Automating Real-Time Testing for Embedded Software Development

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Embedded Software Development Process

- Requirements Gathering
- Model Simulation
- Rapid Prototyping
- Code Generation and ECU Flashing
- Hardware in the Loop Testing (HIL)
- Field Test
  - Calibration
- Physical Testing
  - Test Cells
Real-Time Testing (RTT)

Test that provides deterministic stimulus for reliability and accurate simulation of an environment

• RTT Types:
  - Model in the loop (MIL)
  - Rapid Control Prototyping (RCP)
  - Hardware in the Loop (HIL)
  - Functional Testing / Test Cells
## Test Continuity

<table>
<thead>
<tr>
<th></th>
<th>MIL</th>
<th>RCP</th>
<th>HIL</th>
<th>Test Cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test</td>
<td><strong>Components</strong></td>
<td><strong>Components</strong></td>
<td><strong>Components</strong></td>
<td><strong>Components</strong></td>
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<tr>
<td>Engine</td>
<td>Simulated</td>
<td>Real</td>
<td>Simulated</td>
<td>Simulated</td>
</tr>
<tr>
<td>ECM</td>
<td>Simulated</td>
<td>Simulated</td>
<td>Simulated</td>
<td>Simulated</td>
</tr>
</tbody>
</table>

- **Simulated**
- **Real**
- **Stimulus, Data Logging, User Interface, Analysis**

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Embedded Software Development Process

Requirements Gathering

Model Simulation

Rapid Prototyping

MIL Testing

Controller

Plant

Code Generation and ECU Flashing

Hardware in the Loop Testing (HIL)

Field Test
- Calibration

Physical Testing
- Test Cells
Model In the Loop (MIL)
Manual Testing
The test system will be used to validate an engine controller model with different environmental parameter values.

Environmental Conditions

- **REQ_CoastalSummer_Conditions**
  Modify the engine model parameters to reflect coastal summer conditions:
  - Ambient Temperature = 90 deg
  - Ambient Pressure = 14.5 psi

- **REQ_MountainWinter_Conditions**
  Modify the engine model parameters to reflect mountain winter conditions:
  - Ambient Temperature = 20 deg
  - Ambient Pressure = 10.5 psi.

Stimulus and Analysis

- **REQ_FTP1000_SpeedProfile**
  Exercise the engine, controller and application model closed loop with the FTP1000 speed profile.

- **REQ_NumExceptions_215**
  Analyze the load torque response vs engine speed. Then compare test results to Mask A. Number of exceptions (points outside the mask) should be less than 215.
Model In the Loop (MIL) Manual Testing

3.1 Coastal/Summer-Engine Speed Test

- **REQ_CoolantConditons**
  - Modify the engine model parameters to reflect coastal summer conditions.
  - Ambient Temperature = 2°F
  - Ambient Pressure = 14.5 ps

- **REQ_Engine_Speed_Start_at_900RPM/ks**
  - Set the engine speed to 900 RPM before test begins.

- **REQ_FTP105_SpeedProfile**
  - Exercise the engine, controller and application model closed loop with the FTP105 speed profile.

- **REQ_NomExhaust_Emission_LT_22500**
  - Analyze the load torque response to engine speed. Then compare test results to N0000. Number of exceptions (points outside the mean) should be less than 2%.
Model In the Loop (MIL)
Manual Testing

Requirements -> Models -> Stimulus Profile

2.1 Coastal Summer-Engine Speed Test

REQ_Control/Engine: Condition
Modify the engine model parameters to reflect coastal summer conditions:
- Ambient Temperature = 80 deg
- Ambient Pressure = 14.3 psi

REQ_Engine_speed_set at 600RPM
- Set the engine speed to 600 RPM before test begins

REQ_TFS1000, SpeedCtrlGain%
- Exercise the engine controller and application model closed loop with the TFS1000 speed profile

REQ_VehEngine_LT_JRMS:
- Analyze the load torque response (g) engine speed. Then compare test results to Table A. Number of exceptions (g) must be less than 0.75
Engine FTP1000 Speed Profile

![Graph showing engine speed profile over time.](image-url)
Model In the Loop (MIL) Manual Testing

Requirements → Models → Stimulus Profile → Analysis

3.1 Coastal Summer-Engine Speed Test

**REQ_Coastal**
- Modify the engine model parameters to reflect coastal summer conditions.
  - Ambient Temperature = 80 deg.
  - Ambient Pressure = 14.13 psi

**REQ_Engine_Speed_Start_at_8000rpm**
- Set the engine speed to 8000 rpm for the test sequence.

**REQ_Engine_Speed_10000rpm**
- Execute the engine control and application model closed loop with the TTP100 rpm speed profile.

