INCOSE International Symposium
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Reducing Scrap & Rework

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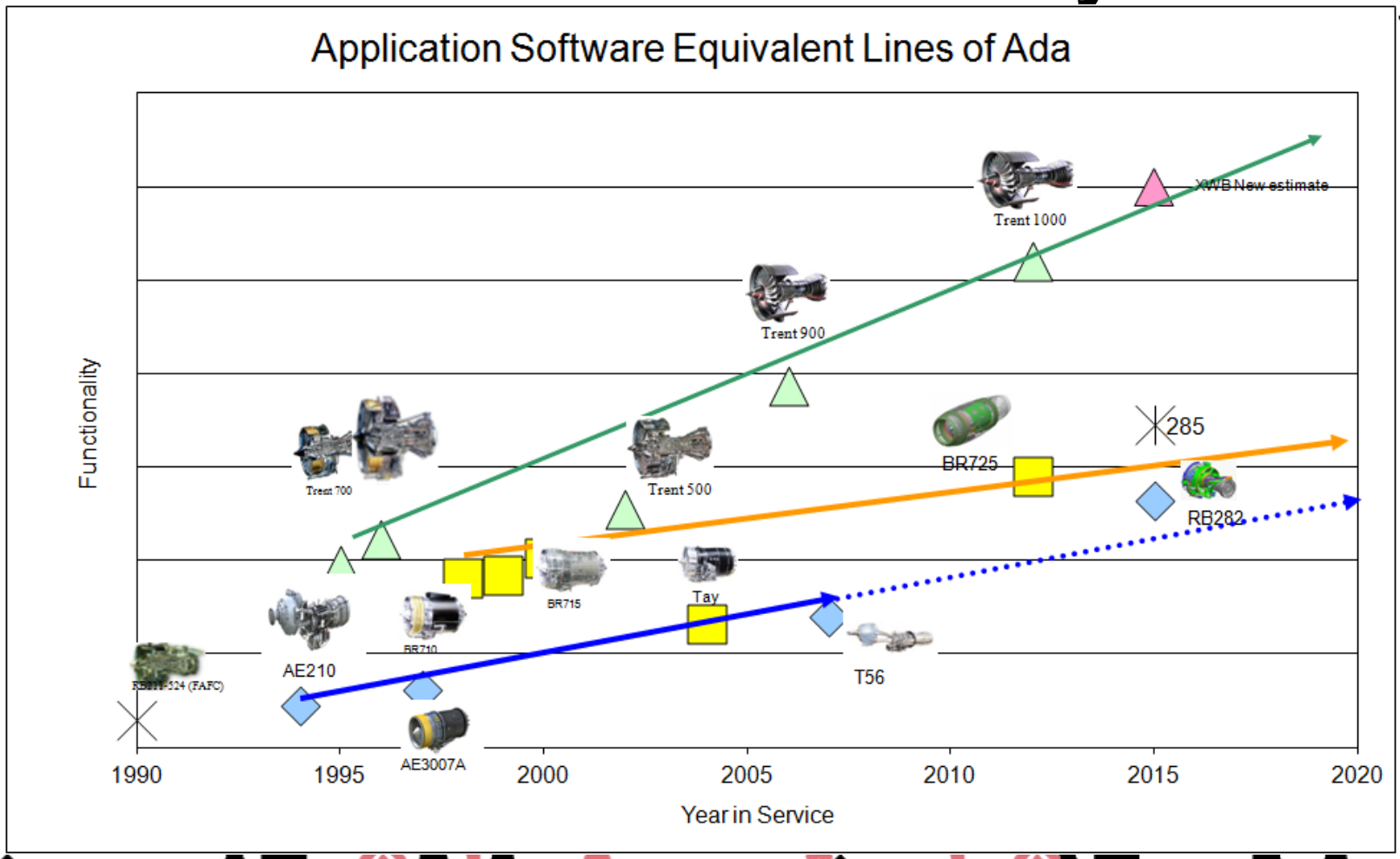
Rolls-Royce

