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KC-135 Simulator Systems Engineering Case Study

Air Force Center for Systems Engineering

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KC-135 SIMULATOR SYSTEMS ENGINEERING CASE STUDY

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FOREWORD

At the direction of then Secretary of the Air Force, Dr. James G. Roche, the Air Force Institute of Technology established the Air Force Center for Systems Engineering (AFCSE) at its Wright-Patterson AFB, Ohio, campus in 2002. With academic oversight by a Subcommittee on Systems Engineering (SE), chaired by Air Force Chief Scientist Dr. Alex Levis, the AFCSE was tasked to develop case studies of SE implementation during concept definition, acquisition, and sustainment. The committee drafted an initial case outline and learning objectives, and suggested the use of the Friedman-Sage Framework to guide overall analysis.

The Department of Defense (DoD) is increasing the acquisition of joint complex systems that deliver needed capabilities demanded by our warfighters. SE is the technical and technical management process that focuses explicitly on delivering and sustaining robust, high-quality, affordable solutions. The Air Force leadership has collectively stated the need to mature a sound systems engineering process throughout the Air Force. Gaining an understanding of the past and distilling learning principles that are then shared with others through our formal education and practitioner support are critical to achieving continuous improvement.

The Air Force CSE has published nine case studies thus far including (1) the C-5A, (2) the F-111, (3) the Hubble Telescope, (4) the Theater Battle Management Core System, (5) the B-2, (6) the Joint Air-to-Surface Standoff Missile, (7) the A-10, (8) the Global Positioning System and (9) the Peacekeeper ICBM. All case studies are available on the Air Force CSE web site [http://www.afit.edu/cse]. These case studies support academic instruction on SE within military service academies, civilian and military graduate schools, industry continuing education programs, and those practicing SE in the field. Each of the case studies is comprised of elements of success as well as examples of SE decisions that, in hindsight, were not optimal. Both types of examples are useful for learning.

Along with discovering historical facts, we have conducted key interviews with program managers and chief engineers, both within the Government and those working for the various prime and subcontractors. From this information, we have concluded that the discipline needed to implement SE and the political and acquisition environment surrounding programs continue to challenge our ability to provide balanced technical solutions. We look forward to your comments on this KC-135 Flight Simulator case study and our other AFCSE published studies.

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1.1 General Systems Engineering Process

1.1.1 Introduction

The Department of Defense (DoD) continues to develop and acquire joint systems and to deliver needed capabilities to the warfighters. With a constant objective to improve and mature the acquisition process, it continues to pursue new and creative methodologies to purchase these technically complex systems. A sound systems engineering (SE) process, focused explicitly on delivering and sustaining robust, high-quality, affordable products that meet the needs of customers and stakeholders must continue to evolve and mature. SE is the technical and technical management process that results in delivered products and systems that exhibit the best balance of cost and performance. The process must operate effectively with desired mission-level capabilities, establish system-level requirements, allocate these down to the lowest level of the design, and ensure validation and verification of performance, meeting cost and schedule constraints. The SE process changes as the program progresses from one phase to the next, as do the tools and procedures. The process also changes over the decades, maturing, expanding, growing, and evolving from the base established during the conduct of past programs. SE has a long history. Examples (e.g. case studies) can be found demonstrating a systemic application of effective engineering and engineering management, as well as poorly applied, but well-defined processes. Throughout the many decades during which SE has emerged as a discipline, many practices, processes, heuristics, and tools have been developed, documented, and applied.

Several core life-cycle stages have surfaced as consistently and continually challenging during any system program development. First, system development must proceed from a well-developed set of requirements. Secondly, regardless of the evolutionary acquisition approach, the system requirements must flow down to all subsystems and lower level components. And third, the system requirements need to be stable, balanced, and must properly reflect all activities in all intended environments. However, system requirements are not unchangeable. For example; as the system design proceeds, if a requirement or set of requirements is proving excessively expensive to satisfy, the process must rebalance schedule, cost, and performance by changing or modifying the requirements or set of requirements.

SE includes making key system and design trades early in the process to establish the system architecture. These architectural artifacts can depict any new system, legacy system, modifications thereto, introduction of new technologies, and overall system-level behavior and performance. Modeling and simulation are generally employed to organize and assess architectural alternatives at this introductory stage. System and subsystem design follows the functional architecture. System architectures are modified if the elements are too risky, expensive, or time-consuming. Both newer object-oriented analysis and design and classic structured analysis using functional decomposition and information flows/data modeling occurs. Design proceeds logically using key design reviews, tradeoff analysis, and prototyping to reduce any high-risk technology areas.

Important to the efficient decomposition and creation of the functional and physical architectural designs are the management of interfaces and integration of subsystems. This is applied to subsystems within a system, or across large, complex systems of systems (SoS). Once a solution is planned, analyzed, designed, and constructed, validation and verification takes place to ensure satisfaction of requirements. Definition of test criteria, measures of effectiveness (MOEs), and measures of performance (MOPs), established as part of the requirements process, takes place well before any component/subsystem assembly design and construction occurs.

There are several excellent representations of the SE process presented in the literature. These depictions present the current state of the art in the maturity and evolution of the systems engineering process. One can find SE process definitions, guides, and handbooks from the International Council on Systems Engineering (INCOSE), Electronics Industrial Association (EIA), Institute of Electrical and Electronics Engineers (IEEE), and various DoD agencies and organizations. They show the process as it should be applied by today's experienced practitioner. One of these processes, long used by the Defense Acquisition University (DAU), is depicted by Figure 1. It should be noted that this model is not accomplished in a single pass. This iterative and nested process gets repeated to the lowest level of definition of the design and its interfaces.

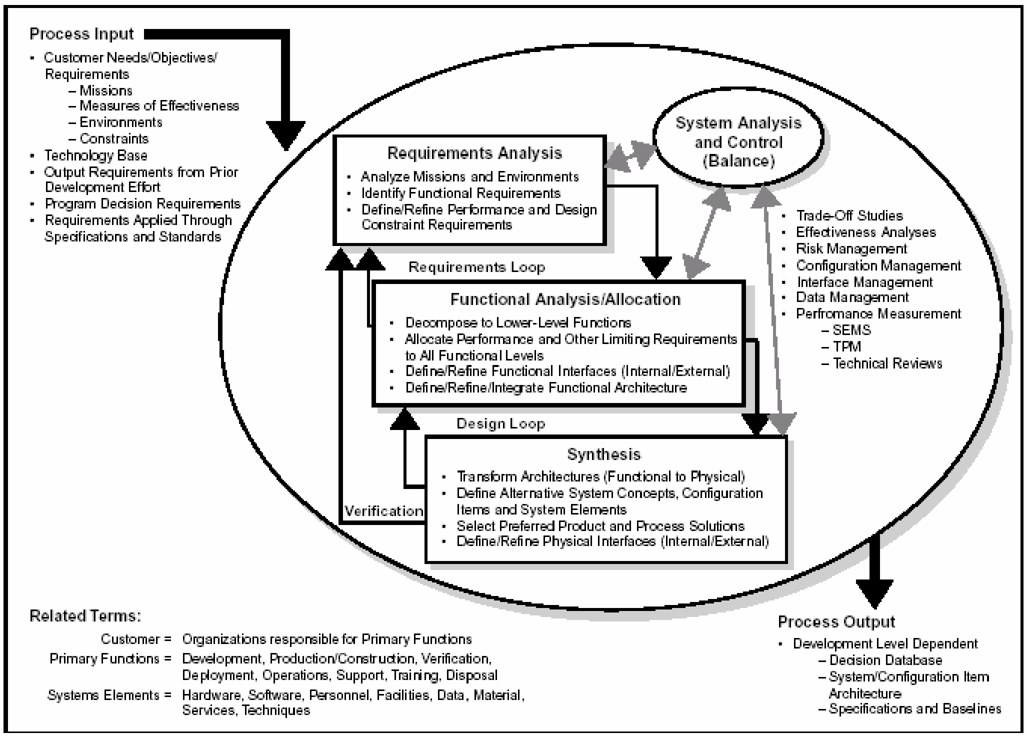

Figure 1. *The Systems Engineering Process as presented by the Defense Acquisition University.*

1.1.2 Evolving Systems Engineering Process

The DAU model, like all others, has been documented in the last two decades and has expanded and developed to reflect a changing environment. Systems are becoming increasingly complex internally and more interconnected externally. The process used to develop aircraft and other weapons of the past was a process effective at the time. It served the needs of the practitioners and resulted in many successful systems in our inventory. However, the cost and schedule performance records of the past programs are fraught with examples of both well-managed programs and programs with less than stellar execution. As the nation entered the 1980s and 1990s, large DoD and commercial acquisitions were overrunning costs and running behind schedule. The aerospace industry and its organizations were becoming larger and more geographically and culturally distributed. The SE process, as applied within the confines of a single system or a single company, was no longer the norm.

Today, many factors overshadow new acquisitions; including SoS context, network-centric warfare and operations, and the rapid growth in information technology (IT). These factors have driven a new form of emergent SE, which focuses on certain aspects of our current process. One of these increased areas of focus resides in the architectural definitions used during system analysis. This process is differentiated by greater reliance on reusable, architectural views describing the system context and concept of operations, interoperability, information and data flows and network service-oriented characteristics. The DoD has recently made these architectural products, described in the DoD Architectural Framework v.2.0 (DoDAF), mandatory to enforce this new architecture-driven systems engineering process throughout the acquisition life cycle.

1.1.3 Case Studies

The SE process to be used in today's complex SoS projects is a process matured and founded on the principles of systems developed in the past. The examples of SE used in other programs, both past and present; provide a wealth of lessons to be used in applying and understanding today's process.

The purpose of developing detailed case studies is to support the teaching of SE principles. Case studies facilitate learning by emphasizing to the student the long-term consequences of the SE and programmatic decisions on program success. The systems engineering case studies assist in discussion of both successful and unsuccessful methodologies, processes, principles, tools, and decision material to assess the outcome of alternatives at the program/system level. In addition, the importance of using skills from multiple professions and engineering disciplines and collecting, assessing, and integrating varied functional data is emphasized. Analysis of these aspects will provide the student with real-world, detailed examples of how the process plays a significant role in balancing cost, schedule, and performance.

The utilization and misutilization of SE principles are highlighted, with special emphasis on the conditions that foster and impede good SE practices. Case studies should be used to illustrate both good and bad examples of acquisition management and learning principles, to include determining whether:

- Every system provides a balanced and optimized product to a customer;
- Effective requirements analysis was applied;
- Consistent and rigorous application of SE management standards was applied;
- Effective test planning was accomplished;
- Effective major technical program reviews were conducted;
- Continuous risk assessments and management were implemented;
- Reliable cost estimates and policies were developed;
- Disciplined application of configuration management was demonstrated;
- A well-defined system boundary was established;
- Disciplined methodologies were developed for complex systems; and
- Problem-solving methods incorporated understanding of the system within the bigger environment (customer's customer).

A key tenet of the SE process is to transform an operational need into a set of verifiable system elements. These system elements are allocated and translated by the SE process into detailed requirements. The SE process, from the identification of the need to the development and utilization of the product, must continuously integrate and optimize system and subsystem performance within cost and schedule to provide an operationally effective system throughout its life cycle. Case studies highlight the various interfaces and communications to achieve this optimization, which include:

- The program manager/SE interface, which is essential between the operational user and developer (acquirer) to translate the needs into the performance requirements for the system and subsystems.
- The government/contractor interface, essential for the practice of SE to translate and allocate the performance requirements into detailed requirements.
- The developer (acquirer)/user interface within the project, essential for the SE practice of integration and balance.

The SE process must manage risk, known and unknown, as well as internal and external. This objective specifically focuses on external factors and the impact of uncontrollable influences, such as actions of Congress, changes in funding, new instructions/policies, changing stakeholders or user requirements or contractor and government staffing levels.

Lastly, the SE process must respond to mega-trends in the SE discipline itself, as the nature of SE and related practices vary with time.

1.1.4 Framework for Analysis

This case study is presented in a format that follows the learning principles specifically derived for the program, utilizing the Friedman-Sage framework to organize the assessment of the application of the SE process. The framework and the derived matrix can play an important role in developing case studies in SE and systems management, especially case studies that involve systems acquisition. The framework presents a nine row by three column matrix (Figure 2).

Concept Domain	Responsibility Domain		
	1. Contractor Responsibility	2. Shared Responsibility	3. Government Responsibility
A. Requirements Definition and Management			
B. Systems Architecting and Conceptual Design			
C. System and Subsystem Detailed Design and Implementation			
D. Systems and Interface Integration			
E. Validation and Verification			
F. Deployment and Post Deployment			
G. Life Cycle Support			
H. Risk Assessment and management			
I. System and Program management			

Figure 2. *Friedman- Sage Framework of Key Systems Engineering Concepts and Responsibilities.*

Six of the nine concept domain areas in Figure 2 represent phases in the systems engineering life cycle:

- Requirements Definition and Management
- Systems Architecting and Conceptual Design

- Detailed System and Subsystem Design and Implementation
- Systems and Interface Integration
- Validation and Verification
- System Deployment and Post Deployment

Three of the concept areas represent necessary process and systems management support:

- Life-Cycle Support
- Risk Assessment and Management
- System and Program Management

While other concepts could have been identified, the Friedman-Sage framework suggests these nine are the most relevant to SE in that they cover the essential life-cycle processes in systems acquisition and the systems management support in the conduct of the process. Most other concept areas identified during the development of the matrix appear to be subsets of one of these areas. The three columns of this two-dimensional framework represent the responsibilities and perspectives of Government and Contractor, and the shared responsibilities between the Government and the Contractor.

The Friedman-Sage matrix is not a unique SE applications tool, but rather a disciplined approach to evaluate the SE process, tools, and procedures as applied to a program. It is based on two major premises as the founding objectives:

1. In teaching SE, case studies can be instructive in that they relate aspects of the real world to the student to provide valuable program experience and professional practice to academic theory.
2. In teaching SE in DoD, there has previously been little distinction between duties and responsibilities of the Government and industry activities. More often than not, the Government's role in SE is the role of the requirements developer.

1.2 KC-135 ATS Major Learning Principles and Friedman-Sage Matrix

The authors' selection of learning principles and Friedman-Sage matrix are reflected in the Executive Summary of this case (separate attachment).

2. The KC-135 System Description

2.1 KC-135 Aircraft Overview

The KC-135 is a short-to-medium range tanker aircraft. First flight occurred in August 1956 with Initial Operational Capability (IOC) occurring in June 1957 at Castle AFB, California. A total of 732 aircraft were produced and are operated by Air Education and Training Command (AETC), Air Mobility Command (AMC), Pacific Air Forces (PACAF), United States Air Forces Europe (USAFE), Air national Guard (ANG), and the Air Force Reserve (AFRC). In addition to supporting USAF aircraft the KC-135 fleet also supports the United Sates Navy (USN), United States Marine Corps (USMC), and allied aircraft.

The mainstay of the USAF tanker fleet, the long serving KC-135 is similar in size to the commercial Boeing 707 but was designed to military specifications incorporating different structural details and materials. The KC-135 fuel tanks are located in the aircraft's "wet wings" and below the floor in the fuselage.

The original KC-135A powered by J57 turbojets has since been modified to other versions. A major re-engine program upgraded USAF, AFRC, and ANG KC-135As to KC-135Es with JT3D turbofans and related components removed from surplus commercial 707s. Fuel carrying capacity was increased by 20 percent. The KC-135E in service with the ANG represents some of the oldest aircraft in the USAF inventory. USAF planned on retiring all E models by 2008 but status remains uncertain at the time this report was written.

