Cost and Risk Considerations for Test and Evaluation of Unmanned and Autonomous Systems of Systems

Authors:

Indira Deonandan, Ricardo Valerdi, JoAnn Lane, Filiberto Macias

Presented By: Indira Deonandan Dual S.M. Aeronautics and Astronautics and Technology and Policy Program

Massachusetts Institute of Technology Cambridge, MA, 02139

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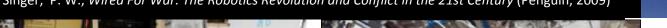
The Challenge

What is a UAS? Why UAS?

Why UASoS?

The evolutionary nature of Unmanned and Autonomous Systems of Systems (UASoS) acquisition needs to be matched by evolutionary test capabilities yet to be developed.

Singer, P. W., Wired For War: The Robotics Revolution and Conflict in the 21st Century (Penguin, 2009)







Introduction

Objectives

Motivation

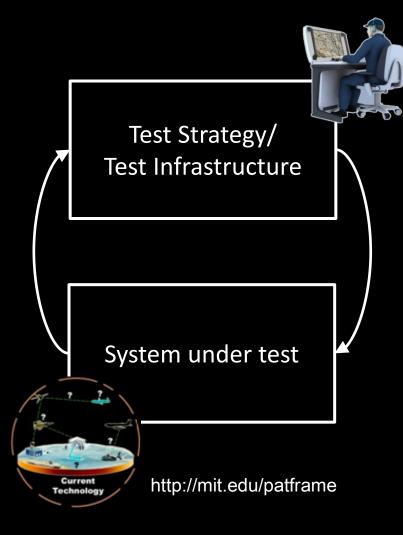
Methodology

Results

Impact

Summary

The Prescriptive and Adaptive Testing ^{3 of 15} Framework (PATFrame)



Why focus on testing?

- Need for T&E processes to recognize levels of effectiveness
- Need to focus on the interactions between components and emergent behaviors
- Need to move away from boundaries between DT and OT
- Need ability to make effective contingency plans as requirements change

Introduction

Objectives

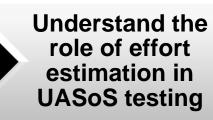
Motivation

Methodology

Results

4 of 15

Three main objectives



Understand the limitations of existing cost estimation models Show how our model can be merged with cost estimation processes

Introduction

Objectives

Motivation

Methodology

Results

Impact

The need for effort estimation of UASoS testing

- There comes a point when effort invested does not reduce risk at a justifiable rate
- Emergent properties especially when UASoS fielded for the first time drive up costs
- Current projects are based on similar past projects and extrapolations that do not account for other risks
- Produce strategic options and guidance to improve confidence and ability to prioritize
- Avoid unreliable estimates and unfavorable system performance
- Finding problems before delivery is much cheaper and less time consuming

Motivation

Methodology

Results



Data Sources

Literature Review	 Existing DoD procedures on testing Cost modeling techniques Risks and costs of UASoS 						
Interviews	 Program managers, researchers, subject matter experts, DoD personnel Risks identification and Resource estimation 						
Surveys	 Gather cost driver data from subject matter experts 						
Case Studies	Quantitative inputs to cost modelValidation of cost model						
PATFrame Workshops	 Use these as an opportunity for interviews and feedback 						
n Objectives Motivation	n Methodology Results Impact Summ						

Existing Cost Modeling Approaches (1)

Cost Estimation Method	Focus	Limitations			
COSYSMO Constructive Systems Engineering Cost Model (Valerdi, 2008)	Estimate system engineering effort	Only applicable at the single system level			
COSOSIMO –Constructive Systems-of Systems Integration Cost Model (Lane, 2009)	Estimate the system engineering effort for development of SoS, integration of the SoS components into the SoS framework	Does not account for flexibility and emergent behaviors of complex SoS testing			
"Bridge the gap between software test processes and business value" (Li et al, 2009)	Value based testing to better align investments with project objectives and business value	 More applicable to business critical projects rather than safety critical domains Is tailored to software testing 			
ntroduction Objectives Mo	otivation Methodology	Results Impact Summary			

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Existing Cost Modeling Approaches (2)

Cost Estimation Method	Focus	Limitations			
"Managing your way through the integration and test black hole" (George)	Integration effort = (number of predicted defects * average time to find and fix a defect) + (number of test cases * the average time to run a test case)	 Assumes only issue with integration testing is defects which are easy to find Assumes fixing one defect does not create another 			
"Sizing systems test for estimating test execution effort" (Aranha and Borba, 2007)	Estimate the size of a software test which is required to determine the test execution effort	 Assumes test size = number of steps to complete test and complexity = relationship between tester and product Does not account for other cost drivers in UASoS testing 			

