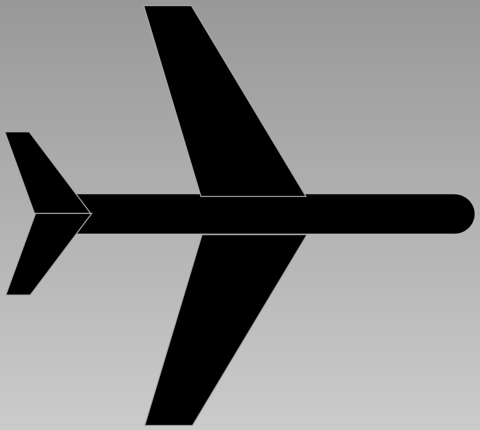
Flight Simulation
Year in Review
FY00

Foreword

This document is the Fiscal Year 2000 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 the more significant events of FY00. What follows are an Executive Summary with comments on future plans, the FY00 Simulation Schedule, a projection of simulations to be performed in FY01, performance summaries that report on the simulation investigations conducted during the year, and a summary of Research and Technology Upgrade Projects.



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Acknowledgment

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About the Cover

Front cover: The picture shows the B747-400 Navigation Display with new symbology from the AATT Integrated Tools Study/Air-Ground Integration Experiment (AGIE). In a conflict alert situation, the new symbology shows a straight line time predictor for both the B747 and the conflicting aircraft indicating the predicted time of the conflict. The call sign of the conflicting aircraft is also displayed. In addition, in the lower right hand corner of the display, the annunciation "ALERT" is shown along with the time to conflict readout and the call sign of the conflicting aircraft. (For more information, see page 27)

Back cover: The Vertical Motion Simulator plays a key role in the Joint Shipboard Helicopter Integration Process (JSHIP) program. This program is sponsored by the Office of the Secretary of Defense. It examines the relationship between the fidelity of a simulation and its ability to predict the wind-over-deck launch and recovery flight envelope for a ship/helicopter combination. (For more information, see pages 21 and 37)

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Executive Summary

The Simulation Laboratory Facilities (SimLab) of the Aviation Systems Division of the NASA Ames Research Center are pleased to present this Annual Report to summarize the major achievements accomplished during FY 2000. Specifically reviewed are the Vertical Motion Simulator (VMS) and the Crew-Vehicle Systems Research Facility (CVSRF). A brief description of these facilities is included in the Appendix.

The mission, purpose, and focus of the simulation facilities, flight simulation research and development, remain unchanged. However, there have been substantial internal and external pressures and developments that have shaped the operational philosophy of the SimLab. The two major challenges faced this year were substantial cost reductions and a renewed and enhanced focus on the integration of cutting edge information technologies. The impacts of these challenges are discussed in the body of this report as they affect SimLab's approach in developing and supporting experiments and projects. In addition, safety remains SimLab's highest priority, running from designing for safety to the safety of our guests, staff, and systems.

This report is organized into sections starting with the 1) FY00 simulation schedules and summaries, and planned FY01 projects for both the VMS and the CVSRF, 2) a brief review of each of the projects completed in the laboratories, 3) a description of the current research and technology upgrades being made to the laboratory infrastructure, 4) a list of facility specific acronyms, and finally 5) the Appendix which provides a more thorough discussion of the facilities.

A Very Full FY00 Schedule

The simulation experiments conducted in VMS and CVSRF came in a wide variety of "shapes and sizes." Many of the experiments were planned for and expected well in advance. Others, as in past years, arrived somewhat unexpectedly, as a result of an urgent Center or Headquarters request. These range from key NASA Programs, to DoD Projects, to the technology research and development programs in Air Traffic Management and aerospace vehicle safety.

Regardless of their origin or urgency, these programs are at the core of the NASA mission and critical to the nation's air transportation system, aerospace and defense needs. There were 18 major simulation experiments conducted in FY 00. Each of these experiments are reviewed in the project Summary Section of this report. Three projects completed this year, Joint Shipboard Helicopter Integration Process (JSHIP), Civil Tiltrotor 9 (CTR-9) and Center TRACON Automation System Flight Management System 2 (CTAS/FMS 2) in particular, demonstrated the overall significance of the Laboratories.

The JSHIP project, a very ambitious undertaking, came to the VMS from the Office of the Secretary of Defense. An interchangeable cab was completely refitted to meet JSHIP specifications and a UH-60 Blackhawk math model was integrated with the ship-deck air wake and ocean-wave effects to address the issue of shipboard helicopter integration with wind–over-the-deck launch and recovery. CTR-9 required the development of a fully functional Air Traffic Control (ATC) environment for the first time at the VMS, significantly upgrading its capabilities. The CTAS/FMS 2 project was run on the Advanced Concepts Flight Simulator in the CVSRF. This simulation required the rehosting of the main computer and the development and integration of two significant new features, i.e., Traffic Collision Avoidance System (TCAS), the Crew Activity Tracking System (CATS), and the enhancement of FMS Vertical Navigation (VNAV) functions.

Looking Ahead

On the strength of the staff and skill base within the Simulation Facilities, the Simulation Complex continues to meet the challenge of present-day needs while at the same time opening windows into tomorrow's simulation technologies.

Demand by researchers for time on the simulators continues to be strong, and there is an ever-increasing demand to support Air Traffic Management, safety, and risk reduction research topics. Anticipating this demand, the laboratories have embarked on an aggressive course to upgrade, modernize and increase capacity, all the while reducing total annual operating expenditures. Both of the laboratories have integrated new, more capable host computers into the simulators. Substantial performance and cost savings have been realized by replacing last generation graphics computers with today's high-end desktop solutions.

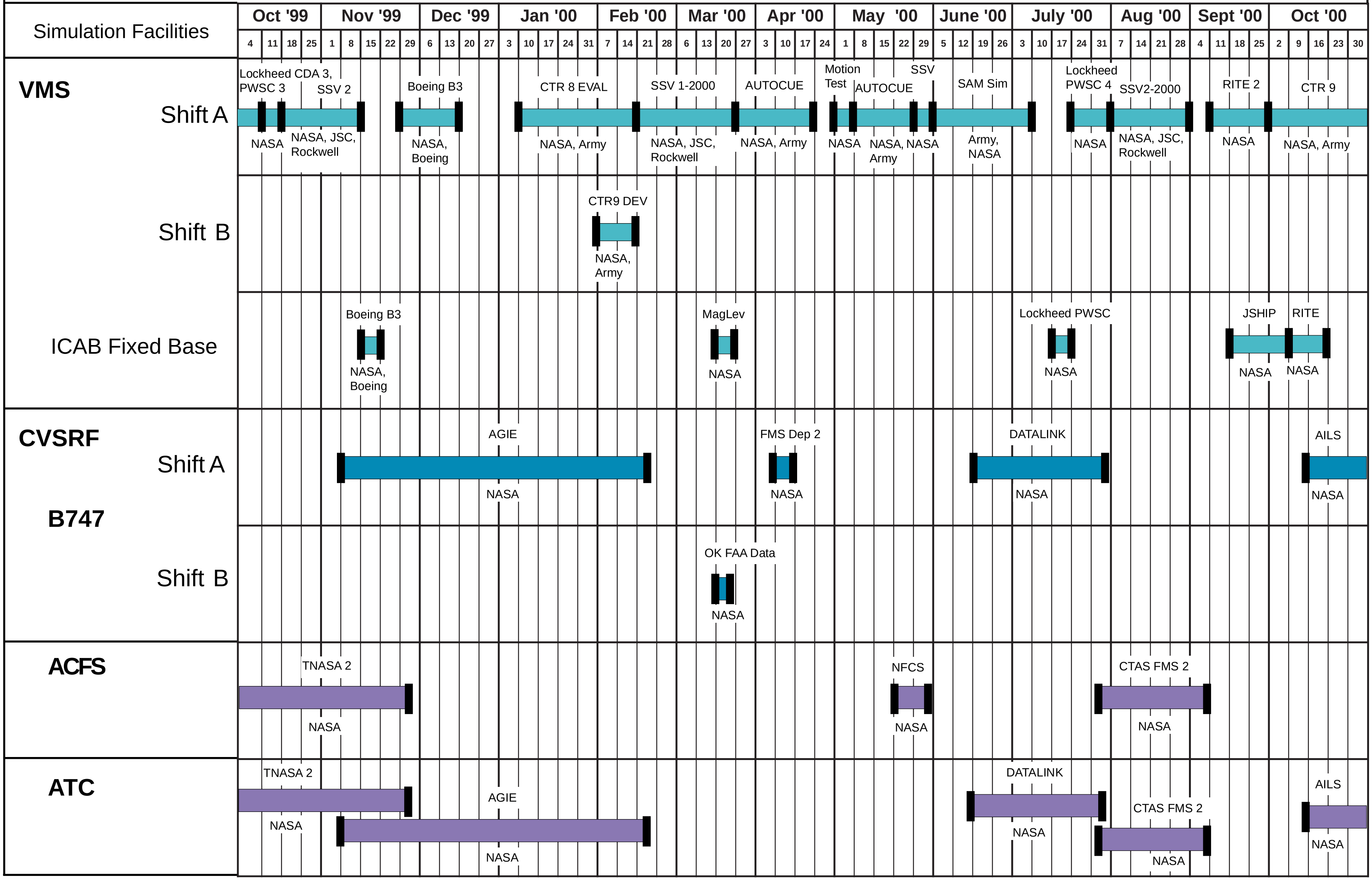
With the interconnected, leading edge technologies of the VMS and the CVSRF, SimLab offers our customers the opportunity to conduct research in a high fidelity, full-mission environment with ATC integration from either facility. Additionally, through Virtual Laboratory (VLAB), SimLab continues to develop the ability for remote users to collaboratively conduct and manage research experiments. These activities and technologies have become the cornerstone for the future of the flight simulation laboratories. Aggressive use of networking and information technologies has enhanced the facility capabilities while reducing overall operating costs.

Strategic Planning

The need for large-scale system level simulation capabilities is appearing on the horizon. The networking of national simulation facilities across the nation will be required to solve some of the nation's most pressing airspace operations challenges. The simulation laboratories at Ames Research Center are at the focal point to consolidate and coordinate these resources. This past year the Simulation Planning Office has begun to define the process to provide these fully integrated capabilities. Through the use of proven networking technologies and the VLAB the Flight Simulation Laboratories are positioning themselves to be key to the development and validation of the future national Air Transportation System.

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

FY00 Simulation Schedule



FY00 Project Summaries

VMS Flight Simulation Projects

1. Lockheed Martin CDA 3
2. Lockheed Martin PWSC 3
3. Lockheed Martin PWSC 4
Sept 13–17, 1999 (FB); Sept 20–Oct 15, 1999 (VMS), July 24–Aug 4, 2000 (VMS)
Aircraft type: X-35 Joint Strike Fighter
Purpose: To support Lockheed's design and development of the X-35 and to advance NASA-sponsored research.

4. Space Shuttle Vehicle 1999–2
Aug 30–Sept 3, Oct 18–Nov 5, 1999 (VMS)
Aircraft type: Space Shuttle orbiter
Purpose: To provide training in orbiter landing and rollout for astronauts and astronaut candidates.

5. Boeing B3
Nov 15–19, 1999 (FB); Nov 29–Dec 16, 1999 (VMS)
Aircraft type: X-32 Joint Strike Fighter
Purpose: To support Boeing's design and development of the X-32.

6. Civil Tiltrotor 8 EVAL
Jan 10–Feb 18, 2000 (VMS)
Aircraft type: XV-15 tiltrotor
Purpose: To investigate approach profiles for noise abatement and to evaluate a new stability and control augmentation system.

7. Space Shuttle Vehicle 2000–1
Feb 21–Mar 23 (VMS)
Aircraft type: Space Shuttle orbiter
Purpose: To determine feasibility of landing on short East Coast Abort landing runways, and to determine adequate hydraulic flow protection for single APU landings. To provide the astronaut corps training in orbiter landing and rollout.

8. AutoCue
Mar 27–Apr 20, May 8–26 (VMS)
Aircraft type: UH-60 Black Hawk helicopter
Purpose: To investigate the impact of various visual and motion cues in a training simulator on pilot performance during an autorotation maneuver.

9. Magnetic Levitation Vehicle Demonstration
Mar 27–31 (VMS)
Vehicle type: Magnetic Levitating Train
Purpose: To investigate a conceptual high speed Magnetic Levitation vehicle and to identify critical system design parameters.

10. Situational Awareness Model
June 5–July 6 (VMS)
Aircraft type: UH-60 Black Hawk helicopter
Purpose: To test a computational situational awareness model used in human factors studies by simulating full-mission flights of the UH-60.

11. Space Shuttle Vehicle 2000-2
Aug 7–31 (VMS)
Aircraft type: Space Shuttle orbiter
Purpose: To evaluate: (i) feasibility of expanding the night Transatlantic Abort Landing crosswind limit (ii) the maximum speedbrake setting limit for the new short-runway option, and (iii) an adaptive speedbrake option. To provide the astronaut corps training in orbiter landing and rollout.

12. Joint Shipboard Helicopter Integration Process
Sept 18–Oct 6 (FB); Nov 27–Dec 21 (VMS)
Aircraft type: UH-60A helicopter
Purpose: To develop and test the processes and mechanisms that facilitate ship-helicopter interface testing via man-in-the-loop simulators.

13. Rapid Integration Test Environment 2
Sept 11-28 (VMS)
Aircraft type: Space Shuttle orbiter
Purpose: To investigate the procedures and infrastructure developed during phase one by testing various Space Shuttle orbiter's nose section geometry designs in piloted flight simulations.

14. Civil Tiltrotor 9
Oct 2–Nov 17 (VMS)
Aircraft type: CTR 4/95 NASA tiltrotor
Purpose: To investigate handling qualities and flight operations issues related to operating a tiltrotor aircraft at a vertiport.

VMS Technology Upgrades

1. Virtual Laboratory
Purpose: To enhance the capabilities of a system that enables remote researchers to collaborate in and manage live experiments at the VMS.

2. Joint Shipboard Helicopter Integration Process Simulation Technologies
Purpose: To develop and integrate new technologies into the SimLab environment to achieve the JSHIP simulation goals.

3. Development Work Station Graphics Upgrade Project
Purpose: To upgrade the graphics capability of the DWS, an

Continued next page...

FY00 Project Summaries

engineering environment for researchers to develop VMS-compatible simulation models at their engineering sites.

4. Air Traffic Control for Vertical Motion Simulator
Purpose: To augment VMS simulations by integrating the Air Traffic Control (ATC) capability for the CTR program.

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

6. Video Distribution System Upgrade
Purpose: To implement a major capacity upgrade of the Video Distribution System to meet increasing research requirements and improve maintainability.

7. Alpha Host Computer Upgrade 2000
Purpose: To upgrade the host computers with new systems that meet the compute requirements of the most demanding VMS simulations.

8. Head-Down Display Graphics Engine Upgrade
Purpose: To provide new, state-of-the-art graphics engines to support expanded VMS research needs in a cost-effective manner.

CVSRF Flight Simulation Projects

1. Taxiway Navigation and Situation Awareness 2
Aug 10,1999–Nov 9 (ACFS)
Purpose: To evaluate the use of a head-up display and an electronic moving map to improve Low-Visibility Landing And Surface Operations (LVLASO).

2. Integrated Tools/Air-Ground Integration (AGIE)
Dec 1,1999–Feb 25, 2000 (B747)
Purpose: To conduct an early evaluation of air-ground integration procedures and concepts in a dynamic environment where the control of aircraft can be centralized or distributed.

3. Flight Management System Departure Procedures 2
April 10–13 (B747)
Purpose: To construct and perform viable FMS departure routings in order to support efforts for revising current RNAV departure standards.

4. Neural Flight Control System
May 22–23 (ACFS)
Purpose: To examine the effectiveness of various neural flight control system architectures to control damaged aircraft to a safe landing.

5. Controller-Pilot Data Link Communication Procedures
June 19–July 17 (B747)
Purpose: To examine the impact of data link and voice procedures upon crew error-detection and recovery.

6. Center TRACON Automation System Flight Management System 2
Aug 3–Aug 30 (ACFS)
Purpose: To evaluate a concept for integrating CTAS with the Flight Management System for operations in terminal airspace.

7. Airborne Information for Lateral Spacing
Development Jan 5–Sept 30
Purpose: To examine the utility and viability of two systems designed to increase airport efficiency during Instrument Meteorological Conditions (IMC). To evaluate flight crew and ATC interactions during the pairing of aircraft for independent (AILS) and dependent approaches.

CVSRF Technology Upgrades

1. Advanced Concepts Flight Simulator Host Computer Upgrade
Purpose: To upgrade the ACFS host computer to meet demanding computational and input/output requirements of planned and projected ACFS simulation experiments.

