Enabling Situational Awareness and Network Centric Operations for Systems utilizing FACE™ Open Systems Architectures

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ABSTRACT

This paper presents an industry-unique approach to facilitate Network Centric Operations (NCO) and enhance Situational Awareness (SA) for rotorcraft platforms. Flight risks and mishaps including controlled flight into terrain under degraded visual environments can be reduced as a direct result of providing pilots with an enhanced view of the battlespace. A toolset is described which fuses Modeling and Simulation (M&S), modular open architectures, and sensors integration techniques into a single package to enable rapid design, development, testing, and deployment of new interoperable SA enabling systems. This industry-unique approach is targeted to support the US Army's Joint Common Architecture (JCA) program and is aligned to the Future Airborne Capability Environment (FACE™) technical reference architecture.

INTRODUCTION

The advent of the information age offers both benefits and challenges. It requires us to balance between having access to a plethora of information while avoiding the bombardment of a constant stream of quasi real-time data. As an example of this, consider the daily effort expended to distinguish meaningful email required to support one's work role from unnecessary and distractive spam.

The challenge in the military aviation community is to create and operate efficiently within a network-centric battlespace where information must stream at speeds sufficient to support flight operations. This requires real-time flight-worthy open systems architectures that are interoperable so that the assets and capability suites on-board one platform can be effectively shared with the battlespace forming a Common Operating Picture (COP) that can be used to enhance the situational awareness of that space.

THE NEED

Tucson Embedded Systems (TES) is addressing the need to rapidly design, integrate, and verify complex embedded systems-of-systems that can be used to support network-centric operations in a virtual simulation collaborative environment. This is the essential first step in the formation of an interoperable environment.

This need then can be extended for use beyond any single systems-of-systems platform evaluation and beyond any single branch of the military – it can be used to realistically model collaborative enterprise systems-of-systems and evaluate capabilities of multi-branch multi-service operations, those that will occur if the Joint Systems of Systems vision, and Joint operations are to become reality.

A quick study of Figure 1 below shows the need to share situational awareness of local airborne assets to formulate an enhanced situational awareness of the battlespace. Here the data from collaborate battlespace assets are used to formulate information needed for a mission reroute for safer travel.

Figure 1. US Army JCA OV-1 Mission Survivability

Background

Tucson Embedded Systems (TES) began working with the US Army Aviation branch on its Common Software Initiative in 2003. During this 10 years' time, TES developed an approach to rapidly design, develop, integrate, and verify common reusable airworthy software for use on complex embedded systems-of-systems like the US Army rotary helicopters. TES prototyped common reusable software and demonstrated this capability to the US Army's Program Manager of Aviation Mission Equipment (PM-AME), platforms, and AMRDEC SED and AED organizations[1].

More recently TES has been tasked to use these capabilities and design and develop the common standard interfaces for the Army's common communications program[2], the Army's Modular Integrated Survivability program, now ROSAS[3], and most recently the data model for the Army's Joint Common Architecture (JCA) program[4]. All of these efforts are purposely aligned with the FACE™ technical reference architecture[5] definition for next generation open system standards for US military aviation products. Additionally, TES has been tasked to deliver automated test architectures[6] [i] [ii] stemming from this same industry-unique approach and toolset.

During the last decade of supporting the US Army, TES has been able to spend its R&D dollars and refine its capabilities and deliver products to the US Army in a successful symbiotic relationship. All products developed from TES' capabilities are delivered to and are owned by the Government.

This paper describes TES' industry-unique approach and presents how it is being used to facilitate Network Centric Operations (NCO) and enhance Situational Awareness (SA) for aviation platforms. The approach and supporting toolset fuses Modeling and Simulation (M&S), Modular Open Systems Architectures (MOSA), and sensor integration techniques into a single package to enable rapid design, development, integration, testing, and deployment of new interoperable SA enabling systems.

The Army has an ongoing need to integrate Aviation Mission Equipment products into aviation platforms. This integration can occur at aircraft delivery or as an aircraft upgrade. The integration cycle includes a significant effort in developing software to interface to new and changing AME products and certifying those products onto the Army's fleet of Aviation Platforms.

ENABLING SA FOR NCO

Bottom-up and Top-down approach to Systems Design

TES believes that the key to a successful integration approach includes a combination of bottom-up and top-down activities. This bi-optic approach interweaves the details required to functionally operate integrated devices hosted on a platform with the high-level operational requirements of common capabilities provided by a fleet of dissimilar aircraft platforms. The byproduct is an abstracted common interface used to hide proprietary implementation details from the platform integrators, and shield platforms from device-level changes.

