THE USE OF SIMULATION AND MODELING FOR ACQUISITION, REQUIREMENTS, AND TRAINING (SMART) IN THE VIRTUAL COCKPIT OPTIMIZATION PROGRAM (VCOP)

Jimmy Moore
Quality Research, Inc.
Huntsville, Alabama

Scott Dennis
U.S. Army Aviation and Missile Command
Redstone Arsenal, Alabama

Michael Thome
Aircrew Integrated Systems (ACIS) Program Office
Redstone Arsenal, Alabama

W. Douglas Scalf
Vice President
Quality Research, Inc.
Huntsville, Alabama

ABSTRACT

The Virtual Cockpit Optimization Program (VCOP) is providing an answer to the problem of information overload for pilots of modern military aircraft while reducing the cost of upgrading legacy aircraft. *The concept of the virtual cockpit program is to provide the pilot with information such as situational awareness, sensor imagery, flight data, and battlefield information in a clear, non-confusing and intuitive manner, thus making the aircraft easier and safer to fly while also improving mission performance*. The majority of the VCOP activity involves the integration of advanced technologies into a single system that represents a significant leap ahead in cockpit design philosophies. Rather than concentrating on the aircraft and how it can be retrofitted to meet the needs of the next generation warfighter, VCOP furnishes pilots with the necessary enhanced capabilities to perform their job more efficiently. VCOP is comprised of the following five independently developed technologies: Full color, high resolution, high brightness helmet-mounted display (HMD) that incorporates Virtual Retinal Display (VRD) technology; Three Dimensional (3D) audio; Speech recognition; Intelligent information management; and Crew-aided cognitive decision aides. These technologies will be integrated based upon the principles of Simulation and Modeling for Acquisition, Requirements, and Training (SMART), the application of Modeling and Simulation (M&S) techniques and technologies to the entire product development cycle of a system.

Jimmy Moore, Quality Research, Inc., Huntsville, Alabama
Mr. Moore is a Senior Engineer and Technical Lead for Synthetic Environments for the Advanced Prototyping, Engineering, and eXperimentation (APEX) Lab. He has 5 years of experience developing 3D terrain databases, models, and virtual prototypes in multiple formats for multiple platforms. He holds a BSE from the University of Alabama in Huntsville.

Scott Dennis, U.S. Army Aviation and Missile Command, Redstone Arsenal, Alabama
Mr. Dennis is an Electronics Engineer supporting the Advanced Prototyping, Engineering, and eXperimentation (APEX) Lab. He has over 6 years of experience with missile six-degree of freedom simulation. He holds a BSEE from Auburn University.

Michael Thome, Aircrew Integrated Systems (ACIS), Program Office, Redstone Arsenal, Alabama
Mr. Thome is lead engineer for the Virtual Cockpit Optimization Program (VCOP) for the U.S. Army PEO-ACIS Project Office. He has 11 years active service in Army Aviation as an instructor pilot in the AH-64 and AH-1 Cobra and Gazelle helicopters. He holds a BSCE from the University of Alabama.

W. Douglas Scalf, Vice President, Quality Research, Inc., Huntsville, Alabama
Mr. Scalf is Vice President of the Modeling and Simulation Operation of Quality Research, Inc. where he performs all aspects of program management and technical oversight activities for a staff of over twenty-five engineers, computer scientists and system analysts. This encompasses requirements definition and technical oversight for numerous DoD Distributed Interactive Simulation (DIS) and High Level Architecture (HLA) programs at the US Army Aviation and Missile Command's Advanced Prototyping, Engineering & Experimentation (APEX) Laboratory. He has 17 years of experience with simulation based acquisition and holds a BSE from the University of Alabama in Huntsville.