2. Enhanced Ground Proximity Warning System
Purpose: To enhance system fidelity by upgrading the B747-400 flight simulator from an older Ground Proximity Warning System (GPWS) to the state-of-the-art Enhanced Ground Proximity Warning System (EGPWS).

3. Air Traffic Control Pseudo Aircraft System
Purpose: To upgrade the ATC simulator in order to meet emerging Air Traffic Control (ATC) research requirements.

4. Voice Disguiser System Upgrade
Purpose: To increase the voice disguiser system capability and features to enhance realism in simulation experiments.

5. Traffic Collision and Avoidance System Implementation and Upgrade
Purpose: To integrate an FAA/MITRE supplied code implementation of the TCAS II Change 7 specification into the ACFS and to upgrade TCAS in the B747-400 simulator from version 6.04A to Change 7.

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

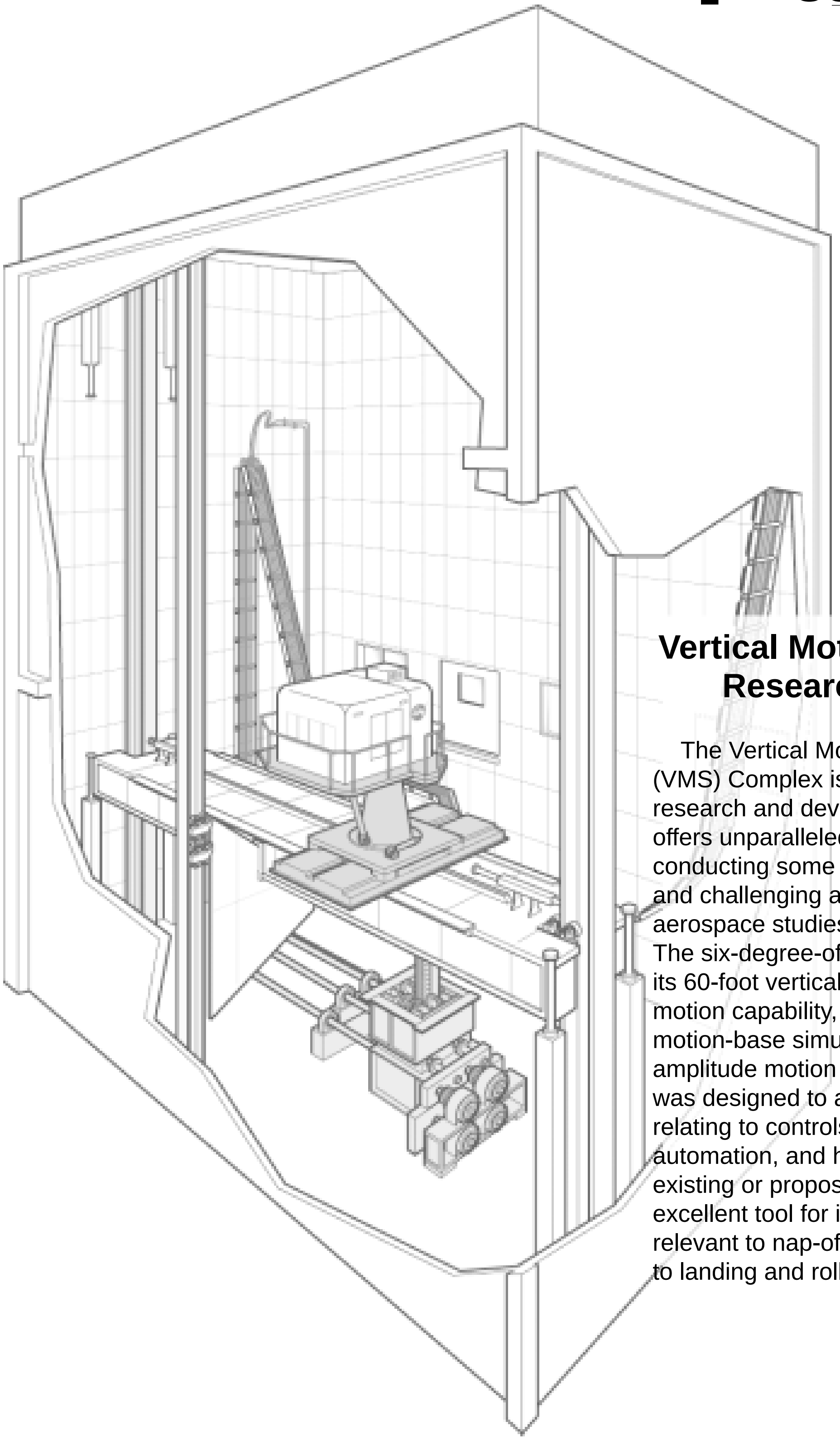
FY01 VMS Simulation Projects

PROJECT	PROGRAM SUPPORTED	CUSTOMERS	TEST OBJECTIVES
Civil Tiltrotor 9	Aviation Systems Capacity/Short Haul Civil Tiltrotor	FAA, NASA	Investigate airspace integration issues using full-mission simulation for civil tiltrotor transports operating independently of conventional runways.
Joint Shipboard Helicopter Integration Process (JSHIP)	Department of Defense	Navy	Support the verification and validation for JSHIP's Dynamic Interface Modeling and Simulation Systems Project. Develop and test the processes and mechanisms that facilitate ship-helicopter interface testing via man-in-the-loop simulators.
Space Shuttle Vehicle 1 & 2 (SSV-1 & SSV-2)	Human Space Flight	NASA Johnson Space Center, United Space Alliance, Boeing, Rockwell	Investigate the Space Shuttle Orbiter's landing systems and directional control handling qualities. Investigation elements include feasibility of landing on shorter abort runways, study of handling qualities when operating with reduced auxiliary power and expanded weather conditions. Provide training to the astronaut corps for orbiter landing and rollout.
Civil ADS-33E	Army	Army, NASA	Support the rotorcraft vehicle research in handling qualities, design specifications, and advanced concepts.
Civil Tiltrotor 10	Army Aviation Systems Capacity	FAA, NASA	Investigate complex futuristic airspace issues for Civil Tiltrotor operations. To support this full-mission study, essential simulation elements such as new Auto-Pilot and FMS feature for the aircraft and Air Traffic Management environment will be developed.
Crew Transportation Vehicle (CTV)	Information Technology Base Program NASA	NASA	Demonstrate the application of the Rapid Integration and Test Environment (RITE) to the next Generation Space Transportation vehicle. The RITE process will facilitate rapid design iterations by using advanced information technologies and simulation as an integral part of the design cycle.

FY01 CVSRF Simulation Projects

PROJECT	PROGRAM SUPPORTED	CUSTOMERS	TEST OBJECTIVES
Integrated Neural Flight & Propulsion Control 1 & 2 (ACFS)	Intelligent Controls & Operations – IT Base Program	NASA Computational Division	Evaluate alternative flight and propulsion control technologies to control aircraft during a malfunction or failure to its primary control system.
Airborne Information for Lateral Separation – AILS (747-400)	Terminal Area Productivity	NASA, FAA, Avionics Manufacturers	Assess flight crew and air traffic controller responses to AILS implementation and procedures based on advanced alerting algorithms.
Boeing Noise Program (747-400)	Flight Simulator / Community Noise Interface Program	Boeing, Acoustics Technology	Study the fidelity of Boeing's acoustic prediction model and terminal procedures to minimize airport noise while increasing air traffic capacity.
ATC Fidelity (747-400)	FAA	FAA	Measure the degree to which ATC fidelity affects the training environment in full-mission simulators.
FAA Flight Standards (747-400)	FAA Oklahoma City	FAA	Examine operational issues associated with improving terminal capacity and efficiency without compromising safety.
CDTI + Weather (747-400)	Advanced Air Transportation Technologies Office	FAA, NASA, NATCA, ALPA & APA, RTCA	Examine human factors, in the cockpit and tower, related to shared separation for various weather conditions.
ADS-B/Ground (ACFS & 747-400)	FAA	FAA, NASA	Simulate terminal and airspace environment to assess tools for the cockpit and air traffic control (ATC) tower.
Motion Fidelity FAA/Volpe (747-400)	FAA AFS-230	FAA, DOT -Volpe Center	Determine effectiveness of motion-cueing for air carrier pilot training and qualification.
LAX – FFC (747-400)	FAA's Safe Flight 21	FAA, Cargo aircraft operators	Evaluate an advanced surface automation aid to improve terminal area ground operations.
Self-Separation Negotiation (ACFS)	Advanced Air Transportation Technologies	NASA, FAA	Evaluate pilot negotiation issues in conducting self-separation in a futuristic free-flight environment.

VMS PROJECT SUMMARIES



Vertical Motion Simulator Research Facility

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

Lockheed Martin CDA 3, PWSC 3 and 4

**John McCune, Mark Tibbs, Eric Somers, Lockheed Martin; Jack Franklin, Duc Tran, NASA ARC;
Chuck Perry, Luong Nguyen, Norm Bengford, Ron Gerdes, Logicon/LISS**

Summary

Lockheed Martin's X-35 Joint Strike Fighter model was simulated to support the design and development of the X-35 and to advance NASA-sponsored research in guidance systems, display technology, and short takeoff/vertical landing controls. This year's three experiments addressed conventional, carrier, and short-takeoff/vertical-landing (STOVL) operations.

Introduction

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

Requirements for the JSF are as follows:

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

The Department of Defense awarded the Lockheed Martin Corporation one of two JSF contracts, each calling for two concept demonstrator aircraft. These simulations, using the large motion base at the VMS, were conducted to complement Lockheed Martin's in-house simulations as part of the design and development process. The JSF is expected to enter service in 2008.

The objective of the experiments included evaluation of the X-35's flying qualities, control laws, and advanced controls and displays.

Simulation

Objectives of the experiments included evaluation of the X-35's flying qualities, control laws, and advanced controls and displays. The three simulations of the X-35 included three weeks of fixed-base simulations in preparation for a total of six weeks of motion-base operations. The fixed-base sessions were designed to validate the simulation system response and to finalize flight tasks and scenarios in preparation for each of the motion-base experiments. The response validation phase was a critical step since the computer code for the entire aircraft model was generated by Lockheed Martin and directly integrated into the VMS's simulation environment. Pilots and engineers from Lockheed Martin, the U.S. Navy and Marine Corps, British Aerospace, and NASA participated in the evaluations.

Results

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

For SimLab, this simulation marked a continued success in integrating the entire aircraft model and cockpit display software provided by a customer directly into VMS's real-time system. This mode of operation was not only cost-effective but also allowed Lockheed Martin to test several last-minute design changes, which were expediently integrated by SimLab engineers.

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

Investigative Team

Lockheed Martin
NASA Ames Research Center
JSF Program Office
U.S. Marine Corps
U.S. Navy
Logicon Information Systems and Services
British Aerospace

Space Shuttle Vehicle 1999-2

**Howard Law, NASA JSC; Ed Digon, Boeing; Alan Hochstein, USA;
Estela Hernandez, Leslie Ringo, Logicon/LISS**

Summary

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

Introduction

The Space Shuttle Orbiter model has been simulated at the SimLab since the mid 1970s. The basic model has evolved and matured over the intervening years to reflect improved model characteristics and updates made to the orbiter fleet. Today, the VMS continues to simulate and provide astronaut training with realistic touchdown and rollout of the orbiter twice each year.

The orbiter presents challenging conditions by landing at 230 miles per hour, which is nearly two times the speed at which most aircraft would land. With no engines operating, the orbiter glides to touchdown without propulsion power for maneuvering or going around. This makes realistic training for astronauts critical. At the VMS, pilots experience various flight conditions and system failures to prepare them for this important phase of flight.

Simulation

Astronauts were given a number of flight and atmospheric conditions during simulation, including runway location and type, vehicle weight, visibility, and wind direction and speed. Periodically, astronauts rehearsed recovering from failures to the tires, drag chute, auxiliary power units, and automatic derotation system.

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

Results

The simulation was completed with 39 pilots and five mission specialists completing a total of 875 data runs. The crew familiarization phase of the simulation reinforced the importance of the VMS in preparing upcoming crews for the landing and rollout phase of the mission and for possible failures during that phase of flight.

Investigative Team

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

Col. James Halsell, commander of STS-101, prepares for a training (crew familiarization) session in the VMS. The VMS provides unique training for astronaut pilots.

Boeing B3

Larry Moody, Tom Wendell, The Boeing Company; Jack Franklin, NASA ARC;
Leslie Ringo, Estela Hernandez, Ron Gerdes, Logicon/LISS

Summary

This VMS simulation was conducted to support the design and development of the Boeing X-32 Joint Strike Fighter. Three variants of the aircraft will be built: a conventional takeoff and landing (CTOL) version for the U.S. Air Force, a carrier version (CV) for the U.S. Navy, and a short-takeoff/vertical-landing (STOVL) version for the U.S. Marine Corps and British Royal Navy/Air Force.

Introduction

NASA Ames Research Center plays an important 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 fighters for the U.S. Navy (USN), Air Force (USAF), Marine Corps (USMC), U.K. Royal Navy, and other potential U.S. allies. The aircraft will feature highly common and modular construction to significantly reduce the cost of development, production, and maintenance.

The military services have stated their needs for the JSF as follows:

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

The Boeing Company is one of two manufacturers selected to build and fly a pair of JSF concept demonstrator aircraft. Real-time, piloted flight simulation is an important step in Boeing's approach to JSF design and development. The VMS, which produces the most realistic motion cueing environment in ground-based simulators, provides a unique complement to Boeing's in-house simulations prior to in-flight simulation and flight-testing.

Simulation

The simulation objectives included evaluations of aircraft handling qualities and determining effects of motion on handling qualities. Participating test pilots were from Boeing, USMC, Royal Navy, and NASA. Three weeks of the motion-based experiment were preceded by one week of fixed-base operations to validate the simulation system response and to finalize flight tasks and scenarios. Validation of the response was critical because Boeing's updated aircraft simulation software was directly integrated into the VMS.

Results

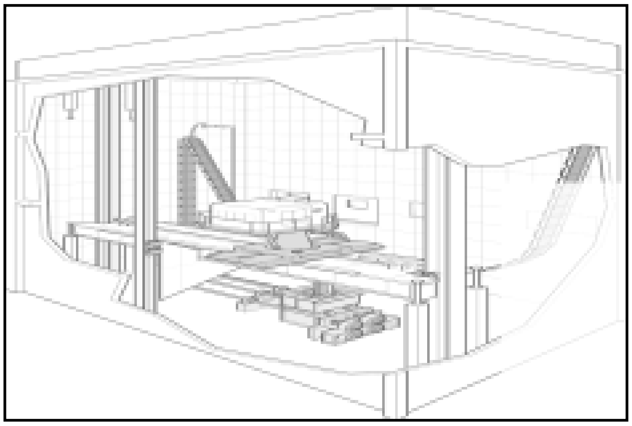
The primary objectives of the simulations were met, and the customer obtained considerable information for design analysis and evaluation. Test pilots were favorably impressed with the important role that the VMS' large motion cueing played in evaluating the JSF's handling qualities and mission capabilities.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

With this simulation, SimLab continued to integrate the aircraft model software provided by the customer into the VMS simulation system. This reduced the simulation development time and costs to the customer. SimLab personnel also implemented graphics changes and incorporated specialized hardware for the Boeing experiment.

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

Investigative Team

The Boeing Company
NASA Ames Research Center
JSF Program Office
U.S. Marine Corps
Logicon Information Systems and Services
DERA, U.K.
U. K. Royal Navy



This VMS simulation was conducted to support the design and development of the Boeing X-32 Joint Strike Fighter.

Civil Tiltrotor 8 EVAL

William Decker, Jack Franklin, Adolf Atencio, NASA ARC; Steve Belsley, Emily Lewis, Joseph Ogwell, Phil Tung, Logicon/LISS; Pete Klein, Helmuth Koelzer, Bell Helicopter Textron

Summary

The Civil Tiltrotor 8 Evaluation simulation studied reduced noise approach profiles for the XV-15 tiltrotor aircraft to relatively small vertiports. The simulation also evaluated a new Stability and Control Augmentation System.

Introduction

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

The simulation's primary goal was to evaluate the XV-15 tiltrotor's handling qualities during approach profiles designed to minimize noise near vertiports. Other objectives were to develop a Dynamic Inverse Stability and Control Augmentation System (SCAS), and to evaluate the travel and force characteristics of a programmable sidestick controller for the XV-15.

