Leveraging Open Standards in Future Vertical Lift (FVL)

The FVL Mission Systems Architecture (MSA) Approach to the FACE™ Technical Standard and other emerging Open Architecture Initiatives

Air Force FACE™ TIM Paper by: US Army PMO FVL

Matthew Sipe
Systems Engineering Branch Chief / MSA Lead, Tech Management Division, ITE/FVL PO

John T. Stough
Senior Software Architect, JHNA supporting FVL

17 March, 2017

THIS PAPER PROVIDES NEITHER DIRECTION NOR AUTHORIZATION TO COMMENCE ANY WORK ON BEHALF OF THE GOVERNMENT WHATSOEVER. THIS IS NOT AN OFFICIAL STATEMENT AS TO ANY CURRENT OR FUTURE GOVERNMENT REQUIREMENT. NOTHING HEREIN SHALL COMMIT THE GOVERNMENT WITH REGARD TO ANY FUTURE REQUIREMENT OR PROCUREMENT.

Table of Contents

Executive Summary

Defense aviation is at a critical pivot point with the emerging acquisition lifecycle for Future Vertical Lift (FVL). This will be a software intensive major acquisition program, with possibly more than half of the total program cost being allocated to software. We envision that FVL will need to fly and fight synergistically alongside legacy systems that will be a century old by the time they are scheduled for replacement. We believe that the architect should be an agent of the buyer, rather than of the seller, because the architecture encapsulates business objectives. The key issue for FVL, as well as for meaningful acquisition reform, centers on architectural control. The Army was an early adopter of the Future Airborne Capabilities Environment (FACE™)[1] Technical Standard (TS) and Business Guide (collectively referred to as the FACE approach). This paper addresses some of the issues the FVL team is exploring in the context of leveraging Open System Architecture (OSA), including specifically the FACE approach. It goes beyond simply adoption of one or more standards to introduce proper constraints and agility built into the architecture and process. Our goal is to see the Army maximize parallel efforts (including legacy synergy) and ultimately shorten timelines while simultaneously reducing cost.

We intend to be strategic in the measurement of openness, such as provided by the FACE Conformance program, in FVL procurement. Openness alone, however, does not ensure reuse or interoperability. Alignment with existing systems at the component level will enable legacy synergy as well as unlocking benefits for future capability insertions and upgrades. In this time of historically constrained budgets, we can ill afford to sit on our laurels and await the future to emerge, we must seize it. The Army FVL Mission Systems Architecture (MSA) Working Group is driving down acquisition risk towards through realizable goals discussed within. Leveraging key lessons from existing efforts, particularly legacy upgrades and S&T innovations, the FVL MSA team is actively progressing towards realistically achieving these goals. Adoption of measurable open standards allows us to move forward with confidence that reuse and integration are now proven beyond speculation. What we do with that confidence and knowledge will critically shape defense aviation acquisition for the next several decades, thus we must move forward with measured confidence and decisive action towards putting into practice the lessons we are currently learning. Lessons are not truly learned until they are acted upon.

[1] The FACE™ adjective and logo design are trademarks of the Open Group in the United States and other countries.

Shaping the Path Forward

Leadership objectives are not always directly actionable. For example, affordability is inherently difficult to measure and specify in contractual language. In order to meet the objectives of Modular Open Systems Approach (MOSA) that are well established in the communication of DoD senior leadership, some method of decomposition from broad leadership objectives (e.g. affordability) that can be achieved through MOSA is necessary. Simply declaring a system as modular or open does not mean that one can afford it; likewise, affording a system may have little to do with either modularity or open interfaces. This may be especially true if only focused on the initial procurement, rather than full lifecycle sustainment, where the majority of the cost is incurred. Alignment of these leadership objectives to clear business drivers and technical enablers will be key to achieving the intent behind MOSA initiatives. The MSA team is working to decompose these leadership objectives into business drivers that can be leveraged on contact. This is expressed in Figure 1: Decomposition of Leadership Objectives as each maps directly to business drivers which are in turn achieved through specific application of certain technical enablers. This results in a large matrix of considerations where a single technical enabler supports multiple objectives that are desired from a business perspective. For example, partitioning enables reduced qualification cost as well as potential innovation by allowing one partition to change without affecting another, amongst other benefits; however, determining what our business objectives are help shape HOW we partition the software, not just THAT we partition it! Clearly mapping out this understanding helps to build an achievable strategy that provides guidance for leveraging technology, rather than technology for its own sake. This ensures that the technology (how we do it) is used with directed purpose to a specific goal and that it can be contractually measured against business drivers (why we do it).

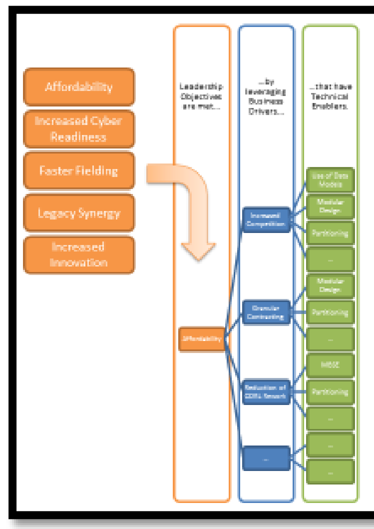

Figure 1: Decomposition of Leadership Objectives

Examples of the how these objectives can be mapped to actionable mechanisms in acquisitions may take the following form [Objective] is achieved through [business driver] leveraging [technical enabler], as in:

- Affordability is achieved in part through the business drivers of: increased competition, reduction of lifetime buy decisions through obsolescence avoidance and management; reduction of rework; etc. These drivers are technically enabled by standardized partitions; identification and enforcement of key and standardized interfaces; machine-readable shared models of both data and behavior; etc.
- Increased Cyber Readiness is achieved in part through the business drivers of: competitive procurement at a granular level (where defects can be patched quickly by the best provider); replacement of obsolete or vulnerable technology; elimination of defects in code or documentation; etc. These drivers are technically enabled by partitioning that considers cyber change cycles and isolation; key interfaces defined at cyber-relevant boundaries; model-based behavioral analysis for complex systems; etc.
- Faster Fielding is achieved in part through the business drivers of: granular competition that allows rapid innovation and selection of best of breed emerging technology; integration efficiency that prevents delays in testing and airworthiness qualification; planning for replacements along well-defined boundaries;

increased safety through isolation of criticality and complexity behind well-defined interfaces; redirection of efforts from rework to new capability procurement; etc. These drivers are technically enabled by partitioning strategies that consider replacement and upgrades; key interfaces aligned to rapidly changing or evolving capabilities; model-based analysis of behavior and data flow implications of proposed changes prior to integration; etc.

