

NASA Ames Simulation Laboratories

2005
Year in Review

www.simlabs.arc.nasa.gov

About the cover

SimLabs' flexible facilities, tools, and talented staff are capable of simulating a wide range of aerospace and aeronautic scenarios. The diverse projects hosted at SimLabs this year included an Unmanned Aerial Vehicle simulation in the Vertical Motion Simulator, a long-range fatigue study in the Crew-Vehicle Systems Research Facility, and an examination of a potential new airport configuration at FutureFlight Central. Aspects of all these projects are depicted on this year's cover, and details of the experiments can be found in the body of this report.

Acknowledgements

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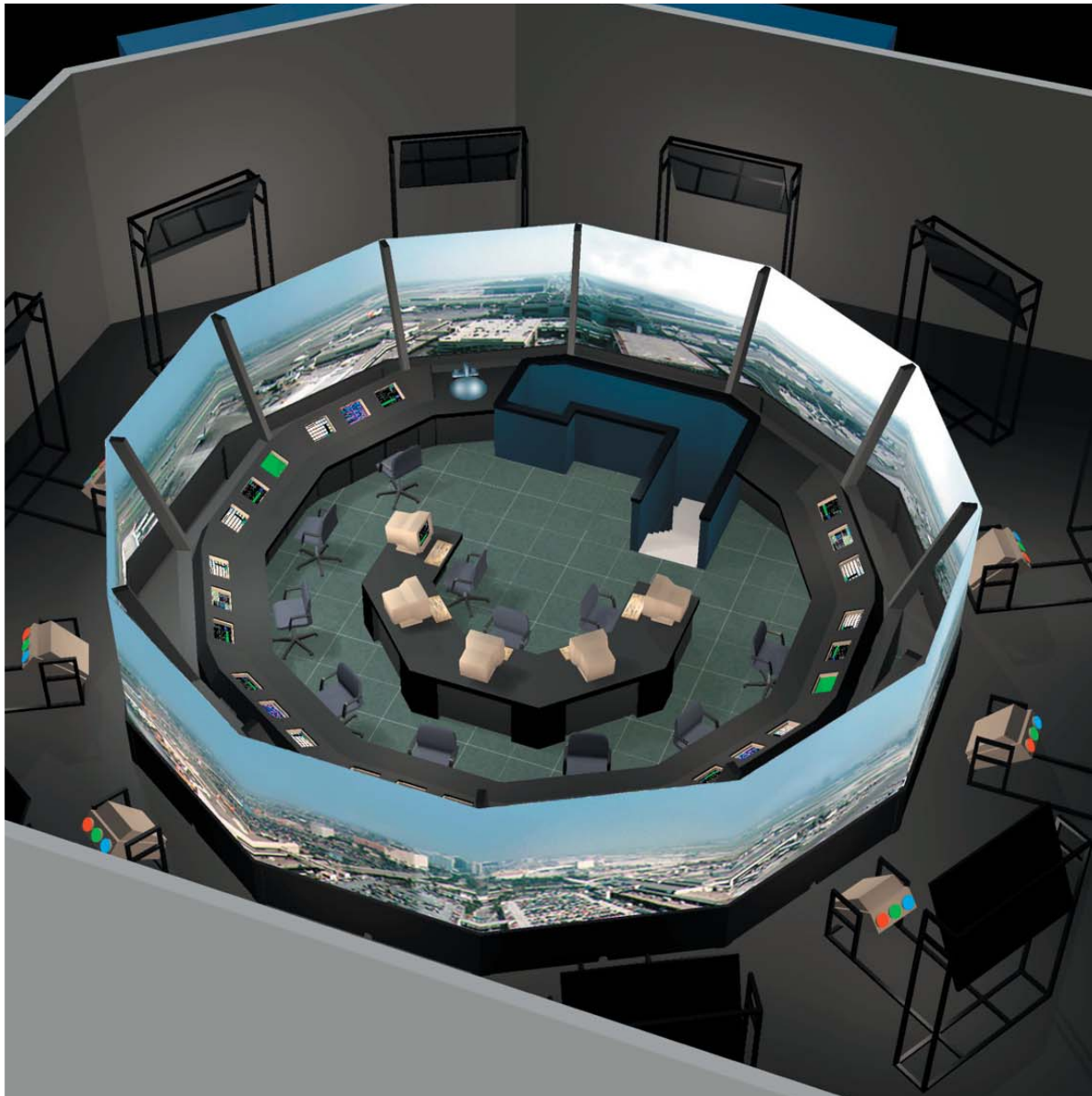


SimLabs, located at NASA Ames Research Center, Moffett Field, California, houses some of the most sophisticated simulation facilities in the world. SimLabs supports a wide range of research, with emphasis on aerospace vehicles, integrated system-level simulation, human factors, accident investigations, airport operations, and studies aimed at improving aviation safety and capacity. SimLabs has partnered with numerous government agencies, industry, and academia, and is strategically important in meeting the Nation's present and future aerospace needs.

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The FutureFlight Central tower cab provides a visually immersive 360-degree field-of-view.



Executive Summary

SimLabs is proud to present our Year in Review for Fiscal Year 2005. This report documents the simulation research and technology projects accomplished in the Simulation Laboratories (SimLabs) that fulfill vital roles in NASA's Missions.

During the past year—and as it has for four decades—SimLabs has made essential contributions to flight vehicle development, aviation safety, Space Shuttle landing operations, flight control and display systems, and the national airspace system. SimLabs has changed significantly over the years with the evolution of NASA's research agenda and the challenge of full cost recovery. However, the requirement for high-fidelity, human-in-the-loop simulation has remained strong.

The Ames Simulation Laboratories consist of three separate motion platforms, four fixed-base development platforms, a virtual air traffic control tower, and air traffic control simulation laboratories.

These capabilities are housed in three complexes referred to as the Vertical Motion Simulator Complex, the Crew-Vehicle Systems Research Facility, and FutureFlight Central. The Aerospace Simulation Operations Branch manages and operates the facilities and contracts with Science Applications International Corporation, which assists NASA in the operation of SimLabs. With this premier suite of facilities and expert staff, SimLabs has the capability for high fidelity, human-in-the-loop 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 the facilities with the highest level of safety, consistently excellent quality, and dedication to customer satisfaction.