This section describes a methodology to organize actual Interface Control Document (ICD) sensor data into capabilities, or logically grouped sets of functions or domains, within a toolset.

TES has patented a process referred to as Capability Driven Architecture (CDA)[iii]. The TES CDA process is used to import device ICD and other interface definitions into the CDA toolset. Engineers, knowledgeable in the field, in an iterative fashion, logically group sets of functions or domains within a toolset. The products produced are common reusable platform and hardware independent Application Program Interface (API) definitions for the set of grouped sensor capabilities.

[1] U. S. Army Aviation and Missile Research Development and Engineering Center (AMRDEC) Software Engineering Directorate (SED) is a recognized leader in supporting the acquisition, research, development, and sustainment of some of our Nation's sophisticated weapon systems. The Aviation Engineering Directorate (AED) is the Airworthiness authority for Army-developed aircraft.

[2] R2C2 - Reusable Radio Control Component – is a FACE™ candidate communications domain application. R2C2 is written to FAA's DO-178B Level-C Design Assurance Level (DAL), and is aligned to the FACE™ reference architecture standard and to the FAA's AC-20-148 guideline for reusable software components.

[3] MIS – Modular Integrated Survivability – is a FACE™ candidate situational awareness domain product and simulation. Our simulation suite models the aircraft platforms, simulates flight, and controls the operations of actual or simulated aircraft survivability equipment (ASE) to illustrate enhanced situational awareness (SA) of the platform in flight in DVE conditions. ROSAS – route optimization for survivability against sensors, is the follow on program of the MIS S&T effort.

[4] The JCA data model product will be built upon open systems modular approaches, align itself with the FACE™ technical reference architecture, support software reuse across the Joint Multi-Role (JMR) fleet, and embrace automation to support lifecycle and airworthiness efforts.

[5] FACE™ enables portability and reuse to enhance the interoperability of systems of systems in a network-centric operational battlespace. A FACE tenant is that FACE compliant software written for one aviation platform can be ported and reused on a different platform.

[6] TES' Automated Comprehensive Control Testing (ACCT) automates routine tests of modern military radios operating in bus-controlled avionics architectures. ACCT validates modern military radios in 1553 bussed environments. The results support Army Aviation's box qualification processes, ensures compliance with the device's MICD standards and ensures that the internal control software performs optimally under both normal and abnormal input conditions.

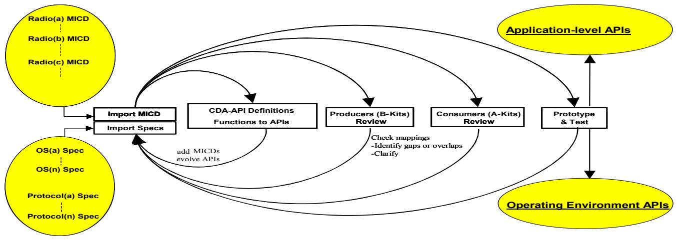

Figure 2. TES CDA Process

As illustrated in Figure 2, proprietary device ICDs and specifications are imported into our CDA system (left side of the flowchart). Produced are open common non-proprietary APIs for device control across dissimilar operating environments.

Similar to the architecture being defined by the FACE Consortium, TES' CDA includes three levels of interface definitions, those being the application-level APIs, the device Input/Output (I/O) APIs, and the Operating Environment (OE) APIs. Conveniently, this aligns our CDA produced products with the FACE™ technical reference architecture. An example is shown in Figure 3 the illustration of one of our produced products, R2C2, overlaid into the FACE™ architecture.

