The METASAT Hardware Platform: A High-Performance Multicore, AI SIMD and GPU RISC-V Platform for On-board Processing

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Introduction

Current and upcoming space missions become increasingly complex, incorporating new functionalities including Artificial Intelligence (AI) for on-board processing.

Need for more powerful hardware architectures which can provide the computational power required.

Current use of multicores is limited to the execution single threaded tasks on different cores, but not real parallel processing.

Solutions:

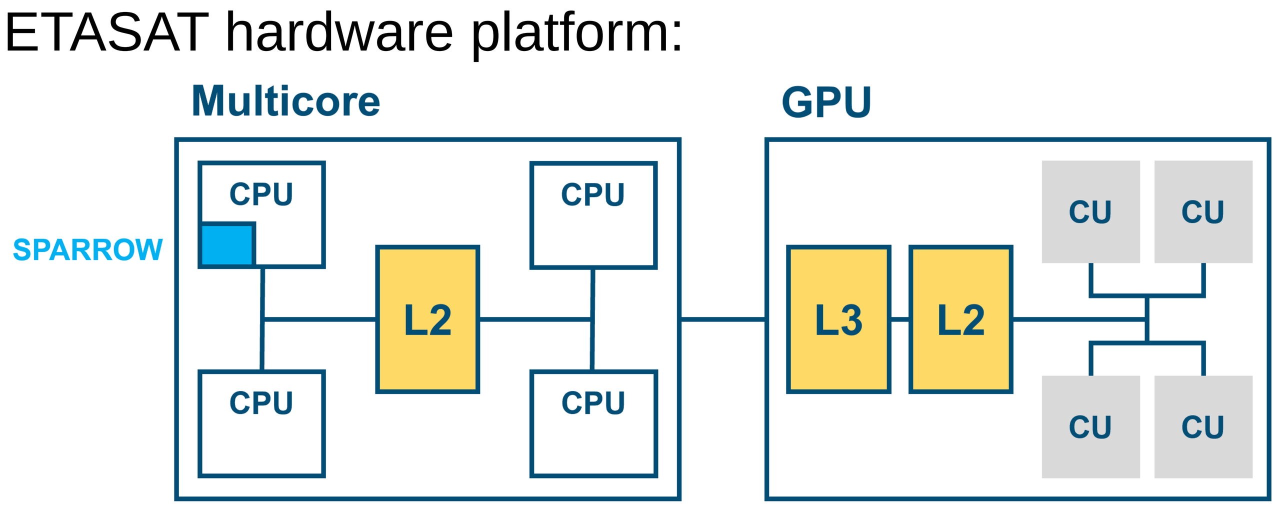
- more capable hardware such as accelerators require complex programming models and software stacks
- more complex software, using new parallel programming models like OpenMP, OpenCL, Vulkan SC etc

The increased complexity of both hardware and software of future space platforms is hard to manage, so model-based engineering approaches are increasingly employed in the design of space systems. ESA has developed the open source TASTE framework which is constantly under development with new functionalities.

The Horizon Europe project METASAT will develop model-based design approaches which will help to manage the complexity of programming such advanced high performance platforms, including AI accelerators and GPUs.