Introduction

Objectives

Motivation

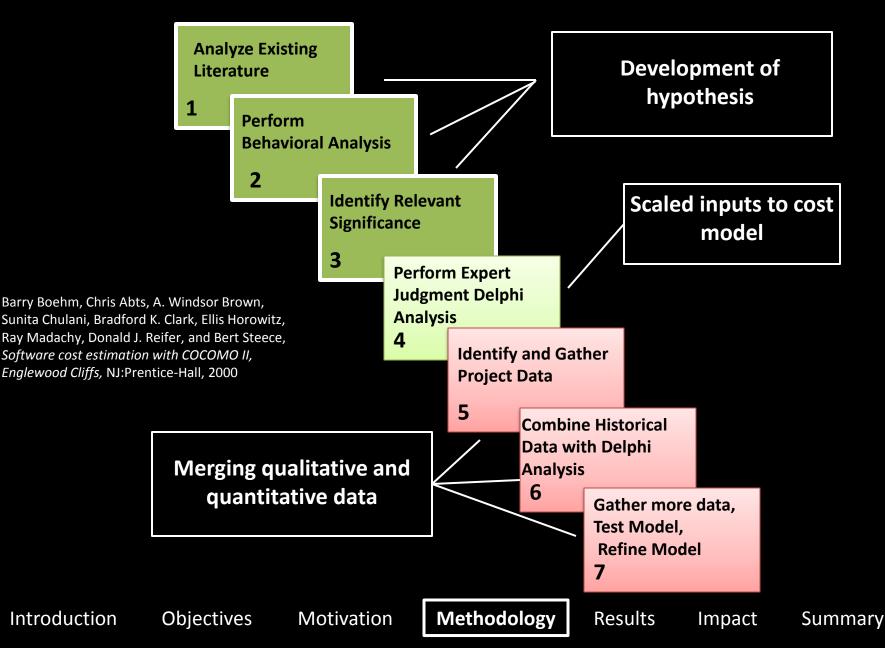
Methodology

Results

Impact

Summary

The Boehm Seven Step Modeling Methodology



10 of 15

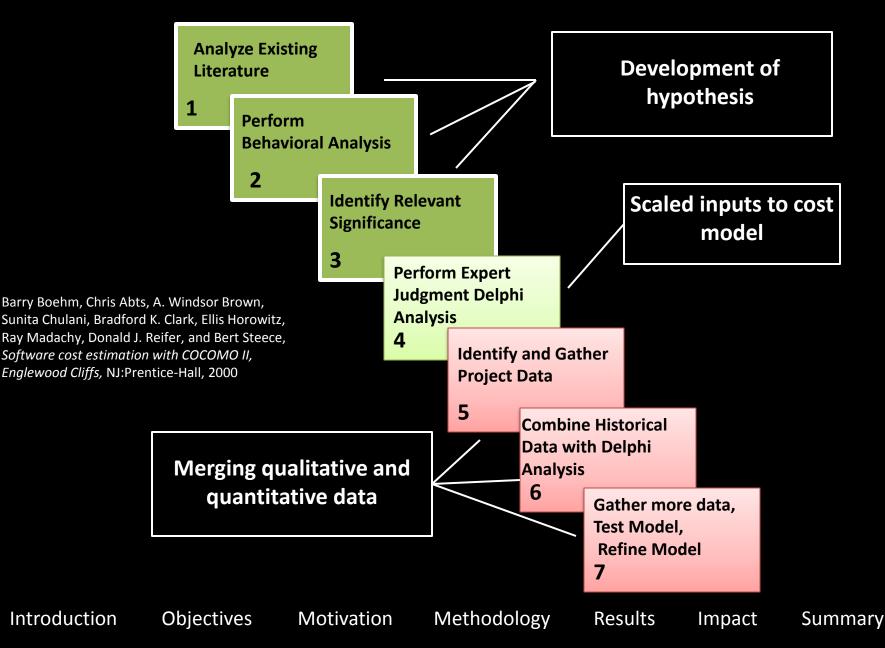
Ranking of Technical Cost Drivers | n=10

