FACE™ Cross-Integration Successes – Honeywell, RTI, TES-SAVi, Wind River, and Mercury Systems, 2017 June BITS Event

Model-based tools used for rapid FACE development and integrations

NAVAIR FACE™ TIM Paper by:

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Executive Summary

The complexity of next-generation aircraft is expected to increase. They will be interoperable system-of-systems, integrated from individually developed avionic capabilities, likely from different developing entities, using advanced lifecycle modeling tools and processes [*c.f.*, ref. 1,2,5,6,7,8,9, and 10 – Figure 1].

This paper is a continuance of a case study of the benefits emerging from open systems standards, e.g., the FACE™ Technical Standard, HOST, OMS, JCA, SOSA, and the recent innovations of model-based systems engineering (MBSE) practices and tools. Collectively they bring forth a new age in software portability, software reuse, and the opportunity for rapid integration of multiple interoperable military aviation capabilities and their applications hosted on safe and secure modular avionics architectures. The trend that is pushing open systems modular capability developments is multiple vendors can develop and submit *plug-n-play* software and hardware thereby presenting buyers with *best-of-breed* advanced capabilities and avoiding obsolesce of systems and components.

Figure 1 - System-of-Systems - Complexity of Next-Generation Aircraft developed by different developing entities

The FACE IWS BITS events represent opportunities for FACE member organizations to *test out* just how multiple organizations can actually share individually developed capabilities, testing modeling and code sharing processes, working through data rights sharing, and publish and share *just how to* techniques.

At the June 2017 FACE Member's Meeting BITS event, five company participants, namely: Honeywell, Real-Time Innovations (RTI), and TES-SAVi, Wind River, and Mercury Systems set-forth to cross-integrate and combine individual FACE-aligned efforts, i.e., Honeywell's FACE Conformant EGI software and RTI's DDS, demonstrating plausibility of rapid integration benefits of the FACE Technical Standard, currently version 2.1, operating these product alongside of the FACE IWS BALSA on Wind River's FACE Conformant VxWorks 653 Operating System operating on flight-ready processing hardware capable of hosting software aligned to the FACE Technical Standard. This paper shares the findings of these latest successes.

Aligned with the FACE IWS Charter

What is the purpose of the FACE Integration Workshop (IWS)? Why is the FACE IWS BITS (i.e., BALSA Integration and Test Session) event important to the momentum of the FACE Consortium? And how do cross-integration efforts push-forward the adoption of the FACE Technical Standard? The answer to these questions continues to motivate organizations to join our FACE Integration Team (FIT) and efforts.

The Charter of the FACE Integration Workshop

The Charter of the Integration Workshop (IWS) is to:

- Collaborate with the Business and Technical Working Groups (BWG & TWG) to establish and enforce technical entrance criteria for public FACE Consortium sanctioned Technical Interchange Meetings (TIM) and similar events, and
- Discover, evaluate, and produce FACE reference implementation examples and facilitate adoption and publication of those reference examples.

The FACE BITS Events supporting FACE Developments and Integrations

IWS' BITS (i.e., BALSA Integration and Test Session) are events designed and coordinated by the FACE IWS to encourage and assist FACE Software Suppliers to develop and integrate their FACE products to the FACE Technical Standard. The objective of BITS is to facilitate adoption of FACE Technical Standard, assist FACE Software Supplier's through the initial "on-ramp" of FACE developments, and leverage the lessons learned experiences for the sake of Consortium product improvements. The criteria of the BITS events are to: use the FACE Software Suppliers Getting Started Guide, integrate to the BALSA reference architecture, run their product against the FACE Conformance Test Suite to show alignment, demonstrate operations on the FACE BALSA, and share Lessons Learned. The first (or Pilot) event of BITS was held in December of 2016 at the FACE Face-to-Face Member's meeting hosted by Harris Corporation at their Headquarters in Melbourne, Florida. Five FACE Consortium Member Organizations volunteered to participate, namely

- US Army AMRDEC-SED, Honeywell, with TES-SAVi, Infinite Dimensions, Real-Time Innovation (RTI), and Textron Systems.

Each Organization was afforded the opportunity to present their efforts, demonstrate operations, and share lessons learned. The Pilot Event was deemed a success as out-briefed to the Consortium's General Session.

The FACE IWS Challenge – Cross Integrate Individual FACE Development Efforts

At the conclusion of the five BITS presentations, the FACE IWS Vice-Chair posed a challenge to Honeywell and RTI for them to investigate the cross-integration of their individual efforts. Honeywell and RTI, together with TES-SAVi accepted the challenge and produced a fully functional cross-integration of the Honeywell/TES-SAVi demonstration with the RTI TSS.

Cross-Integration of the FACE Technical Standard

Higher-order fidelity is demonstrated when two or more individual efforts are combined. It helps to illustrate that system-of-systems integration is not only possible, but can be achieved in a rapid manner with well-defined open interface specification, like the FACE Technical Standard, and with the use of model-based tools built to support the eco-system.

The Scope of the Cross Integration

The integration team included 5 FACE member organizations with individual BITS participant's products. Brief summaries of the participant's products are introduced below, with details of the cross-integration efforts.

