Case Study: Integrating FACE™ Aligned Componentry

A study in creating a demonstration platform using multiple vendor FACE aligned components

US Army Aviation FACE TIM Paper by:

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Executive Summary

The primary objective of the FACE Technical Standard is to define a reference software architecture. The Reference Implementation Guide documents approaches and best industry practices to instantiate the reference software architecture for developing and verifying infrastructure software components and application components. This paper will examine a case study of such a reference implementation in order to demonstrate capabilities that can be integrated using FACE aligned components. These components include:

- An Operating System Segment (FACE Safety Base Profile aligned) utilizing both C and C++ runtimes
- A Transport Services Segment (TSS) utilizing DDS and ARINC port services
- A Platform Specific Services Segment (PSSS) including Graphic Services
- A Portable Components Segment (PCS) implemented within a partition providing the Primary Flight Display.
- An IO Services Segment (IOS) including the adapters to the low device drivers in use on the platform, specifically the serial and Ethernet.

Establishing the baseline platform

Detailed list of requirements

In order to establish the initial platform, a short set of requirements for the demo were required that went beyond just the requirement for using FACE aligned components. Based on input from Marketing, the following were selected as the platform requirements:

- The demo shall use multiple memory spaces (partitions) scheduled in an ARINC 653 manner.
- The demo shall provide a graphical component that can be externally controlled
- The demo shall use a Transport Services Layer employing both DDS and ARINC ports for inter-partition and off module communication
- The demo shall be portable to multiple hardware platforms/architectures
- The demo shall be extensible
- The demo shall provide a demonstrable path for certification of the software components employed in its operation

Based on these criteria and hardware availability, a Freescale P4080 processor was chosen for the reference CPU. This allowed for the use of at least 2 hardware platforms, a GE-IP FORCE1 which included Ethernet and a ATI Radeon e4690 based graphics XMC interface as well as a Wind River P4080 reference board employing a PCI Express e4690 based graphics interface. Additional platforms added later include a P2020 based CES RIO6 employing a different graphics adapter. The FACE standard places no restrictions upon additional CPU/hardware architectures except for what is supported by the Operating System Segment (OSS) and its Board Support/Architecture Support Package availability.

Determining the OSS Configuration and FACE profile

Wind River has a number of RTOS offerings but to satisfy the operational, safety and FACE requirements an ARINC 653 compliant operating system was chosen which was VxWorks 653. Since VxWorks 653 offers a number of both safety critical and non-safety critical configurations and capabilities, the decision to use the safety subset was chosen and drove the use of the FACE Safety Base Profile. This offers both ARINC 653 and POSIX APIs as listed in The FACE Technical Standard (Section 3.11and Appendix A).

Based on the stated requirements, a 2 partition configuration was chosen. One partition would contain the portable graphics application component (Unit of Portability) and the second partition would contain the TSS providing the connection between the outside control system and the graphics application. The underlying transports for the TSS include DDS using a publish/subscribe model to connect to a standalone tablet also running DDS to send pitch, roll and airspeed data to the graphics application via an ARINC sampling port. All configuration is accomplished by XML and inclusion of API specific libraries in shared library format for the partitions and OSS. This includes a baseline Health Monitor and Fault Management (HMFM) providing a concise and configurable response to platform and application related errors and messages. It also provides interfaces required for process level HMFM for both ARINC 653 and POSIX based applications per FACE Technical Standard (Section 3.16.3 Operating System Segment Health Monitoring Requirements).

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Establishing this baseline configuration and operation of the OSS required approximately 3 hours total time owing to a fairly concise set of requirements as well as a set of well-defined Board Support and Architecture Support Packages for the hardware platform.

Based on this work we have instantiated a portion of the FACE Reference Architecture, Figure 1 from the FACE Technical Standard is shown below. These segments include:

- Operating System Segment
- Portions of the IO Services Segment (as needed for serial and Ethernet)
- Portions of the Platform-Specific Services Segment (specifically the common services)
- Provided memory containers (partitions) for the Portable Components Segment and their associated ARINC 653 APIs (graphics component) and POSIX APIs (transport services/DDS component).
- A Transport Services Segment reference implementation.

