MULTI-CONFIGURATION CONCURRENCY PILOT TRAINING USING RE-CONFIGURABLE DESKTOP SIMULATORS

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ABSTRACT

The present and future cargo transport and gunship fleet of aircraft will consist of multiple block configurations. Once a conventional training simulator is modified to a new block configuration, the old block material that can be taught or simulated is limited. Air Force and industry partners have developed a transportable PC and SUN based, real-time, Re-configurable Desktop Simulator to resolve this issue. This paper presents RDS methods, technology and design features used to drive down cost and maximize functionality. These include single and dual aircraft configurations that represent one aircraft with two pilots or two aircraft with each pilot flying separate missions using the same or different block configurations simultaneously. This paper presents the method used to enable a Distributed Interactive Simulation environment for formation missions including the training and evaluation of formation lead using logging and playback feature.

The RDS is equipped with satellite imagery integrated with World Wide Digital Terrain Elevation Data level 1 for out-of-the window visual presentation of terrain and selected airfields. A generic runway can be selected to represent any airfield that is not in the visual database. This paper explains the technology and the methodology used for dynamically generating and loading out-of-window visual data during flight. Pre-designed RDS training scenarios include flight profiles for airland, airdrop, formation and air refueling rendezvous missions. System specific profiles are provided for Global Air Traffic Management with a Ground Earth Station, Traffic Collision Avoidance System, Terrain Awareness Warning System and future changes. Free Play permits "what if" scenarios for all of the above listed missions. This paper emphasizes the coordination and integration of the associated activities, and technologies applied to present and future flight training concepts.

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INTRODUCTION

The fleet of cargo and gunship aircraft consists of multiple blocks of configurations. Previous simulator training addressed only the latest block configuration. Once a training simulator is modified to a new block configuration, the old block material that can be taught or simulated is limited or non-existent. Through the collaboration of Air Force's Aeronautical Systems Center (ASC/YWMA) and Boeing, a Reconfigurable Desktop Simulator (RDS) has been designed and produced to enhance training of future aircraft changes as well as the variety of configurations that currently exist in the fleet. The RDS is a part task trainer whose fidelity fits between knowledge and performance measured criteria on the training scale. Pilots can accomplish a computer based training lesson and go to a first level part task trainer (Cockpit Systems Simulator) or proceed straight to the RDS for mission computer and avionics equipment hands-on training. The RDS provides the fidelity of training needed prior to advancing to the Weapon System Trainer (WST). Today's "glass cockpit" aircraft are capable of changing blocks of software rapidly so pilots need to stay aware of the latest features and changes to previously understood menus, formats, protocols and pages. The WST is a very capable but quantity and location limited motion and visual flight simulator. The RDS greatly expands the potential of training aircraft changes and allows for more quality time in the WST by moving time consuming tasks out of the WST to the RDS. The flexibility of the RDS allows the pilots free-play time to conduct "what-if" scenarios or to rehearse WST or real mission scenarios.

SYSTEM REQUIREMENTS

Training needs and costs led to the development of a new flight simulator. The characteristics of this new simulator include:

1. It must provide training for new aircraft changes and multiple aircraft configuration training.
2. It must require minimum pilot workload to set up a mission
3. It must allow free-play.
4. It must allow inter-cockpit crew coordination for formation flight and therefore requires the incorporation of Distributed Interactive Simulation (DIS) or High Level Architecture (HLA) technology.
5. It must be low cost for development, operation and maintenance. Therefore it must use low cost standard commercial off-the-shelf equipment and software packages with zero to minimum run time license fees.

To fulfill these objectives, the Air Force and industry partners have developed a transportable Personal Computer (PC) and SUN System Computer (SUN) based, real-time, pilot-in-the-loop Re-configurable Desktop Simulator (RDS).