Re-engined KC-135A/Es with F-108 turbofans are designated KC-135 R/Ts. The first KC-135R flight was in October 1982 and deliveries began in July 1984. They embody modifications to 25 major systems and subsystems and not only carry more fuel farther but have reduced maintenance costs, are able to use shorter runways, and meet stringent noise abatement requirements. Additional modifications extend the capability and operational utility of the KC-135 well into the 21st century. The Pacer Compass Radar and Global Positioning System (CRAG) avionics modernization program, completed in 2002, installed a new compass, radar, and GPS navigation system, a traffic alert and collision avoidance system (TCAS), and new digital multifunctional cockpit displays. Pacer CRAG Block 40 capabilities initiated in 2003 meet global air traffic management (GATM) standards ensuring the KC-135 unrestricted access to global air routes. Forty KC-135R/T aircraft are also outfitted with the capability to relay LINK 16 tactical information beyond line of sight of other aircraft.

Currently the KC-135 Total Active Inventory (TAI) is comprised of approximately 450 aircraft. Included in the TAI, the KC-135T aircraft (formerly KC-135Q), which were capable of refueling the now-retired SR-71s, still retain the capability to carry different fuels in the wing and body tanks. Eight KC-135Rs are air refuelable while 20 R models have wing-mounted refueling pods for enhanced refueling of USN and NATO aircraft.

2.2 KC-135 Aircrew Training System (ATS) Overview

2.2.1 KC-135 ATS Mission

The principal function of the KC-135 ATS is to instruct pilots, copilots, and boom operators on the procedures and techniques required to safely and effectively operate the KC-135 aircraft thereby ensuring the air refueling needs of USAF bomber, fighter, cargo, and reconnaissance aircraft are met. Through use of the ground-based simulator, knowledge and proficiency is gained in the operational use of all controls and instruments during takeoff, landing, transition, instrument flight, tactical missions, formation flight, and emergency procedures.

2.2.2 KC-135 ATS Historical Background - Pre 1992

The KC-135 simulator started life in the early 1960s as a Cockpit Procedures Trainer (CPT), Mission Design Series MB-26, with the Strategic Air Command (SAC). Training was aimed chiefly at ensuring proficiency on emergency procedures, especially landing and takeoff emergencies, and to conduct instrument training. Because of the number of SAC bases located across the country the user approached training with a unique concept. SAC would provide schoolhouse training at the 93rd Bomb Wing Combat Crew Training School at Castle AFB, California with three simulators, provide seven simulators at other fixed sites, and service other operational sites with nine mobile simulators.

The mobile KC-135 simulators were housed in railroad cars that could be transferred around the country to provide required cockpit procedures training. One such KC-135 mobile simulator, shown in Figures 3 and 4, was moved on a routine route that included Barksdale AFB (Bossier City, Louisiana), Dyess AFB (Abilene, Texas), Columbus AFB (Columbus, Mississippi), and

Carswell AFB (Fort Worth, Texas). Another unique feature of this simulator was the use of a crude visual display which incorporated an opaque windscreen that had lights behind it that would flash simulating lightning. The instructor, utilizing an Instructor Operator Station (IOS) was able to simulate system problems and weather but any true visual cues to the outside world were lacking. [1]

Figure 3. *KC-135A Instrument Flight Trainer Railroad Car.*[2]

Figure 4. *KC-135A Instrument Flight Trainer Railroad Car.*[3]

[1] Info from Simulator Technician Jeff Beish website
[2] Photo from Wildfire Productions
[3] Info from Simulator Technician Jeff Beish website

SAC saw a need for increased simulator realism to not only provide better training and improve crew coordination but to decrease on-aircraft flight time because of rising fuel costs in the late 1970s. Advances in simulator technologies in the latter 1970s also enabled this possibility.

At the same time the Air Force Simulator System Program Office (SIMSPO) at Wright-Patterson AFB decided to implement an acquisition strategy to encourage competition among simulator manufacturers in new acquisitions. Initial candidates for this policy included two weapon system trainer complexes for the B-52 and KC-135 aircraft. Competition was further enhanced through the use of a preliminary design review process that promised to result in acquisition and life-cycle cost savings. Following this preliminary design review competition one company would be selected. On May 1, 1980, the winner of this competition was Singer-Link Company. The goal was to equip each base that had a B-52 WST with a KC-135 WST that had complete flight and navigation stations. The first complex was ready for training at Castle AFB, California, in late 1981. This Weapon System Trainer (WST) complex offered a sophisticated and integrated training system. In the end, the B-52 WST went into production and because of funding limitations the KC-135 WST did not.

Since funding for new KC-135 trainers was not available, it was decided to approach this need from another direction and funding was procured to award the refurbishment/enhancement of the existing MB-26 KC-135 Instrument Flight Simulators in 1985. These KC-135A/R simulator trainers were designated as A/F 37A-T87, -T88 respectively. This contract was competed and won by Boeing Co., Huntsville, Alabama. Redifussion of the United Kingdom was selected as the visual system subcontractor. These refurbished trainers referred to as Operational Flight Trainers would have fully operational cockpits with state-of-the-art visual systems (dusk and night only with no daytime capability) and a flight instructor station. While the original requirements did not require a motion system, the system platforms were in fact, designed to accommodate a motion system in the future. Although the details of how this decision was made have been lost, designing the platform to be compatible with a motion system paid dividends later in the system's lifecycle by providing a growth path which facilitated the implementation of future upgrades.

2.2.3 Training System Evolution in Capabilities

The complexity, costs, and operating environment of modern aircraft has resulted in a broader use of advanced simulation for crew training within the USAF. Simulators can provide more in-depth training than can be accomplished in airplanes and provide a very high transfer of learning and behavior from the simulator to the airplane. The use of simulators, in lieu of airplanes, has resulted in safer flight training and cost reductions for the operators as well as improved fuel conservation and reduction in adverse environmental effects.

In order to realize the goal of increased usage of the ATS for KC-135 crew training, a cultural change was needed within the Air Force in that effective training could be achieved by effective use of ground-based trainers. Money had to be allocated to effectively operate, maintain, and upgrade ATS capabilities; and corresponding improvements to the hardware and software had to be realized in a cost-effective manner.

Against this backdrop, larger policy issues within the DoD were being played out across various systems development and sustainment strategies. Then Secretary of Defense William Perry had recently cancelled all Military Specifications and Standards concluding that reliance upon commercial standards and emerging marketplace trends would sustain DoD capabilities and ensure the Department's ability to stay on the cutting edge of technology and commercial best practices. The implementation of this policy, however, was not as smooth as expected. Impacts to the KC-135 simulators were not anticipated, but remained uncertain regarding future consequences.

Beginning in 1992, Air Mobility Command (AMC), under their commander General Fogleman, began an extensive upgrade of its simulators.[4] The goal of the approximately $300M program was to upgrade the command's simulators to the equivalent of FAA Level C (a standard used by the commercial airline industry for training flight crews). AMC offered to trade in flying hours in exchange for funding to upgrade its flight simulator fleet. The agreement, which AMC worked with the Air Staff, called for AMC to fund 60 percent of the cost of the upgrades (to be funded with flying hour reductions) with the Air Staff funding the remaining 40 percent. One reason the Command believed this was a reasonable approach is because the commercial airline industry had successfully migrated a majority of its training to flight simulators in the past decade resulting in significant cost savings to the airlines. The KC-135 simulator upgrade program which was initiated in 1992 addressed four major areas of the KC-135 OFTs: computer systems, aerodynamic models, motion, and visual systems.[5]

2.2.4 KC-135 ATS Key System Capabilities Post 1992

The KC-135 ATS provides for initial qualification, re-qualification, upgrade training, difference training, conversion training, the central flight instructor course, and selected continuation training to pilots, boom operators, and instructors. Currently, in order to qualify as a new KC-135 aircrew member, students typically go through a year of Undergraduate Pilot Training in either the T-1 or T-38. Tanker candidates then go to Altus AFB for initial qualification training at the schoolhouse. Upon graduation they leave Altus AFB as both pilot and co-pilot qualified. Although still considered co-pilots once they reach their initial unit, the level of training they received at the schoolhouse facilitates their upgrade training. At this point they undergo continuation training using Operational Flight Trainers (OFTs) and other training system media/ courseware located on site. With over 3,000 crewmembers located in 50+ Squadrons at 38 locations worldwide, the KC-135 ATS is considered by AMC to arguably be the Air Forces' largest aircrew training program.

The KC-135 ATS OFTs are geared toward accurately duplicating the movements of a KC-135 in flight. In addition to meeting formal training requirements the system enables aircrews to practice emergency-avoidance maneuvers in a safe and controlled environment. Flight instructors use computer-based programs within the simulators to imitate a wide variety of potentially-dangerous scenarios, such as engine fires, hydraulic and electrical malfunctions, to test the aircrews' abilities to react appropriately. Instructors can also simulate actual flight lines, surrounding terrain/features, and realistic atmospheric conditions of almost any base or airfield in the world. This allows pilots to practice instrument approaches and departures they would use

[4] AMC Website Orange Book Info

[5] These planned upgrades have realized significant savings to AMC. It costs about $5,000 an hour to operate the KC-135 versus about $500 an hour to operate the KC-135 simulator. In a normal four-hour mission, the Air Force is saving approximately $38,000. To illustrate the potential for savings, a series of planned upgrades to the KC-135 schoolhouse at Altus AFB for undergraduate pilot training have resulted in increased ground-based simulator training from 16 to 24 missions including instrument and qualification evaluation, while reducing the requirement for in-flight training at the schoolhouse from 10 flights to just four. The addition of a third simulator at the McConnell Aircrew Training Facility is expected to increase aircrew training missions from more than 750 per year to more than 1,200 per year.

at these different locations before actually visiting those places. If a student or crew member does not handle the situation properly the first time, the instructors have the capability to duplicate and/or repeat the scenario and train them to a proficiency level where, if these things do occur in the airplane, they will be ready to handle them.

2.2.5 KC-135 ATS System Description – Post 1992

The current KC-135 Aircrew Training System consists of 19 KC-135R model Operational Flight Trainers (OFTs), two Boom Operator Part Task Trainers (BOPTT), one KC-135E Weapon System Trainer (WST), 27 Global Air Traffic Management (GATM) Interactive Hand Controller (IHC) Part Task Trainers (GIPTTs), eight Cockpit Familiarization Trainers (CFT), one Navigator Trainer, 258 Desktop Computer Based Training Workstations (CBT), 16 Pacer CRAG Table-Top Trainers, one Cargo Loading Trainer (CLT), 40 Air Force Mission Support System (AFMSS) Computers, and 112 CBT portable laptop computers.

Each of the OFTs that comprise the most significant element of the overall ATS is a full-sized, mechanical replica of a KC-135 cockpit that offers aircrews a virtual-reality flying experience. The windows, which line the front and sides of the mock cockpits, are actually visual system computer-generated screens that display genuine flight lines, simulate realistic scenery as well as weather conditions and other aircraft both tankers and receivers.

The OFT is a fully replicated and functional cockpit trainer with a visual system capable of meeting FAA level C certification, see Figure 5. All 19 OFTs are equipped with a full six-Degree of Freedom motion system. The OFTs are located both in CONUS and overseas with one each at Mildenhall, UK and Kadena, Korea. (Appendix C)

The single WST, which was never a part of the simulator upgrade program, is a fully replicated and functional cockpit trainer built initially for the KC-135E model aircraft with a visual system and a three Degree of Freedom (DOF) motion system. One additional difference between the OFT and the WST is that on the WST the KC-135E cockpit configuration aft of the pilot and co-pilot seats is realistically represented (e.g., circuit breaker panels).

Figure 5. *KC-135 OFT with Six Degree of Freedom Motion Base.*[6]

The Boom Operator Part Task Trainer (BOPTT) consists of a complete boom compartment that provides the student with the capability to practice normal refueling procedures. The initial BOPTT was developed by Aeronautical Systems Division (now Aeronautical Systems Center) in the late 1970s as a proof of concept device to study the training aspects of boom operator tasks. This device was upgraded and a second device was built in the 1980s. Both BOPTTs have been refurbished over the years as funds became available in order to provide increased reliability, maintainability, and supportability. These refurbishment efforts included a new visual system, new databases, control loading, and sound, as well as onboard and off board Instructor Operator Stations, see Figure 6. These improvements now offer boom operators the same levels of training pilots and copilots are currently obtaining.

In addition, AETC has recently completed the development and production of two Boom Operator Weapon System Trainers that are currently being installed at the school house located at Altus. These devices will have a distributed mission operation capability within the schoolhouse that when linked to the OFTs will allow for initial interactive crew (pilot, co-pilot, boom operator) training.

[6] Altus AFB, Photo courtesy of MacAulay Brown

Figure 6. *Boom Operator Part Task Trainer.*[7]

Cockpit Familiarization Trainers (CFTs) see Figure 7, basically consist of non-powered cockpit panel replications that are used for training switch position, gauge position, and limited normal procedures training. The Global Air Traffic Management (GATM) Interactive Hand Controller Part Task Trainer (GIPTTs) (Figure 8) supports familiarization and dexterity training for the new GATM interactive hand controllers. The CBTs are used to teach various topics (e.g., system theory) through interactive software. The CLT is a full-sized trainer that uses a modified KC-135 fuselage to train boom operators on cargo loading and handling. The Air Force Mission Support System (AFMSS) computers are used to train students in fully utilizing the Air Force mission planning system and assist with flight planning of training missions.

Figure 7. *Cockpit Familiarization Trainer (CFT).* [8]

[7] Acme-worldwide.com

Figure 8. *GATM IHC Part Task Trainers (GIPTT).*[9]

3. KC-135 ATS Upgrade Program

3.1 ATS System Acquisition Team

3.1.1 ATS Stakeholders

The KC-135 community is one of the largest in the Air Force, and therefore, has a broad group of stakeholders with specific roles and responsibilities associated with the operation and maintenance of the training system. AMC/A3T, Scott AFB, Illinois, establishes ATS policy direction, identifies training requirements, and sets program priorities. AMC also has responsibility for planning, programming, budgeting and execution of resources necessary to support ATS programs as well as funding, acquiring, and maintaining aircrew training devices to a single baseline at both Formal Training Unit (FTU) and Continuation Training (CT) locations. Key stakeholders include the following organizations.

The 551st Aircraft Sustainment Squadron at Tinker AFB is responsible for identifying requirements for hardware and software upgrades to the flight simulators based on aircraft weapon system modifications in order to maintain ATS simulator concurrency with the aircraft's fielded configuration. Funding for these modifications, which is included in the budget for the specific aircraft modification program, comes from AMC to the KC-135 program office.

The 507th Aircraft Sustainment Squadron, Ogden Air Logistics Center (OO-ALC), Hill AFB, Utah, has the responsibility to provide the engineering, contractual, and administrative expertise

[8] Altus AFB, Photo courtesy of MacAulay Brown
[9] Altus AFB, Photo courtesy of MacAulay Brown

and sustainment support to ensure that the simulator requirements identified by AMC and the KC-135 Program Office are implemented. In addition, Ogden is also responsible for managing simulator technology upgrades and identifying future requirements based on needed improvements to flight simulator fidelity, reliability, and maintainability. Funding for modifications that are directly the result of aircraft modifications are obtained from the 551st Aircraft Sustainment Squadron whereas modifications resulting from the need to either address technology upgrades or life cycle related improvements come directly from AMC.