Architectural design

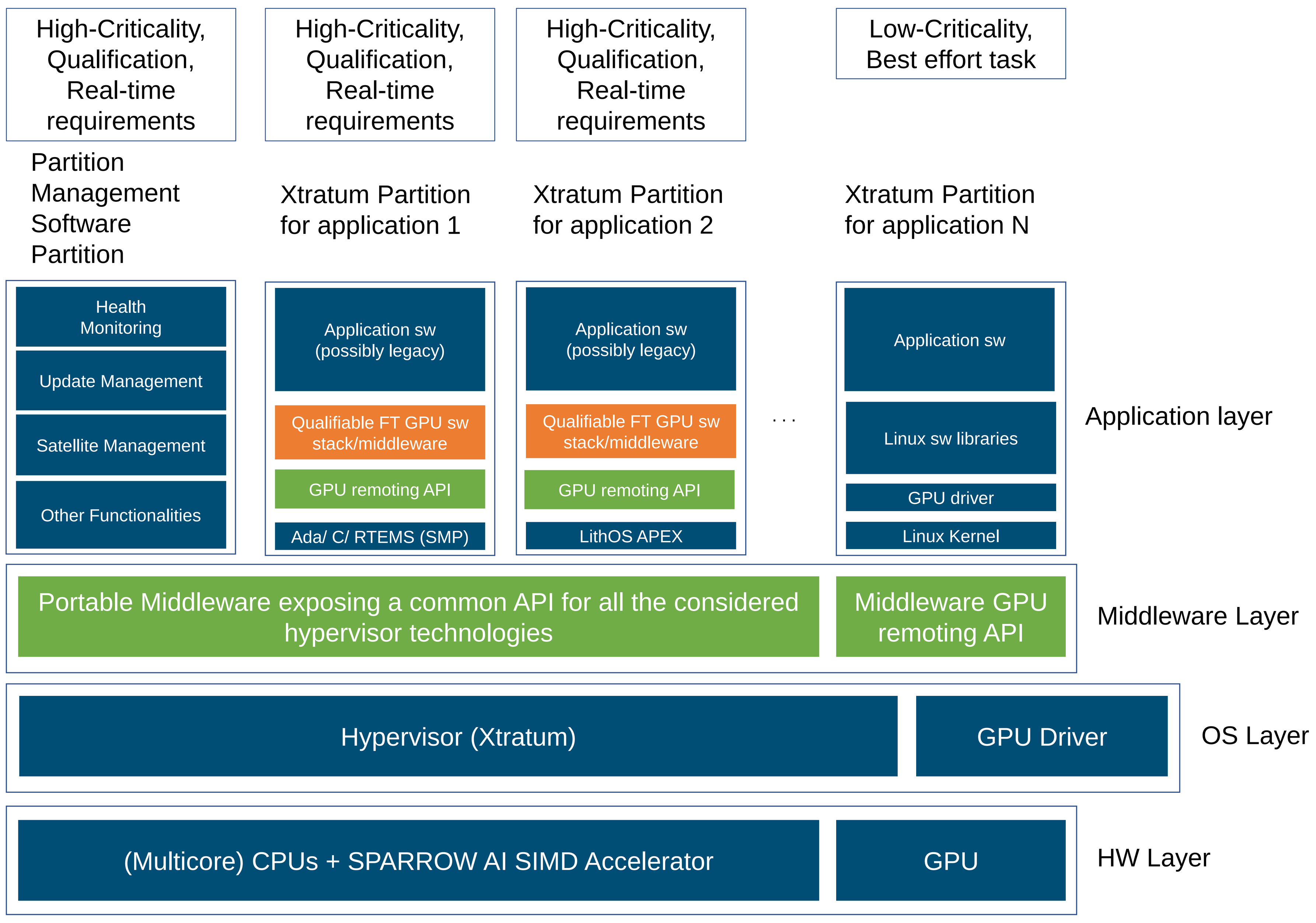
The METASAT hardware platform:



- **mixed-criticality platform** allowing the deployment of software of different criticality on the same hardware, employing the concept of virtualisation by using the Xtratum Hypervisor
- **high-performance design**, in which partitions of different criticality will be assigned to separate CPU cores, employing a multicore version of Front-Grade Gaisler NOEL-V RISC-V CPU, enhanced with AI processing capabilities, through integration with the SPARROW open source AI SIMD (Single Instruction Multiple Data) unit [1]. This will satisfy the AI needs of applications with moderate acceleration needs, with low latency requirements and with the need of high criticality, qualifiable software.

Open source RISC-V based GPU [2] for applications with much higher performance needs:

- *Real-time improvements*:
  - Worst Case Execution Time (WCET) computation of GPU tasks
  - reduction of interference between multiple GPU tasks executed concurrently on the GPU
- *Reliability improvements*:
  - ECC protection in various structures required for use in space



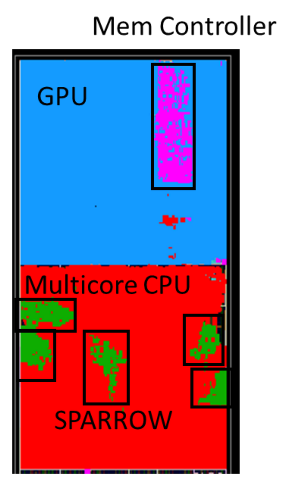
Limitations of existing GPUs for institutional missions of high criticality:

- most GPUs require device drivers and user space libraries for non-qualifiable operating systems like Linux and Android
- their closed source nature prevents their porting to qualifiable, Real-Time operating systems used in space like RTEMS

Solution:

- adapting Vortex's bare metal open source GPU driver
- develop a portable method for sharing the GPU among partitions

Current Status & Future Work



Hardware prototype on **Xilinx VCU118**.

A preliminary synthesis of the METASAT platform:

- 8 64-bit configurations of NOEL-V with SPARROW AI accelerators with a 48% utilisation
- half of the FPGA is left for the implementation of a multicore Vortex GPU consisting of 4 64-bit shader cores and a 64KB L2 cache

Currently the integration between the CPU and GPU is on-going.

Design space exploration to follow to decide the exact CPU and GPU configuration according to the needs of the project use cases.

The platform will be released as open source as well as its software stack.

References

[1] M. Solé et al, SPARROW: A Low-Cost Hardware/Software Co-designed SIMD Microarchitecture for AI Operations in Space Processors, DATE 2022
[2] B. Tine et al. Vortex: Extending the RISC-V ISA for GPGPU and 3D-Graphics, MICRO 2021

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