Avionics Open Systems Architecture Standardization

Karl Shepherd
Pr. Systems Architect
Rockwell Collins
Cedar Rapids, IA, USA

Jeremy Wills
Pr. Systems Engineer
Rockwell Collins
Cedar Rapids, IA, USA

ABSTRACT

The United States (US) Department of Defense is requiring the use of open systems architectures to reduce the lifecycle cost and enable a more frequent upgrade of capabilities in current and new weapon systems. The US DoD and its military services are actively engaged in the development of many open architecture standards efforts, such as the FACE™, HOST, OMS, UCI, and SOSA™ Standards, through participation in standards consortiums and US Government led standards working groups. Our research builds upon Rockwell Collins prior and ongoing work in the development of open standards and implementation in our solutions. This paper will introduce relevant avionics open architecture standards, discuss the key attributes of each standard, compare the relationship among the standards, and examine technical approaches to develop integrated avionics solutions through the integration of systems and subsystems implemented with different open architecture standards. Following the discussion of the main concepts, the paper will present a case study detailing a hypothetical VTOL avionics system requiring integration of multiple OSA standards. The case study will concentrate on not only the technical aspects of physical/logical integration, but also on the procedural aspects of system engineering methodology.

INTRODUCTION

Open Systems has been an emphasis within the United States Department of Defense (DoD) for twenty years, initially focused on the interoperability of weapon systems. The DoD’s approach to Open Systems has evolved from weapon systems interoperability to include reuse of commercial technologies, and now with new DoD Acquisition Reform policies (i.e., Better Buying Power 3.0, etc.) (Ref. [1]), there is now a focus on open systems as part of the total life cycle to ensure weapon systems are affordable over their life. Specific aspects of the Acquisition Reform policies that are influencing the DoD’s Modular Open System Approach are:

- Achieve Affordable Programs
- Incentivize Innovation in Industry and Government
- Promote Effective Competition

More specifically, the United States National Defense Authorization Act (NDAA) for Fiscal Year 2017, Section 805 on Modular Open Systems Approach in Development of Major Weapon Systems states “A major defense acquisition program that receives Milestone A or Milestone B approval after January 1, 2019, shall be designed and developed, to the maximum extent practicable, with a modular open system approach to enable incremental development and enhance competition, innovation, and interoperability.” (Ref. [2])

Figure 1 provides a summary view of the architectural aspects and system depth across the Key Open Architecture Standards.

As a result of ongoing acquisition reform, there are a number of new open systems standards initiatives across the DoD and industry that are relevant for VTOL platforms. Those initiatives include but are not limited to:

- Future Airborne Capability Environment (FACE™)
- Hardware Open Systems Technologies (HOST)
- Open Radio Architecture
- Sensor Open Systems Architecture (SOSA™)
- Open Mission Systems (OMS)
- Joint Common Architecture (JCA)

Figure 1

This paper presents some updates on Rockwell Collins ongoing open systems experimentation and implementation activities, building off of our work (Ref. [3]) to implement a FACE computing environment in fielded systems and migrating key software capabilities to be FACE conformant. The rest of the paper is structured into sections that provide an overview of the above mentioned Open
Systems Architecture standards initiatives and a section that presents an analysis of how these Open Systems Architecture standards could be applied to a new VTOL aircraft development program.

**FACE ARCHITECTURE OVERVIEW**

The Future Airborne Capability Environment (FACE) initiative is focused on the creation of a common architecture that supports portable software capability reuse across systems. Some example Avionics software capabilities include: route planner, flight management system, digital map, and data link message processing. The FACE reference architecture is defined and documented in a technical standard (Ref. [4]) and a business guide (Ref. [5]).

The vision of the FACE Consortium (Ref. [6]) is to achieve the following objectives:

- “Standardized approaches for using open standards within avionics systems
- Lower implementation costs of FACE systems
- Standards that support a robust architecture and enable quality software development
- The use of standard interfaces that will lead to reuse of capabilities
- Portability of applications across multiple FACE systems and vendors
- Procurement of FACE conformant products
- More capabilities reaching the warfighter faster
- Innovation and competition within the avionics industry”

The FACE Technical Standard and business strategy development activity occurs through The Open Group FACE Consortium, a government and industry partnership. The FACE Consortium is a voluntary group with over 85 member organizations from the United States Department of Defense, Industry, and Academia. Rockwell Collins is one of the founding members of the consortium and shares sponsorship of the consortium along with US Navy (NAVAIR), US Army (PEO-Aviation), US Air Force (AFLCMC), Boeing, Lockheed Martin, and Raytheon. The FACE Consortium has been making incremental improvements to the technical standard as the government and industry has learned from experiments, and has recently released Edition 3.0 of the FACE Technical Standard. Edition 3.0 included key enhancements for portability and interoperability.