An example of the re-configurable simulator has recently been delivered to the C-17 Aircrew Training System at three locations – Altus AFB, OK, Charleston AFB, SC and McChord AFB, WA. Future locations are anticipated. The C-17 ATS provides services for a realistic multi-position training capability on all C-17 aircraft configurations in the Air Force inventory starting with a block developed in 1999. This service, Multi-Configuration Concurrency Training (MCCT) uses the Re-configurable Desktop Simulator (RDS), a contractor owned device. The RDS will enable the aircrews to train and maintain proficiency on a fleet with multiple aircraft block configurations and will include visual presentations, simulated avionics controls and displays, and generic throttles and control sticks. The RDS design provides the capabilities for the pilots to train together or separately on the same or on different block configurations. The students will be able to train in either an instructor led or a non-supervised environment.

The RDS encompasses several USAF and FAA approved laws of learning. These include readiness, exercise, primacy, intensity and recency. By interacting with simulated cockpit panels associated with aircraft upgrades, simulating flight and interacting with the current and new Operational Flight Program (OFP) software, the user will acquire the desired knowledge and proficiency level for advancement to the next higher fidelity trainer, or, even qualify for aircraft operations depending on the level of difficulty. The RDS complements and provides continuity with other training devices.

RDS operation involves two stages of learning. In stage 1, student training includes initial login and an automated "first time" scenario to learn about selecting mission scenarios, airfields and loading flight plans. As proficiency advances the level of possibilities in training also advance. This includes flight profiles for airland and system specific profiles for Global Air Traffic Management (GATM), Traffic Collision Avoidance System (TCAS), Terrain Awareness Warning System (TAWS) and future changes.

In advanced RDS operation, the user attains a level of proficiency that allows for more effective use of the Free-Play and fidelity features of the training device. This permits "what if" scenarios for airland, air refueling, formation and airdrop profiles. This level addresses pilot/copilot Phase Training, Retro Training and self-improvement training environments. The graphical user interface (i.e., Windows like) approach best achieves the desired learning outcomes with the least cost and greatest training efficiency.

Photo 1

This RDS is flying in Dual Mode that is split cockpit or two separate aircraft. The instructor at the rear station (3rd seat) can make inputs to both mission scenarios

DESIGN SOLUTIONS

Hardware

The RDS design is a dual pilot/copilot station (see photo 1). The station consists of five flat touch screen monitors controlled by three PCs.

1. One pilot screen with Multi-Function Displays, also called Head Down Displays and COMM/NAV Control, one copilot screen with the same.
2. One shared screen in the center which contains the automatic flight control system panel with other glare shield displays,
3. One pilot/copilot screen placed horizontally in the middle with Mission Computer Display, Multi-Function Control, Mission Computer Keyboard arrangements and the Air Drop System panel.
4. One center pedestal communication screen for 3rd Seat operations (login, mission and communication setup, and Ground Earth Station (GES) and Defensive System panels).

The RDS Out-of Window Displays use two 42-inch plasma flat screens, each controlled by a single PC. The Out-of Window visual includes terrain, airfields and flying models overlaid with Head Up Displays.

The servers for this system are two Sun workstations capable of providing the speed and capacity for future upgrades.

An intercom system facilitates crew coordination and Central Aural Warning System (CAWS) annunciations. Each seat has its own CAWS input, which is selectable for headset or speakers. The system consists of speakers, headsets, switch boxes and pilot/copilot/instructor controls.

Six C-17 RDS trainers and one prototype RDS station have been delivered. Two RDSs have been installed at each site (Altus, Charleston and McChord Air Force Bases) and the prototype is located at Long Beach, CA. Primary technical support for the RDS resides with Boeing Airlift and Tanker Simulation at Long Beach. A&T Simulation designed and developed the RDS and all of the subsequent block upgrades using the prototype.

Photo 2 shows the RDS with the pilot and copilot setup in the single aircraft block configuration. At the time of student login, each student has the option of selecting the aircraft block configuration they wish to use for training. With the RDS in a split (dual) configuration it is possible for one student to be in one block configuration and the other in another block configuration.