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INTRODUCTION

On the modern battlefield, information is the key to providing swift, decisive victory. Nowhere is this more evident than in the cockpits of today's military aircraft. Technology has provided unprecedented situational awareness to pilots who are constantly inundated with ever-increasing amounts of flight, status, safety, and battlefield information. Consequently, the speed with which a pilot must assimilate and react to mission critical information is also increasing. The solution to this problem must overcome three significant obstacles:

1. The pilot must receive information from the aircraft in a clear, non-confusing, intuitive manner and format.
2. The man-machine interface in the aircraft must be sufficiently simple to permit the pilot direct and unobstructed access to critical aircraft and mission information.
3. Information must be delivered utilizing the pilot's entire multi-sensory (visual, aural, and tactile) capability – increasing the bandwidth of information transfer from the platform to the pilot.

Additionally, current weapon system acquisition cycles within the DoD range between 10 and 20 years. In order to provide a viable solution in a timely manner, this time must be reduced. Modeling and simulation provides the most effective means to achieving reduced cradle-to-grave weapon system development cycles [1].

This paper will discuss how the Virtual Cockpit Optimization Program (VCOP), which is being managed by the Army's Aircrew Integrated Systems (ACIS) Program Office, is providing a solution to the problem of information overload exerted on pilots of modern military aircraft. In addition, it will also discuss how VCOP is being implemented with the SMART approach, and what tangible results have been observed.

BACKGROUND

The man-machine interface implemented in the design of current cockpits relies on the pilot to perform unnecessary data processing. For example, conventional panel-mounted head-down displays (HDD) require pilots to refocus their attention from out-the-window to inside the cockpit wasting valuable "heads-up" time. Heads Up Displays (HUD) reduce this problem; however, they only provide information across a limited field of view (FOV) and currently are not able to provide instrument symbology as well as world-referenced information simultaneously. Additionally, all current man-machine interfaces fielded today rely on the pilot to comprehend and evaluate information about a three-dimensional (3D) world from two-dimensional (2D) cockpit displays.

VCOP will integrate several independently developed advanced technologies across multiple platforms into a single system to deliver information to the pilot in a clear, concise, and intuitive manner and format. The goals of VCOP are as follows:

- Provide Efficient Access to Critical Information
- Minimize Pilot Work Load
- Reduce Costs in Upgrading Cockpits
- Conform to Hands-On Philosophy
- Minimize and Effectively Manage Errors
- Maximize Situational Awareness
- Reduce Cost of Advanced Cockpits
- Minimize "Head Down" Time
- Maximize System and Mode Awareness
- Formulate "Standardized" Head Down/Panel Mounted Requirements

These technologies are being integrated into a single approach based on evolutionary principles developed through Department of Defense (DoD) and industry initiatives called Simulation Based Acquisition (SBA). The concept behind SBA is to integrate Modeling and Simulation (M&S) tools and technologies into the acquisition process to provide a higher quality product at a lower cost and in a shorter amount of time than traditional methods. The goals of SBA are to:

1. Substantially reduce the time, resources, and risk associated with the acquisition process;
2. Increase the quality of the resulting product while reducing Total Ownership Costs (TOC) throughout the system life cycle; and
3. Enable Integrated Product and Process Development (IPPD) throughout the life cycle of the acquisition process [2].

SBA principles can be applied to more than just the acquisition community. To provide the soldier with high quality systems in a cost and time efficient manner, M&S tools must be extended to the requirements and training communities as well. In an initiative called Simulation and Modeling for Acquisition, Requirements, and Training (SMART), the Army utilizes the SBA principles not only in the acquisition phase of weapons system development, but also in the Advanced Concepts Requirements (ACR) and Training, Exercises & Military Operations (TEMO) domains (see figure 1) [3]. By utilizing the SMART concept with existing technologies, VCOP is furnishing the aviation community with a highly sophisticated pilot-platform interface that will enhance pilot performance and safety while minimizing the schedule, cost, and technical risk inherent in upgrading legacy aircraft.

