Crew Mission Station Reuse

Proof Conformance to the FACE™ Reference Architecture Provides a Platform for Rapid Integration

Air Force FACE TIM Paper by:

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June, 2019

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Executive Summary

The project vision for the US Army's Crew Mission Station (CMS) is to define an enduring Open Systems Architecture (OSA) approach and management strategy capable of providing new capabilities to the UH-60 fleet in the shortest timeframe possible. This vision stemmed from a set of technical and business objectives expressed by the US Army stakeholders.

Software reuse is a business objective of the Department of Defense (DoD) and has been included in the CMS architecture. Adherence to this principal should result in a set of configurable, reusable software components that may be put together in different combinations to meet the needs of the host platform. Throughout the CMS development, software reuse at the component level has been a goal. The attractiveness of reuse for the CMS architecture and the CMS components led to the demonstration of the CMS Architecture as a Rapid Integration Framework (RIF). This framework is not limited to use as a Crew Mission Station.

This paper will examine the reuse of CMS software components across four Programs, eight Integration Demonstrations, two completed Test Bed activities and five more active/planned activities. The reuse of CMS components is examined, as well as the effectiveness of the RIF in providing for rapid integration.

While many of these programs could be viewed as the natural growth of a single CMS program, they contain a different set of capabilities affecting the software components. An examination of the effects such changes have on the software components, and the adaptability of the framework, is the subject of this paper.

CMS and the Rapid Integration Framework

The requirements and architecture for CMS were developed in 2015. During the time the CMS project was in the planning stages, the Future Airborne Capability Environment (FACE) Consortium had published its business guide and the Technical Standard, Edition 2.1 was in the release process. The business objectives for the FACE™ business strategy clearly align with the vision for CMS, so the FACE Technical Standard was included in the CMS architecture to define Units of Conformance (UoCs) aligned to this standard.

Development of CMS follows the FACE Technical Standard Edition 2.1 (FACE Consortium, 24 Jun 2014) and many of the UoCs have passed the FACE Conformance Test Suite,
Version 2.1.1. Use of the FACE Technical Standard allows CMS to rapidly integrate software aligned to the FACE Technical Standard (Edwards, Price, & Mooradian, The Impact of the FACE Technical Standard on Achieving the Crew Mission Station (CMS) Objectives, October, 2017), was proven at US Army FACE Technical Interchange Meeting (TIM).in September of 2018.

Early in the development of the CMS architecture and requirements, the desire for reuse led to a different understanding of the need for document requirements for hosted capabilities separate from the core system. This approach to reusable artifacts has been applied to CMS components (Edwards C. J., Developing Portable/Reusable Certification Artifacts, January 2016).

The concept of a core system and its hosted capabilities is directly derived from the Federal Aviation Administration's (FAA) guidance on Integrated Modular Avionics (IMA) found in RTCA DO-297 (RTCA, Inc, November 2005). IMA provides a path to airworthiness for qualification of an IMA platform and independent qualification of IMA hosted applications that could be installed on that platform. The final qualification of the combined system is then easier; reducing the qualification efforts of the final integrated system.

Through the use of IMA, a platform consisting of the hardware and software needed to support additional capabilities can be developed and complete some level of qualification. In the RIF, this platform is called the Core System.

"Hosted Capabilities" that are developed to deploy with a Core System follow IMA's hosted application approach and can achieve their own level of qualification independent of the core system. The integration of the Hosted Capabilities onto the Core System should greatly reduce the qualification efforts when they are reused in subsequent combinations.

The application of this Core System and Hosted Capabilities, as well as the selection of Core Components, can be extrapolated to other systems, not just Crew Mission Stations. Several aspects of the CMS program should fit within the concepts of an Objective Architecture within a Comprehensive Architecture Strategy (Edwards & Mooradian, The FACE Technical Standard Applied to a Comprehensive Architecture Strategy, September, 2017).

A lot of thought around reuse went into the development of CMS, its architecture, requirements, design, and development. This paper takes a look at the impacts of the resulting work as it applies to the many projects where CMS UoCs have been used.

Many Forms of Reuse

Following the CMS requirement and architecture development in 2015, CMS was demonstrated in early 2017 flight testing. Since then, it has been deployed to active duty Army personnel during a limited user evaluation (LUE) on the UH-60. In the summer of 2019, it was installed on the US Air Force HH-60G. Over that time, CMS has been utilized as a test bed platform for experiments in new technologies and capabilities under consideration for use within Army Aviation. In September of 2018, variations of CMS were demonstrated as Rapid Integration Platforms under a common Rapid Integration Framework (RIF) at the US Army FACE Technical Interchange Meeting (TIM). Core sections of CMS were replaced and new capabilities were demonstrated. All of this was accomplished using the same architecture, with most of the same applications.