While airplanes normally approach airports on a 3° glide slope, tiltrotor aircraft can approach at steeper angles to avoid obstacles and airspace reserved for other aircraft. Steep approaches might require complex noise abatement procedures that increase a pilot's workload. The noise abatement profiles flown by Bell Helicopter during the October 1999 flight-tests performed at their facility were therefore evaluated for feasibility and for possible improvements.

Simulation

The CTR-8 EVAL simulation used the aircraft model structure of the Generic Tiltrotor Simulation (GTRS), Rev. C, configured for the baseline XV-15 aircraft. Two control systems were integrated: the standard XV-15 SCAS and the Dynamic Inverse SCAS developed by J. Franklin. Control features developed by NASA, such as the Discrete Nacelle Movement system and the Conversion Protection system, were tailored for this aircraft. An XV-15 specific Landing Gear model was adapted from a previous tiltrotor experiment. The left seat sidestick controller, a new programmable Sterling Dynamics Inc. (SDI) Active Sidestick, was used almost exclusively with the Dynamic Inverse SCAS.

Noise abatement profiles flown in the October 1999 flight test were successfully replicated in the simulator. This simulation also evaluated the impact on handling qualities of three control response types: rate command, rate command/attitude hold, and attitude command/attitude hold.

The XV-15 tiltrotor aircraft conducting noise abatement profile testing from profiles generated at the VMS.

The Dynamic Inverse SCAS was derived from the NASA modified Neural Network SCAS, which was used in the previous simulation. The Neural Net "Inverse Aircraft" was replaced with stability derivative look-up tables. The control system features retained from the CTR-8 Dev simulation were: selectable Attitude Command and Rate Command Attitude Hold in the pitch and roll axes. The SCAS response was tuned for the center stick and the SDI sidestick. The SDI active sidestick was also evaluated using two ADS-33 tasks, precision hover and pirouette, with different force versus displacement characteristics.

Results

For the XV-15 Noise Abatement Approach Handling Qualities study, the VMS simulation successfully evaluated the October 1999 flight test profiles developed by Bell Helicopter. It was found that attitude stabilization improved handling qualities in adverse weather with Attitude Command used during the final deceleration to hover. Rate Command Attitude Hold was preferred during large trim changes or maneuvers. Guidance was deemed essential to aid in the control strategy shift as nacelle angle varied during the approach. Automatic actuation of flaps were favored for the approach profiles. During the simulation, full envelope SCAS using Dynamic Inverse control design was developed. Acceptable handling qualities were achieved with the active sidestick while flying with the Dynamic Inverse SCAS.

Investigative Team

NASA Ames Research Center
Logicon Information Systems and Services
Bell Helicopter Textron
The Boeing Company
Sikorsky Aircraft
Federal Aviation Administration

Space Shuttle Vehicle 2000-1

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Summary

Simulations of the Space Shuttle orbiter are performed at the VMS to fine-tune the Shuttle orbiter's landing systems and to provide landing and rollout training for the astronaut corps. The engineering goals for this simulation were to determine the feasibility of landing within 7500 feet on East Coast Abort Landing runways and to determine adequate hydraulic flow protection for single auxiliary power unit (APU) landings.

Introduction

The Space Shuttle orbiter has been simulated at the VMS twice each year since the mid 1970s. Researchers have examined modifications to the flight-control system, guidance and navigation systems, head-up displays, flight rules, and to the basic simulation model. The simulations also provide astronaut training with realistic landing and rollout scenarios.

Simulation

One objective of the Space Shuttle Vehicle (SSV) 2000-1 simulation was to investigate the feasibility of landing within a 7500 feet East Coast Abort Landings (ECAL) runway using the carbon brake model and the flight hardware anti-skid box. Currently, certain runways in Africa and Spain, and the Kennedy Space Center (KSC) have been designated for abort landings in case of failures during launch. A steeper launch trajectory, planned to support increased International Space Station (ISS) flights, may allow abort landings at runways on the East Coast of the United States. However, these ECAL runways are shorter (7500 - 8500 feet) than the currently designated Space Shuttle runways (12,000 - 15,000 feet). The simulation investigated six different landing techniques to determine the minimum length required to land safely on abort runways. Two new out-the-window databases representing ECAL sites were developed and integrated by SimLab personnel for this simulation: Otis Air Force Base in Massachusetts and Myrtle Beach in South Carolina.

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

The second objective was to determine adequate hydraulic flow protection for a single auxiliary power unit (APU) landing. Normally, three APUs power the control surfaces. In the event of a single or double APU failure, priority rate-limiting (PRL) software prevents hydraulic flow over-demand by limiting the rate at which the various control surfaces move. Results from the February 1999 study of the orbiter hydraulic system indicated that the PRL software does not limit control surface rates enough to remain within the hydraulic pump flow capacity of a single APU. Hence for this simulation, tighter limits for the speedbrake, landing gear hydraulic flow, aileron and rudder rates were evaluated during single APU.

Another objective of SSV 2000-1 was to train upcoming mission crews and astronaut candidates through a series of flights. Various runways, visibility and wind conditions were simulated along with periodic system failures throughout the landing and rollout phase.

Results

A total of 1268 runs were completed with 39 pilots during five weeks of simulation. Preliminary results indicate that the current baseline technique and several of the proposed ECAL landing techniques require a stopping distance greater than 7500 feet. However, manually increasing the currently used auto guidance speedbrake setting by 20% met the 7500 feet test-objective 97% of the time. Further testing will be conducted to verify this setting. Results indicate that it is essential to determine a maximum speedbrake limit. Not having a limit for manual or automatic flight procedures might result in expending too much of the orbiter's energy. The single APU hydraulic flow protection analysis indicates that cases of concern are only those when extraordinary maneuvers are executed before main gear touchdown. There are no over-demands or pressure drops after nose gear touchdown.

The crew familiarization session reinforced the importance of the VMS in preparing upcoming crews for the landing and rollout phase of the mission and for possible failures during that phase.

Investigative Team

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

AutoCue

Jeff Schroeder, Munro Dearing, Adolf Atencio, NASA ARC;
Norm Bengford, Robert Morrison, Logicon/LISS

Summary

The AutoCue simulation investigated the tradeoff between pilot performance of an autorotation maneuver and appropriate visual and motion cues. This was accomplished by varying the texturing and resolution content of simulated runways and by varying the motion cueing environment. The experiment also researched the ability of a pilot to recognize relative rates visually in a non-motion simulation environment.

Introduction

The helicopter autorotation maneuver is employed when flight conditions warrant a minimum or no power descent and landing. This could occur through loss of engine power or through loss of fully effective flight controls. The maneuver allows the pilot to execute a safe, survivable landing depending on the availability of appropriate terrain. Because practice autorotations to landing carry high risk, a need for a helicopter autorotation simulator is growing to address the safety and cost concerns. Therefore, it is necessary to establish minimum cueing specifications for both visual and motion systems. The AutoCue simulation was designed to determine the tradeoff between pilot-vehicle performance and workload versus visual and motion cues.

Simulation

One objective of the Autocue simulation was for the pilot to execute an autorotation using standard autorotation procedures and technique to a desired position on the runway, with minimum forward ground speed and minimum rate of descent. From the visual cues of perceived height and depth perception, the pilot would try to perform an autorotation to a touchdown with a maximum groundspeed of less than 25 knots and a maximum rate of descent of less than 5ft/sec.

For each run, the pilot had to autorotate the helicopter from an initial altitude of 1000 ft. and an initial airspeed of 80 knots to land at a designated spot on the runway. The autorotation runs were done for twelve different runway visual cue environments, ranging from no texture and little scene content to a high scene density runway. The pilot rated each autorotation according to the airspeed, rotor RPM control, rate of descent, and touchdown position by assigning a Handling Qualities Rating (HQR) and answering a questionnaire.

The second objective of the simulation, “PsychoPath” was designed to determine the pilot visual threshold of closure rate in a no motion environment. The pilot was positioned 100 ft. in front of the runway threshold at 100-ft. altitude and an initial airspeed of 20 knots. Consecutive runs of differing descent rates to the same runway texture density were given to the pilots. The pilot determined which sink rate was larger before moving to the next pair of runs.

The UH-60 Blackhawk helicopter model was used to examine different visual and motion cues during an autorotation maneuver.

The visual cueing database had the capability to vary the runway texture density from maximum possible down to zero texture, resulting in 12 different selectable data scenes. Both textures derived from actual photographs of a runway and a random noise database were used for each runway scene. Other outside cues from the database, such as buildings, towers, hangars, trees, etc. were eliminated. The motion cueing environment included the full VMS motion system, no motion, and limited motion to model a hexapod simulator with a 15 inch actuator stroke.

Results

During the seven weeks of this simulation a total of nineteen subjects including 11 pilots and 8 non-pilots participated. 1544 autorotation data runs and 182 psychopath data runs were collected. Preliminary results show that the effect of the database changes produced an unexpected trend. Further analysis of the data is needed to study these effects.

Investigative Team

U.S. Army
NASA Ames Research Center

Magnetic Levitation Vehicle Demonstration

Charlotte Thornton, Stanford University;
Julie Mikula, NASA ARC; Joe Ogwell, John Bunnell, Logicon/LISS

Summary

This fixed-based experiment was to demonstrate a conceptual high speed mass transport vehicle, i.e., Magnetic Levitation (MagLev) train, to improve the traffic capacity between major cities. The primary objectives of the entry were to identify basic parameters for a MagLev vehicle such as optimal track height above terrain, passenger height above the track, human visual speed tolerance, design of instrument displays, display parameter groupings and control hardware.

Introduction

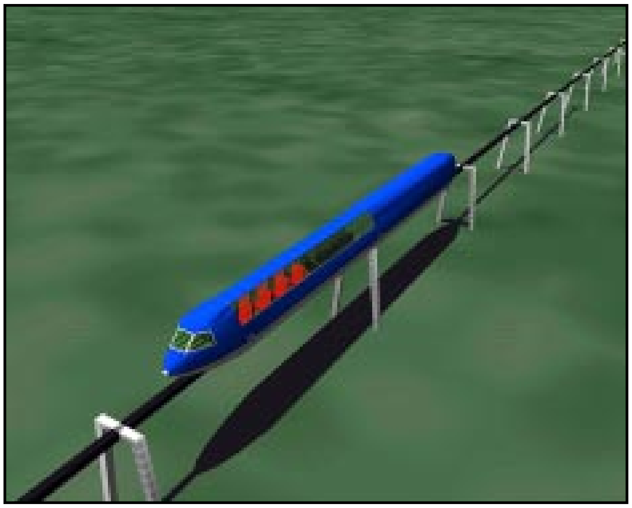
The MagLev Simulation Capability Demonstration entry was conducted for the Stanford Product Design Group in partnership with Richardson, Robertson Partners, Architects. The purpose of the demonstration was to use the capabilities of the SimLab facility to visually simulate a magnetic levitation train route. The focus of the program was to obtain basic design guidelines for magnetically levitated freight and passenger trains, guideway design, ride quality, and safety issues.

This MagLev entry was only for a demonstration to investigate feasibility issues in the early conceptual design. A set of guidance algorithms based on the track profile was developed to generate the out-the-window eyepoint view for the conductor and passengers to follow along a guideway track. Different track heights were also investigated.

Simulation

Due to the limited scope of this experiment, a simple MagLev train model was developed by SimLab engineers to use the specified track profile to provide the speed control of the train. A stretch of approximately 35 miles of the track between Palmdale and Burbank, CA was developed by SimLab. The challenge was to create the visual database for this long stretch of track going up and over mountains, compute where the track was located, and guide the vehicle along this track.

Since the vehicle had to follow the guideway track defined in the ESIG visual database, data from the ESIG had to be processed to produce a list of coordinates for the vehicle to follow. A processing program was developed to convert the ESIG visual database data into a three-dimensional table to provide coordinates for each track segment. This data was then converted to the proper format to be used in the map display software and in the speed control model.



Magnetic Levitation train travels at high speed along a guideway between Palmdale and Burbank.

In order to travel along the track, a filtered speed command was developed to give the conductor ways to control the speed of the train while accelerating, making turns, going up and down, braking, and coming to a stop.

Results

The researcher learned a great deal regarding a range of issues to be considered when trying to build an elevated MagLev train with a maximum speed approaching 300 miles per hour. The sharpness of the turns and the steepness of the banks of the turns are major issues to be considered.

A grand total of 22 visitors from a broad spectrum of backgrounds were shown the demonstration. There were academics, engineers, urban planners, transportation professionals from Ecuador, and entrepreneurs involved with this particular project. Four video and six audio tape recordings were made and retained by the researcher. These recordings will help the researcher better define requirements for future simulation entries.

Investigative Team

Stanford University
Universal MagLev
NASA Ames Research Center

Situational Awareness Model Simulation

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Summary

SAMSIM tested a computational situational awareness model used in human factors studies by simulating full-mission flights of the UH-60 Blackhawk helicopter.

Introduction

In 1997, human factors researchers developed and integrated a computational situational awareness model (SAM) into the Man-machine Integration Design and Analysis System (MIDAS). MIDAS is an overall cognitive model that combines graphical equipment prototyping, a dynamic simulation, and human performance modeling on a computer workstation. The goals of MIDAS are to reduce design cycle time, support quantitative predictions of human-system effectiveness, and improve the design of crew stations and their associated operating procedures.

Part-task simulations for both military and civil environments have tested SAM and found high correlation between its predictions and the measures subsequently collected from pilots. SAMSIM further tested SAM in a higher fidelity full-mission simulator, the Vertical Motion Simulator (VMS) using the UH-60 Blackhawk helicopter model.

Simulation

The principal objectives of the simulation experiment were to:

(1) Evaluate the validity of SAM in a high fidelity rotorcraft simulation, and
(2) Demonstrate two key features of the model: context changes and actual versus perceived situational awareness.

In the simulation experiment, each pilot used a map to fly a mission along a designated route above hilly and rolling terrain. Each route started and ended at a hover pad in a village with several waypoints in between. At each waypoint was a red flag to mark its location, and a half-mile beyond it on the way to the next waypoint was a yellow flag.

The pilot was given the following tasks to perform during the mission:

- Maintain a prescribed airspeed and radar altitude.
- Use localizer guidance to fly to each waypoint.
- After the last waypoint, fly back to the village using only the map (guidance was turned off and visibility was reduced).
- Report all ground vehicles (tanks or vans) by radio, indicating their map locations.
- Report any equipment failures.

Combinations of four different routes and two different placements of ground vehicles were used for the missions. For one placement, the vehicles were farther from the route than the other. In addition, visibility was varied between high and low, and stability augmentation system was turned on or off.

For the simulation, SimLab personnel developed software to simulate equipment failures, calculate the pilot's reaction times to the failures; provide localizer guidance; automatically reduce visibility after the last waypoint; perform statistical calculations of aircraft heading, radar altitude, and airspeed; calculate the ranges from the helicopter to the ground vehicles; and determine which three vehicles were closest. SimLab personnel also developed visual models of the vehicles and flags and placed them along each route on the visual database according to the maps. In addition, they developed graphics to display the maps and cockpit instruments in the lab.

Ground vehicles (a tank and a van), placed on hilly terrain were used as targets to test the situational awareness of pilots during the flight of a mission.

Results

Each of four pilots flew the simulated UH-60 helicopter on full mission flights to perform the tasks specified by the researchers. After each mission, the pilot rated the aircraft's handling qualities and answered a detailed questionnaire. The pilots completed a total of 65 data runs, each lasting for about 15 minutes. The experiment was successful, meeting all principal objectives. Results of the experiment were pending at the time this report was written.

Investigative Team

U.S. Army
NASA Ames Research Center

Space Shuttle Vehicle 2000-2

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Summary

Simulations of the Space Shuttle orbiter are performed at the VMS to fine-tune the Shuttle orbiter’s landing systems and to provide landing and rollout training for the astronaut corps. The engineering goals for this simulation were to determine the feasibility of expanding the night Transatlantic Abort Landing (TAL) crosswind limit from 12 to 15 knots with regards to crew safety, handling qualities and vehicle limits; to evaluate a limit for the maximum speedbrake setting when using the new short-runway speedbrake option; and to evaluate an adaptive speedbrake model.

Introduction

The Space Shuttle orbiter has been simulated at the VMS twice each year since the mid 1970s. Researchers have examined modifications to the flight-control system, guidance and navigation systems, head-up displays, flight rules, and to the basic simulation model. The simulations also provide astronaut training with realistic landing and rollout scenarios.

Simulation

The primary objective of this entry was to evaluate the feasibility of expanding the night TAL crosswind limit from 12 to 15 knots with regards to crew safety, handling qualities and vehicle performance limits. Higher crosswind limits will mean better chances of meeting launch windows for the increasing number of flights required to support current and future space station missions. Based on studies in ’95 and ’96 the daytime crosswind limit was increased to 15 knots. However, the night landing limit was nominally set at 12 knots to account for reduced depth perception at night. This experiment specifically studied the higher crosswind limit impact on handling qualities and performance margins for the night environment.

