

# AIR

## AIR – ARINC 653 Interface in RTEMS

(Proof of Concept)

ESA Innovation Triangle Initiative (ITI) 3<sup>rd</sup> Final  
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## AIR Project Summary:

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In both avionics and space industries, the safety concept is of paramount importance. The ARINC 653 standard was developed with the purpose that all safety critical software embedded in a system must follow very strict and demanding rules both in terms of operation and certification.


ARINC 653 and Integrated Modular Avionics (IMA) are the answers provided by the civil aviation world to problems that are also identified in the space world. The space world is looking for a standardized interface for the Operating Systems (OS) located on board the spacecrafts. Most of the requirements from the civil aviation world that led to the definition of ARINC 653 are also requirements from the space world and thus the adaptation of the specification to the space world needs can be performed with minor changes, keeping its basic principles.

The adoption of the **ARINC 653 concept in space on-board software** will not only provide the space industry the same benefits the aviation industry has already profited with by adopting the standard – software portability and modularity, partitioning and less certification effort, etc. It will also promote the reusability of Research and Development (R&D) efforts already invested in the scope of another industry domain, further increase the synergies in the development of software for the parallel domains of civil aviation and space and potentiate reduction in the development costs of on-board software. Finally, the space world will benefit from ARINC 653's improvement in the development framework available for both application developers and integrators.

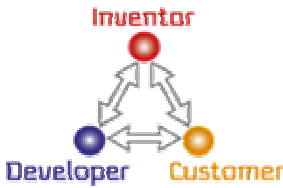
Furthermore, there is a general demand for the use and re-utilization of commercial off-the-shelf (COTS) components in the design of complex embedded systems, such as those found in aerospace applications. The AIR – ARINC 653 Interface in RTEMS – innovation initiative has emerged complying to this requirement, exploiting the utilization of a COTS licence-free open-source real-time operating system, the Real-Time Executive for Multiprocessor Systems (RTEMS). The use of RTEMS is particularly interesting given its qualification for critical on-board software of unmanned space programs.

However the AIR Project went one step further, defining a design approach allowing the fundamental AIR concept to be applied to other COTS real-time operating system (RTOS) kernels. Different RTOS kernels may even operate in the same system. This definition of a very flexible and versatile architecture, making use of a comprehensive set of systems and tools, opens room for the application of the AIR concept to the different RTOS technologies and to several application sets, thus standing for the general designation: ARINC 653 Interface in RTOS kernels.





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## AIR – ARINC 653 Interface in RTEMS (A – Proof of Concept)




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## AIR Activity


- **Proposed Problem:** tailor the RTEMS to the ARINC 653 specification:
  - Implementing the partitioning concept:
    - spatial segregation
    - temporal segregation
  - Mapping the APEX services:
    - through RTEMS available primitives – native and POSIX
    - use POSIX as to make the AIR APEX implementation more system independent
- **Activity Motivation:**
  - First step towards the creation of an ARINC 653 compliant RTOS aimed for the space market
  - Provide evidence of the utility and usability of the ARINC 653 concept for space based applications



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## AIR Activity


- **Proposed Solution:**
  - Investigate which modules in the RTEMS kernel need to be added, modified, replaced and/or removed.
  
- **Project Consortium:**
  - **Skysoft:** use ARINC 653 know how to specify, design and implement a demonstrator of the ARINC 653 services over RTEMS
  - **FCUL:** use knowledge of RTEMS as to tailor it to the ARINC 653 partition requirements


  
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## Origin of the technology


- **Integrated Modular Avionics (IMA) and the ARINC 653 standard:**
  - becoming a *de facto* technology for software development on the aeronautics market.
  
- **The foreseen advantages are:**
  - Provide easier system integration and validation
  - Provide a standard development platform
  - Inter-operability of different systems
  - Physical advantages – less energy consumption/less weight/more free space

  
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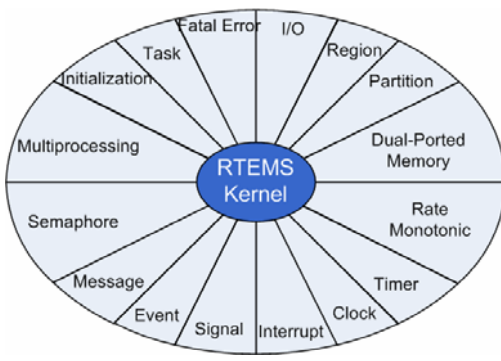
Innovation Triangle Initiative Innovation content 


- Applicability of IMA and ARINC 653 concepts on a space context.
  - AIR aimed to use a open-source, licence-free real-time operating system: RTEMS (Real-Time Executive for Microprocessor Systems).
- But AIR activity went further and...
  - defined a general architecture for an ARINC 653 compliant RTOS.

