Pioneering FACE on Legacy Systems

Programatic Lessons Learned from putting the FACE Technical Standard on Contract, UH-60V

US Army Aviation FACE™ TIM Paper by: Utility Helicopters Project Office (UHPO), H-60V Product Office

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Executive Summary

The UH-60V program is developing an Integrated Avionics Suite in conjunction with the Prototype Integration Facility (PIF), Redstone Defense Systems (RDS), and Northrop Grumman Corporation (NGC). This effort began prior to establishment of the first FACE Verification Authority (VA). Therefore, the requirements were constructed under the guidance that "all new and modified software shall align to the FACE 2.0 Technical Standard." During the course of development, it was determined that the program would be better served by using version 2.1. The program is developing 22 components that are aligned to the Standard, with favorable data rights for the Government and a Transport Services Segment layer that is being developed to support DO-178 requirements. Because the UH-60V program is an early adopter, there are few existing opportunities to reuse other existing FACE Units of Portability (UoPs). It is the program expectation to provide candidate UoPs for future programs. The program has been coordinating with other Utility Helicopters programs and PM Future Vertical Lift (FVL) towards that goal. Beyond reuse, the incorporation of the FACE Technical Standard provided an important architectural constraint to help define "highly aligned and loosely coupled" when creating the High Level Requirements for the UH-60V. The use of the FACE Technical Standard has proved to be of great value to the inherent program objectives in terms of reducing time to field, controlling cost, and providing a path for sustainability. Because verification is for conformance, not compliance, the programmatic schedule for completing the software in time for first flight and Operational Test (OT) does not result in complete verification of all components that are being aligned to the FACE Technical Standard. The specific additional efforts, including production of all required verification artifacts, such as Conformance Verification Matrix (CVM) and Conformance Statements for each component, the potential for CCB actions, and test-fix-test interactions present possible risks to program cost and schedule, are efforts that are not currently planned by the UH-60V program. The purpose of the program is to field a system guided by operational requirements, not the production of individual components or UoPs (as would be, for example, a requirement of a common system Program of Record, such as a radio or other LRU). This presents an interesting challenge and opportunity because verification is at the component level, thus there is no "system" verification for FACE. The challenge is how far a program goes to verify components, since the specific components were not known prior to the design, nor were any existing components available to provide as Government Furnished Equipment / Information (GFE / GFI). The opportunity generated by the UH-60V program is the components developed to align to the FACE Technical Standard, with favorable rights, that other programs can take to completion. Therefore, we recommend the development of an Army-wide strategy for production and verification of individual high-value reusable components, which can leverage work developed by existing programs such as the UH-60V, to enable re-use by other programs.

Overview of the UH-60V Program

The UH-60V BLACK HAWK will update the existing H-60L analog architecture to a digital bussed infrastructure, providing commonality of Pilot Vehicle Interface (PVI) and training with the H-60M (see Figure 1: UH-60V Configuration and Material Solution). The program will address current capability gaps and meet operational requirements by employing an evolutionary acquisition approach to leverage mature technologies that have been successfully integrated on other military aircraft. The UH-60V program will equip the existing H-60L aircraft with integrated situational awareness, communications, and navigation data.

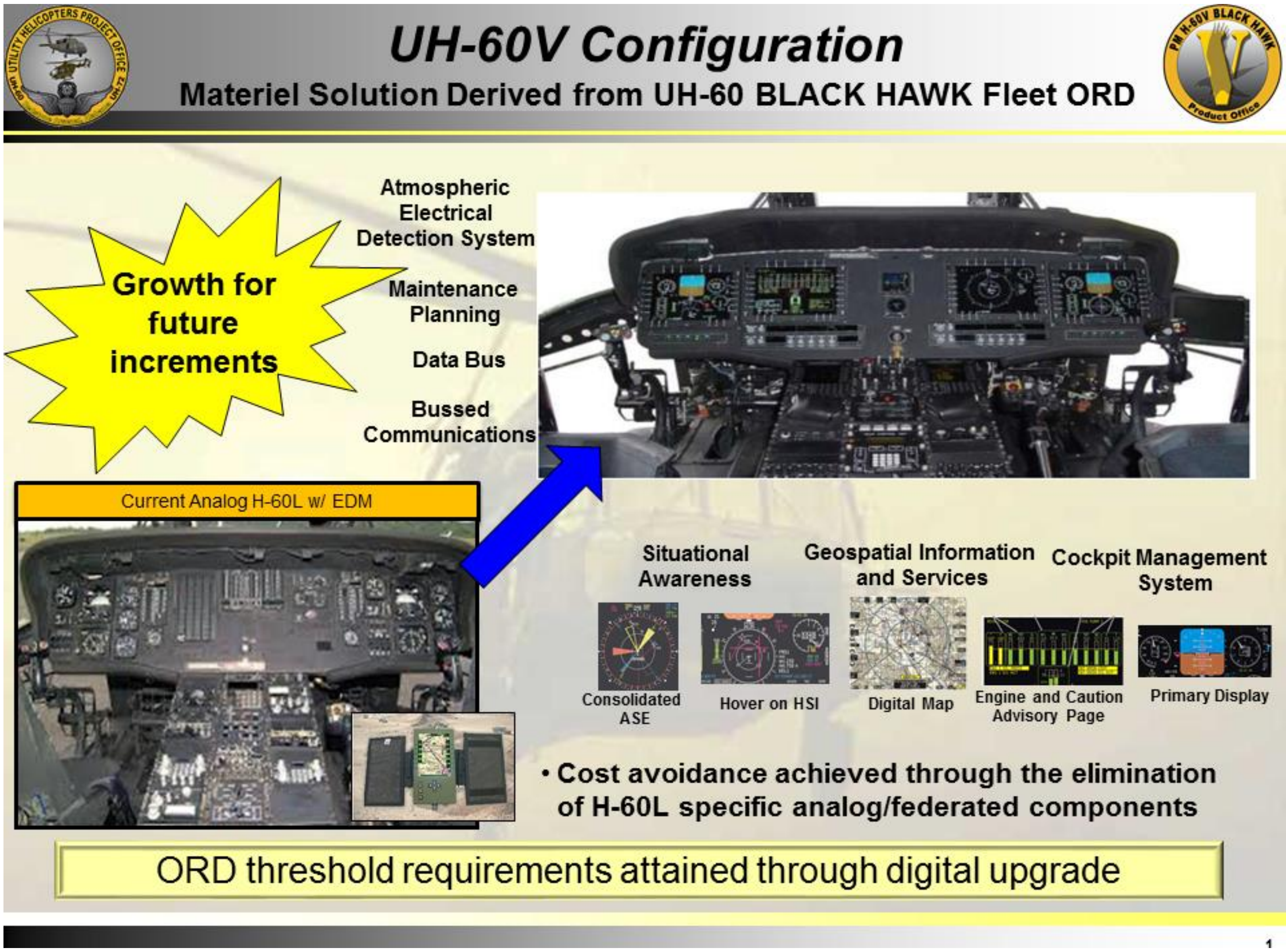

Figure 1: UH-60V Configuration and Material Solution

The primary mission of UH-60 is to perform vertical envelopment and vertical replenishment as well as MEDEVAC and C2. It provides Mission Command interfaces to exploit the capabilities of a joint force and support the maneuver force commander. It interfaces the common operational picture providing platform location and status. UH-60 messaging supports text and graphics exchange with other battlefield systems. UH-60 contributes to enhanced situational awareness and survivability through active and passive countermeasures and joint command and control interoperability. The communications suite requires multiple transmit and receive waveforms that support voice, data, line-of-sight and beyond line-of-sight connectivity, depicted in Figure 2: UH-60V BLACK HAWK Operational View (OV) 1.

