EagleEye TSP Porting to HWIL Configuration (RTB)

Final project presentation

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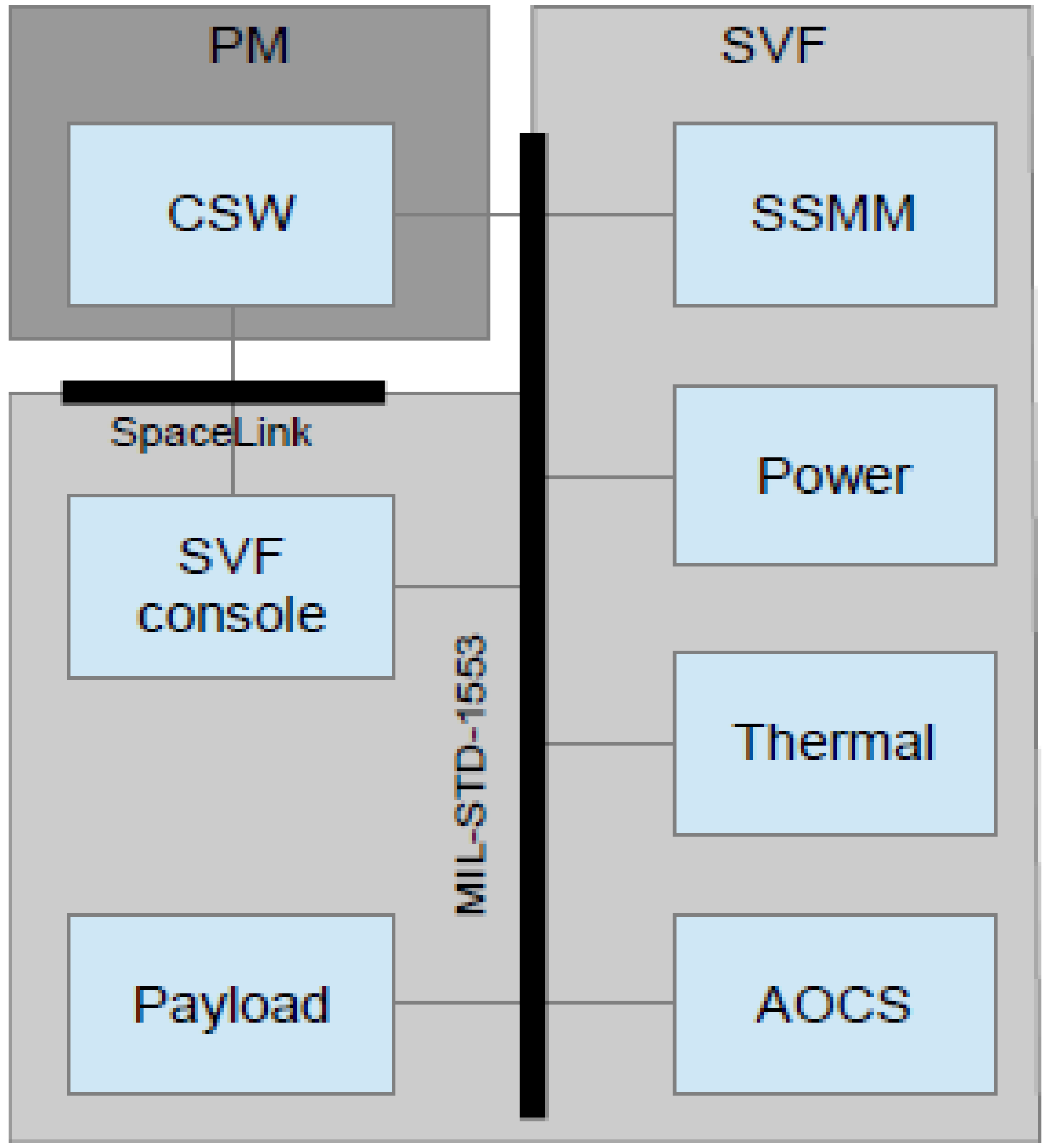
Overview_

- Background
- Team
- Goals
- Execution
- Results
- Future

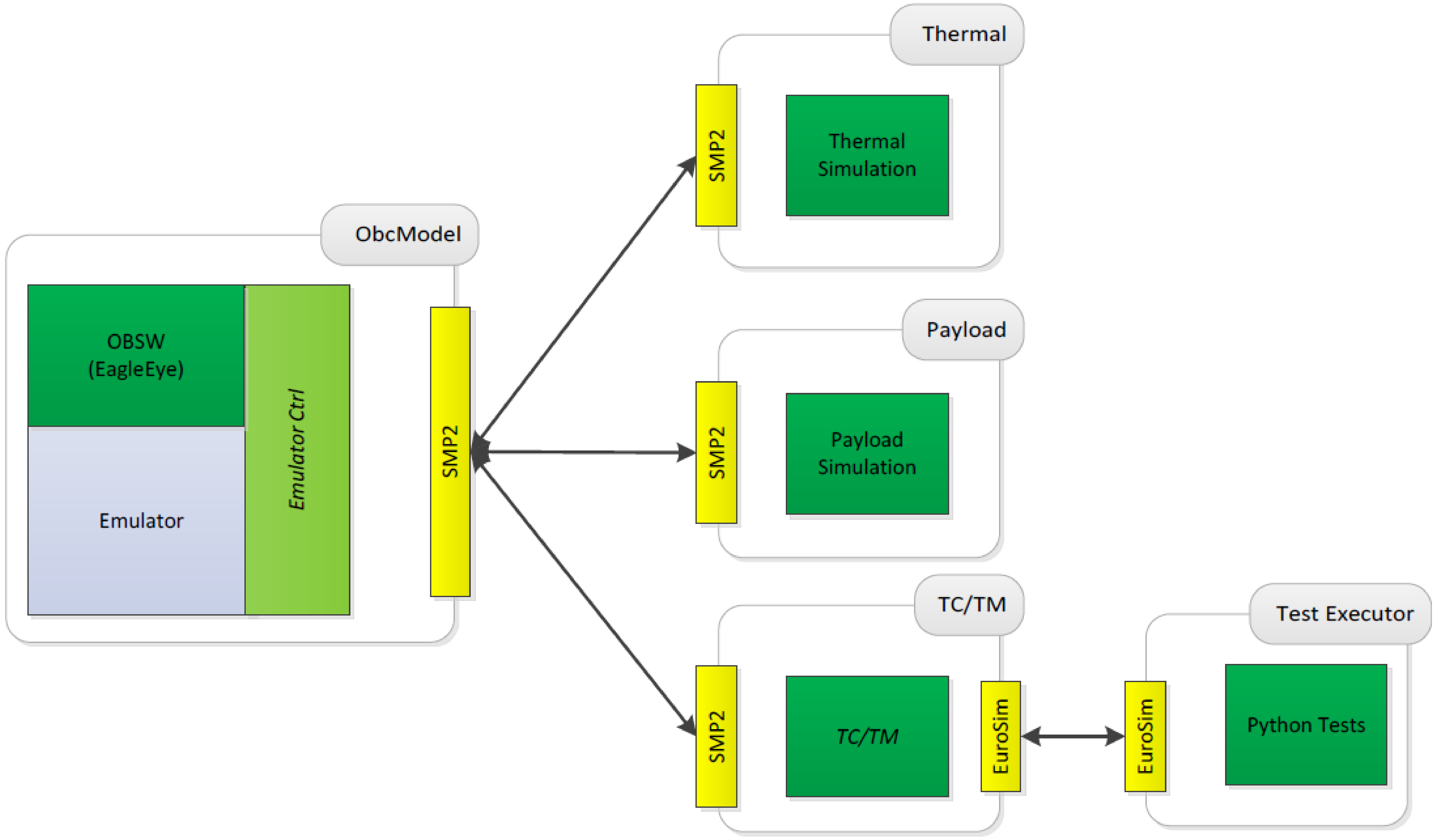
Background_

- EagleEye is an ESA reference mission for an earth observation satellite with a single imaging payload (GoldenEye).
- EagleEye runs on the ESA Avionics Test Bench in SVF and RTB configurations.
  - Central Software (CSW) representing the on-board software of the satellite.
  - Software Validation Facility (SVF) simulating the spacecraft environment, hardware and ground segment.
- EagleEye TSP (Time and Space Partitioning) CSW v5 provided as CFI running on TSIM3 for LEON3 in the SVF configuration.