Some instances of the CMS have been installed on aircraft and used in evaluation or deployment to active duty personnel. These programs are instances in which CMS was used to meet mission objectives. Its initial eight capabilities were modified following the initial CMS Demonstration and each program has continued to grow and affect the software components.

The CMS Software has been showcased at several integration events including the first BALSA Integration & Test Session (BITS) event, the FACE TIMs of 2016 and 2017 and particularly the FACE TIM of 2018. The TIM of 2018 showcased software and hardware developed by other vendors integrated into the CMS software through an objective architecture known as the Rapid Integration Framework (Edwards, Price, & Mooradian, Sep. 2018). In the near future CMS will be used in a Hardware Open Systems Technologies (HOST) Integration Event in 2020.

Once CMS was installed on a test aircraft, its ability to serve as a host platform for other experiments in flight testing was obvious. CMS has been used as an avionics mission system to support experiments/prototyping in a test bed environment for experiments in Army aviation and software engineering.

Following this realization. CMS was quickly selected as a platform for experiments in other flexible lab test beds within the US Army Combat Capabilities Development Command Aviation & Missile Center System Simulation, Software and Integration Directorate (CCDC AvMC S3I). Application of the Rapid Integration Framework to these platforms should greatly reduce the integration time for these projects however, these test bed applications haven’t yet provided sufficient reuse information to be considered for the remainder of this paper.

UoC Reuse across Projects

The use/reuse of each component is analyzed below using the following criteria:

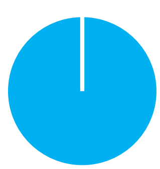
	Complete Binary Reuse, no modification needed
	Modifications were made introducing a new version, results would provide complete binary reuse to prior programs
	An entirely new UoC was developed
	Recompilation of source code was needed, no change in requirements, source changes can be fed back into baseline for reuse
	Recompilation was needed, some source code changes were made specific to the program, backward compatibility was broken

This analysis includes an examination of actual programs using CMS, demonstrations that used CMS in the past, as well as planned projects and potential projects discussed with the CMS team. This provides the broadest sense of reuse across the known proposals. The following sections will discuss what was different in each of these projects/experiments, but it is important to remember how much remained untouched, or modified by configuration.

During the 2018 Army FACE TIM, several alternative implementations of the CMS platform were demonstrated using alternative hardware and software components. These platforms included the White, Yellow, Green, Red, and Blue implementations. Each featured products from participating vendors integrated in alternative versions of a CMS. This was made possible through the CMS alignment to the FACE Technical Standard and a solid understanding of the standard among the participating organizations.

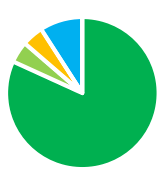
Each of these projects are listed in order of the work completion to show the reuse of components developed by prior programs. For each project a pie chart is shown. The pie charts depict the number of components used in the reuse colors above. Table 1- UoC Reuse in the Analysis section on page 13 provides the source information for each of these pie charts.

Program: CMS Demonstration Flight



The initial CMS project was to perform a demonstration of a ruggedized avionics system mounted for the UH-60 Crew Chief's use; and providing that Crew Chief with added Situational Awareness (SA) and other capabilities. For the demonstration, eight Hosted Capabilities were demonstrated, including a Manned/Unmanned (MUM) capability that was later removed due to the dependency on additional radio equipment.

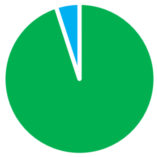
Experiment: IDM



To better show the IDM functionality of new IDM software, CMS was used as a display of IDM data. The bulk of CMS could simply be reused. Within a matter of weeks the experiment was a success. The CMS was extended with a Platform Specific Services Segment (PSSS) Device Service to communicate with the IDM, another PSSS Device Service to tune a radio, and an ARINC-661 User Application (UA) to send and receive Joint Variable Message Format (JVMF) messages. These were additions to the CMS, the integration required definition of a few new Transport Services Segment (TSS) messages and some configuration changes.

CMS Reuse: FACE Reference Architecture Provides Rapid Integration

Integration: ADS-B/BALSA

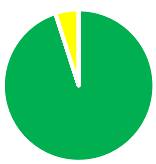


Another experiment conducted while CMS was in its initial development occurred during the first BITS event. A User Application (UA) was added to CMS that took a set of ADS-B messages from BALSA and displayed an aircraft symbol in cyan on the CMS map for each unique aircraft identifier in the ADS-B message stream. The Map UA's definition file and the connector reference table were modified, nothing else in CMS changed. This integration was completed in less than one week.