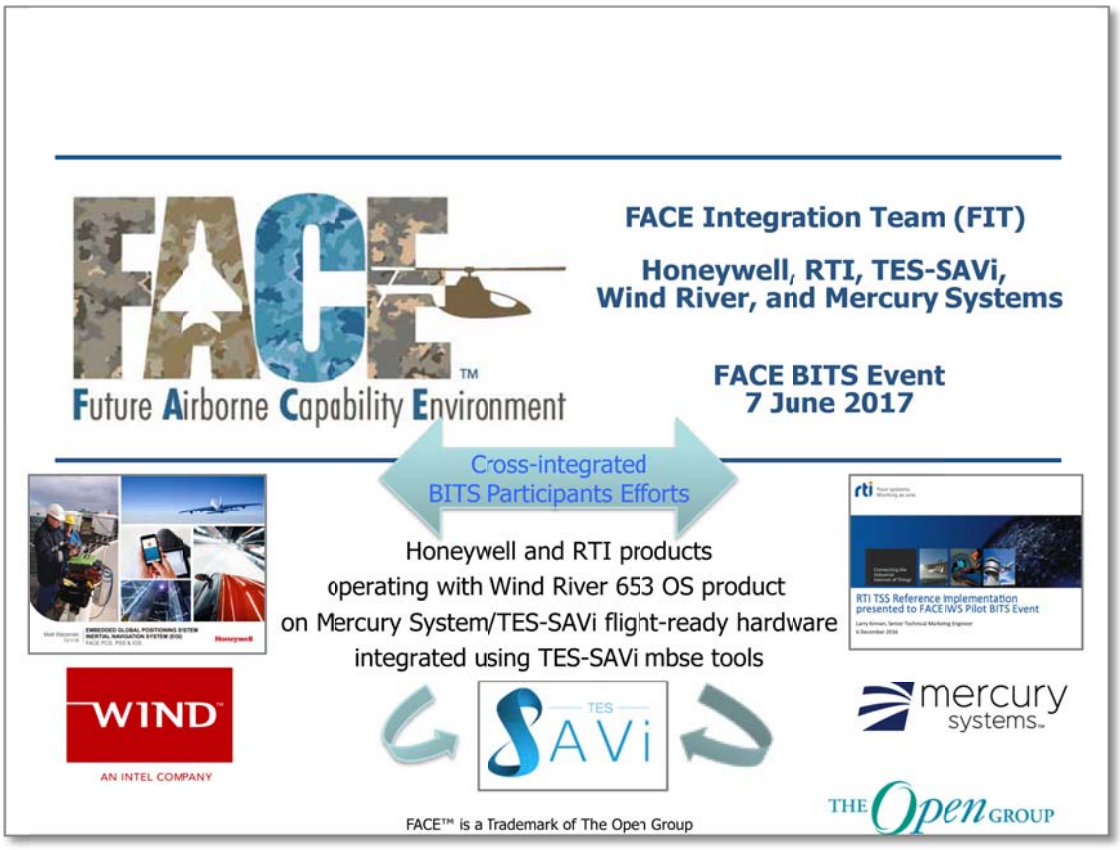
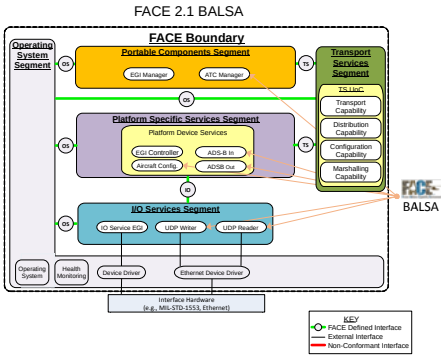


Figure 2 - Individual BITS Efforts – Available on FACE Plato Site

Our approach to FACE BALSA integrations was to begin with the FACE reference architecture implementation (i.e., BALSA) and progressively layer in and integrate each participant's product. The table below illustrates this sequential progression with corresponding descriptions of each participant's FACE product.



FACE BALSA, v 2.1

Reference Architecture

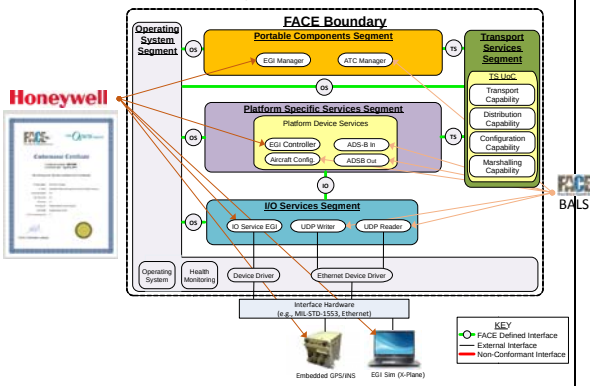
All BITS participants must begin with BALSA, the FACE Reference Architecture implementation. The BALSA Software, FACE USM (user supplied model) for BALSA, and corresponding FACE artifacts are available only to FACE Consortium Members at

https://www.opengroup.us/face/BITS/protected/documents.php

click on the "Documents" tab

Honeywell

Honeywell EGI – FACE 2.1 BALSA



***FACE Conformant,* April 2017**

The Honeywell EGI – Embedded Global Positioning Systems-Inertial Navigation System (EGI)

Honeywell's EGI began as a Army/Navy/Air Force program that developed a small, reliable, lightweight navigation and guidance unit that contains precise position service GPS on one standard electronic module, and has a ring laser gyro inertial navigation system.

Enhanced FACE Conformant software allows for the rapid integration into FACE open architectures. To reduce integration costs, and increase interoperability, Honeywell chose the FACE Standard, for it has become the de facto standard interface of choice for current military aviation acquisition efforts.

Honeywell's EGI includes a FACE PCS, TSS, PSS, and a FACE User Supplied Data Model. The software suite and data model is FACE Conformant. TES assisted Honeywell align the EGI software with the FACE Technical Standard and supported Honeywell during the BITS Pilot Event. Post event, Honeywell contracted TES-SAVi FACE VA services.

Honeywell

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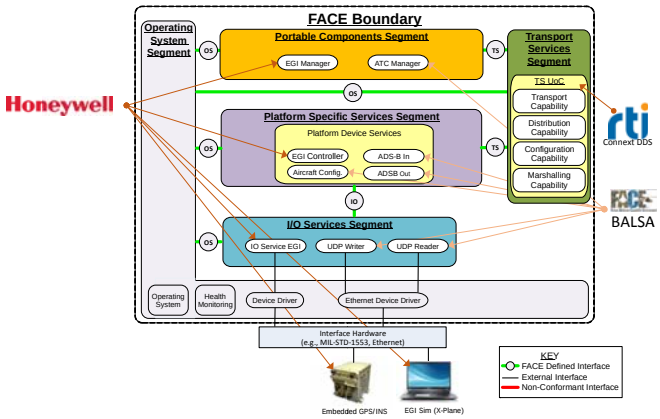
Honeywell EGI – FACE 2.1 BALSA



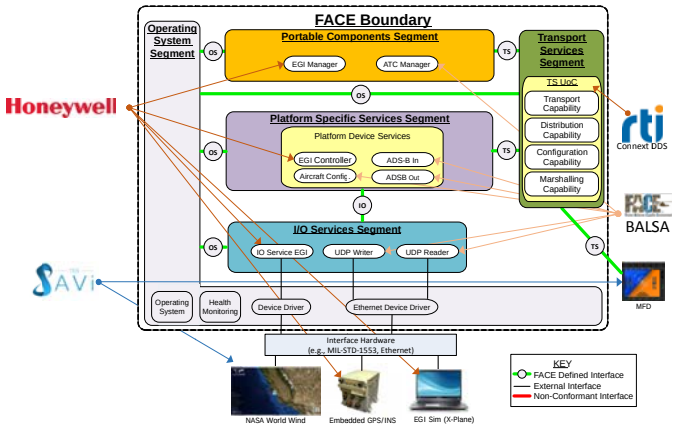
RTI's DDS – FACE TSS Implementation

(submitted to FACE VA)

RTI Connext DDS (Data Distribution Service) is a DDS specification compliant middleware product line that provides well-defined interfaces and plug-and-play interoperability between heterogeneous system components. It simplifies communications with high-level APIs for data sharing, publish-subscribe, request-reply and queuing. Libraries support all major programming languages and operating systems. Tools support monitoring, debug, database integration, data recording and data playback.

