analysis increases estimating flexibility and accuracy

• Allows analysts to develop estimates without reliance on SLOC, ESLOC, or productivity-rate metrics

• Based on actual historical DoD software development efforts

Relationships Can be Derived Using Any Available Subset or Category
Future Work

• Contacts:
  – Nicholas Lanham, NCCA
  – Dr. Corinne Wallshein, NCCA
  – Dr. Wilson Rosa, NCCA

• Future Work:
  – Analyzing software development phasing
  – Improving SRDR data quality via SURF
  – Updating SRDR dataset from April 2014 on
Backup
Model Acceptance Criteria

<table>
<thead>
<tr>
<th>Measure</th>
<th>Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAD</td>
<td>( \leq 45% )</td>
</tr>
<tr>
<td>CV</td>
<td>( \leq 45% )</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>( \geq 55% )</td>
</tr>
<tr>
<td>t-test</td>
<td>&gt; Two tailed critical value (( \alpha = 0.05 ))</td>
</tr>
</tbody>
</table>

- Zero / blank input values were excluded to generate comparative CERs and SERs

Primary Programming Language:
- 185 records

Process Maturity Level:
- 183 records

Cost Plus Contract Type:
- 157 records
## Development Process

### Spearman Correlation Matrices

#### Waterfall Spearman

<table>
<thead>
<tr>
<th>Final-Hours</th>
<th>Final-Month</th>
<th>Initial-Hours</th>
<th>Initial-Req</th>
<th>Initial-Peak-Staff</th>
<th>Init-New-LS</th>
<th>Init-Mod-LS</th>
<th>Init-Reuse-LS</th>
<th>Init-Auto-Gen-LS</th>
<th>Init-SLOC-LS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final-Hours</td>
<td>1.00</td>
<td>0.04</td>
<td>0.95</td>
<td>0.56</td>
<td>0.87</td>
<td>0.04</td>
<td>0.85</td>
<td>0.32</td>
<td>-0.06</td>
</tr>
<tr>
<td>Final-Month</td>
<td>1.00</td>
<td>0.03</td>
<td>0.26</td>
<td>0.16</td>
<td>0.83</td>
<td>0.30</td>
<td>0.26</td>
<td>0.39</td>
<td>-0.07</td>
</tr>
<tr>
<td>Initial-Hours</td>
<td>1.00</td>
<td>0.52</td>
<td>0.87</td>
<td>0.06</td>
<td>0.86</td>
<td>0.32</td>
<td>0.16</td>
<td>-0.18</td>
<td>0.03</td>
</tr>
<tr>
<td>Initial-Req</td>
<td>1.00</td>
<td>0.57</td>
<td>0.14</td>
<td>0.55</td>
<td>0.36</td>
<td>0.34</td>
<td>0.36</td>
<td>-0.03</td>
<td>0.65</td>
</tr>
<tr>
<td>Initial-Peak-Staff</td>
<td>1.00</td>
<td>0.17</td>
<td>0.78</td>
<td>0.45</td>
<td>0.36</td>
<td>0.12</td>
<td>0.71</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial-Month</td>
<td>1.00</td>
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#### Spiral Spearman

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#### Incremental Spearman

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#### Iterative Spearman

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• Development processes result in similar distribution shapes

• Lowest standard deviation for Spiral development process

• When development process is known, PC effort hour uncertainty may be explicitly modeled, based on empirical data

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Filter: Development Process, less than +700%
## Effort Models

| Subset     | Records | Equation                                         | R2 in Fit Space | R2 in Unit Space | SE   | RMS of % Errors | MAD  | CV (MAD Res/Avg Act) | MMRE | PRED(30) | Min Value | Max Value | Min Value | Max Value |
|------------|---------|--------------------------------------------------|-----------------|-----------------|------|-----------------|------|--------------------|------|----------|-----------|-----------|
| Waterfall  | 56      | aHr = 8.66 * eHr ^ 0.82                          | 0.87            | 0.85            | 21717.62 | 0.74 | 0.49             | 0.24 | 0.49               | 0.50 | 184      | 99520     |           |
| Waterfall  | 56      | aHr = 10957.7 + 0.98 * eHr                       | 0.83            | 0.83            | 22983.37 | 7.33 | 2.13             | 0.27 | 2.13               | 0.43 | 184      | 99520     |           |
| Waterfall  | 55      | aHr = 7.3 * eHr ^ 0.8 * eREQ ^ 0.1               | 0.88            | 0.83            | 23180.96 | 0.67 | 0.46             | 0.24 | 0.46               | 0.49 | 184      | 99520     | 2        | 407      |
| Waterfall  | 55      | aHr = 11120.1 + 0.98 * eHr + 0.08 * eREQ        | 0.83            | 0.83            | 23406.36 | 7.51 | 2.18             | 0.27 | 2.18               | 0.44 | 184      | 99520     | 2        | 407      |
| Spiral     | 56      | aHr = 3.16 * eHr ^ 0.9                           | 0.70            | 0.62            | 32202.62 | 1.14 | 0.66             | 0.42 | 0.66               | 0.38 | 1496     | 191013    |           |
| Spiral     | 56      | aHr = 7592 + 1.02 * eHr                          | 0.65            | 0.65            | 31455.92 | 1.90 | 0.99             | 0.43 | 1.22               | 0.36 | 1496     | 191013    |           |
| Spiral     | 56      | aHr = 4.8 * eHr ^ 0.77 * eREQ ^ 0.17             | 0.74            | 0.69            | 29286.93 | 1.04 | 0.59             | 0.37 | 0.59               | 0.50 | 1496     | 191013    | 8        | 8850     |
| Spiral     | 56      | aHr = 4207 + 0.94 * eHr + 8.77 * eREQ           | 0.73            | 0.73            | 27873.17 | 1.41 | 0.78             | 0.37 | 0.78               | 0.39 | 1496     | 191013    | 8        | 8850     |
| Iterative  | 23      | aHr = 77 * eHr ^ 0.6                             | 0.47            | 0.61            | 21850.02 | 0.86 | 0.62             | 0.41 | 0.62               | 0.30 | 2235     | 156650    |           |
| Iterative  | 23      | aHr = 14042.6 + 0.75 * eHr                       | 0.70            | 0.70            | 19551.64 | 1.07 | 0.76             | 0.39 | 0.76               | 0.35 | 2235     | 156650    |           |
| Iterative  | 23      | aHr = 52.8 * eHr ^ 0.5 * eREQ ^ 0.2              | 0.52            | 0.62            | 21526.76 | 0.72 | 0.55             | 0.37 | 0.55               | 0.30 | 2235     | 156650    | 55       | 2400     |
| Iterative  | 23      | aHr = 10415.75 + 0.7 * eHr + 10.4 * eREQ        | 0.73            | 0.73            | 18949.39 | 0.92 | 0.67             | 0.35 | 0.67               | 0.39 | 2235     | 156650    | 55       | 2400     |
| Incremental| 44      | aHr = 2 * eHr ^ 0.96                             | 0.83            | 0.76            | 28330.60 | 0.56 | 0.37             | 0.27 | 0.37               | 0.59 | 1104     | 141000    |           |
| Incremental| 44      | aHr = 2544 + 1.4 * eHr                           | 0.78            | 0.78            | 27260.82 | 0.77 | 0.52             | 0.31 | 0.52               | 0.45 | 1104     | 141000    |           |
| Incremental| 44      | aHr = 2.55 * eHr ^ 0.88 * eREQ ^ 0.11            | 0.84            | 0.79            | 26091.05 | 0.51 | 0.35             | 0.25 | 0.35               | 0.59 | 1104     | 141000    | 7        | 2521     |
| Incremental| 44      | aHr = (-1521) + 1.189 * eHr + 26.5 * eREQ       | 0.82            | 0.82            | 24631.07 | 0.86 | 0.50             | 0.27 | 0.50               | 0.57 | 1104     | 141000    | 7        | 2521     |
Development Process

Waterfall

Kurkovsky, S. Central Connecticut State University (CCSU), Department of Computer Science
Ref: http://www.cs.ccsu.edu/~stan/classes/CS530/Notes14/02-SoftwareProcesses.html
Ref: https://courses.cs.vt.edu/csonline/SE/Lessons/Spiral/Lesson.html
Development Process

Iterative

Ref: https://wiki.nci.nih.gov/display/CommonProjects/Iterative+Software+Development+Approach
Development Process

Incremental

Kurkovsky, S. Central Connecticut State University (CCSU), Department of Computer Science
Ref: http://www.cs.ccsu.edu/~stan/classes/CS530/Notes14/02-SoftwareProcesses.html
TruePlanning® Risk & Uncertainty Analysis:
Best Practices

August 2016
Agenda

- Overview of PRICE® Approach
- Risk and Uncertainty
- Parameters used in Cost Uncertainty Analysis
  - Size
  - Functional Complexity
  - Reuse
  - Technology
- Uncertainty Options with TruePlanning
Overview of PRICE® Approach
One View of Risk

- “… All projects should be budgeted at a 70% confidence level”

Risk and Uncertainty
Risk versus Uncertainty

**Risk**
- Known Unknowns
- Implies that Probabilities can be Assigned to an Event
- Risk exists when the decision maker is in a position to assign probabilities to various outcomes. This occurs when there is historical data on the basis in which you can assign probability to other projects of the same nature.

