Introducing Combinatorial Testing in a Large Organization: Experience Report Jon Hagar¹, Rick Kuhn², Raghu Kacker², Tom Wissink³

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Problem: Is combinatorial testing practical for real world high assurance software?

Approach: Eight pilot projects, over two years, applying combinatorial testing in Lockheed Martin (LM), one of the world's largest aerospace firms.

Lockheed Martin/NIST Cooperative Research and Development Agreement

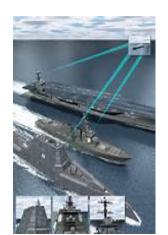


Objective 1. Investigate applicability of CT in a variety of application areas, including system, software, and hardware testing. *Objective 2.* Determine effectiveness of CT for improving fault detection. *Objective 3.* Study potential for reducing test cost or overall lifecycle cost by finding errors earlier in the process.



Application Areas: eight pilot projects

- Flight Vehicle Mission Effectiveness (ME) compare w/ tests from statistical analysis tool
- Flight Vehicle engine failure modes compare w/ existing tests
- Flight Vehicle engine upgrade –combinations of flight mode fac comparison with existing tests
- F-16 Ventral Fin Redesign Flight Test Program application to problem analysis (system-level evaluation rather than software testing)
- Electronic Warfare (EW) system testing evaluating and extending existing tests
- Navigation Accuracy, EW performance, Sensor information, and Radar detection



- Electromagnetic Effects (EMI) Engineering compare w/existin
- Digital System Command testing testing file functions with multiple parameters





Software tools

- NIST & U. of Texas Arlington: ACTS
- Air Academy Associates: SPC XL, DOE KISS, DOE PRO XL, DFSS MASTER
- Phadke & Associates: rdExpert
- Hexawise: Hexawise tool

		Saved Parameters	Saved Parameters	
System Name	TCAS	Paramater Name	Parameter Value	
System name		Cur_Vertical_Sep	[299,300,601]	
		High_Confidence	[true,false]	
System Parameter		Two_of_Three_Reports	[true,false]	
		Own_Tracked_Alt	[1,2]	
Parameter Name		Other_Track_Alt	[1,2]	
		Own_Tracked_Alt_Rate	[600,601]	
Parameter Type	Boolean 👻	Alt_Layer_Value	[0,1,2,3]	
		Up_Separation	[0,399,400,499,500,639,640,7	
		Down_Separation	[0,399,400,499,500,639,640,7	
Parameter Values		Other_RAC	[NO_INTENT,DO_NOT_CLIMB,	
Selected Parameter	Boolean	Other_Capability	[TCAS_CA,Other]	
		Climb_Inhibit	[true,false]	
Simple Value				
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	true,false			
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Results and Evaluation

Positive results - Demonstrated the ability to reduce test cost in a variety of areas; teams found many tools practical

- Roughly 20% cost reduction
- 20% 50% better test coverage

Mixed results – Reluctance of many engineers to adopt new methods; some teams did not identify significant improvements

Lessons learned – Most critical factors affecting adoption: availability of education and training for the new method; clear demonstration of value.

Recommendations

- Develop and improve education and training materials
- Incorporate combinatorial methods into DoD guidance and industry standards; best practices
- Expand internal company guidance developing a community of practice
- Greater availability of tools to support combinatorial testing improved usability; matching tool to problem

NIST

Number of tests

7489 tests, 82 paran

2 way stats: Combinations: 3,321 Var/val coms: 14 761 otal coverage: 0.940

Combinations: 88,560 Var/val coms: 828 135 al coverage: 0.83

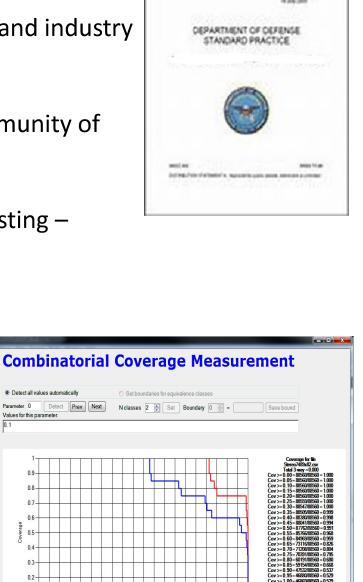
Number of parameters 82

Compute 2-way coverage Compute 3-way coverage Clear chart

Exit X = proportion of combinations r = combination variable-value

Save chart

- Modify approaches to using combinatorial testing –
 - integrating combinatorial testing with other test practices – measure combinati coverage and extend as needed
 - ability to adopt CT partially or gradually



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