RTI has developed a reference implementation for a FACE TSS on top of its Connext product which is a technology readiness level (TRL) level 9 product. The TSS is implemented as a software adaptation layer over RTI's core Connext DDS functionality. This combination provides a TSS implementation that exposes an open wire-standard protocol, Real-Time Publish Subscribe (RTPS), enabling use of existing RTI and third-party software tools without modification.

Honeywell EGI – FACE 2.1 BALSA



TES-SAVi – Model-Based Tools for FACE Product Development

FACE Verification Authority, sanctioned May 2014

TES resources with TES-SAVi tools were used to develop and integrate Honeywell and RTI FACE software products; and TES-SAVi FACE VA resources were contracted to conduct the verification efforts for the Honeywell EGI and Wind River VxWorks 653 products.

(see http://www.opengroup.org/face/third-party-tools ;

and https://tes-savi.com/services/face-verification-authority/)

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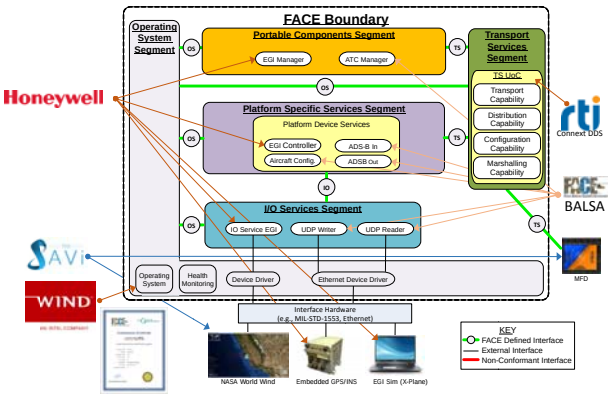
Honeywell EGI – FACE 2.1 BALSA



FACE Conformant, March 2017

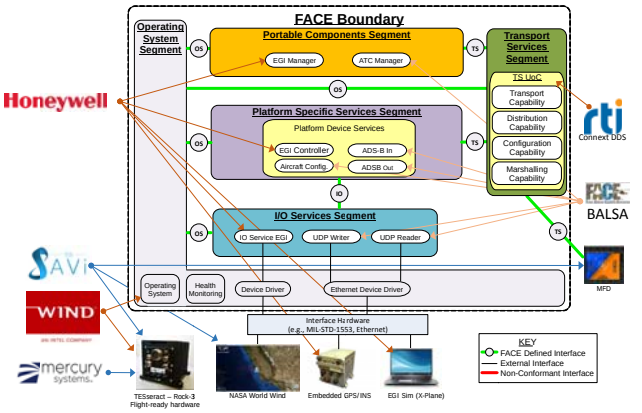
Wind River's VxWorks 653

Wind River's VxWorks 653 product is the global standard for open, partitioned critical systems and is now used in over 4000 programs, by over 200 customers in 80 aircraft using the ARINC 653 standard with RTCA DO-178B and DO-178C certification requirements for both single-core and multi-core systems.

VxWorks 653 supports multiple levels of safety on a single compute platform, and has COTS DO-178C DAL A certification evidence available for FAA-certified systems.

WIND
AN INTEL COMPANY

Honeywell EGI – FACE 2.1 BALSA



mercury systems™

TES SAVi

Mercury Systems & TES-SAVi

Mercury Systems / TES-SAVi Flight-Ready Processing Hardware prepared specifically for Developments and Deployments of FACE Products

Introducing TESseract™ for FACE Developers and FACE Platforms. TESseract™ (a Tucson Embedded Systems, Inc.,TES-SAVi, Mercury Systems, and FlightWire partnership) is a scalable off-the-shelf solution for rugged, flight capable UAS computers hosting FACE architectures. TESseract VNXx4 is the first in a line of expanding systems, which can grow as needs change, from a small 2-card systems, to a fully redundant 8-slot solutions.

TES-SAVi's TESseract™ processor is loaded with a common operating environment for FACE v2.1 and architecture libraries.

TESseract™ is prepared to support a wide-range of Military avionics, embedded development or real-time safety-critical operations (see https://tes-savi.com/services/face-verification-authority/).

FACE Integration Team Combined Integration Efforts

An illustration of the 5 member team products once integrated, looks like Figure 3.

