IMA-IHPA – Final Presentation

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IMA for Space: Development of Inflight Hosted Prototype Application

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Agenda

- 30 minutes presentation followed by 15 minutes Q/A

- Introduction - IMA, IMA-SP, IHPA, Application
- IMA-SP Platform
- STIX Application
- AIMs and Objectives
- Conclusion
- Backup Slides (Development, RTEMS)

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Introduction

Application Supplier

- **Integrated Modular Avionics (IMA):**
  - is rapidly expanding and is found in all classes of **aircraft**;
  - **RTCA/DO-297**: Integrated Modular Avionics (IMA) Development Guidance and Certification Considerations;
- **Integrated Modular Avionics for Space (IMA-SP):**
  - is a spin in of the corresponding aeronautic concept into the **spacecraft** avionics architecture;
- IMA-**IHPA**
  - Activity, in which already existing PROBA 2 SW was ported to IMA-SP system (by Spacebel),
  - and into which the STIX payload application was created by adapting already existing legacy STIX flight software.

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Application Supplier

- IMA/IMA-SP Roles
  - System Architect (SA);
  - System Integrator (SI);
  - IMA-SP Platform Supplier (PS);
  - **Application Supplier** (AS).
- **An APPLICATION** can be any of the following:
  - software;
  - hardware;
  - **hardware and software.**

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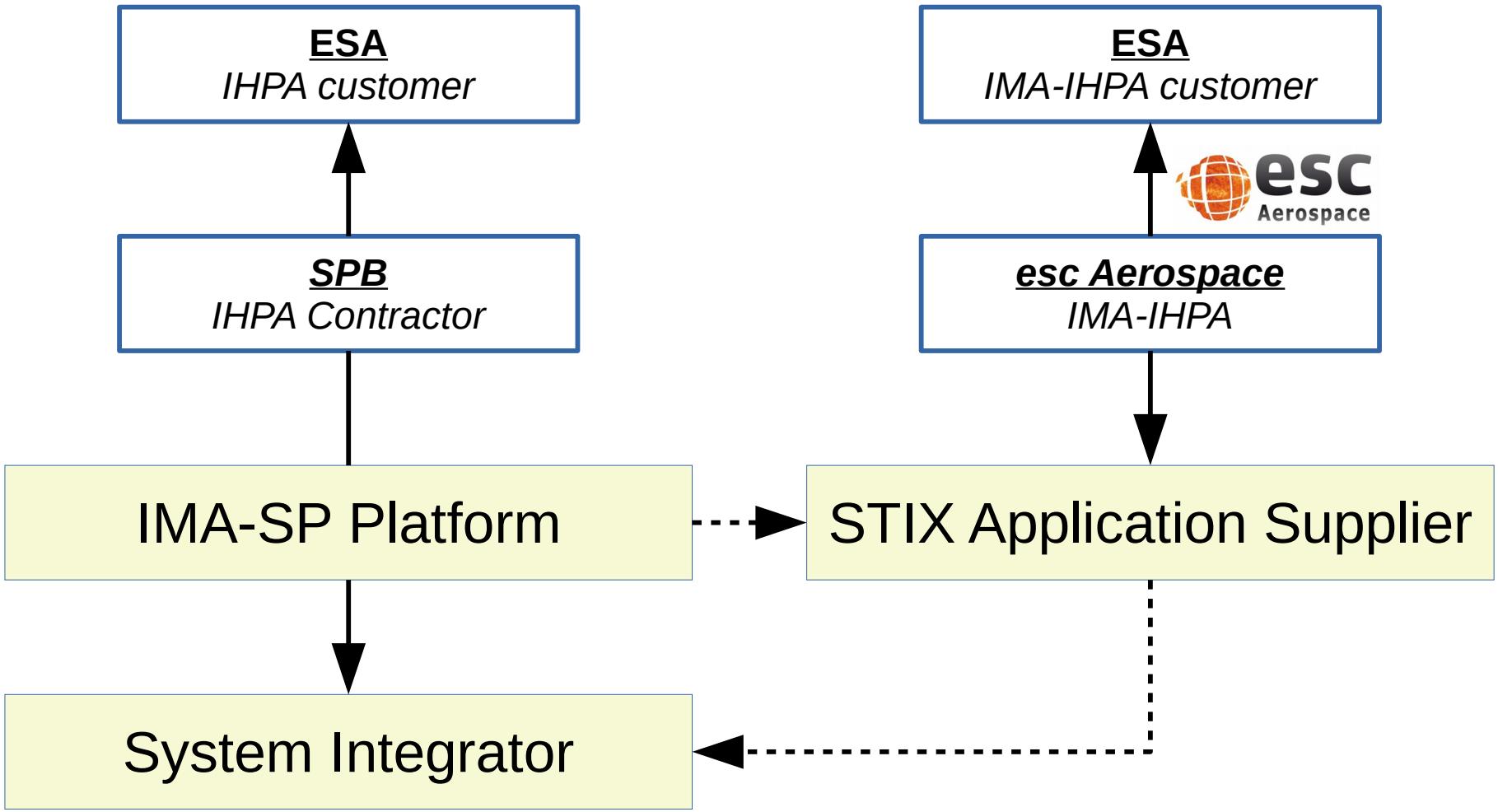
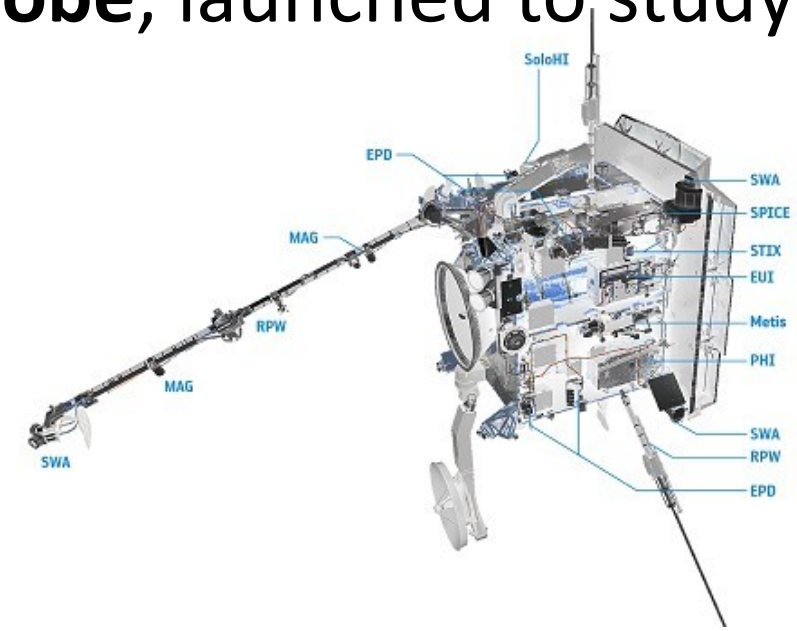
Industrial Organization