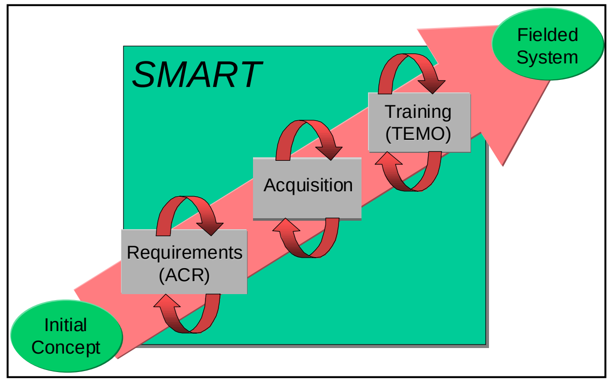

Figure 1. SMART Product Development Cycle

Upon completion of the simulation demonstration (FY99), VCOP will transition to a flight demonstration (FY01). This will effectively end the Requirements phase of the SMART process. The program will then transition to acquisition. This phase will include Engineering and Manufacturing Development (FY02) and Army Procurement Appropriation (FY05). Finally, the program will be fielded in a UH-60A cockpit and all M&S activities will transition to the Training phase of the development cycle.

OVERVIEW OF VCOP TECHNOLOGIES

The VCOP approach represents a significant advancement in the state-of-the-art for pilot-platform interfaces because it exploits the pilot's ability to process visual and aural information in 3D. The increased computer processing power now available in airborne applications will enable the advanced software and display technology of VCOP to present information to the pilot in a spherical world (see figure 2). Thus, the virtual cockpit provides a solution to the data processing problem by providing information (whether out-the-window or cockpit-internal) directly to the pilot in a highly graphical, intuitive, and spatially relevant manner.

The advanced technologies included in VCOP are a Head Mounted Display (HMD) Virtual Retinal Display (VRD) System, 3D Audio, Speech Recognition, Intelligent Information Management, and Crew-Aided Cognitive Decision Aides. These technologies will be incorporated into a single product that will be available across all Army Aviation platforms.

Figure 2. Conceptual “Virtual Cockpit”

VIRTUAL RETINAL DISPLAY (VRD)

VCOP supplies graphical information to the pilot via Microvision, Inc.'s patented VRD-based head-mounted display (HMD) (see figure 3). This design consists of a powerful system processor and graphics generator that offers the advantages of color purity, brightness and increased resolution over conventional screen display systems by projecting imagery directly onto the pilot's retina. The device gathers information from aircraft systems and superimposes the graphical data in the pilot’s field of view (FOV), providing a see-through or "augmented vision" capability [4]. This apparatus utilizes head tracker technology that allows the pilot to view different imagery at different locations in 3D space, i.e. "what you see depends on where you look" [5]. These displays consist of a pilot perspective view of a virtual terrain representing his current position, a view of critical cockpit instrumentation, and a 2D/3D moving map perspective view that provides mission specific symbology. Other data that may be relayed through this device are visual warning, caution, and advisory cues, aircraft performance parameters, and targeting and navigational aids. By providing a means to display critical information in a highly graphical and intuitive manner within the pilot's natural field of view, the VRD system minimizes the pilot’s “head down” time and work load, and maximizes the pilot’s situational, and system awareness [6]. By providing efficient access to critical information, this device also allows the pilot to minimize and effectively manage errors.

