Flight Simulation
Year in Review
FY 01

Foreword

This document is the Fiscal Year 2001 Annual Performance Summary of the NASA Ames Vertical Motion Simulation (VMS) Complex, the Crew Vehicle Systems Research Facility (CVSRF), and FutureFlight Central (FFC). It is intended to report the more significant events of FY 01. What follows are an Executive Summary with comments on future plans, the FY 01 Simulation Schedule, a projection of simulations to be performed in FY 02, 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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Acknowledgments

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About the Cover

Front cover: This year's cover depicts simulations that occurred at each of the SimLabs facilities. The ship pictured at top was used during the Joint Shipboard Helicopter Integration Process experiments (see pp. 17 and 22) undertaken at the Vertical Motion Simulator. The ribbons represent airflow over the ship's deck. The second image depicts the set-up of the Crew Vehicle Systems Research Facility's Neural Flight Control simulation. This experiment is described in detail on p. 29. The last picture was taken from FutureFlight Central's simulations of Los Angeles International Airport. Two experiments were conducted; details can be found on pp. 35 and 36.

Back cover: The three facilities that constitute SimLabs are capable of fully integrated simulations for a broad spectrum of aerospace research. All three labs have conducted studies relating to different aspects of commercial transport vehicles, similar to the one depicted here.

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Executive Summary

Introduction

The staff of the National Aeronautics and Space Administration (NASA) Ames Simulation Laboratories is pleased to present the Annual Report for Fiscal Year 2001 (FY 01). This report documents the simulation experiments and technology projects accomplished in three major facilities: the Crew Vehicle Systems Research Facility (CVSRF), FutureFlight Central (FFC), and the Vertical Motion Simulator (VMS). Once again, the year was characterized by a highly diverse set of experiments covering a broad spectrum of aerospace technologies exemplified by studies to improve airport safety for cities, developments to improve air transportation capacity for the nation, and research and engineering to increase aircraft/ship interface operational safety for the military.

The Simulation Laboratories (SimLabs) are operated and managed by the Aviation Systems Division at NASA's Ames Research Center. The FutureFlight Central facility was added to the Division's responsibilities at the start of the fourth quarter and is being integrated into the overall simulation capability of the Center. With this suite of facilities, Ames has the unique capability to simulate all elements of aerospace vehicle and transportation systems to very high fidelity, including airport ground operations, air traffic management, crew station issues, crew/vehicle interfaces, vehicle design, dynamics, and handling qualities. Throughout the year, the SimLabs staff has operated all of the facilities with the highest levels of safety, consistently excellent quality, and complete customer satisfaction. The most challenging efforts have involved the planning and implementation of both a new business environment and new research initiatives. We will continue to work diligently with our new and our long-time customers and research partners to improve SimLabs' operation and efficiency and to meet the challenges of future research and economic trends.

Some Highlights from Fiscal Year 2001

• The **Crew Vehicle Systems Research Facility** features the highest fidelity, full-mission, motion-based flight simulation capabilities. There are two simulator cockpit systems in the CVSRF: a B747-400 (B747) Level-D certified simulator and the Advanced Concepts Flight Simulator (ACFS). Additionally, a full-featured Air Traffic Control simulation facility is integrated with each of these simulators. One example of the many significant simulation experiments conducted in the CVSRF is the Integrated Neural Flight and Propulsion Control System (INFPCS) project. This study examined the ability of the INFPCS to automatically compensate for an aircraft's damaged or failed flight control system. The results were very encouraging and demonstrated that the INFPCS was able to stabilize the aircraft without significant pilot compensation.

• **FutureFlight Central** is an Air Traffic Control/Air Traffic Management test facility featuring a 360-degree, full-scale visual simulation of an airport environment as viewed from within the control tower. The control tower interior space accommodates a full compliment of air traffic controllers and airport operations personnel. This past year, FFC was used by NASA, the Federal Aviation Administration (FAA), United Airlines, and the Los Angeles World Airports to study the FAA's top priority problem: runway incursion. In the first phase of this project, FFC was configured to simulate Los Angeles International Airport (LAX) to evaluate the degree of realism possible in a simulation environment. Results were very positive, with actual LAX controllers rating the simulation "about the same as LAX" in several objective and subjective criteria. The second phase of the project identified two promising solutions to reduce the potential of runway incursions at LAX.

• The **Vertical Motion Simulator** is a complex of simulation capabilities, including five reconfigurable cockpits, two large multi-channel visual systems, and the world's largest-amplitude motion cueing system. A very successful program completed this year was the Joint Shipboard Helicopter Integration Process (JSHIP), directed by the Office of the Secretary of Defense. The objectives of JSHIP were to evaluate the concepts and address the issues that occur in joint military operations involving Army helicopter units onboard Navy ships. Additionally, the VMS was employed to evaluate the effectiveness of using simulation as an alternative to costly at-sea studies of the helicopter/ship dynamic interface. Varying levels of visual and motion cueing fidelity were investigated, and preliminary results indicate that simulation could be a plausible compliment to at-sea testing.

• Some of our accomplishments serve to provide a seamless operation among different facilities. The Virtual Laboratory (VLAB), the Rapid Integration Test Environment (RITE), and the interconnection of the CVSRF and FFC via a High Level Architecture interface are examples of progress toward an integrated, interoperable set of simulation assets and capabilities. These integrated tool sets provide collaborative redesign capability, access to design data from various sources, and participation in flight simulation evaluations from remote locations. A major accomplishment for RITE this year was to rapidly evaluate vehicle redesigns in a four-day turnaround demonstration.

Looking Ahead to Fiscal Year 2002

In planning for future simulation activities, one of our biggest challenges will involve adjusting our capabilities and services to meet the growing interest and requirement for “system level” simulations, such as will be seen with the Aviation System Technology Advanced Research (AvSTAR) Program, while maintaining our excellence in traditional flight simulation. SimLabs is responding proactively to these challenges and the new opportunities they represent. Fiscal Year 2002 will be a transitional year, involving adjustment to difficult financial challenges, evolution of the extant facilities into more adaptable and efficient configurations, and development of new simulation applications.

One of the new activities into which we plan to expand in FY 02 is the Virtual Airspace Simulation Technology (VAST), the system simulation portion of AvSTAR. This work will begin with detailed planning and definition phases. Additionally, we are working with the Space Launch Initiative management and planners to find ways of supporting design and development of the Crew Transfer Vehicle as well as other system visualization types of simulation. With the uncertainties of NASA’s Rotorcraft Technology Program, we are re-establishing our relationship with the Army’s Aeroflightdynamics Directorate to continue Ames’ excellence in rotorcraft simulation. These and other opportunities will be explored and developed to ensure the future strength and crucial contributions of SimLabs.

What Can Be Found in This Annual Report

The first section of the Annual Report contains the FY 01 Simulation Schedule, Project Summaries, and next year’s simulation plans. This report also contains synopses of the Simulation Projects completed in the CVSRF, FFC, and the VMS, as well as the Research and Technology Upgrade Projects. Finally, the reader will find a list of acronyms used throughout the report and an appendix containing facility descriptions.

For additional information about our facilities and for past annual reports, please visit our website at www.simlabs.arc.nasa.gov.

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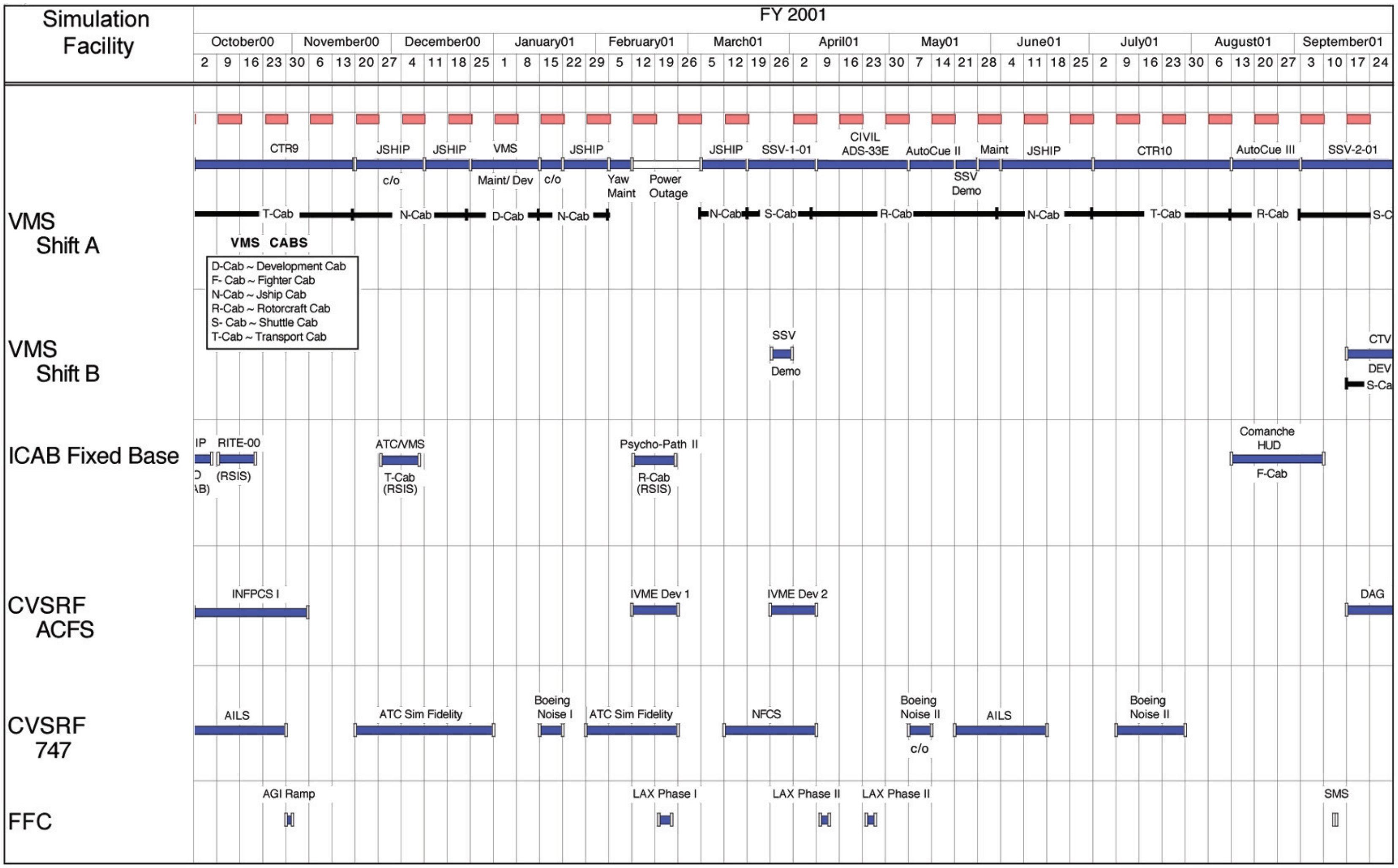
FY 01 Simulation Schedule



FY 01 Project Summaries

VMS Simulation Projects

1. Civil Tiltrotor-9
Date: Oct 2 - Nov 17, 2000 (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.

2. Joint Shipboard Helicopter Integration Process
Date: Dec 11 - Dec 21, 2000; Jan 22 - Feb 1, 2001; Mar 5 - Mar 23, 2001 (VMS)
Aircraft type: UH-60A Black Hawk helicopter
Purpose: To conduct and evaluate simulated shipboard landings and take-offs using the LHA/UH-60A combination for a range of subsystem fidelity levels.

3. Visual Scene Height Perception (PsychoPath) II
Date: Feb 12 - Feb 26, 2001 (FB)
Aircraft type: Civilian helicopter
Purpose: To investigate the impact of various visual and motion cues in a training simulator on pilot performance during an autorotation maneuver.

4. Space Shuttle Vehicle 2001-1
Date: Mar 19 - Apr 6, 2001 (VMS)
Aircraft type: Space Shuttle Orbiter
Purpose: To evaluate an updated adaptive speedbrake model and to provide the pilot astronaut corps with training in orbiter landing and rollout.

5. Civil Army Design Specification
Date: Apr 9 - May 4, 2001 (VMS)
Aircraft type: MD-500 civilian helicopter
Purpose: To establish characteristics associated with the lowest levels of Stability Augmentation Systems, autopilot, and cockpit displays to safely operate single-pilot helicopters operating under Instrument Flight Rules.

6. AutoCue II
Date: May 5 - May 18, 2001 (VMS)
Aircraft type: UH-60A Black Hawk helicopter
Purpose: To determine the impact of various visual and motion cues on pilot workload and performance during an autorotation maneuver.

7. Joint Shipboard Helicopter Integration Process II
Date: Jun 6 - Jun 28, 2001
Aircraft type: UH-60A Black Hawk helicopter
Purpose: To define launch and recovery wind-over-deck flight envelopes for the UH-60A helicopter and LHA ship combination.

8. Civil Tiltrotor-10
Date: Jul 2 - Aug 9, 2001 (VMS); Sep 18 - Oct 4, 2001 (FB)
Aircraft type: CTR 4/95 NASA tiltrotor
Purpose: To investigate handling qualities and flight operations related to operating a tiltrotor aircraft at a vertiport.

9. Space Shuttle Vehicle 2001-2
Date: Sep 3 - Sep 28, 2001 (VMS)
Aircraft type: Space Shuttle Orbiter
Purpose: To provide the pilot astronaut corps with training in Space Shuttle landing and rollout.

CVSRF Simulation Projects

1. Integrated Neural Flight and Propulsion Control System I
Date: Oct 2 - Nov 2, 2000 (ACFS)
Purpose: To examine the effectiveness of a Neural Flight Control system in controlling a damaged aircraft.

2. Air Traffic Control Simulation Fidelity
Date: Nov 29, 2000 - Mar 28, 2001 (B747)
Purpose: To evaluate the efficacy of Air Traffic Control simulation in providing airline aircrews with a training and evaluation environment comparable to actual line operations.

3. Boeing Noise I
Date: Jan 16 - Jan 19, 2001 (B747)
Purpose: To demonstrate the use of noise analysis tools integrated with the Boeing 747-400 flight simulator to measure noise under the flight path.

4. Boeing 747 Neural Flight Control System
Date: Apr 24 - May 14, 2001 (B747)
Purpose: To determine if NASA's Neural Flight Control System could drive a cable-driven aircraft system.

Continued next page...

FY 01 Project Summaries

5. Airborne Information on Lateral Separation
Date: May 7 - Jun 15, 2001 (B747)
Purpose: To study the implementation of a system that supports closely spaced parallel runway approaches during Instrument Meteorological Conditions.

6. Boeing Noise II
Date: Jul 9 - Jul 26, 2001 (B747)
Purpose: To evaluate the feasibility and human factors issues of current and proposed Noise Abatement Procedures in noise-sensitive airports.

7. Distributed Air-Ground Demonstration
Date: Sep 17 - Sep 19, 2001 (ACFS)
Purpose: To demonstrate technologies and procedures related to the Distributed Air-Ground concepts.

FFC Simulation Projects

1. AGI Ramp Controller Training
Date: Oct 30 - Oct 31, 2000
Purpose: To train ramp controllers for the new International Terminal "A" at San Francisco International Airport.

2. LAX Phase I
Date: Feb 20 - Feb 23, 2001
Purpose: To determine if FFC could represent LAX with sufficient realism in preparation for runway incursion studies.

3. LAX Phase II
Date: Apr 10 - Apr 12, 2001; Apr 24 - Apr 26, 2001
Purpose: To evaluate alternatives to reduce runway incursions at LAX.

4. Surface Management System: First Simulation
Date: Sep 13, 2001
Purpose: To evaluate the effectiveness of a decision-support tool that will help manage airport surface traffic.

Research & Technology Projects

1. Rapid Integration Test Environment III
Purpose: To merge advanced Information Technologies to facilitate flight simulation as an integral part of the design process.

2. Virtual Laboratory
Purpose: To enhance and deploy a collaborative engineering tool for researchers to actively interact with VMS experiments from remote locations.

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

4. Air Traffic Control for the VMS
Purpose: To augment VMS simulation capability by integrating Air Traffic Control capability for the Civil Tiltrotor program.

5. Kaiser HMD and Head Tracker
Purpose: To integrate a commercial off-the-shelf helmet-mounted display and head-tracking system to support a Comanche helicopter simulation.

6. Navigation Database: Automation
Purpose: To automate the process of updating the airport and runway record database files for use by the Flight Management System in the ACFS.

7. High Level Architecture to FFC
Purpose: To demonstrate simulation interoperability between full-motion flight simulators in the CVSRF and the airport surface operations simulator in FFC using the High Level Architecture interface.

8. Integrated Vehicle Modeling Environment Development
Purpose: To provide a flexible architecture in the ACFS to simulate various aircraft models.

