Evolving the NG-ULTRA and NG-LARGE SoC software ecosystem

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The company

fentISS at a glance

PRODUCTS

XtratuM Hypervisor

Partition Guest Operating Systems (LithOS, RTEMS BSP, Linux BSP)

Support Tools: Configuration, Real-Time Scheduling, Observability & Simulation

SERVICES

Support

Porting and customization

Training

EU H2020, HEP

ESA Projects

CNES Projects

RESEARCH EXPERTISE

AIRBUS DEFENCE & SPACE

esa European Space Agency

cnes CENTRE NATIONAL D'ÉTUDES SPATIALES

THALES

CUSTOMERS

LEO missions with fentISS' products

2019-2023
OneWeb
Constellation with 600+ satellites
XtratuM + RTEMS

2022
SWOT
SURFACE WATER & OCEAN TOPOGRAPHY
XtratuM

2023
SVOM
XtratuM + LithOS

2023
kinéis
25 nano-satellites
XtratuM + LithOS

2024
MERLIN
XtratuM

2019
angels
XtratuM + LithOS

2023
NESS
XtratuM + LithOS

2023
PLATiNO
XtratuM + RTEMS

2019
eyesat
XtratuM + LithOS

2024
CO3D
5 -20 satellites
XtratuM + RTEMS

Deep space missions with fentISS' products

NG-ULTRA

HERMES project: basic data

Qualification of **H**igh p**E**rformance p**R**ogrammable **M**icroprocessor and d**E**velopment of **S**oftware ecosystem

- Start date 1 March 2021, end data 29 February 2024
- Grant agreement ID: 101104203
- Total cost: 3 059 001,25 €
- Topic: SPACE-10-TEC-2018-2020 – Technologies for European non-dependence and competitiveness
  - Call for proposal H2020-SPACE-2018-2020
  - Sub call: H2020-SPACE-2020
- Funding scheme: RIA (Research and Innovation action)

HERMES project: consortium

HERMES project: objectives

Main objectives to reach a TRL6 from TRL4

a) Development and testing of very complex ceramic hermetic package CGA 1760

b) Space ECSS evaluation of the rad-hard FPGA (NG-ULTRA) developed under ESA, CNES and EU projects

c) Development and validation by end-users of several software tools including BAMBU HLS (High Level Synthesis), XtratuM-NG (XNG) hypervisor and BL1

HERMES project: fentISS contributions

- Integrating NG-ULTRA support in XtratuM-NG (XNG)
  - Updating related supporting tools (`xcparser`, `xci`, `xcon`, `xtraceviewer`)
  - Delta-qualifying XNG for ECSS category-B
- Adapting RTEMS as a XNG NG-ULTRA partition
- Adapting MMU-less Linux as a XNG NG-ULTRA partition

NG-ULTRA main challenges

A) Lack of cache coherence among cores at hardware level
- Software must be aware, several approaches are possible:
  - Disabling L1 cache for shared resources
  - Invalidating L1 cache before accessing a shared resource

B) Global exclusive monitors only supported by ERAM
- Atomic and locks must be located at ERAM