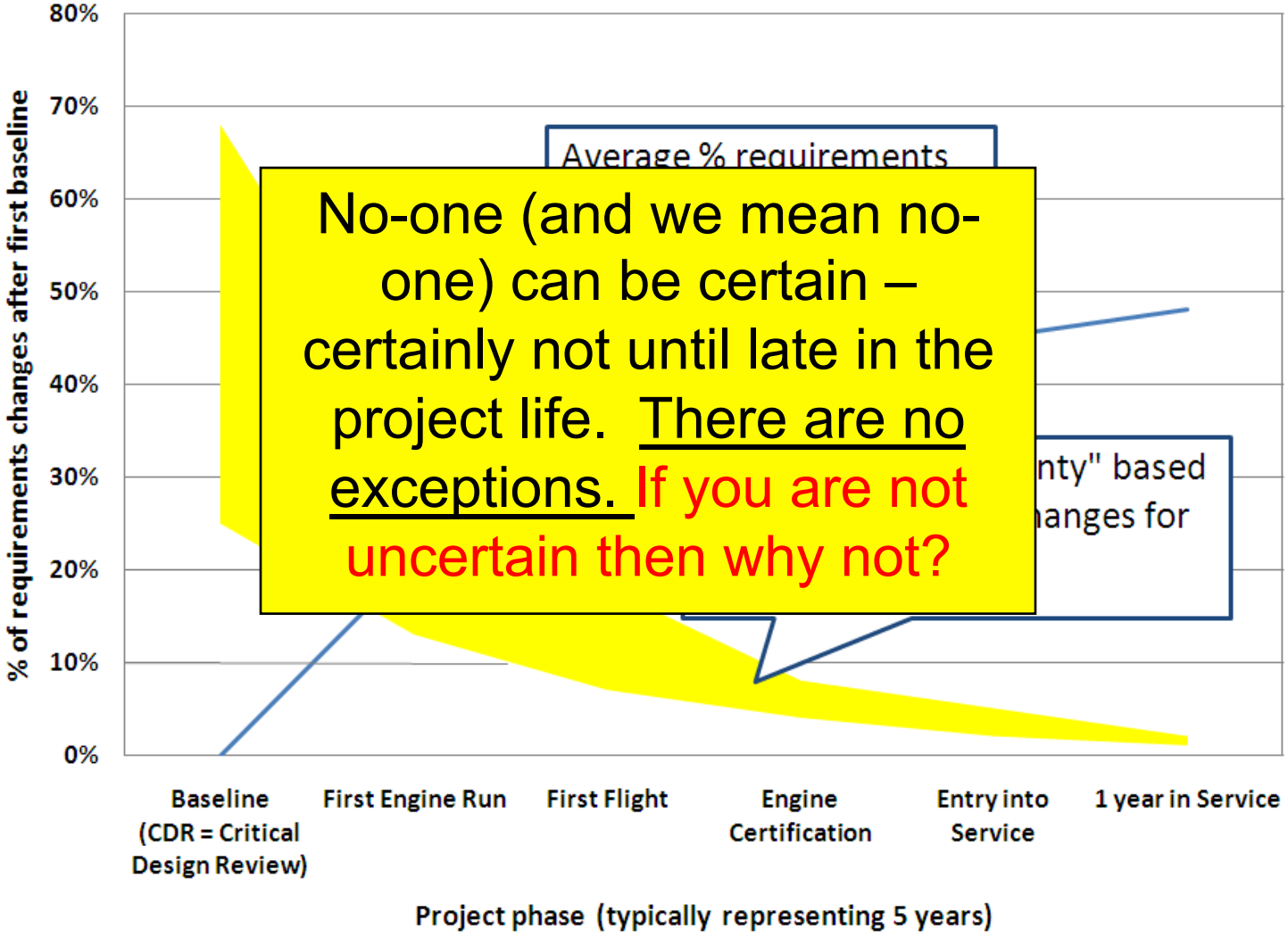
Presentation Structure

- Background - Increasing Complexity
- Requirements Maturity and Product Maturity
- Scrap and Rework
- Cost of Late Detection
- Program Pressures
- Technical Risk Management
- Solutions – Examples
- Outcomes
- Conclusions

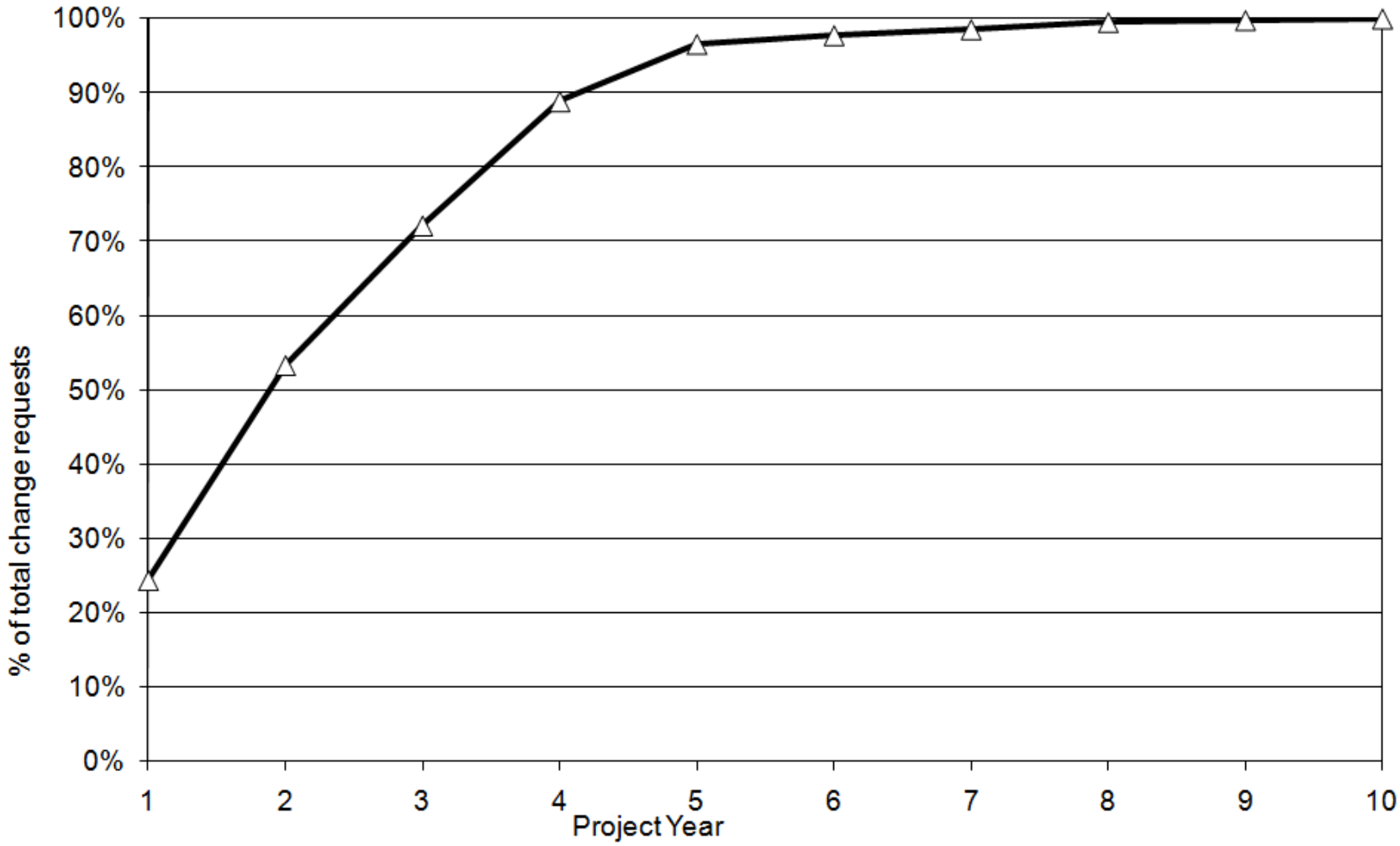
Engine Electronic Control System Relative Software Functionality