**Uncertainty**
- Unknown Unknowns
- Implies that Probabilities Cannot be Assigned to an Event
- Uncertainty exists when the decision maker has no historical data from which to develop a probability distribution and must make intelligent guesses in order to develop a subjective probability distribution.
Risk versus Uncertainty

“Risk is measurable uncertainty”

“Uncertainty is unmeasurable risk”

Risk Components

Performance Risk
- The degree of uncertainty that the product will meet its requirements and be fit for its intended use.

Cost Risk
- The degree of uncertainty that the project budget will be maintained.

Support Risk
- The degree of uncertainty that the resultant product will be easy to maintain, correct, and enhance.

Schedule Risk
- The Degree of uncertainty that the project will be maintained and that the product will be delivered on time.
Risk Analysis Projection

- Risk Projection, also called Risk estimation, attempts to rate each risk in two ways
  - The likelihood or probability that the risk is real
  - The consequences of the problems associated with the risk, should it occur

![Risk Matrix Diagram]
General Types of Uncertainty

Requirements

- Imperfect Knowledge about State of the World
- System Requirements Change over the Course of its Development, Which are Beyond the Control of the Program Manager

Cost Estimating Uncertainty

- Statistical Uncertainty
- Data can be very Subjective
- Sampling Techniques have Random Error

Technological Uncertainty

- Is the Technology Mature Enough to Allow Development and Integration Into the System?
Techniques for Uncertainty Analysis

- Sensitivity Analysis
  - Requirements Uncertainty

- Approximation
  - Cost Estimating Uncertainty

- Simulation
  - Technical Uncertainty
Sensitivity Analysis

- Compute Baseline System Point Estimate
- Select Equipment Parameters that will have the greatest impact on Total Project Cost
- Determine Parameter Ranges
- Re-Estimate System Costs
  - Change one Parameter Value at a Time
  - Compare new System Estimate to Baseline
Approximation

- Normally Accomplished at System Level
  - Determine or Identify Items containing Uncertainty
  - Rate the Uncertainty as Nominal, Low, or High
  - Based on Rating, Apply Uncertainty Percentage to System Level Cost
Simulation

- Best Methodology for Developing Probabilistic Estimate
- More Time and Effort Consuming
- Requires Identification of Uncertain Elements
  - Input Parameter Ranges Entered for Each Uncertainty Element
    - Triangular, Normal, Uniform, Beta
- Monte Carlo Simulation Should then be Used for Calculation of Probabilistic Estimate
Parameters used in Uncertainty Analysis
Parameters used in Uncertainty Analysis (SW)

- **Software Size (SLOC, Function Points, COSMIC)**
  - For Uncertainty Analysis, uncertainty in software size should be considered a first order driver
  - Uncertainty values can include:
    - *Contingency*
    - *Expected code growth based on similar past projects*
    - *Factors by subsystem (based on contingencies or default percentage) from Optimistic (e.g., Current Best Estimate mass), to Most Likely, to Pessimistic*
  - Code Growth set specifically by Component based on knowledge of technology readiness
Parameters used in Cost Uncertainty Analysis(SW)

- **Reuse**
  - The assignment of design reuse is typically a judgment call. Often, the level of cost savings associated with reuse that is realized in development is different from that expected based on the proposal. Cost risk due to reuse should be assessed for each component.
  - In True S Reuse is indicated by the amount of Adapted and Reused Code.
  - Other factors typically associated with Reuse:
    - *Scope of Design*
    - *Experience of the Team*

- **Technology Changes/Functional Complexity**
  - Technology changes may occur after the initial proposal. The cost risk of technology changes can be estimated by identifying elements that have a possibility of changing and using relevant calibration values to represent possible best/worst case scenarios.
Types of Cost Uncertainty Analyses Supported by TruePlanning® Framework

- **Method of Moments**
  - FRISK methodology
  - Performed within TruePlanning® framework
  - Simple, fast, accurate
  - Allows estimator to model correlation among components

- **Monte Carlo Simulation**
  - Crystal Ball® and @Risk®
  - Performed outside of TruePlanning® framework
  - TruePlanning® interfaces with applications through “companion apps”
  - Third-party software license required
FRISK: Set Cost Uncertainty Inputs
FRISK: View Cost Uncertainty Outputs at Object-level
## MONTE CARLO: Simulation in Crystal Ball

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<td>1</td>
<td>Risk Example -- Communication System - TruePlanningAdmin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Cost Object Name</td>
<td>Cost Object Type</td>
<td>Cost</td>
<td>Input Name</td>
<td>Value</td>
<td>Unit</td>
</tr>
<tr>
<td>3</td>
<td>Risk Example -- Communication System</td>
<td>System Folder</td>
<td>$78,241,377</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Program Management</td>
<td>System</td>
<td>$78,241,377</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Project Initiation and Planning for Development</td>
<td></td>
<td>$716,990</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Project Management and Control for Development</td>
<td></td>
<td>$3,452,238</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Assembly, Integration &amp; Test</td>
<td>Assembly</td>
<td>$60,854,459</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>8</td>
<td>System Design</td>
<td></td>
<td>$935,740</td>
<td></td>
<td></td>
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<tr>
<td>9</td>
<td>Software Integration and Test</td>
<td></td>
<td>$1,885,016</td>
<td></td>
<td></td>
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<tr>
<td>10</td>
<td>Datalink Antenna</td>
<td>Hardware Component</td>
<td>$175,538</td>
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</tr>
<tr>
<td>11</td>
<td>Development Engineering</td>
<td></td>
<td>$103,427</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>12</td>
<td>Production Manufacturing</td>
<td></td>
<td>$47,100</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>13</td>
<td>Pre-Amplifier</td>
<td>Hardware Component</td>
<td>$12,642,313</td>
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<td>14</td>
<td>Development Engineering</td>
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<td>$4,153,041</td>
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<td></td>
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<tr>
<td>15</td>
<td>Production Manufacturing</td>
<td></td>
<td>$5,847,789</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Communications Mgt Unit</td>
<td>Hardware Component</td>
<td>$9,930,876</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Development Engineering</td>
<td></td>
<td>$3,975,417</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Crystal Ball: View Cost Risk Outputs at Any Level

Forecast: Communications Mgt Unit 3 Production Manufacturing

Summary:
- Entire range is from 94,944.52 to 138,515,241.77
- Base case is 4,177,469.71
- After 100 trials, the std. dev. of the mean is 2,494,778.64

Statistics:
- Trials: 100
- Base Case: 4,177,469.71
- Mean: 16,859,927.72
- Median: 6,514,855.45
- Mode: 6,514,855.45
- Standard Deviation: 24,947,766.96
- Variance: 628,579,664,306
- Skewness: 2.65
- Kurtosis: 11.11
- Coeff. of Variability: 1.48

Forecast values:
- 0%: 94,944.52
- 10%: 675,921.92
- 20%: 1,379,911.20
- 30%: 2,176,221.74
- 40%: 4,041,551.55
- 50%: 6,399,090.31
- 60%: 11,920,821.00
- 70%: 16,254,762.92
- 80%: 25,564,138.85
- 90%: 41,321,563.62
- 100%: 138,515,241.77
Observations/ Q&A
Backup
Parameters used in Cost Uncertainty Analysis (HW)

- **Mass (aka, Weight)**
  - For Risk Analysis, uncertainty in mass is used as a first order driver
  - Uncertainty values can include:
    - *Contingency Mass (proposed)*
    - *Expected weight growth based on similar past projects*
    - *Factors by subsystem (based on contingencies or default percentage) from Optimistic (e.g., Current Best Estimate mass), to Most Likely, to Pessimistic*
  - Mass Growth set specifically by Component/Instrument

