

# Space Qualification for Open-Source Real-Time Multicore OS RTEMS

*Matthias GÖBEL, Sebastian HUBER and Thomas DÖRFLER*

*embedded brains GmbH, GERMANY*

# Overview



## Introduction

## Background of RTEMS & SMP features

## Space qualification of RTEMS SMP

- Concept
- Process
- Deliveries

## Experience with Open Source approach in professional environments

# Intro: embedded brains GmbH



Small company ~ 15 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



...and it works!



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 to (TDB by end 2021)

## Application areas

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

# RTEMS mission launches

## NASA Perseverance Mars Rover

SPARRC v7 based Command and Data Management Unit (CDMU) and Altitude Control Computer (ACC)



## NASA Parker Solar Probe

SPARC Flight Computer

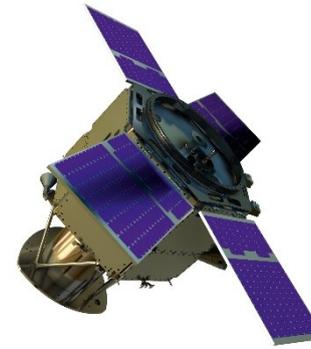
## DLR Eu:CROPIS

SPARC based life-support, growing tomatoes in space

<https://www.rtems.org/>



...and it works!



## UAE KhalifaSat

SPARC LEON3 based remote sensing satellite capable of imaging the earth at 0.7 meters

## NASA ICESat-2

Advanced Topographic Laser Altimeter System (ATLAS) runs RTEMS on a mix of SPARC and PowerPC CPUs

## ESA BepiColombo

RTEMS on MERTIS (MErcury Radiometer and Thermal infrared Imaging Spectrometer)



# RTEMS features



*...and it works!*



- 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
- Current release 6.1
- Wide range of 32/64 bit microcontrollers 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



...and it works!



- BSPs supporting SMP:
  - SPARC (1 to 4 cores): GR712C and GR740
  - PowerPC (1 to 24 cores): QorIQ (e.g. P1020, P2020, T2080, T4240)
  - ARMv7-A (1 to 4 cores): Altera Cyclone V, Xilinx Zynq, Raspberry Pi2
  - RISC-V (1 to 2 cores)
- 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



## Aim

- Provision of a free „starter-kit“ for RTEMS qualification
- Low-threshold qualification process

