USC CSSE Annual Research Review
17 March 2008

Attendees	
Ricardo Valerdi (via telecon)	Dan Ligget (Softstar)
Howard Schimmdler(via telecon)	Jim Cain (BAE Systems)
Garry Roedler (LMCO)	Merilee Wheaton (Aerospace)
Jared Fortune (PhD @ USC, Aerospace; carry on Ricardo's)	Gary Hafen (LMCO)
Gan Wang (BAE, Reston VA)	Miles Nesman (pm)
Cindy Nikolai (PhD student, Notre Dame)	Rick Selby (Northrop Grumman) (pm)
Jeff Allen (via telecon) (pm)	Elizabeth (Beth) O'Donnell
Darryl Webb (Aerospace Corp) (pm)	JoAnn Lane (pm)
Ali Nikolai (pm)	Barry Boehm

1. Level setting

Most attendees have background knowledge of COSYSMO and efforts.
Context setting, discussion on COSYSMO 2.0 improvements, prioritization exercise

Best practice guidance – how to use the model to get the best results
Modeling organizational factors in space systems (sent out with this set of files?)

2. Context setting (see charts; obtain updated charts)

- SE Defined - EIA/ANSI 632, Processes for Engineering a System, 1999; requirements are addressed in ISO/IEC 15288 (revision approved December)
- COSYSMO Origins

Key point for COSYSMO – 2 current SE standards used (EIA-632, ISO/IEC 15288)
S/W cost models → integration of assessment models
Will continue to work within framework of modeling methodology.

- COSYSMO Scope – addresses first four phases of the SE life cycle (hybrid adapted from ISO/IEC 15288); considers standard SE WBS tasks (per EIA/ANSI 632).
- COSYSMO Operational Concept, Model Form – same as before
- Size Drivers vs. Effort Multipliers: Still must keep in mind the concept difference (Size drivers → additive, incremental; Effort Multipliers → multiplicative, system-wide); for recursive levels, need to think more in how to apply in model such that we don't miscount/misinterpret.
- Size driver Weights
- Cost Driver Clusters – people factors seems to be an area where we get poor input.
- Cost Driver Rating Scales – result of the Delphi process – looking @ how these are interrelated; somewhat refined through analysis of the data. New way of presenting them.
- Cost Drivers ordered by Effort Multiplier Ratio (EMR) – which drivers have the biggest impact; higher EMR – drives estimates further from nominal.
- Effort Profiling – layout resulting from work done so far; ramping up in Conceptualize, most effort in develop, etc. (Ricardo: All based on actual data. Matrix. Needs to be done proportionally better; green (system design) and purple (product realization) are biggest.)
- Impact: model → academic curricula → commercial implementations → proprietary implementations (industry); will continue to be differences

3. COSYSMO 2.0 Improvements

Recommended improvements from user community. (Won't discuss estimation in O&M phase and requirements volatility today. No O&M data, and arena is changing, i.e., performance based logistics contracts – different business model.

Central questions, Hypothesis(es), POC(s), Reference(s)

i. Reuse – what is the effect of reuse in estimating SE size/effort?
ii. Integration of SwE and SysE estimation – will need to look at, and review areas of potential overlap; John Gaffney is doing work in this regard for LM.
iii. Linearity in COSYSMO cost drivers – characterizing non-linearity of cost drivers across the life cycle.
iv. Effect of cost drivers and scale factors – somewhat related to previous item; can some of the cost drivers become scale factors in the CER calibrated by the new data set. Following COCOMO model. Cost drivers have non-uniform impact on the life cycle. Potential relationship between this and improvement #7 (vii), best practices; time will tell; also perhaps a tie between #5 (v), recursive levels.
v. Number of recursive levels in design – integration complexity of system elements is a predictor of SE effort; seems also to be related to SoS problem/effort. In a SoS, there are a couple of other factors (beyond what we are converging to for system of interest) – i.e., governance of SoS.
vi. Risk Modeling – quantification of risk associated with COSYSMO estimate; how to get away from single point estimates; go to ranges to better look at field of the possible.
vii. Best practice guidance for the use of Cost drivers – leverage what we've been doing over time; how to generate better estimates in our organizations; ensure don't get tolerance buildup; get consistency in our estimates; no overestimating (seen more than underestimating). Marilee Wheaton volunteered to work this also (with Garry and Gan).
viii. Consideration of SoS scope in COSYSMO – updating to address SoS estimation
ix. Estimation in Operation & Maintenance Phase – how to estimate SE effort in O&M phase; deferred to later; must identify the players who can provide any/good data for O&M; define what is really happening in this phase (general for all/most).
x. Requirements volatility – how to quantify the effects of requirements volatility on SE effort through the life cycle; will be deferred to later.