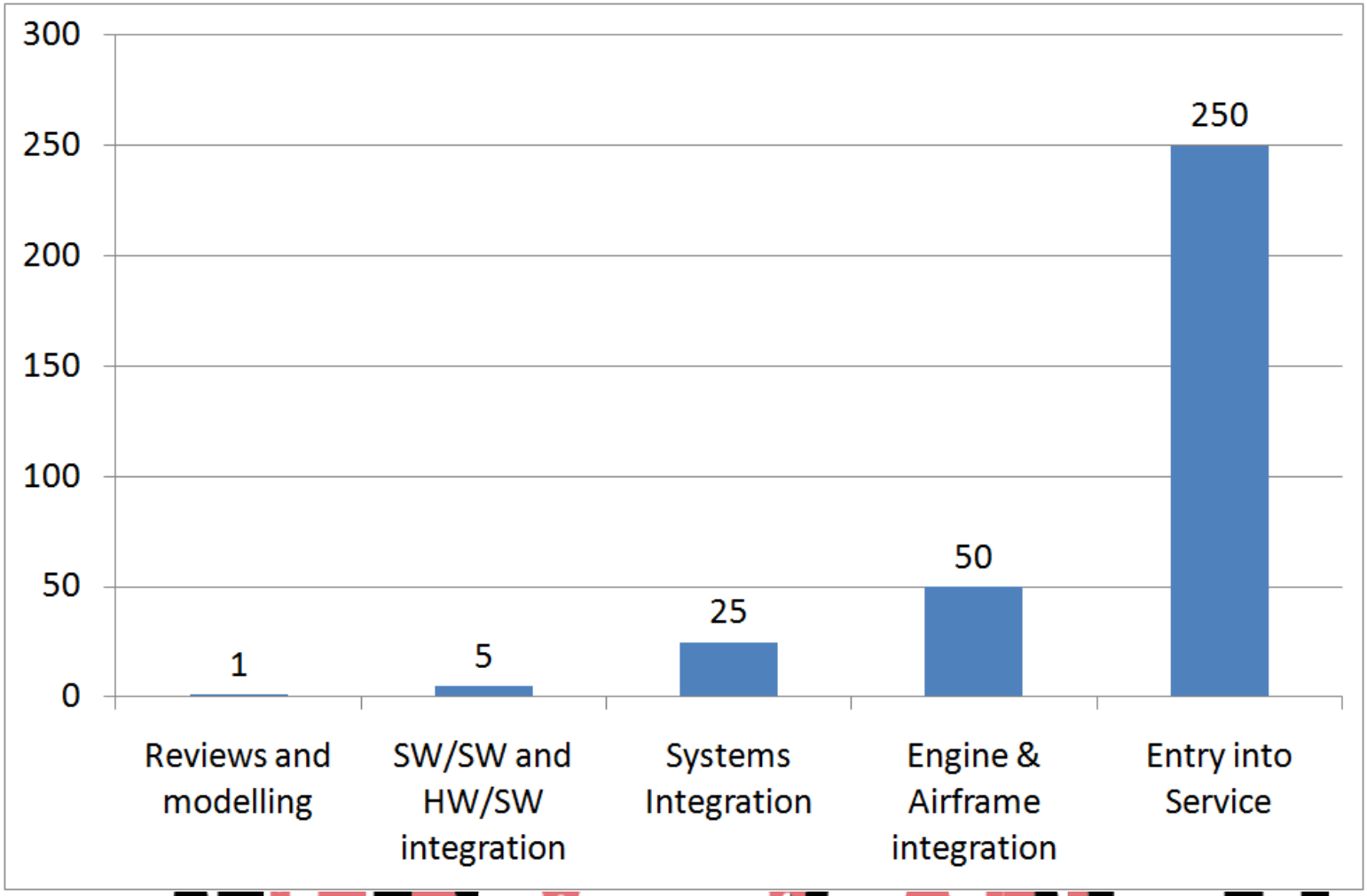
Historic Volatility



Product maturity takes time



....but the cost to mature a product varies over time



The cost of Maturity

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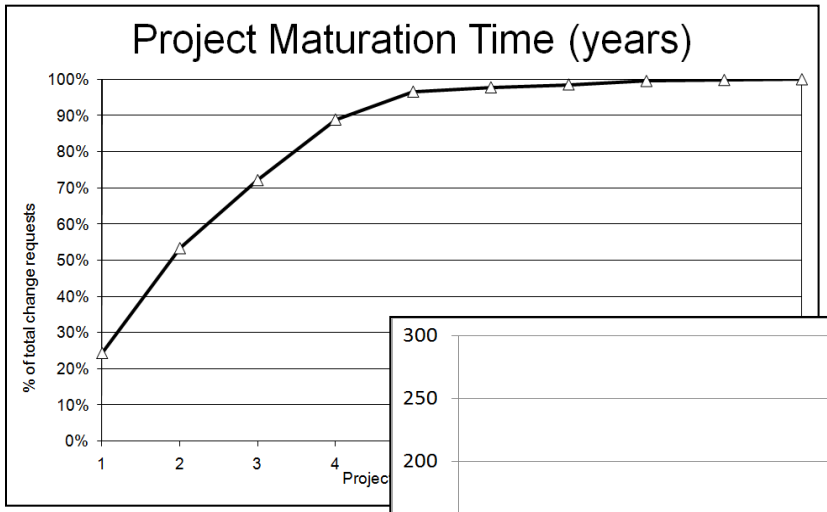
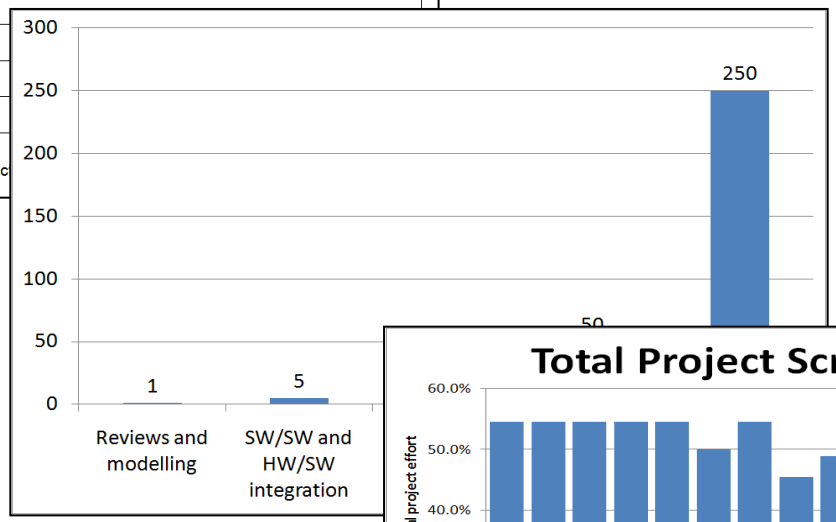
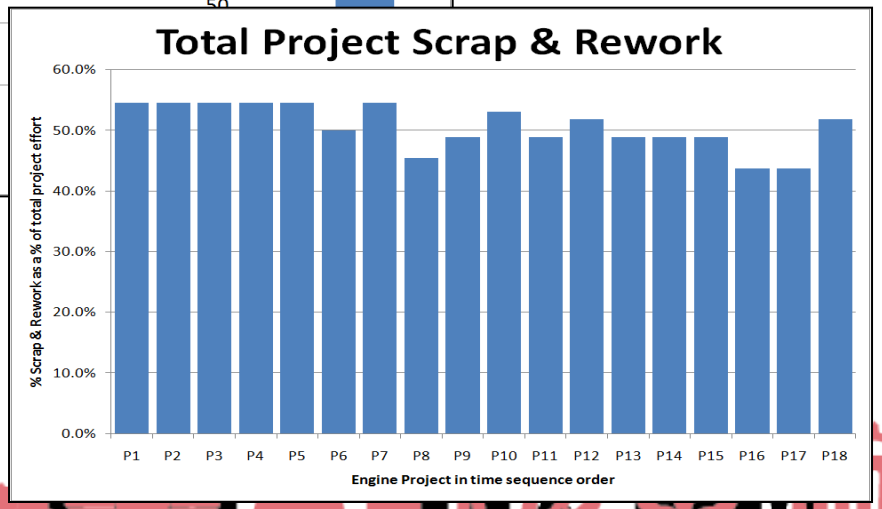