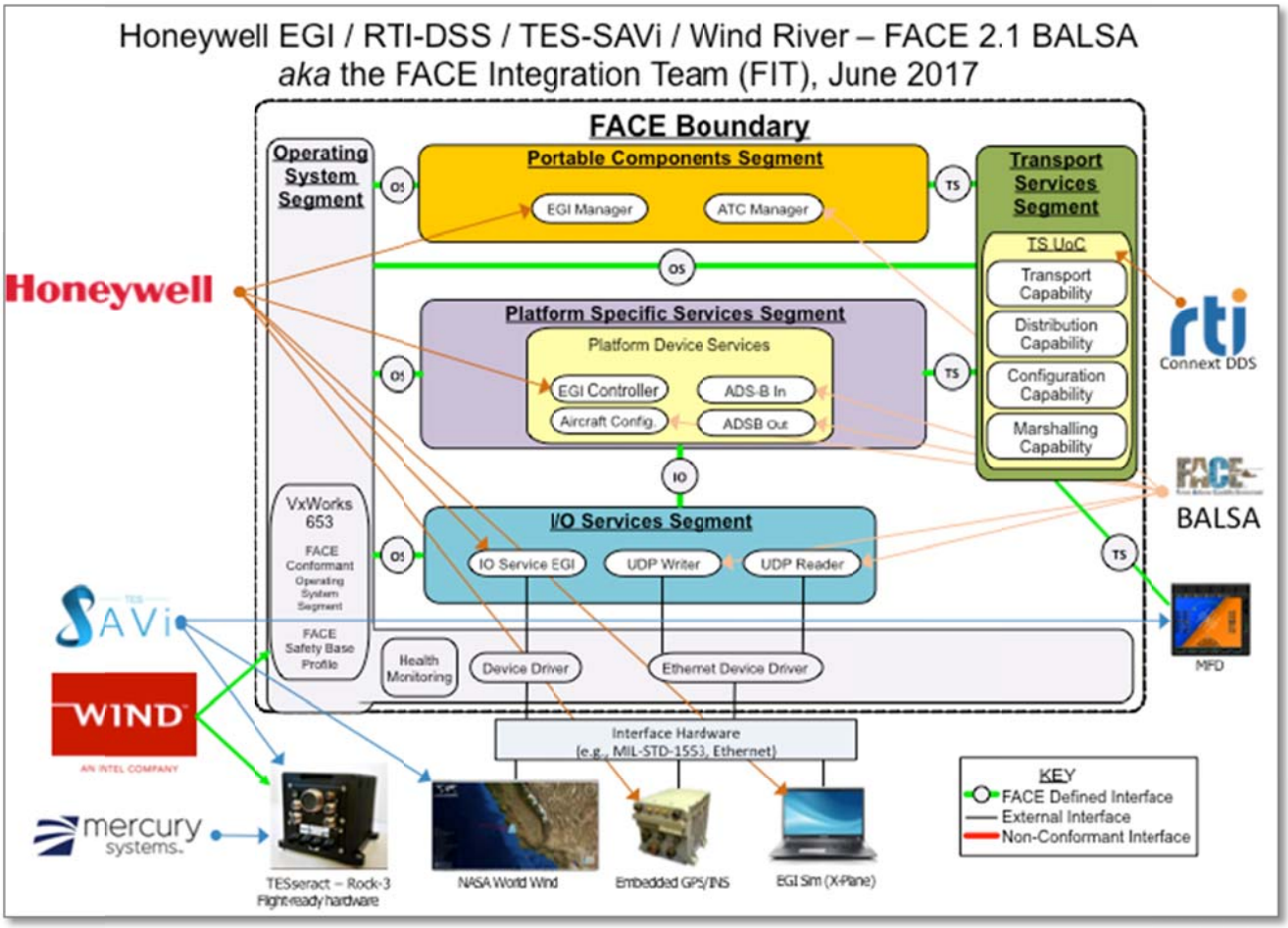


Figure 3 - Five Member Product Integration Efforts

TES/TES-SAVi assisting the cross-integration with FACE aligned Tools and Experience

Firstly, it helped that TES was well versed with the Honeywell EGI ahead of the Pilot BITS event, for they had worked with a previous implementation of the Honeywell EGI PSS driver, which was previously used on an Army program[1].

[1] US Army AMRDEC-SED EGI Integration efforts into AMRDEC's Modular Integrated Survivability (MIS) S&T project.

FACE Cross-Integration Successes – Honeywell, RTI, TES-SAVi, Wind River, and Mercury Systems, 2017 FACE BITS Event

During the EGI FACE Development and BALSA integration effort, TES converted the existing Honeywell FACE data model, modifying it to be aligned with the existing BALSA Data Model. These components pass the sanctioned FACE conformance test suite (CTS) for v2.1. For demonstration purposes, the scope of Honeywell EGI development was constrained to four of the most commonly used messages for EGI data.

TES was able to leverage their TES-SAVi FAME™ and AWESUM® model-based tools suite[2] for the FACE data model development, the auto-generation of EGI control code, the auto-generation of the full type specific TSS code including marshalling and de-marshalling code, and the auto-generation of the artifact documentation -- with all of these by-products aligned to the FACE Technical Standard, v2.1, and used to support Honeywell EGI's FACE Verification efforts.

After the conclusion of the FACE BITS Event, and in support of the IWS cross-integration challenge, TES resources worked with RTI resources and cross-integrated these individual FACE implementations. TES merged the Honeywell EGI429 data model and the FACE BALSA v2.1.1 data model; TES and RTI removed the BALSA TSS, and compiled in RTI's DDS TSS. TES and RTI resources used 3rd party tools (i.e., TES-SAVi AWESUM® and FAME™) and auto-generated the IDL data types from the merged Honeywell BALSA data model. They leveraged RTI tools to monitor message TSS message traffic during integration efforts.

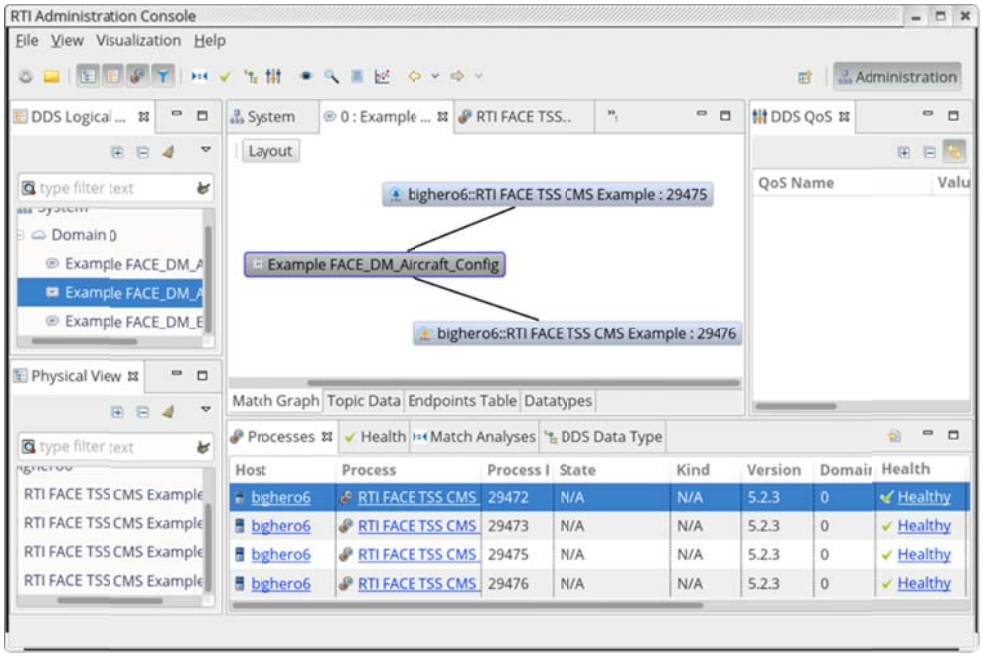


Figure 4 – Admin Console Screenshot of the RTI FACE BALSA Cross-Integration

[2] Visit https://tes-savi.com/awesum-products/ for additional information on these products

Shown above in Figure 4, RTI's Administrative Console was used by these FACE BALSA cross-integrators to enhance the visibility of TSS message traffic and endpoints. Other RTI tooling supports monitoring, database integration, and data recording and playback. Open standards underlying the RTI Connext DDS implementation permitted the use of this tool, and helped speed integration efforts.

After a few iterations, the Honeywell EGI and RTI DDS with Wind River's VxWorks 653 FACE Conformant operating system running on the TESseract™ hardware cross-integration were complete.