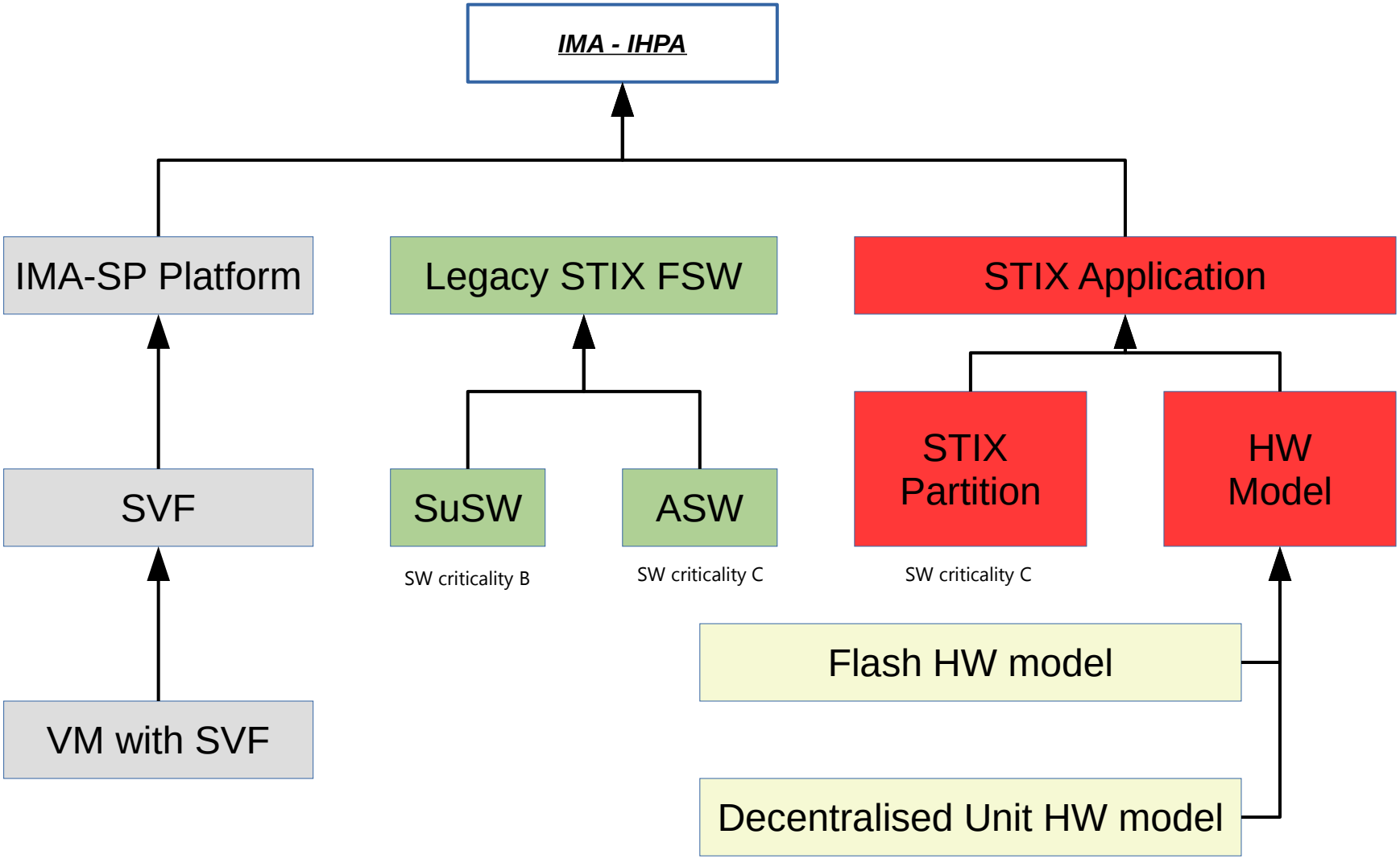


Introduction

- **Application Supplier** (esc Aerospace, CZ) adapted legacy **STIX payload** software to **a partition**, which is executed on SVF environment of IMA-SP Platform provided by SpaceBel.
- The **STIX payload** is one out of ten payloads hosted on the **Solar Orbiter probe**, launched to study the Sun in February 2020.



Product Tree



IMA-SP Platform

Roles and Suppliers

Role	Supplier	Partitions	Note
System Architect	N/A	N/A	No System Architect role was executed in IHPA.
IMA-SP Platform	SPB	OBSM, CDHS	This shall be provided to Application Suppliers. The listed OBSM, CDHS are needed to enable independent development for each Application Supplier Hypervisor: XtratuM
Application Supplier #1	SPB	ASW1	-
Application Supplier #2	ESC	ASW2/STIX	STIX payload (Flight SW)
System Integrator	SPB	OBSM, CDHS, ASW1, ASW2	-

CDHS Partition

- The CDHS and OBSM partitions are responsible for the Watchdog.
- The CDHS partitions is responsible for Watchdog kicking. This functionality is implemented in the scope of the System Manager of PROBA-2. In fact, there are several watchdogs in the PROBA-2 avionics. The CDMS partition kicks the watchdog the MPM (main processor module i.e. LEON2) cyclically. Note that the kicking of the MPM watchdog depends also on the raw battery voltage monitoring of the S/C. There is also a second watchdog located in the REM (reconfiguration electronic module) of the PROBA-2 avionic.
- The CDHS partition kicks the MPM and REM watchdogs if requested (there are telecommands to manage the configuration of the MPM/REM watchdog).
- Unless STIX wants to manage the MPM and REM watchdog, indicate that the full management of the MPMand REM watchdogs is performed by the CDHS partition.

OBET

- OBET is provided by IMA-SP Platform
- OBET can be read by partition (application)

Memory Address	32-bit Register	Detail
0x2000 0018	ETCR	Elapsed Time Coarse Register
0x2000 001C	ETFR	Elapsed Time Time Register

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Partition Interfaces

- IMA provides the following interfaces
  - **Shared physical memory**: OBET can be implemented as hardware timer to which the R/W access will be granted to OBSM only. All remaining partitions have read-only access.
  - **Shared logical memory**: Logical memory access means that a partition is requesting read access from a virtual address, then a system partition can reply to this request by providing data. If this is possible, there will be still an overhead (in accessing real hardware). This option has no advantage to previous one.
  - **Sampling port**, which can be updated only when a partition time slot is not executed. In this case, jitter can be as high as time slot duration.
  - **Queuing port**, which is FIFO, thus there can be a non-constant jitter.

