Crew Mission Station (CMS) Comprehensive Architecture Strategy

Impact of applying The FACE Technical Standard to the CMS Architecture

NAVAIR FACE™ TIM Paper

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Executive Summary

The CMS Architecture Project encompassed the development of an architecture, detailed design, implementation, flight demonstration and flight test for a Crew Mission Station (CMS) system based on the business and technical requirements from the Utility Helicopters Program Office (UH-PO) for the UH-60M.. The design and implementation were developed to be representative of the architectural components to a sufficient level to explore architectural concepts and prove the validity of implementing a Comprehensive Architecture Strategy (CAS) and defining and managing a tiered architecture for a CMS Family of Systems (FoS). The architectures defined during the project included a CMS Technology Independent Architecture (TIA) and a CMS Procurement Architecture (PA), designed to the level needed to procure system components. The CMS team then developed a demonstration system based on this architecture for use in a laboratory demonstration, flight demonstration and inflight testing.

As required by the Army Common Operating Environment (COE) and PEO Army Aviation policy for any new start aviation effort involving software, the FACE Technical Standard served as the software technical reference framework (TRF) for the CMS FoS. In addition, the CMS team identified other widely used open industry standards to meet the business and technical needs of the UH-60 customer. The role of the FACE Technical Standard in the architecture definition and the benefits of implementing the FACE Technical Standard are highlighted throughout this document.

The main objectives of CMS Project included engaging in a pathfinding activity on the requirements and verifying key aspects of the TIA and PA in order to enable a future, competitive, production effort. The lessons learned as part of this risk reduction activity should be of interest to many FACE stakeholders since the processes and activities to define and manage the architecture for the CMS FoS involved policy makers, program managers, integrators and software suppliers.

Introduction

While the benefits of Open Architecture (OA) and mandates for its use have been discussed for decades, experience has shown that singularly focused architectural approaches and broad mandates to “do Modular Open Systems Approach (MOSA)” have not provided the expected improvements in affordability, program schedules, and warfighting capability. OA concepts require a more comprehensive, strategic approach to yield the maximum benefit across multiple systems and domains.

Today’s architectures are too often a byproduct of system design. System integration activities often generate the architecture and design of a system rather than system design following architectural guidance or constraints. A better approach is for a procuring organization to determine the architecture characteristics needed to meet high level requirements and business drivers. Procured systems can then be designed according to the prescribed architecture, resulting in systems that are more robust, consistent, interoperable and affordable.

Government control and management of the Crew Mission Station (CMS) architecture is just one piece of an emerging, recommended overall Open System Architecture (OSA) strategy under consideration by the Program Executive Office for Aviation (PEO AVN), which includes a Comprehensive Architecture Strategy (CAS) and Software Product Line (SPL) approach to integrate the engineering and management activities across PEO AVN Program Offices.

The CMS project provided an excellent opportunity to test out and refine the CAS concepts of using a tiered set of architectures to derive systems that can share software while still meeting the other UH-PO CMS project goals. The decision to include the FACE Technical Standard as part of the CMS architecture fulfilled the requirement for a software Technical Reference Framework (TRF) per the CAS guidelines as well as complied with Army COE mandates. The CMS project allowed the team to accomplish a ground-breaking analysis on the CAS process and efficiencies, in addition to evaluating the efficacy of the FACE Technical Standard as the software technical reference framework for the CMS architecture (and by inference, the Army COE). The analysis validated certain aspects of the CAS strategy, Army COE and FACE approach while raising additional questions that will be answered in future activities.

CMS Project

What is the CMS?

The CMS is a system for use by aircrew for mission functions beyond those provided by the existing aircraft systems. It includes capabilities and additional displays to improve situational awareness (SA) of crew members in the cabin area, improve task performance and to shed pilot tasking. In order to achieve maximum reuse and interoperability, the project sponsor, Utility Helicopters Program Office (UH-PO), determined that the CMS system would be designed based on open architecture principles, including definition of a government owned and directed OSA, to enable the government's technical and business objectives. One of the primary business objectives was to increase speed to field of mission capabilities in order to more rapidly meet the needs of the war fighter.

The CMS Project Team was charged with defining and demonstrating an open systems architecture and management strategy capable of providing new capabilities to the UH-60/HH-60 fleet in the shortest timeframe possible. Targeting a legacy upgrade, the CMS Team set out to prove the application of open architecture strategies by developing an OSA, a management strategy and a demonstration system. Efforts included gathering stakeholder requirements, building the system hardware and software, conducting crew station working groups (CSWG), a series of initial UH-60M systems integration lab (SIL) demonstrations, a CMS flight demonstration and two weeks of CMS flight testing. The flight test effort focused on the feasibility of incorporating a system that would provide increased situational awareness to the crew chiefs in the UH-60M. The UH-60M was the targeted platform for the initial flight demonstration and flight testing, but the CMS system is applicable to the UH-60 and HH-60 family, as well as other aircraft.