The FACE Technical Standard defines a modular software architecture, a common set of APIs, a data architecture, safety and security profiles, and conformance processes for independent verification and certification activities. The FACE architecture with its software segments and key interfaces are shown in Figure 2.

**Figure 2. FACE Architecture**

The architecture is divided into five segments in which software components with defined interfaces are allocated. The FACE segments provide architectural boundaries with defined key interfaces to support relevant applications of software modularity necessary to enable reusable software capabilities that lead to more affordable system life cycle. The five segments are:

- Portable Components Segment (PCS)
- Transport Services Segment (TSS)
- Platform Specific Services Segment (PSSS)
- I/O Services Segment (IOSS)
- Operating System Segment (OSS)

The architecture includes three key application program interfaces (APIs) to support both vertical and horizontal component to component interactions within the FACE architecture, and with aircraft sub-system components outside of the FACE architecture. The key APIs are:

- Operating System (OS) interface
- Transport Services (TS) interface
- Input Output (IO) interface

Key attributes of the FACE Technical Standard are summarized in Table 1.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>FACE™ Notes</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Open Systems Focus</strong></td>
<td>Portable Avionics SW Applications</td>
<td></td>
</tr>
<tr>
<td><strong>Sponsor</strong></td>
<td>USN NAVAIR, USA PEO-Aviation, USAF AFLCMC</td>
<td>Industry Sponsors Boeing, Lockheed Martin, Raytheon, and Rockwell Collins</td>
</tr>
<tr>
<td><strong>Platform Domain</strong></td>
<td>Avionics</td>
<td>Expanding outside of Cockpit Avionics to Avionics Mission Systems and Training</td>
</tr>
<tr>
<td>Product Domain</td>
<td>SW</td>
<td></td>
</tr>
<tr>
<td>---------------</td>
<td>-------------------------</td>
<td></td>
</tr>
<tr>
<td>Widely Adopted</td>
<td>Emerging Being used in DoD and Industry experiments, Government RFIs and RFPs; and select DoD Programs of Record</td>
<td></td>
</tr>
<tr>
<td>Growth Path</td>
<td>Yes Ongoing efforts to incorporate lessons learned to improve the standard</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Key FACE Standard Attributes

The FACE Technical Standard provides a reference architecture that enables the DoD and other user communities to achieve greater competition and cost saving through reuse of software capabilities across platform types, missions, and military services. To achieve the vision of the FACE Consortium and realize benefits to the DoD, aircraft will need to implement in part or in whole a computing environment that meets the FACE Reference Architecture. Rockwell Collins sees the FACE approach as part of a continuing evolution of open systems architectures and standards in the Aerospace and Defense Market that we have been part of for the past 20 years. We are supporting the development of the FACE Technical Standard and investing in the development of FACE implementations within our Avionics Systems. One example is Rockwell Collins is implementing a FACE Computing Environment and our Avoidance Re-Router (ARR-7000) FACE Conformant Certified software product in CAAS for a DoD Program. Another example is Rockwell Collins’ is implementing FACE software as part of the US Navy Tactical Combat Training System (TCTS) Increment II Program.

HOST ARCHITECTURE OVERVIEW

Hardware Open Systems Technologies (HOST) is a multi-tiered approach to specify embedded computing hardware components and systems making use of COTS technologies whenever possible. The goal of HOST is to reduce the cost and schedule impacts of acquiring, integrating and upgrading mission computing systems, through standardization, and ultimately commoditization, of interchangeable components. By compiling a registry of conforming hardware elements produced by multiple companies, HOST intends to avoid proprietary computing solutions which can lead to vendor-lock and obsolescence issues.