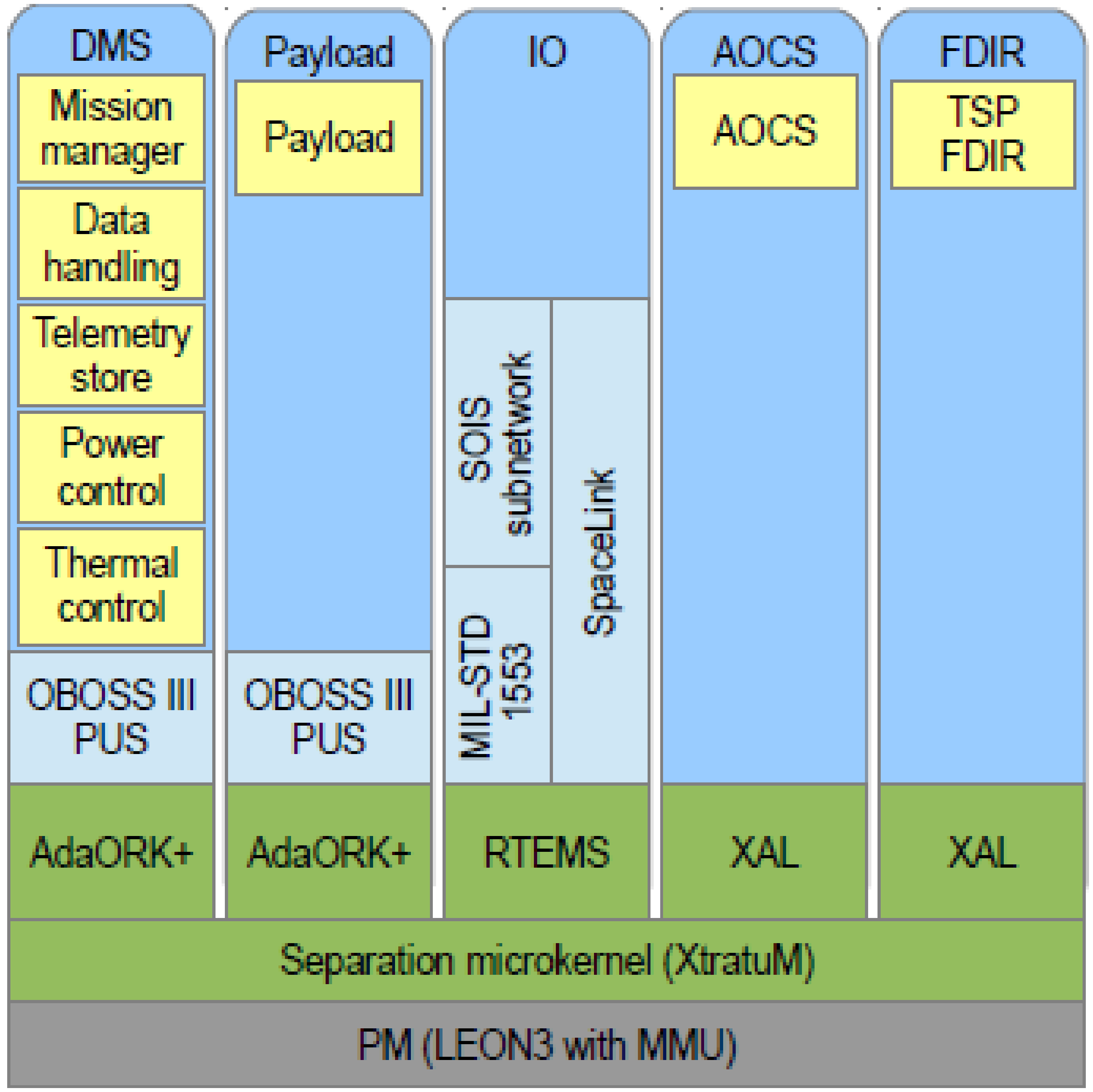
Background – SVF V4.2

- The environment includes models for the onboard computer (OBC), payload, sensors and actuators.
- EagleEye runs on TSIM emulator of ObcModel
- EagleEye SW and ObcModel use shared memory to communicate TM/TC packets and MILBUS data.
- Test executor consists of TM/TC database.
- Test scripts load the database to send TCs.



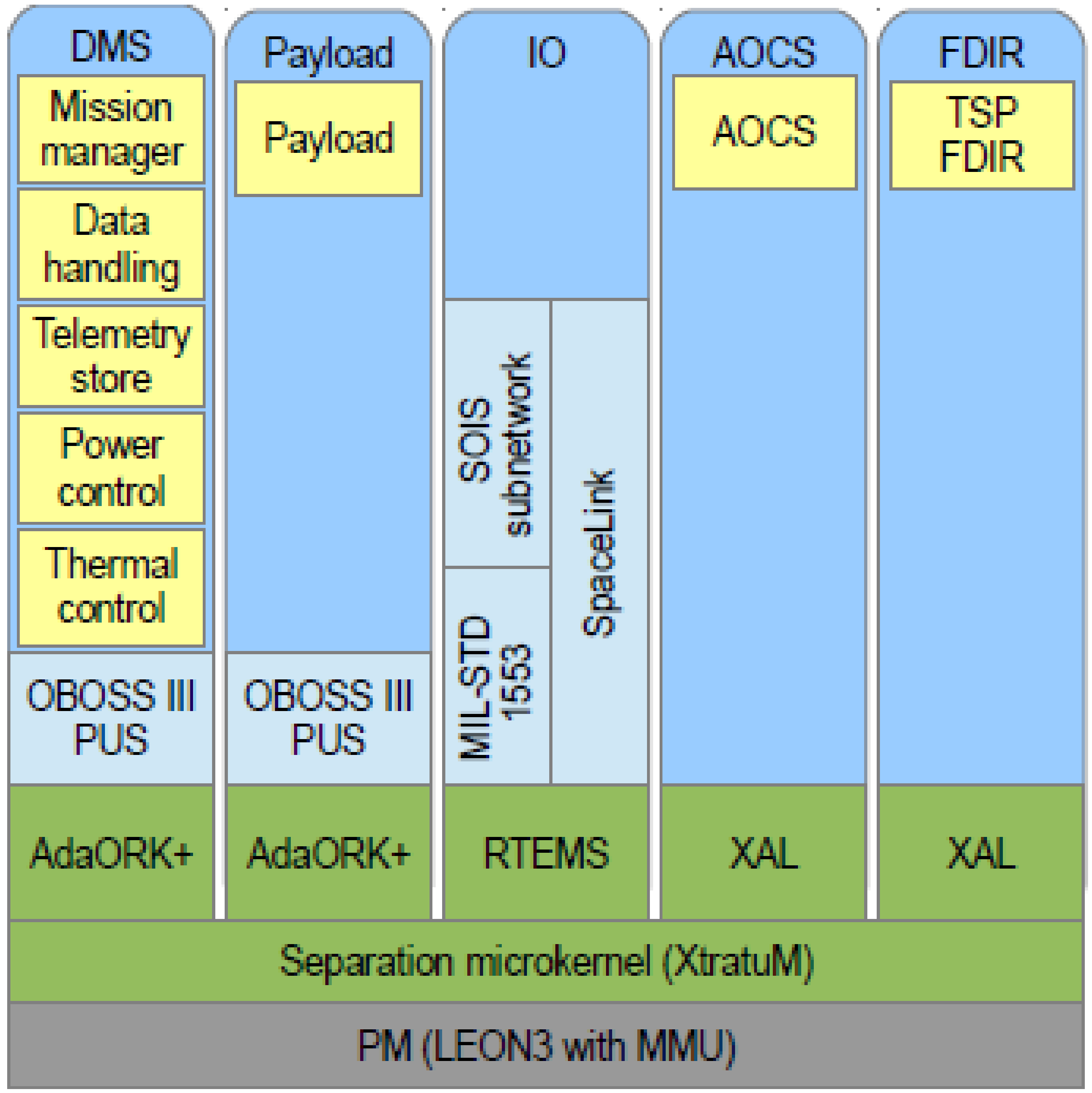
Background – EagleEye CSW v5_

- Time and Space Paritioning (TSP) through the use of the XtratuM separation microkernel.
- Five separate Partitions:
  - DMS and Payload implemented in Ada and running on GNAT/ORK+.
  - AOCS and FDIR implemented in C and running on XAL.
  - IO partition implemented in C and running on RTEMS.