The 677th Training System Product Group (Aeronautical Systems Center, Air Force Materiel Command, WPAFB, Ohio,) provides additional simulator expertise and acquisition support to the 507th Aircraft Sustainment Squadron when needed. The overall mission of the Training Systems Product Group is to provide the development, acquisition and sustainment effort needed to meet the major commands' simulation and training requirements.

Air Education and Training Command (AETC), Randolph AFB, Texas, has overall responsibility to train the Air Forces' aircrews for all its flying systems. In April 2006, the KC-135 ATS program realigned training responsibilities between the major team players. AMC delegated to AETC oversight of Formal Training Unit (FTU) training at AETC bases. Specifically, the 97th Air Mobility Wing (headquartered at Altus AFB, Oklahoma) has the responsibility to provide the ground and flight aircrew training needed to keep the KC-135 aircrews operationally ready. AETC has the responsibility for developing the syllabus for initial crew training at the schoolhouse as well as responsibility for accepting all KC-135 ATS courseware. AMC retained responsibility for continuation training (CT) at KC-135 operational locations. This was a significant organizational change to the composition of the KC-135 stakeholders.

AMC Air Operations Squadron DET 2 (stationed at Altus AFB) has the responsibility for overall simulator quality assurance, which includes review of all Engineering Change Proposals (ECPs) and Acceptance Test Procedures (ATPs) and verifying and validating that the contractor has met the Air Force requirements as specified.

FlightSafety Services Corporation (FlightSafety), headquartered in Centennial, Colorado, provides all KC-135 ground-based training. Also covered under this contract is KC-135 ATS program management, staffing of qualified instructors, logistics, aircrew training device (ATD) operations and maintenance, training system support center (TSSC) operations, including configuration/concurrency management of hardware, software, and courseware for both the schoolhouse and various operating sites, Simulator Certification (SIMCERT) support, and training management system (TMS) operations. FlightSafety's 15-year contract for KC-135 training was awarded in 1992, with a three-year extension in 2007. Today, some 3,900 aircrew members receive FlightSafety training on the KC-135 every year at bases in the United States, United Kingdom, and Japan.

3.1.2 Teaming Relationship

The philosophy employed by the KC-135 ATS senior engineering and management leadership emphasizes the importance of open communication lines between the various stakeholders. Since the beginning of the current O&M contract phase, which began in 1992, the various stakeholders who comprise the KC-135 ATS team, have evolved a professional partnership that is highlighted by a non-adversarial relationship based on a recognition of and willingness to champion the program's common goals and objectives. As a result, the team has established a level of trust between all members, communications/dialogue is very open, and Government involvement is encouraged. The result has been a capability to deal with challenges and setbacks without personal recriminations and the development of a solution-oriented mindset. Major modifications, particularly to the Operational Flight Trainer (OFT), have been successfully planned for, budgeted, and implemented over the past 17 years. There are several reasons on why this teaming relationship has succeeded.

Typically with acquisition programs the program manager or chief engineer charged with the development program would chair major reviews (like the KC-135 ATS System Review Board [SRB]) with the using command (in this case AMC) providing a briefing of their issues and concerns at the SRB. However, the arrangement that has evolved for KC-135 ATS, which has proven to be very effective, is that the AMC manager co-chairs the SRB forum. This arrangement started at the initiation of the current contract in 1992. The Program Manager realized that sharing responsibility would give AMC ownership in the success of the ATS. He made it a practice to invite representatives from all of the host squadrons (where the OFTs were located) around the world. All were given an opportunity to air their grievances and actions were taken to address them. The team believes the KC-135 ATS program is far too big, with too many team members and with far too much activity, to accept passive leadership. Having this level of commitment and active engagement from all of the stakeholders has facilitated obtaining the funding and support needed to ensure the program goals of achieving and maintaining concurrency, training effectiveness, etc., are realized.

The KC-135 aircrew training system has developed an infrastructure that provides for ready and efficient simulator training for KC-135 refueling crews stationed around the world. The team determined that separate Integrated Product Teams (IPTs) for each individual modification/upgrade can't be effectively used, given the small staffs assigned and the highly intertwined nature of the programs. Often modifications are combined or delayed at certain locations to accommodate local training needs and schedules, as well as coordinate with the arrival of modified aircraft to prevent having capabilities out of sync for too long of a period of time. This occurs with a great deal of collaboration and planning between all parties, including the KC-135 aircraft program office. AMC, the ATS Program Office, and the prime contractor(s) draw on support as needed to ensure proper staffing is available for program execution. Another reason for the team's success is their ability to be flexible and react quickly to customer needs. For example, the O&M contractor has a flat management structure. The number of management levels between the senior ATS systems engineer and the division vice president is two. The advantage of such an organizational structure is the ability to rapidly elevate major program issues to senior leadership, including possible mitigating actions, in order to achieve timely program resolution.

Another major reason for the KC-135 ATS success, as viewed by many of the stakeholders, in implementing all these upgrade modifications is the fact that the entire KC-135 Simulator team understands the warfighters' training needs, because they are, in the case of the O&M contractor, the trainers. They are invested in the success of the program. The products developed, either by FlightSafety or other third-party contractors, are used by themselves. Therefore, they have good insight into what the products must do. In other words, FlightSafety is the user (instructors and maintainers).

Furthermore, a close relationship between the training community and the aircraft community has been encouraged and supported. This relationship was not always so congenial. A great deal of effort was made in the 1994 timeframe where members of the 507th continually were "inserting" itself to plead that simulators and training requirements not be forgotten, as has been the case in many Air Force programs in the past. History shows that the training system has, in many cases, been viewed not as a critical part of the overall weapon system but as a funding source for addressing other aircraft related developmental issues thereby impacting schedule. Furthermore, this lack of senior-level support for the concurrent development of a training system has resulted in many training systems being late to need. Over time, this relationship between the KC-135 aircraft program and the KC-135 ATS program has evolved and become more formalized. Because aircraft upgrades are identified by the KC-135 Program Office at Tinker AFB there are roadmap meetings held at Tinker where upcoming modifications to the KC-135 aircraft are discussed. The KC-135 ATS O&M contractor and the Training System Program Office at Ogden now are present to assess those modifications and ensure the ATS requirements are included in the early planning process. In addition, the O&M contractor does have the ability to go through the KC-135 ATS Program Office at Ogden to request approval to attend the KC-135 program Office CCBs at Tinker AFB if there is an indication an upcoming modification to the aircraft may affect the ATS. This strategy allows for the aircraft modification to account for and fund the simulator modification from one single program activity. This early involvement also provides the ATS community with an opportunity to begin the planning and coordinating process for incorporating training system requirements into the aircraft program as needed thereby reducing cost and schedule risk to the ATS upgrade. Because of the early success of this approach with the Pacer CRAG modification, these practices have become institutionalized.

Although FlightSafety is the O&M contractor responsible for maintaining and operating the ATS as well as retaining responsibility for meeting overall Air Force training needs, there have been cases where the Government has opted to contract with a third party for specific upgrades to the ATS. It was recognized by all stakeholders that meeting Air Force training requirements was at risk without proper involvement by FlightSafety early in the contracted effort. A more formal process has evolved to ensure early involvement by the O&M contractor in the development effort to ensure training needs continue to be met. The process has evolved from the painful lessons learned in some of the earlier efforts, particularly two of the simulator upgrade efforts, the visual system upgrade and the aerodynamic upgrade.

AMC and AETC communicate often to ensure that the training systems and the schoolhouse are meeting the demands of the user. The ATS program manager has a direct interface with AETC. These two organizations communicate either informally via telephone calls or more formally at focused reviews (e.g., SRBs). Their formal relationship is described in AFI 11-202 Volume 1, as lead command or AETC as training command. They also operate under a command-to-command memorandum of agreement (MOA). This process, which has continued to evolve, has improved the team's ability to identify and resolve issues early thereby reducing the incident of last minute/uncoordinated changes to the program. One of the challenges faced by the team which has been overcome through close cooperation among all stakeholders affects courseware development. FlightSafety is responsible for developing all the KC-135 ATS related courseware with all courseware including continuation training courseware going through AETC. Although all instructors at the schoolhouse are AMC assets and requirements for courseware are driven by AMC, courseware must be developed using AETC approved processes with all courseware developed by FlightSafety is evaluated by Subject Matter Experts (SMEs) from AETC's 97th AMW. At the time of the change of the schoolhouse location from Castle AFB to Altus AFB, FlightSafety was directed to incorporate Instructional Systems Development processes into their courseware development as embodied in AFMAN 36-2206, etc. The process was formalized with a contract change. Close cooperation by all team members is essential to ensure courseware development is complete, accurate, and timely. Another challenge that needed to be addressed involved obtaining permission for simulator instructors to go on KC-135 training sorties. Prior to 1993 while the schoolhouse was at Castle AFB and run by AMC, the military simulator instructors were permitted to fly on these training sorties. AETC's position was basically simulator instructors don't fly! It took years to overcome this reluctance and obtain permission for simulator instructors to fly on training sorties. Developing and fostering a professional relationship over time can facilitate resolution of these types of challenges.

In addition to major program reviews, such as the SRB, the team relies on working groups comprised of all the stakeholders to assist in the day-to-day management of the training system. For example a Training System Configuration Working Group (TSCWG) meets at Altus monthly to review the status of all hardware, software, and courseware tasks/modifications requested, the configuration of the ATS, and all change requests submitted by the government or contractor personnel. The TSCWG then prioritizes this new work for incorporation into the ATS. For example, Altus was experiencing power fluctuations in the schoolhouse. These power fluctuations affect simulator availability thereby affecting training throughput. FlightSafety advised the ATS Program Office at Ogden of the problem and a new system was installed.[10]

The team also utilizes a requirement verification and prioritization review board (called the SPRR System Priority Requirements Review) that, in addition to upgrades driven by weapon system changes, addresses sustainment related hardware and software deficiencies/upgrades required to improve flight simulator fidelity. Prioritization reviews include representatives from the KC-135 Program Office, Ogden, Contractors (aircraft and simulator), and user. Requirements driven by aircraft modifications and/or sustainment upgrades are reviewed and prioritized. The O&M contractor then costs out the proposed program based on prioritized requirements and conducts a risk assessment. The KC-135 ATS Program Manager, based on this information, gives the "go-ahead" and the Program Office or AMC provides the appropriate funding to Ogden for implementation. While this arrangement was not always the case, professional relationships and early successes by the program have formalized this relationship.

Additionally, the contractor utilizes a Database Working Group to assess any applicable simulator models (i.e., visual system markings, flight line configurations, etc.) to ensure the updated database will support meeting training requirements. The training team also participates in the KC-135 Cockpit Working Group at Tinker AFB. The Cockpit Working Group, which is comprised of representatives from the KC-135 Program Office at Tinker, AMC, and the KC-135 tanker prime contractor (Rockwell Collins), is tasked with the responsibility of assessing each potential change to the aircraft from a training perspective and identifying potential impacts to the aircraft training system. This is accomplished by reviewing all applicable Form 1067s [11], Modification Proposal, which identify pending modifications to the aircraft. If the O&M contractor for the training system sees something that may affect the ATS they notify the ATS Program Office. If the proposed change is within the contract's level of effort (LOE) then the

[10] Ogden scrambled and collaborated with AMC to redirect or find additional dollars to pay for the power conditioners—some of the collaboration was with the C-5 program, schoolhouse and government simulator program management (also located at Ogden). Together, AMC and Ogden were able to facilitate a win-win solution benefiting multiple parties.

[11] AFI 63-1101

TSCWG can incorporate without further contract action. If the scope of work is outside the LOE then it is out of scope for the TSCWG and a letter is sent to ATS Program Management identifying the need for either an Engineering Change Proposal (ECP) or a Contract Change Proposal (CCP). The ATS Program Office at Ogden ALC and AMC then prioritize the change and a formal request is made for a proposal to incorporate the change into the ATS. The existence of LOE is in essence a type of management reserve, however, it has always been protected from cuts due to the common (although faulty) understanding that it is for software maintenance.

3.2 KC-135 ATS Performance Requirements

AMC has emphasized two key program goals that formed the foundation of the KC-135 ATS upgrade strategy. The first addressed the need for concurrency, which is to ensure the OFT is upgraded and ready for training prior to the aircraft with its modifications being fielded. The second addressed General Fogleman's goal to upgrade operational flight simulator training effectiveness. The first goal emerged as a result of early successes in the execution of the simulator's upgrade strategy concurrent with a major aircraft upgrade and modification program.

To address the issue of concurrency, AMC initiates all new requirements for simulator modifications with a goal of modifying the simulators 60-days ahead of the operational deployment of the aircraft. This practice emerged in the mid-90s as the KC-135 aircraft was undergoing the Pacer CRAG modification. The fact that these upgrades were being done at roughly the same time as the separate simulator upgrade program added to the complexity and challenges faced by the simulator Government and contractor personnel. Given the early success of having the simulators ready to train aircrews prior to the first aircraft arriving set the standard for all future modifications to the simulators. To ensure the proper emphasis is placed on concurrency, KC-135 ATS systems engineers both within the Government and the ATS support contractor review every modification to the aircraft to determine if the modification will affect the OFT and aircrew training programs.

As mentioned earlier, with the progression of technology and the capabilities of flight simulation were recognized, Federal Aviation Regulation (FAR) revisions were made to permit the increased use of simulators in approved training programs as defined by the Federal Aviation Administration (FAA) Advanced Simulation Plan. To support this plan, the National Simulator Evaluation Program was established by the FAA in October 1980. The need for standard criteria was necessitated by the use of simulators for training and checking. The evolution of simulator technology and the increased permitted use required a similar evolution of the criteria for simulator qualification. Minimum requirements for qualifying aircraft simulators to Level A (non visual system equipped), Level B, Level C, or Level D are specified in FAA 120-40 Simulator Standards and Appendix 1 to FAA Advisory Circular (AC) 120-40B. The procedures and criteria for simulator evaluations under the National Simulator Evaluation Program are contained in FAA AC 120-40B. This AC provides an acceptable means of compliance with the FAR regarding the evaluation and qualification of airplane simulators used in training programs or airmen checking under Title 14 Code of Federal Regulations (CFR). Criteria specified in this AC are those used by the FAA to determine whether a simulator is qualified and the qualification level. While these guidelines are not mandatory, they are derived from extensive FAA and industry experience in determining compliance with the pertinent FAR.

Flight simulator subsystems and/or functions that would typically be impacted by compliance to the guidelines of the National Simulator Evaluation Program would include: the cockpit physical geometry; controls, and displays; aerodynamic modeling; cockpit sounds; the motion system; and the visual system. For example, some of the minimum requirements needed to qualify an aircraft simulator to Level C would include:

- A full-scale replica of the airplane's cockpit including all relevant instruments involved in the simulation automatically responding accurately to control movement by a crewmember or external disturbances such as wind shear or turbulence.
- Control forces and control travel corresponding to that of the replicated aircraft.
- Instructor station to enable an instructor to control all required system variables including abnormal or emergency conditions.
- Aircraft sounds corresponding to those of the airplane.
- Effect of aerodynamic changes for various combinations of drag and thrust encountered in flight corresponding to actual flight conditions.
- Brake and tire failure dynamics based on airplane-related data.
- Visual cues sufficient to assess sink rate and depth perception during takeoff and landing.