This simulation conducted studies to determine the crosswind limit during night landings on Transatlantic Abort runways.

The second goal of this entry was to evaluate the limit for the maximum speedbrake setting when using the new short-runway speedbrake option. Results from the March 2000 study to develop landing and rollout procedures for short runways showed that it was essential to determine a maximum speedbrake limit. Not having a limit for manual or automatic flight procedures might result in expending too much of the orbiter’s energy. During this session, the researchers examined the handling qualities and performance effects of a range of maximum speedbrake limits.

The third engineering goal of this entry was to perform a preliminary evaluation of an adaptive speedbrake model, which will allow continuous changes of the speedbrake angle. The current model positions the speedbrake at specific angles during the final approach and landing phases.

Another objective of SSV 2000-2 was to train upcoming mission crews and astronaut candidates through a series of flights. Various runways, visibility conditions, and wind conditions were simulated, and system failures were periodically introduced during the training matrix.

Results

During the four weeks of the simulation, thirty-three pilots completed 818 training and engineering data runs. The crew familiarization session reinforced the importance of the VMS in preparing upcoming crews for the landing and rollout phase of the mission and for possible failures during that phase.

Preliminary results of the engineering studies indicate that: (i) the higher night TAL crosswind does not compromise safety, handling qualities or performance. The researchers will recommend raising the flight rule limit on night crosswinds from 12 knots to 15 knots; (ii) the maximum speedbrake limit with the short-runway speedbrake option should be set at 75 percent in order to achieve the best energy results; and (iii) pilots did not discern a significant difference between the adaptive speedbrake model and the baseline model. The adaptive speedbrake improved performance, measured in terms of normalized touchdown position and speed, on some runs and on other runs it hurt performance slightly when compared to the baseline.

Investigative Team

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

Joint Shipboard Helicopter Integration Process

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Summary

The Joint Shipboard Helicopter Integration Process (JSHIP) - Joint Test and Evaluation program is sponsored by the Office of the Secretary of Defense (OSD) to develop and test the processes and mechanisms that facilitate ship-helicopter interface testing via man-in-the-loop simulators. For this purpose, SimLab has developed a simulation that replicates at-sea conditions for an LHA class ship and UH-60A Blackhawk helicopter. The JSHIP program completed a fixed-base validation session in October 2000; motion-based simulations are planned for December 2000 and June 2001.

Introduction

The specific purpose of the JSHIP program is to increase the interoperability of joint shipboard helicopter operations for helicopter units that are not specifically designed to go aboard Navy ships.
An important issue of shipboard helicopter integration is the wind-over-deck (WOD) launch and recovery flight envelope. For the Navy, WOD flight envelopes have been established for specific ship and aircraft combinations using at-sea flight tests. JSHIP is examining the potential of ground based flight simulation as a cost-effective and controlled alternative for WOD flight envelope determination.

Simulation

The purpose of this phase was to validate the models and subsystems integrated at VMS and to determine the impact of various fidelity configurations of each subsystem on accurately predicting the LHA / UH-60A WOD launch and recovery flight envelopes. The subsystems tested included the GenHel UH-60 math model, control loader forces, landing gear, visual scenes, aural cueing, dynamic seat, Computational Fluid Dynamics (CFD) generated airwake, ship motion model, and the UH-60 cab.

For this simulation, the UH-60 cab was completely re-built from the ground up. A new rear projection visual display system was installed to provide wider field-of-view (FOV) in the cockpit. The flight deck was constructed to duplicate the right seat of an UH-60 helicopter. The control loaders were checked versus forces from a UH-60 report.

The math model was verified to be representative of the UH-60. CFD generated airwake gusts were implemented into the math model at nine different places on the helicopter, including the outer segments of each rotor blade, the rotor hub, the fuselage, the stabilator, the tail rotor, and the horizontal tail. The landing gear was checked versus drop test data. Ship-motion was simulated using a complex model developed by the Navy.

The high fidelity visual model of an LHA ship is shown which was used for landings and launches during the JSHIP wind-over-deck envelope determination study.

For body force cueing, a dynamic seat was obtained from the Apache Longbow program. It was tuned to provide the vertical accelerations generated by a UH-60. The ESIG 4530 image generator with a 3D-sea state wave model, consisting of a series of realistic waves, was used with a highly accurate LHA ship model. The UH-60 sound environment was reproduced with three separate aural cueing models.

Results

All required models and subsystems were developed by SimLab personnel in record time: less than a year. The subsystems were successfully validated in September/October 2000. Their detailed configurations were documented in preparation for the December 2000 simulation. For this upcoming simulation, the fidelity level of each subsystem will be varied to determine a minimum level required to accurately predict the launch and recovery WOD flight envelope. In the June 2001 simulation, a fidelity algorithm will be developed that applies a confidence factor to predicted WOD envelopes as a function of the fidelity of the simulation.

Investigative Team

JSHIP Joint Test and Evaluation Office
Information Spectrum, Inc.
NASA Ames Research Center
Logicon Information Systems and Services

Rapid Integration Test Environment 2

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Summary

This is the second phase of an effort to develop a Rapid Integration Test Environment (RITE) for air-vehicle design, that is to develop a process and infrastructure to facilitate the use of Computational Fluid Dynamic (CFD), wind tunnel, and/or flight data in a real-time, piloted flight simulation and apply return knowledge to the design team to continuously improve and optimize the vehicle performance. The objectives are to reduce the design cycle time, and maximize the performance and the utilization of resources. The Space Shuttle Orbiter was used to demonstrate this fast turn-around process which includes a baseline aerodynamic model generated from wind tunnel, geometry variations generated from CFD, and a high fidelity pilot-in-the-loop motion-based flight simulation.

Introduction

During the second phase of the technology development for RITE, the main focus was to evaluate the quick turn-around capability of the interface, integration, and performance evaluation process developed during the first phase of this program in responding to design variations.

The nose section of the Orbiter was chosen as the design parameter. Three geometry variations of the nose section of the Orbiter were developed prior to the flight simulation, and the fourth was generated during the experiment. The four configurations were designed using HYPERVIEW, a Newtonian based hypersonic aerodynamic analysis tool. The configurations were optimized to give the best hypersonic lift-to-drag ratio using new Ultra-High Temperature Ceramic (UHTC) material. The UHTC material enables the use of sharp leading edges on vehicles for hypersonic flight. Grids for the new geometry were generated using a beta version of Three-Dimensional Cartesian Simulation System for Complex Geometry (CART3D). The grids were then used to calculate flow solutions using an inviscid flow solver module for CART3D, named TIGER.

Simulation

The simulation experiment ran with each of these aerodynamic data sets including the baseline model. The main task was to approach and land from Heading Alignment Cone (HAC) and 10,000 feet altitude initial conditions on to Kennedy Space Center (KSC) runway in wind and turbulent weather conditions. Forward and aft center-of-gravity configurations were also tested.

Vehicle performance and aerodynamic data were collected and analyzed during these runs to determine the effects that changes in nose geometry have on vehicle flight performance. Pilot evaluations were also taken to determine differences in handling qualities characteristics between the aerodynamic data sets. VLAB capability was used throughout the simulation to facilitate exchanging design modifications and simulation results among the team members.

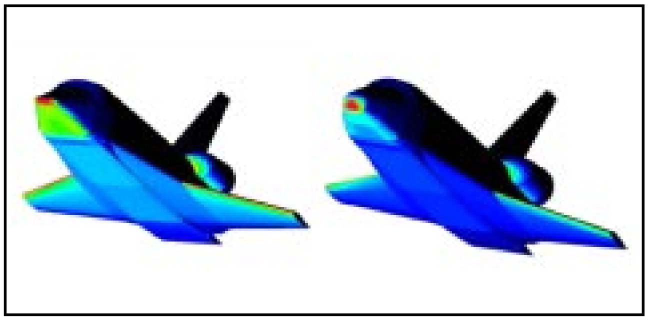
Results

- RITE is a viable and useful concept.
- VLAB enhances the usefulness of RITE.
- Grid-to-flight scenario was proven.

The RITE II simulation experiment demonstrated the capability of integrating CFD, flight, and wind-tunnel data into a simulation rapidly and seamlessly. Three new math models for three different configurations were implemented and evaluated during the simulation runs. The handling qualities of each configuration were compared to the baseline space shuttle configuration and evaluated using Cooper-Harper ratings. Four pilots evaluated each of the configurations. The resulting Cooper-Harper ratings for each of the three configurations were, in general, very similar to the baseline shuttle configuration. These results indicated that there was no loss in handling qualities during approach and landing due to the changes made to the nose configuration. These findings were communicated back to the design group.

Investigative Team

NASA Ames Research Center
Caelum Research
MCAT Inc.
Logicon Information Systems and Services



Flow visualization of different space shuttle orbiter nose geometires simulated during RITE 2.

Civil Tiltrotor 9

Bill Decker, Dan Dugan, Jack Franklin, NASA ARC; Helmuth Koelzer, Pete Klein Bell Helicopter Textron; Dan Bugajski, Honeywell; Gordon Hardy, Ron Gerdes, Logicon/LISS

Summary

Civil Tiltrotor (CTR) 9 was a continuation of the CTR series of simulations that investigated handling qualities and flight operational issues, such as noise abatement and approach/departure procedures related to operating a tiltrotor aircraft at a vertiport. The CTR 9 simulation was a large integration effort involving modifications to the cab flight deck as well as large scale software development to support the handling qualities research and flight management investigations. The simulation planned to investigate tiltrotor guidance profiles, Take Off/Go Around (TOGA) performance and profiles, one engine inoperative (OEI) operations, and two flight control systems with autopilot functionality for terminal area flight and noise abatement procedures. Research into integrating the tiltrotor aircraft into the airspace with Air Traffic Control (ATC) was also part of this effort.

Introduction

The CTR series of simulation experiments have investigated certification and operational issues affecting terminal operations of a civil tiltrotor transport. In addition to flying qualities of the CTR in and out of the terminal area, the investigation effort has begun focusing on operational issues under normal airspace management procedures. More thought has been placed on how the tiltrotor will fit into the existing airspace with vertiport sites located near existing airports or in congested downtown areas. Noise abatement, approach and departure profiles and procedures, and pilots work load and their interaction with ATC controllers are issues to be addressed.

Simulation

The cab interior was redesigned to account for newly designed and fabricated thrust control levers (TCL) and a new instrument panel to support the ATC flight management investigation. A second analog computer was added to provide two full sets of controllers for a two-man crew.

Two separate flight control systems, or stability and control augmentation systems (SCAS) were developed. Bell Helicopter Textron's SCAS is a modification of the 1985 JVX SCAS and is a full authority SCAS. In conjunction with the SCAS development, Bell developed an autopilot function based upon previous XV-15 work that was coordinated with the Honeywell Vertical Navigation (VNav) System and the Mode Control Panel (MCP). The second SCAS system, which is also a full authority SCAS, was a dynamic inverse (DI) design developed by NASA Ames researcher Jack Franklin.

A full suite of avionics including updated Navigation displays, primary flight displays (PFD), and MCP displays were integrated into the experiment. Two critical flight management functions were also developed. These included a VNav system developed by Honeywell and a lateral navigation system (LNav) developed by Logicon, based on existing lateral guidance.

In preparation for FAA certification for tiltrotor aircraft, the Pseudo-Aircraft System (PAS), an ATC simulation software tool, was integrated into the simulation. PAS generated pseudo aircraft traffic based on the air traffic scenarios and sent the aircraft traffic information to the CTR simulation to be displayed on the Navigation display and ESIG out-the-window views to simulate other aircraft traffic in the area. Voice communications with an ATC controller were also integrated into the simulation.

Results

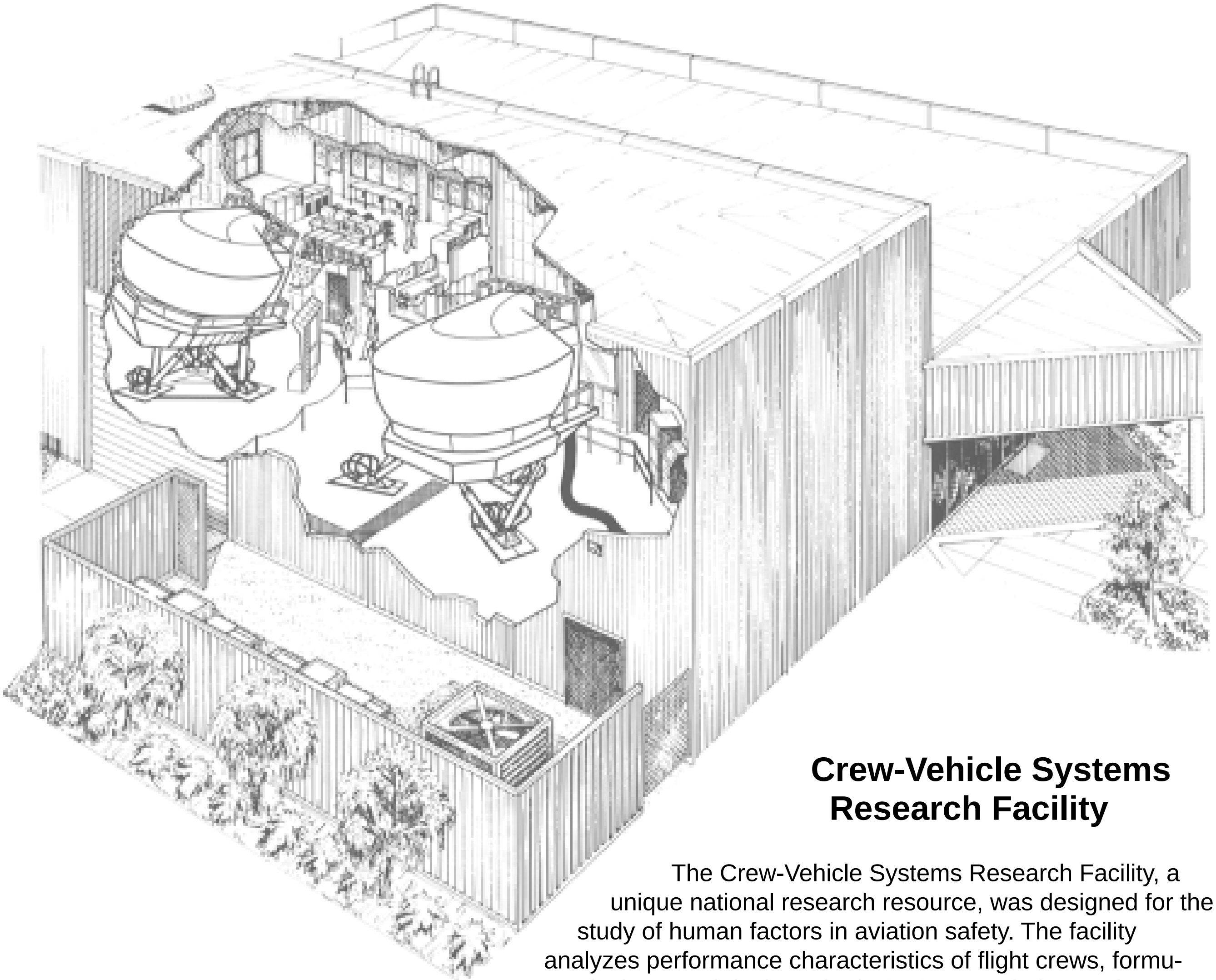
The CTR 9 simulation ran a checkout simulation in the RSIS fixed base area for four weeks from September 4th to September 29th and began the VMS operations starting October 2nd. Consequently, no results are available from the simulation.

Investigative Team

NASA Ames Research Center
Logicon Information Systems and Services
Bell Helicopter Textron
Honeywell
Federal Aviation Administration

A simulated civil tiltrotor flies over San Francisco towards a landing at a vertiport near the Bay Bridge.

CVSRF PROJECT SUMMARIES



Crew-Vehicle Systems Research Facility

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

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

Taxiway Navigation and Situation Awareness 2

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Summary

This follow-up study evaluated the use of a Head-Up Display (HUD) and an Electronic Moving Map (EMM) to provide navigation and guidance information to airplane flight crews for airport runway turn-off and surface taxi operations. The goal of the technology is to improve these airport ground-taxi operations in low visibility weather conditions to increase airport capacity and improve aviation safety. This experiment supported the Low-Visibility Landing and Surface Operations (LVLASO) element of the Terminal Area Productivity (TAP) Project.

