

# RTEMS State of the World

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December 2016

# Overview

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- Some mission updates
- Information on 4.11 releases
- Improvements already merged for 4.12
- Introduction of new features
- Desirable changes

# Some RTEMS Missions

- NASA Solar Dynamics Observatory (SDO)
  - Seven years in flight
- NASA Magnetospheric Multiscale (MMS)
  - Approaching two years
- ESA Planck
  - Seven years in flight
- NASA Fermi Gamma-ray Space Telescope
  - Eight years so far
- Upcoming missions:
  - APL Solar Probe Plus, GSFC WFIRST, ESA Exomars

# Why So Long?

- Many code improvements
  - SMP, New TCP/IP Stack, ports, etc., etc.
- Many non-code project process improvements
  - RSB instead of shipping tool binaries
  - Project hosting moved to OSU OSL
  - New “getting started”
  - Tool Changes
    - Revision Control Change: CVS to Git
    - Bug Tracking/Wiki Change: Bugzilla/Mediawiki to Trac
    - Documentation System Change: Texinfo to Sphinx
    - Introduction of waf build system
- Release process and supporting scripts completely broken by tool changes. Rewritten and now in git. Works great!
  - 4.11.1 released one day after 4.11.0 to correct packaging issue

# RTEMS 4.11 Features

- SMP is functional, but considered experimental
  - SPARC up to four cores with LEON3 (GR712RC) and LEON4 (GR740)
  - PowerPC up to 24 cores on NXP QorIQ T4240
  - ARM on Xilinx Zynq, Altera Cyclone V, Realview
  - x86 needs context switch algorithm fix and APIC support
- New architecture ports
  - ehipany, moxie, nios2, or1k, sparc64, v850
  - New ports collectively added 12 new BSPs
- Many other new features
  - JFFS2, dynamic loading, tracing, warning removal, etc.

# New BSPs in 4.11

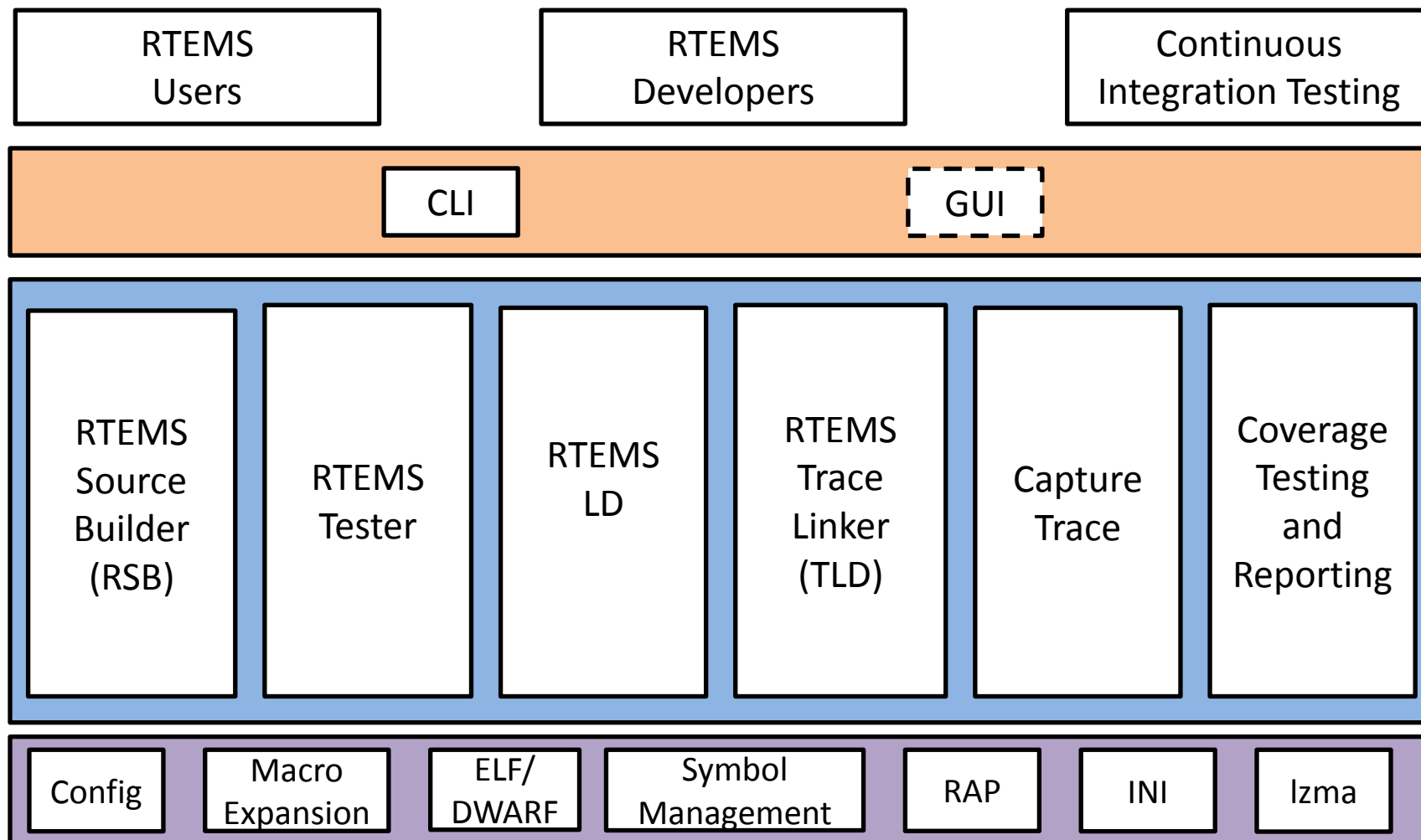
- 59 more BSPs than in 4.10 even after removing some
- This table is ONLY BSPs added to existing ports