- **Example distributions for Mass Growth**

<table>
<thead>
<tr>
<th>Weight of Structure/Electronics</th>
<th>Approach #1</th>
<th>Approach #2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Optimistic</td>
<td>Optimistic</td>
</tr>
<tr>
<td></td>
<td>Most-Likely</td>
<td>Most-Likely</td>
</tr>
<tr>
<td></td>
<td>Pessimistic</td>
<td>Pessimistic</td>
</tr>
<tr>
<td>CBE</td>
<td>CBE</td>
<td>(CBE + (CBE*Cont)) *1.3</td>
</tr>
<tr>
<td>CBE*(1+ Growth)</td>
<td>Likely*1.3</td>
<td>(CBE*Cont) *1.3</td>
</tr>
</tbody>
</table>

- Mass-growth contingencies, by subsystem, are assigned individually for each Spacecraft Bus element and Payload instrument, via a Dictionary in the Crystal Ball solution below
Parameters used in Cost Uncertainty Analysis (HW)

- **Heritage**
  - The assignment of design heritage is typically a judgment call. Often, the level of heritage cost saving that is realized in development is different from that expected based on the proposal. Cost risk due to heritage may be addressed by bounding the best/worst case heritage for specific components or the system in general.
  - Heritage affects Percent New Design (Structure and Electronics):
  - It also affects Engineering Complexity
    - *Scope of Design*
    - *Experience of the Team*

- **Manufacturing Complexities**
  - Technology changes may occur after the initial proposal. The cost risk of technology changes can be estimated by identifying hardware elements that have a possibility of changing and using relevant calibration values to represent possible best/worst case scenarios.
### Uncertainty Ranges

- Example distributions for TruePlanning parameters

<table>
<thead>
<tr>
<th>Functional Complexity</th>
<th>Approach 1</th>
<th>Approach 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Optimistic</td>
<td>Most Likely</td>
</tr>
<tr>
<td>Optimistic</td>
<td>.85*CBD</td>
<td>CBE</td>
</tr>
<tr>
<td>Most Likely</td>
<td>.95*CBE</td>
<td>CBE</td>
</tr>
<tr>
<td>Pessimistic</td>
<td>1.05*CBE</td>
<td>CBE</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reused Size</th>
<th>Approach 1</th>
<th>Approach 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Optimistic</td>
<td>Most Likely</td>
</tr>
<tr>
<td>Optimistic</td>
<td>.95*CBE</td>
<td>CBE</td>
</tr>
<tr>
<td>Most Likely</td>
<td>.95*CBE</td>
<td>CBE</td>
</tr>
<tr>
<td>Pessimistic</td>
<td>1.15*CBE</td>
<td>CBE</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Organizational Productivity</th>
<th>Approach 1</th>
<th>Approach 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Optimistic</td>
<td>Most Likely</td>
</tr>
<tr>
<td>Optimistic</td>
<td>.98*CBE</td>
<td>CBE</td>
</tr>
<tr>
<td>Most Likely</td>
<td>.95*CBE</td>
<td>CBE</td>
</tr>
<tr>
<td>Pessimistic</td>
<td>1.05*CBE</td>
<td>CBE</td>
</tr>
</tbody>
</table>
Step-By-Step Process:
Crystal Ball Methodology to Assess Risk
TruePlanning / Crystal Ball Solution Usage

1. Launch the latest version of the TruePlanning/Crystal Ball Solution.
2. Select the TruePlanning ribbon.
3. Click the “Create Dictionary” button and provide a name for the dictionary and a path to the target project.
4. Click the “Open Project” button.
5. Select the inputs to be used in the analysis.
6. For each selected input, select a min/mid/max formula, growth value and indicate if the dictionary should be used.
7. Select the dictionary to be used.
8. Click OK and provide the path to the TruePlanning project to be used.
TruePlanning / Crystal Ball Solution Usage

1. Launch Crystal Ball. This will result in Excel opening with the Crystal Ball ribbon.

2. Open a copy of the TruePlanning / Crystal Ball Solution in the instance of Excel that opened when Crystal Ball was launched.

3. Click on the TruePlanning ribbon.
TruePlanning / Crystal Ball Solution Usage

4. Create a dictionary by clicking the “Create Dictionary” button. Note: If the dictionary to be used already exists, skip to step 9.

5. Provide a name for the Excel sheet that will receive the dictionary information and provide the path to the TruePlanning *.tpprj file that contains the TruePlanning project to be analyzed. Click “OK”.

6. If prompted, select the appropriate connection name. The default connection name is “(local)”. It is unlikely that users will be prompted to select a connection name.
7. A sheet with the name provided in the above dialog will have been created and populated with the PBS from the selected TruePlanning project. Additionally, 5 columns are created to represent the 5 inputs that can be set up as Crystal Ball assumptions.
8. On this sheet, growth or contingency values can be entered for specific PBS elements. They will be used later in the setup of Crystal Balls’ assumption distributions.
TruePlanning / Crystal Ball Solution Usage

9. Click the “Open Project” button on the TruePlanning ribbon.

10. The Setup Run dialog is launched.
11. The Setup Run dialog allows users to configure up to 5 inputs from the Hardware Component Cost Object to be used as assumptions in the Crystal Ball analysis.

12. To setup an input 6 attributes must be set:
   a. Name of input
   b. Optimistic / Min formula
   c. Likely / Mid formula
   d. Pessimistic / Max formula
   e. Provided Growth/Contingency value
   f. Use Dictionary Growth/Contingency checkbox

13. List of available inputs:
   a. Weight of Structure
   b. Weight of Electronics
   c. Percent of New Structure
   d. Percent of New Electronics
   e. Engineering Complexity
   f. Manufacturing Complexity of Structure
   g. Manufacturing Complexity of Electronics
TruePlanning / Crystal Ball Solution Usage

14. List of formulas:
   a. 80% of CBE
   b. 90% of CBE
   c. 95% of CBE
   d. CBE
   e. 102% of CBE
   f. 105% of CBE
   g. 110% of CBE
   h. 120% of CBE
   i. CBE * (1 + Growth)
   j. Likely * 1.3
   k. CBE * 1.3
   l. (CBE + (CBE*Contingency))*1.3

15. Growth / Contingency values: The “Setup Run” dialog has two settings for supplying growth/contingency values to the formulas used to set up the Crystal Ball assumptions.
   a. Provided Growth input: this input allows users to set a single value for all assumptions created for an input.
   b. Use Dictionary Growth: this check box indicates that formulas for this input should obtain their growth/contingency values from the selected dictionary. This allows unique growth/contingency values to be used for each PBS element.
16. Presets: There are four radio buttons in a group box at the bottom of the Setup Run dialog. Selecting one of these radio buttons will fill in the settings of the dialog for a preconfigured setup. This allows users to quickly reproduce the same setup. The settings defined by a preset can be configured.
17. Select a dictionary to be used. Note: A dictionary must be selected. The selected dictionary needs to have a PBS structure that matches the TruePlanning project that will be selected for use with the Crystal Ball analysis. Use the pulldown at the bottom of the dialog.
18. Click “OK” on the Setup Run dialog to setup the Crystal Ball forecasts and assumptions. Users will be prompted to select a TruePlanning project file (*.tpprj). When complete “Sheet 1” will contain the PBS of the targeted TruePlanning project with the appropriate Cost Objects’ estimate costs set as forecasts and the selected inputs set as assumptions.
Observations/ Q&A
Using Functional Size and Source Code to estimate ERP and Cloud Based Big Data Analytics

Software & IT CAST
NGA
August 2016

David P. Seaver
Senior Technical Analyst
National Security Agency
Unclassified for official use only
Outline

• Counting before Estimating
• Size Estimation
• Functional Size Example
• NSA Sizing Customizations
  – Analytics
  – ERP/COTS
• Wrap up
Before you estimate you need to Count!

Count what you have done before, so you can estimate using historical data.

