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How Cost Effective is your V&V?

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Presentation Structure

- Background – Verification and Validation (V&V)
- V&V Effectiveness Assessment
- Cost Effectiveness and V&V Effectiveness
- Scope of Coverage of V&V Methods
- Selection of V&V Methods
- Technical Risk Management
- Process Sequence Matters!
- Conclusions

Verification and Validation

- System validation confirms that the system, as built (or as it will be built), satisfies the stakeholders' stated needs. Validation ensures the requirements and the system implementation provide the right solution to the customer's problem. In other words, "you built the right thing". Verification, on the other hand, means that "you built the thing right" (SE Handbook, v.3.2.2, section 4.8.2.1)

Gas Turbine Engine Electronic Control & Monitoring Unit Context

- Requirements are validated with the customer. This may include requirements review and the development of models which represent the planned functionality and physical attributes of the system to test for a consistent mutual interpretation of the requirements.
- The design is reviewed, analyzed and tested to verify compliance to requirements
- The product is delivered for engine test, flight test and service, where performance in these environments validates if the product is meeting the customer (propulsion system team, airframer and operator) needs.

V & V Effectiveness Assessment

Software Problem Report Analysis Should have been found during: --> Found during:	Requirements Validation	Design Review	Code Review	Component test	Software verification	System verification	Bench/Test Rig	Engine d'vt test	Engine cert test	Flight test	Flight in service
Requirements Validation	36%										
Design Review	7.4%	4.3%									
Code Review	4.3%	1.9%	5.7%								
Component test	0.0%	0.1%	0.4%	0.2%							
Software Verification	2.5%	4.2%	3.8%		1.5%						
System verification	7.9%	1.1%	0.2%		0.9%	2.0%					
Bench/Test Rig	0.5%	2.5%	1.3%			0.0%	0.3%				
Engine d'vt test	0.1%	0.4%					0.1%	0.2%			
Engine cert test	0.9%	0.4%			0.1%	0.1%		0.1%			
Flight Test	1.3%	1.2%	0.1%		0.3%	0.3%	0.0%	0.1%		0.4%	
Flight in Service	0.5%	1.0%				0.0%	0.0%		0.2%	0.7%	2.2%
Total Escapes	26%	13%	5.9%	0.0%	1.3%	0.6%	0.2%	0.2%	0.2%	1.1%	
Total Found	36%	12%	12%	1%	12%	12%	5%	1%	2%	4%	5%
Effectiveness	58%	48%	67%	100%	90%	96%	95%	78%	90%	78%	100%
Cost to Perform	12%	11%	4%	19%	23%	18%	12%	0%	0%	0%	0%