We invite the reader to peruse the articles contained within this report to discover the myriad technological issues benefiting from research conducted in the Ames Simulation Laboratories.

Tom Alderete and Dean Giovannetti,
Aviation Systems Division
October 2005



The Advanced Concepts Flight Simulator can be customized to simulate a variety of aircraft.

Simulation Facilities

Ames' Simulation Facilities are national resources, providing unique, strategic capabilities to the research community. The facilities are connected by a High Level Architecture interface, allowing for distributed simulations. A brief description of each facility follows. More detailed information can be found on our website: www.simlabs.arc.nasa.gov.

FutureFlight Central (FFC) Research Facility

FutureFlight Central is a world-class airport operation simulation facility that has the look and “feel” of an actual Air Traffic Control (ATC) tower. This unique facility offers a “fully immersive” virtual airport environment in which planners, managers, controllers, pilots, and airlines can work together in real-time to test software performance, safety, and reliability under realistic conditions. FFC is dedicated to solving present and emerging capacity problems of the nation’s busiest airports and has the capability to support cost-benefit studies of planned airport expansions.

At FFC, it is possible to simulate the most complex airport operations, including real-time peak air traffic control with 12 controller positions, eight ramp tower positions, and 13 pseudo-pilot positions. The controller positions are interchangeable to accommodate any air traffic control tower configuration. FFC’s full-size tower cab is equipped with functional consoles and interactive radar displays. The facility has a modular design that enables information sharing among multiple users with 360-degree views. High-fidelity simulations can be run from the tower under a variety of variable conditions (e.g., weather, time of day, visibility).



The tower cab at FFC.

The simulation facilities at FFC adhere to an open architecture which allows flexibility of operational use and custom configurations. For example, components can be configured to support a variety of subsystems that might exist in some airport facilities but not others. FFC’s open architecture system allows new technologies to be

incorporated during the design phase and life cycle upgrades. The environment at FFC provides a stable platform from which new requirements can be derived, offering pilots and controllers an opportunity to evaluate changes to any airport.

The sophisticated capabilities of FFC allow it to be used as more than just an ATC tower simulator, however. Indeed, FFC can be thought of as a *visualization tool*. For example, FFC possesses a Mars database and could be used as a simulated control center for directing future Mars-based robotic missions. FFC can also be used as an “eye in the sky,” depicting, for instance, spacecraft operations in the vicinity of the International Space Station. For simulations where it is advantageous to visualize scenarios using a three-dimensional, 360-degree format, FFC is the tool of choice.

Crew-Vehicle Systems Research Facility (CVSRF)

The Crew-Vehicle Systems Research Facility was designed for the study of human factors in aviation. The facility is used by researchers to analyze performance characteristics of flight crews, formulate principles and design criteria for future aviation environments, evaluate new and existing air traffic control procedures, and develop new training and simulation techniques required by the continued technical evolution of flight systems. The CVSRF facility supports NASA, the Federal Aviation Administration (FAA), and industry research programs.

Studies have shown that human error plays a part in 60 to 80 percent of all aviation accidents; therefore, continued research to improve safety technologies and procedures is imperative. CVSRF allows scientists to study how errors occur and assess the effects of automation, advanced instrumentation, and factors such as fatigue, on human performance.

The facility includes two full-motion, full-mission-capable flight simulators—a Boeing 747-400 Level D-certified simulator and an Advanced Concepts Flight Simulator (ACFS)—and a simulated Air Traffic Control environment that operates with the Ames-developed Pseudo-Aircraft Systems software. Both flight simulators are capable of full-mission simulation and have advanced visual systems that provide out-the-window cues in the cockpit.

Each simulator has a dedicated experimenter's station for monitoring and controlling the simulator. The experimenter's station contains a suite of computer graphic displays, keyboards, and terminals for interacting with the simulation computers, status lights and emergency controls, communication and audio systems, and other useful equipment. In addition to the main experimenter consoles, each of the simulators has an observer station on board from which experimenters can communicate with the simulator crew or observers.



Pilots flying a test run in the Boeing 747 simulator.

Boeing 747-400 Simulator

The Boeing 747-400 Level D simulator represents the cockpit of one of today's most sophisticated airplanes. It is equipped with programmable flight displays that can be easily modified to enhance the flight crew's situational awareness and thus improve systems safety. In addition, the simulator offers a 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 747-400 simulator provides all modes of airplane operation, from cockpit preflight to parking and shutdown at the destination. The simulator's crew compartment is a fully detailed replica of a current airline cockpit, and all instruments, controls, and switches operate in the same way as they do in an actual aircraft. To ensure simulator fidelity, the 747-400 is maintained to the highest possible level of certification established by the FAA for airplane simulators, which adds to the credibility of the research results collected in the simulator.

Advanced Concepts Flight Simulator (ACFS)

This research tool simulates a generic commercial transport aircraft and employs many advanced flight systems representative of the newest aircraft being built today. The ACFS generic aircraft was conceived and sized on the basis of projected usage needs in the 21st Century. Among its many advanced systems, the ACFS includes touch-sensitive electronic checklists, state-of-the-art graphical flight displays, aircraft systems schematics, and a flight management system. The ACFS is mounted atop a six-degree-of-freedom motion system and uses side-stick controllers for aircraft control.

The ACFS' visual generation and presentation systems closely match those of the 747-400 simulator, and the visual scenes can depict specific airports and their surroundings as viewed from the cockpit at day, twilight, or night. Currently, the ACFS is used to simulate a generic 757-size aircraft and a C-17 transport vehicle. However, the system's built-in flexibility allows it to be configured to simulate a wide range of other flight vehicles in the future, including new aerospace prototypes.