FACE Conformance Testing

One criteria of the FACE BITS event, and a metric of success, is to integrate with BALSA and demonstrate the alignment to the FACE Technical Standard by verifying that the implementation "PASSED" the FACE Conformance Test Suite (i.e., CTS version 2.1.0r4). After TES and RTI integrated, compiled, and worked through a few integration issues, they were able to run the CTS and obtain "PASSED" results, as shown below in Figure 5. These passing results also helped support Honeywell's FACE Conformance efforts.

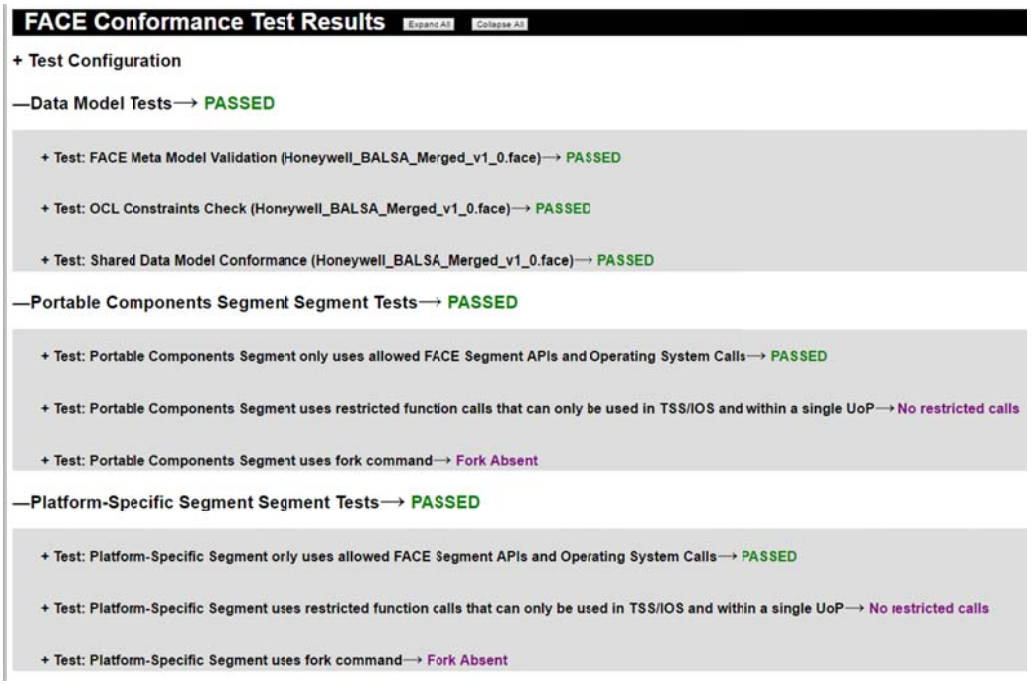


Figure 5 - FACE Conformance Test Results of Cross-Integration

Figures 3 & 5 reveal the complexity and scope of the FACE developments and cross-integrations performed by these 5 FACE Consortium Organizations, e.g., Data Modeling, PCS, PSSS segments, and DDS TSS.

Demonstration of the Cross-Integration

The cross-integration team was able to run the operations of the 6-product combined cross integrated.

Figure 6 – Demonstration of Operations of the 6-product Cross-Integration

Figure 6 above shows the operations of the Honeywell EGI operating within the FACE BALSA, transporting messages across the RTI DDS TSS, on Wind River's VxWorks 653 FACE Conformant operating system product. Each UoC is color-coded corresponding to its segment (i.e., PCS, PSS, TSS). TES-SAVi's PVI (pilot vehicle interface) displays and a common operation view[3] help confirm proper operations of the virtual integration and demonstrate functionality. A movie of these operations is available to the reader embedded within the presentation located on the FACE Plato site[4], https://www.opengroup.us/face/BITS/protected/documents.php.

Quantifications of LOE

A stated objective of the BITS event was to quantify the level-of-effort (LOE) of FACE integration efforts using BALSA. Individual and combined BALSA integration efforts are summarized.

Honeywell noted that the FACE EGI development and FACE BALSA integration, included the FACE software development of multiple FACE UoCs and efforts to develop a FACE user supplied data model,

[3] Applications written using DiSTI and NASA WorldWind software development kits (SDKs)
[4] FACE IWS Integration Workshop (IWS) Standing Committee – BITS Pilot Event – Cross Integration of BITS Participants Efforts, December 2016, FACE Plato Site.

required approximately 4 weeks of 2 engineers. Noteworthy is that these 2 senior software engineers had extensive FACE experience, including FACE data model experience, and access and experience with in-house TES-SAVi MBSE tools for FACE Developments. As mentioned earlier, the FACE EGI *development scope was limited to 4 EGI messages.*

RTI noted that replacing the FACE BALSA TSS with the RTI TSS reference implementation required 6 person days of engineers with extensive TSS experience. Manual generation and testing of the IDL, which is the required input format for the reference implementation based on RTI Connext DDS, from BALSA C++ source files required 3-person days. Another 3-person days were required for modifications required to fully integrate and test the TSS reference implementation with BALSA. RTI invested a total 2+ weeks of effort. The *scope transport services segment was limited to only 3 message types.*

Post BITS Pilot event, TES and RTI resources occupied Harris Corporation's hallway space, shared code and performed the cross-integration. They spent 4 hours using 2 experienced resources, began during the lunch break and by the close-of-business (COB) they completed the cross-integration of FACE BALSA efforts. These efforts were in part due to the well-defined interfaces specified by the FACE Technical Standard, and in part due to convenient access to 3rd party tools that support FACE software development (further discussed in the last section of this paper, with automation capabilities leveraged).

First-time Cross-Integrations of Commercial Products

The June 2017 BIT event represented the first-time cross integration of a real-time operating system and hardware processing platform added the element of configuring three commercial products; 1) communication of the RTI (micro) DDS TSS, with 2) Wind River's 653 operating system, operating on TES-SAVi's TESseract™ based on Mercury Systems' Rock-3 processing hardware. Three organizations each with one engineer, with TES engineering, estimate the level of effort for the integration to be 3 man-weeks each.

Cross-Integration Lesson's Learned and Experiences

Honeywell – RTI DDS -- Most of the time was spent identifying and synchronizing the usage of dissimilar BALSA builds, i.e., Honeywell-TES used BALSA v.2.1.3 whereas RTI used BALSA v.2.1.1. A key enabler was having TES-SAVi automate IDL generation for the BALSA and non-BALSA data types produced from the data model. This allowed quick integration with the RTI TSS reference implementation. Then with visibility to individual efforts, some additional time was spent correcting the usage of message types. Overall, the cross-integration of these individual efforts aligned to the FACE Technical Standard went fairly smoothly for these two strongly motivated resources were eager to prove-out and showcase the benefits of the FACE Technical Standard.