STIX Application

IMA-SP Platform

- Partitions

ID	Partition	Supplier	Purpose
P0	**OBSM**	**SPB**	**IMA-SP Platform**
P1	**CDHS**	**SPB**	**IMA-SP Platform**
P2	AOCS	SPB	AOCS Application Supplier (optional)
P3	ASW1	SPB	ASW1 Application Supplier (optional)
P4	**ASW2/ STIX**	**ESC**	**Mission flight software for adapted STIX**

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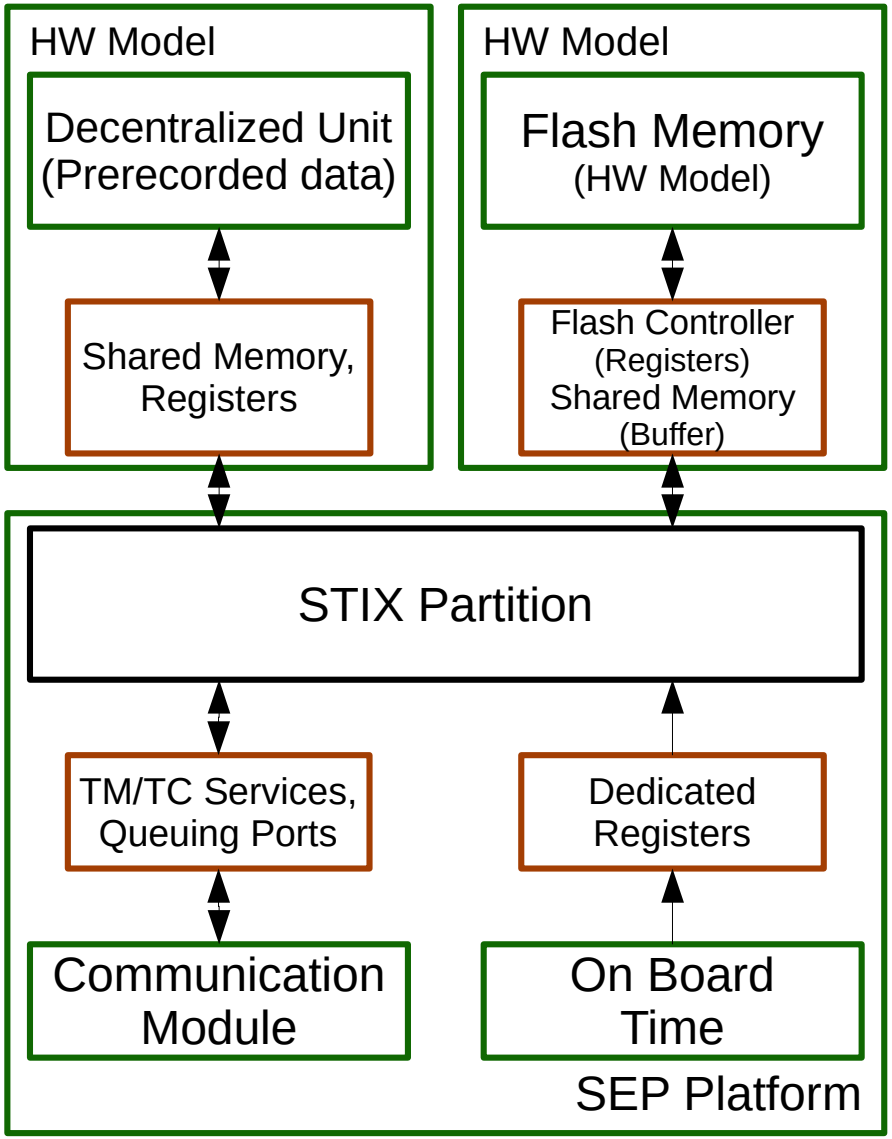
STIX Payload

- STIX payload was selected
  - one (1) out of ten (10) payloads hosted on the Solar Orbiter probe
  - launched to study the Sun in February 2020.
- STIX payload
  - Hardware
    - Attenuator
    - Detector
    - Instrument Data Processing Unit (IDPU)
    - Large Archive Memory (16 GiB)
  - Software
    - SuSW
    - ASW

STIX Partition and Interfaces



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Memory and CPU Budget

Memory type and content	Original STIX		STIX Partition Limits
	Size	ASW Use Estimate	
Internal FPGA RAM for data and code	4 kiB	N/A	N/A
External SDRAM for data and code	64 MiB	**15 MiB**	**3 MiB**
External SDRAM for rotating buffer	64 MiB	-	HW Model
Flash memory for each ASW image	4 MiB	< 800 kiB	< 800 kiB
Flash memory for archive	16 GiB	< 16 GiB	HW Model

