



Systems Engineering Reuse: A Report on the State of the Practice

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Outline

- Research Motivation
- Reuse Overview
- State of the Art
- State of the Practice
- Implications for COSYSMO 2.0

Research Motivation

Successful and Accepted

- Proprietary versions of COSYSMO developed at several aerospace contractors
- Model implemented in commercial software packages
- Taught in over five university graduate courses

...Areas for Improvement

- Practitioners realized COSYSMO estimate errors a result of significant amounts of reuse
- Accounting for reuse identified as the most critical area of improvement for model

A green arrow pointing to the right with a yellow-to-green gradient. The text 'COSYSMO 2.0' is written in bold black letters inside the arrow.

COSYSMO 2.0

What is Systems Engineering *Reuse*?

- Systems engineering activities are support-focused
 - Do not produce physical products (HW, SW, etc.)
 - Produce architectures, requirements, test plans, and other technical documents
- Systems engineering products can be viewed as “artifacts”
 - Encapsulation of systems engineering knowledge in a document or process
 - Representative of systems engineering effort
- Reuse of an artifact *should* reduce the expected systems engineering effort for the development of a new system

How Do We Estimate Reuse?

- Known need to account for reuse in COSYSMO
- Proposed approaches
 - Valerdi: Size driver extensions
 - Gaffney: COSYSMO-R
 - Wang: “Bottoms-up”

What is the best approach? Missing anything?

- First, look at the academic and industrial literature

State of the Art

How does the systems engineering literature handle reuse?

				<i>Discuss Reuse?</i>	<i>Artifact Reuse?</i>	<i>Systems Engineering Reuse?</i>
Systems Engineering	Texts	Maier and Rechtin	The Art of Systems Architecting (2002)	✓		
		Blanchard and Fabrycky	Systems Engineering and Analysis (1998)			
	Handbooks	INCOSE	Systems Engineering Handbook (v 3.1)	✓	✓	✓ (1 instance)
		NASA	Systems Engineering Handbook (2004)	✓		
	Standards and Procedures	NASA 7123.1A	NASA Procedural Requirement--Systems Engineering Processes and Requirements (2007)	✓		
		IEEE 1220-2005	Systems Engineering--Application and Management of the Systems Engineering Process	✓		
		ANSI/EIA 632	Processes for Engineering a System (2003)	✓		
Software Engineering		IEEE 1517-1999	Software Life Cycle Processes--Reuse Processes	✓	✓	

State of the Art (cont.)

*How does the **software** engineering literature handle reuse?*

Observations

1. Reuse is done for the purpose of economic benefit, intending to shorten schedule, reduce cost, and/or increase performance [Lam, Stephens]
2. Reuse is not free, upfront investment is required [Poulin, Mili]
3. Products, processes, and knowledge are all reusable artifacts [Basili, Prieto-Diaz, Davis]
4. Reuse needs to be planned from the conceptualization phase of programs [Lynex, Layzell]
5. Reuse is as much of an organizational issue as it is a technical one [Griss, Poulin]
6. The benefits of reuse are limited to related domains and do not scale linearly [Bollinger, Selby]

State of the Art (cont.)