<b>ARM</b>	altcycv_devkit, altcycv_devkit_smp, beagleboardorig, beagleboardxm, beagleboneblack, beaglebonewhite, lm3s3749, lm3s6965, lm3s6965_qemu, lm4f120, lpc1768_mbed_ahb_ram, lpc1768_mbed_ahb_ram_eth, lpc1768_mbed, lpc17xx_ea_ram, lpc17xx_ea_rom_int, lpc17xx_plx800_ram, lpc17xx_plx800_rom_int, lpc23xx_tli800, lpc24xx_plx800_ram, lpc24xx_plx800_rom_int, lpc40xx_ea_ram, lpc40xx_ea_rom_int, lpc32xx_mzx, lpc32xx_mzx_stage_1, lpc32xx_mzx_stage_2, raspberrypi2, raspberrypi, realview_pbx_a9_qemu, realview_pbx_a9_qemu_smp, stm32f105rc, stm32f4, tms570ls3137_hdk, tms570ls3137_hdk_intram, tms570ls3137_hdk_sdram, xilinx_zynq_a9_qemu, xilinx_zynq_zc702, xilinx_zynq_zc706, xilinx_zynq_zedboard
<b>I386</b>	edison, pcp4
<b>MIPS</b>	malta
<b>PowerPC</b>	brs6l, dp2, br_uid, mpc8309som, qemuprep-altivec, qemuprep, mpc5566evb_spe, mpc5643l_dpu, mpc5643l_evb, mpc5668g, mpc5674f_ecu508_app, mpc5674f_ecu508_boot, mpc5674fevb, mpc5674fevb_spe, mpc5674f_rsm6, phycore_mpc5554, qoriq_core_0, qoriq_core_1, qoriq_p1020rdb, qoriq_t2080rdb, qoriq_t4240rdb, t32mppc, virtex4, virtex5
<b>SPARC</b>	NGMP

## 4.11 Cross Development Tools Versions

- Cross development tools
  - GCC – 4.9.3
  - GNU Binary Utilities – 2.26
  - GDB – 7.9
  - Newlib – 2.20 snapshot from 20150423
  - Autoconf – 2.69
  - Automake – 1.12.6
- Qemu – Git snapshot with patches
- DTC – 1.4.1
  
- NOTE: Some may have patches applied by RSB and some targets may not use these versions