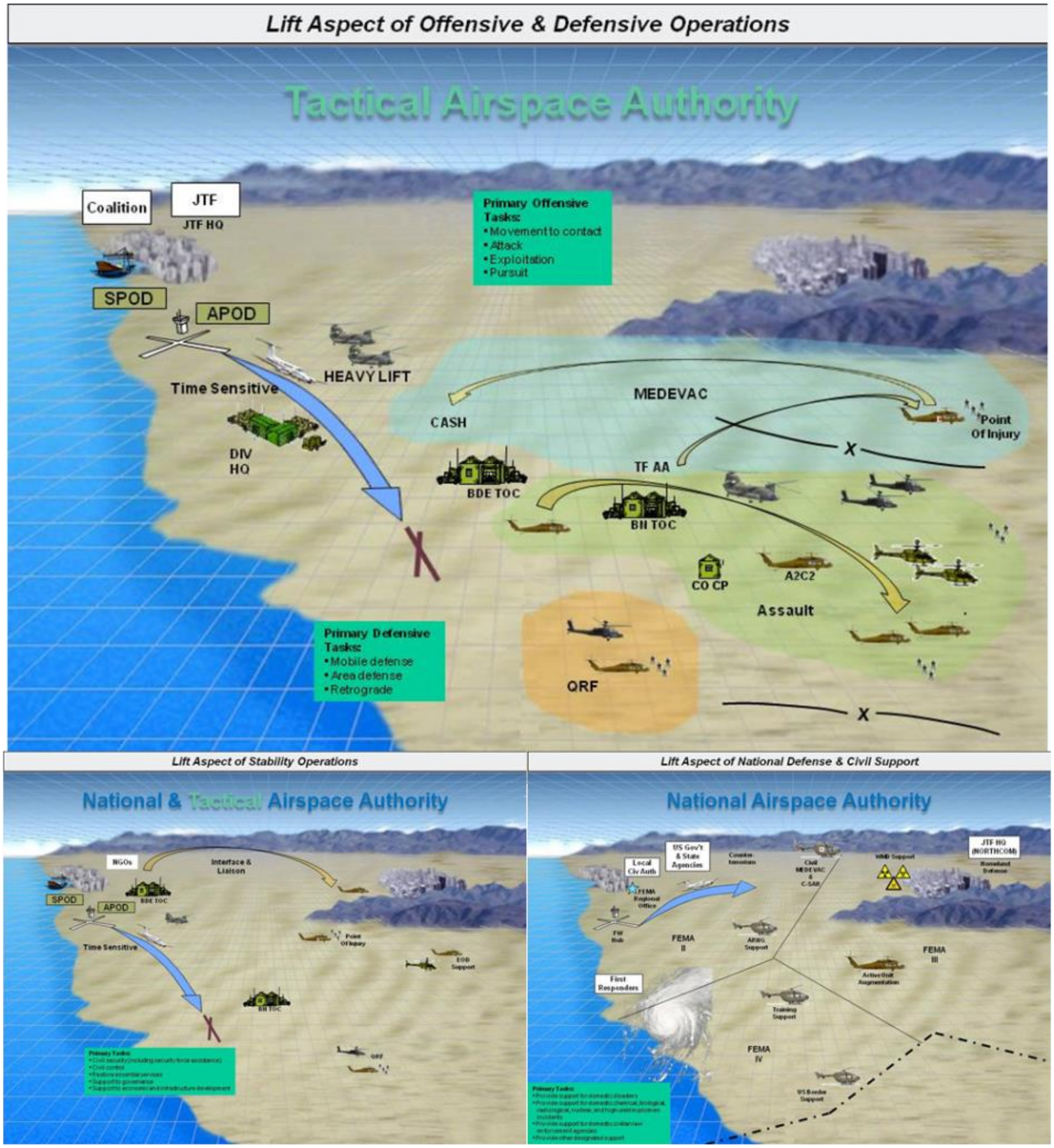

Figure 2: UH-60V BLACK HAWK Operational View (OV) 1

Timelines and Program Objectives

The UH-60V Program will produce a material solution that upgrades the current fleet of analog UH-60L aircraft with a digital cockpit that brings the entire UH-60 BLACK HAWK fleet in accordance with threshold operational requirements. In addition to ensuring compliance with operational requirements, alignment of the

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UH-60V cockpit PVI with the production UH-60M enables commonality in training and operational employment across the BLACK HAWK fleet, requirements clarity, common training, and the ability to leverage common documentation. Further, by synchronizing integration of the UH-60V materiel solution with the UH-60 Recapitalization program, we are able to affordably and efficiently modernize the BLACK HAWK fleet while extending the service life of the airframe; maximizing value to the War Fighter and tax payer.

The UH-60V program successfully completed a Materiel Development Decision Review in June 2013 with direction to enter at Milestone B. A successful Milestone B Decision Review was conducted in March 2014 with designation of the UH-60V as an Acquisition Category (ACAT) II Program of Record. Following Milestone B, the program entered into the Engineering and Manufacturing Development (EMD) Phase and has successfully progressed through preliminary and critical design. The program remains on track to enter Milestone C in 2018.

Looking Back, Pre-Milestone B

Based on the operational capability gaps to be addressed by the UH-60V program, it was assessed early on that the materiel solution would drive a software-intensive program with a new development using modern avionics. As a result, an early challenge was how to incorporate Integrated Modular Avionics, DO-178, and Future Airborne Capabilities Environment (FACE) requirements into the contract. A particular challenge that emerged was how to contractually require "highly aligned and loosely coupled software." Attempting to uniquely define and document to these terms in a way that is actually scalable would require excessive pages of requirements and would not ensure alignment with anything other than the UH-60Vprogram or replicability with components from other programs. For this reason, use of the FACE Technical Standard is important in the acquisition of software, future or legacy. If the FACE Consortium cannot capture this in the several hundreds of pages produced under its charter, then there is little hope that an individual program would be able to effectively do so.

