

Schedule optimization for ARINC 653-based Integrated Modular Avionics (IMA)



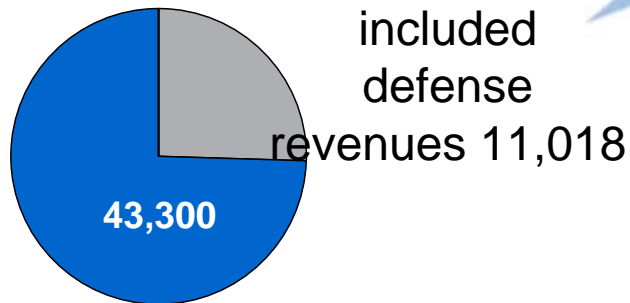
Markus Breunig, EADS Deutschland GmbH

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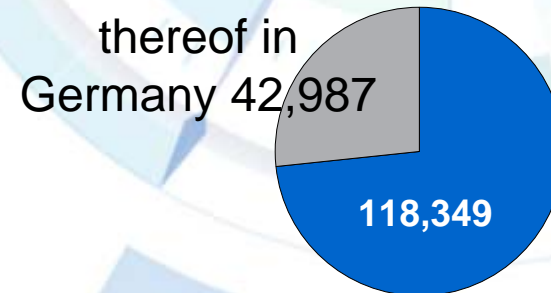
EADS at a Glance

- European Aeronautic Defence and Space Company EADS N.V. is located in Leiden, The Netherlands
- EADS was founded on July 10, 2000 and includes the activities of DASA (Germany), Aerospatiale-Matra (France), CASA (Spain) and Airbus activities of BAE Systems (UK)

EADS Revenues in million €
(2008)



Total Number of Employees
(31.12.2008):



EADS Divisions and Products



Airbus

No. 1 Commercial Aircraft



Eurocopter

No. 1 Helicopters



EADS Defence & Security



EADS Astrium

No. 1 Commercial Launch Vehicles

Integrated Modular Avionics (IMA)

- Avionics are one of the cost factors in modern aircrafts.
- Integrated Modular Avionics is an approach to realize benefits in complete avionics life cycle for
 - Airlines,
 - Airframe Manufacturers,
 - Equipment Manufacturers and
 - Certification Authorities.

IMA Technical Goals

- Usage of standardized building blocks.
- Maximum use of common resources.
- High integration of HW.

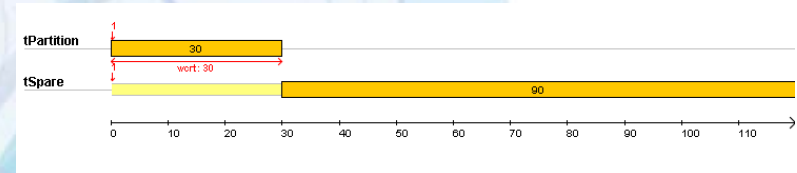
- Functional independence of SW application.
- Standardization of SW / RTOS Interface (APEX ARINC 653).
- Virtualization of equipment.

With IMA it is possible to upgrade software without having to upgrade the Hardware and vice versa (within technical limits).

IMA Equipment Virtualization

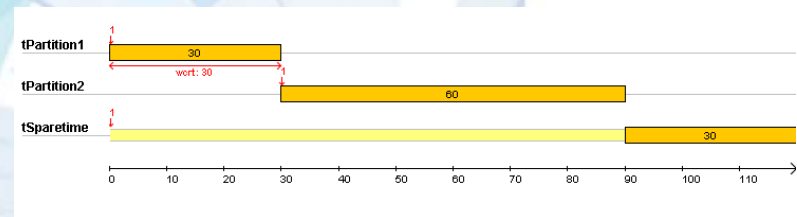
Application Functions in Partitions have

- guaranteed memory space and
- guaranteed execution time.