Introduction

Current airport surface operations are handled with verbal instructions over the radio, and the aircraft crew uses paper maps to navigate around the airport. In bad weather (low visibility) and at night, this can lead to very slow taxi operations and potentially dangerous situations. Under these conditions, many major U.S. airports have taxi capacity limitations, and several taxi accidents occur each year. Although, many commercial airliners are now equipped with electronic navigation displays and Head-Up Display systems, little effort has been developed to utilize these display systems for ground-taxi operations.

The Taxiway-Navigation and Situation Awareness (T-NASA) System assumes that in the future taxi clearances from terminal controllers will be datalinked to the cockpit, allowing flight crews to receive and display both textual and graphical ground-taxi information, to improve taxi route conformance and traffic flow. The T-NASA-2 experiment followed the concept of electronically loading the taxi route into an on-board system and displaying the route graphically on both the Head-Up Display (HUD) and Electronic Moving Map (EMM). New technologies introduced for this simulation included the use of the Roll-Out and Turn-Off (ROTO) HUD, 3-D audio alerts and warnings, and a two-way ATC-Pilot datalink communication interface.

Simulation

Eighteen commercial airline crews completed 14 low visibility (RVR 1000’) land-and-taxi scenarios that included both nominal taxi events (such as hold shorts and route amendments) and off-nominal events (such as near traffic incursions, clearance errors, and display information inconsistencies). Crews ground-taxi responses and performance were evaluated under three test configurations, i.e., 1) Current Procedures: Using standard operations and equipment which included voice communications, ground clearances, and Jeppesen charts for navigation; 2) Transition Operations: Provided Air Traffic Control (ATC) communications by using both voice and datalink; and 3) Advanced Operations: Designed to accommodate an expected three-fold increase in airport traffic, provided ATC communications via datalink only, and included advanced features such as airborne taxi clearances.

Results

T-NASA increased taxi speeds by 16% (or 2.2 kts) over current day scenarios while simultaneously eliminating major navigational errors, e.g., making a wrong turn or failing to turn, which occurred in 20% under the current procedures. Further, the revolutionary changes embedded in the Advanced Operations package produced large efficiency benefits. Specifically, when taxi clearances were datalinked to pilots while airborne (outside outer-marker), the time spent stopped after runway turnoff was eliminated (saving approximately 10 sec. per trial), and taxi speeds during this typical bottle-necked phase of taxiing increased by approximately 78% (or 7.4 kts). Also, the Advanced Operations package provided substantial improvements in ATC-Pilot communication efficiency by reducing radio congestion and communication errors. These results suggest not only that T-NASA can provide substantial benefits for the efficiency and safety of surface operations, but also that further gains may be realized by incorporating revolutionary changes to surface operations such as the use of datalink and airborne taxi clearances.

Investigative Team

NASA Ames Research Center
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Electronic Moving Map display during the TAXI operation.

Integrated Tools/Air-Ground Integration

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Margaret Mackintosh, Alison McGann, SJSU; Jerry Jones, Rod Ketchum, George Mitchell,
Diane Carpenter, Ghislain Saillant, Ian MacLure, Fritz Renema,
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Summary

This experiment conducted an early evaluation of air-ground integration procedures and concepts. It was a joint research effort involving both the William J. Hughes FAA Technical Center (FAATC) and NASA Ames in order to obtain data pertaining to interactions among controllers of the ground system and flight crew on the flight deck.

The overall goal was to conduct an early examination of procedures and events in a dynamic environment where the control of aircraft can be centralized or distributed, i.e., conventional ATC procedures or self-separation, respectively. This study was conducted in conjunction with the Human-Automation Integration Research Branch (IHI) at NASA Ames Research Center.

Introduction

In the free flight environment, aircraft will presumably be able to maneuver with more autonomy and flexibility. However, free flight will require definition of new zones around each aircraft, similar to the zones currently provided by the TCAS alert algorithms. These zones will be defined as the alert and protected zones. Roles and responsibilities associated with transgressions of these zones need to be defined and evaluated to determine if there may be difficulties in coordination between the controllers and the flight crew in cases where separation authority is provided to the flight crew.

Simulation

This research investigating free flight, a future flight rule being considered by FAA, included researchers and laboratories located at the FAATC in Atlantic City, New Jersey, and at the CVSRF at NASA Ames Research Center. Flight crews from the B747-400 and pseudo pilots, using the Pseudo Aircraft System (PAS) at the CVSRF, and pseudo pilots from FAATC followed designed traffic scenarios and flight procedures to interact with ATC controllers located at the FAATC. All air traffic other than the B747-400 and the PAS intruder aircraft that were local to CVSRF were generated at the FAATC and sent to the CVSRF.

AGIE Symbology on Navigation Display

For this experiment, a new dedicated T1 line was installed between NASA ARC and the FAATC. The T1 line was used to send/receive voice information, using Voice Over IP (VOIP) technology, and aircraft data. The software used for this study on the B747-400 flight simulator was an upgrade to the previous AATT3 experiment software. The majority of this new software developed was in support of the new interface to the FAATC.

Results

Crews reported that the alerting logic gave them adequate time to resolve the conflicts, yet better altitude filtering of the traffic would be beneficial. In this study aircraft heading changes, as opposed to altitude or speed changes, seemed to be the preferred method of traffic conflict resolution.

Investigative Team

NASA Ames Research Center
San Jose State University
William J. Hughes FAA Technical Center

Flight Management System Departure Procedures 2

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Summary

With the implementation of today's Flight Management Systems (FMS), as well as the navigation concept of Required Navigation Performance (RNP), conventional area navigation (RNAV) departure procedures using the FMS can now extend the overall navigation capability. The objective of this study was to evaluate a new departure proposed for noise abatement addressing concerns that variations of the aircraft's speed and weight may lead to possible waypoint overshoots.

Introduction

Federal Aviation Administration (FAA) Order 8260.44 provides criteria for constructing instrument flight rules (IFR) RNAV departure procedures. Procedures designed to meet the current criteria are for use by aircraft with only RNAV or Global Positioning System (GPS) RNAV capability. The data derived from this examination will assist in the development of departure procedure design standards for FMS/RNP/RNAV departures based on operational and system requirements. At certain locations, obstacles or noise sensitive areas close to the departure track create a requirement for highly accurate systems and special operational procedures to enter and maintain a narrow departure corridor. This project will identify operational and system requirements that must be considered in the total development of Terminal Procedures RNAV Departure Procedure criteria.

A map showing the ground track of the aircraft with respect to the FMS computed track (solid line) part way through a departure at unrestricted airspeed.

Simulation

Using the NASA 747-400 Simulator, a number of runs of the planned departure were conducted while capturing aircraft parameters at a two Hertz rate. The parameters collected include aircraft position relative to the intended flight track, airspeed, heading, vertical speed, height above ground, flap position and FMC LNAV bank command. The departure route was constructed by the FAA Flight Procedure Standards Branch in Oklahoma City and was manually entered into the B747-400's FMC as latitude/longitude waypoints. Takeoffs were made from runway 9L at Atlanta at both light and heavy weights, at both constant and unrestricted airspeeds and with winds that were either calm or a ten knot tailwind from 273 degrees.

Results

Eight data runs were completed for this study. All runs were flown by CVSRF staff pilots. The collected data was sent to the FAA in Oklahoma City. Data is being evaluated by the FAA and results of this investigation will be utilized in future studies.

Investigative Team

Federal Aviation Administration, Oklahoma City
NASA Ames Research Center

Neural Flight Control System

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Summary

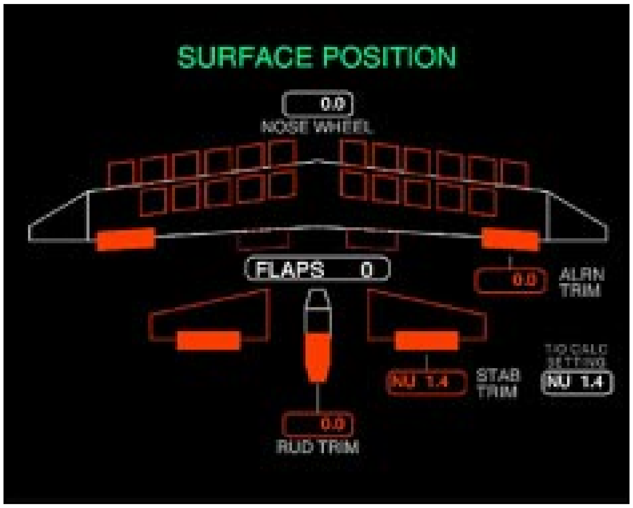
A number of high profile aircraft accidents involving full or partial loss of control during flight have sparked an interest in research to implement alternative methods of controlling damaged aircraft. This experiment evaluated the use of adaptive flight controllers based on “Neural Net” technologies as a possible solution.

Introduction

Current research efforts include development of flight control systems which can adapt themselves to compensate for damage to the aircraft control system using any remaining control authority of the primary systems plus auxiliary means to maintain control during flight. The Neural Flight Control Systems Study incorporated a “Neural Net” based controller in the Advanced Concepts Flight Simulator (ACFS). The study was intended as a proof of concept of various controller algorithms but primarily of Neural Net based technology.

Neural networks are processing systems which do not require explicit equations relating input to output. They are capable of learning the relationship between input to a system and the resulting output by analysis of examples of desired system behavior. A neural net can be thought of as an intelligent, and to some extent a self generated, lookup table. Whether they are in hardware or software form, a neural net consists of large numbers of relatively simple processing elements connected in multiple ways.

The Control Page for the NFCS Experimenter’s Operation Station



Failed Control Surfaces Display

Simulation

For this study the simulated aircraft was a Boeing 757-class generic transport. The neural net had knowledge of the desired handling qualities of the vehicle. When presented with a control system malfunction it was able to adapt to the degraded situation. A Neural Net type controller was capable of responding to the damaged aircraft and adapt pilot inputs to provide flight control in a manner that is easily understood by the crew.

Results

NASA pilots flew 39 experimental data runs. Handling qualities were assessed for the fully functional aircraft and for the damaged aircraft, subjected to a variety of control failure conditions while equipped with different controller algorithms. Performance of the various controllers was measured for each failure condition. Audio/Video recordings were made of the test runs and data was collected using the simulator’s built-in data collection system. Preliminary results indicate that Neural Net based controllers might provide a viable option to control damaged aircraft to a safe landing.

Investigative Team

NASA Ames Research Center

Controller-Pilot Data Link Communication Procedures

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Summary

This study examined Controller-Pilot Data Link Communications (CPDLC) in the domestic enroute environment. Specifically, the cockpit crews' ability to detect and recover from message errors was investigated in three communication environments: voice only, data link only, and mixed – voice and data link.

Introduction

Flight operations in the National Airspace System (NAS) depend on the timely and accurate exchange of information between aircraft and various air traffic control (ATC) facilities. CPDLC is a new means of communication between controllers and pilots using electronic messaging (data link). This new communication function presents the need to establish new procedures to generate effective communication between controllers and the flight crew. Previous research has shown that a mixed media environment may change the nature of ATC communications. This study is a follow up to previous research in which voice transaction times were found to have lengthened in a mixed media environment compared to a pure voice environment. In addition, planned distractions to the data link task were examined to uncover procedural vulnerabilities. Potential problems with procedural steps required for the crew to initiate a request to the controller were also examined.

Simulation

The objective of the CPDLC study was to examine the impact of data link and voice procedures upon the crew. ATC clearances and requests in voice only and data link only modalities were represented. In other cases, use of data link and voice messages were mixed. The crews' ability to detect and recover from message errors was evaluated. Also, the impact of varying time intervals between messages on the cockpit crew was investigated.

The CVSRF staff added the capability to uplink a group of ATC messages to the cockpit, via a simulated ATC ground station. For this study a message group contained up to 3 clearances and/or requests.

Results

Seven airline crews participated in 7 training runs and 42 experiment data runs. Overall, pilots seemed to find the mixed voice/data link condition the most difficult. Pilots did indicate that time-sharing of the Flight Management System Control Display Unit (FMS CDU) for both data link communications and FMS operations was somewhat disruptive and that the time required to detect, read and respond to a data link message on the CDU was only moderately acceptable. However, flight crews reported that overall data link improved the effectiveness of air-ground communications and that they would be very satisfied with data link as a safety enhancement for the enroute phase of flight.

Investigative Team

NASA Ames Research Center
San Jose State University

```
        ATC LOG        1/1
 2128Z                  NEW
↑ TURN L HEADING 050°..>
 2124Z                 OPEN
↑ CLIMB TO AND MAINTA..>
 2123Z             ACCEPTED
↑ CLIMB TO AND MAINTA..>
 2122Z             ACCEPTED
↑ PROCEED DIRECT TO O..>
 2120Z             ACCEPTED
↑ TURN L HEADING 040°..>
------------------------
<INDEX        ERASE LOG>
```

Control Display Unit (CDU) showing ATC log page with uplink messages.

Center TRACON Automation System Flight Management System 2

Everett Palmer, Terry Rager, NASA ARC; Todd Callantine, Thomas Prevot, Stephan Romahn, SJSU;
Don Bryant, George Mitchell, Ramesh Panda, Anna Dabrowski, Dave Brown,
Ian Maclure, Tom Prehm, Fritz Renema, Gary Uyehara, ManTech

Summary

CTAS/FMS2 was a follow on study to evaluate new concepts of integrating the Center TRACON Automation System (CTAS) with the Flight Management System (FMS). This research was part of the NASA Terminal Area Productivity Project for safely increasing traffic capacity in the arrival and terminal airspace.

Introduction

Envisioned to be operational in the 2010 time frame, improvements in flight management automation both in the cockpit and the Air Traffic Control (ATC) facilities are expected to provide benefits in alleviating air traffic problems related to aircraft arrival to major airports. The goal is to provide safe and efficient flow of enroute traffic into the TRACON airspace which in turn can deliver the aircraft to the approach control handled by the airport tower.

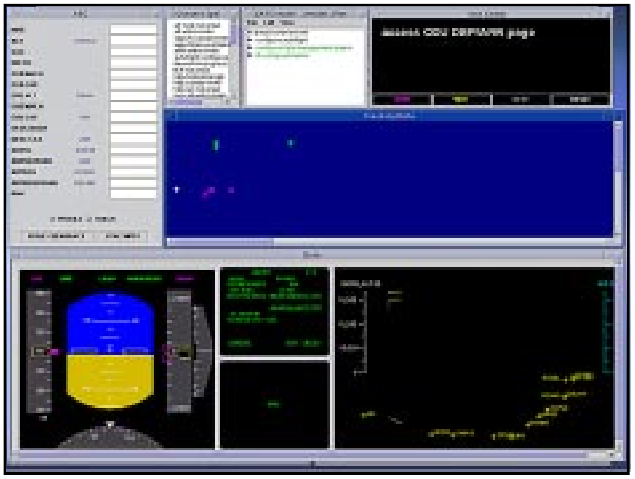
The FMS continues to be the key component providing enhanced cockpit automation capabilities while a set of CTAS software tools forms the basis for TRACON ATC automation.

In addition to using the flight crews as study subjects in the previous CTAS/FMS study, ATC controllers were also included as experiment subjects for this vastly enhanced simulation investigation.

Simulation

Two piloted flight simulators, the ACFS at CVSRF and a B757 at Langley Research Center (LaRC) took part in this experiment. Live and scripted Pseudo Aircraft System aircraft and the CTAS controller stations, located in the Airspace Operations Lab (AOL) in N262, simulated TRACON traffic and ATC controller functions remotely through a gateway to CVSRF. A Voice Over IP communication link was setup between the CVSRF and the AOL to provide voice communications.

The ACFS was configured for full mission operations in Center and TRACON airspace for arrivals into Dallas/Fort Worth. Features carried over from the previous study were a Boeing 777 type data link system, FMS route clearance loading, and a Vertical Situation Display. Enhancements developed for this experiment included additional FMS Vertical Navigation functions such as wind planning to include forecast winds, and capabilities to modify the flight plan via up-linked information, such as clearances, cruise speeds, descent speeds, and descent forecast winds, from ground stations. A standard Traffic Collision Avoidance System was added for this experiment. Additionally, a 3D wind model was integrated providing realistic and consistent wind profiles to all participants in the simulation.



Crew Activity Tracking System

The Crew Activity Tracking System (CATS), which receives real-time simulation data to analyze crew performance, was integrated into the simulation for the first time. CATS, located remotely from the simulator and interfaced via the data network, displays a facsimile of the aircraft's data including the primary flight display, the FMS flight plan, and the lateral and vertical flight profiles. Additionally, CATS can analyze the actions performed by the flight crew. For this simulation, CATS was also used as the primary data collection system.

Results

A total of eight crews from major commercial air carriers with glass cockpit type rating took part in the study. Six scenarios were flown by each crew. The B757 simulator at LaRC and air traffic controllers in AOL also participated in the study.