- Legacy Synergy is achieved in part through the business drivers of: aligning competitive procurements where possible to be reused on multiple systems; multi-vendor solutions that drive and open new innovation potential; reduction of integration cost / effort associated with component-based acquisition; reduction of wasted resources and effort on obsolesce management; integration efficiency; etc. These drivers are technically enabled by partitioning strategies that consider multiple families of systems; key interfaces aligned to common reuse points; model-based analysis of cross-platform integration; etc.
- Increased Innovation is achieved in part through the business drivers of: granular competition allowing competitors to highlight unique advantages; reduction of integration barriers to allow new innovations to more directly align to existing architectures; use of common interface definitions that properly separate concerns and allow component-level innovation and replacement; etc. These drivers are technically enabled by partitioning strategies that consider areas where innovation is desired; key interfaces that allow for replacement by new capabilities without affecting retained sub-systems; model-based analysis of various ways that new capabilities can be achieved prior to finalizing requirements; etc.

Leadership objectives capture the stakeholder context of the supporting business drivers that can be met by common technical enablers. Because these objectives are very consistent, program alignment should be a natural byproduct of this decomposition. Provided that programs are aligned, using the FACE approach allows for a more direct measure of openness when competing subcomponents and system upgrades. It does not, however, describe what components must be built and tested for conformance – this requires an architecture development effort. Efforts such as the Joint Common Architecture (JCA) aim to fill that gap. Meanwhile, Army initiatives in Science and Technology (S&T) such as the Mission Systems Architecture Demonstration (MSAD) and other early adoption efforts by the Army act to simultaneously mature the FACE ecosystem, while also aiding the Army with valuable lessons regarding putting open systems requirements on contract. Moreover, reuse is being proven not just for finished components but also models, documentation, analysis and other scaffolding[2] that can be built early. While much more work in this area is needed, we certainly have the confidence now that open systems can be technically achieved in procurement; FACE Conformance is a significant technical enabler towards that objective.

Careful inspection demonstrates that while the same technical enablers support several business drivers, that the objective entirely shapes the effort to be tailored in a way that accounts for these often competing priorities. The more granular the consideration of these common enablers, the more likely that these competing priorities are brought into alignment. The bedrock level of these technical enablers and corresponding business drivers demonstrates that open and broadly adopted standards are critical – without a

[2] Just as in real physical architecture, scaffolds are used to support various internal or external work efforts and are intended as temporary structures. A variety of such temporary software structures are necessary in designing, constructing, and testing reusable software components.

standardized definition of a partition there would be no hope of achieving the objective through judicious partitioning strategies. The standard must be, therefore, broadly adopted and directly applicable to the problem being addressed by the need statement. Both the broad adoption and direct applicability of the FACE Standard to the avionics domain make it a critical component of the Army's MOSA strategy for Aviation and, in particular, the FVL MSA procurement strategy.

Interface Boundary Definitions are Critical

The FACE Standard and corresponding Business Guide are useful and properly scoped for creating interface-level contractual agreements, through data model exchanges and rapidly orchestrated architectural working groups that result in real agile integrations which are much simpler than expected. Adoption of the FACE Technical Standard alone, however, is necessary but insufficient for complete boundary definitions and certainly not for determining criticality, which can only be determined by the system owner through business analysis. This is because any unstated business drivers become incorporated into the architecture and thus necessarily shape the particular platform, resulting in different boundary definitions. System alignment using the FACE approach allows for the unique determination of component designs by the designer because the Transport Services and Data Model prescribes how the components will exchange information. Without this common interface contract between the components, one developer could not reliably ensure that the necessary services would be provided. The ITE/FVL MSA team is actively working to align numerous activities for use alongside the FACE approach to provide a bedrock foundation that can be used to support core system architectural infrastructures for legacy and current aircraft; these alignment efforts include: DoDAF, SysML, standards addressing hardware, sensors, behavioral analysis, and common systems.

We Can Start Much Earlier

Alignment to the FACE approach enables potential separation of concerns along a known interface structure that allows us to independently design components. This has a beneficial side effect for complex systems because we can build scaffolding and infrastructure and prototypes very early. Because concerns are separated in this way, components can mature independently over time. Additionally, the scaffolding and artifacts actually act to help identify, construct, and reuse some of the core infrastructure elements that are found in the early integration. In order to make the system information exchange work, notional data publishing and processing services can be built to glue the system together in a realistic architectural lab environment. This can be done when the components themselves are just prototypes; transport service elements, process control components, behavioral models, and data models, for example, will scale with the iterative development as functional components mature. This allows us to begin building and notionally integrating virtual components very early. Some key early considerations of the FVL MSA team include:

- The importance of and technical complexity of Transport Services (TS) necessitate that early integration testing and alternative TS interoperability testing will be key to achieving reuse as well as lab-to-platform separation that will aid in both prototyping and fielding. Practically speaking, this means that the more testing we do and independence we can gain from any specific platform. Also, the better we define early data models and the corresponding data transport, the more likely we will be able to reliably test and qualify components in isolation from any particular air vehicle or hardware implementation.

- The behavioral characteristics that are critical to the actual platform integration testing can be separated (for now) from the functional capabilities (such as those represented in JCA) and put back together in the component design. Therefore, we can work on functional decomposition (and even speculatively assign component level budgets for things like timing constraints) well in advance of integration. We may not yet be able to specify what components make up the entire system, but we know more than enough to do component level development and integration in ways that are both useful and reusable in FVL MSA.

