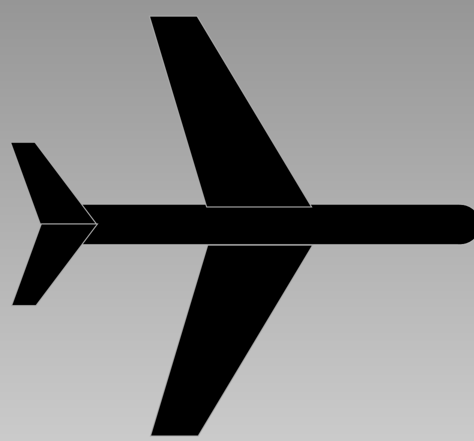
Flight Simulation Year in Review FY97

Foreword

This document is the Fiscal Year 1997 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 FY97. What follows are an Executive Summary with comments on future plans, the FY97 Schedule, a projection of simulations to be performed in FY98, performance summaries that report on the simulation investigations conducted during the year, and a summary of Simulation Technology Update Projects.



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Acknowledgment

Special thanks to Tom Alderete, Matthew Blake, Girish Chachad, Ron Gerdes, Margaret Salas and Barry Sullivan for contributions made to the production of this document.

This Annual Report addresses the major simulation accomplishments of the Aeronautical Test and Simulation Division of the NASA Ames Research Center. The Ames Simulation Facilities operated by this Division consist of the Crew-Vehicle Systems Research Facility (CVSRF) and the Vertical Motion Simulation Complex (VMS). In addition to the continuing efforts to streamline and reduce facility operations costs at NASA, paramount to Division operations has been the continuing commitment to uncommon excellence in the development and production of efficient, real-time, high fidelity, safe, piloted flight simulations. The Division has also continued to aggressively modernize in order to maintain reliability, our competitive edge and enhance 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 simulation customers.

The simulation laboratories, contained in two separate buildings at Ames Research Center, are part of the Aeronautical Test and Simulation Division organization. The CVSRF comprises a Boeing 747-400 simulator, the Advanced Concepts Flight Simulator (ACFS), and an Air Traffic Control (ATC) simulator. The VMS Complex comprises the Vertical Motion Simulator (VMS), five Interchangeable Cockpits (ICABs) and two fixed-base simulation labs. A brief description of these facilities follows this report in Appendix 1.

The purpose of this document is to briefly describe our accomplishments of the past year. Its outline includes the Executive Summary, Simulation Schedule for FY97, Planned Projects for FY98, VMS Simulation Projects, CVSRF Simulation Projects, and Technology Upgrades. The “Simulation Projects” sections state the goal of each simulation and discusses high level results. Researchers and pilots from NASA and private industry are identified as well as simulation engineers from the staff. The “Technology Upgrades” section reports changes made, or in-process, 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 FY97 include:

There were 22 major simulation experiments conducted in the flight simulation laboratories in FY97. These simulations reflect a continued concentration on NASA’s focused programs such as High Speed Research (HSR), Advanced Subsonic Technology (AST), NASA’s Space Operations, and FAA/NASA Airspace Operations Systems. Support was also provided to other Government research issues with emphasis in Army Rotorcraft and the Joint Strike Fighter (JSF) programs. In addition, there were several technology upgrade projects either completed or with significant progress being accomplished during the year.

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 “Simulation Projects” sections of this report.

Technology upgrade projects for the past year include:

Within the CVSRF, a major upgrade to the capabilities of the Advanced Cockpit Flight Simulator was completed this year. Host computers and Cockpit Graphics Systems were replaced by state-of-the-art systems which have substantially reduced operational cost with improved capabilities as well. The ACFS also received a new advanced Vital VIII(i) image generation system with a 180 degree image presentation system as part of the upgrade. Finally, the cab interior was completely reconfigured to better represent future commercial airliners. The 747-400 also received a new advanced Vital VIII(i) Image Generation Systems with a 180 degree Image Presentation System to complete its upgrade begun in FY96.

At the VMS, the new Transport Interchangeable Cab (TCAB) was completed this year and utilized in an HSR simulation in August. This effort was in direct response to HSR and AST customer requirements for a transport cockpit that better supported their future research needs.

The VMS developed a rapid response plan to replace an obsolete Computer Generated Image (CGI) system used in the Vertical Motion Simulator. A 12 year old, 3-channel Evans & Sutherland(E&S) CT5-A was replaced by a state-of-the art ESIG 4530 also built by E&S of Salt Lake City, UT. This was accomplished in an innovative and cost effective manner by obtaining a surplus system from Johnson Space Center(JSC). In a separate action, Ames is contracting for additional channels to bring the system to its full 8-channel capability. When fully expanded, this new system will be used by both the High Speed Civil Transport and Civil Tiltrotor programs in the new TCAB in the Ames Vertical Motion Simulator Complex.

The Virtual Laboratory, or VLAB, project was conceived this year and conducted a very successful demonstration with the June Space Shuttle Vehicle simulation at the Johnson Space Center. The VLAB project was to develop a prototype that demonstrates the technology and methodology for remote access to a research facility employing an interactive, virtual reality interface. Although VLAB was prototyped in the VMS, the concepts being developed have a much broader applicability - essentially to any remote access, virtual control room situation, such as wind tunnels, flight test facilities, and multiple, interoperable labs.

Future Plans

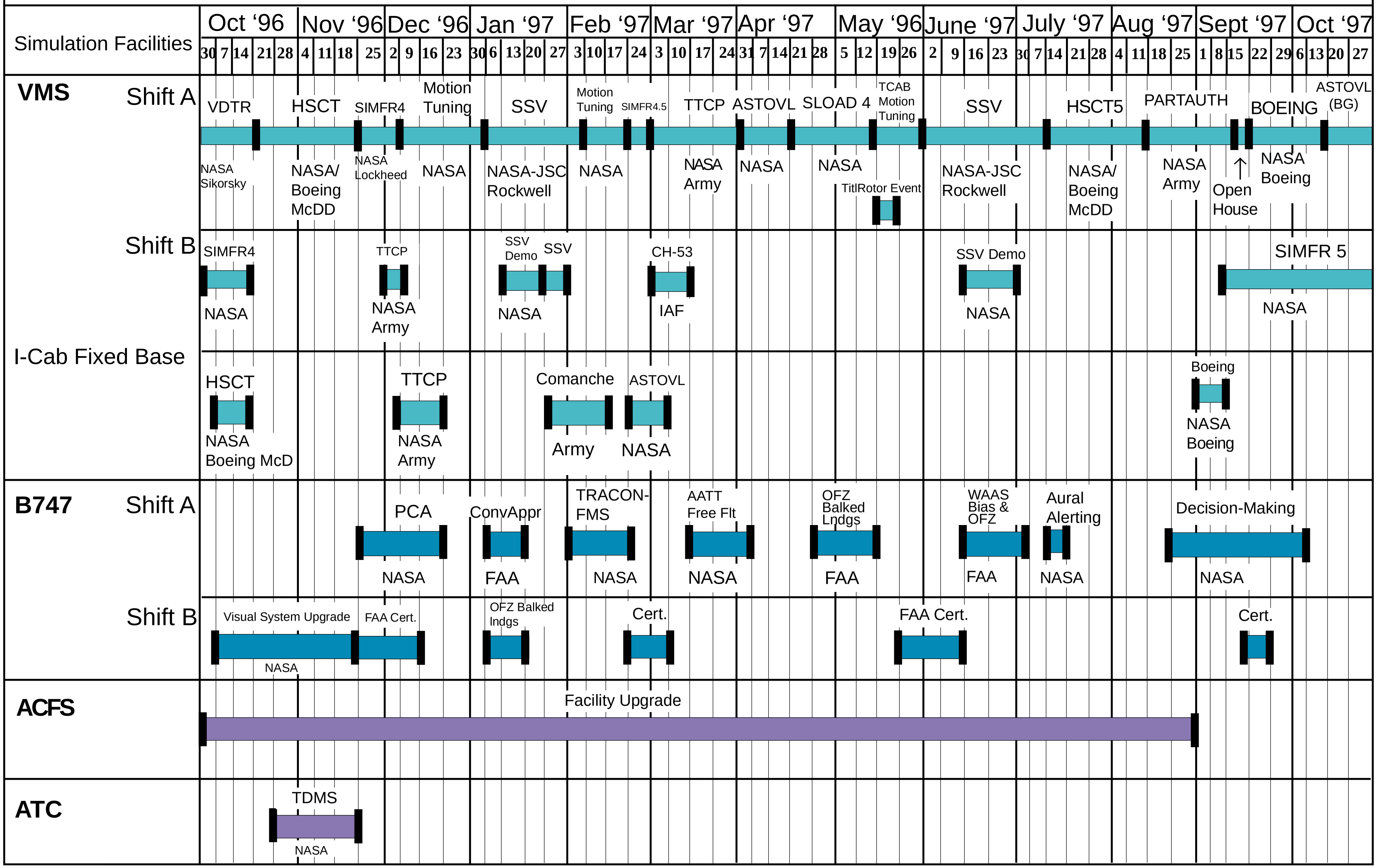
All of the simulation facilities continue to be in high demand. There is a full list of projects for FY98 that build on past research efforts and bring some new activities as well. We will continue our tradition of supporting mainstream NASA and national aeronautical development programs and being second 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 continuing efforts.

The new ESIG 4530 will be expanded to at least 5 channels and begin production operations by the 3rd Q. of FY98

The VLAB activity began last year to make NASA simulation resources and research facilities more accessible, will continue. Using concepts such as Virtual Reality and other modern techniques, enhancements to Virtual SimLab will be demonstrated. Next year will also see increased emphasis in interoperability between Ames Facilities and outside customers.

Simulation Operations Branch
Aeronautical Test and Simulation Division
Ames Research Center

FY97 Simulation Schedule



VMS Flight Simulation Projects

1. Variable Diameter Tiltrotor (VDTR)
Sept 9 - Oct 18 (VMS)
Aircraft type: Variable Diameter Tiltrotor
Purpose: To quantify VDTR performance and handling qualities in terminal area operations.

2. High Speed Civil Transport 4 (HSCT 4)
Oct 7 - 18 (FB); Oct 21 - Nov 21 (VMS)
Aircraft type: High Speed Civil Transport
Purpose: To investigate handling qualities, control requirements and guidance concepts for this type of aircraft.

3. The Technical Control Panel 1 (TTCP 1)
Dec 2 - 5 (FB); Dec 9 - Dec 27 (FB)
Aircraft type: UH-60 Black Hawk helicopter
Purpose: To investigate a helmet-mounted display alerting system.

4. Space Shuttle Vehicle (SSV)
Dec 28 - Feb 1 (FB); Jan 6 - Feb 7 (VMS)
Aircraft type: Space Shuttle Orbiter
Purpose: To study the directional control handling qualities and other orbiter landing issues.

5. Comanche
Jan 27 - Feb 13 (FB)
Aircraft type: RAH-66
Purpose: To implement and validate the math model.

6. Advanced Short Takeoff and Landing (ASTOVL)
Feb 24 - Mar 7 (FB); Mar 31 - Apr 18 (VMS)
Aircraft type: ASTOVL Lift Fan Aircraft
Purpose: To study the control mode integration and head-up display conformality.

7. The Technical Control Panel 2 (TTCP 2)
Mar 3 - Mar 27 (VMS)
Aircraft type: UH-60 Black Hawk Helicopter
Purpose: To demonstrate the helmet mounted display alerting system.

8. CH-53 Accident Investigation
Mar 3 - Mar 17 (VMS)
Aircraft type: CH-53D
Purpose: To investigate a CH-53D accident.

9. Slung Load 4 (SLOAD 4)
Apr 21 - May 16 (VMS)
Aircraft type: UH-60 Black Hawk helicopter
Purpose: To further study cargo-class helicopter operations with an external load.

10. Space Shuttle Vehicle (SSV)
June 2 - July 11 (VMS); June 16 - July 27 (VMS Demo)
Aircraft type: Space Shuttle orbiter
Purpose: To study the directional control handling qualities and other orbiter landing issues.

11. High Speed Civil Transport 5 (HSCT 5)
July 14 - Aug 14 (VMS)
Aircraft type: High Speed Civil Transport
Purpose: To investigate handling qualities, control requirements and guidance concepts for this type of aircraft.

12. Partial Authority (PARTAUTH)
Aug 18 - Sept 11 (VMS)
Aircraft type: CH-53 helicopter
Purpose: To study the effects of partial-authority control laws on longitudinal handling qualities.

13. Boeing-1
Sept 1 - Sept 11 (FB); Sept 22 - Oct 17 (VMS)
Aircraft type: JSF
Purpose: To test control law refinement, flying qualities development and pilot induced oscillation.

VMS Technical Upgrades

1. Transport Cab (TCAB)
Purpose: To support the special needs of the Civil Tiltrotor and High Speed Civil Transport programs.

2. Virtual Laboratory (VLAB)
Purpose: To develop, integrate and operate a remote-access system that facilitates interactive participation for off-site VMS customers.

3. Simulation Fidelity Requirements (SIMFR)
Purpose: To improve simulation fidelity by evaluating and modifying the motion and visual cueing system performance.

(FB) - Fixed Base Simulators
(VMS) - Vertical Motion Simulator

CVSRF Flight Simulation Projects

1. Tactical Decision-Making System (TDMS)
Nov. 5 - Nov. 22 (ATC)
Purpose: To examine workload issues for Free-Flight and the transition from an overloaded free-flight environment to a ground controlled environment.

2. Propulsion Controlled Aircraft 2 (PCA 2)
Nov 25 - Dec 20 (B747)
Purpose: To examine the use of a fly-by-throttle control system as a backup primary flight control system for a four engine transport aircraft in the event of an emergency or malfunction.

3. Converging Approaches
Jan 6 - Jan 17 (B747)
Purpose: To examine potential operational efficiencies during converging approach operations utilizing the capabilities of modern flight management systems.

4. TRACON-Flight Management System (FMS) Trajectory Synthesis 2
Feb 3 - Feb 21 (B747)
Purpose: To evaluate the human factors issues associated with pilots' abilities to fly optimized trajectory approaches utilizing the advanced automation capabilities of today's flight management systems and data-link.

5. Advanced Air Transportation Technologies (AATT) Free Flight 2
Mar 17 - Mar 31 (B747)
Purpose: To evaluate the "alert" and "protected" zone airspace definitions for free flight and pilots interpretations of applying visual flight rules right-of-way procedures to the "free flight" environment.

