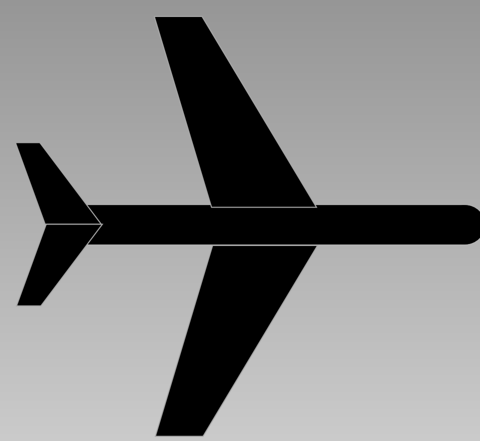
Flight Simulation
Year in Review
FY99

Foreword

This document is the Fiscal Year 1999 Annual Performance Summary of the NASA Ames Vertical Motion Simulation (VMS) Complex and the Crew Vehicle Systems Research Facility (CVSRF). It is intended to report to our customers and management on the more significant events of FY99. What follows are an Executive Summary with comments on future plans, the FY99 Simulation Schedule, a projection of simulations to be performed in FY00, performance summaries that report on the simulation investigations conducted during the year, and a summary of Technology Upgrade Projects.



Aviation Systems Research,
Technology, & Simulation Division
NASA Ames Research Center
Moffett Field, California 94035

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Acknowledgment

Special thanks to Tom Alderete, Dave Astill, Dave Carothers, Girish Chachad, William Chung, Ron Gerdes, Scott Gilliland, Jennifer Goudey, Joe King, Scott Malsom, Julie Mikula, and Terry Rager for contributions made to the production of this document.

About the Cover

Front cover: The Vertical Motion Simulator plays a vital role in the ongoing development of the Space Shuttle. The first experiment at the VMS simulated the Space Shuttle orbiter in 1981. Recently, the VMS demonstrated its many years of contributions to the Shuttle program at the first annual Space Shuttle Development Conference, including a display of remote laboratory technology. (For more information, see pages 16, 20, and 34.)

Back cover: The Advanced Concepts Flight Simulator examined a system for improving the safety and efficiency of airport surface operations in low visibility. This cockpit navigation and guidance system displays taxi routes on both an electronic moving map and a head-up display. (For more information, see page 33.)

Table of Contents

Executive Summary

This Annual Report addresses the major simulation accomplishments of the Aviation Systems Research, Technology, and Simulation Division of the NASA Ames Research Center. The simulation facilities, contained in two separate buildings at Ames and operated by this division, consist of the Crew-Vehicle Systems Research Facility (CVSRF) and the Vertical Motion Simulation (VMS) Complex. The CVSRF is comprised of a FAA certified Level D Boeing 747-400 simulator, the Advanced Concepts Flight Simulator (ACFS), and an Air Traffic Control (ATC) Laboratory. The VMS Complex is comprised of the Vertical Motion Simulator (VMS), five Interchangeable Cockpits (ICABs), and two fixed-base simulation labs. A brief description of these facilities is included in the Appendix.

From a management perspective, Fiscal Year 1999 was dominated by several important events. First was NASA's continuing efforts to move towards full-cost accounting. This activity continues to lead SimLab to streamline and reduce facility operations costs. Another event was the Center's achievement of ISO 9001 Certification. SimLab, which was independently certified in May 1998, began efforts towards joining the Center's ISO Certification in November of this year. A third significant event is a SimLab organizational transition that is just beginning. In addition to changing the organization structure of SimLab, the division will be renamed the Aviation Systems Division (AF). The final management and operational change has been the transition to a new Performance Based Contract. Logicon Information Systems & Services was awarded the contract last year, began transition in December 1998, and assumed full service in January. This has involved a significant learning effort by all of the SimLab staff as this new contract is task-order based.

In addition to these activities, paramount to SimLab operations has been the continuing commitment to uncompromising excellence in the development and production of efficient, high-fidelity, safe, real-time piloted flight simulations. SimLab has also continued to aggressively modernize in order to maintain reliability, our competitive edge, and our responsiveness to users' needs. The staff places very high value on customer relations and has successfully provided highly responsive, cost-effective, value-added simulation support to all customers.

The purpose of this document is to briefly describe our accomplishments of the past year. Its outline includes the Executive Summary, Simulation Schedule for FY99, Planned Projects for FY00, VMS Project Summaries, CVSRF Project Summaries, and Technology Upgrade Projects. The Project Summaries sections state the goal of each simulation and present high-level results. Researchers and pilots from NASA and private industry are identified as well as simulation engineers from the staff. The Technology Upgrade Projects section reports changes made in order to keep our simulation facilities state-of-the-art. Finally, a List of Acronyms is included for the reader's convenience.

Notable accomplishments for FY99 include the following:

All simulation experiments conducted at Ames support significant research that is responsive to the needs of the nation with a focus on applied aeronautics research. Diversity, fidelity, and breadth of simulation distinguish the research projects conducted at Ames, as can be seen by reviewing the Project Summaries sections of this report.

There were twenty-one major simulation experiments conducted in the flight simulation laboratories in FY99.

Technology upgrade projects for the past year include:

Projects at the CVSRF automated the process of updating many records in the ACFS navigational databases and upgraded the ACFS Flight Management System to support advanced terminal approach procedures. A visual database was developed for envisioning an aircraft's flight through the Martian atmosphere. Finally, extensive Year 2000 preparation included an upgrade to the B747-400 simulator software, evaluation of two candidate systems for upgrading the ATC Laboratory, and modernization of networking equipment, computers, and operating systems throughout the facility.

Several VMS upgrade projects were completed or reached major milestones. The VMS Modernization project, which will ultimately increase the reliability and performance of the VMS, continued progressing as the preliminary engineering study and the detailed Maintenance Requirements Documentation phases were completed. Highlights of the Virtual Laboratory project include the first deployment of a desktop client that allows researchers to participate in VMS experiments from their own desktop computer systems, and the highly successful deployment at the Space Shuttle Development Conference. A new Remote Development Environment was developed and delivered that promises to reduce the time and cost of developing research experiments at remote sites prior to full VMS simulations. Also, a Rapid Integration Test Environment project developed and implemented procedures and infrastructure to facilitate importing aeronautical data from other research facilities into VMS simulations, enabling reduced aircraft development cycle time and costs.

Some future plans:

All of the simulation facilities continue to be in high demand. There is a full list of projects for FY00 that build on past research efforts and bring some new activities as well.

VMS Plans a major upgrade, a Modernization Project, to convert from analog to digital, the VMS drive power and controls. Hands-on work is scheduled to begin in FY02. The goal for FY00 is completion of the design and planning phases. The VMS will upgrade its host computer systems to meet increasing demands of our simulation customers. In turn, the real-time executive program will be upgraded to support the newer versions of OpenVMS run on the DEC Alpha systems we will acquire. The Video Switch will be upgraded to handle ever increasing device and bandwidth requirements.

The CVSRF will continue to search for new and innovative ways to help researchers study the interaction of the flight crew with the aircraft and flight environment. With an upgrade to its host computer, the ACFS will join with the ATC Laboratory and 747-400 simulator with increased capability to connect to others such as the VMS, the FAA Tech Center and the Future Flight Center. This interoperability with other world-class facilities can foster multifaceted real-world simulations maximizing the utility of each simulator while optimizing time and resources.

We will continue our tradition of supporting mainstream NASA and national aeronautical development programs, being second to none in state-of-the-art real-time simulation and enabling technologies. Automated tools for simulation and modeling, improvements in graphics and displays, and efficient computational environments are other continuing efforts.

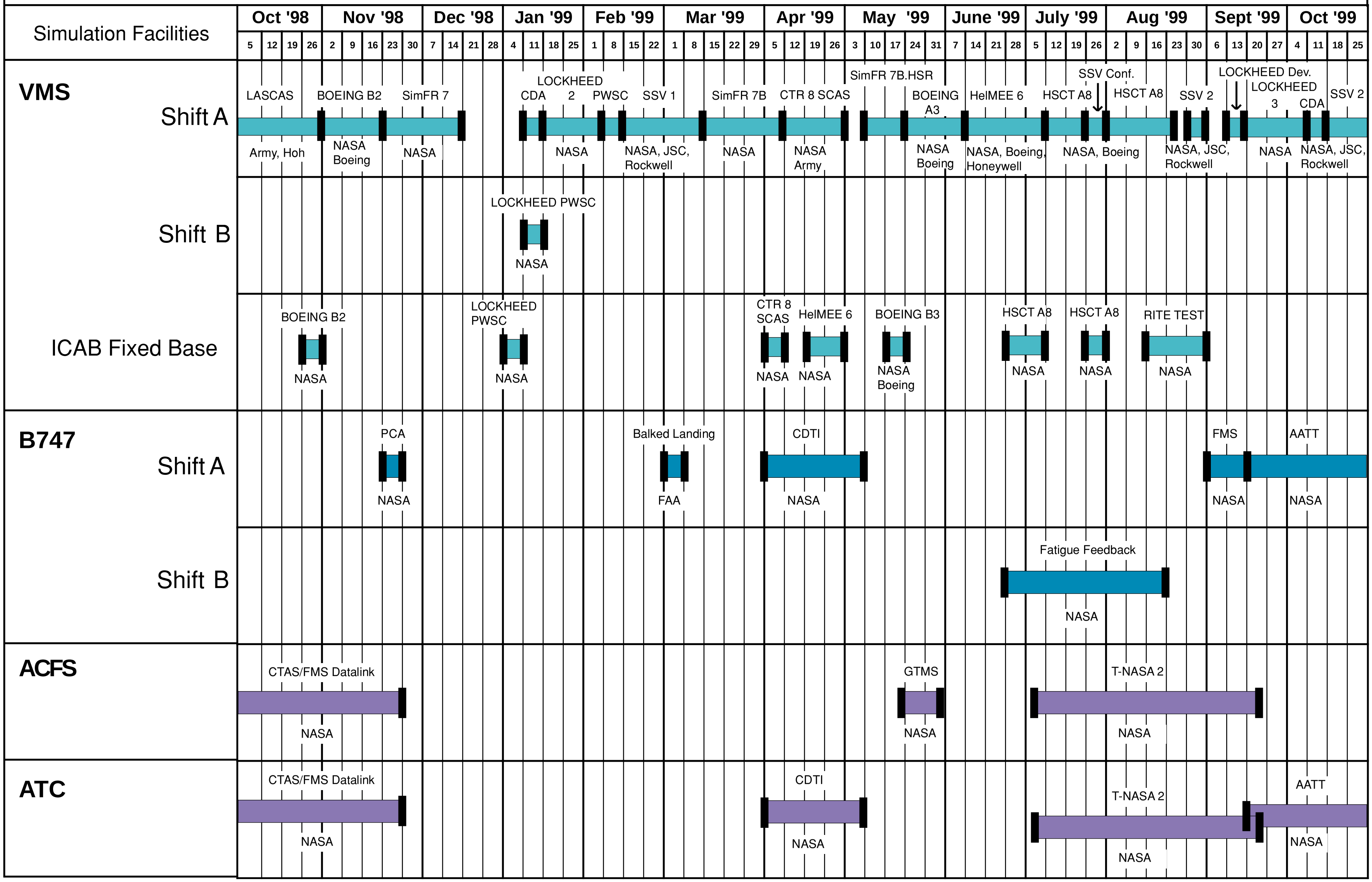
In addition, significant efforts continued in planning the VMS Modernization project currently scheduled for FY02. The project will replace obsolete mechanical drives and control equipment with state-of-the-art systems. When complete, the VMS will set the standard for cost-effective, high-performance, reliable motion-base simulators.

A. David Jones

Associate Chief-Simulations
Aviation Systems Research, Technology, & Simulation Division

Simulation Experiments Branch
Aviation Systems Research,
Technology, & Simulation Division
Ames Research Center

FY99 Simulation Schedule



FY99 Project Summaries

VMS Flight Simulation Projects

1. Limited-Authority Stability and Control Augmentation System (LASCAS)
Sept 24–28, Oct 5–30 (VMS)
Aircraft type: UH-60 Black Hawk helicopter
Purpose: To investigate a flight control system designed to improve helicopter operations in degraded visual environments.

2. Boeing B2
3. Boeing A3
Oct 26–30, May 17–21 (FB);
Nov 2–20, May 24–June 11 (VMS)
Aircraft type: X-32 Joint Strike Fighter
Purpose: To support Boeing's design and development of the X-32 and to advance NASA-sponsored research.

4. Simulation Fidelity Requirements (SimFR) 7
Mar 15–Apr 9 (VMS)
Aircraft type: Generic helicopter and jet
Purpose: To confirm the fidelity criteria for roll-lateral motion in simulation and to take data for investigating pitch-longitudinal motion.

5. Lockheed Martin CDA
6. Lockheed Martin 2
7. Lockheed Martin PWSC
8. Lockheed Martin 3
Jan 4–15, Sept 13–17 (FB);
Jan 11–Feb 12 , Sept 20–Oct 15 (VMS)
Aircraft type: X-35 Joint Strike Fighter
Purpose: To support Lockheed's design and development of the X-35 and to advance NASA-sponsored research.

9. Space Shuttle Vehicle (SSV) 1
Feb 15–Mar 11 (VMS)
Aircraft type: Space Shuttle orbiter
Purpose: To investigate control-surface rate limits and trim switch conditions and to provide astronaut training.

10. Civil Tiltrotor (CTR) 8 SCAS
Apr 5–8 (FB); Apr 12–30 (VMS)
Aircraft type: XV-15 tiltrotor
Purpose: To evaluate two stability and control augmentation systems and to evaluate flight profiles for noise abatement.

11. Helicopter Maneuver Envelope Enhancement (HelMEE) 6
Apr 19–30 (FB); June 14–July 9 (VMS)
Aircraft type: UH-60 Black Hawk helicopter
Purpose: To investigate flight-envelope limits and their communication to the pilot using side-stick controllers.

12. High-Speed Civil Transport (HSCT) A8
June 28–July 9, July 26–30 (FB); Aug 2–23 (VMS)
Aircraft type: High-speed civil transport
Purpose: To measure the handling qualities of the current design of a supersonic passenger airplane and to finalize flight-control standards.

13. Space Shuttle Vehicle (SSV) 2
Aug 30–Sept 3, Oct 18–Nov 5 (VMS)
Aircraft type: Space Shuttle orbiter
Purpose: To provide training in orbiter landing and rollout for astronauts and astronaut candidates.

VMS Technology Upgrades

1. Virtual Lab (VLAB)
Purpose: To enhance the capabilities of a system that enables remote researchers to participate in live experiments at the VMS.

2. Remote Development Environment (RDE)
Purpose: To create an engineering environment for researchers to develop VMS-compatible simulation models at their own sites.

3. Rapid Integration Test Environment (RITE)
Purpose: To develop the procedures and infrastructure necessary to import aeronautical data from research facilities directly into the VMS.

4. VMS Modernization
Purpose: To increase the reliability and maintainability of the VMS by replacing major system elements.

FY99 Project Summaries

CVSRF Flight Simulation Projects

1. CTAS/FMS Data Link
Sept 29–Nov 27 (ACFS)
Purpose: To evaluate a concept for integrating CTAS with the Flight Management System for operations in terminal airspace.

2. Propulsion Controlled Aircraft (PCA) Ultralite
Nov 23–27 (B747)
Purpose: To evaluate a low-cost, fly-by-throttle control system as a backup to an airplane's primary flight control system.

3. Balked Landings
Mar 1–5 (B747)
Purpose: To examine large air-carrier flight tracks and height-loss arrest points during crew-induced aborted or balked landings.

4. Cockpit Display of Traffic Information (CDTI)
Apr 5–May 7 (B747)
Purpose: To evaluate the interaction of flight crews and Air Traffic Control in the presence of a CDTI.