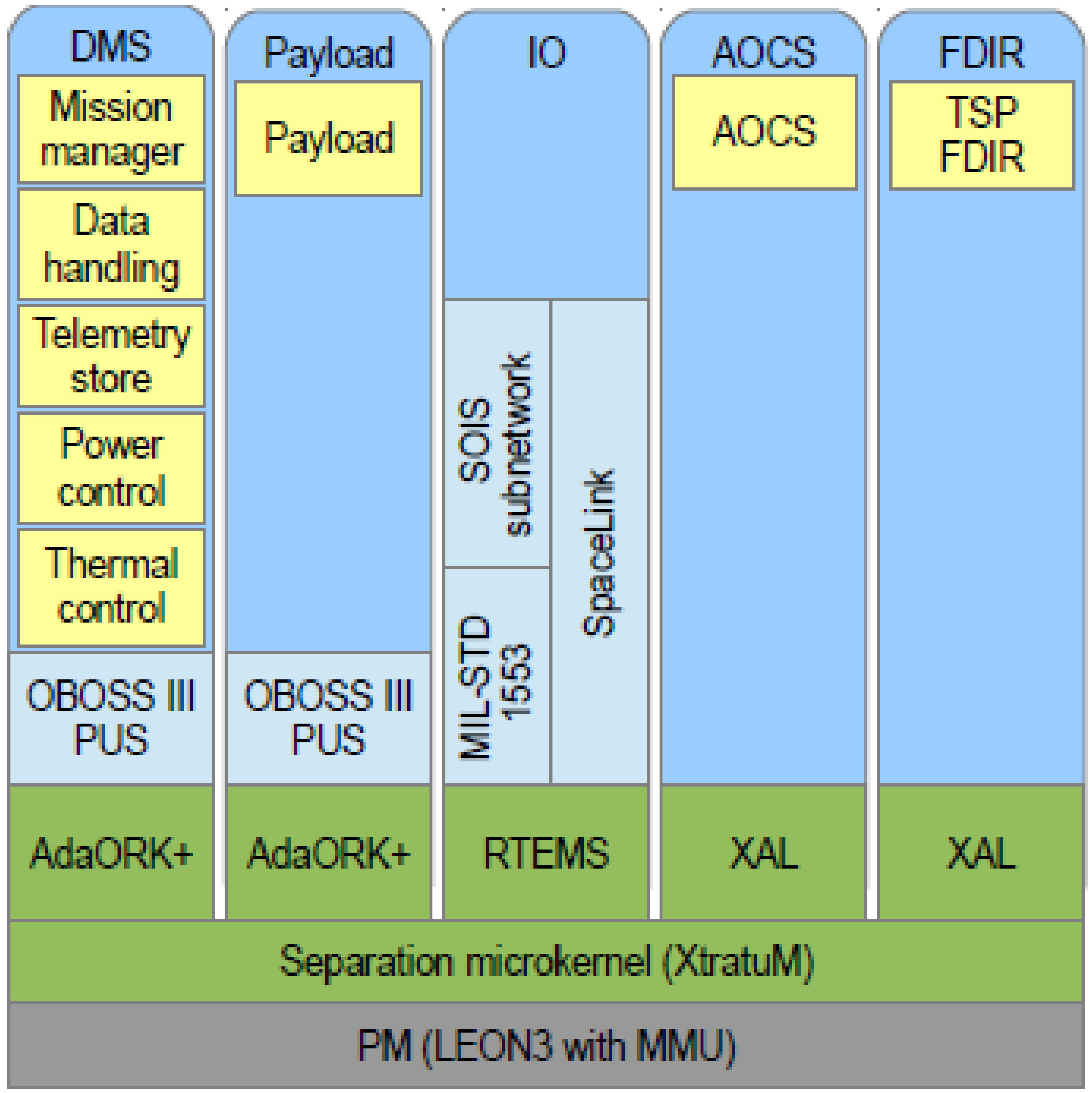
Background – EagleEye CSW v5

- DMS
  - Handles following PUS services: Mission manager, Data handling, Telemetry store, Power control, Thermal control, TSP FDIR
- Payload partition handles payload PUS services.
- AOCS handles S/C modes and AOCS modes.
- FDIR is the system partition which has access to all memory areas, it also handles TSP functionality.
- IO is responsible for MILBUS and TM/TC communication.



Background – EagleEye CSW v5

- XtratuM, It provides services to partition such as
  - Inter-Partition communication (IPC),
  - Partition health monitoring,
  - Changing state of each partition and
  - Changing state of the system.
  - Partition schedule plan switching
  - Memory read/write access.
  - Virtual interrupts for partition state change.
  - Timer services
- Different partition schedule plans can be configured during compilation.



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Team – Project Consortium_

- Project implemented by the same consortium responsible for CSW v5, consisting of SSF, Fentiss and UPM.
- Fentiss provide XtratuM and RTEMS upgrade for LEON 3 and LEON 4 HW platforms.
- UPM provide GNAT/ORK+ upgrade for LEON 3 and LEON 4 HW platforms.
- SSF provide the EagleEye CSW upgrades.

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Project Goals_

- Port EagleEye CSW V5 to run on LEON3 GR-RASTA-105 and LEON4 GR-CPCI-LEON4-N2X HW platforms (NGMP).
- EagleEye CSW version that can be compiled for different platforms (i.e. LEON3-TSIM, LEON3/LEON4 HW)
- Upgrade SVF to support HWIL configuration with the HW platforms.
- Upgrade XtratuM, RTEMS and GNAT/ORK+.
- Upgrade EagleEye CSW to support multicore execution of partitions on LEON4.
- Ensure all existing EagleEye validation tests execute successfully.
- Provide new test scenarios to demonstrate benefits of multi-core utilisation.
- Adapt MILBUS schedule to partition schedule for all platforms.

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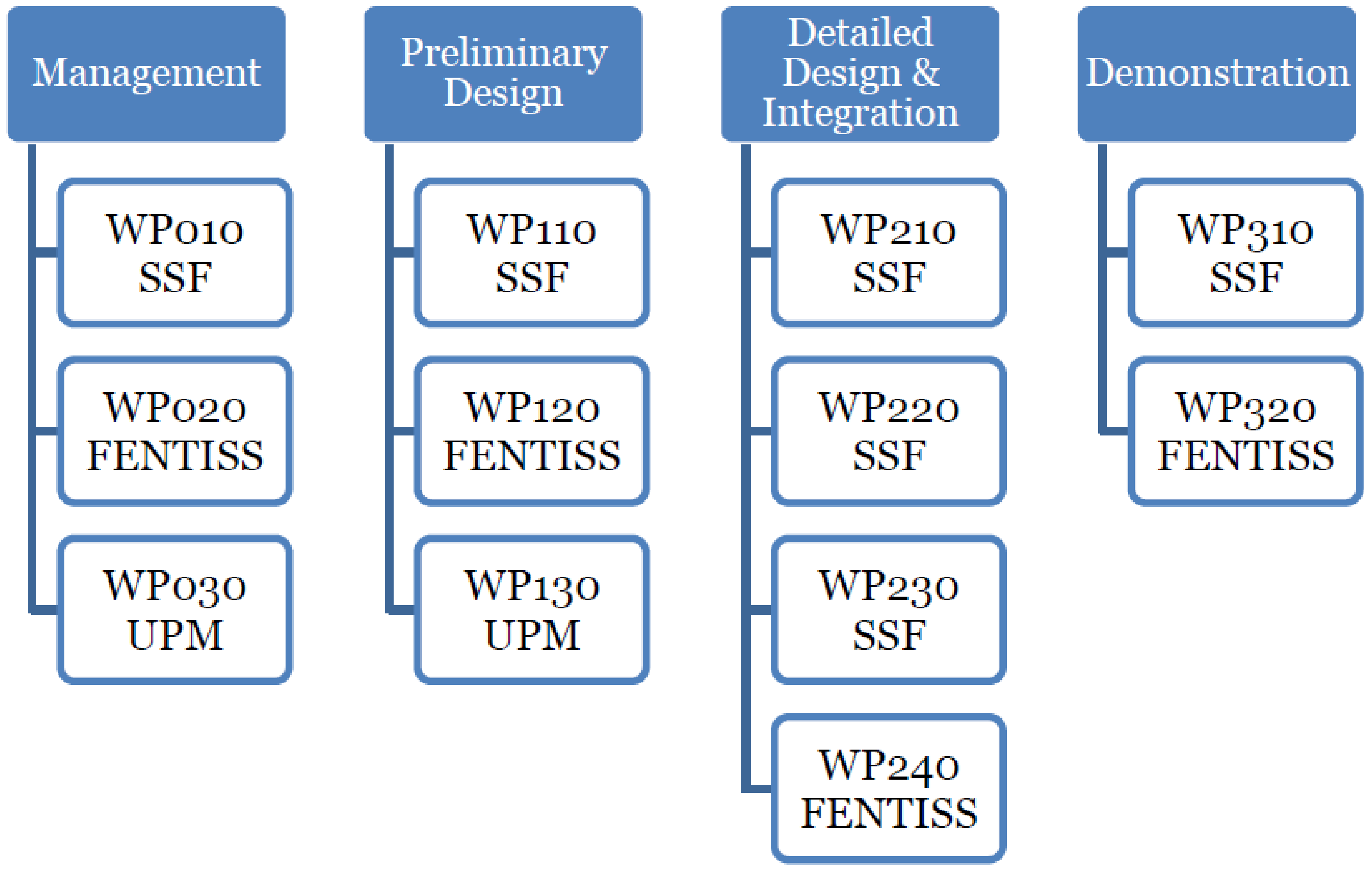
Execution – WP_