# RTEMS Tools



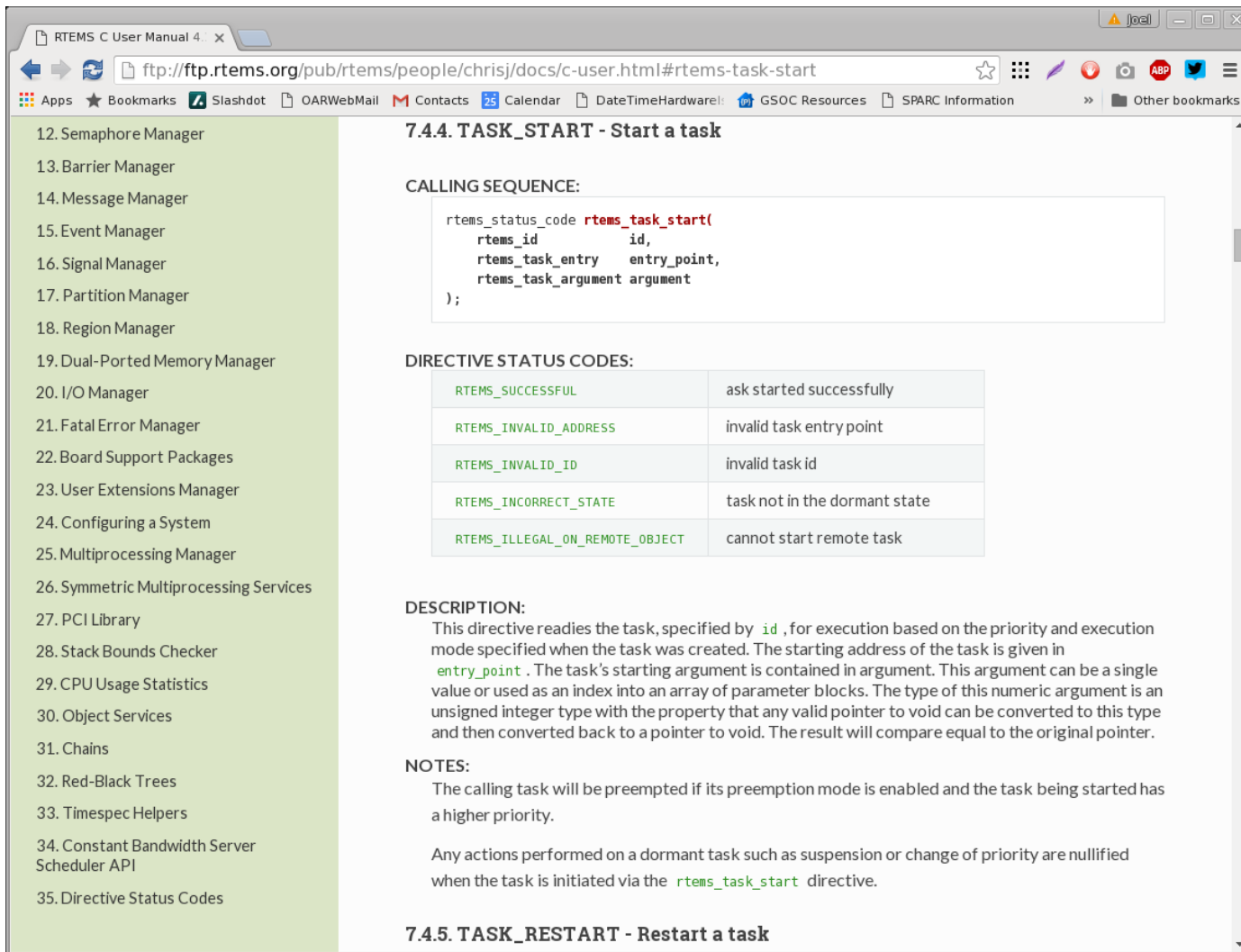


# RTEMS Tools Status for 4.11

- RTEMS Source Builder to build cross development tools, supporting tools, and target libraries
  - provides source and reproducible results appropriate for configuration control
- RTEMS Tester to enable users to test on the own hardware or simulators
- 4.11 includes initial release or significant update of
  - RTEMS Trace Linker
  - RTEMS Dynamic Loader and RTEMS LD
  - RTEMS Capture Engine
- Possible: More granular coverage test reporting

# New Sphinx Documentation

- Sphinx
- Used by Python and recently adopted by Linux kernel
- Simple ASCII markup
- [sphinx-doc.org](http://sphinx-doc.org)
- Wanted:
  - Inline programming examples
  - BSP Specific Howtos
  - Guides to common tasks and problems
  - Inclusion of newlib documentation
  - Easy to contribute!



