Open-Source RTOS Space Qualification
An RTEMS Case Study

Scott Zemerick
Systems Engineer
TMC Technologies
NASA’s IV&V Program

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NASA RTOS Usage

- VxWorks
- Green Hills Software
- INTEGRITY
- μC/OS
- RTOS and Stacks
- concurrent REAL-TIME
- Embedded With RTEMS
- free RTOS
- Linux

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Open-Source RTOS Considerations

Open-Source Advantages

- Projects desire to own/control all source code forever
- Not locked into specific vendor/version for many years
- Not locked into proprietary build environment / tools
- Don’t have to pay third-party for upgrades / new features
- Successful heritage and flight experience
- No budget for purchases

Open-Source Barriers

- Unable to be (easily) flight qualified
- No artifacts, little or limited documentation, no test cases
- Lots of internal development / testing may be needed
  - Example: custom drivers
- Nothing is guaranteed to work “out of the box”
- Could require more testing than COTS
- Many forks, no central/core version, fixes/features not fed back to project
Terminology

• Qualification vs Certification
  – *The process of developing and documenting quality software by utilizing a formal process and artifact generation*

• **Pre**-Qualification is *jump start on qualification with core artifacts and processes*

• Final “Flight” Qualification
  – Performed on specific flight board/system
  – Qualified to a chosen standard
    • Examples: DO178-B/C, NASA 7150.2B
  – Tested and documented
Open-Source Qualification Example

• Core Flight System (CFS) Class A Certification
  – Performed by JSC for the Orion Program
  – LEON3/VxWorks

• Certification Included
  – Full coverage UT-assert unit test cases
  – API unit tests
  – Vertical integration tests
  – Test matrix, test plan, procedures, test report
  – VDD, User’s Guide
  – Code inspections, static analysis
  – Coverage analysis results

Lorraine Prokop, Ph.D.
Software Manager, Advanced Exploration Systems
Avionics & Software Project NASA
Johnson Space Center (JSC)
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Research Goals

• Increase the quality and maturity of open-source RTOS by identifying a lean, mean, PRE-qualification process
  • Process should be driven by standard(s)
  • Process has to be simple, not overwhelming, leverage existing / free tools, and not scary

• Processes are scary for open-source projects
  • Limited resources
    • No time, money, expertise, or manpower
  • Not agile – too rigid for open-source paradigm
Research Goals

• Imagine: FSW Lead on New Mission
  • What RTOS? Open-source or COTS?
  • IF Open-Source:
    • Flight heritage?
    • Hardware profiles? LEON3/4, RAD750?
    • Maturity?
    • Flight Qualification Possible?

• Maturation Metrics
  • How to measure maturity?
  • How to measure software quality?

• Choose open-source RTOS that is pre-qualified
  • Ease and jump-start the qualification process
  • Review state of the open-source RTOS
    • What is complete? Tested?
    • What holes are missing? What needs tested?
Research Goals

GSFC Flight Software Open Source Flight Software Stack
- Completely Open Source Flight Software
- “Qualifiable” due to this research
- Applicable to both small and large NASA missions
Research Tasks

• **Task 1**: Find DO-178B and 7150.2B Overlap

• **Task 2**: Review Overlap and Trim to Core Artifacts

• **Task 3**: Generate *Core-Artifacts-List*

• **Task 4**: Apply *Core-Artifacts-List* to Open-Source Project
### Core-Artifacts-List

<table>
<thead>
<tr>
<th>Category</th>
<th>Artifact</th>
<th>Artifact Intent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirements</td>
<td>Software Requirements Specification</td>
<td>Documentation of software requirements</td>
</tr>
<tr>
<td></td>
<td>Requirements Test and Traceability Matrix</td>
<td>Maintain bidirectional traceability between the software requirement and the higher-level requirement.</td>
</tr>
<tr>
<td></td>
<td>Software Assurance Plan / Validation</td>
<td>Requirements validation to ensure that the software will perform as intended in the targeted environment.</td>
</tr>
</tbody>
</table>