- Management Work Package continue for the duration of the activity.
- Preliminary Design:
  - Fentiss perform XtratuM and RTEMS upgrades and testing.
  - UPM perform GNAT/ORK+ upgrades and testing.
  - SSF design CSW and SVF architecture and prepare all documentation for PDR.
- Detailed Design:
  - SSF perform CSW and SVF upgrades.
  - SSF responsible for integration supported by Fentiss.
- Demonstration:
  - SSF provide multi-core demonstration scenarios supported by Fentiss.



Execution – Output Documents_

- CSW and SVF design documents
- CSW and SVF build and installation documents
- CSW and SVF unit test plan documents and reports
- CSW system test plan and reports
- CSW integration test plan and reports
- Consolidated CSW requirements document
- SVF requirements document
- Demonstration test plan and report
- CSW budget report
- Final report

All test reports are html documents
generated by the python test scripts.

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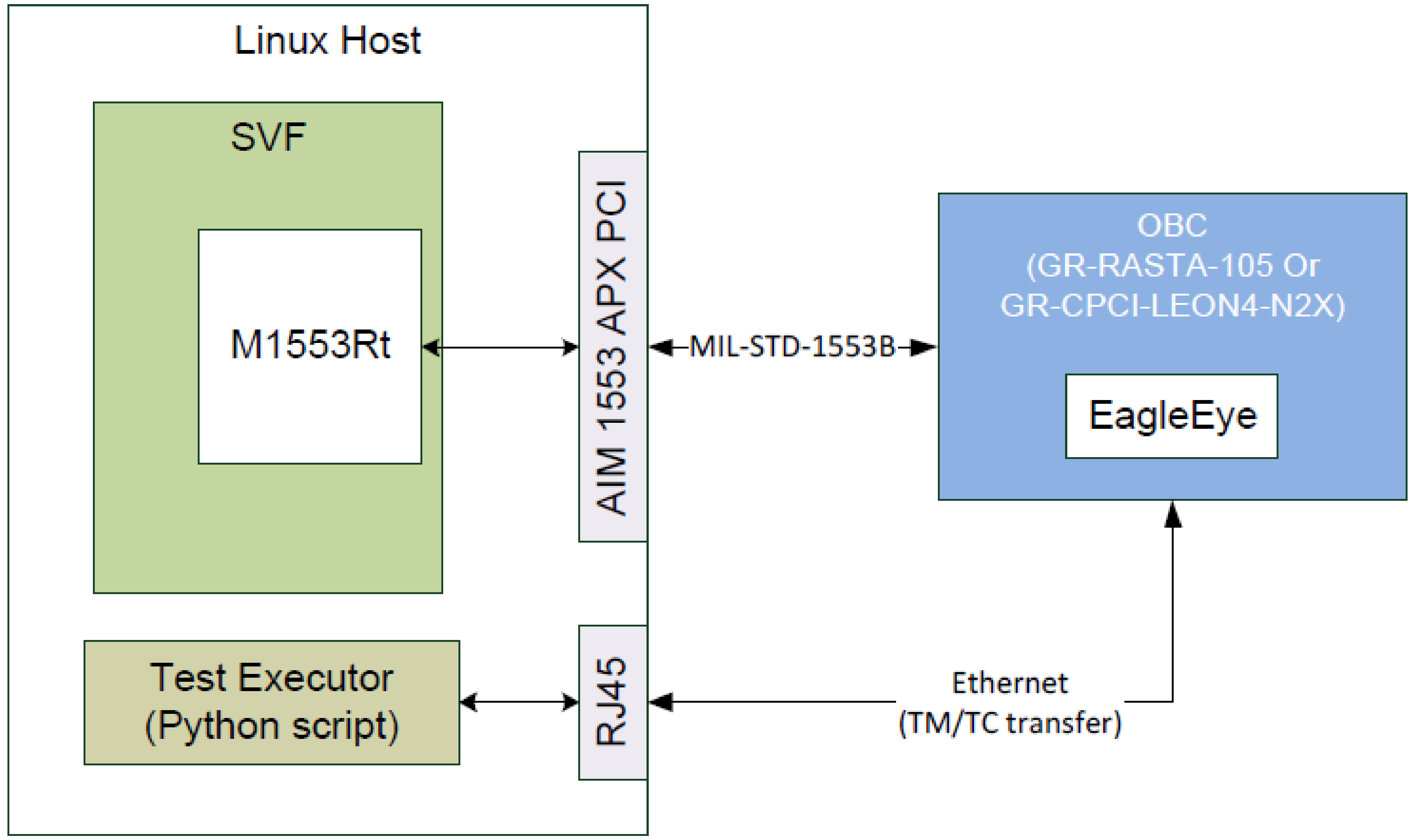
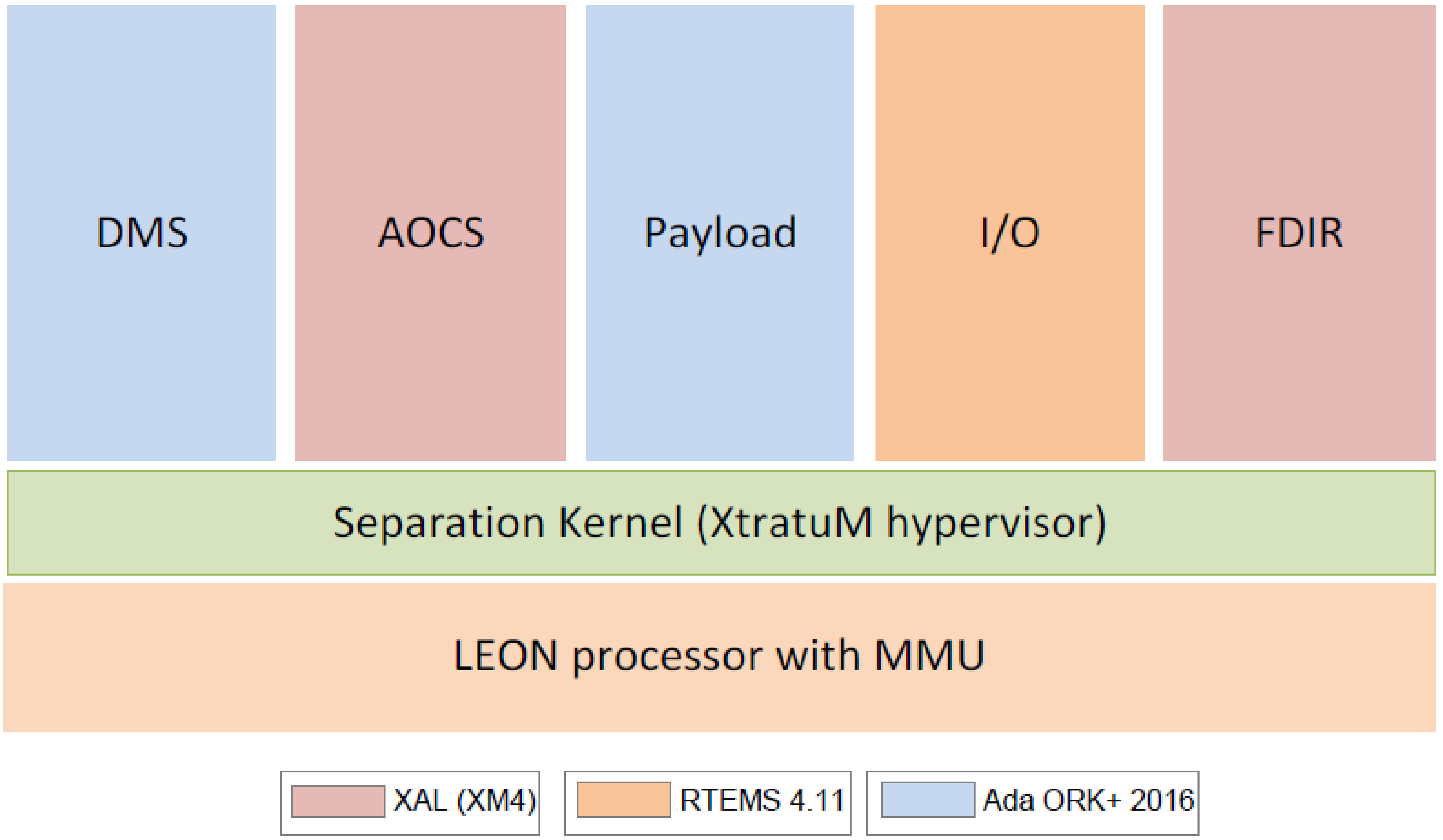
Execution – SVF V6