FY 02 VMS Simulation Projects

FY 02 VMS Simulation Projects			
PROJECT	**PROGRAM SUPPORTED**	**CUSTOMERS**	**TEST OBJECTIVES**
Runway-Independent Aircraft Operations	Capacity (Runway-Independent Aircraft)	NASA Rotorcraft	Focus on rotary-wing aspects of increasing the capacity of the national airspace through the study of using self-separation in various landing areas both associated with and independent from normal airport runways.
Rapid Integration Test Environment III	Computing, Information, and Communications Technology (CICT)	NASA CICT Program	Study variants of the Crew Transfer Vehicle using the Rapid Integration Test Environment. Determine working handling qualities requirements for re-entry vehicles to aid in automated control system design and configuration.
Turbulence	Army	Army	Develop helicopter turbulence models through performance comparison with instrumented flight test data. Evaluate with coordinated concurrent flight testing.
Carefree Maneuvering	Army	Army	Study freeflight rotorcraft operations to determine effectiveness in flying minimum noise paths or paths that alleviate the Air Traffic Control burden.
Civil IFR Handling Qualities	NASA Rotorcraft	NASA Rotorcraft	Evaluate handling qualities and instrument flight of low-performance civil helicopters in a flight environment that alleviates airport traffic loads.
Advanced Theater Transport	NASA Rotorcraft	NASA Rotorcraft	Determine control system design guidelines for Super Short Take Off/Vertical Landing (STOVL) transport aircraft.
Space Shuttle Vehicle	Space Shuttle Program	Space Transportation	Investigate the Orbiter's landing systems and directional control handling qualities. Examine feasibility of landing on shorter abort runways, study handling qualities while operating with reduced auxiliary power and expanded weather conditions, and study adaptive speedbrake and wind vector estimator. Provide training to the astronaut corps for Orbiter landing and rollout.
Virtual Airspace Simulation Technology	Virtual Airspace Modeling System	NASA Capacity Program	Provide human-in-the-loop simulations of the National Air Space system to improve efficiency and safety.

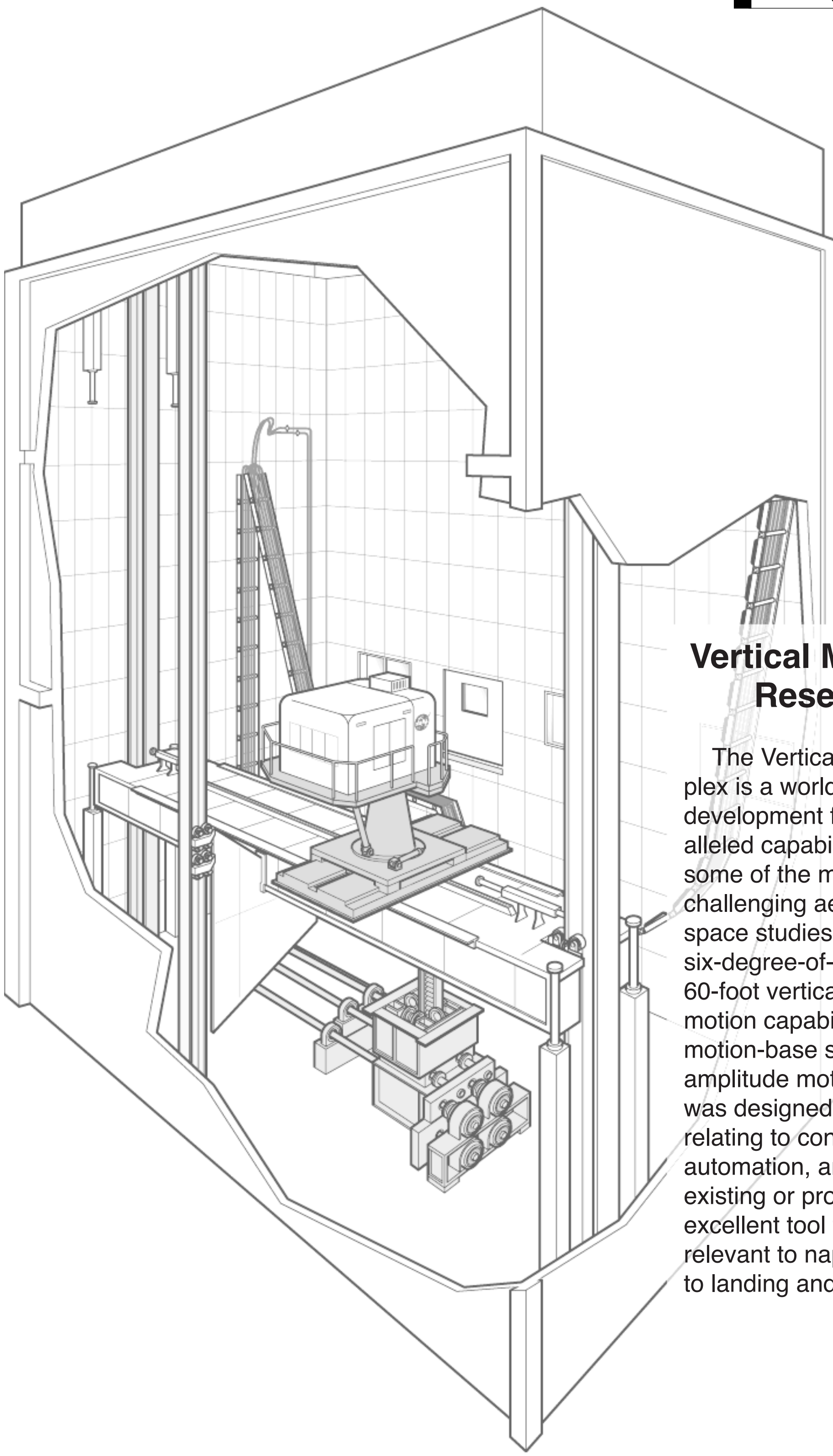
FY 02 CVSRF Simulation Projects			
PROJECT	PROGRAM SUPPORTED	CUSTOMERS	TEST OBJECTIVES
Self-Separation	Capacity (Advanced Air Transportation Technologies)	NASA Human Factors Division	Examine the use of advanced self-separation, traffic, and collision avoidance system display symbology during cruise, descent, and approach phases of flight.
C-17	Computing, Information, and Communications Technology	NASA Computing, Information, and Communications Technology Program	Integrate the C-17 aircraft model into ACFS and verify its functionality. The enhanced Neural Flight Control System will then be integrated into the C-17 model for studies of neural-net learning systems on current day transports.
Boeing Community Noise	NASA Quiet Aircraft Technology Program	Boeing, NASA Quiet Aircraft Technology Program, Massachusetts Institute of Technology	Evaluate the potential impact of an advanced flight management system (Center-TRACON Automation System/Flight Management System) on community noise when used to enhance Noise Abatement Procedures.
Data Link	Federal Aviation Administration	NASA Human Factors Division	Continue evaluating procedural and interface design issues associated with expanded cockpit data-link communications.
Virtual Airspace Simulation Technology	Virtual Airspace Modeling System	NASA Capacity Program	Provide human-in-the-loop simulations of the National Air Space system to improve efficiency and safety.

FY 02 CVSRF Simulation Projects

FY 02 FFC Simulation Projects

PROJECT	PROGRAM SUPPORTED	CUSTOMERS	TEST OBJECTIVES
Surface Management System: Second Simulation	Capacity (Advanced Air Transportation Technologies), Federal Aviation Administration Free Flight	NASA Ames Research Center, Federal Aviation Administration	Evaluate the next iteration of the Surface Management System, including its interoperation with the Traffic Management Advisor tool, to help traffic management coordinators with flow management planning.
National Transportation Safety Board Recommendations	Federal Aviation Administration Runway Safety Office	Federal Aviation Administration	Evaluate the safety and capacity implications of NTSB recommendations regarding runway procedure changes.
Awareness Information Requirement for Ground Operation	Federal Aviation Administration	Federal Aviation Administration and NASA	Determine the ground controller information requirements for increasing the efficiency and safety of airport surface operations.
Virtual Airspace Simulation Technology	Virtual Airspace Modeling System	NASA Capacity Program	Provide human-in-the-loop simulations of the National Air Space system to improve efficiency and safety.

VMS PROJECT SUMMARIES



Vertical Motion Simulator Research Facility

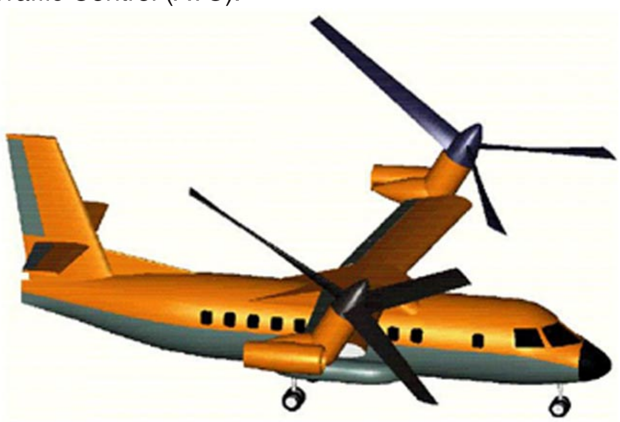
The Vertical Motion Simulator Complex is a world-class research and development facility that offers unparalleled capabilities for conducting some of the most exciting and challenging aeronautics and aerospace studies and experiments. The six-degree-of-freedom VMS, with its 60-foot vertical and 40-foot 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.

Civil Tiltrotor-9 (CTR-9)

Bill Decker, Dan Dugan, Jack Franklin, NASA ARC; Helmuth Koezler, Pete Klein, Bell Helicopter Textron; Dan Bugajski, Honeywell; Gordon Hardy, Ron Gerdes, Phil Tung, Emily Lewis, Steve Belsley, Northrop Grumman IT

Summary

Civil Tiltrotor (CTR)-9 was a continuation of the CTR series of simulations that investigated handling qualities and flight operational issues related to operating a tiltrotor aircraft at a vertiport. The simulation also investigated flight profiles designed for noise abatement, One-Engine-Inoperative (OEI) operations, and two flight control systems with autopilot functionality. This research also studied integration of the tiltrotor aircraft into existing airspace with Air Traffic Control (ATC).



This is the CTR 4/95, a notional aircraft developed by NASA. It's designed as a civil transport regional airliner and has a 40-passenger capacity.

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 inside and outside of the terminal area, past research has focused on operational issues under normal airspace management procedures. Recently, more emphasis has been placed on fitting the tiltrotor into the existing airspace with vertiport sites located near existing airports or in congested downtown areas. The CTR-9 study investigated aspects of this issue, including noise abatement, approach and departure profiles and procedures, pilot workload, and pilot interaction with ATC controllers.

Simulation

During the simulation, pilots flew several Take Off/Go Around (TOGA) profiles designed to reduce noise impact on surrounding areas. They also responded to OEI scenarios and studied two flight control systems with autopilot functionality.

The cab interior was reconfigured to incorporate newly designed Thrust Control Levers (TCL) and a new instrument panel to support ATC flight management. A second computer was added to provide two full sets of controllers for a two-person crew.

Two flight control systems, known as Stability and Control Augmentation Systems (SCAS), were developed. Bell Helicopter Textron's (BHT) SCAS is a full authority SCAS, meaning that the system can command the actuator and control surfaces through their full ranges of travel. Bell also developed an autopilot function based on previous tiltrotor work that was coordinated with the Honeywell Vertical Navigation (VNav) system and the Mode Control Panel (MCP). The second SCAS was a Dynamic Inverse (DI) design developed by Jack Franklin of NASA Ames. Two versions of the DI SCAS were studied.

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 the VNav system developed by Honeywell and a lateral navigation system (LNav) developed by Northrop Grumman Information Technology (IT).

In preparation for FAA certification for tiltrotor aircraft, the Pseudo-Aircraft System (PAS), an ATC simulation software tool, was successfully integrated into the simulation. PAS generated pseudo-aircraft traffic, which was displayed on the navigation display and on the Out-The-Window (OTW) views to simulate other aircraft traffic in the area. Voice communications with an ATC controller were also integrated into the simulation.

Results

Researchers were satisfied with the performance of the BHT SCAS and the two DI SCAS. The autopilot algorithm worked correctly with some minor tuning required so that it worked more "tightly" with both SCAS. Some features on the MCP and VNav did not function as anticipated and were targeted for further development. Based on pilot comments, the TOGA profiles will require some redesign in the future. On the hardware side, the TCL will be redesigned, as many pilots were uncomfortable with the TCL angle.

Investigative Team

NASA Ames Research Center (ARC)
Northrop Grumman IT
Bell Helicopter Textron
Honeywell
FAA

Joint Shipboard Helicopter Integration Process (JSHIP)

Mike Roscoe, Colin Wilkinson, Bob Nicholson, Denver Sheriff, Information Spectrum, Inc.;
Chuck Perry, Norm Bengford, Christopher Sweeney, Northrop Grumman IT

Summary

The JSHIP program of the Office of Secretary of Defense (OSD) is tasked with evaluating concepts and addressing issues related to joint military helicopters aboard Navy ships. As part of the JSHIP effort, the Dynamic Interface Modeling and Simulation System (DIMSS) team is developing a process using simulation to establish Wind-Over-Deck (WOD) flight envelopes and providing a high fidelity simulation for training aircrews specifically for launch and recovery operations at sea.

Introduction

DIMSS is tasked with defining modeling and simulation products that replicate the aircraft and pilot workload for launch/recovery operations from Navy ships. DIMSS will also develop a process to integrate simulation subsystems into operational flight trainers. The focus is on nine subsystems: flight deck, aircraft aerodynamics and engine, landing gear, pilot control force/feel, ship motion, ship airwake, body force and motion cueing, aural, and visual cueing.

This simulation attempted to determine the minimum simulator fidelity required to accurately predict the WOD launch and recovery flight envelope for the UH-60A helicopter and LHA ship combination. Different fidelity levels (I, II, III, etc.) for the aural, body force, and visual cueing subsystems were tested in different combinations of sensitivity configurations. Pilots flew these configurations to determine the minimum levels required for WOD envelope prediction.

Simulation

The goals of the simulation were as follows:

• Evaluate simulated shipboard landings and takeoffs using the LHA/UH-60A combination for a range of subsystem fidelity levels;

A UH-60A Black Hawk helicopter lands on a ship.

• Evaluate a range of simulated shipboard Army Design Specification (ADS)-33 tasks or Mission Task Elements (MTE) for a range of fidelity levels;

• Record pilot ratings, pilot comments, and aircraft data with which to validate the simulation against real-life data;

• Identify the minimum sensitivity configuration required to accurately predict the WOD envelope; and

• Provide the data and experience necessary to develop a fidelity algorithm.

Considerable development was done in almost every area of the simulation. The cab was modified with a complete UH-60A field of view, including an actual UH-60A door. An existing UH-60A aerodynamic and engine model was integrated with delivered force/feel characteristics and newly modeled landing gear. The CARDEROCK ship motion program was modified for an LHA ship and used in a real-time simulation for the first time. Computational Fluid Dynamics (CFD)-derived ship airwake data files were integrated into the aerodynamic model at 24 separate locations and run in real-time. A Camber four-axis dynamic seat was reverse-engineered, tuned, and integrated into the hexapod and VMS motion drives. Three aural models were developed based on flight test data. For visual cueing, the Evans & Sutherland Image Generator (ESIG) 4530 was updated with 3D Sea-State software, and an entirely new image generation system using simFUSION PCs was integrated.

Results

During five weeks of simulation, five pilots completed 1689 runs. The WOD launch and recovery runs were successfully simulated for the entire test matrix. Tests using the standard Useable Cue Environment (UCE) maneuvers helped differentiate between the simulation fidelity configurations. Results identified the preferred fidelity levels for different cueing subsystems. They were: Visual Level II (ESIG 4530 enhanced with 3D Sea-State model), Aural Level II and Level III (generated using flight test data), and Body Force Level IV (using the VMS and dynamic seat motion).

Investigative Team

JSHIP Joint Test and Evaluation Office
Information Spectrum, Inc.
NASA ARC
Northrop Grumman IT

Visual Scene Height Perception (PsychoPath) II

Munro Dearing, Jeffery Schroeder, U.S. Army/NASA Rotorcraft Division;
Robert Morrison, Northrop Grumman IT

Summary

The PsychoPath II simulation made a second evaluation of the effect of terrain representation on the pilot's perception of sink rate for a helicopter on approach to a runway. By using significantly improved logic for controlling the experiment, the simulation sought to obtain more conclusive results, compared with those of the first evaluation, for the pilot's minimum perceptible threshold of sink rate for each of 12 different terrain representations.

Introduction

In an emergency caused by loss of engine power or impaired flight controls, a helicopter pilot can usually perform an autorotation maneuver to make a safe landing. Successful completion of this maneuver requires much practice; unfortunately, practice in a helicopter is risky and expensive. Therefore, a low-cost autorotation simulator is needed in which pilots can obtain the necessary experience. For such a simulator to be effective, however, minimum specifications for visual cueing must be established.

An important aspect of visual cueing is the pilot's perception of sink rate, which is critical to executing the autorotation maneuver. This perception is influenced by the representation of terrain in the visual scene of the simulator. The results of the previous evaluation were inconclusive because of deficiencies in the logic used to control the experiment. With the deficiencies corrected, the current simulation sought to conclusively determine the effect of terrain representation on a pilot's perception of sink rate.

Simulation

SimLabs personnel significantly modified the software from the previous PsychoPath simulation to implement improved controlling logic, a new data format for end-of-run printouts, and logic for a remote terminal to display the data during the experiment for each terrain representation.

The visual scene consisted of a 600-ft-long generic runway with a surrounding grass infield area. The texture density of the runway and grass area could be varied from zero to the maximum value possible, resulting in the 12 different selectable terrain representations. The textures were derived from photographs of a runway and a random noise database. Vertical cues such as buildings, towers, and hangars were not provided.