Air Traffic Control (ATC) Simulator

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

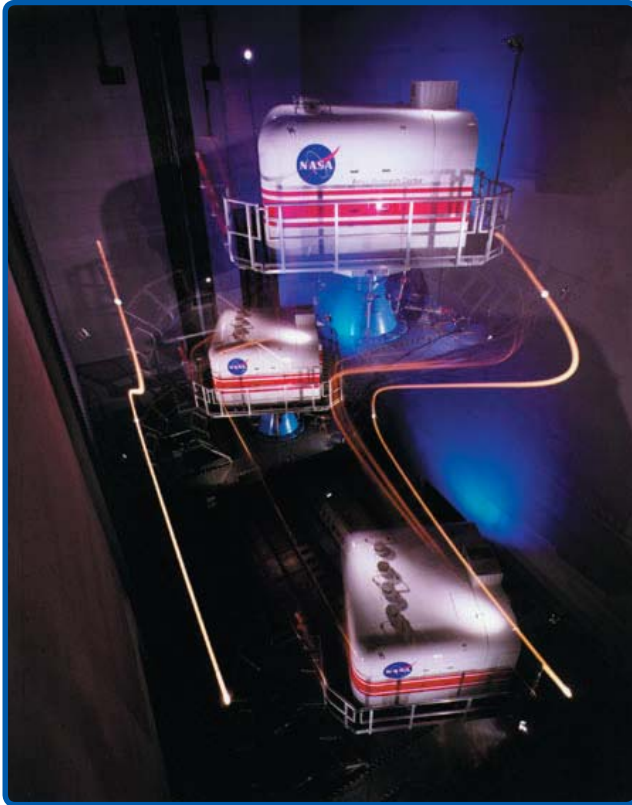
CVSRF's ATC simulator is capable of operating in three modes: stand-alone, without participation by the rest of the facility; single-cab mode, with either the ACFS or the 747-400 participating in the study; and dual-cab mode, with both cabs participating.



CVSRF's ATC simulator can operate independently or linked with the flight simulators.

Vertical Motion Simulator (VMS) Complex

The VMS complex is an important national resource that supports many of the country's most sophisticated aerospace research and development programs. Its motion base has the largest vertical displacement of any simulator in the world, allowing the VMS to provide the highest level of motion fidelity available in the simulation community.



The VMS is the world's largest high-fidelity motion-based simulator.

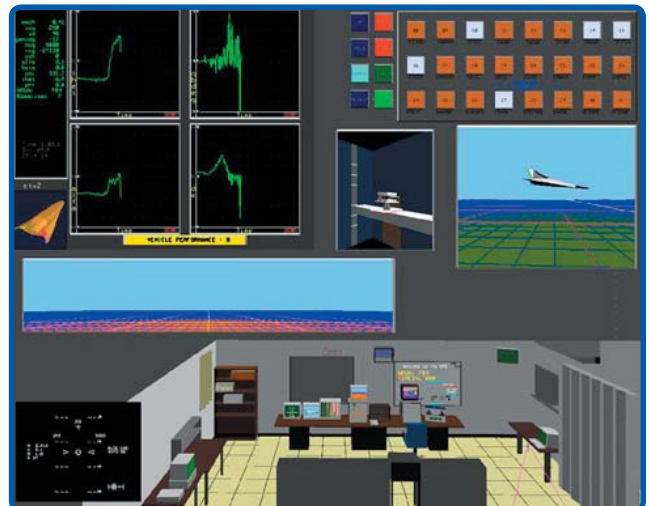
The VMS supports research with three dynamic, flexible laboratories: the motion lab and two fixed-base labs. These laboratories readily lend themselves to simulation studies involving controls, guidance, displays, automation, handling qualities, flight deck systems, accident investigations, and training. Other areas of research include the development of new techniques, technologies, and methodologies for simulation and the definition of requirements for other training and research simulators.

Housed in a ten-story tower, the large amplitude motion system allows the simulator to travel up to 60 feet vertically and 40 feet laterally. The simulator operates with three translational degrees of freedom (vertical, lateral, and longitudinal) and three rotational degrees of freedom (pitch, roll, and yaw), and it can perform at maximum capability in all axes simultaneously.

The operational efficiency of the laboratory is enhanced by the Interchangeable Cab (ICAB) system, which consists of five different interchangeable and completely customizable cabs. The flexibility of the ICAB system allows the VMS to simulate any type of vehicle, whether it is already in existence or merely in the conceptual phase. Each ICAB is customized, configured, and tested at a fixed-base development station, after which it is either used in-place for a simulation at one of the VMS's fixed-base labs or moved onto the motion platform.

Digital image generators in the laboratory provide full-color scenes on six channels, multiple eye points, and include a chase plane point-of-view. The VMS labs maintain a large inventory of customizable visual scenes with a unique in-house capability to design, develop, and modify the inventory of its 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.

Virtual Laboratory (VLAB) is a software tool within the VMS complex that provides a unique approach to aerospace research and development, allowing researchers at distant locales to participate in VMS simulations in real-time. The software is flexible, portable, and capable of operating on a variety of platforms including PC, Macintosh, and SGI. VLAB presents a virtual replica of the VMS lab environment in which a remote user can interactively define specific data and display configurations that will afford the most productivity. Currently, VLAB is used for all VMS Space Shuttle simulations, permitting researchers at Johnson Space Center to participate without leaving their home base. The VLAB concept, however, has a much broader potential, offering researchers the ability to monitor and actively participate in simulations using wind tunnels, flight test facilities, and interoperable labs from any location within the U.S. by remote access.



VLAB allows remote researchers to participate in VMS simulations in real-time.

The Vertical Motion Simulator's completely customizable interchangeable cabs allow virtually any vehicle to be simulated.



Research at SimLabs

Handling Qualities Assessment of the CH-47F/MH-47 Chinook Digital Automatic Flight Control System

Principal Investigators: Chris Blanken and Jeff Lusardi, US Army

Summary

This simulation supported the development and evaluation of the CH-47F/MH-47 Digital Automatic Flight Control System (DAFCS) through piloted flight simulation on the NASA Ames Vertical Motion Simulator (VMS). Evaluations were performed to compare the current CH-47 operational model against expected improvements gained from modern control laws in both nominal daytime and degraded visual environments.