Reuse success factors

1. Platform

- Appropriate product or technology, primed for reuse

2. People

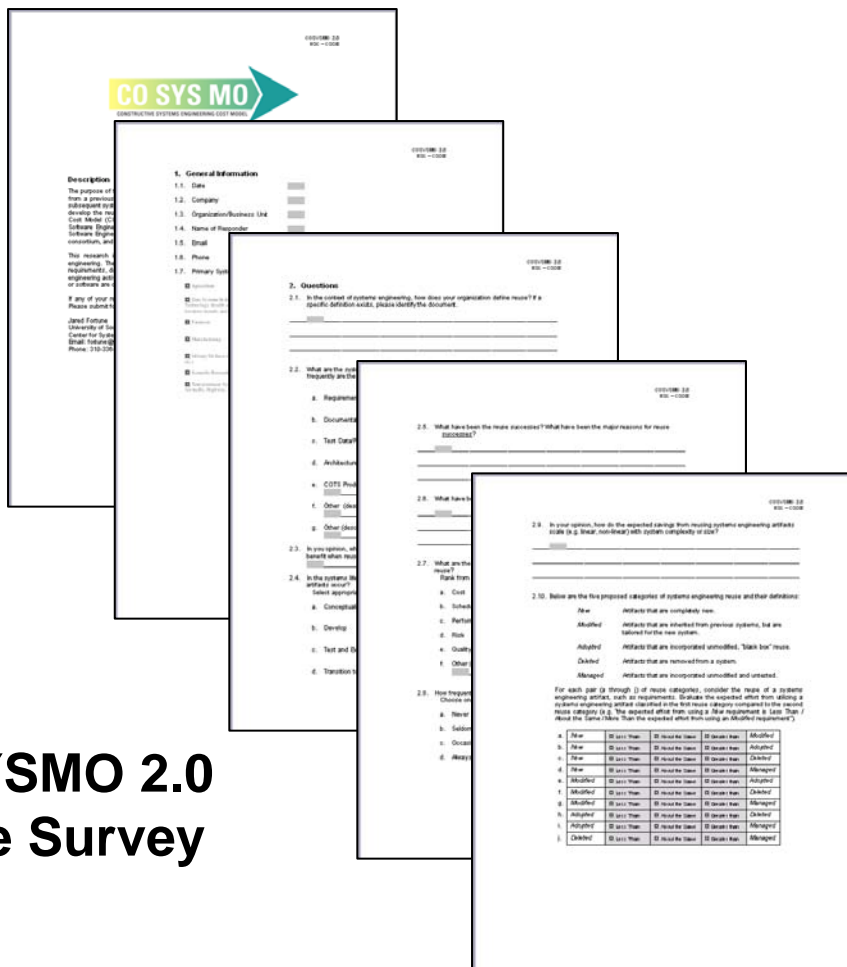
- Adequate knowledge and understanding of both the heritage and new products

3. Processes

- Sufficient documentation to acquire and capture knowledge applicable to reuse as well as the capability to actually deliver a system incorporating or enabling reuse

State of the Practice

How does industry handle reuse?



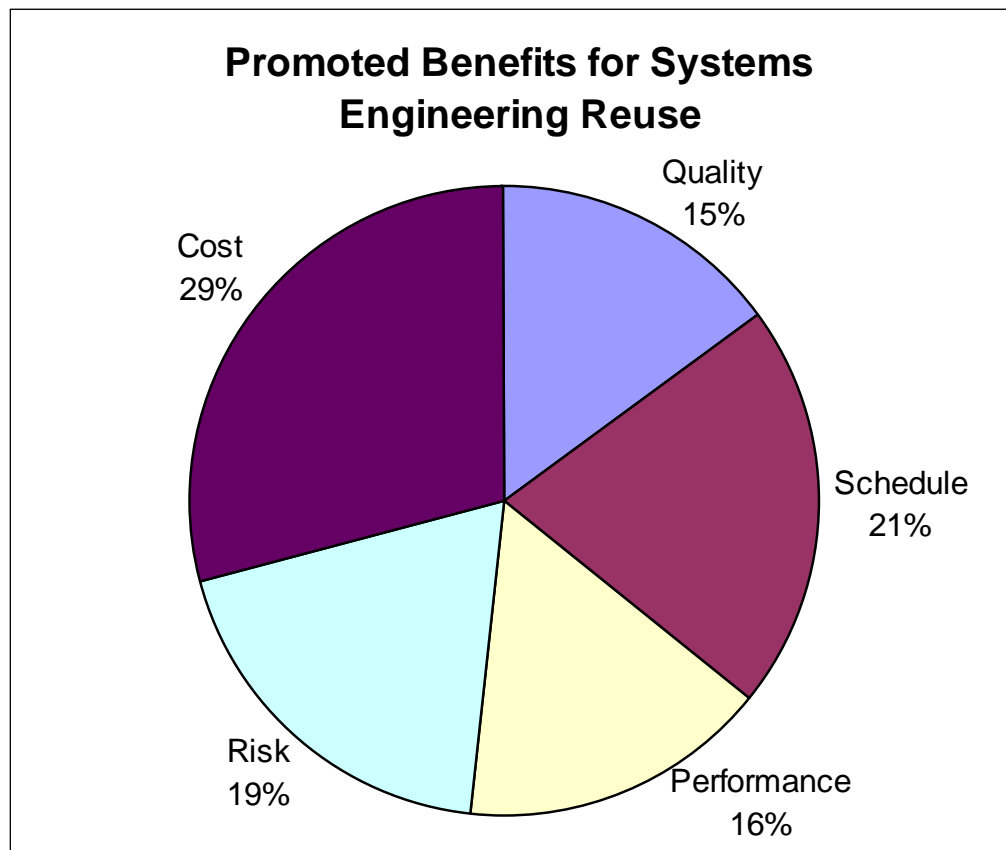
The image shows a stack of survey forms for the COSYSMO 2.0 Reuse Survey. The top form is the title page, which includes the USC CSE logo and the text 'COSYSMO 2.0 REUSE SURVEY'. Below the title page are several pages of questions, including sections for 'General Information', 'Questions', and 'Reuse Survey'. The questions cover topics such as the purpose of the reuse, the reuse process, and the reuse categories. The forms are stacked and slightly offset to show multiple pages.

