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COSYSMO Calibration and Next Steps

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Overview

- COSYSMO Model
  - COSYSMO Cost Drivers
  - COSYSMO Data Sources
  - COSYMO Cost Estimating Relationship
- RMS Calibration of COSYSMO
  - 5-Step Calibration Process
  - Project Methodology
  - Results
- On-Going Work

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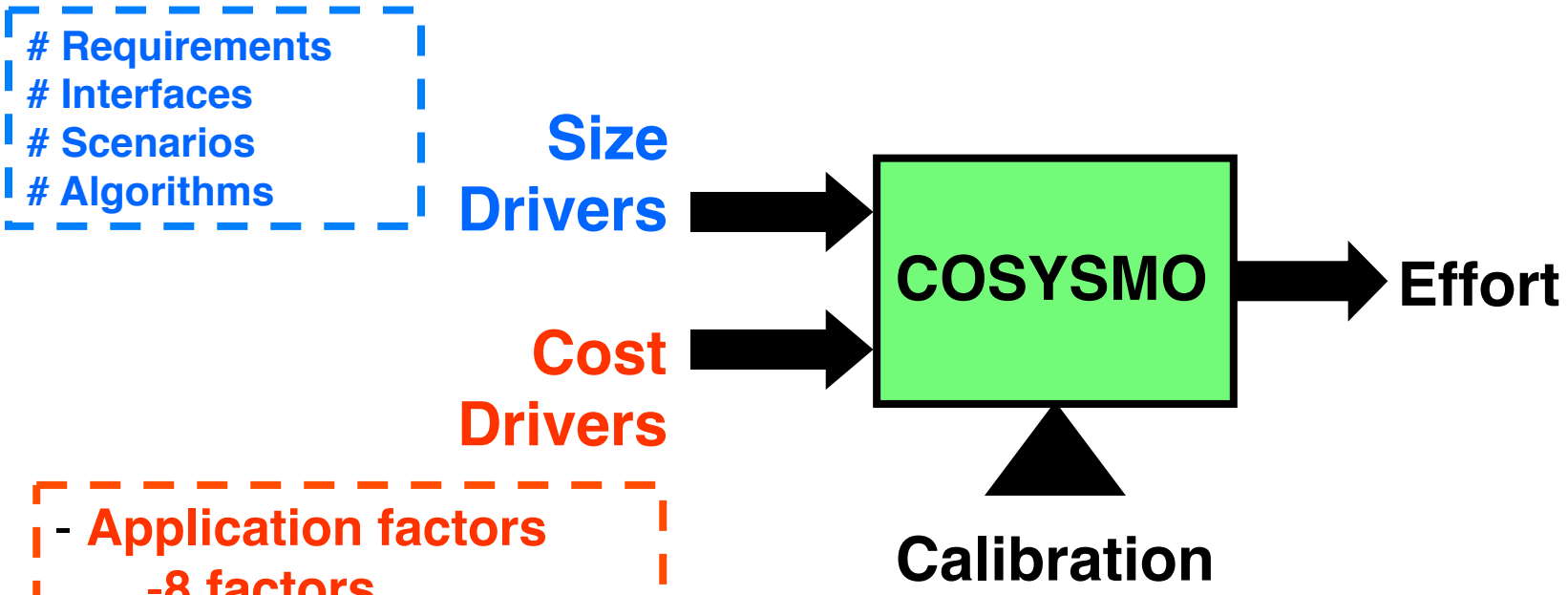
COSYSMO Model



WBS guided by EIA/ANSI 632

How much systems engineering effort is needed on projects?

COSYSMO Cost Drivers (14)

UNDERSTANDING FACTORS
- Requirements understanding
- Architecture understanding
- Stakeholder team cohesion
- Personnel experience/continuity

COMPLEXITY FACTORS
- **Level of service requirements**
  - *Used in RMS calibration*
- **Technology Risk**
  - *Evaluated by RMS but not used*
- # of Recursive Levels in the Design
- Documentation Match to Life Cycle Needs

OPERATIONS FACTORS
- # and Diversity of Installations/Platforms
- Migration complexity

PEOPLE FACTORS
- Personnel/team capability
- Process capability

ENVIRONMENT FACTORS
- Multisite coordination
- Tool support

Raytheon Missile Systems (RMS) calibration only used Level of Service Requirements (second largest Effort Multiplier Ratio)

Academic COSYSMO Calibration Sources

Raytheon	*Intelligence & Information Systems (Garland, TX)*
Northrop Grumman	*Mission Systems (Redondo Beach, CA)*
Lockheed Martin	*Transportation & Security Solutions (Rockville, MD)* *Integrated Systems & Solutions (Valley Forge, PA)* *Systems Integration (Owego, NY)* *Aeronautics (Marietta, GA)* *Maritime Systems & Sensors (Manassas, VA; Baltimore, MD; Syracuse, NY)*
General Dynamics	*Maritime Digital Systems/AIS (Pittsfield, MA)* *Surveillance & Reconnaissance Systems/AIS (Bloomington, MN)*
BAE Systems	*National Security Solutions/ISS (San Diego, CA)* *Information & Electronic Warfare Systems (Nashua, NH)*
SAIC	*Army Transformation (Orlando, FL)* *Integrated Data Solutions & Analysis (McLean, VA)*