Photo 2

RDS in single mode or single ship configuration meaning both pilots are flying in the same aircraft

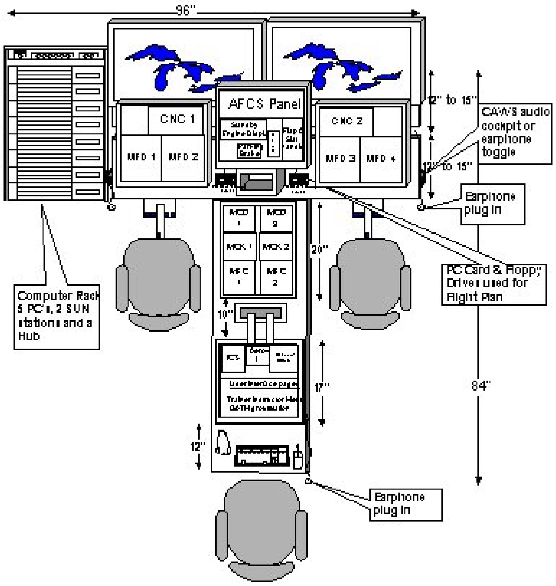

Figure 1
Components of the MCCT Re-configurable Desktop Simulation

Software

Software for the RDS consists of C-17 flight simulation and communication databases used by the actual C-17 aircraft and commercial software to run the out-of-window terrain graphics and other displays. With the exception of the C-17 specific software, the software used by the RDS is Commercial Off-The-Shelf (COTS), such as Windows 2000 and MultiGen Creator Pro. The simulated panel displays and Operational Flight Program (OFP) will be upgraded with each aircraft block upgrade.

Commercial Off-The-Shelf Software

The following COTS software packages are required for the development of the C-17 RDS software:

1. Microsoft Windows 2000, and Sun's Solaris 6.0
2. Microsoft Development Studio with Visual C++ 4.0 and FORTRAN PowerStation 4.0
3. MultiGen Creator Pro
4. TerreX's TerraVista
5. Development and runtime GVS Licenses

RDS Software

The RDS software includes:

1. Software for the aircraft (C-17) aerodynamics and flight controls,
2. Software for cockpit panel displays and controls,
3. Software for trainer scenario generation and activation.
4. Software for the Earth Ground Station
5. Software for the aircraft (C-17) Core Integrated Processor and Communications Control Unit operational flight programs.

DYNAMIC RDS FEATURE

Out-of-Window Terrain

Many features came out of the development of the RDS. One of which is the low cost in generating out-of-window terrain. The terrain is generated using the satellite imageries mapped on to the Digital Terrain Elevation Data (DTED) level 1 via a commercial off-the-shelf software package. This image generation can be done within a few hours up to a few days dependent on the image size. The images are then rendered at run-time via commercial off the shelf inexpensive PC graphic cards. In the course of the development, we found that we are able to generate and render generic images during a training session wherever we have DTED data, which gives us worldwide coverage from +80.0 degrees to –80.0 degrees latitude. A generic terrain is a terrain of brownish or greenish color on a DTED level 1 wire frame that looks like solid ground. We also found that we were able to load satellite image terrain while we are flying a different image terrain. This rendered a continuous although not seamless terrain from one airfield to another for the entire training session, such as the entire Afghanistan area on the current RDS.

The RDS uses the National Image and Mapping Agency's (NIMA) worldwide navigational aids, airports, runways and obstacle databases to enable worldwide coverage. These databases are updated yearly to ensure their currency. In designing the training session to have the ability to cover all airfields anywhere in the world, the RDS developed the "Anytown" airfield visual object and the capability to lay this object on the generic terrain at that region. However, this capability is not yet perfected. The problem being that the area required for the "Anytown" airfield may be on uneven terrain. In the beginning of this development, the generic airfield object was on a "never-never land"[i] terrain. Currently, the "Anytown" airfield lies evenly at the highest point within the airfield object area. This sometimes gives the unrealistic look of a floating airfield and occasionally the aircraft will be initialized under ground. We are currently working on an acceptable solution, such as generating the generic terrain outside of the anywhere airfield object area.