**COSYSMO 2.0
Reuse Survey**

Reuse Survey Responders
BAE Systems
General Dynamics
Lockheed Martin
Orbital Sciences
Raytheon
Reynolds, Smith, and Hills

Survey Results (1)

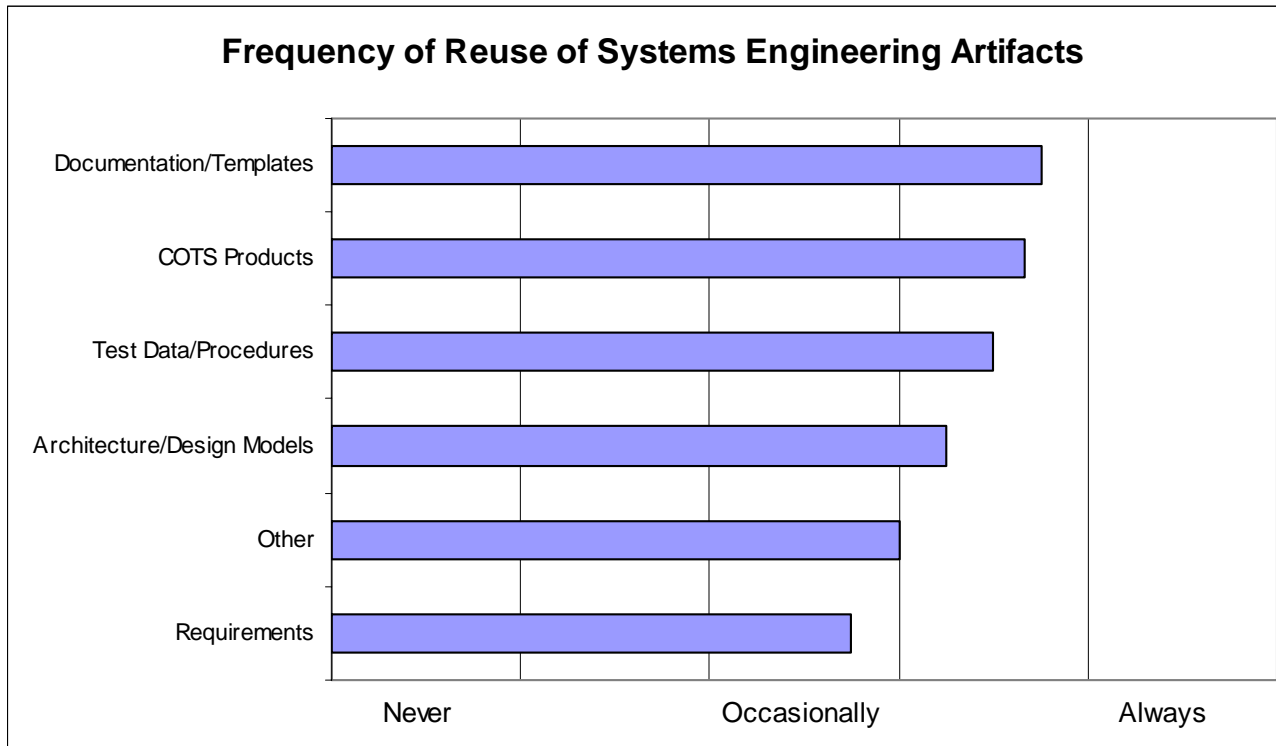
What are the most frequently promoted benefits as justification for systems engineering reuse?