- Data Modeling needs to start early and be as holistic as possible, requires special training, and is critical to achieving the good benefits promised through integration risk reduction. We know that the benefits are real, but that does not mean that the old paradigms will shift easily to front-load data modeling efforts. These efforts can be started now even before the component boundaries are identified because the data itself is much more tolerant to how it is packaged, transported, and consumed. This is one of the less obvious strengths of the FACE Data Architecture that will emerge in later years through broad adoption – once the data is modeled, the model exists and will get reused, repackaged, and re-transported throughout the life of the system. Components will come and go, whereas data can be transformed and then it persists through multiple lifecycles.

FACE Verification and Conformance are Important

We know that FACE Verification and Conformance is possible and commercial companies will invest in open interface conformance if the government requires it. However, until recently conformance could not be required because the costs and/or risks were unknown. The availability of the FACE Conformance Program makes it possible to require procured components to pass Verification and become Conformant. However, it would be unwise for the PM to mandate Conformance for all elements in procurement, particularly if they are prototype, never intended for reuse / replacement, or for numerous other business reasons. These decisions are yet to be made, for the analysis of WHAT components are to be procured must precede HOW they are procured. Nonetheless, Verification and Conformance are extremely powerful tools in the hands of the PM FVL MSA team as we establish key interfaces and ensure that they conform absolutely to the standards prescribed by our architectural team. More work is needed to fully understand the costs and risks of mandating conformance, but this is now both knowable and measurable. Both cost and risk will be reduced though increased use of these valuable programs.

FVL Intends To Procure FACE Conformant Components

We intend to procure the FVL system using a granular approach that defines key interfaces to ensure than components can be reused and replaced based on the needs of the government. Industry has responded that the government should signal a desire to see more Conformant products, so we are signaling; are our signals providing clear enough guidance towards success in Mission Systems Architecture? Admittedly, the answer is no or at least not yet. What is not now known and cannot be stated this early in the FVL program is which components should be Conformant. We encourage companies, within their own business drivers, to be proactive in working through the Verification and Conformance programs at a granular level. The chances that the FVL MSA team will specify singular large blocks of functionality for conformance are slim. Instead, our intent is to procure components at a more granular level, identifying our business drivers through the architecture, to isolate areas of anticipated change. Much of our early analysis indicates that broad leadership objectives require us to be able to isolate and replace components at the most granular level feasible; for example, cyber readiness requires an architecture that can ensure that components are not vulnerable through backdoor undeclared interfaces. This will align to the emerging FVL business drivers that will necessarily shape how we leverage FACE Conformance, which would prevent undeclared interfaces. We intend to leverage FACE Conformance where it is critical and, where appropriate, allow alignment with less burden of proof on less important things. The resulting obvious signal to Industry, then, is to introduce products aligned to the FACE standard the intent is to market these products as potential parts of the MSA for legacy and future air vehicles; beyond this, however, it is also important to think small, develop modularly, work collaboratively, and verify often because the FVL MSA objectives will anticipate granularity.

What We Don't Yet Know

There is still much to learn about how to drive down cost and risk. We certainly would like to learn everything we can. However, at this point we know enough to properly shape our approach to the architectural objectives so that the FVL MSA procurement can be specified to meet the emerging leadership objectives. What we do not yet know are the specific interfaces, components, and technologies that will be required and available. We also do not yet know how we will specify artifacts or the best data rights strategy as these are necessarily based on what kinds of components are needed and how often they will change. Therefore, we have a number of activities to learn these important lessons prior to writing the detailed FVL MSA specifications. The ITE/FVL team believes that a Government-owned and Government-specified MSA will allow for independent design innovation and granular component-level competition, but no decisions have been made for FVL as we are currently well in advance of the Analysis of Alternatives (AoA) that will eventually define in our actual system requirements and shape the boundaries of that architecture. We also believe that a platform independent architecture has the potential for use across the various Family of Systems (FoS) and Capability Sets (CS) represented by the FVL domain; whether such an architecture is used as a whole or as a constraint to a set of reusable components is not fully specified at this early stage.

Our Learning Approach

Mission Systems Architecture Working Group

Architecture is a product to be owned and managed by the system owner and, thus, the architect should be an agent of the buyer, rather than the seller, of technology that the owner seeks to employ. The term architecture has been used variously to refer to a process, a singular artifact (typically a non-standardized "wiring diagram" of components), a set of standardized artifacts (such as SysML, UML, or DoDAF products), or a document with architectural requirements. Included in this broad terminology use is the FACE Technical Standard's own internal statement of a FACE Reference Architecture (some have proposed using "technical reference framework", further highlighting that we often mean different things by our common terms). An excellent definition of architecture is: "…an integrated business and technical strategy for competitive and affordable acquisition and sustainment of a new or legacy system [or component] over the entire system life cycle… that defines key interfaces based on widely supported consensus-based standards for which conformance can be verified." (BBP 3 MOSA Study Team Final Report, 7 July 2016)

The FVL MSA team further refines this to mean that the MSA includes a set of architectural decisions and constraints levied in efforts to achieve the PM FVL defined business objectives and ensure technical strategy is measurably implemented in final designs. Many that work actively within the FACE ecosystem understand that the standard alone is necessary but insufficient to fully define an avionics architecture; we all know that it is not "instant (architectural) oatmeal – just add water." For starters, the system requirements and actual data modelling work must be completed. However, since the FVL team is not a commercial entity building a product for financial incentive; we are representatives of the material developer (PEO) for the Army building a product for our warfighters. Naturally, our business objectives and architectural needs will differ from those of others. We must do more than simply add requirements for new software be FACE Conformant in the system specifications if we expect to achieve what we actually desire. Thus the FVL MSA must necessarily be more than a collection of FACE components and more than a purchased third-party open architecture that incorporates FACE components. The difficulty in using the proper terms is amplified when the term we prefer to use (e.g. architecture) has different meanings to the various entities that use it – we may agree in an "architecture-centric approach" and yet mean very different things about what is actually central to that approach.

