

# A Generalized Systems Engineering Reuse Framework and Its Cost Estimating Relationship

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# Outline

- Problem and motivations
- Model definition
- Cost estimating relationship
- Delphi for calibration
- Usage
- Conclusion



# Contrastable Manners of Reuse

- **Ad Hoc / Opportunistic Reuse**
  - Search & discover reusable resources
  - Adapt to current application
    - E.g., “Code scavenging”
  - Deal with problems
- **Planned / Systematic Reuse**
  - Strategy, portfolio and roadmap
  - Explicit processes and standards
  - Investment decisions



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# Problem & Motivations

- Leverage is critically important in today's development
  - Traditional focus is on *leveraging* previous artifacts
  - An inherent *assumption* that there's something there to reuse in the first place
- However, product line decision makers must consider:
  - Cost of leveraging (not free!)
  - *Leverage vs. invest – cost tradeoffs*
  - When and how to invest
- Need to explore both sides of decision making
  - In the context of project planning
- The goal is an industry-wide agreed model
  - Design sensitivity analysis
  - Product line investment decisions



# Two Interactive Processes

## Development For Reuse (DFR)

- Producer's View
- Production of reusable resources

## Development With Reuse (DWR)

- Consumer's View
- Consumption of reusable resources

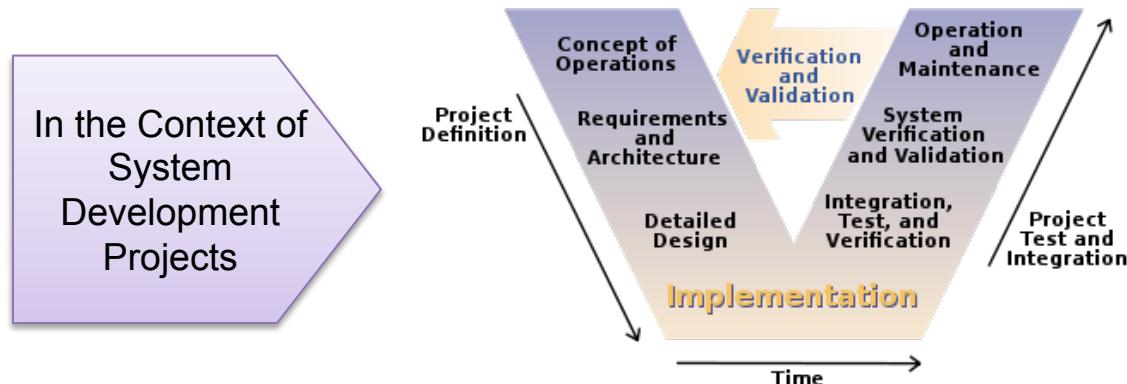


Key is How to Plan and Balance Both in a Development Project



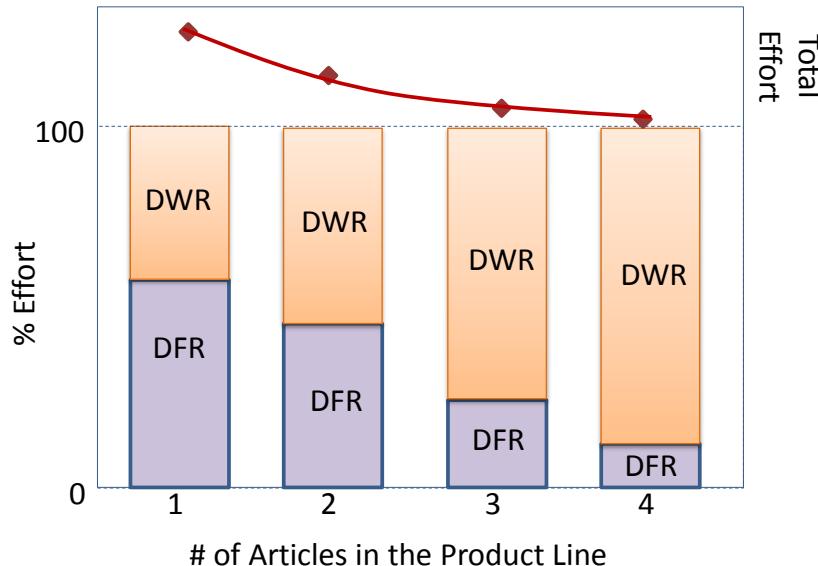
# Reuse Framework - Definitions

- *Development with Reuse* (DWR):
  - Development activities that focus on gaining benefits from utilizing or leveraging previously developed reusable artifacts, either in a planned or unplanned manner
- *Development for Reuse* (DFR):
  - Development activities with a focus on developing reusable artifacts for future usages, generally in a planned manner or through an investment effort