The screenshot shows a web browser window displaying the RTEMS C User Manual. The address bar shows the URL: `ftp://ftp.rtems.org/pub/rtems/people/chrisj/docs/c-user.html#rtems-task-start`. The page content is as follows:

## 7.4.4. TASK\_START - Start a task

CALLING SEQUENCE:

```

rtems_status_code rtems_task_start(
  rtems_id          id,
  rtems_task_entry  entry_point,
  rtems_task_argument argument
);

```

DIRECTIVE STATUS CODES:

RTEMS_SUCCESSFUL	ask started successfully
RTEMS_INVALID_ADDRESS	invalid task entry point
RTEMS_INVALID_ID	invalid task id
RTEMS_INCORRECT_STATE	task not in the dormant state
RTEMS_ILLEGAL_ON_REMOTE_OBJECT	cannot start remote task

DESCRIPTION:

This directive readies the task, specified by `id`, for execution based on the priority and execution mode specified when the task was created. The starting address of the task is given in `entry_point`. The task's starting argument is contained in `argument`. This argument can be a single value or used as an index into an array of parameter blocks. The type of this numeric argument is an unsigned integer type with the property that any valid pointer to void can be converted to this type and then converted back to a pointer to void. The result will compare equal to the original pointer.

NOTES:

The calling task will be preempted if its preemption mode is enabled and the task being started has a higher priority.

Any actions performed on a dormant task such as suspension or change of priority are nullified when the task is initiated via the `rtems_task_start` directive.

## 7.4.5. TASK\_RESTART - Restart a task

## 4.12 Overview

- Significant improvements to SMP
  - SMP now considered production quality
- RTEMS libbsd TCP/IP stack status
- General additions
- BSP specific improvements
- Removed obsolete ports and BSPs
- Tool Updates

# SMP Application Features

- Clustered scheduling
  - Flexible link-time configuration
  - Fixed-priority scheduler
  - Job-level fixed-priority scheduler (EDF)
- C11/C++11 thread-local storage
- SMP features supported in Classic and POSIX
  - Mutex locking protocol, affinity, scheduler

# Multicore Programming Libraries

- OpenMP 4.5
  - See <http://www.openmp.org> for specification
  - Included in standard RTEMS GCC via libgomp
  - See <https://gcc.gnu.org/onlinedocs/libgomp>
- Embedded Multicore Building Blocks
  - See <https://embb.io/> for details
  - Code is at <https://github.com/siemens/embb>

# SMP Locking Improvements

- State of the art locking protocols for application mutexes
  - O(m) Independence-Preserving Protocol (OMIP, priority inheritance)
    - Reference: Bjorn Brandenburg . “A Fully Preemptive Multiprocessor Semaphore Protocol for Latency-Sensitive Real-Time Applications.”  
<https://people.mpi-sws.org/~bbb/papers/pdf/ecrts13b.pdf>
  - Multiprocessor Resource Sharing Protocol (MRSP, priority ceiling)
    - A. Burns and A.J. Wellings. “A Schedulability Compatible Multiprocessor Resource Sharing Protocol – MrsP.” Proceedings of the 25th Euromicro Conference on Real-Time Systems (ECRTS 2013). July 2013.
- Internal locking
  - RTEMS core uses fine-grained locking
  - Lock profiling is supported
  - Lock-free timestamps (see <https://devel.rtems.org/ticket/2271>)
  - Scalable timeout support (see <https://devel.rtems.org/ticket/2554>)
  - Capture (e.g. trace) engine is lock-free on SMP

# SMP Capable BSPs

- SPARC
  - GR740: Quad-Core LEON4
  - GR712RC: Dual-Core LEON3FT
- PowerPC
  - NXP QoriQ: various up to 24 processor T4240
- ARM
  - Xilinx Zynq: Dual-Core Dual-Core Cortex-A9
  - Altera Cyclone V: Dual-Core Cortex-A9
  - Raspberry Pi2: Quad-Core Cortex-A7
- x86
  - x86 needs context switch algorithm fix and APIC support

# SMP Libraries Likely Undesirable to Support

- Cilk™ Plus
  - See <https://www.cilkplus.org/> for details
  - Supports multicore and vector processing
- OpenACC (Open Accelerators)
  - See <http://www.openacc.org/> for details
  - Focus is heterogeneous CPU/GPU systems
- Both are currently supported in GCC but are single vendor solutions. Neither appears to have developed a community or be cross architecture.



