Flight Simulation
Year in Review
FY 02

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FOREWORD

This is the Fiscal Year 2002 Annual Report for NASA Ames FutureFlight Central (FFC), the Crew Vehicle Systems Research Facility (CVSRF), and the Vertical Motion Simulation (VMS) Complex. It is intended to report the more significant events of FY 02 and includes an Executive Summary with comments on future plans, the FY 02 Simulation Schedule, performance summaries of investigations conducted during the year, and a summary of Research and Technology Upgrade Projects.

Aviation Systems Division
NASA Ames Research Center
Moffett Field, California 94035
25 September 2002

Acknowledgments

Special thanks to Tom Alderete, Dave Astill, Deborah Ballinger, Jim Blount, Dave Carothers, Girish Chachad, Paul Chaplin, William Chung, Bill Cleveland, Steve Cowart, Nancy Dorighi, Dean Giovannetti, Scott Malsom, Joanna Martin, Joe Mastroieni, Julie Mikula, Terry Rager, Kathleen Starmer, Barry Sullivan, and Nancy Tucker for contributions made to the production of this report.

About the Cover

Front cover: Simulations from each of the three SimLabs facilities are depicted on this year's cover.

- FutureFlight Central's Surface Management System (SMS) study is shown at the far left. This was the second SMS simulation, and it further evaluated the SMS concept; it also tested the combined functionality of SMS with the Traffic Management Advisor (TMA). Details can be found on p. 30.

- The center image was created by Ken Lindsay (NASA NeuroEngineering Lab) and is from the Crew Vehicle Systems Research Facility's (CVSRF) second study of the Integrated Vehicle Modeling Environment (IVME). IVME provides a flexible simulation architecture that allows CVSRF to conduct simulations with a variety of aircraft models on one simulator, the Advanced Concepts Flight Simulator. More information about this project can be found on p. 27.

- The picture on the far right shows test pilot Ron Gerdes (Northrop Grumman Information Technology) during the Polhemus Head Tracker Project, conducted at the Vertical Motion Simulator (VMS). This project successfully determined the viability of using a magnetic head tracking system in an interchangeable cab operating in the electromechanical environment of the VMS. Details about this study may be found on p. 37.

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 G-2 aircraft (Dave Carothers, Northrop Grumman Information Technology) depicted here.

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Executive Summary

Introduction

The staff of the NASA Ames Simulation Laboratories is proud to present the Annual Report for Fiscal Year 2002. This report documents the Simulation Experiments and Research and Technology Projects accomplished in three major research and test facilities located at the NASA Ames Research Center: FutureFlight Central (FFC), the Crew Vehicle Systems Research Facility (CVSRF), and the Vertical Motion Simulator (VMS). The year was highly productive, and the staff--teamed with researchers from around the world--successfully accomplished a broad range of aerospace technology research experiments. The scope of research was focused on crucial topics of importance, such as aerospace transportation safety, air transportation system capacity, innovative information technology applications, and the development of advanced aerospace vehicle concepts.

The Aviation Systems Division is responsible for the suite of Simulation Laboratories (SimLabs) at NASA's Ames Research Center. Within the Division, the Aerospace Simulation Operations Branch manages and operates the facilities, the Simulation Planning Office performs the business development functions, and Northrop Grumman Information Technology (IT) performs support tasks as a NASA contractor. With this premier suite of facilities and expert staff, Ames has the capability for high fidelity simulation of all elements of aerospace vehicle and transportation systems, 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 level of safety, consistently excellent quality, and dedication to customer satisfaction. We continue to work with our customers and research partners from government, industry, and academia, to find ways to improve SimLabs' operation and efficiency and to meet the challenges of future research and economic trends.

Key Activities in Fiscal Year 2002

- 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 facility serves as an excellent tool to solve current operational issues at airports, as well as to explore new and exciting concepts for the future. With the Surface Management System (SMS) Project, FFC played a key role, providing the research team with a realistic working environment, essential to designing and integrating a useful decision support tool for managing airport traffic. After six days of testing in FutureFlight Central, preliminary results indicated the SMS has the potential to be an effective tool.
- The Crew Vehicle Systems Research Facility features very high fidelity, full mission, motion-based flight simulation capabilities. There are two hexapod motion base simulator cockpit systems in the CVSRF: a B747-400, FAA Level D certified simulator, and the Advanced Concepts Flight Simulator. Additionally, a full-featured air traffic control (ATC) simulation facility is integrated with each of these simulators. A significant simulation in FY 02 was in support of research that integrated the Neural Flight Control System (NFCS) with the Integrated Vehicle Modeling Environment/C-17 aircraft model. Simulated flight tests were conducted to document the airplane's characteristics and evaluate its handling qualities in normal and failure modes. The NFCS noticeably improved the flight of the aircraft when impaired by failed control surfaces.

- The Vertical Motion Simulator is a complex of simulation capabilities which includes five interchangeable, reconfigurable cockpits, three large multi-channel visual systems, and the world's largest amplitude motion cueing system. An Air Force/Boeing Team utilized the unique capabilities of the VMS to develop flight control system configurations and landing requirements for the Advanced Theater Transport (ATT) project. ATT is an aircraft concept designed for Super-Short Take Off and Landing (SSTOL) operation. This advanced vehicle concept features tilting wings and no tail surfaces. The simulation met all the research objectives and also generated considerable information for design analysis and evaluation. Test pilots and engineers were favorably impressed with the important role that large motion cueing played in evaluating the SSTOL class of aircraft.
- The SimLabs staff made significant progress in the initial stages of the Virtual Airspace Simulation Technology Real-Time (VAST-RT) Project, which will interconnect simulation facilities anywhere in an open architecture and is being demonstrated with the simulators in the Aviation Systems Division. Specifically, the purpose of VAST-RT is to develop real-time simulation tools for exploring new air traffic management technologies that will facilitate an increase in air traffic and ground capacity while simultaneously improving safety and efficiency. The team utilized FY 02 to ascertain and formulate the preliminary Project requirements. This culminated in a successful Preliminary Design Review and delivery of a Preliminary System Design Document.

Looking Ahead to Fiscal Year 2003

SimLabs will begin what is expected to be a long and exciting partnership with the Lockheed Martin Company to develop and conduct Joint Strike Fighter (JSF) simulations. Over the last few years, SimLabs worked with both Lockheed Martin and Boeing during the JSF Concept Demonstrator Aircraft phase. We will now work with Lockheed Martin on the Engineering , Manufacturing, and Development phases, assisting in their study of the aircraft's Short Take Off/Vertical Landing (STOVL) characteristics.

SimLabs is reinvigorating a fruitful partnership with the National Transportation Safety Board (NTSB), assisting the NTSB in accident investigation work. As the understanding of accident causes and causal factors improves, the emphasis in investigations is shifting from final-factor analysis to a forensic approach, which holds promise to yield greater benefits to the safety of the aviation system.

Another long-term effort that has been gaining momentum is the VAST-RT activity, an element of the Virtual Airspace Modeling and Simulation (VAMS) Project. The planning and design effort mentioned above will continue into FY 03, and the work of implementing the various designs and plans will also get underway. The emphasis will shift from requirements definition and preliminary design to building a series of simulations. The VAST design, integrated with existing facilities, will demonstrate the project's capabilities in a series of simulations scheduled in FY 03-04.

What Can Be Found in This Annual Report

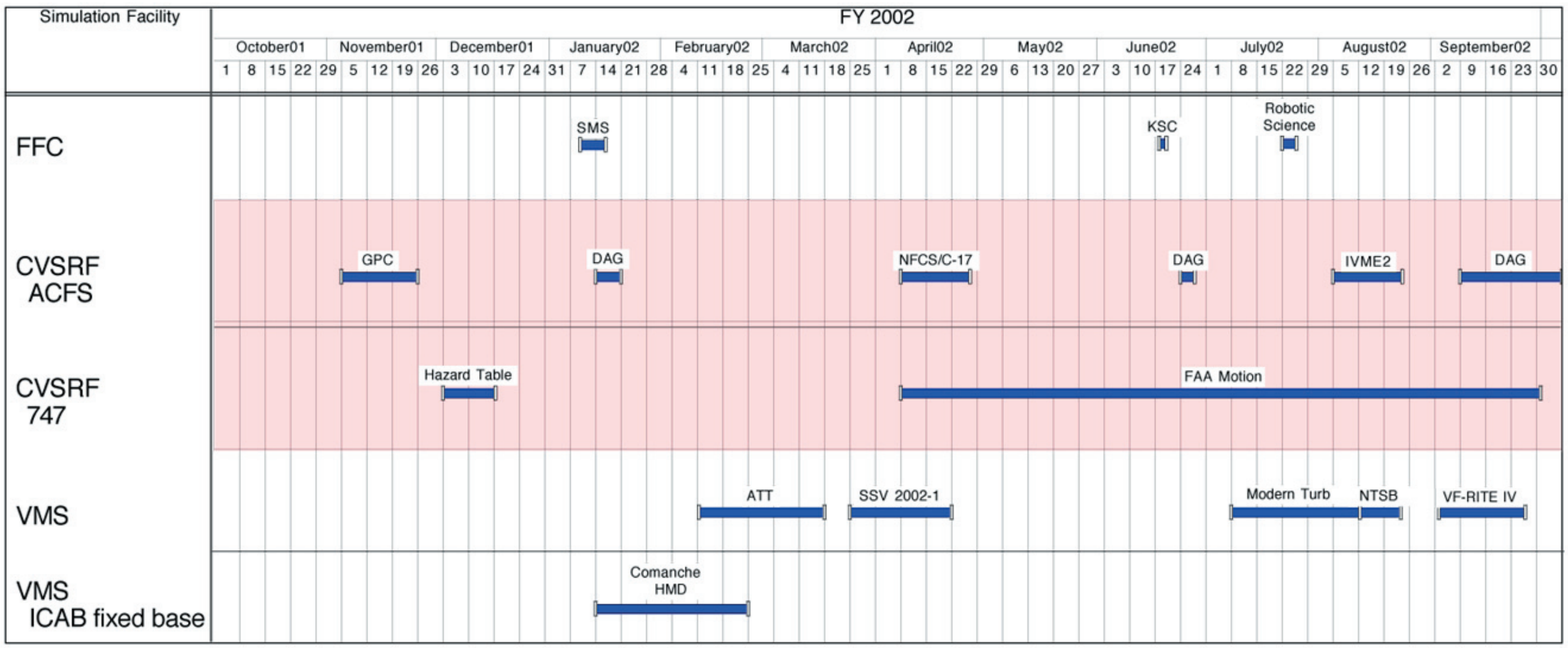
The first section contains the FY 02 Simulation Schedule and Project Summaries. The following sections provide information about the simulation Projects completed in FFC, CVSRF, and the VMS, as well as the Research and Technology Upgrade Projects. Finally, the reader will find a list of acronyms used throughout the report and an appendix containing facility descriptions.

Tom Alderete
Chief, Simulation Planning Office
Aviation Systems Division

Barry Sullivan
Chief, Aerospace Simulation
Operations Branch
Aviation Systems Division

Aerospace Simulation Operations Branch
Aviation Systems Division
Ames Research Center

FY 02 Simulation Schedule



FFC LEGEND:
SMS=Surface Management System
KSC=Kennedy Space Center
Robotic Science=Human-Operated Robotic Science

CVSRF LEGEND:
GPC=Generalized Predictive Control
Hazard Table= Aircraft Hazard Table Development
DAG=Distributed Air-Ground Demonstration
NFCS/C-17=C-17 Neural Flight Control System
IVME2=Integrated Vehicle Modeling Environment

VMS LEGEND:
Comanche HMD=Comanche Helmet-Mounted Display
ATT=Advanced Theater Transport
SSV=Space Shuttle Vehicle
Modern Turb=Modern Turbulence
NTSB=National Transportation Safety Board
VF-RITE=Virtual Flight Rapid Integration Test Environment

FY 02 Project Summaries

FFC Simulation Projects

1. Surface Management System: Second Simulation
Date: Jan 10 - Jan 17, 2002
Purpose: To further evaluate the effectiveness of a decision-support tool which will aid in management of airport surface traffic and to investigate its combined functionality with the Traffic Management Advisor tool.