Count what you are going to do, so you can have configuration control of your cost estimate and your program.
## Count, Calculate, Judge and Advise

<table>
<thead>
<tr>
<th>Count if possible</th>
<th>Calculate when done counting</th>
<th>Judge and Advise only as a last resort</th>
</tr>
</thead>
</table>
| • Earlier is always better than latter  
• Must be correlated to the scope of what you are estimating | • Convert what you have counted into an estimate using history from somewhere. Local history is always best.  
• History has to relate to what you count | • Only when you don’t have data  
• Pressure will be to be optimistic away from reality |
<table>
<thead>
<tr>
<th>NSA Counts.....</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Source code for every possible project.</strong></td>
</tr>
<tr>
<td>- Use a NSA tailored version of University of Southern California UCC</td>
</tr>
<tr>
<td>- Customization identifies</td>
</tr>
<tr>
<td>- GOTS, COTS and FOSS</td>
</tr>
<tr>
<td>- Test Code</td>
</tr>
<tr>
<td>- Duplicate code</td>
</tr>
<tr>
<td>- Auto-generated Code</td>
</tr>
<tr>
<td><strong>Functional size of Requirements using a streamlined Function Point technique</strong></td>
</tr>
<tr>
<td>- Simple Function Points</td>
</tr>
</tbody>
</table>
NSA Does Not Count

Delivered Function Points

- Information is not accessible
- Difficulty in obtaining access to working applications
- Not enough resources to perform manual counts

We are evaluating an automated function point capability that we will be piloting in the Fall of 2016

- CAST Software’s implementation of the CISQ functional size standard
- www.cisq.org & www.castsoftware.com
- Automated Counts will be done in tandem with USC UCC code counts on projects that are at or near completion
Size: Source Lines of Code Issues and Solutions

- No defined counting rules of standards organization
- Inconsistent rules mean there is no reliable and verifiable industry data
- Penalizes efficient software writing and incentivizes poor coding
- Heavily dependent on developer skills and style
- Difficult to estimate early in life cycle.
- Not all development creates source code

- Use USC UCC to standardize rules
- Don’t pay for lines of code, We purchase systems not code
- Use functional size too
- Easy to count at completion
- Agree, and most developers don’t use code to plan projects

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Functional Size

Why does NSA use Functional Size?

What is Functional Size?

What are Simple Function Points (SFP)?
## Software Size

<table>
<thead>
<tr>
<th>Source Lines of Code (SLOC)</th>
<th>Functional Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Difficult for now SW engineers to estimate source code early in a program (and most for most SW engineers too)</td>
<td>• Can be estimated early in the program</td>
</tr>
<tr>
<td>• Only becomes really viable during the design phase</td>
<td>• Easy to link to requirements</td>
</tr>
<tr>
<td>• Complications</td>
<td>• Can be used to estimate code size</td>
</tr>
<tr>
<td>• DBMS</td>
<td>• Can be used to estimate effort and cost per requirement</td>
</tr>
<tr>
<td>• COTS, FOSS and GOTS</td>
<td>• <strong>Function Point metrics not meaningful to anyone who is not a cost estimator</strong></td>
</tr>
<tr>
<td>• Difficult to link code back to requirements</td>
<td></td>
</tr>
<tr>
<td>• Can be measured on a completed project</td>
<td></td>
</tr>
<tr>
<td>• <strong>Code metrics not meaningful to developers</strong></td>
<td></td>
</tr>
</tbody>
</table>
Function Point Analysis

Classic Function Point analysis (IFPUG version) is based on 5 components:

- Inputs (adding, updating, deleting data in an application)
- Outputs/Reports that displays or sends data that is processed
- Queries that retrieve and display data (no processing of the data)
- Internal Logical Files which is data maintained by your application by either an input or a report
- External Interface Files which is data maintained in another application that your application interfaces with for to accomplish user required functionality
Function Point Analysis

Function points are calculated by assigning a complexity to the transaction or data entities based on the number of unique fields in each, the files referenced to meet user requirements, or the data types for each of the logical file categories.

- Based on scoring complexity are Low, Average or High
- Function Points scores can range between 3, 4, 5, 7, 10 and 15 function points depending on the complexity

- [www.ifpug.org](http://www.ifpug.org)
Input Transaction: New Contact

- Can input, edit or delete data on this screen
- 3 transactions one data entity (save)
- 26 fields 9(detail button)
- Map It could be a query
- Buttons are for navigation?

Inputs process information that enters the application, the information maintains a logical file
Logical File

- Employees
  - Salaried
    - Technical
    - Management
    - Human Resources
  - Hourly
    - Call Center
    - Contractor
    - Part Time

External Vendor Data Read-Only

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NSA Reality

• Estimates are required very early in the life cycle
• We don’t have design artifacts
• We estimate from a variety of requirements documents
  – Do not have level of detail of fields on screens
  – Can’t count or estimate fields in a database table
• We have adopted a streamlined Functional Size technique called Simple Function Points.
Simple Function Points

• Simple Function Points (SFP)
• SFP counts two components
  – Elementary Process: which is defined as the smallest level of activity that is meaningful to the user
  – Logical Data Groups: A user identified group of data or control information maintained by an application
    – www.sifpa.org/en/index.htm for more information
• Since we are counting requirements it is not possible to perform an IFPUG function point count.
• User group meetings are in Italy
Process to Estimate Software

1. Start here
2. Description of Solution
   - Identify the boundary of the application
     - What data is maintained by the application
     - What data feeds need to be accommodated
     - External data sources
   - Count elementary processes
     - Create, Update, Delete, Report, Read/Query
   - Count data groups
     - Maintained by elementary process
     - Data in other applications that is utilized to support an elementary process
3. Enter information in SFP Toolkit
4. Calculate Software Size, Effort and Schedule
5. Review with Stakeholders and revise as needed
6. Calibrate
   - SLOC from UCC
   - Automated Function Points

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The RV Baseball Analytics
This is based on a real life example, the words have been changed to protect the innocent

EXAMPLE
The RV Baseball Analytics

• **Program Description:** The RV Baseball Analytic (RVBA) Ingest and process all available data from MLB ballparks and Television Broadcasts to provide state of the art analytics for MLB teams and MLB.

• 5 RVBA Requirements were identified
  – Ingest and Automation
  – Balls and Strikes Analytics
  – Instant Replay Analytics
  – Umpire Analytics
  – Baseball Commissioner Analytics
## Functional Size Ingest and Processing

<table>
<thead>
<tr>
<th>Sort</th>
<th>Requirement</th>
<th>Requirement Description</th>
<th>Note</th>
<th>Create</th>
<th>Update</th>
<th>Delete</th>
<th>Read</th>
<th>Report</th>
<th>Save</th>
<th>Multiplier</th>
<th>Data Multiplier</th>
<th>Transaction Count</th>
<th>Data Count</th>
<th>Function Points</th>
<th>ESLOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Data Ingest &amp; Processing</td>
<td>&gt; 70 different data types</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>75</td>
<td>75</td>
<td>1</td>
<td>75</td>
<td>225</td>
<td>75</td>
<td>1,560</td>
<td>85,800</td>
</tr>
<tr>
<td>1</td>
<td>Data Ingest &amp; Processing</td>
<td>meta data associated with core data types</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>75</td>
<td>75</td>
<td>225</td>
<td>75</td>
<td>1,560</td>
<td>85,800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Data Ingest &amp; Processing</td>
<td>Monitoring and screening of the data ingest stream</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
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<td>21</td>
<td>1,144</td>
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</tr>
<tr>
<td></td>
<td>Subtotal</td>
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<td>453</td>
<td>151</td>
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<td>172,744</td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>
# Functional Size for Analytics

<table>
<thead>
<tr>
<th>Sort</th>
<th>Requirement</th>
<th>Requirement Description</th>
<th>Note</th>
<th>Create</th>
<th>Update</th>
<th>Delete</th>
<th>Read</th>
<th>Report</th>
<th>Save</th>
<th>Multiplier</th>
<th>Data Multiplier</th>
<th>Transaction Count</th>
<th>Data Count</th>
<th>Function Points</th>
<th>ESLOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Balls and Strikes Analytics</td>
<td>GUI for configuration, 5 data toggles per analytic</td>
<td></td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>28</td>
<td>4</td>
<td>4</td>
<td></td>
<td>157</td>
<td>8,624</td>
</tr>
<tr>
<td>2</td>
<td>4 Analytics</td>
<td>2 reports per analytic (table and graphic) 4 additional configuration options in the report itself</td>
<td></td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>32</td>
<td>0</td>
<td>147</td>
<td>8,096</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Instant Replay Analytics</td>
<td>GUI for configuration, 8 data toggles</td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>21</td>
<td>1,144</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2 Analytics</td>
<td>two different video options, same controls</td>
<td></td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>9</td>
<td>506</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Umpire Analytics</td>
<td>GUI for configuration, 8 data toggles</td>
<td></td>
<td>1</td>
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Sizing Frameworks for Analytics

Data Ingest and processing

- Content data - the basic data you want to analyze
- Metadata - data that provides context for your content data
  - Weather
  - Time of Day
- Reference Data – other data sources that may be referenced
  - Ball park dimensions and features

Object Creation – process data to prepackage information of interest and make it readily accessible