RTI and Wind River on Mercury/TES-SAVi Hardware -- The first-time cross integration of FACE Conformant Wind River VxWorks 653 real-time operating system, and the communication component of RTI's Connext DDS Micro required several engineers time to configure and match memory allocations to application needs.

Importance to FACE and Future System-of-Systems Cross-Integrations

The FACE™ Technical Standard is one solution envisioned to assist with future needs foreseen for the Future Vertical Lift Family of Systems (FVL FoS) [5,6,7,8]. Other solutions include HOST, OMS, JCA, and SOSA. These Open Systems Standards along with the recent innovations of model-based systems engineering (MBSE) practices and tools[9], brings forth a new age in software portability, software reuse, and the opportunity for rapid integration of military aviation capabilities and their applications hosted on safe and secure modular avionics architectures.

> "Efficient and cost-effective deployment of software intensive cyber physical systems (CPS) in military aircraft remains one of most complex and challenging issues facing Government Program Managers. Current tools and methodologies are not adequate for the development and certification of CPS as they create affordability and schedule dilemmas for current and future programs." "Furthermore, aircraft systems are composed of numerous CPS in a system-of-systems framework." [10] (c.f., Figure 1 - System-of-Systems - Complexity of Next-Generation Aircraft)

Cross-integration studies like these conducted with the FACE IWS BITS event using FACE Open Systems products will further the *state of knowledge*, help prepare the FACE community toward building our next-generation war-fighting capabilities, and position us to align with Better Buying Power initiatives. This is why this FACE BITS event and these FACE cross-integration successes are so important to the Government Military Aviation Community.

Acknowledgment and Thanks to FACE IWS

The Authors would like to thank the Leadership and Members of the FACE Integration Workshop for their efforts on the FACE Software Supplier Getting Started Guide and the FACE BITS Event, which together serve to accelerate the momentum of the FACE Consortium and push-forward the adoption of the FACE Technical Standard.

> Alicia Taylor, IWS Chair and Stephen Simi, IWS Vice-Chair; and BALSA Developers, Joel Sherrill and Chris Crook. FACE Consortium Membership, Michael Hickey, and FACE Consortium Leadership, Judy Cerenzia, and Kirk Avery, Chair of Technical Working Group

[5] "*Aviation 2050 Vision - Technology for Tactics*", 2013, Dr. Bill Lewis, Director of the AMRDEC's Aviation Development Directorate

[6] Innovation and Modernization Projects Affecting Capabilities and Technology (IMPACT): The Airworthiness of Complex Systems, Final Report v1.0, US Army Aviation Development Directorate (ADD), January 2015, Contract W31P4Q-10-D-0092 DO84, prepared by The University of Alabama in Huntsville.

[7] US Army AMREDEC, *"Future Vertical Lift Science and Technology Industry Review" briefings, March 2016*

[8] US Army AMREDEC, *"ADD Industry Days" briefings, March 2016*

[9] Innovation and Modernization Projects Affecting Capabilities and Technology (IMPACT): The Airworthiness of Complex Systems, Final Report v1.0, US Army Aviation Development Directorate (ADD), January 2015, Contract W31P4Q-10-D-0092 DO84, prepared by The University of Alabama in Huntsville.

[10] Next-Generation Model-Based Systems Engineering Processes and Tools Supporting the Airworthiness of Cyber Physical Systems, AHS 72nd Annual Forum, 2016, Simi, Mulholland; and Merrit-AMRDEC-ADD.

A look behind the scene Developing to the FACE Technical Standard using MBSE tools and processes

Model-based Tooling used for FACE Development efforts

Besides having motivated teams of experienced FACE Developers at Honeywell, TES-SAVi, and RTI, success of this FACE cross-integration was in-part achieved by model-based system engineering (MBSE) processes and tools specifically designed to produce product that aligns to the FACE Technical Standard and aligned to Airworthiness qualification processes. Those familiar with the RTCA DO-178C[11] and its model-based supplement DO-331[12], have heard the theory…

> *Once a model is sufficiently described, then one can generate control software, tests, and lifecycle documentation.*

TES has experience with FACE Data Modeling, and after a few attempts they were successful developing the Army's First FACE Verified Product – R2C2[13]. And with their previous experience with Honeywell's EGI, and access to their FAME™ and AWESUM® MBSE tool-suites, they were in prime position to support FACE development services for these cross-integration efforts. Success of this cross-integration under this short-time line was indeed aided by RTI's very experienced FACE developer.

Model-based Tooling used for FACE Development effort – Honeywell EGI efforts – Top-Down

Using MBSE tooling, TES developed a fully-conformant FACE Data Model for the Honeywell EGI (i.e., 4 messages), merged that model with the FACE BALSA data model. After the data model merge, they ran and verified the combined models with the FACE CTS to ensure alignment to the Standard. Next TES used the AWESUM® Develop module and auto-generated 100% of the FACE TSS C++ Honeywell EGI Control and message code. Again they ran and verified the combined models and the FACE UoCs with the FACE CTS to ensure alignment to the Standard (results shown in Figure above). Lastly, using the AWESUM® Qualify module, TES auto-generated the Honeywell EGI Capability Interface Description (CID), design documentation useful for FACE verification efforts. More information on these MBSE tools is available on TES-SAVi website.

[11] RTCA DO-178C – "*Software Considerations in Airborne Systems and Equipment Certification*", December 2011.
[12] RTCA DO-331 – "*Model-Based Development and Verification Supplement to DO-178C and DO-278A*", RTCA Dec. 2011.
[13] R2C2 - Reusable Radio Control Component – is a FACE™ verified communications domain application, August 2016. R2C2 is written to FAA's DO-178B Level-C Design Assurance Level (DAL), is aligned to the FACE™ reference architecture standard, and to the FAA's AC-20-148 guideline for reusable software components. R2C2 has been experimentally integrated by two other FACE Consortium organizations supporting US Army Aviation studies.

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Model-based Tooling used for FACE Development effort – US Army R2C2 efforts – Bottom-Up

While the above process represented a *top-down* data model design process, in an adjunct *bottom-up* process specifically that used in the aforementioned Army's R2C2 FACE development effort, TES began with an STT/Link-16 device Interface Control Document (ICD), entered the device ICD into the AWESUM® Development module. They auto-generated Device capabilities, then auto-generated 60% of the FACE Data Model (v2.1)[14], 100% of the TSS C++ control code and the CID[15] documentation. It is these MBSE tools and processes that assisted in the FACE development, BALSA integration, and cross-integration efforts in short time lines.