2. Kennedy Space Center Tower and Console
Date: Jun 18 - Jun 20, 2002
Purpose: To validate optimum tower location, height, and interior layout for the new control tower planned for Kennedy Space Center.

3. Human-Operated Robotic Science Evaluation
Date: Jul 22 - Jul 26, 2002
Purpose: To help develop methods for remote exploration of distant locations.

CVSRF Simulation Projects

1. Generalized Predictive Control for Reconfigurable Flight Control
Date: Nov 05 - Nov 25, 2001 (ACFS)
Purpose: To compare the Generalized Predictive Control System with the Neural Flight Control System for reconfigurable control of a damaged aircraft.

2. Aircraft Hazard Table Development for Turbulence Prediction and Warning Systems
Date: Dec 03 - Dec 17, 2001 (B747)
Purpose: To generate data to aid in the development of a hazard table for four-engine, heavy transport aircraft.

3. Distributed Air-Ground Demonstration 2002
Dates: Jan 14 - Jan 19, 2002; Jun 24 - Jun 28, 2002;
Sep 09 - Oct 04, 2002 (ACFS)
Purpose: To examine interactions between airborne flight crew and ground-based air traffic controllers, with specific emphasis on human factors.

4. C-17 Neural Flight Control System
Date: Apr 08 - Apr 26, 2002 (ACFS)
Purpose: To integrate the Neural Flight Control System of the ACFS with the Integrated Vehicle Modeling Environment of the C-17 model and document handling characteristics under normal and failure conditions.

5. FAA Motion
Date: Apr 08 - Jun 01, 2002 (B747)
Purpose: To investigate the effects of simulator motion cueing in airline pilot transfer of training.

6. Integrated Vehicle Modeling Environment Development II
Date: Aug 05 - Aug 23, 2002 (ACFS)
Purpose: To provide a flexible architecture in the ACFS to simulate various aircraft models, with specific focus on the Boeing C-17 model.

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

Continued next page...

FY 02 Project Summaries

VMS Simulation Projects

1. Comanche Helmet-Mounted Display (HMD) Simulation
Date: Jan 14 - Feb 22, 2002 (FB)
Aircraft type: RAH-66 Comanche helicopter
Purpose: To compare pilot performance using both new contact analog symbology and standard compressed symbology under identical flight scenarios.

2. Boeing Advanced Theater Transport (ATT)
Date: Feb 11 - Mar 15, 2002 (VMS)
Aircraft type: ATT 187-202 transport
Purpose: To examine control system guidelines and landing requirements for the ATT aircraft.

3. Space Shuttle Vehicle 2002-1
Date: Mar 25 - Apr 19, 2002 (VMS)
Aircraft type: Space Shuttle Orbiter
Purpose: To maintain concurrence with upgraded Orbiter software and provide the pilot astronaut corps with training in Orbiter landing and rollout.

4. Modern Turbulence
Date: Jul 08 - Aug 08, 2002 (VMS)
Aircraft type: UH-60A Black Hawk helicopter
Purpose: To evaluate a new rotorcraft turbulence model and examine new control laws which could assist pilots when flying in tight quarters and under degraded visual conditions.

5. National Transportation Safety Board (NTSB)
Date: Aug 12 - Aug 23, 2002 (VMS)
Aircraft type: Commercial transport
Purpose: To assist the NTSB with future transport accident investigations.

6. Virtual Flight Rapid Integration Test Environment IV
Date: Sep 03 - Sep 27, 2002 (VMS)
Aircraft type: CTV8
Purpose: To merge advanced Information Technologies to facilitate flight simulation as an integral part of the vehicle design process.

Research & Technology Projects

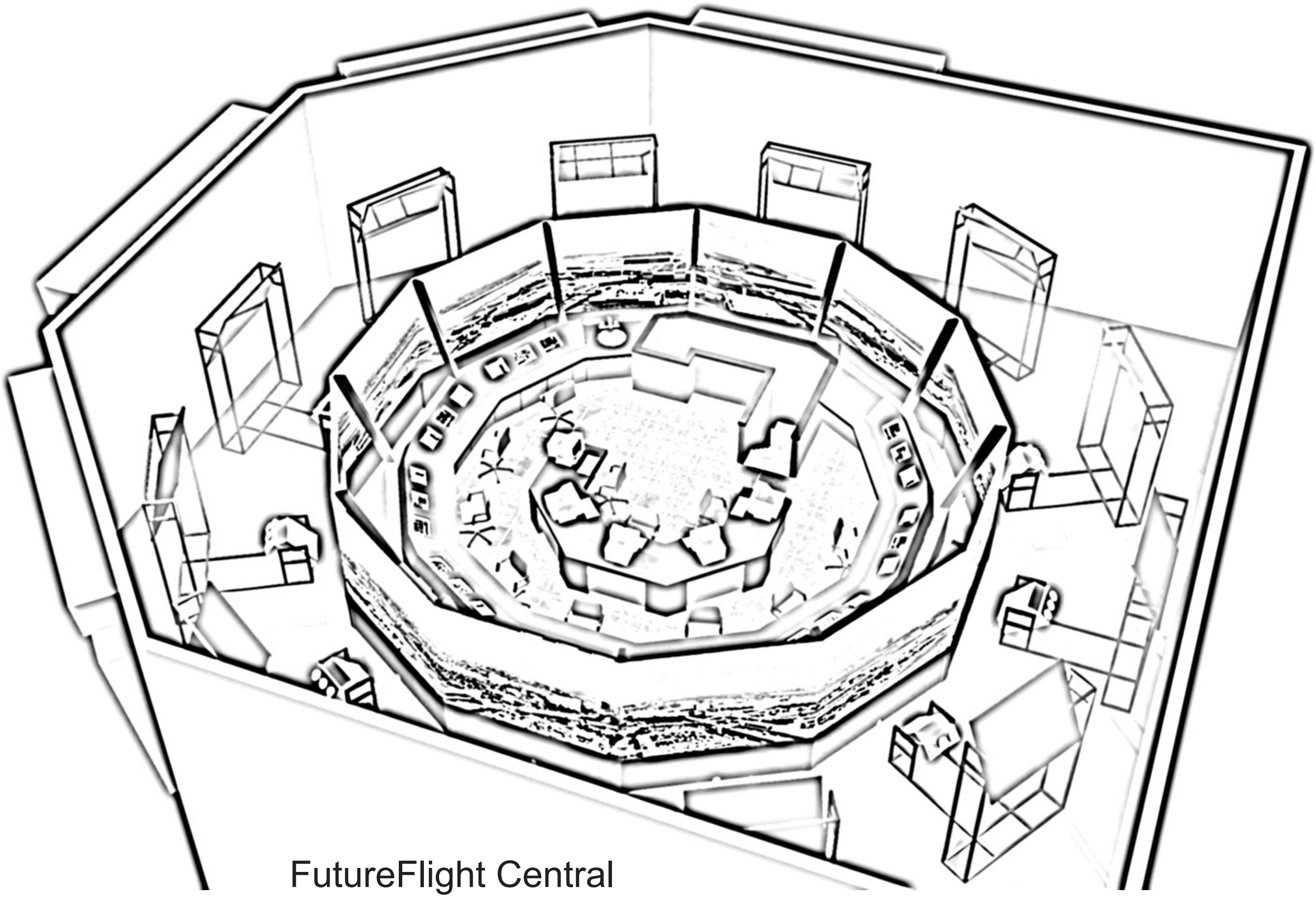
1. Virtual Airspace Simulation Technology Real-Time (VAST-RT)
Purpose: To develop real-time simulation tools for exploring new air traffic management technologies that will facilitate an increase in air traffic and ground capacity while simultaneously improving safety and efficiency.

2. Virtual Laboratory (VLAB)
Purpose: To enhance and deploy a collaborative engineering tool for researchers to interact in real-time with VMS experiments from various remote locations.

3. VMS Digital Motion Control Unit
Purpose: To replace the VMS's analog-based Motion Control Unit (MCU) with a modern programmable digital MCU.

4. Polhemus Head Tracking System (PHTS) Motion Study
Purpose: To determine the viability of using a magnetic head tracking system in an Interchangeable CAB operating in the electromechanical environment of the VMS.

5. Air Traffic Control Lab Upgrade
Purpose: To integrate PC-based systems in the CVSRF while increasing simulation capabilities and reducing maintenance costs.



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.

FutureFlight Central provides capabilities for research in Air Traffic Control and human factors via 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.

Surface Management System: Second Simulation

Deborah Walton, Mike Madson, Marlene Hooten, Boris Rabin, Ken Christensen, Betty Silva, Stephen Atkins, NASA ARC; Chris Brinton, Metron; Susan Lockwood, Seagull Technologies; Jim Hitt, Booz-Allen Hamilton; Farid Haddad, Jim McClenahen, Raytheon; Chris Murphy, Claudine Herbelin, Northrop Grumman Information Technology (IT)

Summary

The Surface Management System (SMS) is a decision-support tool that will help controllers and air carriers manage airport surface traffic. The goal of this second simulation was to further evaluate the SMS concept and performance, and to test the combined functionality of SMS with another tool, the Traffic Management Advisor (TMA).

Introduction

NASA Ames Research Center's Advanced Air Transportation Technologies (AATT) Project, in cooperation with the FAA, is studying automation for aiding surface traffic management at major airport facilities. The SMS is an enhanced decision-support tool that will help controllers and airlines manage aircraft surface traffic at busy airports, thus improving safety, capacity, efficiency, and flexibility.

NASA's goal is to transfer SMS to the FAA by December 2003, for deployment in the Free Flight Phase 2 program to modernize the National Air Space through the introduction of new technologies and procedures. The first SMS simulation (September 2001) evaluated the effectiveness of SMS alone. The second simulation's goal was twofold: to test the combined functionalities of SMS and TMA, and to further evaluate the SMS concept and performance.

TMA, currently in use at the Fort Worth Center, is one of the Center-TRACON (Terminal Radar Approach Control) Automation System tools. It assists TRACON and Center traffic management coordinators (TMCs) in arrival flow management planning. SMS helps tower controllers and TMCs manage departures. The successful linking of SMS's departure management and TMA's arrival management may improve the overall efficiency of an airport.

Simulation

The east side of Dallas/Fort Worth International Airport (DFW) served as the test bed for the simulation study. Five certified professional controllers from the DFW tower, including a TMC and a supervisor, participated in the simulation, controlling simulated aircraft from the east tower. Two other tower controllers from Memphis and Norfolk, VA, airports, as well as representatives from several air carriers observed portions of the simulation and provided additional feedback.

Three of the experiment's six days were dedicated to interviewing the controllers in order to better understand how controllers managed traffic under varying conditions and to evaluate their perception of SMS's performance. During the other three experimental days, three conditions were tested: baseline, SMS alone, and SMS with TMA. Each hour-long scenario was based on actual traffic observed at DFW. The SMS display format was the same for all controller positions.

FutureFlight Central'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. A High Level Architecture (HLA) interface transferred the necessary information to the SMS software.

Results

Interoperability between SMS and TMA was successfully demonstrated. Specifically, cooperative management of arrivals and departures, by using TMA and SMS information together, maximized the use of runways, taxiways, and gates, and thus minimized delays. Additionally, several key observations were made regarding procedures and preferences of local and ground controllers and TMCs.

Stephen Atkins, NASA's Project Lead for SMS, noted, "We learned a tremendous amount…about how controllers assign departures to runways, sequence departures, and select taxi routes, and how SMS can better help tower controllers perform these tasks."

Investigative Team

NASA Ames Research Center (ARC)
Metron
Seagull Technologies
Booz-Allen Hamilton
Northrop Grumman IT
Raytheon

Controllers managing DFW east side traffic in FutureFlight Central, with SMS displays visible.

Kennedy Space Center Tower and Console

Dr. Dawn Elliott, NASA Kennedy Space Center; Ken Christensen, Mike Madson,
Boris Rabin, Betty Silva, NASA ARC; Doug Ernest, Northrop Grumman IT

Summary

A new air traffic control tower is planned for the Kennedy Space Center Shuttle Landing Facility (SLF). This tower will improve safety and efficiency of operations during Space Shuttle landings. FutureFlight Central developed a virtual model of the new tower so that the design could be evaluated by users, thus validating an optimum tower position and interior cab configuration before beginning construction.