5. Fatigue Feedback
June 28–Aug 20 (B747)
Purpose: To evaluate the effectiveness of fatigue-related feedback on flight-crew performance and to assess a system for the detection of drowsiness.

6. Taxiway Navigation and Situation Awareness (T-NASA) 2
July 6–Sept 22 (ACFS)
Purpose: To evaluate the use of a head-up display and an electronic moving map to improve airport surface operations.

7. FMS Departure Procedures
Sept 6–17 (B747)
Purpose: To evaluate FMS departure routings in executing departure legs coded in conformance with ARINC 424 standards.

8. Integrated Tools/Air-Ground Integration (AGIE)
Sept 20–Jan 27, 2000 (B747)
Purpose: To evaluate air-ground integration procedures and to collect data pertaining to users of the ground system and on the flight deck.

CVSRF Technology Upgrades

1. Navigational Database Upgrade
Purpose: To create an automated process for compiling updated navigational databases for the ACFS.

2. CVSRF Year 2000 (Y2K) Compliance Upgrades
Purpose: To upgrade networking equipment, computers, and operating systems for Y2K compliance.

3. Air Traffic Control (ATC) Upgrade
Purpose: To evaluate the Pseudo Aircraft System and Route Traffic Manager as possible upgrades to the ATC Laboratory.

4. Martian Airplane Visualization
Purpose: To create a virtual-reality visualization of a probe's flight through the Martian atmosphere.

5. Flight Management System Upgrade
Purpose: To provide the capability to support advanced terminal approach procedures using curved segments and a variable final approach length function.

FB—Fixed-Base Simulators
VMS—Vertical Motion Simulator
ACFS—Advanced Concepts Flight Simulator
B747—Boeing 747 Simulator

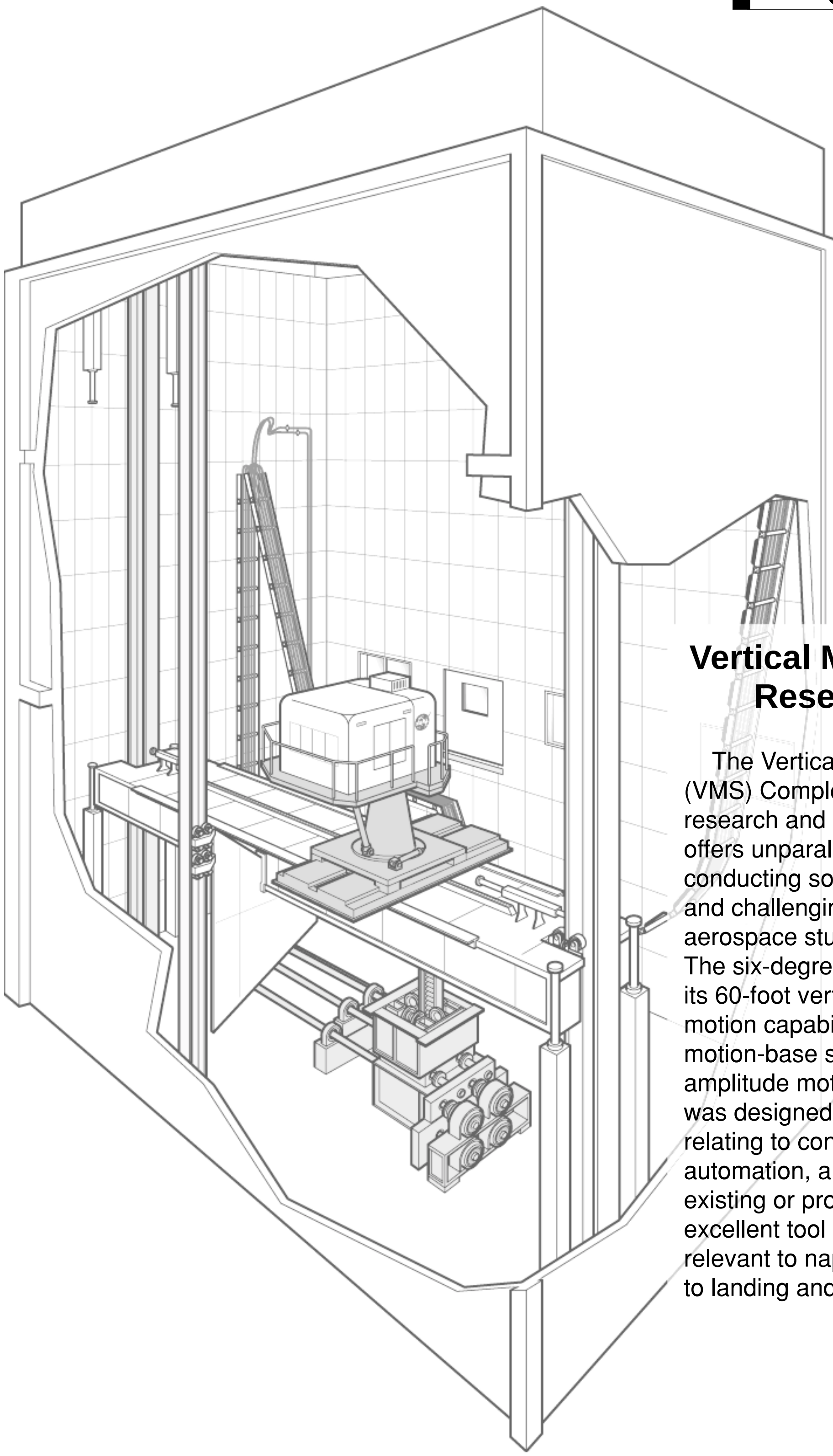
FY00 VMS Simulation Projects

PROJECT	PROGRAM SUPPORTED	CUSTOMERS	TEST OBJECTIVES
Space Shuttle Vehicle 1 & 2 (SSV 1 & SSV 2)	Human Space Flight	NASA Johnson Space Center, United Space Alliance, Boeing, Rockwell	Investigate the Space Shuttle orbiter's landing systems and directional control handling qualities and provide astronaut training. Primary elements of investigation are to investigate the hydraulic systems to support the potential replacement of the current auxillary power units (APUs) and to investigate other guidance and navigation systems.
ASTOVL - Type Vehicle (Advanced Short Takeoff and Vertical Landing)	Department of Defense	NASA, Department of Defense	Evaluate advanced control and display mode operations for STOVL variant aircraft. Operations will include takeoff, transition, hover, and landing at shore-based sites and LHD-class ships.
Joint Shipboard Helicopter Integration Process	Department of Defense	Navy	Support the verification and validation of the Joint Shipboard Helicopter Integration Process (JSHIP) for the Dynamic Interface Modeling and Simulaton Systems (DIMSS) Program.
Rotorcraft Aircrew Systems Concepts Airborne Laboratory	Safe All-weather Operations for Rotorcraft	Army	Support the Rotorcraft Aircrew Systems Concepts Airborne Laboratory (RASCAL).
Auto-Rotation	Army	Army, NASA	Isolate visual system and motion cueing requirements for performing auto-rotation manuevers for helicopter operations.
Army Rotorcraft	Army	Army, NASA	Support the Army and rotorcraft vehicle research in handling qualities, design specification, and advanced concepts.
Civil Tiltrotor 8 Eval (CTR 8B Eval)	Aviation Systems Capacity/ShortHaul Civil Tiltrotor	FAA, NASA	Evaluate XV-15 Tiltrotor side-stick, neural-net control laws, and candidate low-noise approach procedures.
Civil Tiltrotor 9 FMS 1 (CTR 9 FMS 1)	Aviation Systems Capacity/ShortHaul Civil Tiltrotor	FAA, NASA	Investigate airspace integraton issues using full-mission simulation for civil tiltrotor transports operating independently of conventional-takeoff-and-landing runways.

FY00 CVSRF Simulation Projects

PROJECT	PROGRAM SUPPORTED	CUSTOMERS	TEST OBJECTIVES
Pilot Negotiation Issues in Self Separation (747-400)	Advanced Air Tranportation Technologies	Human Factors Research and Technology Division	Evaluate pilot negotiation issues in conducting self separation in a futuristic free-flight environment.
Closely Spaced Parallel Approaches (747-400)	Terminal Area Productivity	Human Factors Research and Technology Division	Evaluate human factors issues in the use of an advanced navigation guidance/avoidance system allowing the ability to conduct closely spaced parallel approaches.
Contoller-Pilot Data Link Communications Interface (747-400)	FAA Data Link	Human Factors Research and Technology Division	Evaluate human factors issues pertaining to the use of pilot-controller data-link communications.
Multiple Parallel Approaches (747-400)	FAA Technical Center	FAA	Evaluate traffic handling capabilities and spacing requirements for running multiple parallel approaches in instrument meteorological conditions.
Flight Procedures Standards I (747-400)	FAA Oklahoma City	FAA	Examine operational issues associated with improving terminal capacity and efficiency while maintaining or improving operational safety.
Flight Procedures Standards II (747-400)	FAA Oklahoma City	FAA	Examine operational issues associated with improving terminal capacity and efficiency while maintaining or improving operational safety.
CTAS Flight Management System Integration (DAG) (ACFS)	Terminal Area Productivity/Advanced Air Tranportation Technologies	Human Factors Research and Technology Division, FAA	Evaluate the integration of advanced air traffic control tools with on-board autoflight systems to improve terminal area capacity.
Intelligent Flight and Propulsion Control System (IFPCS) (ACFS)	Propulsion Controlled Aircraft	Computational Sciences Division	Evaluate alternative flight control technologies for the event that an aircraft experiences a malfunction to its primary flight control system.
Enhanced MarsPlane Demo (ACFS)	Base R & T	Aeronautics Directorate	Investigate enhanced graphical displays of Martian terrain, the MarsPlane aerodynamic model, and Martian atmosphere characteristics.

VMS PROJECT SUMMARIES



Vertical Motion Simulator Research Facility

The Vertical Motion Simulator (VMS) Complex is a world-class research and development facility that offers unparalleled capabilities for conducting some of the most exciting and challenging aeronautics and aerospace studies and experiments. The six-degree-of-freedom VMS, with its 60-foot vertical and 40-foot lateral motion capability, is the world's largest motion-base simulator. The large amplitude motion system of the VMS was designed to aid in research issues relating to controls, guidance, displays, automation, and handling qualities of existing or proposed aircraft. It is an excellent tool for investigating issues relevant to nap-of-the-earth flight and to landing and rollout studies.

Limited-Authority Stability and Control Augmentation System

David Key, U.S. Army AFDD; Robert Heffley, R. Heffley Engineering; Roger Hoh, Hoh Aeronautics; Steve Belsley, Luong Nguyen, Logicon/LISS

Summary

This simulation investigated a flight control system that would enable conventional helicopters to operate with increased safety and effectiveness in degraded visual environments. This methodology, using new flight control software and requiring virtually no hardware changes, will be considered for incorporation into upgrades of the Army's UH-60 Black Hawk helicopter.

Introduction

Limited-Authority Stability and Control Augmentation System (LASCAS) examined a methodology for improving helicopter operations in a degraded visual environment (DVE). In a DVE, such as while using night-vision goggles on a moonless night, pilots have difficulty perceiving fine-grained texture. This is an essential cue for the precise control of attitude and position during low-speed and hover operations. Without this cue, precise control requires intensive workload, leaving little capacity for maintaining situation awareness or for accomplishing tasks.

A simulated flight control system demonstrated improved helicopter handling qualities in degraded visual environments.

A stability and control augmentation system (SCAS) increases a helicopter's stability and enhances the capabilities of its flight controls. A helicopter with a SCAS that achieves attitude command/ attitude hold (ACAH) can automatically maintain its attitude. This significantly reduces the pilot's need to perceive fine-grained texture, which in turn increases safety and frees the pilot to perform other tasks.

For safety, a conventional helicopter SCAS is limited to +/-10% authority, in which the SCAS actuators can move the control surfaces only +/-10% as much as the pilot. This enables the pilot to compensate for system failures. A limited-authority SCAS, however, has not been used to achieve ACAH because the actuators saturate during aggressive maneuvers.

Simulation

LASCAS investigated a methodology for accommodating this actuator saturation. One key is to use a limited-authority SCAS to provide ACAH for modest maneuvers but to remove it for aggressive maneuvers. A scheme was developed to provide a gradual transition between the augmented and unaugmented states. Another key to the LASCAS methodology is to supplement the limited-authority actuators with the trim servo actuator. This introduces additional movement of the stick that the pilot must learn to accept.

VMS simulation engineers replaced the SCAS of the complex Black Hawk simulation model. Night conditions were simulated, and tasks were flown using U.S. Army PNVS-6 night-vision goggles. Six configurations of SCAS were evaluated during four different flight tasks.

The cab, which recreates the cockpit, was usually oriented to provide 40 feet of lateral travel and 8 feet of longitudinal travel. However, for stronger longitudinal cues during one of the tasks, it was rotated 90° to provide 40 feet of travel in the longitudinal direction.

Results

The VMS proved critical in providing accurate cues for the simulation of the flight tasks that are most difficult in a DVE. In particular, the large motion base produced high-fidelity motion cues for low-speed and hover operations. Six pilots flew 1632 data runs for evaluation and 222 check runs for documenting the characteristics of the different SCAS configurations.

Pilot ratings indicated that handling qualities improved significantly using the LASCAS methodology. A preliminary assessment suggests that a limited-authority SCAS can improve handling qualities sufficiently to make the operation of conventional helicopters in DVEs safer and more efficient.

Investigative Team

U.S. Army AFDD
NASA Ames Research Center
R. Heffley Engineering
Hoh Aeronautics
U.S. Navy NTPS
U.S. Army ATTC
Sikorsky Aircraft

Boeing B2, A3

Larry Moody, Paul McDowell, The Boeing Company; James Franklin, NASA ARC; Leslie Ringo, Estela Hernandez, Emily Lewis, Chuck Perry, Ron Gerdes, Girish Chachad, Logicon/LISS

Summary

In the Fiscal Year 1999, two separate simulations were conducted to support the design and development of the Boeing X-32 Joint Strike Fighter. The experiments addressed conventional, carrier, and short-takeoff/vertical-landing (STOVL) operations. They also advanced NASA-sponsored research in guidance systems, display technology, and flight controls for STOVL aircraft.

Introduction

NASA Ames Research Center plays a key role in support of the U.S. Government's Joint Strike Fighter (JSF) Program. This program is developing a family of advanced supersonic strike fighters that will feature different configurations for multiple branches of the military and for certain allies. The aircraft will feature highly common, modular construction to significantly reduce the cost of development, production, and maintenance.

Requirements for the JSF are as follows:

- U.S. Air Force—a multi-role aircraft for conventional takeoff and landing
- U.S. Marine Corps—a STOVL aircraft with good controllability at zero airspeed and during transition between hover and wing-borne flight
- U.S. Navy—a strike fighter with outstanding handling at low speeds and adaptations for catapult launches and arrested landings
- U.K. Royal Navy—a STOVL aircraft similar to the U.S. Marine Corps version

The Boeing Company is one of two manufacturers selected to build and fly a pair of JSF concept demonstrator aircraft. Real-time, piloted flight simulation is an important step in Boeing's approach to JSF design and development. The VMS, with its large motion travel, complemented Boeing's in-house, ground-based simulation prior to in-flight simulation and flight testing. The two simulations investigated control laws, flying qualities, and advanced control and display design.

Simulations

Participating test pilots came from Boeing; the U.S. Navy, Air Force, and Marine Corps; and the U.K. Royal Navy and Royal Air Force. Simulations were conducted for a total of six weeks on the motion base. In preparation for the motion-base experiments, two weeks of fixed-base simulations were conducted to validate the simulation system response and to finalize flight tasks and scenarios. Validation of the response was critical because Boeing's updated aircraft simulation software was directly integrated into the VMS.