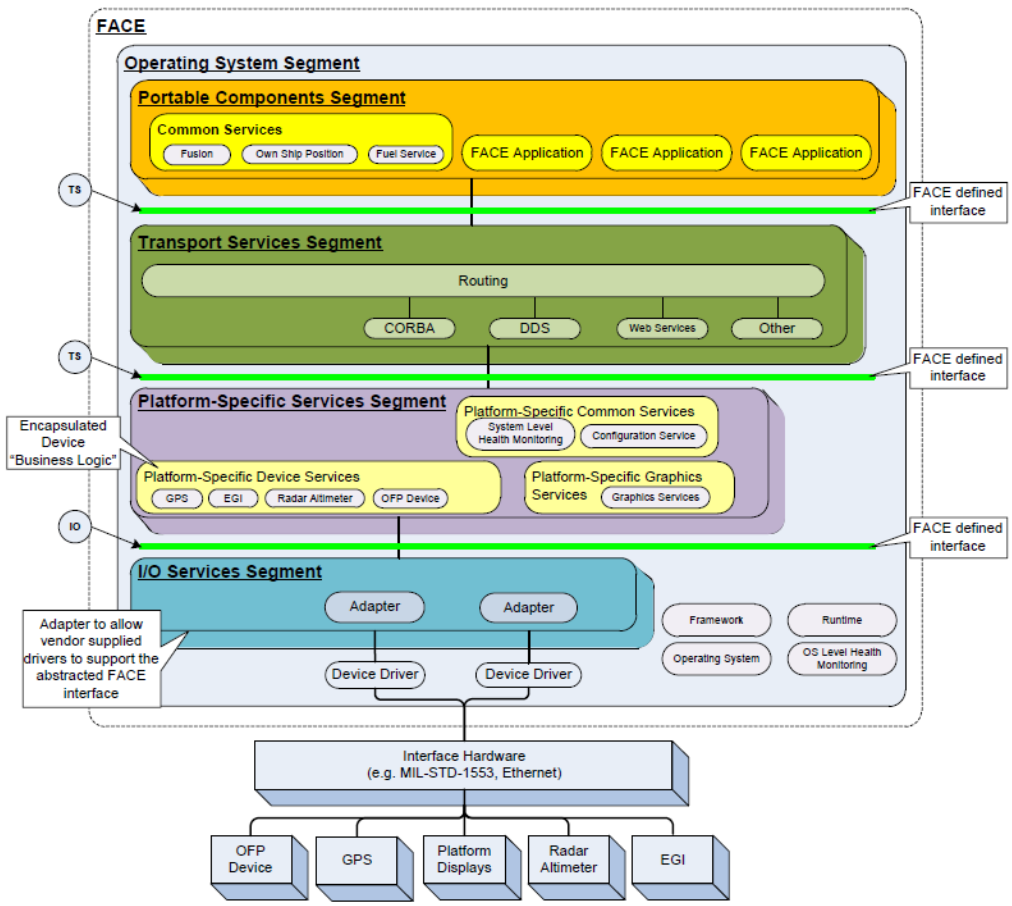

Figure 1

Architectural Segments Example

Integrating the Graphical Component

The graphical portions of the demonstration platform are provided by two vendors. CoreAVI provides IO Services Segment adapter to the graphics device driver which can include a full DO-178B, Level A certification data package. Esterel (Ansys) provides the portable application that creates and drives the GUI. This GUI is actually code that is auto-generated by the SCADE™ line of tools which include a qualified code generator that is qualified to DO-178B Level A.

As part of the integration effort the following tasks must be accomplished:

- Integration of the adapter and device driver into the IO Services Segment
- Integration of the Graphics Services into the Platform-Specific Services Segment
- Integration and addition platform specific initialization of the portable application and configuration
- Memory mapping tasks for the frame buffer and registers of the device driver into the application space (ARINC 653 Memory Blocks)

Device Driver and Adapter Integration

The device driver is installed into the OSS by OSS unique APIs. The adapter is provided in two components, a component installed into the IO Services Segment that will perform the necessary device discovery and configuration. A second component is installed in the PCS to be used by the portable graphics application to perform the necessary steps as described above to discover and configure the physical device which is done at supervisor level by the OSS on behalf of the portable application.

Graphics Services and the Platform-Specific Services Segment

The Graphics Services provide are comprised of the OpenGL SC stack used by the portable application to render the screen elements. This is comprised of a linkable library that the portable application accesses via direct path for local rendering as shown in Figure 55 in the FACE Technical Standard Edition 2.0 on page 152.