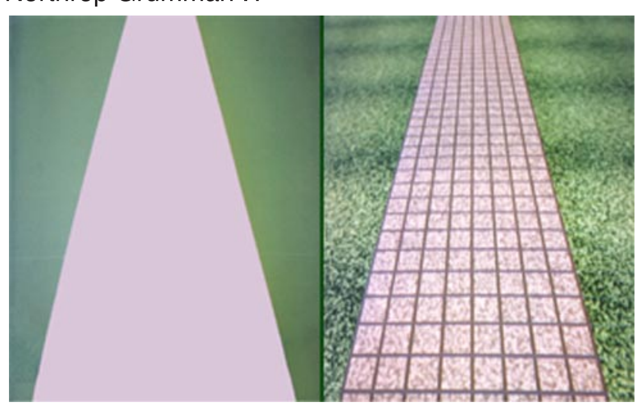
During the simulation, each subject was presented with one of 12 different terrain representations. The subject was then given a pair of four-second runs with different sink rates, the subsequent run beginning one second after the initial run. In each run, the simulated helicopter started from 100 ft in front of runway threshold at a 100-ft altitude and an airspeed of 20 knots, flew level for one second before descending to an 80-ft altitude, and then leveled off. A random number generator determined whether the run with the fastest sink rate occurred first or last. After the two runs, the subject indicated which one had the fastest sink rate before starting the next pair of runs. Consecutive pairs of runs were given to the subject until the controlling logic determined that the minimum perceptible threshold of sink rate had been determined and that the experiment for a given terrain representation was complete. The simulation experiment was then repeated with the subject for each of the other terrain representations.

Results

Fifteen subjects, eight of whom were pilots, completed a total of 14,064 data runs. The simulation was successful and met its objectives. Results of the investigation were pending at the time of this writing.

Investigative Team

U.S. Army
NASA ARC
Northrop Grumman IT



The PsychoPath II simulation made a second evaluation of the effect of terrain representation on the pilot's perception of sink rate. The image on the left shows the most basic representation of a runway, while the one on the right depicts the highest resolution simulated.

Space Shuttle Vehicle 2001-1

Howard Law, Alan Poindexter, Ken Ham, Chris Ferguson, Greg Johnson, NASA JSC; Ed Digon, Boeing; Peter Dailey, Lockheed Martin; Jim Harder, United Space Alliance; Estela Hernandez, Jeff Homan, Northrop Grumman IT

Summary

Simulation of the Space Shuttle orbiter was performed at the VMS to provide landing and rollout training for the astronaut corps. The engineering phase of the simulation studied the adaptive speedbrake model. Improvements to the simulation model were made to incorporate a Global Positioning System (GPS), vehicle mass modifications to the guidance and flight control systems, and additional wind profiles.

Introduction

The Space Shuttle Vehicle (SSV) is simulated at the VMS twice each year. During these simulations, researchers examine issues such as modifications to the flight-control system, flight rules, and the basic simulation model. The simulations also provide astronaut training with realistic landing and rollout scenarios.

The main objective of SSV-2001-1 was to train upcoming mission crews through a series of flight simulations. To improve the training experience, changes were made to the math model for vehicle mass and wind profiles.

In addition to training, GPS capability was incorporated into the math model. An engineering study was also conducted, focusing on the implementation of an adaptive speedbrake.

Simulation

The first model modification entailed the addition of 75 flight wind profiles for improved crew training. During the simulation, the 102nd Shuttle crew returned from orbit, so the wind profile recorded during their landing was implemented to provide added realism for training. Additionally, reenactment of this landing allowed the pilot of the 102nd mission to validate the accuracy of the VMS simulation model.

The second model modification incorporated a separate "vehicle mass" value for guidance. Formerly, one variable in the model supplied a weight value to both the physics and guidance models. With the incorporation of a second variable, the physics model will utilize the actual weight variable, and the guidance model will utilize the assumed "vehicle mass" variable. The two separate mass variables result in more accurate simulations of the approach and landing phase.

The third change incorporated an elaborate GPS model. If an error occurs during launch, the Shuttle must be able to make a safe landing at a designated abort site; consequently, flight conditions are impor-

The training that astronauts receive at the VMS is instrumental in producing safe, successful landings of the Space Shuttle.

tant during launch. However, the flight weather conditions currently approved for the Shuttle are far stricter than for other aircraft, and if minimum weather conditions aren't met, the launch must be postponed. With the implementation of GPS, the Shuttle will be able to safely navigate in a wider variety of weather conditions. This will save taxpayers millions of dollars in aborted launch costs.

The fourth math model change implemented the latest updates to the adaptive speedbrake. The orbiter's current speedbrake is positioned at several discrete angles during the final approach and landing phases, whereas an adaptive speedbrake will allow continuous changes in the speedbrake angle, providing more accurate control of descent velocity. Researchers incorporated adaptive speedbrake designs into the simulation to determine how to optimize speedbrake change effects that are dependent upon GPS accuracy.

Results

During the three weeks of simulation, 37 astronaut pilots and seven mission specialists completed 692 training runs. The researchers achieved their objectives for the three weeks of training. 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. The GPS model was successfully implemented and will be available for future experiments.

Investigative Team

NASA Johnson Space Center (JSC)
Boeing North American
Lockheed Engineering and Services Corp.
United Space Alliance
Norhrop Grumman IT

Civil Army Design Specification

Chris Blanken, Army; Roger Hoh, Alfredo Arencibia, Dave Mitchell, Hoh Aeronautics, Inc.; Emily Lewis, Luong Nguyen, Northrop Grumman IT

Summary

The Civil ADS experiment was the first of a series of experiments intended to improve civilian flight for helicopters operating under Instrument Flight Rules (IFR). The goal of this inaugural simulation was to develop the necessary tools and gather preliminary data to gain insights into these topics.

Introduction

The Civil ADS simulation series supports the "Civil Helicopter IFR" program, a sub-task of the NASA "Safe All-Weather Flight for Rotorcraft" program. Studies show that helicopter accident rates are much higher than those of commercial airliners, probably because most helicopters are not certified for IFR flight. The "Civil Helicopter IFR" program will identify ways to advance IFR operations in civil helicopters and consequently increase their safety. To that end, the Civil ADS simulation series will quantify what is safe for helicopter IFR by defining a standardized set of IFR tasks--including Stability Augmentation System (SAS) failures--and defining criteria that will result in an acceptable workload for civilian IFR tasks.

Simulation

For this experiment, a MD-500 helicopter was used as the model, and four vehicle configurations of varying stabilities were simulated. Three SAS types were developed: a series SAS (10% authority), a parallel SAS (full authority), and a rate SAS (for both the series and parallel systems). The parallel SAS was expanded to two versions, each optimized for different vehicle configurations. An autopilot with attitude hold, altitude hold, glideslope capture, heading hold, and navigation modes was designed and implemented for this simulation.

Engineers developed a civil IFR visual database, which included many airports in the San Francisco Bay area, Very High Frequency Omni-Directional Ranges (VOR), and intersections, such that VOR and Instrument Landing System (ILS) precision approaches could be performed using IFR charts and procedures. Two displays, an instrument display and a moving map/navigation display, were developed for viewing in the cab. Displays developed for observation in the lab were: an aircraft position trace display; a repeater of the mechanical instruments, buttons, and lights in the cab; and a real-time data display.

Four task scenarios, representative of realistic, high workload, single-pilot IFR situations, were used in this experiment. The scenarios were broken into three segments: 1) an IFR departure starting at 40 knots, with a 50-foot flight altitude, and including navigation to final approach; 2) execution of an ILS, Localizer, or Localizer-Type Directional Aid (LDA) approach, with weather below minimums and execution of the initial portion of a missed approach, culminating in a holding pattern; and 3) a missed approach procedure with a holding pattern assigned in climb and the execution of a non-precision approach.

Results

During this experiment, four pilots flew 47 half-hour data runs to evaluate the simulation. All pilots agreed that the simulation was a valid tool for the stated objectives. Turbulence and winds were found to be major contributors to IFR pilot workload. The autopilot resulted in satisfactory pilot workload. Pilots liked the parallel SAS configuration; however, they had to keep their hands off the stick when performing non-control tasks. SAS-off runs resulted in unacceptably high pilot workload, even for the configuration that meets FAA requirements for helicopter IFR. The highest tendency for serious errors occurred late in the run during the missed approach, probably due to a combination of light stick forces, divided attention, and fatigue.

Investigative Team

Aeroflightdynamics Directorate
Hoh Aeronautics, Inc.
Northrop Grumman IT

The establishment of IFR for civil helicopters should decrease the number of accidents and fatalities for this type of aircraft.

AutoCue II

Munro Dearing, NASA ARC; Norm Bengford, Northrop Grumman IT

Summary

The AutoCue II simulation investigated the impact of appropriate visual and motion cues on pilot performance during a helicopter autorotation maneuver simulation. 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 of descent 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. The maneuver allows the pilot to execute a safe, survivable landing depending on the availability of appropriate terrain. Because practice autorotations are expensive and carry high risk, there is a need for a helicopter autorotation simulator. Such simulators require the establishment of minimum cueing specifications for both visual and motion systems. The AutoCue II simulation was designed to determine the tradeoff between pilot-vehicle performance and workload versus visual and motion cues.

A UH-60A Black Hawk helicopter model was used to examine visual and motion cues during an autorotation maneuver.

Simulation

The first AutoCue experiment demonstrated the need for enhanced visual cues during the helicopter autorotation maneuver. In support of this goal, six wickets were placed across the runway at different longitudinal and vertical positions. These wickets helped the pilot stay on glideslope and assisted the pilot in determining when to begin descent arrest. The wickets were used for practice runs and were removed during rated runs.

For each run, the pilot autorotated the helicopter from an initial altitude of 1000 ft and an initial airspeed of 80 kts to land at a designated spot on the runway. The runs were done using two different runway visual cue environments: one with no texture and little scene content, and one with high scene density. The motion cueing environment included the full VMS motion system, no motion, and limited motion to emulate a hexapod simulator with a 15-in actuator stroke. For each run, the pilot performed an autorotation to touchdown with a maximum airspeed of less than 25 knots and a maximum rate of descent of less than five ft/sec. Pilots rated each autorotation according to the speed, rate of descent, and touchdown position.

A secondary goal of the simulation was to develop an R-22 helicopter model. An R-22 is more representative of the civilian helicopters that this research is intended to benefit. SimLabs personnel developed the model from documentation supplied by the researcher, information obtained from the library, and computer archive files from simulations run in 1983 and 1985.

The computer code was converted to the proper format and syntax to run on the current Alpha host computers and built into a running simulation model. This model was tested with static trim checks, stability derivative checks, and time history dynamic checks. After comparing the new check data with the old, the models matched very well. The R-22 math model and checks were then thoroughly documented to assist future development and use.

Results

During the two weeks of this simulation, 11 subjects (six pilots and five non-pilots) participated. 167 data runs and 112 non-data runs were collected. The objectives of the simulation were met. Data analysis was in progress during publication of this report.

Investigative Team

U.S. Army
NASA ARC
Northrop Grumman IT

Joint Shipboard Helicopter Integration Process (JSHIP) II

Mike Roscoe, Colin Wilkinson, Bob Nicholson, Denver Sheriff, Gary VanderVliet, Information Spectrum, Inc.; Chuck Perry, Jeff Homan, Christopher Sweeney, Northrop Grumman IT

Summary

As part of JSHIP, the DIMSS project was formed to develop a process to establish WOD launch and recovery flight envelopes for helicopter/ship combinations using simulation. In this study, shipboard landings and take-offs were simulated to define WOD envelopes for the UH-60A helicopter/LHA ship combination.

Introduction

The primary goal of the JSHIP process 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 definition of WOD launch and recovery flight envelopes to ensure safe and consistent operations. For the Navy, WOD flight envelopes have been established for specific ship and aircraft combinations using at-sea flight tests. For each new helicopter/ship combination, WOD flight envelopes must be developed before operations commence. This flight testing involves taking an aircraft to the ship and conducting numerous (50 to 100) launches and recoveries from and to the ship while incrementally varying the WOD conditions (5 knots or 15 degree azimuth changes). For ships with multiple landing spots, flight envelopes must be developed for each spot. This process must be repeated for each aircraft configuration, ship class, landing spot, and approach style. DIMSS is therefore investigating the use of ground-based flight simulation as a cost-effective and controlled alternative for WOD flight envelope determination.

Simulation

The specific goals of the simulations were:

• To evaluate simulated shipboard landings and take-offs using the LHA/UH-60A combination for a range of subsystem fidelity levels;

• To record pilot ratings, comments, and aircraft data to validate the simulation against real-life data;

• To identify the configuration with the minimum fidelity required to predict the WOD envelope; and

• To conduct a General Utility Assessment and determine if the simulator can be used to extend/modify Field Deck Landing Practice/Deck Landing Qualification requirements.

The simulation was based on the development and evaluations of previous JSHIP simulations (see report for JSHIP, p. 17). Changes made involved: replacement of the dynamic seat with a single-axis shaker, enhancement of the ESIG 4530 visual system to include a person providing landing signals, updating the math model to include a modification to the helicopter off-axis responses, and modification of the ship-airwake code to more accurately model the airflow around the LHA.

The central task for this simulation was to conduct landings and take-offs to define the WOD envelopes. Three configurations were tested for four landing spots on an LHA ship. The simulation was also demonstrated to various military training organizations.

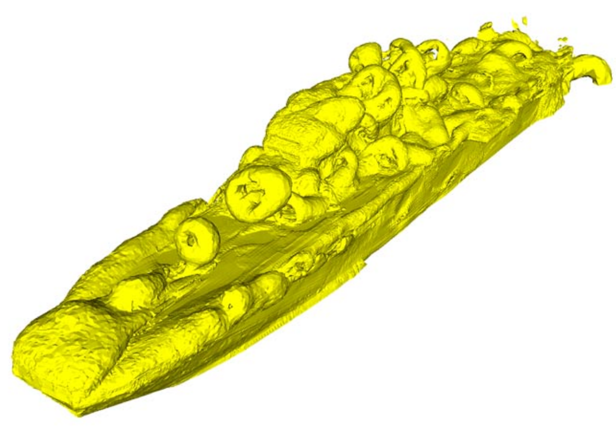
Results

During the first three weeks of simulation, four pilots completed 1245 WOD runs to define the launch and recovery envelopes. During the final week, 11 pilots flew 68 runs to assess the value of DIMSS technologies for training purposes.

Preliminary comparisons indicate envelopes developed with the highest simulation fidelity level and the envelopes developed at sea are very close. One pilot commented that the airwake was "very representative of actual airwake on a ship under the same conditions." The lowest fidelity configuration tested (fixed base with seat shaker and PC-based visuals) was found to be unsatisfactory for envelope development and frequently induced simulator sickness. The simulation has good potential for training pilots. Pilots indicated that the simulation would be a valuable tool to help pilots meet current requirements.

Investigative Team

JSHIP Joint Test and Evaluation Office
Information Spectrum, Inc.
NASA ARC
Northrop Grumman IT



This image depicts wind turbulence over the deck of an LHA ship.

Civil Tiltrotor-10 (CTR-10)

Bill Decker, Dan Dugan, NASA ARC; Robert Fortenbaugh, BHT; Dan Bugajski, Mike Jackson, Honeywell; Gordon Hardy, Steve Belsley, Ron Gerdes, Emily Lewis, Phil Tung, Northrop Grumman IT

Summary

CTR-10 was a continuation of the CTR series of simulations that investigated handling qualities and flight operational issues related to operating a tiltrotor aircraft at a vertiport. During this experiment, a “full mission simulation” of tiltrotor terminal area operations was conducted.

Introduction

Research requirements will arise in the near future to integrate the civil tiltrotor-class aircraft into the common airspace. To this end, the CTR series of simulation experiments have investigated certification and operational issues affecting terminal operations of a civil tiltrotor transport. This CTR experiment was the last scheduled activity of the NASA Short Haul Civil Tiltrotor (SHCT) Program. For the SHCT program, CTR-10 fulfilled the requirements of a Level 1 Milestone: demonstration of Civil Tiltrotor operability in an ATC environment. This simulation also studied operational issues under normal airspace management procedures.

Simulation

This experiment was conducted in a “full-mission” environment, including air traffic, controlled air space, low visibility, and winds. Specifically, the simulation studied:

- TOGA strategies and guidance;
- OEI recoveries before and after landing decision;
- Approach profile limitations (turn radii, winds, and other air traffic);
- Testing of Ames flight path vector guidance; and
- Implications of a “fixed configuration” Instrument Landing System approach to a runway.

To achieve these objectives, many software improvements were made to the CTR mathematical model. Modern aircraft features such as AutoPilot functions, an MCP, and a Flight Management System (FMS) were used or improved upon from previous CTR simulations. BHT improved the yaw axis of the CTR-9-developed BHT SCAS, added a height damper, and enabled the control system to switch modes upon pilot request. Honeywell developed the VNav system (core structure of the future FMS). The MCP was modified from a version which was previously used for High Speed Civil Transport (HSCT) research. A modern navigation display based on the Boeing 777 version (with a Traffic Collision Avoidance System) was upgraded. The ATC/PAS interface and graphics drivers (navigation display and ESIG 3000 visual system) were developed and integrated into the simulation. SimLabs also developed a new communication infrastructure to support future joint simulation operations.

The Quickened Inverse (QI) flight director and TOGA profiles were designed by Ames researchers and used during the simulation. The QI flight director was the focus of the fixed-base study that followed the simulation. The flight director gains were fine-tuned. During the fixed-base period, stability derivative data were generated in support of future flight control system development.

Results

During the CTR-10 simulation, 560 pilot-in-the-loop VMS data runs and 433 fixed-base data runs were generated. The researchers and project office involved in the SHCT program were extremely pleased to have completed the Level 1 milestone during the fiscal year. Modifications to the Bell SCAS, the Honeywell vertical guidance algorithms, the approach profiles, and the flight director were completed in time for pilot evaluation and were well received by the pilot community.