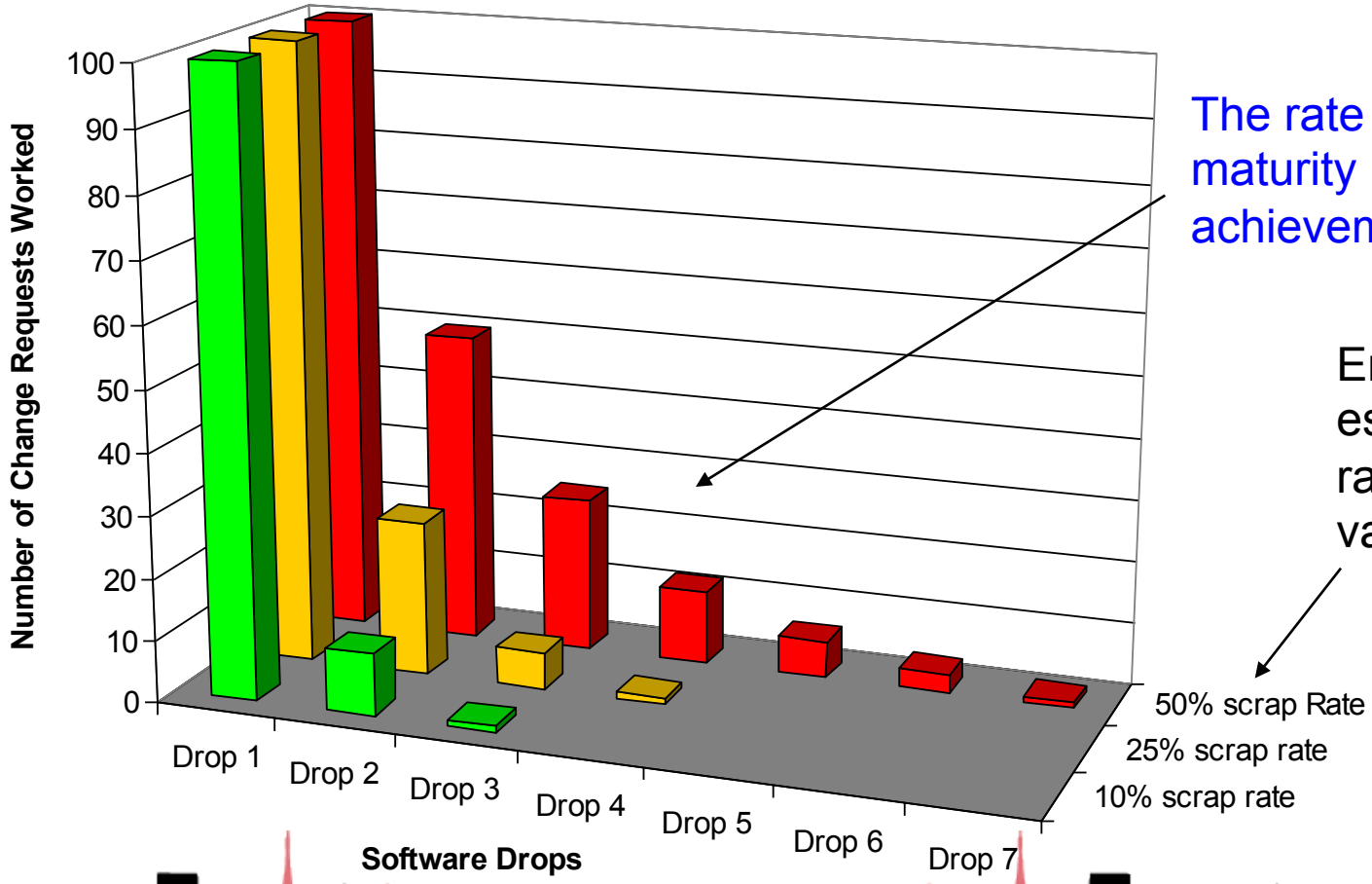
When the changes arise

Multiplied by the cost per change

= Scrap & Rework



The Compounding effect of Scrap & Rework



Cost of Late Detection – Example

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Software Problem Report Analysis Found during: \ Should have been 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%