Platform Specific Initialization of the Portable Graphics Application

The Portable Graphics Application is created through the use of modelling tools provided by Esterel(Ansys). These tools model both the appearance as well as the operational characteristics of the overall application. The generated code is tailored to specific requirements of the OSS and graphics device driver as provided by a number of vendors (in this case Wind River and CoreAVI respectively). This code generated has provisions to generate a number of versions and profiles of OpenGL including OpenGL ES to align with the FACE Technical Specification. The only additional work required was to integrate in the data source for the roll, pitch and air speed values being provided by the external tablet device via the TSS. This required the additional of the ARINC port read via the TSS operation and supplying of that data to the input engine of the application. Minor work was then required to create and start the process that ran the graphic application which was OSS specific to VxWorks 653 which is consistent with the ARINC 653 and FACE Technical Standard.

Memory Mapping Tasks

In order for the portable application to access the frame buffer without the need for time consuming system calls into the OSS, OSS can be configured to map this memory area directly into the application space as an ARINC 653 Memory Block (also referred to as a shared data region in VxWorks 653). This is accomplished in the Platform-Specific Services Segment, specifically the Configuration Services.

The total effort required to integrate the graphical application into the platform was roughly 4 hours after becoming familiar with the required elements through the provided documentation. Clear and concise documentation allowed for a quick and relatively problem free integration onto the platform. One area that still required manual integration work was the changes to the memory layout which was specific to the hardware platform being used. Since a number of variables are in effect with the layout of memory, especially the physical addressing of the devices on the external bus, this is likely to be a continuing effort to simplify in the future. Referring back to the figure on page 5, this completed the integration of the Platform-specific graphics services within the Platform-Specific Services Segment as well as adding the first of the two Portable Components.

Integrating the Transport Services and Data Distribution Services (DDS)

The Transport Services Segment is a thin layer provided as part of the RTI DDS Connext® product. This provides mapping of FACE connection to the underlying DDS publish/subscribe topics, in this case the pitch, roll and airspeed data that is published by the external tablet device. This shows that a device with software not using the FACE architecture can send data to a FACE aligned platform using standard communication protocols, in this case DDS over Ethernet via the PSSS. In addition to providing the TSS APIs the service also provides scaling of the data for presentation to the graphics component which is also a TSS capability. Although this is not a fully implemented TSS it demonstrates the necessary principles involved in creating and integrating FACE portable components.

After configuring the data topics which DDS subscribes to, the implementation is generated in source form and integrated into the portable component space provided (partition). The architecture specific libraries are then linked to the implementation along with the necessary OSS library which in this case is the support for ARINC 653 ports and HMFM APIs since only POSIX sockets and ARINC sampling ports are being used for this example.

The RTI TSS reference implementation is implemented to support communication between any PCS and PSSS UoPs. It is not hard coded to any specific instantiation of the data model. RTI provides a compiler that takes the Interface Definition Language (IDL) expression of a UoP Supplied Model (USM) and compiles it to the C++ type-specific Transport Services (TS) interface. This generated interface, which is data model specific, is then linked against the corresponding PCS or PSSS UoP.

As part of the generation of the implementation, a publisher is also created which is a Java applet executed on the external ARM based tablet device. This is loaded onto the tablet and controlled by the user. The applet reads the gyro in the tablet and formats the data for publishing on the wireless network connection. This data is then read by the TSS/DDS component on the reference platform, scaled and then sent to the graphics portable component via a TSS/ARINC 653 sampling port.

Overall the integration of the TSS/DDS component only required one hour. This did not include creation of the necessary data topics and creation of the implementation files via supplied RTI tooling.

Final Integration Steps

Upon completion of the previous steps, a complete platform is now ready for demonstration. Some minor network maintenance operations are needed such as defining IP address ranges to serve to each of the devices and allowing the target platform access to the binaries that constitute the run time system

Figure 2 is an overview of the final demonstration system showing the tablet using DDS and the FACE aligned target platform. Following this is a completed FACE Architectural Segment showing the target platform