A simulated tiltrotor lands at a vertiport in San Francisco, CA.

Investigative Team

NASA ARC
Northrop Grumman IT
Bell Helicopter Textron
Honeywell
FAA

Space Shuttle Vehicle 2001-2

Howard Law, Greg Johnson, Ken Ham, Chris Ferguson, Alan Poindexter, NASA JSC; Ed Digon, Boeing; Peter Dailey, Lockheed Martin; Jim Harder, United Space Alliance; Estela Hernandez, Jeff Homan, Northrop Grumman IT

Summary

Simulations of the Space Shuttle orbiter were performed at the VMS to fine-tune the Shuttle's landing systems and provide landing and rollout training for the astronaut corps. Upgrades to the math model were made to increase its fidelity.

Introduction

The Space Shuttle orbiter landing and rollout is simulated at the VMS twice each year. Researchers have examined modifications to the flight-control system, guidance and navigation systems, Head-Up Displays (HUD), flight rules, and the basic simulation model. The simulations also provide astronaut training with realistic landing and rollout scenarios. Although there were no engineering studies during this simulation, upgrades to the math model were made to increase the fidelity of the orbiter model.

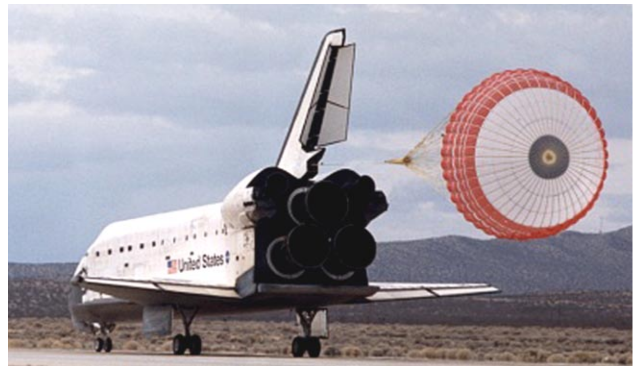
Simulation

The primary objective of SSV-2001-2 was to train upcoming mission crews and astronaut candidates through a series of flights. During this simulation, various runways, visibility conditions, and wind conditions (including the profiles recorded during the 104th and 105th Shuttle flights) were simulated, and system failures were periodically introduced. One system failure duplicated an actual problem that occurred during a flight, when the HUD was misaligned by 0.5 degrees.

Additions to the math model included: the spiral heading alignment cone (HAC) data on the Horizontal Situation Indicator (HSI) instrument, wind estimation on a Head-Down Display, the ability to induce HUD symbology misalignment, a wet runway model at Kennedy Space Center (KSC), and flight wind profiles.

The astronaut office requested the implementation of a spiral HAC on the HSI instrument. Prior to landing, the orbiter loops around a theoretical inverted cone (the HAC) for proper landing alignment. While looping around this cone, it is important that the astronauts have an accurate indication of their position with respect to a defined flight profile. Hence, computer guidance systems run algorithms during the approach which continually display error indications. Two of the Shuttle's displays which indicate errors are based upon the inverted cone algorithm, but a third display--the HSI--uses a cylinder in its calculations, making the HSI readout less accurate. The spiral HAC was implemented and tested.

The second math model change involved the onboard wind estimator. This estimator displays rough wind magnitude and direction during the guidance, approach, and landing phases. Winds during the final phase of entry directly affect energy conditions while flying around the HAC and at touchdown; however, there is currently no onboard wind information available. The new wind estimator uses two methods to calculate the wind direction and magnitude, each with a different reference frame.



Space Shuttle landings and rollouts are simulated at the VMS twice each year.

Preparation was made for potential engineering research involving wet-weather landings at KSC. Shuttle Flight Rules limit wet-weather landings to grooved runways, to provide the necessary "grip" for the orbiter's tires. KSC's runway poses a unique challenge, since it is part smooth and part grooved. The two sections were modeled and tested by SimLabs for future studies.

Results

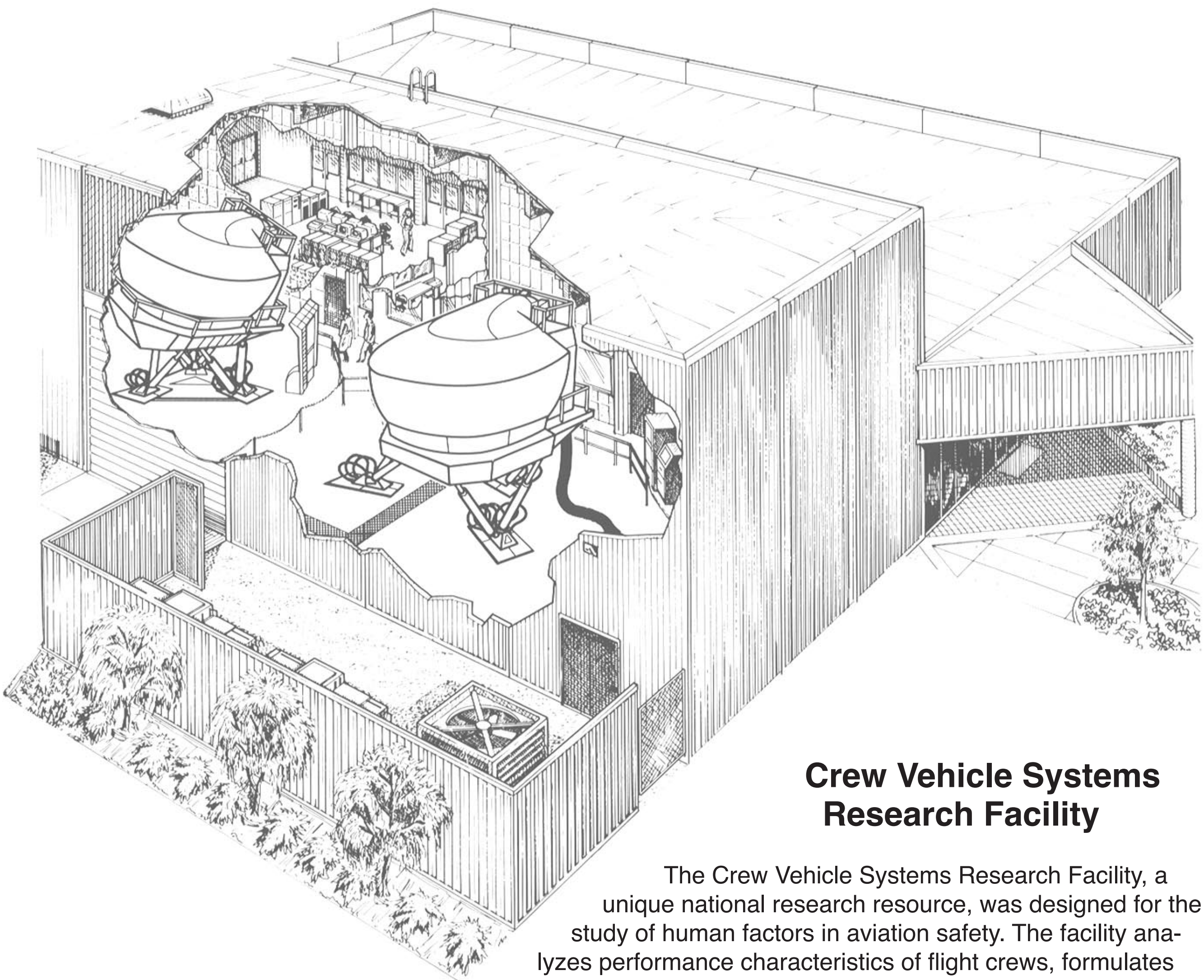
During the simulation, 39 pilots and two Flight Directors flew 576 training runs. Thirteen mission specialists also received training in the jump seat position. The researchers met their objectives for the three weeks of training.

Based upon pilot comments, the crew familiarization phase of the simulation reinforced the importance of the VMS in preparing upcoming crews for the landing and rollout phase of Shuttle missions and for possible failures during that phase.

Investigative Team

NASA JSC
Boeing North American
Lockheed Engineering and Services Corp.
United Space Alliance
Northrop Grumman IT

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.

Integrated Neural Flight Propulsion Control System (INFPCS) I

John Kaneshige, Karen Gundy-Burlet, Don Soloway, NASA; Don Bryant, Dave Brown, George Mitchell, Northrop Grumman IT; Ian MacLure, Anna Dabrowski, ManTech

Summary

This experiment examined the effectiveness of an INFPCS as a means of controlling a damaged aircraft. Experimental results indicated that the system operated successfully.

Introduction

This experiment is a follow-up experiment to the Neural Flight Control System Experiment conducted in May 2000. Neural networks are processing systems that do not require explicitly defined characteristics relating input to output; rather, they are capable of learning the relationship between input to a system and the resulting output by analysis of desired system behavior. Neural nets can be composed of hardware or software and consist of large numbers of relatively simple processing elements connected in multiple ways.

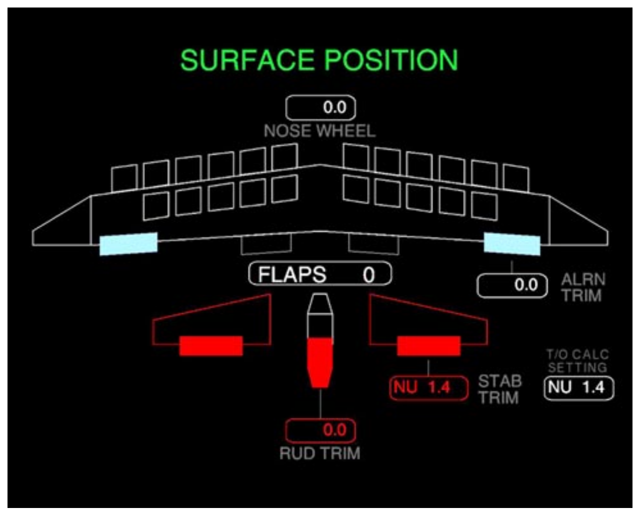
The purpose of this experiment was to examine the effectiveness of an INFPCS as a means of providing higher levels of adaptability and autonomy than current state-of-the-art systems. The goal was to develop a system capable of automatically compensating for aircraft damage or failures and further reduce the costs associated with flight control law development. The approach was to evaluate second generation neural flight control architectures, apply these to generic transport aircraft applications, and utilize alternate sources of control power for increased control authority and redundancy. This was accomplished by applying direct adaptive inverse control architecture, incorporating Propulsion Control Aircraft (PCA) technologies, and utilizing a daisy-chain approach for applying alternate control sources while simulating a broad range of damage or failure conditions.

Simulation

The AFCS was used as the test platform. The ACFS simulates a Boeing 757-class generic commercial air transport, having a wide body, a T-tail, low wings, and twin turbo-fan engines located beneath the wings.

Tests consisted of select flight maneuvers as well as approach and landing scenarios under different flight conditions. The performance of different controllers was evaluated under nominal and simulated failure conditions. Additional control authority was developed using symmetric ailerons (for pitch), symmetric thrust (for pitch), yaw-based roll control (for roll), and differential thrust (for yaw). Simulated failures included frozen flight control surfaces, offset flight control surfaces, and shifts in center of gravity (longitudinal and lateral).

Evaluation criteria used included handling quality maneuvers based on gross acquisition tasks, fine tracking tests, and approach and landing tasks. Audio and video recordings were made of the test runs, and a specified set of data was collected using the simulator's built-in data collection system.



ACFS Surface Position Indicator Cockpit Display showing a tail failure.

Results

Experiment runs were conducted by test pilots from NASA and by three crews from commercial airlines. Each airline crew flew two full-mission scenarios and was confronted with en route cascading failures. Handling qualities, pilot workload, and task performance of the fully functional aircraft and of the aircraft under a variety of control failure conditions were assessed. Results indicate that the INFPCS controller was able to stabilize the aircraft without significant pilot compensation under simulated failure conditions. All pilots were able to land safely using the INFPCS controller. The Investigative Team has been awarded a NASA Group Achievement award, and this work has received attention from NASA Headquarters, Congress, and the national media.

Investigative Team

NASA ARC
Northrop Grumman IT
ManTech

Air Traffic Control Simulation Fidelity

Alfred T. Lee, Ph.D., Beta Research, Inc.; Barbara Kanki, Ph.D., Terry Rager, NASA ARC; Diane Carpenter, Eric Gardner, Carlos Gomez, Jerry Jones, Rod Ketchum, David Brown, George Mitchell, Tom Prehm, Dan Renfroe, Gary Uyehara, ManTech

Summary

This simulation evaluated the efficacy of ATC simulation in providing airline aircrews with a training and evaluation environment comparable to actual line operations. Crews operating in a typical training environment responded to emergency scenarios more quickly than crews operating under simulated actual operations.

Introduction

The level of ATC fidelity achieved in simulation training and evaluation affects the workload experienced by the human participants, particularly in crew coordination and communication exercises. The goal is to present simulation workloads comparable to real-life operational levels. Reduced simulation fidelity may engender unrealistic crew behaviors and expectations in training and evaluation that would not be consistent with line operations.

This study investigated a Line-Oriented Flight Training scenario for a flight between LAX and San Francisco International Airport (SFO). Comparisons were made between the "experimental condition" using the ATC simulation environment and the "control condition" using standard line training procedures.

Simulation

The B747 simulator was configured to set aircraft and environmental conditions and to activate requested malfunctions. A separate voice scenario was created to maintain repeatability, and this was used by ATC personnel to create the ATC chatter for the "control condition" group.

Twelve crews participated. Six crews were assigned to a low radio communications simulation (RCS) which was comparable to the level provided in training environments, and six crews were assigned to a high RCS condition comparable to actual line operations. The two groups were matched for flying experience. The crews received a briefing package necessary to complete a flight from LAX to SFO. They boarded the aircraft at the gate and began necessary procedures to make the flight.

Upon taxi out to the active runway, visual ground traffic was programmed to increase crew interaction and radio chatter. As the flight proceeded, destination weather was changed and the Automated Terminal Information Service (ATIS) was updated; both events required additional crew interaction. When the flight neared approach, a nose gear malfunction was activated, necessitating a missed approach procedure and eventual routing to a holding fix to resolve the problem. This required additional input to the FMS and increased crew workload. After solving the nose gear problem and advising ATC, revised runway visibility and breaking actions were issued, requiring further crew coordination. Subsequent approach, landing, and taxi to the gate were conducted under standard conditions.

Data collection commenced when the aircraft descended below 10,000 ft on arrival. Video and audio data were collected for the entire session, beginning as the crew entered the cockpit.

Results

The crew's planning activity was reduced significantly in the high RCS fidelity condition, with smaller increases shown in situation awareness and workload management. Crews also initiated ATC communications more often in the high RCS fidelity condition. In the high RCS condition, there was a significant increase in the reliability, and hence validity, of instructor evaluations. Crew-system performance was affected, as well, by RCS fidelity. High RCS fidelity led to substantially increased time for execution of a missed approach, possibly due to increased time spent on crew-ATC communication. These findings suggest that there is a marked influence of RCS fidelity on crew workload, on the reliability of instructor evaluations, and on the crew coordination processes.

All research goals for this simulation were met. Possible follow-on studies will depend on future funding and interest from the aviation community.

Investigative Team

Beta Research, Inc.
NASA ARC
ManTech

Air traffic system in use at the CVSRF.

Boeing Noise I

Kevin Elmer, Daniel McGregor, Joseph Wat, Belur Shivshankar, The Boeing Company; Terry Rager, NASA ARC; Jerry Jones, Rod Ketchum, George Mitchell, Fritz Renema, Diane Carpenter, Ghislain Saillant, David Lambert, Northrop Grumman IT

Summary

The Boeing Noise Experiment is a joint effort between Boeing and NASA Ames Research Center to demonstrate the use of noise analysis tools integrated with the Boeing 747-400 flight simulator to measure noise under the flight path. The goal is to demonstrate that noise issues can be successfully studied in a simulation environment. This capability would serve as a useful tool for researchers, airports, and communities studying ways of minimizing noise impact on communities adjacent to airports.

Introduction

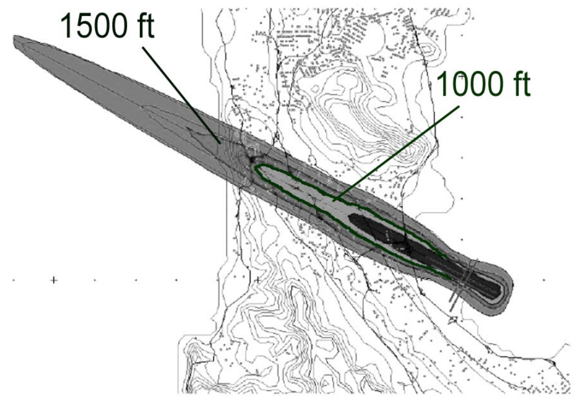
The impact of aircraft noise on communities has become an important element of consideration in airport operation. Some airports near noise-sensitive communities have established special noise abatement protocols that modify existing instrument flight procedures to minimize noise impact. This project investigated a methodology for developing additional tools to minimize noise impact by examining the noise differences generated by varying approach and departure procedures of the Boeing 747-400.

Simulation

Using NASA's B747-400 simulator, 90 runs were conducted consisting of four types of Standard Instrument Departures and two types of Instrument Approach Procedures. Aircraft flight path data and the resulting noise levels were collected at a rate of 3.3 Hertz. The parameters collected were the distance from initial position, ground distance under the flight path, lateral offset relative to the flight path, altitude, equivalent airspeed, net thrust, net-corrected high pressure rotor speed, scenario time, engine pressure ratio, and pitch euler angle. The resulting flight path data files were read into a program called "Integrated Noise Model" which then generated the noise contour footprint illustrated here. The noise contours were continuously displayed in the cockpit.