- The RTB configuration consists of all the SVF models without OBSIF model and adding MIL1553 model
- It uses a MIL-1553 PCI card to communicate with the OBC HW.
- Modified the python TM/TC interface script to send and receive UDP packets using Ethernet port.



Execution – Eagle Eye CSW V6_

- Retains all the SW components and partitions of CSW V5.
- Can be compiled for three platforms:
  - LEON3-TSIM
  - LEON3 HW
  - LEON4 HW
- XtratuM upgraded and compiled for three platforms. Added virtual interrupts for IPC.
- RTEMS upgraded and compiled for three platforms. Added Ethernet and MILBUS drivers.
- GNAT/ORK+ upgraded and supports all three platforms.



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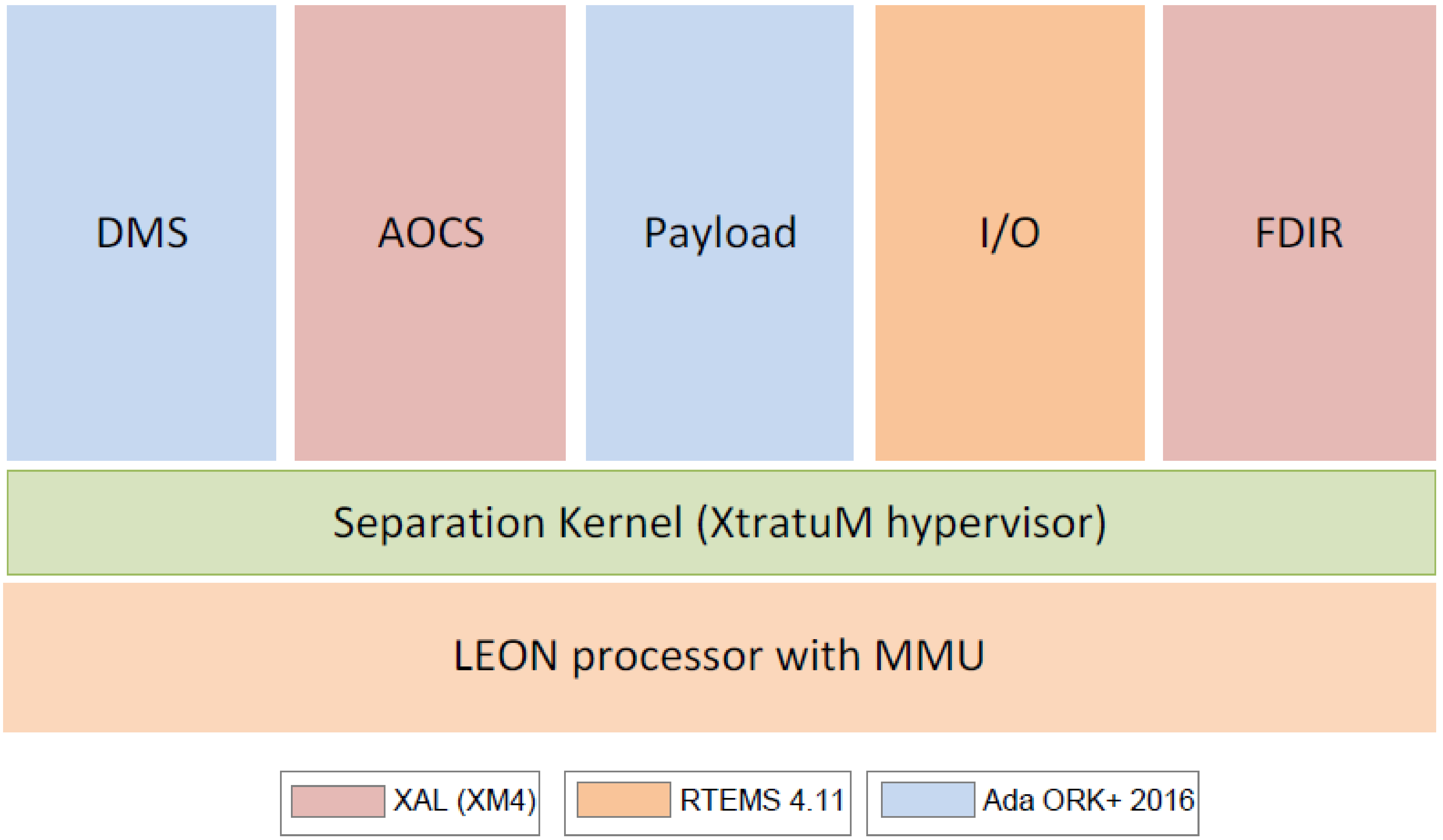
Execution – EagleEye CSW V6_