VMS personnel developed head-up display graphics and guidance logic for the simulations and incorporated specialized hardware. VMS personnel also adapted the visual system, providing two different views from the carrier deck for landings at sea.

Results

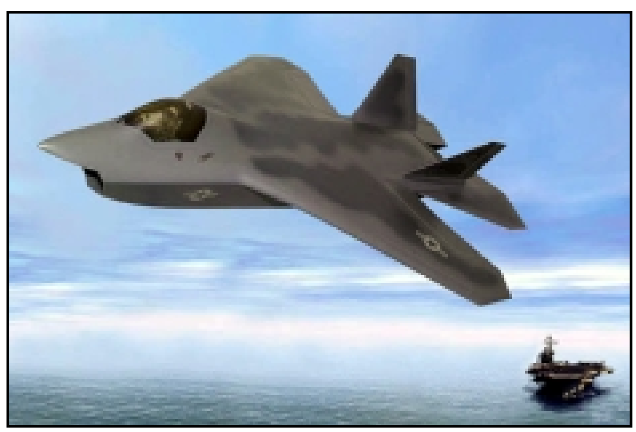
The primary objectives of the simulations were met, and the customer obtained considerable information for design analysis and evaluation. Test pilots were favorably impressed with the important role that large motion cueing played in evaluating the JSF's flying qualities and mission capabilities. The competition sensitive nature of this project precludes the inclusion of detailed results in this report.

With these simulations, SimLab continued to integrate the aircraft model software provided by the customer into the VMS simulation system. This reduced both simulation development time and costs to the customer.

For more information, refer to the web pages for Boeing (http://www.boeing.com) and the JSF Program (http://www.jast.mil).

Investigative Team

The Boeing Company
NASA Ames Research Center
U.S. Air Force
U.S. Marine Corps
U.S. Navy
U.K. Royal Navy
U.K. Royal Air Force



The Joint Strike Fighter will be an advanced supersonic fighter with four versions featuring modular construction for affordability.

Simulation Fidelity Requirements 7

William Chung, Logicon/LISS; Duc Tran, Julie Mikula, NASA ARC
Leslie Ringo, Logicon/LISS

Summary

This experiment confirmed the fidelity criteria for roll-lateral coordinated translation motion involving a tracking task and generated the subjective and objective data needed to investigate the fidelity requirements for pitch-longitudinal motion.

Introduction

Simulation Fidelity Requirements 7 (SimFR 7) was the latest in an ongoing series of simulations that is investigating motion cueing fidelity at the VMS. The results contribute to establishing motion fidelity requirements, quantifying the benefits of motion in flight simulation, and improving the accuracy of motion cues at the VMS.

The approach of the fidelity research is to focus on the roll and lateral degrees of freedom (DOF) using a side-step task and on the pitch and longitudinal DOF using a dash-and-quick-stop task. Once the motion effects and criteria are identified and developed, the results can then be applied to more complicated tasks and maneuvers.

Simulation

For comparison, flight tasks were flown with three levels of motion fidelity developed as a function of motion travel. The experiment used a one-to-one motion cueing configuration for reference.

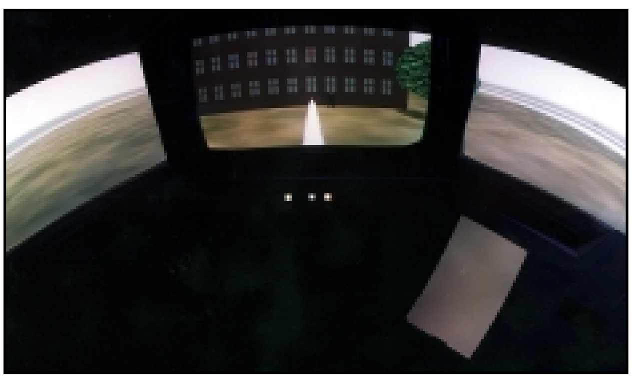
The two tasks for the roll-lateral DOF included a side-step task to investigate fidelity requirements for helicopters and a lateral formation flying translational task to examine fidelity requirements for fixed-wing aircraft. The third task, limited to the pitch-longitudinal DOF, featured a helicopter in a dash-and-quick-stop task.

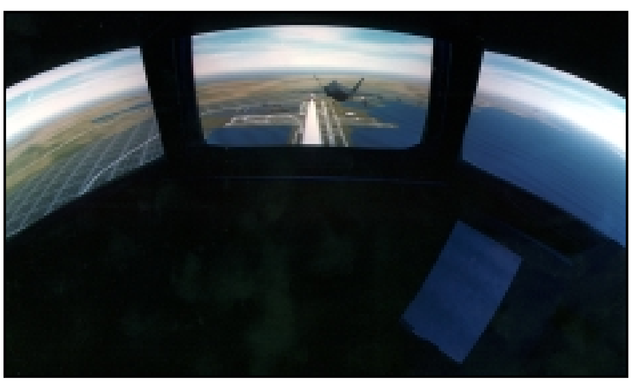
Results

The simulation was successful in confirming the fidelity criteria for roll-lateral motion. It was conducted in three parts, with a total of 4 weeks of simulation and 1700 data runs. Subjective data was collected from the pilots using a motion fidelity scale and handling qualities ratings. Objective data was documented including time performance, position error performance, specific force, and control input activities. In addition, the subjective and objective data needed to investigate the fidelity requirements for pitch-longitudinal motion were generated.

Investigative Team

NASA Ames Research Center
Logicon Information Systems and Services





This motion fidelity experiment simulated three tasks: a helicopter side-step (top left) and fixed-wing formation flying (bottom left) for the roll-lateral degrees of freedom and a helicopter dash-and-quick-stop (right) for the pitch-longitudinal degrees of freedom.

Lockheed Martin CDA, 2,PWSC, 3

Mark Tibbs, Lockheed Martin; James Franklin, NASA ARC; Robert Morrison, Leslie Ringo, Chuck Perry, Norm Bengford, Luong Nguyen, Joe Ogwell, Philip Tung, Ernie Inn, Logicon/LISS

Summary

Three simulations of Lockheed Martin's X-35 Joint Strike Fighter were conducted to support the design and development of the X-35. The experiments addressed conventional, carrier, and short-takeoff/vertical-landing (STOVL) operations. They also advanced NASA-sponsored research in guidance systems, display technology, and flight controls for STOVL aircraft.

Introduction

NASA Ames Research Center plays a key role in support of the U.S. Government's Joint Strike Fighter (JSF) Program. This program is developing a family of advanced supersonic strike fighters that will feature different configurations for multiple branches of the military and for certain allies. The aircraft will feature highly common, modular construction to significantly reduce the cost of development, production, and maintenance.

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- U.K. Royal Navy—a STOVL aircraft similar to the U.S. Marine Corps version

The Joint Strike Fighter will feature versions for the U.S. Air Force, Navy, and Marine Corps and the British Royal Navy.

The Department of Defense awarded the Lockheed Martin Corporation one of two JSF contracts, each calling for two concept demonstrator aircraft. These simulations, using the large motion base at the VMS, were conducted to complement Lockheed Martin's in-house simulations as part of the design and development process. The experiments addressed the X-35's flying qualities, control laws, and advanced controls and displays.

Simulations

The three simulations of the X-35 included three weeks of fixed-base simulations in preparation for a total of seven weeks of motion-base operations. The fixed-base sessions validated the simulation system response. This was a critical step because the updated computer code for the aircraft model was generated by Lockheed Martin and directly integrated into SimLab's simulation environment. Specialized hardware was also incorporated for Lockheed Martin. Pilots from Lockheed Martin; the U.S. Air Force, Marine Corps, and Navy; U.K. Royal Air Force and Royal Navy; and British Aerospace participated in the evaluations.

Results

The primary objectives of the simulations were met, and significant amounts of evaluation data were collected. The large motion cueing of the VMS system played a critical role in evaluating the flying qualities and mission capabilities of the X-35. Due to the competition sensitive nature of the project, detailed results cannot be included in this report.

For SimLab, these simulations marked continued success in integrating the aircraft model and cockpit display software provided by a customer directly into SimLab's real-time system. This mode of operation allowed Lockheed Martin to test several last-minute design changes, which were expeditiously integrated by SimLab engineers.

For more information, refer to the web pages for Lockheed Martin (http://www.lmco.com) and the JSF Program (http://www.jast.mil).

Investigative Team

Lockheed Martin
NASA Ames Research Center
U.S. Air Force
U.S. Marine Corps
U.S. Navy
U.K. Royal Navy
U.K. Royal Air Force
British Aerospace

Space Shuttle Vehicle 1

Howard Law, Charles Hobaugh, NASA JSC; Kyle Cason, Boeing North American; Estela Hernandez, Christopher Sweeney, Logicon/LISS

Summary

Simulations of the Space Shuttle orbiter are performed at the VMS to fine-tune the Shuttle orbiter's landing systems and to provide landing and rollout training for the astronaut corps. The engineering goals of this simulation were to investigate control-surface rate limits for landing with reduced hydraulic flow and to research the appropriate speed for enabling redundancy for the trim switch.

Introduction

The Space Shuttle orbiter is simulated at the VMS twice each year. Researchers have examined modifications to the flight-control system, guidance and navigation systems, head-up displays, flight rules, and the basic simulation model. The simulations also provide astronaut training with realistic landing and rollout scenarios.

Twice yearly, the Space Shuttle orbiter is simulated for engineering studies and astronaut training.

Simulation

One objective of Space Shuttle Vehicle 1 (SSV 1) was to investigate control-surface rate limits for landing with reduced hydraulic flow. Normally, three auxiliary power units (APUs) power the control surfaces. In the event of a single or double failure, priority rate-limiting software prevents over-demand by limiting the rate at which the various control surfaces move. This study examined two new configurations of software to reduce over-demand and maintain handling qualities during single-APU landings. (Such a landing has never been necessary in the real orbiter.) Maintaining handling qualities is especially critical in the moments after touchdown of the main landing gear when the control surfaces are used extensively and hydraulic demand is high.

A second objective was to examine the appropriate speed for enabling redundancy for the trim switch. This switch initiates derotation, the lowering of the nose gear to the ground after the main landing gear has touched down. Current software logic in the pitch control system makes the switch inoperative if either of two electrical contacts fails; the pilot must then achieve derotation manually. New logic was added to allow the switch to operate with a single contact below an airspeed to be determined in this study.

The third objective of SSV 1 was to train upcoming mission crews and astronaut candidates through a series of flights. Various runways, visibility conditions, and wind conditions were simulated, and system failures were periodically introduced.

Two new out-the-window databases representing landing sites were introduced in this simulation: Cherry Point in North Carolina and Oceana in Maryland.

Results

A total of 961 runs was completed with 38 pilots during four weeks of simulation. The crew familiarization session reinforced the importance of the VMS in preparing upcoming crews for the landing and rollout phase of the mission and for possible failures during that phase.

Preliminary results show that reductions in the elevator and aileron rate limits after main-gear touchdown eliminate almost all of the over-demand in the hydraulic system during single-APU landings. This rate-limit reduction in less critical controls allowed pilots to move more critical surfaces as quickly as desired.

Initial testing indicates that the optimum speed for enabling redundancy for the trim switch is 185 knots, the speed pilots currently use as a cue to initiate derotation. Further testing will be conducted to verify this setting.

Investigative Team

NASA Johnson Space Center
Boeing North American
Lockheed Engineering and Services Corp.
United Space Alliance

Civil Tiltrotor 8 SCAS

William Decker, James Franklin, Laura Iseler, Dan Dugan, NASA ARC;
Ron Gerdes, Logicon/LISS; Carl Griffith, Roy Hopkins, Bell Helicopter Textron;
Rolf Rysdyk, Georgia Tech; Steve Belsley, Emily Lewis, Philip Tung, Logicon/LISS

Summary

Civil Tiltrotor 8 SCAS simulated the XV-15 tiltrotor aircraft to aid the development of two stability and control augmentation systems. In addition, this simulation evaluated flight profiles designed for noise abatement in the terminal area.

Introduction

Civil Tiltrotor 8 SCAS (CTR 8 SCAS) was the latest in a series of simulations investigating issues that include CTR certification, vertiport design, and terminal area operations including noise abatement procedures.

This simulation implemented two new stability and control augmentation systems (SCASs). An aircraft's SCAS is the hardware and software that augments an aircraft's stability and control characteristics in response to pilot inputs and gusts. The SCASs were simulated to aid in their development prior to formal evaluation in CTR 8 EVAL.

CTR 8 SCAS also evaluated the handling qualities of approach profiles designed to reduce noise near airports and that are under consideration for a September 1999 flight test. While airplanes normally approach airports on a 3° glide slope, tiltrotor aircraft can approach at steeper angles to avoid obstacles and airspace reserved for other aircraft. Steep approaches might require complex noise abatement procedures that increase a pilot's workload. The profiles were therefore evaluated for feasibility and for possible improvements.

Simulation

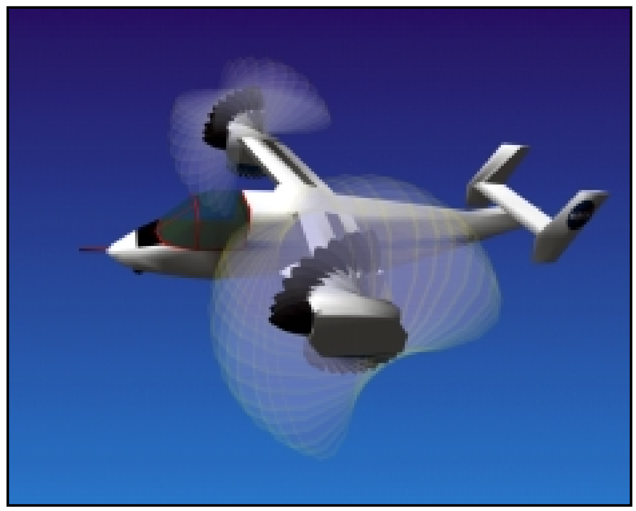
The first XV-15 SCAS implemented during CTR 8 SCAS was the current Bell Helicopter rate-command digital SCAS. Augmenting the SCAS was an optional limited-authority, rate-command/attitude-hold function, which reduces workload and enhances precision control. This function will be flight tested later in the year.

The second SCAS implemented was a neural-network dynamic inverse SCAS developed at the Georgia Institute of Technology. A neural-net SCAS continuously adapts flight control characteristics to changing conditions during flight. This capability will be especially helpful in providing the pilot with the desired control properties during conversion between helicopter and airplane modes, when a tiltrotor aircraft's stability and control characteristics change radically.

Four noise abatement profiles were simulated for evaluation and possible inclusion in the September flight test. The profiles included a 3° approach, two 9° approaches, and a segmented approach that began with 3° and ended with 9°.

Results

The two SCASs were successfully implemented, and the VMS provided an excellent platform for the investigation of pilot interaction with the control systems. Early results led to changes being incorporated and evaluated during the simulation. The Bell Helicopter SCAS was improved, and areas were identified for fine tuning; this process required a fraction of the time it would take in flight testing. The neural-net SCAS was also improved but requires further development.



This time-lapse illustration depicts the XV-15 converting from helicopter mode to airplane mode.

NASA and Bell Helicopter pilots evaluated the handling qualities of the four approach profiles. This portion of the simulation yielded important feedback to acoustics and handling-qualities engineers. One of the 9° approaches had severe handling-qualities deficiencies and will not be implemented for flight. Handling qualities evaluations of the other three approaches suggested improvements that will be implemented for the flight test.

Investigative Team

NASA Ames Research Center
Logicon Information Systems and Services
Bell Helicopter Textron
Georgia Institute of Technology

Helicopter Maneuver Envelope Enhancement 6

Matt Whalley, Army/NASA Rotorcraft Division;
Chuck Perry, Norm Bengford, Logicon/LISS

Summary

This simulation experiment investigated the prediction of helicopter flight envelope limits and the communication of those limits to the pilot using active side-stick controllers.