Program: CMS LUE

After the demonstration flight, a program was initiated to bring CMS to active duty personnel as part of a Limited User Evaluation (LUE). CMS was used by active duty personnel as they performed their duties in an operational environment for two months in 2019. For the LUE, several aspects of the software were improved and the MUM capability was removed. Half of CMS components remained unchanged, the other changes were driven by requirement changes. Several experiments were conducted while the LUE was under development.

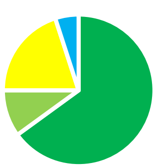
Experiment: Wireless Networking (Sierra Nevada)



Sierra Nevada has a secure ultra-wideband networking capability that can be used in the cabin of the Blackhawk that allows for use of wireless tablet capabilities, use of wireless medical devices or in other cases where network wiring would hinder the mission. This demonstration loaded CMS software on a tablet computer using this wireless network to communicate to the CMS IO and Video converters.

Display size changes discovered issues in the base implementation. The placement of CMS on the tablet forced a reconfiguration and recompilation of the ARINC-661 Cockpit Display System (CDS) component. A change was needed to the External Source Table in the CDS that forced this recompile. These issues have been noted as a need to improve the CDS source. The resizing of the screen led to a need for altering the UA Definition Files (DF), including the Super Layer, used by the CDS. The configuration files for applications that render to external sources in pixels needed to change to reflect the new screen sizes. These applications included the Map, Streaming Video, and Publications (E-Reader). UAs that needed updates to support configuration of these values were updates so future screen size changes can be made in configuration only.

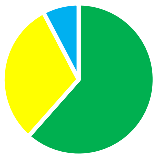
Integration: 2018 FACE TIM - White Platform



The current state of the LUE Project was demonstrated at the 2018 TIM. This included the work accomplished so far on use of a Real Time Operating System (RTOS) utilizing VxWorkss 653, as well as the use of the EGL Compositor Extension to allow multiple applications to utilize the Graphics Processor Unit (GPU) under such an RTOS. Most of the applications in CMS could simply be reused. Effort for porting of CMS to the RTOS and compositor was two engineers over four months with support of SMEs from the vendors.

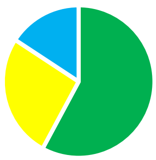
CMS Reuse: FACE Reference Architecture Provides Rapid Integration

Integration: 2018 FACE TIM – Red Platform



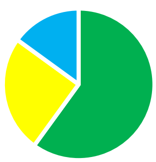
The Red Platform demonstrated at the 2018 TIM included an integration of CMS with the Rockwell Collins (now Collins Aerospace) CH-47F cockpit. The TSS was replaced, a few applications were ported to a T2080 processor, and a Chinook EICAS page was added to CMS. This allowed for some UoCs to be eliminated, and the bulk simply to be reused.

Integration: 2018 FACE TIM - Green Platform



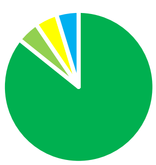
The Green Platform showed that CMS use of network I/O Converters provides a demonstration of how CMS can be expanded to support new I/O capabilities without replacement of central processing units. North Atlantic Industries (NAI) devices using DEOS OS replaced CMS I/O. Along with this, the Map capability was expanded. The CDS was replaced on one display. Yet the majority of the CMS code was reused with another large portion was just recompiled.

Integration: 2018 FACE TIM – Blue Platform



The Blue Platform demonstrated alternative map options, porting the CMS software to LynxOS, and execution of the Display Software on a mission computer with a dumb display. There were two different map applications demonstrated. A multicore processor was divided among multiple OS guests using Lynx Software’s separation kernel. All of this was done without major changes to CMS applications.

Integration: 2018 FACE TIM - Yellow Platform

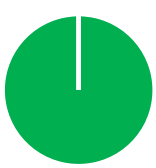


The Yellow Platform demonstrated at the 2018 TIM included the use of the Dorner Works Virtuosity operating system, the integration of BALSA 3,0, the display of the Sierra Nevada wireless communications, and the use of the MUM capability from the initial demonstration running with the latest LUE software.

The Virtuosity OS is a FACE Conformant Operating System based on an open source Linux distribution. The integration of the Virtuosity OS was completed without recompile of the CMS components.

The integration of components developed to FACE Technical Standard, Edition 3.0 (FACE Consortium, December 2017) was proved through the use of the DDS transport to communicate between TSS APIs for each of the two FACE Technical Standards. CMS software was completely reused, the BALSA software was completely reused. A simple transform was written in the TSS library linked into the BALSA application to translate CMS information over to the messages BALSA expected for aircraft position data.

