

# Summary and Updates to the GR740 Software Ecosystem

GR740 User Day 2022



# Software

- Complete ecosystem
- A combination of Gaisler and 3<sup>rd</sup> party software

## Tool chains, Operating systems and compilers

- Bare-C
- Linux
- RTEMS
- VxWorks
- Zephyr

## Partner software

Time-and-Space Partitioning:

- FentISS XNG
- SYSGO PikeOS
- Wind River VxWorks RTOS

## Boot loaders

- GRBOOT
- GRBOOT-STANDBY
- MKPROM2

## Development tools

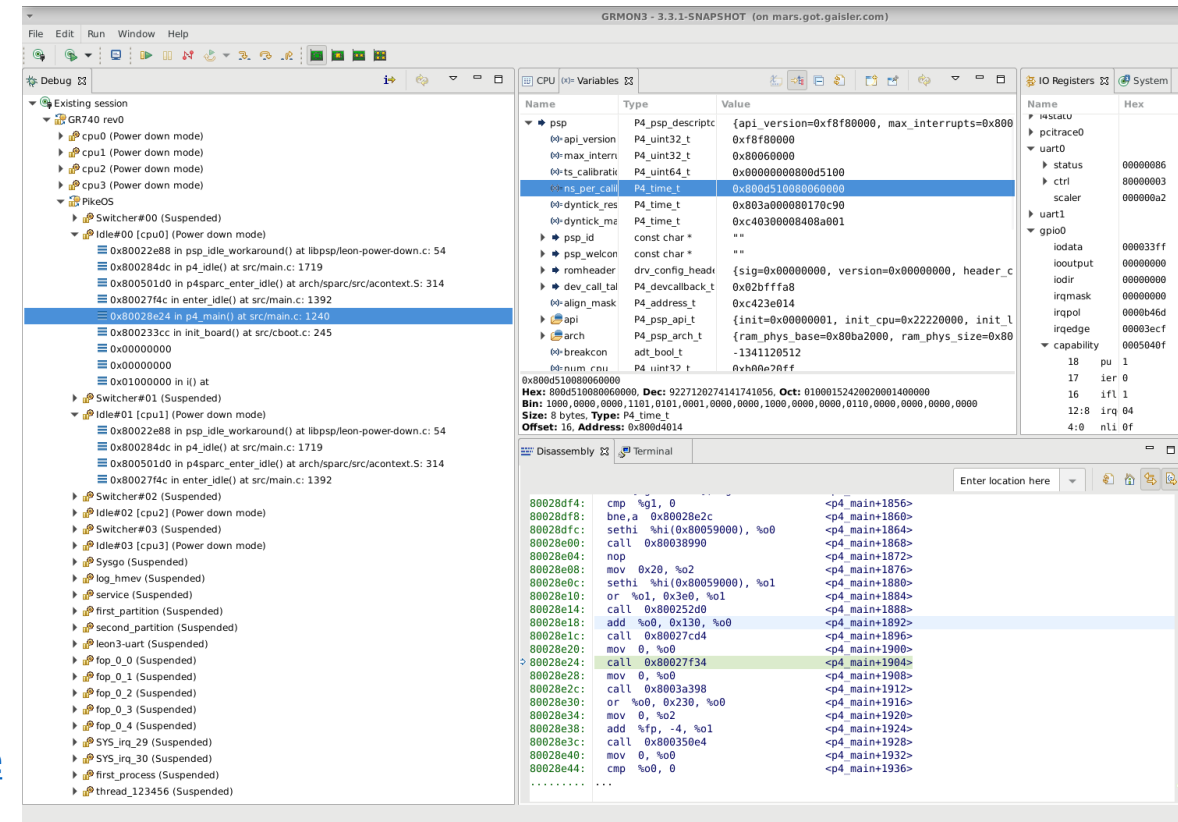
- TSIM3 simulator
- GRMON3 debugger
- GCC compilers
- LLVM/Clang compilers