# Product Line Perspective

- Two sides of development decision making:
  - DWR for leveraging
  - DFR for investment
- Leveraging is about reducing new development (LCC, sch'd) over time



Investments in Development for Reuse (DFR) are leveraged to reduce Product Line Cost

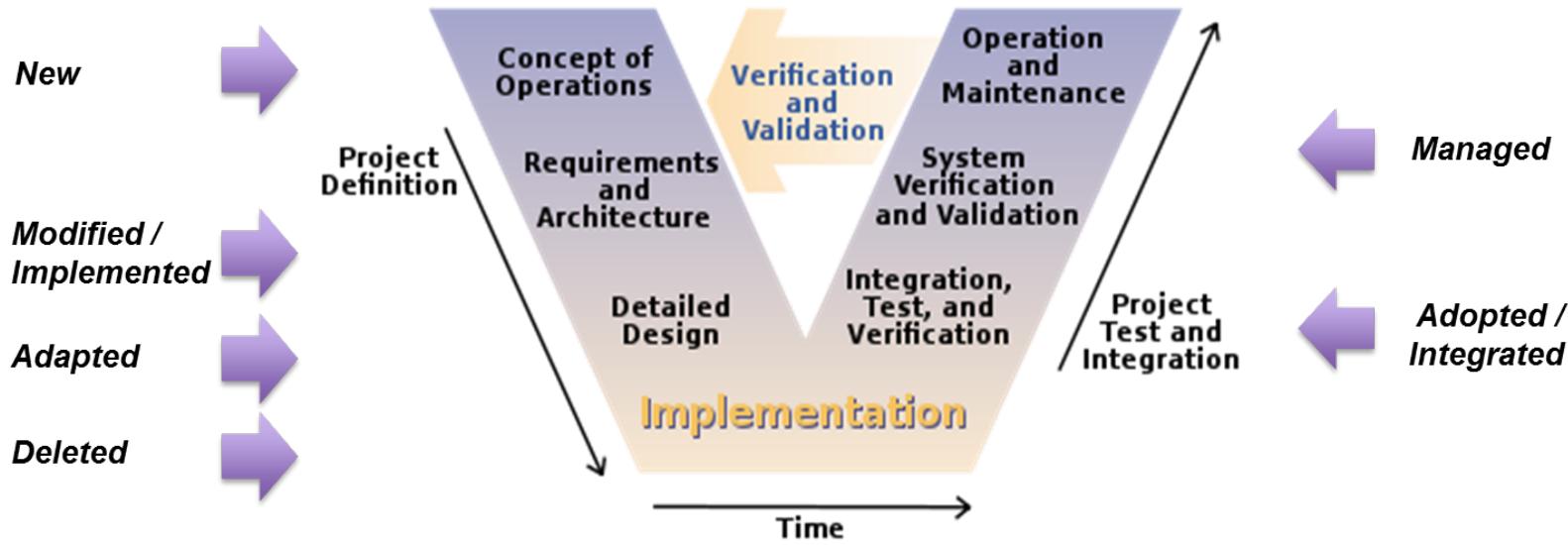


# DWR Categories

Category	Required Activities	Leveraging
<b>New</b>	<ul style="list-style-type: none"> <li>• Develop anew</li> <li>• Complete revamp of existing</li> </ul>	<ul style="list-style-type: none"> <li>• Concept</li> </ul>
<b>Modified (Implemented)</b>	<ul style="list-style-type: none"> <li>• Build from design</li> <li>• Refactor existing</li> </ul>	<ul style="list-style-type: none"> <li>• System design</li> <li>• Built component</li> </ul>
<b>Adapted</b>	<ul style="list-style-type: none"> <li>• Adapt and tailor for integration</li> </ul>	<ul style="list-style-type: none"> <li>• Built component</li> </ul>
<b>Deleted</b>	<ul style="list-style-type: none"> <li>• Disintegrate</li> <li>• Test</li> </ul>	<ul style="list-style-type: none"> <li>• Integrated system</li> </ul>
<b>Adopted (Integrated)</b>	<ul style="list-style-type: none"> <li>• Integrate</li> <li>• Test</li> </ul>	<ul style="list-style-type: none"> <li>• Build component</li> </ul>
<b>Managed</b>	<ul style="list-style-type: none"> <li>• Manage</li> <li>• Inspect</li> </ul>	<ul style="list-style-type: none"> <li>• Integrated &amp; verified component</li> </ul>