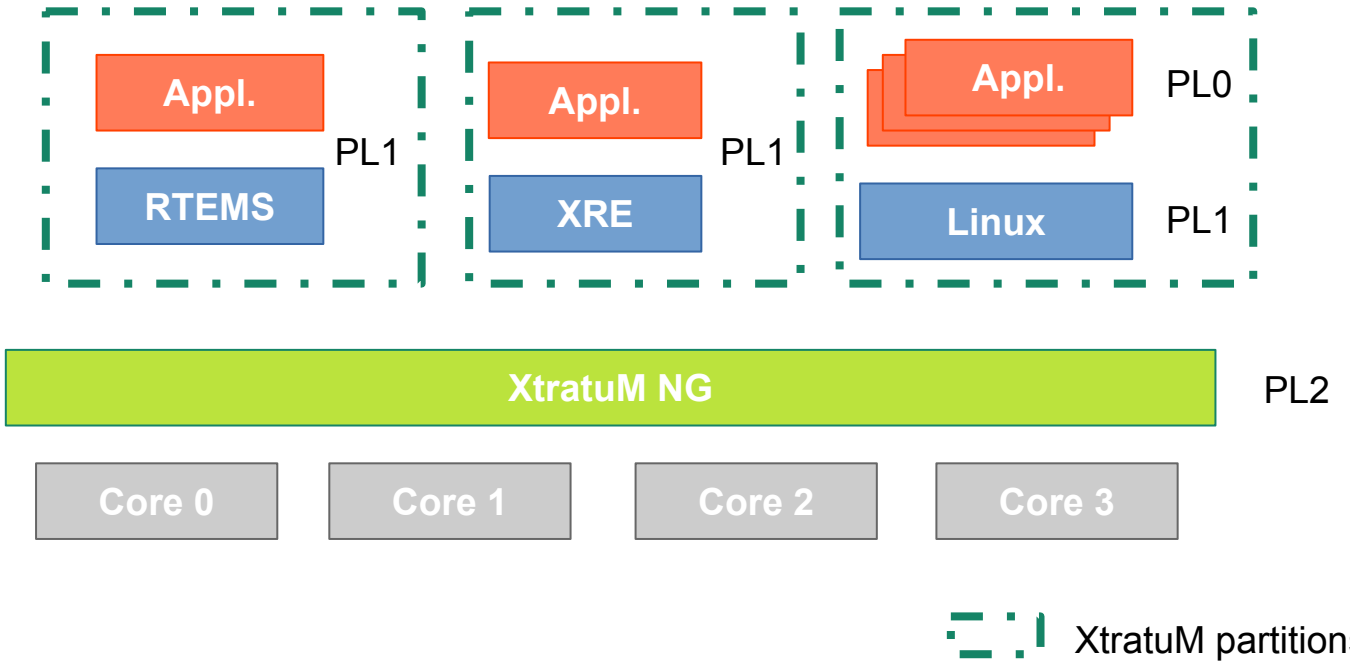
C) Each CPU cluster integrates its own isolated GIC distributor
- IPIs cannot be notified among clusters
- **[Solved]** By using the Multi-Cluster Interrupt Controller (MCIC) soft IP
  - Developed by ADS-F and TAS-F within the scope a CNES' study
  - Allows us to notify IPIs as SPIs

XNG for NG-ULTRA (I)

- XNG 1.4.5 selected as baseline
  - SMP model implemented (4 cores)
    A) Cache coherence issue solved by software at hypervisor level
      - **At partition level, partition must manage this lack of coherence by itself**

    B) All atomic and lock variables located at ERAM
  - XNG takes advantage of the Cortex-R52 virtualization support
    - Hypervisor runs on PL2
    - Partitions run on PL1&PL0
  - Requires
    - MCIC soft IP (IPIs generation among cores)
    - BL1 bootloader (HERMES outcome)
- Current status
  - Prototype available
  - ECSS delta qualification started

XNG for NG-ULTRA (II)



XNG for NG-ULTRA QDP

1. Software Development Plan (SDP)
2. Software Configuration Management Plan (SCMP)
3. Software Configuration File (SCF)
4. Software Requirements Specification (SRS)
5. Interface Control Document (ICD)
6. Software Design Document (SDD) common
7. SDD AARCH32-PMSA-FV
8. XNG AARCH32-PMSA-FV+NG-ULTRA operational package
9. Software User Manual (SUM) common
10. SUM AARCH32-PMSA-FV
11. Software Integration Test Plan (SITP) common
12. SITP AARCH32-PMSA-FV
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20. Software Validation Report (SValR) AARCH32-PMSA-FV
21. Acceptance tests – TN
22. Acceptance tests suite
23. Acceptance tests - SVS,
24. Acceptance tests - SValR template
25. ECSS Compliance Report (ECR)
26. Software Product Assurance Plan (SPAP)
27. Software Product Assurance Milestone Report (SPAMR)
28. Software Verification Plan (SVerP)
29. Software Verification Report (SVR)

RTEMS BSP for NG-ULTRA

- ESA RTEMS6 QDP selected as baseline
- Two flavors
  - RTEMS BSP mono-core
  - RTEMS BSP SMP (first approach)
    A) Cache coherence issue bypassed by keeping cache disabled
       - Performance degradation
    B) `libatomic` library updated for instantiating variables in ERAM
       - RTEMS core and application impacted
- Current status
  - Prototypes available
  - Under validation by using RTEMS test suite

MMU-less Linux BSP for XNG NG-ULTRA (I)

- Kernel 6.10 selected as baseline
  - Only mono-core version is supported
  - Created a new Linux XNG-ARM-R BSP
- Standard distributions are not supported by MMU-less Linux
  - MMU-less Linux root filesystem based on busybox created for this porting
- Integrated XNG inter-partition communication (IPC) support
  - Applications can interact with other partitions

MMU-less Linux BSP for XNG NG-ULTRA (II)