# GRMON3 - LEON and NOEL-V debugger

## GRMON3 is a hardware monitor optimized for SPARC/LEON and RISC-V/NOEL-V systems

- Provides a non-intrusive debug environment
- Graphical User Interface, Command Line Interface, and GDB
- Tcl interpreter and Tcl scripting
- Supports many debug link interfaces (JTAG, Ethernet, SpW, ..)
- Support for multiple CPUs and OS threads
  - PikeOS thread support available in next release (see picture)
- Built-in disassembler and trace buffer management
- C/C++ source level debugging (see next slide)
- Remote connection to GNU debugger (GDB)
  - IDE support via the GDB connection, see [Eclipse Quick Start Guide](#)
- SPI memory programming and Common Flash Interface (CFI) for Flash PROM programming
- Error injection for LEON3/4 systems
- Provided for Linux and Windows

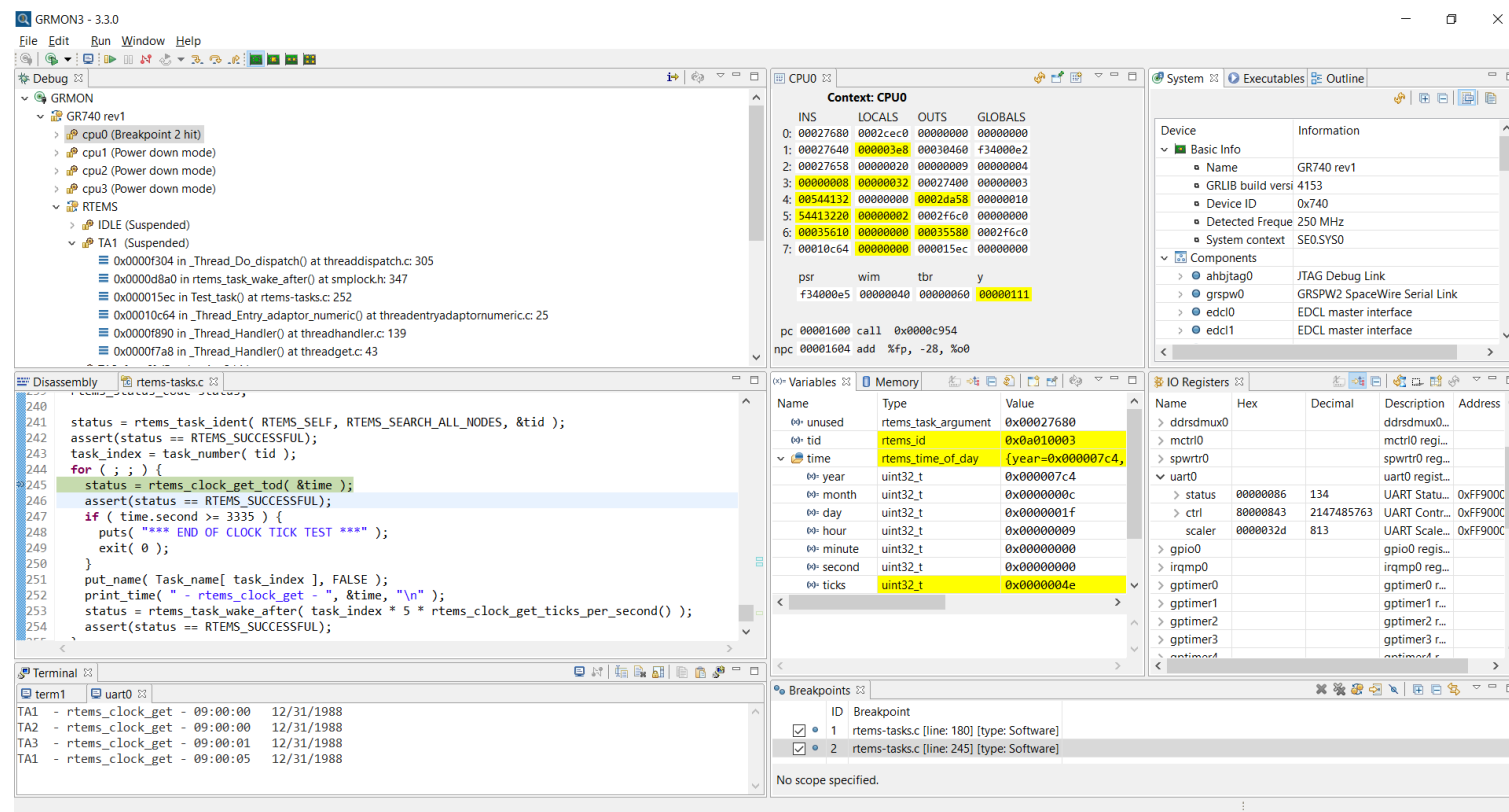


**GRMON3**  
debugging made easy

# GRMON 3.3 released in Q4 2022

## GRMON 3.3 introduces C/C++ language debugging support in Graphical User Interface

- Based on Eclipse CDT and TCF - familiar
- No dependency on GDB
- GDB still supported
- C/C++ source level debugging
  - Extended existing Views
  - New Views
  - Not in Command Level Interface
- C/C++ source code view
- Mixed Disassembly/C/C++ mode view
- C/C++ line execution control (step, step into, ..)
- Line breakpoints and watchpoint View
- C/C++ line display in Function call back trace
- C/C++ Variables View
  - Global Variables
  - Local stack frame Variables
- Symbols view listing global C/C++ symbols



**GRMON**  
debugging made easy



- **Accurate behavioral simulator**

- Precise behavior and timing in terms of simulation time
- Algorithm performance evaluation
- Deterministic execution