The capabilities, henceforth called User Level Capabilities, provided by the CMS would take the form of new software components and, in some cases, include new hardware components. Addition of new User Level Capabilities is a key concept in the CMS architecture and drove many of the architectural decisions. The User Level Capabilities in the tested CMS system included: Flight Display Readouts, Engine-Indicating and Crew-Alerting System (EICAS), Fuel Calculation, Flight Plan, Moving Map, Belly Camera Video Feed, display of Manned-Unmanned (MUM) data, and E-Reader for Publications. The CMS systems developed for the lab and flight demonstrations and inflight testing were representative of the CMS architectural components to a sufficient level to prove validity of key aspects of the architecture. The CMS Limited User Evaluation (LUE) project is an extension of the initial CMS demonstration project to include an evaluation of the CMS capabilities by two active duty units.

CMS Comprehensive Architecture Strategy

Stakeholder business and technical objectives

The CMS Team was directed to develop a government-managed open architecture in order to promote competition, innovation, mission agility, and the rapid and affordable replacement, integration and upgrades of capabilities. The CMS team centered their approach on determining the requirements for an architecture or set of architectures, henceforth referred to as the CMS OSA, that instantiated the following business and technical objectives from CMS project stakeholders:

Business objectives

- Provide independence from a singular System Integrator (SI); meaning the ability to recompete the SI role
- Minimize dependency on an aircraft's existing avionics system integrator when deploying CMS onto an aircraft
- Utilize the government as Design Authority for the CMS OSA
- Separate the roles of architecture maintainer and system integrator
- Improve speed to field
- Meet regulatory and government mandates
- Reduce duplicative development and improve reuse across platforms
- Leverage work from FACE and other OSA communities

High level technical objectives

- Identify key interfaces
- Create highly portable/reusable capabilities
- Provide interfaces for future capabilities integrations
- Separate the system requirements from the system design

The combination of these business and technical objectives formed the basis of the architecture, design, and implementation mechanisms and decisions for a CMS system designed to improve crew SA, reduce pilot workload, and provide a computational platform to assist in crew chief tasks.

CMS Comprehensive Architecture Strategy

Addressing Army COE and OSA mandates

The National Defense Authorization Acts (NDAAs) of 2015 and 2017 strengthened the OSA requirements for programs in development. The Army has answered these and previous OA mandates with the Army Common Operating Environment (COE). PEO AVN addressed the Army COE mandate by issuing a policy stating their selection of the FACE Technical Standard as the Real Time Safety Critical Embedded (RTSCE) Computing Environment (CE) for Army Aviation.

The CMS OSA and resulting product line approach is just one piece of an emerging overall OSA strategy recommended for PEO AVN, which includes a Comprehensive Architecture Strategy (CAS) and Software Product Line (SPL) approach. In response to the Army COE, the PEO is providing more direction to integrate engineering and management activities across the PEO. CMS is one of the initial projects to test the waters and is evolving and learning together with other programs such as Joint Common Architecture (JCA), Future Vertical Lift (FVL), and Joint Multi-Role Technology Demonstrator (JMR TD) Mission System Architecture Demonstration (MSAD). Part of the JMR TD MSAD effort conducted by AMRDEC is the development and refinement of the CAS. Lessons learned from CMS and other programs will help PEO AVN make better architectural decisions and provide options to achieve open architectures, rather than settling on a single approach or standard.

The basis of the proposed CAS is to define a Reference Architecture (RefArch) to meet program needs across PEO AVN. At its simplest, this RefArch will consist of a purpose, guiding principles, policy and technical positions, patterns, and a vocabulary that result from the convergence of stakeholder, technical and business contexts across the PEO. The RefArch will provide governance as well as a superset of tools, methods, process and standards supporting key business drivers, policy and regulatory concerns.

Adherence to the PEO AVN RefArch will enable maximum opportunities for commonality and interoperability across the entire area of interest. The RefArch will guide and constrain the instantiations of all subsequent architectures and solutions. The RefArch will encapsulate, and be the authoritative source for, a common definition of User Level Capabilities and the architectural governance for the application of these capabilities. Ideally, the RefArch will not provide performance requirements or implementation details; these decisions and constraints will be left to subsequent architecture analysis and addressed in lower level tiers.