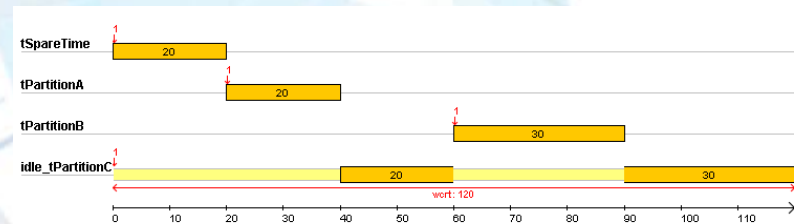
Application Functions

- don't know if they use exclusively a complete CPU or share it with other partitions and
- may not run as one monolith block.



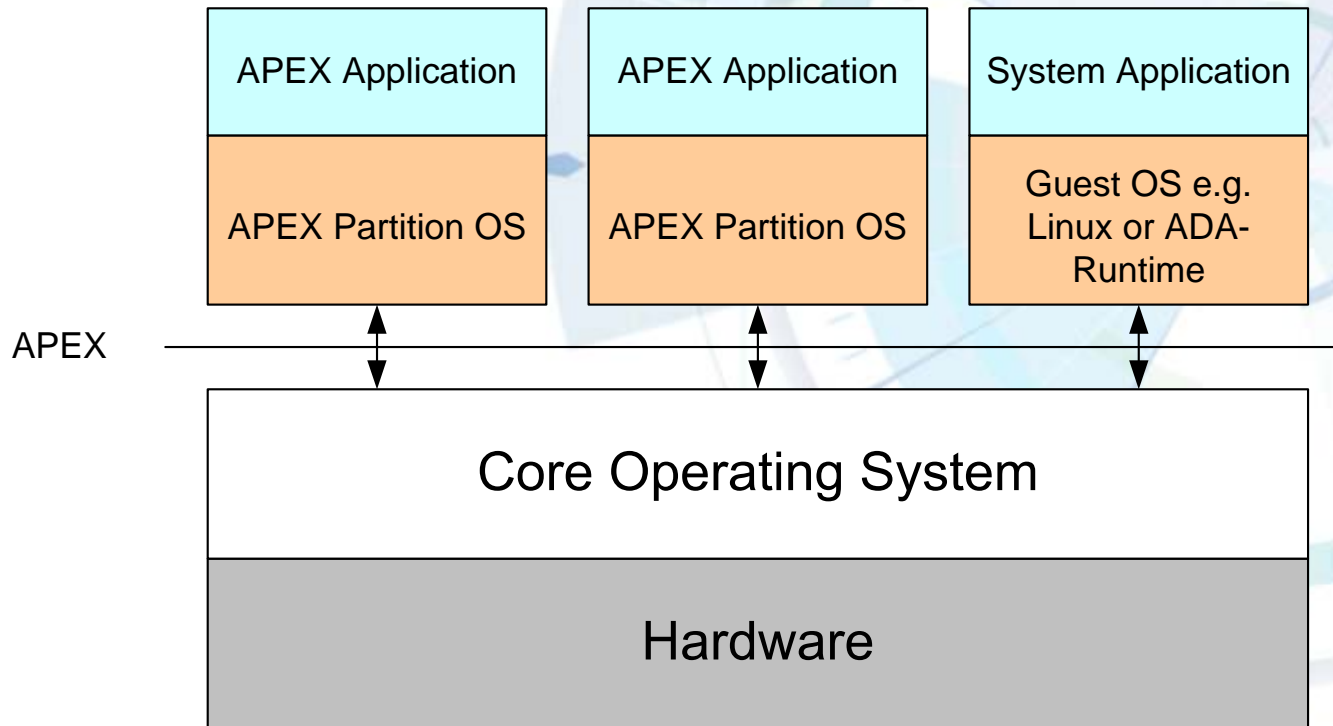
Application Functions

- communicate via data orientated ports, connection to data sinks and sources is done in equipment integration process by configuration.
- are delivered as (binary) executables with certification artifacts.