# Activity-Based View of DWR



## Activity-based Model

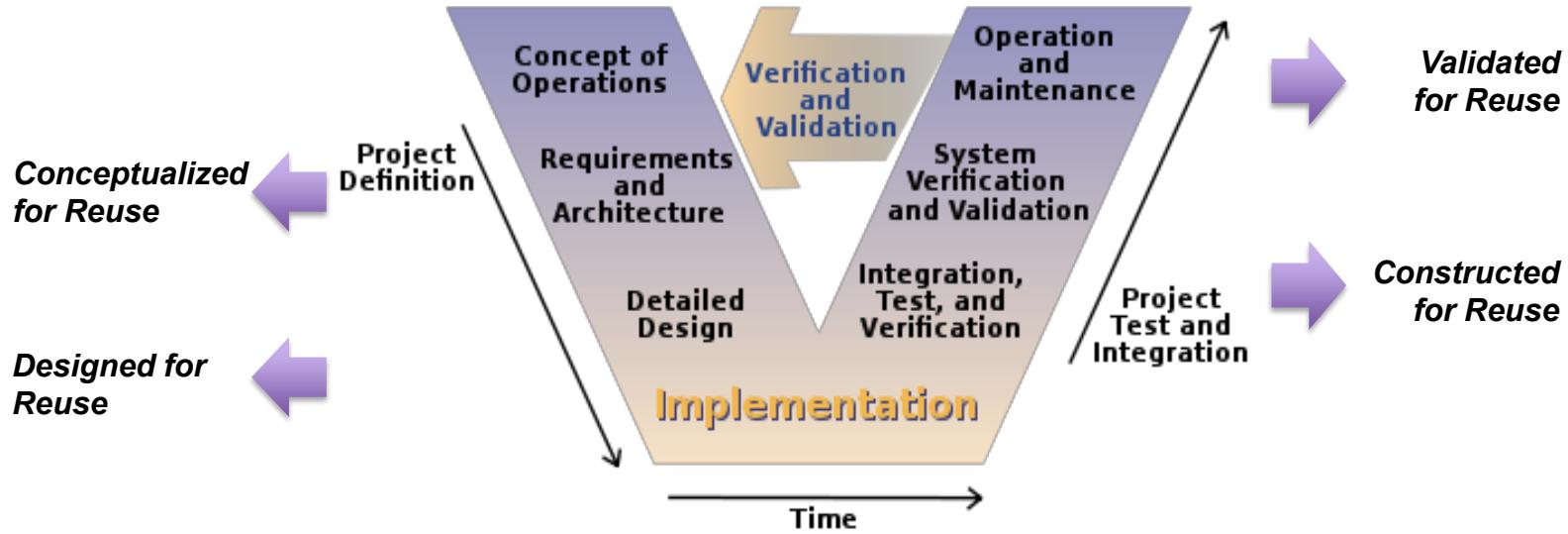


# DFR Categories

Category	Required Activities	Delivering (for reuse)
<i>No DFR</i>	<ul style="list-style-type: none"> <li>• N/A</li> </ul>	<ul style="list-style-type: none"> <li>• Little / accidental</li> </ul>
<i>Conceptualized For Reuse</i>	<ul style="list-style-type: none"> <li>• Analysis</li> <li>• Architecture</li> </ul>	<ul style="list-style-type: none"> <li>• Functional &amp; Logical architecture baselines</li> </ul>
<i>Designed For Reuse</i>	<ul style="list-style-type: none"> <li>• Analysis</li> <li>• Architecture</li> <li>• Design</li> </ul>	<ul style="list-style-type: none"> <li>• Physical architecture baseline</li> </ul>
<i>Constructed For Reuse</i>	<ul style="list-style-type: none"> <li>• Design</li> <li>• Build</li> <li>• Unit test</li> </ul>	<ul style="list-style-type: none"> <li>• Built component with configuration</li> </ul>
<i>Validated For Reuse</i>	<ul style="list-style-type: none"> <li>• Design</li> <li>• Build</li> <li>• System test</li> </ul>	<ul style="list-style-type: none"> <li>• Deployed system</li> </ul>