6. Obstacle Free Zone (OFZ)
Jan 6 - Jan 17, Apr 28 - May 14, Jun 16 - Jul 2 (B747)
Purpose: To define the safe spacing and dimension requirements for new and existing large transport aircraft when conducting aborted takeoffs or balked landings below established decision heights.

7. Wide Area Augmentation System (WAAS) Bias Error
June 16 - July 6 (B747)
Purpose: To examine the maximum bias error acceptable to pilots for Category I landings in large carrier aircraft when conducting Wide Area Augmentation System (WAAS), like precision approaches.

8. Aural Alerting
July 14 - 18 (B747)
Purpose: To evaluate whether or not the aural height cue enhances pilot performance during landing operations.

9. Decision-Making
Aug 28 - Oct 8 (B747)
Purpose: To examine flight crew communications in low and high risk situations, and how these risks affect pilots decision-making.

CVSRF Technical Upgrades

1. 747-400 Simulator Visual System Upgrade
Purpose: Increase the fidelity of the 747-400 simulator's visual system in order to enhance its realism for human factors and airspace operations research, primarily during ground operations.

2. Advanced Concept Flight Simulator (ACFS) Upgrade Phase 3
Purpose: To ensure the simulator remains capable of supporting mission critical research in the areas of human factors and aviation safety for NASA.

Special Events

1. Civil Tiltrotor's 20th Anniversary
May 22 (VMS)
Aircraft type: Civil Tiltrotor
Purpose: To commemorate the 20th anniversary of the XV-15 development and first flight.

2. NASA Ames Open House
Sept. 18 - 20 (VMS & CVSRF)
Aircraft type: Civil Tiltrotor, 747, ACFS
Purpose: To demonstrate the Ames simulation capabilities to the community and visitng VIPs.

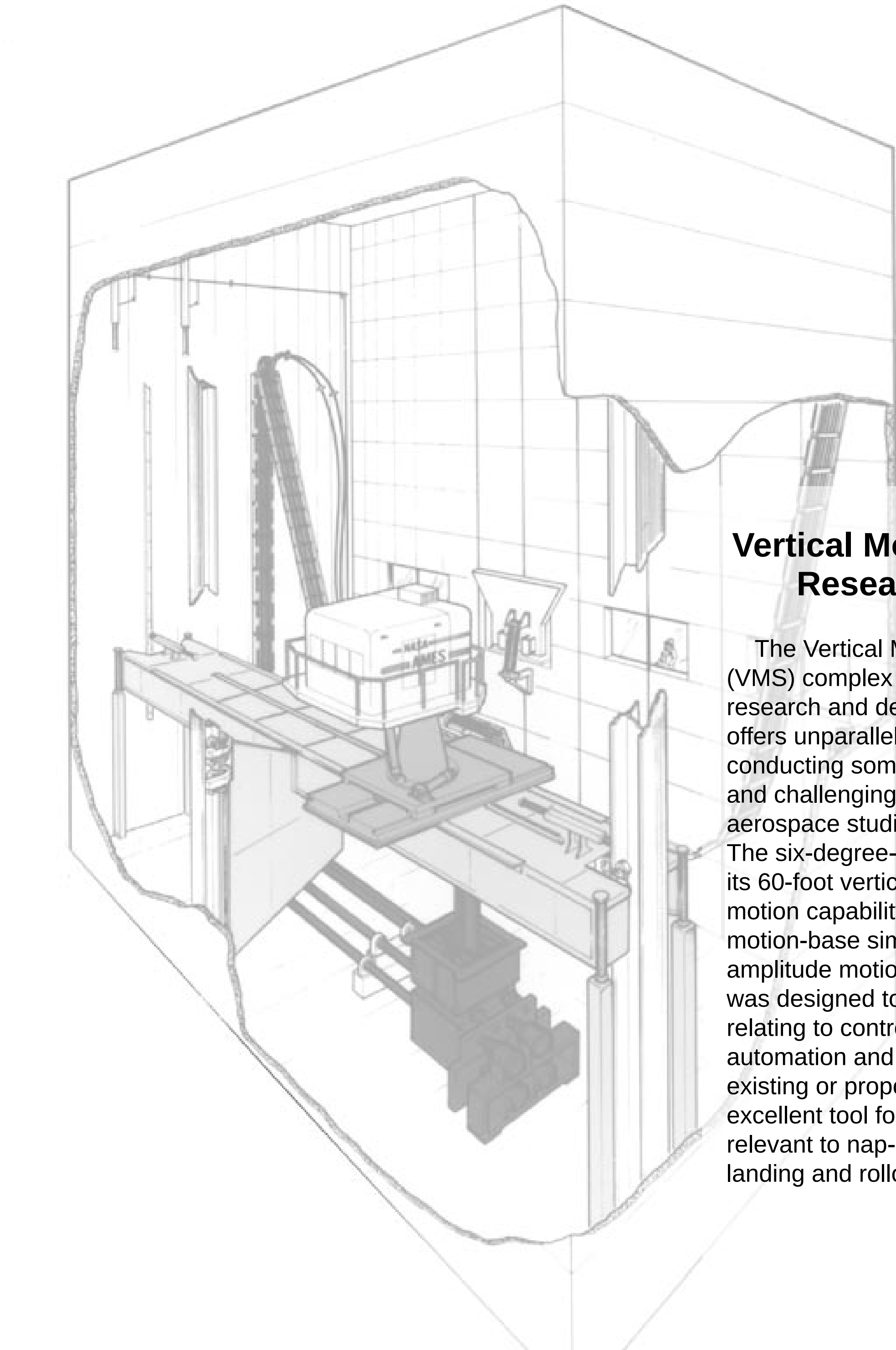
(ATC) - Air Traffic Control Simulator
(B747) - Boeing 747 Simulator

FY98 VMS Simulation Projects

PROJECT	PROGRAM SUPPORTED	CUSTOMERS	TEST OBJECTIVES
Boeing	DoD	Boeing, NASA Ames, US Air Force, Marines, & Navy	Investigate handling qualities, control requirements and guidance concepts for an lift fan type of aircraft.
Boeing-A1DoD (Advanced Flight Control Systems 1)	Boeing	NASA Ames, US Air Force, Marines, & Navy	Investigate an advanced flight control system as well as handling qualities, control requirements and quidance for a lift fan type of aircraft.
Simulation Fidelity Requirement - 5 pilot-vehicle	Other	Lockheed Martin, NASA Ames	Improve simulation fidelity by evaluating and modifying the motion and visual cueing system performance. This particular simulation period focuses on linear oscillations.
Civil Tiltrotor 7 (CTR7)	AST	FAA, NASA Ames	Continue investigation of tiltrotor aircraft vertiport design, terminal area operations and certification issues.
Lockheed	DoD	Lockheed Martin, NASA Ames, US Air Force, Marines, & Navy	Investigate handling qualities, control requirements and guidance concepts for a lift fan type of aircraft.
Space Shuttle	Space Ops	Rockwell, Honeywell, JSC	Study directional contol handling qualities and other orbiter landing issues.
OH-58	DoD	US Army, NASA Ames	In vestigate techniques being developed to support the DoD Air Platform, rotary wing sub area to improve the agility and maneuverability of the OH_58D Kiowa Warrior aircraft.
ADS33	DoD	US Army, NASA Ames	To access, develop and revise the Army's rotor craft handling qulaitites specification, the ADS-33D by using the Army/NASA/UH-60 helicopter model and the VMS.
Catagory-A One Engine Inoperative (CATA-OEI)	FAA	FAA, NASA Ames	To evaluate flight procedures, advanced cockpit displays, pilot inceptor cueing, and auditory cueing which assist the pilot in conducting safe optimal recoveries from engine failures.
Boeing - 2FY98	DoD	Boeing, NASA Ames, US Air Force, Marines, & Navy	Investigate handling qualities, control requirements and guidance concepts for a lift fan type of aircraft.
Boeing-A2 (Advanced Flight Control Systems 2)	DoD	Boeing, NASA Ames, US Air Force, Marines, & Navy	Investigate an advanced flight control system as well as handling qualities, control requirements and guidance concepts for a lift fan type of aircraft.
High Speed Civil Transport 7 (HSCT7)	AST	Boeing, NASA Ames	Investigate handling qualities, control requirements and guidance concepts for a high speed type of aircraft to be used for civilian transport.
Partial Authority	DRA	US Army, NASA Ames	Apply and evaluate a new Partial Authority SCAS concept integrated in a helicopter.
Slung Load	DoD	US Army, NASA Ames	Study cargo-class helicopter operations in a degraded visual environment with an external load.
Space Shuttle	Space Ops	Rockwell, Honeywell, JSC	Study directional contol handling qualities and other orbiter landing issues.

FY98 CVSRF Simulation Projects

PROJECT	PROGRAM SUPPORTED	CUSTOMERS	TEST OBJECTIVES
Decision Making	TAP (747-400)	NASA Flight Management & Human Factors Division	Examine flight crewcommunications in low and high risk situations, and how these risks affect pilots decision making.
Propulsion Controlled Aircraft	PCA (747-400)	NASA Ames, NASA Dryden	Evaluate the use of a low cost fly-by-throttle control law systems as an emergency backup flight control system in the event of a hydraulic system failure.
Taxiway Navigation & Situation Awareness (T-NASA)	TAP/LVLASO (ACFS)	NASA Flight Management & Human Factors Division	Increase safety and efficiency of aircraft movement on the airport surface through use of a Head Up Display (HUD) & Electronic Moving Map (EMM).
Obstacle Free Zone	FAA (747-400)	FAA Aeronautical Center (Oklahoma City)	Explore airspace and dimension requirements for new and large transport aircraft to conduct aborted takeoffs or landings in below weather minimums.
Air-Ground Communications	AATT (747-400)	NASA Flight Management & Human Factors Division	Evaluate human factors issues associated with the use of automated air-ground communications in high density terminal area operations.
Cockpit Situational Display Features	AATT (747-400)	NASA Flight Management & Human Factors Division	Examine the use of advanced self separation and traffic and collision avoidance system display symbology in support of free-flight.
Propulsion Controlled Aircraft	PCA (ACFS)	NASA Ames, NASA Dryden	Evaluate the use of a low cost fly-by-throttle control law systems as an emergency backup flight control system in the event of a hydraulic system failure.
Multiple Parallel Approaches	FAA (747-400)	FAA Technical Center	Evaluate traffic handling capabilities and spacing requirements for running multiple simultaneous parallel approach operations.
Taxiway Navigation & Situation Awareness (T-NASA)	TAP/LVLASO (ACFS)	NASA Flight Management & Human Factors Division	Increase safety and efficiency of aircraft landing & taxing on the airport surface through integrating T-NASA and a Roll Out & Turn Off (ROTO) system.
Airborne Instrumentation for Lateral Spacing (AILS)	TAP (747-400)	NASA Langley	Evaluate independent instrument approach operations to closely spaced parallel runways in adverse weather conditions utilizing advanced/emerging technologies.
Flight Replanning	AATT (747-400)	NASA Flight Management & Human Factors Division	Assess flight crews' strategies for making flight replanning decisions under current or "free flight"rules.
CTAS/FMS Data-link	AATT (ACFS)	NASA Flight Management, FAA	Investigate pilot performance utilizing automatic data-link of CTAS approaches into on-board Flight Management Computers (FMS).
Roles & Responsibilities	AATT (747-400)	NASA Flight Management & Human Factors Division	Explore the determination of roles & responsiblities between the ground operators and pilots in the "free flight" environment.



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 qualitites of existing or proposed aircraft. It is an excellent tool for investigating issues relevant to nap-of-the-earth flight, and landing and rollout studies.

Variable Diameter Tiltrotor

Karen Studebaker, NASA ARC
Steven Belsley, Philip Tung, Norm Bengford, Logicon Syscon/Syre

Summary

The Variable Diameter Tiltrotor is a Sikorsky Aircraft Corporation concept in which the rotors change diameter during flight in an attempt to optimize the performance characteristics of the rotor. The rotor operates at maximum diameter in helicopter mode and decreases in size during conversion to 66% diameter in airplane mode (Figure 1). This small diameter in airplane mode has the benefit of reduced tip speed for low noise and results in higher propulsive efficiency.

Introduction

In 1992, a wind tunnel test was conducted jointly by Sikorsky and NASA of a 1/6-scale Variable Diameter Tiltrotor (VDTR) rotor. The rotor was successfully converted between helicopter and airplane modes by remotely changing the rotor diameter and nacelle angle. Figure 2 shows the blade retraction mechanism from the test consisting of a jackscrew which moved an outer blade in and out over an inner torque tube to change diameter. This demonstrated the feasibility of the VDTR concept and motivated continued VDTR development including the current simulation activity to address the challenges of the Short Haul Civil Tiltrotor (SHCT) Program.

The simulation's primary objective was to quantify the performance and handling quality characteristics of the VDTR to that of a fixed diameter tiltrotor CTR-8/96, for a SHCT mission. The test points included steep approach procedures, terminal one engine inoperative (OEI) approach and departure procedures, and all engine inoperative procedures.

Related research includes ongoing VDTR activity such as vehicle sizing and economic analysis for the SHCT mission, proprotor aerodynamic design optimization and acoustic analysis. Also planned are isolated rotor and full-span wind tunnel tests at Ames and Langley tunnels.

Simulation Results

Preliminary results showed that both aircraft exhibited Level I, or satisfactory handling qualities during normal operations. However, for the more demanding tasks such as 9-degree instrument approaches, OEI operations and power-off autorotations, the VDTR exhibited superior performance and improved handling qualities.

For example, VDTR Category A type continued takeoff distances were typically 1/3 of that required by the fixed diameter tilt rotor, and rejected takeoff distances were about 1/2.

During Category A type landing procedures, the VDTR's ability to safely fly at lower airspeeds with one engine inoperative enabled it to be flown on a 9 degree glide slope to a lower decision height than the fixed diameter tiltrotor aircraft, resulting in a more comfortable approach and landing touchdown.

Evaluation pilots were universally enthusiastic about the performance improvements attributable to the VDTR's lower disk loading and higher rotor inertia. Pilot workload during power-off autorotations was significantly reduced with touchdown airspeeds as low as 25 knots; about half of that of the fixed diameter tiltrotor case.

Investigative Team

The Boeing Company
Sikorsky Aircraft
Federal Aviation Administration
NASA Ames Research Center

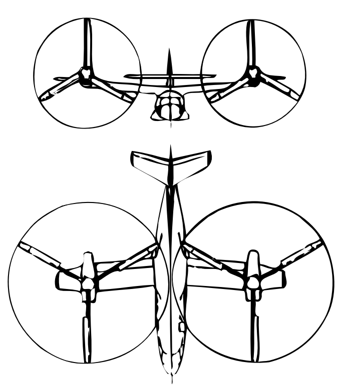


Figure 1. The VDTR shown airplane and helicopter modes.