Investigative Team

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NASA Langely Research Center
San Jose State University

Airborne Information for Lateral Spacing

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Summary

Airborne Information for Lateral Spacing (AILS) is an airborne-based concept for independent, instrument approaches to closely-spaced parallel runways that enables the use of both runways during instrument approach conditions. AILS provides an independent instrument approach capability applicable to parallel runways with centerline spacing between 4,300 and 2,500 feet, the range of runway spacing for most domestic airlines' hub airports. The airlines' ability to maintain schedules is severely impacted when one or more airports are forced to curtail independent parallel approaches because of inclement weather. The AILS system safely maintains high airport acceptance rates, not possible with current systems and procedures, during low visibility conditions.

Introduction

This investigation will examine the utility and viability of the two systems designed to increase airport efficiency during IMC. Evaluation of flight crew and Air Traffic Control (ATC) interactions during the pairing of aircraft for independent and dependent approaches using AILS and CSPA, respectively, will be conducted, as well as the re-engagement of interactions when a break off maneuver is required.

Simulation

This simulation will be conducted with scenarios utilizing the airspace in and around the Seattle International Airport.

Seattle is undergoing a new runway addition, which will give the primary runways approximately 2500 ft centerline separation between the two outer runways, allowing use of the AILS/CSPA technologies if adopted.

The CVSRF's B747 full mission simulator was adapted to accept revised primary flight display and navigation display (see figure) information.

Additional modifications mandated by the study included increasing the messaging capabilities and creating new aural cues for use in the B747 cab. The Seattle runway scene depicted in the B747 simulators' visual system was modified to represent the addition of the new runway. Additionally, a custom Flight Management System (FMS) navigation database software file was designed and loaded into the FMS, for use with the "new" Seattle approaches.

Navigation display of closely spaced parallel approaches.

The CVSRF's ATC lab was configured to represent the SEATAC feeder sector, departure sector, tower position, and adjacent airspace positions, all utilizing the Pseudo Aircraft System (PAS). A separate final approach controller station was created in an isolated area for controller evaluation.

PAS was heavily modified to incorporate changes required of the researchers.

Additional video cameras, video splitters, routers and other hardware, were installed to collect the requested audio and video data for both the B747 flight deck crew and the isolated ATC controller station.

Scenarios began with air-traffic routed to the Seattle airport for runways 17 L/R. The B747 simulator was released into this traffic flow via automated software programs that also "paired" conflict traffic for a subsequent "blunder" or breakout maneuver.

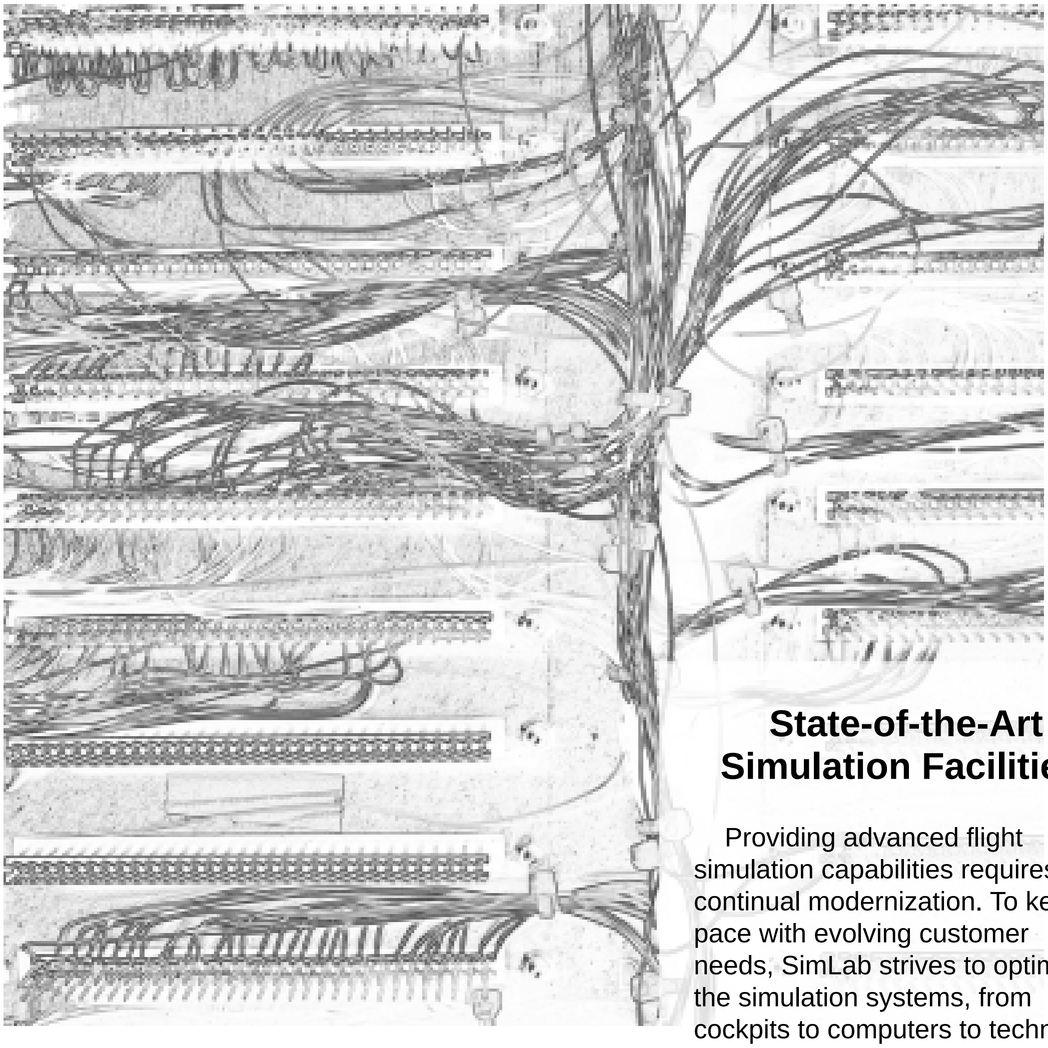
Results

Extensive system integration and checkout were completed. A preliminary system test with a flight crew and controllers was conducted to identify experiment functional and operational issues. Experiment will be run next year.

Investigative Team

NASA Ames Research Center

RESEARCH & TECHNOLOGY UPGRADE PROJECTS



State-of-the-Art Simulation Facilities

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

Virtual Laboratory

Summary

The Virtual Laboratory (VLAB) is a suite of real-time, interactive, engineering research tools that allows remote users to participate in live flight simulation experiments, conducted at the VMS Laboratories from their desktops. Significant accomplishments for FY2000 included two major simulation deployments, and the further development of PC-based client systems to enhance capabilities and reduce deployment costs.

Capabilities

Using VLAB, remote researchers navigate through a three dimensional virtual VMS laboratory control room environment. With the click of a mouse, remote users select, view, and position the same data displays available in the actual lab to suit their personal needs, on their own desktop workstation. The VLAB system consists of four functional components: (1) the client system presents the virtual lab and its displays; (2) a network-based video transmission system provides the pilots OTW visuals; (3) a network-based audio transmission system provides ambient laboratory sound, pilot communication, and private voice channels; and (4) A workstation (SGI O2) furnishes video conferencing and post-run data analysis capabilities. VLAB's modular architecture allows for scalable deployment of remote client systems.

PC Based Client Systems

The VLAB client system was successfully migrated to cost-effective desktop and laptop systems from the original high performance graphics workstation. The VLAB client is fully supported on Apple Macintosh desktop and PowerBook class systems. Work continues to migrate to Windows and Linux based PCs as well.

Ambient and two-way audio communication tools were integrated into the desktop/laptop client systems this year. This eliminates the need for an independent audio transmission system.

Simulation/Applications Deployments:

SSV: The February '00 SSV simulation featured the first deployment of a PowerBook VLAB client with embedded audio transmission. Researchers were able to monitor and respond to ambient audio, pilot comments and private communications directly from the PowerBook client.

RITE: The RITE simulation experiment deployment marked several VLAB firsts. The client suite was deployed to two separate laboratories at NASA/Ames for team participation and monitoring of the simulation. A real-time plotting function was added to the VLAB tool suite for RITE. The RITE simulation experiment marked the first use of "multicast" clients which allows support of unlimited remote clients while reducing network bandwidth requirements. Also of note was the first deployment of a PowerBook client using wireless LAN technology.

Future Plans

Future plans for the VLAB client suite include: further development of real-time plotting capability, extended use of multicast transmission, continued investigation of wireless LAN technologies, enhancements to existing display elements, and multi-platform, multi-OS, PC-based client systems. VLAB will investigate technologies that allow migration of the video conferencing, OTW visuals, and post data reduction tools into the VLAB client interface. The goal is to integrate all four functional components into a single hardware system controlled and operated from within the VLAB interface.

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

Development Team

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Engineers using VLAB to conduct research with the VMS lab from remote locations.

Joint Shipboard Helicopter Integration Process Simulation Technologies

Summary

The JSHIP study examined the relationship between the fidelity of a simulation and its ability to accurately predict a wind-over-the-deck (WOD) launch and recovery flight envelope for the LHA and UH-60A ship/helicopter combination. To assist in this effort, new technologies were developed and integrated into the SimLab environment to achieve the simulation goals.

Cab

The JSHIP study required the simulation to replicate the field-of-view (FOV) of a UH-60A BlackHawk helicopter which could not be met with any of the existing interchangeable cabs. To meet this requirement, one of the existing SimLab rotorcraft cabs (N-Cab) was stripped to the floor and rebuilt. In order to meet a 220 x 70 degree out the window FOV from the pilot's view, a completely new visual display system was designed in-house. The system consists of five off-the-shelf, high output cathode ray tube (CRT) projectors combined with custom flat mirrors and high gain rear projection screens. The system is non-collimated and places the screens at approximately 39.7" from the pilot as a necessary compromise to fit in the tight VMS envelope. Total cost for implementing the solution was approximately one fifth of competing designs (spherical mirrored Wide Angle Collimation (WAC) windows or vacuum formed dome projection systems) while maintaining a serviceable quality image.

The newly rebuilt N-cab undergoing modification to enhance the field of view with five projectors displaying the out-the-window view for the pilot.

Image Generator

The JSHIP project plan called for three separate levels of visual fidelity. The first was the existing ESIG 4530 ocean database and ship model as used in previous simulations at VMS. The second added the 3-D Sea State model from Evans and Sutherland (E&S) and an enhanced LHA model developed specifically for the JSHIP project. The third level is a proof of concept visual system using lower cost PCs and high powered graphics boards to drive the out the window displays.

The third level entailed integrating a new image generation (IG) system into the SimLab video system. The selected system was Carmel Applied Technology Inc.'s (CATI) X-IG Real-time Software package hosted by a set of five Quantum 3D Alchemy 8164, Pentium III based graphics subsystems. This visual fidelity level also included an enhanced synchronized ocean wave model, LHA ship model, and animated Landing Signal Enlisted (LSE) man. At this writing, an evaluation of actual performance remains to be done.

Dynamic Seat

The JSHIP project plan varies the levels of fidelity for the body force cueing (motion) system to evaluate the effectiveness of alternative motion cueing devices. In addition to the large motion provided by VMS and a motion envelope similar to a conventional hexapod system, a 4-axis limited travel Dynamic Seat made by Camber Corp./Boeing has been integrated into the cockpit to allow JSHIP to investigate the required motion fidelity requirements.

CFD Airwake

One of the challenges of creating the proper flight envelope for wind over deck launch and recovery is to correctly simulate the airwake generated by a ship with a large superstructure on one side of the landing deck. This airwake is highly complex and varies drastically depending on the direction of the incoming wind. It is, however, one of the most critical elements a pilot must deal with while landing a helicopter on a ship. An airwake model, based on time-history data developed using computational fluid dynamics (CFD) method, has been integrated with the GenHel blade-element UH-60 model. This is a first-of-its-kind implementation ever to be used for flight simulation applications.

Development Team

Colin Wilkinson, Mike Roscoe, Bob Nicholson, Denver Sheriff, Information Spectrum, Inc.; Chuck Perry, John Bunnell, Bill Chung, Norm Bengford, Christopher Sweeney, Steve Belsley, Marty Pethtel, Bosco Dias, Tim Trammell, Ron Lehmer, Ed Rogers, Dan Wilkins, Logicon/LISS; Dean Giovanneti, NASA ARC

Development Work Station Graphics Upgrade Project

Summary

The Development Work Station (DWS) was enhanced by the adding four new graphics systems. The DWS is a suite of hardware and software subsystems that enables users to develop VMS-compatible aircraft simulation models at their own engineering sites. These models can then be imported expediently into the VMS complex for conducting man-in-the-loop motion experiments. The Civil Tilt Rotor (CTR) program is one of the key customers using the DWS.

System Capabilities

The DWS is a hardware and software environment for developing VMS-compatible simulation models and graphics displays. The system enables development of models, which can be imported directly into piloted simulations at the VMS. Compatibility is achieved since the DWS uses the same computers, operating systems, simulation executives, model support libraries, aircraft model interfaces, and user interactions as in the VMS operational environment. The DWS is an extensive enhancement of its predecessor, the Remote Development Environment (RDE), which was completed by VMS personnel in early 1999. This latest graphics upgrade adds four additional pilot and performance displays, which greatly add to its value as a simulation development tool.

The DWS consists of three major parts: the control console, the graphics displays, and the host computer.

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

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

The suite of graphics displays include a Primary Flight Display, a combined Horizontal Situation Indicator and Navigation display, a Flight Management System display, a Side View of the aircraft, a Mode Control display, and optionally, an Experimenter's general purpose display.

Graphics Display Upgrade

The Graphics Display Upgrade entailed procurement of the system components, developing the functionality of the various simulation graphics, integrating and validating them. Four display-generating computers, often referred to as "graphics engines", were added to the DWS: One Silicon Graphics, Inc. (SGI) Octane running at 300 MHz., and three SGI 230s. The 230s were selected as a cost-effective solution for a PC-based machine running under Linux with OpenGL and a Graphics Accelerator. Upon delivery, the machines were configured with Linux and networking communication software to interface with the AlphaServer host computers. All the simulation programs were converted from GL, a proprietary graphics language, to OpenGL, the emerging standard. The Graphics Upgrade configuration was tested and accepted by the CTR customer and has been in production since July 2000.

Future Plans

The ability to develop VMS-compatible aircraft models, like the CTR, will be expanded to include more of the terminal area flight operations aspects as opposed to pure handling qualities simulations. One of the steps towards this goal, to include Air Traffic Control (ATC) features, is in preliminary development using the DWS. This entails incorporation of new pilot to ATC tower communication and the generation of air traffic (other aircraft) in the out-the-window displays.

Development Team

Martin Pethtel, Philip Tung, Emily Lewis, Rachel Wang-Yeh, Hai Huynh, Dave Darling, Dan Wilkins, Chuck Gregory, Logicon/LISS

Air Traffic Control for the Vertical Motion Simulator

Summary

The main objective of this project is to support one of the Civil Tiltrotor (CTR) Program's milestone which is to demonstrate its operability in an Air Traffic Control (ATC) environment. This project integrates the CVSRF's ATC Simulator with the VMS to conduct full-mission studies of operating CTR in normal air traffic around the terminal area, and to assess their impact on flight procedures and traffic capacity.

Introduction

The CTR researcher has requested development of air space operations to demonstrate CTR's operability under the FAA normal approach and departure procedures. The first milestone is to demonstrate limited air space operations with simplified Flight Management System (FMS) and navigation systems in October 2000 during the CTR9 experiment. The second milestone is to demonstrate full air space operations in CTR10 simulation (Summer 2001).

The ATC capability is currently residing in Crew Vehicle Systems Research (CVSRF) Facility with the ability to generate air traffic as well as controlling air space with air traffic controllers. The objective of this project is to fully integrate that ATC capability with the existing VMS CTR program via networking connections between the two SimLab facilities, i.e., VMS and CVSRF.

Development

A two-phase approach was developed to take into account the resources and schedule. In Phase I of the project, an ATC system infrastructure was first developed within the VMS facility which included providing a local Pseudo Aircraft System (PAS), which generates air traffic scenarios, and voice communication to the laboratories. This included establishing real time communications between the host computers and the PAS workstations as well as voice communications with the controllers and pilots. High Level Architecture (HLA) was chosen as the host communications protocol to be compatible with the CVSRF system configuration. The VMS host computer would receive air traffic data from PAS and display the traffic on the out-the-window visual system, and CTR traffic displays.