Changes to IO partition

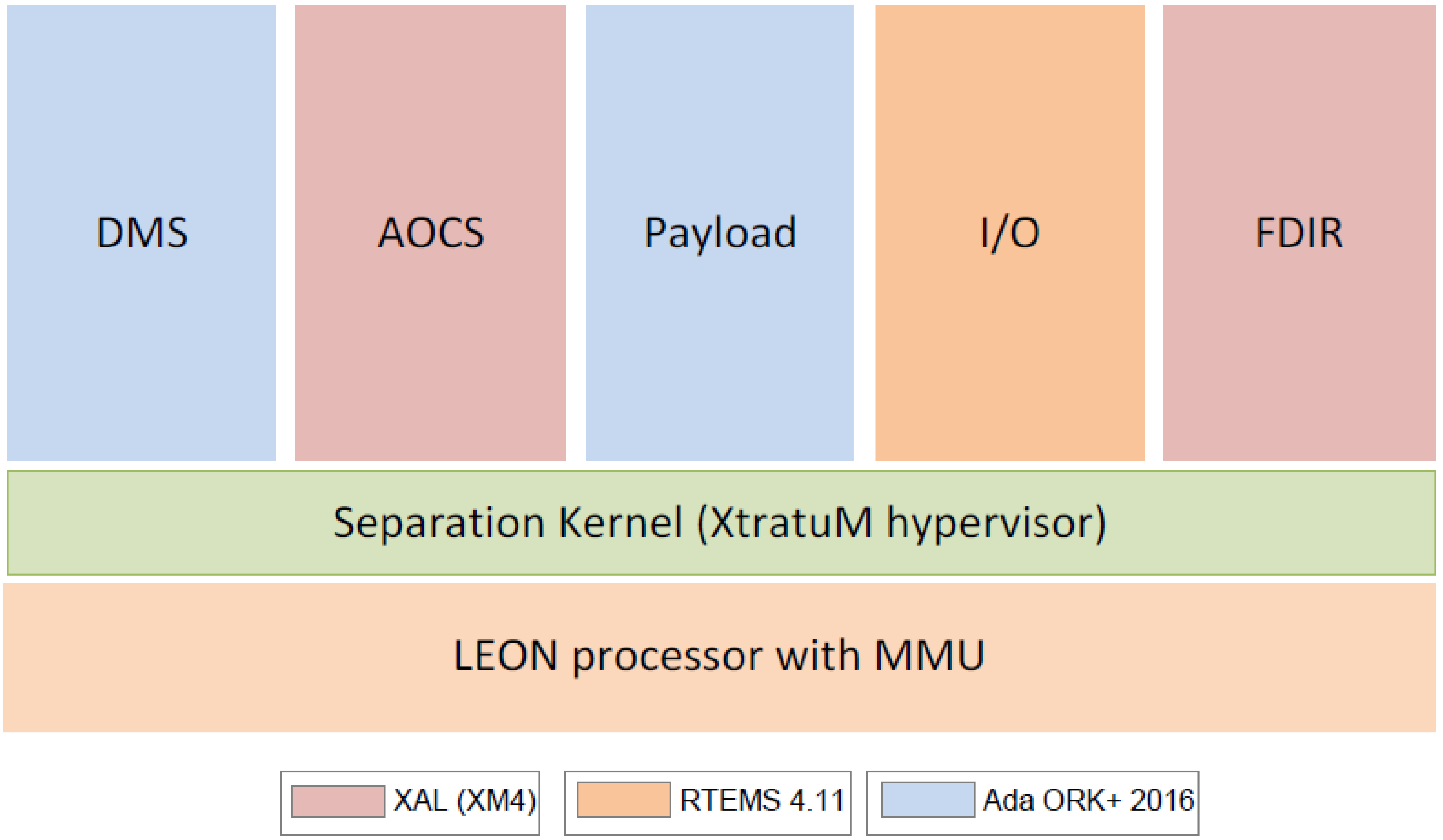
- Using RTEMS 4.11 device drivers for Ethernet and MILBUS.
- SVF configuration retains the MILBUS and Ethernet implementation.
- In RTB configuration the MILBUS list is executed on a dedicated HW.
- A task handles reading and writing to MILBUS slot addresses, which is in sync with the execution of list on MILBUS HW.
- TM/TC UDP packets use Ethernet interface.
- SOIS implementation to separate MILBUS and application layer.
- Using IPC virtual interrupts to receive communication from other partitions



Execution – EagleEye CSW V6

Changes to FDIR partition

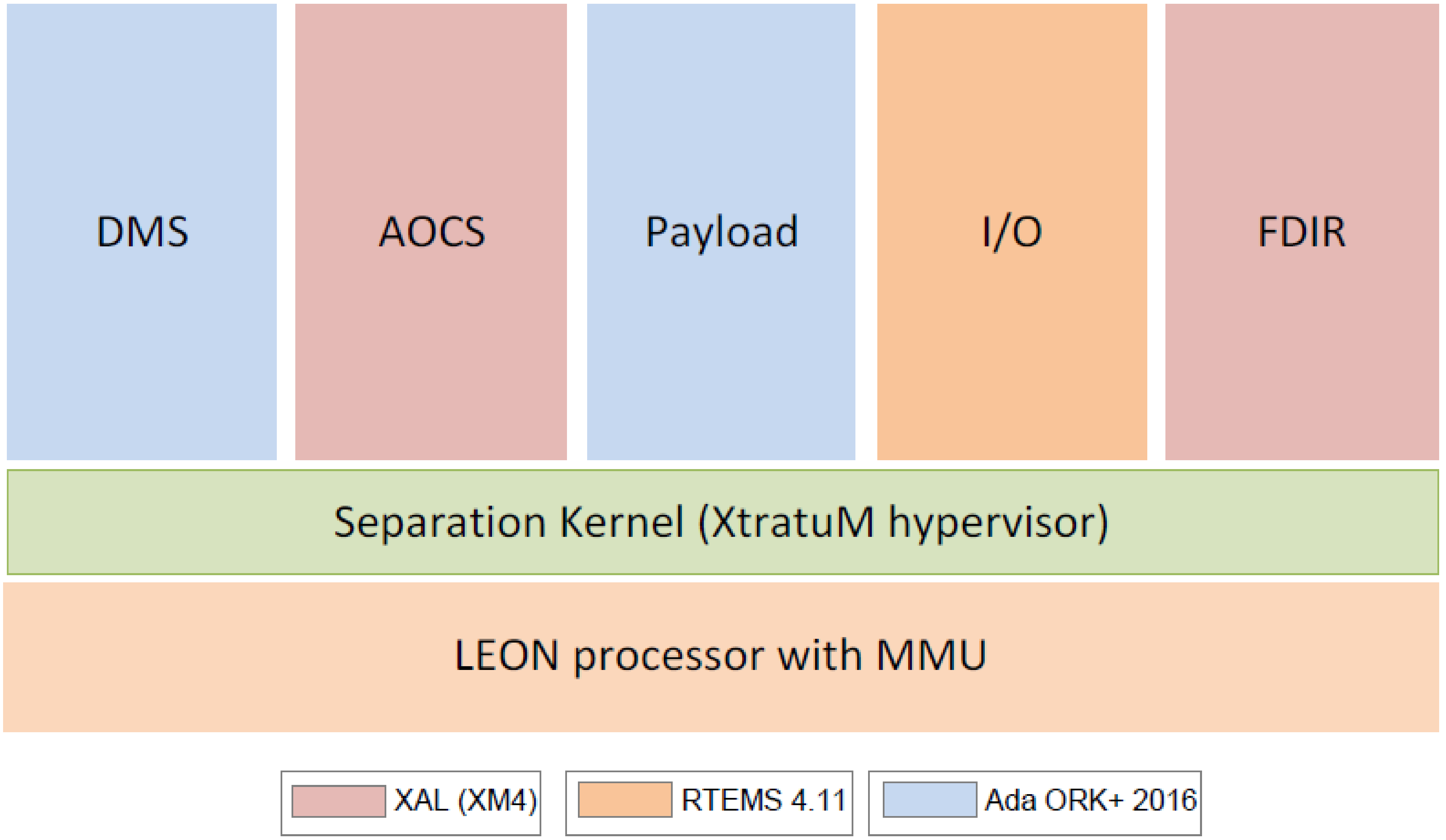
- Using IPC virtual interrupts to receive communication from other partitions.
- Health monitoring is now timed for every MAF cycle.
- Partition's HK data is timed to be sent every 1 second.
- Updated to handle partition schedule plan switching TC.



Execution – EagleEye CSW V6_

Changes to DMS partition

- Using IPC virtual interrupts to receive communication from other partitions.
- Updated to handle new PUS service related to partition plan switching.



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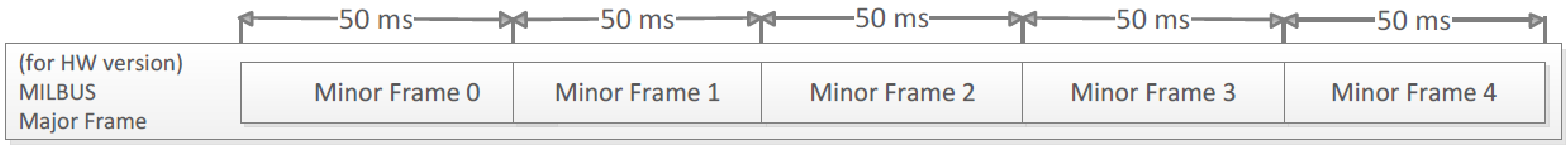
Execution – Overall Changes_

- Milbus schedule for RTB configuration is changed to.



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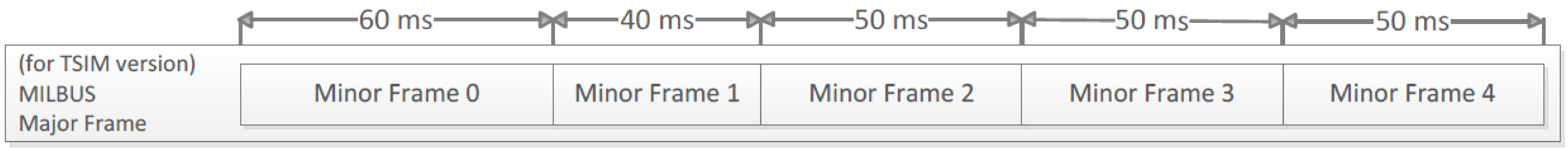

- Increase in RTEMS memory requirement as Ethernet related stack (semaphores, tasks) demands extra memory.
- MILBUS execution functionality of IO partition is replaced with simple MILBUS memory read and write operations since, the list is executed by a dedicated MILBUS hardware.