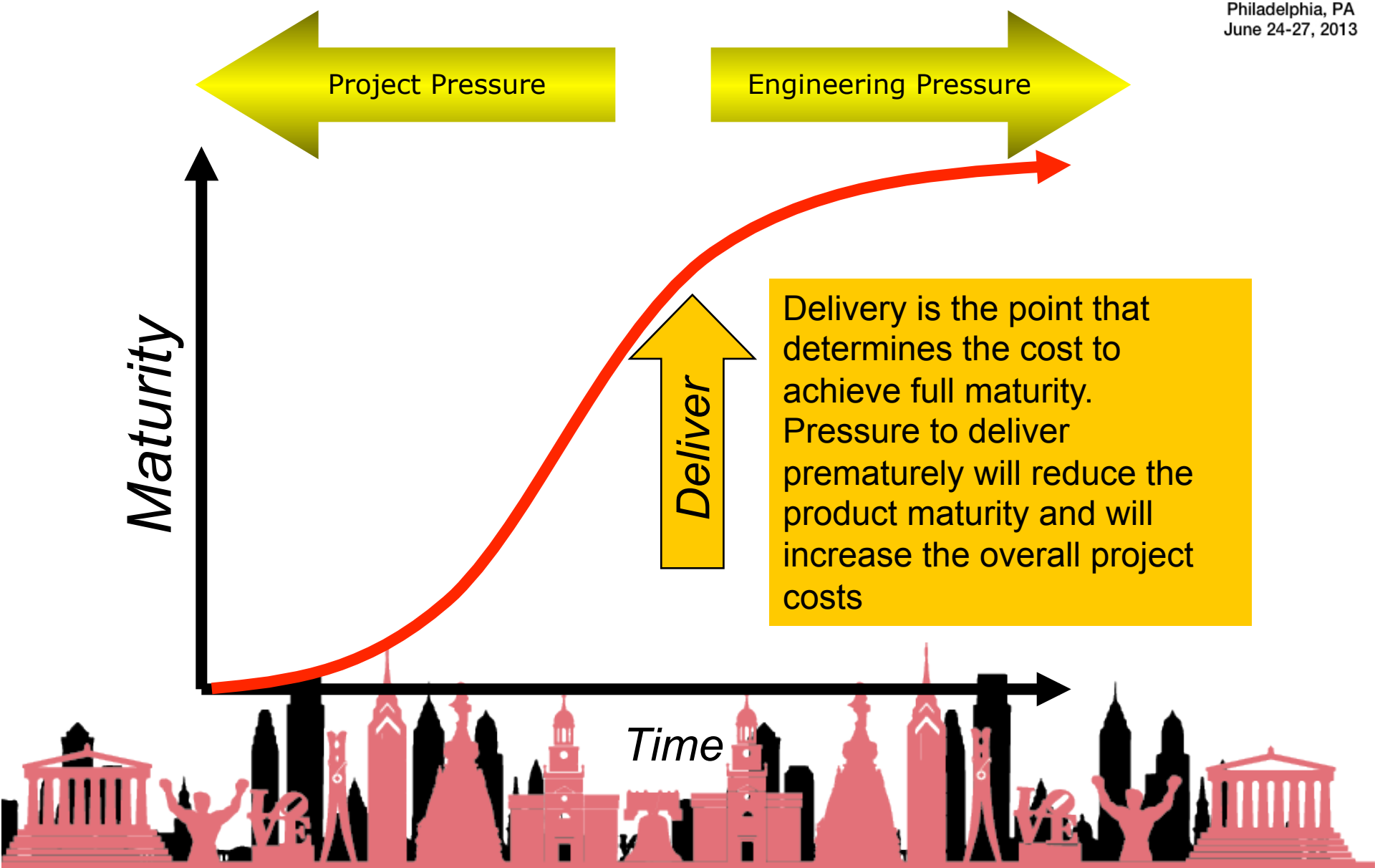
What the method actually detected

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%

The battle between engineering and projects



Delivery is the point that determines the cost to achieve full maturity. Pressure to deliver prematurely will reduce the product maturity and will increase the overall project costs

How will the outcome differ between the following?