Introduction

Located at Cape Canaveral, Florida, and specially designed for landing NASA Space Shuttle Orbiters, the Kennedy Space Center (KSC) Shuttle Landing Facility first opened for flights in 1976. Recently, KSC has planned a more modern control tower that will make Shuttle operations safer and more efficient.

FutureFlight created a virtual model of the SLF so that KSC could evaluate design choices before beginning construction on the new tower. The simulation objectives were to:

- validate the selected location and height of the proposed tower;
- obtain the most usable tower interior design by employing human factors analysis; and
- check for visual obstructions at various tower heights.

The virtual Space Shuttle Orbiter lands in full view in the FutureFlight Central tower.

Simulation

FutureFlight staff developed the 3D model used to create the out-of-the-window view of KSC. The day scene featured vegetation lining the runways and swampy areas; the night scene depicted runway lights and xenon searchlights, thus virtually mirroring the actual environment. FutureFlight also added the Orbiter, the Shuttle carrier, and unique ground support vehicles as new models for this simulation. Other typical KSC aircraft which were modeled included T-38s, G-2s, 747s, and helicopters.

KSC controllers, using the new tower location's view, were able to evaluate three prospective interior tower cab configurations under varying visibility and weather conditions while virtual aircraft took off and landed. In addition, various tower heights and locations were tested.

Results

FutureFlight successfully met KSC's requirements for the simulation of its new tower: the tower location was confirmed, various bush and tree obstructions were noted for future abatement, and an optimum interior tower design was selected. Additionally, the simulation allowed controllers to interact with their new workplace and learn how to operate with increased safety and efficiency in the new environment.

Ed Taff, NASA Shuttle Launch Facility Operations Manager, noted: "FutureFlight Central is a unique NASA capability. It will optimize the working environment...and offer future safety training opportunities. We are fortunate to have this facility available to us as we start our new tower." Dr. Dawn Elliott, KSC Principal Investigator, added, "To conduct a true assessment, it is important to be able to closely replicate the workplace–here lies the strength of this simulator."

In FY 2003, KSC is planning several training simulations, taking advantage of the already-created SLF visual database and unique aircraft models at NASA Ames. In this way, controllers can be trained virtually in preparation for Orbiter landings.

Investigative Team

NASA Kennedy Space Center
NASA ARC
Northrop Grumman IT

Human-Operated Robotic Science Evaluation

Brian Glass, Geoff Briggs, Richard Alena, Kelly Snook, Mike Madson, NASA ARC; Jeff Moersch, University of Tennessee; Jim Saunders, Auburn University; Virginia Gulick, SETI; Stephen Braham, Simon Fraser University; Jen Jasper, Titan; Lori Blaauw, QSS Group, Inc; Samantha Domville, Victor Rundquist, FCCD; Claudine Herbelin, Northrop Grumman IT

Summary

Emulating remote science on Mars, field staff from the Human-Operated Robotic Science Evaluation Project transmitted live panoramic images from the Canadian Arctic to FutureFlight Central's 360-degree tower screens. The research team studied the degree to which reducing communications time delay between controllers and robotic rovers could increase scientific productivity of remote exploration on Mars' surface.

Introduction

Since 1997, geologists and biologists from the Haughton-Mars Project have been studying the Haughton Crater located on Devon Island in the Canadian High Arctic. Researchers have chosen this site because it is an unusually good Mars analog: a well-preserved meteorite impact crater in a frigid, glaciated region with thick underlying permafrost. The conditions there approximate those of the Mars environment at present or earlier in its history.

Future Mars exploration will be carried out by robots controlled from Earth, and the minimum two-way communication delay between Earth and remote robots will be many minutes. When human exploration of Mars begins, crews will operate with much faster communications between themselves and their robotic rovers. As part of the effort to prepare for eventual Mars exploration, the project team studied the degree to which reducing communications time delay between controllers and robots could increase the productivity of remote exploration on Mars' surface.

To accomplish this goal, field staff transmitted live panoramic images from the Canadian High Arctic to FutureFlight Central's 360-degree tower screens, thus connecting by satellite the field team with geologists in FutureFlight's 360-degree field-of-view simulator.

Experiment

Researchers compared three conditions: baseline data collected by a geologist in the field last year; remotely-obtained data; and time-limited data, emulating what might be obtained by a human in a spacesuit prototype. The all-terrain vehicles (ATVs) in the field were operated by humans obeying remote commands; this mimicked the action of robotic rovers. The scientists at Ames, using written instructions, directed the movement of the ATVs in order to collect panoramic, standard, and close-up digital views. Each remote image increased understanding of the local geological features, providing a basis for further field exploration.

Return of the data from the remote sites was a complex task involving the Ames Mobile Exploration System computing and wireless communications infrastructure and a satellite link jointly provided by Simon Fraser University and the Communication Research Centre of Canada. Once the digital images reached FutureFlight Central, they were uploaded to its supercomputer, SGI's Onyx 2 Reality Monster. A script was written to detect new images, make necessary modifications, and then, in near real-time, display them in the 360-degree visual system.

To complete the experiment, a geologist in the field, wearing a spacesuit prototype, surveyed the same sites visited by the field staff on ATVs.

One of many panoramic images transmitted from the Canadian High Arctic for display in FutureFlight Central.

Results

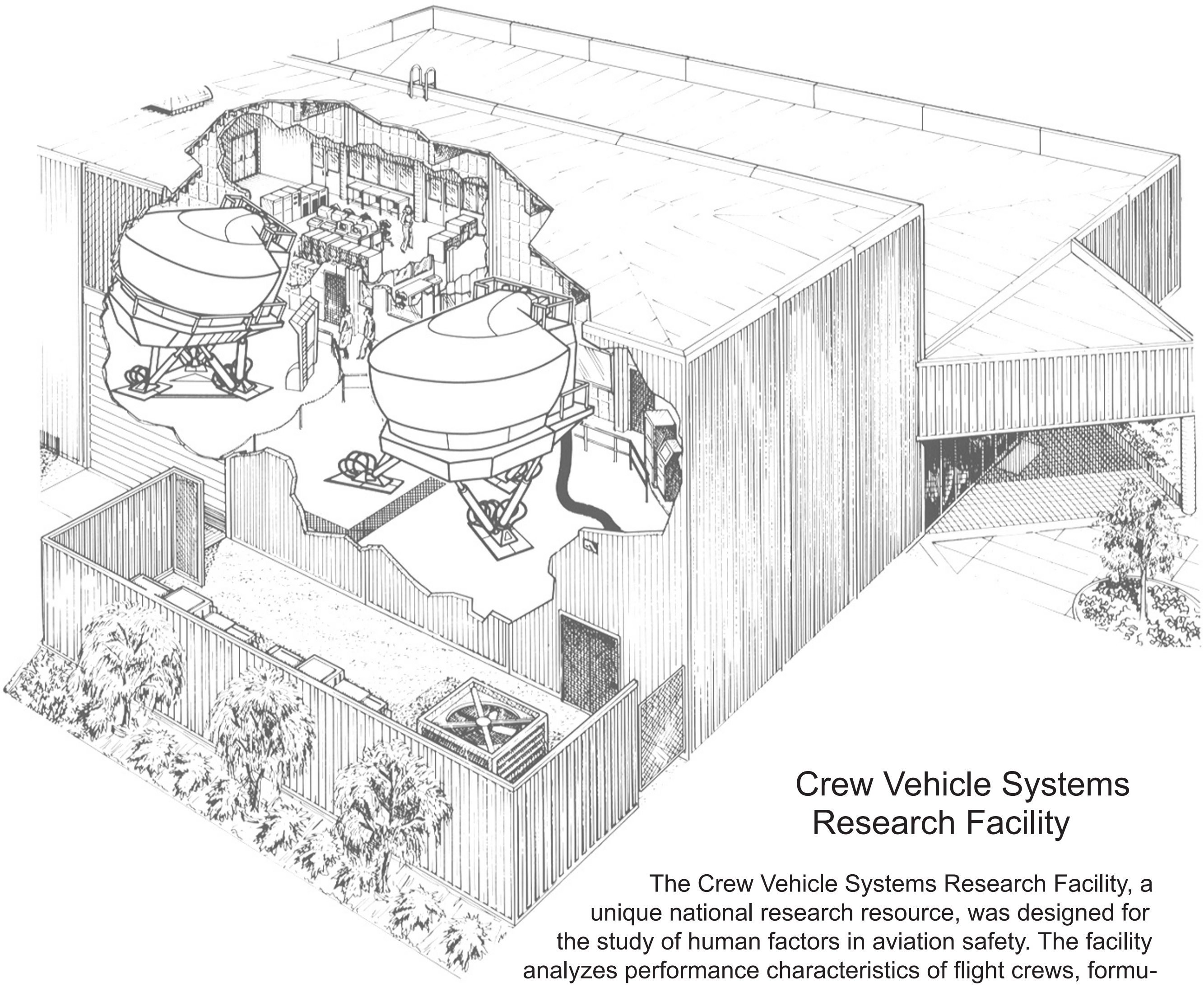
Detailed results are pending. However, "One thing is already clear," said Principal Investigator Geoffrey Briggs, "Our science team found that the panoramic perspective of FutureFlight Central provided them with excellent situational awareness." Based on observational studies in the tower cab, improvements to the software may include more navigational, image processing, and rock/soil sample cataloging tools.

This research demonstrated an alternative use of FutureFlight Central's visual display system. Furthermore, the ability of the facility to receive and display remote-sensing data represents a building block towards a potential future in which real air traffic control could be enhanced using virtual technology.

Investigative Team

NASA ARC
University of Tennessee
Auburn University
SETI (Search for Extraterrestrial Intelligence) Institute
Simon Fraser University
Titan
QSS Group, Inc.
Foothill Community College District (FCCD)
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.

Generalized Predictive Control for Reconfigurable Flight Control

Don Soloway, Karen Gundy-Burlet, Krishna Kumar, NASA ARC;
Don Bryant, Ramesh Panda, David Brown, Northrup Grumman IT

Summary

The purpose of this study was to compare the Neural Flight Control System (NFCS) design with the non-adaptive Generalized Predictive Control (GPC) system design for reconfigurable control of a damaged aircraft. Preliminary results showed that the GPC system performed as well as the NFCS.

Introduction

NFCSs 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. In the Fall of 2000, the Integrated Neural Flight Propulsion Control System (INFPCS) experiment was conducted to examine the effectiveness of NFCS as a means of controlling a damaged aircraft.

GPC uses predictive control schemes that are based on a general model of how an aircraft will respond. In this scheme, the predictive controller works with reference inputs (the pilot's control inputs) and calculates necessary changes to the aircraft control surface positions; this achieves a corresponding reference trajectory that fulfills the intent of the pilot's control input. By focusing on the reference trajectory called for by pilot input, the effects of modeling errors, over-and under-parameterization, sensor noise, system response lags and any effects of aircraft damage are overcome.

View of ACFS cockpit and displays.

This experiment was a follow-on to the INFPCS study. The goal of this study was to investigate an alternative approach to NFCS capable of automatically compensating for aircraft damage or failures. Such a development could reduce the costs associated with flight control law development. Specifically, researchers used this experiment to compare NFCS and GPC under various failure conditions and also to examine the handling qualities of both controllers.

Simulation

The Advanced Concepts Flight Simulator (ACFS) was used as the test platform. The ACFS simulates a Boeing 757-class generic commercial air transport with a wide body, a T-tail, low wings, and twin turbofan engines located beneath the wings.

The tests performed consisted of selected flight maneuvers as well as approach and landing scenarios. The performance of three different controllers was evaluated under normal flight and simulated failure conditions. An additional control authority was developed using symmetric ailerons for pitch control. Simulated failures included frozen flight control surfaces and a failed engine.

Evaluation criteria was based on handling quality ratings for pitch and roll acquisition tasks, fine tracking tasks, 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.

Results

Seventy test runs were flown by NASA test pilots over a three-day period. GPC and NFCS were compared both with and without adaptation. These initial tests show the GPC to be as powerful as an adaptive system and suggest that a non-adaptive controller can work as well as an adaptive controller.