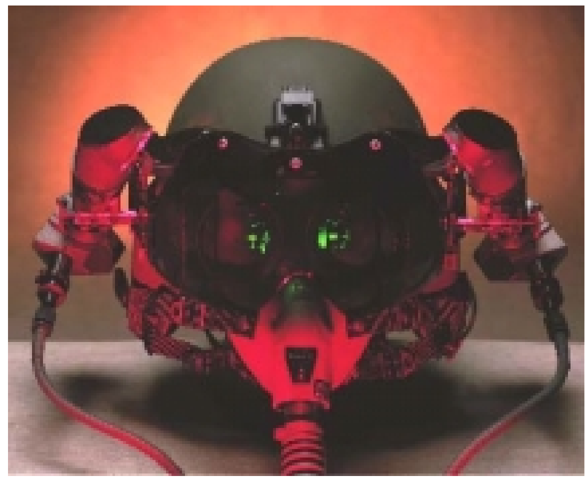

Figure 3. Virtual Retinal Display based HMD

THREE-DIMENSIONAL AUDIO

VCOP will use multi-sensory presentation of information to enhance information transfer. The 3D visual system will be augmented with 3D audio, which will provide a 3D aural representation of the pilot’s environment. Audio cues for caution, warning, and advisory data and certain cockpit communications will be presented with three dimensional encoding so as to sound as though they are localized within the pilot’s helmet, to provide the pilot with faster and more accurate situational awareness. For example, a low oil warning for the left engine will be communicated to the pilot as a low oil warning sound that emanates from the left and slightly behind. Thus the pilot will intuitively realize that there is a problem with the engine on his left side.

SPEECH RECOGNITION

VCOP provides the pilot with “hands off” control of specified cockpit instrumentation using spoken commands for rapid control input by implementing voice recognition software in the cockpit. For example, the pilot could say “Show me an alternate route” and cause his navigation display to compute and draw a different flight route to, say, bypass a threat. By providing the pilot with voice control capabilities, VCOP will enhance the pilot's ability to perform specified tasks without removing his hands from the flight controls, thus conforming to the "hands-on" philosophy.

INTELLIGENT INFORMATION MANAGEMENT

The Intelligent Information Management component of VCOP consists of an electronic data management system that is in the form of a traditional kneeboard (see figure 4). This component will serve several roles for the pilot:

- Mission Planning
- GPS location system
- Aircraft Checklists
- Performance Calculations
- Low Altitude Approach Plates
- Digital Messaging
- Electronic Notepad.

This will dramatically decrease the pilot's workload in preparation for and during missions. All data relevant to the pilot's mission can be uploaded from the unit to the aircraft and accessed by the pilot at any time throughout the mission.

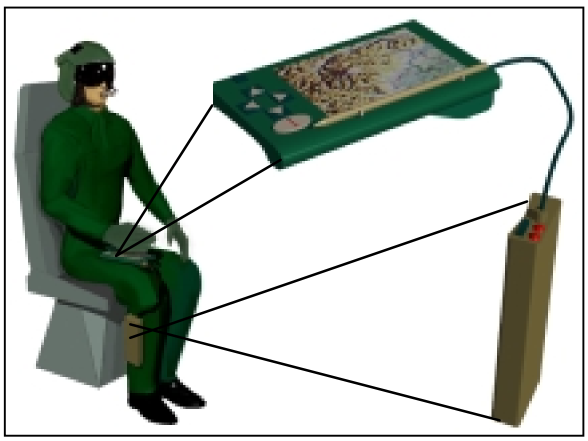

Figure 4. Electronic Data Manager Kneeboard

CREW-AIDED COGNITIVE DECISION AIDES

The U.S. Army Rotorcraft Pilot's Associate (RPA) software, developed by Boeing - Mesa, will be implemented for use with VCOP. The RPA is a cognitive decision aid designed to improve the quality of the tactical decisions made by the pilot. RPA enables a fast operational tempo via pilot-centered automation, including tactical decision aids, crew coordination aids, and cockpit information management techniques. The RPA automatically performs authorized tasks on behalf of the aircrew, and makes recommendations based upon appropriate tactics, techniques, and procedures.

OVERVIEW OF SMART

SMART and SBA promote the integration of M&S capabilities across all phases of a program's acquisition cycle to reduce risk by increasing the likelihood of producing systems that have "better" performance, "faster" schedule, and "cheaper" cost. The five essential aspects of SBA are:

1. Balancing Requirements
2. Numerous Design Alternatives
3. Iterative Design Process
4. Test as an Integral Part of Design, and
5. Decision Risk Analysis (DRA).