# libbsd TCP/IP Stack Status

- Currently based on FreeBSD 9.3
- BSPs supported
  - ARM: Realview, Zynq, atsamv, Cyclone V, LPC24xx
  - M68K: genmcf548x
  - PowerPC: some QorIQ
  - x86: pc386 (multiple families of PCI NICs)
- Many features including IPV4, IPV6, packet filtering, USB mass storage, and more
- Update to FreeBSD 12 is near completion.
  - Includes basic support for Wifi

# General Improvements

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- Linux compatible interface for i2c/SPI
- Dynamic Driver Manager
- Enhance PCI Bus Library
- Dynamic Library supports more architectures
- Multithreaded GDB remote server!!

# RTEMS Debug Server

- GDB debug server which conforms to the latest GDB remote protocol.
- Thread aware support.
  - You can get a list of all stopped tasks and you can switch to a thread and inspect the stack.
- No GDB patches required.
- Simple IDE integration where GDB is supported.
  
- Fast with support for range stepping.
- Full attach and detach support.
- Supports the 'stop-all' model where all tasks are stopped on connection, break-point, watch-point, crash and ctrl-C. Support for 'non-stop' could be added.
- An unhandled exception such as a machine check or bus error leaves you on the offending instruction.
- Invasive debugging agent, linked to the application. It uses target resources such as the CPU, memory and networking.

# RTEMS Debug Server Status

- Available on “master” as *cpukit/libdebugger*
- Architecture support is currently limited to i386 and ARM Cortex-A9
- Only transport to host supported is TCP/IP
- We welcome support and funding to add more targets and transports

# Debug Server Console Output

\*\*\* LIBBSD DEBUGGER 1 TEST \*\*\*

RTEMS Shell on /dev/console. Use 'help' to list commands.

[/] # nexus0: <RTEMS Nexus device>

cgem0: <Cadence CGEM Gigabit Ethernet Interface> on nexus0

miiibus0: <MII bus> on cgem0

e1000phy0: <Marvell 88E1512 Gigabit PHY> PHY 0 on miiibus0

e1000phy0: none, 10baseT, 10baseT-FDX, 100baseTX, 100baseTX-FDX, 1000baseT-FDX, 1000baseT-FDX-master, auto

cgem0: Ethernet address: fa:69:35:9e:04:2f

zy7\_slcr0: <Zynq-7000 slcr block> on nexus0

notice: cgem0: link state changed to DOWN

add host [10.10.5.1](http://10.10.5.1): gateway cgem0

add net default: gateway 10.10.5.1

rtems-db: remote running

rtems-db: tcp remote: listing on port: 1122

notice: cgem0: link state changed to UP

rtems-db: tcp remote: connect host: 10.10.5.2

rtems-db: remote running

rtems-db: arm debug: (v3.0) ARMv7 [v7, all CP14 registers] breakpoints:5 watchpoints:3