Investigative Team

NASA ARC
Northrop Grumman IT

Aircraft Hazard Table Development for Turbulence Prediction and Warning Systems

James Watson, NASA LaRC; Terry Rager, NASA ARC;
Paul Robinson, Roland Bowles, Bill Buck, AeroTech Research (USA), Inc.;
Diane Carpenter, Jerry Jones, Jim Miller, Charlie Ross, Ghislain Saillant, Northrop Grumman IT

Summary

Researchers generated data to aid in the development of a hazard table for four-engine, heavy transport aircraft. The hazard table will subsequently be used in conjunction with turbulence detection systems to decrease in-air, turbulence-related accidents.

Introduction

Federal Aviation Administration data show that turbulence is the primary cause of in-flight injuries in non-fatal accidents. Furthermore, while turbulence alone doesn't cause crashes, it can set off a cascade of events that ultimately lead to disaster. To address the problem of in-flight turbulence, NASA has established a Turbulence Element under the Aviation Safety Program. As part of its mission, the Turbulence Element mandates the development of a turbulence warning system. To function effectively, this system will require hazard tables for different classes of aircraft. These hazard tables will ultimately work in concert with turbulence detection systems to predict the stresses on aircraft in a given turbulence scenario. Turbulence that is predicted to generate "g-loads" in excess of safe limits will be avoided by pilots in flight; conversely, pilots will be able to save time by not avoiding areas of turbulence predicted to generate acceptable g-loads. SimLabs is helping to fulfill Turbulence Element requirements by supplying data for the development of a hazard table for the "four-engine, heavy transport" class of aircraft using its 747-400 Level D simulator.

Simulation

Simulations were performed for 144 different turbulence scenarios generated by a turbulence spectral model. The scenarios depicted turbulence that was considered likely to be encountered during normal operation of a 747-400. Several variables, including vertical acceleration response of the 747-400 to wind gusts (Figure 1), the aircraft's inboard elevator angle, and the pitch and roll of the aircraft body were measured. Data and pilot comments were collected, and calculations were performed to estimate hazard table values.

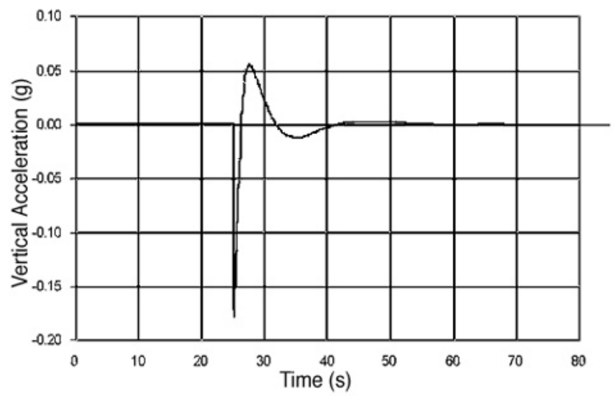


Figure 1. Vertical acceleration response of a 747-400 to a step gust input.

Results

Data for the 144 test conditions were successfully collected. The information generated in this study will be used in conjunction with performance characteristics, altitude, true airspeed, and vehicle weight to determine hazard tables for individual aircraft types and fulfill a critical requirement of the Turbulence Element of NASA's Aviation Safety Program.

Investigative Team

NASA Langley Research Center (LaRC)
NASA ARC
AeroTech Research (USA), Inc.
Northrop Grumman IT

Distributed Air-Ground Demonstration 2002

Richard Mogford, Sandy Lozito, Everett Palmer, Vernol Battiste, Walter Johnson, Nancy Smith, Terry Rager, NASA ARC; Mietek Steglinski, Steglinski Engineering; Thomas Prevot, San Jose State Univ.; Robert Cornell, David Brown, Dave Darling, Ramesh Panda, Gary Uyehara, Dan Wilkins, Ron Lehmer, Joel Rosado, Burnett Lee, Mike Izrailov, Marty Pethtel, Tom Crawford, Northrop Grumman IT

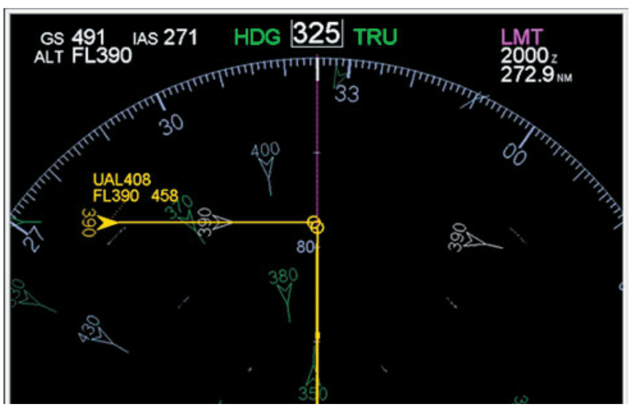
Summary

Distributed Air-Ground (DAG) research examines interactions between the airborne flight crew and ground-based air traffic controllers. A controller facility and several separate locations of simulated piloted aircraft were linked to create the air traffic environment. This simulation demonstrated technologies and procedures related to DAG concepts in the Advanced Concepts Flight Simulator (ACFS).

Introduction

Distributed Air-Ground research is a part of the Advanced Air Transportation Technologies (AATT) Project. It explores three aspects of the National Airspace System: the flight deck, the Air Traffic Control (ATC) environment, and dispatch. This research focuses on human factors.

As part of the research, demonstrations were conducted during January, June, and September of 2002. Each demonstration built upon the previous one. The goal was to integrate and demonstrate incremental improvements in the DAG system. By linking the ACFS and the Airspace Operations Laboratory (AOL), pilots and controllers were able to use DAG tools in real-time simulation scenarios.



CDTI display during a traffic alert.

Simulation

SimLabs' development effort focused on the ACFS. Cockpit Display of Traffic Information (CDTI), a key element of 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 logic. All elements were hosted on a Windows PC. 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 to the ACFS host simulation via the Aeronautical Datalink and Radar System (ADRS). The ADRS, in turn, acted as a gateway to the simulated air traffic and the Center and Terminal Radar Approach Control (TRACON) environments remotely located in the AOL.

The ACFS integrated new versions of CDTI and ADRS as they evolved. For the June demo, ADRS was integrated into the most current ACFS configuration. Changes were also made to the flight management system of the ACFS to accommodate new datalink messages and to improve vertical navigation (VNAV) performance.

A separate project team was created to improve the communications link between the Crew Vehicle Systems Research Facility (CVSRF) and the AOL. Previous experiments reported severe echo feedback and voice clipping when using Voice Over Internet Protocol to connect the CVSRF audio system with the AOL audio system. The team was able to identify and correct a number of hardware problems, as well as create a new radio model for the ACFS ASTi system; this resulted in a reliable connection for an ACFS VHF radio with multiple controller stations in the AOL.

The ACFS was linked to the AOL for the demonstration runs. The AOL provided the simulated air traffic and the Center and TRACON controllers. Flight crews flew the ACFS during the scenarios employing DAG tools. The CDTI airborne logic was used in the Center environment to self-separate traffic conflicts. Self-spacing speed algorithms developed by NASA Langley were available in the Approach phase of flight to examine increased traffic flow.

The Crew Activity Tracking System was integrated into the setup and used to collect data for the final demonstration in September. Data was also collected with the ACFS built-in data collection system.

Results

The ACFS's DAG system was successfully improved with each demonstration. The audio system became more robust with the incorporated improvements which were made throughout the year. Research results are pending.

Investigative Team

NASA ARC
Steglinski Engineering

C-17 Neural Flight Control System

Karen Gundy-Burlet, Krishna Kumar, Craig Pires, NASA ARC;
Dan Renfroe, Bob Cornell, Ramesh Panda, David Brown, David Darling, Northrop Grumman IT;
Don Bryant, Greg Limes, QSS Group, Inc.

Summary

The Neural Flight Control System (NFCS), previously developed on the Advanced Concepts Flight Simulator (ACFS), was integrated with the C-17 aircraft model installed using the Integrated Vehicle Modeling Environment (IVME) architecture. Simulated flight tests were conducted to document the airplane's characteristics and evaluate its handling qualities in normal and abnormal modes. The NFCS noticeably improved the controllability of the aircraft when impaired by failed control surfaces.

Introduction

In the wake of recent commercial airliner accidents, NASA is pursuing the development of intelligent flight control systems that will allow alternative control of aircraft should the primary systems malfunction or fail. The C-17 cargo transport was selected as the model system for use in these developments, and a representative C-17 model was integrated into the ACFS adaptive architecture in 2001.

This experiment was a follow-up study to the Integrated Neural Flight Propulsion Control System (INFPCS) experiment conducted during the previous fiscal year. The goal of this simulation was to integrate the existing ACFS damage-adaptive control systems with the C-17 model and then document the handling characteristics under normal and abnormal conditions.

Simulation

The ACFS was used as the test platform. The simulation model was a wide-body, fly-by-wire C-17 military transport. The aircraft has a four-engine, high-wing, T-tail configuration. Simulated failure conditions consisted of flight control surface failures (e.g., select actuators becoming jammed at a fixed position) and aircraft damage modeled as shifts in the center-of-gravity. NASA test pilots evaluated handling qualities (using Cooper-Harper ratings) during select maneuvers and approach and landing scenarios. Audio and video recordings were made of the test runs, and data were collected using the simulator's built-in data collection system.

Several new capabilities were added to the ACFS. The lower Engine Indication and Crew Alerting System display's Surface Position Indicator was changed to toggle between the C-17 and the Advanced Concepts Transport (default aircraft model) aircraft configurations, displaying the appropriate number of surfaces for the selected aircraft. Additionally, the Experiment Operator Station (EOS) was enhanced to allow the IVME C-17 experiment page to select, modify, and execute all failures and restore the aircraft to a non-failed state. These included the capability to fail flaps independently, as well as symmetrically, and to fail the rudder in the reverse condition relative to pilot input. The EOS Malfunctions Page was enhanced to add the newly created failures. A new Aircraft Set Page was also created on the EOS to adjust cargo and fuel weights as well as the center of gravity of the airplane model.

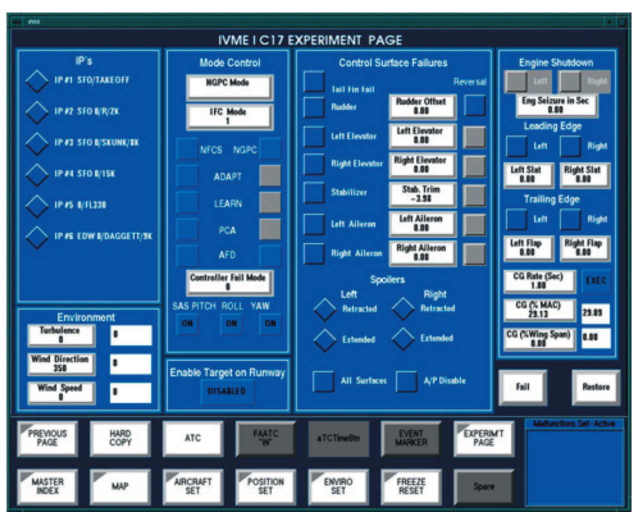
Results

Audio responses of the pilot were recorded, as was video of the out-the-window visual display and selected aircraft cockpit instrumentation. Time histories collected by the ACFS data collection system included pilot inputs, failure modes, and aircraft dynamics, such as, weight, inertia, control surface position, and engine performance. Parameters of interest to the intelligent flight control system were also recorded for further analysis.

The integration of the NFCS controller with the C-17 aircraft model was successful. The controller noticeably improved the flight characteristics of the aircraft in the presence of failed surfaces. This effort will facilitate future research on the application of the NFCS to the C-17 model and lay the groundwork for reconfigurable control design applications on a joint Air Force/NASA C-17 research aircraft.

Investigative Team

NASA ARC
Northrop Grumman IT
QSS Group, Inc.



NFCS experiment control page.

FAA Motion

Judith Burki-Cohen, Yongki Go, DOT Volpe Center; Dave Astill, NASA ARC;
William Chung, Jerry Jones, Charlie Ross, Dan Renfroe, Dave Lambert, Ghislain Saillant,
Diane Carpenter, Jim Miller, Norm Gray, Tom Standifur, Northrop Grumman IT

Summary

This study was part of a joint program by NASA, the Department of Transportation (DOT) Volpe Center, and the FAA to use the B747-400 Level D flight simulator to investigate motion cueing effects in transfer of training.