A summary of the HOST architectural goals (Ref. [7], [8] and [10]) are:

- Reduce reliance on proprietary and platform specific hardware
- Leverage industry standards for form factors and interfaces
- Provide open access to information necessary to produce hardware and software modules that are fully interoperable and interchangeable
- Establish registry of compliant components
- Provide a common hardware baseline for multiple applications (mission computers, displays, radios) and platforms (air, sea and ground vehicles), allowing economies of scale to reduce overall cost to the armed services

HOST specifications are organized into three tiers of documentation as shown in Figure 3.
Tier 1 is a single document that contains the overarching tenets of the open system, defines common terminology, and lays out the basic makeup of the architectures physical and logical domains. Tier 1 is agnostic to specific technologies and platforms. At a high level it defines a physical domain made up of modules, enclosures, external interfaces and transmission components as well as a logical domain governing resources, protocols and a high-level chassis management scheme (Ref. [7]).

Tier 2 documents are specific to a given core technology, such as OpenVPX, VME or others. While being platform agnostic, Tier 2 provides detailed requirements for the chosen technology. There is currently one Tier 2 specification available which utilizes the VITA 65.0 OpenVPX System Specification as the core hardware technology, and the VITA 46.11 and Intelligent Platform Management Interface (IPMI) standards for hardware management (Ref. [9]).

Tier 3 specifications define a particular component, flowing down Tier 2 requirements and potentially adding platform and performance specific requirements. While the actual low-level implementation of a component can remain proprietary, Tier 3 specifications are intended to provide sufficient detail to allow components from multiple vendors to be interchangeable (Ref. [7]). For example, a Tier 3 specification for a general purpose computing module would define a form factor (ie 3U OpenVPX Plug-In module), base technology (e.g. PowerPC), interface requirements, minimum performance and environmental requirements. A variety of modules could meet the basic requirements of the Tier 3 spec while differing significantly in processor generation used (e.g.7447, 7448, T2080) and additional features/capabilities.

Architecturally, HOST is organized into logical and physical domains as shown in Figure 4.
The Physical Domain includes the hardware modules, the enclosure that houses them and the physical interfaces that connect them both internally and to the external world. The Logical Domain defines a set of commonly required resources, transmission interfaces (protocols), and a Chassis Management scheme designed to monitor and organize hardware and software health status. Individual hardware modules can be optimized to support a given subset of logical resources depending on required functionality, while maintaining conforming interfaces to the chassis backplane and the wider system. The HOST Chassis Management protocol aides this modularity by creating a hierarchical scheme with each module performing a participant function interfacing with a single chassis manager function (manager is hosted on one of the modules as determined by the integrator). Participants provide status to, and respond to commands from, the manager. The Manager collects and organizes participant status, disseminates chassis-wide events and commands, and serves as an interface to higher level system managers.

Key Attributes of the HOST standard are summarized in Table 2.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>HOST</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Systems Focus</td>
<td>Reusable HW Modules</td>
<td>VITA 84 working group established for industry collaboration</td>
</tr>
</tbody>
</table>

The HOST effort is developing a reference architecture and standard for embedded computing with the goal of enabling the DoD and other user communities to achieve greater competition and cost saving through reuse of embedded computing hardware modules across platform types, missions, and military services. Rockwell Collins is actively involved in the HOST effort. The HOST standard continues...
to evolve and expand its scope of standardization definition. Rockwell Collins is building next generation computing system components which provision for HOST requirements as currently defined and recognizes the potential benefit to its own open system architecture product lines.

OPEN RADIO ARCHITECTURE OVERVIEW

The Open Radio Architecture is a concept activity to assess and investigate an architectural approach to modularize communication radios into reusable hardware and software modules. There are pockets within the industry and DoD looking at the viability of a communication radio architecture standard. As an example, the US Air Force released the Open Radio Communication Architecture (ORCA) RFI (Ref. [11]) to collect input from the market on architectural concepts that could be used to inform a framework for an Open Radio Architecture. There are similar concepts being led by the US Army CERDEC for a ground vehicle Modular Open Radio Frequency Architecture (MORA). Lockheed Martin has also released an Open Radio Architecture standard (ORA) which has been used in multiple demonstration programs to continue to develop and validate the architecture concepts.

A national architecture is shown in Figure 5 that could build off of the VITA 65.0 OpenVPX Standard for the definition of reusable hardware modules.