Software item	CPU freq.	CPU Time for Mission	Total budget of Mission
Legacy STIX	10 MHz	100%	10 MHz
STIX Partition	50 MHz	12.5%	6.25 MHz

AIMs and Objectives

AIMs

- AIM1: (This aim is omitted and is listed here only for completeness)
- AIM2: **Demonstrate and assess off-line integration** of different applications in a partitioned execution environment.
- AIM3: **Demonstrate and assess upload and on-line integration** of new and/or updated applications in a partitioned execution environment.
- AIM4: **Demonstrate and assess software development process and roles** across different software teams. The contractor is asked to assess those objectives in a dedicated task

AIM2

- AIM2: Demonstrate and assess off-line integration of different applications in a partitioned execution environment.
  - Objective 2.1 (has been met)
    - Define allocation of computing and system resources for a number of applications.
      - **12.5% CPU running at 50 MHz that equals to CPU 6.25 MHz;**
      - **SDRAM 3 MiB (initially 10 MiB).**
    - The resources include, but are not limited to, execution time, memory and I/O.
      - STIX peripherals: 10 MiB;
      - interrupts: 10, 12, 13, 15.
      - **a new OBET peripheral: 4 KiB;**
      - **a communication link implemented as two queuing ports (TM and TC);**
      - **a heartbeat implemented as sampling port.**
    - This allocation shall be mirrored in a corresponding partitioning scheme
  - Objective 2.2 (has been met)
    - Procure application software developed in accordance with the different defined resource allocations.
    - Each application shall be verified and validated individually by the application supplier.
      - **The Application Supplier was able to verify and validate in a parallel when a minimum set of partitions (CDHS, OBSM) was already implemented and provided (verified and validated)**

AIM2

- AIM2: Demonstrate and assess off-line integration of different applications in a partitioned execution environment.
  - Objective 2.3 (has not been met but the issue was not caused by IMA-SP process)
    - Integrate the procured applications individually with the rest of the FSW in the previously set up simulator and laboratory environment(s)
    - and verify that the functionality of the integrated applications is according to specification,
    - and verify that the resource usage is within the allocated means
      - **It is impossible to handle as STIX ASW functionally was totally changed and influenced by the low memory size allocation, which was due to the total physical memory availability. The virtual memory allocated can not exceed the physical one.**

AIM3

- AIM3: Demonstrate and assess upload and on-line integration of new and/or updated applications in a partitioned execution environment.
  - Objective 3.1 (has been met)
    - Define protocol for uploading application software to a spacecraft, which is on-line and in orbit
      - **PUS TM/TC; It was demonstrated by ESC (with SPB support) that e.g. small part of partition can be updated.**
  - Objective 3.2 (has been met)
    - Define procedure and technical solution for installing updated and/or new application software in a partition while all other partitions execute normally
      - **Halt (or suspend) the partition to be updated;**
      - **Upload an updated (new) image for the partition;**
      - **Reload the halted partition with the new image.**

- AIM3: Demonstrate and assess upload and on-line integration of new and/or updated applications in a partitioned execution environment.
  - Objective 3.3 (has been met)
    - Define on-line procedure for starting/re-starting a partition after the corresponding updated or new application software has been properly installed.
      - **Application specific: Send TC to prepare application to be in safe-mode or maintenance mode. Which is very similar to procedure when the partition (or IMA-SP Platform) is powered off;**
      - **Halt the partition (no code is executed);**
      - **Update partition software;**
      - **Start the partition, by TC(8,1) Reload Partition with cold restart of the updated partition (IMA-SP**
      - **provides cold and warm restart).**
  - Objective 3.4 (has been met)
    - Determine which boot sequence/boot loader approach is more suitable for on-line integration of applications: 1) having a specific boot partition in charge of all other partitions, or 2) having a local boot loader in each partition dealing with that particular partition
      - **Option 1 is the best approach in case of the STIX. Only ASW needs to be adapted to IMA-SP. This results in less code lines, less testing, and focusing developont on real mission needs instead of hardware needs.**

AIM3

- AIM3: Demonstrate and assess upload and on-line integration of new and/or updated applications in a partitioned execution environment.
  - Objective 3.5 (has been met)
    - Implement ground tool for on-board software maintenance, which uploads application software built on the protocol and procedures defined and monitors the state of the spacecraft and the various partitions, along with other relevant information, in order to follow the progress of the on-line integration and identify any malfunctions or integration failures during the process so that debugging can be done.
      - **Spacebel already developed OBSM Ground Tool.**