AMC recognized the guidelines defined by the FAA Standard and the AC provided a means by which improvements to the KC-135 OFTs could be assessed to ensure they achieve their goal of meeting FAA Level C simulator requirements. It also provided a benchmark against which AMC could transfer aircrew training activities to the simulator without compromising aircrew proficiency or safety. In order to qualify the KC-135 ATS system to this higher standard certain new capabilities, in addition to those driven by aircraft concurrency, needed to be planned for and incorporated into the flight simulator through an ongoing comprehensive simulator upgrade program which was initiated in the early 1990's.

Effectiveness of the KC-135 ATS is a key input into the requirements generation process associated with the simulator program. Effectiveness is the degree of mission accomplishment of a system used by representative personnel (trainees) in the planned environment. Effectiveness is also a measure of concurrency with the aircraft system as represented by the training equipment and courseware. The effectiveness of the training and equipment is determined by the criteria of student throughput and student success rate.

To support this long term upgrade initiative by AMC, a support services contract was competitively awarded to FlightSafety Services Corporation, Centennial Colorado in 1992. Under this contract the contractor agreed to provide, within the schedule requirements and at the prices stated, all KC-135 aircrew members ground-based training required to meet the qualification levels as listed in the KC-135 ATS System Specification, SS-07878-7010, dated 23 March 1992 and the Air Force instruction AFI 11-202 Volume 2 "Aircrew Standardization/Evaluation Program." The Air Force retained final authority on the satisfactory completion of the guaranteed student qualification.

In addition, the KC-135 ATS program defined system performance by essentially three key requirements all of which were included in the Operations and Maintenance Contract with FlightSafety: 1) the KC-135 ATS shall provide the capability to meet AMC student throughput requirements; 2) the contractor shall ensure formal school students graduate the academics portion on time; and 3) the ATS contract guarantees trained students meet government standards (i.e., success rate). This latter point is referred to as guaranteed aircrew qualification levels.

Successful training is defined by the user as the devices needed to provide the training as required by the KC135E/R Master Task List (MTL), and by providing that training in an effective manner. Any remediation training determined to be required by the Government will be, according to the contract, provided by FlightSafety at no cost to the Government. The MTL provides a baseline document that describes those aircraft tasks that are to be trained on the KC135E/R Aircrew Training System. This baseline MTL is under strict configuration control by AMC. All modifications and updates to any ATS device are tested to the MTL. In addition, the KC-135 ATS team relies on course ending surveys/comments prepared by students, which includes a rating of the training value received (scale of 1 to 5), consistent monitoring of student's performance and progression, and, as a final proof, a Government-conducted check ride to ensure this requirement is met. Through consistent monitoring of the student during training FlightSafety can and will recommend a student be washed out by the Government. This has proven not to be a typical occurrence. The fact that this very rarely happens has been attributed to the quality of the incoming students. Data has shown that only two students have required remedial training since the current O&M contract has been in effect (reference contract F33657-91-C-0072, PWS). Feedback is taken seriously and modifications are considered if training effectiveness can be improved within the requirements of the MTL.

3.3 KC-135 ATS Systems Engineering Process

The SE process employed by the KC-135 ATS team consists of an integrated System Engineering process tailored to the development, implementation, and maintenance of aircrew training systems. At contract award in 1992 FlightSafety was not required to follow an SE standard since many of the applicable MIL-SPECS and Standards that would have applied had been cancelled by senior DoD leadership under streamlining initiatives then in vogue. Commercial best practices were to be employed on all Air Force contracts at that time. Fortunately FlightSafety did have an internal corporate level SE process they were obliged to follow on their programs. The SE process was initially based on the American National Standards Institute/Electronic Industries Association Standard 632 (ANSI/EIA-632) Processes for Engineering a System modified to account for the training system development domain. This process has continued to evolve and mature based on lessons learned gained from facing and overcoming challenges presented by the upgrade program, by increased Air Force emphasis on SE, and willingness by the user to identify the dollars necessary to fund the implementation of SE activities within the program. For example, one of the early challenges faced by the team was maintaining cognizance over risk management/risk mitigation to ensure issues were being identified and resolved in a timely manner. The team recognized that added emphasis had to be placed on managing risk mitigation in order to ensure the right people were assigned to work the problem, mitigation plans were realistic and implementable, and that the required work was on track to being completed on schedule. Since one of the primary focus areas of the contractor's In Process Reviews is deficiency correction and mitigation planning the team developed a process by which the reviews would have an additional agenda item which was to track these mitigation efforts. As a result, the team developed and initiated a specific 30/60/90 day get-well process that is now employed on all contracts thereby ensuring proper emphasis is placed by the team on the tracking and timely resolution of key mitigation actions. SE has since been incorporated into the ATS contract.

The current maturity level of the contractor's SE process is reflected in the contractor's Systems Engineering Plan (SEP) dated February 1, 2008. Based on the SE process, as documented in the

SEP, specific SE related tasks for each contract action are identified for the Systems Engineer to implement. These are formally documented in the KC-135 ATS Performance Work Statement (PWS) and applicable Statement of Work (SOW) associated with the specific modification program. Some of the key tasks that illustrate the Systems Engineer's roles and responsibilities on these programs/modifications include: translating user goals into verifiable and measureable program technical requirements, tracking cost and schedule performance; conducting risk assessments; and tracking applicable program metrics (e.g., spare IO, memory, design status percent complete; test status percent complete; test failure reports) to ensure program requirements continue to be met.

One aspect which should be noted at this point is that the KC-135 systems engineering process does not utilize an Integrated Master Plan (IMP) per se, but focuses on a project's unique milestone schedule, which includes schedule risks and schedule metrics that reflect the incremental milestone achievements. This detailed program schedule with metrics is similar in content to the Integrated Master Schedule (IMS). This "IMS" also has the capability to assess critical paths for the various projects, as required. This is where the "contractor format" was deemed sufficient since at the time of the contract award, most formal SE processes were traded or "contractor best practices" were deemed sufficient.

In addition, while specific requirements (products, milestone events) for each program are formally spelled out in the applicable engineering change proposals (to include schedules, data deliverables, SOW, and flow-down of Government regulations and conditions), system engineering process related requirements are not formally flowed down to vendors. FlightSafety has their preferred suppliers with proven track records and their internal processes are well understood. To date, this has not been a real issue with known suppliers.[12] ECPs typically require the following:

- Executive Summary
- SOW
- Program Schedule
- A description of the effect the ECP will have on the product Configuration Identification Specifications
- A description of the effect the ECP will have on the Integrated Logistics Support elements
- A description of the effect the ECP will have on the operational employment (maintainability, reliability)
- Proposed changes to the contract
- Specification Change Notices
- System Safety Report

3.3.1 Requirements Process

The contractor, either the O&M support contractor or third party contractor is responsible for identifying, allocating, and documenting requirements in the applicable system/subsystem

[12] This commercial "best practice" is well known within the Lean community and is a practice most readily attributed to the experiences of Toyota in its product development process.

specifications through change pages for each modification.[13] For example, requirements that can be quantifiably verified for the visual system such as resolution and brightness, shadows, antennas, and hinge lines are documented in the specifications.

The verification process relies on acceptance test procedures (ATPs). New or modified ATPs may be required. For example, the visual system upgrade required a new stand-alone ATP, manuals, etc. These ATPs are conducted to verify compliance of the modification with the requirements as specified in the Prime Item Development Specification. Low-level detailed testing by subcontractors and/or third-party contractors is performed to validate the subsystem performance. Functional mission tests are Government conducted tests of the prototype modification which utilize Government defined scenarios to evaluate the operational characteristics of the systems within the context of conducting the mission. Both the Government and the O&M contractor have a stated common objective to ensure student throughput is minimally impacted by software updates or configuration changes. Therefore, the contractor usually develops a prototype trainer modification and schedules the prototype which is used to validate system performance at a site with multiple trainers so that impacts affecting student throughput are minimized. This is a “best practice” that has emerged through the experience of the contractor while performing simulator modifications and upgrades.

Revisions to courseware products, such as, classroom lecture, computer based training (CBT), training device, and aircraft lessons are verified and validated via the formative evaluation processes that include subject matter expert (SME) review, and individual tryouts (ITOs) and small group tryouts (SGTOs) where applicable. SGTOs and ITOs are applicable for more complex projects that include task/objective changes, new lessons, or major changes to existing lessons. In the case of training devices, Instructional System Development (ISD) derived training objectives are translated into measurable and verifiable performance requirements and verified, along with Performance Specification requirements, as part of the Development Test and Evaluation (DT&E) process. Operational Evaluation is carried out continuously via collection of student and instructor comments and by evaluation of student performance.

The O&M support contractor focuses on training mission needs and training value. Formal SIMCERTS conducted approximately every six months by the Air Force, verifies the ATS continues to meet system specification requirements for the hardware and software. As a part of the contractor’s systems engineering process the contractor’s various site managers typically run an internal SIMCERT checklist annually in conjunction with Quality Assurance from FlightSafety at Altus to ensure continued compliance with requirements. The entire ATS is reviewed at quarterly SRBs while student critiques are reviewed during monthly Training System Configuration Working Group (TSCWG) meetings at Altus. The entire KC-135 training program is reviewed annually in group forum via the Realistic Training Review Board (RTRB).

Ultimately for an OFT to be effective as a training device the aero models, visual system models, aircraft/cockpit sounds, etc., must provide the student with sufficient cues that are realistic enough to provide for realistic training. For ground-based training devices, this is really a qualitative assessment about the realism of the simulator meaning, it’s a judgment call by the test crews and Air Force instructors about the systems “training value.” To the systems engineer, this issue of subjective testing has been an ongoing simulator dilemma. It has proven extremely

[13] This is a direct result of what the Air Force would consider the Total System Performance Responsibility FSSC has for the KC-135 ATS.

difficult for systems engineers to quantitatively specify this training value. No matter how much experience a team has quantifying and measuring simulator performance, in reality it remains a qualitative assessment about the realism of the simulator. The challenge for the systems engineer in a training program is to not only develop performance requirements that can be measured and verified but also develop the process by which "training value" can be qualitatively assessed while protecting against personality-driven assessments that can change with Government personnel turnover.

3.3.2 Risk Management

FlightSafety's risk management process (Figures 9 and 10) employs typical risk management categories, i.e., risk identification, assessment, handling, and monitoring. Any member of the KC-135 ATS team, contractor or Government, may identify a risk. Sources of information used to identify risks include; lessons learned on similar programs, expert interviews and studies, plans and documents evaluations (e.g., PWS, Specification, etc.), management reports, formal Contract Data Requirements List (CDRL) documentation and observations. Risk management is in accordance with FlightSafety's established processes as outlined in their Systems Engineering Plan and risk disposition is always considered a purposeful action with moderate or high risk disposition activities always including the Government to ensure their continuous visibility into risk mitigation and closure planning/action. Risk management is assessed at all major design and program reviews including joint meetings between the aircraft and training communities. For example, the KC-135 aircraft Cockpit Working Group, which has FlightSafety and Ogden participation, reviews all aircraft related program risks, current mitigation status, and whether those risks have implications to the training system. In addition, the KC-135 ATS SRB, which has KC-135 Program Office participation, also reviews all training system-related risks from both an aircraft and training system perspective. These joint meetings ensure the risk management process assesses not only those risks associated with the development and fielding of a specific system but look across the portfolio of programs to ascertain the possible inter-reaction these risks may have on other elements of the weapon system.

An example of the program's approach to risk mitigation is in the area of courseware development which is somewhat constrained by the availability of aircraft technical orders (TOs). Many times these TOs are late to need because of a variety of reasons (budget constraints, schedule slippages to kit proofing of an aircraft modification). The preferred approach is to not release the courseware until the final TOs are released unless the changes are considered minor (redlined TOs). In some cases, these red lined documents must be used to develop the required courseware for the ATS. In those cases, any release of courseware based on incomplete technical orders is mutually agreed upon by all stakeholders, the risk noted and accepted by all parties, and risk mitigation planning put into place to address issues which may arise as a result of then incorporating the finished documents. This highlights some of the frustrations that did exist between the KC-135 program office and the ATS program office. If the ATS program office is not aware of or included in 135 modifications and tech order publication issues, training is often degraded. Where the ATS remains involved, the risk can be mitigated by having some insight (or advance copies) of the new TOs. Nevertheless, this risk is completely out of the control of the ATS contractor and if not addressed during the development phase of the 135 program can threaten the ability of the ATS to meet its goal of having training available and in place 60 days before the delivery of a modified aircraft.

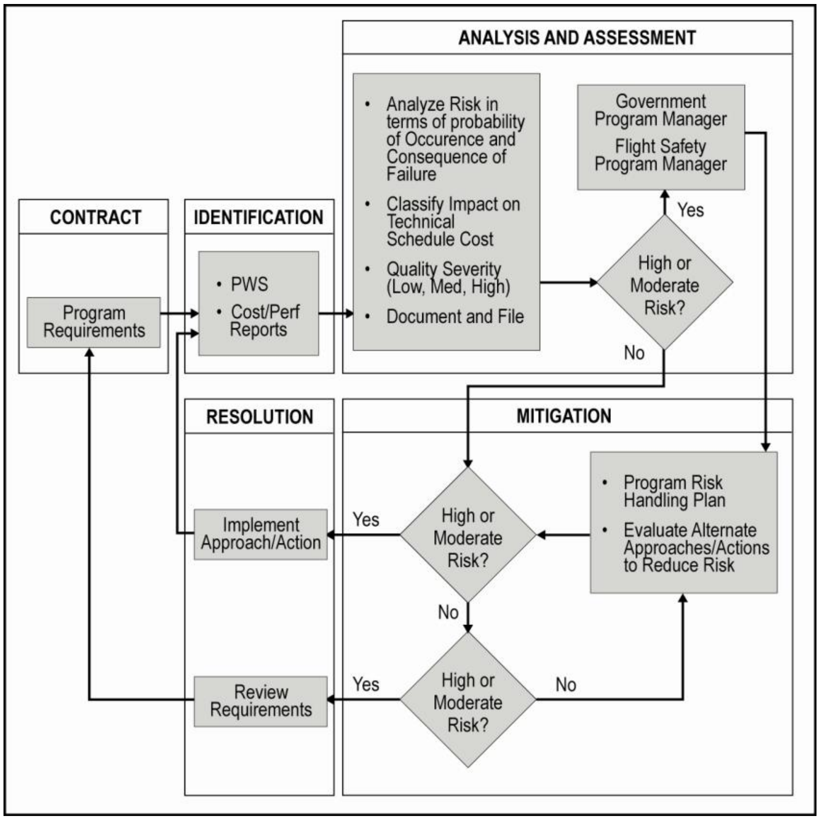

Figure 9. *Risk Management Process.*[14]