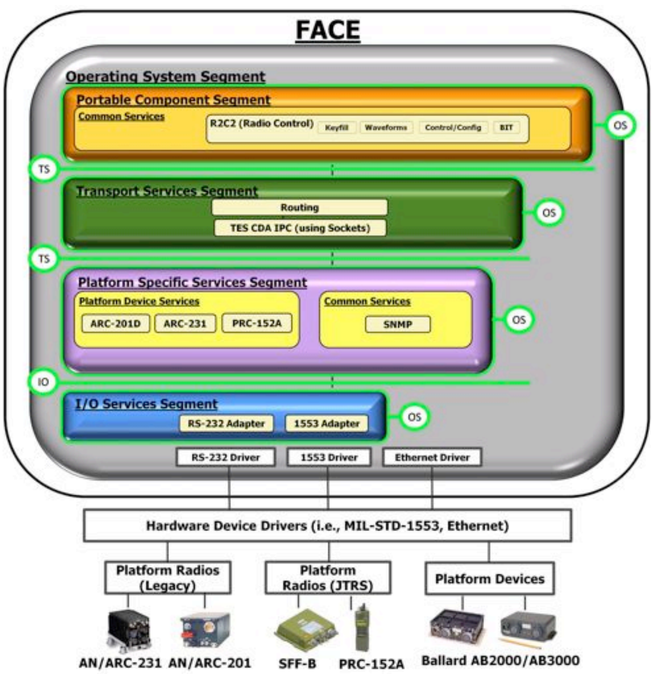

Figure 3. US Army Common Communications Program overlaid on to the FACE™ architecture

These three levels of APIs, along with an Inter-Process Communication (IPC) for the exchange of data among multiple threads in one or more processes, are used collectively to control and verify multiple dissimilar devices across a fleet of dissimilar aircraft with one Reusable Software Component (RSC)[iv]. Readers interested in the CDA process, its product APIs, and inherent verification capabilities of the CDA-produced APIs should refer to two previous AHS papers [v], [vi].

Controlling Devices and Protecting Device Manufacture's Intellectual Property (IP)

Provided that the device ICD has been imported into the tool, engineers using the toolset have the ability to auto-generate device control code thereby mapping the common control API to the actual hardware device. In this manner, as illustrated in Figure 4, this hides implementation details of devices from the platform integrator, thereby speeding device integration and reducing the effect on device-level changes on the platforms.

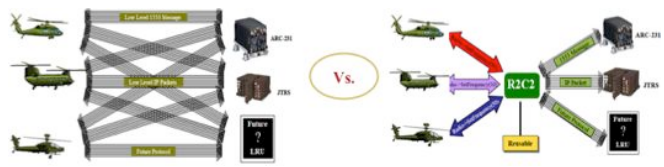

Figure 4. Addressing Stovepipe Integration issues with Open Systems and Standardized Interfaces

Required then is a configuration file that identifies the types of devices and specific operating systems of the target platform being simulated. With this, the TES CDA toolset now includes the ability to functionally operate, through the common reusable control APIs, the hardware devices in a representative platform on that platform's actual Real-Time Operating System (RTOS).

The US Army's R2C2 and MIS candidate FACE™ applications and the common control capabilities of these programs were demonstrated at the FACE™ Navy Exposition at the Naval Air Base in Solomons Island Maryland, and the FACE™ Army TIM 2012 in Huntsville Alabama respectively. The FACE Air Force TIM is planned for spring 2013 at Wright-Patterson Air Force Base in Ohio.

Figure 5. TES demonstrating candidate FACE™ applications and reusable control capabilities at the FACE™ Army TIM 2012 in Huntsville, AL

Baseline capabilities used to build up a representation of a Platform's Systems of Systems

Within the TES CDA toolset is the ability to incrementally develop a systems model from the platform's capabilities.

For example, using the Army's Common Communications program, R2C2, TES imported the ICDs corresponding to the Army's legacy and next generation Solider Radio Waveform (SRW) and and Wideband Networking Waveform (WNW) JTRS radios. Users of the toolset can build up platform representations. They rapidly integrate device capabilities by selecting a graphical icon of platform devices (e.g., an AN/ARC-231 radio), and assigning them the interface protocol (e.g., MIL-STD-1553, Ethernet, or RS-232) to the platform's mission processor. Then we can actively control actual or simulated hardware from our toolset.

Since the fleet of dissimilar US Army platform host different mission processors with a variety of real-time operating systems (RTOS)[7], TES has partnered with device and system providers[8] to demonstrate the portability of the common reusable APIs on rugged embedded processors. Thus far, and efforts continue to progress, TES has ported and demonstrated reuse on Windows, Linux, and VxWorks. The porting efforts of the LynxOS and Integrity RTOS are to follow.

Functional Requirements and Operational System Modeling and Evaluations

To model and evaluate device and sensor performance under operational flight conditions[9], TES has integrated the capability to model and simulate flight. TES integrated its CDA toolset with TITAN Global. As shown in Figure 6 below, TITAN has the capability to simulate real-word data, terrain, and environmental conditions. Added into TITAN are simulations of real-word objects, threats, and flight models.