Program Objectives

When the system went on contract, we were leaning significantly forward under the "do no harm" policy that appropriately recognized the relatively recent publication of the FACE Standard. The programmatic objectives then, as now, that we hope and plan to achieve by leveraging the FACE Technical Standard include the following:

- To build a platform upon which FACE Units of Portability (UoPs) that are anticipated to be available in the future could be added with minimal impact to the fielded system;
- To ensure the use of non-proprietary interfaces, standards, and protocols;
- To ensure agility in the design, such that modifications to specific performance requirements would be reasonably isolated to the concerns of only those components related to that requirement, and thus improve responsiveness to changing requirements both during development and after the system was fielded; and
- To ensure delivery of a Technical Data Package that maximizes the PM's competitive options throughout the life of the program, including Government Purpose Rights where feasible.

Note that it was not an intent of the program to create specific reusable components for other programs because that would require soliciting requirements from other programs outside of our scope. While it is an objective to provide for reuse, the specific needs of other programs are the responsibility of those programs. Instead, what is within the UH-60V scope is to procure the documentation necessary to support future competitive upgrades and support. Therefore, we are procuring our system with favorable data rights and providing our TDP, lessons learned, and components to other programs in the hopes that they will be able to reuse these valuable investments. It should be made clear that the absence of reuse as a programmatic objective does not imply intent – the UH-60V program intends to provide applications that can be reused by other programs. However, as an objective for the program, and thus as a system level requirement that would result from such an objective, we cannot speculate all of the requirements for components that may be reused by other programs as the UH-60V Program of Record is limited to addressing only those requirements defined in the Fleet Operational Requirements Document (ORD) for Modernization of the BLACK HAWK. For the UH-60V program, use of the FACE Technical Standard does enable a reduction in time to field, cost control, and an affordable and efficient path for sustainability.

FACE References In The Requirements

Understanding the correct way to include contractual requirements were limited by two significant factors. First, there were relatively few examples of other programs with FACE system level requirements. As guidance, the UH-60V program leveraged existing Navy language, as well as the FACE Contract Guide. Second, there was no VA at the time the SOW was issued. Although the Army VA was close behind, the actual SOW went under contract before it was approved. As a result, proposals were written against the requirements without the necessary cost accounted for verification, which at the time could only be assumed since no product had ever gone through a VA. Although the requirements are without specific reference to the VA, we have worked with our vendor to ensure that the entire verification process will be exercised with several components in an effort to provide metrics, understand the scope of verification, provide risk reduction to other programs, and support the FACE ecosystem. The term "align" was chosen to ensure that we could place a system level requirement on contract without knowing the specific details of which components would be produced. With this in mind, measuring effective "alignment" to the standard is subjective in both:

- Intent (align everything or just the components that are planned for reuse?) and
- Design constraint (align the components to what, given no reuse constraint for other programs?)

The subjective nature of interpreting the requirement to align is particularly evident since the requirement is on the system as a whole, not just the components that make up the system. This can be resolved if specific individual reusable components are known to be intended for production up front, or where existing components can be specified for use in the system; neither was available when UH-60V began. One of the early lessons learned in production of the system was how to measure this alignment while balancing the reuse of early development activities provided by the vendor.

Significant CDRLs and Deliverables

For the requirements at the time they were issued, the following categories applied. The requirements are not restated here verbatim, but are summarized into the major areas where requirements were determined to be necessary to achieve the programmatic objectives. The summary statements below contain multiple requirements that are combined for brevity and readability. This represents a small subset of the overall contractual requirements related to software, which include Software Metrics, Problem Reports, Product Specifications, Test Plans, Stage of Involvement (SOI) Audits, Structural Coverage, etc. FACE requirements are an integrated part of the whole system and must be meshed with other programmatic requirements, even though FACE requirements are focused on individual components within an architecture. For example, in order to provide the required artifacts, a program needs not only to supply a CVM, but also the associated design and test documents. As a result, enforcing that these documents are aligned to the same nomenclature and consistent will aid in Verification.

Table 1: Contractual Requirements mentioning FACE in the 60V SOW

Contractual Requirement	CDRL	Lesson Learned
All new and modified software shall align with the FACE Technical Standard, Edition 2	None	This was later updated (around PDR) to Version 2.1, which had not yet been released at the time the program went on contract.
The Contractor shall prepare an OSMP containing details of how the FACE Standard is implemented in the design	OSMP	The OSMP proved to be a very useful early deliverable for more than just a description of the architecture, but also for the third party applications integrated into the system.
The Contractor shall prepare a FACE Conformance Verification Matrix, updated at significant design reviews	CVM	One of the early lessons learned is that there is not a system-level CVM, but one per UoP, thus our requirement was later modified to read “for each FACE UoP”.
The Contractor shall prepare a FACE Architecture Summary Document that contains top level architecture diagrams, an architecture description of major components, and a list with brief descriptions of each Unit of Portability (UoP), ad defined in the FACE Technical Standard.	FACE Architecture Summary Document	The intent of the summary document is to be a brief and practical explaination of how the product implements the FACE Technical Standard. Emerging discussions within the FACE Consortium about system level views and integration documentation came later.
The Contractor shall devlop detailed software Architectural Modeling documentation with sufficient information to address DO-178, consistent with the SDD, containing details of all FACE UoPs listed in the Architecture Summary documentation, containing details of the interfaces to drivers, libraries, or third party compoenents sufficinet to define boundaries of any code that is not delivered as source, and an analysis of timing, throughput, sizing, and safety partitioning.	Architectural Modeling	This set of requirments was intended to be the detailed models to accompany the design documentation contained in the SDD and summary information in the OSMP and Architecture Summary.

The Learning Curve

The FACE Technical Standard has a significant learning curve. The existence of a Contracting Guide and a Business arm of the FACE Consortium is certainly of significant advantage. Nonetheless, there is a perceived and actual risk in early adoption of the standard in a major ACAT II system. We believe that the requirements which we put on contract did, in fact, strike the balance we were hoping to achieve by adopting FACE as a system level requirement and we hope to decrease the slope of the learning curve for future programs. A few of the significant factors for this learning curve that would benefit future acquisition professionals when considering FACE requirements are the following:

- Develop an understanding of FACE UoPs and how the FACE Technical Standard defines a portable component, consider how to incorporate that into system level requirements;
- Develop an understanding of the FACE Segments, particularly the Transport Services;
- Consider the implications of the FACE Data Model, particularly from a programmatic perspective rather than a technical perspective, meaning both the production of the data models and how assumptions in interface documentation can be tested in a data model;
- Start early with the Verification process, understand the needs and timelines of the VA and how they are tied to existing programmatic deliverables (design and test);
- Lastly, but perhaps most importantly, consider how FACE requirements factor into the long-term sustainment of a program (replaceability and upgradability) rather than only reusability.

Software Architecture Overview

UH-60V Physical Architecture

The UH-60V Digital Cockpit system consists of the Technical Refresh Mission Computers (TRMCs), displays, and other elements. The data bus architecture is comprised of open standard buses, without proprietary interface designs. The redundant Ethernet backbone is primarily for high data rate synchronization communications by the TRMCs, Control Display Units (CDU), Data Transfer System (DTS)/Network File Server and tactical modem. Redundant Ethernet switches provide for a fault tolerant solution. The system is designed with four independently redundant MIL-STD-1553B busses, of which two are used, and the other two are spares for future growth. The majority of the legacy avionics interfaces are on either 1553B data busses or ARINC 429 interfaces. Both TRMCs provide primary and backup bus controller modes of operation. Redundant hardware devices for navigation, communications, and data concentrators are allocated to separate 1553B busses for fault tolerance purposes. Aircraft analog and discrete signals are interfaced through the Data Concentrator Units (DCU), which concentrate such signals into 1553 messages for the TRMCs.