Introduction

The FAA is considering a requirement that will mandate simulator use for all airline pilot training, testing, and checking. Researchers conducted this experiment to investigate whether the effects of motion aid transfer of training. A previous FAA experiment concluded that platform motion did not have an effect on transfer of training for the maneuvers tested, but concerns were raised on the quality of the motion cues provided by the test simulator. This experiment's objective was to eliminate these concerns by using the NASA Ames FAA Level D-certified B747-400 simulator, with the simulator adjusted to provide more responsive motion cues. Two groups of B747-400 pilots flew scenarios designed with the specific intent of revealing a difference between the effects of motion and no motion.

Simulation

The experiment procedure was comprised of three phases: evaluation, training, and transfer testing. All three phases contained maneuvers chosen from the FAA practical test standards. Four specific maneuvers were selected which, due to their nature, may reveal the effect of motion: V1 Cut, V2 Cut, Precision Instrument Approach, and Sidestep with a Vertical Upset. V1 Cut and V2 Cut involve one-engine failure during take off; Precision Instrument Approach and Sidestep are approach and landing tasks.

Test runs were flown by flight crews consisting of either a Captain or First Officer and a non-flying staff pilot. Half of the subjects went through training with the motion system turned on, and the other half were trained without motion. The two subject groups then flew a final phase with motion on to compare the training effects. Statistical analyses were developed to study a specific subset of parameters in the subjects' performance and workload.

The NASA Ames B747 Level D flight simulator is shown above. The motion actuator drive equations were tuned to use the full range of actuator extension.

Results

Forty current and qualified airline pilots participated in the study, and over 600 runs were recorded. The data for the experiments are being analyzed, and results are pending.

Investigative Team

DOT Volpe Center
NASA ARC
Northrop Grumman IT

Integrated Vehicle Modeling Environment Development II

Karen Gundy-Burlet, Craig Pires, Kalmanje Krishnakumar, Terry Rager, NASA ARC;
Robert Cornell, David Brown, David Darling, David Lambert, Ramesh Panda, Northrop Grumman IT; Don Bryant, Gregory Limes, QSS Group, Inc.

Summary

The Integrated Vehicle Modeling Environment (IVME) provides a flexible software architecture to the Advanced Concepts Flight Simulator (ACFS) which allows for a choice of aircraft models in simulation experiments. The Boeing C-17 aircraft model is the focus of the current research. Data from this project will support the continued integration of a neural flight controller into the ACFS.

Introduction

The IVME architecture was implemented in the ACFS primarily to support Intelligent Flight Control (IFC) research goals. IFC research requires the capability to integrate and test neural flight control schemes for a variety of civil and military aircraft.

During the initial IVME development effort in Fiscal Year 2001, the ACFS was converted to a flexible, multi-airframe simulation architecture, allowing the ACFS to simulate a Boeing C-17 transport aircraft in addition to the original B757-class Advanced Concepts Transport (ACT). In the second part of this ongoing IVME development, additional improvements were made to both the simulation infrastructure and the C-17 computer models to support the integration of a neural flight controller into the ACFS.

Simulation

The ACFS/ACT is a full-mission simulation, 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. The ACFS/C-17 simulation has its own basic aerodynamics, flight controls, engines, and ground handling models, but it uses generic ACFS simulation components in cases where the C-17-specific components are not provided (e.g., avionics).

In support of this study, further improvements were made to the C-17's aerodynamics, flight controls, and engine models. This was done to meet the fidelity requirements for the various normal and failure mode conditions necessary for integrated tests with the neural flight controller. Requirements include the ability to fail individual control surfaces with associated aerodynamic effects and implementation of engine seizure malfunctions.

In addition, the default auto throttle controller was modified to work with the C-17 model. Flight deck displays, including the Head-Up Display, were modified to provide added functionality and symbology more closely depicting C-17 data. The experiment scenario control and aircraft configuration set pages in the Experimenter Operator Station were also tailored for the C-17 and experiment-specific functionality.

The side stick and pedal control force characteristics were completely redesigned to provide desirable handling qualities for ACT operations, as well as meet the C-17-specific requirements. In the case of the C-17, the control rates in pitch, roll, and yaw were matched with US Air Force Acceptance Test Guide (ATG) data for the aircraft.

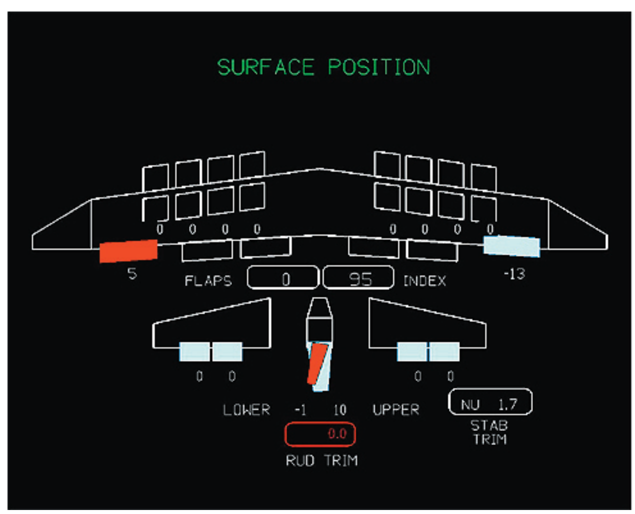
A significant emphasis was placed on model verification by setting up and running C-17/ATG test cases. These tests included take off and landing, pitch, roll and yaw response characteristics. Additional tests to verify engine acceleration, deceleration, and gear change dynamics were also generated.

Results

Development for this activity was completed in August 2002. Piloted runs are tentatively scheduled for FY 03.

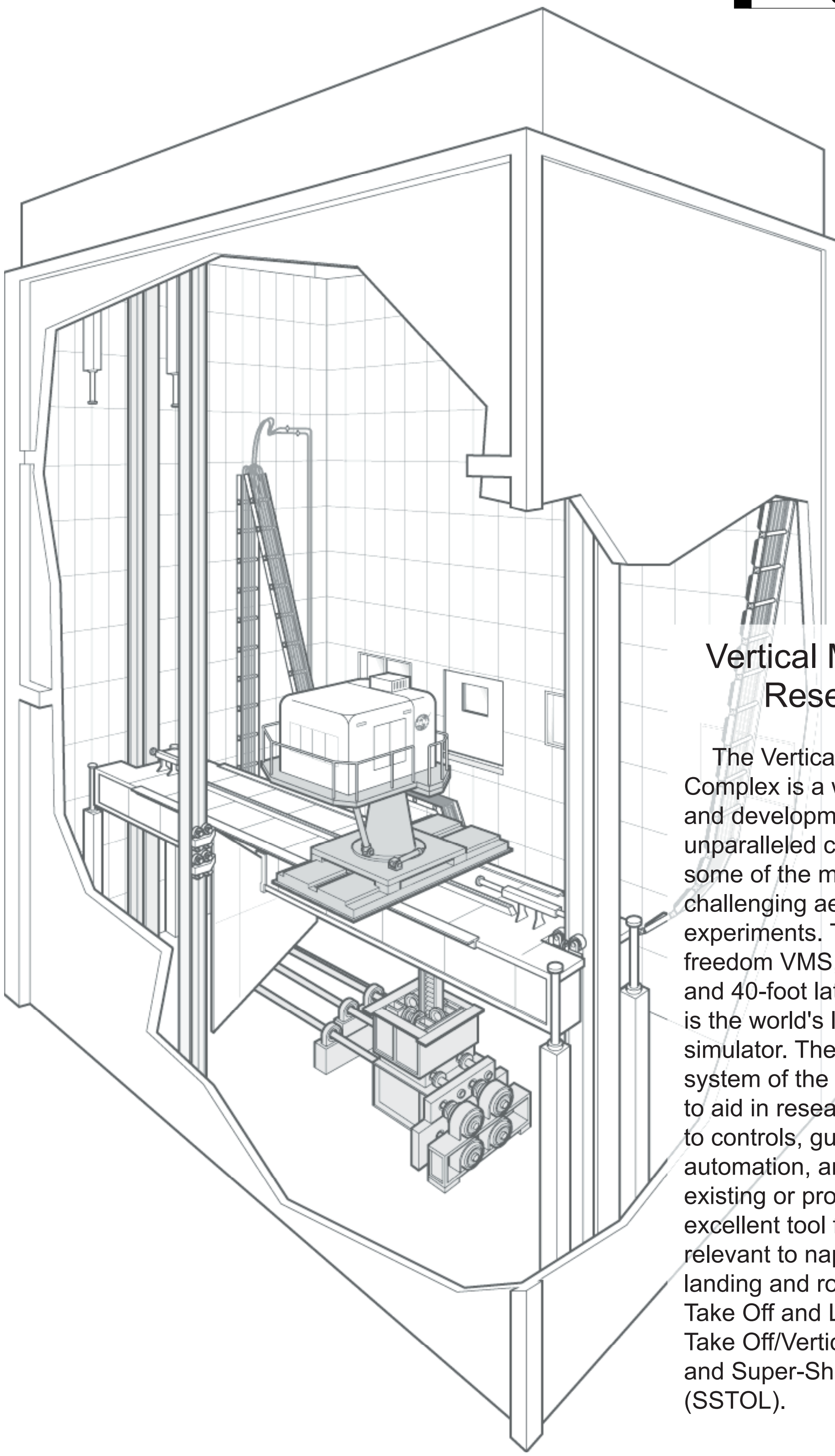
Investigative Team

NASA ARC
Northrop Grumman IT
QSS Group, Inc.



ACFS/C-17 Surface Position display.

VMS PROJECT SUMMARIES



Vertical Motion Simulator Research Facility

The Vertical Motion Simulator Complex is a world-class research and development facility offering unparalleled capabilities for conducting some of the most exciting and challenging 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, landing and rollout studies, Vertical Take Off and Landing (VTOL), Short Take Off/Vertical Landing (STOVL), and Super-Short Take Off and Landing (SSTOL).

Comanche Helmet-Mounted Display (HMD) Simulation

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Susan Dowell, San Jose State University Foundation; Robert Morrison, Chuck Perry,
Estela Hernandez, Shelley Larocca, Russ Sansom, Dan Wilkins, Northrup Grumman IT

Summary

This purpose of this simulation was to compare performance of the Comanche flight symbology with that of the Apache symbology. Emphasis was placed on the differences in heading tapes and horizon lines. This simulation is considered a first step in a series of symbology evaluations.

Introduction

The Comanche is the U.S. Army's next generation scout and attack helicopter and the cornerstone of the Army's Force XXI Aviation Modernization Plan. The Comanche makes use of the latest advancements in technology, including a binocular HMD known as the Helmet Integrated Display Sighting System (HIDSS). The HIDSS will serve as the pilot's primary flight display and uses newly-developed symbology designed to meet the demands of flying the aircraft in all weather and lighting conditions.

Preliminary tests of the Comanche HMD symbology by Army test pilots revealed issues regarding the HIDSS's new symbology presentation style. The simulations conducted at the Vertical Motion Simulator (VMS) addressed these concerns by comparing pilot performance using both the new Comanche contact analog symbology (wherein symbols appear to overlay the real-world objects they represent) and the standard Apache compressed symbology under identical flight scenarios.

Simulation

The principal objectives of the simulation were to study the Comanche implementation of the heading tape, address issues associated with its implementation, and assess symbology usability. To conduct the evaluation, each pilot flew the simulated Comanche while wearing the Comanche helmet upon which a sensor was mounted for tracking head movement. The pilot used the Comanche symbology to fly several runs and perform assigned flight tasks. For all runs, the helicopter's automatic flight control system and forward-looking infrared visual system were used. The pilot then repeated the same runs using the Apache symbology.

To prepare for the simulation, SimLabs personnel modified an RAH-66 simulation model (previously developed at NASA ARC) to implement and validate Boeing's latest flight control system. Engineers developed software to use head tracker information to drive the visual scene and symbology on the HMD, collect and display data for the flight tasks, and provide guidance symbology to the pilot on the HMD. SimLabs developed real-time graphics for the Comanche and Apache symbologies, lab data displays, static map, and Comanche flight instruments. Sikorsky drive laws for the Comanche symbology were integrated into the graphics program, and drive laws were coded for the Apache symbology. The new magnetic head tracker and HMD system were integrated and tested thoroughly prior to simulation use. For additional information, please refer to the "Polhemus Head Tracking System (PHTS) Motion Study" elsewhere in this report.

