Bridging Open Source and Critical Space Applications

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Overview

Introduction

Background of RTEMS

RTEMS-SMP features

Space qualification of RTEMS SMP

Experience with Open Source Software

Qualification of Open Source Software

embedded brains GmbH

Small company ~ 10 employees

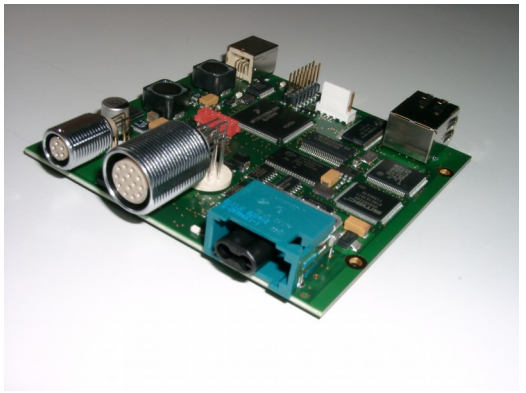
Founded in 2004

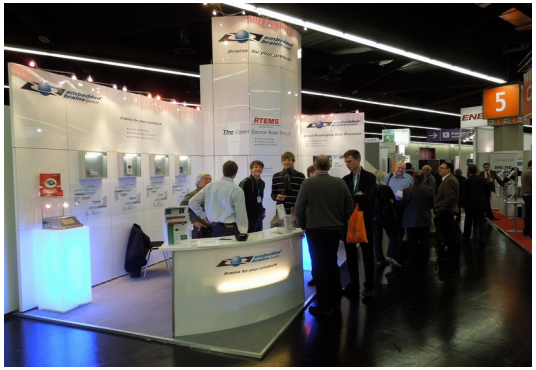
Specialised on hard- and software-engineering for high-performance systems

Main RTEMS developer and supporter in Europe

Domains:

- Aerospace
- Automotive
- Industrial automation





RTEMS Background

RTEMS: Real Time Embedded Operating System

Origins from US Army in the 1980s (**R**eal-**T**ime **E**xecutive for **M**issile **S**ystems)

Since 1990s continued as Open Source Software („GPLv2 w/linking exception" moving to "two paragraph BSD")

Symmetric Multiprocessing (SMP) since 2015 (developed by embedded brains)

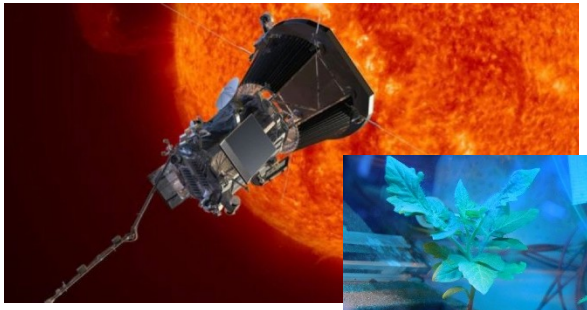
ECSS Space pre-qualification in progress

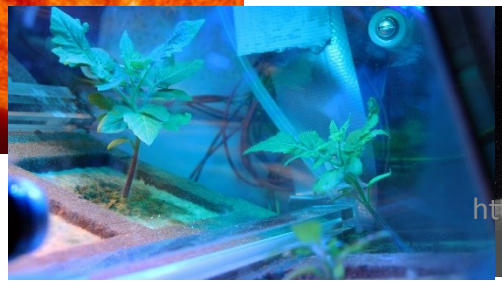
Application areas

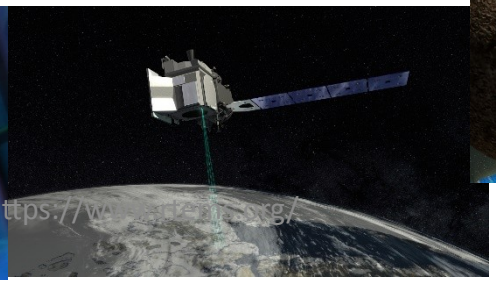
- Space industry (satelites)
- Industrial equipment (e.g. hand tools, autonomous vehicles, maintenance of bank notes)
- Professional audio
- Machine control (e.g. for radio telescopes)

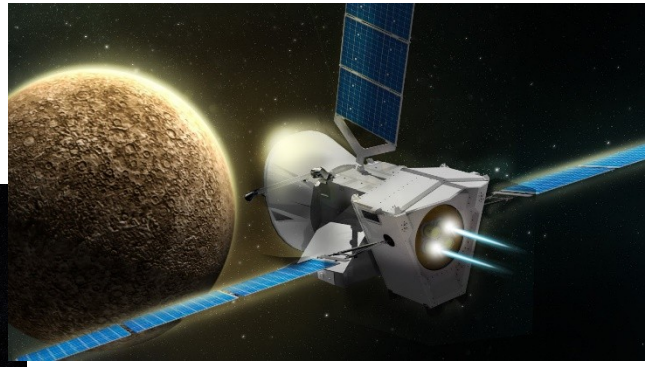
RTEMS mission launches

- NASA Parker Solar Probe
  - Launched 12 August 2018
  - SPARC Flight Computer runs RTEMS
- DLR Eu:CROPIS
  - Launched 19 November 2018
  - SPARC based life-support, growing tomatoes in space
- UAE KhalifaSat
  - Launched 29 October 2018
  - SPARC LEON3 based remote sensing satellite capable of imaging the earth at 0.7 meters
- NASA ICESat-2
  - Launched 15 September 2018
  - Advanced Topographic Laser Altimeter System (ATLAS) runs RTEMS on a mix of SPARC and PowerPC CPUs
- ESA BepiColombo
  - Launched 8 October 2018
  - RTEMS on at least MERTIS (MErcury Radiometer and Thermal infrared Imaging Spectrometer)