Introduction

The objective of the Helicopter Maneuver Envelope Enhancement (HelMEE) series of experiments is to develop improved methods for alerting pilots to operational limits during helicopter flight in order to enhance safety and reduce pilot workload.

Conventional helicopter controls are mechanically connected to control surfaces, enabling the pilot to feel forces that reflect the state of the aircraft. In contrast, side sticks are connected to control surfaces electronically (fly-by-wire), and therefore control forces do not vary with the aircraft's state. The use of active side sticks would enable the programming of force characteristics to reproduce the feel of mechanical systems and to communicate additional information about flight envelope limits to the pilot.

Simulation

The objectives of HelMEE 6 were to:

- Integrate active side sticks into the UH-60 Black Hawk simulation in place of the conventional cyclic (center stick) and collective.
- Evaluate the side sticks with the cueing of flight envelope limits developed in previous HelMEE research.
- Introduce a new limit cue for mast bending moment during ground handling, such as taxiing and slope landings.

Simulation development focused on integrating a new digital, two-axis side sticks developed by Stirling Dynamics. The side sticks combine a computer controller and electric motors in a self-contained unit. Force characteristics are continuously updated via a high-speed Ethernet connection with the host computer. A new interface program was implemented that bypassed the normal digital-to-analog interface.

Pilots flew four test configurations: no cues, tactile cues only, head-up display (HUD) cues only, and both tactile and HUD cues. Tactile cues included stick shaking for all three limits tested. Three tasks were flown: bobup/bobdown, acceleration/deceleration, and a maximum performance turn. A new slope landing task was implemented, but no data was taken for this task.

Limit	Control	Cue
Transmission torque	Collective	Softstop
Blade stall	Cyclic	Aft cyclic softstop
Mast bending moment	Cyclic	Damping (in flight) Softstop (on ground)

Results

Over 300 data runs indicated that the active stick cueing significantly improved pilot performance and ratings. Transmission torque exceedances were reduced 90% for two of the tasks and eliminated completely for the third task. Blade stall exceedances were reduced 75% in the task that induced this limit most. Improved airspeed control was exhibited in the maximum performance turn. Mast bending moment was not significant in the tasks flown. Overall, pilot comments were quite favorable in regard to the effectiveness, smoothness, and responsiveness of the side sticks.

Investigative Team

Army/NASA Rotorcraft Division
NASA Ames Research Center
Bell Helicopter Textron
Boeing Helicopters
Logicon Information Systems and Services
Sikorsky Aircraft
U.S. Army

In simulation of the Black Hawk helicopter, new electronic side sticks were programmed to feel like conventional flight controls and to communicate additional tactile cues.

High-Speed Civil Transport Ames 8

Gordon Hardy, Logicon/LISS; Todd Williams, James Ray, Ed Coleman, Boeing; Chris Sweeney, Emily Lewis, Philip Tung, Joe Ogwell, Logicon/LISS

Summary

This simulation measured the handling qualities and general performance of the current design of a supersonic passenger airplane. In addition, it finalized flight-control standards for this class of aircraft.

Introduction

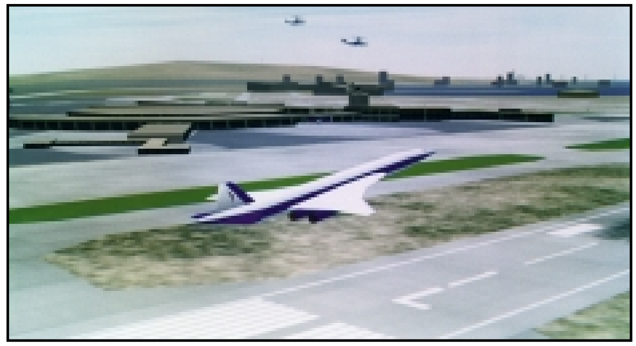
NASA's High-Speed Research (HSR) Program was initiated in 1990 to develop essential technologies for a High-Speed Civil Transport (HSCT) in cooperation with the U.S. aeronautics industry. The aircraft would carry 300 passengers at Mach 2.4. NASA is now ready to pass the program results on to industry.

HSCT Ames 8 (HSCT A8) was the last of more than a dozen simulations that researched flight control, navigation, and guidance systems. To complete the simulation series, HSCT A8 focused on measuring the current design's performance and finalizing flight control standards.

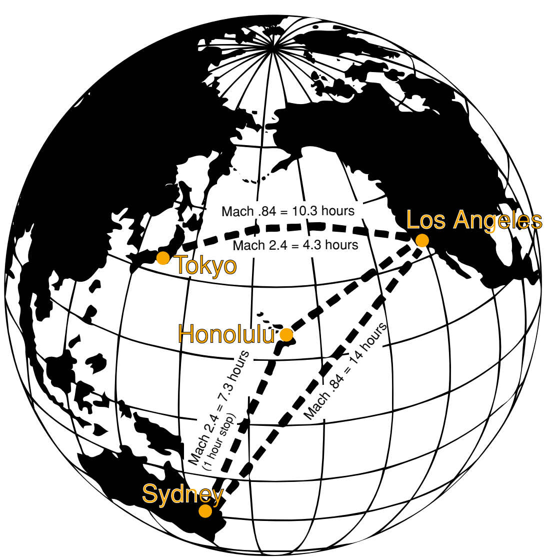
Simulation

Part 1 of HSCT A8 measured the handling qualities and performance of the current design against the HSR Program's standards as set forth in the Aero Performance 8 Metric. Particular attention was paid to takeoff and landing, including crosswind landings and go-arounds. Methodology for the head-up display used in takeoff and landing was also investigated. Finally, an autoland system, including guidance and control displays, was tested for the first time.

Part 1 included the dynamic aeroservoelastic (DASE) portion of the simulation model. DASE is the interaction of aerodynamic, structural (elastic), and inertial forces that can lead to unwanted vibrations in both subsonic and supersonic flight. Structural mode control manipulated the control surfaces to minimize these vibrations.



This simulation concluded a series of experiments critical to the development of technologies for a supersonic passenger airplane.



The High-Speed Civil Transport would significantly reduce flight times for transoceanic travel.

Part 2 of HSCT A8 updated the flight control requirements for the HSCT class contained in the HSR Program's Flight Control System Requirements Specification. It concentrated on the longitudinal flight control requirements because a unique flight-path-rate command system was used instead of the more conventional attitude command type of control. This is the first time that flight-path-rate command has been seriously considered for a proposed aircraft. Part 2 also continued the development of lateral-directional flying qualities criteria.

Results

With its large motion base and realistic cues for piloted simulation, the VMS proved invaluable in reproducing the handling qualities of the uniquely configured HSCT. A total of 1496 data runs with eight pilots were completed. Even with the adverse effects of the DASE, Part 1 showed a significant improvement in the Aero Performance 8 Metric due to enhancements to the control system and pilot displays. Part 2 indicated that even with the unique longitudinal control law, current specifications for flight control systems are still generally acceptable and may even be relaxed in some areas.

Investigative Team

NASA Ames Research Center
The Boeing Company
NASA Langley Research Center
Veridian Engineering (Calspan)
Honeywell

Space Shuttle Vehicle 2

Howard Law, Paul Lockhart, NASA JSC; Ed Digon, Boeing; Brian Bahari, Lockheed; Estela Hernandez, Leslie Ringo, Logicon/LISS

Summary

This one-week simulation of the Space Shuttle orbiter featured crew familiarization for astronauts and astronaut candidates.

Introduction

The very first VMS simulation, conducted in 1981, simulated the Space Shuttle orbiter. Today, the VMS continues to simulate touchdown and rollout of the orbiter twice each year.

The orbiter presents challenging landing conditions. With no engines operating, the orbiter glides to touchdown without power for maneuvering or going around. It touches down at approximately 235 miles per hour, more than twice the speed at which most aircraft land. This makes realistic training for astronauts critical. At the VMS, pilots experience various flight conditions and system failures to prepare them for this important phase of flight.

Simulation

Astronauts experienced a number of variables during simulation:

- Runway location and type
- Vehicle weight
- Visibility
- Wind direction and speed

The VMS simulates eight landing sites in the U.S. including the dry lake beds at Edwards Air Force Base and White Sands Missile Range. The VMS also simulates the four Transoceanic Abort Landing (TAL) sites. A TAL would occur in the event of a major system failure during launch; if it were too late to return for landing at Kennedy Space Center and too early to circle the earth for another opportunity to land in the U.S., the orbiter would land on the far side of the Atlantic Ocean. There are two TAL sites in Spain, one in Morocco, and one in Gambia.

Astronauts also rehearsed procedures for handling failures to the:

- Tires
- Drag chute
- Auxiliary power units
- Automatic derotation system

Results

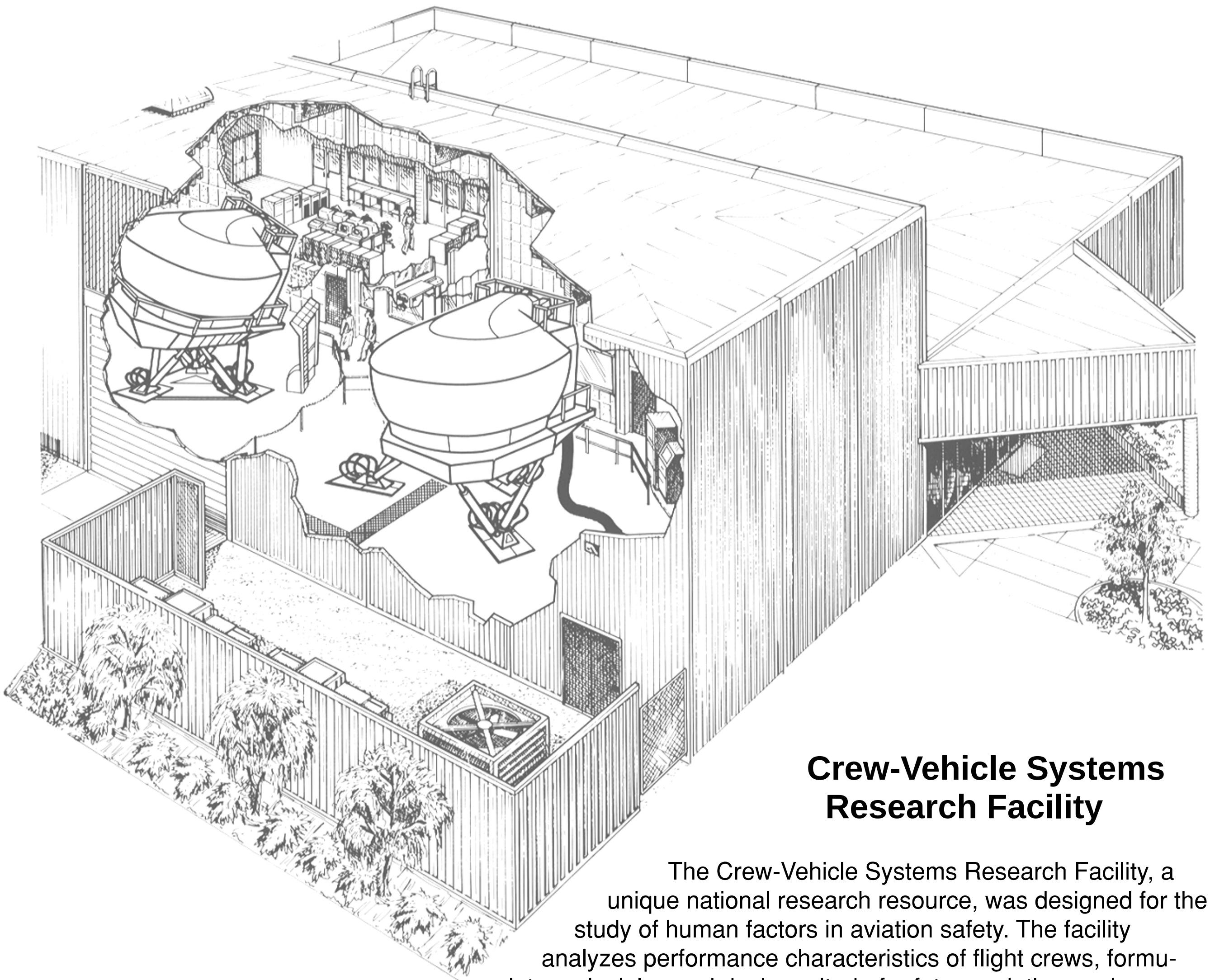
In one week of simulation, 18 pilots few over 300 data runs. Simulation provided the real-time delivery of high-fidelity cues, including realistic out-the-window scenes, instrumentation, and motion. This simulation reinforced the importance of the VMS in preparing upcoming crews for the landing and rollout phase and for possible failures during that phase.

Investigative Team

NASA Johnson Space Center
The Boeing Company
Lockheed Martin
United Space Alliance

Eileen Collins, first woman to pilot the orbiter and to command the Shuttle, prepares for crew familiarization. The VMS provides important training for orbiter pilots.

CVSRF PROJECT SUMMARIES



Crew-Vehicle Systems Research Facility

The Crew-Vehicle Systems Research Facility, a unique national research resource, was designed for the study of human factors in aviation safety. The facility analyzes performance characteristics of flight crews, formulates principles and design criteria for future aviation environments, evaluates new and contemporary air traffic control procedures, and develops new training and simulation techniques required by the continued technical evolution of flight systems.

Studies have shown that human error plays a part in 60 to 80 percent of all aviation accidents. The Crew-Vehicle Systems Research Facility allows scientists to study how errors are made, as well as the effects of automation, advanced instrumentation, and other factors, such as fatigue, on human performance in aircraft. The facility includes two flight simulators—an FAA certified Level D Boeing 747-400 and an Advanced Concepts Flight Simulator as well as a simulated Air Traffic Control System. Both flight simulators are capable of full-mission simulation.

CTAS/FMS Data Link

**Everett Palmer, Terry Rager, NASA ARC; Barry Crane, Thomas Prevot, SJSU;
Don Bryant, Ramesh Panda, Fritz Renema, Rod Ketchum, ManTech**

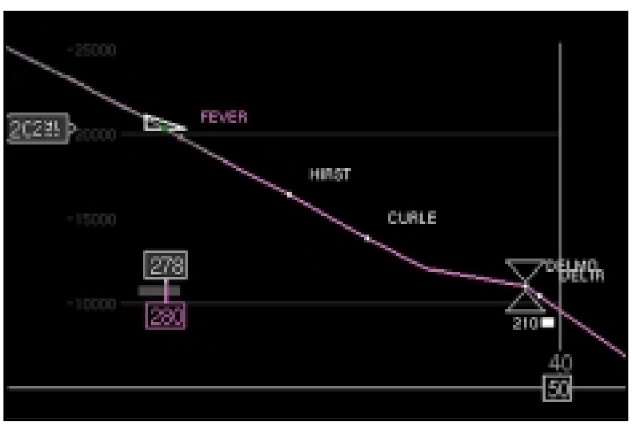
Summary

This study evaluated a new concept for the integration of the Center TRACON Automation System with the Flight Management System for operations in terminal airspace. It was conducted in the Advanced Concepts Flight Simulator to improve efficiency and maximize airport capacity without compromising safety.

Introduction

Arrival and approach traffic flow management to airports is still accomplished via analog communications and tactical vectoring, a method that needs to be upgraded. The Flight Management System (FMS) installed in most of the current transport aircraft is already capable of computing and flying optimal trajectories from the origin airport to the destination airport. However, the FMS is seldom used in the arrival phase due to route change programming steps involved in terminal-area Air Traffic Control (ATC) vectoring.