There are eight key elements that will be addressed by the PEO AVN RefArch and further refined by the next two tiers:

- Key Business Drivers of the organization
- Key Architectural Drivers
- Policy and/or Regulatory Constraints that have been flowed down to the organization
- Reference Functional Architecture(s) (RFA)
- Software Architecture (Software TRF)
- Hardware Architecture (Hardware TRF)
- Data Architecture (including Domain Specific Data Model)
- Governance (of the architecture, contract and acquisition guidance, data rights strategies)

CMS Comprehensive Architecture Strategy

From the PEO AVN RefArch, there will be multiple Objective Architectures (ObjArch). An ObjArch is a technology independent architecture derived from the RefArch, incorporating additional business drivers to tailor the RefArch to a more specific set of stakeholder and operational level requirements. The ObjArch represents a level around which to identify and exploit opportunities for commonality that reflect an SPL approach. The ObjArch guides and constrains the instantiations of subsequent system architectures (e.g., specific products of a SPL.) Included in the ObjArch is further refinement of User Level Capability allocation to system components. This allocation aids in the creation of capability software that is portable between all systems meeting the ObjArch.

The System Architecture (SysArch) is an architecture product that expresses the system level architecture needed for procurement. The SysArch is developed from the ObjArch based on additional requirements from a performance specification. It represents the fundamental organization of a system, embodied in its components, their relationships to each other and the environment, and the principles governing its design and evolution. It is also known as 'Design-to Architecture'. While the ObjArch expresses the needs of all participating programs, the implementation independent SysArch will express the specific needs of a particular program's mission and performance requirements.

These three tiers of architectural analysis and documentation (RefArch, ObjArch and SysArch) are necessary to provide the required guidance at each level of organizational control to achieve the desired business drivers established for each tier. This method of applying a tiered architectural approach will enable controlled elaboration and provide traceability between the outcome of decisions (choices) and the business drivers behind the decisions. This method will allow for a large degree of flexibility and innovation at the ObjArch and SysArch levels through the application of systems engineering principles to determine the right blending of OA approaches (specifying COTS, interface management, functional architecture management, data architecture management, etc.) capable of meeting desired high level or operational goals specified in the RefArch.

Additional tenets AMRDEC is applying to the CAS Architecture strategy are:

1. An avionics mission system's architecture is severable from an avionics mission system's detailed design and implementation.
2. An avionics mission system architecture encapsulates the acquiring organizations (BUYER) technical and business objectives, given the acquirer's specific mission, vision, and strategy.
3. It is a conflict of interest for the BUYER to procure an avionics mission system architecture from the avionics mission system supplier (SELLER).
4. This CAS has been formulated to achieve strategic BUYER reuse which is a mechanism to achieve speed to field.
5. The level of detail present in BUYER's avionics mission system architecture is at whatever level determined to be needed to meet the BUYERS technical and business objectives. Or in other words, the BUYER's architecture is whatever the BUYER makes contractually obligatory of the SELLER's detailed design.

CMS Architecture Strategy for the CMS FoS

The CMS Team aimed to implement a comprehensive, strategic approach to open architecture by defining a CMS OSA that met policy and mandate guidelines, conformed to Army COE goals, and that could be used across a FoS. Using the guidance outlined in the emerging, proposed PEO AVN CAS, the CMS team centered their approach on government control of a CMS OSA that would instantiate the CMS stakeholders' business and technical objectives.

The key tactics identified to keep the Government in control of the architecture include:

- Introducing the role of an Architecture Maintainer (AM) as a new entity reporting to the PM to capture the business and technical objectives of the customer into the architecture.
- Defining and managing a Technology Independent Architecture (TIA) aligned to the CAS ObjArch
- Defining and managing a Procurement Architecture (PA), with input from the System Integrator, aligned to the CAS SysArch
- Defining a process roadmap to maintain the CMS OSA and add new capabilities

If adopted, the CMS OSA, which includes the TIA and PA, will provide the architecture strategy for programs wanting to implement a CMS solution. The CMS OSA focuses on the architectural elements that must be mandated to ensure deployment to multiple platforms. The architecture precepts, component definitions, architectural requirements, along with the architectural and design mechanisms identified in the CMS OSA, which include the use of the JCA functional decomposition and the FACE Technical Standard, describe a technical framework and product line approach for a CMS FoS. The CMS OSA defines a set of common core components and services, as well as a common data model to manage component interfaces. The development efforts that conform to the CMS OSA will result in a CMS FoS and a product line of common software components that can be integrated into CMS systems across the fleet.