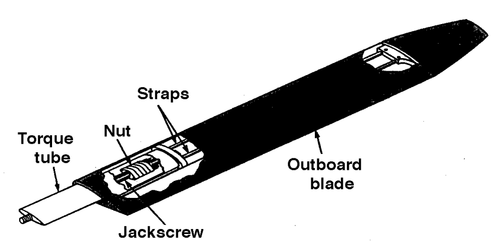


Figure 2. The VDTR blade used in the 1992 wind tunnel test.

High Speed Civil Transport 4

Dan Dorr, Joe Conley, NASA ARC
Chris Sweeney, Robert Morrison, Emily Lewis, Logicon Syscon/Syre

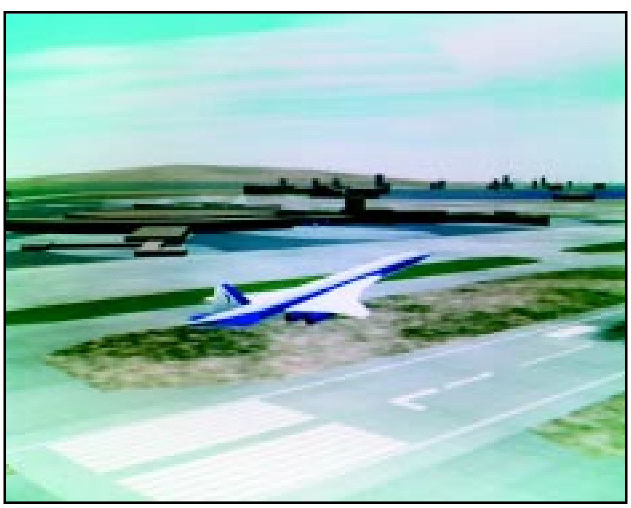
Summary

This piloted VMS investigation studied the selection of an optimum arrangement of flight control inceptors for the High Speed Civil Transport. Results indicated a slight preference for a center-mounted stick over the wheel column or sidestick.

Introduction

The High Speed Research (HSR) program is a collaborative effort among NASA and the Boeing Aircraft and McDonnell Douglas Aerospace companies. The goal is to develop the high leverage technologies necessary for an environmentally acceptable, economically viable high speed civil transport (HSCT) that provides a three hundred passenger, Mach 2.4, intercontinental service beginning in the year 2005. In support of this goal, the HSR program's Guidance and Flight Controls (GFC) team is conducting a series of simulations and flight tests designed to validate guidelines and methods to meet the flying qualities and certification criteria for an HSCT development program.

The VMS has played a significant part in its development. There have been seven HSR simulation sessions at the VMS since 1993. These simulations researched flight control systems, guidance algorithms, HUD issues, and aircraft configurations. The simulations used Boeing's basic airframe model, which has been evolving since its first release in July, 1994. Each new release incorporates further wind tunnel testing, computational fluid dynamics analyses, and modeling improvements.



The goal is to develop the high leverage technologies necessary for an environmentally acceptable, economically viable high speed civil transport.

The simulation objective was to provide handling quality comparisons and pilot commentary of wheel/column, center stick, and side stick control inceptors to support the GFC team's inceptor recommendation.

Simulation Development

Simulation modifications showed incremental gains being made toward the HSCT development. The baseline used was the Ref H-Cycle IIb version of the Boeing basic airframe model. Routines for the Boeing flight control system were updated from the previous simulation as was the McDonnell Douglas lateral-directional control system. Modifications were made to the landing gear side force model and the wind model for better realism. A soft-stop was added to the pitch and roll axes of the wheel and column and side stick inceptors.

Remarkable competence and efficiency was shown by the VMS hardware group. The test plan called for each pilot to evaluate three control inceptors. This required the exchange of inceptors being pulled out of the cab and replaced by another inceptor on a daily basis. Reconfiguration included disassembling the cab, removal of the incepter, installation of another inceptor and reassembling the cab. Final steps included verification of the entire simulation system with each new installation. Simlab's performance demonstrated its versatility and flexibility in meeting our customer requirements.

Simulation Results

Preliminary results indicate a slight pilot preference for the center stick. Of the ten pilots in the study, three significantly preferred the center stick, one preferred the wheel and column, and one preferred the side stick. Others said any of the control inceptors would be acceptable with training, because they did not identify any handling qualities deficiencies between the three choices.

Investigative Team

Boeing Aircraft Company
McDonnell Douglas Aircraft Corp.
NASA Ames Research Center

The Technical Control Panel 1

Joseph DeMaio, U.S. Army ATCOM
Luong Nguyen, Logicon Syscon/Syre; Duc Tran, NASA ARC

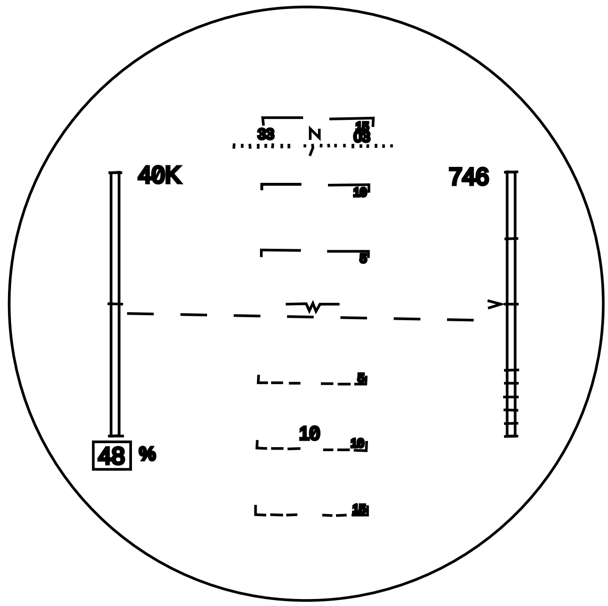
Summary

A helmet-mounted display equipped with an ambient vision system was evaluated for alerting the pilot. It was also compared to the conventional panel-mounted display. Improved performance reduced response times, and favorable pilot comments were noted.

Introduction

This was the first experiment in a series to evaluate a novel approach to alerting through the helmet-mounted display using the pilot's ambient vision system. The ambient system allows perception without attention, making it the primary visual pathway for alerting an observer to a change in an unattended part of the visual field. The ambient system draws from the entire retina, and the strength of its output is proportional to the area of the retina stimulated. Therefore, it is most effective when there is a sudden change in the stimulation of a large retinal area.

The second objective established the interaction between the field-of-view of the display and the area reserved for symbology. Past work showed that presentation of symbology at an angular separation that is greater than twenty degrees from the center of the display is not very effective. Therefore, it might be expected that the effective field-of-view for symbology might be restricted to about 40 degrees, while that for imagery might be 80 to 100 degrees. The research examined acceptability and effectiveness of symbolic arrays that are 40 degrees wide when they are superimposed upon imagery displays of the same or greater fields-of-views.



The HMD ambient vision system above shows the symbology used to alert the pilot.

The ambient system allows perception without attention, making it the primary visual pathway for alerting.

Simulation Results

Overall, the ambient helmet-mounted display (HMD) alerting mode eliminated very long (> 6 s) response latencies. It was speculated that such long latencies occur because the pilot becomes absorbed in flying and forgets the alert. The reduced set of test field-of-views yielded comparable flying performance results to those obtained with larger sets in prior research. Results also showed that the HMD alerting was not disruptive and pilots' comments were generally favorable.

Investigative Team

British Defense Evaluation Research Agency
Hughes Training Systems
NASA Ames Research Center

Space Shuttle Vehicle

Howard Law, NASA JSC
Chris Sweeney, Estela Hernandez, Leslie Ringo, Logicon Syscon/Syre

Summary

The Shuttle orbiter landing and rollout studies are an ongoing part of the Space Program. Every six months simulations are performed at the VMS to fine-tune the Shuttle orbiter's landing systems. Nose gear loads, aiming point position vs. speed brake angle, drag chute deployment speed, and single Auxillary Power Unit landings were investigated. Also, upcoming crews and astronaut candidates were provided training.

The orbiter model used in this simulation was the baseline model used previously at the VMS complex with model options and improvements specific to this simulation.

Introduction

The Space Shuttle orbiter model has been simulated at SimLab since the late 1970s. The basic model has evolved and matured over the years. The simulation at Ames has been used to test flight control improvements, safety features, head-up display development, proposed flight rule modifications, and model changes. The guidance and controls include the latest modifications (OI-24). The simulation is also used to give astronauts realistic landing and roll out scenarios, including some with system failures, as part of the training.

Many of the Shuttle orbiter's components were investigated and evaluated. Objectives included: (1) Studying the effects of an extended nose gear strut with I-load changes to the flight control system, and evaluating the effects of the nose gear extension on slapdown, gear loads, load persistance and derotation speed. (2) Studying the vehicle's handling qualities and performance using the close-in aimpoint versus a large speedbrake angle, and evaluating the pilots preference. (3) Studying a proposed flight rule to deploy the drag chute ten knots prior to derotation. (4) Studying the effects of a single Auxillary Power Unit (APU) landing. (5) Provide upcoming crews and astronaut candidates with training.

Simulation Results

The data gathered on the extended nose gear strut showed the proposed lengths of seventeen and twenty-five inches were found to greatly reduce the maximum gear load on the main gear struts. No adverse roll out handling qualities were observed. Preliminary results further showed that an extended nose strut and a change to the elevon trim position during slapdown would allow the orbiter to survive a tire failure.

Data gathered on the vehicle's handling qualities and performance using the close-in aimpoint versus a large speedbrake angle showed that handling qualities are not a problem with a large speedbrake angle landing. The findings were in view of the main concern with landing into a head wind, the inner aimpoint may be required to have enough energy to land. Another concern was landing into a tail wind, which may result in the degradation of handling qualities. Pilots did not have a preference between the large speedbrake angle or close-in aimpoint. Other considerations, such as sun glare, were of greater concern.

Another preliminary result was the flight rule for the drag chute may be modified to specify that drag chute deployment should be ten knots prior to derotation for all vehicles. The final study of the single Auxillary Power Unit showed that a single APU landing may be handled as long as the pilot minimizes control inputs in order to avoid control surface saturation.

The training session of the simulation reinforced the importance of the VMS in preparing upcoming crews for the landing and roll out phase as well as for possible failures at that time.

Investigative Team

Boeing North American
NASA Ames Research Center
NASA Johnson Space Center
Rockwell International
Rockwell Space Operations Company

Comanche

John Mayo, Sikorsky; Hossein Mansur, U.S. Army, AFDD
Chuck Perry, Leslie Ringo, Logicon Syscon/Syre

Summary

The purpose of this simulation was to implement the RAH-66 Comanche math model and validate the entire flight envelope on the VMS. U.S. Army and Sikorsky personnel concluded that the implementation of the real-time, pilot-in the loop math model was both accurate and complete.

Introduction

The RAH-66 Comanche is a reconnaissance/attack helicopter being developed by the Boeing-Sikorsky team as a replacement for the U.S. Army's OH-58 Kiowa Warrior and the AH-1 Cobra helicopters. The U.S. Army's Aeroflightdynamics Directorate (AFDD) began an effort in 1993 to acquire a real-time, pilot-in-the-loop Comanche simulation. The contract was awarded to Boeing-Sikorsky in 1994 to provide engineering documentation and check cases for the Comanche math model. Subsequently, SimLab engineers were assigned the task to code and verify the complete computer model.

The goal of the simulation was to validate the entire flight envelope of the real-time Comanche math model and correct any discrepancies in the SimLab version of the model.

The complex math model for Comanche was entirely implemented and integrated by SimLab engineers over a period of two years. Sikorsky provided the airframe model and Boeing provided the control system. The major subsystems modeled were: the airframe, rotor (using blade element approach), engine/fuel control, drive train, core and mission Primary Flight Control System (PFCS), and the Automated Flight Control System (AFCS). The final step was to validate the model with a pilot-in-the-loop fixed-base simulation this February at SimLab. The goal of the simulation was to verify the math model implementation at SimLab and validate it over the entire flight envelope of the Comanche.

Simulation Results

Prior to the fixed-base session, the model was rigorously verified by running a multitude of static and dynamic checks at the module and system level. During fixed-base operations, the model validation was accomplished by test pilots flying specific tasks as defined in the "Handling Qualities Requirements for Military Rotorcraft (ADS-33)" document and other aggressive maneuvers designed to exercise the entire flight envelope of the helicopter. Four NASA pilots and one Syre pilot flew over 250 data runs as well as numerous additional runs to flush out and correct any discrepancies in the model.

The U.S. Army and Sikorsky investigative team declared the simulation to be successful and were very satisfied with the accurate implementation of this first real-time Comanche simulation model. AFDD now has a fully validated, pilot-in-the-loop, Comanche model ready for future simulations at the SimLab facility. The model has also been transferred to an AFDD workstation where it is used for engineering studies.

Investigative Team

U.S. Army, AFDD
NASA Ames Research Center
Sikorsky Aircraft

SimLab engineers were assigned the task to code and verifiy the complete computer model for a real-time, pilot-in-the-loop Comanche simulation.

Advanced Short Takeoff and Vertical Landing

James Franklin, NASA ARC
Steven Belsley, Norm Bengford, Phil Tung, Logicon Syscon/Syre

Summary

A piloted simulation of an Advanced Short Takeoff and Vertical Landing Lift Fan aircraft was conducted to demonstrate control mode integration and head-up display conformality to Joint Strike Fighter program participants. Major contributions to Joint Strike Fighter design and operational procedures were realized, and the unique capabilities of the VMS were also demonstrated.

Introduction

NASA Ames Research Center is participating in technology development for advanced short takeoff and vertical landing fighter aircraft as a member of the Advanced Research Projects Agency's (ARPA) Advanced Short Takeoff and Vertical Landing (ASTOVL) program. Integration of flight and propulsion controls is one of the critical technologies being pursued in that program. NASA's role is to develop design guidelines for integrated flight/ propulsion controls, support ARPA technology development for ASTOVL demonstrator aircraft, and provide consultation on integrated control design to ARPA contractors. Specifically, NASA will carry out design guidelines analyses for the control system and conduct piloted simulations on the Ames Research Center Vertical Motion Simulator to assess the merits of contending design approaches.