- Player objects
  - Pitcher
  - Fielder
  - Batter
  - Catcher
COTS AND ERP APPLICATIONS

A brief discussion on how this works for COTS and ERP Applications
ERP Perspective

- ERP platform is PEOPLESOFT
- Financials and HR
- RICEW work unit
  - Reports 390
  - Interfaces 97
  - Conversions 50
  - Enhancements 224
  - Workflow 7

% of RICEW Type:
- Reports: 51%
- Enhancements: 29%
- Interfaces: 13%
- Conversions: 6%
- Workflows: 1%
Ongoing Work COTS and ERP

- Developed SFP size for all COTS estimates to date, on average 24 Function Points/Work Unit
- Attempting to derive a Function Point/Person Month metric
- Working with PEOPLETOOLS to update size metrics
  - Outputs CEMLI metrics (next slide) and RICEW object counts
- Running CAST analysis on PEOPLESOFT Code
  - Automated Function Points does not work on PEOPLESOFT
- Attempting to incorporate configuration activities into sizing and estimation of COTS. Have been using $ per work unit for configuration work to date
- Developing a framework to estimate the O&M costs for PEOPLESOFT suite
## COTS Sizing Framework-CEMLI

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<tr>
<th>Sizing Categorization</th>
<th>Sizing comment</th>
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<tr>
<td><strong>Configurations</strong> : Configure the existing, pre-built application features according to your client's requirement. Changing setups and profile values can be the example of configurations.</td>
<td>Typically no code developed, use applications existing screens to implement capability</td>
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<td><strong>Customization</strong> : Customization means altering/changing the standard objects or creation of custom object to meet client's business need. It may be Extensions or Modifications.</td>
<td>Custom Code</td>
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<td><strong>Extensions</strong> : Extension means creating custom code from scratch, existing objects (views, packages and java classes etc) can be used. It is having different behavior from seeded one.</td>
<td>Custom Code</td>
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<td><strong>Modifications</strong> : Modifications is enhancing/changing the existing code to meet the client's requirements. It is the modification of seeded behavior.</td>
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<td><strong>Localization</strong> : It is to define the different legislative support provided by oracle Applications based on country/region/language requirements.</td>
<td>Typically no code developed, use applications existing screens to implement capability</td>
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<td><strong>Integration</strong> : It can be Data Integration or Application Integration, options for these two are Open Interface tables, APIs, EAI(Enterprise Application Integration Tools), BPEL, AQ, EDI etc.</td>
<td>Can be either a configuration activity or require code development.</td>
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<td><strong>Personalization</strong> : Tailoring the layout or visibility of page content to meet client requirements is Personalization. Changing the user interface (UI) look-and-feel, making any field visible/enabled/disabled/mandatory/non mandatory comes under Personalization.</td>
<td>Typically no code developed, use applications existing screens to implement capability</td>
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Conclusions

• We are pleased with SFP results to date
• Estimates are produced more quickly with less overhead
• Workload includes more projects with little or no code developed focus mostly in the business side of the agency
• Will update on progress with CAST at a later date. Install was completed August 16. Will be running some cloud based analytics and PEOPLESOFT as our initial test cases
Back up slides

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### NSA UCC output

Perl shell reads file path and flags GOTS, COTS or FOSS, Identifies duplicate files, test code and flags code as developed or not developed.  

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Analyst filters code > 1000 Logical SLOC and Comments < 5, and manually flags it as auto generated. (Based on NSA data analysis)
# UCC Report

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Query Transaction

A Query lets you retrieve data.

This example has 4 search variables:

1 transaction

A Query retrieves and displays information already in the system, or another system.
A report displays or transmits data that is processed when the report runs. Typically this is some kind of mathematical processing.

This example would be 2 reports one for the table one for the chart.

7 data elements
Function Points +/- for NSA

• Pros:
  – Consolidated by several decades of use
  – Many benchmarks available (ISBGS)
  – Detailed documentation
  – Training
  – Certification

• Cons
  – Time consuming
  – High level of detail required for IFPUG count
  – The wealth of rules are not always easily applicable
  – Limited DoD or US Government data
Count before you Estimate

- How many Jelly Beans in the Jar?
- Closest guess gets a candy bar?
Software Development Agility Scale

Aaron Gregory, Michelle Jones, Geoff Pierce, Ryan Timm, Jenny Murrill

August 2016
Agenda

- Informative References
- Objectives of our Study
- Our Survey
- Our Process for Analyzing Results
- Cross-Agency Participation
- Discussion
The NRO CAAG is encountering more and more programs using agile software methodology, or Scaled Agile Framework (SAFe) in software development.

Government program managers can benefit from the software development team’s responsiveness to change and increased insight into status and backlog compared to programs employing waterfall development methodology.

Programs using agile claim the potential for lower cost: reduce integration cost due to continuous testing, reduce sustainment cost because defects are corrected sooner. These claims are hard to quantify or substantiate, and often involve an up-front investment in automated testing or other infrastructure.

Agile sizing metrics are not standard: the amount of work that equates to a “story point” varies by company, by project, and by team.

The objective of this research project is to better understand business practices associated with Agile, so we can improve cost estimates and Integrated baseline review support for programs applying agile.
The CAPs model identifies commercial practices which reduce costs and provides an adjustment factor for estimating the associated savings.

Could this approach apply to estimating Agile Software Development efforts?
Informative References

Measuring Agility in Software Development. Dan Houston & Steve Rosemergy. Aerospace Corporation, Software Acquisition and Modeling Department

A Model for Estimating Agile Project Process and Schedule Acceleration. Dan Ingold, Barry Boehm, Supannika Koolmanojwong Center for Systems and Software Engineering University of Southern California


Agile Metrics: Progress Monitoring of Agile Contractors. Will Hayes, Suzanne Miller, Mary Ann Lapham, Eileen Wrubel, Timothy Chick. Software Engineering Institute

A Primer on Agile Software Development for Cost Analysts. Qualis Corporation

Maturing the Economics of Agile Development. Jennifer Manring. MITRE.

Our approach is to learn from current research efforts
The paper identifies potential for cost impact of using agile, and concludes the largest area of potential decreased cost lies in sustainment.
Measuring Agility in Software Development

General Agile Characteristics
- Interpersonal interaction
- Working product or service
- Customer/user collaboration
- Responsiveness to change
- Continual delivery of customer value
- Self-organizing, multifunctional collaboration
- Leadership by the motivated
- Technical excellence and simplicity

Similarity: Measuring Agility model surveys projects to measure agility to help programs become more agile

Difference: Our study has a neutral perspective and does not advocate Agile over Plan Driven
A Model for Estimating Agile Project Process and Schedule Acceleration

- Effort is constant and duration can be impacted by a series of factors relative to agility

\[ D = \prod F_i \sqrt{PM} \]

- Similarity: Measuring Agility to estimate an impact to schedule, clearly articulating the factors that make a difference
- Difference: Their assumption is that effort is constant, although the schedule can be compressed
Objective of the Software Development Questionnaire

Objectives

- Develop criteria to place software development programs on a continuum from plan-based to agile
- Identify differing characteristics of software development methodology, testing protocol, and customer interaction associated with agile software methodology
- Quantify potential cost impacts associated with a program’s agility
  - Total Cost
  - Cost Profile
  - SEITPM vs Development vs SW Test

Applications

- Define “agile” based on software development business practices rather than assertions
- Begin to investigate/quantity potential savings associated with agile methodologies (if any) to better estimate costs
- Better informed IBR support.