**REQ_Neal_Station_17_Juli0509**
- Analyze the load target response and engine speed. Then compare test results to Mask A. Numerical oscillations (peaks across the mode) should be less than 25.

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Speed/Torque Mask A Analysis

![Graph showing load torque against engine speed](image-url)
Model In the Loop (MIL)
Manual Testing

Requirements ➔ Models ➔ Stimulus Profile ➔ Analysis

3.1 Coastal Summer Engine Speed Test
- Modify the engine model parameters to reflect coastal summer conditions
  - Ambient Temperature = 30 deg
  - Ambient Pressure = 14.1 psi

REQ Engine Speed Start at 035256
- Set the engine speed to 035 256 rpm before test begins

REQ_TIT100(LoadProfileGT)
- Execute the engine, controller, and application model closed loop with the TIT100 speed profile

REQ_NeedEvolution 1.7 J13587
- Analyze the load impact response vs. engine speed. Then compare test results to Mask A.
  - Number of occurrences (points outside the mask) should be less than 25.
Model In the Loop (MIL) Manual Testing

3.1 Coastal Summer Engine Speed Test
- Modify the engine model parameters to reflect coastal summer conditions.
  - Ambient Temperature = 80 deg
  - Ambient Pressure = 14.3 psi

REQ_0002 Method:
- Set the engine speed to 650 RPM in three steps:
  - 450 RPM
  - 650 RPM
  - 200 RPM

REQ_0003 Method:
- Execute the engine, controller, and application model closed-loop with the FTP05 speed profile.

REQ_0004 Method:
- Analyse the load torque response vs. engine speed. Then compare test results to Table A. Number of acceptable profiles outside the model should be less than 10.

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Manual Testing Demo
Model In the Loop (MIL)
Automated Testing

Requirements → Models → Stimulus Profile → Analysis

Stimulus Profile → Analysis

Stimulus Profile → Analysis

Stimulus Profile → Analysis
Model In the Loop (MIL)
Automated Testing
Model In the Loop (MIL) Automated Testing

- Requirements
- Models
- Stimulus Profiles
- Analysis

- Workspace
- Models
- Stimulus Profile
- Export Channels
- Import Channels
- Run Script
Model In the Loop (MIL)
Automated Testing

Requirements

- Open VeriStand (VS)
- Open VeriStand Config File
- Set Model Parameters
- Run Stimulus Profile
- Open DIAdem
- Export Log
- Run Analysis Script
- Close DIAdem
Automated Demo
Model In the Loop (MIL)
Scripting Real-Time Tests

• Abstract the complexity of the test sequence creation
  ▪ Define the test procedure
  ▪ Provide a single tool that abstract other tools
  ▪ Talk the same language as the user
Model In the Loop (MIL) Scripting Real-Time Tests

Automated Test Sequence

- Open MIL_NIGEL_EngineController.rig
- CalibFile_CoastalSummer.csv
- engine1000.et1
- Wait
- Do While
  - Wait for profile to finish
  - Wait
- End
- Get log file path
- Open DD Ref
- Export Log Path
- Export Working Dir
- Run NIGEL_MaskA_Analysis.VBS
- Get test results
- Pass Fail Test:NIGEL_MaskA_Analysis.VBS
- Close DD Ref

Scripting Test

- Use the MIL_NIGEL_EngineController.rig as VeriStand configuration file
- Use the CalibFile_CoastalSummer.csv as model parameters file
- Use the engine 1000.et1 as the stimulus profile
- Use the NIGEL_MaskA_Analysis.VBS as the analysis script and reporting
Model In the Loop (MIL)
Scripting Real-Time Tests

Scripting
Requirements

Automation
MIL Scripting Demo
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HIL Scripting Demo
Questions?