- AIM4: Demonstrate and assess software development process and roles across different software teams. The contractor is asked to assess those objectives in a dedicated task
  - Objective 4.1 (has been met)
    - Define roles and responsibilities as well as overall coordination and development process for the activity in accordance with the IMA-SP development process (i.e., tailor the overall role, responsibility and process descriptions to fit the activity). There shall be more than one application supplier.
  - Objective 4.2 (has been met)
    - Assign persons and/or organisations to the defined roles. Ideally, there are at least two different groups assigned as application suppliers, and the links between these groups should be kept to a minimum

- AIM4: Demonstrate and assess software development process and roles across different software teams. The contractor is asked to assess those objectives in a dedicated task
  - Objective 4.3 (has been met)
    - Develop the system according to the defined organisation and assess the suitability of the defined roles, responsibilities and process.

Partitions: Integration process	OBSM	CDHS	ASW1	ASW2	Remark
OBSM, CDHS	Y	Y	-	-	After this integration, iMA-SP Platform can be provided to independent Application suppliers
ASW1	Y	Y	Y	-	Independent integration of Application Supplier #1
ASW2 (STIX)	Y	Y	-	Y	Independent integration of Application Supplier #2
Complete system	Y	Y	Y	Y	Final integration

Conclusion

Summary

- Application Supplier (ESC) adapted legacy STIX software to partition.
- Even the functionality could not be transferred fully (because of limited memory and CPU budget), new issues were identified related to the IMA-SP.
- All issues described in project shall be considered as input for risk management.
- The issues do not block to study IMA-SP itself and point to new topics which comes with IMA-SP.
- SW development shall consider IMA-SP.

Questions

THANK YOU!

time for any questions

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discussion

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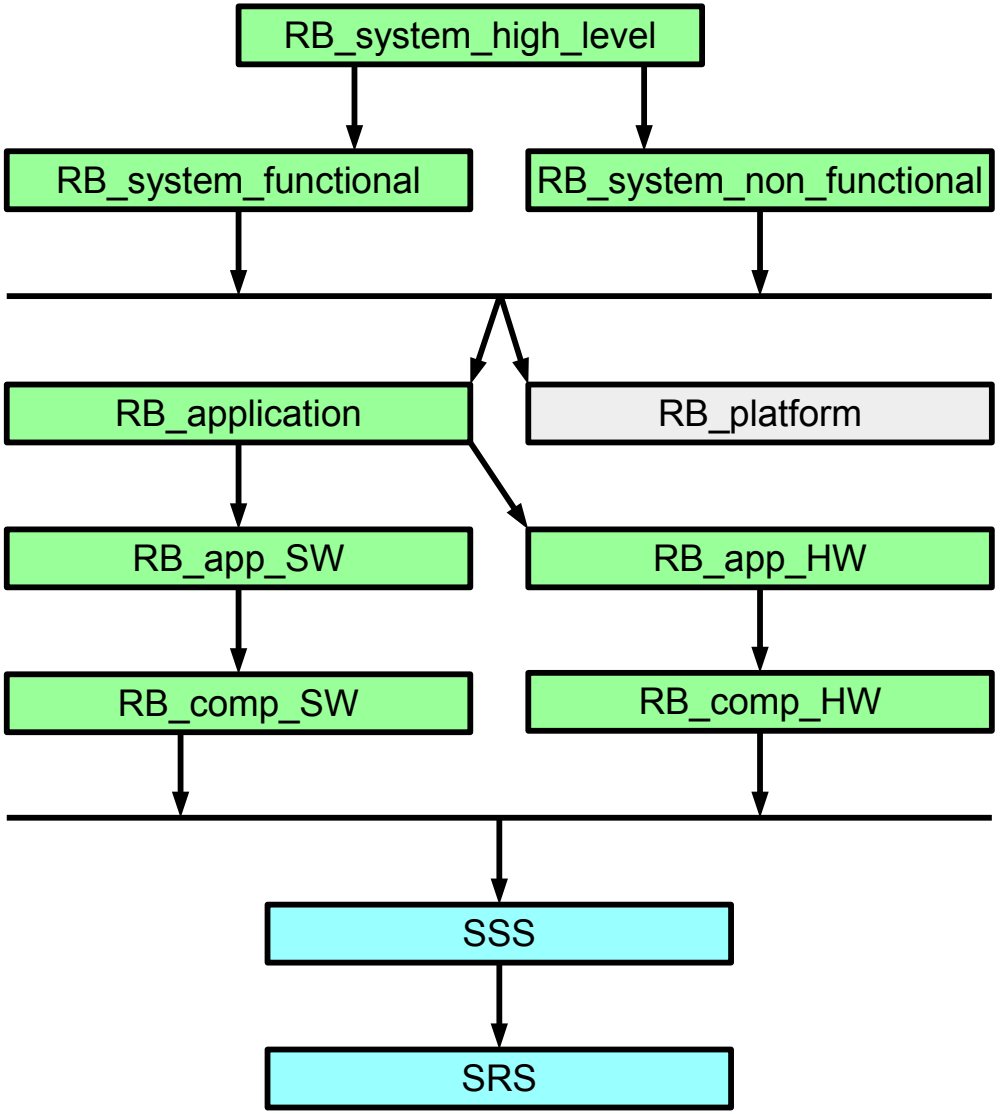
Development (backup slides)