What the method actually detected

What Escaped

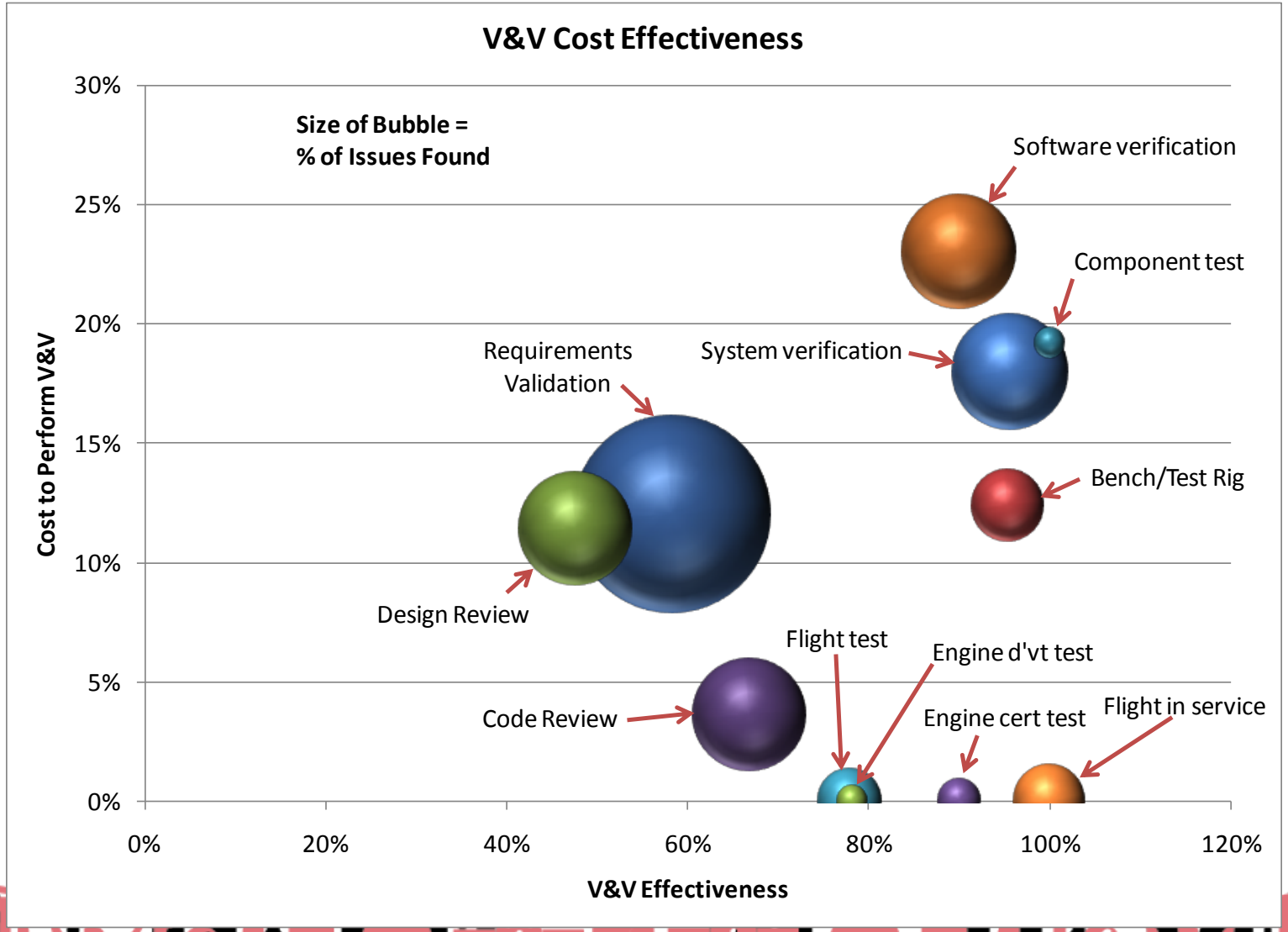
Key:	
>= 8%	
4% to 8%	
2% to 4%	
1% to 2%	
<1%	
	48%
	100%
	100%

Cost Weight	Cost if found at right stage	Actual cost
1	0.613	0.358
1	0.171	0.117
1	0.116	0.119
5	0.009	0.039
25	0.704	3.012
25	0.646	3.047
50	0.277	2.378
50	0.208	0.416
50	0.092	0.831
50	0.531	1.870
200	4.340	9.234
Total:	7.708	21.420
Cost Ratio:		278%