rtems-db: sys: : suspending

rtems-db: sys: thd: 0a010001: signal: 0

rtems-db: sys: thd: 0a010002: signal: 0

rtems-db: events running

rtems-db: tcp remote: disconnect host

rtems-db: events finishing

rtems-db: sys: : resuming

rtems-db: tcp remote: listing on port: 1122

# GDB Session with Debug Server

```
$ /opt/work/rtems/4.12/bin/arm-rtems4.12-gdb-nx ./build/arm-rtems4.12-
xilinx_zynq_zedboard/debugger01.exe
GNU gdb (GDB) 7.12
Copyright (C) 2016 Free Software Foundation, Inc.
License GPLv3+: GNU GPL version 3 or later <http://gnu.org/licenses/gpl.html>
This is free software: you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law. Type "show copying"
and "show warranty" for details.
This GDB was configured as "--host=x86_64-freebsd10.3 --target=arm-rtems4.12".
Type "show configuration" for configuration details.
For bug reporting instructions, please see:
<http://www.gnu.org/software/gdb/bugs/>.
Find the GDB manual and other documentation resources online at:
<http://www.gnu.org/software/gdb/documentation/>.
For help, type "help".
Type "apropos word" to search for commands related to "word"...
Reading symbols from ./build/arm-rtems4.12-xilinx_zynq_zedboard/debugger01.exe...done.
(gdb) target remote 10.10.5.15:1122
Remote debugging using 10.10.5.15:1122
arm_interrupt_disable () at
../cpukit/./../xilinx_zynq_zedboard/lib/include/rtems/score/cpu.h:344
344 __asm__ volatile (
(gdb) info thread
Id Target Id Frame
* 1 Thread 1.167837697 (U11 (0a010001), priority(c:254 r:254), stack(s: 32768 a:0x429448),
state(SUSP)) arm_interrupt_disable () at
../cpukit/./../xilinx_zynq_zedboard/lib/include/rtems/score/cpu.h:344
2 Thread 1.167837698 (SHLL (0a010002), priority(c: 1r: 1), stack(s: 32768 a:0x431c08),
state(SUSP)) arm_interrupt_disable () at
../cpukit/./../xilinx_zynq_zedboard/lib/include/rtems/score/cpu.h:344
(gdb) bt
#0 arm_interrupt_disable () at
../cpukit/./../xilinx_zynq_zedboard/lib/include/rtems/score/cpu.h:344
#1 _Thread_Do_dispatch (cpu_self=<optimized out>, level=<optimized out>) at
/opt/work/chris/rtems/kernel/rtems.git/c/src/./../cpukit/score/src/threaddispatch.c:206
#2 0x0021e5be in nanosleep_helper (discipline=WATCHDOG_ABSOLUTE, rmtpt=0x4313c0,
timeout=0x431368, ticks=<optimized out>, clock_id=1) at
/opt/work/chris/rtems/kernel/rtems.git/c/src/./../cpukit/posix/src/nanosleep.c:69
#3 nanosleep (rqtp=rqtp@entry=0x4313c0, rmtpt=rmtpt@entry=0x4313c0) at
/opt/work/chris/rtems/kernel/rtems.git/c/src/./../cpukit/posix/src/nanosleep.c:156
#4 0x00210fba in sleep (seconds=seconds@entry=60) at .././.././.././../gcc-6-
20161110/newlib/libc/posix/sleep.c:17
#5 0x001048c0 in test_main () at .././testsuite/debugger01/test_main.c:66
#6 Init (arg=<optimized out>) at .././testsuite/include/rtems/bsd/test/default-network-
init.h:293
#7 0x00204ffc in _Thread_Handler () at
/opt/work/chris/rtems/kernel/rtems.git/c/src/./../cpukit/score/src/threadhandler.c:88
Backtrace stopped: previous frame identical to this frame (corrupt stack?)
(gdb) thread 2
[Switching to thread 2 (Thread 1.167837698)]
#0 arm_interrupt_disable () at
../cpukit/./../xilinx_zynq_zedboard/lib/include/rtems/score/cpu.h:344
344 __asm__ volatile (
```

```
(gdb) bt
#0 arm_interrupt_disable () at
../cpukit/./../xilinx_zynq_zedboard/lib/include/rtems/score/cpu.h:344
#1 _Thread_Do_dispatch (cpu_self=<optimized out>, level=<optimized out>) at
/opt/work/chris/rtems/kernel/rtems.git/c/src/./../cpukit/score/src/threaddispatch.c:206
#2 0x001f72da in _Thread_Dispatch_direct (cpu_self=<optimized out>) at
/opt/work/chris/rtems/kernel/rtems.git/c/src/./../cpukit/score/src/threaddispatch.c:250
#3 0x001f33f2 in rtems_task_wake_after (ticks=ticks@entry=1) at
/opt/work/chris/rtems/kernel/rtems.git/c/src/./../cpukit/rtems/src/taskwakeafter.c:51
#4 0x001efb0 in fillBufferPoll (tty=0x431470) at
/opt/work/chris/rtems/kernel/rtems.git/c/src/./../cpukit/libcsupport/src/termios.c:1334
#5 rtems_termios_read_tty (tty=tty@entry=0x431470, buffer=0x407d6b "", initial_count=1)
at /opt/work/chris/rtems/kernel/rtems.git/c/src/./../cpukit/libcsupport/src/termios.c:1429
#6 0x001efcbe in rtems_termios_read (arg=0x4396e8) at
/opt/work/chris/rtems/kernel/rtems.git/c/src/./../cpukit/libcsupport/src/termios.c:1462
#7 0x0020415a in rtems_deviceio_read (iop=0x313188 <rtems_libio_iops>, buf=<optimized
out>, nbytes=<optimized out>, major=<optimized out>, minor=minor@entry=1) at
/opt/work/chris/rtems/kernel/rtems.git/c/src/./../cpukit/libcsupport/src/sup_fs_deviceio.c:
81
#8 0x0020370c in device_read (iop=<optimized out>, buffer=<optimized out>,
count=<optimized out>) at
/opt/work/chris/rtems/kernel/rtems.git/c/src/./../cpukit/libfs/src/imfs/deviceio.c:65
#9 0x00211224 in __sread (ptr=<optimized out>, cookie=0x407d28, buf=<optimized out>,
n=<optimized out>) at .././.././.././../gcc-6-20161110/newlib/libc/stdio/stdio.c:48
#10 0x00210c1a in __srefill_r (ptr=ptr@entry=0x407bd0, fp=fp@entry=0x407d28) at
.././.././.././.././../gcc-6-20161110/newlib/libc/stdio/refill.c:119
#11 0x00210d24 in __srget_r (ptr=ptr@entry=0x407bd0, fp=fp@entry=0x407d28) at
.././.././.././.././../gcc-6-20161110/newlib/libc/stdio/rget.c:43
#12 0x00209e66 in fgetc (fp=fp@entry=0x407d28) at .././.././.././../gcc-6-
20161110/newlib/libc/stdio/fgetc.c:133
#13 0x001ff130 in rtems_shell_getchar (in=in@entry=0x407d28) at
/opt/work/chris/rtems/kernel/rtems.git/c/src/./../cpukit/libmisc/shell/shell_getchar.c:124
#14 0x001fe1f0 in rtems_shell_line_editor (size=128, out=0x407da8, in=<optimized out>,
prompt=<optimized out>, count=<optimized out>, cmds=0x4399d8) at
/opt/work/chris/rtems/kernel/rtems.git/c/src/./../cpukit/libmisc/shell/shell.c:220
#15 rtems_shell_main_loop (shell_env_arg=<optimized out>) at
/opt/work/chris/rtems/kernel/rtems.git/c/src/./../cpukit/libmisc/shell/shell.c:878
#16 0x001fee2a in rtems_shell_task (task_argument=<optimized out>) at
/opt/work/chris/rtems/kernel/rtems.git/c/src/./../cpukit/libmisc/shell/shell.c:674
#17 0x00204ffc in _Thread_Handler () at
/opt/work/chris/rtems/kernel/rtems.git/c/src/./../cpukit/score/src/threadhandler.c:88
Backtrace stopped: previous frame identical to this frame (corrupt stack?)
(gdb) q
A debugging session is active.

Inferior 1 [process 1] will be detached.

Quit anyway? (y or n) y
```