The FVL MSA team has initiated a Working Group (the MSA WG) that functions similarly to an IPT where participants from various Army PMs, other services, and external groups, can collaborate on open issues – like an agreeable definition of what artifacts are minimally required to have a truly PM FVL specified MSA that results in PM FVL actually asking for what it actually desires to achieve. One of the functions of the MSA WG is to feed into the emerging architectural products, including the DoDAF All View (AV) 2, a common lexicon for the program where terms like architecture will be defined for the program; we may not be able to gain global concurrence, but we must have programmatic adherence to common terms. Another major function of the MSA WG is to stimulate the early churn required to get to real lessons learned, which requires more than just recommendations but also corresponding actions. A lesson is not actually learned until the required change is put in place.

Many of the DoDAF required products and transformations of Operational Views (OV) to System Views (SV) can be leveraged the new architectural paradigms that the FACE standard brings to the table. This is true even if many of the OV products will not be available until after AoA because certainly some of the mission threads will remain similar to current fleet operations – we still do much of the same basic things, like basic civil airspace navigation and route planning. In the area of civil airspace flight in particular we must both keep pace with civil requirements (as any airline would) while also ensuring that we can seamlessly move into tactical operations and back again. Therefore, we can and should actively look at existing programs and legacy systems to consider how we will build those products in the future. We should also be looking at commercial aviation innovations. The MSA WG actively discusses and coordinates on issues such as this with external stakeholders, including accepting briefings from industry as time and resources are available.

In the period awaiting the completion of the AoA, along with the finalization of top level Army (and Joint) requirements for FVL, the foundational work of clarifying how the Government should specify future architecture work has already started. Regardless of the platform requirements that will emerge, some things about military avionics are already very well known today. Specifically, the air vehicle will be in service for many decades and must be able to support numerous avionics and mission systems upgrades throughout its lifecycle at a faster pace than once each decade. That is today's reality forecasted to FVL and does not even account for the potential of rapidly evolving threats that may require just-in-time patches and upgrades during conflict. The FVL MSA WG is working on this and other complex issues as we prepare for Milestone A.

Existing OSA Programs in PEO Aviation

Common Army Avionics System (CAAS)

The Army is not entirely new to the idea of building a common set of avionics that is reusable. Efforts from a decade ago serve the very valuable lesson of demonstrating why an avionics system must allow for lifecycle upgrades, as CAAS will continue forward on systems that will continue to fly for several decades alongside FVL platforms. While CAAS is now considered legacy technology from the perspective of FVL MSA, many valuable lessons (such as the way functions were defined, how changes were identified and managed, how modularity was expected to be handled versus how it actually evolved) are being studied by the FVL MSA team. Amongst the many lessons the Army has already learned from CAAS, we are asking additional questions such as:

- How would CAAS have looked differently if the FACE standard and similar standards existed then?
- If CAAS were being specified now, given its own lessons learned and emergence of new technology, what would the change points (functional and technical) be?
- Was the specification detailed enough and how would it be different given new specification tools (SysML, Data Models, AADL, DoDAF, etc.)?
- What functional definitions of CAAS have deep legacy that did not and may not change, thus should be retained (at least from a nomenclature, if not training and doctrine, perspective)?
- How was CAAS divergent between the Special Operations, Cargo, and Utility communities that inherited it, and how should that shape our concept of architected-for-reuse in the FVL FoS?

UH-60V Is Still In Development

Congratulations to the entire UH-60V team for a successful First Flight! The UH-60V effort continues to provide very valuable information and lessons learned regarding the development of a modular open system that is separate from the air vehicle. This effort has highlighted several things worth noting here. Lessons from this program on how to specify interfaces, data rights, tool chains, access to qualification records, customization of common tools, airworthiness in model based development, and specific contractual language are being learned by FVL. Even with things going well, this program is still a singular effort with a single developer/integrator that is pre-release, thus lessons will continue. Transition to Milestone C and into sustainment will bring new lessons as we continue to learn what works well and cooperate with industry to build an open system that the Army can maintain for many decades to come. One of those specific key lessons that we are actively working towards now is that, if it had existed, a well-defined Air-Vehicle (A/V) to MSA Interface would have made the process from competition through testing more efficient. A subset of that is that Mission Equipment Packages (MEP), such as radios and survivability equipment, are a necessary but insufficient to define the overall MSA interface. We are grateful to the UH-60V team for their support as we are also learning much about component level testing, airworthiness qualification with Model Based Systems Engineering (MBSE), and reuse of commercial avionics systems for military applications.

UH PO Crew Mission Station (CMS)

The UH-60 Crew Mission System (CMS) vision is to define an enduring Open Systems Architecture (OSA) approach and management strategy capable of providing new capabilities to the H-60 fleet in the shortest timeframe possible in a systems integrator agnostic manner. The management strategy is encapsulated in the Master Project Plan, which describes the new processes and techniques recommended for maintaining the CMS architecture. Additionally, it provides insight and guidance for the building, upgrading and deployment of a CMS. The CMS OSA is a government owned and managed architecture that expresses modularity and key interfaces that enable the government's technical and business objectives. Primary within these objectives is increased speed to field of mission capabilities that meet the needs of the war fighter. A comprehensive overview of the CMS OSA is provided in this document.

This effort has provided insight to the FVL MSA team with respect to clarifying the fuzzy the line between architecture and design (terms that are often used interchangeably). Additionally, it has helped us better grasp how architectural constraints can significantly drive conceptual design decisions, thus providing the learning point that the government must be careful and cautious in making architectural decisions and ensure that the government is transparent with industry with respect to these decisions.

Component Programs and S&T Efforts

Besides full scale existing platforms, there are also a number of individual component programs and the U. S. Army's Aviation and Missile Research Development and Engineering Center's (AMRDEC) S&T initiatives exploring component level reuse where we are actively learning lessons. One of the foundational elements that separates FVL from most previous Army procurements is the significant leveraging of S&T. Many of these programs have significant cross over, sharing resources and expertise by necessity. All of these programs have an Open Systems bent that leverages FACE and other standards.