Results

In addition to the 90 runs originally planned, the Boeing team collected 18 extra runs to enhance the test matrix under different approach procedures. Representatives from United Airlines, the Coalition for San Francisco Neighborhoods, and the SFO Aircraft Noise Abatement office attended noise demonstration runs.



This noise footprint displays results of Noise Abatement Departure Procedures from SFO runway 28R. The dark gray shows climb thrust initiation at 1500 ft, while the light gray shows climb thrust initiation at 1000 ft reflecting less noise.

This simulation leaves a valuable legacy for future noise abatement and Air Traffic Management research. By using the noise analysis tools integrated in the simulator, researchers can study the noise impact of a large number of flights in a very short time. Also, by immediately observing the results of operating procedures via the noise contour in the cockpit and lab, it will be possible to fine-tune procedures in real-time.

Boeing and NASA have planned to continue noise studies in this program. Phase II was completed this year; its description is included on p. 31. These further studies will elucidate human factor issues related to current and proposed Noise Abatement Procedures (NAP), as well as examine their feasibility.

Investigative Team

The Boeing Company
NASA ARC
Northrop Grumman IT

Boeing 747 Neural Flight Control System

Joe Totah, Karen Gundy-Burlet, John Kaneshige, Don Soloway, NASA;
Jerry Jones, George Mitchell, Rod Ketchum, Diane Carpenter, David Lambert, David Brown, ManTech

Summary

This study determined if the Neural Flight Control System (NFCS) developed by NASA earlier this year could successfully drive a cable-driven aircraft system and provide damage-adaptive capability to such an aircraft.

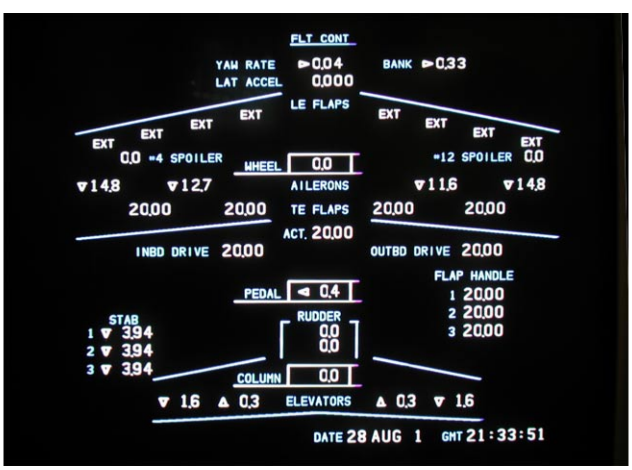
Introduction

The test platform selected for the NFCS retrofit study was the B747-400 flight simulator. Previous PCA studies conducted on the B747 simulator demonstrated that an automated full-authority propulsion control system retrofit is not economically viable for this aircraft. Therefore, this experiment's objective was to evaluate the feasibility of implementing the NFCS (which has no propulsion control element) in assisting pilots with controlling the airplane in a failure situation.

Two retrofit systems that provided rate command attitude hold with auto-trim capabilities and varying levels of damage adaptation were investigated. The first system involved a simple cable retrofit in which the roll, pitch, and yaw axes were decoupled from each other. The second system entailed coupling between the roll and yaw axes with a daisy-chain approach for moving control authority for pitch to the ailerons as needed. This second approach may require fly-by-wire system implementation with central computational capability overlaid on the existing cable-driven system.

Simulation

The resulting two retrofit options were evaluated by NASA test pilots in a series of handling qualities tests consisting of fine-tracking maneuvers as well as approach and landing scenarios under different flight conditions. The objective was to compare the performance of the NFCS with that of conventional aircraft systems. The evaluation criteria were based upon performance measurements, Cooper-Harper handling qualities ratings, and pilot comments. The simulated failure conditions consisted of flight control surface failures and aircraft damage affecting aerodynamic stability and control characteristics. These failures included a full-tail failure, a failure of two engines on one side of the aircraft, and a stabilizer/rudder failure. Approach and landing scenarios were incorporated under runway incursion and non-incursion conditions. Weather scenarios consisted of no turbulence, light turbulence, and moderate turbulence under clear visibility conditions. Audio and video recordings were made of the test runs, and a specified set of real-time digital data was collected.



Control Surfaces Display during tail failure.

Results

It was determined that both retrofit options could adapt for the two-engine-out and stabilizer/rudder failures. However, the second retrofit option was necessary for successful damage adaptation for full-tail failure scenarios, and both inboard and outboard ailerons were necessary for sufficient pitch control (in the absence of the integrated propulsion control). Three test pilots from NASA Ames Research Center and one test pilot from NASA Dryden evaluated the NFCS systems. Under nominal flight conditions, the pilots determined the NFCS controller to be on par with the handling qualities of the normal aircraft. The NFCS controllers received favorable comments in the damage scenarios. The most critical phase of flight was from the transition into ground effect and roll out. Ground effect reduced control authority, and rudder cable breakage scenarios made nose-wheel steering difficult on roll out.

Investigative Team

NASA ARC
NASA Dryden
ManTech

Airborne Information for Lateral Separation (AILS)

Vernol Battiste, Walter Johnson, Terry Rager, NASA ARC; David Brown, Diane Carpenter, Eric Gardner, Nabil Hanania, Jerry Jones, Rod Ketchum, Dave Lambert, Ian Maclure, George Mitchell, Craig Pires, Tom Prehm, Fritz Renema, Ghislain Saillant, Gary Uyehara, ManTech

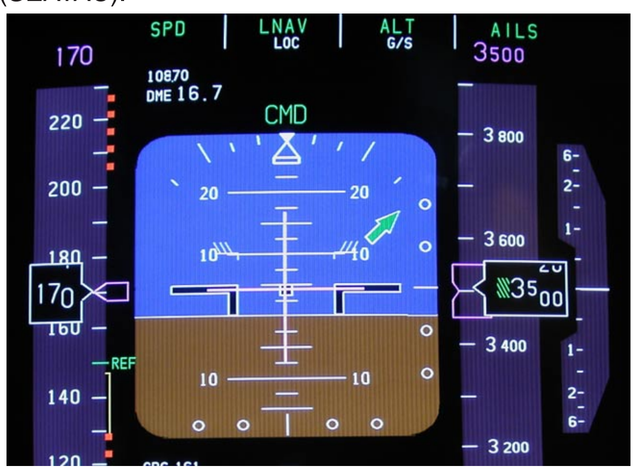
Summary

This study examined the operational implementation of an airborne system that would support Closely Spaced Parallel Approach (CSPA) operations at airports with parallel runways during Instrument Meteorological Conditions (IMC). Data analyses are in progress.

Introduction

Several major airports in the United States have parallel runways that are in close proximity. When visual contact between aircraft is possible, capacity is greatly increased by having aircraft fly closely spaced parallel visual approaches. Under IMC, airports with runways closer than 4300 ft are required to revert to a single runway operation or to run dependent approaches, each greatly reducing the number of landing aircraft.

This study investigated the utility and viability of a flight-deck-based display and alerting system that supports flight crews' situational and traffic awareness during all phases of an ILS approach. The study also examined flight deck and ATC final controller roles and responses during dual independent parallel approach operations at Seattle-Tacoma Airport (SEATAC).



PFD depicting an armed AILS approach.

Simulation

This simulation was conducted with scenarios using the airspace in and around SEATAC. This site was selected to evaluate the Airborne Information for Lateral Separation (AILS) concept because the airport is undergoing a new runway addition which will give the primary runways approximately 2500 ft centerline separation. This configuration lends itself to use of the AILS and CSPA technologies. Additionally, the FAA and managers at SEATAC were interested in supporting and implementing the results of this study.

The CVSRF's B747 full-mission simulator was adapted to accept AILS symbology on the PFD and to present CSPA information on the navigation display. Initial positions were created to allow the B747 simulator to enter the scenario at desired points. The SEATAC runway scene depicted in the B747 simulator's visual system was modified to represent the new runway. Additionally, a custom FMS navigation database was designed and loaded into the FMS for use with the new approaches.

PAS was heavily modified to incorporate changes required to support traffic flow realism into SEATAC. The CVSRF's ATC Lab was configured to represent the SEATAC feeder sectors, departure sectors, a tower position, and adjacent airspace positions; all used PAS. A separate final approach controller position was created in an isolated area of the lab for controller evaluation. Based on controller estimates of normal traffic flow to dual parallel runways, a single controller handled 48 aircraft per hour.

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

Scenarios began with air traffic routed to 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

The flight crew's assessment of the AILS concept was of primary interest for this experiment. This included all aspects of the AILS concept from system initialization and display status through the responses of the flight crew and the aircraft systems to an intruding or "blundering" aircraft.

Flight crew workload and performance data were collected using both objective and subjective assessment methodologies. Data analyses are in progress.

Investigative Team

NASA ARC
ManTech
SEATAC

Boeing Noise II

Kevin Elmer, Gary Gershzohn, Joseph Wat, Belur Shivshankar, Jack Dwyer, Daniel McGregor, The Boeing Company; Len Tobias, NASA ARC; J. P. Clark, Nhut Tan Ho, MIT; Jerry Jones, Dan Renfroe, Rod Ketchum, George Mitchell, Diane Carpenter, Ghislain Saillant, Estela Hernandez, David Lambert, Northrop Grumman IT

Summary

The purpose of the Boeing Noise Phase II experiment was to conduct a pilot-in-the-loop simulation to evaluate the feasibility and human factors issues of current and proposed NAPs in noise-sensitive airports. The flight crew's performance in the NAPs, as well as the impact of the NAPs on noise reduction, was examined.

Introduction

In the past, researchers used computer simulation and actual airport operations to study the feasibility of different NAPs. It was determined that only selected NAPs were useable in the Air Traffic Management (ATM) and FMS's of the time. Modern ATM and FMS systems will increase the feasibility of utilizing additional NAPs, but the new NAPs must be evaluated before they can be implemented. The controlled environment of the CVSRF was ideal for studying the results of different NAPs on crew performance and on noise reduction.

A noise graph depicting decreasing noise levels as the 747 departs London Heathrow. As the altitude increases and net thrust decreases, the resultant noise level decreases.

Simulation

Using the B747-400 flight simulator, three departure and four arrival NAPs were evaluated for the London Heathrow airport. Heathrow was chosen for the experiment because it has a stringent noise impact policy and monitoring plan. Aircraft flight path data and the resulting noise levels were recorded for each run. Sixty-nine additional variables were collected, including aircraft performance variables, controls movement, and autopilot events. Statistical data were also recorded for specific aircrew activities, such as when turns were made, when climbs and descents were initiated, and when systems were activated.

Results

A total of 318 data runs were completed for three departure NAPs on two separate routes, and for four arrival NAPs flown in both "auto" and "manual" modes. Collected data are being analyzed. Of the NAPs tested, those that have the most noise reduction benefit and least impact on the flight crew will be selected for further study. Human factors results will be provided to the Massachusetts Institute of Technology (MIT) for inclusion in a statistical model to study aircraft separation in a "noise flight procedure" and in heavy workload situations. Information from this study will benefit NASA by providing critical data for its Quiet Aircraft Technology Program.

Investigative Team

The Boeing Company
Massachusetts Institute of Technology
NASA ARC
Northrop Grumman IT

Distributed Air-Ground Demonstration

Sandy Lozito, Vernol Battiste, Walter Johnson, Nancy Smith, Terry Rager, NASA ARC;
Thomas Prevot, San Jose State University;
Don Bryant, David Brown, Ramesh Panda, Gary Uyehara, Northrop Grumman IT

Summary

This simulation demonstrated technologies and procedures related to the Distributed Air-Ground (DAG) concepts in the ACFS. DAG research pertains to interactions between the airborne flight crew and ground-based air traffic controllers.

Introduction

Distributed Air-Ground research is a part of NASA's Advanced Air Transportation Technologies (AATT) Program. It is intended to explore the triad for the National Airspace System: the flight deck, the ATC environment, and the dispatch system. This research specifically focuses on human factors issues.

As part of the DAG research, a demonstration was conducted in September of 2001. The goal of the demonstration was to construct and accomplish the initial testing of the air and ground simulation environments, using the Airspace Operations Laboratory (AOL) and the ACFS. Emphasis was placed upon the ability to configure and collect data necessary to test human performance parameters of pilots and controllers.

Simulation Description

Several researchers and developers were involved in the overall planning and development of the various components in the DAG architecture. The participating organizations were NASA Ames Research Center, San Jose State University, and Northrop Grumman IT.

For SimLabs, the development was focused on the ACFS. Cockpit Display of Traffic Information (CDTI), a key component of the DAG research, was integrated into the ACFS. The CDTI, developed separately by the DAG research team, consisted of display graphics and both self-separation and conflict detection logic. All elements were hosted on a Windows PC environment. Two PCs were used to drive the captain's and first officer's displays. The CDTI display graphics were video switched into the Navigation Display (ND) locations in the ACFS cockpit. The CDTI computers were interfaced with the ACFS simulation host via the Aeronautical Datalink and Radar System (ADRS). The ADRS, in turn, acted as a gateway to the simulated air traffic and to the Center and Terminal Radar Approach Control (TRACON) environments located in the AOL.

Several additional modifications were made to the ACFS in support of this study, including the automation of the self-spacing speed mode. This mode helps maintain safe separation distances between aircraft without pilot intervention. The Crew Activity Tracking System (CATS) was also integrated with the simulator to collect additional data during demonstration runs.

The ACFS was linked to the AOL for the demonstration runs. The AOL provided the simulated air traffic and the Center and TRACON environments. Two flight crews participated in experiment runs in the ACFS. The flight scenario commenced from the Dallas/Ft. Worth (DFW) Center airspace, continued through the approach environment, and concluded with a landing back at DFW. The CDTI and airborne logic to self-separate in a scenario with a few conflicts was used in the Center environment. Self-spacing algorithms developed by NASA Langley Research Center were used in the approach environment.

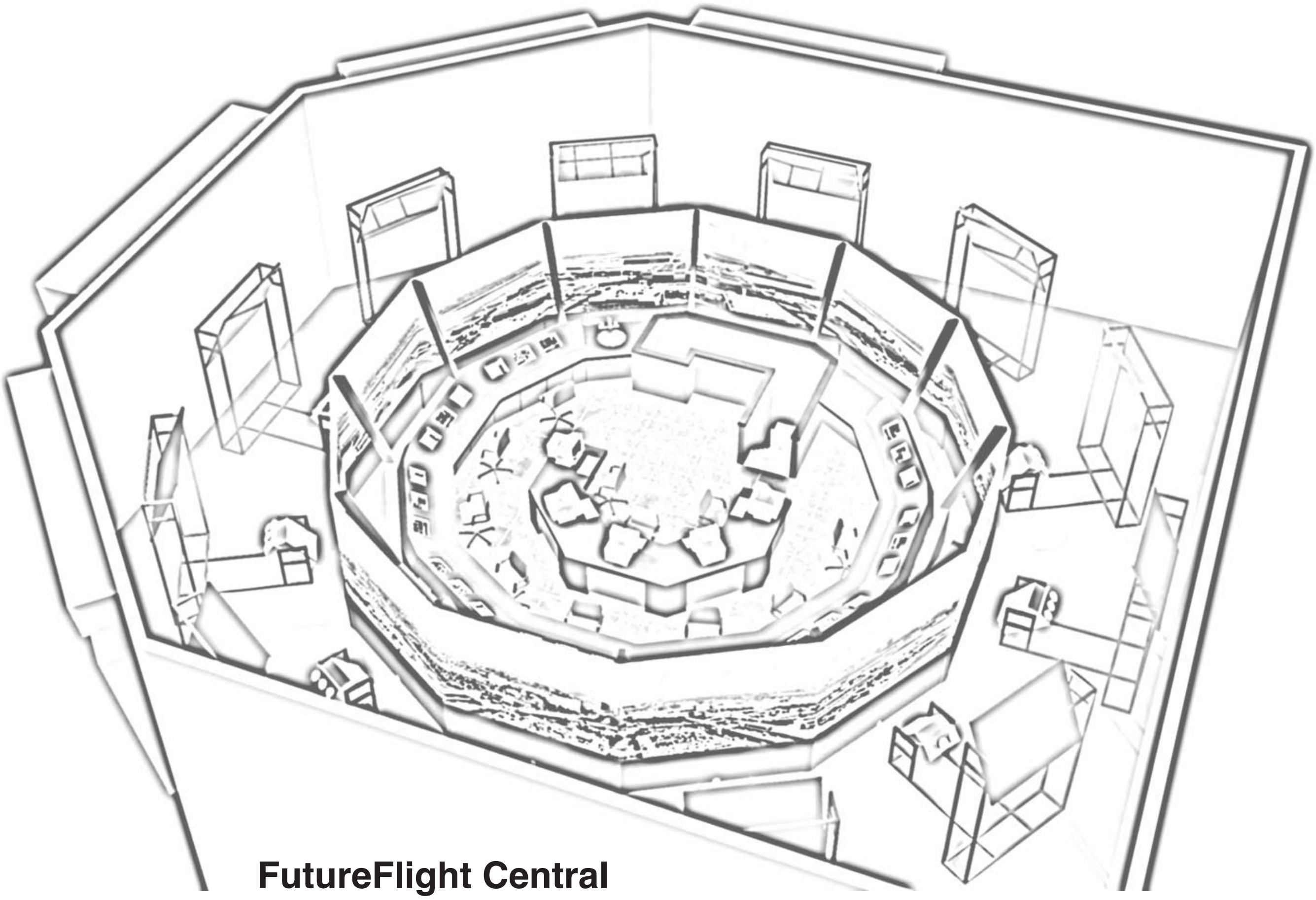
Results

The goals of the demonstration were accomplished. Test results indicate that the integration of air and ground simulation environments, using the AOL and the ACFS, was quite successful. Data collection capability was also validated, and some new data requirements were identified. The integrated system will serve as a valuable resource for NASA's air transportation system research.