A piloted simulation of an ASTOVL Lift Fan aircraft was conducted on the Vertical Motion Simulator. The simulated aircraft was a Harrier-like strike fighter with a propulsion system consisting of a turbofan lift-cruise engine equipped with a two-dimensional cruise nozzle in addition to vectorable lift nozzles and a shaft-driven lift fan for low speed and hover flight.

This experiment investigated control mode integration and head-up display conformality over a range of STOVL aircraft operations applicable to that of the Joint Strike Fighter (JSF). Ames was joined by engineers and pilots from the U.S. Marine Corps and Navy, the United Kingdom Defense Research Agency, and Boeing and Lockheed Martin, the two contractors competing in the JSF program.

The specific objectives for the experiment were as follows: (1) Evaluate the integration of the throttle-type controller with flight control laws that provide for controllability during transition from cruising flight to hover. (2) Evaluate control mode blending for pitch, roll, yaw, and flightpath control during transition. (3) Evaluate the effect of conformal vs. non-conformal HUD presentation of flightpath and guidance symbology. (4) Demonstrate advanced control and display systems for STOVL operations to visiting JSF program pilots and engineers.

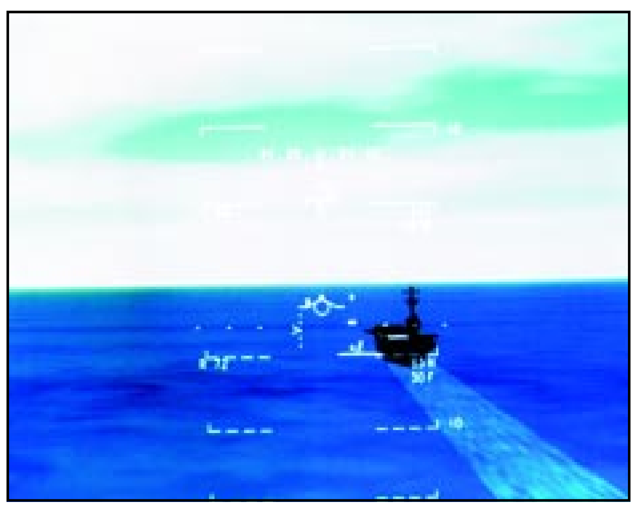
Simulation Results

The demonstrations gave the JSF visitors a view of alternative control design concepts and how they function for all aspects of STOVL operations, landbased and aboard ship. The simulation allowed all involved to experience ground operations, short and vertical takeoffs, transition to and from cruise flight, approach to landing, precision hover, and vertical and slow landings. They were able to see how the various control modes blended from one flight phase to another and the interface of the controllers and cockpit displays with these modes.

The government and industry participants departed with a number of applications to design their flight control systems and cockpit interface. They also recognized the unique capability that the VMS offers for evaluating their respective designs.

Investigative Team

The Boeing Company
British Defense Research Agengy
Lockheed Martin
NASA Ames Research Center
U.S. Marine Corps



This experiment investigated control mode integration and head-up display conformality over a range of STOVL aircraft operations.

The Technical Control Panel 2

Joseph DeMaio, U.S. Army ATCOM
Luong Nguyen, Logicon Syscon/Syre; Duc Tran, NASA ARC

Summary

The second experiment in The Technical Control Panel series, evaluated a helmet-mounted display alerting system. The alert signals the pilot to attend to an immediate issue in the cockpit. In addition, two navigation displays, which were integrated into the helmet-mounted display to supplement paper or moving maps, were also investigated. It was found that a timely alert response was achieved with the ambient alert system. Neither of the two navigation displays was particularly effective when the moving map was available as a head-down display.

Introduction

The Technical Control Panel (TTCP) series of experiments evaluate a novel approach to alerting the pilot through the helmet-mounted display using the pilot's ambient vision system. The ambient system allows perception without attention, making it the primary visual pathway for alerting an observer to a change in an unattended part of the visual field. The ambient system draws from the entire retina, and the strength of its output is proportional to the area of the retina stimulated.

This simulation was the second experiment in the series. The objectives of this simulation were: (1) To compare an ambient visual processing Helmet Mounted Display (HMD) alert with a focal processing alert to draw the pilot's attention into the cockpit. The ambient alert consisted of flashing of all symbology displayed on the HMD. The focal alert consisted of flashing only the alert symbol itself. The pattern of stimuli and responses were similar to that on the AH-64 Comanche. The pilot's response was measured in a laboratory task intended to capture the characteristics of an actual flight procedure. (2) To evaluate two navigation displays integrated into the HMD display, similar to the Comanche, with an "instrument" presented on the HMD.

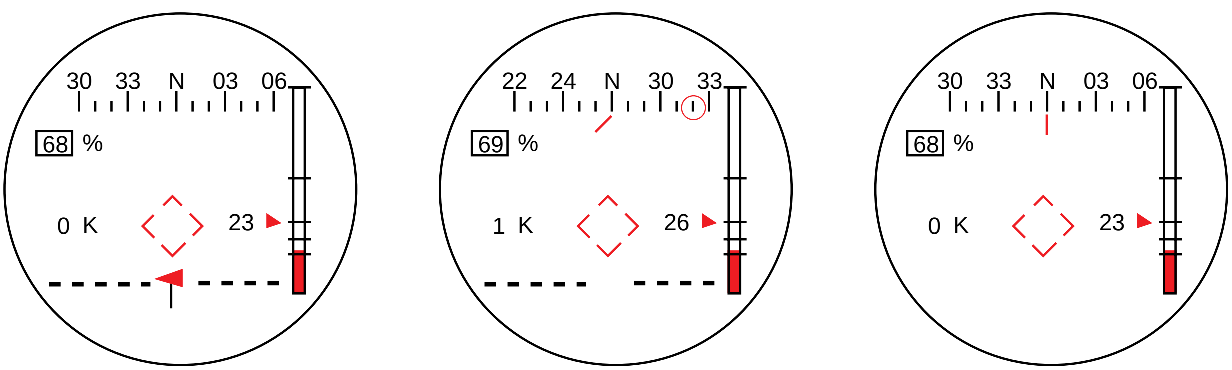
The simulation used the UH-60 math model and an IHADSS HMD with standard AH-64 cruise mode symbology. Two focal and two ambient alerts were used in the display, informative and non-informative. Focal and ambient flashing was defined as in the TTCP1 simulation.

Simulation Results

Preliminary analysis shows that: (1) The low alert frequency, stresses the pilot's vigilance in a realistic way, resulting in occasional missing of alerts. This tendency to miss alerts was eliminated by the ambient alert presentation. (2) Neither of the two navigation displays was particularly effective when the cockpit moving map was available. When the moving map was made stationary, the pilots were able to use the nav aid displays. The Course Deviation Indicator (CDI) did not provide a clear indication when the pilot had passed the waypoint, and if the pilot strayed from the course, neither CDI or Lolipop waypoint marker provided adequate information to avoid disorientation.

Investigative Team

British Defense Evaluation Research Agency
Hughes Training Systems
NASA Ames Research Center
U.S. Army ATCOM



Three helmet-mounted displays are shown. The first, at left, shows a lollipop symbology that indicates the next waypoint is to the left. The middle display shows a short angled line beneath the N that indicates the waypoint is to the left by 50 degrees. And the far right display, shows a short straight line below the N that indicates the waypoint is directly ahead.

CH-53 Accident Investigation

Zvi Avigal, Israeli Air Force
Chris Sweeney, Robert Morrison, Logicon Syscon/Syre

Summary

This simulation was effectively used to assist members of an investigation team in analyzing the cause of a fatal accident involving a mid-air collision of two CH-53D helicopters. A study of the recreated trajectories of the two helicopters indicated that one of them may have unknowingly descended upon the other.

Introduction

On February 4, 1997 at 7:00 P.M., two Israeli Air Force (IAF) CH-53D helicopters collided while ferrying troops, killing all 73 passengers and crew. An accident investigation committee was formed to study the incident and to discover why it had occurred. Two members of the accident investigation team contacted the Vertical Motion Simulator (VMS) SimLab for assistance.

The request for help was received on the 3rd of March. A math model of the CH-53 helicopter was brought up. Verification of the model and integration with the existing cab in the VMS was completed during the 1st week of March. The capability of driving and viewing two separate CH-53D graphical images was also verified.

The simulation goals were identified as: (1) To recreate the last two minutes of flight of the IAF CH-53D helicopters to help give insight into the accident. (2) To create a video showing the collision of the helicopters from varying viewing angles. (3) To recreate the final thirty seconds of the incident when one of the helicopters inflight tail section broke off and the helicopter spun to the ground.

The accident investigation team members arrived on March 10th with eyewitness testimony and a radar map of the positions of the two helicopters. The radar map contained eleven points for one helicopter and sixteen points for the other during the final ninety seconds of flight. These points were time tagged, but did not include altitude data. Since this map was two dimensional and the time of each point was not correlated, the investigation team members wished to get a graphical viewing of the events leading to the collision.

The map was placed on a digitizing tablet and the positions of the points were recorded into a file. This file was reformatted to be read real-time into the drives for the two helicopters. After fine tuning the trajectories to make the helicopters fly reasonably well, without the jerkiness apparent with so few data points, runs were recorded on video. The video showed sixty different angles of the collision, including each of the pilot's views, “chase plane” viewpoints of the incident, a view from the eyewitness perspective, and straight overhead views. The investigation team left March 13th with the desired data and videos as well as a better understanding of the collision.

Simulation Results

As the primary goal of the simulation, the trajectories of the two CH-53D helicopters were successfully replayed and video recorded. These trajectories led the accident investigation team to re-examine the original hypothesis of how the collision may have occurred. Results indicate that one helicopter may have unknowingly drifted over the flight path of the other helicopter before descending practically on top of it; however, more analysis of the crash site and tapes is needed before a final conclusion can be reached.

Preliminary results of the accident investigation indicate that one helicopter may have unknowingly drifted over the flight path of another helicopter before descending practically on top of it.

Slung Load 4

Chris Blanken, U.S. Army AMCOM
Bob Morrison, Soren LaForce, Luong Nguyen, Logicon Syscon/Syre

Summary

The US Army's heavy cargo helicopter, the Boeing CH-47D "Chinook," was simulated for the U. S. Army Aeroflightdynamics Directorate. In support of the U.S. Army's Improved Cargo Helicopter program, the aircraft was simulated with and without external slung loads. Findings will be used to upgrade the cargo helicopter through the year 2025.

Introduction

The fourth experiment in the Slung Load series, was conducted by the Aeroflightdynamics Directorate (AFDD) with participation from Boeing Helicopter, ATTC at Ft. Rucker, R. Heffley Engineering, and Hoh Aeronautics, Inc. The focus of the experiment was to obtain further data for expanding the U.S. Army's rotorcraft handling qualities specification (ADS-33D), which includes cargo helicopters, especially for slung load operations. This research is being conducted in support of the U.S. Army's Improved Cargo Helicopter (ICH) program, which is a plan to upgrade its cargo helicopters in order to sustain them through the year 2025. In addition, this research is needed to correct deficiencies in the helicopters that adversely affected their mission operations during Desert Storm.

For the experiment, the Boeing CH-47D "Chinook," the U.S. Army's heavy cargo helicopter, was simulated with and without an external slung load weighing 16,000 pounds. With a slung load, the dynamics of the aircraft are affected by not only the basic aircraft response but the coupled response from the external load configuration.

The experiment had the following principal objectives: (1) Refine the pitch and roll bandwidth data base relative to the current boundaries using the ADS-33D tasks and their equivalent cargo/slung load tasks. (2) Refine the definition/characterization of heading hold. (3) Add roll-due-to-yaw and yaw-due-to-roll coupling requirements.

Simulation Results

Various configurations of the helicopter, with and without a slung load and with different control gains, were investigated. The configurations included single and dual point suspended loads with various sling lengths and hook-to-aircraft-cg distances.

Various configurations of the helicopter, with and without a slung load and with different control gains, were investigated.

Five pilots, two from NASA Ames and one each from the U.S. Army, Boeing, and Syre, flew the different configurations to perform the lateral reposition, precision hover, hover turn, and acceleration/deceleration tasks to assess handling qualities with and without a slung load. Frequency sweeps of the configurations were performed with a pilot in the cab in both motion and fixed base. The researcher analyzed the data using comprehensive identification from frequency responses (CIFER) to determine bandwidths. The experiment was very successful, completing 1,693 runs and meeting all principal objectives.

Investigative Team

U.S. Army Aeroflightdynamics Directorate
Airworthiness Qualification and Test Directorate
Boeing Defense & Space Group,
Helicopter Division
NASA Ames Research Center
Hoh Aeronautics Inc.
R. Heffley Engineering
Naval Air Test Center

Space Shuttle Vehicle

Howard Law, NASA JSC
Chris Sweeney, Estela Hernandez, Logicon Syscon/Syre

Summary

Space Shuttle orbiter landing and rollout studies are conducted at the VMS to evaluate the Shuttle orbiter's landing systems. The major goal of this simulation was to study the proposed forward expansion of the center of gravity envelope. This experiment indicated that the center of gravity expansion results in acceptable handling qualities and structural safety margins for the orbiter.

Introduction

The Space Shuttle orbiter has been simulated at SimLab since the late 1970s. The basic model has evolved and matured in the intervening years. The simulation at Ames has been used to test flight control improvements, safety features, head-up display development, proposed flight rule modifications, and orbiter model changes. The simulation is also used to give astronauts realistic landing and rollout scenarios, including some scenarios with system failures, before their flight. The guidance and controls include the latest modifications (OI-27).

The simulation objectives were: (1) Evaluate forward center of gravity (c.g.) limit expansion. The space station assembly flights will require a more forward c.g. than is currently certified. The effect of this forward movement on nose gear slapdown rates, main gear loads, and handling qualities were studied. (2) Evaluate an extended nose gear with the proposed center of gravity extension. (3) Study a flight rules issue concerning ceilings and visibility. (4) Study tire failure/tire certification flight rules. (5) Evaluate the usefulness of the Ames Virtual Laboratory (VLAB) at JSC.

Simulation Development

Model development for this simulation focused on ensuring the nose gear slapdown and main gear loads data generated at Ames agreed with the high frequency Boeing North American loads simulation. After a week of data collection, a discrepancy was found between the Ames data and the loads simulation. Many comparison checks were run and the runs disclosed that the loads simulation was running with an old aerodynamic database. After updating the aerodynamics, the loads simulation delivered a new aero increment for the main gear loads and the simulations matched more closely. The tire failure model was updated to include the temperature and pressure of the tires.