The CMS OSA is intended to guide the development and integration of new CMS implementations and new capabilities added to an existing CMS system. To develop and integrate CMS systems and CMS capabilities, vendors will select from a defined set of architecture and design patterns allowed by the CMS OSA to create CMS system design solutions and CMS implementations. A CMS System Integrator and Capability Suppliers will utilize the CMS OSA to define solution requirements, interfaces, data models and designs in a more detailed and rigorous manner than is described by the OSA.

The CMS project's overall approach includes participating within a community of interest working to achieve common architectures across a FoS through the employment of common architectural and technical reference frameworks. In addition, new capabilities must be accessible and designed with commonality in mind to ensure they are portable, reusable, and easily integrated. There are presently several Communities of Interest (COI) working on establishing Enterprise level OSA architectures in the DoD aviation domain. The CMS project is running slightly ahead several of them, but is monitoring and aligning to the maximum extent to JCA and others as they develop. It will be imperative for program offices to be fully vested in the FoS community of interest in order to achieve maximum benefit across the enterprise.

CMS Comprehensive Architecture Strategy

Figure 1 illustrates the CMS COI and how the CMS OSA aligns with the Comprehensive Architecture Strategy reference architecture tiers being drafted by AMRDEC as part of the JMR TD MSAD program.

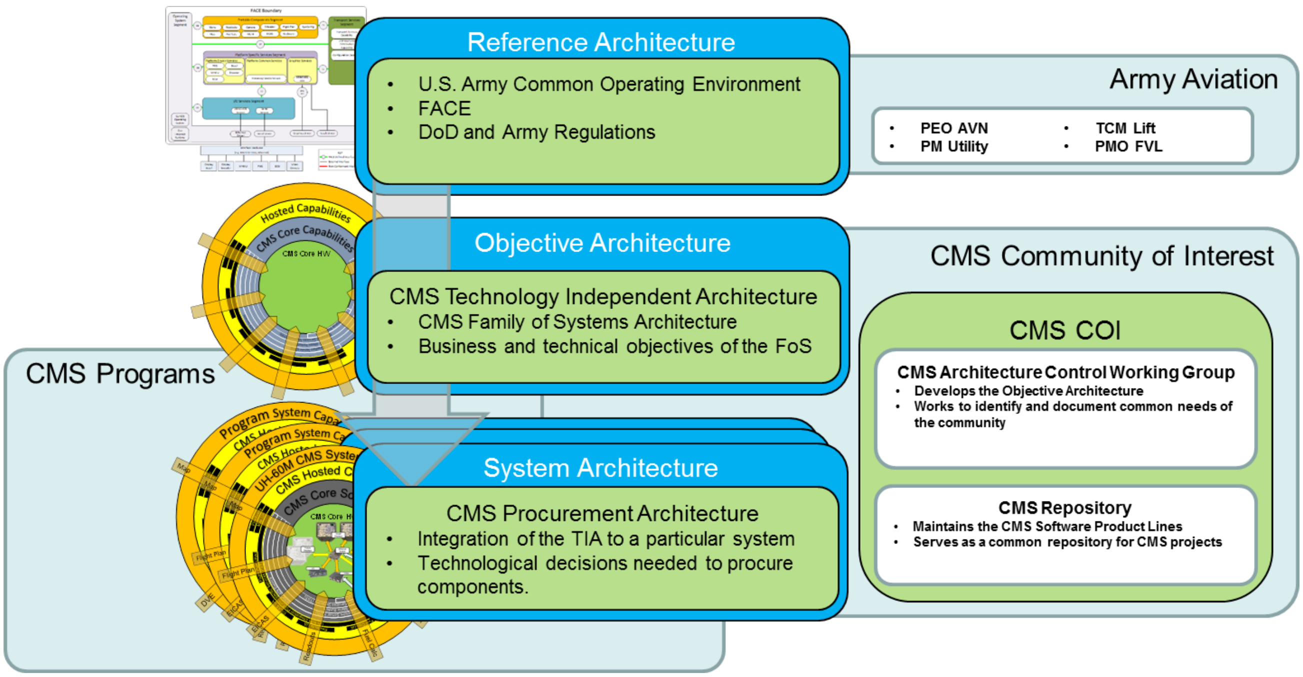

Figure 1 Potential CMS COI and Alignment with CAS Tiers

Sources of the CMS architecture requirements

Some of the resulting architectural decisions for CMS were directed by Army regulations and mandates, others were the result of synthesizing the customer's business and technical objectives. The existence of AMRDEC's Joint Common Architecture (JCA) project, tasked with functional allocation of avionics systems, also seemed to play well in feeding direction into the CMS OSA. The collection of these initial inputs formed a loose Reference Architecture that could become more formalized as CMS and other projects within PEO Aviation progress.