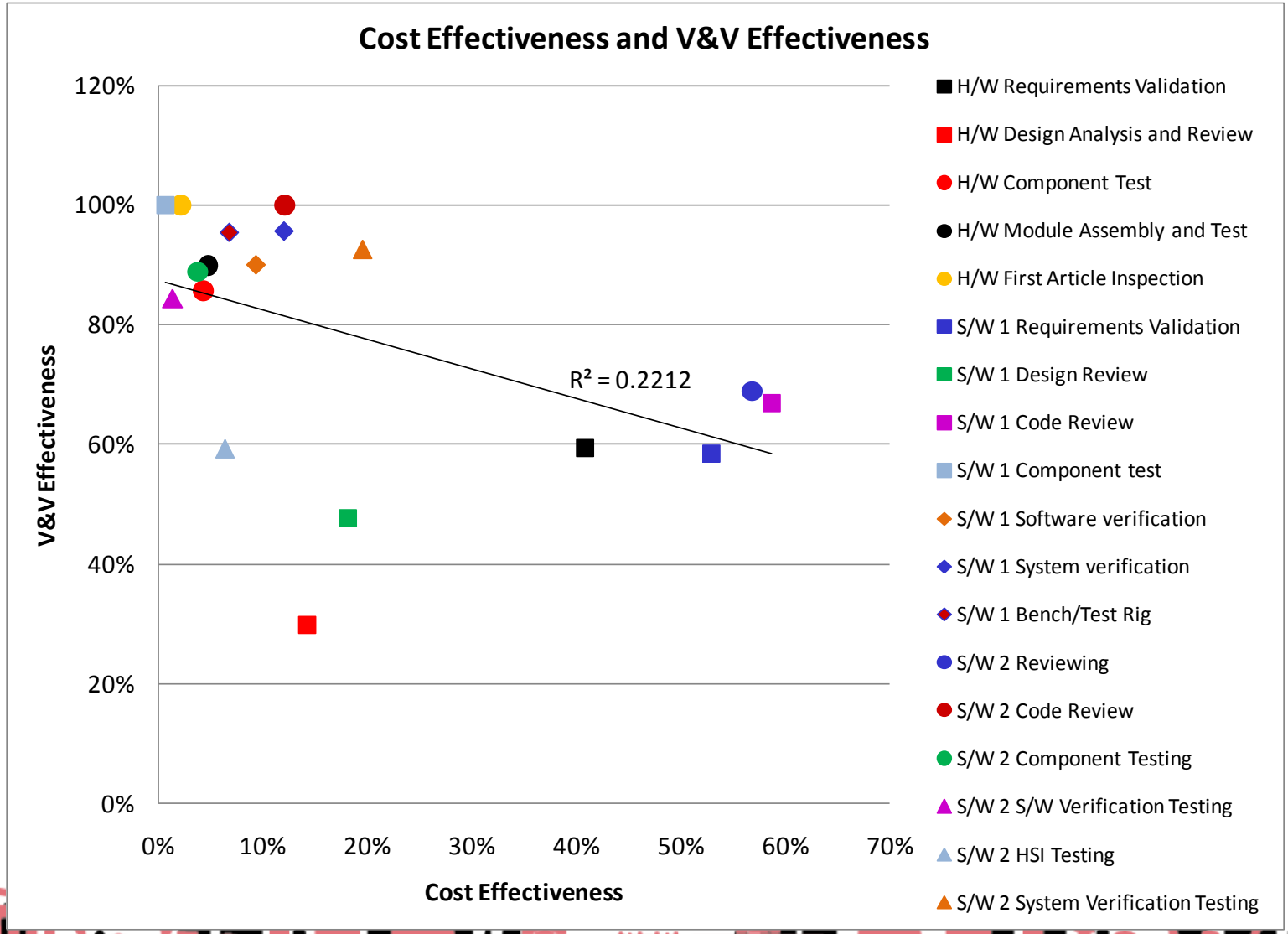
V&V Effectiveness & Cost Effectiveness

- *V&V Effectiveness = 1 – (What Escaped)/(What Escaped +What the Method Detected*)
- Zero effectiveness means the method detected no issues but should have detected some.
- 50% means the method missed as many things as it detected
- 100% means the method detected everything it should have and there were no escapes
- *Cost Effectiveness = (Number of Issues Detected)/(Cost to Detect)*