Results

Seven pilots used the HMD with the two different symbologies to fly the simulated Comanche helicopter. The experiment was successful, completing 866 data runs and accomplishing all objectives.

Results of the investigation, in terms of performance, handling qualities, workload, and pilot comments, produced results for which the numerical differences between the two symbologies were small and the symbology sets yielded categorically similar data. This simulation is the first step of a series of evaluations which will be increasingly operationally-relevant in context.

Investigative Team

U.S. Army
Turpin Technologies
San Jose State University Foundation
Northrup Grumman IT

Pilots were shown an out-the-window view similar to this one while participating in the simulation.

Boeing Advanced Theater Transport (ATT)

Ken Rossitto, Edmond Field, Todd Williams, The Boeing Company;
James Franklin, Chad Frost, NASA ARC; Gordon Hardy, Philip Tung,
Emily Lewis, Steve Belsley, Joe Ogwell, Ron Gerdes, Northrop Grumman IT

Summary

The ATT is an aircraft concept designed for Super-Short Take Off and Landing (SSTOL) operation. The Boeing ATT 187-202 model used for this experiment was a tilt-wing design with four propellers attached by nacelles to the leading edge of the main wing. This study investigated flight control system configurations and landing requirements. The ATT simulation model was developed entirely with Matlab/Simulink Commercial-Off-The-Shelf (COTS) software.

Introduction

Military operations are increasingly taking place in austere settings; consequently, there is a growing need for transports that can travel long distance, carry sizeable payloads, and operate on short, unprepared runways. The ATT is a next-generation military tactical transport that could serve as a replacement for the aging C-130 fleet. Using an ATT model that was developed entirely with off-the-shelf software, researchers designed the simulation to provide control system guidelines and to determine landing requirements for the new aircraft.

The ATT features a tilt-wing configuration.

Simulation

The Boeing ATT 187-202 model was used for this experiment. It is a tilt-wing configuration with four propellers attached by nacelles to the leading edge of the main wing. Critical design factors for this aircraft include the control authority, control actuation rates, and control response types required to perform SSTOL operations in demanding weather conditions. Current information comes from Short Take Off and Landing (STOL) flight and simulation experience collected over three decades ago, and it relates to aircraft configurations with conventional aerodynamic surfaces, mechanical controls, simple rate damper type stability augmentation systems and primitive instrument displays. Consequently, the first stage of the simulation focused on obtaining pilots' evaluation for a range of control response type characteristics and levels of static longitudinal and directional stability specific to the ATT. The modern designs employed in this simulation made full use of digital fly-by-wire controls and electronic displays, and the basic aerodynamic configuration tended toward relaxed static stability with minimal or no tail surfaces.

The second stage of the simulation concentrated on landing performance. SSTOL operations requiring high precision landing touchdowns have generally used a no-flare technique to minimize longitudinal touchdown dispersions. However, the resulting high touchdown sink rates impose significant weight, volume, and complexity penalties on landing gear design. The use of a full or partial landing flare was investigated as a means of increasing touchdown accuracy. Additionally, the effect of a high precision flared landing on pilot workload was investigated.

Simulations were conducted for a total of five weeks on the motion base. In preparation for the experiments, two weeks of fixed-base simulations were performed to validate the simulation system response and finalize flight tasks and scenarios.

Boeing supplied the ATT Simulink block diagrams, and VMS personnel converted the diagrams to C code by using a COTS real-time code generator. This reduced both simulation development time and costs to the customer. Ames-developed Head-Up and Head-Down Displays (from previous simulations) were integrated with the real-time C code and VMS real-time FORTRAN structure. Additionally, a new visual database was built and used for this study.

Results

The simulation met all the research objectives and also generated considerable data for design analysis and evaluation. Test pilots and engineers were favorably impressed with the important role that large motion cueing played in evaluating the SSTOL class of aircraft. They were also impressed with the efficiency of VMS personnel and their ability to build a new simulation from scratch. The proprietary nature of this project precludes the inclusion of detailed results in this report. For more information, refer to the web page http://www.boeing.com/phantom/att.html.

Investigative Team

The Boeing Company - Phantom Works
NASA ARC
Northrup Grumman IT

Space Shuttle Vehicle 2002-1

Howard Law, Greg C. Johnson, Chris Ferguson, George Zamka, Ron Garan, NASA JSC; Ed Digon, Boeing North American; Peter Dailey, Lockheed Martin; Jim Harder, United Space Alliance; Jeff Homan, Estela Hernandez, Northrop Grumman IT

Summary

Simulations of the Space Shuttle Orbiter were performed at the Vertical Motion Simulator (VMS) to provide landing and rollout training for the astronaut corps. Upgrades were made to the math model to increase its fidelity.

Introduction

The Space Shuttle Orbiter is simulated every nine months at the VMS. Researchers have examined 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.

Simulation

Training was provided for upcoming mission crews through a series of flights. Various runways, visibility conditions, and wind conditions were simulated, and system failures were periodically introduced. The math model was enhanced by including the latest software upgrades to the Head-Down Displays (HDD), a wind estimation indicator on a HDD, a new option for the speedbrake logic, the ability to induce Head-Up Display (HUD) symbology misalignment, and additional wind profiles. Two end-of-run data displays were also redesigned to provide more information to both the crew and the researchers.

Space Shuttle landings are simulated every nine months at the VMS.

Some pilots flew a demonstration of Transoceanic Abort Landing (TAL) sites with reduced landing aides. Combinations of the Ball-Bar, HUD, and the Precision Approach Path Indicator lights were disabled for the demonstration. Pilots were asked to rate the difficulty in landing under such conditions in an effort to determine the impact on mission safety.

Modifications to the Head-Down Multifunction Electronic Display Subsystem were made to conform to the latest upgrades in the Orbiter. Changing display colors and some data units have increased display readability and consistency to better assist the crew in landing.

An on-board wind estimator was implemented. Winds during the final phase of entry directly affect energy conditions while flying around the Heading Alignment Cone (HAC) and at touchdown. Currently, no onboard information regarding wind magnitude and direction is available to the crew. The crews evaluated the wind estimator for potential implementation on the actual Orbiter.

The speedbrake model was updated to include changes made to the Shuttle's software. A new short-field speedbrake option for runways less than 8500 feet long was added. This option allows the Orbiter to touch down at slower speeds to stop safely when using shorter runways. This capability is important in an abort situation where the available runway is shorter than nominal.

Researchers also requested the capability to induce a HUD misalignment, because this occurred during one of the actual Shuttle flights. Modifications to the code were made to simulate a hardware misalignment of 0.5 degrees in azimuth on the HUD.

Finally, the STS-108 actual flight wind profile was reproduced in the simulation and flown by the crew during their training.

Results

During the four weeks of the simulation, thirty-eight pilots flew 779 training runs. Ten mission specialists also received training in the jumpseat. All objectives were met for the four-week training. Based upon pilot comments, the crew familiarization phase 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.

All math model upgrades were successfully verified for future use. The TAL Landing Aides Demonstration was completed with two pilots flying 40 data runs. Based on the data and pilot ratings, researchers have concluded that the model at the VMS is ready for a full study of reduced landing aides in the future.

Investigative Team

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

Modern Turbulence

Chris Blanken, Jeff Lusardi, US Army; Vineet Sahasrabudhe, Sikorsky; Steve Belsley, Pat Burnside, Estela Hernandez, Emily Lewis, Northrop Grumman IT

Summary

The Modern Turbulence program was a helicopter handling qualities simulation focusing on turbulence modeling for rotorcraft and modern control laws for the UH-60 Black Hawk. A new turbulence model and advanced Stability Augmentation System (SAS) control laws were implemented. Along with collective tactile cueing, the control laws were tested for improving handling qualities and reducing workload in a degraded visual environment.

Introduction

Typically, turbulence models have been based on fixed-wing aircraft and are not valid near hover. Therefore, helicopter handling quality testing considering the effects of turbulence is challenging. The Army Aeroflightdynamics Directorate (AFDD) of the US Army Aviation and Missile Command developed a new technique--the Gust Extraction to Mixer (GEM) transfer function--to extract the gust characteristics from helicopter flight test data. A gust model generated from this method for a hovering UH-60 was used in this study.

The control system for the current fleet of Black Hawks was designed for daytime flight in good visual conditions. However, the capability is now needed to fly in tight quarters and at night when the visual cues, which pilots need for stabilization, are greatly reduced. Augmentation of the SAS can compensate for loss of these visual cues. The AFDD, in support of a National Rotorcraft Technology Center program, tasked Sikorsky to design an improved SAS. The Modern Turbulence experiment is one step towards putting these modern control laws onto the UH-60M version of the Black Hawk.

Simulation

In this experiment, researchers used the Gen Hel Black Hawk with the baseline UH-60 SAS and the established SORBET turbulence model developed by SimLabs. The first phase of the experiment tested the GEM turbulence model. The second phase evaluated Sikorsky's modern control laws. A number of improvements were made to the graphics to add realism to the out-the-window scenes. A new model of the San Francisco Coast Guard Station was created, and the fidelity of the Moffett Field database was increased. Several new task targets were built, and the task performance displays were optimized through several revisions.

Before the simulation, flight test data were taken at the Coast Guard Station (CGS) at San Francisco Airport using the building as a turbulence generator. The turbulence data were extracted to generate a set of transfer functions representing the gusts.

During the GEM testing, pilots flew the matrix of four turbulence levels with both head and crosswinds, hovering in front of the CGS for two minutes. Data and pilot comments were used to assess the realism and validity of the GEM model. For comparison, equivalent runs were completed using SORBET.

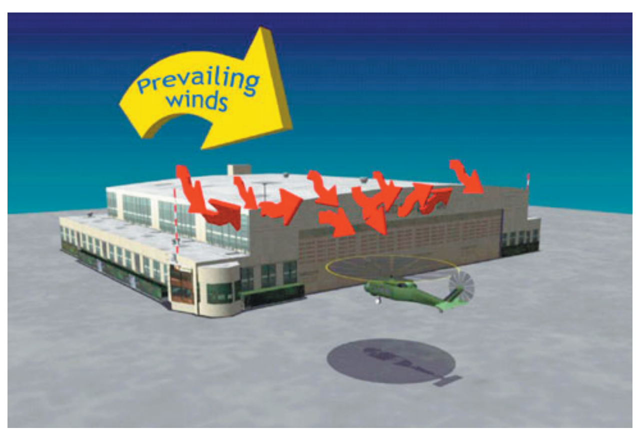
Sikorsky's Modern Control Laws (MCLAW) were delivered in Matlab Simulink diagrams which were used to generate model code. An interface was developed so that Sikorsky variables could be changed and monitored in real-time. The task matrix was comprised of five maneuvers (depart/abort, hover, lateral reposition, pirouette, and vertical) and included flights with the MCLAWs and the baseline UH-60 SAS. Each task was flown with a daytime scene, as well as at night with night vision goggles. Time-history data, pilot comments, and Cooper-Harper handling quality ratings were recorded to evaluate the effectiveness of the new SAS.

Results

Six pilots performed 569 data runs. Pilots reported that the GEM turbulence was very realistic. With these promising results, the researchers are pursuing implementing the GEM model on the RASCAL helicopter. The Sikorsky's MCLAWs showed an overall improvement in handling qualities for all pilots and all maneuvers. Pilot comments were favorable, also, when flying in the degraded visual environment.

Investigative Team

US Army (AFDD)
Sikorsky Aircraft Corporation
Northrop Grumman IT



When wind flows around a large structure, such as a hangar, turbulent airflow is created.

National Transportation Safety Board (NTSB)

Bart Elias, Kris Poland, John O'Callaghan, National Transportation Safety Board (NTSB);
Estela Hernandez, Bob Morrison, Greg Davis, Bill Chung, Northrop Grumman IT

Summary

An evaluation of the Vertical Motion Simulator's (VMS) simulation cueing capability was conducted to determine if the VMS could provide the needed fidelity to meet future NTSB accident investigation requirements.