Linux applications implement the FDPIC ABI

- Features
  - Suitable for the MMU-less Linux execution environment
  - Supports shared libraries
  - Supports static binaries
  - Supports multi-threading
- Drawbacks
  - **Static stack**: the processes stack cannot grow dynamically so it is allocated at compile time
  - **fork() vs vfork**(): Only vfork() is supported, vfork() stops the parent execution until either exec() or exit() are called by the child process
  - **malloc()**: Implemented using a shared memory pool
  - **No memory protection** between applications: Only the kernel is protected by the MPU

MMU-less Linux BSP for XNG NG-ULTRA (III)

NG-LARGE

XtratuM-NG porting and qualification on NG-LARGE

- CNES study
  - Step required for enabling the use of CNES' LVCUGEN
- Goals
  - Adding NG-LARGE support to XNG
  - Validating LithOS for running as XNG NG-LARGE partition
  - Delta qualifying both softwares for ECSS category B

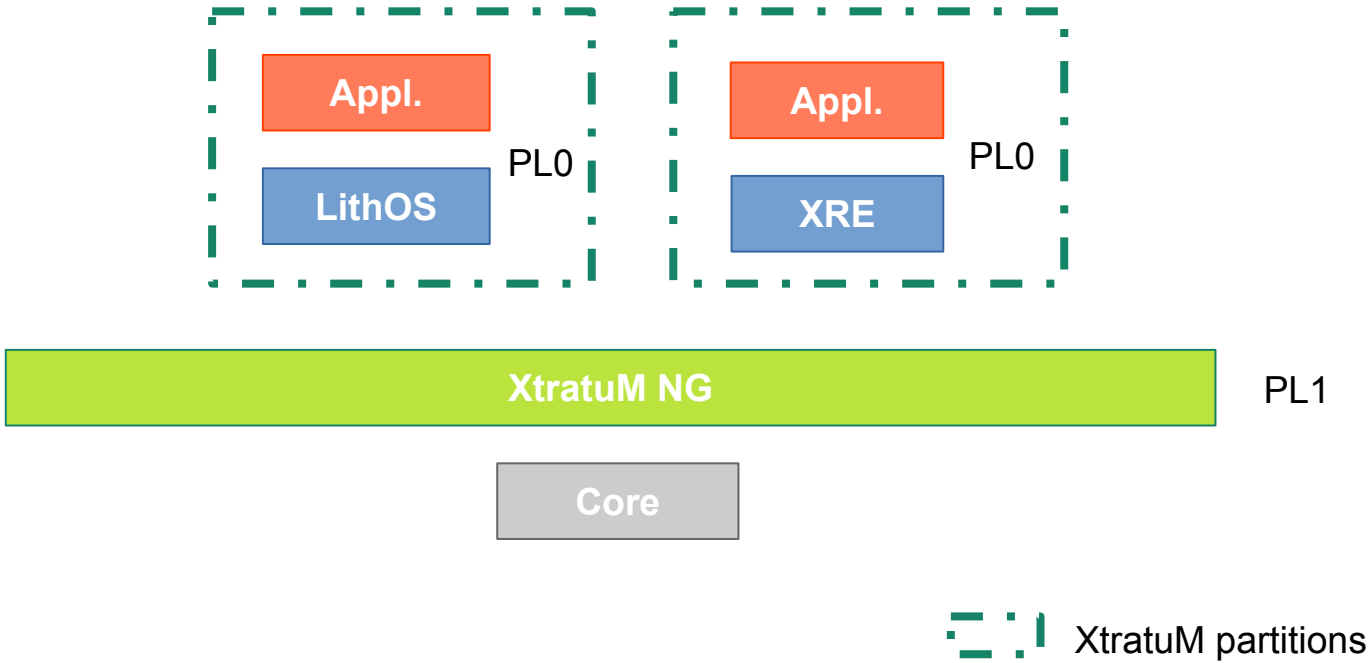
NG-LARGE main challenges

- The SoC only integrates a Cortex-R5
- CNES provides the required soft IPs (AMBA bus, UART, BRAM, SRAM, …)
  - Lack of interrupt controller
    - **Solved** at software level
  - Lack of DRAM memory controller
    - **Under development**

XtratuM-NG for NG-LARGE (I)

- XNG 1.4.5 selected as baseline
  - Mono-core model implemented (1 core)
  - Tested with small systems (< 512KB)
    - Waiting the availability of a SDRAM memory controller
- Hardware virtualisation not supported
  - Partitions must be para-virtualised
    - Hypervisor runs on PL1
    - Partitions run on PL0
- Current status
  - Prototype available
  - ECSS delta qualification started

XtratuM-NG for NG-LARGE (II)



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Thank you for your attention!