Execution – Budget report

Real-time measurements were carried out

- Stack measurement
- Task scheduling
- CPU load/margin
- MILBUS load/margin

Execution – Major obstacles_

- Debugging run-time issues with DMS partition, we came across issues such as program counter resetting to zero, race conditions, task halting and heap overrun.
- The minimum memory area aligned is 4KB using MMU by XtratuM, in LEON3 Ethernet device and other devices fall in a memory area which is less than 4KB. The XtratuM provides a workaround with IO ports configuration with APIs that can be used to access these memory areas.
- Cold reset of IO partition (uses RTEMS 4.11) was not available right away, readonly and read-write memory areas had to be defined during compile time for this functionality.
- LEON4 board by default doesn't handle denormal numbers, setting ns bit of FSR register during boot time was used. LEON3's FPU can flush denormal numbers to zero by design.
- Synchronising MILBUS scheduling and IO partition's application scheduling for RTB configuration.
- Integrating new versions of RTEMS, XtratuM resulted in changes to existing APIs functions, using page table memory allocation, creating three platform configuration, etc.

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Execution – Validation Tests_

All Validation tests were performed for EagleEye running on all the three platforms, the tests are:

- Data Handling test
- Memory Management test
- TSP FDIR test
- Mission manger test
- AOCS acceptance test
- Power control test
- Thermal control test
- AOCS test

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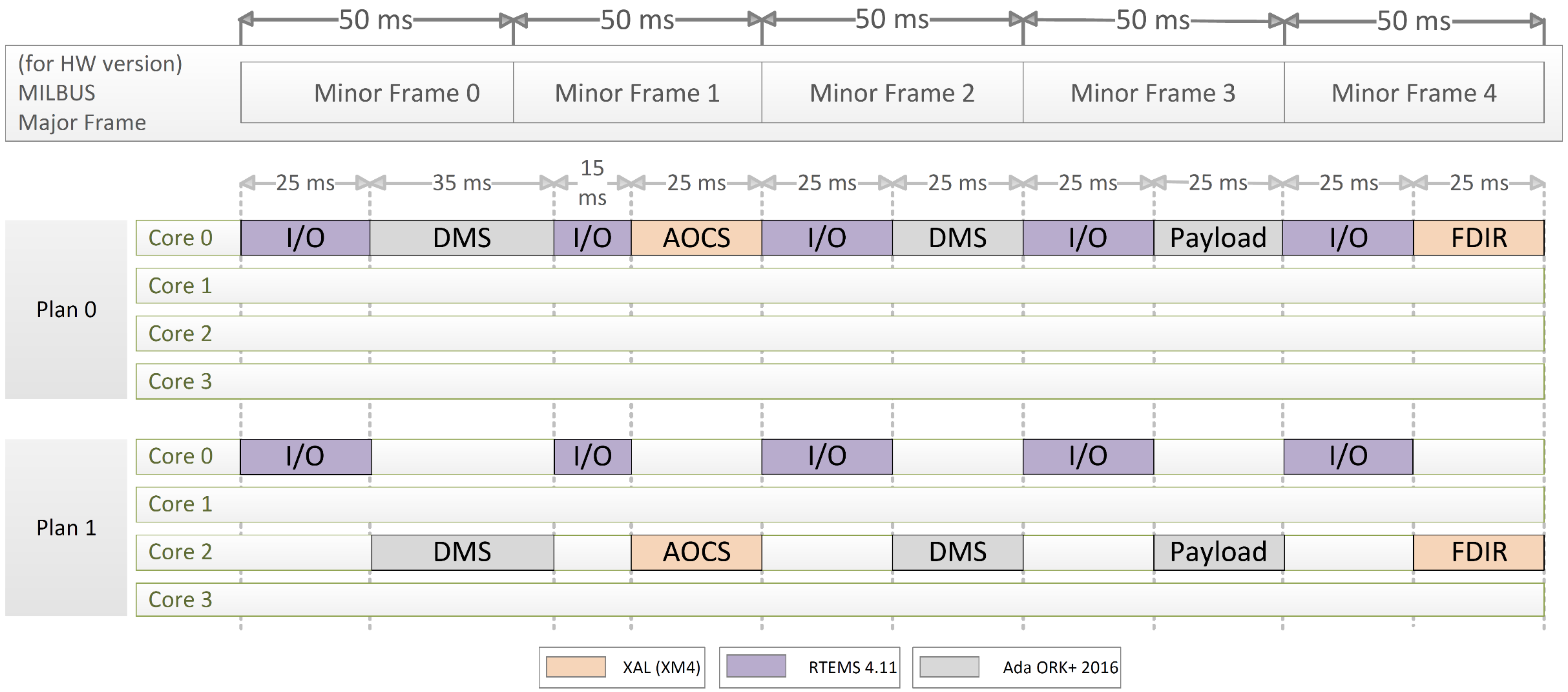
Result – Multicore Demonstration_

- Three Multi-Core Demonstration Scenarios implemented
- Scenario 1: Core Redundancy



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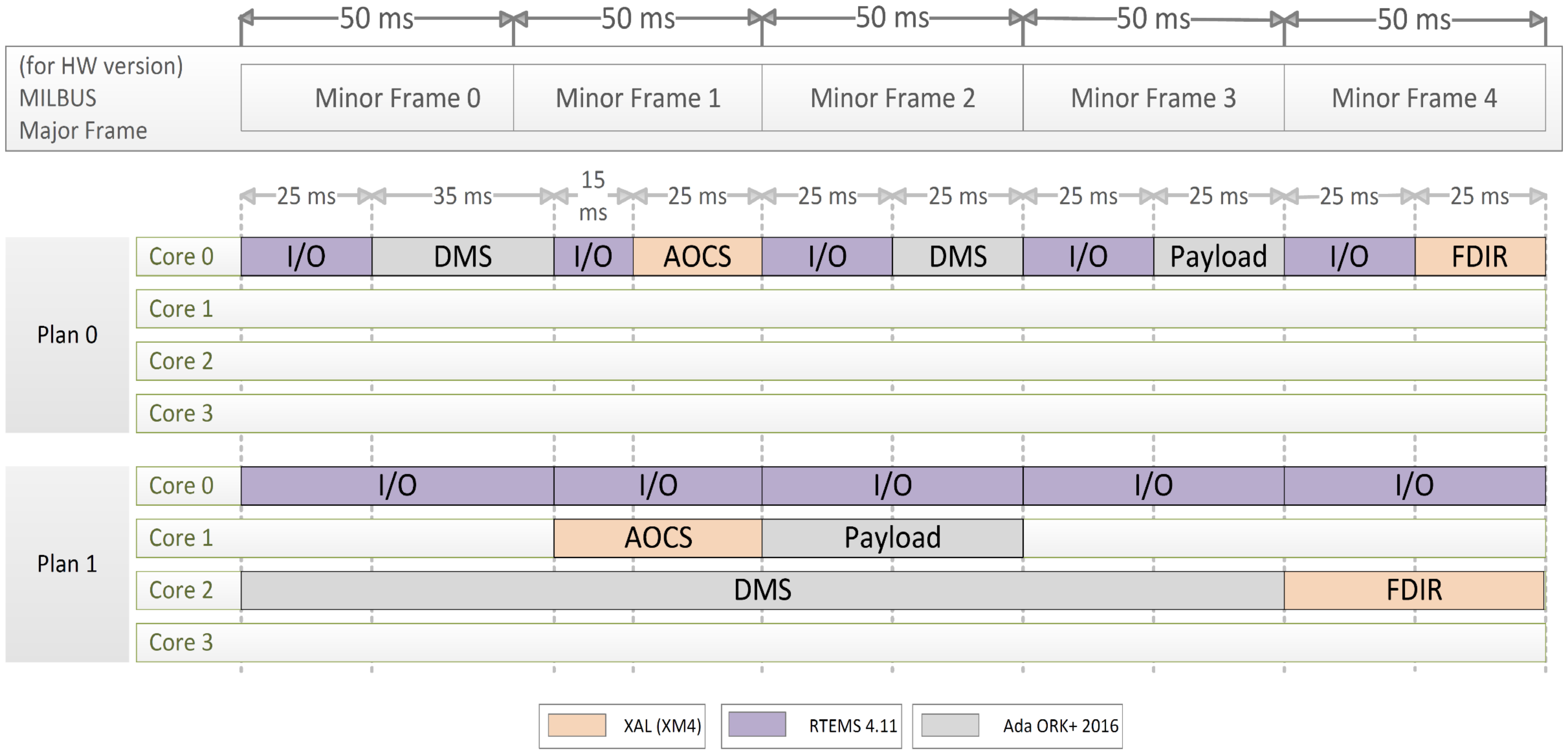
Result – Multicore Demonstration_