Reviews

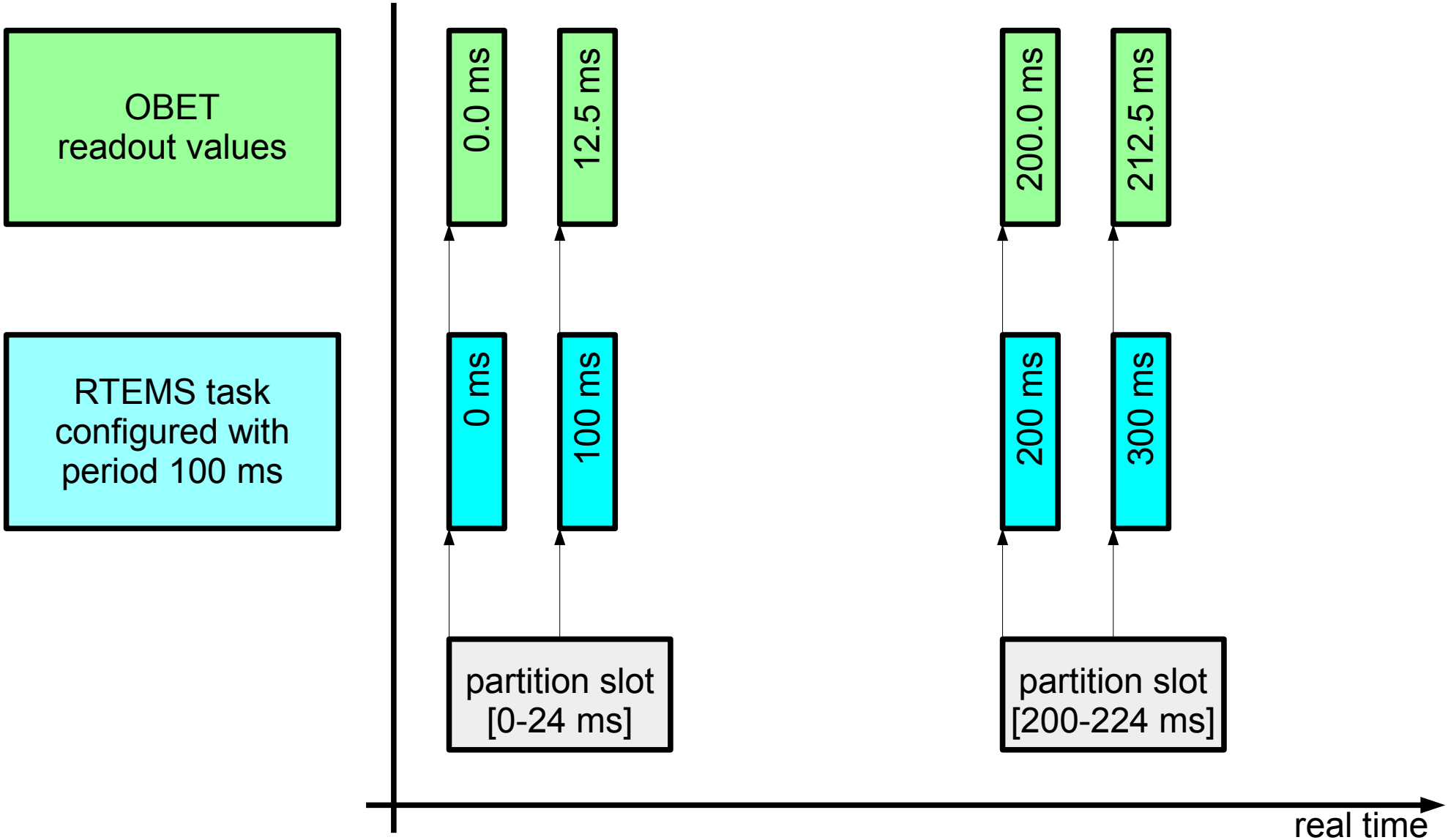
ECSS Review	IMA-SP Process
SRR	System Specification Component Reuse Analysis and Evaluation
PDR	Component Specification Partitioning and Resource Allocation System Feasibility Assessment
TRR	Procurement (reuse) Component Development
CDR	Unitary Partition Validation System Feasibility Assessment
QR	Partition Qualification
AR	System Integration System Acceptance