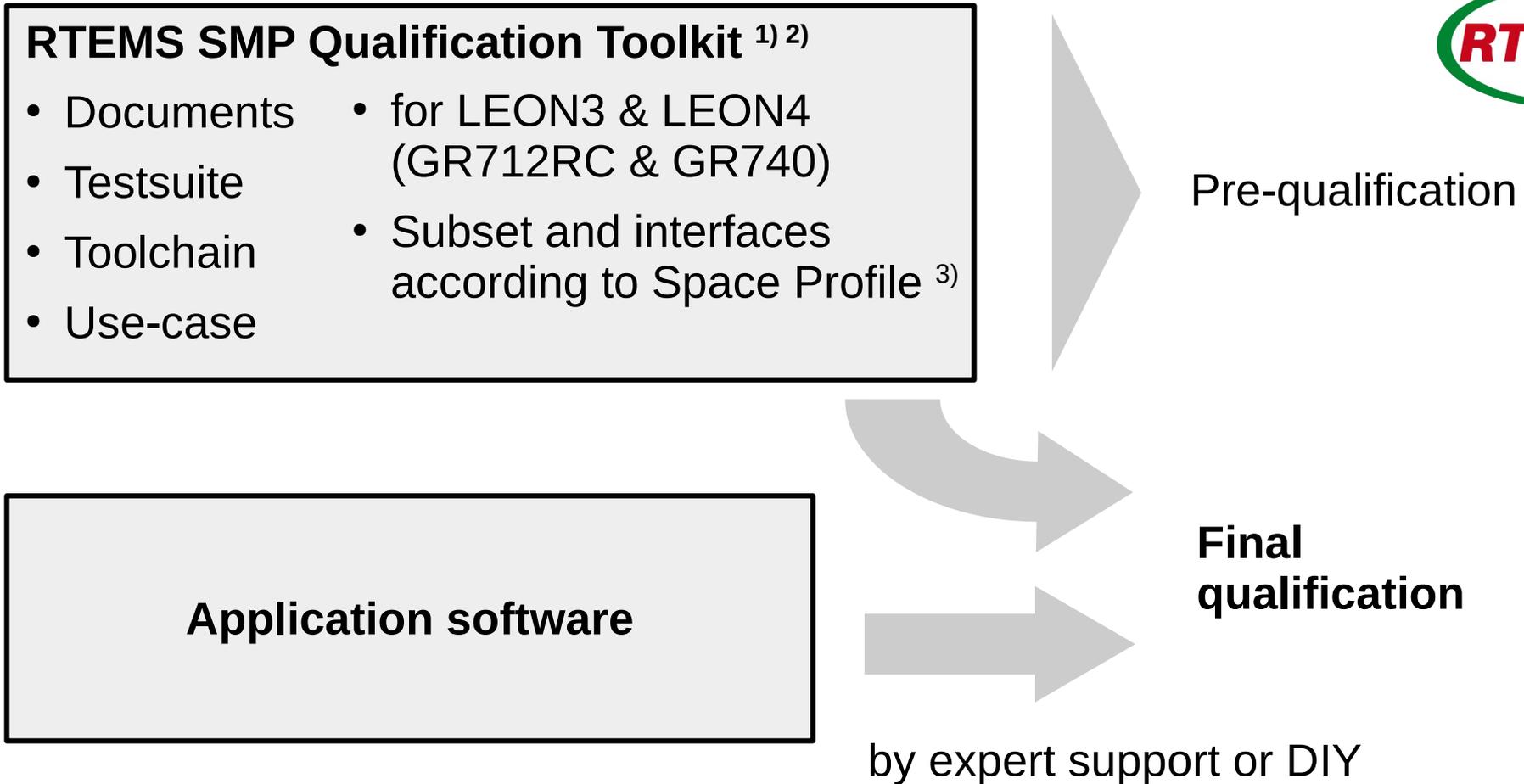
## Includes

- Pre-qualification for ECSS Cat. C and D for selected configurations
- Verification evidence for RTEMS and a selection of libraries
- Validation evidence to demonstrate that requirements are met
- Guidance to end-users on how to replicate and use (or extend) these results for a full qualification

## 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 – Dec 2021

# How does it work



<sup>1)</sup> Can be extended for other controllers and further interfaces and subsets

<sup>2)</sup> Subset of the full RTEMS repository (both updated synchronously)

<sup>3)</sup> <https://rtems-qual.io.esa.int/qdp/tn-space-profile.pdf>

# What to expect



...and it works!



## Qualification Data Package (QDP)

### Includes

- Project results,
- All source code,
- Documents,
- Binaries,
- Test-suites,

### Verification activities performed

- Static code checker results from Coverity, CLANG, and CppCheck
- Product and process metrics
- Assessment of testing and validation activities and
- Problem and the none-conformance reports

### Ready to

- Build applications,
- Re-run tests and
- Work with qualification documentation

**For free!**

# Open Source – the key to independence and affordability (1)?



...and it works!



## The positives

- No loyalties
- Easy start without bureaucrazy
- 100% transparency for source code
- Supportive community (hopefully...), no monopoly for product support
- No changes in business model of supplier
- No obligation to update according to suppliers plans

## The risks

- Providing own contributions to competitors for free
- No active marketing
- Difficulties to address strategic investments
- License conditions may imply restrictions for own source code
- Solidity of roadmap

for  
independant  
projects

# Open Source – the key to independence and affordability (2)?



...and it works!



## Risks (cont.): The DYI Sydrom

- Underestimation of the resources required for creating new functions / interfaces
- Creation of a „private“ version: earlier or later this will be completely outdated (as the public version will develop separately)
- Need to keep updated with many (or all main) developments in the community version

## Outlook

- RTEMS Foundation
  - Coordination of activities
  - Protecting investments in an appropriate way
- Provision of supporting expertise (different sources)

# Outlook



...and it works!



## RTEMS SMP Qualification Toolkit

- for LEON3 & LEON4 (GR712RC & GR740)
- Subset and interfaces according to Space Profile

available to public  
(completed by 12/21)

## QDP's for other controllers

- DAHLIA SoC
- various ARM-cores (BSPs available)
- RISC-V (BSP available)

## Further interfaces and drivers

- .....

## Extended RTEMS subset

- .....

by expert support,  
community effort,  
or DIY



## Conclusion

RTEMS provides an attractive option for a long-standing Open-Source-Real Time Operating System

RTEMS-SMP extends functionality for high-performance multicore systems such as GR740, DAHLIA Soc and RISC-V

The RTEMS SMP qualification toolkit adds a free framework of documents and test software in order to facilitate ECSS qualification. This provides a low-threshold entry to qualification (cat. C and D)

An ISVV is on its way for ECSS cat. B qualification

The framework can and shall be extended for further controllers and interfaces

A cooperative approach involving expert support and community is not imperative (but more efficient)

# RTEMS Space Qualification



...and it works!



## *Thank you!*

Further information:

<https://rtems-qual.io.esa.int/>

[www.embedded-brains.de](http://www.embedded-brains.de)

Author contact:

Dr Matthias GÖBEL

[matthias.goebel@embedded-brains.de](mailto:matthias.goebel@embedded-brains.de)

embedded brains GmbH  
D-82178 Puchheim, GERMANY

Phone: +49 89 189 4741 20