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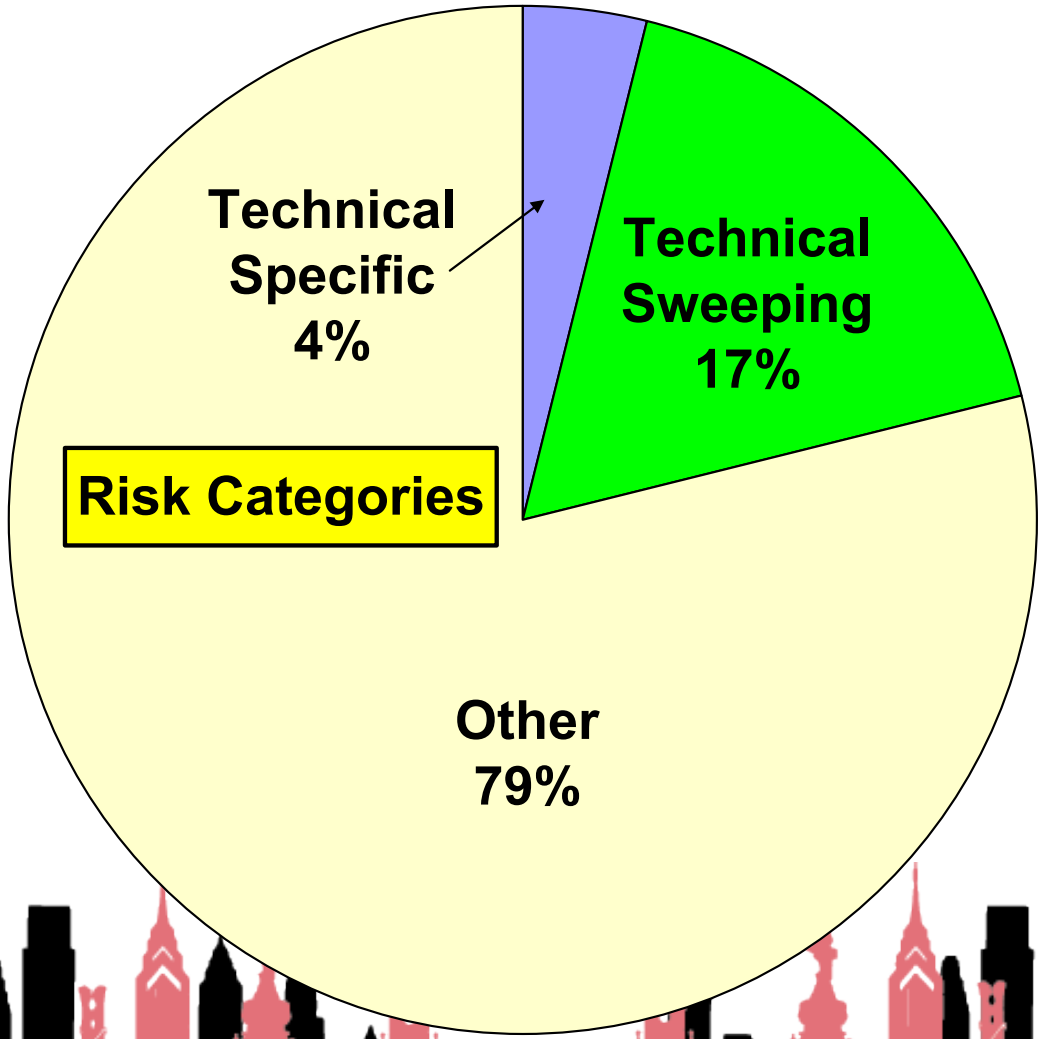
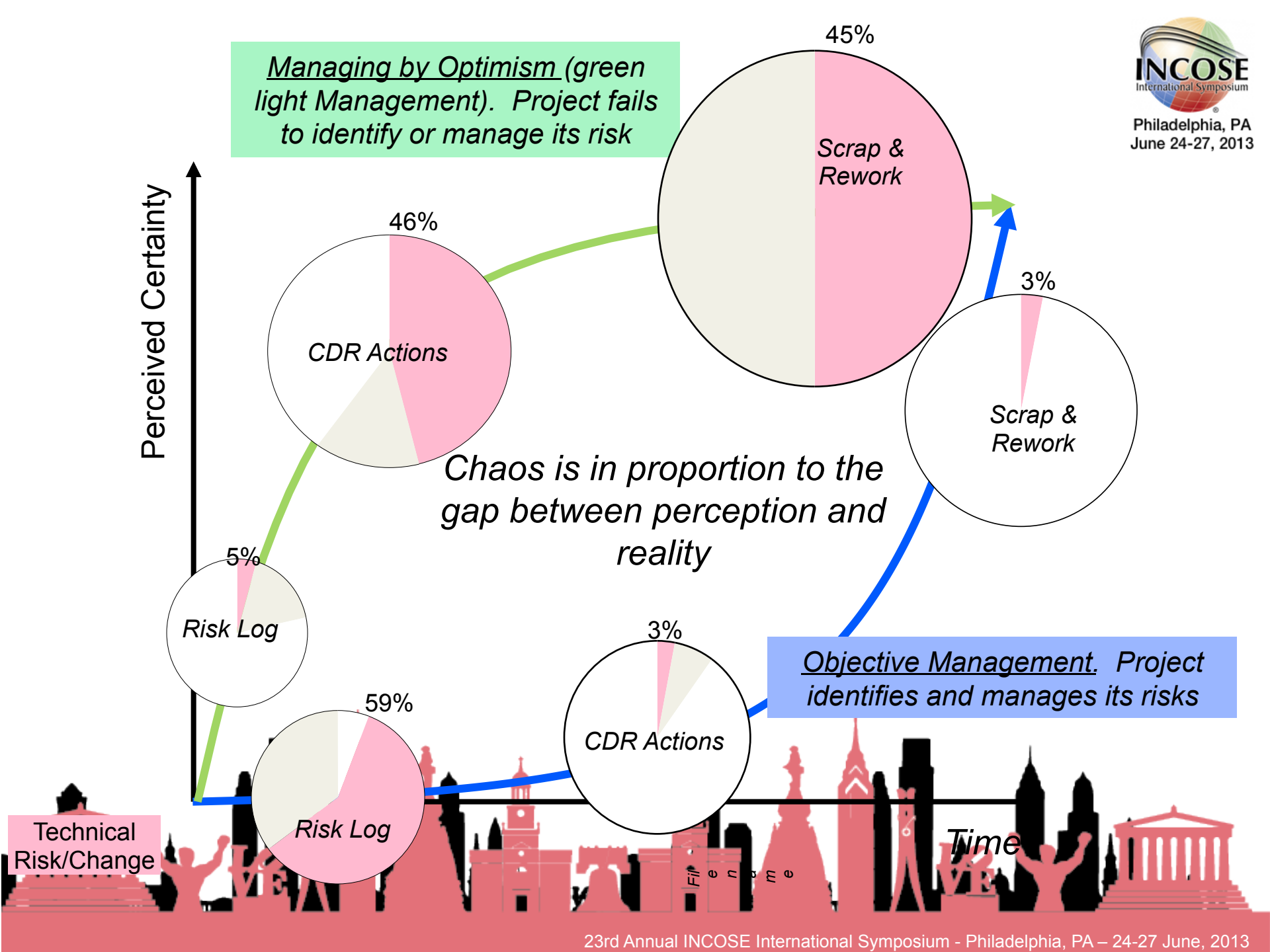
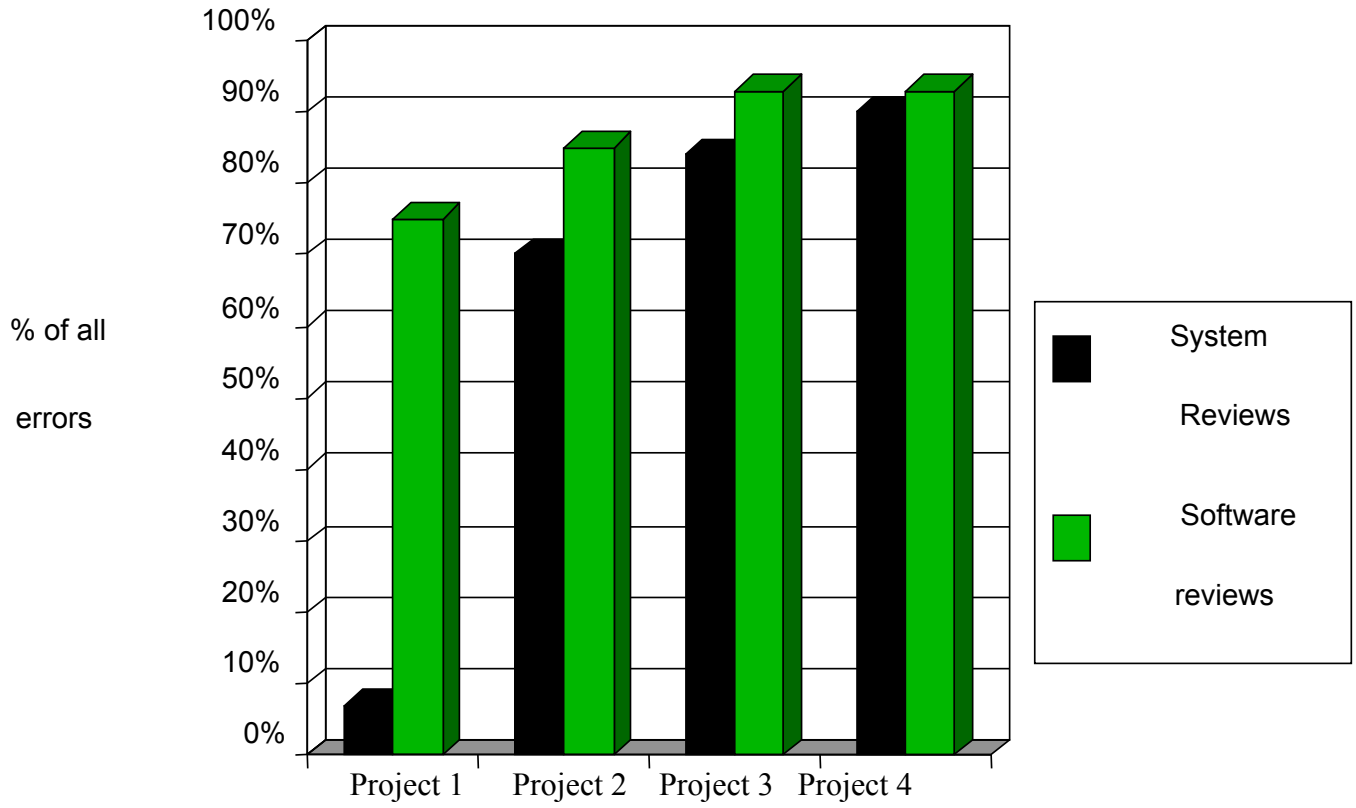
Make it	Deliver	Capture requirements	Review requirements	Test
Make it	Capture requirements	Deliver	Review requirements	Test
Capture requirements	Make it	Deliver	Review requirements	Test
Capture requirements	Review requirements	Make it	Deliver	Test
Capture requirements	Review requirements	Make it	Test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