Introduction

The CH-47 Chinook is the U.S. Army's cargo-class helicopter and has a rate command response type control system. It was designed in the 1960s when the Army operated primarily in the day, but with changing missions, the Chinook now operates mainly at night while still using the original flight controls. This has resulted in degraded handling qualities during nighttime operations and has contributed to increased accident rates.

Recently, the U.S. Army CH-47 Program Management Office (PMO) initiated a program to upgrade the flight control system of the CH-47F/MH-47 model with new digital flight control computers, new sensors, and the installation of a Common Avionics Architecture System (CAAS) cockpit. These upgrades will allow for the incorporation of modern flight control laws that can improve the aircraft's handling qualities, especially in the degraded visual environments associated with night, poor weather, and brown-out conditions.

Simulation

Boeing Rotorcraft Systems and the U.S. Army's Aeroflightdynamics Directorate (AFDD) were contracted by the PMO to procure and integrate the new CH-47F hardware and develop modern control flight laws. AFDD support included an assessment of the CH-47 DAFCS control laws in the VMS through piloted evaluations. The motion-based simulations made possible by the VMS are important in providing accurate, realistic proprioceptive cueing for pilots in both hover and low speed environments.

To facilitate the piloted evaluation, a Usable Cue Environment (UCE) rating system was used. The UCE includes all visual information that pilots use to operate a vehicle, including instrumentation and vision aids, such as Night Vision Goggles (NVG). For a clear day, the UCE is 1; at the opposite end of the scale, a moonless, overcast night receives a UCE of 3. For this study, night scenes were flown with NVG, and the night visual environment was modified to obtain a UCE rating of 3 for the hover and depart/abort tasks. A day UCE rating of 2 was evaluated for the hover task, and a rating of 1 was evaluated for the depart/abort task.

Boeing Rotorcraft Systems provided a blade-element math model of a Chinook helicopter. An emulation of the CAAS primary flight display was incorporated into the VMS. Configurations included a baseline CH-47D and various iterations of the DAFCS control laws; environmental conditions included winds, turbulence, clear day scenes, and degraded visual scenes.

Evaluations were conducted using the US Army's handling quality requirements standards for rotorcraft (ADS-33E-PRF). Pilots performed one or more training evaluations per aircraft/task configuration. This was followed by at least three evaluations for use in actual data collection, comprised of pilots' comments and handling quality ratings using the Cooper-Harper rating scale.

Results

The simulation was divided into two sessions. The first session was conducted over two weeks in late August 2004 and resulted in a series of recommendations for incorporation into the second session. The second session was conducted in October and November 2004 for four weeks. Over the course of the study, ten pilots flew 1059 runs. The simulation was successful in adding confidence to the control laws design and ultimately reducing actual flight test time, highlighting the role that Ames' VMS can play in a major acquisition program.

Investigative Team

Boeing Rotorcraft Systems
NASA Ames Research Center
Northrop Grumman Information Technology
US Army



A CH-47 in flight over the Iraqi desert.

The Effects of Ultra-Long Range Fatigue on the Alertness and Performance of Aviators

Principal Investigator: Melissa Mallis, NASA Ames Research Center

Summary

This simulation utilized the Crew-Vehicle Systems Research Facility's (CVSRF) B747-400 simulator to investigate the effects of ultra-long-range flights on the alertness and performance of aviators. Each data collection session was conducted over a period of three days and included a flight from Los Angeles to Singapore that was 19 hours in duration.

Introduction

Long, uneventful flights characterized by physical inactivity, the requirement to remain vigilant for low-frequency occurrences, low light levels, limited social and cognitive interaction, and minimal environmental manipulations present a situation in which any existing sleepiness is likely to emerge. This sleepiness can then result in compromised vigilance, reduced alertness, and impaired performance. New ultra-long range flights, with flight times over 18 hours, may result in crew management challenges and fatigue-related issues that have not previously been encountered. In support of the NASA Ames Fatigue Countermeasures Program, the CVSRF's B747-400 simulator was used to evaluate a representative ultra-long range flight.



Pilots were monitored to evaluate their alertness and performance during ultra-long range flights.

Simulation

Ten flight crews participated in the study between October 2004 and January 2005, with each crew participating over a period of three days. During the first day, two flights were conducted: one for crew training, and a subsequent baseline flight from San Francisco to Los Angeles with a diversion to Ontario Airport. During the second and third days, the ultra-long range flight was a line-oriented flight-training scenario conducted from Los Angeles to Singapore. To support the long-range flight, CVSRF was staffed overnight. Half of the flights were scheduled to depart at 10:57am and land at approximately 6:15am the following day, and the other half were scheduled to depart at 10:57pm and land at approximately 6:15pm the following day. Since timing of the ultra-long range flight was critical to the study, the flight plan was automatically uploaded from the B747-400 host computer, thereby reducing variability in crew cockpit preparation time prior to departure.

During the ultra-long range flight, diversions were encountered due to weather, and the pilots were asked to hand fly segments without autopilot assistance for data collection purposes. Digital, audio, and video data were recorded, and a voice detection circuit was designed and integrated into the B747-400 audio system to detect radio transmissions for use in recording pilot response times. A representative flight plan and scripts for Air Traffic Control and other aircraft communications were created to add realism to the scenario. Members of the research staff used the scripts and participated in the roles of Air Traffic Controllers and pseudo pilots.

Results

Data are currently being evaluated by the Fatigue Countermeasures Program, and the findings will be published for the aviation community's use.

Investigative Team

NASA Ames Research Center
Northrop Grumman Information Technology
San Jose State University

Cockpit Display of Traffic Information II

Principal Investigator: Gordon Hardy, Northrop Grumman Information Technology

Summary

The Cockpit Display of Traffic Information (CDTI) II simulation builds upon research conducted in 2003-2004 and will examine ways of improving safety and efficiency for closely spaced parallel approaches (CSPA) during Instrument Flight Rules (IFR) conditions. Effectiveness of updated cockpit displays, with specific emphasis on traffic and wake information, will be studied.