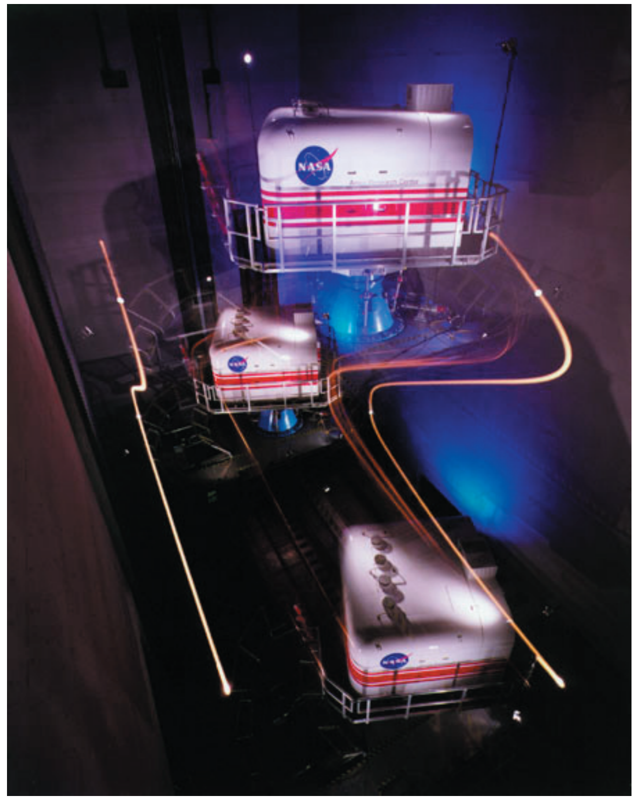
Introduction

To aid the NTSB in aircraft accident investigations, a simulation facility that can recreate the extreme flight conditions experienced in accidents with a high degree of fidelity would certainly be beneficial. The VMS has the world's largest vertical motion system and modular architecture, and, as such, has the potential to become a credible asset for the NTSB when investigating human-in-the-loop issues related to accidents.

Simulation

Three specific simulation capabilities--motion cueing, visual cueing, and aural cueing--were evaluated by the NTSB during this effort. In addition, the capability to reproduce control loader characteristics was also tested to check the compliance of given specifications.

The VMS's motion drive algorithms were adjusted to reproduce the pilot station acceleration cues experienced under extreme flight conditions. All six-axis motion travels in the VMS, including the large vertical and lateral travels, were fully utilized to achieve maximum possible motion sensations. The accelerations produced by the VMS matched the NTSB-provided time traces very well.



The VMS's interchangeable cabs have a full range of motion capabilities.

Various graphic displays, including instrument displays, data displays, and out-the-window visual scenes, were tested to ensure that the VMS had the resources and flexibility to meet NTSB-specified visual cueing and data display requirements. Representative flight test runs were conducted to check and validate the data collection, display, and analysis procedures. A closed audio network was also developed to connect the simulator cockpit and investigator stations, thereby ensuring the security level required by the NTSB.

An example of a simulated aircraft subjected to the extreme flight conditions of a steep angle.

Results

All NTSB-specified cueing requirements were met. Based on NTSB investigators' comments, the NTSB was pleased with the capabilities and performance of the VMS.

Investigative Team

National Transportation Safety Board

Northrop Grumman IT

Virtual Flight Rapid Integration Test Environment IV

Mary Livingston, Jorge Bardina, Susan Cliff, David Kinney, Mark Tischler, Julie Mikula, NASA ARC; Chun Tang, Veronica Hawke, ELORET Corp.; John Bunnell, Joe Ogwell, Jeff Homan, Dan Wilkins, Russ Sansom, Northrop Grumman IT; Kenny Cheung, Sean Swei, Raytheon

Summary

The objective of the Virtual Flight Rapid Integration Test Environment (VF-RITE) project is to produce systems and infrastructure to facilitate the use of aerodynamic data [developed using Computational Fluid Dynamics (CFD) technology] and other Information Technology (IT) tools in a real-time, piloted flight simulation. VF-RITE IV continued to improve the RITE process while studying a new version of the Slender Hypersonic Aerodynamic Research Probe (SHARP) Crew Transfer Vehicle (CTV) developed at NASA Ames.

Introduction

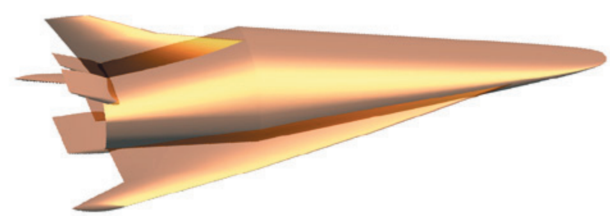
The objective of the VF-RITE project is to produce systems and infrastructure to facilitate the use of aerodynamic data developed using CFD technology and IT tools in a real-time, piloted flight simulation. The subjective and objective flight simulation data will allow the design team to apply "return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

The VF-RITE project is multi-phased. The first phase united separate aerodynamic disciplines to establish the infrastructure for rapid integration of CFD data into flight simulation. The second phase involved redesign of the Space Shuttle's nose for back-to-back comparison of cases with different geometries and the application of return knowledge to the design team. The third phase applied the IT tools developed during the first two phases to the preliminary design of a SHARP CTV. Specifically, RITE III compared newer designs for a SHARP CTV with the previously designed HL-20 and the Space Shuttle Orbiter. This fourth phase studied the latest SHARP concept vehicle, with the goals of improving the flight controls and Head-Up Display and of further improving the RITE process itself.

Simulation

A SHARP CTV geometry was designed, and a baseline aerodynamic model was developed using CFD methods. The flight control system used the architecture developed in RITE III and incorporated improvements derived from previous pilot comments. The control gains were calculated using a control system optimization tool. In addition to the Rotational Hand Controllers (RHCs) currently found in the Space Shuttle, the simulator was equipped with sidestick controllers. Additionally, the CTV's HUD was modified to behave more like the Shuttle's.

Upon completion of the development process, the CTV's stability, control, and handling qualities were evaluated through real-time piloted simulation in the Vertical Motion Simulator. Astronaut-pilots flew three different approach and landing tasks: a straight-in approach with no wind; a lateral offset approach with no wind; and a straight-in, 20-kt wind scenario.



The SHARP CTV8.

The simulation included various options for changing the aerodynamic performance of the CTV in order to assess the potential for design improvements. The rapid development of a failure mode control reconfiguration was also demonstrated.

During the simulation, Virtual Laboratory (VLAB) was used to allow remote participation by researchers at other facilities. The use of VLAB helped facilitate real-time system analysis between the multiple disciplines at different sites.

Results

Design modifications to the SHARP CTV were successfully accomplished using the VF-RITE process. This was done via software changes relating to the geometry, aerodynamic characteristics, and control systems of the vehicle. Modifications were made in support of design and systems analyses to investigate a wide range of lifting body vehicle designs and approach procedures. Tools were utilized to enable rapid changes to the control system and vehicle parameters.

Astronaut-pilots gave Cooper-Harper ratings of the various iteration of the simulated vehicles, providing input for modifications to the vehicles and feedback to the designers. This feedback impacted the designs of the control system architectures, landing gear location, determination of speed-brake gearing, and vehicle lift-over-drag studies. A preliminary control inceptor study was also completed during the course of this simulation.

Investigative Team

NASA ARC
ELORET Corporation
Northrop Grumman IT
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.

Virtual Airspace Simulation Technology Real-Time (VAST-RT)

Summary

The VAST-RT Project was established to help create air traffic management technologies that will facilitate an increase in air traffic capacity while simultaneously increasing safety and efficiency. VAST-RT completed a major milestone in August 2002 with the delivery of the Preliminary Design Review; a preliminary System Description Document was subsequently delivered in September. The major thrust for this Project now turns from requirements gathering and design to constructing the operational code through a series of releases and simulations.

Introduction

The capacity of the nation's air transportation system continues to increase, and according to some analysts, is expected to double over the next ten years. Consequently, much work is being conducted to develop and field new decision-support tools with the goal of improving the air traffic management (ATM) system. These tools, however, are projected to provide only incremental improvements to today's ATM system. In order to meet the demands of the future, revolutionary technologies must be developed to meet the envisioned growth. NASA, working with the Federal Aviation Administration (FAA), academia, and industry, is currently developing a new research program which will create air traffic management technologies that facilitate the doubling of capacity while simultaneously increasing safety and efficiency. Much of the preliminary work in this area will be conducted under a new project, the Virtual Airspace Modeling and Simulation (VAMS) Project.

Project Description

One of the critical elements of the VAMS Project is the establishment of a new virtual airspace modeling and simulation capability for evaluating ATM concepts at both the systems and local levels with the requisite degrees of fidelity. This new capability will examine critical core component technologies and candidate system level concepts and architectures to meet the requirements of the air transportation system of the future. The goal of this new capability is to provide a safe, cost-effective, common, flexible, and accessible platform for evaluating human performance issues related to the development and implementation of future ATM concepts.

The VAST capability consists of two elements: a non-real-time modeling and simulation capability and a real-time, human-in-the-loop simulation capability. The non-real-time system focuses on the development and validation of models and methods for non-real-time assessments of candidate operational concepts. Efforts within this element will produce a suite of tools composed of interoperable models representing the gate-to-gate actions and highly coupled interactions of the key components of the air transportation system. Results and models from the non-real-time element will be applied to VAST-RT.

The VAST real-time simulation will provide a gate-to-gate, national-airspace-wide, human-in-the-loop simulation capability for the assessment of human interactions with airspace operational concepts and their supporting technologies. The real-time simulation will ensure that adequate and credible real-time models and necessary interfaces to human-in-the-loop laboratories and simulators are available to perform high-fidelity human performance and human factors studies to better understand human/system interactions. VAST will provide a national-airspace-wide "closed-loop" environment where decisions made at the local level propagate to the system level and vice versa. VAST will also enhance and expand current human-in-the-loop simulation capabilities, making them more flexible and extensible.

Accomplishments and Plans

The VAST-RT Team has completed the requirements definition phase of the Project and has delivered the Preliminary System Description Document (SDD) to the Project Office. The SDD provides the Project Office and the user community with the requirements and preliminary design for the VAST-RT product as well as providing theory of operations instructions and other supporting documentation. The Project emphasis will now shift to producing the items described in the SDD and to producing simulations. VAST-RT will produce four simulations in FY 03 using all of the NASA SimLabs facilities. At the completion of each simulation, the VAST-RT Team will have demonstrated a new set of tools and will have provided the Project Office with a new capability for use in selecting and evaluating the air traffic management/air traffic control concepts of the future.

Development Team

Scott Malsom, Bill Cleveland, John Griffin, Steve Cowart, NASA ARC; Rod Ketchum, FAA; Leighton Quon, Ron Lehmer, Carla Ingram, Marty Pethtel, Ernie Inn, Paul Chaplin, Bill Chung, Northrop Grumman IT

Virtual Laboratory (VLAB)

Summary

VLAB is a suite of tools that extends the real-time flight simulation engineering and research capabilities of the Vertical Motion Simulator (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 (ARC), Johnson Space Center (JSC), and Marshall Space Flight Center.

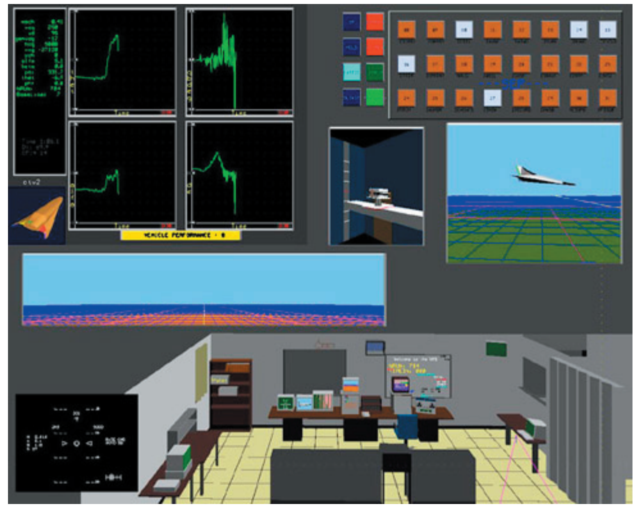
Introduction

The VLAB client system features a fully-navigable 3D replica of the VMS laboratory. It has the capability of moving beyond the physical walls of the lab 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 out-the window (OTW) display, a 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. Hence, both the client and server elements have recently been ported to laptop platforms. In addition to live client systems, a stand-alone demonstration version of the VLAB client system has been developed. Wireless networking has been implemented on Apple client platforms. This provides a truly "portable" client system.