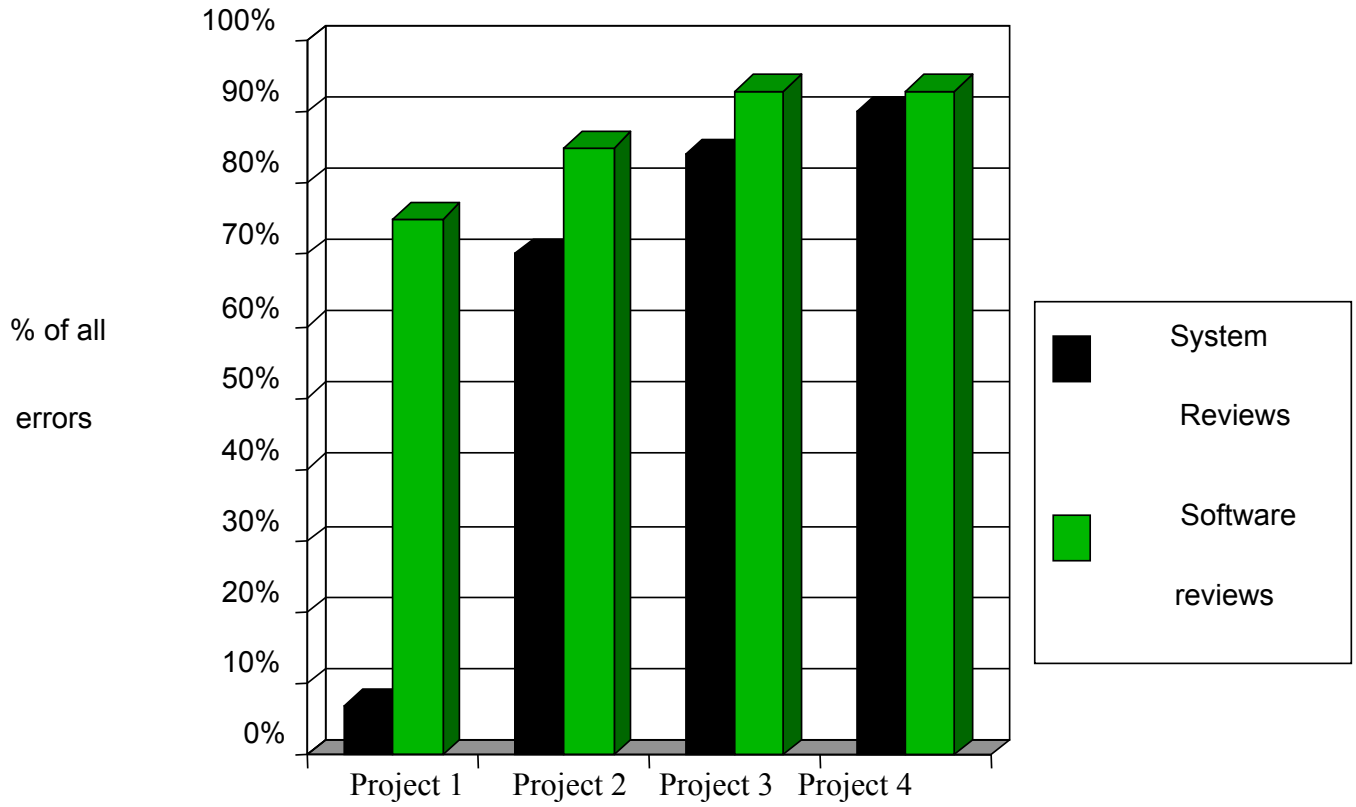
V&V Cost Effectiveness



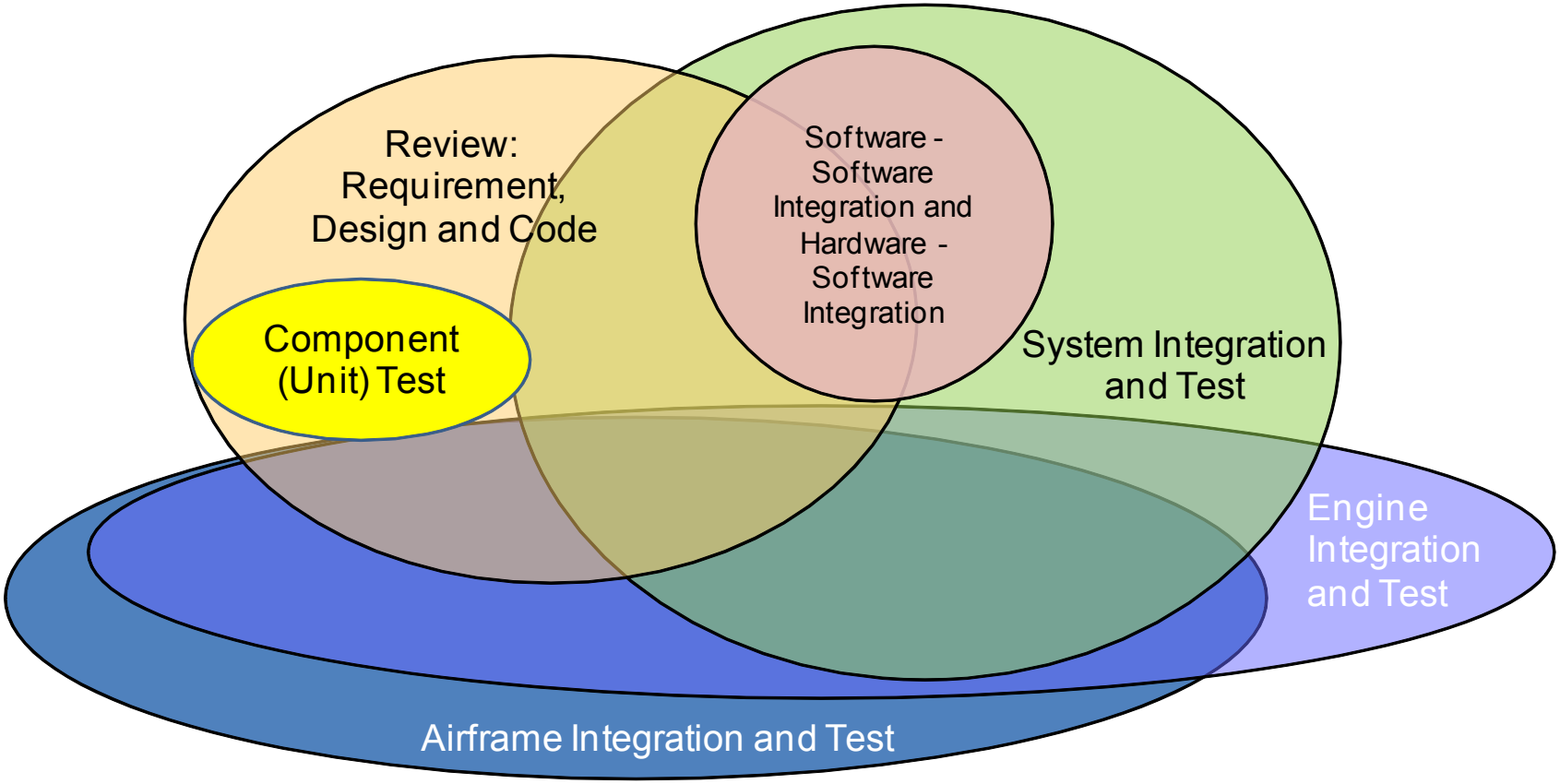
Cost and V&V Effectiveness



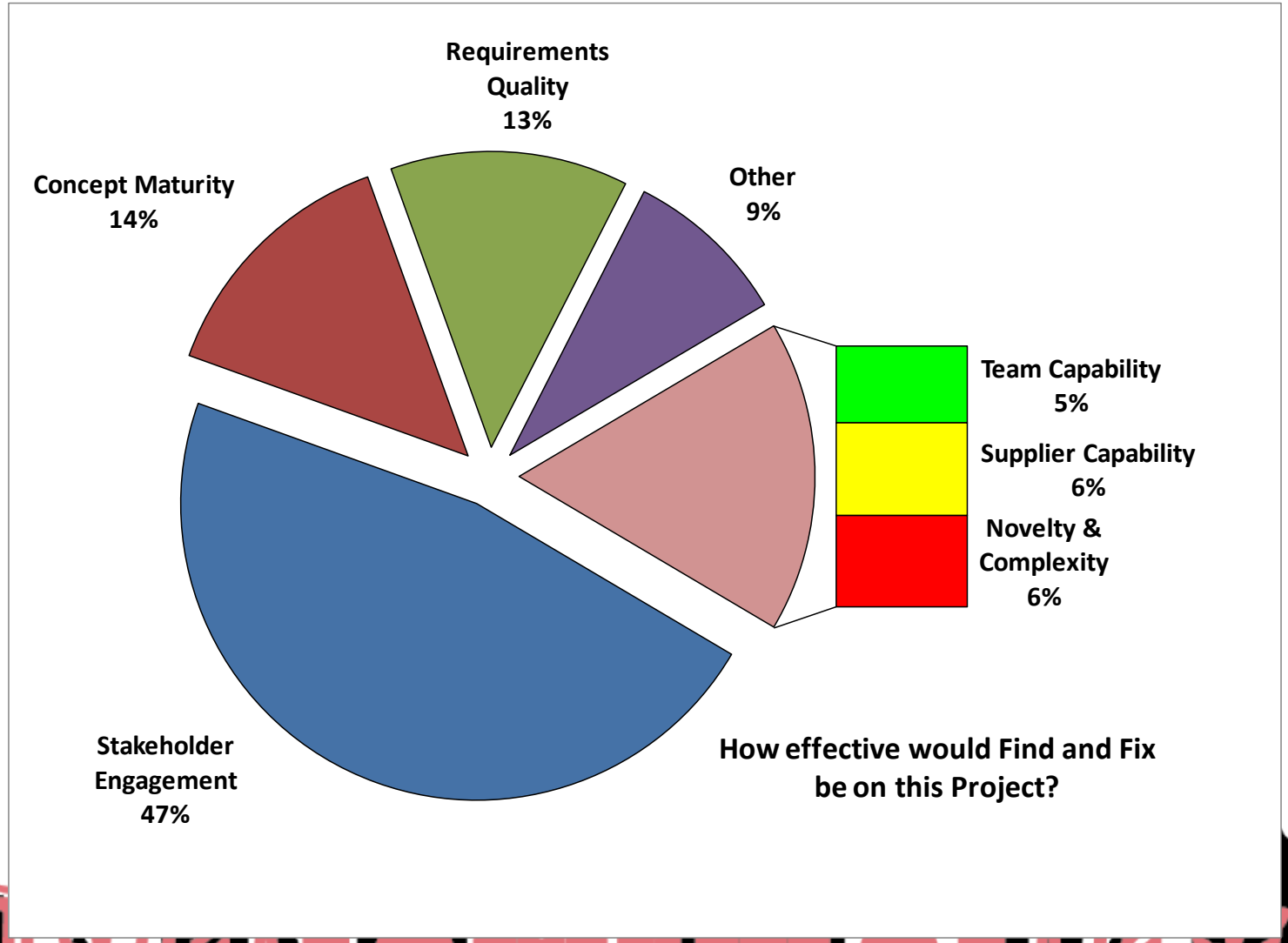
Improving Review Effectiveness



Scope of Coverage of V&V Methods



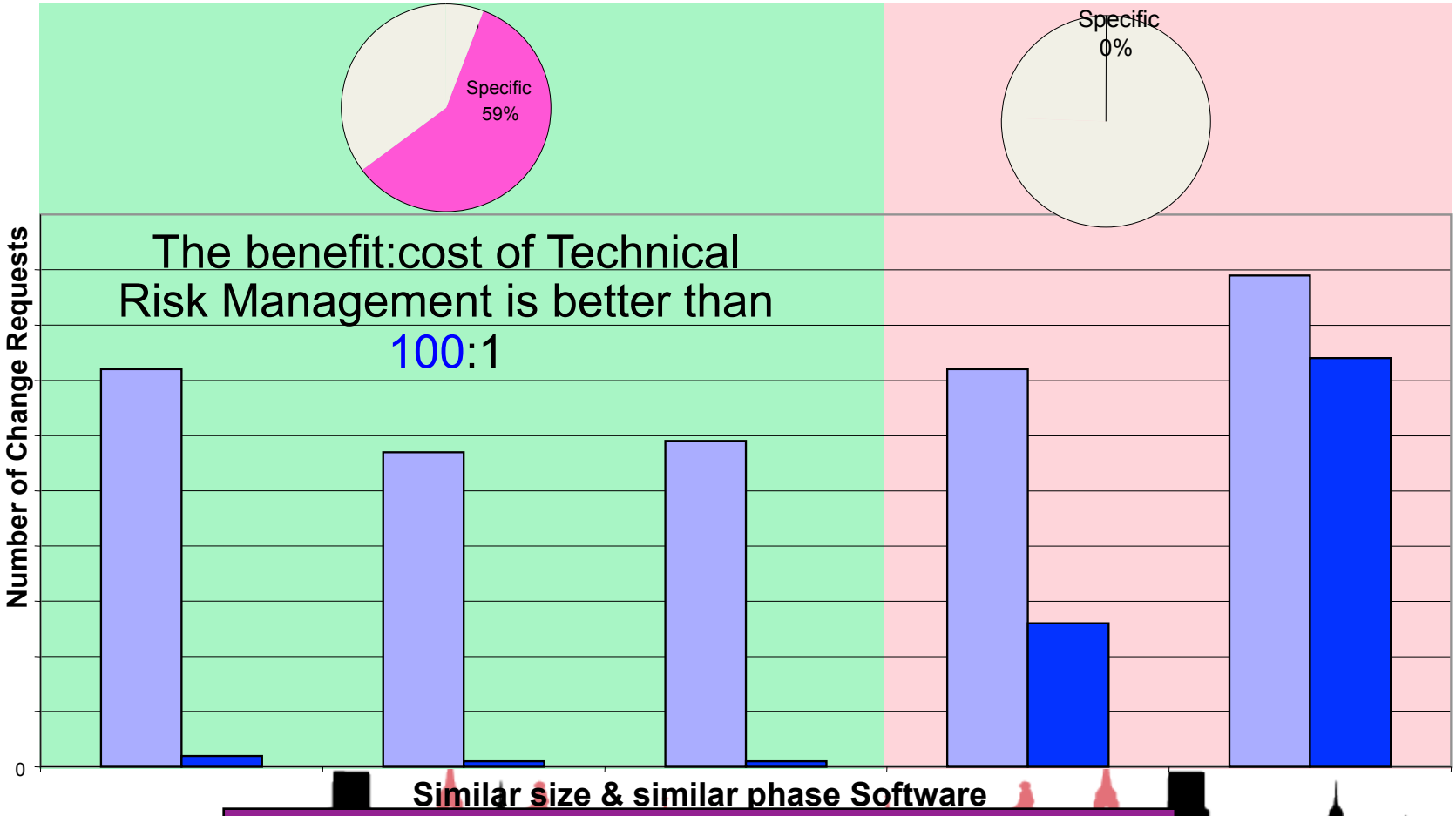
Risk Classes & Selection of V&V Methods



Matching the Mitigation to the Risk