Key attributes of the Open Radio Architecture concept are summarized in Table 3.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Open Radio Architecture</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Systems Focus</td>
<td>Reusable HW Modules</td>
<td>Define modules as well as architecture, hardware and software interfaces</td>
</tr>
<tr>
<td>Sponsor</td>
<td>N/A</td>
<td>US Air Force has issued an RFI to gather industry input related to this concept, and there is industry experimentation to assess the feasibility of the concept</td>
</tr>
<tr>
<td>Platform Domain</td>
<td>Avionics</td>
<td></td>
</tr>
<tr>
<td>Product Domain</td>
<td>Communication Radios</td>
<td></td>
</tr>
<tr>
<td>Widely Adopted</td>
<td>No, Conceptual</td>
<td>Open Radio Architecture is currently conceptual, no standards group has been formed to develop a standard</td>
</tr>
<tr>
<td>Growth Path</td>
<td>TBD</td>
<td>Open Radio Architecture is currently conceptual, no standards group formed to develop and sustain a standard</td>
</tr>
</tbody>
</table>

Table 3. Key Open Radio Architecture Standard Attributes

The Open Radio Architecture concept is exploring the possibility of a communication radio architectural approach that modularizes the hardware and software to achieve greater openness and competition and decreased lifecycle costs.

SOSA ARCHITECTURE OVERVIEW

The Sensor Open Systems Architecture (SOSA) initiative is focused on the creation of a common sensor architecture that enables hardware and software module reuse across sensor types and solutions. Example sensor types are: Radio Detection and Ranging (RADAR), Signals Intelligence (SIGINT), Electronic Warfare (EW), Electro-Optical / Infrared (EO/IR), and Communication. The SOSA reference architecture, technical standard (Ref [12]), and business guide (Ref. [13]) are in development with periodic snapshots being created and released in draft form.
The vision of the SOSA Consortium is to create “Business/acquisition practices and a technical environment for sensors and C4ISR payloads that foster innovation, industry engagement, competition, and allow for rapid fielding of cost-effective capabilities and platform mission reconfiguration while minimizing logistical requirements” (Ref. [14]).

The SOSA architecture and standards development activity is modeled after the FACE architecture and standards development activity and occurs through The Open Group SOSA Consortium, a government and industry partnership. The SOSA Consortium is a voluntary group with 35 member organizations from the United States Department of Defense and Industry. The US Air Force (AFLCMC), US Army (PEO-Aviation), US Navy (NAVAIR), Lockheed Martin, Raytheon, and Rockwell Collins are the sponsoring members of the SOSA Consortium. The SOSA Consortium is composed of a Business Working Group; and four Technical Working Groups: Architecture, Electrical/Mechanical, Hardware, and Software to collaboratively develop the reference architecture and technical standard.

The SOSA Standard is defining a modular sensor architecture with well-defined external electrical, mechanical, and software interfaces; componentized internal hardware and software modules; and a conformance process.

The SOSA System Interfaces are shown in Figure 6.

![Figure 6. SOSA System Interfaces (Ref. [12])](image)

The SOSA Architecture supports sensors integrated directly to the platform and as part of a detachable pod subsystem.

The functional decomposition of the SOSA Sensor is divided into six top level modules:

- Manage SOSA Sensor
- Collect
- Process Signals / Targets
- Analyze / Exploit
- Convey
- Support System Operation

That are further decomposed into twenty-five services that a SOSA sensor may implement, depending upon the type of the sensor.

The architecture is building off and aligning with other standards activities for internal hardware and software modules, and leveraging the Open Mission Systems (OMS) Standard Messaging API for the external software interfaces. Thus defining a sensor specific standard between the OMS Standard at the subsystem level and the OpenVPX / HOST Standards at the hardware module level.

Key attributes of the SOSA Technical Standard are summarized in Table 4.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>SOSA™</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Systems Focus</td>
<td>Reusable HW/SW Modules</td>
<td></td>
</tr>
<tr>
<td>Sponsor</td>
<td>USN NAVAIR, USA PEO Aviation, USAF AFLCMC</td>
<td>Industry Sponsors Lockheed Martin, Raytheon, and Rockwell Collins</td>
</tr>
<tr>
<td>Platform Domain</td>
<td>Avionics (Payload)</td>
<td></td>
</tr>
</tbody>
</table>
The SOSA Consortium is developing a reference architecture and standard with the goal of enabling the DoD and other user communities to achieve greater competition and cost saving through reuse of sensor hardware and software modules across platform types, missions, and military services. Rockwell Collins sees the SOSA Standard as building off of the success of open systems architecture for Avionics Computing and enabling increased openness for sensors.