- Provides a pre-qual starting point
- Friendly names
- Should not be surprising
- Category-based
- “Hidden” pre-qual with focus on process and testing

### Design and Implementation

<table>
<thead>
<tr>
<th>Artifacts</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software Development or Management Plan</td>
<td>The Software Development Plan includes the objectives, standards and life cycle(s) to be used in the software development process.</td>
</tr>
<tr>
<td>Software Configuration Management Plan</td>
<td>To identify and control major software changes, ensure that change is being properly implemented, and report changes to any other personnel or clients who may have an interest.</td>
</tr>
<tr>
<td>Implementation</td>
<td>Implement the software design into code which is maintained in a version control system.</td>
</tr>
<tr>
<td>Coding Standards Report</td>
<td>Software coding methods, standards, and/or criteria are adhered to and verified.</td>
</tr>
<tr>
<td>Version Description Document (VDD)</td>
<td>Document that provides release information including versions, change history, and dependencies.</td>
</tr>
</tbody>
</table>

### Testing and Software Assurance Activities

<table>
<thead>
<tr>
<th>Artifacts</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software Test Plan</td>
<td>Document describing the testing scope and activities.</td>
</tr>
<tr>
<td>Software Assurance / Testing Procedures</td>
<td>To define the techniques, procedures, and methodologies that will be used.</td>
</tr>
<tr>
<td>Software Change Report and Problem Report</td>
<td>Reviews of software activities, status, and results with the project stakeholders and track issues to resolution.</td>
</tr>
<tr>
<td>Software Schedule</td>
<td>Project milestone and schedule is updated accordingly.</td>
</tr>
<tr>
<td>Software Test Report / Verification Results</td>
<td>Record, address, and track to closure the results of software verification activities.</td>
</tr>
</tbody>
</table>

### Usability

<table>
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<tr>
<th>Artifacts</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software User's Manual</td>
<td>Software User Instructions</td>
</tr>
</tbody>
</table>

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Applicable to RTEMS

- **Task 4**: Apply *Core-Artifacts-List* to Open-Source Project
- Chose RTEMS
  - Significant NASA / ESA flight heritage
  - Professional, well-managed open-source project
  - Desires to incorporate pre-qualification into their open-source process – but can’t be a burden – wants a lightweight process
  - Has some existing processes, tests, documentation in place

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**“RTEMS Software Engineering Standards” Template**

1. Introduction to Qualification / Purpose
2. Software Development Management
   - a. Implementation Details
   - b. Coding Standards
   - c. Change Management
   - d. Issue Tracking
3. Software Test Plan Assurance and Procedures
   - a. Scope, Procedures, Methodologies, Tools
4. Software Release Management
     - Review process, workflows, etc
   - b. Version Description Document generation
     (generated by Issue Tracker)
5. User’s Manuals
6. Licensing Requirements

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“RTEMS Software Engineering Standards” Template

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Next Steps
- Dive into more details
- Provide scorecard on areas that can be improved
- Leverage open-source tools to generate artifacts
- Think about requirements more
**RTEMS Space Qualification Test Bed (REST)**

- REST is a virtual environment with LEON3 instruction set simulator
- Goal will be a basic set of checkout tests and suitable for pre-qualification testing
- Repeatable test results

**Pre-Qualification Space Profile**

- LEON3
  - (WFIRST uses LEON4)
- LEON3
  - Xilinx Spartan6
  - JSTAR Hardware
- TSIM2
  - Virtual
- QEMU
  - Virtual

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Ongoing FY18 Work

- Continue working with RTEMS community on pre-qualification

- Investigate RTOS security and how to assess
  - How much should we care about embedded RTOS security?

- Mature cFS CryptoLib and Release
  - CryptoLib implements SDLS procedures and allow for easy integration into existing CFS command ingest and telemetry output applications
  - Integrate into NOS3 – http://www.nos3.org