Detailed documentation of the CMS OSA requirements was actually an activity that took place after the laboratory, flight demonstrations and flight testing due to schedule constraints. At the start of the project, there was no PEO or Enterprise level RefArch or ObjArch to guide CMS architecture development, but the team realized during the process that what was evolving as the implementation architecture could, with analysis, serve as the ObjArch for the CMS FoS.

CMS Comprehensive Architecture Strategy

CMS architecture tiers

The CMS Team's strategy included the idea of a Technology Independent Architecture (TIA) from the beginning. The government would own this TIA, while the designed-to system would be produced by the System Integrator and the Capability Suppliers. As work progressed on the concepts of a Comprehensive Architecture Strategy being defined as part of the MSAD project, the CMS Team saw clear parallels within the CMS project and consistently leveraged key concepts from the CAS RefArch, ObjArch and SysArch tiers to mature the CMS TIA.

When CMS performed its first flight demonstration, the value of the architecture and the resulting system became apparent to interested parties both within SED and the UH-PO, as well as other projects within the Army and other services. The CMS Team once again compared its current state against the current thoughts on the CAS, and realized that with little effort the CMS FoS could be realized as multiple SysArchs under one ObjArch, which was satisfied by the TIA.

In order to enable the government's ability to procure best-of-breed solutions at the component level, two architecture levels were ultimately defined for the CMS OSA; both levels align with the CAS architecture tiers.

Technology Independent Architecture

The Technology Independent Architecture (TIA) is a technology agnostic logical expression of the stakeholders' high-level business and technical requirements. It is most closely aligned with the CAS definition of an ObjArch since it includes some architectural decisions, such as the use of FACE as the software TRF and the incorporation of JCA as the functional decomposition.

The TIA is an architecture from which many CMS systems using differing technologies could be developed. It defines key interfaces and captures the government's business and technical objectives of an open, vendor neutral architecture capable of rapidly fielding new capabilities. Defining architectural requirements and their associated allowable architecture mechanisms in the TIA and PA was the method the CMS Team used to capture and trace back to the business and technical objectives of the stakeholders. These architecture mechanisms will be the basis for architectural trades to meet differing stakeholder objectives. The TIA includes a minimal set of design mechanisms deemed necessary to meet particular functional or performance requirements.

Procurement Architecture

The Procurement Architecture (PA), aligned to the CAS definition of a SysArch, is an optimization of the TIA that adds the necessary technology decisions to define procurable components needed to realize an instantiation of the CMS system. The PA adds architectural requirements and architectural mechanisms to the TIA in order to address additional stakeholder concerns and technical objectives. Implementation or technology agnostic design mechanisms are also be captured by the PA; the majority of design mechanisms are at this architectural level. The PA captures the technology decisions that are made, through both architectural trades and procurement decisions. These decisions refine the modularity and interfaces of the Core Capabilities expressed in the TIA as well as express the need for additional Core Capabilities. The goal of the PA is to provide a System Integrator and Capability Suppliers with a specification from which they will generate the CMS Core System and/or Hosted Capability detailed designs.

Implementation of the FACE Technical Standard

The application of well-defined standards within a common set of mandates has been beneficial, but has not led to the portability and reusability needed within the Department of Defense (DoD). Initiatives like FACE approach are addressing those gaps by providing a technical framework for the development of software with well-defined interfaces. The decision to implement the FACE Technical Standard was influenced by the CMS stakeholders' business and technical objectives, and further reinforced by the need to meet policy mandates for the Army COE.

Software technical reference framework

Standardizing hardware and software TRF's, along with functional definitions and a data architecture, fosters competition and reuse in systems and can reduce development and fielding time for new capabilities. Promoting architectural consistency enables a product line approach for addressing key business drivers such as affordability, time to field, competition, and innovation. The use of a software TRF to enforce common, applicable standards and specifications reduces the likelihood that a platform will develop a unique and difficult-to-support solution.

One of the CMS decisions to support reuse was to implement the FACE Technical Standard as the software TRF. The FACE Technical Standard provides a framework for developing independent reusable components and its accompanying business processes include a registry for certified conformant components.

