Verification of Avionics Systems Using Simulink Test and Simulink Real-Time

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Agenda

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Introduction
Maciej Stefaniak
Advanced Lead Engineer, Systems Engineering, Avionics

Maciej has been responsible for development of new framework for system verification of avionics using Simulink Test, Simulink Real-Time and Real-Time platform from Speedgoat. The framework was successfully deployed in several projects, supporting development according to standards like ARP 4754A or DO-178C. His area of interest beyond Model In the Loop, Hardware In the Loop testing is control systems modelling and Model Based Systems Engineering. Maciej holds Master of Science degree in Radiocommunication from Warsaw University of Technology, Faculty of Electronics and Information Technology.
At GE Aerospace, we **invent the future** of flight, lift people up, and bring them **home safely**.
We are a world-leading provider of jet engines, components and integrated systems for civil and military aircraft.

We see an industry that matters to the world

- History of innovation
- Purpose-driven people
- Technologies to enable net-zero flight

Photo courtesy of Boeing featuring Craig Bomben, Boeing's Enterprise Chief Pilot and VP of Flight Operations. Photo taken prior to COVID-19 restrictions.
GE Aerospace has achieved the following firsts:

- U.S. jet engine & U.S. turboprop engine
- Mach 2 engine
- Composite fan blade in airline service
- World record for thrust – GE90 & GE9X
- Additive jet engine parts approved by U.S. FAA
'22 GE Aerospace... $26.1B revenue

Commercial Engines & Services ... $18.7B

Military Engines & Services ... $4.4B

Aviation Systems ... $1.6B

Avio Aero & Turboprops ... $0.9B

Additive & Other ... $0.5B

(a) Includes CFM and EA revenue
CFM is a 50/50 Joint company between GE and Safran Aircraft Engines and
Engine Alliance (EA) is a 50/50 Joint company between GE and Pratt & Whitney
Commercial Engines revenue includes Aeroderivative business unit
GE Aerospace global footprint

North America
• Canada
• Mexico
• U.S.A.

Asia & Australia
• Australia
• China
• Malaysia
• Korea
• Singapore
• Taiwan
• United Arab Emirates
• Qatar
• India

South America
• Brazil

Europe
• Czech Republic
• France
• Hungary
• Italy
• Poland
• Romania
• Turkey
• United Kingdom
• Germany

By the numbers
• ~45,000 employees
• 62+ manufacturing locations
• 10+ overhaul and component repair locations
• 7 engineering centers
Objectives & Challenges
Business context

- Safety on the first place
- Highly regulated industry
- Certification – evidence of compliance
- Requirements Based Testing - every requirement needs to be verified
Automation

Real-Time  MiL Cost saving

HiL  Reuse  Easy to

Unified  Certification  use

Generic
Automation

- Reduce Human factor impact
- Test management
- Test preparation (compile&deploy)
- Test execution
- Test Result generation
- Test Report generation
- Test Result analysis
Generic & Reuse

- Common for all projects – projects are standardised
- Applicable to whole group of systems rather single product
- Building qualified test system - reuse of models, code and documentation*

* RTCA DO-330 - Software Tool Qualification Considerations
Generic & Reuse

Each project builds its own Test Rig

Each project reuses Test Rig Framework
Real-Time

- Accurate and precise sample time representation
- Preferred 10 times faster than Unit Under Test (UUT)
- Both model & test executed in Real-Time on Target computer
Hardware in the Loop (HiL) & Model in the Loop (MiL)

- Verification in open and closed control loop
- Different variety of interfaces: analogue and digital
- High range of communication protocols supported:
  - ARINC 429 (Serial)
  - ARINC 664 (Ethernet)
  - ARINC 825 (CAN)
- Integration with 3rd party Test&Measurement equipment
- MiL & HiL shall share common test
- Reduce Test Rig availability bottleneck
Unified & Easy to use

- Verification Team should focus on the UUT not tool itself
- Graphical User Interface (GUI)
- User Experience
- Fast to learn
- Predefined list of Input and Output signals (drop-down lists)
- Support for manual results analysis/debugging
Certification

- Deliver evidence to show compliance
- Traceability – "The recorded relationship established between two or more elements of the development process"
- Scale and complexity is challenging
- Coverage matrix generation
- Requirements verification
- Requirements validation
Requirements validation