**OMS ARCHITECTURE OVERVIEW**

The Open Mission Systems (OMS) standard initiative is focused on the creation of a common architecture for mission system payloads and subsystems that enable greater reuse and decreased integration risk for mission systems.

The OMS reference architecture is defined and documented in a technical standard that is managed by the Air Force Life Cycle Management Center (AFLCMC) and its distribution is currently limited to the DoD and DoD Contractors. The material presented in this section is derived from publicly available information (Ref. [15], [16], [17], and [18]).

“The goal of Open Mission Systems (OMS) is to develop industry consensus for a non-proprietary mission system architectural standard that enables affordable technical refresh and insertion, simplified mission systems integration, service reuse and interoperability, and competition across the lifecycle.” (Ref [18])

The OMS architecture and standards development activity was initiated by the Air Force Rapid Capabilities Office in 2010 as a government funded collaborative working group with members from industry. This approach created an initial baseline in 2014. Incremental updates have been made based on knowledge gained through increased government and industry experimentation and demonstrations using OMS. In 2018, responsibility for the OMS standard transferred to the Open Architecture Management Office (OAMO) within the AFLCMC to sustain the OMS standard, provide training, and acquisition support to Program Request For Proposal (RFP).

The OMS Standard defines an aircraft mission system architecture that employs a service oriented architecture, defined message schema and software services API, and isolation from safety-critical aircraft subsystems.

The OMS architecture is shown in Figure 7.
Key attributes of the OMS Standard are summarized in Table 5.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>OMS</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Systems Focus</td>
<td>Mission Payload Reuse /</td>
<td>Originated with the USAF Rapid Capabilities Office (RCO), but is</td>
</tr>
<tr>
<td></td>
<td>Interchangeability</td>
<td>transitioning to the USAF AFLCMC</td>
</tr>
<tr>
<td>Sponsor</td>
<td>USAF AFLCMC</td>
<td></td>
</tr>
<tr>
<td>Platform Domain</td>
<td>Avionics (Mission System)</td>
<td></td>
</tr>
<tr>
<td>Product Domain</td>
<td>Mission Payloads</td>
<td></td>
</tr>
<tr>
<td>Widely Adopted</td>
<td>Emerging</td>
<td>Being used in government and industry experiments, government RFIs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and RFPs; and select government Programs of Record.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Interchangeability of like mission payloads across multiple suppliers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>demonstrated</td>
</tr>
<tr>
<td>Growth Path</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

**Table 5. Key OMS Standard Attributes**

The US Air Force through its collaboration with industry on the OMS FACE Systems Development (OFSD) (Ref. [17]) activity performed an assessment and experimented with how to enable interoperability between the OMS Standard and the FACE Technical Standard. The UCI messages were implemented using the FACE Data Model to demonstrate that mission software services could be implemented using the FACE Technical Standard and communicate with OMS mission payloads via the FACE Data Model implementation of the UCI messages. Rockwell Collins was a key industry partner with the US Air Force on the OFSD Program, providing analysis and recommendations on interoperability approaches for OMS and FACE; and experimentation through the integration and demonstration of our Mission FMS and Avoidance Re-Route FACE Conformant software applications.

The OMS Standard defines a reference architecture that enables the DoD to achieve cost savings through greater mission payload and software services reuse, while reducing the platform mission systems integration effort.