Simulation Results

Results of the forward c.g. expansion study indicate acceptable handling qualities and structural safety margins for accepting the more forward c.g.. Preliminary results of the extended nose gear study show an increase in safety margin with the longer nose gear as well as no degradation in handling qualities. Preliminary results of the visibility and ceiling matrix indicate the flight rules should remain at the current levels as lowering the ceilings and visibility does not give enough benefits. Preliminary results of the tire failure study show no changes should be made to flight rules due to low pressure or low temperature tires. Results of the VLAB trial at JSC were very successful. The researchers who saw VLAB thought it was a great tool and should be used for all orbiter simulations.

Investigative Team

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

The major goal of this simulation was to study the proposed forward expansion of the center of gravity envelope.

High Speed Civil Transport 5

Tod Williams, Boeing; Gordon Hardy, Logicon Syscon/Syre
Chris Sweeney, Robert Morrison, Joe Ogwell, Jennifer Moga, Logicon Syscon/Syre;
Duc Tran, NASA Ames

Summary

A two-phase piloted experiment was conducted for the High Speed Research program. Part one studied flight envelope protection, head-up display symbology, and some preliminary vertical guidance algorithms. Part two studied the refinement of the lateral flying qualities criteria for High Speed Civil Transport, specifically the roll control effectiveness criterion, and evaluated the lateral-directional characteristics of the current model.

Introduction

The High Speed Research program is a collaborative effort between NASA and The Boeing Company. The goal of this effort is to develop the high leverage technologies necessary for an environmentally acceptable, economically viable, High Speed Civil Transport (HSCT) providing a three hundred passenger, Mach 2.4, intercontinental service beginning in the year 2005. In support of this goal, the HSR program's Guidance and Flight Controls team is conducting a series of simulations and flight tests designed to validate guidelines and methods to meet the flying qualities and certification criteria for an HSCT development program.

Part one goals were to provide pilot opinion regarding the current state-of-flight control envelope protection, downselect a variety of head-up display (HUD) symbology, and give feedback on the current vertical guidance algorithms. Part two goals were to refine the lateral flying qualities of an HSCT and evaluate the lateral-directional characteristics of the current aircraft model.

Simulation Development

The airframe model was upgraded to Ref. H-Cycle III for this simulation. The major revisions for the upgrade were to the aerodynamic database and the engine model. The Cycle III aero model included data from three Langley wind tunnel tests. The longitudinal flight control system was updated as was the lateral-directional flight control system. Modifications were made to the HUD driver in order to display various new symbols needed for part one of the simulation.

Simulation Results

Part one results indicated that pilots believed the envelope protection (annunciation and flight control system intervention when limits were exceeded) was appropriate for the aircraft. They felt that it could have been more aggressive in preventing the pilot from exceeding structural limits. The preliminary guidance algorithms were acceptable, and the added HUD symbology was helpful. Part two data is helping to define a database of acceptable criteria for an HSCT.

Investigative Team

The Boeing Company
Federal Aviation Administration
Honeywell
NASA Ames Research Center

A series of simulations and flight tests are designed to validate guidelines and methods to meet the flying qualities and certification criteria for an HSCT development program.

Partial Authority

Chris Blanken, U.S. Army AMCOM
Estela Hernandez, Luong Nguyen, Logicon Syscon/Syre

Summary

This simulation experiment was conducted in preparation for a flight test program to develop a flight control system upgrade for an Improved Cargo Helicopter. The Improved Cargo Helicopter program will sustain the CH-47D fleet into the next century. Since it was not possible to flight test all significant variants of the existing analog flight control system, they were simulated at the VMS instead. The simulation objective was to explore two types of variations. The first was to explore variations in baseline system parameters (Boeing 8/4/97 version), and the second was to explore alternative mechanization concepts.

Introduction

The Boeing CH-47D “Chinook” is the US Army’s heavy cargo helicopter. The Chinook first flew as the YCH-47 in September 1961. There have been several modernization plans over the years which have upgraded the aircraft from the A-model to the “B-”, “C-” and to its present CH-47D configuration. The first D-model has been in service for 15 years since its remanufacture. As the end of the century approaches, CH-47D’s operational costs will increase and its readiness will deteriorate as the aircraft reach the end of their economic life.

At the request of the U.S. Army Aviation and Missile Command (AMCOM), the U.S. Army Airworthiness Qualification Test Directorate (AQTD), located at Edwards Air Force Base, conducted handling qualities flight tests with a CH-47D. The purpose of these flight tests were to document the CH-47D dynamic response characteristics and to develop and refine a set of flight test maneuvers specifically for evaluating cargo helicopters and sling load operations. The results of the AQTD flight test formed a basis from which piloted simulations have been conducted by Boeing and the U.S. Army Aeroflightdynamics Directorate (AFDD) toward development of criteria for this size and class of helicopter. These simulations have been used to investigate different control response types and dynamics, different aircraft load configurations, reduced thrust margins, interactions between the slung load and the aircraft Advanced Flight Control System, and the potential for achieving attitude stabilization through the partial authority control system.

The Boeing CH-47D “Chinook” is the US Army’s heavy cargo helicopter. There have been several modernization plans over the years which have been used to upgrade the aircraft.

This simulation was the last opportunity to investigate/resolve issues prior to submitting initial handling qualities requirements for the Improved Cargo Helicopter program. The focus of this simulation was to refine the CH-47D partial-authority control laws to improve the longitudinal handling qualities for aggressive maneuvering. Based on the VMS investigation of alternate control laws, the best designs will be implemented into a CH-47D flight control computer and flight tested at the U.S. Army Aviation Technical Test Center, Ft. Rucker, Alabama.

Simulation Results

Pilots from the Army, NASA, Navy, and Boeing flew 1159 data runs, which included a variety of low altitude, low speed precision flight task. In addition, some forward flight tasks were evaluated. These consisted of an Instrument Landing System (ILS) approach, transition to hover, missed approach and traffic pattern back to the ILS. A total of eight flight control system variations were studied. After further analysis of the data, the best designs will be identified and selected for flight testing at Ft. Rucker, AL.

Investigative Team

U.S. Army Aeroflightdynamics Directorate
Aviation Technical Test Center
Boeing Defense & Space Group, Helicopter Division
NASA Ames Research Center
Hoh Aeronautics, Inc.
R Heffley Engineering
Naval Air Systems Command

Boeing-1

Boeing Aircraft Company
William Chung, James Franklin, NASA ARC
Chuck Perry, Leslie Ringo, Girish Chachad, Al Sanchez, Logicon Syscon/Syre

Summary

A piloted simulation of Boeing's X-32 Joint Strike Fighter (JSF) design was conducted as part of their design and development process. Boeing ran their aircraft model on SimLab's large motion VMS to complement their in-house simulation. Boeing, U.S. and U.K. Service, and NASA test pilots evaluated Boeing's JSF design utilizing the unique capabilities of the VMS.

Introduction

NASA Ames Research Center is playing a key role in support of the U.S. government's Joint Strike Fighter (JSF) Program which will field an affordable, highly common family of next-generation multi-role strike fighter aircraft for the Navy (USN), Air Force (USAF), Marine Corps (USMC), United Kingdom Royal Navy and other U.S. allies. The Military Services have stated their needs for the JSF as follows:

The Joint Strike Fighter is envisioned as the next generation fighter to replace several aircraft in service with the United States Air Force, Navy, Marines, the United Kingdom Royal Navy and several other countries.

• USN - first day of war, survivable strike fighter aircraft to replace the A-6 and F-14 and complement the F/A-18E/F

• USAF - multi-role aircraft (primary-air-to-ground) to replace the F-16 and A-10 and to complement the F-22

• USMC - STOVL aircraft to replace the AV-8B and F/A-18A/C/D

• United Kingdom Royal Navy - STOVL aircraft to replace the Sea Harrier

The Boeing Company is one of two manufacturers selected to build and fly a pair of (X-32) JSF Concept Demonstration Aircraft (CDA). Real-time, piloted flight simulation is an important step in Boeing's approach to JSF design and development. Simulations using the large motion-base at Ames' VMS were conducted by Boeing to complement their in-house simulation efforts prior to conducting in-flight simulations and flight testing. The objectives of the VMS simulation included control law refinement, flying qualities development, pilot-induced oscillation (PIO) analysis.

Besides Boeing pilots, Navy, Air Force, Marine Corps, United Kingdom Royal Air Force and Royal Navy and NASA test pilots participated in the evaluations.

The simulation ran fixed-base for two weeks, followed by 4 weeks of motion-based operations. The fixed-base session was primarily to validate the simulation system, finalize flight tasks and scenarios and exercise data collection processes in preparation for the motion-base experiment. The validation was a critical step since the computer code for the entire aircraft model generated by Boeing was integrated into SimLab's simulation environment. The validation was performed with Boeing personnel on site.

Simulation Results

The primary objectives of the simulation were met, and 819 piloted evaluation runs were completed. Pilots from Boeing, U.S. and U.K. Services and NASA were favorably impressed with the important part that large motion cueing played in enhancing their evaluations of Boeing's JSF flying qualities and mission capabilities in general.

For SimLab, this simulation marks the first time that a customer's entire aircraft model has been integrated into SimLab's real-time system. Also, special security measures were put in place to safeguard information relating to Boeing's simulation hardware and software due to the competition sensitive nature of the project, thus limiting the details contained in this write-up.

Note: For further information regarding the Boeing JSF program, please refer to the Boeing and JSF Program Office World Wide Web pages:
http://www.boeing.com

Civil Tiltrotor's 20th Anniversary

William Decker, NASA ARC
Steve Belsley, Philip Tung, Logicon Syscon/Syre

Summary

Ames Research Center celebrated the 20th Anniversary of the first flight of the XV-15 Tiltrotor. After hundreds of hours of flight, the XV-15 is still a critical link in tiltrotor research and future development of this technology.

Introduction

On May 22, 1997, Ames Research Center celebrated the 20th Anniversary of the first flight of the NASA/ Army/ Bell XV-15 Tiltrotor Research Aircraft. A new era in aviation was introduced with the V-22 Osprey tiltrotor aircraft and the announcement of the Model 609 Civil Tiltrotor by Bell Helicopter Textron and Boeing Helicopters. The technology development and the demonstration of capability achieved with the XV-15 was essential to the launching of these aircraft. As such, the XV-15 Tiltrotor Research Aircraft is one of the most versatile aircraft ever designed.

Tiltrotor aircraft combined features of helicopters and fixed-wing aircraft. They have the vertical takeoff and landing capability of the helicopter and the cruise speed, range, and fuel economy of fixed-wing aircraft. Tiltrotors achieve this by the use of proprotors that operate like helicopter rotors during takeoff and landing, then tilt to provide horizontal thrust acting like turboprops during cruise.

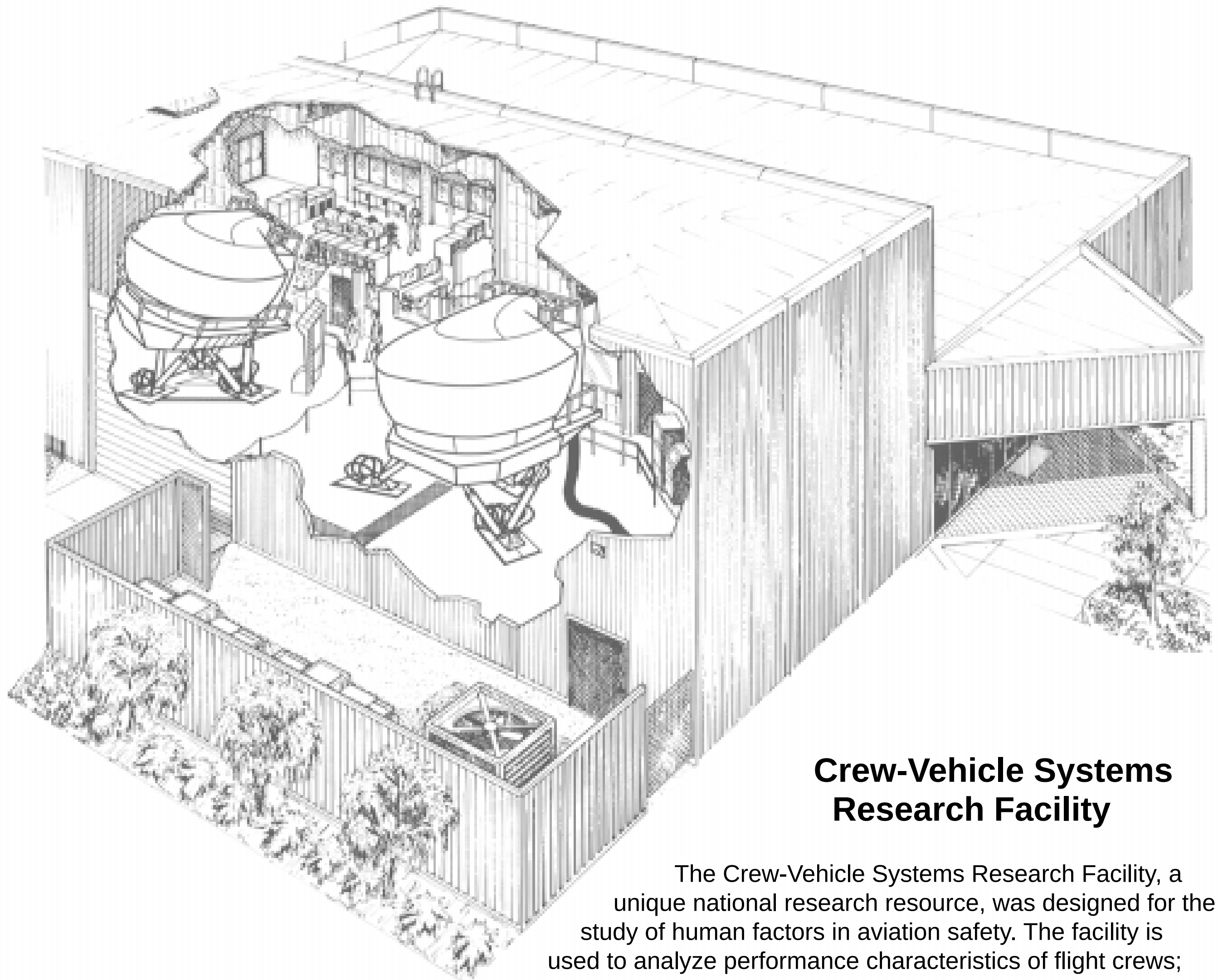
The development of the XV-15 Tiltrotor was initiated in 1973 with joint NASA/Army funding, and SimLab was involved from the start to support its development. In the early 70’s, the Flight Simulator for Advanced Aircraft (FSAA) was used for XV-15 simulation, evaluation and contractor downselect to Bell. By the mid 70’s, the FSAA assisted the design and development of the XV-15 prior to its first flight. The late 70’s and early 80’s saw the XV-15 further developed and its operational use evaluated. Also at this time, a transition was made from the FSAA to the Vertical Motion Simulator (VMS). Early 80’s research led to the V-22 program and evaluations of the Army LHX. Finally, the Civil Tiltrotor (CTR) series began in 1989 and is still in development.