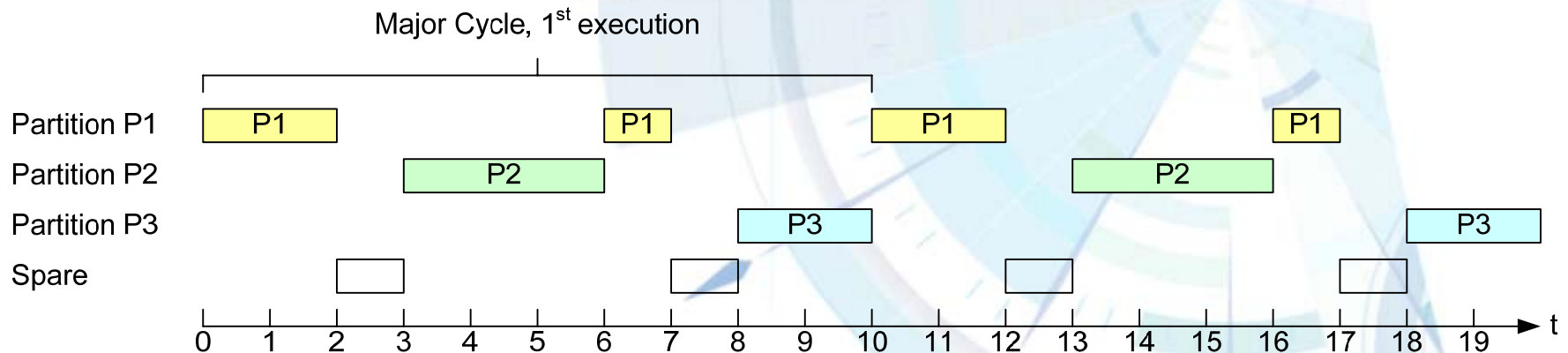
ARINC 653 APEX

- To keep applications independent from RTOS and HW, the following model is used:



ARINC 653 Partition Scheduling

- Partitions are scheduled according Time Division Multiple Access (TDMA).
- Execution times, number of partitions windows and offsets are defined in the Major Cycle.
- The APEX Partition OS supports Priority Preemptive Scheduling.



IMA in Practice – Dominant Design for next Aircraft Generation

	Number of Applications running on IMA computers	Number of different IMA computers	Number of Application Suppliers
A380 (first flight 2005)	21	7	11
A350 XWB (first flight 2012, announced)	35	2	
B787 (first flight 2009, announced)	70 - 80		15+

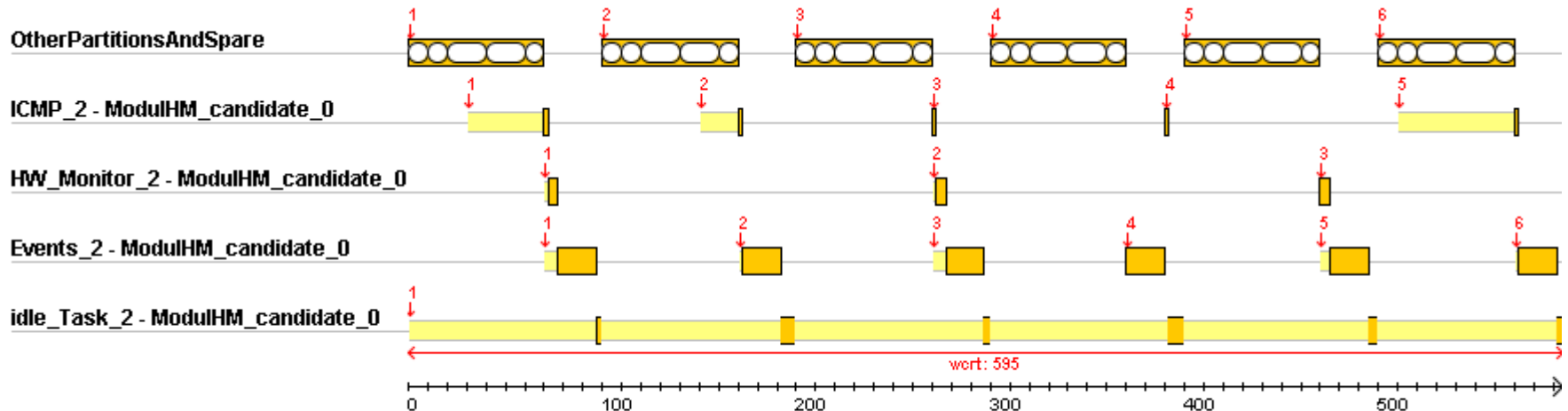
Data collected from Avionics Magazine issue February 2007 and July 2008