Figure 6. Afghan Landscape used for Mission Rehearsals

[7] Wind River's VxWorks653 hosted on the OH-58D Kiowa Warrior; LynuxWorks™ LynxOS-178 hosted on the CH-47F Chinook and UH-60M Black Hawk, and Green Hills Intergity®-178B – hosted on the AH-64D Apache

[8] Ballard Technologies' family of rugged embedded computers, and Wind River's VxWorks RTOS.

[9] RTCA DO-178C, "Software Considerations in Airborne Systems and Equipment Certification," accepts Model-Based Development (MBD) and verification technologies per DO-331, and DO-333 addresses formal methods to complement (but not replace) testing.

Using the TITAN system 3D planetary engine ensures fidelity of the simulation by providing seamless planet rendering from space down to the surface of the Earth. Through the use of their fractal algorithms this entire dynamic range can be modeled from an abitary resolution down to one centimer.

To support mission rehearsals, a typical simulation will contain an inserted named area of interest (NAI). With the NAI in place, geometry is added to represent buildings, bridges, and roads. Shown in Figure 6 above is an Afghan landscape with object geometry added.

Further up the Afghan valley, as shown in Figure 7, roads and bridges were inserted to help evaluate sensor performance during flight with respect to terrain and man-made objects under controlled Degraded Visual Environmental (DVE) conditions (i.e., light, fog, brown-out, white-out).

Figure 7. Landscape with man-made obstacles to evaluate the performance of airborne sensors

These illustrations were developed by and are the courtesy of TITAN Global, Robert Francis.

TES has been working closely with TITAN's developers. TES integrated its CDA toolset and architectural APIs with TITAN's Modeling and Simulation (M&S) environment on an individual platform perspective. With this enhancement, TES has the ability to conduct M&S of the systems in flight, and to demonstrate the performance and interoperability of a sensor suite [i.e., Aircraft Survivability Equipment (ASE)] using synthetic terrain data and controlling Degraded Visual Environmental (DVE) conditions.

Illustrated in Figure 8 below is a screen capture of this combined capability. It comes from our demonstration of the US Army's Modular Integrated Survivability (MIS) program, which includes TITAN's integrated vehicle and aircraft physics engines used to drive flight input into the M&S system to evaluate the efficacy of the Aircraft Survivability Equipment (ASE) and platform sensors.

Figure 8. TES' M&S Rapid Integration Toolset integrated with TITAN's and World Wind's moving map

In Figure 8, the top-right pane shows the flights of two platforms being simulated to show flight interactions. Out-front of the OH-58 Kiowa Warrior cockpit viewport is an AH-64D Apache. The Apache model has integrated ASE, and at this moment is shown detecting a tower obstacle within its flight path. The top-left pane illustrates the TES CDA systems view of our toolset. It shows the Apache platform configuration and the sensor data bus traffic during the operations of the simulated flight. It is important to note that behind each systems display icon is the complete data model corresponding to the device ICD. The bottom left panes show an Apache simulated Multi-Function Display (MFD) with the tower visible to enhance the SA to the pilot, and a simulated mission processor also identifying the threat information and data from the on-board sensor equipment. The bottom-right pane is a real-time updated NASA World Wind moving map display of the battlespace.

While only illustrating the flight dynamics of one platform in this pane, this World Wind moving map view will become the common operational picture (COP)[10] display of the battlespace. We are working toward modeling mission rehearsals corresponding to the illustration presented in the introduction.

The World Wind display will be layered with corresponding MIL-STD-2525C symbologies of multiple platforms, hostile threats, terrain, and obstacles. As shown, our US Army's MIS software has the MIS APIs and ability to detect and report on hostile threats, terrain, and obstacles.

Systems-of-Systems Integrations and Interoperability Evaluations

Individual platform simulations can be added to form a collaborative interoperable environment.

More recently TES and TITAN have focused on a simulation capability of an enterprise. Each platform with its individual flight models and unique configurations can be added into a collaborative virtual simulated environment. With this we can represent the common operations of the battlespace in a net-centric arena. These simulations can drive actual or simulated hardware on representative mission processors.

TES' enterprise M&S capability can show flight interactions among multiple aircraft platforms with environment, sensors, and threats to evaluate interoperability issues between the disparate platforms. TES' capability provides the means to stage and conduct simulated mission rehearsals in a standard collaborative environment. In order to completely define such an environment one selects an Area of Operation (AO), place threats, detect those threats, and communicate those threats to the COP of the battlespace in a network fashion.