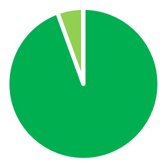
Integration: 2018 TIM – Skayl Booth



Skayl provided a demonstration of tooling at the Transport and Data Model level by driving CMS software from a 4586 simulation. Neither the CMS software nor the simulation software was recompiled. This demonstration only used transforms in the transport layer.

CMS Reuse: FACE Reference Architecture Provides Rapid Integration

Experiment: Cockpit Display

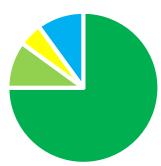


Placing a display up-front for use by the Pilot and Co-pilot in the UH-60 was considered early in the CMS program. After initial demonstration this objective was put on hold while attention was focused on integrating and demonstrating capabilities for the non-rated crew members.

CMS conducted a Crew Station Working Group (CSWG) on the use of placing a CMS display where the pilots could see and use it. The display was limited in function to prevent duplication of information from the Primary Flight Displays (PFDs). These limitations were implemented through modification of the menu configuration file (no source was changed). The demonstration included improvements to the Map UA for display of 3D symbology.

The Map UA used in the CSWG was an extension of work done for the 2018 TIM Green Platform. A lack of 3D (elevation) data in the ARINC-661 interface led to the development of a semi-transparent wall-style flight path. Recommendations for inclusion of 3D features are being passed to the ARINC standards committee supporting-661.

Program: US Air Force HH-60U



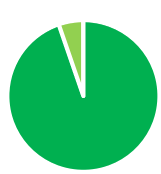
Some of the USAF HH-60Us have been fitted with CMS for use by crew members. The original LUE functions were used with additional functions related to a gimbal mounted sensor. CMS enhancements include the display of sensor video, sensor footprint on the map, as well as tasking the sensor to map coordinates. The installation also eliminated the need to change the aircraft Integrated Vehicle Health Monitoring Unit (IVHMU), including an MIL-STD 1553 connection for access to the Embedded GPS/Inertial Navigation System (EGI) data.

The Map UA was improved to find the intercept of the sensor visual trajectory with the terrain and to render a sensor footprint at that location. This was a simple modification of the Map UA that now allows the Map UA to detect visual intercepts and depict symbology at those intercepts. This change was made in conjunction with the MX-15 Sensor update with a plan to allow more sensor footprints from other aircraft in the future.

A PSSS was added to interface with the MX-15 Sensor on the HH-60U This PSSS sends the sensor status, field of view and direction onto the TSS. It also utilizes the CMS Menu Interface related to map locations. This interface was designed for configurability at run-time, this allowed support of tasking the sensor to a point without a change to either the Menu System or the Map UA.

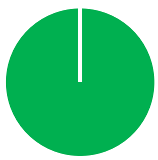
Earlier versions of the CMS software relied on a modification to the IVHMU software to forward avionics data. This created an external dependency on an update to aircraft software that provides other avionics functions. By enabling access to the 1553 bus (as a bus monitor) all data could be received by CMS without the need to modify the IVHMU software. CMS software changes included only the creation of the two new PSSS UoCs and the addition of the 1553 interface. The ARINC-429 processing was also updated to properly handle the SDI bits.

Future Experiment: UAV display and Control



A current development using CMS will display the locations and sensor feeds for multiple Unmanned Arial Vehicles (UAVs) in the vicinity of the Blackhawk. This project will eventually include experiments with tasking the UAVs. The Map extensions for display of sensor foot-print will be further extended to support multiple UAVs. The streaming video processing will be updated to include multiple streams supporting meta-data decode with multiple TSS connections for each stream. The addition of UAV interactive features can be added through the existing menu system interface for map related objects.

Future Experiment: HOST Interoperability



Another current project is to demonstrate CMS interoperability with the Hardware Open Systems Technologies (HOST) standard. An integration event of CMS using a HOST processer will be conducted in early 2020. While this project could be completed without modification of any CMS UoCs; this project might experiment with a replacement CDS, porting of CMS to other processors, or new IO.

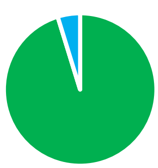
Future Program: CMS Production

The CMS team has begun working on what will be the production version of CMS for deployment to the UH-60M. The production effort will include the capabilities of the LUE, include the 1553 connection developed for the USAF, and will include a re-planning and competition of the CMS hardware.

The initial production software for CMS will be minimally changed from the LUE version. Feedback from the LUE will potentially change some software functions, but will unlikely include any major new features.

New hardware will be evaluated as CMS moves to production. This will include looking at the HOST standard for a potential improvement to the Mission Computer and I/O converter architecture. It will also include development of Display requirements that support faster processors as well as off-loading video decoding to a GPU.