[14] KC-135 Aircrew Training System Engineering Plan CDRL A027, 1 Feb 2008

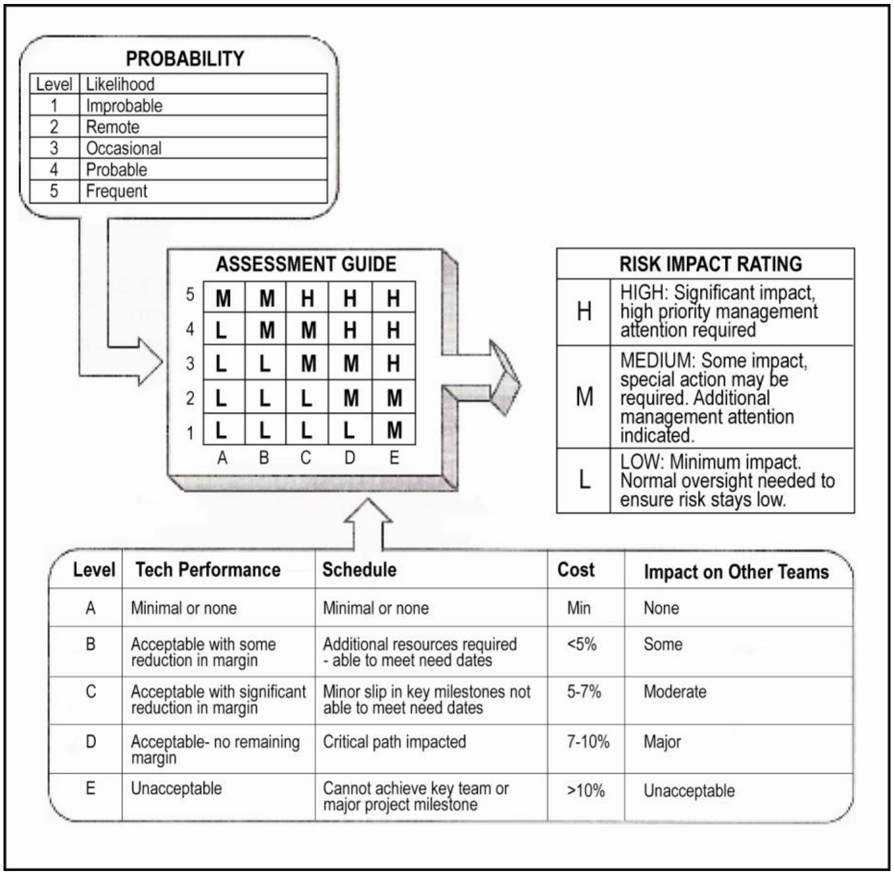

Figure 10. *Risk Assessment Model.*[15]

3.3.3 Configuration Management

FlightSafety operates the KC-135 Simulator configuration management (CM) system in accordance with the cancelled MIL-STD-973 and MIL-HDBK-61 as a guide. These items were originally referenced in the original contract RFP and bidders were asked to incorporate these into their processes. Additionally, many other ANSI, ATSM, etc., standards that existed were available in the early years of the current contract. The government team was fortunate that many of these standards were freely available before commercial standard organizations figured out how to charge money for them. Once this happened, access to these kinds of standards was often denied or even discouraged by other Government entities (e.g., this is the era of commercial best practices – we'll let them decide what to do – but an unintended consequence was fettered Government understanding of what best practices were actually out there.) Configuration management responsibility rests with the contractor's Training System Support Center (TSSC) at Altus AFB with oversight by both Ogden and DET 2. The Government must approve all Class I ECPs and CCPs. The Training System Configuration Working Group (TSCWG) is the joint contractor and government organization that reviews and coordinates on all changes. A typical agenda of the TSCWG would address Level of Effort (LOE) usage, courseware work status (TSCO status, action items, and new change requests), engineering work status (to include new change requests), other change requests and Government issues. Configuration management, in conjunction with systems engineering, plans for and conducts FCAs/PCAs. The purpose of these

[15] KC-135 Aircrew Training System Engineering Plan CDRL A027, 1 Feb 2008

audits are twofold: verification that the implemented design achieves its goals via systematic comparison of requirements with results of tests, demonstrations, inspections, and analysis as documented in the system performance specification; and verification that the product's documentation provides an accurate description of the product that can serve as the baseline for future modifications.

3.3.4 Design Reviews

The KC-135 program requires formal reviews, tailored based on the size and complexity of the modification program, be held during the development phase to ensure that the entire KC-135 ATS team is working to the same requirements, designing and developing the correct modification, adequately testing the mod and generating the appropriate courseware changes. The reviews employed throughout the modification development and verification process may include a Systems Requirements Review (SRR), Preliminary Design Review (PDR), Critical Design Review (CDR), Test Readiness Review (TRR), Required Assets Available Review (RAAR) and In Process Reviews (IPR). Occasionally, Technical Interchange Meetings (TIMs) will be held to supplement the formal reviews. As a minimum, an SRR and a TRR will be conducted for all modifications. This also includes requiring formal participation by the prime ATS O&M contractor in third-party design reviews of training system modifications as well as participation in design reviews associated with aircraft upgrades to ensure the training community is working in parallel with the aircraft community and that overall training requirements for the system will be met. [16]

The following is a brief synopsis of KC-135 ATS unique systems engineering aspects of these major reviews:

a. System Requirements Review (SRR): The purpose of this review is to ensure that the KC-135 Simulator team has mutual expectations and understanding of requirements and that the contractor's proposed preliminary designs and program plan satisfies the development specification. In some cases based on preliminary assessments of the design the contractor has proposed a more fully functional system than what would be needed to meet specific training needs. An example of this is the incorporation of a Terrain Collision Avoidance System (TCAS) into the OFT. TCAS utilized a commercial model that simulated the entire system and its capabilities. The contractor determined to incorporate every capability regardless if the capability was really needed to address specific near term training needs. Although incorporating full functionality as a given in the overall program strategy provided the ATS with more capability than the student would need for training it did provide the capability for future growth in the system. This is an example of the "systemic thinking" that occurs in the ATS at all levels. The Government suggested to the contractor this would be a good "investment" in the future as GATM and other aircraft modifications were being planned that would require the training and full use of TCAS capabilities. The price difference between the full capability and a marginal capability was deemed minimal and AMC agreed to fund the full capability.

b. Preliminary Design Review (PDR)/Critical Design Review (CDR): The purpose of the PDR and CDR is to review contractor assumptions, design criteria baseline and designs for the modification, and to establish the contractor's readiness to proceed with the design or construction process. These reviews are co-chaired jointly by the Government and contractor.

[16] Lesson learned over the course of the contract. It was not always the case.

As part of the Systems Engineering process, the KC-135 Simulator program utilizes a Requirement Traceability Program (RTP) that identifies, analyses, allocates, tracks and validates both explicit and derived requirements during the modification process. In addition, a syllabus of the training courses to be effected/provided, training material to be used, and preliminary acceptance test procedures (ATPs) are required at these reviews.

c. In Process Reviews (IPR): The contractor conducts one IPR per month between CDR and the Test Readiness Review (TRR). The purpose of the IPR is to review the contractors' detailed progress. These IPRs are supported by contractor personnel (engineering, program management, contracts, etc), and Government program managers, engineers, equipment specialists, end user, and Detachment 2 SMEs. From these IPRs the contractor is able to put a box around what specific capabilities are to be delivered and what data is required. The current O&M support contractor has an advantage here since they already have good insight into the user's training requirements/needs. These IPRs are used to ensure timely involvement by all stakeholders in the design process early rather than waiting for the aircraft and/or simulators to be modified before all stakeholders have the opportunity to identify concerns/issues. The resolution of which would result in more costly changes once hardware has been developed.

d. Test Readiness Review (TRR): The Government and contractor jointly host a TRR immediately before the commencement of the contractor and Government testing of the modification prototypes. The purpose of this review is to ensure that the Configuration Item is ready for commencement of testing, distribute ATP test documents, review the Discrepancy Report (DR) process, and to establish testing and work schedules. The presence of all applicable deliverable technical manuals and engineering documentation are a requirement for commencement of TRR. Engineers define the test procedures including regression testing as required to ensure all functionality designed into the ATS is verified. These Acceptance Test Procedures (ATPs), which are written at the system and subsystem level, are typically reviewed by engineering, quality assurance, and Det 2 Subject Matter Experts (SMEs).

e. Required Assets Available Review (RAAR): An RAAR is held at the completion of each modification installation and evaluation. The purpose of this review is to ensure that all Discrepancy Reports (DRs) that would impact the use of the applicable training system have been cleared, and that all remaining DRs have been prioritized, assigned, scheduled for work, and that authority for clearance of those DRs has been assigned. The RAAR for the prototype system requires completion of the Physical Configuration Audit (PCA). Successful completion of the RAAR and clearance of all "A" Category DRs constitute the modified training system as *ready for training* (RFT).

3.3.5 Instructional System Development

The KC-135 ATS program is supported by two Instructional System Development (ISD) groups: the Courseware Development Department at FlightSafety headquarters (Centennial, CO) and the Courseware Support Center at the TSSC (Altus AFB OK). The TSSC Support Center's primary function is to maintain the existing KC-135 Formal Training Unit (FTU) and continuation/refresher training courseware. ISD consists of five phases: analysis, design, development, implementation and evaluation, along with additional efforts of planning and courseware maintenance. Evaluation is integrated as a function throughout each ISD phase and as a central function of life-cycle operations. The FlightSafety technical approach is based upon a proven ISD model. The model is based on traditional military methodologies such as AFMAN 36-2234 and AFH 36-2235 but also reflects modifications derived from proven commercial practices. Incorporation of the military methodologies was done in the timeframe AETC began insisting on reviewing courseware around the time of the schoolhouse move to Altus AFB.

3.3.6 Integrated Logistics/Supportability

As with aircraft systems, training systems must also have an integrated logistics/maintainability support structure to ensure continued operation. Logistics within the KC-135 ATS program is concerned with the total support of the system to assure its economic and effective operation throughout its life cycle. Logistics objectives for the program include achieving stated readiness objectives such as system availability, programmed flying training throughput; establishment of Reliability and Maintainability requirements needed to support readiness objectives; and emphasizing logistics support considerations in all design trade studies. As a result, during the development phase the systems engineer must maintain cognizant of the program's logistically driven needs such as a system's reliability, maintainability, and availability requirements in order to properly reflect those in the applicable system specification/specification change notices, ensure all design trade studies address these logistics requirements, and that key design reviews are structured to ensure logistics issues are adequately and timely addressed. In addition, it is important for the systems engineer to maintain awareness of potential life cycle issues such as diminishing manufacturing sources (DMS) or parts obsolescence (PO) issues to ensure there is adequate planning early in the design phase in order to mitigate the long-term effects of not adequately planning for the impacts such issues may cause once the design is fielded.

As an example the Pacer CRAG Block 40 upgrade contract specified Critical Single Point Failure Items (SPFIs) will be considered in selection of maintenance concepts and computation of spares requirements.[17] Critical SPFI are to be spared at the site level unless Mean Time Between Failure (MTBF) data indicates the repair cost is sufficiently high and the failure rate low or the item failure will not result in loss of training mission. Critical items are then be stocked at the depot level and supplied with a delay of less than 48 hours. One of the functions of the systems engineer is to ensure early identification of these critical SPFI. Additionally systems engineers ensure issues associated with parts obsolescence, Diminishing Manufacturing Sources, spares, etc. are briefed at the quarterly SRBs. The KC-135 OFT simulator leg refurbishment effort is one example of a legacy issue currently being addressed.[18]

FlightSafety also maintains a list of priority modifications for AMC that can be implemented as fall-out money becomes available. FlightSafety has an ILS manager assigned to the TSSC at Altus who runs the PO/DMS effort. Four to five years ago, for example, the contractor advised AMC of the need for new power supplies. As a result of identifying a potential problem early, FlightSafety provided AMC a proposal for consideration. Due to small business rules that dictate in many cases the Government going directly to the vendor, the power supplies were procured from a third party.

[17] The genesis and incorporation of this ECP was due to a large failure due to a third party modification. The third party was not liable to maintain sufficient spares for the ATS nor responsive to the outage in training caused by the failure.

[18] The leg refurbishment has become an issue as a later modification, the visual system (a third-party modification), added an additional amount of weight to the OFT, causing issues with the structural integrity and life cycle of the simulator legs.

3.4 KC-135 ATS Upgrade Program

Since 1992 the aircrew training system has evolved through a series of complex upgrades supported by a maturing systems engineering process into a highly effective ATS. The complexity of these upgrades rival those associated with development of major aircraft weapon systems. Not only must they replicate the aircraft's physical configuration, performance, and "feel" they must also replicate the total environment in which the aircraft operates. This is an absolutely critical point. Often times a program office, as well as the user, can't fathom why simulator upgrades are so expensive – sometimes rivaling the costs of aircraft modification programs. They often failed to recognize that these modifications and upgrades were new development efforts and not typical sustainment actions.

In order to reach the level of training effectiveness now demonstrated by the KC-135 ATS, a series of upgrades were performed which ensured that both concurrency with the aircraft configuration and improvements to simulator fidelity were achieved and maintained Figure 11).

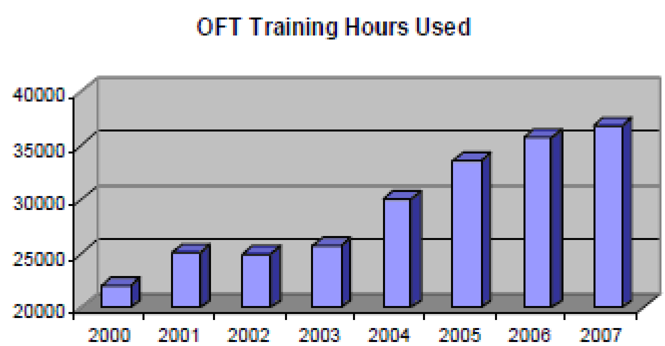

Figure 11. *OFT Training Hours Used 2000-2007*

Major modifications performed during this phase of the program are a mix of 3010 aircraft acquisition (i.e., Pacer CRAG), 3010 simulator upgrade acquisition (i.e., motion, aero package, and visual system), and 3400 Operation and Maintenance (O&M). AMC also uses 3010 funding to address shortfalls in simulator fidelity, such as, upgrades to the visual system.[19] Within existing O&M (3400) funding AMC is able to address repair/replacement of existing hardware with technology refresh efforts (i.e., Boom Operator Part Task Trainer (BIPTT) and the Instructor Operator Station System (IOSS).

The KC-135 ATS program also took advantage of advancements in computing and visual technology to achieve significant improvements in providing cost-effective training to AMC crews. Currently, the 19 Operational Flight Trainers that comprise part of the KC-135 ATS meet FAA Level C simulator requirements as a result of the simulator upgrade program and have demonstrated a 99 percent availability factor ensuring KC-135 air crew training is delivered when and where needed (Figure 12 OFT Training Availability).

Device	CY2008 Jan-Sep	CY2007
OFT #1 Mildenhall	98.7%	99.6%
OFT #2 Grand Forks	100%	100%
OFT #3 Altus	99.6%	99.5%
OFT #4 McConnell	100%	100%
OFT #5 Kadena	100%	100%

[19] Additional modifications to the visual system upgrade, a third-party modification, which fell short of requirements and expectations.