CR #	CR Title	Source of Risk or Uncertainty	Risk	Impact	Score	Mitigation	Priority Development	In-Depth Review	Proto-type	Find and Fix
1	Change Request 1	Concept Maturity	9	9	81	Early proof of concept	Yes	Yes	No	No
2	Change Request 2	Requirements Quality	3	9	27	Review with IPT	Yes	Yes	No	Yes
3	Change Request 3	Concept Maturity	1	9	9	Functional Model	Maybe	Maybe	Maybe	No
4	Change Request 4	Supplier Capability	3	1	3	In-depth review with Supplier, Find and Fix	No	Yes	No	Yes
5	Change Request 5	Team Capability	1	9	9	In-depth review, Find and Fix	No	Yes	No	Yes
6	Change Request 6	Novelty and Complexity	3	1	3	Find and Fix	No	No	No	Yes
7	Change Request 7	Novelty and Complexity	9	9	81	Prototype, Find and Fix	Yes	No	Yes	Yes
8	Change Request 8	Team Capability	3	9	27	In-depth review	Maybe	Yes	No	No
9	Change Request 9	Team Capability	9	1	9	Find and Fix	No	No	No	Yes
10	Change Request 10	Novelty and Complexity	1	9	9	Find and Fix	Maybe	No	Maybe	Yes

Low Scrap and Rework Rates are Achievable



How will the outcome differ between the following?