The development of the XV-15 tiltrotor research aircraft was initiated in 1973 with joint Army/ NASA funding as a "proof of concept", or "technology demonstrator" program, with two aircraft being built by Bell Helicopter Textron.

One way the commercial tiltrotor aircraft could help reduce airport congestion and traffic delay problems would be by using off-airport vertiports for urban area to urban area and city center to city center service, diverting travelers away from crowded hub airports and their access roads.

The Event

To help commemorate this 20th Anniversary, a Civil Tiltrotor was configured on the VMS in order to showcase its unique capabilities. The CTR-6 simulation math model and cockpit hardware arrangement were utilized for the demonstration. Visitors were able to monitor the pilot’s cockpit displays as well as observe the VMS motion system excursions. An Ames research pilot flew the approaches while the project engineer described the various approach segments and associated operational procedures.



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 is used to analyze performance characteristics of flight crews; formulate principles and design criteria for future aviation environments; evaluate new and contemporary air traffic control procedures; and develop 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-- a 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.

Tactical Decision-Making System

Irene Laudeman, NASA ARC
Connie Brasil, San Jose State University

Summary

An experiment was conducted to determine Dynamic Density, which characterizes the transition from unconstrained flight to constrained flight, or from free-flight to ground based Air Traffic Control flight. Additional goals of the study were to identify controller techniques used to transition between control types, evaluate two alert zone graphical displays, and compare route efficiencies for constrained and unconstrained flight.

Introduction

One of the concepts for increasing airspace capacity is the implementation of “free flight,” which allows aircraft on instrument flight plans to provide their own separation independent of ground controllers. Important issues are to determine at what traffic density this becomes a problem and how to safely revert to ground-based control of the aircraft separation. To study these issues, the CVSRF Air Traffic Control (ATC) simulator was configured to use three of the four sector displays as “pilot” stations and one as an ATC Controller Station. Actual FAA controllers performed as both pilots and controllers. Three of the controllers were positioned at the pilot sector displays and each controlled several aircraft in free-flight mode. They were provided with graphical conflict alert ellipses around each aircraft in order to identify aircraft flight paths in conflict. They would then radio the other aircraft crew and agree on a maneuver to avoid collision. A fourth controller, stationed at the ATC controller station sector display, was to intervene if the aircrafts were not able to maintain safe separation.

Simulation Results

For this study, the ATC simulator was modified to support 20 ATC sector displays, which provided stations for 19 pilots and one controller. Data was collected regarding Dynamic Density, procedures, alert zone graphical displays, and route efficiencies for constrained and unconstrained flight. A second experiment is planned to further study the performance of pilots concurrently. Although the experimental setup is complete, the series of studies has been put on hold pending NASA and FAA agreement on program responsibility issues.

The Air Traffic Control (ATC) simulator was configured to use three of the four sector displays as “pilot” stations and one as an ATC Controller Station.

Propulsion Controlled Aircraft 2

Robert Mah, NASA ARC
John Bull, CAELUM Research Corp.

Summary

The second experiment in the PCA series, examined the use of a fly-by-throttle control system as a backup flight control system in the case of an emergency, or malfunction to an airplane's primary flight control system.

Introduction

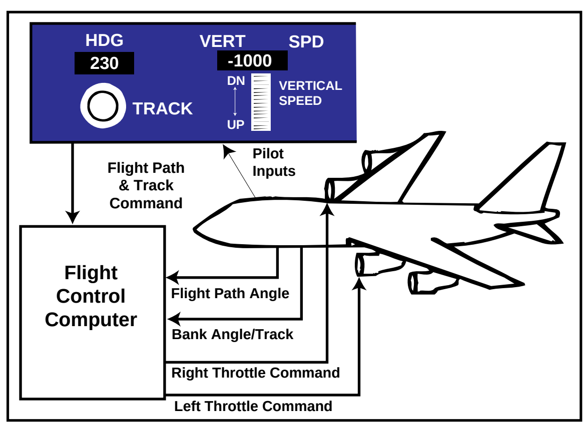
Over the years, numerous aircraft accidents have been caused as a result of primary flight control system failures. Most vivid is the Sioux City, Iowa incident, where the primary flight controls of a United Airlines DC-10 were rendered inoperable due to a loss of hydraulic power. The pilots were able to land by skillfully manipulating the engine controls, and successfully saved many lives. Subsequent to this accident investigation, the National Transportation Safety Board (NTSB) recommended to NASA the need to *"encourage 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."*

In compliance with the NTSB recommendation, NASA-Dryden in conjunction with Ames Computational Sciences Division, conducted a study which further examined the use of a fly-by-throttle control system as a backup flight control system in case of an emergency, or malfunction to an airplane's primary flight control system. This experiment, called the Propulsion Controlled Aircraft (PCA) 2 study, evaluated the PCA control laws for the 747's full operational envelope in realistic, worst case scenarios. The PCA concept was originally developed at NASA-Dryden, using a two-engine aircraft. Later, this study was moved to NASA-Ames and tested on the Advanced Concepts Flight Simulator, using two- and three-engine aircrafts. Recently, after evaluating PCA control algorithms, it was performed on the 747-400 simulator, using a four-engine aircraft.

Simulation Results

The PCA control laws essentially allow pilots to fly an aircraft using only the throttles for pitch and roll commands, without the use of the airplane's primary flight control systems. When PCA mode is selected, the airplane's pitch and roll commands are controlled by the vertical speed and heading select knobs on the airplane's Mode Control Panel. Using the throttle commands, thrust inputs are translated through software into equivalent pitch and roll commands, allowing pilots to maintain control of the malfunctioning aircraft.

Various scenarios were examined such as jammed controls, hydraulic and engine failures, and out-of-trim roll and yaw moments. Data collected during these runs included performance metrics of aircraft state data, touchdown snapshots, Cooper-Harper Ratings Scale, and post-simulation pilot questionnaires. Participating pilots represented NASA, the US Air Force, Boeing and United Airlines. Findings showed that subject pilots rated the PCA control laws satisfactory to adequate using the Cooper-Harper ratings. It was also determined that the PCA performed well during single-engine failures, recoveries from unusual attitudes (including high altitude conditions), and at aft center-of-gravity conditions.



This simulation focused on the adaptability of the PCA control laws for a four-engine aircraft during approach and landing operations.

Converging Approaches

Ralph Dority, FAA System Capacity Office, Washington D.C.
Allen Jones, Frank Hasman, FAA Standards Dev. Branch, Oklahoma City
Barry Scott, FAA Field Office, NASA ARC

Summary

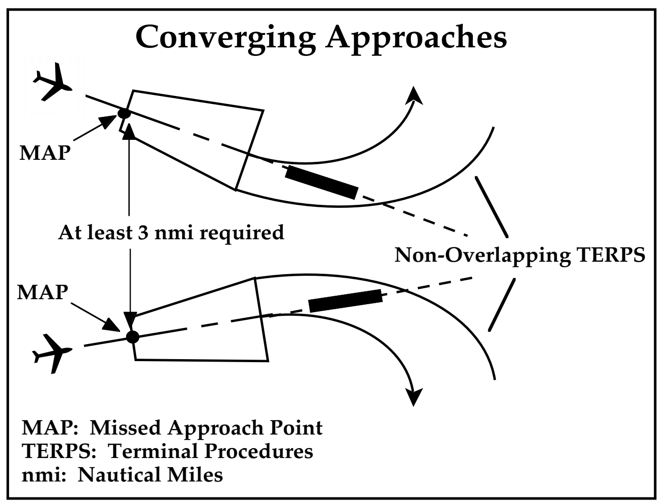
Potential operational efficiencies were further tested, utilizing the capabilities of modern flight management systems during converging approach operations.

Introduction

This series of study, conducted by the System Capacity Office, Federal Aviation Administration (FAA) in Washington D.C., in cooperation with the Standards Development Branch at the FAA Aeronautical Center in Oklahoma City, tests increasing airport capacities to develop a standard for air-carrier airplanes equipped with state-of-the-art Flight Management Systems (FMS). Also studied are simultaneous Instrument Landing System (ILS) approaches and missed approaches on a primary traffic flow runway and on a converging runway by airplanes utilizing a modern FMS. The FAA with participation from the airlines, aircraft manufacturers and oversight agencies have been investigating flight-track data obtained as a result of using high-end FMS equipped air-carrier-aircraft simulators when operating with FMS Lateral Navigation (LNAV) guidance. To further enhance data previously obtained, additional testing is necessary to assess the safety aspects of the converging missed approach during FMS LNAV tracking as well as evaluating flight-crew human factors issues.

Simulation Results

This experiment was designed to examine the use of a revised missed approach procedure for FMS equipped aircraft. Specific goals were to determine: 1) aircraft geographic position relative to the runway threshold position during missed approach procedures, 2) aircraft state versus geographic position during the missed approach maneuvers, and 3) if there are any human performance issues associated with flying these specialized procedures. The experiment examined the use of a lateral course offset from the localizer using Chicago O'Hare's runway 4R and the aircraft's FMS for positive guidance during the converging missed approach operation. To support the converging missed approach, a customized FMS database was provided by Honeywell through the FAA, in order for pilots to fly the given procedure. Conclusive statements are pending.



This simulation examined the use of a revised missed approach procedure for FMS equipped aircraft.

TRACON-Flight Management System Trajectory Synthesis 2

Rhonda Slattery, NASA ARC
Beverly Sanford, Katherine Lee, Sterling Software

Summary

A pilot's ability to fly optimized trajectory approaches utilizing today's flight management systems and advanced features such as data-link was evaluated.

Introduction

The Human-Automation Integration Research Branch of the Flight Management & Human Factors Division conducted a study on the 747-400 simulator to evaluate the feasibility of using current data-link messages to perform Flight Management System (FMS) operations in the terminal area. Quantitative flight path tracking data (using FMS data) were compared to similar results of an earlier study, but flown manually or as autopilot assisted. Trajectory approaches for both studies were generated by the Center TRACON Automation System (CTAS), which was developed by NASA. CTAS is an automated air traffic control system designed to allow more efficient flight in the national airspace system without jeopardizing safety. Other factors studied were the effects of various arrival procedures on pilot workload, communications and coordination, and head-down time. This study was conducted in support of the Terminal Area Productivity (TAP) Program.

Simulation Results

Scenarios consisted of approaches from the southeast, with landings to runway 17C at the Dallas-Fort Worth International (DFW) Metroplex. Line qualified 747-400 crews participated in this study. Data collection included aircraft position and state data, videotapes and pilot questionnaires. In addition to the quantitative flight path tracking data that was collected, subject pilots were asked to provide ratings of the FMS approach procedures and phraseology to determine whether Future Air Navigation System (FANS) messages and data-link interfaces are acceptable for terminal area operations.

Preliminary results indicate the necessity for clear representation of the exact route changes on the pilot's navigation displays, with the ability to review previous clearances as compared to the new routes, and to depict route compliance with airspace restrictions. In addition, subject pilots had acceptability issues using the FANS data-link messages with the tested procedures. Speculation suggests this may be due to FANS messages, which were originally designed for the oceanic arena and not the terminal area. Other issues included timeliness of reviewing changes, inexperienced pilots using vertical navigation (VNAV) in the terminal area, and the amount of head-down time it took the pilots to review and implement the revised route changes. Conclusive statements are pending.

A study was conducted on the 747-400 simulator to evaluate the feasibility of using current data-link messages to perform Flight Management System (FMS) operations in the terminal area.

Advanced Air Transportation Technologies Free Flight 2

Sandy Lozito, NASA ARC
Alison McGann, Margaret-Anne MacKintosh, Patricia Cashion, San Jose State University

Summary

This study evaluated the “alert” and “protected” zone airspace definitions for free-flight and investigated pilots’ interpretation of Visual Flight Rules right-of-way procedures and their application to the free-flight environment.

Introduction

The Human-Automation Integration Research Branch of the Flight Management & Human Factors Division conducted a study to evaluate the “alert” and “protected” zone airspace definitions for free-flight and investigate pilots’ interpretation of Visual Flight Rules (VFR) right-of-way procedures and their application to the free flight environment. In the free-flight environment, aircraft will presumably be able to maneuver with more autonomy. However, free-flight will require the definition of new zones around each aircraft, similar to the zones currently provided by the Traffic Alerting and Collision Avoidance System (TCAS) alert algorithms. These zones will be defined as the “alert” and “protected” zones. Further, roles and responsibilities associated with the transgression of these zones need to be defined and evaluated. Unlike an earlier experiment in this series, this test examined higher density levels of traffic.

The continued use of a new alerting scheme logic, developed by MIT, further defined “alert” and “protected” zones around the ownship of an aircraft and provided intruder information up to 100 miles beyond the currently used TCAS zones. The “alert” zone is defined by a complex algorithm based on the spatial geometry between an aircraft’s ownship position and that of an intruder, the probabilities of a conflict, and the ability to maneuver out of the conflict. The “protected” zone is within the alert zone and is defined as the separation distance of five miles between two aircraft. In order to make the flight crew aware of their situation with respect to other aircraft, new symbology was also developed and integrated on the flight crew’s navigation displays. Whenever an intruder penetrates the “alert” zone of the 747, prediction lines extend from the 747’s ownship position to the point of closest approach on its route, as well as from the intruder aircraft’s ownship to the point of closest approach on the 747’s route. At that time, an aural warning is triggered to alert the 747’s flight crew.

Another tested feature was the use of a customized “predictor” control panel. This control panel enabled subject pilots to determine the position of intruders up to ten minutes ahead of time in order to avoid possible encounters or potential collisions.

Simulation Results

Experiment runs consisted of several enroute scenarios flown in the Denver airspace. Scenarios involved the 747 simulator and other pseudo-aircraft generated by the CVSRF’s Air Traffic Control (ATC) simulator. Depending on the threat levels of the pseudo-aircraft, subjects were required to negotiate with another aircraft and to execute an avoidance maneuver. Data runs, with the assistance of line-qualified 747-400 flight crews, consisted of four training legs and eight data recorded legs, including videotapes and pilot questionnaires. Conclusive statements are pending.