4. Prioritization Exercise
   - factors to consider
   - availability of data
   - Impact on total cost of ownership
   - Frequency of use
   - Compatibility with other models (not specific to any one)
   - Address future trends
   - Factor interactions
   - Do we truly need all the factors/cost drivers we have?

5. (Again) Recommended improvements (from user community) – Discussion with respect to Prioritization Exercise. Reuse and risk modeling off the table, since already being addressed; 9 and 10 also off, as previously mentioned. LM is already using risk and reuse in their model (successfully) now. Jared Fortune is working part of this (for PhD); really only has data from BAE.

- Matrix – improvement (1-10) vs factors to consider; High, Medium, Low

Jared Fortune (Aerospace, USC PhD student) – Reuse

1. Reuse
2. Proposed Reuse Terminology – based on discussions from PSM conference.
3. Reuse Continuum – Reuse weighting ; close to zero for managed;
4. Approaches for handling
5. Bottoms-up activity-based (EIA 632 activities vs life cycle phases); where these would fall into for the drivers
6. Next steps
   - reach conclusion on reuse weights ('forced' on you)
   - determine scalability of reuse ('forced' on you)
   - examine effect of SE "designed" for reuse ('planned')
   - apply methodology

Comments:
(Gan) guidance alone may help resolve
(Garry) Two aspects to it; (1) do a Delphi to assess → best practice guidance; (2) Use data to get to something firmer; can we get (enough of) those types of data to assess for statistical significance.
(Gan) If can find one anecdotal example that some organization can clear – use the drivers, illustrate an example of how it can work.
(Garry) Jared can do Delphi (prepare for next meeting); do a SHORT survey (back to the same players) – where done opportunistic vs. systematic reuse; will be difficult to do – will have to first teach what is meant by that.
(Barry) – considering having DEN students do a term project; familiar project and find COSYSMO cost drivers. (Still have proprietary issues that must be carefully addressed.)

** ELO: Take back request for data for this to SECET.

Jared will email charts out.

(Gan Wang)

WBS vs. Function – who is responsible (WBS elements only include items with engineering scope)
Functions: Systems, Software, Electrical, Mechanical, Supportability, PEM
PEM → covers engr scope not covered by other individual functions

1.0 Electronic/automated software system
- 1.1 IPM
- 1.2 Sys Engr (in this terminology, only a piece of what we call SE)
- 1.3 PMP
- 1.4 Platform Integration
- 1.5 ST&E
- 1.6 Training (probably inconsistency; primary Supportability)
- 1.7 Data Mgmt

1.8 Peculiar Support Equipment
1.9 Common Support Equipment
1.10 Operational / Site Activation
1.11 Industrial Facilities

Identify the ownership of the element (who has the budget), not who does the work
Common denominator – relationship exists where common element; also identifies where potential overlap.

Y = covered by COSYSMO
X = not covered or not covered consistently

Overview of Addressing Risk with COSYSMO (Garry Roedler)

LMCO Risk Enhancements to Academic COSYSMO
Results from the COSYSMO Workshop @ PSM (July 2007)

Four major functions
Focus here Estimation of Cost/Effort and Schedule Uncertainties: Risk and Confidence

COSYSMOR User enters 3-value estimates for model parameters (data entry effort) A and E (exponent), scope or project size characteristics, equivalent size drivers, cost/performance drivers

How to better hone in on things… should be part of Best Practice guide.

If doing for a bid, can NOT go outside of your auditable data. Better off to do estimate without touching A and E, and providing rationale for adjusting estimate.

Once calibration derived, that is your statistical

Details concerning risk distribution… see chart

Next version is COSYSMO 2.0 – hoping that book will be baseline. Suggested peer review (for math behind…), i.e., by Steve Book, Paul Garvey

Distribution chosen could be refuted.

Life Cycle Impact of COSYSMO Cost Drivers (Gan Wang)

Questions, Hypothesis

Each cost driver has different impact to the nominal effort in different life cycle phases; impacts are also different on smaller vs. larger projects, (therefore)

Exercise:
Assess the life cycle impact of each driver, relative to system life cycle phases based on ISO 15288
Caveats:

- We recognize that all cost drivers have influence over the entire project life cycle
- So we are looking for where the ***major*** impact is in time
- Think of dominator impact factors – the 'heavy hitters'
- Focus on the development phases only for now (first four phases, where we have data)

Cost drivers (14 + 2) vs. (tailored) life cycle phases

Where is the major impact if the implementation is imperfect (dealing with uncertainties); at the beginning, assess the uncertainty. For sure things will change, but don't know where end point is. Making assessment based on Starting Point….