- Scenario 2: Improved Schedulability



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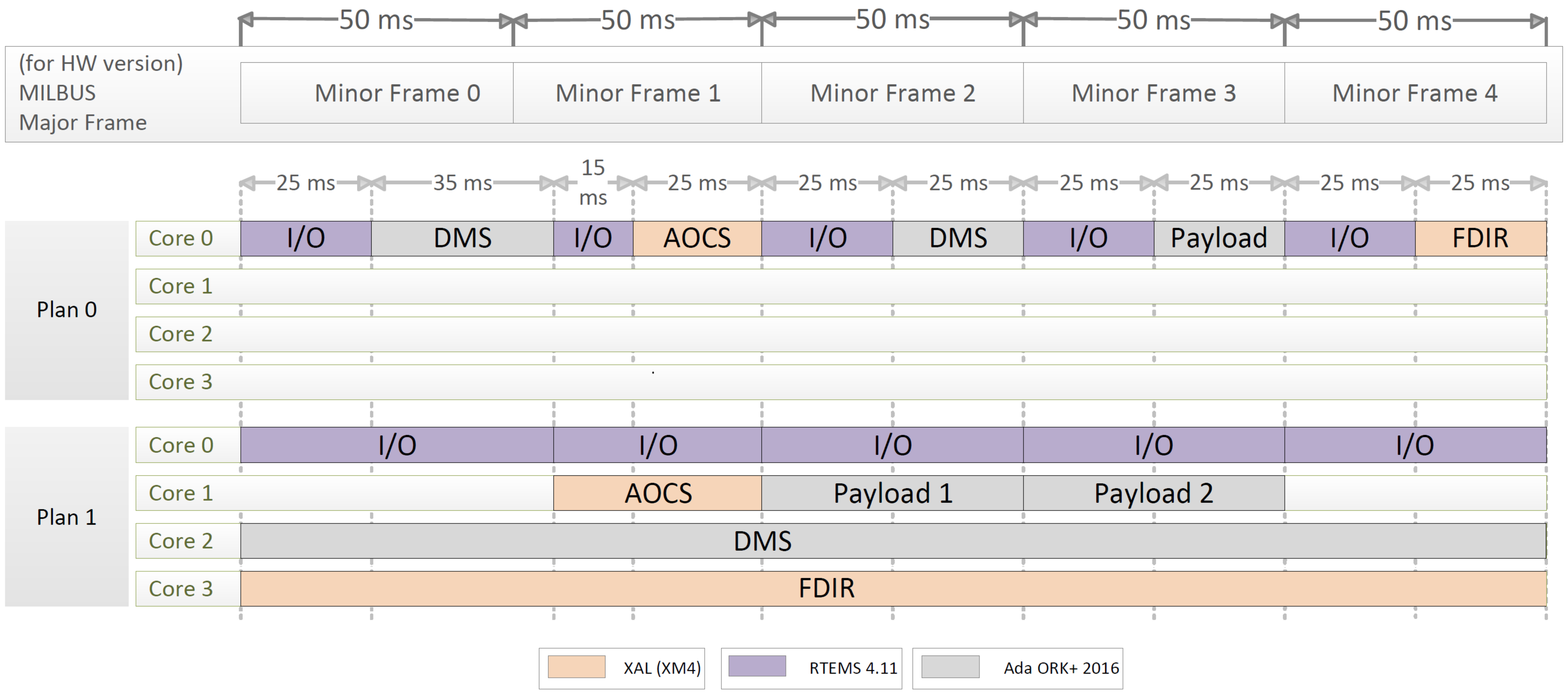
Result – Multicore Demonstration_

– Scenario 3: Improved FDIR Responsiveness



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Recommendations for Future Work_

- Studying Fixed priority partition scheduling feature of XtratuM in multi-core and single-core scenarios.
- Upgrade of DMS and Payload partitions to fully use SOIS.
- FDIR upgrade to handle partitions when run in multi-core.
- Analysing SMP feature of RTEMS in combination with TSP and in multi-core.
- Further analysis of different scheduling policies in Spacecraft on-board SW with multi-core.
- Replacing the complex DMS partition with a standard PUS library.
- Possibility of distributed PUS services handling by each partition.

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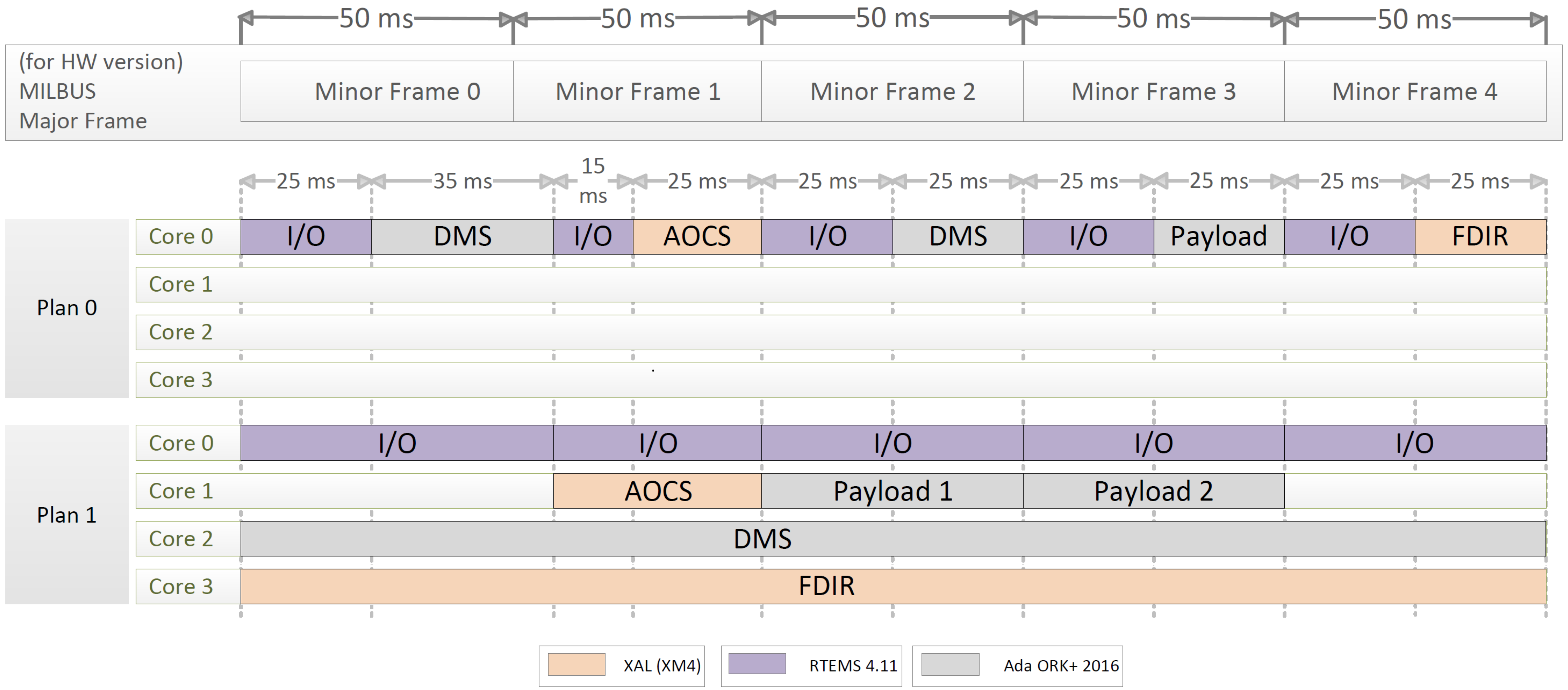
Recommendations for Future Work_

- Many further possibilities for multi-core scenarios.
- E.g. Demonstration of improved resource utilisation with multiple payloads.



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