The Center TRACON Automation System (CTAS) is a set of automation tools developed at Ames to aid the controller with aircraft sequencing, separation, flow control, and scheduling. Final Approach Spacing Tool (FAST) is one of the components of CTAS used for managing traffic in the TRACON airspace. A variant of FAST is currently being field tested in the Dallas/Fort Worth Metroplex. FAST can provide landing sequences, runway assignments, and speed and heading advisories to help the aircraft meet computed trajectories. The present study utilized an advanced version of FAST with Data Link capabilities to uplink a desired route directly to the FMS.



This Vertical Situation Display is one tool being evaluated that is intended to safely maximize airport capacity.

Simulation

The main objective of this study was to evaluate the human-factors benefits in terms of crew performance, workload, and flight-deck communication; the interface; and the procedures involved in the CTAS and FMS integrated operations.

The experiment configuration consisted of the Advanced Concepts Flight Simulator (ACFS), CTAS, and Pseudo Aircraft Simulation (PAS) stations, which supplied simulated traffic. The ACFS included an FMS enhanced with customized FMS approach procedures and Data Link for clearance loading capabilities. A Data Link display for pilot viewing of uplinked ATC message text was integrated into the upper Engine Indication and Crew Alert System display. Special Data Link buttons were also provided on the glare shield for message response inputs.

A Vertical Situation Display (VSD) integrated into the Navigation Display helped evaluate a related research concept. The VSD graphically displayed the planned vertical profile including various speed and altitude constraints in the active trajectory. For pilot preview, a modified clearance could be overlaid in a different color highlighting the new profile against the active profile. The VSD may enhance situational awareness as many FMS automation related problems are associated with vertical flight-path management.

Results

The full-mission simulation study in the ACFS was set in the Dallas/Fort Worth terminal airspace. A total of twelve crews participated from major commercial air carriers with Type ratings on the Boeing 757/767, 737-500 and 777. Seven descent scenarios were flown combining current day, FMS, and CTAS/FMS procedures. This study validated the viability of FMS and CTAS/FMS descent procedures. A follow-on experiment is planned to validate use of these procedures in higher pilot workload conditions.

Investigative Team

NASA Ames Research Center
San Jose State University

Propulsion Controlled Aircraft Ultralite

John Bull, Caelum Research Corp.; Frank W. Burcham, NASA Dryden; Edward Kudzia, Foothill DeAnza College; John Kaneshige, NASA ARC; Diane Carpenter, Jerry Jones, ManTech

Summary

The B747-400 simulator was used to examine a low-cost, fly-by-throttle control system as a backup for use in the event of an emergency or a malfunction of an airplane's primary flight control system.

Introduction

In the last 25 years, at least 10 aircraft have experienced major flight-control system failures where the crew had to resort to engine thrust for emergency flight control. In most cases, these attempts resulted in crashes. In 1989, the National Transportation Safety Board recommended "research and development of backup flight control systems for newly certified wide-body airplanes that utilize an alternate source of motive power separate from that source used for the conventional control system."

The NASA Dryden Flight Research Center has developed a Propulsion Controlled Aircraft (PCA) system in which computer-controlled engine thrust is used to provide emergency flight-control capability. Aircraft not equipped with full-authority digital engine control require implementations of PCA technology that can be installed on existing systems. Piloted transport aircraft simulation studies at Ames have examined a PCA Ultralite concept, in which thrust control is provided through a combination of the autothrottle system and manual pilot control with the aid of flight director guidance.

Simulation

This study evaluated the PCA Ultralite concept, which consists of automatic PCA commands for symmetric engine thrust to control pitch and manual pilot commands for asymmetric engine thrust to control roll.

The real-time software module created for previous B747 PCA experiments was modified for use with this study. The module consists of a set of control laws simulating a closed-loop control system designed to maintain adequate controllability and maneuverability of the aircraft in flight using only thrust modulation with the normal flight-control system inoperative.

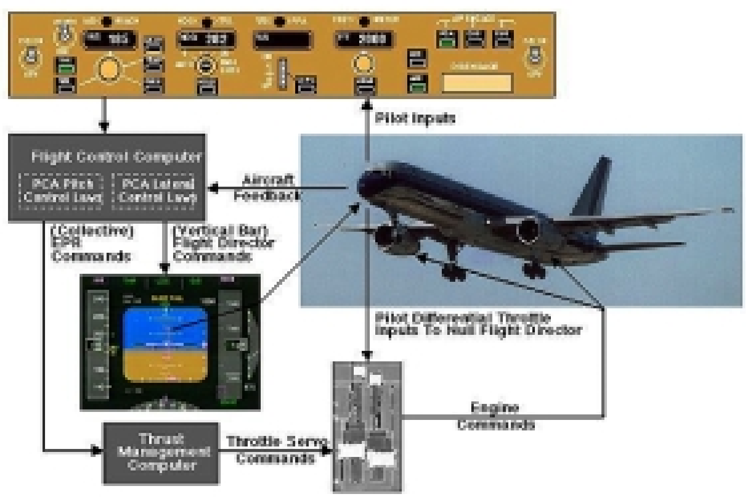
The software module was modified to add a calculation for flight director commands that drive the flight directors displayed on the Primary Flight Display whenever the PCA system was engaged. Two different modes of roll flight director operation were implemented. The first mode was a bank flight director that used the PCA bank command to drive the roll flight director. The second mode was a throttle flight director that used the error between the throttle servo command and the throttle position to drive the roll flight director. Data was gathered using the IBM Data Gathering System.

Results

With the addition of PCA Ultralite providing automatic pitch control, pilots commented that "single tasking the pilot makes this acceptable (or at least tolerable)" and that "without pitch being handled automatically (a misaligned approach) would be unsalvageable." While the PCA flight director provided quicker feedback, allowing for significantly smaller throttle corrections, achieving a stabilized approach still varied among evaluation pilots.

Investigative Team

Caelum Research Corporation
NASA Ames Research Center
NASA Dryden Research Center



The Propulsion Controlled Aircraft Ultralite concept, diagrammed here, could lead to a low-cost, emergency backup to an airplane's primary flight control system.

Balked Landings

Dave Lankford, Shahar Ladecky, FAA, Oklahoma City; Barry Scott, FAA, NASA ARC;
Jerry Jones, Rod Ketchum, Diane Carpenter, ManTech

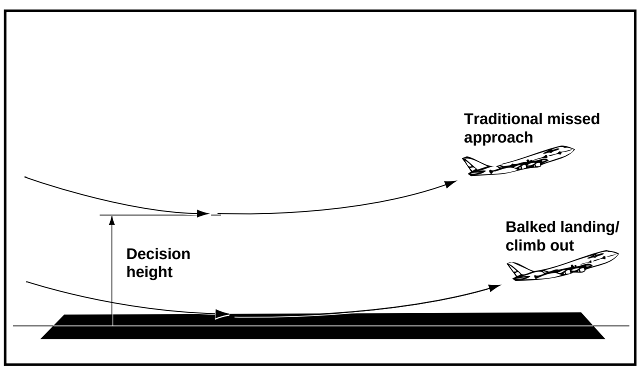
Summary

This test involving the B747-400 simulator is the latest in a series that examined large air carrier aircraft flight tracks and height-loss arrest points during crew-induced aborted or balked landings. These aborts were initiated upon reaching published decision height/altitude and beyond to a minimum of 30 feet above ground level. Category I Instrument Landing System approaches were conducted using the auto-land systems for each of the runs. The results are analyzed relative to Obstacle Free Zone space and dimension requirements.

Introduction

The Federal Aviation Administration's (FAA) Advisory Circular 150/5300-13, Airport Design, accounts for many elements including runways, shoulders, blast pads, clearways, runway safety areas, and adjacent taxiways. This advisory circular mandates Obstacle Free Zone (OFZ) dimensions for airplanes with wingspans up to 262 feet. For larger aircraft, information is needed for calculating the OFZ to provide safe conditions below the decision height.

The FAA's Flight Procedure Standards Branch conducted these simulations to assess various go-around call heights for the development of standards and operation criteria.



This study examined Obstacle Free Zone dimensions for balked landings and traditional missed approach.

Simulation

This study consisted of a series of approaches to Denver International Airport with representative weather conditions. Flight-track and height-loss data occurring subsequent to arrival at Category I decision heights was collected for missed approach and aborted/balked landings. Particular attention was paid to introducing all possible extreme wind and other conditions allowable for the type approach under test. This enabled the possible impact on OFZ-required space and crew response/techniques to be evaluated. No variations in aircraft gross weight were introduced for these runs. Six days of data runs were completed for this study totaling 60 runs, utilizing ManTech and NASA flight crews. Data collection included digital readouts of aircraft state and performance data.

Results

Test results will support Monte Carlo simulation studies using the FAA's Airspace Simulation and Analysis for Terminal Procedures (TERPS). These simulations calculate the probabilities of collisions during aborted landings of new larger aircraft. This work will in turn assist the New Larger Airplane Working group of the International Civil Aviation Organization in developing guidance for the introduction of new, larger airplane operations to existing airports.

Investigative Team

FAA, Oklahoma City
NASA Ames Research Center

Cockpit Display of Traffic Information

Vernol Battiste, Walter Johnson, NASA ARC; Jerry Jones, Rod Ketchum, George Mitchell, Diane Carpenter, Ghislain Saillant, Ian MacLure, ManTech

Summary

The objective of this study on the B747-400 simulator was to evaluate flight crew and Air Traffic Control interaction when an advanced Cockpit Display of Traffic Information was used by the flight crew.

Introduction

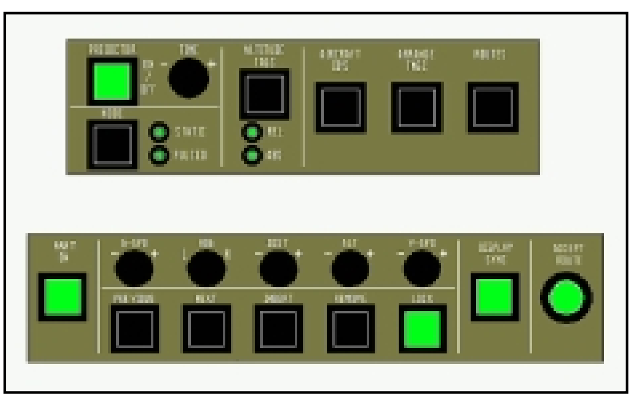
This study was conducted by the Human Information Processing Research Branch at Ames. It was a follow-on investigation to the Free-Flight Demonstration conducted in the spring of 1997. The Cockpit Display of Traffic Information (CDTI) system used Global Positioning System (GPS) data link position reporting with display of all traffic, conflict detection (Kuchar's logic), conflict resolution tools (Route Assessment Tool, or RAT), and flight plan information for all participating aircraft.

The aircraft navigation display and RAT developed for this study were directed towards free flight, concentrating on the en-route segment and collision avoidance. For the concept of free flight to work efficiently, intent information (future position) is required. Flight plans provide the required intent information; thus, flight plans are tightly coupled with this work. The CDTI display, the Advanced Route Assessment and Planning Tool (ARAT) and the Predictor control were designed for this study so that the flight crew can visually define an alternate en-route flight plan that is free of the probability of collision with other traffic.

Simulation

The CVSRF staff created several new software modules and modified many existing modules on the B747 host computer. The research staff provided two computers, configured with the CDTI-display software, that were used as the primary hub of information exchange. These computers communicated with the B747 simulator and the Pseudo Aircraft System (PAS) via TCP/IP. When the MAP navigation display mode was selected by a pilot in the cockpit, CDTI displays switched into view. The ARAT and Predictor Control Panels then interfaced with the CDTI display. PAS generated traffic for each scenario. Software modifications were made on the B747 host computer to accommodate the transfer of information between the CDTI computers and the B747 Flight Management Computer and CDTI control panels.

This Navigation Display was designed to help flight crews visually define safe flight plans in a free-flight environment.



Two panels designed for this study were the Advanced Route Assessment and Planning Tool Panel (top) and the Predictor Control Panel (bottom).

Results

Thirteen qualified airline crews participated in 91 training runs and 104 experiment data runs. The simulation allowed line pilots to have input regarding the technology while the researchers evaluated usability and pilot interaction. Research findings are forthcoming.

Investigative Team

NASA Ames Research Center

Fatigue Feedback

Dr. David Neri, NASA ARC; Ray Oyung, SJSU; Rod Ketchum, Jerry Jones, George Mitchell, Ghislain Saillant, Fritz Renema, Craig Pires, Jason Hill, Eric Gardner, Vic Loesche, Diane Carpenter, ManTech

Summary

This ongoing study investigates the effectiveness of fatigue-related feedback on the alertness, neurobehavioral performance, and behavior of flight crews and evaluates the feasibility and utility of a video-based, automated system for detecting drowsiness and providing feedback to flight crews.

Introduction

Long, uneventful flights in modern, highly automated aircraft are characterized by unique conditions; physical inactivity, dim light levels, steady background noise; and limited environmental manipulations. In addition, extensive pilot monitoring of aircraft systems, increased vigilance for low-frequency occurrences, and reduced social and cognitive interaction are new elements with which flight crews must deal. Together these factors create a context in which underlying sleepiness is likely to manifest itself in the form of reduced alertness, compromised vigilance, and impaired performance. If the flight occurs during hours when the biological clock is programming the body for sleep, fatigue and sleepiness levels are further increased and can significantly reduce the safety margin.

Pilots were videotaped and monitored to gauge their alertness on a long, late-night flight simulation.

The Percent Closed (PERCLOS) data system was a primary element of this experiment. PERCLOS is a self-contained, infrared camera data collection and alerting system tested by the Federal Highway Administration in commercial trucking. This technology is currently being evaluated for use in the aviation environment.

Pilots were videotaped and monitored to gauge their alertness on a long, late night flight simulation.

Simulation

The Systems Safety Research Branch of the Human Factors Research and Technology Division conducted this study, also called the Evaluation of In-Flight Alertness Management Technology. The experiment involved a six-hour, night, over-water flight scenario, looking at the effect of feedback on subsequent alertness, cognitive performance, and other behaviors. Twelve flight crews from six different airlines were the subjects of this study. The nature of this experiment was such that performing it during nighttime hours was critical. Due to this requirement, the facility was staffed from 11:00 p.m. through 8:00 a.m. with the simulation running from 2:00 a.m. through 8:00 a.m.

PERCLOS devices were mounted on the flight deck to collect information from each pilot's face and provide necessary feedback. VCRs were set up with a quad display and full-screen recording of the pilot's face. The quad display contained video from overhead flight deck cameras with pan and tilt capability as well as views of each of the pilot's faces.

All physiological, vigilance performance, and subjective data was collected with portable equipment furnished by the Fatigue Countermeasures Program.

Results

Data is currently being evaluated by the Fatigue Countermeasures Program and the findings will be published for the aviation community's use as well as to determine the size and scope of further studies.

Investigative Team

NASA Ames Research Center
San Jose State University

Taxiway Navigation and Situation Awareness 2

Dave Foyle, NASA ARC; Becky Hooey, SJSU;
Don Bryant, Anna Dabrowski, Rod Ketchum, Ian MacLure, ManTech

Summary

This follow-up study using the Advanced Concepts Flight Simulator evaluated the use of a head-up display and an electronic moving map to provide navigation and guidance information to aircraft flight crews. The goal is to improve airport runway turn-off and surface taxi operations in bad weather and at night to increase airport capacity and improve aviation safety.

Introduction

Current airport surface operations are handled with verbal instructions over the radio with flight crews using paper maps to navigate around the airport. In bad weather (low visibility) and at night, this can lead to very slow taxi operations and potentially dangerous situations. Under these conditions, many major U.S. airports have taxi capacity limitations, and several taxi accidents occur each year. Many commercial airliners now have electronic-navigation and head-up displays installed, but they are not utilized in any significant way for taxi operations. This experiment supported the Low-Visibility Landing and Surface Operations element of the Terminal Area Productivity Program.