- Improved debugging capabilities (infinite tracing and event logging)
- Evidence gathering for software qualification (code-coverage, error-injection)
- Significantly higher performance than a SoC VHDL/VLSI/System-C model, hardware simulator
- User extendable
- Simulates specific LEON2, LEON3, LEON4 components and generic LEON2 and LEON3 systems

- **Supports three operating modes:**

- Standalone frontend with Tcl support for scripting and automation
- Used as a library to be included in larger simulator frameworks (C API is provided)
- Attached to GDB (allowing to connect Eclipse or other IDEs, see [quick start guide](#))

- **TSIM3 LEON4 models GR740**

- Quad core LEON4 with GRPFU and MMU
- L2Cache, SDRAM, PROM
- Ethernet, CAN, SPI
- IOMMU, AHBSTAT
- Timers, UARTs, GPIO
- GRSPW2 cores as stand-in for SpaceWire router
  - SpaceWire Router IP model is under development (started 2022)
  - Prototype of the model released as part of TSIM3-GR716B



Visit the [webpage](#) for more information

- Other vendors provide Simulation solutions for GR740
- Complements TSIM3 usage, TSIM3 does not cover real-time for GR740 and faster
- Faster simulators allows running the final application in real-time
- QEMU open-source simulator has limited support for LEON today
- Real-time simulation solutions with GR740 models,
  - TERMA TEMU
  - Wind River Simics
  - KARI LAYSIM
- Vendor Presentations at GR740 User Day 2022 for more information

# GRBOOT - Flight Software Boot Loader

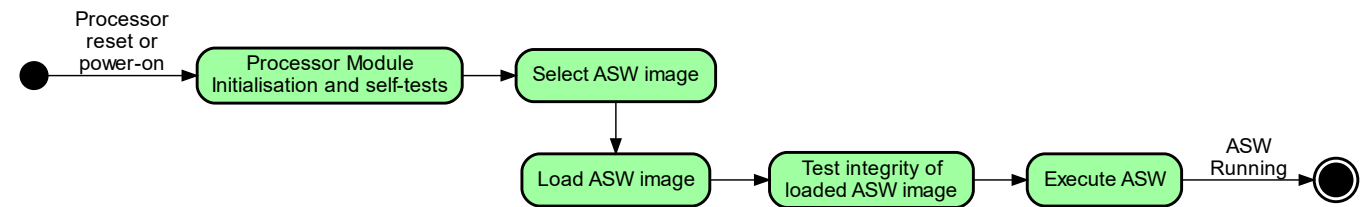
**GRBOOT is a flight system software suite targeting LEON based systems. It provides initialization, self-test and application loading functionality to payload and on-board computers**