COSYSMO Cost Estimating Relationship

$$PM_{NS} = A \cdot \left(\sum_{k} \left(w_{e,k} \Phi_{e,k} + w_{n,k} \Phi_{n,k} + w_{d,k} \Phi_{d,k} \right) \right)^{E} \cdot \prod_{j=1}^{14} EM_{j}$$

Where:

PM_{NS} = effort in Person Months (Nominal Schedule)

A = calibration constant derived from historical project data

k = {REQ, IF, ALG, SCN}

w_x = weight for "easy", "nominal", or "difficult" size driver

Φ_x = quantity of "k" size driver

E = represents diseconomy of scale

EM = effort multiplier for the j_{th} cost driver. The geometric product results in an overall effort adjustment factor to the nominal effort

Cost Drivers ($\prod_{j=1}^{14} EM_j$) affect only the A coefficient, not E

Difficult form to calibrate

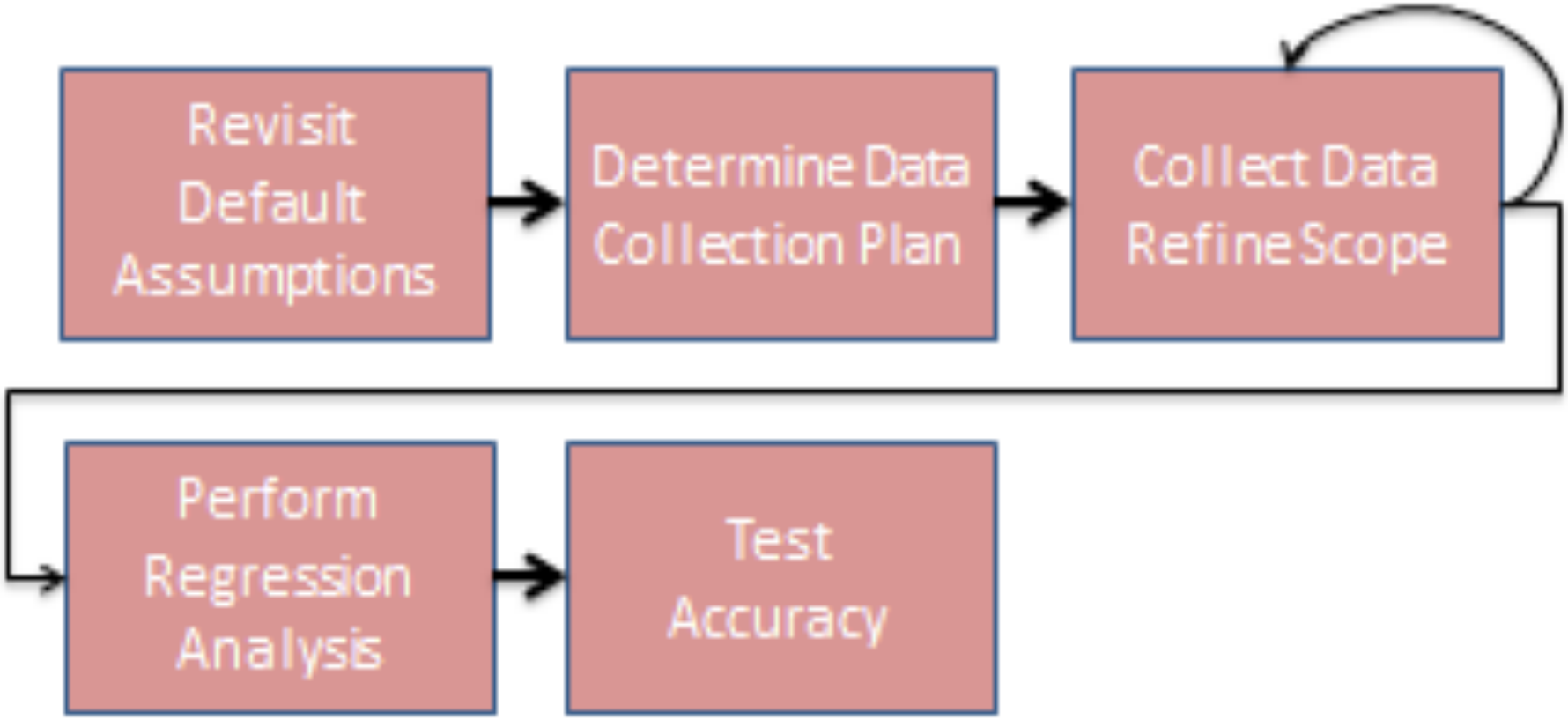
RMS Calibration of COSYSMO

- Valerdi moved to Tucson to teach at the University of Arizona
  - Fall, 2011
  - Christopherson suggested local calibration of COSYSMO as a work project
- Goal was to calibrate local values for A and E that matched actual costs of RMS programs
  - Had to re-write the equation so that the cost drivers could be used to calibrate both A and E parameters
    - Cost drivers scale the size drivers in new equation
  - Standard learning curve format ($a*x^e$) where x = eShalls scaled by cost drivers
    - Simple linear regression methodology (in logarithms) solves for both A and E

$$PM_{NS} = A \cdot \left(\left(\sum_{k} w_e \Phi_e + w_n \Phi_n + w_d \Phi_d \right) \cdot \prod_{j=1}^{14} EM_j \right)^E$$