Device	CY2008 Jan-Sep	CY2007
OFT #6 Grissom	99%	99.2%
OFT #7 March	96.9%	99.2%
OFT #8 Fairchild	100%	100%
OFT #9 Pease	100%	99.9%
OFT #10 McConnell	100%	100%
OFT #11 Meridian	100%	99%
OFT #12 Altus	98.1%	99.9%
OFT #13 Robins/Scott	99.7%	98.8%
OFT #14 Altus	100%	100%
OFT #15 Fairchild	100%	100%
OFT #16 G Forks/McConnell	100%	99.1%
OFT #17 Milwaukee	100%	100%
OFT #18 Altus	99.9%	99.1%
OFT #19 MacDill	100%	99.1%
AVERAGE	99.4%	99.5%

Figure 12. *OFT Training Availability.*[20]

3.4.1 Motion System Upgrade

One of the first major upgrades to the OFTs occurred in May 1995 when the Government directed the O&M Contractor FlightSafety to install and interface a high performance Commercial Off The Shelf (COTS) based 6 Degrees Of Freedom (DOF) motion system and related software onto the existing A/F 37A-T88 OFTs. As stated previously the OFTs were initially designed by Boeing Training Systems to accept a 6 DOF motion system. This early decision by the ATS team facilitated the successful upgrade to all 19 devices (reference ECP-0072-003 6 DOF Motion System).). The motion system upgrade also drove some unintended consequences. Many of the enclosures the trainers were housed in, particularly at Guard and reserve units, were converted aircraft hangers and other "adapted" buildings. One such consequence of bringing motion to the simulators related to the "excursion envelope" the motion system required for the trainer within the facility. In some cases, the facility was a few inches too small. In other cases, a new facility was required. Early interaction with local units and the detailed engineering studies of the new motion system requirements allowed local MILCON budgets to be modified and/or initiated so that the facilities would be ready for the motion system. Many times, the timing of when a particular unit would get the motion system was adjusted until the building modifications were completed.

Another example was that adding motion required a reinforced concrete pad. Where hangars and facilities were engineered to support the weight of a tanker, little change was needed. However, in a few facilities, a reinforced pad was required to ensure the safety of the system and crew so that the motion system wouldn't rip itself out of the ground during a simulated flight maneuver. Again, close interaction between the simulator program office and the host units was usually sufficient to align the resources required or to get MILCON to pay for these changes. In a few cases, the motion upgrade was delayed until this work could be finished.

3.4.2 Computer Rehost Program

In October 1995, the Government requested an Engineering Change Proposal (ECP) to rehost the simulator's computer and upgrade the instructor/operator station. The final configuration installed an IBM RISC 6000 computer system and SUN Micro based instructor/operator station. This ECP upgraded all 19 OFTs. In addition, the contract included an upgrade of the Software

[20] KC-135 ATS SRB 63, 18 Nov 2008

Support Center computer at the Altus Training System Support Center (TSSC) as well as options for a KC-135 OFT control loading system upgrade and Boom Operator Part Task Trainer computer upgrade. The original proposal called for a less capable computer that would barely meet requirements over the initial two to three years. During the initial TIM, several questions were posed about future memory requirements and processing capabilities by the Government chief engineer. Additional questioning garnered acknowledgement that additional potential computing issues were likely to unfold within a few years of the upgrade including the possibility of a need for future growth to a distributed simulation training capability. Because it was determined the original proposal offered minimal spare computing capacity a more capable computer with a significantly lower price was obtained.

Improved instructor performance was also achieved in the OFT by providing a powerful graphics-based, multi-display touch screen based instructor station. It was also noted by the team that the original graphics generator system was becoming unsupportable. The ATS contractor was in fact down to one spare for all 19 OFTs. The contractor was directed to seek an innovative way of finding recycled and used projection tubes (CRTs) to bridge the gap until the visual system upgrade could be installed, while the government would seek the required funding. As a result of the Government's decision to obtain the necessary funding for the replacement modification a serious parts obsolescence issue was resolved. This is a great example of where the system 'broke down' under the normal processes. It wasn't until a crisis stage was reached that enough momentum was created to motivate finding necessary funds. However, the result could be construed as an example of the team's proactive systems engineering process of life cycle management being correctly applied to an ongoing Air Force-wide issue regarding parts obsolescence and/or Diminishing Manufacturing Sources.

In addition, by incorporating growth requirements into the design process systems engineering ensured replacement of the host computer would provide the infrastructure necessary to enable future visual system and aerodynamics programming upgrades to the OFT and WST as well as providing liberal performance margins for future planned aircraft modifications such as Pacer CRAG (Reference ECP-0072-012 Computer System Rehost). It was a combination of the right people in the right places at the right time – and the deliberate system 'big picture' perspective used by many people involved in the modification.

3.4.2.1 Third-Party Contracts

The Computer System Rehost program was awarded as a third party contract outside the purview of the current ATS O&M contract.[21] Although FlightSafety is the prime contractor responsible for maintaining and operating the ATS, there have been cases where the government has opted to contract with a third party for specific upgrades to the ATS. For those third-party contracts the Government Program Office prepares a Request for Proposal (RFP) and conducts a formal source selection. Although the prime contractor selected has a system specification and

[21] However, the contractor selected turned out to be Flight Safety International, a member of the same family of companies that FSSC belonged to. This decision was fortuitous as the government sought to avoid the overhead cost that FSSC would place on the contract for essentially pass-through administrative costs. The government considered the risks such an arrangement would bring but felt that by requiring the contractor to enter into an Associate Contractor Agreement (ACA) with FSSC, most risks could be mitigated. The fact that the contractor turned out to be FSI was serendipitous and the arrangement worked out well. However, such contracting arrangements went counter to the TSPR philosophy (which by then had fallen out of favor) and pressure mounted within the program office to use alternative arrangements for modifications. Unfortunately, the track record of using other third party contractors was not as good as this example.

Statement of Work (SOW) for the capability under development. FlightSafety, as the KC-135 ATS prime contractor, still retained responsibility for meeting overall Air Force training needs.

It was recognized by all stakeholders that meeting Air Force training requirements was at risk without proper involvement by FlightSafety early in the contracted effort. This was a difficult problem for FlightSafety particularly in regard to aircraft modifications. Initially the process utilized for obtaining the KC-135 ATS prime's support, which was basically voluntary, to ensure modifications by third-party contractors did not affect their ability to meet student training needs varied in scope. In the past, such third-party modifications to the ATS were not thoroughly tested, documentation was not in a usable format, interfaces were not well-defined, ATPs needed to be properly structured in order to validate performance of the system under development, no spares were bought, etc. In addition, maintaining configuration control of the ATS was an issue since the ATS prime did not have much of a hammer to ensure documentation/drawings provided by third-party contractors was correct and of good quality. There were work-arounds available to the Government if the product did in fact impact negatively on training. For example, requests for equitable adjustment could be made to incorporate fixes so that training needs could be met. For example, a third party contractor added tabletop Multifunctional Displays (MFDs), Control Display Unit (CDU), and control panel to one of the training devices but the drawings and documentation were lacking so FlightSafety, at the request of the Government simulator program office, under a future modification program (Pacer CRAG Block 40), was contracted to correct the deficiencies.

As a result of these lessons learned, a more formal process was developed to ensure early involvement by the KC-135 ATS prime in the development effort. This first large scale attempt at making these arrangements happened during the Pacer CRAG modification. Over time, this process of ensuring all stakeholders were properly involved in the development process early on has continued to evolve and mature. Frequently, an associate contractor agreement (ACA) between the subsystem prime contractor and the KC-135 ATS O&M contractor was typically used to support the contract. Later as the process evolved more formal contractual tasking (for example, a Performance Work Statement (PWS)) was implemented in order to identify specific tasks to be accomplished by the KC-135 ATS prime to ensure training needs continue to be met (The IOSS which will be discussed later is an example of this approach).

3.4.3 Pacer CRAG

In April 1996, the KC-135 ATS program underwent a comprehensive and complex ECP that modified the performance of the KC-135 Operational Flight Trainers to the applicable characteristics of the KC-135E/R model aircraft as modified to the Pacer CRAG configuration. The government initially asked for a preliminary estimate from FSSC for the cost to incorporate the modification into the trainers. The resulting proposal was extremely cost prohibitive. In essence, the proposal called for FlightSafety to reverse engineer or use best-guess engineering to mimic what was being put into the aircraft.

The Government program management was aware of previous efforts to incorporate aircraft hardware into simulators to avoid the additional engineering costs. The Government engineer found an existing commercial standard, ARINC 610, would enable most of the modified aircraft hardware to be installed.

The aircraft SPO approached the prime contractor (Rockwell) for the cost to incorporate the standard into their system. The resulting price was orders of magnitude lower than having FSSC engineer a separate solution. Nevertheless, incorporating the ARINC 610 standard was seen as a huge risk to the aircraft program. A great deal of discussion was done along with engineering analysis by the program office and the prime. Eventually, they saw the risks as acceptable. However, getting FSSC to become part of the existing logistics stream and relying upon government furnished equipment was seen as a huge risk. After a concerted effort among all parties, these concerns were resolved and resulted in a win-win for all parties. Additionally, the ATS actually played a larger role in acceptance testing for the aircraft as many unusual and potentially dangerous flight modes and configurations could be simulated without risk to an aircraft.

The change included installation of an aircraft glare-shield; aircraft control panels, multifunctional displays, a CDU 900B Control Display Unit, and replacement of the existing Main Instrument Panel for Pilot and Copilot, as well as simulator software for the new systems. In addition, several features were added to the OFTs to improve training utility – for example the following features were implemented: flight freeze; lat/long freeze; altitude freeze; and 30 additional system instructor controlled malfunctions. These features were actually part of the ARINC 610 standard and were an additional bonus unanticipated by the decision to use the standard. Including these functions, however, was common practice among the commercial industry, and not new to the prime contractor (Rockwell) which had already done this for many of their commercial airline customers, but this was the first time such things would be included in a USAF system. The successful implementation of this standard set the stage for many other AMC (and USAF) programs to incorporate this technology into their systems.

Previously, in 1995, FlightSafety Services conducted a trade study to determine future requirements for the Combat Crew Training School (CCTS). That study recommended Computer Based Training (CBT) be used more in the CCTS for training students, as well as enhancing Instructor-Based Training (IBT) through the use of “The Animated Classroom”. FlightSafety incorporated the results of that study into the requirements for the Pacer CRAG modification by utilizing CBT as the media of choice to introduce students in the CCTS to the new Pacer CRAG avionics. FlightSafety developed the appropriate CBT courseware at its Littleton, Colorado, facility using the Instructional System Development (ISD) process at the request of the government. Both Government Subject Matter Experts (SMEs) and FlightSafety instructors from the Altus CCTS participated in the courseware development. The Pacer CRAG CBT lessons are now being used for both CCTS training and continuation training.

A Pacer CRAG Part Task Trainer (PTT) was developed to simulate the aircraft system control panels and display systems in an existing PC environment. The PTT allowed the student to become familiar with the Pacer CRAG system operation and presentations through an interactive mode and a tutorial mode without the need of an instructor. The PTT used Commercial-off-the-shelf (COTS) software and existing CBT PC computers. This was an interesting development as it happened before it became common practice in the commercial world for the original equipment maker to develop a windows-based emulator for their terminals. Nevertheless, it saved a lot of money and allowed for rapid deployment of training across the ATS.

As with the CCTS, CBT is used as the medium of choice to introduce qualified KC-135 crewmembers to the PACER CRAG suite of equipment during continuation training. Once CBT lessons are completed, students are authorized to practice on the PTT, fly the OFT, and receive aircraft certification. By relying on CBT and PTT as the primary method of instruction, the contractor ensures training system concurrency by ensuring all KC-135 units receive Pacer

CRAG instruction prior to receiving their first modified aircraft.

In addition to the hardware and software development efforts associated with Pacer CRAG the contractor developed courseware for Initial Qualification, Differences Training, and Continuation Training required for the new components of Pacer CRAG for the KC-135. Initial Qualification training focuses on students new to the KC-135; Differences Training focuses on pilots and copilots that are current in the KC-135 and are transitioning to the glass cockpit KC-135; Continuation Training is part of the crewmember's annual training. This was a great collaborative effort identified through the discussions of the TSCWG, Government personnel in the ATS program office, the command, and the contractor and otherwise would have been missed…everyone assumed that the modifications would happen quickly and everyone would be trained the right way. But the reality of the situation was much harder and collaboration between the various groups was a key to their success. (Reference ECP-0072-014R1 Pacer CRAG)

3.4.4 Visual Upgrade Effort (VUE)

The next major upgrade occurred in January 1997 with the Government issuing an Engineering Change Proposal to upgrade the OFT visual system. The upgrade was driven by limited field of view (FOV) issues, lack of FAA Level C Certification, and lack of cockpit cross visualization capability that was determined to be required to provide the capability needed for training the task of aerial refueling.

The VUE program replaced the KC-135R OFT night/dusk Novoview SP-1 visual system with a high brightness, high resolution, wide FOV, day/night/dusk visual system. The SP1T was a wide area collimated (WAC) window system with four windows. One window each was located on the front and side for the pilot and a similar configuration for the copilot. The system did not allow for cross window coherence. Under this effort, the SP-1 was replaced by an ESIG 4530 five channel image generator (IG), which drives five Thomson Phebus V color projectors to produce a continuous 225 degree horizontal by 45 degree FOV. The visual system was designed to meet FAA AC 120-40B Level C requirements as well as provide enhanced capabilities and sufficient fidelity to enable aircrew members to log currency credit for such maneuvers as takeoffs, landings, circling approaches, visual approaches, and certain air refueling related maneuvers such as air refueling formation and receiver rendezvous. A major requirement was also that the visual system support KC-135R asymmetric thrust, engine-out training since there was no motion on the existing OFT. The normal initial cue for asymmetric thrust would be from motion. Without motion the visual system must provide the initial cues using a large horizontal FOV. The enhanced thrust of the KC-130R engines magnified the urgency of engine out reaction time training.

3.4.4.1 Context of VUE Program

The VUE program was awarded as a third party contract outside the purview of the current ATS O&M contract. The visual system, which included the IG, display systems, and all parts/components required to adapt the new VUE system to the KC-135R OFTs, was delivered to FlightSafety Services as Government-Furnished Product (GFP) to be installed and integrated onto the 19 KC-135 Operational Flight Trainers.

The strategy of the VUE program was to capitalize upon economies of scale afforded by having the government purchase additional systems tailored to different platforms. The strategy, conceived and managed by the 677th Training System Product Group, was to conduct a combined acquisition featuring a core visual system that would go on to the KC-135 OFTs as well as the KC-10 Simulators. The RFP for the VUE highlighted the government's desire to leverage "commercial best practices."

There were several technology risks that played a larger role in the modification than the Government realized at the time. First, the technology for cross-window coherent, wide field-of-view visual systems existed, but had never been scaled to the dimensions required to support air refueling and engine out requirements. The contractor was confident this could be done quite easily and convinced the government team during source selection. The SE Requirements allocation process failed to identify this as a risk and assumptions were made about the capacity of the motion platforms for both the KC-135 as well as the KC-10 simulators.

These technical issues, combined with those arising from the differences between the two simulator systems, caused severe schedule delays in delivery to the Government. These delays had negative impacts upon FSSC maintenance and other ECPs as installation schedules were in a lot of flux trying to minimize training impacts across the ATS. Although consideration was given to the Government by the VUE contractor, significant impacts were felt across the ATS.

3.4.4.2 KC-135 ATS Contractor Role

As part of the VUE Installation and Integration (I&I) effort, FlightSafety was formally tasked to support the VUE contractor in their design effort and to assist the Government in factory acceptance testing. In addition, FlightSafety was tasked to conduct a trade study to investigate additional training capabilities gained by the new day/night 225 degree wide FOV visual system. Specifically they were to investigate training utility of the OFT in the areas of training day/night landings, circling approaches, and visual/radar cell procedures during air refueling formation flight and update formal CCTS and continuation training in order to benefit from this increased training capability provided by the VUE system. The new system allowed reuse of the Evans & Sutherland (E&S) airfield data from their library of databases. Requirements existed for certain airfields but E&S supplied additional ones for compensation consideration for being late on schedule. A separate database generation system (DBGS) develops, integrates, and maintains the VUE databases under a separate contract.