# Activity-Based View of DFR



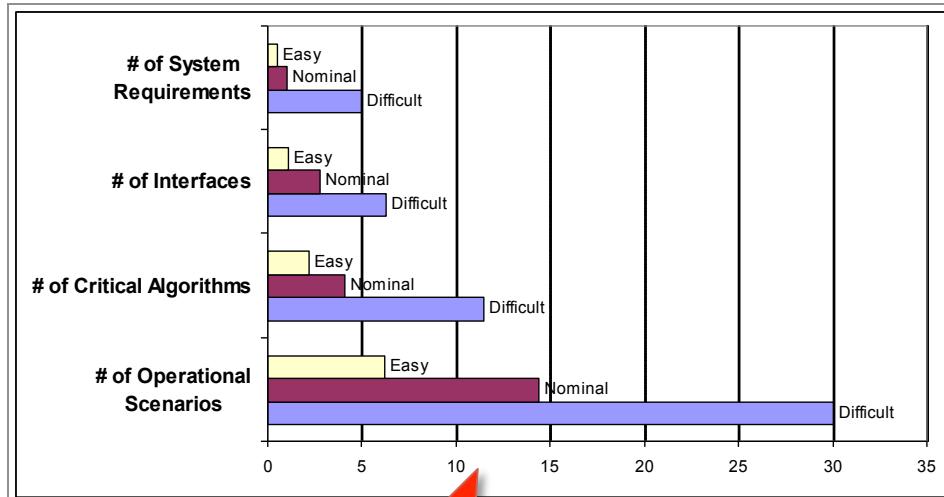
## Activity-based Model



# COSYSMO 1.0 – Original Model Form

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

- $PM_{NS}$  = effort in Person Months (Nominal Schedule)
- $A$  = calibration constant derived from historical project data
- $k = \{\text{REQ, IF, ALG, SCN}\}$
- $w_x$  = weight for “easy”, “nominal”, or “difficult” size driver
- $\Phi_x$  = quantity of “ $k$ ” size driver
- $E$  = represents (dis)economies of scale
- $EM_j$  = effort multiplier for the  $j$ th cost driver; the geometric product results in an overall effort adjustment factor to the nominal effort.



No Reuse Considerations



# COSYSMO 2.0 – DWR Model

$$Total Project Effort = DWR Effort$$

$$PM_{DWR} = A \cdot \left[ \sum_k \left( \sum_r w_r (w_{e,k} \Phi_{e,k} + w_{n,k} \Phi_{n,k} + w_{d,k} \Phi_{d,k}) \right) \right]^E \cdot CEM$$

## Categories:

- *New*
- *Modified*
- *Deleted*
- *Adopted*
- *Managed*
- *Designed for Reuse*

Where:

**PM<sub>DWR</sub>** = effort in Person Hours/Months (Nominal Schedule)

**A**<sub>1</sub> = DWR constant derived from historical project data

**k** = {REQ, IF, ALG, SCN}

**r** = {New, Modified, Deleted, Adopted, Managed, Designed for Reuse}

**w<sub>r</sub>** = weight for defined levels of size driver reuse

**w<sub>x</sub>** = weight for “easy”, “nominal”, or “difficult” size driver

**Φ<sub>x</sub>** = quantity of “k” size driver

**E<sub>1</sub>** = represents diseconomy of scale in DWR

**CEM<sub>1</sub>** = composite effort multiplier for DWR

Partial Considerations



# COSYSMO 3.0 – Gen. Reuse Framework

$$TotalProject\ Effort = DWR\ Effort + DFR\ Effort$$

$$PM_{DWR+DFR} = A_1 \cdot \left[ \sum_k \left( \sum_r w_r (w_{e,k} \Phi_{e,k} + w_{n,k} \Phi_{n,k} + w_{d,k} \Phi_{d,k}) \right) \right]^{E_1} \cdot CEM_1$$
$$+ A_2 \cdot \left[ \sum_k \left( \sum_q w_q (w_{e,k} \Psi_{e,k} + w_{n,k} \Psi_{n,k} + w_{d,k} \Psi_{d,k}) \right) \right]^{E_2} \cdot CEM_2$$

Where:

**PM<sub>DWR</sub>** = effort in Person Hours/Months (Nominal Schedule)

**A<sub>1</sub>** = DWR constant derived from historical project data

**k** = {REQ, IF, ALG, SCN}

**r** = {New, Modified, Adapted, Deleted, Adopted, Managed}

**w<sub>r</sub>** = weight for defined levels of size driver reuse

**w<sub>x</sub>** = weight for “easy”, “nominal”, or “difficult” size driver

**Φ<sub>x</sub>** = quantity of “k” size driver

**E<sub>1</sub>** = represents diseconomy of scale in DWR

**CEM<sub>1</sub>** = composite effort multiplier for DWR

Where:

**PM<sub>DFR</sub>** = effort in Person Hours/Months (Nominal Schedule)

**A<sub>2</sub>** = DFR constant derived from historical project data

**q** = {Conceptualized, Designed, Constructed, Validated}

**w<sub>q</sub>** = weight for defined levels of size driver reuse

**w<sub>x</sub>** = weight for “easy”, “nominal”, or “difficult” size driver

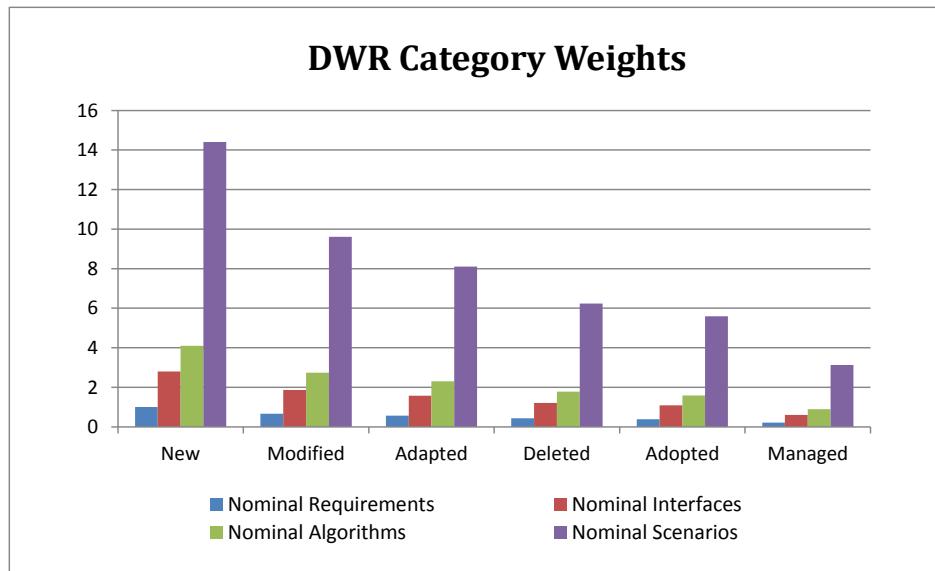
**Φ<sub>x</sub>** = quantity of “k” size driver