IMA Specific Challenges for Timing Analysis

1. Analyzing the timing inside a partition.
2. The IMA approach with independent applications on a single computer generates shared resources in the computer, e.g. the communication interface.
3. Partition unsynchronized parallel tasks (e.g. interrupts) may have impact to independent applications.

ARINC 653 Scheduling Analysis

- On Partition basis it is possible to analyze the system while adding other partitions as “highest priority tasks” with fixed schedule and static execution time.
 - Usage of common analyzing methods and tools possible.



Shared Functions

- Shared functions are equipment specific and it is not possible to describe it in general.
- One general aspect for HW interfaces
 - HW interfaces used by more than 1 application need the possibility to “address” messages to single applications.
 - Parallel access to “application specific” data is required for efficient, deterministic message access.
 - “Ethernet” does support this feature (e.g. by UDP Port addressing) only in software, a specific interface partition is needed and consumes CPU time.
 - AFDX offers this support in HW, more CPU time is available for applications.

But: An equipment supplier has only small influence on interface selection and usage!

Interrupts in IMA Systems

One of the partition requirements is to guarantee a specific execution time to an application in a partition.

Interrupts “steal” execution time of a partition.

- Simple solution:
 - Do not use interrupts!
- **Problem:**
 - In practice, at least the partition and task scheduler require an interrupt.

Interrupts in IMA Systems

All interrupts of an IMA System have to be analyzed

- Not used interrupts → no influence on scheduling ✓
- Interrupts strictly periodic → static overhead proportional to execution time ✓
- Interrupts indicating fatal errors → scheduling stopped, deterministic behavior ✓
- Operational interrupts asynchronous to partition execution → needs investigation (lot of work and poor worst case result expected – don't use it)
- Operational interrupts as response to function request → needs investigation
- Exceptions to switch from (partition) user mode to (CoreOS) supervisor mode are dedicated to partition time of caller.

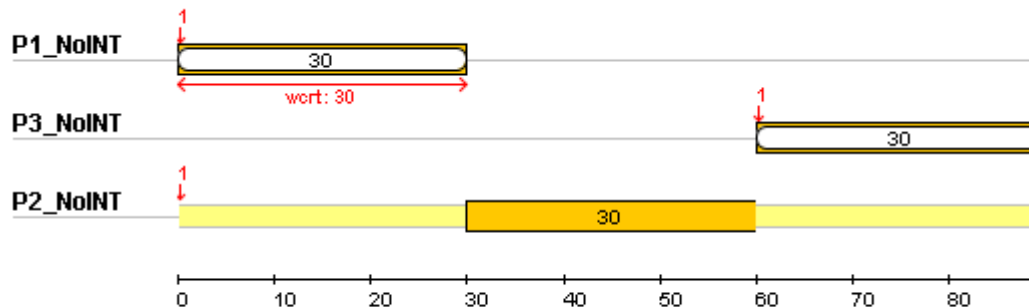
Example Interrupt

- As a standard avionic requirement events are logged in a non volatile memory (NVM). The message writing is “atomic” with response to flash, otherwise the flash message structure is corrupted.
- NVM is a flash device. Flash device characteristics:
 - Maximum 64 byte in block write with 1 operation
 - Worst case block write time is 200 μ s, block write time in practices is ca. 60 μ s.
- Different partitions use the NVM and max. message size is 512 Byte.