Aircraft Survivability Equipment (ASE) Common Component Prototype

The FVL MSA team also monitors various programs that reflect the emergence of future common systems and components. One such programs is the "ASE FACE UoP SW Development - FACE conformant software for ASE equipment" from PMO-ASE, supported by AMRDEC's Software Engineering Directorate (SED), to develop a FACE UoP for Integrated Aircraft Survivability Equipment (IASE) upgrade project leveraging the UH-60V ASE component. The ASE lab at SED will develop a new IASE software component capable of interfacing with the APR-39C(V)1 and APR39D(V)2 and with the Aviation Systems Integration

Facility (ASIF) lab at SED will integrate the software into a reference 60V mission processor (MP) system acquired from the manufacturer. As the 60V MP uses a FACE architecture, the standard will enable efficient integration of a new capability into a complex system. Success will prove that a 3rd party software provider can develop software without foreknowledge of the system's infrastructure specifically it's message transport mechanism which can be integrated with that infrastructure because of the layered FACE architecture. The hardware component vendor was not required to deliver a data model, SED will develop the data model in house and align it to the existing ASE message formats to facilitate straight forward replacement of the component. From an FVL perspective, this opens the clear possibility that rapidly evolving capabilities such as ASE can be quickly developed, tested, and integrated across an entire fleet without requiring unique efforts – saving cost, for sure, but more importantly fielding this critical need to the warfighter as quickly as possible. Success will prove the openness of the 60V MP and provide insight into the level of effort required to replace a software component within a FACE architecture.

Reusable Radio Controller Component (R2C2) and Reusable IDM

The FVL MSA team planning to leverage the efforts of PM Aviation Systems (AS) and SED to mature the Reusable Radio Control Component (R2C2) and the ongoing work for next-generation Improved Data Modem (IDM) requirements. The R2C2 software is currently in the late stages of development, including the ongoing work with the Army FACE Verification Authority, and we anticipate learning how it will be integrated into existing legacy platforms as a pure software capability reuse at the component level. The IDM is a mainstay component in legacy Army Aviation and we are participating in the requirements development, which will include FACE UoP consideration, for the next generation functionality.

Modular Integrated Survivability (MIS)

The purpose of the MIS Project is to provide substantial evidence that it is feasible to design an Open Systems Architecture (OSA) that integrates aircraft survivability materiel solutions in a manner that results in significant reductions in overall cost, schedule, and risk. Currently, airworthiness qualification/certification represents a significant portion of the cost and schedule to field software associated with Army aviation. Therefore, the MIS solution is intended to expedite the current airworthiness qualification process while maintaining the integrity/objectives of the overall airworthiness qualification program. The solution must also provide an integration approach for existing aircraft that decreases cost, schedule, and risk. AED has participated in the development of this new integration approach.

The Common Capability Interface to Platform (CCIP) Strategy document explores the MIS integration approach of developing and utilizing capability interfaces to integrate entire avionics system suites. This document also discusses how incorporating the FACE Reference Architecture into the approach promotes software portability and reuse to reduce integration effort.

Synergistic Unmanned Manned Intelligent Teaming (SUMIT)

SUMIT is a 6.3 Advanced Technology Development science and technology program in the AMRDEC Aviation Development Directorate (ADD). This research effort will integrate candidate technologies provided by each selected offeror in a common Government-owned simulation environment using a common set of operational scenarios and conduct a series of user evaluations with a common set of evaluation metrics. The intent is to gather simulation data and user observations and assess simulation evaluation metrics related to situational awareness, mission effectiveness, workload, and usability in an airborne battlefield environment for each offeror’s autonomy, decision aiding and Human-Machine Interface (HMI) technologies.

Future Vertical Lift Leverages FACE™

The overarching objective of the SUMIT program is to evaluate the impact of new and recent autonomy, decision aiding, and HMI technologies in the execution of Army Aviation missions that utilize manned-unmanned teaming (MUMT). The program seeks to inform future acquisition planning and requirements definition related to advanced MUMT capabilities in both current Army Aviation programs as well as the FVL Program of Record. The SUMIT program comprises three phases beginning with the development of a dedicated Government-owned simulation environment, followed by independent simulation evaluations of third party products, and optionally, in later years, flight demonstrations.

TTCP Alignment of Multinational Open Systems Architecture (AMOSA)

The Technical Cooperation Program (TTCP) has performed a Framework Interface Alignment (FIA) study on the methods by which the member nations' Open System Architecture (OSA) approaches can interoperate and integrate. The purpose of the Alignment of Multinational Open System Architectures (AMOSA) Collaborative Project (CP) is to prototype the recommendations of the FIA Study Report to determine the best method for integration of software capabilities across multiple OSA approaches. This will allow the TTCP to clearly define a path towards increased interoperability, portability of components, and access to wider software markets for both suppliers and customers in a multinational environment.

The CP's stated objectives are to:

- Identify and investigate challenges and problem areas affecting technical interoperability and integration between disparate OSA approaches (through experimentation and analysis).
- Outline the challenges associated with the Airworthiness and System Security Engineering processes that might limit the portability of OSA components.
- Demonstrate effective development and deployment of an integrated software system built with Member Nation OSA approaches.

JMR MSAD

Joint Multi-Role (JMR) Mission Systems Architecture Demonstration (MSAD) is the key S&T effort with respect to computing and data transferring/processing environments. The program is not only advancing concepts and implementing emerging technical standards like the FACE standard but is also providing tremendous feedback to those standards as MSAD team members interface directly through participation in FACE Consortium product development. The objective of the MSAD is to ensure that a potential FVL FoS Program of Record (PoR) has the processes, tools and standards necessary to specify, design, analyze, implement, acquire, qualify, certify and sustain a MSA that meets the performance requirements and business goals of the DoD. MSAD is focused on three main areas meant to address the complexity and cost of implementing mission systems architectures across the FVL Family of Systems. Those areas of interest are:

- Implementation of OSA principles
- Application of MBE/MBSE
- Execution of an Architecture Centric Virtual Integration Process (ACVIP)

MSAD is investigating these three main areas through collaborative efforts with industry and academia that leverage or develop the supporting standards and tools necessary to implement a mission systems architecture as well as through increasingly complex demonstrations. Standards and initiatives such as FACE, AADL, Joint Common Architecture (JCA), and Hardware Open Systems Technologies (HOST) are examples of OSA enablers being investigated. These are used in demonstrations such as JCA Demo, AIPD, and Capstone.