This capability will facilitate the evaluation of Network Centric Operations (NCO) and enhance Situational Awareness (SA) for platforms, both manned and unmanned. If translated to and used in actual flight, it is envisioned that flight risks and mishaps including Controlled Into Terrain (CFIT) under Degraded Visual Environments (DVE) can be reduced as a direct result of providing pilots with an enhanced view of the battlespace. All this can be evaluated in a safe, controlled, and realistic collaborated simulated environment.

Figure 9. Afghan Landscape with the US Army's fleet of rotary aircraft

This illustration shows the ability to introduce aircraft and simulate the flight interactions of multiple airworthy platforms. Shown is the US Army's fleet of rotary aircraft (i.e., UH-60M Blackhawk, OH-58D Kiowa Warrior, CH-47F Chinook, and AH-64D Apache) over the Afghan landscape.

Next Steps – Modeling and Simulating Joint Operations

As illustrated in the introduction, TES' objective is to develop and model an interoperable joint common architecture and show how network-centric operations can be used to enhance the SA of the COP.

By combining the capabilities and assets of the three US Army programs (R2C2, ROSAS/MIS and JCA) TES can

[10] A display of relevant (operational) information (e.g. position of own troops and enemy troops, position and status of important infrastructure such as bridges, roads, etc.) shared by more than one Command. A COP facilitates collaborative planning and assists all echelons to achieve situational awareness. Reference Wikipedia.

demonstrate the transmission of MIS sensor data/information over actual military communications equipment and evaluate enhancements to the SA battlespace domain. Figure 10 below shows an example of NASA's World Wind moving map display depicting multiple aircraft and the corresponding landscape of Figure 9.

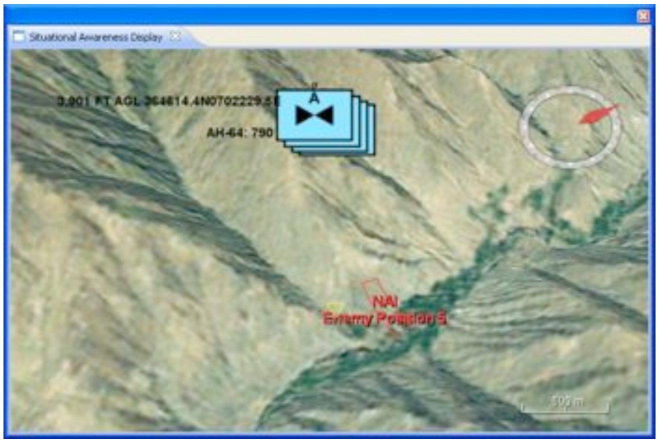

Figure 10. NASA's World Wind moving map of the simulated Common Operating Picture (COP)

This simulated collaborated interaction will occur among airborne platforms, ground platforms, and command and control elements [e.g., Tactical Operations Centers (TOC) / Network Operations Centers (NOC)].

To meet this objective, we have the models prepared of unmanned platform systems and will introduce these valuable airworthy Intelligence Surveillnce & Reconnance (ISR) assets into our modeling environment. In Figures 11 and 12 respectively, shown are the US Army's Grey Eagle and the US Navy's Fire Scout. These will help us to complete the assets identified in the JCA OV-1 Mission Survivability exercise shown above in Figure 1.

Figure 11. US Army's Grey Eagle

Figure 12. US Navy's Fire Scout

CONCLUSIONS

TES has an industry-unique embedded lifecycle capability that is being used to design, develop, and evaluate virtual systems of systems, and the interoperability of those systems in a collaborative virtual environment. Our capability is being used to evaluate the Network Centric Operations (NCO) and the enhancement of Situational Awareness (SA) for airborne and ground platforms either manned or unmanned. This approach is targeted to support the U.S. Army's Joint Common Architecture (JCA) program and is aligned to the Future Airborne Capability Environment (FACE™) technical reference architecture.

This capability may well revolutionize how the military evaluates requirements and aircraft equipment performance for NCO and enhance SA. TES' industry-unique approach may well assist with the integration of platform capabilities of open systems architectures hosted on the next generation joint multi-role aircraft. Our mission is to produce capability that can be used by our military to preserve and protect the dominance of our Warfighting capabilities.

For additional information about software reuse and TES' industry-unique capabilities, contact Tucson Embedded Systems, Inc. Mr. Stephen Simi, TES–US Army Aviation Program Manager at 520.575-7283x154.

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