Example Interrupt 1

No interrupt used

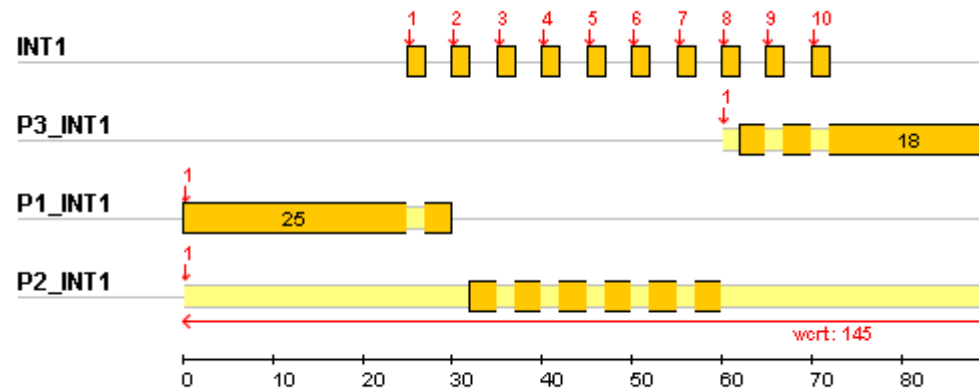
- Option 1: Core Task with high priority
 - P2 tasks get no execution time till flash task is ready
 - P2 access to flash is delayed till flash task is ready, maybe for more than 1 Major Cycle
- Option 2: Core Task with lower priority
 - P2 tasks get immediate execution time of partition
 - P2 access to flash is delayed at least till next partition window



Example Interrupt 2

Flash write takes worst case time

- P2 execution time is limited by interrupts
- P2 access to flash is delayed till flash task is ready, in this example at least till next P2 partition window.

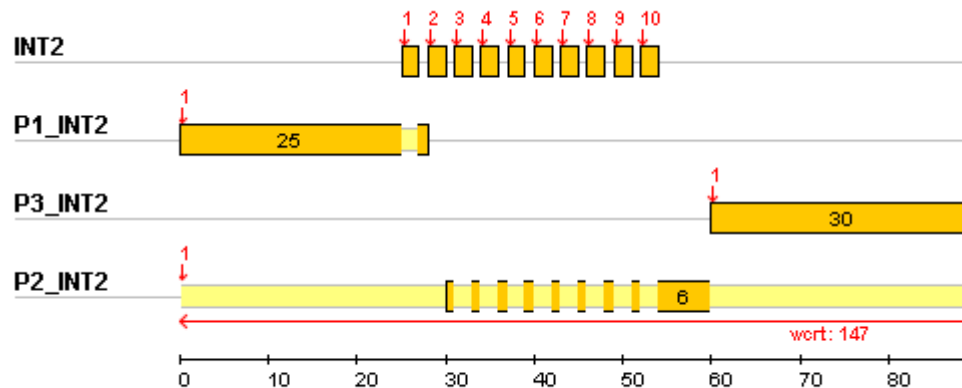


All values for illustration only.

Example Interrupt 3

Flash write takes flash write time in practice

- P2 execution time is more limited by interrupts
 - P2 access to flash is delayed till flash task is ready, task can run in this partition window
- ➔ Effect is positive to reduce P2 flash task blocking but is negative for P2 execution time.



All values for illustration only.

Example Interrupt Improvements

- Analyze the usage of the flash driver in detail for each partition to reduce the worst case number of interrupts after each partition.
 - ➔ reduce the “time steal effect”.
 - max. message size flash device driver is 4096 Byte ➔ 64 interrupts
 - max. message size Partition 1 is 512 Bytes ➔ 8 interrupts
 - max. message size Partition 2 is 128 Bytes ➔ 2 interrupts
 - max. message size Partition 4 is 64 Byte ➔ 1 interrupt
- Change Major Cycle in such a way, that Partition using the flash driver are not scheduled in sequence.
 - ➔ eliminate the blocking of partitions.
 - make sure the partition following Partition 1 is not using the flash device driver

Conclusion

The whole computer need to be designed for IMA.

IMA is
NOT
“yet another Real Time Operating System”

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