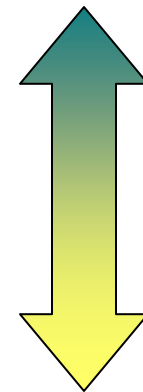
Cost benefits implied in others?

Survey Results (2)

What are the systems engineering artifacts your organization reuses and how frequently are they reused?



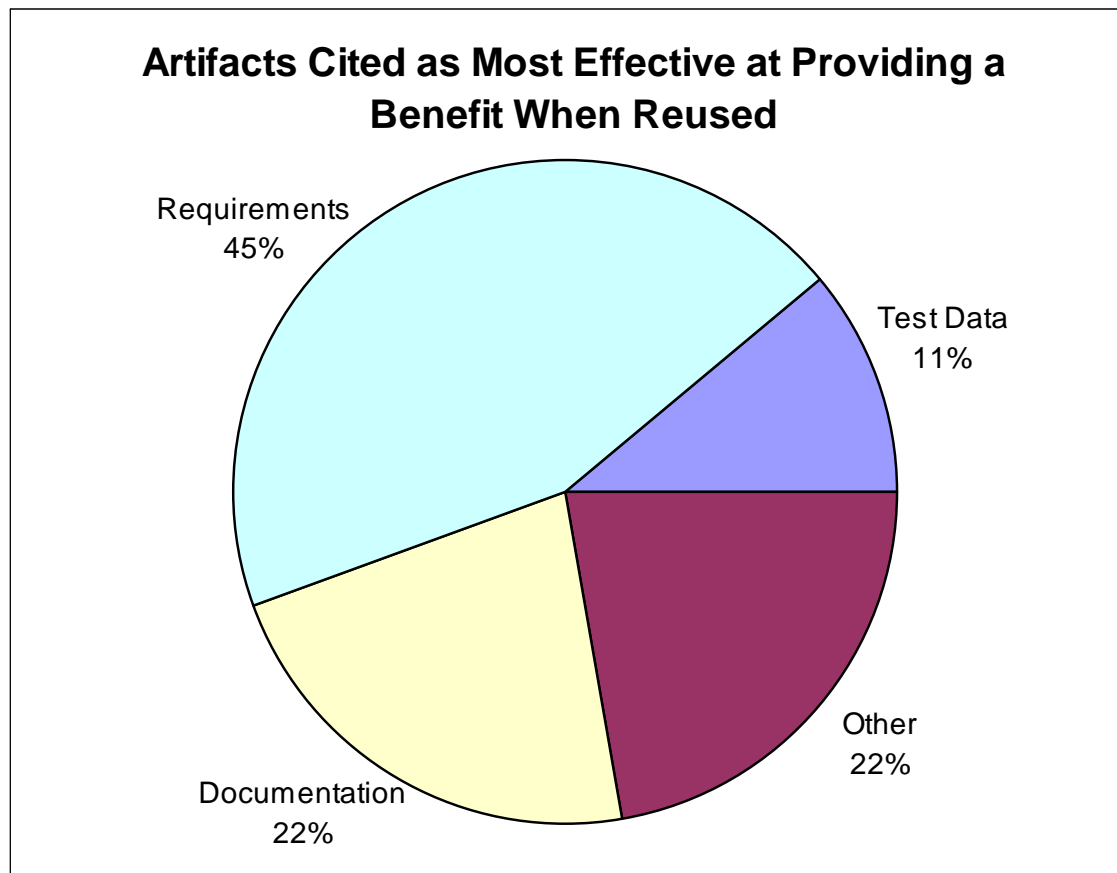
General



Specific

Survey Results (3)

Which of the artifacts listed above is the most effective at providing a net benefit when reused?