For this effort an Associate Contractor Agreement (ACA) was signed between FlightSafety and the VUE contractor to facilitate the exchange of data and information to support the design, integration, operational and logistic support of the VUE installations on the OFTs.[22] Specifically this ACA addressed such FlightSafety specific tasks as attending and assisting the Government at: VUE technical and program management reviews, Contractor Engineering Validation Tests (CEVT), Joint Ready to Ship Assessments (JRSA), and Functional Configuration Audit/Physical Configuration Audit (FCA/PCA). In addition FlightSafety was to support the VUE contractor in accomplishing VUE visual system to KC-135 interface design; evaluate impact of the visual system installation design on the OFT facilities; sponsor and arrange access to KC-135 OFTs and data as requested by the VUE contractor; ensure visual system to OFT integration allowed full operation of all required VUE system features; prepare an ATP that fully tests the VUE system as installed and integrated with the OFT; and conduct final acceptance testing on the installed visual system. Although Ogden and FlightSafety were involved in all design reviews the O&M contractor was a non-voting participant. Ogden and FlightSafety were only able to offer their

[22] Unfortunately, having an ACA in place does not guarantee a cordial working relationship. The VUE contractor saw FSSC as a direct competitor since it belonged to the same family of companies the VUE contractor competed against, e.g. Flight Safety International.

opinions and concerns. After receiving initial cadre training on the VUE system, the FlightSafety was to provide operations and maintenance training to site personnel; revise CCTS and continuation training courseware as necessary to make optimum use of the new system capabilities; and perform configuration management of the installed visual systems over the life cycle of the ATS to ensure uniform configuration. (Reference ECP-0072-018 Visual Upgrade Effort)

As a part of the VUE prime contractor's systems engineering process, the contractor was responsible for allocating functional requirements down to the subsystem level and verifying that system's performance against an Acceptance Test Procedure (ATP), which they developed and the Government approved. The systems engineering process followed by the team resulted in several success stories. For example, to ensure a common design and minimize impacts resulting from PO/DMS issues state-of-the-art chip design was specified for many of the subsystems comprising the VUE. The design approach specified required the system to be designed around a family of chips that were essentially backward and forward compatible. This commonality of design aided the support system contractor in maintaining system concurrency. In fact, when some memory chips became obsolete on the 4530 before all IGs were delivered the contractor was able to deliver the remaining IGs with a new 5530 configuration and upgrade the delivered 4530s to 5530 configuration at minimal cost to the government.

3.4.4.3 Lessons Learned

One of the shortfalls with the systems engineering process identified by the team employed on the VUE program specifically addressed the requirements process. There was no formal Systems Engineering process followed for requirements allocation. The mantra of using "best commercial practices" was now well entrenched across the defense industry and the phrase "best commercial practices" had been at that time interpreted to mean using the contractor's internal processes, without regard to their "goodness" or not. The key issue is to make sure all requirements are adequately defined early in the development phase, that they reflect obtainable characteristics, and that the dialogue that must occur between Government program engineers, the contractors, and the user covers all potential performance requirements and sustainment issues. Since there was no formal requirements process, this did not happen. For example, extreme visual system field boundary limit physics did not support the design collimation requirements as stated by the Government. The Government was not aware of these issues until well after the contractor had done significant work on the system and concluded that the requirement could not actually be met (despite the fact that this was a risk identified from the beginning by the source selection team). Collimation is defined as the act of making a beam of light parallel by a suitable arrangement of lenses or mirrors (a collimator). Convergence and divergence rays of light need to focus on the eye plus-or-minus a range and the outer edges as specified exceeded this tolerance allowance. This resulted in the need to relax the collimation requirement. Failure in this area struck at one of the primary or core issues behind the official need for the visual system upgrade---to allow cross-cockpit visual system cues for in-flight refueling and meeting the requirements for Level C. In addition, there was no requirement in the System Requirements Document (SRD) for auto alignment of the visual system. The need for auto-alignment is derived from the fact that the shaking and movement of the motion platform would eventually knock the system out of alignment and result in a degraded visual sight picture. This capability, which would have reduced the amount of manual alignments required to maintain the system's performance had a direct effect on the sustainment of the visual system, was identified too late in the design process and incorporating such a capability at that time would have a significant cost and schedule impact[23].

3.4.5 Aerodynamic Upgrade Enhancement (AUE)

In addition to hardware modifications, extensive work needed to be done to improve the aerodynamic models of the simulators. The C-141, C-5, and C-17 aerodynamic simulation models already met (or were in the process of meeting) the FAA Level C equivalent requirement, but the KC-135 and KC-10 did not. In addition, none of the command's trainers had high quality aerial refueling simulation models. To deal with this problem the command undertook an extensive flight data-gathering program. Seven aircraft (two KC-135Rs, two KC-10As, a C-17, a C-5, and a C-141) were flown at Edwards AFB in a two-year data gathering effort. During this time, these aircraft flew over 1000 test hours gathering the necessary data. In addition to the basic data required for FAA certification of simulators, aerial refueling data was gathered for all tanker and receiver combinations.

3.4.5.1 Context of AUE Program

The AUE followed the same acquisition strategy and design as the VUE program. The 677th Training System Product Group managed this program and the KC-135 and KC-10 simulator program offices at Ogden and the ATS contractors were tangentially involved in the effort as described below.

In July 1997, the KC-135 ATS program initiated an AUE program to upgrade the existing OFTs to meet the fidelity requirements of FAA AC 120-40B Level C. Flight Safety International at Tulsa assisted the Air Force in determining what testing needed to be done during the initial data gathering phase of the program. Tulsa took the raw data collected during the flight test and using models developed by Coleman Industries [24]modified applicable software packages used in the OFT simulator. Typical KC-135 OFT software packages address such aircraft system functions as avionics, engine, control forces, lighting, radios, etc. The packages most affected by the AUE program were the aero and engine packages. The motion system was also impacted. The data package was then delivered to FlightSafety Services Corporation to integrate into the KC-135 ATS.

The O&M contractor (FlightSafety) was tasked to install the AUE into the KC-135R OFT and update the product baseline and technical publications managed by the KC-135 ATS Training System Support Center (TSSC). FlightSafety validated the models based on the flight test data and company subject matter experts then subjectively verified the simulator when the new software updates "reacted and felt good."

3.4.5.2 Systems Engineering Issues

To the systems engineer this issue of subjective testing has been an ongoing simulator dilemma. Even when instrumented aircraft data is collected, the modeling use of data extrapolation and curve fitting, while being representative of the aircraft, does not exactly replicate the aircraft "feel." The contractor does specify quantitatively many requirements in the system/subsystem specifications for each modification, such as, for the Visual System upgrade, resolution and brightness, shadows, antennas, and hinge lines. But, in the end, the model must be correct

[23] The unintended consequence of this oversight was that the original system only required one hour per week for alignment but the VUE system requires up to 3 hours per week or more for alignment activities.

[24] The AUE contractor

enough to allow training, which means it's a judgment call by the test crews and Air Force instructors about the system's training value. It has proven extremely difficult for systems engineers to quantitatively specify this training value. No matter how much experience a team has quantifying and measuring simulator performance, in reality it remains a qualitative assessment as to the realism of the simulator. The Air Force has typically had the user identify what the Air Force used to call a "golden arm" to provide the official acceptance and tweak the system to provide close to realistic refinement. Sometimes groups of multiple pilots are used to get a consensus for the adjustments. While this approach can work, it can sometimes lead to extended test periods without conclusive results especially when Government personnel continue to change while the system undergoes validation. While each aircraft has its differences the idea is to get the simulator as close to an aircraft feel as possible. The approach taken by the KC-135 ATS team was ensure consistency of the evaluation process by utilizing one to two contractor instructor pilots and one Air Force instructor pilot to provide this qualitative assessment of the system's training value (reference ECP-0072-021 Aerodynamic Upgrade Enhancement) .

3.4.6 Pacer CRAG Block 40

In August 2001, the Government initiated a modification program to address changes required to reconfigure the existing 19 KC-135R OFTs in order to maintain concurrency with the KC-135 aircraft which was undergoing an upgrade to the Pacer CRAG Block 40 configuration. These aircraft changes included the addition of the Global Air Traffic management (GATM) modifications. The major aircraft modifications encompassed three main areas: A Communication Management Function (CMF) which manages a Controller-Pilot Data Link system that supports data communications for the Air Traffic Services including both Line Of Sight (LOS) and Beyond Line Of Sight (BLOS) surveillance; Improvements to the Navigation system to meet the requirements of Required Navigation Performance (RNP)-4 and below; and Improvements to the Surveillance capability by implementing Automatic Dependent Surveillance-Addressed (ADS0A) operational capability with growth to ADS-B (Broadcast) capability.

The OFT modifications included, in addition to the aircraft driven changes, a replacement host computer system, the capability to emulate the Block 40 ground station network to support Controller Pilot Datalink Communications training, including an off board operator station, modified Instructor Operator Station (IOS) controls, and, as an option, equipment and software to enable the OFT to be configured as either a Block 30 or a Block 40 configuration.

Comprehensive systems engineering requirements were detailed out in a SOW to both the ATS prime contractor FlightSafety and the KC-135 Pacer CRAG Block 40 prime contractor. A key requirement which led to the success of the program was to hold a combined post-award conference and System Requirements Review within 30 days of contract award for the purpose of jointly reviewing the SOW, Development Specifications, and other requirements to ensure that both the Government and Contractor personnel from the ATS and KC-135 Pacer CRAG teams had reached a level of mutual expectations and understanding of requirements. With Block 40 (mid-2000s), everyone was already familiar with the arrangement of simulator code in flight qualified hardware. With this increasing trust between simulation providers and the aircraft SPO, these arrangements were easily facilitated. In addition to jointly participating in the KC-135 Pacer CRAG design reviews to ensure training requirements were identified early in the Pacer CRAG development cycle, a Required Assets Available Review was held to ensure all Discrepancy Reports, which directly impact training, had been cleared or a mitigation plan approved.

This contract also provides some insight into the KC-135 ATS team's evolving systems engineering approach to managing the training system. Regarding the KC-135 Block 40 upgrade which was developed by Rockwell-Collins, FlightSafety sent instructors and maintenance personnel to Rockwell-Collins in order to obtain specific Block 40 Type 1 Training as well as attending all of their design reviews to ensure they (FlightSafety) understood fully how the system was intended to function on the aircraft. By working closely with Rockwell-Collins during this early phase of development the ATS team ensured simulator specific needs were addressed in the aircraft design. For example, Rockwell-Collins modified the aircraft software to incorporate software "hooks" that were needed to facilitate training system development thereby ensuring the fielding of a Block 40 configured training device before aircraft arriving on the ramp. The incorporation of software hooks into a design is a technique used to alter or augment the behavior of an operating system or application, often without having access to its source code. In the flight simulator arena the application of hooks into the aircraft's operational flight software allows the training system to easily incorporate such simulator unique functions as freeze frame or halting the simulation and return to a previous state of simulation such as repositioning the aircraft on final to repeat a landing sequence. This is the essence of the ARINC 610 standard. Rockwell-Collins made these modifications because they were on contract to do so and FlightSafety was prepared to offer assistance because they were on contract to do so. Furthermore, the terms of the existing contract still stood, so FlightSafety was motivated to ensure the system would work properly so they could still train and "graduate" students when they successfully passed their aircraft check ride.

As a part of the Block 40 program, a FlightSafety systems engineer recognized a potential issue associated with the future operation and maintenance of Block 40 configured OFTs at multiple KC-135 bases and as a result initiated a program requirement for system reconfiguration. Since modifying aircraft from a Block 30 configuration to a Block 40 configuration involved major changes to the aircraft and ATS, systems engineering's assessment was that a scheduling nightmare might occur given the uncertainty of which bases and which batch of aircraft would get the Block 40 modification. Their derived requirement for system convertibility, which was flowed down to their subcontractors, was to be able to convert a Block 30 simulator to a Block 40 configuration in eight hours by two people in order to maintain the required training schedule and student throughput. The actual conversion takes less than four hours today and is a main contributor to the OFT's availability for training. (Reference ECP-0072-031 ATS Block 40 Upgrade)

3.4.7 Distributed Mission Operations

In 1996, General Fogleman, AMC/CC issued a message "Revolutionizing Training." The message urged the major commands to develop a joint synthetic training environment utilizing simulators, networking, and other technologies. Shortly thereafter, the Undersecretary of Defense for Acquisition and Technology (USD /A&T) Mr. Paul Kaminski published a memorandum which mandated that all simulators comply with high level architecture (HLA), a structure for networking simulations. In response to this direction AMC began programs to develop

Distributed Mission Training (DMT) capabilities for all its simulators. Nevertheless, the technology for implementing DMT capability was not yet mature at this time[25].

In 2004, the KC-135 ATS program initiated a phased approach for achieving a virtual environment for integrated cooperative training.[26] This phased approach, which runs concurrent with but is not considered a part of the ATS upgrade program, started with an initial demonstration of the feasibility and potential of such a distributed mission training capability at Altus. This capability, which the KC-135 ATS program refers to as Distributed Mission Operations (DMO), was completed in August 22, 2005. A key element in achieving this capability was the necessity for the program to achieve an HLA certification of Compliance from the Director, Defense Modeling and Simulation Office, which was obtained on June 2, 2005

Following this demonstration, the capability was expanded to McConnell AFB. This DMO capability allowed any trainer at the site to operate while hearing and seeing other co-located trainers flying in the same training environment. In essence, the simulators are linked such that aircrews operating them can communicate with each other and, in conjunction with state-of-the-art visual systems, practice formation flying. The next step in the plan was to link Altus with McConnell expanding the virtual battle-space to include geographically separate areas yet having the sites close enough to facilitate debugging of the system and then in FY2007 the capability was expanded to include both Fairchild and Grand Forks AFBs. In FY2009 the two Boom Operator Weapon System Trainers located at Altus will be integrated with the OFTs providing a DMO capability at the schoolhouse.[27]

3.4.8 Instructor Operator Station System

This effort was awarded in December 2007 when the Government awarded a third-party contract to upgrade the Instructor Operator Station System (IOSS). This third-party contractor was tasked to essentially replace the current IOS computational system, the dual IOS displays, and the remote control unit in each of the 19 OFTs. The goal of this program was to minimize OFT downtime and attendant training throughput.

A Contract Change Proposal (CCP) was issued to FlightSafety, the O&M contractor that described the activities required by them in support of the IOSS contractor. Their primary role was to provide supplementary integration support for the IOSS replacement via design review and technical/testing assistance support to the IOSS contractor as required by the SOW. In this CCP, FlightSafety was tasked specifically to support a Systems Requirements Review, Preliminary and Critical Design Reviews, review all design documents, assist the IOSS contractor in integrating the new data package into the current data library, coordinate with the IOSS contractor during equipment installation and testing, assist with the Physical Configuration Audit, provide test personnel and assistance for the contractor and government acceptance tests, and provide test pilots and instructor personnel for subject matter expert support to the IOSS contractor. In addition, FlightSafety would receive maintenance training from the IOSS contractor and FlightSafety TSSC software engineers would receive training on the new IOSS development system. (Reference CCP-0072-265 IOSS)

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[25] The online gaming industry spurred most of the technological developments and breakthroughs required to make DMT a realistic venture.

[26] The long pole associated with the implementation of a DMO capability within the KC-135 ATS program was limited funding.