All of the integrated avionics system software is resident in the TRMCs. This includes the flight management software, the software to generate all of the data on the displays, as well as the software to allow the operators to control all of the attached devices.

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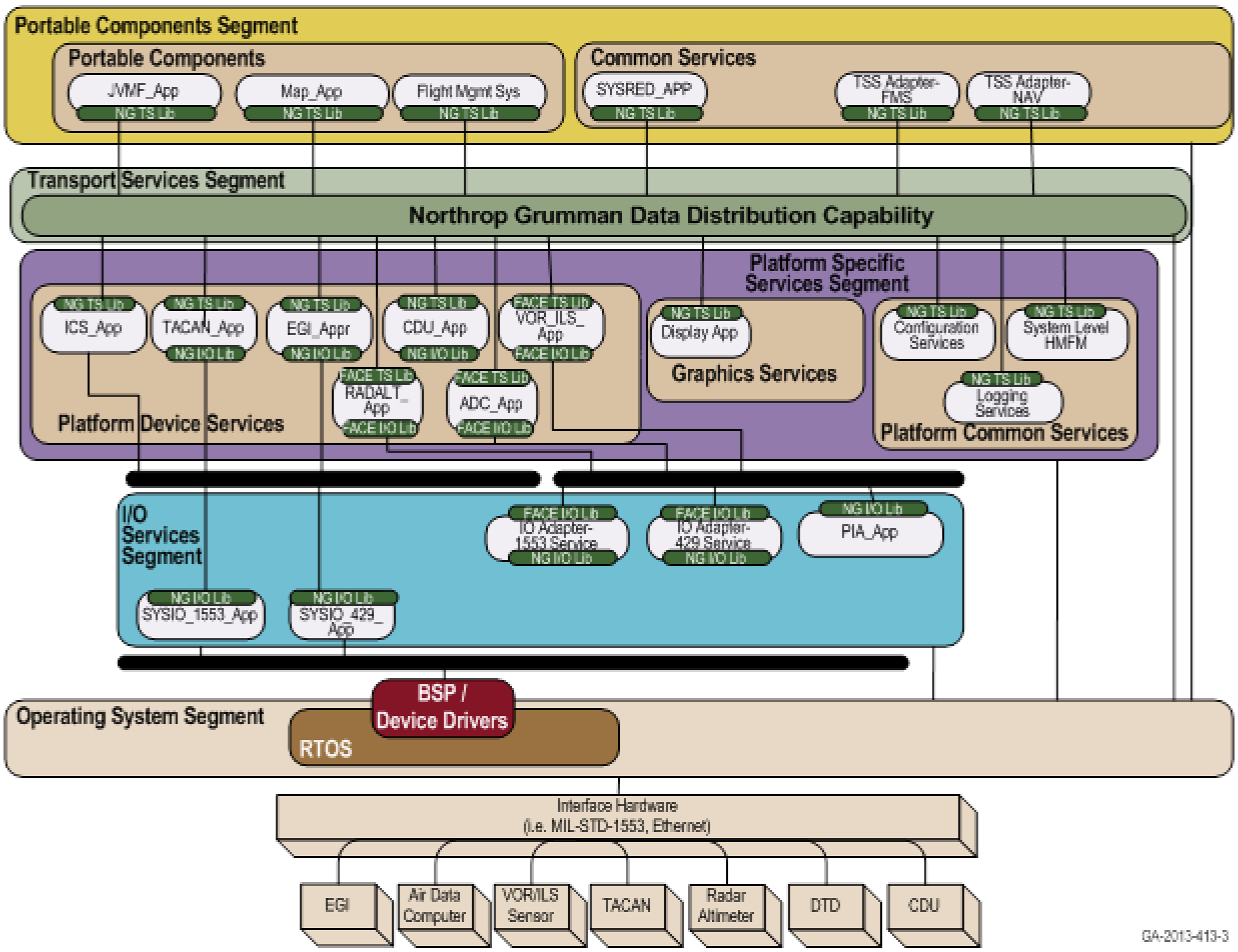

Figure 3: UH-60V FACE Architecture Summary

FACE Architecture Summary

A graphical overview of the UH-60V design is depicted in Figure 3: UH-60V FACE Architecture Summary. The UH-60V System includes software developed for all of the FACE segments with the exception of the Operating System Segment, which was obtained as Commercial Off The Shelf (COTS). The architecture provides for 22 specific components aligned to the FACE Technical Standard as well as a Transport Services Segment (TSS) wrapping the Northrop Grumman developed Data Distribution Capability (NG DDC). The UH-60V program has obtained Government Purpose data rights for each of these with the full intention of leveraging this valuable investment to the benefit of the BLACK HAWK fleet and other defense programs.

Application Architecture

An understanding of FACE UoPs and how the FACE Technical Standard defines a portable component; since there is no such thing as a “FACE System”, the understanding of the way applications, functions, and components are used within the system is key. Because not all of our components will be verified at the time of this paper, we are using the term “apps” (reflecting consistency with vendor documentation) for the broad category of these software units, some of which will be specifically FACE UoPs.

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Transport Services

An understanding of the Transport Services, particularly the implications to modular software design, are critical. Figure 4: Partitioned Architecture through Transport Services, shows an example in the UH-60V architecture of an existing Line Replaceable Unit (LRU) that would provide data to the rest of the system, the Improved Data Modem (IDM). In this case, the IDM software resides in a Design Assurance Level (DAL) D Partition space and communicates only through the IDM Interface App, which in turn communicates to the Transport Service (NG DDC) and from there to the rest of the system. This paradigm is in alignment with the FACE Technical Standard even though the legacy system was not originally developed with a FACE UoP to interface with. For clarity, even though the IDM Interface App is not being put forward as a UoP that will be verified, the component will now exist. Other programs, such as the UH-60 Futures team, are looking at reuse of this app.