## Features

- Implements ESA "SAVOIR Flight Computer Initialization Sequence" (SAVOIR-GS-002)
- Developed in accordance with ESA software engineering standards ECSS-E-ST-40C and ECSS-Q-ST-80C, criticality category B.
- Multiprocessor support (AMP, SMP)
- Self-testing of external memory and internal caches, register files
- Support for user extension point
  - GRBOOT-STANDBY extension point based on SAVOIR Standby mode
  - Run application from extension point (ROM resident application)
- Loader with ASW image integrity check and fallback image(s)
- Generates Boot Report for ASW or external access
- Prepares environment compatible with multiple operating system:
  - RTEMS, VxWorks, Linux, PikeOS, BCC, SMP, AMP, etc.
- Support for GR740, GR712RC and UT700 devices (support for GR765 planned)
- Supports in-flight patching by ASW (ASW image not linked to boot loader)

## Test and validation

- Fully automated test suites
- Unit tests executing on target hardware and with TSIM3 LEON simulator.
- Code coverage captured using TSIM3 LEON
- Validation test suite executes on target hardware, checks software and system behavior



*GRBOOT boot sequence*

Visit the [website](https://www.gaisler.com/grboot) for complete information: [gaisler.com/grboot](https://www.gaisler.com/grboot)

# STANDBY – SpaceWire/PUS remote terminal

## GRBOOT STANDBY

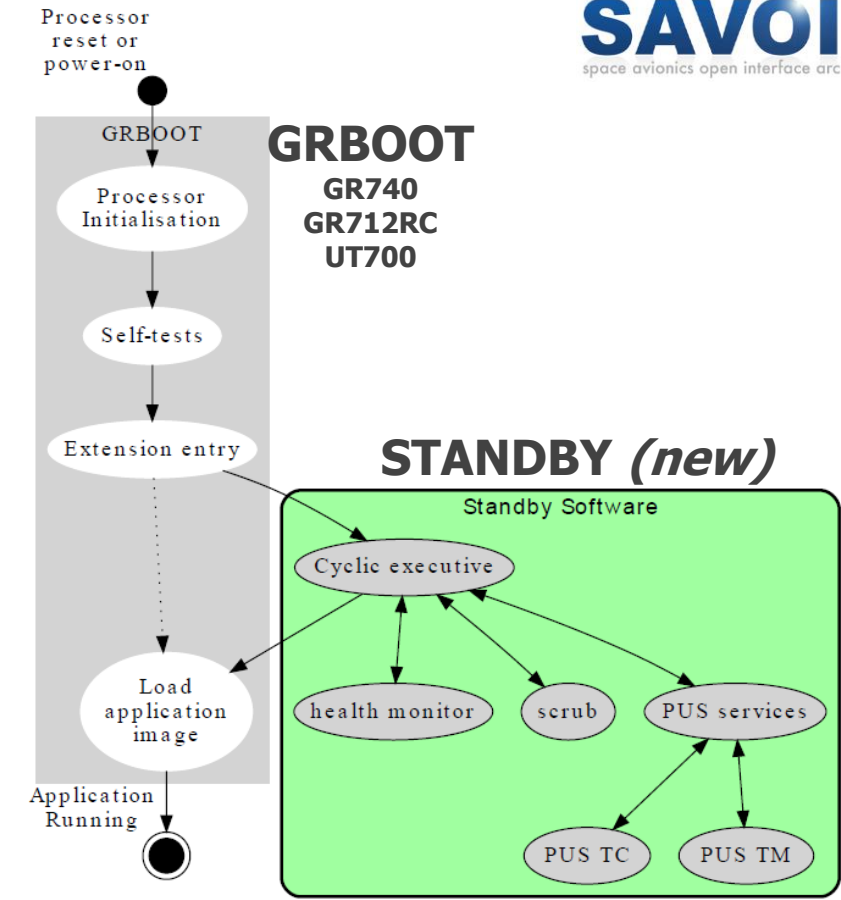
- Implements the SAVOIR *Standby mode* where GRBOOT implements *the Boot SW Nominal Sequence Mode*
- Based on JUICE GR712RC DPU Boot Software
  - Redesign with support for GR740 and GR712RC
- ECSS-E-ST-40C and ECSS-Q-ST-80C Category B. (same as GRBOOT)
  - Design Documentation
  - Unit-tests
  - Validation tests
- Maintenance operations before application is started