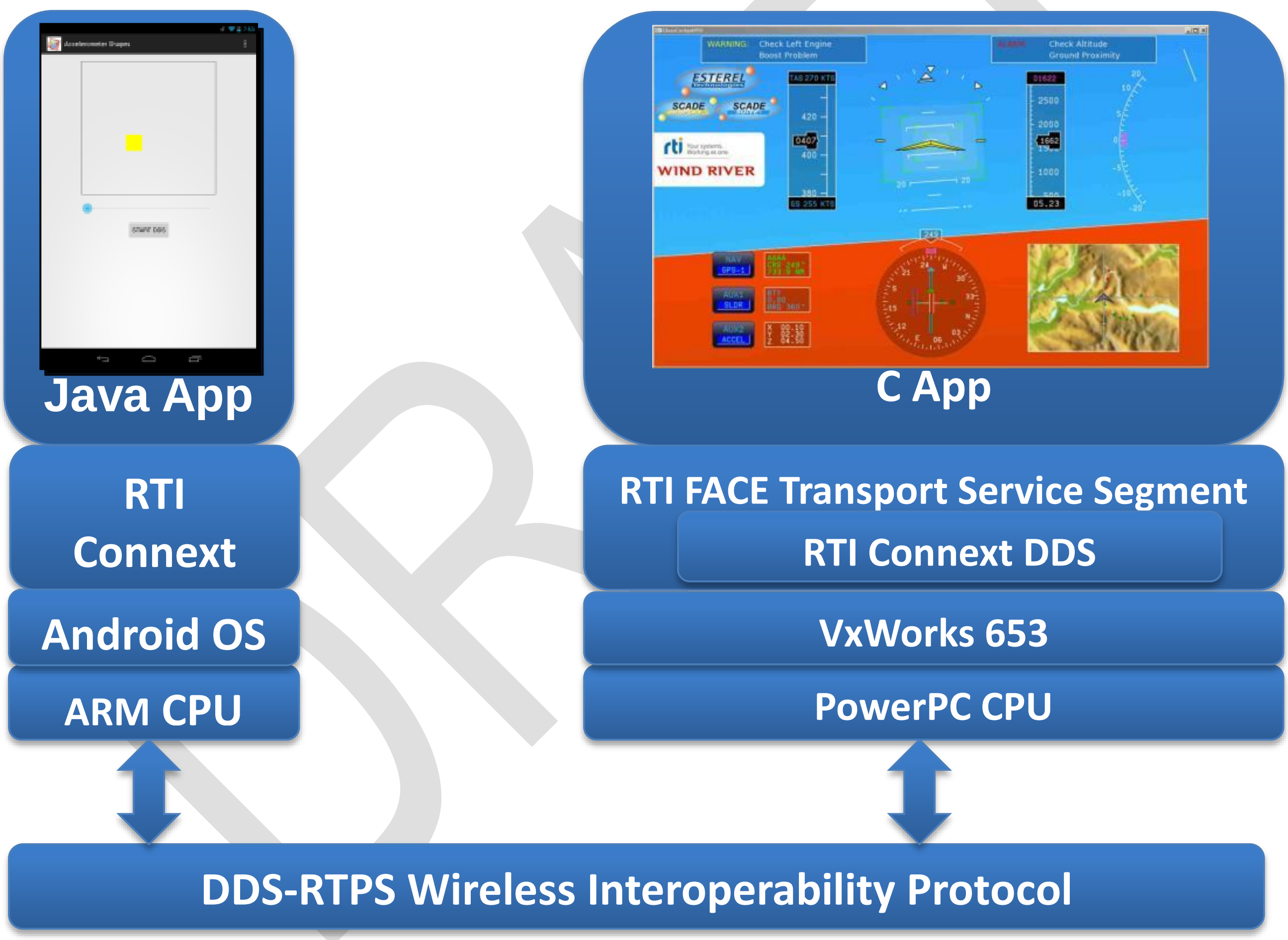

Figure 2

Instantiated target Platform and the control tablet overview

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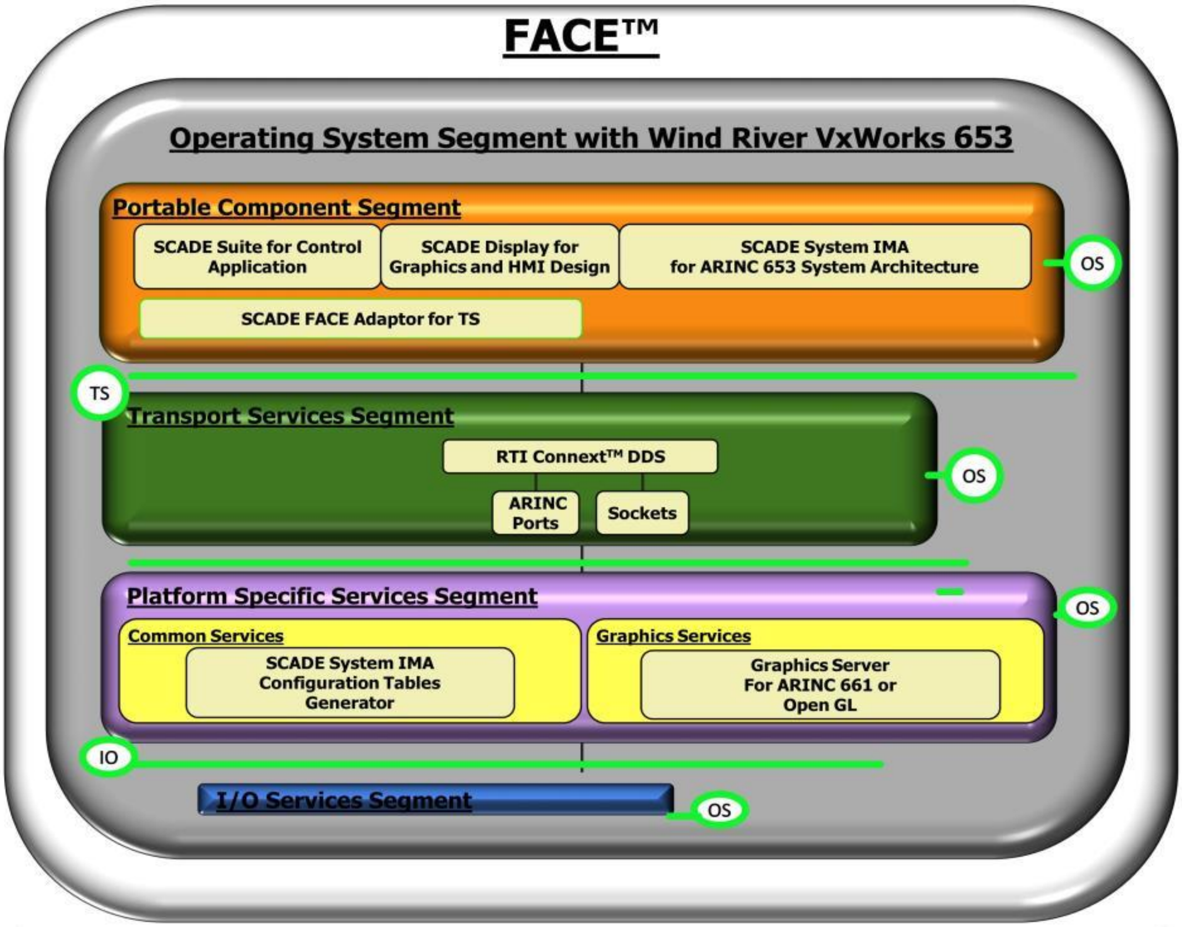

Figure 3

Architectural representation that shows the locations of the components and services provided by the suppliers and how they integrate into the FACE defined segments.

Summary

The final integrated platform clearly demonstrates the key goals of FACE by showing the ease of integration, reusability and extensibility. By using industry standards and APIs it allows the developer and integrator to create and deploy reusable components and establish platforms that can be reused to serve numerous functions.

Additional extensions planned for this demonstration platform is extending it to a multi-module configuration that is synchronized using hardware and software running as part of the Transport Services Segment employing hardware provided by TTTech. It is also planned to incorporate the FACE data model to fully build out the TSS. Other extension points include including streaming video data to the target for display by the graphic portable component.

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About the Author

Larry Kinnan is a Principal Technologist for Avionics and Safety Critical Systems at Wind River in the Technical Marketing Group. Larry has worked at Wind River for more than 16 years in various Services and Field Engineering roles with a primary focus on safety-critical systems and ARINC 653 solutions.

Larry has extensive experience with numerous aerospace programs such as the Boeing 787, KC-46 Tanker, C130-AMP and other commercial and military aircraft as well as multiple space borne systems. Prior to joining Wind River, Larry was employed in the medical device community where he was involved in safety-critical device design, development and deployment of computed tomographic and nuclear medicine systems.

Larry's personal interests are model rocketry, local politics and commercial spaceflight systems.

About The Open Group FACE Consortium

The Open Group Future Airborne Capability Environment (FACE) Consortium, was formed in 2010 as a government and industry partnership to define an open avionics environment for all military airborne platform types. Today, it is an aviation-focused professional group made up of industry suppliers, customers, academia, and users. The FACE Consortium provides a vendor-neutral forum for industry and government to work together to develop and consolidate the open standards, best practices, guidance documents, and business strategy necessary for acquisition of affordable software systems that promote innovation and rapid integration of portable capabilities across global defense programs.

Further information on FACE Consortium is available at www.opengroup.org/face.

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