Introduction

Lateral spacing requirements during CSPA at airports are set so that landing aircraft can avoid turbulence wakes generated by other aircraft during a parallel approach. Landing operations during Visual Meteorological Conditions (VMC) require a minimum lateral spacing between parallel runways of 750 feet (ft). However, during low-visibility (i.e., IFR) conditions, the spacing requirement increases to at least 2500 ft. Consequently, at an airport like San Francisco International where the parallel runways are spaced 750 ft apart, incoming traffic acceptance rate is effectively cut in half during IFR conditions.

Since the original CSPA spacing requirements were determined, new technologies such as the Global Positioning System have been developed. Such technologies offer the possibility of narrowing separation distances for simultaneous approaches during IFR conditions to those used during high-visibility conditions which could, in turn, increase the landing capacity of large airports during inclement weather. Additionally, new algorithms for predicting wake vortex movement may allow instrument operations to be conducted with greater safety than exists for present visual operations.

CDTI research supports NASA's Advanced Air Transportation Technologies Program, which explores prom-

ising technologies for modernization of the National Airspace System. This study is the second in a series that addresses how best to utilize new navigational technologies, synthesize information, and present it to pilots in a useful manner for application during CSPAs.

Simulation

A Civil Tilt Rotor (CTR) was used as the test vehicle for the first iteration in this experimental series. During the inaugural study, a new CDTI was created by modifying the Navigation (NAV) Display to show traffic and wake information. In contrast to the initial test vehicle, CDTI II will use two Conventional Take-Off and Landing (CTOL) aircraft as study vehicles because they are more common and thus of more concern for airports in the near term.

A wake prediction algorithm, developed at NASA Ames and improved specifically for CDTI II, will be implemented to depict predicted hazardous wake areas. This new information, as well as traffic information, will be incorporated into both the Primary Flight Display (PFD) and the NAV display. An improved flight director and pursuit guidance will also be incorporated into the PFD to allow more precise piloting performance during CSPAs.

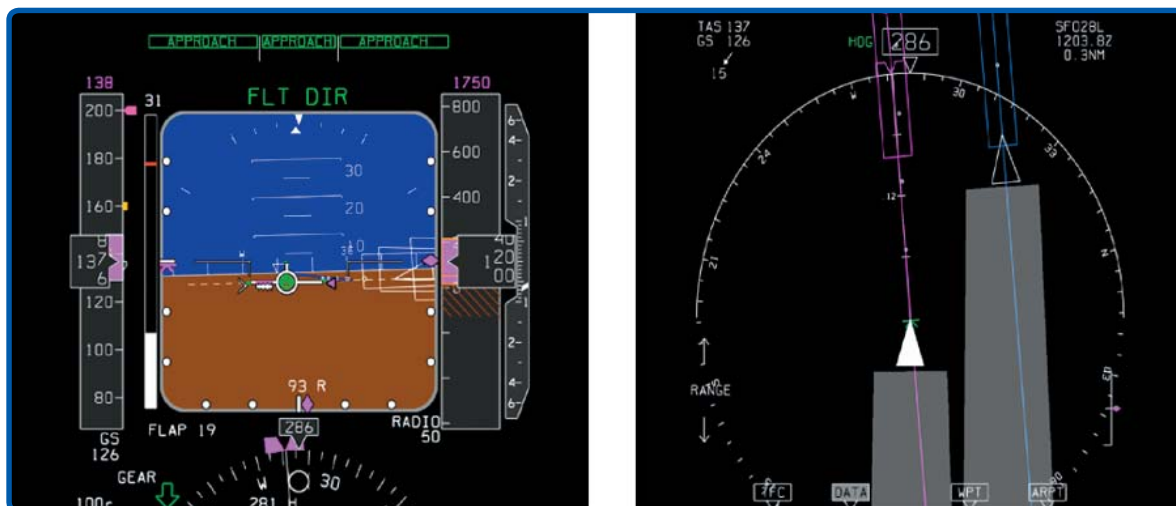
Piloted simulations are pending. Ultimately, researchers will study how CTR pilots utilize the enhanced cockpit displays to avoid wake encounters under varying environmental conditions, including crosswinds, headwinds, and navigational position errors.

Results

Please visit the SimLabs website at www.simlabs.arc.nasa.gov for the most recent status.

Investigative Team

NASA Ames Research Center
Northrop Grumman Information Technology



The candidate Primary Flight Display is shown on the left, and the candidate Navigation Display is shown on the right.

End-Around Taxiway Standards

Principal Investigator: Mark Reisweber, Federal Aviation Administration

Summary

This simulation investigated the use of a barrier and a depressed taxiway to assist pilots in distinguishing whether an aircraft was incurring on an active runway or traveling on an End-Around Taxiway (EAT).

Introduction

A “runway incursion” is defined by the Federal Aviation Administration (FAA) as any occurrence in the airport runway environment involving an aircraft, vehicle, person, or object on the ground that creates a collision hazard. For incursions involving aircraft, one way to reduce such incidents is to minimize the number of runway crossings. At airports with multiple parallel runways, such as Dallas/Ft. Worth International Airport (DFW), these crossing can number close to 2000 per day! The EAT concept addresses this issue by causing airplanes to skirt the main operational areas, preventing the aircraft from crossing active runways while taxiing from one runway to another.

There are presently no regulatory criteria or standards that specifically dictate EAT design or operation. Thus, the FAA is now developing an “End-Around Taxiway National Standard,” of which this evaluation was a part.

Administrators at DFW are considering the construction and operation of EATs for the airport’s north/south runways. A proof-of-concept demonstration was conducted at NASA Ames’ Crew-Vehicle Systems Research Facility (CVSRF) in August 2004 for a proposed EAT at Runway 17R. The demonstration (FAA Technical Report #DOT-FAA-AFS-440-6) indicated that it was difficult for pilots to determine whether an aircraft was incurring the runway or safely operating on the respective EAT. This study was a follow-on investigation to collect data on pilots’ ability to discriminate between aircraft on an EAT versus an active runway and provide initial insight into how any limitations in perception might be addressed.