**JCA ARCHITECTURE OVERVIEW**

The Joint Common Architecture (JCA) effort is a portion of the overall Joint Multi-Role (JMR) Mission System Architecture Demonstration (MSAD) for the Future Vertical Lift (FVL) program. JCA aims to make use of Open System Architecture (OSA) concepts and Model Based System Engineering (MBSE), to decompose the FVL Family of Systems (FoS) capabilities down into Low-Level Components (LLC) which can be modeled, grouped and then procured (Ref [19]). The ultimate goal of JCA is to create a framework that allows for efficient acquisition and planned reuse of hardware/software components across the FVL family of aircraft as well as legacy aircraft updates. JCA will define a Functional Reference Architecture (FRA) which is government-owned technology/implementation independent conceptual framework defining the functionality, boundaries and data interfaces of individual components. The JCA FRA is closely related to the FACE reference architecture, with the FACE architecture providing the software operating environment and JCA defining the high-level functionality of the components that will reside in that environment. See Figure 8 for a representation of the JCA process including FACE elements.
JCA FRA makes use of the following levels of functional decomposition (Ref [19] and [20]):

- **FVL Family of Systems**: System of Systems that provides the entire capability set for the aircraft
- **System**: Portion of the FoS made up of hardware and software which implements a cohesive subset of functionality (ie Avionics System, Electrical System, Rotor System, …)
- **Subsystem**: Portion of the System made up of hardware and software which implements a cohesive subset of functionality (ie Comm, Mission Computer, Sensors, HMI)
- **Domain**: High-Level grouping of tasks the Subsystem will accomplish
- **Sub-Domain**: Further decomposition of tasks into sub-tasks
- **Mission Level Component (MLC)**: A notional grouping of LLCs, organized and named to convey meaning and understanding of an overall set of required mission functionality.
- **Lower Level Component (LLC)**: The lowest level of avionics functionality specified by JCA; a functional description and the data required in order to accomplish the capability and the data provided by the capability.

Definitions of LLC functionality, data required and data produced are captured in EXtensible Markup Language (XML) models. The LLC models feed together into a unified JCA Functional Model and a JCA Data Model which describe the entire FRA. LLC are also grouped together using both technical and business criteria into JCA Components which move into the FACE domain as UoPs.

Key attributes of the JCA initiative are summarized in Table 6.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>JCA</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Systems Focus</td>
<td>Portable and Reusable Avionics SW Applications</td>
<td>Functional Reference Architecture enabling SW application reuse across the FVL FoS</td>
</tr>
<tr>
<td>Sponsor</td>
<td>USA AMRDEC</td>
<td></td>
</tr>
<tr>
<td>Platform Domain</td>
<td>Avionics</td>
<td></td>
</tr>
<tr>
<td>Product Domain</td>
<td>SW Capabilities</td>
<td>Functional Reference Architecture and Model Based Systems Engineering of Reusable SW Capabilities</td>
</tr>
<tr>
<td>Widely Adopted</td>
<td>Emerging</td>
<td></td>
</tr>
<tr>
<td>Growth Path</td>
<td>TBD</td>
<td>Architecture is emerging</td>
</tr>
</tbody>
</table>

Table 6. Key JCA Standard Attributes
The JCA effort under the Joint Multi-Role (JMR) Technology Demonstration (TD) Program is creating functional reference architecture with the goal of enabling the DoD and other user communities to achieve greater competition and cost saving through reuse of software capabilities across the FVL Family of Systems (FoS), other platform types, missions, and military services. Rockwell Collins is actively involved in the JMR TD Mission Systems Architecture Demonstration (MSAD) Architecture Implementation Process Demonstration (AIPD) Program to assess and experiment through the use of Model Based Systems Engineering tools go from a reference architecture to an implemented system architecture.

### OPEN SYSTEMS ARCHITECTURE STANDARDS SUMMARY

This section provides a summary of VTOL relevant open system architecture standardization efforts to highlight areas of commonality and overlap among the open systems efforts. Three views are provided for comparison of the relevant open systems architecture standards:

- **Key Attributes**
- **Reference Logical View**
- **Reference Functional View**