Planned: Door Gunner Targeting



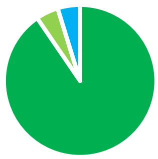
One of the programs that CMS could support in the future is related to relaying of Door Gunner information to the pilot. The pilot of the UH-60 is responsible for the actions of the men under his command, this includes the authorization to fire the door guns. A system to show the pilot where the door guns are pointing, along with the symbology of known friendly and enemy locations, can greatly enhance the ability for the pilot to make those calls.

Through the discussions with the related program, it became apparent that integration with CMS would greatly enhance the capabilities of both systems. If the CMS display with IDM symbology was already developed, and a display for the pilot was deployed, the display of door gun trajectory on the map is a simple extension of work done for USAF.

If the door gun was fitted with an electronic scope, it is also possible to implement an ARINC-661 CDS in the door gun display of its scope. This would allow additional symbols to be displayed on the scope from other CMS functions, such as friendly and enemy locations and aircraft related alerts. This project was discussed but not bid.

CMS Reuse: FACE Reference Architecture Provides Rapid Integration

Planned: Radios



A developing program within the Army is to test new radios on test aircraft. This program will test new radios planned for use in future communications. Data from the CMS will be transmitted between aircraft and the ground.

The addition of a radio status and tuning UA will be accomplished using the lessons learned from the MUM and IDM experiments. This will lead to a new version of the Radio Tuning UA and a new radio tuning PSSS.

The routing of data over an IP radio will include modifications to the TSS domains and potentially adding virtual networks to the CMS network architecture. Some of the lessons learned from the TSS Configuration in the 2018 TIM should allow this update without further changes to CMS software.

Planned: Aircraft Weight

This developing program is exploring the use of new sensors to more accurately determine the weight of the aircraft, eventually providing a better way to calculate weight for input into the related FMS calculations. The initial demonstration will be to host a user interface on CMS to display the values.

Sensors will be added to the aircraft for obtaining weight. This information will be read by a PSSS Device Service.

A PCS Component that performs the weight calculations will be developed with the intent to be portable. This PCS will not include any aspects of displaying the data. This component should be portable to future production efforts.

A User Application will be developed to show the results of the calculations on the CMS display. This user interface will likely only be for demonstration purposes.

Analysis Data

The analysis includes a notation of the version of the UoC. This version indicates when changes were made and if the version was compatible across the set of projects. Note: changes to support bug fixes are not marked as new versions.

Table 1- UoC Reuse

		Programs				Test Bed						TIM Platforms							
		Demo	LUE	USAF	Prod	IDM	Wireless	UAV	Radio	Weight	Gunner	BALSA	White	Red	Blue	Yellow	Green	Skayl	HOST
Core UoCs	CDS	1	2	2*	4	1	2*	2	2	2	2	1	3	2	2*	2*	A	2	2
	Menu System	1	2	2	3	1	2	2	2	2	2	1	2	2	2	2	2	2	2
	Operating System	C1	C2	C2	?	C1	C2	C2	C2	C2	C2	1	W	C2	L	V	D	C2	C2
	Keyboard	1	2	2	3	1	2	2	2	2	2	1	2	2	2	2	2	2	2
	Steaming Video	1	1	1	2	1	1	2	1	1	2	1	1	1	1	1	1	1	1
	TSS	1	2	2	2	1	2	2	2	2	2	1	3	C	3	2^	3	2+	2
	IOSS	1	2	3	?	1	2	2	2	2	2	1	2	2	2	2	2*	2	2
Hosted UoCs	Map	1	2	3	4	1	2	3	3	3	3	1	2*	2	G+B	2	2+	2	2
	EICAS	1	1	1	2	1	1	1	1	1	1	1	1	C	1	1	1	1	1
	Fuel	1	2	2	2	1	2	2	2	2	2	1	2	2	2	2	2	2	2
	Flight Plan	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Pubs	1	2	2	3	1	1	2	2	2	2	1	1	1	1	1	1	1	2
	Readouts	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Camera		1	1	1		1	1	1	1	1		1	1	1	1	1	1	1
	Mark Points	1	1	1	1		1	1	1	1	1		1	1	1	1	1	1	1
	MUM	1										1				1			
	Radio Tuning	1				2			3										
	JVMF Free Text					1													
	Weight Calculator									1									
	ADS-B In											1							
PSSS Device Service UoCs	IVHMU	1	1			1	1	1	1	1	1	1	1		1	1	1^	1	1
	DCU	1	1	2	2	1	1	1	1	2	2	1	1		1	1	1^	1	1
	FMS	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1^	1	1
	EGI			1	1					1	1								
	Camera		1		?								1						
	Display	1	1	1	?	1	1	1	1	1	1	1	1	1	1	1	1	1	
	IDM					1													
	R2C2/UC3	1				3										2			
	MX-15			1															
	Radio Interface								1										
	Weight Inputs									1									
	Door Gun										1								