# BSP Specific Improvements

- Added ARM ATSAMV BSP for Atmel SAM V71/V70/E70/S70 (Cortex-M7)
- I386/PC
  - Many NICs supported via new network stack
  - Some dependencies on legacy HW addressed
- Raspberry Pi and Beagle variants continue to gain peripherals
  - Pi TCP/IP is close. See <https://lists.rtems.org/pipermail/devel/2016-September/016092.html>

# BSPs and Ports Obsolete in 4.12

- Ports removed:
  - AVR, H8/300, M32R
- This table is ONLY BSPs removed from existing ports

ARM	gba, gp32, nds
M68K	gen68302, idp, mvme136, ods68302, sim68000, simcpu32
MIPS	genmongoosev
PowerPC	ep1a, mbx821_001, mbx821_002b, mbx821_002, mbx860_001b, mbx860_002, mbx860_005b, mbx860_1b, score603e
SPARC	sis

**Please help us identify BSPs and ports for obsolete hardware that are no longer in use**



## 4.12 Cross Development Tools Versions

- Cross development tools
  - GCC – 6.x snapshot now, plan to use 7.x release
  - GNU Binary Utilities – 2.27
  - GDB – 7.12
  - Newlib – 2.4.0 snapshot from 20161025
  - Autoconf – 2.69
  - Automake – 1.12.6
- Qemu – Git snapshot with patches
- DTC – 1.4.1
  
- NOTE: Some may have patches applied by RSB and some targets may not use these versions

# A Few Desirable Improvements

- Conversion of RTEMS to waf build system
  - Build time will go from minutes to seconds
- PC BSP support EFI bootloader, non-legacy hardware, and a clean “non-legacy BSP”
- Pi3 working: UART configuration is different
- More SMP capable BSPs: Pi3 and PC
  - x86 needs context switch algorithm fix, APIC, and APCI support
  - Pi3 needs someone to make it work
- Microblaze port

**Improvements occur only when the  
community supports the project**

# Thank You!

- All of the improvements that have been made are thanks to the community supporting the project via:
  - Funding core developers
  - Contributing new features and fixes

# Contact Information

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