Key attributes of the Open Systems Architecture initiatives are summarized in Table 7.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>FACE™</th>
<th>HOST</th>
<th>Open Radio Architecture</th>
<th>SOSA™</th>
<th>OMS</th>
<th>JCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Systems Focus</td>
<td>Portable Avionics SW Applications</td>
<td>Reusable HW Modules</td>
<td>Reusable HW Modules</td>
<td>Reusable HW/SW Modules</td>
<td>Mission Payload Reuse / Interchangeability</td>
<td>Portable and Reusable Avionics SW Applications</td>
</tr>
<tr>
<td>Sponsor</td>
<td>USN NAVAIR, USA PEO-Aviation, USAF AFLCMC</td>
<td>USN NAVAIR</td>
<td>N/A</td>
<td>USN NAVAIR, USA PEO Aviation, USAF AFLCMC</td>
<td>USAF AFLCMC</td>
<td>USA AMRDEC</td>
</tr>
<tr>
<td>Platform Domain</td>
<td>Avionics</td>
<td>Avionics</td>
<td>Avionics</td>
<td>Avionics (Payload)</td>
<td>Avionics (Mission System)</td>
<td>Avionics</td>
</tr>
<tr>
<td>Product Domain</td>
<td>SW</td>
<td>Embedded Computing</td>
<td>Communication Radios</td>
<td>Sensor Subsystems</td>
<td>Mission Payloads</td>
<td>SW Capabilities</td>
</tr>
<tr>
<td>Widely Adopted</td>
<td>Emerging</td>
<td>Emerging</td>
<td>No, Conceptual</td>
<td>In Development</td>
<td>Emerging</td>
<td>Emerging</td>
</tr>
<tr>
<td>Growth Path</td>
<td>Yes</td>
<td>Planned</td>
<td>TBD</td>
<td>Planned</td>
<td>Yes</td>
<td>TBD</td>
</tr>
</tbody>
</table>

Table 7. Key Open Architecture Standard Attributes

The selection of the attributes and the corresponding values for each open systems architecture initiative is intended to inform the reader of high level aspects of each standard based on our experience with open systems and understanding of the objectives and progress for each standards activity. Rockwell Collins has varying levels of participation in each of the open systems architecture standards consortiums / working groups that was used to inform our assessment.

Comparison of key logical aspects and system depth across Key Open Architecture Standards are shown in Figure 9.
The Reference Logical View shows that there is significant standardization effort occurring to define standards to abstract the computing platform and physical interface agnostic data messages. In addition, there are similar efforts to define standards for hardware modules that can be reused across products and Avionics capabilities.

Comparison of Key Open Architecture Standard applicability within a representative VTOL Avionics functional view is shown in Figure 10.

The Reference Functional View shows that Avionics subsystems may need to support and implement multiple, yet complementary Open Architecture Standards to achieve the greatest benefits of open system architectures.
CASE STUDY: APPLICABILITY OF MULTIPLE OSA STANDARDS TO DESIGN AND INTEGRATION OF AVIONICS FUNCTIONALITY USING TACTICAL DATA LINK AS AN EXAMPLE

In order to further illustrate the scope of and interactions between the OSA standards covered above, a hypothetical tactical data link development for a future VTOL aircraft will be used as a case study. The wide range of aircraft capabilities that make use of tactical data link functionality made it an ideal test case to explore. The attributes of the hypothetical TDL component are as follows:

- Provides defined functionality for JCA Provide_Data_Link Low Level Component (LLC) which traces up to multiple Mission Level Components (MLC)
- Design decision partitioned functionality into two elements: Data Link Message Processing and Data Link Terminal Control
- Data Link Message Processing is implemented by FACE conformant software hosted on a HOST Module within a HOST Enclosure
- Data Link Terminal Control software and hardware conforms to the Open Radio Architecture concept and is hosted along with other RF functions in an ORA enclosure
- Interface Definition for interactions between Data Link Message Processing and the Cockpit Display HMI functionality in the displays as well as Avionics System Data Concentration are covered by FACE Data Models
- Interaction with Mission Sensors is accomplished using SOSA standard
- Interaction with Mission Display HMI is accomplished using the OMS standard
- Status and watchdog management interaction with the HOST Participant Manager software is accomplished via shared memory

A high level context diagram of the Tactical Data Link is shown in Figure 11, and a corresponding physical block diagram is shown in Figure 12. Both figures are color coded to depict the application of the OSA standards to the logical and functional elements.