Balancing Requirements refers to incorporating the end user early in defining, refining, and balancing requirements. This is an evolutionary process that allows the end user to balance what the user wants versus what can affordably be accomplished. SBA offers Numerous Design Alternatives to the program developers by allowing the system designers to try new ideas through virtual prototyping and testing. This eliminates the fear of failure by significantly reducing the cost of testing new ideas. It also allows designers better depth and quality of analysis by giving them the ability to slow down the tests and look at minute details. This also allows system designers to consider the impact of design changes on things like logistics and maintenance early in the design process. Virtual testing also allows developers to push problem-discovery earlier in the development cycle. This allows information to be shared between development tasks allowing changes to be made earlier and at lower cost. The Iterative Design Process and Testing as an Integral Part of Design components allow rapid feedback from design iterations, which helps the team to converge on an optimal solution. Finally, DRA promotes quantifying and integrating cost, schedule, performance, producibility, risk, and quality to perform informed trade-off analysis. This enables the project manager to determine the areas requiring M&S analysis and the level of fidelity required [7]. Through SMART, the Army has recognized that the SBA paradigm includes all three areas of weapons system development, requirements, acquisition, and training. The idea behind this initiative is that the seamless data transfer and interoperability afforded by M&S tools will provide the desired time and cost reductions. This concept has already been tested with great success in the commercial world with the development of the Boeing 777 and the Chrysler Intrepid. Boeing was able to reduce rework by 60% over previous aircraft development cycles. Chrysler saved $75 million by reducing the development time of its Intrepid model by 20%. SMART enables the incorporation of efficient methods throughout the process, reducing TOC and development time as well as resulting in a better product for the customer [3].

USING SMART TO DEVELOP VCOP

VCOP is comprised of complex systems developed by several members of the VCOP integrated product team. To reduce the costs associated with the integration of these systems, it is essential that all team members understand each other's concerns and identify the program's technical obstacles early in the development cycle. The virtual prototypes, models, and simulations that comprise the SMART initiative can provide a common vision of the system design and requirements and provide a tool for analyzing the complex interactions between the components of the proposed system [2].

Utilizing the SMART process, the VCOP enhancements will be embedded in realistic, synthetic environments to support each phase of the acquisition process prior to their testing, evaluation and fielding on aircraft. The systems integration activities will be conducted at the Army's Advanced Prototyping, Engineering and eXperimentation (APEX) Laboratory utilizing the Battlefield Highly Immersive Virtual Environment (BHIVE). The BHIVE is an enclosed environment that uses a Silicon Graphics Onyx Infinite Reality to generate an out-the-window display on a 150 degree by 40 degree curved screen driven by a SEOS Displays Ltd. projection system. The BHIVE also contains a reconfigurable cockpit that utilizes virtually prototyped pilot and co-pilot/gunner interfaces and touch screens to allow a wide variety of vehicles to be implemented within the environment for experimentation purposes (see figure 5).

Figure 5. The BHIVE (Photograph by Glenn Baeske of the *Huntsville Times*).

Rapidly developing a 2D demonstration that emulates 3D imagery viewed by a VCOP Pilot through the Virtual Retinal Display is an example of VCOP utilizing the SMART process. Specifically, a 2D emulation of a VCOP Pilot's VRD generated imagery was developed and rendered in the BHIVE. This imagery depicts the virtual environment (top), the pilot's instrument cluster (center), and a synthetic "over the shoulder" view (bottom) (see figure 6). The 2D VCOP VRD emulation imagery was redirected from the curved projection screens in the BHIVE to an auditorium filled with the VCOP Integrated Process Team (IPT). VCOP IPT members were able to view with their own eyes, what had previously been discussed abstractly. VCOP Human Factors Engineers, VRD Engineers, Rotorcraft Pilot's Associate (RPA) engineers, and test personnel were able to establish a common knowledge base or reference for VCOP concepts, requirements and goals early in the program's life cycle. This reference is still used today to discuss abstract VCOP concepts and requirements.

Another example of applying the SMART process to the VCOP is developing, demonstrating, and testing of VCOP software and hardware in the BHIVE. By using the BHIVE, VCOP is able to develop, demonstrate, and test hardware and software without the expense of UH-60A flight-testing. Changes to VCOP hardware and software are cost effective and efficient when implemented in the BHIVE. Once a VCOP design has been developed that meets all program requirements and exit criteria, flight test integration will begin.