**E<sub>2</sub>** = represents diseconomy of scale in DFR

**CEM<sub>2</sub>** = composite effort multiplier for DFR

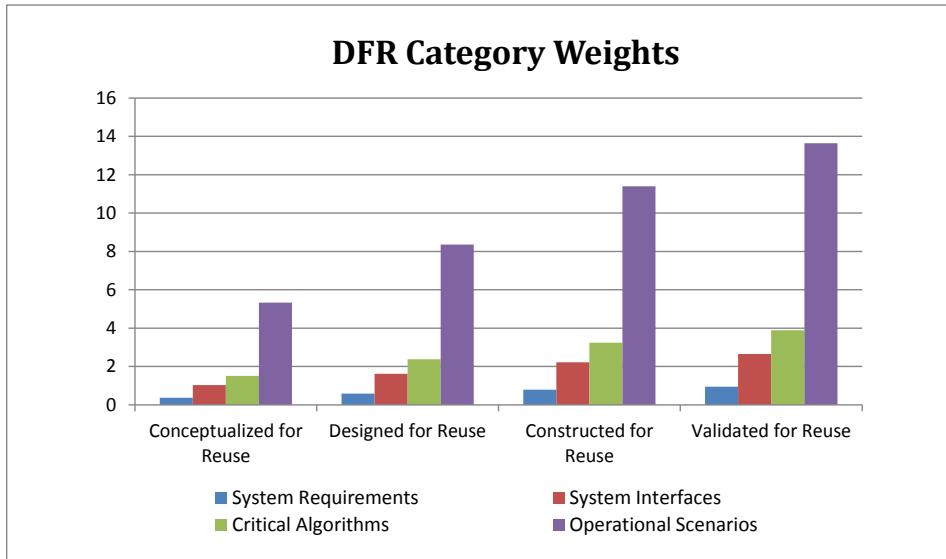


# The DWR Weights



	New	Modified	Adapted	Deleted	Adopted	Managed
	100.00%	66.73%	56.27%	43.34%	38.80%	21.70%
<b>Nominal Requirements</b>	1.00	0.67	0.56	0.43	0.39	0.22
<b>Nominal Interfaces</b>	2.80	1.87	1.58	1.21	1.09	0.61
<b>Nominal Algorithms</b>	4.10	2.74	2.31	1.78	1.59	0.89
<b>Nominal Scenarios</b>	14.40	9.61	8.10	6.24	5.59	3.13

# The DFR Weights



	Nom. Weights	No DFR	Conceptualized for Reuse	Designed for Reuse	Constructed for Reuse	Validated for Reuse
		0.00%	36.98%	58.02%	79.15%	94.74%
<b>System Requirements</b>	1.00	0.00	0.37	0.58	0.79	0.95
<b>System Interfaces</b>	2.80	0.00	1.04	1.62	2.22	2.65
<b>Critical Algorithms</b>	4.10	0.00	1.52	2.38	3.25	3.88
<b>Operational Scenarios</b>	14.40	0.00	5.33	8.36	11.40	13.64



# Industry Delphi Rounds – Determining the Coefficients

- Questionnaire correlating systems engineering activities defined in ANSI/EIA-632-1999 with relative efforts in each of the DWR and the DFR categories
- Data collection and analysis
- Q&A workshops (F2F & Telecoms)
- Over 70 aerospace & commercial participants

## *The Delphi Questionnaire*

Delphi Delphi Function	Delphi Delphi Task	Plan	Review	Method/Planning	Review	Define	Plan/Check	Detail	Plan/Check	Adapt/Change	Review	Review	Review	Review
Initial System	1. Project Acquire	0.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%
	2. Project Acquisition	0.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%
	3. Project Preparation	0.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%
	4. Project Preparation Workshop	0.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%
	5. Technical Specification	0.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%
	6. Schedule and Organizational	0.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%
	7. Technical Plans	0.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%
	8. Technical Review	0.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%
	9. Project System Plan and Schedule	0.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%
	10. Project System Requirements	0.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%
Realize System	11. Technical Review	0.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%
	12. Delays Management	0.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%
	13. Interim Observation	0.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%
	14. Analysis Requirements	0.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%
	15. Other Stakeholder Requirements	0.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%
	16. System Technical Requirements	0.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%
	17. System Technical Requirements Validation	0.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%
	18. System Technical Requirements Verification	0.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%
	19. Other Stakeholder Requirements Validation	0.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%
	20. System Technical Requirements Validation	0.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%
Realize System	21. Log-in System Requirements Validation	0.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%
	22. Design Evaluation Verification	0.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%
	23. End Product Verification	0.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%
	24. Existing Product Realization	0.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%	25.00%

For Each DWR Category	Determine the Nominal Level of Activities Required				
Input Artifacts	System Concept	System Definition	Realized System	Deployed System	
ANSI/EIA-632-1999 Activities (1-33)	Select 0, 25, 50, or 100% effort for each activity	Select 0, 25, 50, or 100% effort for each activity	Select 0, 25, 50, or 100% effort for each activity	Select 0, 25, 50, or 100% effort for each activity	



# Usage Tips for Practitioners

- Tip 1: DFR & DWR in a same project – count the drivers in two passes
  - e.g., “new” requirements
- Tip 2: activities vs. artifacts
- Tip 3: not just physical, but also logical artifacts
- Tip 4: *Consistency, consistency, and consistency!*
  - *Between projects*
  - *Between calibration data and estimating*
  - *System level*



# Conclusion

- *Generalized Reuse Framework* with two interactive processes – DFR and DWR
  - Investment vs. leveraging
  - Both sides of development decision making
- Proposed a cost estimating relationship in COSYSMO
  - Design trades and sensitivity analysis
  - Product line investment decisions
- COSYSMO 3.0 work in progress



# Questions and Comments

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