## Features

- Remote terminal over SpaceWire
- PUS services according to [ECSS-E-ST-70-41C]
- PUS Layer not SpaceWire dependent
- Support for adding mission specific PUS services
- Scrubbing of read-write memories (caches, RAM)
- Monitoring of bit upsets in caches and external RAM
- Validation and Unit tests can be rerun with GRESB

## SpaceWire/PUS Services

- House keeping
- Diagnostics, register access
- Boot Report service
- Memory commands (Read, Write, CRC)



*GRBOOT-STANDBY execution sequence*

Visit the [website](#) for more information



**CAES** PIONEERING  
ADVANCED  
ELECTRONICS

- WINDRVR

VxWorks 7 SMP 32-bit  
Release version: DEVEL-LEON-SR0650  
Build date: Dec 9 2022 13:27:16  
Copyright Wind River Systems, Inc.  
1984-2022

Adding 5440 symbols for standalone.

NAME	ENTRY	TID	PRI	STATUS	PC	SP	ERRNO	CPU #
tExcTask	fde44	1bf860	0	PEND	132ac8	1c39a0	0	-
tLogTask	logTask	2017ea08	0	PEND	131068	20192b60	0	-
tShell0	shellTask	201fd010	1	READY	13ef14	20213af8	0	1
tVxdgTask	da948	201f8390	25	PEND	132ac8	201fbde8	0	-
tNet0	ipcomNetTask	20002870	50	PEND	133260	20008e50	0	-
tNetConf	led14	201dd100	50	PEND	132ac8	201e0b40	0	-
miiBusMoni>	124a94	2018f490	252	DELAY	13cca8	2019aeB8	0	-
tIdleTask0	idleTaskEnt>	1ce000	287	READY	f4054	1cded0	0	0
tIdleTask1	idleTaskEnt>	1da000	287	READY	f4054	1d9ed0	0	-
tIdleTask2	idleTaskEnt>	1e6000	287	READY	f4054	1e5ed0	0	2
tIdleTask3	idleTaskEnt>	1f2000	287	READY	f4054	1f1ed0	0	3
value = 0 = 0x0								
-> [ ]								

- LEON Linux kernel releases
  - Based on 5.10 LTS kernel
  - Abandoned tracking LTSI LTS project
- GR740 Device Drivers
  - SpaceWire Router
  - CAN
  - SPI
  - PCI
  - Ethernet
  - GPIO
  - UART
- Prebuilt toolchains
  - Based on GCC-10
  - GLIBC 2.31 libraries
- MKLINUXIMG Second stage bootloader
  - OpenPROM providing services to kernel
  - Basic initialization of MMU
  - Low-level BSP settings
- LINUXBUILD – custom build flow for LEON
  - Used Buildroot as subcomponent
  - Migration to Buildroot stand-alone for standard build flow
- LEON Buildroot releases
  - Based on upstream Buildroot LTS versions
  - Replaces custom LEON Linux kernel and user space build and development environment
  - Integrated support for all our LEON Linux components
  - Example configurations, including for GR740
  - SDK toolchain build with buildroot libraries
- Documentation
  - Including overview and quick start guide
  - Driver API for specific APIs, such as SpaceWire

## RCC-1.3

- Gaisler's RTEMS-5 distribution
- Support for SMP and AMP
- GR740 BSP
  - Build configuration
  - Drivers included
    - SpaceWire Router
    - SpaceWire Time Distribution Protocol
    - Ethernet
    - PCI and PCI DMA
    - MIL-STD-1553B BC/RT/BM
    - Timer, UART, GPIO, CAN, SPI
    - SDRAM Memory scrubber
    - IOMMU configuration, Level 2 Cache
    - Statistical unit, AHB Status Register Bus monitor
  - User Manual and Driver API documentation
- Main differences from official source:
  - Most code up-streamed, limited differences
  - Toolchain based on GNU GCC-10
  - LLVM/Clang toolchain provided
  - RCC examples for device drivers
  - Additional Documentation