Simulation

Taxiway Navigation and Situation Awareness 2 (T-NASA 2) continued the concept of electronically loading the taxi route into an on-board system and displaying the route on both the head-up display (HUD) and electronic moving map (EMM—see back cover). New technology introduced included roll-out and turn-off (ROTO) HUD guidance and data-linked communications, clearances, and route loading with an active crew interface.

Experiment runs started with crews flying on short final descent to one of several runways at Chicago O'Hare airport. Following landing, the crews taxied to the terminal. The runs included base-line cases with voice communication and paper map only; cases with data-linked route and communications; and cases with data-linked route and communications, EMM, and HUD.

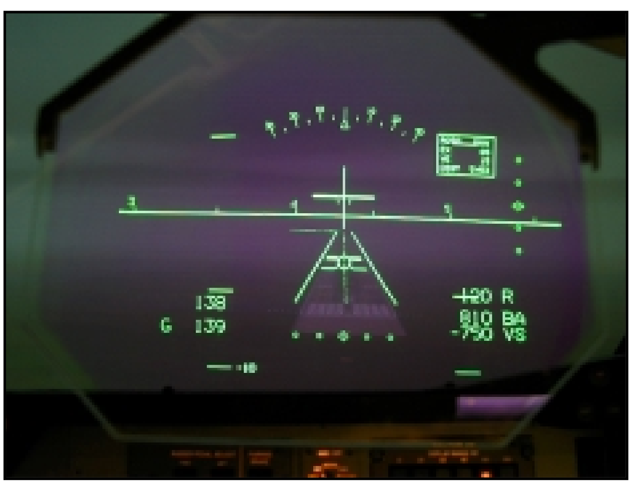
Results

Twenty-one airline crews performed 294 landing and taxi runs. Digital data of runway rollout and taxi performance was collected along with video and audio recordings of the crews' activities. An extensive debrief was performed to get crew comments and opinions on the system.

T-NASA 2 has drawn favorable comments from pilots that evaluated the system. The capability of full-mission simulation has allowed researchers to watch the interactivity of crews with new technology and observe problems not previously identified.

Investigative Team

NASA Ames Research Center
San Jose State University



This experiment evaluated the use of a head-up display and an electronic moving map to improve airport surface operations.

FMS Departure Procedures

Frank Hasman, David Lankford, FAA, Oklahoma City; Barry Scott, FAA, NASA ARC;
Jerry Jones, Rod Ketchum, George Mitchell, Diane Carpenter, ManTech

Summary

With the implementation of today's Flight Management Systems (FMS) and the navigation concept of Required Navigation Performance (RNP), conventional area navigation (RNAV) departure procedures using the FMS can now extend the overall navigation service. The objective of this study using the B747-400 simulator was to evaluate various FMS departure routings, with operational variance in the use of the FMS, in executing departure legs coded in conformance with ARINC 424 standards.

Introduction

Federal Aviation Administration (FAA) Order 8260.44 provides criteria for constructing instrument flight rules (IFR) RNAV departure procedures. Procedures designed using current criteria are for use by aircraft with only RNAV or Global Positioning System (GPS) RNAV capability. The data derived from this examination will assist in the development of departure procedure design standards for FMS/RNP/RNAV departures based on operational and system requirements.

At certain locations, obstacles or noise-sensitive areas close to the departure track create a requirement for highly accurate flight systems and special operational procedures to enter and maintain a narrow departure corridor. This project will identify those operational and system requirements that must be considered in the total development of Terminal Procedures RNAV Departure Procedure criteria.

Simulation

This study examined departure routings of various leg types, waypoint types, and leg lengths; observed the operational performance of those procedures; and collected aircraft flight path data to support efforts in adding to or revising current RNAV departure standards.

A number of runs of each planned type departure were conducted while capturing aircraft position relative to intended flight track. The various departure routes were constructed by the FAA Flight Procedure Standards Branch in Oklahoma City.

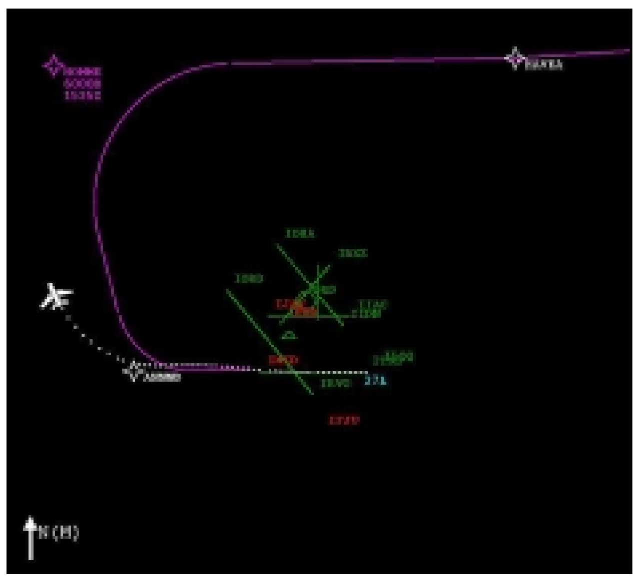
Takeoffs were made at either maximum gross weight or a moderate gross weight from runway 27L at Chicago O'Hare International Airport. Twenty-knot direct crosswinds from the left or the right were examined for their effect on the aircraft ground track with respect to the FMS-computed track. A custom FMS navigational database was created by Honeywell for the ten departure routes used in this study.

Results

The Level D FAA certification of the B747-400 was essential for this study. Ten days of data runs with Boeing 747-400 airline flight crews were completed for a total of 240 runs. Research results are pending.

Investigative Team

FAA, Oklahoma City
NASA Ames Research Center



This map illustrates the aircraft ground track (dotted line) with respect to the FMS-computed track (solid line) during a departure.

AATT Integrated Tools Study/Air-Ground Integration Experiment

**Sandy Lozito, NASA ARC; Patricia Cashion, Victoria Dulchinos,
Melisa Dunbar, Dave Jara, Margaret Mackintosh, Alison McGann, SJSU;
Jerry Jones, Rod Ketchum, George Mitchell, Diane Carpenter, Ghislain Saillant,
Ian MacLure, Fritz Renema, Craig Pires, Joe King, Tom Prehm, Gary Uyehara, ManTech**

Summary

This experiment involving the B747-400 simulator conducted an early evaluation of air-ground integration procedures and concepts. In addition, a joint experiment by the William J. Hughes FAA Technical Center and NASA Ames collected data pertaining to users of the ground system and on the flight deck.

Introduction

In the free-flight environment, aircraft will be able to maneuver with more autonomy and flexibility. However, free flight will require the definition of new zones around each aircraft similar to those currently provided by the alert algorithms of the Traffic Alert and Collision Avoidance System (TCAS). These zones will be defined as the alert and protected zones. Roles and responsibilities associated with transgressions of these zones need to be defined and evaluated. There may be difficulties in coordination between the controller and the flight crew in cases where separation authority is provided to the flight crew.

The overall goal was to conduct an early examination of procedures and events in a dynamic environment where the control of aircraft can be centralized (conventional Air Traffic Control procedures) or distributed (self-separation).

Simulation

This study was conducted in conjunction with the Human-Automation Integration Research Branch at Ames. It involved researchers and laboratories at the Federal Aviation Administration Technical Centers (FAATCs) in Atlantic City and New Jersey and at the CVSRF. Pilots at the CVSRF participated in the B747-400 simulator and at a pseudo pilot station using the Pseudo Aircraft System (PAS). Air Traffic Control test subjects participated at the FAATCs. All air traffic other than the B747-400 and the pseudo pilot were generated at the FAATCs and relayed to the CVSRF.

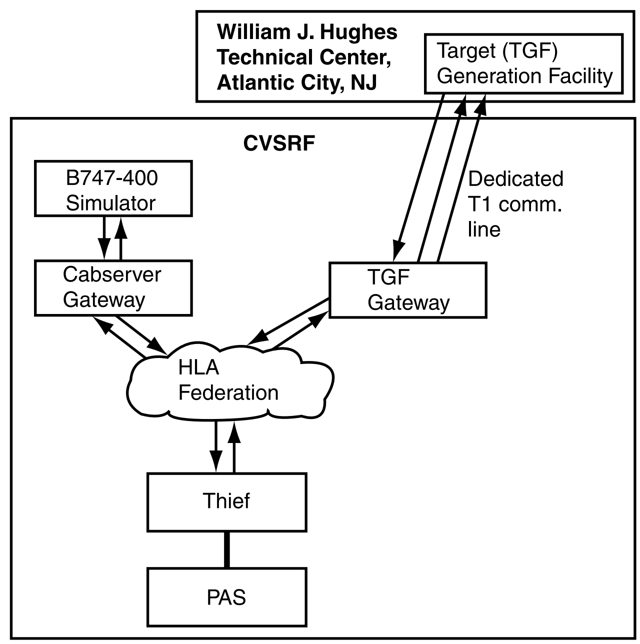
For this experiment, a new, dedicated T-1 line was installed between Ames and the FAATCs. The T-1 line sent and received voice communications using Voice Over IP technology in addition to aircraft data. The software for this study was an upgrade to the previous Advanced Air Transportation Technologies (AATT) 3 experiment software. The majority of the new software was developed to support the new interface to the FAATCs.

Results

This experiment was the first time controller and pilot interaction was studied in a real-time, high-fidelity simulation environment.

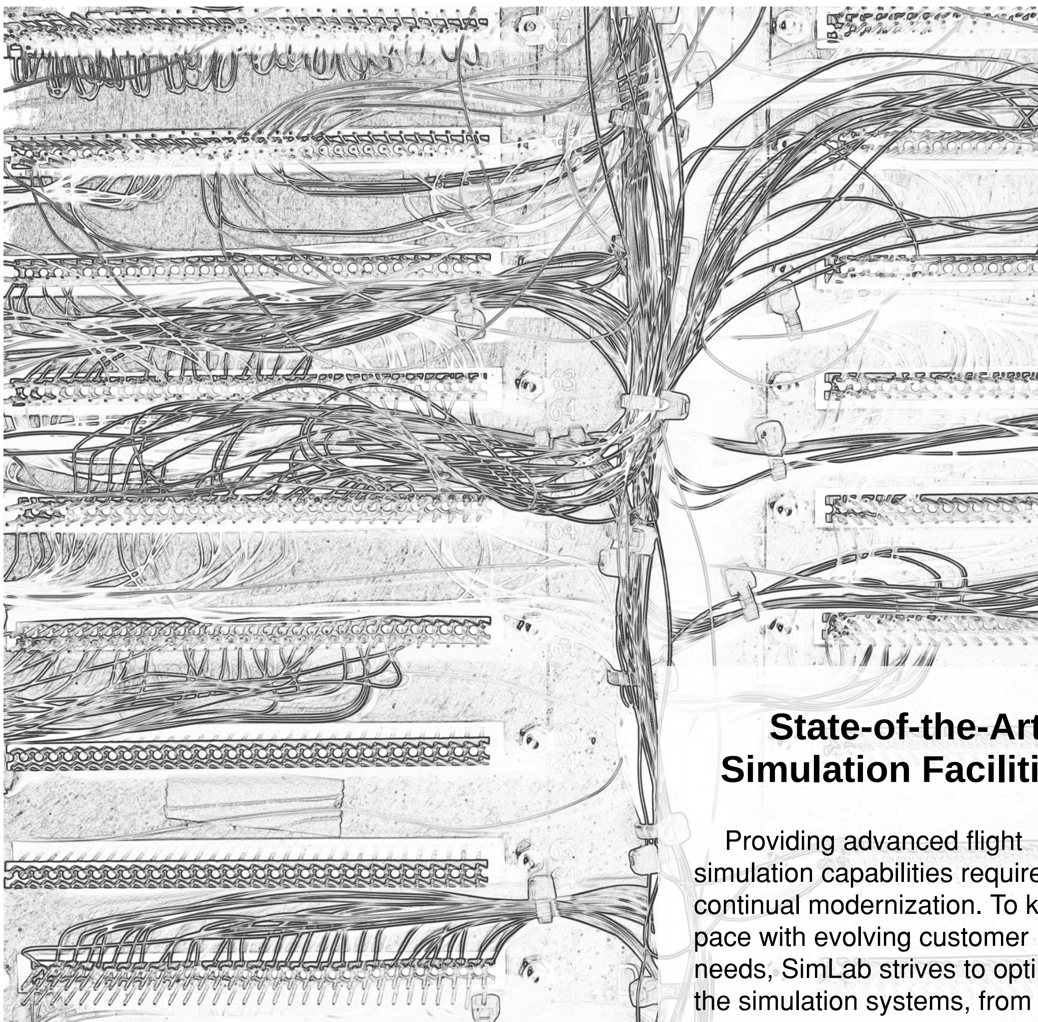
Investigative Team

NASA Ames Research Center
San Jose State University



This diagram depicts the architecture used in a study of air-ground integration procedures and concepts.

TECHNOLOGY UPGRADE PROJECTS



State-of-the-Art Simulation Facilities

Providing advanced flight simulation capabilities requires continual modernization. To keep pace with evolving customer needs, SimLab strives to optimize the simulation systems, from cockpits to computers to technology for real-time networking with flight simulators and laboratories in remote locations.

Virtual Laboratory

Summary

The Virtual Laboratory represents an extensible approach to conducting simulation experiments. It allows researchers at remote sites to interactively participate in live simulation experiments conducted in research laboratories at Ames.

Capabilities

Using the Virtual Laboratory (VLAB), remote researchers navigate through a virtual VMS lab environment. With the click of a mouse, users select, view, and position displays available in the actual lab. These include the pilot's front-window scene, head-up and head-down displays, data displays, and strip charts. Complementing the virtual environment are integrated post-run data analysis tools, two-way audio communication, video conferencing, and ambient sound capabilities.

Implementation

The VLAB system consists of four functional components:

- The VLAB client (SGI Octane workstation) presents the virtual lab and its displays.
- A network-based video transmission system provides the same out-the-window video seen by the pilots at the VMS.
- A network-based audio transmission system provides ambient laboratory sound, pilot communication, and private voice channels.
- A video-conferencing and data-analysis workstation (SGI O2) furnishes video conferencing and post-run data analysis capabilities.

Deployment of a Laptop Client

VLAB's most exciting deployment to date occurred in February during simulation of the Space Shuttle orbiter. This marked the first time that a low-cost desktop VLAB client on a personal computer was deployed for use in conjunction with a live simulation experiment between Johnson Space Center (JSC) and the VMS. For the first time, JSC researchers were able to participate in the experiment from their desktops instead of having to go to a separate lab in their facility.

Space Shuttle Development Conference

In July, the first annual Space Shuttle Development Conference was held at Ames to enable government, industry, and academia to address upgrades to the Shuttle fleet. VLAB was invited to display both the full client suite and the laptop client system in conjunction with a live simulation at the VMS. Several attendees visited both the Virtual Lab facilities and the actual VMS. Visitors and exhibitors alike were impressed with the live capability of the VLAB system.

Future Plans

Future work will include enhancing the fidelity of the immersive nature of VLAB, providing additional user input/output features, increasing VLAB's applicability to several simulation experiments, collaborating with technology experts within and outside of Ames, and increasing its diversity by applying the VLAB technology in areas beyond flight simulation at the VMS.

Future enhancements to the desktop/laptop client systems being considered include: incorporation of two-way voice communication within the client environment, support of multiple platforms, incorporation of full video conferencing capabilities within or in parallel with the VLAB client application, incorporation of post data analysis capabilities within the client platform, and as technologies permit, incorporation of direct out-the-window scene viewing within the VLAB environment.

VLAB embodies Ames Research Center's mission to lead the world in Information Technology. It allows government and industry greater access to NASA expertise in a hands-on fashion. VLAB is an extension of a national research facility that enables industry to improve and accelerate its design process, yielding cutting-edge aeronautical products.