CMS Reuse: FACE Reference Architecture Provides Rapid Integration

Table 2- UoC List

Core UoC	CDS	**1:** Includes the rendering of Map Horizontal symbology
		2: Included the forwarding of Map Horizontal symbology to the Map UA.
		2*: CDS was compiled to different display formats.
		3: Includes the EGL Compositor or use Shared Memory.
		4: address the variable screen size issues.
	Menu System	**1:** Initial version for soft and hard keys.
		2: Add the capability to pop-up geo-referenced menu items.
		3: Address ease of configuration.
	Operating System	**C1:** CentOS 6.7 using startup scripts to run CMS
		C2: Centos7 using Services to launch CMS.
		W: Wind River's VxWorks 653
		L: LynxOS 178 + CentOS7 guest under the LynxOS separation kernel
		V: Dornerworks Virtuosity.
		D: DEOS to the NAI host computer. CentOS7 on Displays.
	TSS	**1:** BALSA Based UDP TSS
		2: RTI DDS Professional
		2^: RTI DDS version with a BALSA 3.0 Translation Component.
		2+: RTI DDS version with a transport bridge to a STANAG simulation.
		3: Combination of RTI DDS Conext Professional and Secure.
		C: Collins Aerospace Transport Used on the CH-47F.
	Keyboard	**1:** Support of Alpha and Numeric keyboard
		2: Support of only a numeric keyboard using a different CDS interface
		3: Re-enable Support of both Alpha and Numeric keyboards
	Streaming Video	**1:** Support of H.264 streaming and decode of embedded meta-data
		2: Support of variable number of meta-data streams
		3: Support of hardware accelerated decode
	IOS	**1:** Initial version, Serial and ARINC 429 (MACC)
		2: Added CAN BUS Support (Avalex)
		2*: Addition of 429 support for NAI Devices for DEOS version.
		3: Added 1553 Support (MACC)
Hosted Capability UoC	Map	**1:** Map UA using FliteScene libraries + FliteScene rendered in CDS
		2: Map UA including FliteScene rendering with CDS forwarded of 661 data
		2+: Additional Map Features for the 2018 TIM and Front Display CSWG
		3: Rendering of the Map through EGL Compositor.
		B: Boeng GEMS version
		G: GE OpenMap version
	EICAS	**1:** Initial version of the UH-60 EICAS page
		C: Collins Aerospace version of EICAS for a CH-47F

	Flight Plan	**1:** Initial version of the flight plan page and rendering of the flight plan points on a map. (note this is implemented as two separate UoCs).
	Fuel	**1:** Initial version of a Fuel Calculator (note this is implemented as two separate UoCs).
		2: LUE version of the Fuel Calculator and Fuel Reserve Panel
	Pubs	**1:** Initial version of the Pubs application using FoxIt
		2: Version of the Pubs application supporting multiple display sizes
	Readouts	**1:** Initial version of Readouts showing Altitudes, Speeds, and Time
	Camera	**1:** Camera UA supporting multiple camera pages and a configurable set of camera commands
	Mark Points	**1:** UA for displaying saved points on the map and in a list
	MUM	**1:** Application for displaying a single MUM aircraft and its sensor footprint through an ARINC-661 item list.
	Radio Tuning	**1:** Radio Tuning UA for commanding R2C2
		2: Radio Tuning application for commanding UC3 and displaying Radio Status.
		3: Next generation radio tuning application
	JVMF Free Text	**1:** Demonstration Application for viewing InBox and sending JVMF Messages
	Weight Calculator	**1:** Demonstration application for displaying weight and balance information from weight sensors. Implemented as two UoCs, one for reuse in an avionics system, the other for display on CMS.
	ADS-B In	**1:** UA for displaying aircraft locations received from ADS-B
PSSS DS UOC	IVHMU	**1:** Initial version of an IVHMU PSSS to translate IVHMU 429 data into TSS messages
		2: Addition of Pitch and Roll messages
	DCU	**1:** Initial version of the DCU PSSS supporting CAS and Fuel Messages
		2: Version of the DCU PSSS supporting the addition of Engine and Transmission data
	FMS	**1:** Initial version of the FMS PSSS supporting the decode of FMS 429 messages for flight plan, time, location, and ground speed
	EGI	**1:** Initial version of an EGI PSSS that monitors 1553 messages related to the EGI.
	Camera	**1:** PSSS DS for communicating to a FLIR camera over CanBUS
	Display	**1:** PSSS DS for interfacing with Display Bezels, a Joystick, and an Encoder Knob (note this is implemented as two separate UoCs).
	MX-15	**1:** PSSS DS for communicating to WesCam MX-15 sensor. Supports reporting sensor status and position as well as tasking the sensor to a map location.
	R2C2/UC3	**1:** Initial version supported Rover radio status and transmit tuning
		2: Version supported Rover Radio receive tuning
		3: Version supports tuning the IP radios
	Weight Input	**1:** PSSS DS for receipt of raw weight sensor inputs
	Door Gun	**1:** PSSS DS for receipt of Door Gun information