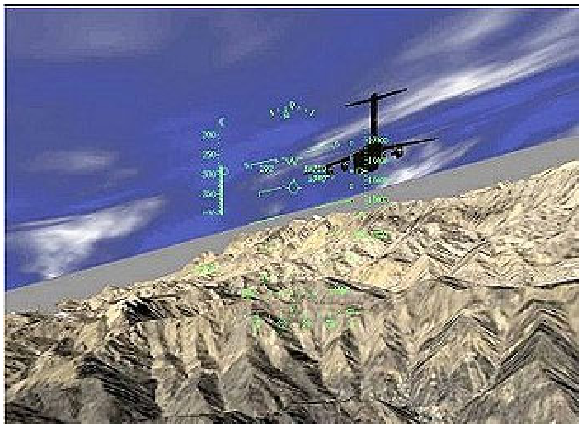

Photo 3
Flying Formation in Afghanistan

Cockpit Graphic Display

The RDS uses PC Based Open System Graphical Language (OpenGL) for the implementation of all of its cockpit displays. In doing so, the RDS is able to take advantage of technology advancement on the newest PC based graphic cards both on cost and on performance. Since OpenGL is supported on most if not all PC graphic cards, no runtime license fee is involved. The OpenGL along with the PC Window technology enables the RDS to underlay the DTED terrain presentation in relation to the position of the aircraft in its Multi-Function Displays as part of the Terrain Awareness Warning System (TAWS). This incorporation of layers for display together with the Distributed Integrated Simulation (DIS) technology paves the way for the future Real-Time Information in the Cockpit[ii] System (RTIC) into the simulators. Because of the open system design and the Windows technology, the RDS was also able to incorporate the Ground Earth Station (GES), a Visual Basic and C++ software package, into the RDS as part of the Global Air Traffic Management (GATM) aircrew training[iii]. We were able to modify the GES package to obtain a much more user-friendly interface for both the instructor/3rd pilot as a GES operator and the pilot because the software is one of our company's products.

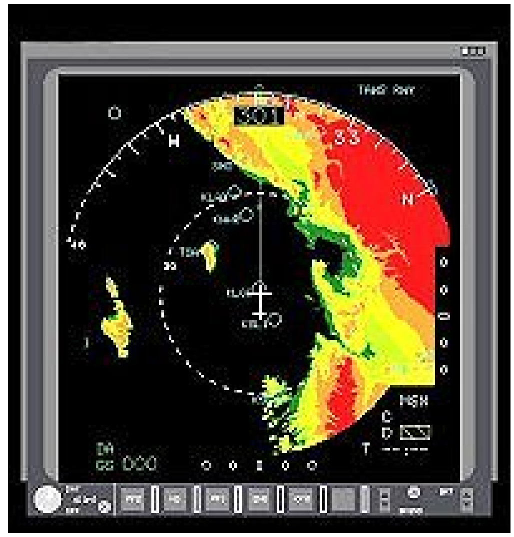

Photo 4
DTED terrain presentation (TAWS)

Photo 5
Digital map with enemy radar (RTIC)

Distributed Integrated Simulation (DIS)

The RDS flight simulator is configured as a LAN with distributed open system design via TCP/IP, UDP/IP protocols using PC and Sun workstations. It was logical and painless to incorporate the DIS protocol into the architecture of the system. In doing so, the RDS offers flight crew inter-cockpit coordination training in formation, airdrop and air-refueling rendezvous mission scenarios. Pilots on the same or different aircraft configuration can fly together in a single formation mission. In the future, different types of aircraft will be able to fly together in a formation mission. Entering an exercise number and pressing a 'Link Enable' button currently enable this capability. The pilots who wish to be in the same training session determine the exercise number, and the 'Link Enable' button allows the pilot to join and/or to separate from the mission. This capability together with the World Wide DTED terrain and "Anytown" airfield allows the formation members to fly the mission rehearsal prior to a real mission. This capability was demonstrated by the C-17 aircrews flying formation airdrops on the RDS using satellite imageries of Afghanistan as the out-of window visual terrain.