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 Rapid Integration Test Environment (RITE) research team uses multiple VLAB clients at several remote locations to participate in the development of the RITE process.



A typical VLAB display used by researchers.

Currently, clients are supported at ARC, JSC, and Marshall Space Flight Center. VLAB client systems were deployed to support Space Shuttle simulations twice in 2002. The VLAB RITE (VLRITE) client was upgraded for deployment to support a RITE milestone for September 2002. A VLAB client system was demonstrated to the National Review Committee in June of 2002.

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. A native Open GL-based client system is currently under development, as is a Linux-based server. Investigation and tests of state-of-the-art desktop videoconference solutions and an alternative for the Quickplot application are also in progress.

Development Team

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VMS Digital Motion Control Unit

Summary

This purpose of this project was to replace the Vertical Motion Simulator's (VMS) analog-based Motion Control Unit (MCU) with a modern programmable digital MCU. The upgrade improved the reliability and maintainability of this critical system, which will contribute to continued cost-effective simulations for the aerospace community. The new MCU can also be easily expanded to provide additional motion control functions in the future.

Introduction

The MCU provides the interface between the digital world of the simulation host computer and the analog world of the VMS motion system and operator console. It also provides signal conditioning and control functions to operate the VMS. The previous analog MCU system was in operation for over 20 years. It was custom-designed and fabricated in-house before the availability of off-the-shelf programmable digital controllers. It functioned well, but future reliability and maintainability were expected to deteriorate due to the system's age and a lack of available commercial spare parts. These factors provided a strong motivation for upgrading the MCU to a modern digital system.

Project Description

The digital MCU consists of two main parts: the run-time system and a personal computer (PC) with software used for model development and monitoring. The run-time system is a VME (Versa Module European) system with a computer board and a number of data acquisition and communication boards. The MCU functions are implemented in software that runs on the VME computer board. The run-time software was developed with a commercial code-generator designed to implement real-time control systems using a graphical modeling technique. This code was downloaded into the VME computer board where it executes in real-time. The PC generates the run-time code and also functions as a display and system-troubleshooting tool.

In addition to replacing the MCU, this project required a significant change to the network between the simulation host computer and MCU. ScramNet, a commercial shared memory network made by Systran, was used to link the host computer with the new MCU. This change simplified the overall system and thus will improve maintainability and reliability.

The new digital MCU allows users to alter the software with a graphical interface instead of physical hardware circuit changes.

The new MCU's network performance and reliability was thoroughly tested off-line. Integration and acceptance testing was performed during a period between scheduled simulations. Extensive acceptance testing ensured that the new MCU functioned as well as--or even better than--the analog system in regard to safety and performance before it was placed into operational service.

Results

The new digital MCU was placed into service in January 2002 and has many advantages: it is software-programmable, easier to maintain, and easily extensible to include new motion control functions if desired in the future. Moreover, the new MCU replaced the functions of the old unit in a transparent manner to users. An additional benefit of the project was the integration of a ScramNet network into the facility that can be used to add new systems into the simulation network. The new digital MCU has been operating flawlessly since its integration into the VMS.

Development Team

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Polhemus Head Tracking System (PHTS) Motion Study

Summary

Results obtained from the PHTS motion study successfully demonstrated the viability of using a magnetic head tracking system in an interchangeable cab (ICAB) operating in the electromechanical environment of the Vertical Motion Simulator (VMS).

Introduction

The PHTS consists of a radio magnetic transmitter/receiver pair that can monitor a pilot's head motion. A single transmitter module is mounted in the cockpit just above and slightly behind the pilot's head. The receiver is mounted onto the pilot's helmet. The PHTS tracks movement of the pilot's head in three dimensions.

The pilot's head position coordinates are sent to the simulation host computer via a high-speed serial data communication link. The host computer utilizes position information from the PHTS to direct visual imagery on the pilot's Helmet Mounted Display (HMD) to the correct field-of-regard indicated by the pilot's head position. Image position is updated every simulation host frame cycle to provide smooth continuous display movement relative to changes of the pilot's head position.

The PHTS system was successfully integrated into a fixed base ICAB system to support the Comanche simulation. The Comanche research team indicated a desire to use the PHTS on the VMS for future experiments. The primary question was whether or not magnetic fields generated by the electromechanical systems--which drive VMS motion--would interfere with the PHTS radio magnetic signal.

Visual imagery was projected on the pilots' HMDs.

Project Description

A series of tests were developed to quantify performance of the PHTS system in fixed-base and VMS motion environments. A special jig was constructed to allow repositioning of the receiver module (on the helmet) in the yaw, pitch, and roll axes. Physical position of the receiver module was measured with a combination of a calibrated protractor system and electronic inclinometer. This data was then logged and compared to actual receiver position data monitored by the host computer as the cockpit was driven by typical motion check maneuvers. Lastly, a pilot was asked to fly several scenarios using the HMD and PHTS systems in fixed base and motion based operation, and then to comment on performance of the HMD/PHTS system.

Initial fixed based mode baseline testing was conducted in the lab. The ICAB system was then moved onto the VMS where the baseline tests were repeated under both fixed base and motion-based operational conditions on the VMS. Piloted flight scenarios were also repeated in fixed and motion base operational modes on the VMS.

Results

Real-time monitoring and post run analysis of the position data returned from PHTS indicate that the VMS motion environment does not adversely affect the performance of the PHTS. Consequently, the PHTS system can be utilized to support future HMD based simulation experiments on the VMS.

Development Team

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CVSRF Air Traffic Control Laboratory Upgrade

Summary

The Crew Vehicle Systems Research Facility (CVSRF) Air Traffic Control (ATC) Laboratory has been upgraded with 12 Solaris-based PC systems. This will result in an increased number of air traffic controller stations while lowering maintenance and support costs for operations.

Introduction

The CVSRF consists of two full-motion flight simulators and an integrated ATC simulator. Prior to the upgrade, an SGI Origin 2000 server and eight SGI O2 workstations supported the ATC Laboratory. An analysis of future requirements for real-time host computers and development systems in the CVSRF showed that the systems in the Laboratory could be used for other applications and could be replaced by lower cost alternatives. After careful evaluation, the project selected PC-based systems running Linux and Solaris operating systems.

The ATC Laboratory at CVSRF.

Project Description

Phase I involved replacing the SGI server with a dual processor VA Linux server. This was accomplished during FY 2000 so that the SGI could be used to upgrade the Advanced Concepts Flight Simulator (ACFS) with a more powerful host computer. The VA Linux system was assigned the file serving tasks, while one of the O2s performed the High Level Architecture (HLA) gateway functions.

Phase II consisted of porting the software components of the current ATC Laboratory to the new PC hardware. Several applications were migrated, including the HLA gateway and the Pseudo-Aircraft Simulator (PAS) application. PAS was developed and continues to be supported on the Sun Solaris operating system. After evaluation, the recently released PC version of the Sun Solaris operating system was selected to support the PAS application. In this case, the PAS GUI worked in an identical fashion on both Sun workstations and PCs. The HLA gateway application was ported to the VA Linux server. This application provides the HLA gateway for PAS and the two flight simulator systems in the CVSRF.

The final phase of the project entailed end-to-end system testing and integration of the new client systems into the Laboratory. A new PAS scenario was developed and executed on both the SGI and PC platforms. Final integration testing of the new HLA gateway between PAS and the CVSRF flight simulators is scheduled for the first quarter of FY 03.

Results

The ATC Laboratory has been successfully upgraded to 12 operational positions for air traffic controllers and pseudo-pilots. The SGI O2s previously used for these functions were distributed to developers in the CVSRF. The selection of Solaris for the PC client systems will reduce future development and porting costs for PAS, since it will continue to use the same operating system as before. The licensing and support costs of Solaris on PC platforms are also very attractive, especially in this application where there are a significant number of production systems.

Development Team

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ACRONYMS

A
AATT .... Advanced Air Transportation Technologies
ACFS.. Advanced Concepts Flight Simulator
ACT .... Advanced Concepts Transport
AFDD.. Army Aeroflightdynamics Directorate
AOL .... Airspace Operations Laboratory
ARC.. Ames Research Center
ASTi.. Advanced Systems Technology Incorporated
ASTOVL .... Advanced Short Take Off/Vertical Landing
ATC .... Air Traffic Control
ATG .... Acceptance Test Guide
ATM .... Air Traffic Management
ATT.. Advanced Theater Transport
ATV.. All-Terrain Vehicle
AvSTAR.. Aviation Systems Technology Advanced Research Program

B
B747 .... Boeing 747

C
CDTI .... Cockpit Display of Traffic Information
CFD .... Computational Fluid Dynamics
CGS.. Coast Guard Station
COTS .... Commercial-Off-The-Shelf
CTV .... Crew Transfer Vehicle
CVSRF .... Crew Vehicle Systems Research Facility

D
DAG.. Distributed Air-Ground
DFW .... Dallas-Fort Worth International Airport
DOT.. Department of Transportation

E
EOS.. Experimenter Operator Station

F
FAA.. Federal Aviation Administration
FB... Fixed-Base
FCCD .... Foothill Community College District
FFC .... FutureFlight Central
FY... Fiscal Year

G
GEM .... Gust Extraction to Mixer
GPC.. Generalized Predictive Control
GUI .... Graphical User Interface

Continued next page…

H

HAC.. Heading Alignment Cone
HDD.. Head-Down Display
HIDSS .... Helmet Integrated Display Sighting System
HLA... High Level Architecture
HMD .... Helmet-Mounted Display
HUD.. Head-Up Display

I

ICAB .... Interchangeable Cab
IFC.. Intelligent Flight Control
INFPCS .... Integrated Neural Flight and Propulsion Control System
IT .... Information Technology
IVME... Integrated Vehicle Modeling Environment

J

JSC... Johnson Space Center
JSF .... Joint Strike Fighter

K

KSC .... Kennedy Space Center

L

LAN .... Local Area Network
LaRC .... Langley Research Center

M

MCLAW .... Modern Control Laws
MCU .... Motion Control Unit

N

NASA... National Aeronautics and Space Administration
NASA ARC .... NASA Ames Research Center
NASA JSC .... NASA Johnson Space Center
NASA LaRC.. NASA Langley Research Center
ND .... Navigation Display
NFCS.. Neural Flight Control System
NGPC .... Non-Adaptive Generalized Predictive Control
NTSB.. National Transportation Safety Board

O

OS .... Operating System
OTW .... Out-The-Window

Continued next page...

P

PAS .... Pseudo-Aircraft System
PC .... Personal Computer
PFD .... Primary Flight Display
PHTS... Polhemus Head Tracking System

R

RHC... Rotational Hand Controller
RITE .... Rapid Integration Test Environment

S

SAS .... Stability Augmentation System
SDD... System Description Document
SGI .... Silicon Graphics, Inc.
SHARP .... Slender Hypersonic Aerodynamic Research Probe
SimLabs .... Simulation Laboratories
SLF.. Shuttle Landing Facility
SMS... Surface Management System
SSTOL.. Super-Short Take Off and Landing
SSV .... Space Shuttle Vehicle
STOL .... Short Take Off and Landing
STOVL.. Short Take Off/Vertical Landing

T

TAL .... Transoceanic Abort Landing
TMA... Traffic Management Advisor
TMC... Traffic Management Coordinator
TRACON .... Terminal Radar Approach Control

V

VAMS .... Virtual Airspace Modeling and Simulation
VAST .... Virtual Airspace Simulation Technology
VAST-RT... Virtual Airspace Simulation Technology Real-Time
VF-RITE .... Virtual Flight Rapid Integration Test Environment
VLAB .... Virtual Laboratory
VLRITE... Virtual Laboratory for the Rapid Integration Test Environment
VMS... Vertical Motion Simulator
VME... Versa Module European
VTOL .... Vertical Take Off and Landing

Appendix
Description of Simulation Facilities

A brief description of the Aviation Systems Division facilities follows. More detailed information can be found at our web site: www.simlabs.arc.nasa.gov.

FutureFlight Central (FFC) 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.

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 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 (ACFS)

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

The Crew Vehicle Systems Research Facility (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 (VMS) 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 Advanced Short Take Off/Vertical Landing (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.

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