	Number of systems to be integrated Integration complexity				4.71	Numb	er of systems
	Complexity of tests				4.43		
	System synchronization complexity				4.43	Integrat	ion complexity
	Technology maturity of SoS				4.43		
	Number of requirements of the SoS				4.43	Comp	lexity of test
	Diversity of tests				4.14		
	, Level of safety				4.14		
	Number of interfaces in the SoS				4.14		
	Changes in the requirements of the SoS				4.14		
er	Type and complexity of operational environment				4.00		
riv	Breakdown in communication links				4.00		
Technical Cost Driver	Varying levels of maturity of technology				4.00		
ost	Number of tests				3.86		
	Coordination requirements to access systems				3.86		
nica	Availability of testing infrastructure				3.71		
chr	Degree of autonomy of individual systems				3.71		
Te	Interoperability of manned and unmanned systems				3.71		
	Migration complexity				3.71		
	Type of testing				3.57		
	Match of material availability and schedule requirements				3.57		
	Reuse of equipment and infrastructure				3.57		
	Number of missions				3.57	Data co	ollection rates
	Coordination of system platforms				3.57		
	Diversity of platforms within the SoS				3.57	Maturit	y level of test
	Rate of test data collection and analysis				3.43		-
	Maturity level of test				3.43	Powe	r availability
	Power availability for adapting new technologies			2.86			
) 1	2	3	4 5		
l	ntroduction Objectives Motiv			Schofogy	Results	Impact	Summary

Ranking of Organizational Cost Drivers | n=10

	Understa <u>ndin</u>	Time const og of the architecture of th		4.62						Time constraints			
		Personnel expe		4.25					Architecture understanding				
		Personnel and team cap		4.25					Personnel experience				
ver		ing of the project require Personnel and team cont							4.25 4.12				
Organizational Cost Driver		sources to assist integrate							4.12				
Cos	Understanding	g of integration of require	ments						4.12				
nal	Appr	ropriate allocation of reso	urces					3.8	88				
atic		Reuse of existing	plans	3.63									
aniz	Reuse of existi	ing test strategies and me	thods	3.63									
Org		Test process cap	ability					3.63					
	Number of orgar	nizations involved in SoS t	esting					3.63		Stakehold	ler team cohesion		
		Security level of the p	roject					3.63		Multici	te coordination		
		Stakeholder team col	nesion				3	.50		IVIUITISI			
		Multisite coordii	nation	3.38				Test plan	ning tool support				
	Su	upport from test planning	tools		3.25								
			C) 1		2	3	4	5				
						Score	9						
Intro	oduction	Objectives	Мс	otivation	ſ	Metho	dology		Results	s Impact	Summary		

The Boehm Seven Step Modeling Methodology



Impact

Test and Evaluation Planners

- provide tradeoff analyses between costs and risk mitigation
- provide support in day to day testing procedures
- helps with more efficient use of time and resources

Program Managers

- better allocation of resources (time and money) based on cost estimates
- better coordination of multiple programs

DoD Policy Makers

- give evidence of budgeting requirements for testing projects
- ensure adequate testing of UASoS to be used



Introduction

Motivation

Methodology

Results



Summary

1. There is need for optimized testing strategies for UASoS

- UASoS are in more demand in the DoD
- The advances in the technology need to be matched by advances in testing capabilities

2. Provide program managers, test conductors, and policy makers

- An integrated decision support system for testing UASoS
- A means to predict how much effort is required to conduct a test of UASoS while minimizing risk
- A basis to perform cost and risk tradeoffs and prescribe how tests can adapt depending on resource or schedule constraints

Motivation

Methodology

Author Contact Information

Indira Deonandan

Department of Aeronautics and Astronautics Massachusetts Institute of Technology Cambridge, MA, 02139 indira@mit.edu

Ricardo Valerdi

Engineering Systems Division Massachusetts Institute of Technology Cambridge, MA, 02139 <u>rvalerdi@mit.edu</u>

Jo Ann Lane

Systems Engineering Research Center University of Southern California Los Angeles, CA 90089 jolane@usc.edu

Filiberto Macias

Systems Engineering Directorate US Army White Sands Missile Range New Mexico <u>Filiberto.a.Macias@us.army.mil</u>

Introduction

Objectives

Motivation

Methodology

Results Impact

Summary

- Test and Evaluation Need
 - Accelerate test planning for UASoS by supporting automation of current human-intensive (thus potentially error-prone) SoS test planning process
 - Optimize the joint mission oriented UAS T&E strategy by addressing and balancing multiple criteria
 - Predict, detect, and adapt to undesirable emergent behavior in UASoS T&E
- Science and Technology Challenge
 - Perform R&D of a multi-dimensional framework for knowledge representation across UASoS
 - R&D an ontology for key UAS SoS elements, relationships, and constraints
 - R&D critical UAS SoS design idioms and rich architectural models
 - R&D parametric UAS SoS project cost/effort models
 - Perform R&D to develop analyses and simulations across SoS models
 - Develop a Decision Support System (DSS) prototype that includes the multidimensional framework for analysis and simulation

Motivation

Methodology

Results Impact