Simulation-Centric Model-Based Development for Spacecraft and Small Launch Vehicles

Mike Briggs, Nathaniel Benz, Doug Forman

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The classic “V-Diagram” for Systems Engineering
MBD fits naturally into the workflow with Models integrated into each phase of the process.
In order to fully take advantage of MBD for complex systems, a tool that can simulate continuous and discrete time dynamics is needed.
Requirements Analysis

MBD Overview

Models

Operational Need

Delivered Capability

Requirements

Validated Solution

Design

Product

Requirements Specification

Acceptance Testing & Operational Support

System Testing & Calibration

Integration Testing

Unit Testing

Auto Code Generation

Detailed Design

System Design

System Specification

Requirements Analysis
• Model created of low cost launch vehicle including vehicle, sensors, actuators, controller & environment
• Monte-Carlo analysis performed to identify required accuracy of sensors to meet objectives
• Use Simulink to create a “plant” model of robotic manipulator
• Design feedback controller using plant model dynamics
• Test controller against requirements and iterate design
• Test controller on hardware and iterate design again
Control of Arm with Haptic Feedback.

Goal: Trace the rectangle with end-effector

Force Applied to haptic device when end-effector reaches edges of rectangle
Implementation: Automatic Code Generation

Requirements Specification
- Requirements Analysis
- System Specification
- System Design
- Detailed Design

Models
- Operational Need
- Delivered Capability
- Realization
- Decomposition
- Design
- Product

Testing
- Acceptance Testing & Operational Support
- System Testing & Calibration
- Integration Testing
- Unit Testing

Auto Code Generation
From block diagrams, tools such as Simulink Coder can generate optimized c/c++ code.

- No need for Software Engineers to translate designs from block diagram to embedded code.

Code can be targeted to:
- Embedded hardware, FPGAs
- Real-Time Operating Systems (VxWorks, RTEMS)
- Middleware (Simitar, cFE/cFS)
Component and System Testing
• Majority of testing process can be automated with MBD
• Simulation of unit tests harness and integrated system models to verify requirements
• Requirements can be linked from source (DOORS, UML) into model for traceability
• Formal Methods can be used on the models to validate all states are tested, and automatically generate test cases that violate requirements
• Automated test reports for version description documents
MBD Overview

System Integration and Model Calibration
• Deployed code can be tested with Hardware-in-the-Loop
• Measured data from actual hardware can be used to improve model fidelity with System Identification methods
• Improved model can be used to improve design
MBD Overview

- Requirements Specification
  - Requirements Analysis
  - System Specification
  - System Design
    - Detailed Design
    - Auto Code Generation

- Operational Need
- Delivered Capability

- Decomposition
- Realization

- Models

- Integration Testing
  - Unit Testing
  - System Testing & Calibration

- Acceptance Testing & Operational Support

Operations
Simulation of models can be used to help debug operational anomalies, and design fixes.
Simulation enables Model Based Design to be at the center of the End-to-End design cycle for complex systems.
Demos and more info on MBD – Visit Millennium at 726