In Phase II, connection to CVSRF's Air Traffic Control Laboratory will be established to allow pseudo pilots and air traffic controllers from CVSRF to directly interact with the CTR experiment in VMS. All interfaces developed in Phase I will be used as the gateway between CVSRF and VMS facilities.

ATC radar display of the San Francisco Bay Area.

Audio communications is provided by the ASTi audio system. The ASTi audio system in VMS required a conversion of the hardware to the latest version to allow the use of Voicenet in all of the laboratories. Along with communications with the controllers in CVSRF, a simulation of Automatic Terminal Information Service (ATIS) will be provided.

Results

Phase I of the project is nearly completed. Local real-time data communication between the CTR host computer and PAS has been established as well as driving the out-the-window aircraft. ASTi audio voice communications between air traffic controllers and CTR pilot has also been developed. The Acceptance Test for Phase 1 has been scheduled. Air traffic scenarios using PAS are being developed to support CTR9 experiment. Some of the Phase 2 activities, such as establishing ASTi audio voice communication with CVSRF, is underway.

Development Team

Ernie Inn, Marty Pethtel, Rachel Wang-Yeh, Emily Lewis, Phil Tung, Tom Crawford, Mike Izrailov, Joel Rosado, Dave Darling, Cary Wales, Logicon/LISS; Craig Pires, Tom Prehm, Joe King, Mantech; Dave Astill, John Griffin, NASA ARC

VMS Modernization

Summary

The VMS Modernization project will upgrade all electrical and control components of the VMS with state of the art components. The upgrade will increase performance and reliability while decreasing maintenance and support effort.

Background

The VMS is the largest vertical displacement "fixed to the earth" flight simulator in the world and provides unparalleled high-fidelity six degree of freedom motion. The VMS is the country's premiere flight motion facility and has been used extensively to support major aeronautical programs for the nation. Since 1981 numerous improvements in control, electrical and mechanical technologies have occurred. These new state of the art technologies have replaced previously aging components, most of which are one of a kind and do not have replacements. While the existing components are still operating they are beyond their design life and the probability of failure is increasing each year.

Objectives

The objectives of the modernization effort are:

- Improved reliability
- Reduction in maintenance and operating cost
- Improved motion performance, i.e., bandwidth and smoothness

The VMS Modernization effort will assure continued reliable operation and enhanced benchmark performance of the nation's premier motion-based aeronautical research simulator.

Design Phase

The project is currently in the Design Phase. Design of major components of this modernization effort is well under way and will be completed in spring 2001. The primary systems to be replaced are all electrical components and controls, lateral rack and pinion with dual tape drives, hydraulic longitudinal axis with dual tape drives, increasing the number of vertical motors from eight to twelve, and replacing the rotational axis with a hexapod system. System performance, maintainability, reliability, safety, and cost are key factors being applied in the design process.

Future Plan

Purchasing and fabrication of new systems is projected to begin in summer 2001 and installation of the equipment to begin in spring 2003. All new systems will be completely checked out and proven operational ready before closing the VMS for modernization and installation. Thorough checkout and operation of the new systems prior to shutting down the VMS will drastically reduce system integration and validation efforts.

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

Development Team

Tim Gafney, Jeff Brown, Dean Giovannetti, Gary French, Khoa Nguyen, Steve Beard, Joel Baldovino, Paul Brown, Doug Greaves, George Wong, Rodger Mueller, Doug Smith , Bob Surratt, Charlie Ady, NASA ARC; Julie Murphy, Bechtel; Bill Manning, Dave Lawrence, Khalid Aram, Sverdrup; Ted Miller, Mike Blum, Johnny Chang, E&C Engineering; Bill Chung, Logicon/LISS

The world's largest Vertical Motion Simulator in operation to support major aeronautical research programs.

Video Distribution System Upgrade

Summary

This project implemented a major capacity upgrade of the VMS Video Distribution System, which provides video signals to cab and laboratory displays from centrally located image generators and workstations. The upgrade was essential to keep pace with increasingly demanding research requirements and to improve maintainability. The Video Distribution System can now support multiple simultaneous simulations within the VMS Complex.

Introduction

The VMS facility supports three laboratories for conducting simulations and development work. Video for out-the-window and instrument displays, as well as laboratory monitors for researchers are supported from image generators and workstations located in two centrally located computer labs. This “video everywhere” approach allows for the most efficient use of limited computer resources and allows for rapid reconfiguration when simulations are moved from an integration lab to the VMS beam.

The upgrade was initiated for three main reasons. The number and complexity of displays required for each simulation has steadily increased in the past few years, as well as the number of workstations used for laboratory and instrument displays. The central video switching system for the high-resolution video was obsolete and becoming more difficult to maintain. Finally, there were insufficient video processing resources to support two operational simulations simultaneously and still allow for simulation development and testing in the third lab.

Implementation

The first phase of the Video Distribution Upgrade improved the cable infrastructure between the central video switch and each of the laboratories. Over 35,000 feet of new coaxial cable was laid in the VMS facility. Combined with the previously existing infrastructure, the new cabling allows for a minimum of 25 high-resolution RGB displays and ten National Television Standards Committee (NTSC) broadcast TV quality displays to be supported in any of the three laboratories.

The second phase of the Upgrade involved the integration of a new central video-switching matrix for the high-resolution video. The new switch more than doubles the number of video source devices that can be connected to the central switching matrix and provides higher bandwidth to the out-the-window displays in the cabs. Since the central switch is required to be operational for any simulation activity to take place, the integration and acceptance testing of the switch was conducted during the end-of-year maintenance period in 1999.

Centralized video switching and processing resources provide the VMS with a highly flexible and efficient environment to support multiple simulations.

The third and final phase involved the integration of a higher capacity central switch for the NTSC video. The new NTSC switch reused parts from the old high-resolution video switch, resulting in significant cost savings to the project. Sufficient spare parts became available as part of this reconfiguration to support the NTSC video distribution system for the next several years.

Features

- Separate high-resolution and NTSC video switching matrices were implemented providing 125MHz of bandwidth for high-resolution video signals and 30MHz for NTSC video.
- The high-resolution video switching matrix can support 64 input devices and 104 output displays. The current configuration can support three multi-channel image generators for out-the-window scenes and twenty workstation systems for instrument and laboratory displays. The NTSC video switching matrix has the capability to support 70 input and 70 output devices.
- The Video Distribution System also supports a variety of special video processing tools and effects generators. These include sixteen video scan rate converters, three high-resolution mixers, three NTSC video mixers, three quad splitters, and three special effects generators.

Development Team

Ronald Lehmer, Gilbert Mink, Tuan Truong, Logicon/LISS

Alpha Host Computer Upgrade 2000

Summary

The Alpha Host Upgrade 2000 Project replaced existing host computers with new systems that will meet the compute requirements of the most demanding VMS simulations well into the foreseeable future. The new systems are capable of speeds over three times faster than the ones they replaced.

Introduction

Alpha Host Computer Upgrade 2000 integrated new, higher-performance host computers into the VMS complex. The new systems replaced host computers that could not meet the anticipated computing requirements of three specific simulations scheduled for FY2000. The requirements of these simulations called for drastic increases of between 2 to 3 times the performance of the existing systems. The project had three principal requirements for the new host computers: computing power capable of meeting future simulation needs, functionality similar to that provided by the systems being replaced, and the ability to obtain repairs in the same time frame.

Performance

Keeping the computer performance ahead of accelerating customers' simulation requirements has always been a solemn goal at SimLab. Fortunately, due to the computer industry's improvements in computer clock speeds and feature-rich capabilities, it was possible to purchase computer systems with the necessary performance from the manufacturer of the existing machines, thereby meeting all three principal requirements.

The new hosts are Compaq AlphaServer DS20E machines, replacing AlphaServer 1000A 5/500s. Benchmark figures from the Standard Performance Evaluation Corporation (SPEC, a standardization body) indicated a 2.4 times improvement in speed. In-house benchmarks confirmed these results and achieved 3.2 times performance increase when using software optimization. Selecting the same manufacturer's operating system allowed similar hardware compatibility with all peripherals. User compatibility was achieved by upgrading MicroTau, the in-house real-time executive/debugger software, to operate on the latest VMS Operating System. The repair turn-around time requirement was maintained easily across machines since they had identical warranties. This solution provided a relatively easy means of satisfying the requirements.

The performance increase of the operational systems easily exceeded the requirements of the FY2000 simulations. The new host systems are capable of frame times of less than one millisecond when only I/O is performed to the motion, laboratory, and cockpit subsystems. Adding the typical aircraft model allows frame times shorter than 2 milliseconds. As a practical matter, most simulations are run at longer frame times, such as 12.5 milliseconds (80 cycles per second), which is more compatible with the 16 2/3 millisecond field time of the associated graphics generators.

Results

The integration of the new systems was completed on schedule in the motion-base and in the two fixed-base laboratories. The new systems are capable of speeds 3.2 times faster than the systems they replaced. By the end of FY2000, the new host computer systems had been used successfully to run operational simulations, including the most compute intensive FY2000 simulations that demanded the host upgrade.

Development Team

Martin Pethtel, Bosco Dias, Christopher Sweeney, Luong Nguyen, Duc Tran, Kelly Carter, MyVan Nguyen, Logicon/LISS

Simulation engineers utilize the new VMS Lab host computer to meet demanding simulation requirements.

Head-Down Display Graphics Engine Upgrade

Summary

Eight PC-based graphics engines were successfully integrated into the VMS environment to increase cockpit avionics display resources needed to meet simulation requirements. This addition nearly doubled the current head-down display (HDD) capacity at VMS. Notably, this marks the first migration from high-end workstations to PC-based graphics engines. It also represents a transition to an open Operating System and Open Graphics Libraries to generate real-time cockpit avionics displays at SimLab.

Introduction

The purpose of this project was to provide additional graphics engines to support expanded research needs in a cost-effective manner. The existing SGI Power Series (IRIS 4D) systems are no longer supported by the manufacturer and they use a proprietary Operating System and Graphics Library. Newer machines with open-standards architectures are very attractive since they promise portability of display code, a greater selection of hardware platforms and software development tools, and reduced acquisition and operational costs.

The SGI IA-230 was identified as a viable replacement. The SGI-IA 230 features a single 733 MHz Pentium III processor driving the latest Nvidia Vpro graphics card. SGI and Nvidia teamed to deliver the first COTS (commercial-off-the-shelf) full performance OpenGL/Linux PC graphics workstation solution that would meet SimLab’s HDD requirements. The SGI-IA 230 provides high performance compute power with full line/pixel anti-aliasing capability.

Project Description

An evaluation team was formed to determine if the SGI-IA 230 could meet SimLab’s requirements. The team quickly converted existing IRIX GL displays from the Power Series systems to OpenGL format under Linux OS on the SGI-IA 230 system. The SGI-IA 230 system was tested and met or exceeded established baseline requirements. Most evaluators could not differentiate between the displays generated by the SGI-IA 230 and those generated by an SGI Octane class workstation in a side-by-side comparison. The evaluation team recommended immediate acquisition and integration of the SGI-IA 230.

An implementation project was initiated for immediate purchase and integration of eight SGI-IA 230 graphics systems. The project began the first week of August 2000 with operational readiness slated for September 1, 2000. The project required hardware modifications to the Cockpit Graphics Lab, Video Distribution System, real-time and development network systems, and the VMS control room. In parallel, a significant software development effort was required to generate new OpenGL displays and convert IRIX GL displays for immediate use in upcoming simulations.

Results

Integration was completed as scheduled on September 1. All eight SGI-IA 230 systems were integrated into production operation in support of real-time HDD graphics displays at VMS. The graphics team delivered all required display software to meet simulation schedules. Additional systems will be purchased to replace the remaining inventory of 4D class HDD graphics engines.

Development Team

Rachel Wang-Yeh, Charles Gregory, Ronald Lehmer, T. Martin Pethtel, David Darling, Ernie Inn, Hai Huynh, Gilbert Mink, Tuan Truong, Kelly Carter, Russell Sansom, Shelly Larocca, Daniel A. Wilkins, Logicon/LISS

Real-time cockpit avionics displays at SimLab are now generated on PC-based graphics engines running an open Operating System and Open Graphics Libraries.

Advanced Concepts Flight Simulator Host Computer Upgrade

Summary

The ACFS host computer was upgraded to meet the demanding computational and input/output requirements of planned and projected ACFS simulation experiments.

A significant improvement in overall performance and a reduction in computer hardware and software maintenance costs were achieved by upgrading to a current technology computer system. The new host computer, an SGI Origin 2000, is expected to easily meet research requirements of all projected simulation experiments.

Introduction

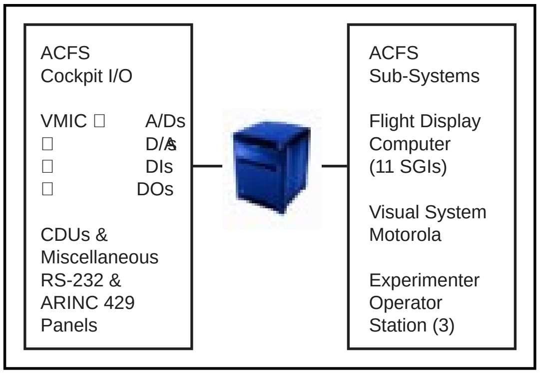
The upgrade consisted of replacing the existing SGI Challenge L computer with an SGI Origin 2000. Certain I/O equipment was also upgraded for compatibility with the new host computer. The Origin 2000 system was acquired from the Air Traffic Control (ATC) simulator and upgraded to meet the ACFS host computational needs.

Performance

Modifications include the addition of another CPU board with 2 MIPS R10000 195MHZ processors and 128 MB of Main Memory. Also needed were additional components to make the Origin 2000 compatible with the ACFS VMIC VME I/O System. This required the purchase and integration of a new VMIC PCI Reflective Memory board, an upgrade to existing VMIC IIOC software, and the purchase of a Fiber-Optic PCI to VME bus adapter.

Acceptance of the new ACFS Host computer consisted of two parts. The first part was baseline testing of each current configuration to ensure retention of ACFS features and functionality. The performance testing phase verified that the new host meets or exceeds projected capacity requirements.

All current active simulation configurations of the ACFS were ported to the new host. A few changes were required due to differences between the VME and PCI drivers to the VMIC IIOC System. No discrepancies were found during testing of the configurations adapted to operate on the new host. All needed changes were merged into the baseline configuration.



ACFS Cockpit I/O on the New Host Computer

Results

All acceptance testing was successfully completed on schedule and the results exceeded expectations. CPU performance improved by 400%. The new host is 12 times faster in transferring UDP packets, both inbound and outbound. Due to the full duplex feature of the 100 Base-TX connection, the TCP packets are now transferred up to 18 times faster than they were using the old host computer.

Development Team

Craig Pires, Anna Dabrowski, Don Bryant, Gary Uyehara, Eric Gardner, ManTech; Terry Rager, NASA ARC

Enhanced Ground Proximity Warning System

Summary

The B747-400 flight simulator maintains the highest possible level of certification as established by the Federal Aviation Administration (FAA) to ensure system fidelity and enhanced credibility to the results of research programs. This is achieved by constantly upgrading the simulator to maintain a configuration match to a specific United Airlines aircraft. An upgrade from the older Ground Proximity Warning System (GPWS) to the state of the art Enhanced Ground Proximity Warning System (EGPWS) was one of the latest efforts.

Introduction

The EGPWS is a terrain awareness and alerting system. It incorporates all of the following aural alerting modes of the basic GPWS: excessive descent rate, excessive terrain closure rate, altitude loss after takeoff, unsafe terrain clearance, excessive deviation below glideslope, advisory callouts and windshear alerting. In addition to these seven basic functions, the EGPWS adds the ability to compare the aircraft position to an internal database and provides additional alerting and display capabilities for enhanced situational awareness and safety (hence the term “Enhanced” GPWS).

Development

Several hardware and software alternatives for the EGPWS upgrade were evaluated. Following extensive research, it was decided to procure, install and integrate the actual aircraft EGPWS box as opposed to developing and installing an EGPWS software model.

The major task in this upgrade project was display integration. Unlike the real aircraft, the simulator uses proprietary graphics controllers and standard Cathode Ray Tubes (CRTs) to display flight information such as that found on the Electronic Flight Information System (EFIS) display. Extensive software development is required to interface the output of the EGPWS with the CRTs and to replace the simulator graphics controllers.