Investigative Team

NASA ARC
San Jose State University
Northrop Grumman IT

CDTI with control interface in the ACFS.



FutureFlight Central Research Facility

NASA FutureFlight Central is a national Air Traffic Control/Air Traffic Management test facility dedicated to solving the present and emerging capacity problems of the nation's airports. The facility was designed in collaboration with the Air Transportation Association, the Federal Aviation Administration, the National Air Traffic Controllers Association, and the Supervisors' Committee.

FFC is operated and managed by NASA personnel, including experts in Air Traffic Control, computer graphics, human factors, and large-scale simulations. The two-story facility offers a 360-degree, full-scale, real-time simulation of an airport, where controllers, pilots, and airport personnel can interact to optimize operating procedures and test new technologies.

AGI Ramp Controller Training

Mike Madson, Marlene Hooten, NASA ARC; Marc Kenyon, AGI;
Farid Haddad, Jim McClenahen, Ron Miller, Christine Wong, Raytheon

Summary

The simulation objective was to train Airport Group International (AGI) ramp controllers for the new International Terminal at San Francisco International Airport.

Introduction

SFO is the seventh-busiest airport in the world. It has recently added two new international terminals as part of a major construction effort.

AGI was contracted to operate Ramp Tower A, located on top of the new International Terminal, “Terminal A.” Efficient ramp operations are crucial to the overall operating efficiency of the airport. The goal of this simulation, therefore, was to train AGI’s ramp controllers for the operation of Terminal A.

Simulation

Utilizing the SFO visual database at FFC, the controller-trainees were provided a 360° visual representation of the view from the ramp tower in different weather conditions. The capability of FFC’s software includes moving the tower eye point to the OTW scene appropriate to the user (in this case, the ramp controller-trainees).

FFC staffed the tower, directing arriving aircraft to appropriate locations when controller-trainees took over. A team of “pseudo-pilots” taxied aircraft into and out of the 26-gate ramp area. The pilots were in two-way radio communication with the controller-trainees, who directed the aircraft into and out of the ramp area in real-life traffic flow situations.

Each trainee was put in charge of an hour-long scenario that varied from a slow tempo to one requiring more complex coordination skills during two days of training. To aid in the controllers’ training, two SFO Tower air traffic controllers were present to critique the trainees’ performance. Although ramp controllers typically receive a printed schedule of the prospective arrivals and departures into their area, the controller-trainees made use of such a schedule only on the first day of training. On the second day, to better focus the training, the trainees just managed traffic.

The indicated area is Ramp Tower A’s responsibility.

120° View of the Ramp Area from Ramp Tower “A."

Results

Using FFC simulation capabilities, AGI was better able to understand the required staffing levels and knowledge for running the new ramp facility. Based on their training, AGI convinced senior management that greater staffing levels and experience were required to successfully operate the ramp tower facility. “[NASA’s FutureFlight Central provided] the very best training environment possible,” said Robert Peterson, Ramp Tower Manager for AGI, “We would like to spend more time in the facility.”

Post-simulation responses on an evaluation survey showed that controller-trainees were highly satisfied with their training experience, which included typical pilot-controller communications. The realism of the OTW scene also received high marks.

Investigative Team

NASA ARC
FAA
Airport Group International
Raytheon

LAX Phase I

Boris Rabin, Richard Haines, Cedric Walker, Michael Madson, Marlene Hooten, Betty Silva, Ken Christensen, NASA ARC; Elliot Brann, FAA; Jim McClenahen, Farid Haddad, Ron Miller, Christine Wong, Raytheon

Summary

The primary objective of the LAX Phase I Baseline simulation was to assess whether FFC could represent the LAX operational environment with sufficient realism to study alternative runway incursion solutions proposed in Phase II. This simulation was the first time a major hub airport has been successfully modeled.

Introduction

The FAA defines a runway incursion as “any occurrence at an airport involving an aircraft, vehicle, person, or object on the ground that creates a collision hazard or results in loss of separation with an aircraft taking off, intending to take off, landing, or intending to land.” Although relatively rare, runway incursions can lead to catastrophic runway collisions, putting many lives at risk. Consequently, the FAA has declared runway incursion problems at U.S. airports a top priority.

Out of 779,000 takeoffs and landings in 1999, LAX experienced 10 runway incursions, almost all of which were attributed to pilot deviation or air traffic controller error. To address this issue, Los Angeles World Airports (LAWA), the FAA, United Airlines, and NASA entered into an agreement to study changes at LAX that would help reduce runway incursions, thus making their runways safer.

FFC proposed a two-phase study. The primary objective in Phase I was to evaluate the realism of an FFC simulation before proceeding to Phase II.

Simulation

In Phase I, FFC designed three types of scenarios: a peak arrival rush operating under visual flight conditions, with 92 arrivals per hour and 78 departures; a peak departure rush operating under visual flight conditions, with 62 arrivals and 107 departures; and a peak arrival/departure rush operating under instrument conditions with 88 arrivals at minimum separation and 107 departures.

Both the north and south runways of LAX were simulated, with a complement of 22 airlines and an aircraft mix representative of LAX in the summer of 2000, for which NASA obtained actual LAX operational statistics. Some aspects of airport operations (e.g., ramp control, ground vehicle traffic, and maintenance operations) were omitted.

Two groups of four LAX controllers worked each of the four tower positions over a two-day period, for a total of four simulation days. Controllers were rotated to ensure that there was no response bias produced by such human factors as over-familiarity with a particular scenario, fatigue, or particular expertise in a position by any individual.

Results

FFC achieved notable success in its replication of realistic LAX operations. Three types of measurements were used to validate the facility: controller ratings, aircraft data, and voice communication recordings. After each run, controllers rated their experience in terms of workload and realism. They judged workload in terms of the amount of coordination and communication required in comparison with the same task at LAX. Controllers rated virtual LAX workload as “about the same as LAX.” Controllers rated realism in terms of the operational efficiency, complexity, aircraft movements, radio communications, and sound effects. For all categories, controllers judged the simulation overall as “about the same as LAX.” Aircraft surface data --including arrival and departure rates, departure taxi times, and runway occupancy times-- also helped to validate the simulation.

Investigative Team

NASA ARC
Raytheon
Los Angeles World Airports
FAA
VOLPE National Transportation Systems Center
United Airlines
Alaska Airlines
Southwest Airlines
American Airlines

Photograph of Local 1 Controller Position at FutureFlight Central, showing the LAX visual scene.

LAX Phase II

Boris Rabin, Cedric Walker, Betty Silva, Michael Madson, Marlene Hooten, NASA ARC; Elliot Brann, FAA; Jim McClenahen, Raytheon

Summary

The objective of the Phase II simulation was to evaluate six alternative changes to the airport surface, airport operations, or both, which could reduce the possibility of runway incursions at LAX. Two favorable alternatives were found during the course of the simulation.

Introduction

This study was the second in a series of runway incursion studies. In the Phase I Baseline Simulation, FFC demonstrated that its simulation was sufficiently representative of LAX operations and thus ready for further studies. The Phase II simulation evaluated several candidate airport changes designed to reduce runway incursion incidents, thus increasing airport safety.

The objective of this study was to assess the impact of each candidate change on surface traffic, overall capacity, and controller workload. Tested conditions concentrated on redistributing surface traffic away from the congested South Complex "hot spots" associated with many runway incursions at LAX.

Simulation

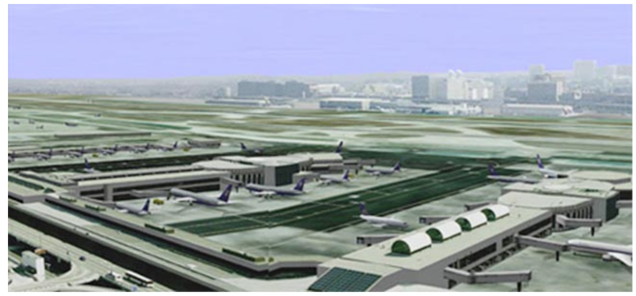
Controllers were presented with a realistic environment to operate in the FFC tower the same way they would in the LAX tower. All operation alternatives were tested for two traffic conditions and under Visual Flight Rules: peak arrivals scenario, consisting of 92 programmed arrivals and 78 departures; and peak departures scenario, consisting of 62 programmed arrivals and 107 departures.

Two groups of four LAX controllers worked several 45-minute sessions over a three-day period for a total of six simulation days. Controllers were rotated by tower position to eliminate response bias produced by over-familiarity with any scenario, fatigue, boredom, or particular expertise in a position by any individual.

Alternatives tested included swapping runways used for arrivals and departures, adding an additional local controller to help manage the south side of the airport, and variations utilizing the proposed B-16 Taxiway Extension under different sets of procedural rules with or without an additional controller.

Results

Data from Phase I were compared with data from the alternatives of Phase II. These comparisons highlighted the strengths and weaknesses of the different alternatives as measured by airport efficiency, capacity, traffic flow, and controller workload.



This FFC view of LAX depicts the airport's south side terminal area overlooking Terminals 6, 7 and 8. It is a heavy-traffic area for LAX's major carrier, United Airlines.

The most favored two alternatives utilized the proposed B-16 extension. Controllers rated these alternatives as having the least potential for a runway incursion and as being safer in comparison with today's LAX operations. Controllers gave the alternatives high marks for traffic management ease and efficiency. Departure rates (another measure of efficiency) were the highest of any of the alternatives.

It was equally important to discover which alternatives wouldn't work. Adding a second controller to south side operations created workload and coordination problems between the local controllers. It was also regarded as unsafe. Although the alternative that involved swapping the runways for arrivals and departures reduced runway crossings, it also increased taxiway congestion. Consequently, this alternative could contribute to a different type of incursion in which landing aircraft occupy the runway longer due to congestion in the exit area.

Frank Sweeney, Support Manager for the LAX tower, summed up the value of the simulation for the airport: "The NASA simulation was remarkably similar to LAX in real life…. Simply put: If we could not get it to work in the simplified NASA version of LAX airport, then it was clearly not going to work at real LAX. This saved the airport a lot of time (and money) in eliminating those untenable procedures and/or options."

Investigative Team

NASA ARC
Los Angeles World Airports
FAA
Raytheon
United Airlines
Alaska Airlines
Southwest Airlines
American Airlines

Surface Management System: First Simulation

Chris Brinton, Metron; Susan Lockwood, Seagull Technologies; Jim Hitt, Booz-Allen Hamilton; Deborah Walton, Mike Madson, Marlene Hooten, Boris Rabin, Ken Christensen, NASA ARC; Farid Haddad, Jim McClenahen, Christine Wong, Raytheon

Summary

The Surface Management System (SMS) is a decision support tool that will help controllers and air carriers manage airport surface traffic at busy airports. The goal of the first simulation was to evaluate the effectiveness of the SMS system at a simulated Dallas-Fort Worth airport.

FFC's depiction of the view from the East Tower at DFW with the SMS display at a controller workstation.

Introduction

NASA Ames Research Center's AATT Project, in cooperation with the FAA, is studying automation for aiding surface traffic management at major airport facilities. The Surface Management System is a decision support tool that will help controllers and airlines manage aircraft surface traffic at busy airports, thus improving safety, capacity, efficiency and flexibility. SMS will also interoperate with the airborne management of arrivals and departures to provide additional benefits.

NASA's ultimate goal is to develop SMS to the point that it can be transferred to the FAA's Free Flight Phase 2 program, the second phase of the FAA's program to modernize the National Air Space through the introduction of new technologies and procedures.

FFC was designed as a test environment for the introduction of new technologies for air traffic control. The SMS display system utilized Dallas-Fort Worth's East Tower operations to try out this new system within a realistic, working environment.

Two simulations of the SMS were planned. The first simulation, which is provisionally completed, utilized the SMS system integrated into the FFC facility; the second simulation will evaluate the next version of SMS, including Traffic Management Advisor's (TMA) interoperation with SMS. (TMA assists TRACON and Center traffic management coordinators in flow management planning.)

Simulation

Simulation conditions for Phase I included daytime operations in visual conditions with a south traffic flow and no ground vehicles. Each of the 45-minute scenarios was modeled from scheduled operations at 8:00 a.m., 11:30 a.m., and 1:00 p.m. at DFW.

The FutureFlight tower cab was configured to match DFW's East Tower layout with two local and two ground controller stations and hanging radar screens. Three SMS workstations were installed at the controller workstations, with an additional workstation at the center console for observers.

During the simulation, the tower was staffed with four controllers from DFW. The controllers' positions were rotated for each scenario so as to avoid any response bias. During the simulation runs, a staff of 18 "pseudo-pilots" controlled the aircraft traffic, as directed by controllers.

On the technical side, FFC's simulation software delivered real-time aircraft updates (including aircraft ID, aircraft type, latitude, longitude, altitude, climb rate, on-ground/airborne status, heading, ground speed, and simulation time) to the SMS. The High Level Architecture interface, a feature developed by FFC, was the means for transferring the necessary data to the SMS software.

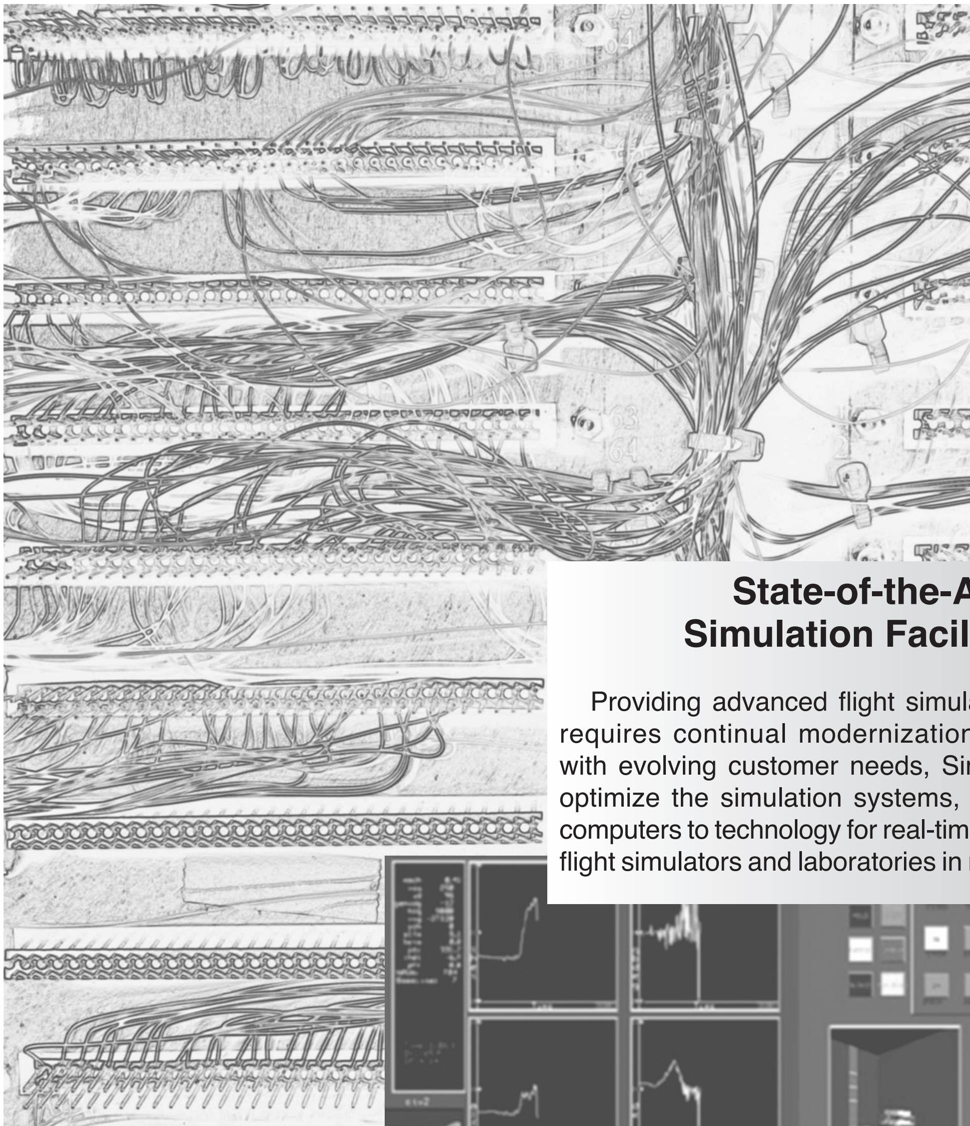
Results

The first simulation of the SMS was completed in September 2001. Each of three test conditions was run once. Input from controllers who utilized the SMS will influence the prototype to be tested in the second simulation. Stephen Atkins, NASA's project lead for SMS, was "very satisfied" with the simulation.

"FFC allows the eventual users to experience SMS in a realistic environment. It's not until controllers try using a [decision support tool] that they can provide the feedback needed to design a usable and useful product," explained Atkins. Complete data analysis is pending.