The desired end state of achieving a CMS FoS requires new capabilities to be accessible and designed with commonality in mind to ensure they are portable, reusable, and easily integrated. The FACE Technical Standard supports this through:

- Common architectural framework or technical reference frameworks
- Decoupling software capabilities from hardware
- Known, standardized interfaces
- An independent conformance testing process for capabilities

FACE Technical Standard provides key interfaces

The CMS Architecture Description Document (ADD) has full information on the key interfaces selected for the CMS architectural tiers. The key interfaces related to the FACE Technical Standard include:

- FACE TS APIs: Since supporting FACE Conformant software products was one of the basic requirements, interface selection and control focused on using the FACE Technical Standard APIs
- FACE Data Model: As a part of the TSS API, the FACE Data Model ensures that components conformant to the TSS API have documented the data utilized by the component in a complete and standardized manner.
- FACE Operating System Interfaces
- ARINC-661 for Graphics, as allowed by the FACE Technical Standard
- FACE IO API

Selecting the FACE Technical Standard as the software TRF provided a reference framework perspective and set of common, open interfaces to meet CMS operational needs. Utilizing the FACE TS enabled realization of the key business drivers of the CMS stakeholders such as portability, interoperability, safety, security, performance, and reusability.

The physical interfaces selected between the modular, functional blocks of the CMS system and the selection of FACE Technical Standard for the software interfaces maximize the ability of the CMS system to accommodate technology insertion. The modular, segmented layers provided by the FACE Technical Standard also support the architectural decision to separate the CMS system into a Core System and Hosted Capabilities, which facilitates insertion of alternative or reusable modular elements. Information on how the FACE Technical Standard supports the ability to separate the Core and Hosted Capabilities is the topic of the TIM paper "Achieving the CMS Objectives: A Core System and its Hosted Capabilities.".

The Architecture Maintainer (AM) for the TIA and PA will control the key interfaces defined in the CMS ADD. The ADD will specify the lowest level at which any proprietary or vendor unique interfaces will be allowable. Software suppliers who are providing software components will be asked to identify proprietary or vendor unique interfaces and describe the possible impact of those interfaces on the proposed modularity and logistics approach. Any FACE conformant components providing a software solution for a User Level Capability will likely be PCS components and the external interfaces will have to conform to the TS or OS API and FACE data model defined in the FACE Technical Standard. Interfaces within PCS components can utilize proprietary or vendor unique interfaces without impacting modularity. Software solutions that are not FACE conformant will likely have to be wrapped in order to utilize the APIs defined in the TIA and PA.

The role of AM will ensure that the final implemented system adheres to the PA, which in turn adheres to the TIA. This approach will facilitate upgrading the system with new capabilities or with capabilities developed for other systems.

The FACE Registry

The FACE Registry and other existing Government repositories were viewed a key benefits to other programs that are looking to increase readiness and mission agility. Reuse of CMS Core or Hosted Capabilities discovered in the repositories will greatly reduce development and integration efforts. As use of the FACE Technical Standard is adopted, the FACE Registry will grow to provide a catalog of software ready to be adopted into the CMS.

Other architectural concepts supported by the FACE Technical Standard

The selection of the FACE Technical Standard as the software TRF was just part of the CMS architecture definition. FACE implementation was useful in meeting the goal of portability and enabling reuse, but was not the complete solution to meet all of CMS's goals. It did however, facilitate or work in tandem with the other mechanisms and elements selected for the CMS architecture, such as the decisions to separate the system into Core and Hosted capabilities and the choice to use JCA as the reference functional architecture/functional decomposition.

Core Capabilities and Hosted Capabilities

At the component level, the CMS TIA and PA identify the Core Capabilities (computational infrastructure, I/O resources, common services and user interface framework) needed to provide a framework for hosting and managing Hosted Capabilities, but do not identify (to the extent possible) the specific technologies used to enable the Core Capabilities. The Core Capabilities defined in the CMS OSA are expected to be present in all CMS instantiations. This basic separation of Core and Hosted Capabilities will provide the scalability and extensibility desired for the CMS system to support as yet undefined capability requirements that can be independently procured and developed. The five segments of the FACE architecture and three key interfaces between the architectural layers, specifically the PSSS and PCS, are optimally suited to the CMS estimate of how a Hosted Capability will be provided. PSSS allows separation of the software needed to integrate an external device from the rest of the software system and PCS allows separation of the software (from the rest of the system software) that enables a Hosted capability. The boundaries between the Core and Hosted Capabilities are the interfaces that UH-PO intends to manage in order to achieve commonality and reuse across CMS implementations. These interfaces will be coordinated interfaces, aligned to the FACE Data Model, with formally defined interface requirements and designs, and will be maintained under Government configuration control.