Component Lessons Learned

Over the development of the CMS software and the past and planned future demonstrations, there are a lot of lessons that can be garnered through the reusability of the CMS components

The FACE Technical Standard Provides for Rapid Integration

Most vendors participating in the 2018 Army FACE TIM were pleasantly surprized at how little effort was needed to integrate with CMS. Participants demonstrated their product working within the Rapid Integration Framework having the CMS SDK for just six weeks.

Several participants in the TIM had developed products aligned to the FACE Technical Standard without knowledge of CMS or the RIF. These products were integrated in the six week time period. This would not have been possible if the interfaces to the OSS and TSS were not well understood and factored into the development of these products. Using the FACE Technical Standard as framework allowed the teams to talk about products developed to work within this architecture using a common vocabulary that conveys a deeper meaning. The use of a data model following the FACE Data Architecture also eased the integration with Collins Aerospace's TSS. SKAYL's demonstration would not have been possible without this well-defined data model concept.

Added Features Can Build on One Another

Having a small team of people aware of many possible uses allows features to be added in a way that can provide maximum benefit to the most programs. As CMS added features it was clear how these features could be added to support multiple projects in the pipeline.

For example: addition of sensor foot-print functions are reusable by on-board sensors and targeting systems as well as UAVs. If these features are added in a configurable way, modification of multiple components may not be necessary as future capabilities are added.

Configuration is Key

CMS components were developed to have configurable core components to support addition of lower Design Assurance Level (DAL) capabilities without recompiling the core components. In many cases, additional configuration capability was added to software components as a manner of providing flexibility when integrating into the aircraft. On more than one occasion late requirement changes were quickly met through configuration changes; or the duplication of a software component and adjustment of configuration on the resulting copies. During the 2018 TIM, configuration of the menu system to support the various Map UAs and alternative displays was quickly accomplished without the need to change the menu code, or even re-compile it.

CDS Recompilation

The CDS has a number of dependencies on screen size, the inclusion of images, and the External Source Table. Future versions of the CDS should make these configurable items.

CMS Reuse: FACE Reference Architecture Provides Rapid Integration

CDS, ARINC-661 and Portability

ARINC-661 as a standard has provided CMS with many benefits for configuration, scalability, and separation of critical applications in a graphical environment. The attempt to port CMS to a new CDS in the 2018 Army FACE TIM also exposed some issues with portability using ARINC 661.

There are not a lot of CDS implementations that support the Map Horizontal and External Source widget features used by CMS. There are also some subtle differences in how one might interact with a CDS. CMS software to interact with the CDS could be modified to provide more flexibility in this area.

ARINC-661 and 3D

CMS uses ARINC-661 as the primary method to display composite graphics from multiple user interfaces into one display capable of supporting mixed DAL. The Map Horizontal widgets in ARINC 661 are instrumental to the combining of SA data onto a map. When the Map is placed in a 3D view, this Map Horizontal widget breaks down. It is easy to imagine a similar widget being used for a camera view if 3D information were available.

The ARINC-661 committee is currently working on including these 3D features in a future supplement to the standard. CMS might add these features as the ARINC committee is working through these features.

TSS Domains

During the development of CMS, the concept of two domains (display-wide and aircraft-wide) was developed and data items were placed on one or the other domain based on the type of data. During the TIM, the plan to move to central sources of PSSS data on some of the platforms led to a need to change which domain these data items were on. This led to CMS configuration of domains on a per-message level.

Video Processing

CMS has been using software decoding of video for the processing of its H.264 video streams. These streams have been used for on-board video as well as for off-board video sources. The dual-core i7 processor in the Avalex displays has not been able to keep up when additional processing is needed. The closed nature of the GPU embedded in the i7 chip has also been a barrier to off-loading decompression. Future displays should be procured with a more open graphics processor that can support a graphics driver developed for a safety domain that includes the EGL Compositor.

Project Benefits

The reuse of CMS components across these projects must be viewed through the context that all of these projects are essentially providing functions to the Crew Chief station in a helicopter. There is little variation in the overall architecture of the various systems, but that is part of what makes a strong case for reuse.