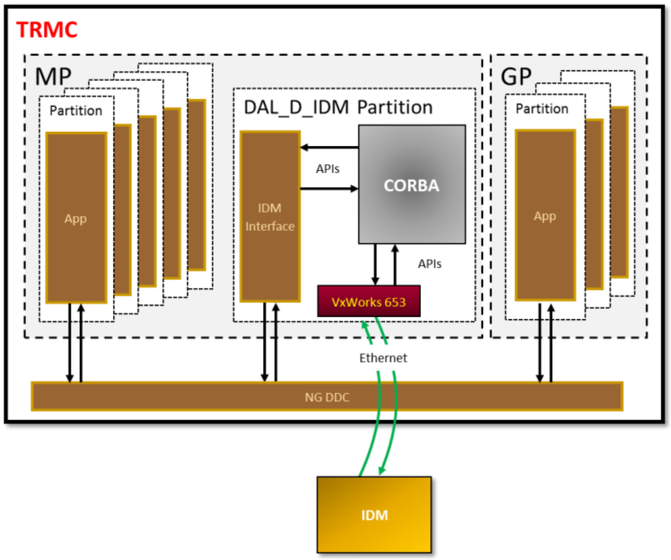

Figure 4: Partitioned Architecture through Transport Services

This is enabled because of a strict adherence to the concept of Transport Services as the means of isolation between apps throughout the system. One question that may arise on the UH-60V program, specifically, is whether the TSS implementation is limited in some way by the use of a specific tool chain (in our case, SCADE for both the PVI and the component applications). We have examples within the existing architecture, however, of applications that are hand-coded or supplied by other entities, such as the U.S. Army Software Engineering Directorate (SED). These third party software products are integrated into the environment but are not built with the same tool chain. The interface, like in the IDM example, to the rest of the system is through the Transport Service. Because of adherence to the Transport Service constraints, these apps communicate and integrate within Publish-Subscribe environment envisioned by the Standard.

Lessons Learned

Finding A Starting Point

One of the most challenging parts of getting a program on contract is striking the balance between effective requirements in the contracting package and yet not assuming the design prior the contract award. We must provide a balanced approach that leads to innovation on the part of the designers but likewise gives us clear and achievable design constraints necessary for reuse and interoperability. While the FACE Technical Standard does an excellent job for much of the design constraint need, it must be leveraged in conjunction with other standards such as 1553 and DO-178C. Each program must look at their overall constraints (for example, moving to fiber instead of using 1553) to put these various standards to effective use. Moreover, the specification of a complete architecture (to include the subcomponent interfaces at the UoP level) is a challenging design constraint, one which implies that the Government already knows the answer to key issues and that adequate subcomponents already exist.

Leveraging the FACE Technical Standard to enforce a layered architecture partially meets this challenge by ensuring the answers to "Highly Aligned to What?" and "Loosely Coupled How?" are given in a consistent way across programs. What the FACE Technical Standard does not provide, however, is the definition of the components themselves. The work of low level requirements development, systems engineering, and design are done after the program is put on contract and, unless components are specified as part of the contract and reused from other systems, it may not be known in advance what design decisions will result from this process. Once components exist in the marketplace, more options will be available to future PMs to specify reuse of existing components. However, when UH-60V initiated development, we could not provide existing components as constraints. So, for example, while we have an application in our architecture that meets the requirements of our program for interfacing to an EGI, we cannot say that it is the right starting point for other programs.

Understanding and Documenting Design Decisions

We hope that by looking at the details of the TDP provided we can get to a common definition for common components. Until then, we can only provide what we have created as a possible starting point for other PMs so that they can leverage from our architecture those components delivered as part of the material solution. The matrix in Table 2: Desired OSA Attributes for Software Components was provided as part of the UH-60V OSMP and creates a starting point for the components we are producing. Using this analysis as an initial consideration, other programs will be able to leverage UH-60V investments that were designed to be reusable from the ground up.

Note: components in yellow cells represent renamed or revised (11%) and those envisioned in the draft OSMP that were not included in the design have been left in the matrix (20%), but are displayed as red cells. The matrix shows that even within the short timespan from producing the OSMP until the design approval at CDR, there were a significant number of design decisions that required applications to be reorganized, repackaged, and redesigned. Design decisions could not have been foreseen by the designers at contract award, much less by the PM prior to getting the designers on contract, including: new applications such as the SYSIO_429_App and SYSIO_1553_App, Flight_Critical_App, and Nav_Manager_App; breaking apart large functions such as the Flight Management System segment to FMS_App_EC and FMS_App_DC; realigning partitions; etc. That implies certain limitations in pre-specifying which components must be reused. We certainly believe we will get maximum value from common software that matches the functionality of common hardware, such as the RADALT and EGI; perhaps confirming that assumption to some degree, those items **in green cells with Bold Text** in the table were more stable from contract award through CDR and, though the design was not yet in place, the purpose and title of the application remained close to what was originally planned.

Table 2: Desired OSA Attributes for Software Components, from Contract Award to CDR

Function	Reconfig	Portability	Maintainability	Tech Insertion	Vendor Indep	Reusability	Scalability	Interoperability	Upgradeability	Supportability	Competition
Operating System	**H**	**H**	**H**	**H**	**H**	**H**	**H**	**H**	**H**	**H**	**H**
NG DDC (FACE TSS)	**H**	**H**	**H**	**H**	**M**	**H**	**H**	**H**	**H**	**H**	**H**
Flight Management System	**H**	**H**	**H**	**H**	**M**	**H**	**H**	**H**	**H**	**H**	**H**
Digital Map	**H**	**H**	**H**	**H**	**M**	**H**	**H**	**H**	**H**	**H**	**H**
MOSArt	*M*	*M*	*M*	*M*	*M*	*M*	*M*	*M*	*M*	*M*	*M*
CORBA	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*
Warning Caution App	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**
Data Concentration Unit App	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**
HUD App	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**
VOR/ILS App	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**
~~Stabilator App~~	~~M~~	~~M~~	~~M~~	~~M~~	~~M~~	~~M~~	~~M~~	~~M~~	~~M~~	~~M~~	~~M~~
AFCS App	*M*	*M*	*M*	*M*	*M*	*M*	*M*	*M*	*M*	*M*	*M*
Reversionary App	*M*	*M*	*M*	*M*	*M*	*M*	*M*	*M*	*M*	*M*	*M*
EGI App	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**
IFF App	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**
FD App	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**
~~Pointing Device App~~	~~M~~	~~M~~	~~M~~	~~M~~	~~M~~	~~M~~	~~M~~	~~M~~	~~M~~	~~M~~	~~M~~
CDU App	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**
TACAN App	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**
ADC App	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**
RADALT App	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**
Stormscope App	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**
ARC201 App	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**
ARC231 App	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**
BFT App	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**
ICS App	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**

CMWS App	*M*	*M*	*M*	*M*	*M*	*M*	*M*	*M*	*M*	*M*	*M*
~~Checklist App~~	~~M~~	~~M~~	~~M~~	~~M~~	~~M~~	~~M~~	~~M~~	~~M~~	~~M~~	~~M~~	~~M~~
Engine Performance App	*M*	*M*	*M*	*M*	*M*	*M*	*M*	*M*	*M*	*M*	*M*
IDM App	**H**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**
IVHMS App	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**
~~Stick App~~	~~M~~	~~M~~	~~M~~	~~M~~	~~M~~	~~M~~	~~M~~	~~M~~	~~M~~	~~M~~	~~M~~
Flip App	*M*	*M*	*M*	*M*	*M*	*M*	*M*	*M*	*M*	*M*	*M*
WAAS App	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**

