COSYSMO 3.0: Updating Systems Engineering Cost Estimation to Support Affordability

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Agenda

Agenda:

- **Affordability issues can be caused by inaccurate estimates of systems engineering cost**
- **Introduction to COSYSMO**
- **Overview of the content of the COSYSMO 3.0 estimating model**
- **System-of-systems estimating: interoperability in COSYSMO 3.0**
- **Summary**

Poor SE Cost Estimation Threatens Affordability

Poor estimates of systems engineering cost can lead to suboptimal systems engineering, resulting in missed engineering opportunities. Here are some example outcomes:

- **Rushed or reduced scope of systems engineering, resulting in increased development costs for other engineering disciplines or missed life cycle considerations**
- **Inadequate time to consider new technologies that could result in major cost reductions**
- **Technical debt (such as defects and unresolved issues) surfacing during operations & sustainment**

Each of these is an affordability problem:

- **Systems engineering cost is reduced, but total life cycle cost is increased**

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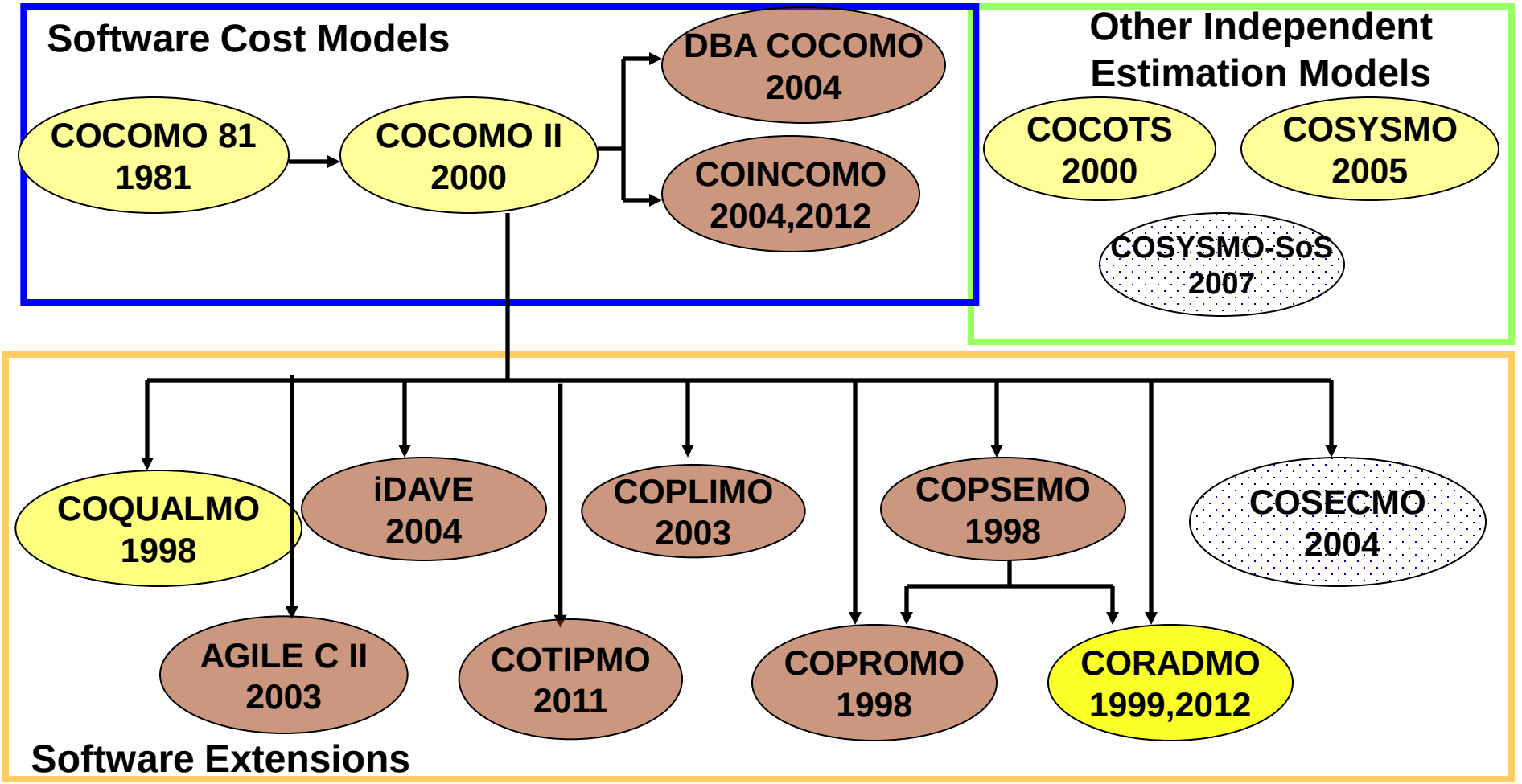
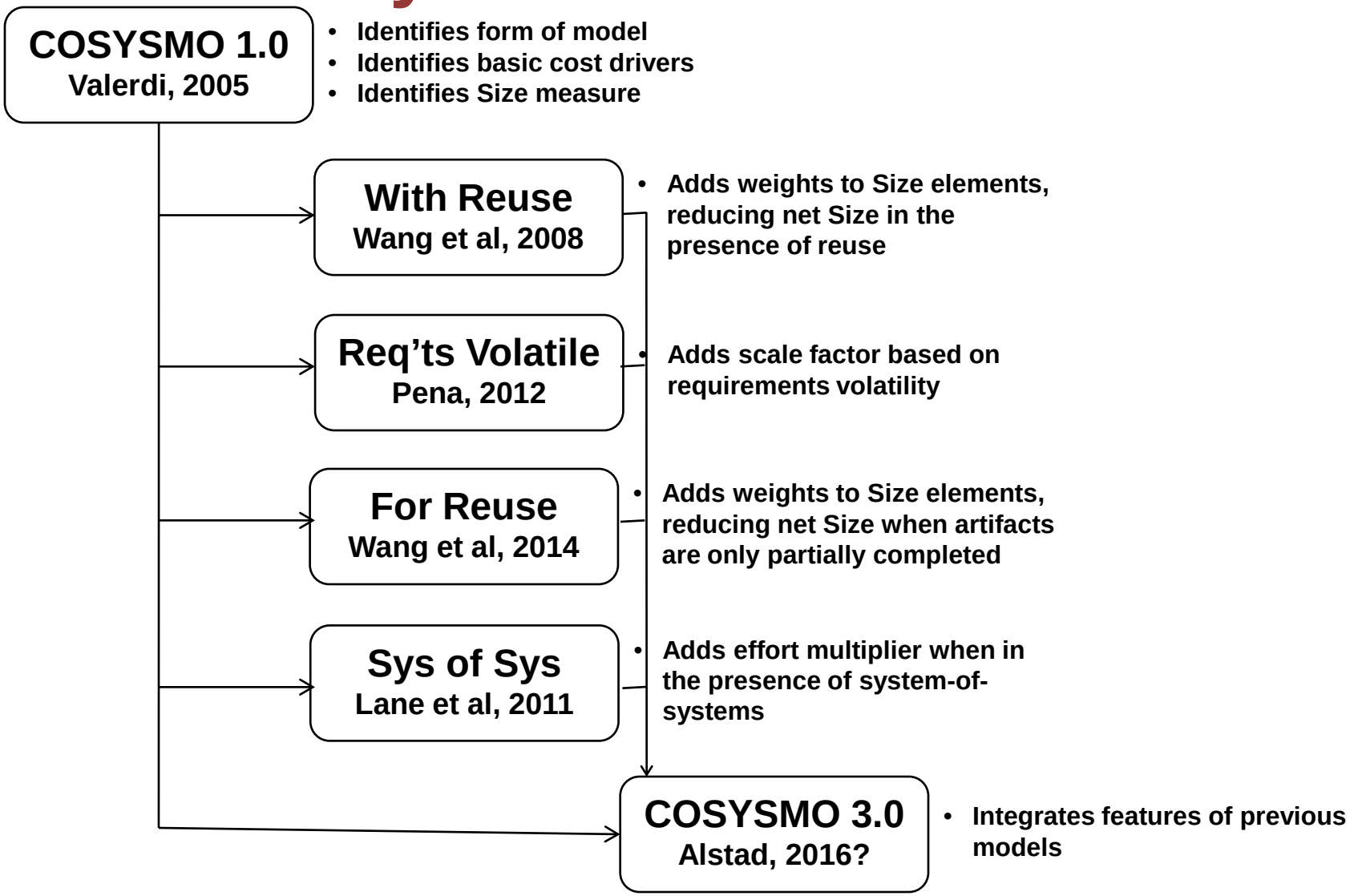
COCOMO Family of Cost Models