Simulation

The CVSRF’s B747-400 simulator was operated in take-off scenarios from Runway 17R at DFW in the perimeter taxiway configuration. Every scenario included one B777 on the EAT, followed by either a second B777 on the EAT or a B767 at the ER crossing. Traffic was activated based on the position of the B747 throttles and began taxiing as the B747 began its takeoff roll. The speed of the taxiing aircraft was adjusted so that it was in line with the runway centerline at either the EAT or Taxiway ER when the B747 reached takeoff decision speed (V1).

To assist pilots in distinguishing whether an aircraft was incurring on the runway or traveling on the EAT, aircraft negotiating the EAT system were “masked” (partially hidden from view). Evaluated masking methods included: 1) construction of a barrier; and 2) a depressed EAT. A new removable barrier was created for CVSRF’s DFW visual database and placed 1100 feet from the end of runway 17R. The barrier was International Orange and spanned 350 feet at either side of the runway centerline. The height was changed to mask the EAT aircraft to the top of the engines or the top of the passenger windows. For the second masking condition, a B777 model was cut off below the engines and windows, giving the appearance that it was traversing the depressed EAT because the vehicle was effectively only half as tall as a regular B777.

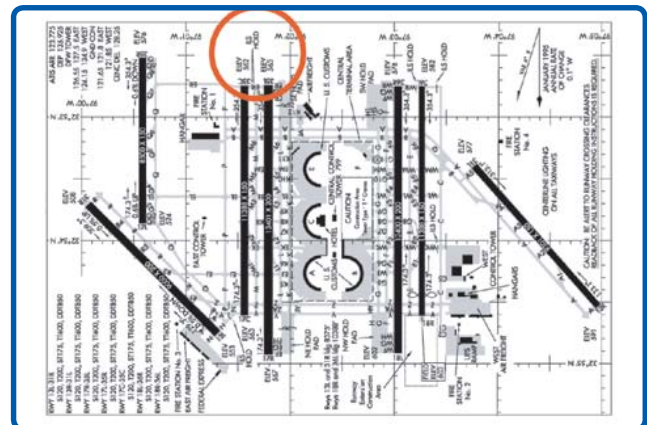
Ten two-person crews participated in this study. Each crew flew 20 scenarios comprised of combinations of no aircraft masking, masking with a barrier at one of two heights, and masking with a depression at one of two heights.

Results

Data will be used to analyze how aircrews develop visual acquisition strategies and how human, environmental, and aircraft design limitations may affect piloting operations. Strategies for dealing with discrimination between aircraft on an EAT and aircraft that may be incurring across the active runway and any potential for desensitization towards those incurring aircraft are of interest.

Investigative Team

Federal Aviation Administration
Dallas/Fort Worth International Airport
NASA Ames Research Center
Northrop Grumman Information Technology



DFW’s current configuration. The dark lines indicate existing runways, and the red circle outlines an area proposed for an EAT.

Space Shuttle Vehicle: Training Sessions in the Vertical Motion Simulator

Principal Investigators: Doug Hurley, Astronaut Office; Jim Harder, Boeing

Summary

Two simulation sessions of the Space Shuttle Vehicle (SSV) were conducted at the Vertical Motion Simulator (VMS) complex to provide landing and rollout training for the NASA astronaut corps. Additionally, SimLabs provided support to the Shuttle Program's engineering and operational safety efforts. These included tire friction model modifications, data capture and display code for threshold crossing parameters, updates to the aero uncertainty data tables, and the development of a new visual database of Halifax International Airport.

Introduction

NASA's Space Shuttle program features the United States' first reusable space vehicle fleet. As originally conceived, the Space Shuttle program was intended to provide routine, economical access to space and deliver a variety of government and commercial satellites to low-Earth orbit. The goals of the Space Shuttle program have evolved over time and now include servicing the International Space Station (ISS), ferrying both cargo and astronauts to and from the ISS.

Since 1980, the Vertical Motion Simulator at NASA Ames Research Center has supported the Space Shuttle program, providing high-fidelity, piloted simulations of Space Shuttle approach, landing, and rollout scenarios for engineering and critical training for the astronaut corps. The corps has extremely high confidence in the technical fidelity of the VMS simulations and all astronaut pilots train at the facility. In addition to giving astronauts experience in landing the Orbiter under typical conditions, the VMS provides a completely safe and cost-effective opportunity for astronauts to train for off-nominal conditions before a possible encounter with such situations during an actual flight. Such conditions include poor visibility, inclement weather, Auxiliary Power Unit failures, Head-Up Display (HUD) misalignment, nose-wheel steering failure, tire failures, and brake failures.

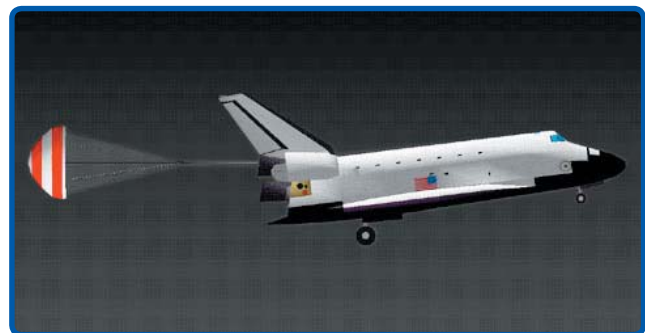
In addition to astronaut training, the VMS offers an efficient, cost effective research platform for subsystem testing and validation of the Orbiter vehicle. Past research has included modifications to the flight-control system, landing systems, and flight rules. That is, in-flight and ground handling qualities can be tested and evaluated in the VMS before the improvements are actually

implemented on the Shuttle. This allows anomalies to be detected and addressed before they become an expensive, in situ problem. Engineering studies are also conducted in the VMS and have contributed greatly to program safety.

The projects and studies at the VMS are enhanced by the use of SimLabs' Virtual Laboratory (VLAB) tool. VLAB's collaborative engineering environment has enabled researchers at Johnson Space Center and Marshall Space Flight Center to interact with VMS experiments in real-time by linking the facilities through a high-speed communications network and interactive software. During Orbiter simulations, remote researchers use VLAB to view live data from the VMS, communicate with the pilot and on-site researchers and engineers, and interact with simulations, thus making efficient use of the Shuttle Program schedule and funding resources.