Managing Expectations for FACE Version Changes

During PDR a question arose due to the shift from using the system design constraint of FACE 2.0 to FACE 2.1 regarding what the approach should be when FACE 3.0 or later versions are published. It was not widely understood by the audience, and should not be assumed to be understood by future audiences, that the version of the FACE Technical Standard is primarily focused on individual components and not on the system as a whole. The expectation is that future components will meet the current version of the FACE Technical Standard, but in order to use them in legacy systems some level of backwards compatibility must be enabled by the architecture. The program has a reasonable expectation that the inclusion of a new component will not change the needs of existing components in publish-subscribe architecture, thus at some future point there may be components in the system conformant to several different versions of the standard. It is not the intent of the program that they will upgrade the components that already exist to keep pace with newer versions of the Standard. Conversely, new components should be able to work in the existing environment with minimal rework. This occurs because of the separation of concerns and the use of Transport Services – the new component can be integrated and can still subscribe to the existing published data already on the Transport (such as aircraft position data or fuel quantity) without requiring those components to be upgraded. Therefore, FACE 3.x UoPs can be added to architecture originally designed against an earlier version of the Standard. The choice to move to Version 2.1 was primarily associated with changes to the Shared Data Model that would have made this transition more difficult in the future.

FACE as a System Design Constraint

One of the key goals of using the FACE Technical Standard as system level requirement is to ensure the design constraint that future components will work in the environment. The OSMP states "*The 60V architecture provides for the creation of FACE™ adapters that would take specific data from our internal components and make that data available for use over the FACE™ Transport Services Segment (TSS). This allows for future UoPs to be integrated into our system and be able to gain access to commonly required data (e.g., GPS, INS).*"

One example that created positive value engineering without a corresponding risk of "gold-plating" is visible in another section of the OSMP, where growth requirements for POSIX are derived from the inclusion of the FACE Technical Standard, even though no POSIX requirements were included in the original contract requirements. "*Besides ARINC 653, our UH-60V Digital Cockpit software architecture supports an OpenGL graphics library, which is compatible with the Graphics Services section in the FACE Reference*

Architecture. Although our Northrop Grumman developed mission computer applications strictly conform to ARINC 653, our UH-60V Digital Cockpit architecture also supports POSIX, which is a FACE™ standard. This support for POSIX allows POSIX avionics components to be integrated into our FACE™ computing environment."

Data Modeling Lessons Learned

The FACE Data Model is necessary for FACE conformance. However, the Data Model as documentation for this purpose is not technically required to make the software work, as the information in the Data Model is contained in the physical software at compile time. Therefore, the Data Model provides a similar function to an Interface Control Document. Testing against the Data Model should provide a level of certainty that the data exchanged through the interface does, in fact, match the model. We see future value in that machine-readable structure, which would avoid misunderstandings and errors in a written ICD by providing a software-constrained machine language ICD that goes directly to the actual interface itself rather than a document that describes it. However, given the high value for speed in development and DO-178C certification using Model Based Systems Engineering, the lack of tooling support to produce the Data Model documentation for the VA will hopefully soon be addressed by industry.

During the course of the design and development, decisions must be made to keep on schedule and within cost. One of those is related to the production of documentation (as the Data Model can be considered) that does not directly affect functionality. The program was presented with a change in which UoPs were candidates for Verification in large part due to Data Model concerns. Northrop originally proposed "*…components [that] already have a high degree of portability so the intent was to develop an adapter between the existing component interfaces (APIs) and the FACE Transport Service Segment (TSS) interface using the FACE Data Model."* After design began and Data Model constraints were applied to these existing components, some concerns arose that prompted a shift to organically produced (rather than "wrapped") components as candidates to ensure that no changes to third party software were required.

Northrop further stated: *"This task involves the creation of a UoP Supplied Model (USM) developed / derived from the FACE Data Model elements and then sending/receiving those messages through the FACE TSS. In order to provide a USM, it requires that all elements in the USM be derived from elements in the FACE Shared Data Model (SDM) or extend the SDM to include new concepts. This derivation from the SDM is required for conformance to the FACE Technical standard and to provide a representation of the FACE Data Model to the FACE Conformance Verification Test Suite. At the time of the proposal, the SDM was at version 2.0 and version 2.1 was in development with several significant changes to certain areas such as measurement units, frame of reference, and enumerations."*

The focus is not to drive the technical development aspects of the Data Model, which is an effort that is best served by entities contracted by the Army, who provide materiel solutions, and the FACE Consortium to enable a consensus-based standards body. What matters is how to transfer to other Program Managers an understanding of how a program is to respond when there is potential misalignment between the intent of a technical requirement and the implementation of that requirement, particularly when the requirement is external and not under the direct control of the PM (and cannot, therefore, be modified by normal PM actions). In this case, there was no specific reason or technical requirement to wrap the legacy third party software component in a FACE UoP, so the target UoPs were adjusted. The goal is to bring such components into alignment in future releases, but that takes time (which correlates directly to schedule risk) and the efforts of skilled technicians (which correlates directly to cost risk). Managing that risk in a way that also meets the objective is the role of the PM. The technical issues discovered on real implementations necessitate that the PM, integrators, and suppliers provide that feedback to the Consortium so that the Standard can be a living document. It is also critically important that industry provide the tooling support necessary to developers and integrators for building and testing these components. Finally, many of these decisions involve third party and common applications managed by other PMs that are upgraded in various timelines. When the alignment occurs the PM can make the appropriate technical decisions to modify the software to come into alignment with the approved modification or to take a variance and the associated technical risk.

This is a technical approach that is informed by a business case analysis because it is always specific to the case in point. In no area is that more clear than with respect to an understanding of the FACE SDM and USM requirements on individual components. This is something that is, at the same time, a deeply technical multi-program common requirement (thus, shared) and also an issue that is particular to a specific program or system design at a specific point in time during its lifecycle.

Looking Forward, Milestone C and Beyond

The cost for verification, including production of all required verification artifacts (such as CVMs and Conformance Statements), the potential for CCB actions, and test-fix-test interactions present possible risks to program cost and schedule; efforts not currently planned by the UH-60V program. The Utility Helicopters Project Office software team is coordinating the delivery and interaction with the VA for programmatic documentation and finally the UoPs, once they are tested by Northrop through the DO-178C process.