JCA and the JCA Demo

The JCA is intended to define Reusable Software Components (RSCs) that reside on the mission computers of the vertical lift fleet. JCA Version 1.0 will comprise a functional description of the RSCs and is being sponsored by the JMR MSAD effort. The primary objective of JCA is to enable the procurement of affordable warfighting capability through the planned and strategic reuse of hardware and software assets across the FVL FoS using a combination of data rights, platform abstraction, data semantics, and functional allocation. JCA is an implementation and technology-independent conceptual framework, providing a common vision and taxonomy that is intended to be used as the starting point for the design and development of FVL and legacy upgrade avionics architectures. The JCA RSC will be implemented as FACE UoPs. JCA follows OSA principles and leverages existing and emerging OSA related efforts to include the FACE Technical Standard and uses a model-driven process and design principles. JCA is being developed, with the help of industry subject matter experts, as a set of three versions, which provides numerous feedback intersection points both to FVL and the FACE Consortium.

The first MSAD demonstration, JCA Demonstration (JCA Demo), was established to verify the JCA concept and reduce risk for subsequent JMR MSAD efforts. The Demo revealed that the FACE Technical Standard provided the common software environment that enabled software portability across operating environments. This portability is critical for efficient software reuse but does not address the functionality and behavior of the component necessary to achieve desired reuse/interchangeability. Modularity was achieved through the functionality constrained by JCA, model-based interface, and textual requirements specification, however, challenges were uncovered pertaining to the need for behavioral modelling, the methods to convey critical architectural context, and the level of requirements specificity necessary to achieve interchangeability. In summary, JCA (providing a “what”) and FACE Standard (providing a “how”) were both found to be necessary to obtain desired levels of reuse/interchangeability, however, neither are independently sufficient.

AIPD

The second MSAD demonstration, Architecture Implementation Process Demonstration (AIPD), is currently executing and is to provide the FVL community of interest with the opportunity to explore the trade space associated with the MSAD areas of interest while expanding the body of knowledge available for making acquisition decisions related to future MSAD experiments and ultimately FVL. JCA Demo proved a basic premise, but it also revealed limitations in meeting desired objectives. AIPD is intended to further the Government’s understanding and to provide an opportunity for the Government and industry to gain experience with implementing new or improved methods (i.e., “learn by doing”) and maturing JCA, FACE products, ACVIP and potentially HOST. AIPD is primarily interested in learning how to apply the necessary concepts, processes, tools and standards; and determining whether they are sufficient, mature and usable. Although the details of the acquisition strategy for FVL won’t likely be completely set for several years, the results of the AIPD and other MSAD demonstrations will be available to inform acquisition planning, which is expected to include OSA, MBE, and ACVIP concepts. Although the details of the available processes, standards and tools may change over time, there are certain concepts that MSAD needs to explore to ensure that the trade space identified and properly understood. AIPD is intended to extend the application of OSA, MBE and ACVIP into areas that require investigation, to leverage the relevant body of knowledge and explore the limits of the trade space, and to provide evidence of the utility of applying these concepts. The primary product of AIPD is knowledge through the documentation of learning with the purpose of influencing future efforts.

MSAD Capstone

The third and final MSAD demonstration concludes in a Capstone Demonstration in FY19-20 that will serve as a pilot project for specifying and implementing aspects of a mission systems architecture relevant to FVL. Planning for the Capstone demonstration is on-going. However, Capstone will be a culminating demonstration that exercises a representative DoD acquisition process augmented by the processes, products, and learning obtained through previous MSAD efforts and demonstrations. Numerous aspects will be demonstrated such as the use of models to support mission system specification and procurement; the use of a Government-driven comprehensive architectural strategy that makes use of open standards such as FACE, and common hardware and software resources; and virtual integration methods and tools intended to identify system integration issues prior to physical integration activities where they are much harder and more costly to correct. Similar to previous MSAD demonstrations, the primary output is transfer of knowledge. However, unlike prior demonstrations, Capstone has the potential to directly inform the acquisition strategy for FVL propagating architectural aspects that satisfy and enable Government objectives.

Capstone will in effect, be a source of experimentation to determine the success of Government attempts to inform and constrain mission system implementations to reflect desired non-functional characteristics such as increased affordability through the application of common and reused resources, reduced time to upgrade and enhance existing capability, and increased system integrate-ability and interoperability. The demonstration will also be an opportunity for industry to demonstrate their use of previous learning as it applies to their particular competencies and to investigate the use of applicable technologies such as fiber optics, system on a chip, and multi-core processing. It will also provide the opportunity to investigate novel methods that support safety, security and airworthiness processes.

Overall, Capstone is expected to provide insight into the application of processes to the development of representative system architecture suitable for implementation by FVL. In essence, to learn by doing. It is an opportunity for Government and industry to gain experience with the application of standards and tools while evaluating and contributing to their maturity and sufficiency, and also provides an opportunity to bridge the gap between research and production processes. Capstone will enable the Government to apply architectural concepts brought together by JCA, FACE and other open systems architectural elements as well as ACVIP and STPA to representative implementations that reflect desired Government characteristics. Lastly, it provides an opportunity to proliferate knowledge throughout the community of interest and influence implementation on FVL and legacy systems.

Current FVL MSA Efforts

Support for S&T

Our connection to the S&T community, specifically JMR MSAD, is active and involved. The FVL MSA team has provided contractual and technical representation for an AIPD effort and we actively participate in reviews on the various S&T programs. We take part in shaping events (concepts, requirements, and desired products or outcomes) whenever possible. S&T representatives are likewise actively involved in the FVL MSA WG activities and thus the connection is mutual – we agree and very much intend that S&T efforts and PM efforts must be aligned to achieve our stated objectives. The FVL MSA team is currently increasing our efforts for communication as time and resources are available (though limited) because of the particular importance of these activities in driving down risk for the FVL program. We are communicating with S&T technical professionals, horizontally to peer platforms leveraging similar S&T efforts, vertically to leadership, and outwardly to industry to align our intent and goals.