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 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 [1]):**
  - **Reuse (partial model—Development With Reuse) [3]**
  - **Reuse (with Development For Reuse) [1]**
  - **Requirements volatility (RV) [4]**

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

Enhancement planned for inclusion:

- **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 [17, 7]**

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COSYSMO 3.0 Top-Level Model

$$PH = A \cdot (AdjSize)^{E} \cdot \prod_{j=1}^{15} EM_j$$

Elements of the COSYSMO 3.0 model:

- **Calibration parameter A**
- **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 EMs**

Harmonized COSYSMO 3.0 Size Model

$$AdjSize = \sum_{SizeDrivers} eReq(Type(SD), Difficulty(SD)) \times PartialDevFactor(RML_{Start}(SD), RML_{End}(SD), RType(SD))$$

- *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**

Size Model – eReq Submodel

- **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:**

Size Driver Type	Easy	Nominal	Difficult
System Requirement	0.5	1.0	5.0
System Interface	1.1	2.8	6.3
System Algorithm	2.2	4.1	11.5
Operational Scenario	6.2	14.4	30.0

Size Model – Partial Development Submodel

- **The basic 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 [1].**
    - **How fully developed was the *SizeDriver*?**
  - **If there is no reuse for this *SizeDriver*, then *PartialDevFactor* = 1 (no adjustment).**

DWR Reuse Maturity Level:	New	Modified	Adapted	Adopted	Managed
DWR % of full-project cost (Table 4):	100.00%	66.73%	56.27%	38.80%	21.70%

COSYSMO 3.0 Exponent Model

- **Exponent model is expanded from Peña [4, 9]**

$$E = E_{COSYSMO1} + SF_{ROR} + SF_{PC} + SF_{RV}$$

Where:

- $E_{COSYSMO1}$ **= 1.06 [2]**
- **SF = scale factor**
- ***ROR* = Risk and Opportunity Resolution**
- ***PC* = Process Capability**
- ***RV* = Requirements Volatility**

The effect of a large exponent is more pronounced on bigger projects

Harmonized COSYSMO 3.0 Effort Multiplier Model

- **Here are the 15 effort multipliers:**

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

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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 systems to provide services to and accept services from other systems and to use the services so exchanged to enable them to operate effectively together.**
- **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 effort multiplier (covered under EMs)
  - Method 2: Adjust the easy/medium/difficult rating scale for system interfaces (part of the Size model)
- The working COSYSMO 3.0 includes both methods; only one would be retained in final COSYSMO 3.0.

Size Model – Adjustment for Interoperability

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):**

Easy	Medium	Difficult
Simple messages and protocols	Moderate communication complexity	Complex protocol(s)
Uncoupled	Loosely coupled	Tightly coupled
Strong consensus among stakeholders	Moderate consensus among stakeholders	Low consensus among stakeholders
Well behaved	Predictable behavior	Emergent behavior
Domain or enterprise standards employed	Functional standards employed	Isolated or connected systems with few or no standards

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Summary

- **COSYSMO 3.0 will provide independent estimates of the cost of thorough systems engineering required based on the project parameters**
  - **Thereby avoiding inadequate systems engineering efforts that tend to lead to affordability problems**
- **COSYSMO 3.0 will provide estimates in the system-of-systems context**
  - **Through applying cost adjustments for interoperability**

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