[27] AMC proposes, based on achieving DMO capability, to transfer 50% of pilot formation training (over 1200 flying hours per year) into simulators with a potential cost avoidance of approximately $2.7M based on FY06 O&M rate.

To ensure adequacy of documentation for the IOS modification, FlightSafety established a technical manual validation program for the modification technical manuals in accordance with existing KC-135 ATS plans. The IOSS contractor was required to validate all data provided to support the modification. Validation was to occur in an environment which closely duplicates that in which the equipment and documentation will be used, i.e., in-plant as a pre-delivery prototype or on-site during prototype acceptance. Technical manual validation was to be accomplished prior to prototype RAAR(s). If commercial manuals or portions thereof were provided that have already been validated or proven by use, the IOSS contractor was to certify the existing commercial manuals and data as "current and accurate."

3.5 KC-135 E/R ATS Follow-on Activities

Follow-on contractual efforts (Post 2010) are planned to focus on incorporating a true Distributed Mission Training (DMT) capability which will provide the KC-135 ATS with a fully interactive system utilizing state-of-the-art simulation technology to permit KC-135 aircrews to train in synthetic battle-space connected electronically to other KC-135 OFTs and aircrews at other dispersed sites operating different aircraft types such as the C-5 and C-17. Importantly, since DMT provides the capability to deliver this enhanced training from the home station, the Air Force believes they can now limit the amount of time airmen spend deployed and facilitate the training of USAF air-expeditionary forces as they prepare for deployment to global crisis zones. In addition, AMC ATS priorities include replacing all visual systems that are currently high maintenance items and add a Boom Operator Weapon System Trainer (BOWST) capability at all active duty bases.

4. Summary

From its beginning in the early 1960s as mobile KC-135 simulators housed in railroad cars the KC-135 ATS has evolved into an effective ground-based aircrew training system while achieving a high level of customer acceptance and approval. In order to realize the goal of increased usage of the ATS for crew training, several key elements needed to be in place: a cultural change was made within the Air Force tanker community in that effective training is achievable by effective use of ground based trainers; money was allocated to effectively operate, maintain, and upgrade ATS capabilities; corresponding improvements to the hardware and software were realized in a cost-effective manner; good relationships between the Government and Contractors have been established and maintained; a competent Government and Contractor team was formed; common goals associated with the development and operation of an effective and efficient training system were established (i.e., emphasizing ATS upgrades to be completed prior to aircraft modifications being fielded); and an effective systems engineering process was put in place.

What drove the requirement for a structured SE process was the need for the contractor to ensure a consistent level of training is provided to the Air Force. Specifically ensuring all courseware, documentation, hardware, and software is sufficient to provide training value. For example, in the area of courseware, there are now formal SOWs and specifications specifically addressing courseware development. There is currently a requirement to show traceability back to these baseline requirements, trace lessons back to their source data (Technical Orders (TOs), Time Critical Technical Orders (TCTO)s, Safety Bulletins), and all courseware must be documented and sanctioned by the Government.

One of the key processes employed by the team is rigorous design reviews, including participating in the OEM's design reviews so that the training community is working in parallel with the aircraft community. As an example, regarding the Block 40 upgrade which was developed by Rockwell-Collins for the KC-135, the ATS prime contractor actually took Block 40 (CNS/ATM) Type 1 training as well as attended all of their design reviews to ensure they (FlightSafety) understood fully how the system was intended to function on the aircraft and, by working closely with the OEM during this phase of development, ensure simulator specific needs were being addressed in the aircraft design. As a result of this close interaction early in the system's development phase Rockwell-Collins was able to modify the aircraft software to incorporate software "hooks" which are needed to facilitate meeting aircrew training requirements. The team's success is also due to their ability to be flexible and react quickly to customer needs.

Achieving the user's mandate to maintain training concurrent with the aircraft, supporting a very active operations tempo (large numbers of students) with approximately 75 percent comprised of Air National Guard and Air Force Reserve Command aircrews without access to on-site flight trainers, ongoing Base Relocation and Consolidation (BRAC) initiatives, which have resulted in various changes in operating site locations, and an impetus to move training from the aircraft to the ATS/simulator, will continue to present new challenges.

Part of the reason for the effectiveness of the KC-135 ATS upgrade program is the simulator team has, over a period of 17 years, evolved into a very effective organization. One of the challenges facing the Government in 2010, when the current contract is recompeted, will be to foster the advantages associated with long-term support contracts (i.e., workforce continuity, knowledgeable support personnel, program stability, sense of ownership, incentives for process improvements, incentive for long-range planning) while meeting the Government's requirements for increased competition and shorter term contracts.

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6. List of Appendices

Appendix A. Author Biographies

Donald Chislaghi

Mr. Chislaghi has over 39 years of engineering experience in the research, development, and acquisition of aeronautical systems. He has served as Director of Engineering, B-1; Chief, Crew Systems Engineering Division; and Chief Support Systems Engineer, Advanced Tactical Fighter/F-22 and AWACS program. As Director of Engineering for the B-1B program he led a team comprised of over 100 engineers from both WPAFB and Tinker AFB. As Chief, Crew Systems Division he led a team of over 200 specialists responsible for the design of advanced cockpits, life support equipment, escape systems, Pilot/Vehicle Interfaces, and cargo handling systems. As Chief Support Systems Engineer for the F-22 he led a team of over 30 engineers and training system Subject Matter Experts responsible for the design and development of advanced crew systems, training systems, and support systems. He has also held the position of System Safety Engineer within both ASC Engineering and the 4950th Test Wing. In this latter position he had responsibility for safety sign-off of all Class II (T-1) modifications. During his assignment to the 4950th Test Wing, and in addition to his system safety duties, Mr. Chislaghi held the position of aircraft structural design engineer responsible for the modification of test wing aircraft. He has successfully designed modifications to fighters, helicopters, bombers, cargo, and trainer type aircraft.

As a Senior Systems Engineer for MacAulay Brown, Mr. Chislaghi is responsible for the analysis, planning, and integration of new or upgraded weapons and other subsystems to DoD aircraft. He supports ASC weapon system program offices and prime integrating contractors in all phases of acquisition. In addition to direct support to such programs as Global Hawk, CSAR, Gunship, P-3A, and WASP, he has been selected to support several independent review teams as a Subject Matter Expert in the area of airworthiness certification. He also led the development of a graduate level Systems Engineering course for AFIT in which he designed and developed a case study specifically to demonstrate the process for analyzing schedule risk assessments utilizing Integrated Master Schedules and tools such as Risk+.

EDUCATION

Master of Science, Engineering Management, University of Dayton,

Dayton, Ohio, 1983.

Bachelor of Science, Aeronautical Engineering, Indiana Institute of Technology,

Fort Wayne, Indiana, 1968.

AWARDS

Meritorious Civilian Service Award, 1992

Air Force Materiel Command Outstanding Chief Engineer Award, 1998

Outstanding Civilian Career Service Award, 2002

Richard Dyer

Mr. Dyer has over 40 years of engineering experience in the research, development, and acquisition of aeronautical systems. Dick Dyer joined MacAulay Brown, Inc. as a Senior Systems Engineer in 2003, providing flight systems, airworthiness and systems engineering support to government weapon systems program offices and airframe prime contractors. He is responsible for the analyzing, planning, and integrating aircraft weapons systems and subsystems. As a Senior Systems Engineer, Mr. Dyer has reviewed and developed numerous program System Engineering Plans and has been name requested to perform independent reviews of DoD program Integrated Master Plans and Schedules (IMP/IMS). He also led the MacAulay Brown Systems Engineering and Airworthiness effort to return the Missile Defense Agency (MDA) Widebody Airborne Sensor Platform (WASP) aircraft back to operational service.

Prior to his employment at MacAulay Brown, Mr. Dyer served as Technical Director, Flight Systems Division in the Engineering Directorate of the Aeronautical Systems Center, and as Chief Engineer and Chief Flight Systems Engineer for the B-2 bomber. He has personally led many independent airworthiness safety review assessments on Air Force systems e.g., CV-22, B-2, A-10, F-35 and F-22. He personally led the Aeronautical Systems Center Engineering Directorate's efforts to produce the Air Force Airworthiness Certification Criteria published in Mar 2000. This document became the foundation for the Department of Defense (DoD) criteria published as a military handbook (Mil HDBK 516) which standardizes airworthiness criteria for all DoD fixed wing aircraft. Mr. Dyer is a resident expert for airworthiness/safety assessments of military aircraft.

EDUCATION

Bachelor of Science: Aeronautical and Astronautical Engineering, 1968

Master of Science:

Aeronautical Engineering, The Ohio State University (OSU), Columbus, Ohio, 1975

Engineering Management for University of Dayton, Dayton, Ohio, in 1981.

AWARDS

DoD Exceptional Civilian Service Award for leading the Joint Strike Fighter Concept Demonstrator Aircraft Independent Review team for airworthiness flight clearance - 25 Sept 01

EN Director's Award for Outstanding Achievement - Sept 01

DoD Award Defense Certification of Recognition for Acquisition Innovation (Joint Service Specification Guides) - 8 Jun 99

Air Force Exemplary Civilian Service Award B-2 Chief Engineer – 25 May 99

Senior Scientist of the Year – Flight Dynamics Laboratory Director's Award – 1982

Jay Free

Mr. Free joined MacAulay-Brown, Inc. as a Senior Systems Engineer in 2002, providing systems engineering and training system support to government and industry clients. He has over 38 years of engineering and management experience in acquisition and sustainment of Air Force weapon systems. While working at MacAulay Brown, he has conducted several research studies for the KC-X Program Office, co-led development of the HC/MC-130 Cost Analysis Requirements Document, provided modification support to the AC-130 Gunship program and supported other program activities.

Prior to his employment at MacAulay Brown, Mr. Free spent 32 years at the Aeronautical Systems Center (ASC), Wright Patterson AFB, Ohio supporting simulator and aircraft acquisition. Early accomplishments included participation in the development of a prototype Digital Radar Landmass Simulator (Project 1183), radar and test engineer of the C-130 Full Mission Simulator and lead engineer on the B-52/KC-135 and EF-111 Weapon System Trainers. As Technical Chief of the ASC/EN Radar and Visual Simulation Branch he was responsible for 20 engineers supporting all simulator programs where he also led the Tanker Transport Training System (T-1A) simulator source selection. He then served as Chief of the ASC Engineering Documents Division where he provided ASC leadership of the Acquisition Reform Program, started in 1994 under Secretary of Defense William Perry, and supported the development of performance based specifications. Following this he served as Chief Systems Engineer for the Joint Primary Aircraft Training System (JPATS), T-6A Texan II, where he completed his DoD career.

EDUCATION

Bachelor of Science, Systems Engineering, Wright State University, Dayton, Ohio, 1970

AWARDS

Outstanding Civilian Career Service Award, 2002

Appendix B. Acronym List

AC	Advisory Circular
ACA	Associate Contractor Agreement
ACIQ	Aircraft Commander Initial Qualification
ADS0A	Automatic Dependent Surveillance-Addressed
AETC	Air Education & Training Command
AFIT	Air Force Institute of Technology
AFMSS	Air Force Mission Support System
AMC	Air Mobility Command
AMCAOS	AMC Air Operations Squadron
ATD	aircrew training device
ATP	Acceptance Test Procedures
ATS	Aircrew Training System
AUE	Aerodynamic Update Enhancements
BLOS	Beyond Line Of Sight
BOPTT	Boom Operator Part Task Trainers
BRAC	Base Relocation and Consolidation
CBT	Computer Based Training
CCTS	Combat Crew Training School
CDR	Critical Design Review
CEVT	Contractor Engineering Validation Tests
CFT	Cockpit Familiarization Trainers
CFR	Code of Federal Regulations
CLT	Cargo Loading Trainer
CM	Configuration Management
CMF	Communication Management Function
CPT	Cockpit Procedures Trainer
CSE	Center for Systems Engineering
CT	continuation training
CW	courseware
DAU	Defense Acquisition University
DBGS	database generation system

DMO	Distributed Mission Operation
DMS	Diminishing Manufacturing Sources
DMT	Distributed Mission Training
DoD	Department of Defense
DODAF	DoD Architectural Framework
DR	Discrepancy Report
EIA	Electronics Industrial Association
IEEE	Institute of Electrical and Electronics Engineers
FAR	Federal Aviation Regulation
FMT	Functional Mission Tests
FlightSafety	FlightSafety Services Corporation
FTU	Formal Training Unit
GATM	global air traffic management
GIPTT	GATM IHC Part Task Trainers
INCOSE	International Council on Systems Engineering
I&I	Installation and Integration
IBT	Instructor-Based Training
IMP	Integrated Master Plan
IMS	Integrated Master Schedule
IOS	Instructor Operator Station
IOSS	Instructor Operator Station System
IPR	In-Process Reviews
IPT	Integrated Product Team
ISD	Instructional System Development
JRSA	Joint Ready to Ship Assessments
LOS	Line Of Sight
MOA	memorandum of agreement
MOE	Measures of Effectiveness
MOP	Measures of Performance
MTL	Master Task List
O&M	Operations and Maintenance
OFT	Operational Flight Trainers
PCA	Physical Configuration Audit

PDR	Preliminary Design Review
PIDS	Prime Item Development Specification
PO	Parts Obsolescence
RAAR	Required Assets Available Review
RFT	Ready For Training
RNP	Required Navigation Performance
RTP	Requirement Traceability Program
SAC	Strategic Air Command
SDRL	Subcontractor Data Requirements List
SEMP	Systems Engineering Master Plan
SIMCERT	Simulator Certification
SIMSPO	Simulator System Program Office
SME	Subject Matter Experts
SoS	system-of-systems
SOW	Statement of Work
SRD	System Requirements Document
SRR	Systems Requirements Review
T&E	Test and Evaluation
TCAS	Traffic Alert and Collision Avoidance System
TIM	Technical Interchange Meeting
TMS	Training Management System
TSCWG	Training System Configuration Working Group
TSPR	Total System Performance Responsibility
TRR	Test Readiness Review
TSSC	training system support center
USD (A&T)	Undersecretary of Defense for Acquisition and Technology

Appendix C. OFT Bases

KC-135 OFT Base Locations

Quantity/Type	1992	#	2008
1-KC-135A OFT	Castle AFB	1	Mildenhall
1-KC-135R OFT	Grand Forks	2	Grand Forks
3-KC-135R OFT	Castle AFB	3	Altus
1-KC-135A OFT	Plattsburg	4	McConnell
1-KC-135R OFT	Kadena	5	Kadena
1-KC-135A OFT	Beale	6	Grissom
1-KC-135A OFT	Carswell	7	March
1-KC-135R OFT	Fairchild	8	Fairchild
1-KC-135R OFT	Malmstrom	9	Pease
1-KC-135R OFT	Dyess	10	McConnell
1-KC-135R OFT	Meridian	11	Meridian
1-KC-135A OFT	Altus	12	Altus
1-KC-135R OFT	Grissom	13	Robbins/Scott
1-KC-135R OFT	Robins	14	Altus
1-KC-135R OFT	Barksdale	15	Fairchild
1-KC-135R OFT	Ellsworth	16	G Forks/McConnel
1-KC-135R OFT	Griffis	17	Milwaukee
		18	Altus
		19	MacDill

1992 Base locations were identified from the 1992 Support Service Contract Appendix C F33657-91-C-0072.

2008 Base locations were identified from the Nov 2008 SRB briefing.