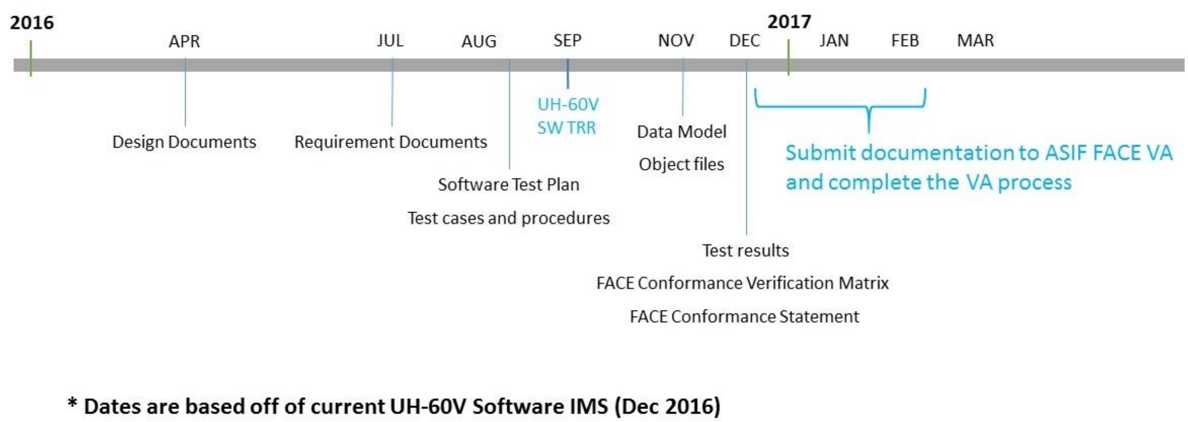

Figure 5: Anticipated Verification Timeline

Conclusions and Recommendations

The UH-60V program has pioneered and learned several valuable lessons for implementing FACE Technical Standard requirements into the system requirements. We have been actively working with the Future Vertical Lift (FVL) architecture team to share these lessons, including dialogue about taking the components that are "aligned" and putting them on contract as GFI as design constraints for prototypes, ensuring both that the components progress and that we prove portability and reusability. Any future announcement of such an opportunity will flow through the standard process. Likewise, we have coordinated internally with the UH-60 Futures team on the potential reuse of the IDM app, amongst other components. We were also recently contacted by another PM responsible for the production of an LRU interested in reuse of a specific component produced by UH-60V as a starting point for their own efforts in delivering a FACE UoP as GFI along with their GFE. While the purpose of the program is to field a system guided by operational requirements, not the individual components or UoPs, reuse is very likely in not only the speculative FACE UoPs that will be produced by the program, but by the other aligned components that may become future UoPs. Our recommendation is that a strategy needs to be initiated by the Army for continued development and verification of common components, which were originally (often partially) developed by one program, to enable re-use by other programs. With this in mind, measuring effective "alignment" to the standard in both intent and design structure of the system as a whole (not just the components that make up the system) has a significant number of lessons that would be beneficial to other programs. Selection of existing reusable components, an option that was not available to our program when we started, is now available to other programs based on the components produced as part of the 60V program, including nearly two dozen individual components and a reusable TSS that could be incorporated into other systems. The cost for completing these components through verification is less of a challenge than determining who owns the charter for the reuse requirements that would make the components valuable to another program. Who determines (from a product line perspective) the requirements for the interface of a Stormscope UoP, a Radar Altimeter UoP, or transponder UoP? We have provided our solution as a possible option, but it was beyond our charter to assume our design choices meet the needs of other programs. In order for other programs, including the future sustainment of the UH-60V, to benefit from a strategic reuse, we recommend the development of a strategy that encompasses development, verification, reuse of high-value common components by multiple programs so that they can be included as GFI on future systems. Such a strategy can significantly leverage work developed by existing programs such as the UH-60V to enable re-use by other programs.

About the Authors

This paper was a collaborative effort by the UH-60V Software Team leveraging significant prior efforts on the part of the Northrop Grumman team. Information was derived from NGC developed graphics, CDRLs, and contract deliverables. Special thanks to the efforts and attention to detail goes to Simona Kelly, Pablo Borruel, Mike Vertuno, and the NGC software team.

Mr. Forrest Wayne Collier

Mr. Forrest Wayne Collier is the H-60V Product Director and manages the development for the UH-60V, an ACAT II program within the Utility Helicopters Project Office under U.S. Army PEO Aviation, at Redstone Arsenal, Alabama. Mr. Collier is a native of Alabama. He earned a Bachelor of Science in Mechanical/Aerospace Engineering in 2002 and a Master of Science in Management in 2006 from the University of Alabama at Huntsville.

Following college, Mr. Collier entered civil service in 2002, assigned as an Aviation Test Engineer with the US Army Redstone Technical Test Center (RTTC). In 2005, Mr. Collier accepted a position as Test Engineer with the UH-60M Product Office, Utility Helicopters Project Office (UH PO) serving as Test IPT Lead; successfully completing system-level developmental and operational tests in support of the UH-60M Full Rate Production Decision. In 2008, Mr. Collier accepted a position as Chief Engineer, Iraqi Armed 407 Helicopter, Armed Scout Helicopter Project Office (ASH PO), a Foreign Military Sales program critical to the handover of defense duties to the Iraqi Ministry of Defense. In 2010, Mr. Collier returned to the UH PO as Chief, Engineering Support Branch, responsible for systems engineering, configuration management, engineering services management, and value engineering of the BLACK HAWK Helicopter fleet. In July 2012, Mr. Collier was selected as Deputy Product Manager, H-60L Digital, UH PO. The H-60L Digital office was re-designated as the UH-60V Product Office following a successful Milestone B Decision Review in 2014. Since that time, Mr. Collier has served as Product Director, UH-60V, responsible for management and execution of the UH-60V ACAT II Program of Record, H-60 Recapitalization Program, and life-cycle management of the H-60A/L BLACK HAWK fleet. Mr. Collier holds Level III certifications in Program Management, Test & Evaluation, and Systems Planning, Research, Development, and Engineering (SPRDE).

In addition to his civilian career, Mr. Collier has spent the last eighteen years as a member of the US Reserve Forces. He earned a Direct Commission as an Intelligence Officer with the Navy Reserve in 2004 following seven years as a Non-Commissioned Officer in the US Marine Corps Reserve assigned to Kilo Battery, 4th Battalion, 14th Marine Regiment, 4th Marine Division. Navy Reserve assignments include billets with NR Defense Intelligence Agency 1567 as an Intelligence Analyst, NR European Command Joint Analytic Center Molesworth 0167 as Administrative Department Head and Chief, Joint Expeditionary Support Branch, and NR ONI 2109 as Training Department Head and Chief, Maritime Technical Analysis Branch. From July 2014 to June 2015, Mr. Collier was recalled to active duty in support of Operation Inherent Resolve with Special Operations Joint Task Force – Fort Bragg, North Carolina, serving as a Senior Intelligence Duty Officer. He was selected as the DIA 1567 Junior Officer of the Year in 2007 and the EUCOM JAC 0167 Junior Officer of the Year in 2010. Mr. Collier is an Information Dominance Warfare qualified. Other personal awards include the Joint Service Commendation Medal (2), Navy and Marine Corps Commendation Medal, Joint Service Achievement Medal, Navy and Marine Corps Achievement Medal, and the Selected Marine Corps Reserve Medal.

Pioneering FACE on Legacy Systems (UH-60V)

MAJ Clayton Bagwell

MAJ Clayton Bagwell is the Assistant Product Director (APD) for the UH-60V Product Office. MAJ Clay Bagwell, a native of Cordele, Georgia, began his military career in April 1994, when he enlisted in the United States Marine Corps Reserves. In 1998, he graduated from The Citadel, The Military College of South Carolina with a Bachelors of Art in Political Science. In November 2000, he enlisted in the South Carolina Army National Guard to pursue a commission through Officer Candidate School. He was commissioned as an Aviation Branch Officer in 2003.