JCA as the functional decomposition

For CMS, User Level Capabilities are defined as functions within an avionics system; the definitions of these functions are based on the JCA functional decomposition. At the TIA level, the CMS architecture defines Hosted Capability software components that meet these functions. For each component, the TIA defines their interfaces, their allocated functionality, and the underlying data models that define the data that they manage and exchange. The FACE Data Model is well suited for this.

Lessons learned

Throughout the CMS architecture project activities, the CMS team noted the following actual or potential benefits of implementing the FACE Technical Standard as part of the CAS.

1. The use of the communications bus, I/O converter and smart displays supporting FACE, ARINC 661, POSIX, and OpenGL interface standards, enable the CMS System to support additional Hosted Capabilities to meet evolving requirements and threats. Because the CMS demonstrations and flight testing were part of a rapid prototyping project, demo requirements and the list of Hosted Capabilities to include were fluid in nature and the inclusion of the FACE Technical Standard and ARINC-661 interfaces provided a consistent and easy way to move capabilities in and out of the CMS system.
2. The use of ARINC 661 to render graphics allows for software partitioning as well as a way to present an integrated display of multiple capabilities. ARINC 661 provides an abstraction from the business logic and the rendering of that logic to the screen.
3. The TIA was planned to be scalable to support yet to be identified capabilities that can be integrated without redesign of the CMS Core System. The modularity inherent in the FACE Technical Standard's layered segments and defined interfaces between those segments enhanced the ability to integrate new capabilities without redesign of the entire CMS system.
4. Interoperability was supported by the implementation of the FACE Technical Standard and a CMS Domain Specific Data Model based on the FACE Shared Data Model and use of other open interface and data exchange standards such as ARINC 661, POSIX, and OpenGL.
5. The use of the FACE Technical Standard interfaces in the TIA and the PA should allow for component replacement and refresh without the need to contact an original suppler. This will assist when upgrading the system with new capabilities or with capabilities developed for other systems.
6. Managing and controlling the TIA and PA, which mandate the FACE Technical Standard and Shared Data Model, should improve the ability to reuse CMS capabilities across a potential family of CMS Systems with little or no modification to the capability code.

Managing the Future of CMS

Control and maintenance of the CMS architecture

Government authority over the CMS OSA, specifically its modularity and key interfaces, will ensure that the government's business and technical objectives will be achieved. This control will lead to more proactive risk management, lower barriers to modernization, strategically determined areas of competition, and provide predictable growth for program planning. Having an architecture specification for CMS will support acquisition planning and budgeting, by providing a common foundation for allocation of new capability requirements and cost estimates. It also supports an open business model that allows many developers to provide CMS products and enables more rapid capability insertion and more effective reuse of previously developed Hosted Capabilities.

Once the CMS OSA has been validated and tested, the proposed plan is for UH-PO to exercise design authority and control over the CMS OSA down to the PA level. The PA will be provided to the eventual system/subsystem integrators and capability suppliers as a template for creating detailed designs and implementing CMS systems and capabilities. The FACE Conformance Program will assist with controlling the CMS OSA since it provides a direct mechanism for validating the software TRF and the associated interfaces and insuring a level of openness and degree of commonality that aligns with CMS business objectives.

Architecture Maintainer role

A key concept of the CMS team's approach was the introduction of the role of Architecture Maintainer (AM). The AM for the CMS project was responsible for the definition and management of the CMS TIA and PA and ensuring that the demonstrated UH-60 CMS system design adhered to the TIA and PA. Each future CMS project will assign an AM who will work with the System Integrator and Capability Suppliers to ensure their system detailed design and implementation solutions align to the CMS PA.

The AM will manage potential changes or enhancements to the OSA, including its common data models, allocated functions, and interface specifications. The main focus of the AM will be on establishing system functional requirements (high level), interface requirements and information exchanges with planned and existing systems and subsystems; and identification of standards supporting CMS goals of reuse and interoperability.

CMS AMs will also participate in or work closely with maintainers of any Reference Architecture or Reference Framework used within the CMS. In some cases, CMS projects will drive changes to these higher level references and the CMS AM will perform the work to integrate the changes into these references.

Procurement of CMS capabilities

Ideally, CMS users should be able to acquire new CMS User Level Capabilities by searching a product registry for available software solutions that can be rapidly acquired or reused from an existing Government repository. The more projects that contribute to this repository will generate more benefits to other programs looking to increase readiness and mission agility. PEO AVN Program managers will be urged to consider the concept of "being a good citizen" of the network of programs that populate the repository so others can harvest a ready supply of innovative product solutions. If the mission requirements do not match a previously developed capability within the repository, CMS programs have processes outlined in the CMS Master Project Plan to create portable, reusable capabilities, which can then be added to the repository so other programs may leverage those advantages.