Figure 6. 2D Representation of VRD Imagery

Because VCOP is being developed through the combination of existing tools and technologies, the simulation support plan for VCOP is based upon the Simulation, Test, and Evaluation Process (STEP). STEP focuses on interoperability and reusability of simulation tools while providing a measured approach to SMART activities. It contributes the structure for an integrated modeling and simulation test and evaluation environment within the acquisition process. Through the use of virtual prototyping, analytical techniques, and Human-In-The-Loop (HITL) simulations, the VCOP plan will identify technical and operational obstacles early in the development process, thus reducing life cycle costs associated with the integration of highly complex systems. The simulations will also serve to provide a common vision of the program goals and insight to the complex interactions between components in the overall system design. Each component of VCOP will be independently modeled and tested in a HITL simulation environment for verification purposes. The components will be merged in the HITL simulation environment and evaluated in an operational capacity. The VCOP system will then be integrated and operationally tested and verified in a prototype flight test demonstration.

This approach allows the use of a "Model-Simulate-Fix-Test–Iterate" approach (see figure 7) that provides for a more efficient acquisition process than the traditional "Test-Fix-Test" approach [8]. The SMART paradigm reduces time, resources, and risk by allowing fixes to be verified through simulation rather than through field tests. Customer and Subject Matter Expert (SME) involvement throughout the process results in a higher quality product that better matches user requirements. Furthermore, through the use of systems engineering software, VCOP requirements will be traced from cradle-to-grave for the system. This will include system specifications, interface control documents, and program exit criteria. The VCOP capabilities will also be studied to determine the proper operational employment techniques for use prior to fielding as well as providing a training device for future users.

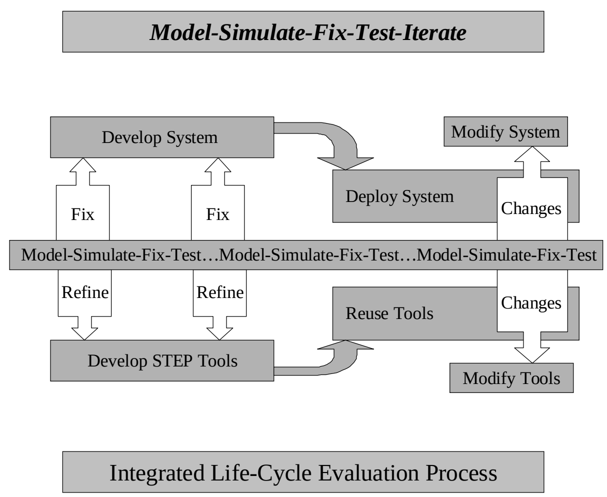

Figure 7. The Model-Simulate-Fix-Test-Iterate Approach

CONCLUDING REMARKS

Although very early in the life cycle of the Virtual Cockpit Optimization Program, Modeling and Simulation has proven to be very effective. It has provided a common knowledge base and has insured that program requirements are traced throughout the life cycle of the program. VCOP has implemented SMART to create a product development environment in which complex systems can be integrated and evaluated by decision-makers efficiently and continuously. The use of this initiative increases the VCOP's probability of success by identifying, minimizing, mitigating, or eliminating risks associated with the design, production and fielding of the system [7].

VCOP provides a platform-pilot interface that addresses the problem of information overload by providing information from the aircraft in a clear, non-confusing, intuitive manner and format across a wider rage of sensory input. Because this system is contained within the pilot's helmet and digital kneeboard, it also represents a significant leap in cockpit technology without requiring the costly upgrade of legacy aircraft.

The application of the SMART paradigm has resulted in the ability to perform VCOP product development and testing in a virtual prototyped environment. By utilizing the SMART initiative, VCOP not only addresses and solves a major problem within the aviation community, but also delivers a high quality product that is exactly what the end user requires in a timely and cost effective manner.

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