In this display, the position of intruder airplanes are depicted by chevrons as well as their predicted positions in seven minutes which are shown by the circles, and their corresponding predictor lines extrapolated from their current positions.

Obstacle Free Zone Balked Landings

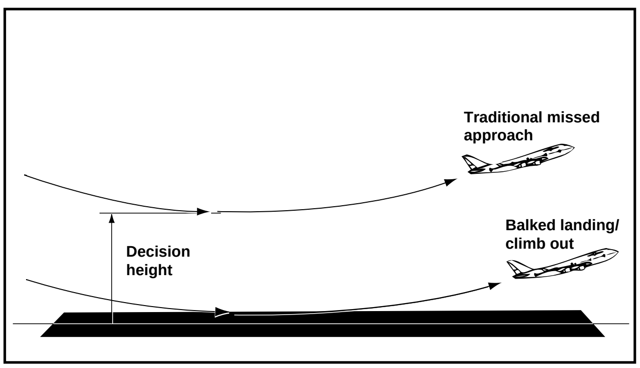
Barry Scott, FAA Field Office, NASA ARC
Frank Hasman, Allan Jones, FAA Standards Development Branch, Oklahoma City

Summary

Large aircarrier aircraft flight-tracks and height-loss arrest points were explored and analyzed relative to Obstacle Free Zone space and dimension requirements.

Introduction

The Federal Aviation Administration's (FAA) Standards Development Branch in Oklahoma City, conducted a series of studies to explore large aircarrier aircraft flight-tracks and height-loss arrest points as a result of crew-induced aborted or balked landings after reaching decision-height altitude and beyond; to a minimum of 50 ft above ground level. Approaches using both auto-land and manual flight procedures were conducted in Categories I and II weather conditions, respectively, and analyzed relative to Obstacle Free Zone (OFZ) space and dimension requirements. Findings will be used in the development of FAA standards and operations criteria and to assist The Boeing Company in new large airplane design.



The Obstacle Free Zone will provide operationally safe conditions below the decision-height altitude.

The *Advisory Circular 150/5300-13, Airport Design* is used to prescribe runway design dimensions for various elements of large airplanes affecting runway utilization, such as runways, shoulders, blast pads, clearways, runway safety areas, and separation requirements to adjacent taxiways. Runway elements and OFZ dimensions are referenced to airplane design groupings based on wingspan. These groupings account for wingspans up to but *not* including 262 ft. For planning future airplane wing designs exceeding 262 ft, data is required to assure that the OFZ needed by these airplanes is calculated to provide operationally safe conditions below the decision-height altitude under all expected conditions of flight.

Simulation Results

Three tests were conducted on the 747-400 simulator throughout this year. The first test studied approaches designed to land at runway 4R at Chicago's O'Hare Airport. Flight-track and height-loss data, occurring subsequent to arrival at Categories I and II decision-height altitudes, were collected for missed approach and aborted/balked landings. Particular attention was given to conditions (i.e. extreme winds and gross weight) allowable for the type of approach being tested and their possible impact on OFZ required space and crew response/ techniques. Data collection included digital readouts of aircraft state and performance data, videotapes and pilot questionnaires. The other two tests focused attention on aborted takeoffs, engine-out takeoffs and traffic conditions. Conclusive statements are pending.

Wide Area Augmentation System Bias Error

Barry Scott, FAA Field Office, NASA ARC
Steve Jackson, Frank Hasman, Standards Dev. Branch, Oklahoma City

Summary

This study examined the maximum bias error acceptable to pilots for Category I landings in large aircarrier aircraft, such as the B-747, while conducting Wide Area Augmentation System-like precision approaches.

Introduction

The Standards Development Branch at the Federal Aviation Administration (FAA) Aeronautical Center in Oklahoma City, examined the maximum bias error acceptable to pilots for Category I landings in large aircarrier aircraft, such as the B-747, using Wide Area Augmentation System (WAAS)-like precision approaches. Because a bias error changes the aircraft aimpoint on the runway rather than just the angle of the glidepath and threshold crossing height, questions are raised about pilot acceptability of the system. Unlike an Instrument Landing System (ILS), the vertical guidance on a WAAS precision approach could be misleading after reaching visual conditions and could provide information which conflicts with the pilot's visual picture and visual landing aid systems. This study supported the FAA in determining the integrity limit for WAAS precision approaches. Further testing may be required to determine ceiling and visibility requirements for actual WAAS approaches, while accounting for variations between Visual Approach Slope Indicator and Precision Approach Path Indicator systems, as well as various lighting systems.

Simulation Results

To simulate a bias type error, Catgeory I approaches were conducted with the Glide Path Intercept point offset along the runway. Bias errors of plus or minus ten meters vertically were introduced into the scenarios, which offset the glideslope intercept point plus or minus 626 ft horizontally along the runway. Each scenario was set up for approaches into runway 35L at the new Denver International Airport. Results were analyzed relative to vertical flight track, threshold crossing height, touchdown point, number of missed approaches, vertical speed required for correcting to the actual glidepath for landings, and pilot comments gathered via post approach questionnaires. Conclusive statements are pending.

The vertical guidance on a WAAS precision approach could be misleading after reaching visual conditions and could provide information which conflicts with the pilot's visual picture and visual landing aid systems.

Aural Alerting

Jeffery Schroeder, NASA ARC
Edmund Field, McDonnell-Douglas

Summary

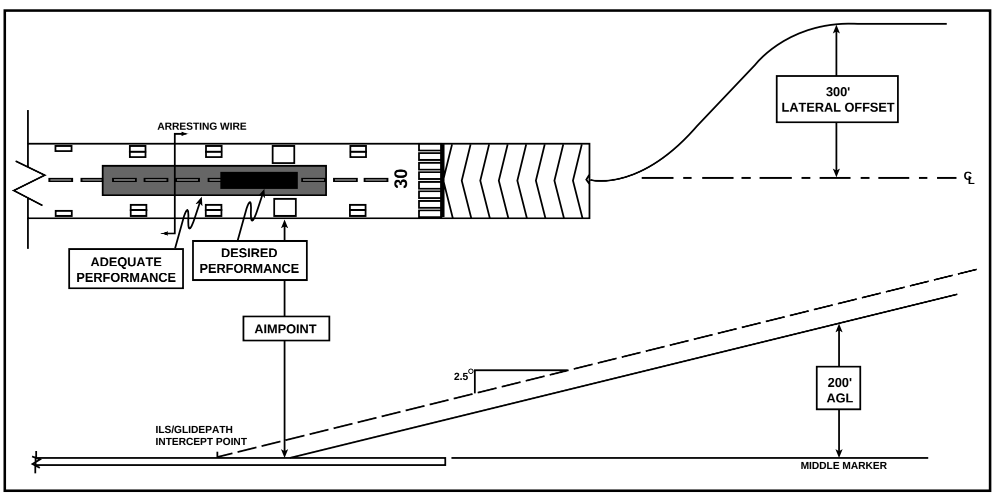
The aural height cue was examined to determine pilot performance during landing operations in large transport category-type aircraft.

Introduction

The Human Information Processing Research Branch, Flight Management & Human Factors Division, in conjunction with researchers from McDonnell-Douglas, conducted a study to quantitatively determine the handling qualities effects of the aural height cue during landing operations. Correlation of results with previous large airplane handling qualities investigations exposed different touchdown performances and handling qualities ratings for similar aircraft-types. A hypothesis is that the presence of the aural height cue improved touchdown-landing performance and handling qualities ratings. This study supported the High Speed Research Program, performed earlier on the Vertical Motion Simulator.

Simulation Results

The 747-400 simulator was used to conduct a series of offset approaches and landings. Subject pilots were asked to fly down a laterally offset glideslope to a predetermined altitude (about 250 ft). Pilots were then instructed to maneuver the airplane to land on the runway at a predetermined landing zone, with and without the help of the aural height cue. Flight conditions included day, night and dusk scenes for runway 30 at Long Beach Airport. To make the approaches more challenging, updrafts were inserted into the simulations through the 747-400 simulator's "Microburst" model, which was modified for this experiment. Approaches were also configured for landings at both light- and heavy-weight conditions. The aural height cue was modified for these tests to "50, 40, 30, 20, 10" as opposed to "50, 30, 10", which is the normal 747-400 aural height cue during landing operations. Test pilots from NASA Ames, NASA Dryden, McDonnell-Douglas and the U.S. Air Force participated in this study. Conclusive statements are pending.



Subject pilots were asked to fly down a laterally offset glideslope to a predetermined altitude (about 250 ft). Pilots were then instructed to maneuver the airplane to land on the runway at a predetermined landing zone, with and without the help of the aural height cue.

Decision-Making

Judith Orasanu, NASA ARC
Jeanie Davison, Laura Tyzzer, Eric Villeda, Lori McDonnell,
Christina Van Aken, San Jose State University

Summary

Flight crew communications in low and high risk situations were examined and analyzed with regard to pilot decision-making.

Introduction

The Aviation Safety Research Branch, Flight Management & Human Factors Division, conducted a study to determine factors that influence pilots' success in monitoring and detecting problems. Identified problems were pilot- or in-flight errors and communication strategies used to call attention to or correct problems. In a 1994 analysis of flight-crew-caused accidents, the National Transportation Safety Board found 31 out of 37 accidents involved "monitoring and challenging" failures. That is, errors and problems were left unattended resulting in an unsafe situation. In most cases, it was the first officer who was unable to get the attention of the captain, or induce him to change his decisions or actions. Little research has been done to determine when crew members notice problems and decide to intervene, and what the selection-process is for choosing the most successful intervention strategy.

Simulation Results

Flight scenarios differed in the degree of pilot-error or problem, and the level of risk posed by the error or problem. Pilot-free problems were mainly caused by either air traffic control, air, traffic, or weather conditions. Pilot error was interpreted as the verbal challenge directed to another crew member of different status. In order to create the "scripted" scenarios, an experienced 747-400 airline captain, played either the pilot or first officer role and committed the scripted errors, according to experimental design. Five different line-oriented flight scenarios introduced low and high risk situations, each designed to look at three factors: (1) crew position - captain versus first officer, (2) risk levels, and (3) face threat (type of problem). Verbal responses to errors and problems created by air traffic controllers or the subject pilot constituted the dependent measure. In addition, the timeliness of pilot response after cues signaling was analyzed. Conclusive statements are pending.

The FAA conducted a study to acquire missed approach tracking data for use in determining the degree of safety and landing operations.

Transport Cab (TCAB)

Dean Giovannetti, NASA ARC
Hai Huynh, Joel Rosado, Logicon Syscon/Syre

Introduction

The aeronautical research done at the VMS assists in the design and development of cutting-edge technology to meet the aeronautical needs of the future. Two such programs that have unique research requirements are the Civil Tiltrotor (CTR) and High Speed Civil Transport (HSCT). Both identified a need for a two-seat, side-by-side, wide out-the-window (OTW) field-of-view (FOV) *civil transport cockpit* simulation capability on the Vertical Motion Simulator (VMS). To support the special needs of these programs, a fifth interchangeable cab, designated the Transport cab (TCAB), was designed and built at the VMS facility.

After a two and a half year effort to design, build and become certified for Human Occupancy, the TCAB was completed on May 27, 1997. The TCAB is a special achievement that provides a newer, larger, and more capable simulator cab for the future needs of aeronautics. It is now part of the VMS interchangeable cab system, and “flew” its maiden mission in July as part of the HSCT-5 simulation.

TCAB represents current and future generation airliners (e.g. 777, 747-400, MD-11, and A320), which have a wide OTW FOV. The visual system provides a 270 deg. horizontal field-of-view (HFOV), which is more than twice the HFOV of any of the four existing I-cabs used on the VMS. The “all glass cockpit” is an instrument console that uses cathode ray tubes (CRT) instead of analog instruments to simplify cockpit layout design and reduce maintenance costs. A collimated display of six CRT monitors casts a high-quality image on six spherical mirrors; the mirrors are arranged to form a dome-like section providing a continuous field-of-view image to the pilot and co-pilot. CRT monitors allow for very low distortion, high brightness, and high resolution image, which typical dome projection simulator systems are not capable of producing. This two-seat cockpit provides both programs the capability to research flight deck designs, crew coordination, and related aircraft handling qualities issues. It also provides the capability towards “full mission” simulation to research the interfaces with the air traffic control system and other terminal area operations.

A compatible ICAB configuration can be used for both programs. The HSCT program will operate from the left pilot seat, and the CTR program will operate from the right pilot seat. Since the opportunity exists for both programs to operate the ICAB simultaneously, the TCAB is configured for “quick” equipment exchanges that may be unique to each program.

TCAB Key Features

- A wide out-the-window field-of-vision of 240° X 60°
- A small “chin-bubble” window on the right pilot seat
- A high resolution video mixing of HUD symbology with the computer generated image (CGI)
- A primary instrument panel that houses six large 8" X 8" CRTs to present the primary flight displays, navigation displays, engine information, etc.
- Two control display units (CDUs) in the center console, one for each pilot
- An audio system to simulate the noise environment typical within the flight deck
- Video cameras to monitor and record flight crew activities

Interior view of the new TCAB with a Civil Tiltrotor out-the-window display.

Virtual Laboratory (VLAB) Demonstrator Project

Introduction

The Virtual Laboratory (VLAB) represents a fresh approach to conducting simulation experiments. It allows researchers at remote sites to interactively participate in live simulation experiments conducted in research laboratories at the Ames Research Center.

VLAB uses enabling technology to provide a virtual reality environment to the remote users, who can “see” various simulation data as if they were physically present in the VMS complex. Currently, VLAB delivers the pilot’s front-window scene, head-up and head-down displays, a graphical depiction of the motion platform, time-history graphs and end-of-run data displays. Also integrated into the package are video-conferencing and two-way ambient sound capabilities for the remote user to actively affect the conduct of the experiment. Future versions of VLAB will feature simulation model control, aircraft controls, display development, virtual prototyping, and data browsing.

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.

Goals

The goal of the VLAB Demonstrator Project was to develop, integrate and operate a remote-access system that facilitates interactive participation for off-site VMS customers. Integral to this goal was the participants’ evaluation of VLAB as a useful research tool. Answers were sought to questions such as: Did VLAB allow users the desired level of interaction? Was the timeliness of information delivered satisfactory? Was the graphical interface inviting and easy to use? Most importantly, did VLAB further enable the users to meet their research goals?