Formation Leader playback

The RDS enables data logging of the aircraft's position and formation command information into a file while the pilot is flying the formation mission. The pilot can then copy this file to his floppy disk or PC Card. This file can later be played back on any RDS station as a simulated formation leader and enables the pilots to fly any position in the formation. This capability enables the pilot to fly as his own wingman or element lead for evaluation purposes. It also enables the lead pilot to send the file by email to his aircrews to practice the mission at their own convenience on any available RDS prior to a real mission. The instructor can also store these files inside the RDS to be evoked by a student pilot for training. Entering a file name and pressing the recording button records the formation lead playback file. Selecting a drive and pressing the "save" button saves the recorded file to the selected drive. Selecting a playback file and pressing the "playback" button enables the playback of that file.

Random Traffic Alert and Collision Avoidance System (TCAS) Training Scenarios

The RDS contains a set of selectable traffic collision scenarios for the TCAS training. The RDS is designed to allow random selection of these scenarios during a training session. The scenarios are built around many types of aircraft and many flight variables such as airspeed, altitude, altitude rates and angles of intercept. The out-of-window display shows the aircraft and the pilot must take the corrective action commanded by the TCAS system to avoid collision. The pilot or the instructor is able to specify the number of traffic cases he or she wants to encounter within a given period, e.g. 3 cases within 30 minutes during a training session. The pilot will then proceed with that training session and the RDS software will randomly select three scenarios from the many predefined scenarios at random intervals within the 30-minute session.

Multi-Configuration

The RDS is designed for single and dual aircraft configurations using the same station equipment. This capability allows one pilot to fly one block configuration of the aircraft with one scenario while the other pilot flies the same or a different block configuration on the same or different scenario simultaneously. This feature is made possible by allowing pilots to log into the RDS via the seat he is going to use on the RDS. The RDS allows the left seat pilot to select the station configuration to be single or dual aircraft in addition to aircraft block configuration. It only allows the right seat pilot to select the aircraft block configuration if the left seat pilot selected the dual aircraft configuration for the station.

Photo 6

RDS configured as a single aircraft

Photo 7

RDS Configured as a dual aircraft

Each instructor and pilot is issued a user name and 4-character alphanumeric pin identification. This user name and pin enable the users to log into any RDS on any site. The RDS automatically logs the user name, time, flight duration and configuration of the training session for each mission. The logged data can be compiled and analyzed to determine trainer utilization.

Speeding through or repeating a portion of the training session

The RDS offers two features that enable the student to quickly fly through non-eventful portions of the flight plan, such as flying over the Atlantic Ocean. The student is able to speed up the aircraft to a ground speed of 3000 feet per second by pressing the “speedup” button, and come back to normal speed by pressing the “normal speed” button. The student is also able to touch the navigation map on the MFD, and press a button to reposition immediately to that touched location and continue the mission. The RDS also offers the snapshot feature that enables the student to repeat a portion of his training session. The aircraft’s present attributes, such as the aircraft’s location, total weight, total fuel, payloads, etc., are saved every time the snapshot button is pressed. The student can then activate one of the saved snapshot case at a later time and restart the training at that location with the saved aircraft attributes.

HTML Web Based Help page On Station and at Website

Most of the computer systems on the RDS are PC systems including the host computer. The current operating system used on these PCs is Microsoft Window 2000. Because of this, it was easy to imbed the Microsoft Internet Explorer software features within the RDS at many levels. The RDS uses the HTML technology via the Microsoft Internet explorer to display flight plan information, route maps and airport/runway diagrams to the pilot. It also allows the pilots and instructors to display and maneuver through the help manual and Frequently Asked Questions section to aid the training session. These HTML help pages are on the station and accessible during training sessions. There is an RDS website on the internal Boeing network where RDS documents and software releases can be downloaded and the Help and RDS related information can be viewed.