RTEMS features

- Scalability: Same software platform for very basic microcontrollers (~ 64kB memory footprint) up to high performance 64bit multicore machines (current industrial applications up to 24 cores)
- Continuous development and availability for >30 years
- Next release 5.1
- Wide range of 32/64 bit microrcontrollers supported (e.g. GR712 and GR740, but also popular ARM cores, PowerPCs, RISC-V and more)
- POSIX and API interfaces
- Open MP support
- C11/C++11 threading and synchronization supported including thread local storage
- Gaisler GRLIB integrated in RTEMS
- Flattened Device Tree (FDT) support
- Support for QorIQ DPAA including 10 Gbit/s Ethernet

RTEMS SMP features

- BSPs supporting SMP:
  - SPARC (1-4 cores): GR712C and GR740
  - PowerPC (1-24 cores): QorIQ (e.g. P1020, P2020, T2080, T4240, etc.)
  - ARMv7-A (1-4 cores): Altera Cyclone V, Xilinx Zynq, Raspberry Pi2
  - RISC-V (1-2 cores): RISCV
- Scalable timer support for SMP systems
  - Priority queues for timers (e.g. red-black trees)
  - Timer expiration distributed across processors
- Fine grained locking (Big Kernel Lock removed)
- Locking Protocols for Mutual Exclusion
  - Transitive priority inheritance tracked across multiple resources
- Priority ceiling
  - O(m) Independence-Preserving Protocol (OMIP)
    - extends priority inheritance to clustered scheduling
  - Multiprocessor Resource-Sharing Protocol (MrsP)
    - extends priority ceiling to clustered scheduling
- Limitation: Memory protection not available

ECSS Qualification of RTEMS-SMP

Objectives

- Pre-qualification Toolkit for ECSS-E-ST-40C and ECSS-Q-ST-80 Level C and D
- Provide verification evidence for RTEMS and all additional libraries to support a specific set of hardware and software configuations.
- Provide validation evidence to demonstrate that a well-defined set of requirements are met for all identified configurations
- Provide guidance to end-users on how to replicate and use (or extend) these results whenever a full qualification is considered.

Organisation

- Funding: ESA (with national partner organizations)
- Consortium:
  - edisoft (Portugal)
  - embedded brains (Germany)
  - Lero (The Irish Software Research Centre / Trinity College Dublin, Ireland)
  - Jena Optronik (Germany)
- Runtime: Dec 2018 – Nov 2020

ECSS Qualification of RTEMS-SMP (cont.)

Output

- Project focus according to *Space Profile* Survey (https://ftp.rtems.org/pub/rtems/people/sebh/tn-space-profile-r2-18072019.pdf)
- Basic documents / templates
- Testsuite
- Toolchain
- Solutions for technical challenges, e.g. how to qualify probabilistic response characteristics
- Example case erperiences

Limitations

- RTEMS and application use a shared memory space → Qualification can be completed only in conjunction with the application.
- Many functions und interfaces not yet considered due to resource limitations

Approach

- Open-Source (Source-Code, Testsuite, Toolchain etc.)
- Close cooperation with RTEMS community

Open Source Experience using RTEMS

Positives

- No loyalties
- No changes in business model of supplier
- No obligation to update according to suppliers plans
- No monopoly for product support
- 100% transparency for source code

Negatives

- Resources required for creating new functions / interfaces
- Difficulties to addressstratgic investments
- License conditions may imply restrictions for own source code
- Solidity of roadmap
- No active marketing

Experiences

- It makes sense to spend effort (→ some budget) for individual features, even if results were shard with the community.
- External expertise for support is mostly availaible and often more economical than provision of own experience.
- Branching-off private versions is not recommended (even if legally possible), as this practically excludes from all progress of the community version.
- Handling different types of license models within one project is challenging.

Open Source and Qualification

Experiences

New topic: qualification of Open-Source Software

How to ensure and sustain compatibility with RTEMS testers and tools?

As each qualification has its owm particualrities, no (integrated) community version of the qualification documents for a public repository may be compiled.

Space qualification requires a huge effort, much more than the product development itself: Who invests while others are getting it for free?

ESA normally limits access of out put to ESA member states – Open Source does not know access limitations

- The Toolkit will effectively help to qualify an RTEMS application with low effort
- Supporting expertise will be available
- Outstanding: Business model

Conclusion

RTEMS provides an attractive option for a Real Time Operating System.

RTEMS-SMP extends functionality for high-performacne multicore systems such as GR740.

RTEMS-SMP has an important limitation due to the lack of protected memory. It is anticipated to use RTEMS in relevent cases with a Hypervisor (e.g. XTRATUM)

Open-Source Software is a viable option for economic and sustainable software systems.

Ongoing RTEMS SMP qualification toolkit will provide a free framework of documents and test software in order to allow easy ECSS qualification.

Still a few questions remain how to share future extension of the qualification framework.

Thank You!

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