MAJ Bagwell has served in a variety of duties as an Aviation Officer. His assignments include Attack Platoon Leader, Company Commander and Battalion Staff for 1-151st Attack Reconnaissance Battalion. During this time, MAJ Bagwell served as the Aviation Liaison Officer on the South Carolina National Guard J3 Staff and supported numerous natural disasters and search and rescue operations requiring the utilization of aviation assets. In April 2011, MAJ Bagwell deployed to Iraq in support of Operation New Dawn (OND) as a Company Commander for Task Force Marauder. Prior to redeployment, MAJ Bagwell served as Task Force Marauder S1 Officer. During this time, MAJ Bagwell continued to fly combat missions.

MAJ Bagwell was selected for the Army Acquisition Corps in 2012 and assessed into the Active Guard Reserve (AGR) program in 2013. His first acquisition assignment was in Washington, D.C. at the National Guard Bureau G-8, Materiel Equipping Division (RMQ) as the Aviation Systems Coordinator. Following this assignment, MAJ Bagwell was assigned to the Utility Helicopter Project Office at Redstone Arsenal in 2013 to serve as the Assistant Project Manager for the UH-72 Lakota. In July 2015, MAJ Bagwell was assigned as the Assistant Product Director for the UH-60V Black Hawk.

His military education includes the Aviation Officer Basic and Captain Career Courses. MAJ Bagwell is scheduled to complete Command and General Staff College Distance Education Program in April 2016. MAJ Bagwell is currently completing a Masters in Procurement and Acquisition Management from Webster University.

MAJ Bagwell’s military awards and decorations include the Senior Army Aviator Badge, the Bronze Star Medal, the Army Commendation Medal with oak leaf cluster, the Army Achievement Medal with oak leaf cluster, Army Reserve Component Achievement Medal with oak leaf cluster, the National Defense Service Medal with bronze star, the Iraqi Campaign Medal with bronze star, the Global War on Terrorism Expeditionary Medal, the Global War on Terrorism Service Medal, the Armed Forces Reserve Medal with hourglass and mobilization device, the Selected Marine Corps Reserve Medal, the Army Service Ribbon and the Combat Service Identification Badge. MAJ Bagwell is DAWIA Level II certified in Program Management.

Dr. Marsha Cagle West

Dr. Marsha Cagle West is the Software Integrated Product Team Lead for the UH-60V program within the Utility Helicopters Project Office under U.S. Army PEO Aviation, at Redstone Arsenal, Alabama. Dr. West earned a Bachelor of Science in Computer Science from the Georgia Institute of Technology in 1985, a Master of Science in Computer Engineering from the University of Central Florida in 1990 and a Doctor of Management in Organization Leadership/Information System Technology from the University of Phoenix in 2010.

Dr. West has over 30 years of experience in software engineering and systems development. After college, Dr. West began her civil service career at the Naval Coastal Systems Center in Panama City, Florida as the lead engineer for Mime Countermeasures (MCM) and Mine Hunter Coastal (MHC) ship navigation, information, and training systems. In 1991, Dr. West accepted a position at Redstone Arsenal in Huntsville, Alabama. Since moving to Redstone, Dr. West has been the lead for multiple aviation programs. Dr. West was the Unmanned Aerial Vehicle (UAV) Computer Resources and Software Lead for the Joint Tactical Unmanned Aerial Vehicle (JT-UAV) Project Office. In 2000, Dr. West accepted a position as the Utility Helicopters Program Management Office (PMO), Software Engineering, Simulations and System Integration Laboratory (SIL) Branch Chief. This Branch in the Utility PMO provided support for software and simulations across all product lines and phases of system acquisition. From 2002 to 2005, Dr. West accepted a position with the Defense Advanced Research Project Agency (DARPA) as the Mission Management and Control Program Manager for the Unmanned Combat Armed Rotorcraft (UCAR) program. UCAR was a combined effort of DARPA and the US Army conducting research on integrating unmanned and manned aircraft. From 2006 to 2014 Dr. West was the Armed Scout Helicopter (ASH) Program Office Software Lead. Dr. West provided oversight and direction for Kiowa Warrior, Armed Reconnaissance Helicopter (ARH), and Iraqi Armed 407 programs. In 2014, Dr. West returned to the Utility Helicopter Program Office as the UH-60V Product Office software lead responsible for design and development of software systems in accordance with DO-178C, DO-254 and Mil-STD-882E.

Dr. West has received the Commanders Award for Civilian Service and holds Level III Certifications in Systems Planning, Research, Development and Engineering (SPRDE), Test and Evaluation Engineering, and Program Management. Dr. West is a member of the Army Acquisition Corps, American Society of Military Comptrollers (ASMC), and American Indian Science and Engineering Society (AISES).

Mr. John T. Stough

Mr. John T. Stough, CISSP, is the SwIPT Lead for the Prototype Integration Facility (PIF) supporting the UH-60V Product Office. Mr. Stough served in the U.S. Air Force from 1993 to 1997 as an Intelligence Operations Specialist with the 23rd Wing "Flying Tigers" and was deployed for Operation Uphold Democracy and Operation Southern Watch. Mr. Stough then moved into the software career field supporting the Parametric Endo-Exoatmospheric Lethality Simulation (PEELS) team in Huntsville, AL. Mr. Stough accepted a position developing commercial software components for other developers, including 3D OpenGL based components. Mr. Stough has supported commercial software efforts as software development manager, project manager, and product manager in the healthcare, automotive, telemetry, environmental engineering, open source software, and intelligence domains. He started a software architecture consultancy (Exocubic, which means "Outside the Box") and has been involved in supporting startup ventures, one of which resulted in listing Mr. Stough as a provisional patent co-inventor (Serial No. 12/686,296, "Human Health Monitoring Graphical User Interface Systems and Methods"). Moving back into the defense domain, Mr. Stough became the software development manager for the Ballistic Missile Defense System (BMDS) Operational Test Agency (OTA).

Mr. Stough joined the H-60L Digital office as the Software IPT Lead in 2013, which was re-designated as the UH-60V Product Office following a successful Milestone B Decision Review in 2014. He then transitioned to the Software Engineering Directorate (SED) to support the Avionics Systems Integration Facility (ASIF) as the deputy for FACE. Mr. Stough rejoined the UH-60V team as the PIF SwIPT Lead at Critical Design Review (CDR). Mr. Stough is the co-chair of the FACE Consortium's Integration Workshop Standing Committee.

Pioneering FACE on Legacy Systems (UH-60V)

Mr. Stough graduated with Bachelors of Science in Business Administration concentrating in Management Information Systems from Columbia College, MO, in 2007. Mr. Stough is a Certified Information Systems Security Professional (CISSP) and has a certificate in IT Project Management from ESI through George Washington University.

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.