Small Business Innovative Research (SBIR)

The future of MSA requires industry and the government to innovate and to stretch our thinking. Small businesses tend to succeed or fail based on their ability to innovate. Use of SBIRs is a great means for the government to communicate vision and desires to industry and utilize the innovative nature of highly motivated small businesses to progress the understanding of a topic and/or push the envelope. Incorporating FACE and other open standards into streamlined SBIR requirements has allowed us true "apples to apples" comparisons and excellent prospect of future integration with the innovations harvested from these efforts. The FVL office currently leveraging 2 SBIR topics to do just this, with more expected in the future.

Innovative Approaches

The first topic has a focus on "Innovative Approaches to Architectures and Tools". There were 17 proposal submissions. That is an exciting harbinger of future activity and interest in our stated approach of component-level competition that can include opportunities for small innovative businesses to solve unique and specialized problems! Over half of these proposals included significant internal Research and Development efforts resulting in real products (even in Phase I), including model based development tools and implementations of component architectures through mature Technology Readiness Levels (TRL 5+). The FVL team is excited to state that the Army is making two awards (Avilution & Dornerworks); more information regarding these awards will come soon. This was a difficult decision because all 17 of the proposals were worthy efforts and the FVL team would have accepted as many awards as the Army was willing and able to afford – but "affordability" requires difficult decisions to be made.

Reusable PVI Widgets

The good news is that we were able to make multiple awards from numerous qualified proposals. The better news is that we will be doing it again and continuing this approach to innovation. The second topic is focused on "Reusable Pilot Vehicle Interface (PVI) Components and Widgets". Commonality and reuse potential is very high in the area of PVI, considering the known early requirements for making training aids, simulators, and multiple aircraft share common PVI wherever possible. The potential cost savings in this area should be obvious for the Army, restated here because we often need to redevelop the exact visual interface requirements over and over due to the architectural differences between not just the platforms but also the training equipment. Early inquiries show a similar response with significant interest from qualified participants, thus we have received numerous excellent proposals for this topic as well – most from companies that did not propose in the first round – which may indicate the strength of the competitive small business market that is eager to be engaged.

More Innovation to Come

More than 25 qualified small businesses are now actively proposing against the SBIRs already issued. There is still time to mature the market, learn and adapt our approaches to contracting, and firmly establish the common technical enablers (including requirements for specific FACE UoPs) leading to FVL actual system procurement. We intend to leverage the SBIR momentum gained with as many as we are able to support. Even so, our present approach to leverage the SBIR process is certainly available throughout the system lifecycle, not just at this early stage in pre-development. Ensuring open interfaces also allows us to lean forward in future SBIR topics that may be much more focused, using the FACE standard and the emerging MSA to isolate the changes to the functions being innovated. When we talk about increasing innovation, this is one area where we can specifically demonstrate it. Both these and future topics are also meant to be a communication avenue to industry of our desires and objectives with respect to MSA.

Coordinating with Other PMs, Services, and Industry Partners

Beyond the few specific programs listed above, the FVL MSA team is actively working to exchange information and coordinate with numerous other programs. Specific projects are not listed here for space or program sensitivity. The general adoption of vernacular and paradigms from the FACE approach has made this type of conversation much more practical. We have both given and received a number of presentations (often through the MSA WG or via IPT participation) in efforts to align with these various programs. Limited details are needed here in support of the overall thesis, however it is important emphasize the point that the professionals working these programs are all seeing many of the same problems in our coordination efforts and are realizing some real synergy as we are tracking towards some of the same longer term goals. This communication is enhanced greatly because we can use common language (such as "portable components" and "transport services" and "hardware independence") knowing that these are enabled by adopting and aligning to the FACE standard. Many of these programs have the very specific problem of preparing for FVL (either as a legacy system flying side-by-side or as a component that must support legacy platforms with upgrades to be interoperable with FVL capabilities) and collectively as an Army Aviation enterprise we are actively looking for opportunities to align our efforts along the way. This takes a variety of forms and happens through a variety of channels that the FVL MSA team is involved with.

The FVL MSA team has been invited to participate in or observe a number of other program IPT activities, including reviewing and commenting on various procurement documents and deliverables. We actively seek these opportunities and will support as we are able given our early stage and limited staffing. Some of the many activities that we are actively supporting include the following:

- **Other Army PM Coordination:** Including UH-60, CH-47, AH-64, UAS, ASE, and AS, as well as specific cross-platform programs such as Degraded Visual Environments (DVE) and various radios.

- **NAVAIR Coordination:** Several great examples of getting commonality on a couple of platforms. Has a big need for recap kind of efforts or big block updates.

Future Vertical Lift Leverages FACE™

- **USAF Coordination:** Coordination on OMS and SOSA. Common messaging being considered, use of an ACWG kind of body.
- **Academia:** Several Army PMs and other gov't orgs have architectural efforts with academia
- **Industry Event Participation:** Supporting FACE Consortium events, specifically the Integration Workshop. Attending Industry Events. Demos, TIMs, etc.

We are interested in what other teams are doing, where they are going, what they are learning, and coordinating wherever possible. We are also certainly interested in leveraging commercial best practices and seeing some of those migrate to the military side of companies.

The Emerging Path Forward

Much of what we are learning involves how to work in the new environment enabled by leveraging the concepts inspired by the FACE approach, particularly the Data Architecture, as a standard method of communicating architectural concerns. We are making progress towards building the comprehensive method for specification of architecture, encapsulating both the business drivers and technical enablers required to achieve our leadership objectives. We intend to achieve a level of architectural oversight that will increase rather than limit innovation in detailed designs. We are dedicated to enabling legacy synergy and we are looking to specific programs to learn the emerging best practices for future applications. For example, JCA will be described to a logical level, thus maintaining its technology/implementation independent characteristics to allow both a higher degree of Government specification, and thus architectural control, while at the same time allowing for industry innovation within the boundaries of the component definition. Simultaneously, we are exploring innovation in SBIRs that may be largely unfamiliar with the experimental aspects of JCA and instead are simply building FACE UoPs to meet a specific need that we will later integrate into the FVL MSA. This is made possible because we can with great confidence specify that the components will need to operate in an architectural environment empowered by FACE UoPs that are also aligned to common capability requirements. Because of this, the FVL MSA team can specify the function and interface definition necessary to enable a product line acquisition approach while leaving the detailed design and implementation within the component up to the respective suppliers.