Model-based Tooling used for FACE Development effort – Cross Integration Efforts

During the FACE IWS BITS cross-integration challenge, TES was able to auto-generate the IDL from the combined Honeywell EGI and BALSA data models. RTI used that IDL to auto-generate the RTI DDS TSS message code. The two TES and RTI software engineers then re-compiled the combined software and checked it using the FACE Conformance Test Suite (CTS).

Indeed these FACE IWS Participants showed that separate software systems provided from different developing organizations, written to the FACE Standard and integrated into common reference architecture (BALSA) that share a common FACE data model, can be effectively and efficiently combined and demonstrated representing an operational systems-of-systems – *Indeed it Can; Indeed they Did!!*

Model-based Tooling used for FACE Development effort – Exhibited at FACE NAVAIR TIM

Showcasing these Successes -- Honeywell, RTI, and TES-SAVi, Wind River, and Mercury Systems plan on exhibiting together and demonstrating these FACE development capabilities to interested Consortium Members during the NAVIAR FACE TIM in Pax River on 18th of October 2017. Come visit us in FACE Exhibitor booths. If you cannot attend this TIM, simply reach-out to any Author to obtain additional information.

[14] TES-SAVi AWESUM® Auto-generated model consists of 100% complete UoP and 100% of the platform models ~60% complete. 40% tasks remain to complete the conceptual and logical models. The conceptual model observables need to be chosen, and the logical model measurements need to be defined.

[15] Capability Interface Description (CID) is an amalgamation of 3 data item descriptions. The combination accommodates higher-order non-language specific interface characteristics of an Interface Control Document (ICD) with lower-level language-specific design descriptions (i.e., IDD & DBDD). This provides complete specificity required for message traffic implementation and platform system integration. Correspondingly, this CID is written in accordance with DI-SESS-81876, MIL-STD-3046 Interface Control Document (ICD), DI-IPSC-81436A – Interface Design Description (IDD), and DI-IPSC-81437A – Database Design Description (DBDD). The CID meets DO-178C objectives identified in the Plan for Software Acceptance Compliance (PSAC). It draws upon guidance from DoD-STD-2167A—Defense System Software Development Best Manufacturing Practices, the Developer's Handbook for Airworthy Reusable FACE Units of Conformance, and the FAA's AC-20-148 Reuse Guidelines documentation.

References

[1.1] U. S. Army Aviation and Missile Research Development and Engineering Center (AMRDEC) Software Engineering Directorate (SED) is a recognized leader in supporting the acquisition, research, development, and sustainment of some of our Nation's sophisticated weapon systems. The Aviation Engineering Directorate (AED) is the Airworthiness authority for Army- developed aircraft.

[1.2] MIS – Modular Integrated Survivability – is a FACE™ candidate situational awareness domain product and simulation. The simulation suite models the aircraft platforms, simulates flight, and controls the operations of actual or simulated aircraft survivability equipment (ASE) to illustrate enhanced situational awareness (SA) of the platform in flight in DVE conditions. ROSAS – route optimization for survivability against sensors, is the follow on program of the MIS S&T

[2] Visit https://tes-savi.com/awesum-products/ for additional information on these MBSE products

[4] FACE IWS Integration Workshop (IWS) Standing Committee – BITS Pilot Event – Cross Integration of BITS Participants Efforts, December 2016, FACE Plato Site.

[5] "Aviation 2050 Vision - Technology for Tactics", 2013, Dr. Bill Lewis, Director of the AMRDEC's Aviation Development Directorate

[6] Innovation and Modernization Projects Affecting Capabilities and Technology (IMPACT): The Airworthiness of Complex Systems, Final Report v1.0, US Army Aviation Development Directorate (ADD), January 2015, Contract W31P4Q-10-D-0092 DO84, prepared by The University of Alabama in Huntsville.

[7] US Army AMREDEC, “Future Vertical Lift Science and Technology Industry Review” briefings, March 2016

[8] US Army AMREDEC, “ADD Industry Days” briefings, March 2016

[9] Innovation and Modernization Projects Affecting Capabilities and Technology (IMPACT): The Airworthiness of Complex Systems, Final Report v1.0, US Army Aviation Development Directorate (ADD), January 2015, Contract W31P4Q-10-D-0092 DO84, prepared by The University of Alabama in Huntsville.

[10] Next-Generation Model-Based Systems Engineering Processes and Tools Supporting the Airworthiness of Cyber Physical Systems, AHS 72nd Annual Forum, 2016, Simi, Mulholland; and Merrit-AMRDEC-ADD.

[11] RTCA DO-178C – “Software Considerations in Airborne Systems and Equipment Certification”, December 2011.

[12] RTCA DO-331 – “Model-Based Development and Verification Supplement to DO-178C and DO-278A”, RTCA Dec. 2011.

[13] R2C2 - Reusable Radio Control Component – is a FACE™ verified communications domain application, August 2016. R2C2 is written to FAA’s DO-178B Level-C Design Assurance Level (DAL), is aligned to the FACE™ reference architecture standard, and to the FAA’s AC-20-148 guideline for reusable software components. R2C2 has been experimentally integrated by three other FACE Consortium organizations supporting US Army Aviation studies.

About the Author(s)

Stephen M. Simi, TES-SAVi - serves as TES-SAVI's Vice-President and Program Manager for Military Aviation programs. Stephen has 30 years of experience design and developing engineering and scientific applications, and managing multiple programs. Since 2010, Stephen has been very active in the FACE Consortium's Integration WorkShop (IWS) – Vice-Chair, the Steering Committee, and Outreach, Conformance, and Airworthiness sub-committees, and has exhibited at every FACE Technical Interchange Meeting (TIM). He is recognized as an industry innovator of agile technologies that can be applied to Joint forces across the common operating picture/battlespace of C4ISR assets, and an industry expert in lifecycle development of reusable software systems. He has authored numerous technical publications and presented to the AHS, AOC, AIAA/IEEE societies, to the FACE Consortium and MITRE on areas of software development, reusable systems, and advanced modeling and simulations of those systems. Stephen has managed 5 US Army programs, JCA, MIS, R2C2, UC3, and MICD for TES, for the US Army Aviation.