Projects needing a display of mission capabilities and SA can make the best benefit of using the RIF as a baseline. Most of the capabilities developed for CMS are for the display of data available from other systems. One lesson from this work is that applications for display of information should be kept as separate UoCs from components that manipulate the data. This would make the display components reusable on SA only systems.

Conclusions

The CMS projects and RIF demonstrations prove there are many benefits to using the FACE Technical Standard and the RIF for projects seeking to rapidly field capabilities and to reuse software components.

Early adaption of the FACE Technical Standard into the CMS Strategy clearly allowed for reuse of CMS components across the varying projects. One key aspect of the FACE Technical Standard is the abstraction of the PSSS device interfaces from the PCS components providing the user interfaces. The benefits of this aspect has been repeatedly demonstrated in the various instantiations of CMS.

As CMS has been reused, lessons learned have been fed into the CMS baseline projects leading to more reusable components. CMS core system components have been fully reusable except in cases where those components were intentionally changed as part of an experiment or integration.

Airworthiness qualified UoCs that are 100% reused without any modification would greatly reduce qualification efforts of new deployments (Edwards C. J., Developing Portable/Reusable Certification Artifacts, January 2016). These components can utilize prior airworthiness qualification as IMA components. CMS Projects have 75% of their components in this ideal state, except in cases where an experiment at the TIM showed an underlying variation in the hardware and OS; or in the case of the LUE, where lessons learned from the Demonstration caused a large number of component requirements changes resulting in new versions. In the cases where components were modified, those modifications were generally minor, leading to strong reuse of the documentation similar to traditional program upgrades.

Projects wanting to provide rapid integration of new capabilities can make use of the CMS architecture, including the Core System components as a basis for a system. These projects would start with a ready-made user interface supporting some common capabilities (like Map and Video). The RIF already has a pattern of functional allocation of user interface components defined, allowing easy sharing between those systems and other projects utilizing the RIF.

As the RIF evolves, changes in ARINC-661 should provide an even greater level of functionality. Defining the correlation of multiple SA sources into common images without the need to change the core components rendering the common images greatly improves the ability for the RIF to provide rapid fielding of these sorts of capabilities. CMS team members and FACE Consortium members involved in the development of the ARINC 661 standard should help guide that standard to solve some of the minor issues discovered in the RIF use of this standard.

The FACE Consortium's Graphics Subcommittee has also been tracking issues with this standard and has provided additional requirements for FACE UoCs using ARINC-661. Changes in FACE Technical Standard, Edition 3.0 around the use of ARINC-661 should be adopted in future iterations of UoCs used within CMS and the RIF.

References

Edwards, C. J. (January 2016). *Developing Portable/Reusable Certification Artifacts.* The Open Group.

Edwards, C. J., & Mooradian, D. (September, 2017). *The FACE Technical Standard Applied to a Comprehensive Architecture Strategy.* The Open Group.

Edwards, C. J., Price, S. P., & Mooradian, D. H. (October, 2017). *The Impact of the FACE Technical Standard on Achieving the Crew Mission Station (CMS) Objectives.* The Open Group.

Edwards, C. J., Price, S. P., & Mooradian, D. H. (September, 2018). *The Evolution of the Rapid Integration Framework.* The Open Group.

FACE Consortium. (24 Jun 2014). *Technical Standard for Future Airborne Capability Environment (FACE), Edition 2.1.* The Open Group.

FACE Consortium. (December 2017). *Technical Standard for Future Airborne Capability Environment (FACE), Edition 3.0.* The Open Group.

RTCA, Inc. (November 2005). *RTCA DO-297, Integrated Modular Avionics (IMA) Development Guidance and Certification Considerations.* RTCA, Inc.

About the Author(s)

Christopher J. Edwards has been working in the avionics industry for 25 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 Systems Engineering Lead for the CMS Project.

Steven P. Price has been working in avionics and embedded software for 30 years. He has worked on several different graphic user interfaces including cockpit systems. He has been a leader in the design and implementation of some of these systems, along with being involved with the testing of some of these systems. Currently Mr. Price is one of the Software Engineers for CMS, and the principal developer of the CMS Menu System. He is a FACE Verification Authority Subject Matter Expert (SME).

About The Open Group FACE™ Consortium

The Open Group Future Airborne Capability Environment (FACE™) Consortium, was formed as a government and industry partnership to define an open avionics environment for all military airborne platform types. Today, it is an aviation-focused professional group made up of industry suppliers, customers, academia, and users. The FACE Consortium provides a vendor-neutral forum for industry and government to work together to develop and consolidate the open standards, best practices, guidance documents, and business strategy necessary for acquisition of affordable software systems that promote innovation and rapid integration of portable capabilities across global defense programs.

Further information on FACE Consortium is available at www.opengroup.org/face.

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