Development Team

Russell Sansom, Chuck Gregory, Rachel Wang-Yeh, T. Martin Pethtel, Tim Trammell, Christopher Sweeney, Thomas Crawford, Paul Chaplin, Daniel Wilkins, Logicon/LISS

Thomas Alderete, Steven Cowart, Julie Mikula, John Griffin, NASA Ames Research Center

For more information, visit VLAB's web site: http://www.simlabs.arc.nasa.gov/vlab.

Using VLAB, researchers in remote locations monitor and interact with VMS simulations as they occur.

Remote Development Environment

Summary

The new Remote Development Environment enables users to develop VMS-compatible aircraft simulation models at their own engineering sites. These models can then be imported expediently into the VMS complex for their experiments.

System Capabilities

The Remote Development Environment (RDE) project created a software environment for developing aircraft simulation models and a graphics environment for visualizing model performance. The system allows a developer to work at a remote site, then import a completed model directly into piloted simulations at the VMS by virtue of model compatibility with the VMS software environment. The RDE was developed by VMS personnel and completed in February 1999.

The system consists of three major parts: the pilot's control console, the Virtual Laboratory display, and the host computer.

The control console combines the capabilities of piloting the airplane and controlling the simulation. The pilot's controls of the first RDE, designed for the Civil Tiltrotor program, consist of a three-axis hand controller for attitude control and a thrust control lever for control of the power. The console also contains push buttons that may be used as pilot control switches or as simulation configuration switches. When the RDE is used within the VMS complex, the facility's out-the-window image generators can provide the pilot's front view.

The capabilities of Virtual Lab (page 34) enable the customized arrangement of most of the displays provided in a VMS lab during a full simulation. This unified display typically includes the primary flight display, an aircraft systems display, a simplified out-the-window graphic, and a side view of the aircraft.

The model development environment is compatible with the VMS since it uses the same computers, operating systems, simulation executives, model support libraries, aircraft model interfaces, and user interactions.

Development

Development of the RDE included procuring system components, providing the functionalities of the development environment, and integrating and validating the system.

Certain areas required extensive development due to the essential differences between the VMS and the RDE. A major data communications development provided real-time timing and pilot controls in a much simpler manner than that required for VMS simulations. Rather than employing the extensive networked system required by the VMS cockpits and laboratories, hardware and software development enabled direct data communication between the console components and the simulation computer.

The thrust control lever was entirely designed and fabricated at the VMS. In addition to the basic control of thrust, the device contains several trim and discrete signal buttons integrated into an ergonomically designed controller. The control console contains 48 push buttons and supporting electronic logic for signal conditioning of the three-axis controller and its associated trim and logic switches.

Future Plans

This new ability to develop VMS-compatible aircraft models at remote sites is expected to reduce the time and lower the cost of developing research experiments prior to full simulation at the VMS. The Civil Tiltrotor program is currently using the RDE for ongoing development of the aircraft model, flight displays, and pilot controls for the program's simulations.

Development Team

William Cleveland, Dale Worth, NASA Ames Research Center; Michael Izrailov, Bosco Dias, T. Martin Pethtel, Russell Sansom, Philip Tung, Logicon/LISS

The Remote Development Environment gives researchers tools for developing and evaluating aircraft models in a simulation environment; these models can then be imported directly into the VMS system.

Rapid Integration Test Environment

Summary

This project developed procedures and infrastructure to facilitate importing aeronautical data from other research facilities into the VMS Complex. This streamlined process was then demonstrated by importing data derived at a computational fluid dynamics facility into the VMS and simulating an advanced fighter aircraft with the updated database.

Introduction

Aeronautical design involves generating data in a number of phases, which may include heuristic methods, computational fluid dynamics (CFD), wind tunnels, and flight tests. Converting the data into a usable form and integrating them into a simulation for testing can be a lengthy process. Rapid Integration Test Environment (RITE) was conceived as a means to expedite the inclusion of data from other research facilities into the VMS.

Development

This first phase of RITE focused on developing the capabilities necessary to import data created using CFD technology into the simulations at the VMS. Software was written to merge data from different sources and to convert the data to the Function Table Processor (FTP) format used in the VMS. Procedures were developed to transfer data, via the Darwin network, to the VMS.

Demonstration

To test and demonstrate the effectiveness of the process, the RITE project was to utilize CFD-derived aerodynamic data in a simulation of the Advanced Short-Takeoff/Vertical-Landing (ASTOVL) aircraft. This single-engine, powered-lift strike fighter model, developed at Ames and simulated previously at the VMS, features advanced integrated controls, guidance, and displays.

The basic lift, drag and pitching moment were computed by solving the inviscid Euler equations on a three-dimensional Cartesian grid for several values of angle-of-attack. These data were used to correct the corresponding sets of coefficients calculated using a less accurate but less computationally intensive vortex-lattice method. The corrected data were then converted to the FTP format and uploaded to a Darwin web site, from which the VMS engineer downloaded them for installation in the simulation. The data were then transferred to the simulation host computer, processed by the FTP, and linked with the simulation.

After incorporating the new data, fixed-base, piloted simulation comparisons were made between the baseline simulation model from 1997 and the two sets of aerodynamic data updated using CFD. Flight tasks involved operations on a short-takeoff-and-landing (STOL) runway and aboard an LPH assault ship.

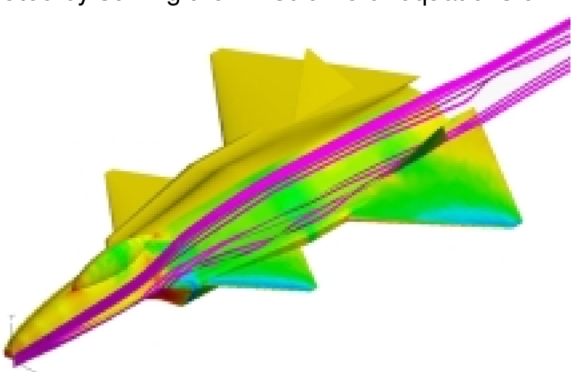
Results

This test successfully demonstrated the effectiveness of the RITE process, integrating otherwise separate design phases in order to streamline the aeronautical design process. The VMS efficiently imported data from another research facility, incorporated the data, and simulated three variations of an aircraft model. Differences were observed in the aircraft's top speed, trim angle-of-attack, and trim canard setting. As expected, little difference was seen in the longitudinal handling qualities due to the robust control system of the subject aircraft.

The procedures and infrastructure established in the RITE project can also be used to transfer data generated by wind tunnels or flight test, via Darwin, into simulation experiments at the VMS.

Development Team

Neal Chaderjian, Karen Gundy, Craig Hange, Terry Holst, Julie Mikula, David Kinney, Mary Livingston, Shishir Pandya, Joan Walton, NASA ARC; Jorge Bardina, Caelum Research; John Bunnell, William Chung, Ron Gerdes, Robert Morrison, Logicon/LISS



This project developed a streamlined process for importing data into the VMS from other aeronautical research facilities. A demonstration imported CFD data (illustrated at left) into the VMS to modify the simulated vehicle (right).

VMS Modernization

Summary

The VMS Modernization project will increase the reliability and maintainability of the VMS by replacing major system elements using improved designs and modern components.

Background

The VMS is the largest amplitude flight simulator in the world and provides unparalleled high-fidelity motion. Since the first simulation in 1981, the VMS has become the premiere motion flight research simulation facility in the country and has filled a demanding two-shift schedule. The exemplary performance of the VMS is now threatened due to its high use and aging components. While maintenance and repair costs are rising, system reliability is falling. Numerous electrical and electronic components of the VMS are out of date, and some replacement components are no longer available. Mechanical components and drives are also showing signs of wear and are nearing the end of their design life.

Simulation is a low-cost alternative to the ever-increasing high cost of aircraft testing and training research. Hence, the aeronautical industry is turning more and more to cost-effective simulation to fulfill its testing and research requirements. Since its inception, the VMS has been the benchmark for large-amplitude motion, and the VMS modernization project will keep the VMS at the forefront of simulation.

Project Phases and Milestones

The project is divided into the following phases:

- Management Planning
- Studies
- Maintenance Requirements Documentation
- Design
- Procurement
- Construction
- Installation
- Test and Verification

To minimize the impact to the simulation schedule, the period for installation and verification will be kept as short as possible.

System Improvements

The major system improvements will include:

- Motion Drives—electrical, mechanical, and control work on all six axes of motion
- Motion Drive Power—installation of new transformers, switchgear, and solid-state components to replace the power distribution system and motor-generator set
- Control System—programmable, digital control system to replace the analog and relay control systems

Benefits

The VMS Modernization is projected to result in many benefits:

- 25% reduction in maintenance costs
- 30% increase in peak accelerations
- 50% increase in bandwidth
- Improved overall system fidelity

The VMS Modernization project affects one of the nation's premier aeronautical research facilities. With these improvements, the VMS will continue to serve to its full potential in the years to come.

See http://vmsproject.arc.nasa.gov/vms1.html for more information.

An extensive project at the VMS will modernize power, drive, and control components to increase reliability and maintainability.

Flight Management System Upgrade

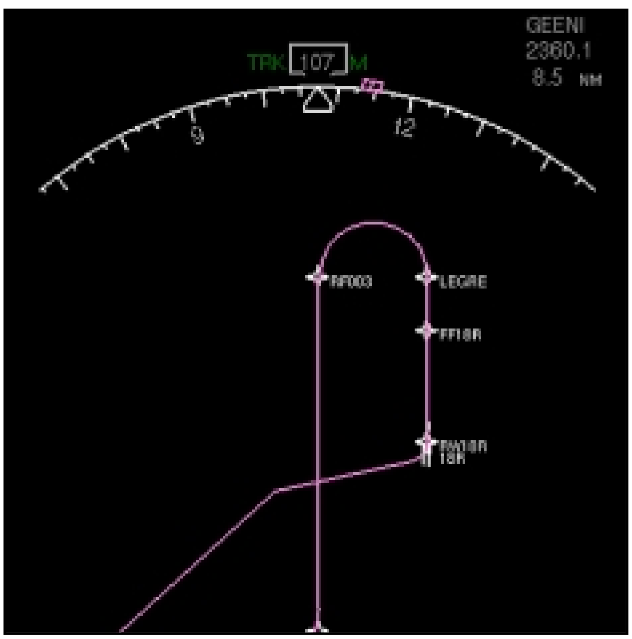
Summary

The Flight Management System avionics software in the Advanced Concepts Flight Simulator continues to be upgraded to support ongoing advanced air-space operations and automation research at Ames. This year's development effort focused on providing additional capabilities to support advanced terminal approach procedures using curved segments and a Variable Final Approach Length function.

Introduction

The Flight Management System (FMS) in a modern glass-cockpit transport aircraft is an on-board computing system that greatly simplifies flight planning, navigation, and guidance aspects of piloting an aircraft. This system, which has become indispensable for long-distance and oceanic flights, can still be cumbersome for terminal-area operations when the pilot workload is generally higher. This is partly due to a dated user interface, but mainly due to the complicated keystroke inputs and response verification required for effecting flight plan modifications.

Any improvements in clearance entry automation will have welcome benefits in reducing pilot workload as well as eliminating the possibility of pilot entry errors. From the Air Traffic Controller perspective, the Ames-developed Center TRACON Automation System (CTAS) assists in optimally scheduling arrival traffic both in terms of maximizing capacity of the destination runways and providing the most efficient route for a given aircraft. The arrival and approach route structures must be flexible for effective interoperability.



This upgrade enables the evaluation of system improvements to include curved segments and variable final approach lengths in approach procedures.

Development

The Variable Final Approach Length (VFAL) is one of the mechanisms being researched at Ames to provide variable approach length routes to the runway. This is accomplished by utilizing a combination of curved and straight length segments. The CTAS algorithms would typically define this route for a given aircraft based on other arriving traffic. This route-change information would then be sent to the FMS via datalink.

The FMS development project has provided the algorithmic and software modifications to let the FMS handle approach procedures that include embedded VFAL segments. A prototype for this FMS function was initially developed in the miniACFS development system and then integrated and verified in one of the simulator configurations.

Several other lateral and vertical flight planning improvements have also been implemented based on the pilot feedback from the CTAS/FMS Data Link study completed in the past year.

Results

The terminal-area approach procedure enhancements to the FMS will allow the experimenter wider flexibility in approach design. This function, combined with associated cockpit datalink features being developed, will be used in a follow-on study of the CTAS/FMS Data Link study.

Development Team

Ramesh Panda, ManTech
Mietek Steglinski, Steglinski Engineering

Martian Airplane Visualization

Summary

Valles Marineris, the Grand Canyon of Mars, will be explored by aircraft on December 17, 2003. The craft's mission is to help scientists determine how the canyons formed and subsequently evolved. A virtual reality demonstration of this flight was created to allow visualization of the craft's journey.

Introduction

The Mars Airborne Geophysical Explorer (MAGE) has been proposed to NASA's Discovery Program for launch in May, 2003. The MAGE aircraft, Kitty Hawk, would carry a payload of gravity, magnetic, and electric field sensors; an infrared imaging spectrometer; and a laser altimeter. It would also carry still and video cameras on the 3-hour, 1100-mile flight over the canyons.

Valles Marineris (Mariner Valley) is a valley system that dwarfs the Grand Canyon of Earth by a factor of ten or more. It reaches depths of 10 miles and widths of 100 miles. The Kitty Hawk will fly under its own power for a few hours, radioing pictures to a probe in Mars orbit, and then it will crash.

Performance

An aircraft visual model and a visual terrain database were developed for use on the Flight Safety Vital VIIIi visual system. The Mars aircraft was made selectable on either the B747-400 Flight Simulator or the Advanced Concepts Flight Simulator from the Experimenter Operator Station.

The terrain database contains a 400-by-400 mile section of the Valles Marineris and was compiled from data collected on the Viking missions. A sample data set was extracted from the Mars Digital Elevation Model created by the U.S. Geological Survey. The database has a grid spacing of approximately 10 miles.

The terrain was covered with geo-specific texture maps. The texture was taken from Viking pictures that have been orthorectified (mapped to actual Mars coordinates). With a resolution of 1.28 miles per pixel, the texture maps look best from above 20,000 feet, which meets the requirements for the high-flying Mars airplane. The San Francisco Airport model was added to the database to provide a familiar object to aid in the correct perception of the size of the Valles Marineris.

Results

One factor identified is the size of the canyon. Valles Marineris is so immense that the aircraft appeared to be standing still even though it was moving at 300 knots.

The landscape is also variable. If the aircraft flies from the top of the canyon wall until it is over the bottom of the canyon, the distance traveled is only 25 miles, but the elevation drops 4 miles. If the aircraft flies another 25 miles, a ridge measuring 13,000 feet appears.

Developer

David Brown, ManTech

In 2003, the Kitty Hawk will be released from a Martian probe to record data in multiple formats.

Navigational Database Upgrade

Summary

The purpose of the Navigational Database Upgrade is to create an automated process for compiling the three navigational databases utilized by the Advanced Concepts Flight Simulator. All required data for the continental U.S. will be available to compile up-to-date files for the Navigation Facilities, Flight Management System, and Navigation Display.

Introduction

The navigational database of the Advanced Concepts Flight Simulator (ACFS) must be updated periodically to reflect changes in the real world. For example, magnetic variation changes over time, and the database needs to be updated periodically to prevent inconsistencies that would be a source of problems in navigation.

Another problem is that changes occur constantly in the thousands of navigational aids (navaids) that exist. The ACFS navigational database could not be automatically updated with the navaid changes purchased from Jeppesen Sanderson, Inc. The task of manually updating the navaids for each experiment was tedious and time consuming.

Visual Omni-Directional Ranges (VORs) are just one element that can be automatically updated as a result of the Navigational Database Upgrade.