Stephen has a B.S. in Physical Sciences (Math, Computer Sciences, and Engineering) and a M.S. in Engineering from the University of Maryland. Before working for TES, Stephen served as the Director of Software Development, and Director of Software Business Development at world-renown optics company Breault Research. He also served as a technical fellow at the MITRE Corporation for the US Army; Boeing Co. working on the International Space Station; was a college professor of Computer Science; and served various other organizations designing, developing, and testing engineering and scientific applications over his 30-year technical career.

Matt Warpinski, Honeywell, is a Principal Software and Systems Engineer with Honeywell. Matt has served on the FACE Consortium for 3 years, implemented a handful of FACE Aligned programs, including the EGI Integration in the Army MIS Lab. He was the Principal Investigator and Verification lead on the JCA Demonstration effort and was a key resource on many other internal FACE programs. He currently sits on the FACE General Enhancements and IWS Subcommittees. He has extensive knowledge in UAV development, requirements verification, and systems and software integration.

Mark Swick, RTI, is a System Architect who provides architecture analysis, guidance, and implementation assistance for a wide variety of developers of real-time distributed computing systems on behalf of Real-Time Innovations. Customers have included the US Navy, US Army, US Air Force, NASA (and their prime contractors), as well as commercial system developers (e.g. automotive, industrial control, medical, and oil and gas). Systems range in scale can complexity from just a few homogenous, self-contained processors and applications over a single network, to hundreds of heterogeneous processors and applications over several networks, which interact with other disparate external systems. Mark has over 35 years of experience with such systems and has a Bachelor of Science in Physics and Mathematics from Mary Washington College.

Mark was the Data Model lead for the Unmanned Aircraft System (UAS) Control Segment (UCS) Architecture effort and worked with FACE in that role to align the respective data models. He participates in the FACE TWG Transport Services Subcommittee.

Andre Odermatt, RTI, is a Senior Technical Marketing Engineer at RTI. Before joining the Products & Markets group at RTI Andre was a Field Application Engineer at RTI for 5 years working with customers on distributed systems. He has been participating in the FACE Consortium's Integration WorkShop (IWS)

meetings. As Field Application Engineer he supported multiple projects including the Ship Self Defense System (SSDS), General Atomics Ground Control Station, Boeing AWACS among others. Andre has over 30 years of experience with embedded systems, distributed applications, and communications protocols.

Ken Erickson, TES-SAVi, is a Software Engineer 5 and our Security Subject Matter Expert within Tucson Embedded Systems and has been with TES for over 19 years. Ken has a B.S. in Computer Science and Bachelor of Computer Engineering from the University of Minnesota, Duluth. Ken has 26 years of experience in real-time and embedded software and systems requirements, design, development, integration and test, including both mission and safety critical systems. He is an active participant in the FACE TWG Transport Services Subcommittee, FACE SECURITY CRADA Working Group, FACE TWG Security Subcommittee, FACE Integration Workshop Standing Committee, and Integration Workshop – Getting Started Guide Subcommittee as well as a member of the TES-SAVi FACE Verification Authority team. Verification work includes conformance testing of TES created FACE 2.0 and 2.1 Technical Standard TSS, PSSS, Data Models and a vendor OSS.

Tom Brixey, TES-SAVi, is a Senior Software and Systems Engineer, a member of the data modeling staff with TES-SAVi Military Aviation Systems Division, and served as a key contributor creating FACE data models for the following US Army projects: Modular Integrated System (MIS), Reusable Radio Control Component (R2C2), and the Honeywell EGI. Tom is a model-based tool developer of the TES-SAVi FAME™ and AWESUM® tool suite. Tom serves as an active participant in the FACE IWS and FACE Data Architecture Working Group (DAWG). Tom is the contributing author of the Data Model Appendix A – Obtaining the FACE USM Data Model and Testing using the Conformance Test Suite of the IWS' Software Supplier Getting Started Guide. Tom a member of the TES-SAVi FACE Verification Authority team. Tom has over 20 years experience in Object-Oriented Analysis and Design and model-driven architecture, simulation, and translation of executable models. He is an advocate of rapid virtual integration and simulation of cyber-physical systems and aircraft modeling to support mission systems design, analysis, and evaluation. Tom has contributed to FACE Technical Interchange Meetings (TIMs) and also co-authored and has presented to American Helicopter Society (AHS) – "Enabling Situational Awareness and Network Centric Operations for Systems utilizing FACE™ Open Systems Architectures", 2013.

Chip Downing, Wind River, is the Senior Director of Aerospace and Defense at Wind River Systems. In this business leadership position he manages Wind River's global aerospace and defense business, and helped drive the ARINC 653 industry standard into the commercial and military aerospace market with the Wind River VxWorks 653 platform, now used in over 400 programs by more than 200 customers in over 80 global aircraft.

Mr. Downing also serves as the elected Business Working Group Chair of the joint industry/government The Open Group Future Airborne Capabilities Environment (FACE™) Consortium, driving integrated modular avionics (IMA) design efficiencies, proven in commercial avionics systems, into next generation military avionics systems, which includes both ARINC 653 and POSIX foundations.

A 20-year veteran of the embedded systems industry and a pioneer in safety certification for commercial RTOSs, he previously was Vice-President of SCADE Global Sales for Esterel Technologies, selling a model-based design and development environment for DO-178B and IEC 61508 control systems. Mr. Downing has also led sales, marketing, and consulting organizations at Validated Software, OnCore Systems, Mentor Graphics, Qualix Group, Ready Systems, and CENCO, now part of the Safran Group, selling and delivering DO-178 and other high reliability and safety solutions.

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Scott Engle, Mercury Systems, is the Director of Business Development for Mercury Mission Systems a Business Unit inside Mercury Systems specializing in safety-critical computer systems. Scott has spent over 20 years in the Aerospace and Defense sector starting as a Systems Engineer at Hughes/Raytheon Missile Systems then over 16 years in the Field Engineering Organization with Wind River Systems. In his Business Development role at Mercury Systems, Scott is focusing on COTS DAL certified computer systems.

About The Open Group FACE™ Consortium

The Open Group Future Airborne Capability Environment (FACE™) Consortium, was formed 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.

About The Open Group

The Open Group is a global consortium that enables the achievement of business objectives through IT standards. With more than 500 member organizations, The Open Group has a diverse membership that spans all sectors of the IT community – customers, systems and solutions suppliers, tool vendors, integrators, and consultants, as well as academics and researchers – to:

- Capture, understand, and address current and emerging requirements, and establish policies and share best practices
- Facilitate interoperability, develop consensus, and evolve and integrate specifications and open source technologies
- Offer a comprehensive set of services to enhance the operational efficiency of consortia
- Operate the industry's premier certification service

Further information on The Open Group is available at www.opengroup.org.