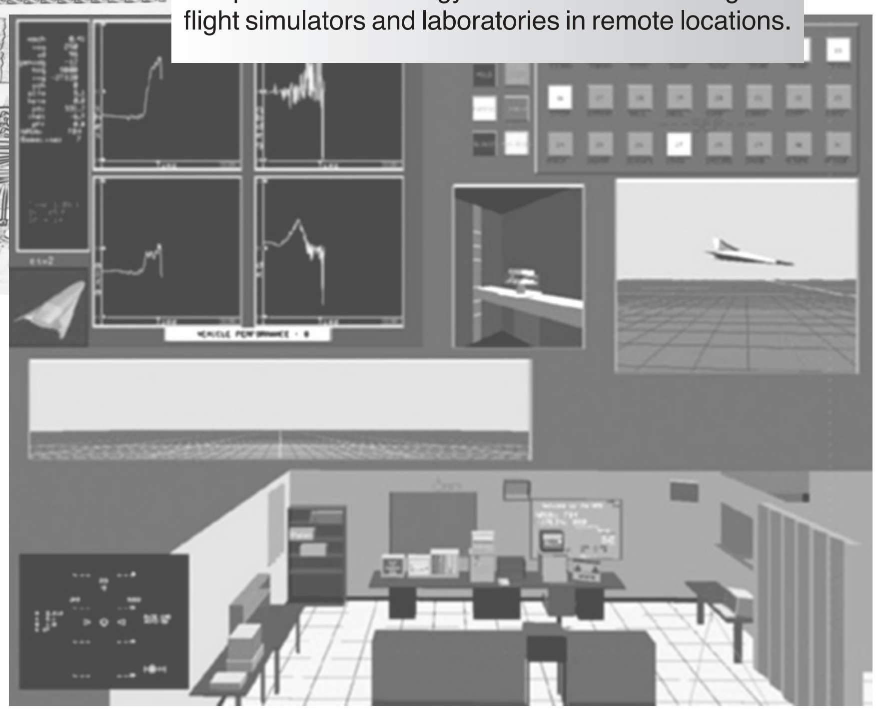
Investigative Team

NASA ARC
Metron
Seagull Technology
Booz-Allen Hamilton
Raytheon



State-of-the-Art Simulation Facilities

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



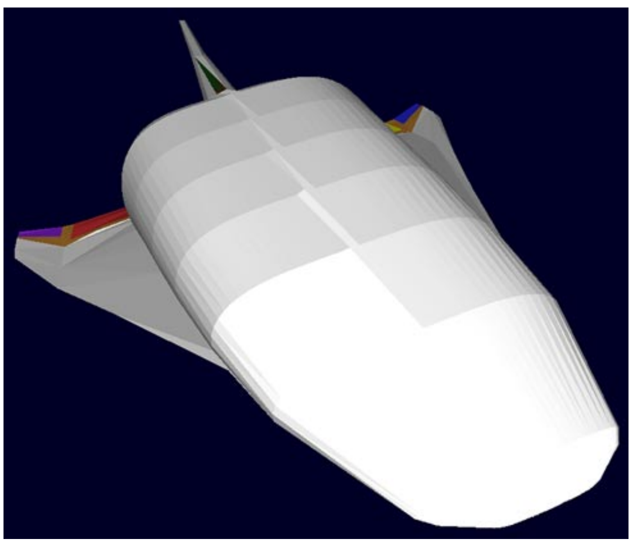
Rapid Integration Test Environment III

Summary

The vision of the RITE program is to merge advanced ITs in such a way as to make flight simulation an integral part of the design process when developing new systems. RITE III compared newer designs for a Crew Transfer Vehicle with the previously designed HL-20 vehicle and the Space Shuttle orbiter.

Introduction

The objective of the RITE program is to produce systems and infrastructure to facilitate the use of aerodynamics data developed using CFD technology in a real-time, piloted flight simulation. The subjective and objective flight simulation data will allow the design team to apply "return knowledge" from simulation to improve vehicle design and performance.



The SHARP CTV was modeled for RITE III.

RITE is a multi-phase program. The first phase united separate aerodynamic disciplines to establish the infrastructure for rapid integration of CFD data into flight simulation. The second phase of RITE was an exercise to redesign the Space Shuttle's nose. RITE application included increased data integration and fidelity, simulation flights of back-to-back cases with different geometries, the application of "return knowledge" by the design team, the development of system analysis data displays, and the enhanced use of VLAB to allow real-time system analysis between the multiple disciplines at different sites.

The goal of RITE III was to apply the process developed during the first two RITE phases to the preliminary design of a Slender Hypersonic Aerodynamic Research Probe (SHARP) Crew Transfer Vehicle (CTV). Specifically, RITE III compared newer designs for a CTV with the previously designed HL-20 vehicle and the Space Shuttle orbiter. Additions to this phase included tool integration (for vehicle optimization) and control system optimization (to improve handling qualities of successive designs).

Project Description

A SHARP CTV geometry was designed, and a baseline aerodynamic model was developed using wind tunnel and CFD methods. A flight control system for the baseline SHARP CTV was designed using the HL-20 control system architecture and optimized using CONDUIT software.

After the baseline version of the CTV was finalized, geometries for other CTVs were developed to improve approach and landing performance. Improvements included using wing optimization techniques, control surface modifications/additions, and modifications to the wing sweep, dihedral, and camber.

The baseline SHARP CTV's stability, control and handling qualities were evaluated through real-time piloted simulations. Pilots' comments were "returned" to the design team for rapid redesign of the aerodynamic model and control system. The revised designs were subjected to further pilot evaluations.

During the simulation, seven vehicles (five CTV versions, the HL-20, and the Space Shuttle) were flown. The pilots flew three tasks: straight-in approach, offset approach, and a 20-kt wind scenario.

Results

The RITE III simulation's objectives of generating vehicle designs, aerodynamics, and flight control systems for a SHARP CTV were met. The designers increased their knowledge of which points and parameters were critical to generate a lifting body aircraft with satisfactory handling qualities. This first use of CONDUIT for RITE resulted in greater understanding of the control system design process and the tool itself. Pilots gave valuable feedback to both the aerodynamic design and control system groups for further study areas. VLAB use was extended beyond ARC to both Johnson Space Center and Marshall Space Flight Center; this will assist in future collaboration efforts between centers.

Development Team

Fanny Zuniga, Julie Mikula, Jorge Bardina, Susan Cliff, John Bunnell, Dave Kinney, Mary Livingston, NASA ARC; Chun Tang, Veronica Hawke, ELORET Corp; Joe Ogwell, John Bunnell, Dan Wilkins, Russ Sansom, Northrop Grumman IT

Virtual Laboratory (VLAB)

Summary

VLAB is a suite of tools that extend the real-time flight simulation engineering and research capabilities of the VMS beyond the physical boundaries of the laboratory and onto the remote user's desktop. With a VLAB client system, remote users receive and interact with live, real-time flight simulation experiments at the VMS. Currently, VLAB clients are supported at Ames Research Center, Johnson Space Center, and Marshall Space Flight Center.

Introduction

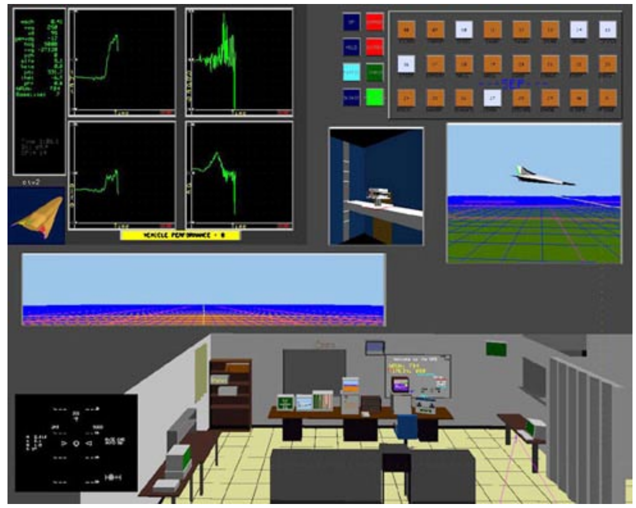
The VLAB client system features a fully-navigable 3D replica of the VMS laboratory and includes the capability to move beyond the physical walls and ceiling to obtain a full-scale view of both the VMS and a mock-up of an interchangeable cockpit. Navigation in the 3D virtual space is accomplished via keyboard commands or a joystick.

VLAB data displays include real-time strip chart displays, an end-of-run data monitor, data plots, and two-way white board text communication. Visual displays include the 3D laboratory environment (with either a full or orthogonal view of the VMS motion system), graphic representations of the OTW display, the chase-plane view, project and simulation engineer control panels, and a real-time Heads-Up Display. VLAB also provides stereo ambient sound and two-way voice intercom between the VMS lab and the remote client. Additional component systems are available for video conferencing, post-run data analysis, and multi-channel voice communication.

Project Description

Initial development and implementation of the VLAB system was accomplished on a mid-range performance workstation. Today's client systems are quickly progressing to desktop and laptop platforms. In addition to live client systems, a stand-alone demonstration version of the VLAB client system has been developed. Recently, both the client and server elements have been ported to laptop platforms. Wireless networking has been implemented on the Apple client platforms. This provides a truly "portable" client system. The server runs on a laptop PC under a Linux Operating System (OS).

A number of client configurations have been developed and deployed for various research teams. The Space Shuttle client configuration is currently used by JSC researchers to participate in live experiments at the VMS lab twice annually. The RITE research team uses multiple VLAB clients at multiple remote locations to participate in the development of the RITE process. Currently, clients are supported at ARC, JSC, and Marshall Space Flight Center. The 2001 implementation of RITE client systems will utilize multicast networking technologies to implement up to five remote clients at separate locations simultaneously.



A typical VLAB display used by researchers.

Future Plans

Future plans for the VLAB client suite include: further development of real-time plotting capability; extended use of multicast network transmission; continued investigation of wireless Local Area Network (LAN) technologies; enhancements to existing display elements; and multi-platform, multi-OS, PC-based client systems. The VLAB project will be investigating 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 platform controlled and operated from within the VLAB interface.

Development Team

Russell Sansom, Chuck Gregory, Rachel Wang-Yeh, T. Martin Pethtel, Christopher Sweeney, Thomas Crawford, Kelly Carter, Dan Wilkins, Northrop Grumman IT; Thomas Alderete, Steven Cowart, Julie Mikula, John Griffin, NASA ARC

VMS Modernization

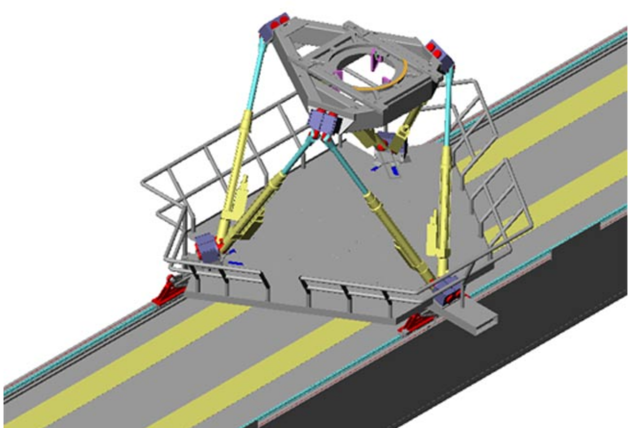
Summary

The VMS Modernization project will upgrade all electrical and control elements of the VMS with state-of-the-art components. The upgrade will increase performance and reliability while decreasing maintenance and support efforts, contributing to continued cost-effective simulations for the aerospace community. The project is currently in the design phase, which is expected to be completed in winter 2001.

Introduction

The VMS is the largest amplitude flight simulator in the world and provides unparalleled high-fidelity motion. As the country's premier motion-base flight simulator, it has been used extensively to support major national aeronautical research programs. Until recently, modern digital control technology was inferior to the analog control systems used on the VMS. However, recent advancements in technology have made replacing the original VMS system with "state of the art" digital systems beneficial, as these systems will reduce costs and enhance performance.

The primary objectives of the modernization effort are to reduce maintenance and operating costs and to improve motion performance. Completion of this project will keep the VMS at the forefront of flight simulation and contribute to continued cost-effective simulations for aerospace research and design.



An extensive project at the VMS will modernize the motion simulator to increase reliability and maintainability.

Project Description

The project is divided into the following phases:

- Management Planning;
- Studies;
- Maintenance Requirements Documentation;
- Design;
- Procurement;
- Construction;
- Installation; and
- Testing and Verification.

The first four phases are complete, and team members are awaiting further funding. The image in this write-up depicts a computer rendering of the mechanical changes to the VMS, which include replacing the existing rack and pinion-driven gimbaled carriage system with a light-weight, tape-driven hexapod carriage. The project also plans to increase the number of vertical motors from eight to twelve. System performance, maintainability, reliability, safety, and cost are key factors being applied in the design process. This phase will be completed in winter 2001.

Future Plans

Purchase and fabrication of the new systems will begin in fall 2002, and installation of the equipment will begin in spring 2004. All new systems will be verified and proven operational on a test bed before final installation in the VMS. The thorough off-line testing will drastically reduce system integration and validation time; consequently, minimizing the unavailability of the motion system for active simulation use.

Development Team

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Air Traffic Control for the VMS

Summary

This project's objective was to support an SHCT program milestone of demonstrating the operability of a CTR in an ATC environment. The project integrated the ATC simulation elements with the VMS. This enabled full-mission studies of CTR operation in air traffic around the airport terminal area and assessment of tiltrotor impact on flight procedures and traffic capacity. The link developed by this project will allow the VMS and CVSRF simulators to jointly participate in large networked simulations.

Introduction

The ATC simulator, which currently resides in the CVSRF, has the capability to generate air traffic as well as control air space. The upcoming and current CTR simulations in the VMS require that the tiltrotor operate in an air traffic environment. Because ATC capability was not originally available to the VMS simulations, this project sought to integrate the ATC simulation elements with the VMS. This addition now provides a full mission environment/capability to the VMS.

The CTR researcher requested development of air space operations to demonstrate the tiltrotor's operability under FAA normal approach and departure procedures. The request was phased: 1) demonstration of air space operations for the CTR 9 simulation (October 2000); and 2) full air space operations for the CTR 10 simulation (July-August 2001).

Project Description

The integration was completed in two phases: Phase I of the project developed the ATC environment capability for the VMS complex, which includes ICAB, RSIS, and the VMS labs. Integration of the ATC environment included real-time communications between the host computers and the PAS workstations, as well as voice communications with the controllers and other air traffic. For host communications, the High Level Architecture (HLA) protocol was used. The VMS host computer received data from PAS and displayed the traffic on the out-the-window visual system. Phase II completed the pilot's interaction with the ATC environment, including communications and navigation.

Audio communication was provided by the Advanced Systems Technology, Inc. (ASTi), digital audio system. The audio system hardware was upgraded to the latest version to allow the use of Voicenet in all of the laboratories. Along with controller communications in the CVSRF, a simulation of ATIS was also provided.

The testing of the ATC for VMS project was accomplished in a two-week fixed-base simulation following the CTR-9 simulation in the year 2000. During the test, data from PAS generated in the CVSRF facility was transmitted using HLA to the Alpha host computer in the RSIS lab of the VMS complex. This data was graphically displayed by the ESIG 3000 Image Generator as aircraft approaching and departing SFO. The data was also graphically represented in the cab on the navigation display as other aircraft in the area of the tiltrotor.

Results

A controlled airspace simulation was developed around SFO to demonstrate the tiltrotor's operability in an ATC environment. Simulated traffic was generated by PAS from the CVSRF and sent to the VMS via a digital link. Real-time data communications between the host computers and PAS was established as well as driving and displaying aircraft on the out-the-window displays and navigation displays. ASTi audio voice communications and a running ATIS were established with the CVSRF. Integration between the PAS ATC lab in the CVSRF and the VMS lab was completed.

Development Team

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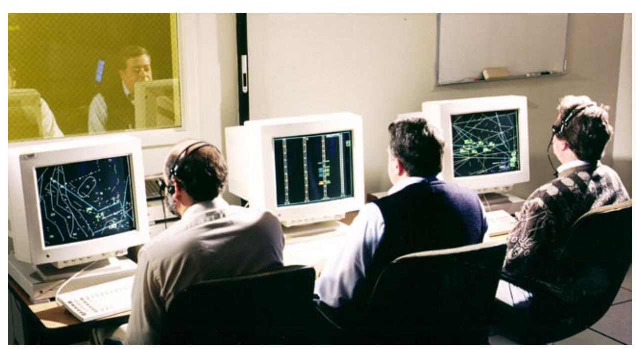

ATC simulation in progress.

Kaiser HMD and Head Tracker

Summary

The purpose of this project is to integrate a commercial off-the-shelf Helmet-Mounted Display (HMD) and head-tracking system to support simulation of Forward-Looking Infrared (FLIR) sensor and a HUD for a Comanche helicopter visual display experiment at the VMS laboratory. Future use may include HUD symbology projected on the HMD with look-through capability onto the existing cockpit display systems.

Introduction

The Kaiser “Proview 50 ST” HMD features state-of-the-art Liquid Crystal Displays (LCD) coupled with lightweight optical projection technology to deliver full color visual imagery to the pilot. Two LCD displays project high-resolution images through an overlapping optical package to deliver a continuous 29˚ (V) x 50˚ (H) Field-of-View (FOV) visual scene. Each LCD generates a full color, progressive scan with 640 x 480 pixel resolution to create a 29˚ (V) x 38˚ (H) monocular display for each eye. The optical package then forms a bi-ocular virtual display with 50% overlap to create the continuous FOV. The pilot’s head movement is tracked by a Polhemus “Fastrack 12” magnetic head tracking system. Feedback from the Polhemus head tracker is then used to move the imagery projected on the HMD. Integration of HMD and head tracking technology into the ICAB systems at VMS will add an important new dimension to the overall simulation capabilities of the VMS.