RDS LIMITATIONS AND LESSONS LEARNED

RDS Limitations

There are a few limitations with the RDS when it is compared with the hardware flight simulator. One of which is the aircraft’s mechanical control, such as the stick control for pitch and roll, the rudder control for yaw and the engine throttle control for thrust. For example, on the C17 RDS, twisting the control stick simulates the rudder control. On the C17 Aircraft, foot pedals control the rudder. The positions and the types of the buttons on the control stick are specially made to match the real stick buttons on the aircraft and their functionality. Other buttons are added to activate aircraft functions such as reverse throttles, speed brakes, etc. They are placed around the control stick and throttle. Reverse throttle is enabled on the C17 aircraft by pulling up the throttles and moving them back. Pressing a button simulates this function on the C17 RDS trainer station. Also on the RDS, the back drives for the stick or the throttle during autopilot control are not simulated. In the aircraft each engine has its own throttle control, but in the RDS a single throttle controls all the engines. Because of this limitation and the not yet perfected vortex turbulence simulation, the RDS is not yet able to offer aerial-refueling training.

Another limitation is the ability of the RDS to process large amounts of data for display in real-time. We currently display an 80 nm area of DTED Level 1 data on the MFD for the TAWS display, while the aircraft is displaying 320 nm area of data for the same function. However, this limitation may be overcome by the advancement of PC technology.

Finally, the RDS is not designed to replicate aircraft malfunctions; therefore, it cannot be used to train emergency procedures.

Flight Instructor and Student Pilot Comments

Since the initial deliveries in 2001, comments and reports have been with ways to improve on the initial design and operating system. While the initial deliveries operate with touch screen flat panel displays, some operators have had some problems adjusting to parallax errors from sitting too far from the screens. The touch screens are equipped with pop-up keyboards for entering data conveniently and the user received this feature very favorably. Also, the system is still upgrading with a schedule that includes formation, linking and block operating system upgrades. This means that the software is still new and developing on a continual basis.

Occasional unstable situations have been quickly resolved through the collaboration of the engineering team and the lead pilot instructor integration team member.

Lessons Learned

Periods for review of lessons learned on the RDS have been pre-programmed into the overall system upgrades and integration. To date lessons learned have involved the following:

1. Familiarity for the instructor operators has been a continuous challenge. In some cases this is due to parts obsolescence and in other cases due to new mission requirements and additional enhancements like Traffic Collision Avoidance System, Terrain Awareness and Warning System and formation avionics upgrades. In most cases these result in changes to the training program. Instructors have requested simplified, compact lesson start up scenarios so the instructor and student can get into the training faster. One of the solutions for this has been the development "Quick Start Checklists", design improvements by consolidating menu options, and close attention to how the instructors are trained in operating the RDS.
2. Anytime a new system is integrated into an already established system there is curiosity as well as some hesitation on the parts of the members of the organization. While this was the case in the first several months of operation, the success of the RDS during Operation Enduring Freedom (Afghanistan) with airfield familiarization has accelerated acceptance and added interest in new applications. Two of these applications are communication simulations like Controller Pilot Data Link, which uses the Ground Earth Station feature of the RDS, and formation linking of RDS to RDS.
3. Guides and abbreviated guides have been developed for students and instructors. While there have been emphasis on on-screen menus and simplified user interfaces, instructors and students have also requested simple step-by-step printed instructions. With all that is occurring to the actual aircraft and other enhancements in computer based training, written procedures continue to be a preferred memory aid for the RDS users.
4. Each instructor has had opportunities to practice with the new RDS features prior to working with students. Following some initial reluctance by some instructors to learn a new device, user feedback has been positive and emphatic on future further incorporation of the RDS into the training curriculum. A C-17 Aircrew Training System (ATS) RDS Integrated Product Team (IPT) has been created to migrate carefully selected training material onto the RDS to take advantage of specific fidelities like the out-of-window display, OFP functions and interaction with the flight management and communication systems.
5. Valuable insight among the engineering and aircrew integration teams has led to more successful integration upgrades. Like many new first time devices, the RDS has experienced discovery in the areas of on-screen displays. As a result, touch screen fields have been optimized to fit large fingers and instant feedback was improved by highlighting the buttons as they are pressed. Growth in memory and operating capabilities was envisioned with the initial design and several upgrades like the addition of terrain data for selected airfields around the world have been added with relative ease. Lessons have been learned about the acquisition of digital terrain databases that will prove valuable for future additions.
6. Good communication among the integration team members has proven effective in dealing with limitations that result from the RDS simulations and its functions as a part task trainer. A blend of software and mechanical engineering expertise and pilot expertise has helped to deliver requested fidelities and increased the potential for expansion in areas such as out-of-window displays, open architecture communications, and future information rich platform/network-centric type arrangements.