Building the CMS FoS

The UH-60M was the targeted platform for the initial flight demonstration and flight testing, but the CMS system is applicable to the complete UH-60 family, as well as other aircraft and possible ground platforms. The CMS OSA has significant long-term value to the UH-60 and other programs in both significant lifecycle cost savings and product quality for new software-intensive product development. The selection of the FACE Technical Standard allows the Army, and CMS, to benefit from a community approach to meeting OA mandates and requirements. Involvement in the FACE Community includes the Army, Navy, Air Force, and a long list of industry participants. This selection promotes an Enterprise level OA strategy shared across Army and other DoD systems, which should avoid the problems experienced with platform-unique solutions.

Conclusion

The CMS project was an excellent opportunity to test out the CAS concepts of using a tiered architectural approach to derive systems that can share software and to evaluate the use of the FACE Technical Standard as the software TRF for the CMS OSA. The lessons learned during this risk reduction activity will help solidify the process for defining architectural requirements and enable future, competitive, production efforts.

The OSA developed for the CMS system incorporates appropriate considerations for reconfigurability, portability, maintainability, technology insertion, vendor independence, reusability, scalability, interoperability, upgradeability, and life cycle supportability. This construct provides the means to acquire CMS capabilities through open (non-vendor locked) competition, which allows program offices to affordably, efficiently and rapidly deliver capabilities to the warfighter. The OSA helps to achieve one of the primary objectives of increased speed to field of mission capabilities that meet the needs of the war fighter.

The FACE Technical Standard provided an ideal software TRF for CMS and the FACE Conformance process will add the necessary mechanism to verify adherence to selected aspects of the CMS OSA. Utilizing the FACE TS enabled realization of the key business drivers of the CMS stakeholders such as portability, interoperability, safety, security, performance, and reusability. Implementation of the FACE Technical Standard also supported CMS business objectives of increased software reuse and portability, reduced duplicative development and availability of a registry of conformant software. Selecting the FACE Technical Standard as the software TRF provided a reference framework perspective and set of common, open interfaces to meet CMS operational needs.

The demonstration of the CMS system drew a lot of interest from other projects, and its flexibility and potential reuse has driven the creation of the CMS FoS. The ground breaking analysis highlighted interesting opportunities for further research into enterprise level reference architectures. The lessons learned and additional questions to be answered that have been identified by the CMS team include:

- The final CMS OSA description should be a strategic business document describing the components and their relationships as well as how the architecture serves the strategic business goals of PEO AVN. Documenting this relationship within each layer and to the layers above and below will identify the areas of commonality that can be realized across the PEO AVN fleet as well as within the CMS family of systems.
- The TIA and PA, (and, by inference, any RefArch, ObjArch and even SysArch) must accept changes from derived systems as much as receive direction from higher levels. These must be maintained as evolving architectures supporting the community that adheres to them.
- The development of truly portable capabilities should derive their requirements from the functional allocation within a RefArch and ObjArch. Functional allocation performed at an architectural level that supports many implementations should result in components portable across those implementations.

References

This paper leveraged other draft documents from the CMS project, to include the CMS Master Project Plan, CMS Architecture Description Document (ADD), CMS Open System Management Plan (OSMP), CMS Reference Architecture Description, and CMS Limited User Evaluation (LUE) Project Plan. In addition, information was taken from several Comprehensive Architecture Strategy (CAS) white papers that have not yet been published.

This paper also references the "Achieving the CMS Objectives: A Core System and its Hosted Capabilities" paper to be published by the Open Group concurrently with this paper.

About the Author(s)

Christopher J. Edwards has been working in the avionics industry for over 20 years, primarily on cockpit systems for military aircraft. In those years he has served in leadership roles in Software, Requirements, System Design, PVI development, Qualification Testing, and Project Management. Mr. Edwards has been the primary author of the FACE Conformance Certification Guide and the Problem Report/Change Request (PR/CR) Process and a contributor to several other documents in both the Technical Working Group (TWG) and Business Working Group (BWG). Mr. Edwards currently serves as a co-lead of the FACE TWG Conformance Verification Matrix Subcommittee, a co-lead on the FACE EA PR/CR Process, the facilitator of the FACE Verification Authority Community of Practice and is the Lead Systems Engineer for the CMS Project.

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