Comprehensive Static Analysis of Embedded Software (C/C++ and Ada) Using Polyspace Products

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What’s the value of verifying mixed generated and hand-written Code?

- Find run-time errors
  - In legacy or hand code
  - In the model caused by mixed code integration
  - In the design - when missed by the workflow

- Prove the absence of run-time errors
  - Prove code is free of run-time errors
  - Check MISRA compliance
  - Prepare for independent code verification (DO-178B, IEC 61508, …)

- Check workflow integrity, including mixed environments
  - Browse code-model level to verify the implementation
  - Catch defects missed by the workflow
  - Find implementation errors
Polyspace results on generated code are traced back to the model.
## Examples of Run-Time Errors Found in Legacy Code, Mixed Workflow, and/or the Design

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<th>Model constructions</th>
<th>Code constructions</th>
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<td>Scaling</td>
<td>Overflows, division by zero, bit-shifts, square root of negative numbers</td>
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<td>Unknown calibrations</td>
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<td>Untested data ranges</td>
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<td><strong>Memory corruption</strong></td>
<td>Array manipulation in Stateflow</td>
<td>Out-of-bounds array indexes</td>
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<td>Handwritten lookup table functions</td>
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<td><strong>Data truncation</strong></td>
<td>Unexpected data flow</td>
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<td><strong>Coding errors</strong></td>
<td>Unreachable states, transitions</td>
<td>Noninitialized data, Dead code</td>
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Example of Workflow

- Every tool chain has redundancy
- The best win is to do early Verification

**Simulation**
- Find design errors
- Find functional errors
- Find arithmetic errors
- Find coverage errors

**Model Verification**
- Modeling guidelines
- Find design errors
- Simplify the design
- Prove coverage
- Find unreachable state, transitions
- Generate test cases

**Code Verification**
- Verify standard compliancy
- Prove the absence of errors
- Verify hand written code
- Find implementation errors
Demo
Zero – MISRA C 2012 Mandatory Violations
Auto Code by Embedded Coder
Practical Use of Polyspace

Three Real World Scenarios

- Scenario #1
  - All handwritten code

- Scenario #2
  - Handwritten code inside generated code (Embedded Coder)

- Scenario #3
  - Generated code inside handwritten code
Scenario #1: All Handwritten Code

- **Embedded software components**
  - Complete system 100s of KLOC
  - Comprise of many functions and tasks
  - All integrated with handwritten code

- **Problems encountered**
  - Runtime bugs in the handwritten and third party code (*inadequate unit or component verification*)
  - How to verify at the interface level
  - Assuring that the entire system is robust
Using Polyspace for Scenario #1

- **Modular or component verification**
  - Run Polyspace on each function
  - **Robustness**: full-range or worst-case conditions, or
  - **Contextual**: apply range limits on interfaces

- **Integration level verification**
  - Run Polyspace on integrated code
  - Practical limits depending on code complexity and LOC
Scenario #2: Handwritten Code Inside MBD

- Generated code for model component
  - Consists of subsystems and model references

- Often includes handwritten code
  - In the form of S-Functions and legacy code
  - Individually, small in size (100s LOC)
  - May be automatically repeated many times within the MBD generated code

- Problems with integration
  - Handwritten code fails (*robustness issue*), or causes generated code to fail
  - Generated code may cause handwritten code to fail (*Interface related failures*)
  - Handwritten code treated as blackbox by Simulink
Using Polyspace for Scenario #2

- Modular verification of S-Functions or legacy code
  - Robustness: full-range or worst-case conditions, or
  - Contextual: apply range limits on interfaces

- Verification of mixed handwritten and generated code
  - Can perform robustness and contextual verification on interfaces of the generated code, including global data
  - Polyspace product traces code level defects back to the Simulink model
  - Handwritten code treated as whitebox by Polyspace
Scenario #3: Generated code inside handwritten code

- **Code integration outside MBD**
  - Generated code integrated together with handwritten code
  - All components integrated into embedded software with handwritten code

- **Problems with integration**
  - Runtime bugs in the handwritten and third party code (*inadequate unit or component verification*)
  - Verifying generated code especially at interface level
  - How to project relevant problems back to the model?
  - Assuring that the entire system is robust
Using Polyspace for Scenario #3

- Modular verification of handwritten or generated code
  - Run Polyspace on each function or file
  - **Robustness**: full-range worst-case conditions, or
  - **Contextual**: apply range limits on interfaces

- Integration level verification
  - Run Polyspace on integrated code
  - *Polyspace* products traces code level defects back to the *Simulink* model
  - Practical limits depending on code complexity and LOC
Verify mixed generated and hand-code
Prove the absence of run-time errors in source code

static void Pointer_Arithmetic (void)
{
    int array[100];
    int i, *p = array;

    for(i = 0; i < 100; i++, p++)
        *p = 0;

    if(get_bus_status() > 0) {
        if (get_oil_pressure() > 0)
            *p = 5;
        else
            i++;
    }

    i = get_bus_status();
    if (i >= 0) { *(p-i) = 10; }

    if ((0 < i) && (i <= 100)) {
        p = p - i;
        *p = 5;
    }
}

Quality improvement
• Prove the absence of errors
• No compilation, no execution, no test cases
• Early verification of C/C++ or Ada

Orange: unproven
Green: reliable
Red: faulty
Grey: dead
Thank You