Source: NIST, Planning Report 02-3 The Economic Impacts of Inadequate Infrastructure for Software Testing
- How did Simulink Test and Simulink Real-Time help us?
Three pillars of modern Test System
Speedgoat as HW platform

- Accelerate the design and testing of control designs and embedded controllers from MATLAB & Simulink
- Achieve most demanding sample rates and compute highly complex applications
- Vast range of supported I/O and large I/O expansion flexibility
- I/O modules are pre-installed at the time the target machine is purchased. Install additional I/O modules on your own at any time.
- Connect the target machine with your hardware, right from Simulink
- Flexible installation
- Maintained for the years to come
Roles in Test System

**Verification Engineer**
- Main Test System User
- Good understanding of requirements (UUT)
- Limited understanding of MATLAB/Simulink
- Uses predefined templates

**Test System Engineer**
- Good understanding of MATLAB/Simulink
- Good understanding of Interface Control Document
- Good understanding of communication protocols
- Good understanding of Speedgoat HW
- Limited understanding of UUT
Test System context of use
Simulink Test hierarchy
Test Sequence

Step

<table>
<thead>
<tr>
<th>Step</th>
<th>Transition</th>
<th>Next Step</th>
<th>Description</th>
</tr>
</thead>
</table>
| Run    | after(1, sec) | step_1 ▼  | % Initialize data outputs.
         |             |           | In powerSupply = false;
         |             |           | In arguments(1).arg1 = 0;
         |             |           | In arguments(1).arg2 = 0;
         |             |           | In arguments(1).operation = operation(Enum.Add);
         |             |           | In arguments = repmat(In.arguments(1), 3, 1); % bus array

| step_1 | after(1, sec) | step_2 ▼  | % turn on cats
         |             |           | In powerSupply = true;

| step_2 | after(1, sec) | step_3 ▼  | % set arguments
         |             |           | In arguments(i).arg1 = input1;
         |             |           | In arguments(i).arg2 = input2;
         |             |           | In arguments(i).operation = operation(Enum.Multiply);

| step_3 | true         | End ▼     | % check results
         |             |           | verify((Out.result(i)) - expectedResult) < TOLERANCE, 'test: result check'. 'Addition failed: result = %f, expected = %f', Out.result(i), exp|

End
Manual testing mode

```plaintext
# Manual testing mode

## Step

Run
ln = [Init;
stopTest = false;
promptMode = winType.NoWindow;
promptMessage = sendmsg("");

OK_dialog
% OK dialog check
promptMode = winType.OK;
promptMessage = sendmsg("Info statement. Press OK.");

OK_dialog_post
promptMode = winType.NoWindow;
verify(testContinue == true, 'test.OK', 'Transition took too long');

Pass_Fail_dialog_pass
% PassFail dialog check (Pass)
promptMode = winType.PassFail;
promptMessage = sendmsg("Pass/Fail evaluation. Select "Pass";

Pass_Fail_dialog_pass_post
promptMode = winType.NoWindow;
verify(logical(userInput) == true, 'test:PassFail_Pass', 'Pass/Fail test failed');

Test Action

- Info statement. Press OK.

- Pass/Fail evaluation. Select 'Pass'

- Input evaluation. Enter input value: 28 and press OK

GE Aerospace
```
Test Harness

Test Sequence

System Under Test
Test Manager: Test Browser
Test Manager: Results and Artifacts
Simulink Requirements

Export to Simulink Requirements

- Export requirements
- Manage requirements within Simulink Requirements
- Trace to Test Cases, Test Steps and Test Model
- Generate Traceability Matrix and others

Integrate with Quality Management System

- Traceability done on QMS level – broader picture
- Test Manager needs to be integrated (execute tests & provide results)
- Better analytical capabilities
- More work and knowledge required
Requirements validation - before
Requirements validation - after

Requirements → Model → Tests → Requirements
Future plans
Future plans

- Transformation into CI/CD workflow
- Requirements based testing – coverage matrix
- Better integration with QMS
- Integration with 3rd party T&M equipment
- Migration to R2020b and beyond (in progress)
- Fixing bugs and improvements