![Figure 11: Tactical Data Link Logical Context Diagram](image-url)
Considerations as part of the Tactical Data Link implementation in support of the JCA LLC Provide Data Link that development teams need to be aware of are:

- Model Based System Engineering methodology used to flow JCA LLC Functional Models down into vendor specified requirements and design. Linking of models through all levels of system, software and hardware allows views to be rapidly generated in order to meet documentation deliveries (share Models and Views rather than word documents)
- Extensive use of I/O data management tools to correlate and adapt between multiple standards and native data element definitions at the aircraft level to ensure a unified data model approach during the System Design Phase. Model Based Systems Engineering Tools can auto-generate Interface Design Documents for software modules that conform to different OSA Standards, and can also auto-generate configuration files for I/O Management services and configurable transport layers.
- Trade Studies required to determine if existing hardware and software modules available in the FACE and HOST Registries, and the DoD Waveform Information Repository are available that satisfies the requirements of the project based on the program technical requirements. If there are existing hardware and software modules available then there may be multiple options to select from. If there is no available hardware or software modules that meet the program technical requirements, then a competition would need to occur to procure the necessary modules from either modified existing modules, or newly developed modules. Similar trade studies will be needed for SOSA and Open Radio Architecture subsystem modules.
- In addition to normal quality driven verification and validation efforts, specific test events and documentation may be required to show conformance to multiple OSA standards. This should be investigated early in the program to identify testing efficiencies.

Due to the broad nature of this paper, the high level focus precluded us from going deeper at this time into areas of synergy or conflict that may occur between standards. Our preliminary analysis provided some initial observations on areas across the open systems architecture standards that require additional investigation, those areas are:

- Top down system level architecture development, like JCA and bottoms up open systems architecture standardization, such as HOST, Open Radio, SOSA, and OMS could have some inconsistencies in architectural boundaries and interface definitions, such as the computing environment specification and data...
models, that may create development and integration challenges. The Air Force OMS FACE System Development Program looked at the architectural boundaries and interface definitions between OMS and FACE to develop approaches and recommendations for alignment between OMS and FACE. This same type of effort needs to occur across the intersection of all of the necessary open systems architecture standards to ensure they are complementary and support the DoD’s acquisition reform policies.

- Many of the open system architecture standardization activities have similar visions and tenets, such as HOST, SOSA, and Open Radio, resulting in a need to harmonize, where practical, hardware and software module definition; and interfaces to increase opportunities for the industrial base to innovate and create product line solutions that accelerate the fielding of new mission capabilities. There is collaboration occurring within the SOSA standards initiative with other standards working groups that needs to be looked at as a collaboration model to ensure harmonization across standards activities
- To illustrate a point, HOST, SOSA and Open Radio Architecture are aligning around the use of the VITA 65.0 OpenVPX standard for hardware modules, which could result in the ability to reduce equipment footprint by using a single cabinet with HOST, SOSA and Open Radio Architecture hardware modules intermixed. However, it is also possible that interface inconsistencies could exist that would preclude such an approach. Beyond physical integration of the standards, there could also be efficiencies gained in the design documentation and acquisition for the program.

**CONCLUDING RECOMMENDATIONS**

Approaches to open system architecture development and standardization for Avionics / Mission Systems have evolved over the past twenty years and are at the next inflection point to enable more affordable system development and sustainment over the life of the weapon system. This inflection point is primarily driven by the acquisition reforms that are trying to achieve more affordable programs. The primary intent of this paper was to provide situational awareness of the multitude of OSA standards in development and an overview of their scope to better inform our Avionics product line activities to ensure they stay aligned with the customer’s needs.

The Case Study presented above was intended to be a small slice of an overall new VTOL aircraft development to highlight a few key Systems Engineering decisions that will need to be made during the acquisition phase to ensure the selection and allocation of Open System Architecture Standards supports the program life cycle objectives. Follow on activities to this paper could include a deeper analysis and experimentation with the Tactical Data Link functionality thread or expansion into other Mission Level Components in JCA.

We see great progress in the development of new Open Systems Architecture Standards and are actively involved in a number of those standards consortiums and working groups. To achieve the maximum customer benefit of the standards activities, we recommend and encourage the continued experimentation within individual and across multiple Open System Architecture standards activities to reduce risk and demonstrate maturity of the standards across multiple use cases.
REFERENCES


[8] “Hardware Open Systems Technologies Tier 1 Standard Version 2.0”: Published by NAVAIR, December 1, 2016

[9] “Hardware Open Systems Technologies OpenVPX Core Technology Tier 2 Standard”: Published by NAVAIR, December 1, 2016


[12] “Technical Standard for SOSTM Reference Architecture (Snapshot)”: Published by The Open Group, February 7, 2018

[13] “SOSTM Business Guide, Version 0.8”: Published by The Open Group, October 31, 2017