Risk Categories




Managing by Optimism (green light Management). Project fails to identify or manage its risk
45%
Scrap & Rework
46%
CDR Actions
3%
Scrap & Rework
Perceived Certainty
Chaos is in proportion to the gap between perception and reality
5%
Risk Log
3%
CDR Actions
Objective Management. Project identifies and manages its risks
59%
Risk Log
Technical Risk/Change
Time
Filename

Improving Review Effectiveness



Gated Reviews and Checkpoints

	Gate 1	Gate 2	Gate 3	Gate 4	Gate 5	Gate 6
Artefact 1	D	R	I			
Artefact 2		D	R	R		I
Artefact 3		D	R	R		I
Test 1		D	X			I
Test 2		D	D	X		I
Test 3		D	D	X		I

D = Draft

R = Review

X = Execute

I = Issue

- **Best practice**
- **Ideal**
- **High risk**
- Do not breach

Use Risk Analysis to identify the uncertain requirements

Impact if requirement were to change	Probability the requirement will change: VL	L	M	H	VH
VH					R1
H				R2	
M			R6		R3
L		R8	R7	R5	R4
VL	R10	R9			

Risk Classes and Mitigation Classes

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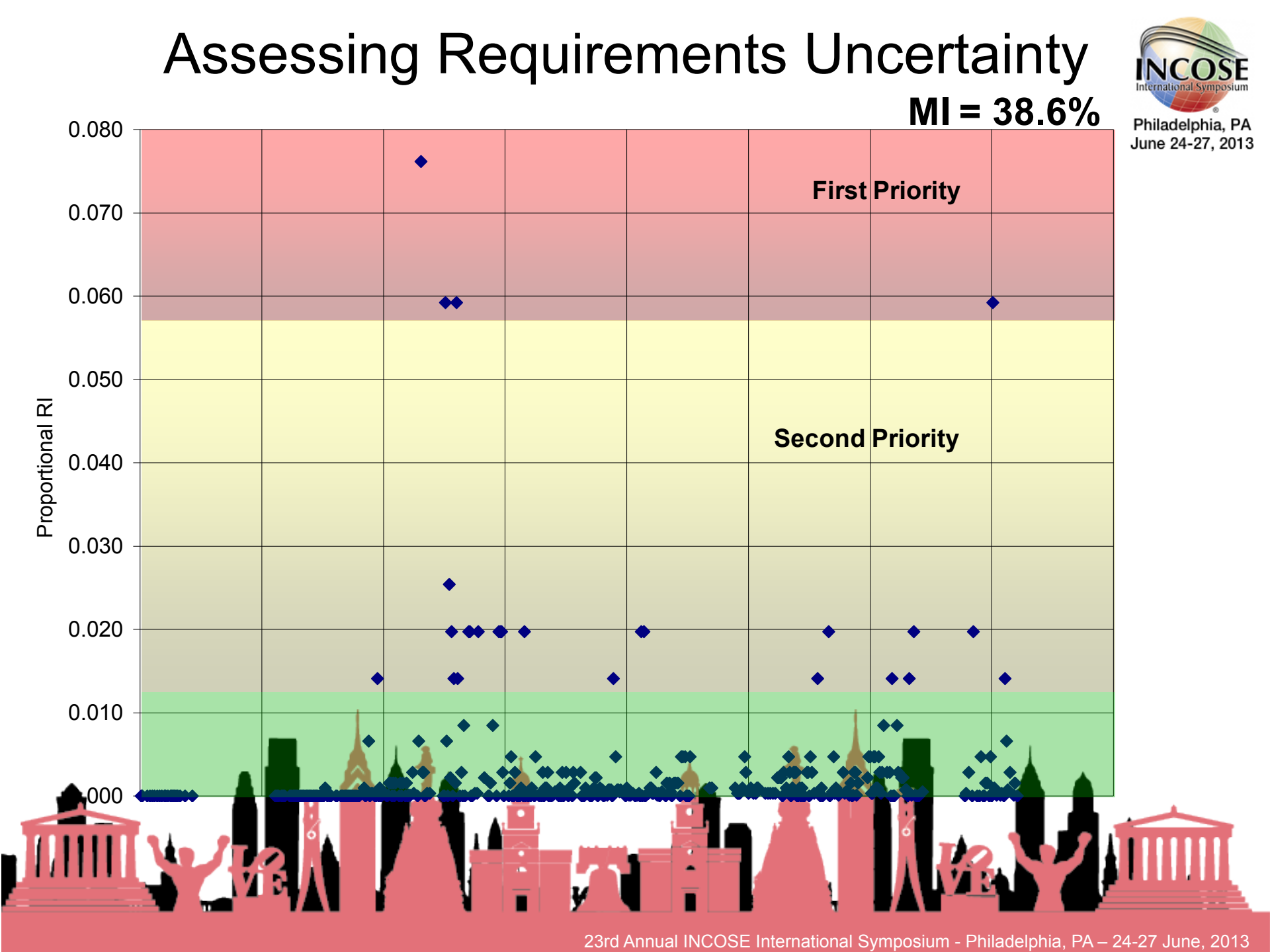
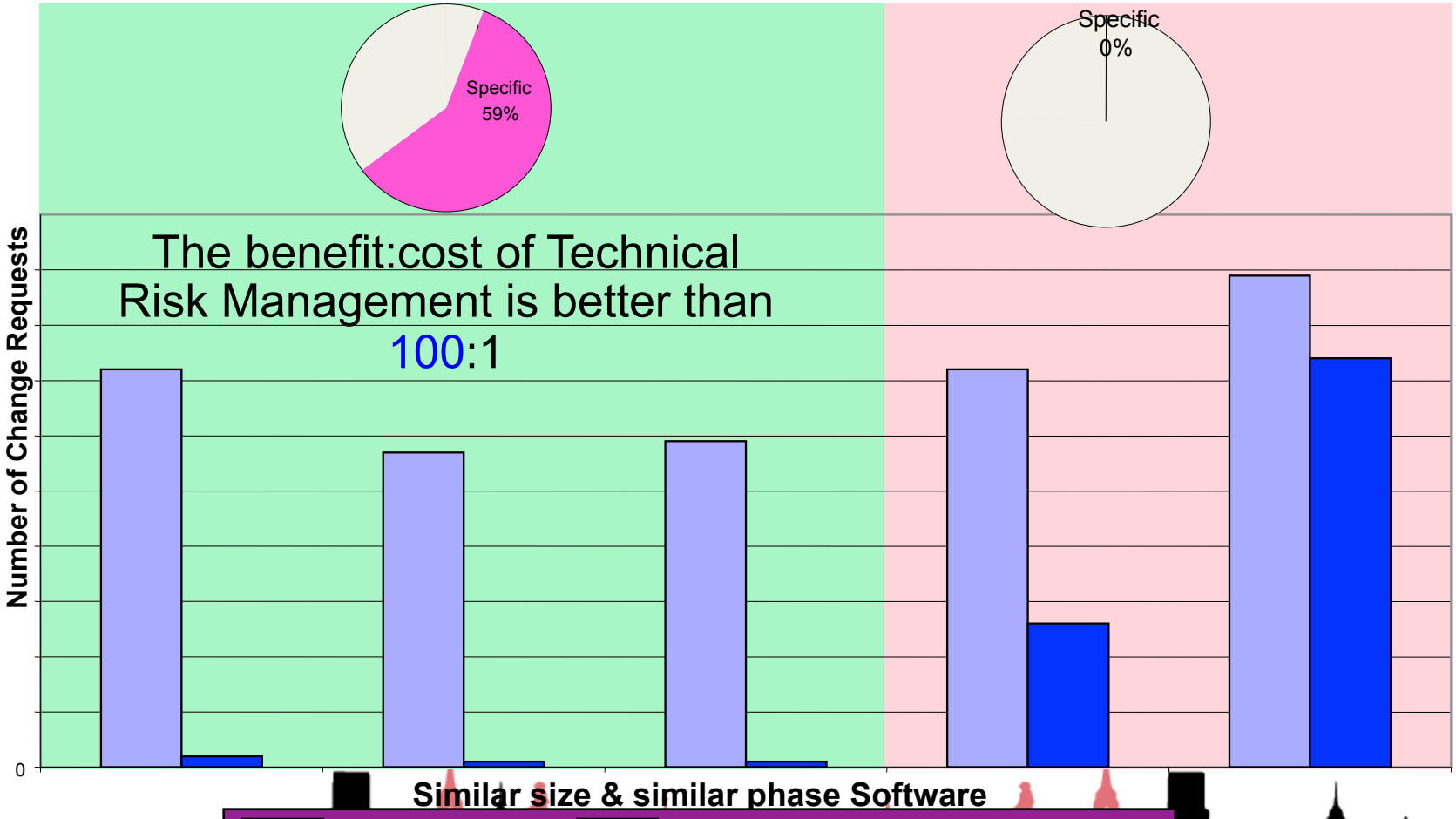
Issues ↓ / Mitigation Strategies →	Reduce the Uncertainty													Reduce the Impact					Plan for the Impact	
	Interviews	Involve all relevant stakeholders	Joint workshops	Independent reviews	Learn from past Projects	Use service experience to justify best practice	Go to the experts	Model the system	Prototype in a representative environment	Joint Risk Management sessions	Early integration and test	Propose "softer" requirements that have a range	Write test cases	Propose a requirement	Build robustness into the architecture/design	Build flexibility into the architecture/design	Isolate uncertainty to minimize the impact	Technical oversight	Proceed but plan for the volatility/iteration	Delay the work until requirements mature
Failing to get Stakeholder agreement			X			X	X								X	X	X		X	X
Late or immature customer requirements	X						X			X					X	X			X	X
Inexperienced customer or suppliers		X	X		X	X	X	X	X	X				X						
The supplier requirements are immature/prone to change			X							X		X			X	X	X		X	X
Issues with complying to requirements				X		X				X	X							X		
Missing requirements	X	X		X	X		X	X	X	X	X								X	
Poorly defined (or missing) interface definitions	X	X						X	X		X				X	X				
Requirements are not realistic or achievable					X		X	X	X	X	X						X		X	
Requirements are untestable				X	X		X				X		X							
Requirements are ambiguous				X			X													
Requirements are in conflict with "best practice" solutions			X	X	X	X	X			X				X						

Assessing Requirements Uncertainty



Low Scrap and Rework Rates are Achievable



Conclusions

- System complexity is ever-increasing
- Product requirements are uncertain at the time of design!
- Assuming certainty can lead to significant scrap and rework
- Pressure to deliver prematurely will reduce the product maturity and will increase the overall project costs
- It's not only what you do, but also when you do it that impacts scrap and rework
- Technical risk management is key to managing requirements uncertainty and product maturity