## Other News

- RTEMS-SMP Qualification Data Pack – Embedded Brains presentation
  - Available for GR740 and GR712RC
  - [RTEMS SMP Qualification Data Pack \(https://rtems-qual.io.esa.int/\)](https://rtems-qual.io.esa.int/)
- Gaisler contributions changed to new RTEMS license
  - Update from old RTEMS open-source license to BSD-2
  - This includes all GR740 device drivers
  - Simplify integration into some space applications
- RTEMS-5.2 release candidate announced (Nov 2022)  
→ pending RCC-1.3 update
- LibmCS - Standard Compliant and Pre-Qualified Math Library
  - Published in December 2022, ESA funded work by GTD GmbH
  - ECSS E-ST-40 and Q-ST-80 Category B, replaces previous MLFS library
  - Comprehends all ISO C and POSIX math functions found in libm
  - CAES Gaisler to evaluate including LibmCS in RCC and/or BCC
  - <https://essr.esa.int/project/libmcs-mathematical-library-for-critical-systems>
  - <https://gitlab.com/gtd-gmbh/libmcs>
  - <https://data.gtd-gmbh.de/libmcs-validation>

<https://www.rtems.org>





## BCC2 – Bare-Metal Cross Compiler

- Prebuilt C11/C++11 cross compiler
  - GNU GCC-10
  - LLVM/Clang
- Newlib C Library
- BCC run-time library for LEON
- Fast interrupt handling
- GR740 BSP
  - Linker-scripts
  - FPU, CAS, SVT, SPARCV8
- GR740 Device Drivers
  - SpaceWire AMBA DMA Port
  - MIL-1553-B BC/RT/BM
  - CAN
  - SPI
  - GPIO
  - UART
  - Timer, IRQ Controller
  - Clock-gating
  - SDRAM memory scrubber
  - AHB Status bus monitor
- Documentation
- Free and open-source

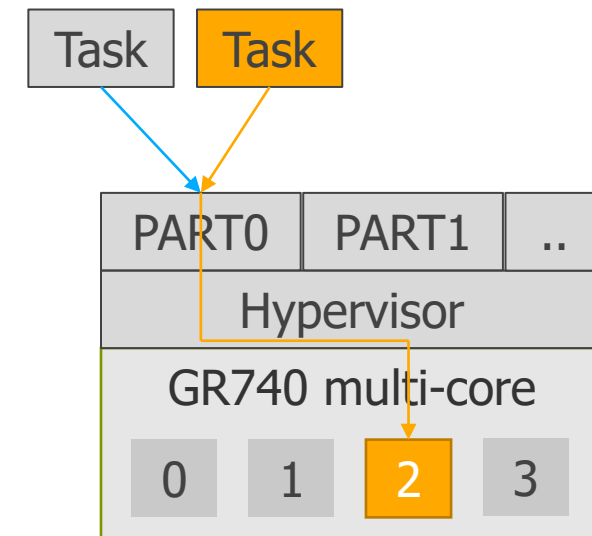
## Zephyr RTOS

- Scalable real-time operating system
  - Small-footprint kernel
- SPARC port, SPARCV8 ABI compliant
- LEON3/4/5 supported by LEON3 BSP
- Interrupt and FPU support
- GNU GCC toolchain SDK
- Contributed by Wind River, organized under Linux Foundation
- Apache 2.0 open-source license
- Wide and active community
- Long-term-stable release planning and test-suite
- Device drivers support
  - Limited to Timer and UART
  - Reuse BCC2 drivers (single-threaded)