Although the FVL AoA and detailed system requirements are still to be completed, we know much today that charts a clear path forward. DoD leaders have continually stated that future weapon systems must be affordable. Affordability has many elements beyond initial cost, including the ability to rapidly adapt the MSA to future emerging warfighter needs. Cybersecurity is critical. Faster Fielding is essential. The FVL MSA team will leverage FACE and other open standards as bedrock foundations upon which the common technical enablers can be built. These will be tailored as our main business drivers emerge with the AoA and system requirements coalesce around these leadership objectives. We will continue in the near term to develop the baseline of the architectural work products that will be completed in later phases. Our guiding principles are clear and we fully understand that the identification of key interfaces is the primary technical foundation for the various work products, S&T efforts, and acquisition strategies that we are developing. Without concurrence to a standard for defining those interfaces, such coordination would not be possible. The FVL MSA team has and will continue to leverage the FACE standard, data architecture, and corresponding guidance for precisely this purpose and augmenting the approach with additional standards (HOST, OMS, AADL, SOSA, etc.) where appropriate. These objectives are possible in FVL and, based on the experience we already have from existing projects and programs, we can demonstrate that key interfaces in a common specification language are critical to business objectives such as this.

- Granular contracting
- Reduced risk for rapid integration
- A multi-vendor component supplier ecosystem
- The separation of architecture from detailed design, allowing for innovation without vendor lock
- Pursuit of affordability in development, integration, and lifecycle sustainment costs

Future Vertical Lift Leverages FACE™

- A new approach to component level acquisition, testing, qualification, and reuse
- Enable reuse/replicability of systems, sub-systems, components, and contractor support
- Provide faster fielding with rapid response to fixes and updates
- Reduced qualification burden. In an age in which complex systems have become the norm, getting a firmer grasp on qualification through separation of concerns and updated processes is a must for the future of aviation
- Hardware Agnostic. Due to the pace of technology advances, hardware obsolescence and need to interoperability, procuring systems that are hardware agnostic are important for the future of Aviation
- Cybersecurity Robustness. Aviation needs to move to a proactive and robust position with respect to cybersecurity while gaining the ability to quickly react to threats
- Enable commonality across FVL FoS, Army Aviation, DoD?

The system we have today is perfectly tuned to produce the results that we currently experience. The status quo has for too long been an increasing complexity of systems, slow development-to-test cycle that hampers rapid fielding needs, significant and expensive rework found late in the program, sacrificing much needed new capability to replace obsolete components. We must do more than hope for better results, we must enact process changes in order to produce those results and extract the potential that is available now. Simply waiting for things to evolve is not progress.

References

Better Buying Power 3 MOSA Study Team Final Report, 7 July 2016

About the Author(s)

Mr. Matt Sipe is the Systems Engineering Branch Chief for the Improved Turbine Engine and Future Vertical Lift Program Office in the US Army. As such, he is responsible for providing overall direction, coordination, and management of Systems Engineering efforts within ITE-FVL PO. He is also the Mission Systems Architecture (MSA) Lead for FVL responsible for progressing Open Systems Architecture concepts and developing acquisition strategies for FVL. Mr. Sipe previously served in the Apache Development and Modernization PM as the Lead Systems Engineer for the AH-64E Version 6 effort and performed APM duties as the lead for the Ground Fire Acquisition and Development effort. Mr. Sipe also served in the AED as the MH-60 platform team lead for airworthiness, the Executive Officer of AED, and a platform engineer on UH-60M and related FMS aircraft. Additionally, Mr. Sipe provided Flight Test and Program Management support to the THAAD program as a support contractor. Lastly, Mr. Sipe served in the USAF as an active duty officer providing program management and engineering expertise to the Special Operations C-130 Program Office where he also became a lead trainer and evaluator in Battle Damage Repair. He is married with 3 kids. He spends the majority of his non-work time "just loving on" his family. Outside of his family, he is involved in a local church in which he leads the men's ministry. For hobbies, he loves to hunt and play any outdoor sport. Mr. Sipe holds a Bachelor of Science degree in Aerospace Engineering from the University of Alabama and a Bachelor of Arts degree in Theology from Life Christian University. Additionally, he is pursuing a Masters Degree in Management and Leadership. He is also a private pilot. He was the 2014 Advanced LIFT class president.

Mr. John Stough started his career as a member of the US Air Force Intelligence Community and afterwards began building intelligence and missile defense analysis tools. From there, Mr. Stough ventured into the commercial software market, working in diverse fields including 3D graphics programming, environmental engineering analysis, artificial intelligence pattern recognition, Geographical Information Systems (GIS), SCADA systems, and healthcare. Mr. Stough is a co-author of a software patent for "Application Server and Graphical User Interface For Real Time Health Monitoring." Currently, John is a Senior Software Architect, supporting the Army Future Vertical Lift (FVL) program through the Software Engineering Directorate (SED) in Huntsville. John was one of the founders of the Basic Avionics Lightweight Source Archetype (BALSA), an Army sponsored Open Source software application for the FACE Integration Workshop standing committee where he serves as co-vice chair. John is a Certified Information Systems Security Professional (CISSP) having received his undergraduate education at Columbia College. Prior to his position with JHNA, Mr. Stough served as the Software Integrated Product Team (IPT) lead for the UH-60V Blackhawk Digital Cockpit, transforming legacy helicopters from analog to digital. He is married with 2 grown daugthers who both have excelled in education and life. John is a big believer in life-long learning, having received a certificates in IT Project Management from ESI / George Washington University, Theology and Ministry from Princeton Theological Seminary, and Architecture and Analysis and Design Language (AADL) from SEI / Carnegie Mellon University. Most weekends you will find John washing dishes in his wife's coffee shop or leading a theology and philosophy discussion over a craft beer.

Special thanks to Mark Jeude, Scott Dennis, Bill Jacobs, Nate Curry, Chris Kellow, Bill Huff, Marcell Padilla, Alicia Taylor, Matt Boddicker, Jason York, and Alan Hammond for their contributions, comments, and encouragement in writing this paper.

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.

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.