Project Description

The project’s first challenge was to determine if the Polhemus magnetic tracking system would operate in an ICAB environment. A two axes jig was created and placed at the pilot’s eye point in FCAB. The magnetic transmitter/receiver pair was manually positioned to known angles in yaw and azimuth, while the serial feedback from the Polhemus system was monitored on a laptop computer. The transmitter was then manually rotated and pitched while monitoring the serial data stream. Initial testing indicated that the Polhemus tracking system would work in a fixed base ICAB.

The next challenge was to merge the separate OTW scene and the HUD graphics into a single image on the HMD. [The OTW and HUD images have different formats since they are generated by different image generators (IG).] This was accomplished using a variety of video post-processing techniques. Once the images were successfully merged, the team set about the process of scaling the merged images to affect conformal image tracking between the HUD and OTW images.

The final step involves static image tracking, and then dynamically driving the HUD and OTW images based on feedback from the head-tracking system. This element involves graphics, systems, network and simulation engineering support.

Integration of the Kaiser HMD and Polhemus tracking system required support from all technical disciplines at SimLabs. The graphics team created the HUD display symbology and additional displays to support alignment and calibration of the HMD system. The network team integrated a serial communication link between the HUD IG and the head tracking system. Graphics programmers integrated the serial feedback to drive the HUD display symbology. Simulation engineers are taking the serial feedback from the HUD IG and using it to drive the OTW IG system.

An off-the-shelf HMD will be used to support Comanche helicopter display experiments.

Project Status

The project is in the final stages of development. Once the displays can be driven satisfactorily from the head-tracking system, performance data will be gathered and documented to baseline the entire HMD system for current and future use. Completion is anticipated in the first quarter of 2002.

Development Team

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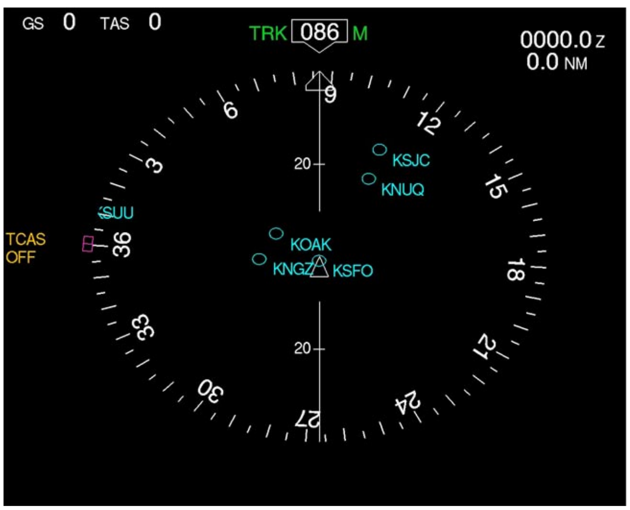
Navigation Database: Automation

Summary

The purpose of the Navigation Database Automation Project was to automate the process of updating the airport and runway record database files for use by the Flight Management System in the ACFS.

Introduction

The navigation databases of the ACFS require periodic updates to reflect the changes in real-world operations. Jeppesen is the source for all the navigation data that is processed via CVSRF's Navigation Database utilities. In the past, these files were manually updated, and the updates were localized to the specific area of interest for a given experiment. Recently, a phased development effort was undertaken to automate the processing of Jeppesen source data.



The ACFS navigation display.

In the ACFS, there are separate databases for the following systems: navigation facilities, navigation displays, the FMS, the Experimenter Operator Station (EOS), and the visual system. Automation of the navigation facilities database, the navigation displays, and a portion of FMS was completed in the first phase of this project. Remaining database files and associated access routines involved in the latter three systems were addressed in the current development.

Project Description

FMS airport and runway databases not previously addressed in Phase I were modified to accept automated Jeppesen updates. The FMS software was also altered to support non-unique waypoints typically present in the navigation database. A special Control Display Unit (CDU) page was created to allow the pilot to select the desired waypoint when more than one waypoint with the same name is present.

The EOS Graphic User Interface uses a database to reposition the aircraft to various airports. This database was previously hand-edited and is now generated by the new software.

The Flight Safety, Inc., Vital 8 visual system has the capability of building a generic airport if the runway length, width, type of lighting, and other parameters are provided. New software was written to incorporate the runway information for all of the airports in the continental United States and generate the desired airport with a runway that meets the criteria mentioned above.

Results

Greater efficiency has been achieved with the current upgrade. Previously, hours of tedious manual labor were required to identify, input, and verify changes made to the navigation aids and airports. Now, when the Jeppesen update is processed, the identification and entering of changes is done automatically, and verification usually shows no errors.

Development Team

David Brown, Northrop Grumman IT

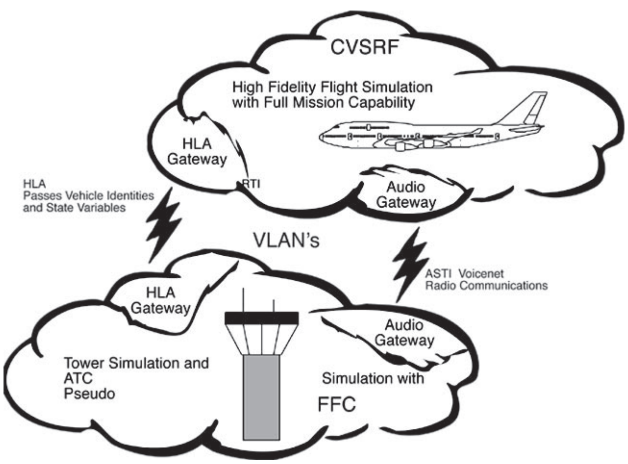
High Level Architecture to FFC

Summary

The physical network and software infrastructure were developed to interconnect the flight simulators in CVSRF with the airport surface operations simulator in FFC. The value of connecting the facilities for integrated simulations was demonstrated, and shortcomings of the current interface were exhibited.

Introduction

Integration of a high-fidelity flight simulation facility with simulations in the FFC, requires both facilities to exchange digital data about aircraft positions and behavior, as well as voice communications. This project provided the first opportunity to interface FFC with another simulation facility, the CVSRF, using the HLA interface.



Virtual representation of the interaction between the FFC and CVSRF simulators.

Project Description

To facilitate the connectivity between FFC and CVSRF, the CVSRF fiber optic network was physically extended. Two Virtual LANs (VLAN) were established over the fiber optics link to logically separate HLA traffic from voice communications. Additionally, FFC implemented a gateway system that isolated the internal FFC network from external network traffic. The HLA gateway provided data to the CVSRF in multicast packets with an update rate of 1 Hz. A significant amount of effort was devoted to integrating and testing the HLA interface.

For the proof-of-concept experiment, two incompatible radio/intercom systems were bridged to integrate audio communications. CVSRF has a radio communications system patterned after ASTi sound modeling systems and can provide remote audio communications with Cisco Voice-over-IP routers. FFC has a proprietary digital audio system for modeling communications for the controllers and pseudo-pilots, and it lacks an external network interface.

The project team implemented an analog bridge solution between the ASTi systems and the FFC system. An ASTi sound system is now located in FFC and is interfaced with CVSRF's ASTi systems via the second VLAN over a dedicated fiber link. The analog audio from the ASTi is patched into one of the communications stations in the FFC, and this provides basic audio connectivity between the two facilities.

The proof-of-concept experiment consisted of the 747-400 and ACFS simulators in the CVSRF joining the existing FFC HLA Federation. Performance was determined by observation of aircraft behavior in the visual system of each simulator.

Results

All of the simulators used their respective LAX airport databases for the proof-of-concept experiment. Although there were minor alignment issues due to differences in the database origin points, the position of aircraft was acceptable. The motion of aircraft in simulations was more problematic. The CVSRF simulators have smoothing algorithms that limit discontinuities in aircraft appearance when HLA data is updated at 1 Hz; however, the FFC simulator does not have such a feature. This led to significant jumping in FFC aircraft position when the data was only updated once per second. At the end of the demonstration period, it was determined that the internal update of aircraft positions in the FFC simulator is done at 5 Hz. If the CVSRF simulators had been configured to send HLA data at the higher rate, the FFC performance may have been more acceptable.

Further investigation of interoperability issues will be undertaken, pending an upgrade to FFC's simulation software. Additionally, a project has been initiated to evaluate the audio communications in all three SimLabs' facilities and to investigate how the audio systems can be upgraded to improve the integrated simulation environment.

Development Team

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Integrated Vehicle Modeling Environment Development

Summary

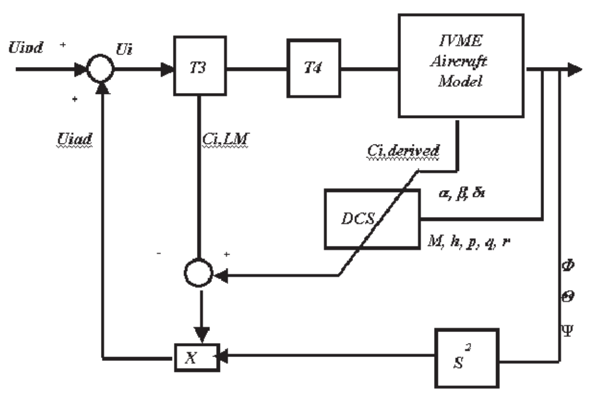
The Integrated Vehicle Modeling Environment (IVME) will provide a flexible simulation architecture in the ACFS to simulate and conduct experiments with various aircraft models. Currently, the ACFS is capable of simulating one type of aircraft: a generic B757-class transport.

Introduction

The IVME is a major effort to support Intelligent Flight Control (IFC) research goals. A primary requirement of the IFC researchers is the capability of integrating various aircraft models into a full-mission simulation environment. This would allow the researchers to develop and evaluate neural flight control strategies on a wide range of civil and military aircraft.

Project Description

The ACFS is currently a full-mission simulator representative of a generic B757-class of passenger transport aircraft. It has state-of-the-art avionics, including simulated flight displays and a Flight Management System.



Neural Flight Control/IVME block diagram.

The current aircraft model architecture utilized by the ACFS is functionally distributed. However, the IVME project required a further restructuring of model sub-systems into airframe-specific and generic subsystems. This was necessary in order to eliminate duplication of software while providing the multiple vehicle model implementation. The data interfaces between the airframe-specific subsystems and the remainder of the simulation components were generalized, thereby ensuring that the simulation provided by the new models would be compatible with all the other subsystems in the simulator.

There are three airframe models which will be initially supported for this project. They include the default ACFS 757-type airframe model, a C-17 model, and a Vortex-Lattice-generated model. SimLabs has an existing C-17 model, and the Vortex-Lattice software will be provided by NASA Code IC. Both of these simulations will be modified to conform to the IVME generalized data interface definition. Within the airframe-specific model subsystems, each of the three airframe models will be allowed to preserve the structural differences of their native implementation. This approach will minimize the implementation effort by making use of a well-established code set.

At the end of the IVME development, basic aerodynamics, flight controls, engines, and ground handling systems will be fully integrated with the rest of the ACFS simulation systems. This will allow researchers to develop adaptive neural controllers to provide both the inner and outer loop control functions. This software will possibly provide the interface to the FMS and other higher level automation available in the default ACFS. The classic autoflight and autothrottle systems, therefore, will not be developed and integrated as part of the IVME effort. The existing C-17 model software includes Fly-by-Wire flight controls with stability augmentation. These systems will be integrated only to serve as a reference for comparative studies of the neural flight controllers.

Results

The complex architectural restructuring of the IVME project is currently underway at the CVSRF. The flexible IVME architecture will greatly enhance the capabilities of the ACFS to simulate various aircraft models to support intelligent flight control and handling qualities research in the near term. With fully developed adaptive automation, the full-mission capabilities can be extended to the other types of airframes in order to support intermediate to long-term research goals.

Development Team

Ramesh Panda, Carla Ingram, Northrop Grumman IT

Acronyms

AATT ...... Advanced Air Transportation Technologies
ACFS...... Advanced Concepts Flight Simulator
ADRS ...... Aeronautical Datalink and Radar System
ADS ...... Army Design Specification
AGI ...... Airport Group International
AIAA ...... American Institute of Aeronautics and Astronautics
AILS...... Airborne Information for Lateral Separation
AOL ...... Airspace Operations Laboratory
ARC...... Ames Research Center
ASTi...... Advanced Systems Technology Incorporated
ATC ...... Air Traffic Control
ATM ...... Air Traffic Management
ATIS...... Automatic Terminal Information Service
AvSTAR...... Aviation System Technology Advanced Research Program
B747 ...... Boeing 747
BHT ...... Bell Helicopter Textron
CATS ...... Crew Activity Tracking System
CDTI ...... Cockpit Display of Traffic Information
CDU...... Control Display Unit
CFD ...... Computational Fluid Dynamics
CICT ...... Computing, Information, and Communications Technology
CRT ...... Cathode Ray Tubes
CSPA...... Closely Spaced Parallel Approaches
CTR ...... Civil Tiltrotor
CTV ...... Crew Transfer Vehicle
CVSRF ...... Crew Vehicle Systems Research Facility
DAG...... Distributed Air-Ground
DFW ...... Dallas-Fort Worth Airport
DI...... Dynamic Inverse
DIMSS ...... Dynamic Interface Modeling and Simulation System
EFIS ...... Electronic Flight Information System
EGPWS ...... Enhanced Ground Proximity Warning System
EOS...... Experimenter Operator Station
ESIG...... Evans and Sutherland Image Generator
FAA...... Federal Aviation Administration
FB...... Fixed-Base
FFC ...... FutureFlight Central
FLIR...... Forward-Looking Infrared
FMS...... Flight Management System
FOV ...... Field-of-View
FY 01 ...... Fiscal Year 2001
FY 02 ...... Fiscal Year 2002
GPS...... Global Positioning System
GPWS ...... Ground Proximity Warning System

Continued next page...

HAC .... Heading Alignment Cone
HLA .... High Level Architecture
HMD .... Helmet-Mounted Display
HSCT .... High Speed Civil Transport
HSI .... Horizontal Situation Indicator
HUD .... Head-Up Display
ICAB .... Interchangeable Cab
IFC .... Intelligent Flight Control
IFR .... Instrument Flight Rules
IG .... Image Generator
ILS .... Instrument Landing System
IMC .... Instrument Meteorological Conditions
INFPCS .... Integrated Neural Flight and Propulsion Control System
IT .... Information Technology
IVME .... Integrated Vehicle Modeling Environment
JSC .... Johnson Space Center
JSHIP .... Joint Shipboard Helicopter Integration Process
KSC .... Kennedy Space Center
LAN .... Local Area Network
LAWA .... Los Angeles World Airports
LAX .... Los Angeles International Airport
LCD .... Liquid Crystal Display
LDA .... Localizer-Type Directional Aid
LNav .... Lateral Navigation System
MCP .... Mode Control Panel
MIT .... Massachusetts Institute of Technology
MTE .... Mission Task Elements
NAP .... Noise Abatement Procedure
NASA .... National Aeronautics and Space Administration
NASA ARC .... NASA Ames Research Center
NASA JSC .... NASA Johnson Space Center
ND .... Navigation Display
NFCS .... Neural Flight Control System
OEI .... One-Engine-Inoperative
OS .... Operating System
OSD .... Office of Secretary of Defense
OTW .... Out-The-Window
PAS .... Pseudo-Aircraft System
PC .... Personal Computer
PCA .... Propulsion Control Aircraft
PFD .... Primary Flight Display
QI .... Quickened Inverse
RCS .... Radio Communications Simulation
RITE .... Rapid Integration Test Environment

Continued next page...

SAS .... Stability Augmentation System
SCAS.. Stability and Control Augmentation System
SEATAC .... Seattle-Tacoma International Airport
SFO .... San Francisco International Airport
SGI .... Silicon Graphics, Inc.
SHARP .... Slender Hypersonic Aerodynamic Research Probe
SHCT.. Short Haul Civil Tiltrotor
SimLabs .... Simulation Laboratories
SMS.. Surface Management System
SSV .... Space Shuttle Vehicle
STOVL.. Short Take Off/Vertical Landing
TCL... Thrust Control Lever
TMA.. Traffic Management Advisor
TOGA .... Take Off/Go Around
TRACON .... Terminal Radar Approach Control
UCE.. Useable Cue Environment
VAST .... Virtual Airspace Simulation Technology
VLAB .... Virtual Laboratory
VLAN .... Virtual Local Area Network
VMS.. Vertical Motion Simulator
VNav... Vertical Navigation
VOR.. Very High Frequency Onmi-Directional Range
WOD... Wind-Over-Deck

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 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 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 Silicon Graphics, Inc. (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.

ATC Laboratory

The Air Traffic Control 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 Research & Development 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.

FutureFlight Central Research Facility

FFC is a full-scale airport operations simulator that has the look and "feel" of an actual air traffic control tower. It supports cost-benefit studies; provides a stable platform from which new requirements can be derived; enables information sharing among multiple users; and tests software performance, safety, and reliability under realistic conditions.

FFC can be configured to support subsystems that may exist in some airport facilities but not in others. The various operational uses of FFC are enabled by the flexibility of its modular design and adherence to open systems architecture. Using an open architecture allows technology insertion during design iterations and throughout lifecycle upgrades.

The FFC ATC Tower Cab has full-scale consoles and functionally accurate computer displays that replicate controller position-specific equipment. FFC's controller positions are interchangeable to accommodate any air traffic control tower configuration.

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