# 3<sup>rd</sup> Party Hypervisor and TSP support

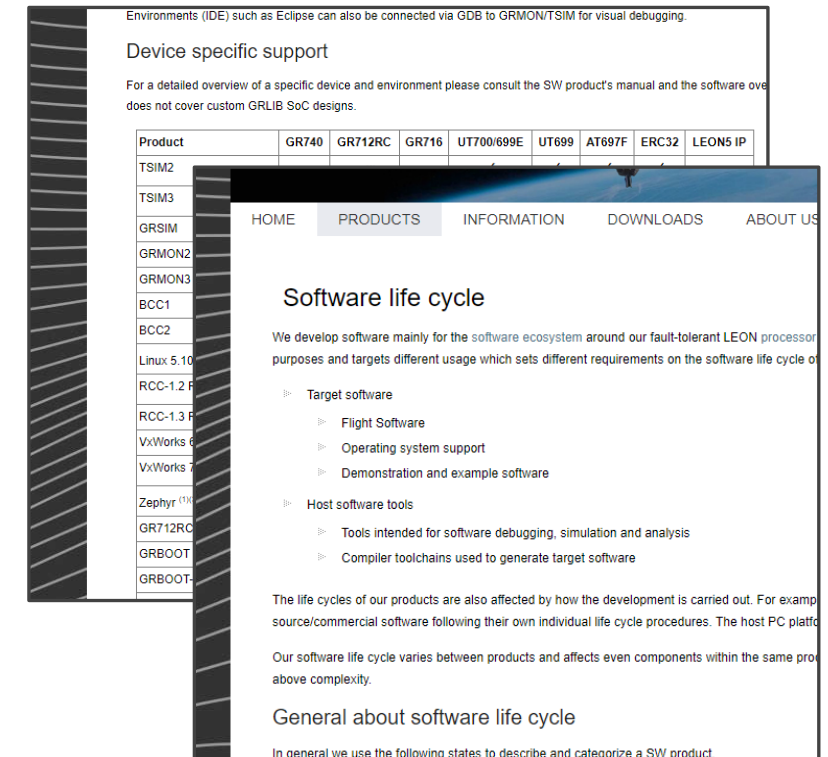
- Time-and-Space Partitioning a trend in space applications
- Multiple functions integrated into the same processor system
- May allow mixed-criticality applications
- Partitions describe separation
- Hypervisor scheduler, separates in time
- Hypervisor resource allocation, separates in space
  - Memory Management Unit (MMU) – limit CPU address space
  - IO MMU – limit DMA address space
- GR740 hardware prepared for para-virtualization
  - Multiple TIMER Cores
  - IRQ(A)MP – multiple independent Interrupt controllers
  - LEON4 Memory Management Unit (MMU)
  - IOMMU for DMA separation
  - LEON4 Statistical Counters – for surveillance and control
  - I/O resources sharing by 4KiB address alignment
- GR740 Solutions available today, see vendor presentations
  - FENTISS Xtratum
  - GMV AIR
  - SYSGO PikeOS
  - Wind River VxWorks Safety Profile (RTP and TSP scheduler)



# GR740 Software Ecosystem

## Resource overview

- Gaisler.com > Products > Software Overview
- Gaisler.com > Products > Software Lifecycle
- Gaisler.com/notes Technical Notes
- GR-CPCI-GR740 Quick Start Guide
- Newsletter for notifications on Updates and Fixes
- Other development, improvements also for GR740
  - RISC-V / NOEL-V
  - LEON5
  - GR765
- GR765 software backwards compatibility with GR740
- GR765/LEON5 SW ecosystem (GSTP 2023 - SNSA funding)
  - GRBOOT update to latest SAVIOR standard
  - GRBOOT ECSS documentation and other improvements
  - GRBOOT development includes GR712RC/GR740 targets
  - Linux BSPs commonalities
  - TSIM3 simulator common improvements





- Collaboration for improving the SW ecosystem together
- Technical help and expertise, development board and simulator access
- Collaborations in reaching out to GR740 users
- Improved visibility for partners planned through website improvements
- Typical areas involve
  - GR740 component support
  - Qualification activities – we are happy to collaborate and support developments!
  - Software tools
- Community feedback welcome!
  - Please share success stories or issues with software components
  - For example, within analysis tools for WCET, MC/DC, static analysis, CPU interference analysis, etc.

- Major new items from CAES Gaisler
  - GRMON-3.3 C/C++ language debugging GUI integration
  - TSIM-3 TLIB for integration and improved GR740 models
  - RCC-1.3 RTEMS-5.1 stable release
  - VxWorks SR0650 support with improved GR740 driver support
  - New Linux 5.10 LTS kernel, GLIBC, toolchain and stand-alone buildroot
  - Common GCC-10 toolchain with DWARF4 support
  - STANDBY remote SpaceWire/PUS terminal
  - Zephyr RTOS support
- Ecosystem for GR740 evolving with new software becoming available
- Thanks to partners and 3<sup>rd</sup> parties for the added value
- Sign up to [CAES Gaisler Newsletter](#) for updates



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