Requirements are the home run of reuse

Survey Results (4)

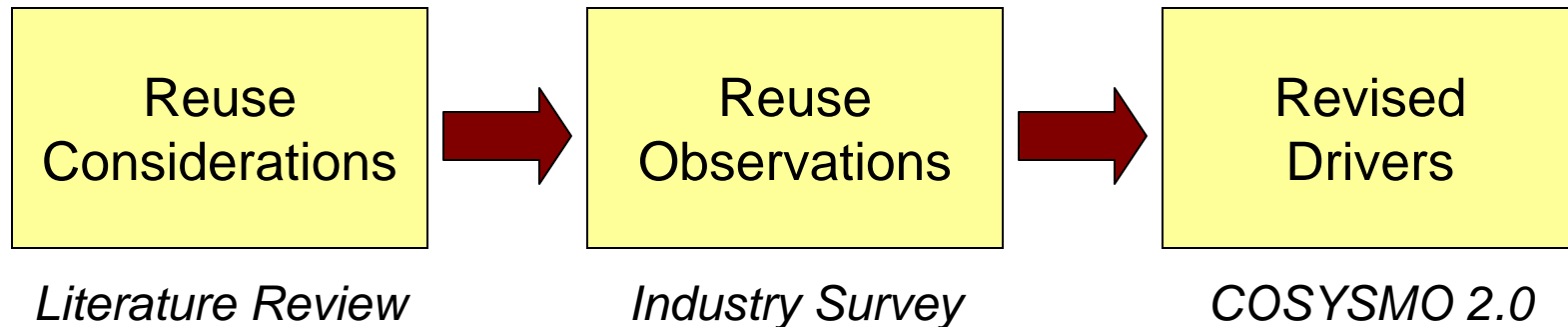
What are the reasons for reuse successes?

- Artifact reused with minimum or no change
- Product lines with significant similarities
- Requirements management
- Utilization of personnel with experience on the project that developed artifact

What are the reasons for reuse failures?

- Underestimated modification required for reuse
- New requirements placed on a modified product
- Customer didn't modify expectation of risk
- Lack of knowledge/understanding

Implications for COSYSMO 2.0



- Current approaches only address reuse in the size drivers
 - Identified need to account for reuse in both size and cost drivers