The VMS is playing a critical role in the fleet's operational safety by providing enhanced training for the corps, not only in the realm of landing and rollout, but also with "abort on ascent" scenarios. In addition to the standard end-of-mission landing sites (including Kennedy Space Center, Dryden Air Force Base, and White Sands Missile Range), the VMS currently has 17 Shuttle abort landing sites in its database, covering most abort options for standard Shuttle missions.

The primary focus of this year's Shuttle simulations was astronaut training. Additional work included tire friction model modifications, data capture and display codes for threshold crossing parameters, updates to the aero uncertainty data tables, and development of a new visual database of Halifax International Airport.



Simulated Space Shuttle with parachute deployed.

Simulation

For this fiscal year, training was provided for upcoming mission crews during two sessions of flight simulations, including a session prior to STS-114 (“Return to Flight”). Various runways, visibility conditions, and wind conditions were simulated, while system failures such as tire failures and HUD misalignment were periodically introduced.



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

The math model for the tire spin-up friction model was enhanced for lake bed landings, such as might be encountered at the Edwards or White Sands landing sites. This new model accounts for spin-up friction on a per-tire basis. A second modification modeled the situation for two tires failing simultaneously.

Several changes were developed for data recording and display of parameters relevant to crossing of actual (nominal) and displaced runway thresholds. Six new navigational offsets were added to the training matrix. Two sets of changes were installed that consisted of updates to the lateral and longitudinal aero uncertainties data tables. All check cases were successfully repeated for validation purposes.

Another modification involved the expansion of the SSV visual database to include the Halifax International Airport in Nova Scotia, Canada. This included four major runways along with the ground markings and navigational aids.

An additional test situation was inserted to support the Shuttle-to-Shuttle rescue capability, called STS-300. This situation involves a quick response to launch a second Orbiter should the need arise to assist in a mission emergency. A special set of conditions (I-Loads) were developed to accurately simulate the landing for an STS-300 mission.

Results

During the crew familiarization simulations, various atmospheric and failure conditions were presented to the pilots, including a variety of winds, visibility, tire failures, chute deployment speeds, wind gusts, night scenes, backup flight system failures, navigation offsets, and TAL/ECAL runways. For the first (Spring) VMS simulation session in FY05, 30 astronaut pilots participated in the Orbiter training matrix and flew 430 training runs. Five mission specialists also participated. In the Fall VMS/Orbiter session, 25 astronaut pilots and eight mission specialists flew 439 training runs.

Based upon pilot comments, the crew familiarization phase of the simulations reinforced the importance of the VMS in preparing upcoming crews for the landing and rollout phase of the mission and for possible failures during that phase. The researchers met all objectives for crew familiarization and training.

Investigative Team

Boeing North American
Lockheed Martin Engineering and Services Corporation
NASA Ames Research Center
NASA Johnson Space Center
Northrop Grumman Information Technology
Science Applications International Corporation
United Space Alliance



Space Shuttle Endeavour landing at Edwards Air Force Base.

Evaluation of Modified Air Traffic Control Phraseology for Area Navigation Standard Instrument Departure Clearances

Principal Investigator: Evan R. Darby, Jr., Federal Aviation Administration

Summary

This study evaluated modified phraseology and procedures proposed for use by air traffic controllers when issuing Conventional and Area Navigation (RNAV) Standard Instrument Departure clearances (SIDs).

Introduction

The FAA has begun deploying new RNAV departure (i.e., SID) procedures at selected airports and monitoring the resultant performance over the past two years. Although the pilots' accuracy and consistency using the new procedures have generally been excellent, several exceptions have been noted. Some of the deviations from the preplanned departure tracks have been attributable to navigational equipment failures and errors; however, many cases of non-compliance have been traced to human factors issues associated with pilot/controller or pilot/Flight Management System (FMS) interaction. These issues included misunderstandings concerning the actual clearance sent and misunderstandings of the intent of the clearance. Because of these anomalies, the FAA and industry have formed an RNAV Task Group to develop more effective guidance and instructions for pilots and controllers when using RNAV SIDs.

In analyzing failures to comply with RNAV SID clearances, one problem that surfaced concerned Air Traffic Control (ATC) phraseology. When issuing clearances to rejoin the departure route after required altitude, speed, and/or heading changes had been achieved, the intent of the issued instruction was not effectively communicated to all pilots. The Pilot/Controller Phraseology and Procedures Action Team (P/CPP AT) was convened to address such issues and has identified an operational need to establish "Climb Via" procedures and phraseology for SIDs. In order to study the new phraseology in an operational setting, the P/CPP AT developed several departure test scenarios for examination in cockpit simulators.

This simulation occurred during the second half of a two-phased study. The first phase involved a series of cognitive walkthroughs with pilots, designed to elicit narrative descriptions of the actions pilots would take in the context of selected departure scenarios and thereby characterize the nature of any potential problems that may exist in interpreting and executing RNAV SID clearances using the newly-proposed "climb via" phraseology. The second phase focused on issues identified as potential problems during Phase One, wherein a one-week simulation was conducted at the Crew-Vehicle Systems Research Facility (CVSRF) to investigate these issues in a realistic flight environment.

Simulation

The B747-400 Simulator was operated in RNAV departure scenarios conducted in the Las Vegas/McCarran International Airport airspace using a modified SHEAD 3 (RNAV) SID. The SHEAD 3 departure was selected because it contains requirements to cross waypoints at or below, at, and at or above specified altitudes.

During each departure scenario, two researchers sat behind the flight crews and performed the roles of ATC and test observer. Multiple variations of control instructions were issued containing proposed Climb Via phraseology. Flight deck observations of pilots' interactions with each other, with flight deck automation systems, and with ATC were noted. Audio, video, and objective measures of performance (aircraft track data, vertical/lateral compliance, etc) from the B747's data reduction and analysis capabilities were also recorded. Afterward, pilot feedback was solicited regarding any confusion or uncertainty with the departure procedures or verbal ATC instructions.