Want to get real data; for now, intuitive assessment; next state
Phase dependent estimate multipliers…
Recognize that there is not complete independence of variables; fairly good level of independence (people factors – one of highest levels of correlation between each other). Highest correlated parameters: personnel experience, migration complexity (0.53)

The steps are too big, too unrealistic – "a change to the basic parametric relationship is imperative"… going down a step may have more of a cost (i.e., rework, etc.) than going up a step. Some have no benefit at all – only penalty.

16 drivers → EMR 44.1K (factor of 10EMR greater than what's in COCOMO…) low to high

Numbers came from Delphi survey; looking at things in a relative fashion.

Two added drivers… Risk and Opportunity Reduction, Schedule Compression (R&O is a scale factor, not a driver, in COCOMO)…

Impact if done wrong.
Late life-cycle drivers (exponential only), early life-cycle drivers (exponential and multipliers), uniform drivers (in skill factors); some of the drivers are very much correlated; different perspective of the same phenomena.

To group them logically – put them in the right place – is the fundamental motivation for this.

Size-based nominal model.
COSYSMO covers more phases than COCOMO…longer in time; further reaching in terms of scope.

Cost drivers vs Scale Factors - Gan Wang, Merilee Wheaton, Ricardo Valerdi, Rick Selby, Jim Cain, Garry Roedler (or John Gaffney), Dan Liggett, Gary Hafen - will work on this offline.

The Cost of Organizational Structures and Interfaces (Darryl Webb)
(see charts)

Working with Vision Analytics.
Start with a bias; often not correct. Often bi-modal.

Bias Description Inventory – pick out a few

- starts with Subsystem TRL
- number of primes
- amount of synergies among the high level org pieces
- lower level complexity

Cost versus number of interfaces:

- as the number of interfaces increases, cost of coordination, control, and management increases
- represents increased communication and coordination between different organizations
- (relative cost – Systems Engineering and Program Management)

Volatility and Organization Type – primary input parameter sensitivity (Jairus M. Hihn of NASA JPL) – cost modifier vs volatility index

Sampling of input parameters

Case 1 – Baseline

- 7 direct interfaces
- 9 indirect interfaces
- 16 total interfaces
- 100% interface complexity

Case 2

- 5 direct interfaces
- 8 indirect interfaces
- 13 total interfaces
- 32% interface complexity

Case 3

- 6 direct interfaces
- 10 indirect interfaces
- 16 total interfaces
- 77% interface complexity

Current Organization Concept Maturity – Hubble space telescope organization complexity: complex cross relationships of conflicting requirements, organizational objectives, politics, H/S vertical and horizontal interfaces and organizations

- contractors, agencies, international, requirements crossing boundary lines; hardware and software – good and very bad match-ups, etc. How organization is set up relative to hardware is extremely important.
- Product is not just H/W and S/W – is also the political

Organization to organization complexity inputs – mapping
Organization and product integration architecture. Sums to an organizational complexity, and also for hardware and software. Vertical and horizontal integration…changes ripple through.

Program Equilibrium Disruptions

Model results

- typical h/w cost model
- cost increases for organizational complexity and 'horizontal' integration
- non-modeled organizational complexity and horizontal complexity has substantial effects upon schedule (per Vision Analytics)

Study results (summarized)
- Study investigated possible cost driving variables that are not currently included in h/w cost models as a general practice. (In addition to observations captured by Vision Analytics and Aerospace in the NASA Space Station Cost Reconstruction Study) A survey was conducted to acquire a model or methodology that contained features desired for the analysis of organizational complexity of programs and facets of integration that are not currently or adequately contained in current parametric cost prediction models. From a large list of cost drivers obtained in the study, a candidate list was used as a supplement to the observations from the Vision Analytics NASA Space Station Cost Reconstruction Study.
- a robust and flexible architecture was developed to enable the organization, study, and testing of the postulate that the considered variables were in fact important to consider in preparing space cost estimates
- cost functions were obtained for the construction of a rapid prototype model built within the framework of that architecture. A low fidelity population of that model was exercised.
- analysis of results and of Space Shuttle and ISS exercises provided strong indicators that program complexity horizontal integration issues and conditions as well as organizational structure and interface complexity are in fact major cost drivers on complex space systems.

Comments
Program realism – ties
Much money going down the drain because priorities don't get set; programs overrun and get cancelled.
Budgets decrease, requirements don't.
How much damage is done when the systems engineering is not done in the front end; or how much it costs when the SE is not done as planned.