Results

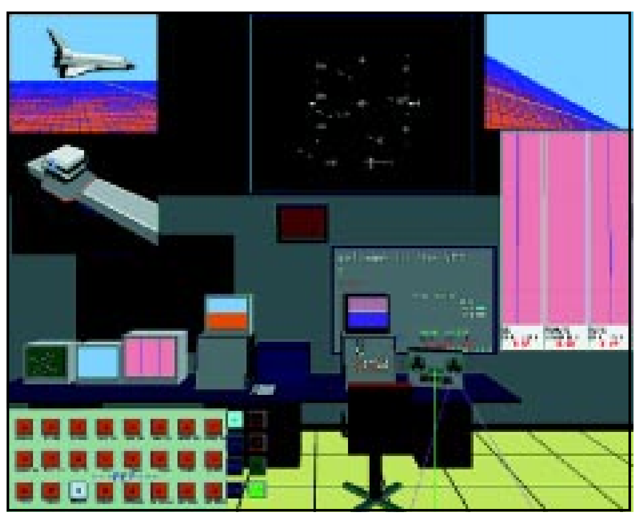
The Virtual Laboratory completed a very successful run of tests, demonstrations, and productive engineering use at the Johnson Space Center. For six weeks, VLAB provided continuous, highly interactive, remote access to the Space Shuttle approach and landing simulation being conducted on the Vertical Motion Simulator at Ames Research Center. The remote users at JSC emphatically responded that VLAB is a very useful tool. All research goals were met. The data transmission rate provided near perfect “remote fidelity,” with little or no delay, including the video of the out-the-window display. Initial estimates put the data rate at between 100 and 150 mega bits/second.

The VLAB client was exhibited at the NREN Workshop, Ames Research Center, and for Ames Community Day, September 20th. As requested, the VLAB will be exhibited at Super Computing ’97.

Future Plans

Future work will include enhancing the fidelity of the “immersive” nature of VLAB; providing additional “user I/O” features; increasing VLAB’s applicability to several simulation experiments; collaborating with technology experts, both within and outside of Ames, and increasing its diversity by applying the VLAB technology in areas beyond flight simulation at the VMS. Other plans include exploring possible partnerships with education and local aeronautics museums.

For more information, including who the principal contributors were, visit VLAB’s website at:
http://www.simlabs.arc.nasa.gov/vlab



Above is a screen capture of the virtual laboratory showing the custom displays.

Simulation Fidelity Requirements

William Y. Chung, Jeffrey Schroeder, Walter W. Johnson, NASA ARC
Soren LaForce, Logicon Syscon/Syre

Goals

To investigate and determine the motion-based flight simulation cueing requirements for visual and motion cues. The investigations determined if previous criteria had general applications with respect to the aircraft characteristics and visual content. Another investigation examined the effects of the motion platform characteristics, such as small motion versus large motion, and the task with various control force gradients.

Investigated simulation cueing requirements focused on roll-lateral degrees-of-freedom (DOF). By using the two DOF aircraft response, a lateral translational task was developed to provide the one-to-one visual and motion cueing response within the Vertical Motion Simulator. This approach isolated the perceived motion cueing abnormality, which is a design parameter to the roll and lateral axes. The one-to-one motion cueing configuration would then provide the near-truth motion cues.

Results

Participating pilots from FAA, Lockheed Martin, NASA and Fort Rucker flew a structured test matrix that included two aircraft roll damping characteristics and two visual density contents. Also pilots flew five motion cueing configurations for the platform characteristics investigation.

Data supported the criteria established from previous study. Criteria for the visual and motion cueing fidelity requirements were: (1) Handling qualities in ground-based flight simulations are affected by more than visual delay. (2) Synchronized motion cues can be allowed to lag, not lead visual cues. (3) Mismatch of no more than 40 msec equivalent time delay between roll and lateral motion cues, and between the visual cues and roll motion cues is recommended.

In the motion platform characteristics investigation, data supported the benefit of the large motion platform. Under large motion configurations, pilot handling qualities ratings showed better matches with predicted handling qualities when control forcegradient were varied.

For further information please refer to the following publications:

"Effects of Vehicle Bandwidth and Visual Spatial-Frequency on Simulation Cueing Synchronization Requirements," AIAA AFM Conference, August 1997.

"An Initial Evaluation of the Effects of Motion Platform and Drive Characteristics," AIAA MST Conference, August 1997.

"Visual and Roll-Lateral Motion Cueing Synchronization Requirements for Motion-Based Flight Simulations " AHS 53rd Annual Forum, April 1997

"Effects of Roll and Lateral Flight Simulation Motion Gains on a Sidestep Task," AHS 53rd Annual Forum, April 1997.

"Phase Response Requirements Between Cross-Coupled Motion Axes for Handling Qualities Research Simulators," AIAA MST Conference, August 1996.

An effort by NASA Ames Research Center was made to determine required cueing fidelities for motion-based flight simulation operations.

747-400 Visual System Upgrade

Introduction

To support research objectives of low visibility conditions and terminal area operations improvement, the NASA 747-400 Simulator was upgraded with a new Flight Safety International VITAL VIIIi visual system. The new visual system is a wrap-around projector based system, which provides a cross-cockpit viewing capability and an enhanced field-of-view (40 degrees vertical by 180 degrees horizontal). The previous system was a CRT monitor-based system, which did not allow pilots to see across the cockpit during taxi operations. This was a limitation when conducting ground operations such as taxiing. The new visual system will support human factors research programs such as the Terminal Area Productivity and the Advanced Air Transportation Technologies Programs.

Accomplishments

The VITAL VIII(i) visual system includes a new MultiView display screen, mirror and plenum, three skylight projectors, optical alignment tools and a new Image Generator (IG). The system replaces the previous Flight Safety International VITAL VIIe system, which was a CRT monitor based system with a limited field-of-view. The VITAL VIII(i) IG is a three-channel system, which provides full color geospecific photo scenes from satellite and aerial imagery, calligraphic lightpoints, elaborate weather and special effects, weather radar system correlation, and full continuous time of day viewing capability. The IG also contains improved texture memory and pixel resolution during both day and night scenes and comes with numerous customized airport database scenes and a “reconfigurable airport”, which is provided to represent any airport that currently does not exist as part of the visual database library. Moving models depicting other aircraft and ground vehicles, weather cells, storms, or storm fronts are also available.

The new visual system was delivered in October 1996, installed in November and acceptance testing was completed in December. Level D recertification of the 747 Simulator by the FAA’s National Simulator Program Office occurred on December 12th.

Principal Contributors

Barry Sullivan, Matt Blake, NASA Ames Research Center; Dave Bent, Joe King, Sil Corpuz, Gary Uyehara, Tom Prehm, David Bayat, Eric Gardner, Glenn Ellis, Jerry Jones, Elliott Smith, Rod Ketchum, Dave Brown, Norm Martello, NSI Technology Services Corp.; Flight Safety International.

The new visual system is a wrap-around projector based system, which provides a cross-cockpit viewing capability and an enhanced field-of-view (40 degrees vertical by 180 degrees horizontal).

Advanced Concepts Flight Simulator Upgrade Phase 3

Introduction

The goal of the ACFS Upgrade Project is to ensure the simulator's capability to continue its support of NASA mission critical research in the areas of aeronautical human factors, aviation safety, and airspace capacity. To accomplish this goal, a comprehensive upgrade of nearly all simulator systems was performed in order to achieve much higher fidelity with systems that are flexible, reliable, and inexpensive to maintain. Phase 1 and 2 of the ACFS Upgrade Project were completed in previous years and comprised the upgrade of many of the simulator computational systems and the cockpit. This included the host computer, flight display computers, Experimenter Operator Station (EOS) computers, data communication systems, the construction of a new cockpit, including elaborate auto-throttle system, new flight displays, and new aural cueing system. The final phase of the upgrade was completed this year and included the installation of a new projection visual system, Input/Output (I/O) system, and Head-Up Display (HUD) device. The specific goal of this final phase was to return the simulator to an operational state and begin conducting experimental research.

Results

A new simulator enclosure and Flight Safety International (FSI) MultiView projection system was installed, which provides 180 degree horizontal field-of-view (FOV) and 40 degree vertical FOV, presenting both raster and calligraphic images. The new image generator is a FSI Vital VIII(i), which presents daylight, dusk, and night scenes with many special effects and includes databases representing numerous airport areas throughout the world. The FSI system provides outstanding visual cue performance. Additionally, a new VME based I/O system was installed to perform all communication between the host computer and the analog devices in the cockpit and a Flight Dynamics Inc. (FDI) HUD projector and combiner were installed in the simulator. The HUD system is capable of presenting existing transport aircraft symbology or new research graphics. The upgraded simulator achieved Human Occupancy Review Board (HORB) approval to return to service on August 25, 1997. The "new" simulator is now capable of providing an excellent research platform for current and future NASA airspace operations research programs.

Plans

The ACFS Upgrade Project is complete. The simulator has now entered an operational phase where most resources are dedicated to specific research programs. An additional effort is currently underway to significantly enhance the Flight Management System (FMS). This effort includes a team comprised of personnel from both the Aeronautical Test and Simulation Division and the Flight Management and Human Factors Division. This system will be integrated into the ACFS in the beginning of FY98. Some possible future enhancements to the ACFS include replacement of some of the cockpit control panels and the motion electronics to improve reliability and installation of additional software systems modeling such systems as weather radar.

Simulation Support Team

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The new ACFS flight deck and visual scene.

AATT .... Advanced Air Transportation Technologies
ACAH .... Attitude Command, Attitude Hold
ACARS .... ARINC Communications & Reporting System
ACFS .... Advanced Concepts Flight Simulator
ADS .... Automatic Dependent Surveillance
AFDD .... Aeroflightdynamics Directorate
AGL .... Above Ground Level
AMCOM .... Aviation & Missile Command, U.S. Army
ANOE .... Automated Nap-Of-the-Earth
AOC DL .... Airline Operational Communications Data-Link
AO Div .... Aeronautical Test & Simulation Division
AQTD .... Airworthiness Qualification Test Directorate, U.S. Army
ARC .... Ames Research Center
ASN .... Advanced Simulator Network
ASTOVL .... Advanced Short Takeoff & Vertical Landing
ATC .... Air Traffic Control
BAC .... Boeing Aircraft Company
BHT .... Bell Helicopter Textron
British CAA .... British Civilian Aviation Authority (regulatory agency)
CAE .... Canadian Aeronautics & Electronics
CATAPOD .... Category A Terminal Area Procedures
CFIT .... Controlled Flight Into Terrain
c.g. .... Center of gravity
CH-47D “Chinook” .... Heavy cargo helicopter, U.S. Army
CIFER .... Comprehensive Identification from Frequency Responses
CTAS .... Center TRACON Automation System
CTR .... Civil Tiltrotor
CVSRF .... Crew-Vehicle Systems Research Facility
DA .... Descent Advisor
DASH .... Differential Air Speed Hold
DARP .... Dynamic Aircraft Route Planning
DOF (6) .... Six Degree-Of-Freedom
DVE .... Degraded Visual Environment
EICAS .... Engine Indication and Crew Alerting System
EOS .... Experiment Operator Station
ESIG-3000 .... Evans & Sutherland Image Generator- 3000
FAA .... Federal Aviation Administration
FANS .... Future Air Navigation System
FCS .... Flight Control System
FMC .... Flight Management Computers
FMS .... Flight Management System
FTE .... Flight Technical Error
GFC .... Guidance Flight Control
GNSSU .... Global Navigation Satellite Sensor Unit
GPS .... Global Positioning System
GTRS .... Generic Tiltrotor System
HDD .... Head-Down Display
HelMEE .... Helicopter Maneuver Envelope Enhancement
HSCT .... High Speed Civil Transport
HSR .... High Speed Research
HUD .... Head-Up Display
IATA .... International Air Transport Association
IBM .... International Business Machines
IC .... Initial Conditions

ICAB .... Interchangeable Cab
ICAO .... International Civil Aeronautics Organization
ICH .... Improved Cargo Helicopter
IHADSS .... Integrated Helmet Display and Sighting System
ILCA .... Integrated Lower Control Actuators
ILS/MLS .... Instrument Landing System/Microwave Landing System
IMC .... Instrument Meteorological Conditions
I/O .... Input/ output
IQS .... International Qualification Standard
KSC .... Kennedey Space Center
LNAV .... Lateral Navigation
MAWEA .... Modular Avionics and Warning Electronics Assembly
MCDU .... Multifunctional Control Display Unit
MCP .... Mode Control Panel
MEDS .... Multifunction Electronic Display System
MIDI .... Musical Instrument Digital Interface
MIT .... Massachusettes Institute of Technology
NASA .... National Aeronautics & Space Administration
NCA .... Neuro Controlled Aircraft
NOE .... Nap-of-the-earth
OEI .... One Engine Inoperative
PCA .... Propulsion Controlled Aircraft
PDG .... Pilot Directed Guidance
PDGTRS .... Preliminary Design Generic Tiltrotor Simulation
PIO .... Pilot-Induced Oscillation
PRM .... Precision Runway Monitor
R-cab .... Rotorcraft Cab
RC .... Rate Command
RNP .... Required Navigation Performance
RTA .... Required Time of Arrival
RTF .... Return To Flight
S-cab .... Space Shuttle (interchangeable) Cab
SATCOM .... Satellite-based Communications
SCAS .... Stability & Control Augmentation System
SFO .... San Francisco International Airport
SGI .... Silicon Graphics Incorporated
SHCT .... Short Haul Civil Tiltrotor
SimLab .... Simulation Laboratories (part of the AO Division)
SSV .... Space Shuttle Vehicle
STA .... Shuttle Training Aircraft
STOVL .... Short TakeOff and Vertical Landing
TAEM .... Terminal Area Energy Management
TAP .... Terminal Area Productivity
TCAS .... Traffic Alerting and Collision Avoidance System
TERPS .... Terminal Procedures
TIFS .... Total In-Flight Simulator
TRACON .... Terminal Radar Control
TRC .... Translational Rate Command
VFR .... Visual Flight Rules
VLAB .... Virtual Laboratory
VMS .... Vertical Motion Simulator
VNAV .... Vertical Navigation
XV-15 .... Experimental Vehicle 15, a tiltrotor
YCH-47 .... 1961 “Chinook”

A very brief description of the Aeronautical Test and 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 which 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 Simulator

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 simulator 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, and accident/incident investigations. Other areas of research include the development of new techniques and technologies for simulation and defining 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. Each of the five simulation cockpits 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 6 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

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