The Most Essential Criteria in developing a Training Simulator

The most important thing we learned in developing the RDS is the benefits we reaped from our endless prototyping sessions we held between the software developers, the instructors and the experienced pilots of the given aircraft. The more these sessions were conducted, the more useful of the simulator. We have found that although not everyone agrees on the best presentation on the pilot interface or on the activation of a training scenario, by presenting all suggestions to the different levels of users and having them actually touch and feel their suggestion in prototyping sessions we were always able to come to an agreeable and better solution. We found that the results are always worth the time required to prototype the suggestions. In the development journey of the RDS, we have found that our instructors and our pilots are the foremost important partners on our team; it is their visions and their commitments that made the RDS useful, usable, and sought after in the fields.

FUTURE OUTLOOK

As the RDS continues to prove itself and the aircraft fleet continues to grow, more RDSs are envisioned to meet the additional training requirements. Besides demonstrating the latest block upgrades, the RDS has value of as a part task trainer in the formal school for beginning students to use the combined fidelities of the flight management system. Students learn the various autopilot heading, altitude and airspeed modes and flight profiles. This Training also combines autopilot and mission computer operations for following a computer generated flight plan that includes automatic airspeed adjustments to arrive over a selected point at the programmed flight plan, time, altitude and airspeed. These features along with several others have drawn interest to other areas of use not originally planned, yet very important to the latest Air Force missions.

The RDS can easily load digital terrain data for selected areas of interest. This allows using the RDS for terrain familiarization and theater flying procedures in the learning environment. There is also interest in deploying RDSs to forward operating bases for concurrency training and mission familiarization rehearsals. The current RDS is easily deployable and because the hardware is "commercially off the shelf" equipment, it has proven to be very reliable. Besides deploying the full-size (three station) RDS, a new concept is in design for a "suitcase RDS" that will accompany each aircraft for aircrew training and avionics maintenance analyses.

As the War on Terror continues, there are many possibilities for expanding the number of airfield databases. This feature has proved valuable for real world mission requirements.

Yet another function of the RDS is as a training platform for future air navigation procedures and pilot techniques used in Global Air Traffic Management (GATM) also known as Future Air Navigation System. Using the RDS, pilots, engineers, and other interested team members can demonstrate cockpit task management in the new GATM environment. The built-in third seat design allows an operator like an instructor or third pilot to function as a ground earth station operator. From this position, the operator can send signals to the crew who then reacts to communications from the ground earth station.

CONCLUSION

The RDS is a new training concept for airlift, tanker as well as other aircraft. It fills a role that developed when simulator resources became limited and aircraft block configurations became numerous. It is an inexpensive quality-training platform that meets the current needs of our airlift fleet. The RDS will continue to develop and mature as training requirements change to meet real world challenges.

[ii] Real-Time Information in the Cockpit (RTIC) is a system to depict weather conditions, area map, enemy weapons and troop locations via satellites or spy aircraft in real-time to the crew.

[iii] The personnel on the ground use the GES to communicate with the aircrew in flight both by voice and by data.

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