In coordination with other space, defense and intelligence agencies, we developed and distributed a software development questionnaire.
Agile Acquisition Model

Project Timeline

- **Develop Data Sheet**: 12/15/2015
- **Feedback on data Sheet**: 12/16/2015 – 2/28/2016
- **Survey Administration and PM Interviews**: 3/1/2016 – 6/30/2016
- **Completed Data Sheets**: 7/31/2016
- **Analysis of Data, Study Results**: 8/31/2016
Survey Content

Demographics

Software Development Process

Communication

Testing
Scoring Approach

Primary Method

- Survey has 26 questions
  - 15 are scored, 11 are for demographic purposes
- Each question has equal weighting
  - May assign varied weightings in future analysis
- Each question is scored on a scale of 0 to 6 points
  - Distribution of points within answer choices varies across questions

Illustration by Program

- Points were totaled for three areas: Acquisition and Development Process, Communication and Testing
  - Maximum score is 90 points
- Points were normalized to 10 and charted on a spider graph
Scoring Example

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*Normalized Score is based on 10 possible points
Adventures in Collecting, Evaluating, and Analyzing Army System Data to Objectively Estimate Software Maintenance Costs

Deputy Assistant Secretary of the Army for Cost and Economics (DASA-CE)

24 August 2016
U.S. Army Software Maintenance Initiative

Provide the Department of the Army with the ability to accurately estimate, budget, allocate, and justify the software maintenance resources required to meet evolving mission and service affordability requirements across the system life-cycle.
Our Immediate Focus

• Collection and evaluation of correlated system SWM cost and technical execution data
  - All Army operational systems
  - System and release level
  - Enterprise data call(s) - Phase I and Phase II

• Generation and validation of effective CERs
  - System software functional domains
  - Army software acquisition and sustainment organizations
  - Government and contractor costs
  - Variable and fixed (core) SWM costs

• Instantiation of systemic Army SWM data collection and analysis processes
  - Valid data collection requirements
  - Adaptation of existing financial and technical ERP systems
  - Populated cost and technical data repository

• Addressing Army SWM policy, business, and technical inconsistencies
  - Legislation, regulation, and policy constraints
  - Financial business processes
  - Software engineering life cycle change process(es)
Army Software Maintenance Conflicts

Statute - Policy Requirements
- SWM a component of depot maintenance
- Antiquated “waterfall” definition of SWM
- Colors of money constraints
  - accounting separation
  - usage restrictions
- Organizational responsibility
- Governance variations
- Contracting

Budgeting-Accounting Process
- Financial vs. Cost accounting constructs
- LOE budgeting/obligation model
- Focus on funding - not execution
- Fixed vs. variable costs
- Execution volatility
- System capabilities/limitations

Software Engineering - Change Integration Process
- Incremental release process - development and sustainment
- Continuous system software life cycle development and update
- “Pre-Planned” technical (mission) debt - deferred functionality
- Financial and technical “spillover” - development to sustainment
- Dedicated system software teams - all life cycle phases
- Emergent software change volume, technical, and management drivers
Overarching Result

There is no direct accounting that relates the dollars expended with the software maintenance products delivered to the warfighter.
Pertinent Discussion Points

• How do we define Army Software Maintenance?
  - What’s In - What’s Out?
  - What are our SWM output products? Changes? Releases? Capabilities?
  - What types of dollars pay for what?
  - Where/how are the dollars executed?
  - Maintenance vs. Sustainment?

• What is the utility of the data we are currently collecting with respect to cost estimation?
  - Satisfaction of system and enterprise stakeholder information requirements?
  - Data characterization and evaluation?
  - Ability to generate valid CERs?
  - How do we improve?

• Can we really expect to implement the changes that we need to effectively manage the operational software change process?
  - Cost accounting rather than financial accounting
  - Cost-to-product allocations in an environment defined by LOE constraints
  - Movement towards data informed - rather than arbitrary - resourcing decisions
  - Execution focus rather than planning focus
  - Software change “portfolio” management within the enterprise
  - Linking dollars to mission capability
DASA-CE SWM Definition

Software Maintenance

• Software maintenance includes all software change activities and products associated with modifying a software system after EMD has completed and a software release has been provided to an external party.

• The release is the primary SWM change product - a composite of one or more changes - it can be either a formal release or an engineering release.

• SWM includes software enhancements and software corrections/adaptations.

• SWM includes activities and change products funded by multiple funding sources (RTDE, Production, OMA, FMS, OCO, etc.).

• Fixed and Variable costs accrued at both the system and organizational levels by both organic and contractor resources.

• Software maintenance and software sustainment are considered to be synonymous.
Army Software Maintenance WBS

Version 4.4d
Notional Cost - Army SWM Change Product

System Release 5-2016 a

- Capability Upgrades
- Release Project Mgt.
- Corrective Changes
- Security Certification
- IAVA Changes
- Adaptive Changes
- Allocated “Core” System & Organizational Fixed Costs

Multiple appropriations funding different types of changes integrated into the same release
Each appropriation requiring a separate accounting path
Army Software Maintenance Data
Software Maintenance Data Call

- **Purpose** - Collect software maintenance data to inform cost models, data availability, data requirements, and to initiate the systemic collection of software cost and correlated technical measures.

- **Phase I Status**
  - Received and verified data from 56 programs
  - Currently developing cost models and cost estimating relationships (CERs) (Nov 2016)

- **Phase II Status**
  - Identified 205 systems for data collection
  - Developed phased plan for data collection and verification
  - Currently validating submissions received to date (65 programs)

- **Ongoing** – Update cost model and CERs on an incremental basis as additional data is received and verified
Data Requirements

- System Level Data
  - Context information
  - Organizations involved

- Annual effort/cost data (WBS elements #2 through #8, plus total annual)

- Release level data
  - Release context information
  - Operating environment
  - Application domain
  - Size data (those that apply)
    - Software requirements
    - External requirements
    - Source Lines of Code (SLOC)
    - Non-SLOC based size (e.g. RICE-FW, use cases, story points)
    - Software changes counts by priority (e.g. change requests, problem reports, defects)
    - IAVAs
  - Release effort/cost (WBS element #1)
  - Schedule - start and end dates

- Details on Software Licenses
  - Right to use and maintenance
Data Evaluation Factors

**Availability**
- Completeness of required data set - compliance to scope
- Underlying SWM business and technical processes are well enough defined to produce objective data on a periodic and/or event driven basis
- IT systems and tools exist to enable systematic and timely data collection
- Stakeholder cooperation

**Integrity**
- Data are derivatives of actual SWM technical and management processes
- All data (measures) are explicitly defined - measurement contexts are known
- Cost data is directly correlated with the WBS defined output products & activities
- Data is consistent - methods exist to address system conflicts (normalization)
- Parameter relationships are consistent

**Usability**
- Data is aligned with stakeholder decision information needs
- Data can be objectively characterized and interpreted
- Mapping and aggregation structures and methods exist to combine data
- Potential emerging information requirements have been considered
## Phase 1 - Program Summary Data

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### Evaluation of Phase 1 Data

#### System Summary Data

- Data was provided for 56 systems
- System data was provided as follows:
  - Total system SWM effort/cost: 42 systems
  - Certification and accreditation cost: 35 systems
  - License costs: 41 systems

#### Total Program Effort/Cost

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<td>G</td>
<td>N/A</td>
<td>N/A</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>PEO 3 SEC 1 System 14 v1</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>N/A</td>
<td>N/A</td>
<td>G</td>
<td>N/A</td>
<td>G</td>
<td>G</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEO 3 SEC 3 System 15 V1</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>N/A</td>
<td>R</td>
<td>N/A</td>
<td>G</td>
<td>G</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEO 3 SEC 3 System 15 V2</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>N/A</td>
<td>R</td>
<td>N/A</td>
<td>G</td>
<td>G</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Release Data**

- Releases are the deliverable software maintenance change products - they incorporate one or more software changes
- Data was provided for 188 releases
- 154 releases could provide at least one size measure
  - 64 releases provided 3 or more size measures
- Data that was usable for creating Estimating Relationships were provided for:
  - Cost (CERs): 65 releases (actual/FTE effort), 46 releases (planning effort)
  - Schedule (SERs): 76 releases, 45 releases

<table>
<thead>
<tr>
<th>Initial Release Overall</th>
<th>Detailed Release Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CER Useability</td>
</tr>
<tr>
<td>R</td>
<td>76</td>
</tr>
<tr>
<td>O</td>
<td>46</td>
</tr>
<tr>
<td>Y</td>
<td>27</td>
</tr>
<tr>
<td>G</td>
<td>38</td>
</tr>
<tr>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>188</td>
</tr>
</tbody>
</table>
SWM Data Collection Challenges

- Master system list
- Collection of both contractor and government data
  - Limited collection mechanisms today for contractor SWM data
  - Government labor
- Government doesn’t always have detailed contractor data
- Availability and quality of data
  - Data in proper units of measurement
  - Data for all WBS elements (e.g. COTS, facilities, C&A)
  - Significant amount of rework/normalization required for analysis
- Wide scale implementation of data
  - Contractor AND government
  - Questionnaire? SRDR-M (revised)? CDRL? Level of automation
  - Ability to collect cost data that ties to SWM technical data
  - Cost CDRL - CEM WBS - SRDR-M - financial systems (Army GFEBS) - invoices
Notional Data Collection Process

- **SWM System Cost**
- **Contractor Cost**
- **Government Cost**
- **Central Repository**
  - Army Wide Accessibility
  - V&V Capabilities
  - Managed by ODASA-CE
  - Analytic Capabilities
- **GFEBS**
  - System Level Cost – via Master Weapon System List