Best Practice guidance (Garry Roedler)
Will work in a separate team.
Garry Roedler, Jared Fortune, Ricardo Valerdi, Dan Liggett will send some input; request to also add Beth O'Donnell (or other Boeing rep)

Cost Drivers vs. Scale Factors (Gan Wang)

- Survey – cost driver correlation; Rate the level of correlation – 0 (no correlation), 1 (weak), 2 (strong); Complete and return by tomorrow.

- Survey from October 2007 – Requirements Reuse – Requirements Understanding; Correlation between 4 size drivers and cost drivers; e.g., if high reuse, what happens to requirements understanding?

most only did this for Requirements size driver →

Requirements reuse – Requirements understanding - most responses (7) showed strong positive correlation (1 – weak negative; 3 – no correlation, 2 weak positive)
Requirements reuse – Architecture understanding (most on the positive)
Requirements reuse – Level of Service (most no correlation)
Requirements reuse – Technology Risk (all over the map…)

Requirements reuse – Documentation match to Life Cycle
Requirements reuse – Number and Diversity of Recursive platforms (most no correlation)
Requirements reuse – Stakeholder cohesion (most no correlation; a couple on the positive)
Requirements reuse – personnel team capability (most no correlation, a few weak positive)
Requirements reuse – personnel continuity (split between no correlation, weak positive, strong positive) - "It depends" - If very reusable product, may not care about continuity of the team.
Requirements reuse – process capability
Requirements reuse – multi-site coordination

Should we have the same categories of reuse for the drivers? 7 – same, 1 - other

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Recursive Levels (Ricardo Valerdi)

Working on clarifying 'number of levels' – try to get a better sense of how people interpret number of levels, and how to clarify it to enable consistent application.

An estimate of the systems engineering at the system of interest level only, but lower levels will cause impact.
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Each of the drivers – where in the range for that driver is based on that system of interest

Provide more guidance than what currently exists (the one line): included effort and excluded effort. (Gan – this is consistent with their training class); Will develop an example also.

Applies only to the system level (system of interest) and the first level of decomposition below the top-level system where systems engineering is being estimated (where the requirements are being flowed down to); includes the SE effort necessary to support these products and components far down on the specification tree, such as schedule coordination and requirements negotiation.

Not cost neutral if number of levels drives your costs. (Whole purpose behind this; expands with levels of recursion.) Currently captured as a cost driver, not a size driver.

Garry: this does not agree with where we intended to go (15288); data calibrated upon *does include* some of which is identified as excluded effort. Intent was not that we would have to collect size at every level down – that was the intent of recursion.

We must just be very clear on what we mean; current included effort and excluded effort is not detailed enough.

Will continue to work this and endeavor to provide the right guidance.

System of System Engineering and Cost Estimation group (JoAnn Lane)

How is membership in an SoS affecting SE effort?

- many systems are part of an SoS or will soon be part of an SoS
- in some cases, systems are part of multiple SoSs

- Concerns:
    i. Additional impact to the se efforts of the constituent system SE teams, above and beyond that associated with an increase in requirements
    ii. Additional effort might be due to increased requirements complexity, additional overhead associated with the SE efforts to participate in SoS-level activities (e.g., working groups, collaboration efforts to analyze desired SoS capabilities, trade studies to explore options, etc.)

Examples shown
Discussions with individuals on SoSs - determine if establishing a formal/acknowledged SoS adds extra complexity or overhead to SE for the constituent systems, simplifies the constituent system SE, or both? (Quantify impact, does it increase as the number of SoSs that a system belongs to increases; does COSYSMO adequately address this, can this be adequately addressed using a Requirements Volatility parameter?)

Concern is that we are still missing some effort…may be increasing as becomes members (or potential member) of other systems.

Review/discussion of survey.

Looking for single system experiences that were part of SoSs.
If only number of interfaces, requirements – zero impact.

Wrap-up (Garry Roedler)

- Item of most dissension/discussion – Levels of Recursion
- Try to set up Best Practices so as to get best results from the model.
- Reuse and Risk – went over, ready to go forward with what we have so far defined; Jared is doing more work (more definitive, quantitative)
- Integration of SysE and SwE – lots of opportunity/potential for overlap here. Will result in additional operational guidance for Best Practices.
- Assumption of linearity in Cost Drivers – another area of opportunity for investigation, understanding; how it ties back with respect to earlier assumptions, etc.
- Priorities (exercise) and recommended improvements (based on priorities)

Q. (Barry) What are the prospects for more COSYSMO data?
A. (Beth) Boeing is working on getting more. (Gan) Focus on how to collect data. (Garry) Also to address programs with re-use.