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INTEGRATION, EXPLORATION, and MBSE

ModelCenter[®]: *The* Framework for Model Based Engineering



Rocket Flight Termination Behaviors Bridged to Analytical Simulation in MBSE

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INTEGRATION, EXPLORATION, and MBSE ModelCenter[®]: The Framework for Model Based Engineering









https://www.youtube.com/watch?v=rxju3eGr_7Y





Introduction

- Showing an example that can be used to guide the development of V&V activities for future applications of mission models
- Bridging to Descriptive Systems Models in Cameo Systems Modeler
- Driving the behavioral model with analytic domain models in Python and ModelCenter
- Demonstrating running regression tests on a SysML State Machine through MBSEPak using DOEs





Presentation Outline

- Pegasus Flight Termination Background
- Motivation for Simulation
- Project Objective, Goals, Obstacles, Solutions
- Descriptive Systems Model
- Domain Analytical Model
- Descriptive to Domain Integration Bridge
- Automated Testing of Behaviors with DOEs





Flight Termination Motivation Protect Against Errant Rocket Flight

Manual Termination If "Out of Bounds"



• Auto Termination If "Inadvertent Stage Separation"







Nominal Mission, Concept of Operation







Ning

Stage 1 Motor



Payload

Pegasus FTS

 Ground-initiated command destruct also has the capability to sense inadvertent stage separation and automatically destruct the Stage 2 Motor rocket if errant flight.

Section Separation System

Avionics

*Stage 3 Motor-

Payload Fairing

Interstage

 The FTS is redundant, with two independent safe and arm devices, receivers, logic units, and batteries.

*Optional 4th Stage Available for Precision Injection

PUG-004

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Aft Skirt

Assembly





Motivation for Simulation





Biggest Simulation Impact is Early in the Design Process



Simulation Motivation - Gain system understanding without manipulating the real system, either because it is not yet defined or available, or because it cannot be exercised directly due to cost, time, resources or risk constraints.

DoDI 5000.02 E3:9 Policy for Management of all Acquisition Programs Instructs SEs Approach to Modeling and Simulation





Industry MBSE and MBE Examples

- DoD Digital Engineering Strategy
 https://www.acq.osd.mil/se/briefs/19819-NDIA17-Zimm-DE-Strat.pdf
- SET Systems Engineering Transformation, Navy

http://www.sercuarc.org/final-technical-report-published-transforming-systemsengineering-through-model-centric-engineering/

• GBSD - Model Based SE, USAF

http://www.afmc.af.mil/News/Article-Display/Article/1260958/afnwc-nuclearexperts-capture-acquisition-awards/

 ARVC iMBE – Integrated Modeling Environment, ARDEC, Army

http://www.sercuarc.org/publications-papers/technical-report-transforming-systemsengineering-through-model-centric-engineering-3/

• Europa Model Based SE, JPL

click on the associated icon text for whitepaper

e.Deorbit, European SA, Airbus

click on the associated icon text for whitepaper













e.Deorbit





Project Objective, Goals, Obstacles, Solutions





Project Objective and Goals

Objective - Path find an MBSE behavioral model Validation and Verification (V&V) approach for FTS logic

Goals - V&V Behavioral Models with Simulations

- Verify State Machine Logic
- Validate Regression Testing of State Machine Logic
- Verify the Bridge between Descriptive and Analytic Simulations





Project Obstacles	Solutions
ITAR restrictions	Genericized the application
Logic Complexity – Well over a dozen States with multiple triggers on each	Simplified the System Architecture Model without sacrificing the Project Objective
Test Complexity	Isolated Testing to avoid Full- Fidelity-Analysis-Model issues and to reduce run times





Project Obstacles	Solutions
Complexity of Repetitive Time Based Activities	Synchronize time between the behavioral and analytical simulations
Multiple Mission Scenarios	Stimulate all scenarios ensuring expected mission outcomes with DOE methods
Each Modeling Layer (STM, ACT, Domain Sim) has Similar Triggers and Responses for Each Event (eg, Inadvertent Stage Sep)	Ensure Capture of Mission Results Occurs in the Behavioral Simulation





The Pegasus FTS Project is a Digital System Model built in three layers using commercial tools



Descriptive Systems Model (Cameo Systems Modeler) Descriptive/Domain Integration Bridge (ModelCenter MBSEPak)

Domain Analytical Models (Python, ModelCenter Integrate)





Descriptive Systems Model





Use Case – Terminate if Inadvertent Stage Separation







Goal – V&V State Machine Logic









Goal – V&V State Machine Logic







Auto Destruct Activity Diagram (State 5) (if inadvertent stage separation occurs)







Domain Analytical Model





Domain Analytic Model: Python mock Mission Simulation

Component Tree		д	2	
Name	Value	Units		
Image: Name Image: Model Image: MissionSim Image:	127 -1 127 false true false	S S S		? missionSim
			2	





Domain Model Verification Test Results

Nominal Mission







Domain Model Verification Test Results

Out of Bounds







Domain Model Verification Test Results

Inadvertent Stage Separation







Descriptive/Domain Integration Bridge





FTS Parametric Diagram







MBSEPak Bridges from Descriptive Parametric Diagram to Domain Analytical ModelCenter Workflow

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ModelCenter Workflow Automatically Generated from the SysML Parametric Diagram







Mission Simulation - Demonstration

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Automated Testing of Behaviors with DOEs





Custom DOE – Goal - Exercise All the Different Scenarios

Inpu	ts		E	xpected Outputs
Inadverte ntStageS epTime	OutOf Bound sTime	SimD urati on (t)	Dest ruct	End State
-1	-1	476	False	Payload Deployed
127	-1	127	True	Terminated Automatically
-1	250	250	True	Terminated by Safety Officer
127	250	127	True	Terminated Automatically
127	100	100	True	Terminated by Safety Officer
500	-1	476	False	Payload Deployed
-1	500	476	False	Payload Deployed





Regression Testing Verifies the Model After Making Changes to the Model

- Software Development Technique
- Leverages Automated Testing
- Repurpose this by re-running the DOE whenever the Model is changed
- MBSEPak Automated Regression Testing





DOE Demonstration of Mission Simulation

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Summary

- Demonstrated running regression tests on a SysML State Machine using DOEs in MBSEPak
- Driven by analytic domain models in Python and ModelCenter
- Bridged to Descriptive Systems Models in Cameo Systems Modeler
- In an example that can be used to guide the development of V&V activities for the actual Pegasus models and future Applications





Thank You



Discovery Canada for the Mighty Planes video clip



No Magic, Inc for the Cameo Systems Modeler Tool



Phoenix Integration for the ModelCenter and MBSEPak Tools

Customers for pulling MBSE into new Programs





Abstract

Bridge development is being evaluated for Rocket Systems between SysML behavioral simulations and analytical simulations to not only verify logical system architecture earlier but also predict consequences of failures earlier in the product development life cycle. The idea of rolling behavioral simulation results across the input bridge from SysML programming into analytical iterations expands the input field. For example, a rocket system termination model progressing through flight states has been simulated for scenario iteration in rocket tracking. Progress on the MBSE bridge development between rocket system behaviors and analytical solutions will be demonstrated.