Unified CDRL

Government Labor Tracking Tool
SWM Phase I CER

Total Cost per IAVA Distribution

ESLOC (K) vs Total Release Cost (K)

- Graph above (left) depicts the distribution of total cost per IAVA
- Graph above (right) shows the relationship between equivalent source lines of code and the total release cost
- This data facilitates informed decision making based on historical program data and can provide a realism check of future estimates
- Cost model will include use cases, directions for implementation, and will address all OMA categories

*CERs displayed are draft and should not be used for decision making
The Way Ahead

• Can we really expect to implement the changes that we need to effectively manage the operational software change process?
  - Cost accounting rather than financial accounting
  - Cost-to-product allocations in an environment defined by LOE constraints
  - Movement towards data informed - rather than arbitrary - resourcing decisions
  - Execution focus rather than planning focus
  - Software change “portfolio” management within the enterprise
  - Linking dollars to mission capability

• Enablers
  - Acquisition focus on life cycle software sustainment cost projections - OSRs
  - Arbitrary and significant OMA funding cuts
  - Significant reduction in OCO funding
  - Emerging Army policy

• Strategy
  - Initiate the implementation of an Army software maintenance “information infrastructure”
  - Systemic system software maintenance data collection using existing ERP assets
  - Enterprise reporting of executed costs
  - Software maintenance data repository
  - Expanded set of SWM CERs - Updated estimation methodology
  - Service and DOD collaboration
Army Directive 2016-16
Changing Management Behavior: Every Dollar Counts

“The goal is to achieve the highest level of readiness given the resources provided”

“Be singularly focused on achieving the highest level of readiness with the greatest efficiency”

“Avoid using budget execution data and obligation rates as the primary measure of fiscal success”

“Tie resource expenditures to outcomes”
Points of Contact

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COSYSMO 3.0: The “Expert” Model

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Software and IT CAST
Lockheed Martin Global Vision Center
August 24, 2016

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  Dr. Barry W Boehm
  Dr. Jo Ann Lane
  Mr. Garry Roedler  Lockheed Martin
  Dr. Gan Wang  BAE Systems
  Ms Marilee Wheaton  The Aerospace Corporation
COSYSMO 3.0 Objectives

• Context:
  – Current and future trends create challenges for full-system cost estimation
    • Emergent requirements, rapid change, net-centric systems of systems, COTS, clouds, apps, widgets, high assurance with agility, multi-mission systems
  – Current development practices can minimize cost of one phase, such as development, while raising full-system cost

• COSYSMO 3.0 is being developed to mitigate this situation by supporting accurate estimates of systems engineering costs, with benefits including:
  – Allowing thoughtful system-level systems engineering during development, which can result in, for example, choosing new technologies that reduce total system cost
  – Allowing thoughtful engineering of systems to support life-cycle flexibility
Agenda:

• The motivation for COSYSMO 3.0
• History of COSYSMO 3.0
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• Summary
COCOMO Family of Cost Models

Software Cost Models

- COCOMO 81 1981
- COCOMO II 2000
- DBA COCOMO 2004
- COINCOMO 2004, 2012

Other Independent Estimation Models

- COCOTS 2000
- COSYSMO 2005
- COSYSMO-SoS 2007

Software Extensions

- COQUALMO 1998
- iDAVE 2004
- COPLIMO 2003
- COPSEMO 1998
- AGILE C II 2003
- COTIPMO 2011
- COPROMO 1998
- CORADMO 1999, 2012

Legend:
- Model has been calibrated with historical project data and expert (Delphi) data
- Model is derived from COCOMO II
- Model has been calibrated with expert (Delphi) data

Dates indicate the time that the first paper was published for the model.
History of COSYSMO Models

COSYSMO 1.0
Valerdi, 2005

- Identifies form of model
- Identifies basic cost drivers
- Identifies Size measure

With Reuse
Wang et al, 2008

- Adds weights to Size elements, reducing net Size in the presence of reuse

Req’ts Volatile
Pena, 2012

- Adds scale factor based on requirements volatility

For Reuse
Wang et al, 2014

- Adds weights to Size elements, reducing net Size when artifacts are only partially completed

Sys of Sys
Lane et al, 2011

- Adds effort multiplier when in the presence of system-of-systems

COSYSMO 3.0
Alstad, 2016?

- Integrates features of previous models
COSYSMO 3.0 Directions

Incorporate and harmonize existing COSYSMO model research and experience for estimating systems engineering effort:

• Several factors affecting the COSYSMO cost model have been shown to be valuable in increasing estimation accuracy (terminology from [24]):
  – Reuse (partial model—Development With Reuse) [3, 24]
  – Reuse (with Development For Reuse) [24]
  – Requirements volatility (RV) [4]

The rating scales for these could be integrated into a comprehensive COSYSMO model.

Enhancement included:

• System-of-system considerations are hypothesized to affect system engineering costs:
  – Interoperability considerations [6]
COSYSMO 3.0 Directions

Part 2

Enhancements under discussion:

• Explore a model for total development cost based primarily on the COSYSMO parameters (following work led by Reggie Cole of Lockheed Martin [17, 7])
Agenda:

- The motivation for COSYSMO 3.0
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COSYSMO 3.0
Top-Level Model

\[ PH = A \times (\text{AdjSize})^E \times \prod_{j=1}^{15} EM_j \]

Elements of the COSYSMO 3.0 model:

- **Calibration parameter A**
- **Adjusted Size model**
  - eReq submodel, where 4 products contribute to size
  - Reuse submodel
- **Exponent (E) model**
  - Accounts for diseconomy of scale
  - Constant and 3 scale factors
- **Effort multipliers EM**
  - 15 cost drivers
Harmonized COSYSMO 3.0
Size Model

\[ AdjSize_{C3} = \sum_{SizeDrivers} eReq(\text{Type}(SD), \text{Difficulty}(SD)) \times \]

\[ \text{PartialDevFactor}(AL_{\text{Start}}(SD), AL_{\text{End}}(SD), RType(SD)) \]

- **SizeDriver** is one of the system engineering products that determines size in the COSYSMO family (per [2]). Any product of these types is included:
  - System requirement
  - System interface
  - System algorithm
  - Operational scenario

- There are two submodels:
  - Equivalent nominal requirements (“eReq”)
    - Raw size
  - Partial development
    - Adjusts size for reuse
The eReq submodel is unchanged from [2].
The submodel computes the size of a SizeDriver, in units of eReq ("equivalent nominal requirements")
Each SizeDriver is evaluated as being easy, nominal, or difficult.
The following table contains conversion factors for the conversion of a SizeDriver to a number of eReq:

<table>
<thead>
<tr>
<th>Size Driver Type</th>
<th>Easy</th>
<th>Nominal</th>
<th>Difficult</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Requirement</td>
<td>0.5</td>
<td>1.0</td>
<td>4.5</td>
</tr>
<tr>
<td>System Interface</td>
<td>1.9</td>
<td>4.0</td>
<td>9.0</td>
</tr>
<tr>
<td>System Algorithm</td>
<td>1.9</td>
<td>3.8</td>
<td>9.8</td>
</tr>
<tr>
<td>Operational Scenario</td>
<td>6.4</td>
<td>13.6</td>
<td>26.3</td>
</tr>
</tbody>
</table>
How Reuse Is Addressed

Reuse has two aspects [1]:

• **Development with reuse (DWR):** previously developed artifacts are reused on the current project
  – Addressed completely by the DWR partial development model

• **Development for reuse (DFR):** the current project is creating artifacts to be reused on other projects
  – One aspect of DFR development is that DFR costs more than ordinary development
    • Addressed by the DFR cost driver (below)
  – Another aspect of DFR is that the artifacts may be only partially completed, as during an IR&D project
    • Addressed by the DFR partial development model
Size Model – Partial Development Submodel

(Concepts here are simplified a little)

The basic DWR concept:

- If a reused SizeDriver is being brought in, that saves effort, and so we adjust the size by multiplying the raw size by a PartialDevFactor less than 1.
- The value of PartialDevFactor is based on the maturity of the reused SizeDriver, and is looked up in a table [24].
  - How fully developed was the SizeDriver?
- If there is no reuse for this SizeDriver, then PartialDevFactor = 1 (no adjustment).