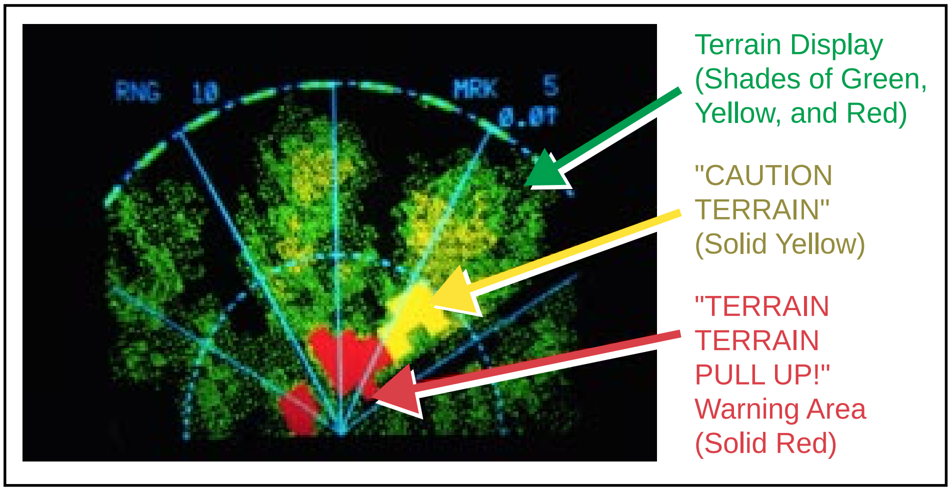
The remainder of the upgrade project involves relatively straightforward hardware modifications. The EGPWS box occupies the same component rack space as the existing GPWS with the necessary rewiring effort. A switch to select the EGPWS terrain display is added to the two cockpit EFIS Control Panels (Captain & First Officer) and a terrain override switch is added to the existing Ground Proximity Warning Panel.

Results

All hardware required for the EGPWS upgrade has been purchased and received. All required modifications to the B747 hardware drawings have been completed. Fabrication was started on the EGPWS Configuration Selection box which will enable reconfiguration of the EGPWS programming pins. The remainder of the upgrade will be completed in the coming year.

Development Team

Joseph King, Ghislain Saillant, Diane Carpenter, ManTech; CDR Robert DeGennaro, Naval Postgraduate School



EGPWS presents a graphical plan view of the aircraft relative to the terrain and advises the flight crew of potential conflicts.

Air Traffic Control Pseudo Aircraft System

Summary

To meet emerging Air Traffic Control (ATC) research requirements and to be Y2K compatible, an upgrade to the ATC simulator was initiated in the CVSRF Air Traffic Control Laboratory. Two complementary ATC applications, the Pseudo Aircraft System (PAS), an application to simulate Center TRACON airspace traffic, and RouTe Maker, an application to simulate ground traffic during taxi, were identified as replacements for the old system. The DODs High Level Architecture (HLA) Protocol was implemented as a means of providing interoperability in a networked environment for both internal and external connections.

Introduction

With awareness that the ATC simulation, as hosted on a VAX 6320, was reaching obsolescence, an investigation of alternatives was conducted. This investigation addressed the options of replacing the dated hardware and software.

The ATC software replacement option involved evaluating a number of possible scenarios including the rehost of the existing system and replacement in whole or in part by other software systems. Candidates for replacement of the old system came out of two separate experiments run for the ACFS and B747 simulators. For airborne applications, PAS would provide most of the capabilities currently available although it does not have the level of ground traffic simulation capability currently available.

To mitigate this limitation, a separate application called RouTe Maker (RTM) was selected. RTM provides highly sophisticated ground traffic simulation capabilities up to full automation of a scenario with proximity, time, and conditional triggering of traffic.

System Integration

Eight SGI O2 workstations replaced the older SGI Personal Iris systems for use as the ATC Controller stations. The four existing X-stations were retained to use as Pseudo Pilot stations. An SGI Origin 2000 system was integrated as the ATC Hub/File Server system.

The ATC/ PAS upgrade was validated during the execution of two experiments. The ACFS T-NASA 2 experiment exercised the new ATC RTM capabilities by providing taxing ground traffic and the B747 AATT Integrated Tools Study/Air-Ground Integration Experiment (AGIE) provided PAS generated airborne traffic.

RTM display for CVSRF ATC upgrade.

The external ATC/PAS HLA interoperability capability was also validated by the B747 AGIE experiment. The new HLA capability has been demonstrated by ATC/PAS generated air traffic simultaneously being displayed in both CVSRF flight simulator's out-the-window visual systems.

Validation of the performance of the newly incorporated Great Circle Route algorithm in PAS was accomplished by a series of test runs involving a number of great circle flight segments between points roughly centered on the Dallas-Fort Worth Area.

Results

The experiments and tests referenced in the preceding section were successfully completed and the results analyzed by the researchers and CVSRF staff. The results indicate the ATC/PAS upgrade is successful and will meet CVSRF research requirements for the foreseeable future.

Development Team

Rod Ketchum, George Mitchell, Ian MacLure, ManTech; Elliott Smith, Steve Bayne, Logicon/LISS

Voice Disguiser System Upgrade

Summary

The CVSRF Voice Disguiser Upgrade project focused on replacing the current voice disguiser system. The former system provided pitch changes only and a maximum of three disguised voices. The voice disguiser system is used for disguising the operator's voice to simulate any number of additional voices to provide realism in an experiment scenario. A number of systems and techniques were considered for the upgrade. A commercial off the shelf system that could be integrated into the existing Air Traffic Control (ATC) Lab and cockpit communications equipment was chosen as the most cost effective way to meet our requirements.

Introduction

The goal for the upgrade was to acquire a system that provided up to eight distinct disguised voices. Options ranging from a custom designed and manufactured system to the acquisition of a modular off the shelf system were discussed. Investigation of available technologies suitable for upgrading the CVSRF's voice disguising capabilities led to the selection of BOSS VF-1 24 bit Multiple Effects Processor.

Performance

The half-rack BOSS VF1 is a compact, ultra-powerful 24-bit multi-effects processor. It provides signal processing using 24-bit Analog/Digital and Digital/Analog converters, and uncompromising sound quality. Currently, 14 disguised voices have been stored for use. In addition, TRIAD SP-67 output isolation transformers were installed to provide proper balanced input from the VF-1 into the existing CVSRF ATC Lab ASTi communication system.

It is possible to run the voice disguisers via computer control with the use of Serial to Midi interface units. The VF-1 presets can be addressed by MIDI program change messages, allowing for automated voice disguise changes. These voice disguise changes would be based on radio frequency changes for controller stations and possibly on pseudo pilot aircraft identification changes in the CVSRF ATC Lab.

The new CVSRF Voice Disguiser system is a fully modular system, with one VF-1 per ATC lab station, with an additional unit integrated to each of the B747-400 communication radios. VF-1 and Midiator units can easily be added to meet any experiment requirements.

Results

The new voice disguiser system was used for the first time, with favorable results, in the Data Link Procedures experiment involving the B747-400 and the ATC lab. The units were used in a manual mode where the controllers were responsible for selecting the desired disguise setting.

Roland's BOSS VF-1 for CVSRF Voice Disguiser Upgrade

The fully automated control software is still under development. Refinement of the VF-1 presets is ongoing. The question of the ability to use the Pseudo Aircraft System (PAS) aircraft identification to trigger Midi addressing remains to be solved. System evaluation and refinement is continuing.

Development Team

Rod Ketchum, Joseph King, Jason Hill, Ian MacLure, George Mitchell, Craig Pires, Thomas F. Prehm, Gary Uyehara, ManTech

Traffic Collision and Avoidance System Implementation and Upgrade

Summary

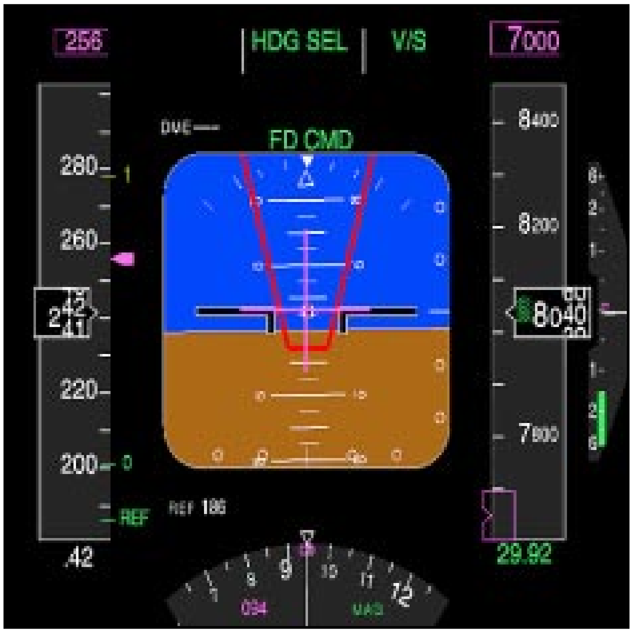
The Traffic Collision and Avoidance System (TCAS) project integrated an FAA supplied code implementation of the TCAS II Change 7 specification to the ACFS, and performed an upgrade of TCAS in the B747-400 simulator. Additional software modifications to the existing ACFS cockpit displays and ASTi aural warning system were necessary since it was not equipped with any TCAS system prior to this project. For the B747-400 simulator, the TCAS system implementation was upgraded from 6.04A to 7.0.

Introduction

TCAS provides the crew with continuous real-time situational traffic awareness, and Traffic Advisory (TA) and Resolution Advisory (RA) messages when a potential collision with another aircraft is being detected. Situational traffic awareness is depicted on the Navigation Display (ND). Normally the crew should respond to an RA by flying the suggested maneuver manually. Escape maneuvers in TCAS are limited to the vertical direction.

Development

On the ACFS: Software modifications were made to the Primary Flight Display (PFD) to incorporate the RA vertical speed constraints on the vertical speed indicator. Another TCAS indication is on the PFD's Attitude Display Indicator (ADI) which instructs the crew to pitch up or down in order to avoid or acquire a certain vertical speed. Software modifications were made to the Navigational Display (ND) to incorporate intruder traffic indication with their respective threat level, altitude and vertical speed profile. Internal logic of the ND displays OFFSCALE TRAFFIC when a threat is out of view; normally, pilots must increase the ND map range to see the threat. Software modifications were also made to the Secondary Flight Display to incorporate a TCAS control panel. The control panel is based on the B747-400 TCAS control panel.



The Primary Flight Display (PFD) showing a descent display.

In addition, a new Experiment Operator Station (EOS) page, the "TCAS Control Page" which is similar to the B747-400 EOS page, was completed. This page allows control of intruder generation up to 10 intruders as selected by the operator from the host computer. These intruders are programmed to fly around the ownship so that a specific TCAS TA and/or RA will appear. A collision may or may not happen depending on the pilot's actions. These intruders are useful to demonstrate the TCAS features and the TCAS TA/RA capabilities. Development of a limited traffic generator was also completed. This traffic generator provides the functionality behind the EOS TCAS Control page. The external ATC or PAS simulator is used for specific intruder trajectories or scenarios. The project also required some modification to the interface between the host computer and the ASTi system to allow simultaneous sounds to be played at the same time, for example the Autopilot Disconnect alarm and one TCAS aural message.

Results

ACFS TCAS functionality was tested during the CTAS/FMS II experiment. Some interface problems were identified when playback PAS intruders were introduced. Otherwise, TCAS performed as expected when traffic was provided by CVSRF's ATC/PAS simulator. Checks of B747-400 upgrades is underway.

Development Team

Ghislain Saillant, Cindy Nguyen, Fritz Renema, Anna Dabrowski, George Mitchell, Dave Brown

Acronyms

AATT	Advanced Air Transportation Technologies
ACFS	Advanced Concepts Flight Simulator
ADI	Attitude Display Indicator
AGIE	Air-Ground Integration Experiment
AILS	Airborne Information for Lateral Spacing
ALPA	Airline Pilots Association
AOL	Airspace Operations Lab
APA	American Psychological Association
APU	auxiliary power unit
ARC	Ames Research Center
ASTi	Advanced Systems Technology Incorporated
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
B747	Boeing 747
CART3D	Three-Dimensional Cartesian Simulation System for Complex Geometry
CATI	Carmel Applied Technology Incorporated
CATS	Crew Activity Tracking System
CDA	concept demonstrator aircraft
CDTI	Cockpit Display of Traffic Information
CDU	Control Display Unit
CFD	computational fluid dynamics
COTS	Commercial-Off-The-Shelf
CPDLC	Controller-Pilot Data Link Communication Procedures
CRT	Cathode Ray Tube
CSPA	Closely Spaced Parallel Approaches
CTAS	Center TRACON Automation System
CTOL	conventional takeoff and landing
CTR	Civil Tiltrotor
CTV	Crew Transportation Vehicle
CV	Carrier Version
CVSRF	Crew-Vehicle Systems Research Facility
DERA	Defense Evaluation and Research Agency of United Kingdom
DI	Dynamic Inverse
DOD	Department of Defense
DOT	Department of Transportation
DWS	Development Work Station
E&S	Evans and Sutherland
ECAL	East Coast Abort Landings
EFIS	Electornic Flight Information System
EGPWS	Enhanced Ground Proximity Warning System
EMM	electronic moving map
EOS	Experimenter Operator Station
ESIG	Evans and Sutherland Image Generator
FAA	Federal Aviation Administration
FAATC	Federal Aviation Administration Technical Center
FB	fixed-base
FMS	Flight Management System
FOV	field-of-view
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
GTRS	Generic Tiltrotor Simulation

Continued next page...

HAC	Heading Alignment Cone
HLA	High Level Architecture
HQR	Handling Quality Rating
HUD	head-up display
ICAB	Interchangeable Cab
IFR	instrument flight rules
IG	image generator
IHI	Integration Research Branch
IIOC	Intelligent Input/Output Controller
IMC	Instrument Meteorological Conditions
IT	information technology
JSC	Johnson Space Center
JSF	Joint Strike Fighter
JSHIP	Joint Shipboard Helicopter Integration Process
JVX	Joint Service Vertical Lift Aircraft
KSC	Kennedy Space Center
LAN	local area network
LaRC	Langley Research Center
LHA	Amphibious Assault Ship
LISS	Logicon Information Systems and Services
LNAN	lateral navigation
LSE	Landing Signal Enlisted
LVLASO	Low-Visibility Landing and Surface Operations
Maglev	Magnetic Levitation
MCP	Mode Control Panel
MIDAS	Man-machine Integration Design and Analysis System
MIDI	musical instrument digital interface
MIPS	million instructions per second
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NASA ARC	NASA Ames Research Center
NASA JSC	NASA Johnson Space Center
NATCA	National Air Traffic Controllers Association
ND	Navigation Display
NFCS	Neural Flight Control System
NTSC	National Television Standards Committee
OEI	one engine inoperative
OS	operating system
OSD	Office of the Secretary of Defense
OTW	out the window
PAS	Pseudo Aircraft System
PC	personal computer
PCI	Peripheral Component Interconnect
PFD	primary flight display
PRL	priority rate-limiting
PWSC	Primary Weapons Systems Concept
R&D	research and development
RA	Resolution Advisory
RDE	Remote Development Environment
RISC	Reduced Instruction Set Computer
RITE	Rapid Integration Test Environment

Continued next page...

RNAV	area navigation
ROTO	roll-out and turn-off
RPM	revolutions per minute
RPN	Required Navigation Performance
RTCA	Requirements, Technology, and Concept for Aviation
RTM	Route Traffic Manager
RVR	runway visual range
SAM	Situational Awareness Model
SCAS	stability and control augmentation system
SDI	Sterling Dynamics Incorporated
SEATAC	Seattle-Tacoma International Airport
SGI	Silicon Graphics, Inc.
SJSU	San Jose State University
SPEC	Standard Performance Evaluation Corporation
SSV	Space Shuttle Vehicle
STOVL	short takeoff/vertical landing
T-NASA	Taxiway Navigation and Situation Awareness
TA	Traffic Advisory
TAL	Transoceanic Abort Landing
TAP	Terminal Area Productivity
TCAS	Traffic Alert and Collision Avoidance System
TCL	thrust control lever
TCP/IP	Transmission Control Protocol/Internet Protocol
TOGA	Take Off/ Go Around
TRACON	Terminal Radar Approach Control
UDP	User Datagram Protocol
UHTC	Ultra-High Temperature Ceramic
U.K.	United Kingdom
USA	United Space Alliance
USAF	U.S. Air Force
USMC	U.S. Marine Corps
USN	U.S. Navy
VLAB	Virtual Laboratory
VME	VersaModule EuroCard
VMS	Vertical Motion Simulator
VNav	Vertical Navigation
VOIP	Voice Over IP
WAC	Wide Angle Collimation
WOD	wind-over-deck
Y2K	Year 2000

Appendix
Simulation Facilities

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

Boeing 747-400 Simulator

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

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

Advanced Concepts Flight Simulator

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

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

Air Traffic Control Laboratory

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

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

Vertical Motion Simulator Complex

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

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

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

For additional information, please contact

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