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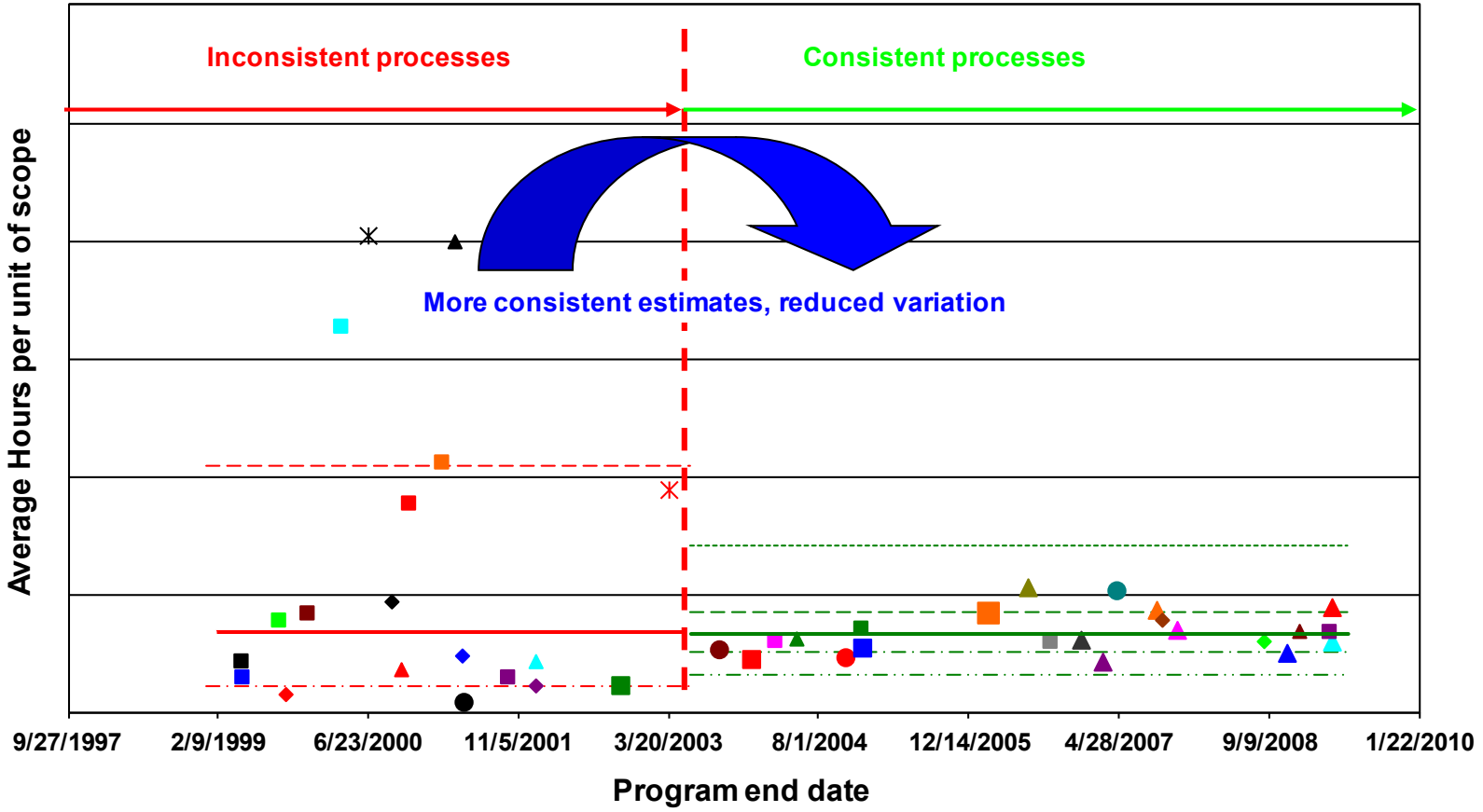
Make it	**Deliver**	Capture requirements	Review requirements	Test
Make it	Capture requirements	**Deliver**	Review requirements	Test
Capture requirements	Make it	**Deliver**	Review requirements	Test
Capture requirements	Review requirements	Make it	**Deliver**	Test
Capture requirements	Review requirements	Make it	Test	**Deliver**

When Should the Verification Team Review the Requirements?



Conclusions

- Different V&V Methods have different effectiveness to detect errors
- Review is less effective at detecting errors, but is very cost effective, compared to testing
- For early design iterations or for non-safety-critical systems, removal of defects may be achieved earlier and more effectively by concentrating more effort on reviews (of requirements and designs)
- Select risk mitigation classes based on risk classes – use technical risk management to achieve low scrap and rework rates
- Process sequence matters! It's not just what you do, but when you do it
- Make sure the Verification team reviews the requirements before the implementation team designs and builds products