COSYSMO equation re-written in standard learning curve format

5-Step Calibration Process



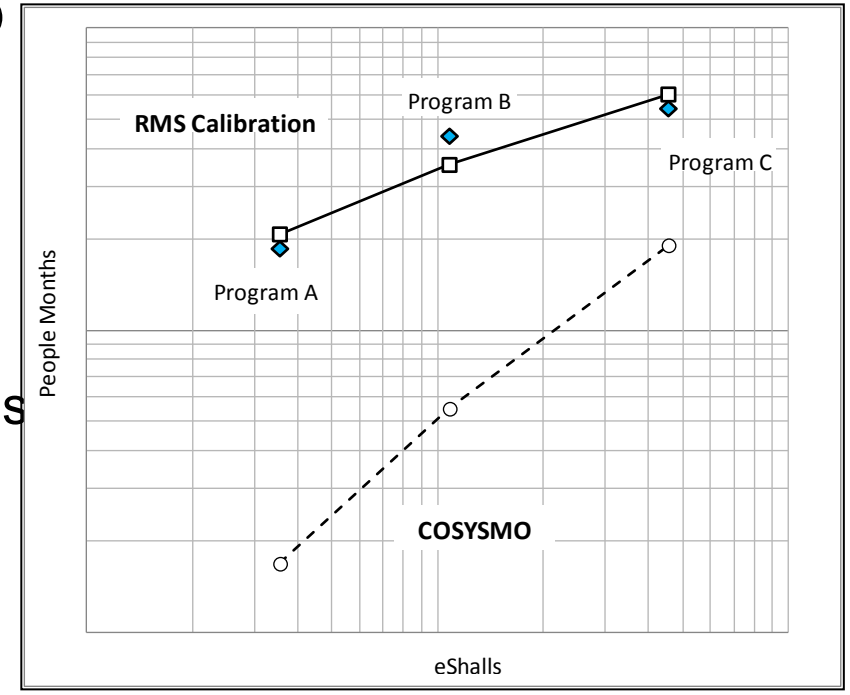
Project Methodology

- Data collection
  - Initial pilot test developed given very short time constraint
    - Only used the requirements size driver representing the left side of the Vee
    - Initial pilot provided proof of concept (Dec 2011)
  - Added remaining size drivers and cost drivers in early 2012
    - Down sized to just one cost driver (Level of Service Requirements)
      - Coupling of Key Performance Parameters (KPPs) was significant for RMS
  - Added systems test hours representing right side of the Vee as final iteration
    - Test and Evaluation of requirements
- Used weighting factors from academic COSYSMO
  - Delphi method deemed as best information source on the topic
    - Used Bayesian calibrated weights for both size drivers and cost drivers
      - Valerdi (2005) Dissertation Table 54 for size drivers and Table 55 for cost drivers

Three iterations of 5-Step Calibration Process

Results

- A and E calibrated for RMS actuals
  - Significantly different than COSYSMO
  - R^2 = 89% for small sample size
- COSYSMO did not include any missile programs
  - RMS SE definition includes Specialty Disciplines (e.g., Cost Engineering, Ris Mgmt) and other processes
- RMS' methodology appears fairly consistent across programs
  - Flatter slope than COSYSMO
- Reduced version accurately predicts systems engineering effort
  - Not all cost drivers are necessary when homogenous programs exist



Project successfully demonstrates local calibration

On-Going Work

- RMS currently developing new Productivity Metric for Systems Engineering using the calibrated model
  - Past metric used only requirements as Systems Engineering tasks
  - New method measures how hours are spent using all COSYSMO size drivers
    - Requirements, Interfaces, Scenarios, and Algorithms
    - Actual hours are then compared to locally calibrated model estimate
      - Includes the one cost driver (Level of Service Requirements)
- Right side of the Vee (Test and Evaluation) work with Raytheon Integrated Defense Systems (IDS)
  - Adjust size and cost drivers to accommodate T&E considerations
  - Develop new size and cost drivers that are relevant to T&E
  - Propose a systems engineering effort allocation for T&E tasks
  - Incorporate reuse considerations related to T&E

Summary

- COSYSMO local calibration methodology demonstrated
  - Equation was re-written as a learning curve
    - Solved for local costs at RMS using simple linear regression methodology
  - New equation allows cost drivers to influence both A and E parameters
    - Still contains the “spirit” of the cost drivers
      - Cost drivers scale the size drivers in new equation
- On-going work includes the following:
  - Systems Engineering productivity metric project
    - Uses four size drivers and one cost driver to represent SE work
  - IDS project focusing on right side of Vee
    - Test and Evaluation

COSYSMO can be calibrated for local business methodology