  
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Innovation Triangle Initiative Technical Details 

- Real-Time Executive for Multiprocessor systems
  - real-time, multitasking kernel, with a modular architecture
  - Set of highly configurable component managers

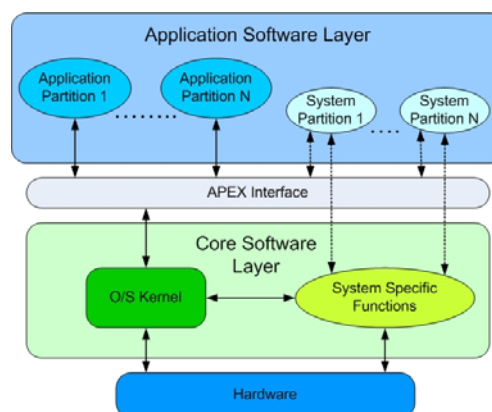


  
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## RTEMS and ARINC 653 Requirements

- RTEMS implements some functionality:
  - Real-Time priority-based pre-emptive task scheduling;
  - inter-task communication and synchronization.
- RTEMS **does not implement** the fundamental:
  - Temporal segregation
  - Spatial segregation

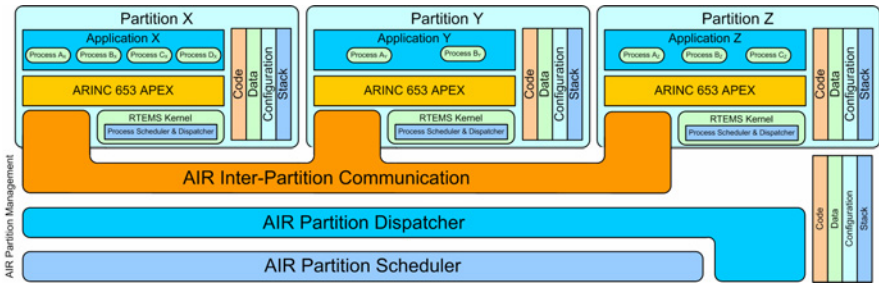
- Partitioning Concept: spatial and temporal.







Innovation Triangle Initiative **Technical Details** 

- one RTOS instance per-partition; one APEX per-partition
- different RTOS may be used at each partition
- minimal changes to native RTOS
- processor architectures: Intel IA-32 (prototyping) / SPARC LEON




The diagram illustrates the architecture of three partitions (X, Y, and Z). Each partition contains an application (Application X, Y, and Z) with multiple processes (Process A, B, C). Below the application is the ARINC 653 APEX layer, which interfaces with the RTEMS Kernel (Process Scheduler & Dispatcher). Each partition also has its own memory stack (Code, Data, Configuration, Stack). The partitions are managed by the AIR Partition Scheduler and AIR Partition Dispatcher, which facilitate AIR Inter-Partition Communication.

  
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Innovation Triangle Initiative **Technical Details** 

## ARINC 653 Interface on RTEMS

- The implemented services for the demonstrator are:
  - The partition management services
  - Some relevant process management services – ARINC 653 processes are mapped as RTEMS tasks
  - The intra partition communication blackboard mechanism
- This set of services provides a relevant set of functionalities to evaluate the APEX full implementation over RTEMS:
  - Processes competing to get the processor;
  - Processes communicating with each other;
  - Processes controlling the execution flow of each other;
  - And, partially, the ARINC 653 initialization schema.

  
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**Innovation Triangle Initiative** **Technical Details** **esa**

- specialized (non-conventional) use of standard built-tools

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**Innovation Triangle Initiative** **Results and tests** **esa**

- Proof of Concept Demonstrator**
- Multi-Executive Core**
  - Intel IA-32 prototype
- Use of standard tools and technologies
- Use of VITRAL window manager for RTEMS

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- **ARINC 653 in Space – Industrial Initiative**
  - Skysoft Portugal SA, FCUL, Thales Alenia Space
- **Design consolidation of main components:**
  - RTOS independence (open-source, commercial)
  - Inter-partition communication and input/output
  - Spatial partition
- **Overall Goals:**
  - Compliance with space requirements
  - Deployment as an advanced prototype
  - Integration and testing with space-related application.