Proposed Size Driver Extensions

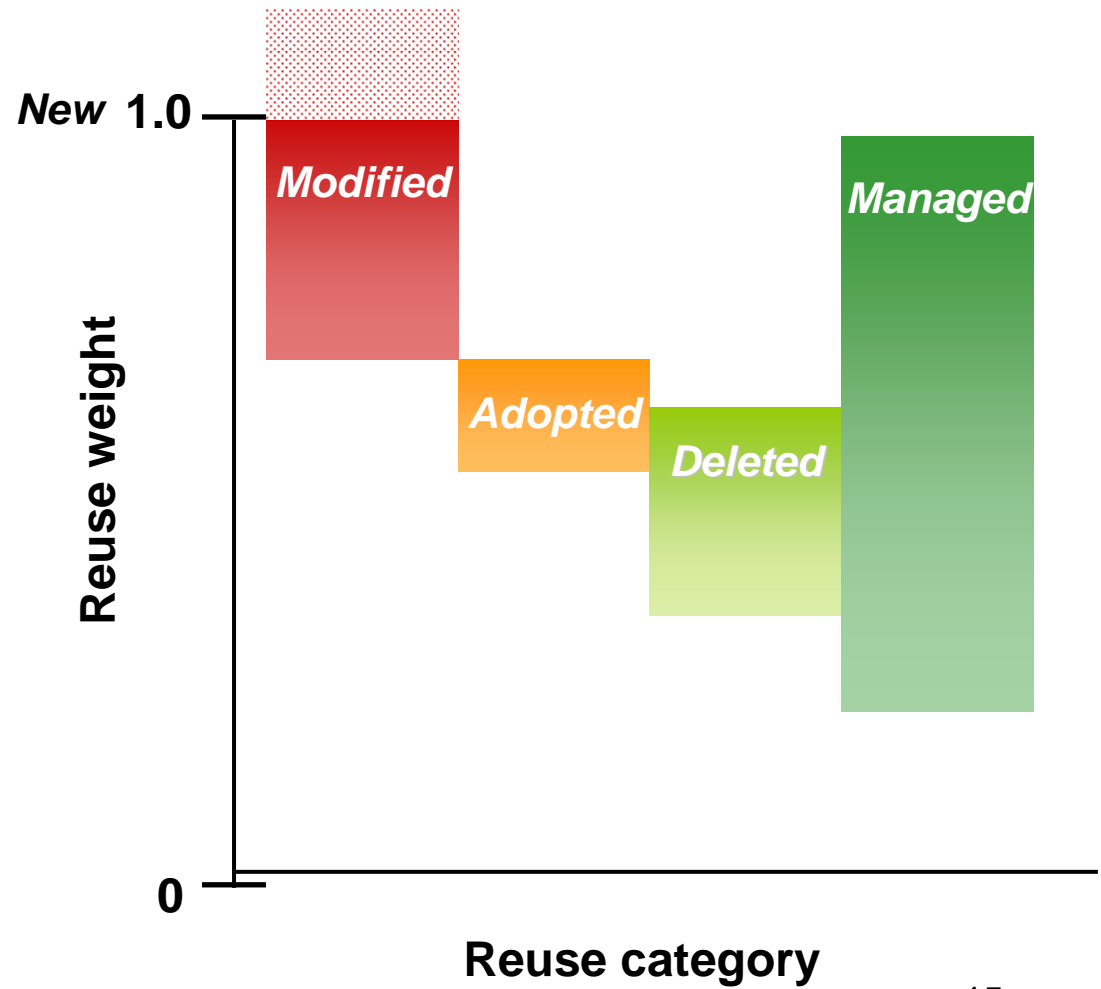
New: Artifacts that are completely new

Modified: Artifacts that are inherited, but are tailored

Adopted: Artifacts that are incorporated unmodified, also known as “black box” reuse

Deleted: Artifacts that are removed from a system

Managed: Artifacts that are incorporated unmodified and untested



Proposed Additional Cost Drivers

Reuse Understanding

Reuse Understanding	
Organization	<i>Processes</i> to capture or implement the reuse of artifacts; repeatable
Domain Applicability	Overlap between the original domain of the artifact and the <i>domain</i> the artifact is being reused within
Technology Comprehension	Availability of <i>documentation</i> or other non-personnel related <i>knowledge assets</i> that provide for or improve the understanding of the technology being addressed in the reused artifact

Artifact Unfamiliarity

Artifact Unfamiliarity	
Completely familiar	Systems engineer directly assisted in the development of the artifact for the original system; continual experience with the artifact; first-hand knowledge of the heritage system is available
Mostly familiar	Systems engineer participated in the development of the artifact for the original system; infrequent experience with the artifact
Somewhat familiar	Systems engineer has some familiarity with the artifact and the original system which it was derived from; no first-hand knowledge of the heritage system
Mostly unfamiliar	Systems engineer has experience with similar artifacts but not the current one being reused; limited knowledge of the heritage system
Completely unfamiliar	Systems engineer has no previous experience with the artifact or the system which the artifact was derived from; completely unknown

Conclusion

- Reuse is both a technical and a non-technical issue
 - Software engineering literature and systems engineering survey cite importance of organizational factors to reuse success
- Reuse needs to be accounted for in the size (technical) and cost (personnel, platform, organizational) drivers
- COSYSMO 2.0
 - Extension of size drivers
 - Addition of two reuse-focused cost drivers

...more details at the workshop!