Performance

This upgrade involved creating a program to read the updated Jeppesen files, compare them with the records in the navigational database, and replace any outdated records. There are separate databases for the following systems:

1. Navigational Displays—These display Visual Omni-Directional Ranges (VORs), way points, and airports. Only VORs and way points have been added in this upgrade. Airports will be added in a later upgrade.
2. Flight Management System—This system has a database of airports and runways. The airports database is now upgraded automatically. The runways database will be added in a future upgrade.
3. Navigational Database—The Auto-Flight System uses an Instrument Landing System and marker beacons for flying the aircraft. This database is now updated by Jeppesen data.
4. Experimenter Operator Station—This graphical user interface (GUI) uses a database to reposition the aircraft to various airports. The database is currently edited by hand and will be upgraded in the future.
5. Visual System—The Flight Safety Vital VIIIi visual system has the capability to build a generic airport given the runway length, width, type of lighting, and a few other parameters. The database needed to support this feature will be added in a future upgrade.

Results

Phase I of the upgrade was successfully completed and has added programmability and functionality to the facility.

Development Team

David Brown, John Guenther, ManTech

Air Traffic Control Upgrade

Summary

A number of technologies have been considered for upgrading the CVSRF's Air Traffic Control Simulator. Two options currently under evaluation are the Pseudo Aircraft System and Route Traffic Manager.

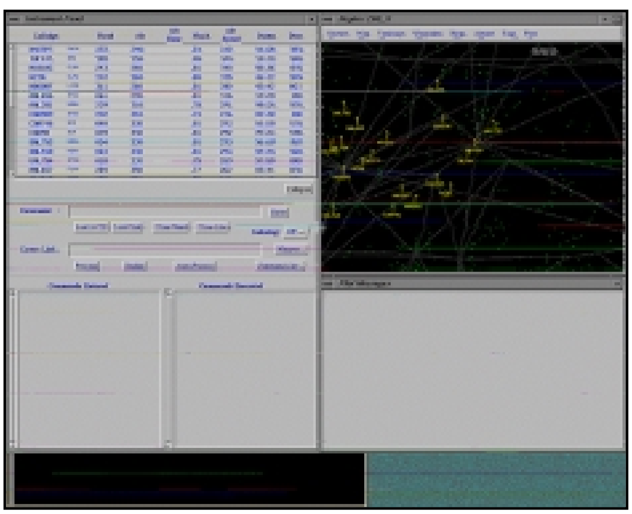
Introduction

It has been recognized for some time that an upgrade to the Air Traffic Control (ATC) Laboratory would eventually be required. A project was therefore initiated to determine the viable possibilities. Options from rehosting the original application up to and including acquiring an entirely new simulation are under examination. As part of an ongoing investigation of suitable technologies, two candidate systems have been examined and used with actual experiments. These are the Pseudo Aircraft System (PAS) and Route Traffic Manager (RTM).

Performance

PAS configurations consist of a number of components, including controller displays and pseudo-pilot stations. The components can be configured using a relatively simple graphical interface that automatically generates and saves the information required to run the components as an integrated system.

It is possible to run multiple, independent PAS sessions in or out of the ATC Lab, which enables the simultaneous execution of several experiments. The ultimate goal is to provide for interoperability with any simulator that implements High Level Architecture (HLA) software.



Pseudo Aircraft System configurations are easy to generate and even easier to understand.

Route Traffic Manager, one of two systems being considered for the Air Traffic Control Upgrade, generated this display.

Current versions of PAS do not have the capability of providing realistic ground traffic. RTM has capabilities that PAS lacks and is capable of providing a certain amount of rudimentary airborne traffic simulation.

PAS and RTM have been integrated with the simulator visual systems to the point where extremely complex patterns of airborne or ground traffic with independent and intricate behavior patterns can be produced for a given simulation. Initial indications are that investigators have minimal trouble designing complex traffic scenarios for experiments with either PAS or RTM.

Results

Both PAS and RTM have now been used during actual experiments with generally satisfactory results. There are a number of areas that require improvement, and the question of integrating air and ground traffic operations must still be addressed. System evaluation continues.

Development Team

Rod Ketchum, Joseph King, Jr., Ian MacLure, Craig Pires, Ghislain Saillant, ManTech

CVSRF Year 2000 Compliance Upgrades

Summary

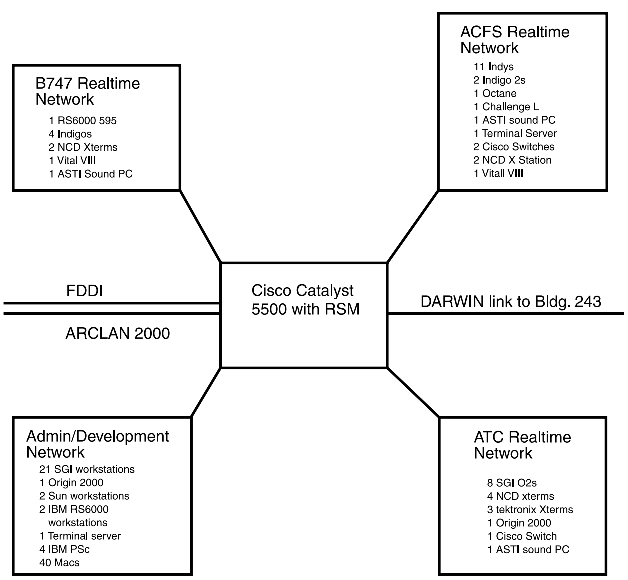
During the Fiscal Year 1999, more than eighty computer and networking systems were upgraded to meet NASA Ames Year 2000 Compliance Standards at the CVSRF.

Introduction

All CVSRF computer systems, network systems, and electronic subsystems were evaluated and tested for Year 2000 (Y2K) compliance. As expected, most systems required modification and, in some cases, replacement to meet Ames Y2K Compliance Standards. The overall project was separated into three smaller, more manageable projects.

The B747-400 simulator required an upgrade of the proprietary CAE Inc. software. This project was accomplished through a contract with CAE, the simulator manufacturer, and is documented elsewhere in this report.

The CVSRF Air Traffic Control (ATC) Laboratory required a major upgrade to the Digital VAX computer system to meet Y2K Compliance Standards. Due to the scope of this effort and to other limitations with the aging ATC Lab, a project was initiated to replace the current ATC with a Y2K-compliant ATC based on the Pseudo Aircraft System (PAS). This project is also documented elsewhere in this report.



Numerous computer and networking systems at the CVSRF were upgraded in preparation for the year 2000.

This write-up addresses the third project, which entailed the procurement and integration of new networking equipment, computers, and operating system upgrades.

Performance

The most extensive upgrade of this project was to the CVSRF Ethernet network. This required changing the central router and Ethernet hub. The manufacturer of the existing Alantec router would not support a Y2K upgrade. The router was replaced with a Cisco Catalyst 5500 Switch with an internal RSM Router Module. This provides all of the functionality of the previous system and allows for future growth. A phased plan was followed in integrating the Catalyst 5500 to minimize network downtime as well as to test new and existing networks. The Catalyst 5500 was ordered in August 1998, was installed in October 1998, and finished migration in January 1999.

Other computer Y2K upgrades included the following systems:

- 50 Silicon Graphics, Inc. Systems
- 3 IBM RS-6000 Systems
- 2 SUN Systems
- 3 ASTi Aural Cue/Communications Systems
- 2 Xylogics Terminal Servers
- 2 Flight Safety International (FSI) Vital VIIIi Visual System Motorola Computers
- 4 IBM Personal Computers
- 40 Apple Macintosh Computers

The largest single operating system upgrade was the installation of the IRIX 6.5 in the 50 SGI computer systems.

Results

Verification and validation in accordance with the Ames Y2K Compliance Standards were successfully accomplished. When appropriate, vendor Y2K compliance certificates and Y2K test results were requested and verified. The NASA-developed Advanced Concepts Flight Simulator was verified in house by performing time warp tests according to Ames Y2K testing standards.

Development Team

Craig Pires, Terry Duncan, ManTech

Acronyms

AATT .... Advanced Air Transportation Technologies
ACAH .... attitude command/attitude hold
ACFS .... Advanced Concepts Flight Simulator
AGIE .... Air-Ground Integration Experiment
AFDD .... Aeroflightdynamics Directorate, U.S. Army
APU .... auxiliary power unit
ARAT .... Advanced Route Assessment Tool
ARC .... Ames Research Center
ASTi .... Advanced Systems Technology Incorporated
ASTOVL .... advanced short takeoff/vertical landing
ATC .... Air Traffic Control
ATTC .... Aviation Technical Test Center
B747 .... Boeing 747
CDA .... concept demonstrator aircraft
CDTI .... Cockpit Display of Traffic Information
CFD .... computational fluid dynamics
CTAS .... Center TRACON Automation System
CTR .... Civil Tiltrotor
CVSRF .... Crew-Vehicle Systems Research Facility
DASE .... dynamic aeroservoelastic
DIMSS .... Dynamic Interface Modeling and Simulation Systems
DOD .... Department of Defense
DOF .... degree of freedom
DVE .... degraded visual environment
EMM .... electronic moving map
FAA .... Federal Aviation Administration
FAATC .... Federal Aviation Administration Technical Center
FAST .... Final Approach Spacing Tool
FB .... fixed-base
FMS .... Flight Management System
FTP .... Function Table Processor
GPS .... Global Positioning System
GTMS .... Ground Taxi Motion Sickness
GUI .... graphical user interface
HelMEE .... Helicopter Maneuver Envelope Enhancement
HLA .... High Level Architecture
HSCT .... High-Speed Civil Transport
HSR .... High-Speed Research
HUD .... head-up display
ICAB .... Interchangeable Cab
IFPCS .... Intelligent Flight and Propulsion Control System
IFR .... instrument flight rules
ISO .... International Organization for Standardization
JSC .... Johnson Space Center
JSF .... Joint Strike Fighter
JSHIP .... Joint Shipboard Helicopter Integration Process
LASCAS .... Limited-Authority Stability and Control Augmentation System
LHD .... Landing Helicopter Deck
LISS .... Logicon Information Systems and Services
LPH .... Landing Platform Dock
MAGE .... Mars Airborne Geophysical Explorer
NASA .... National Aeronautics and Space Administration

NASA ARC	NASA Ames Research Center
NTPS	National Test Pilot School
OFZ	Obstacle Free Zone
PAS	Pseudo Aircraft System
PCA	Propulsion Controlled Aircraft
PERCLOS	Percent Closed
PNVS	Pilot Night Vision Sensor
PWSC	Primary Weapons Systems Concept
RASCAL	Rotorcraft Aircrew Systems Concepts Airborne Laboratory
RAT	Route Assessment Tool
RDE	Remote Development Environment
RITE	Rapid Integration Test Environment
RNAV	area navigation
RNP	Required Navigational Performance
ROTO	roll-out and turn-off
RTM	Route Traffic Manager
SCAS	stability and control augmentation system
SGI	Silicon Graphics, Inc.
SimFR	Simulation Fidelity Requirements
SJSU	San Jose State University
SSV	Space Shuttle Vehicle
STOVL	short takeoff/vertical landing
T-NASA	Taxiway Navigation and Situation Awareness
TAL	Transoceanic Abort Landing
TAP	Terminal Area Productivity
TCAS	Traffic Alert and Collision Avoidance System
TCP/IP	Transmission Control Protocol/Internet Protocol
TERPS	Terminal Procedures
TRACON	Terminal Radar Approach Control
U.K.	United Kingdom
VFAL	Variable Final Approach Length
VLAB	Virtual Laboratory
VMS	Vertical Motion Simulator
VOR	Visual Omni-Directional Range
VSD	Vertical Situation Display
Y2K	Year 2000

Appendix
Simulation Facilities

A very brief description of the Aviation Systems Research, Technology, & Simulation Division facilities follows. More detailed information can be found on the world wide web at: http://www.simlabs.arc.nasa.gov

Boeing 747-400 Simulator

This simulator represents a cockpit of one of the most sophisticated airplanes flying today. The simulator is equipped with programmable flight displays that can be easily modified to create displays aimed at enhancing flight crew situational awareness and thus improving systems safety. The simulator also has a fully digital control loading system, a six degree-of-freedom motion system, a digital sound and aural cues system, and a fully integrated autoflight system that provides aircraft guidance and control. It is also equipped with a weather radar system simulation. The visual display system is a Flight Safety International driven by a VITAL VIIIi. The host computer driving the simulator is one of the IBM 6000 series of computers utilizing IBM's reduced instruction set computer (RISC) technology. An additional IBM 6000 computer is provided solely for the purpose of collecting and storing data in support of experiment studies.

The 747-400 simulator provides all modes of airplane operation from cockpit preflight to parking and shutdown at destination. The simulator flight crew compartment is a fully detailed replica of a current airline cockpit. All instruments, controls, and switches operate as they do in the aircraft. All functional systems of the aircraft are simulated in accordance with aircraft data. To ensure simulator fidelity, the 747-400 simulator is maintained to the highest possible level of certification for airplane simulators as established by the Federal Aviation Administration (FAA). This ensures credibility of the results of research programs conducted in the simulator.

Advanced Concepts Flight Simulator

This unique research tool simulates a generic commercial transport aircraft employing many advanced flight systems as well as features existing in the newest aircraft being built today. The ACFS generic aircraft was formulated and sized on the basis of projected user needs beyond the year 2000. Among its advanced flight systems, the ACFS includes touch sensitive electronic checklists, advanced graphical flight displays, aircraft systems schematics, a flight management system, and a spatialized aural warning and communications system. In addition, the ACFS utilizes side stick controllers for aircraft control in the pitch and roll axes. ACFS is mounted atop a six degree-of-freedom motion system.

The ACFS utilizes SGI computers for the host system as well as graphical flight displays. The ACFS uses visual generation and presentation systems that are the same as the 747-400 simulator's. These scenes depict specific airports and their surroundings as viewed at dusk, twilight, or night from the cockpit.

Air Traffic Control Laboratory

The Air Traffic Control (ATC) environment is a significant contributor to pilot workload and, therefore, to the performance of crews in flight. Full-mission simulation is greatly affected by the realism with which the ATC environment is modeled. From the crew's standpoint, this environment consists of dynamically changing verbal or data-link messages, some addressed to or generated by other aircraft flying in the immediate vicinity.

The CVSRF ATC Laboratory is capable of operating in three modes: stand-alone, without participation by the rest of the facility; single-cab mode, with either advanced or conventional cab participating in the study; and dual-cab mode, with both cabs participating.

Vertical Motion Simulator Complex

The VMS is a critical national resource supporting the country's most sophisticated aerospace R&D programs. The VMS complex offers three laboratories fully capable of supporting research. The dynamic and flexible research environment lends itself readily to simulation studies involving controls, guidance, displays, automation, handling qualities, flight deck systems, accident/incident investigations, and training. Other areas of research include the development of new techniques and technologies for simulation and the definition of requirements for training and research simulators.

The VMS' large amplitude motion system is capable of 60 feet of vertical travel and 40 feet of lateral or longitudinal travel. It has six independent degrees of freedom and is capable of maximum performance in all axes simultaneously. Motion base operational efficiency is enhanced by the Interchangeable Cab (ICAB) system. These five customizable cabs simulate ASTOVL vehicles, helicopters, transports, the Space Shuttle orbiter, and other designs of the future. Each ICAB is customized, configured, and tested at a fixed-base development station and then either used in place for a fixed-base simulation or moved on to the motion platform.

Digital image generators provide full color daylight scenes and include six channels, multiple eye points, and a chase plane point of view. The VMS simulation lab maintains a large inventory of customizable visual scenes with a unique in-house capability to design, develop and modify these databases. Real-time aircraft status information can be displayed to both pilot and researcher through a wide variety of analog instruments, and head-up, head-down or helmet-mounted displays.

For additional information, please contact

A. D. Jones
Associate Chief, Simulations
Aviation Systems Research, Technology, & Simulation Division

(650) 604-5928
E-mail: adjones@mail.arc.nasa.gov