IMA-SP Requirements

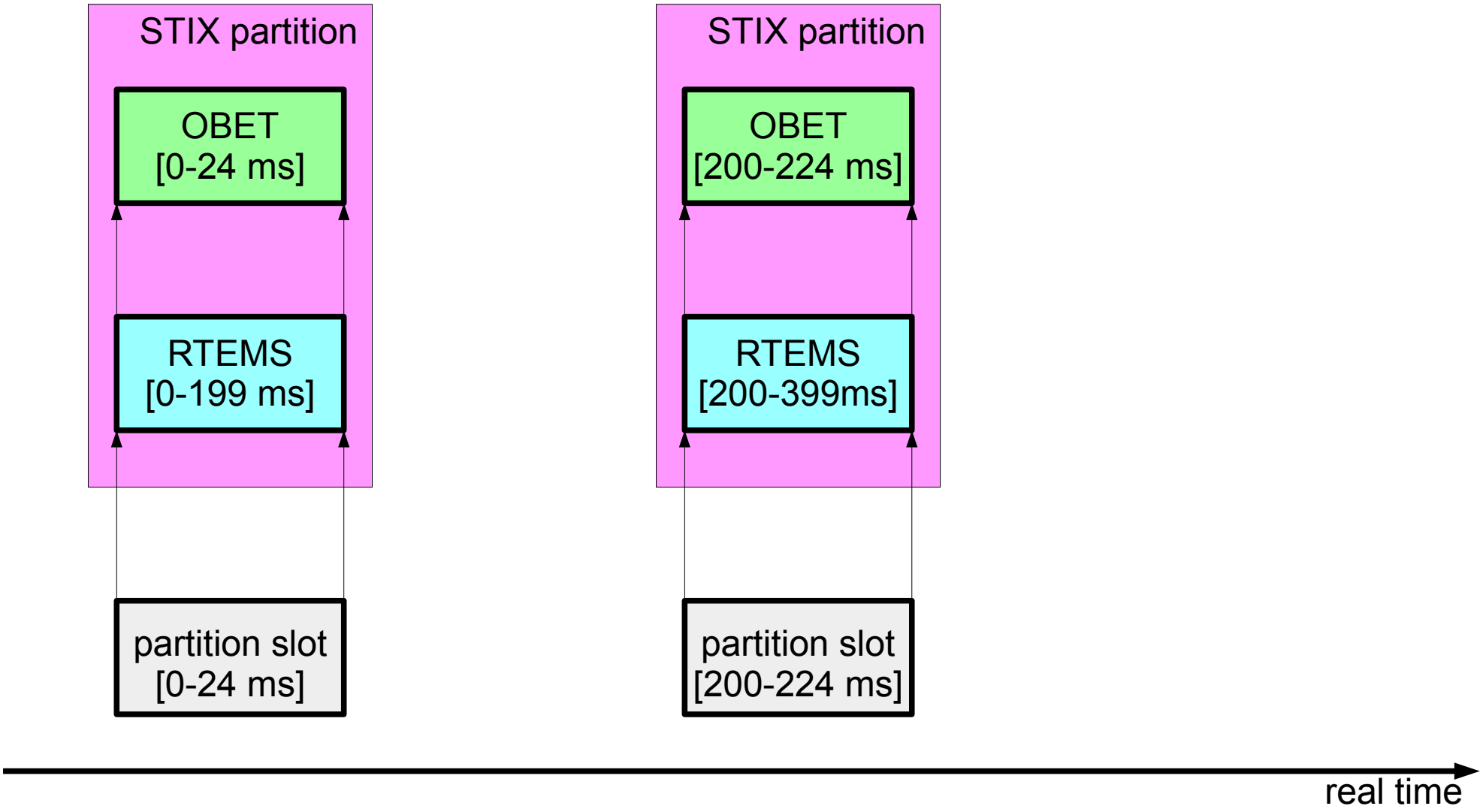


RTEMS
(backup slides)

Partition slots and OBET



RTEMS and OBET



Sharing OBET

- one (1) peripheral, three (3) partitions