<table>
<thead>
<tr>
<th>DWR Activity Level:</th>
<th>New</th>
<th>Design Modified</th>
<th>Design Implemented</th>
<th>Adapted for Integration</th>
<th>Adopted for Integration</th>
<th>Managed</th>
</tr>
</thead>
<tbody>
<tr>
<td>DWR % for this AL through end</td>
<td>100.00%</td>
<td>83.00%</td>
<td>70.13%</td>
<td>56.88%</td>
<td>37.82%</td>
<td>17.50%</td>
</tr>
</tbody>
</table>

The basic development-for-reuse (DFR) concept is analogous:

- A product to be reused may be not be taken through the full development cycle (e.g., an IR&D project)

<table>
<thead>
<tr>
<th>DFR Activity Level:</th>
<th>Conceptualized for Reuse</th>
<th>N/A</th>
<th>Designed for Reuse</th>
<th>Constructed for Reuse</th>
<th>N/A</th>
<th>Validated for Reuse</th>
</tr>
</thead>
<tbody>
<tr>
<td>DFR % from start through this AL</td>
<td>31.96%</td>
<td>54.60%</td>
<td>78.06%</td>
<td>90.69%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
COSYSMO 3.0
Exponent Model

• Exponent model is expanded from Peña [4, 9]

\[
E = E_{\text{Base}} + S F_{\text{ROR}} + S F_{\text{PC}} + S F_{\text{RV}}
\]

Where:
• \( E_{\text{Base}} \) = A minimum exponent for diseconomy of scale
• SF = scale factor
• \( ROR \) = Risk/Opportunity Resolution
• \( PC \) = Process Capability
• \( RV \) = Requirements Volatility

The effect of a large exponent is more pronounced on bigger projects
Harmonized COSYSMO 3.0 Cost Driver Model

Here are the 15 cost drivers:

<table>
<thead>
<tr>
<th>Driver Name</th>
<th>Data Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONOPS &amp; requirements understanding</td>
<td>Subjective assessment of the CONOPS &amp; the system requirements</td>
</tr>
<tr>
<td>Architecture understanding</td>
<td>Subjective assessment of the system architecture</td>
</tr>
<tr>
<td>Stakeholder team cohesion</td>
<td>Subjective assessment of all stakeholders</td>
</tr>
<tr>
<td>Level of service requirements</td>
<td>Subjective difficulty of satisfying the key performance parameters</td>
</tr>
<tr>
<td>Technology risk</td>
<td>Maturity, readiness, and obsolescence of technology</td>
</tr>
<tr>
<td># of Recursive levels in the design</td>
<td>Number of applicable levels of the Work Breakdown Structure</td>
</tr>
<tr>
<td>Development for reuse</td>
<td>Is this project developing artifacts for later reuse?</td>
</tr>
<tr>
<td># and Diversity of installations/platforms</td>
<td>Sites, installations, operating environment, and diverse platforms</td>
</tr>
<tr>
<td>Migration complexity</td>
<td>Influence of legacy system (if applicable)</td>
</tr>
<tr>
<td>Interoperability</td>
<td>Degree to which this system has to interoperate with others</td>
</tr>
<tr>
<td>Personnel/team capability</td>
<td>Subjective assessment of the team’s intellectual capability</td>
</tr>
<tr>
<td>Process capability</td>
<td>CMMI level or equivalent rating</td>
</tr>
<tr>
<td>Personnel experience/continuity</td>
<td>Subjective assessment of staff consistency</td>
</tr>
<tr>
<td>Multisite coordination</td>
<td>Location of stakeholders and coordination barriers</td>
</tr>
<tr>
<td>Tool support</td>
<td>Subjective assessment of SE tools</td>
</tr>
</tbody>
</table>
Harmonized COSYSMO 3.0
Cost Driver Impacts

Cost Driver Impacts (EMRs) in COSYSMO 3.0 v35

- DFR
- Tool Support
- # and Diversity of Installations/Platforms
- Interoperability
- Multisite Coordination
- Migration Complexity
- # of Recursive Levels in the Design
- Personnel Experience/Continuity
- Stakeholder Team Cohesion
- Architecture Understanding
- Process Capability
- Personnel/Team Capability
- Level of Service Requirements
- Technology Risk
- CONOPS & Requirements Understanding

Teambuilding
Staffing
Continuous improvement

08/21
Agenda:

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System-of-Systems and Interoperability

• Suppose that SE work is being done on a system that is a constituent system in a system-of-systems. How is that context manifested in the SE project?
  – Answer: As interoperability requirements
  – Interoperability: The ability of a system to work with another system or group of systems.

• COSYSMO 3.0 includes interoperability as an influence on cost
COSYSMO 3.0
Interoperability Model

• Lane & Valerdi [6] propose that interoperability be considered a cost influence in the COSYSMO family

• Propose this influence could be manifested in two ways:
  – Method 1: Add a new cost driver (covered there)
  – Method 2: Adjust the easy/medium/difficult rating scale for system interfaces (part of the Size model)

• Expert COSYSMO 3.0 includes both methods; only one will be retained in final COSYSMO 3.0.
Adjustment for interoperability (Method 2):

- [6] proposes (in its Table 3) that the table that defines the easy/medium/hard rating scale for a system interface (from [2]) be adjusted by adding a new row (the last row in this table):

<table>
<thead>
<tr>
<th>Easy</th>
<th>Medium</th>
<th>Difficult</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple messages and protocols</td>
<td>Moderate communication complexity</td>
<td>Complex protocol(s)</td>
</tr>
<tr>
<td>Uncoupled</td>
<td>Loosely coupled</td>
<td>Tightly coupled</td>
</tr>
<tr>
<td>Strong consensus among stakeholders</td>
<td>Moderate consensus among stakeholders</td>
<td>Low consensus among stakeholders</td>
</tr>
<tr>
<td>Well behaved</td>
<td>Predictable behavior</td>
<td>Emergent behavior</td>
</tr>
<tr>
<td>Domain or enterprise standards employed</td>
<td>Functional standards employed</td>
<td>Isolated or connected systems with few or no standards</td>
</tr>
</tbody>
</table>
Agenda:

• The motivation for COSYSMO 3.0
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USC-CSSE Modeling Methodology

Figure 4.1 from [22]

- Step 1: Determine Model Needs
  - Analyze existing literature

- Step 2: Perform Behavioral analyses
  - Define relative significance, data, ratings

- Step 3: Perform expert-judgment Delphi assessment, formulate a priori model

- Step 4: Gather project data
  - Determine Bayesian A-Posteriori model

- Step 5: Gather more data, refine model

- Step 6: Working on this step

- Step 7: This step complete (= Expert Model)
Model Status & Plans

• The expert-based version of the COSYSMO 3.0 model has been under development for over a year, with critical input from:
  – The COSYSMO 3.0 Working Group
  – Attendees at conferences like this one
• The Expert Model was completed earlier this year
  – Along with a “Rosetta Stone”, for rerating old projects under COSYSMO 3.0
• Next work items:
  – Data Collection form
  – Gather new calibration data: completed projects
  – See how model works on existing calibration data
Agenda

Agenda:
• The motivation for COSYSMO 3.0
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• Model status & plans
• Numerical values of COSYSMO 3.0 parameters
  – Cost Drivers and Scale Factors
  – (Reuse and Size parameters shown above)
• Summary
<table>
<thead>
<tr>
<th>EMR</th>
<th>Cost Driver</th>
<th>Ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CONOPS and Requirements Understanding</td>
<td>VL</td>
</tr>
<tr>
<td>3.093</td>
<td></td>
<td>L</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N</td>
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<td></td>
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<td>H</td>
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<tr>
<td></td>
<td></td>
<td>VH</td>
</tr>
<tr>
<td></td>
<td>Architecture Understanding</td>
<td>1.76</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.33</td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
<td></td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.57</td>
</tr>
<tr>
<td>2.423</td>
<td>Stakeholder Team Cohesion</td>
<td>VL</td>
</tr>
<tr>
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<td></td>
<td>L</td>
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<td></td>
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<td></td>
<td>VH</td>
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<tr>
<td></td>
<td>Level of Service Requirements</td>
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<td># and Diversity of Installations/Platforms</td>
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<tr>
<td>1.932</td>
<td>Migration Complexity</td>
<td>VL</td>
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<td>L</td>
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# Scale Factor Detailed Parameters

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Agenda:

- The motivation for COSYSMO 3.0
- History of COSYSMO 3.0
- Overview of the content of the COSYSMO 3.0 estimating model
- System-of-systems estimating: interoperability in COSYSMO 3.0
- Model status & plans
- Numerical values of COSYSMO 3.0 parameters
- Summary
Summary

• COSYSMO 3.0 will provide independent estimates of the cost of thorough systems engineering required based on project parameters


Bibliography (5/5)