Results

Twelve two-person crews participated in the study over a period of three days. Preliminary data suggest that without sufficient aircrew training, there is significant potential for the current Climb Via phraseology to generate pilot confusion. This confusion results in additional voice contacts with ATC for the purpose of confirming the intent of a given "Climb Via" instruction and is an undesirable effect. Further detailed analysis of the data will ultimately contribute to several efforts, including further enhancement of Climb Via instructions, Pre-Departure Clearance protocol, and standardization of the depiction of "TOP ALTITUDE" on all SIDs.

Investigative Team

Federal Aviation Administration
NASA Ames Research Center
Northrop Grumman Information Technology



A simulated aircraft on departure.

Manned-Unmanned Teaming Simulation with Control of Multiple Unmanned Aerial Vehicles

Principal Investigators: Susan R. Flaherty and R. Jay Shively, US Army; Terry Turpin, Turpin Technologies

Summary

The US Army conducted a manned-unmanned teaming (MUT) simulation in NASA Ames' Vertical Motion Simulator (VMS) utilizing an attack helicopter flight model networked with a tactical Unpiloted Aerial Vehicle (UAV) ground control station (GCS). Display concepts and potential strategies for control of multiple UAVs teamed with a single, manned aircraft were investigated.

Introduction

Tactical UAVs are generally controlled from either a GCS or from the cockpit of a manned vehicle (e.g., an aircraft.) In the latter case of manned-unmanned teaming, Army experiments have found that UAV pilots can incur a high workload, likely due to the non-optimized pilot-vehicle interface currently employed in such operations. These complicated interfaces include displays for maps, navigation aids, and sensor information from both the ownship and the UAVs under the pilot's control. Several studies and flight tests are underway with the goal of streamlining and optimizing these interfaces, thereby reducing the pilots' workload. One such study was the MUT simulation, conducted at the VMS in 2005. This study was an extension of previous Army studies and investigated aircraft control relationships and display concepts for multiple UAVs controlled from a single manned aircraft.

Simulation

The primary objectives of this experiment were to: 1) investigate the effect of different UAV employment techniques on mission effectiveness; and 2) to compare pilot workload and performance under different display presentations. Test pilots flew simulated missions in the role of a co-pilot gunner controlling 2 UAVs from an attack helicopter. Pilots' mission performance and workload were examined for various display configurations, vehicle control relationships, and levels of control (LOC). Specifically, three display configurations of the sensor views (from the two UAVs and the ownship) were presented on two multi-function displays. Additionally, pilots could control the two UAVs via either a "yoked" relationship or as two independent UAV entities. The LOC varied by allowing the pilot to control both the flightpath and the sensors of the UAVs, or only the UAVs' sensors.

This simulation leveraged the High Level Architecture (HLA) in place at the VMS, which was originally employed for the Virtual Airspace Simulation Technology Project (see page 22 of this report). Rather than port

a UAV simulation into the VMS' systems, the VMS was linked to the Army's Unmanned Air Vehicle simulation (USIM) laboratory. While the manned attack helicopter was simulated using a model on the VMS host computer, the USIM generated UAVs and their associated subsystems to interact with the piloted simulation in the VMS in real time.

In addition to the HLA link, SimLabs' staff developed several simulation-critical components specifically for this study. These included unique display graphics, target acquisition logic, and data collection software.



A pilot operates a UAV from the cockpit of an attack helicopter.

Results

Over the course of four weeks, seven test pilots flew 24 missions with varying combinations of display presentations, UAV control relationships, and levels of control. Performance data related to target acquisition, active use of sensors, accuracy, and reaction times to pre-recorded audio commands were collected. Workload ratings, subjective questionnaires, and pilot comments were also gathered. Simulation data are being analyzed, and final results are pending.

Investigative Team

NASA Ames Research Center
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Science Applications International Corporation
Turpin Technologies
US Army Aeroflightdynamics Directorate

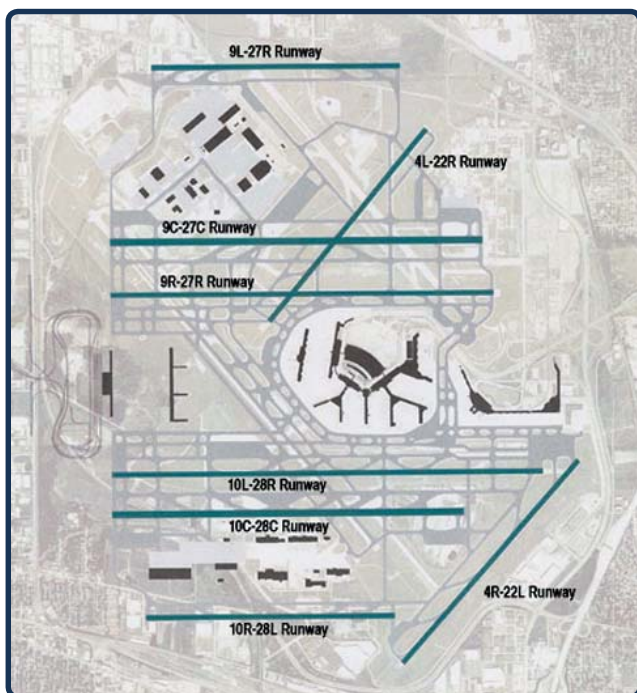
Chicago O'Hare Modernization Program Ultimate Phase

Real-Time Simulation and Workload Evaluation Project

Principal Investigators: Kevin Markwell and Bill Spencer, Federal Aviation Administration

Summary

The O'Hare Modernization Program (OMP) proposes to reconfigure O'Hare International Airport's (ORD) intersecting runways into a parallel layout that will improve efficiency and reduce delays. A real-time, human-in-the-loop (HITL) simulation was conducted at FutureFlight Central (FFC), in which controllers from O'Hare operated the proposed layout with the increased traffic levels envisioned after build-out of the new plan.



OMP airport layout plan. The dark lines indicate new runways.

Introduction

Chicago O'Hare is one of the world's busiest airports, serving about 70 million passengers annually. It also encounters the most delays of any airport, mainly because all but one of the runways intersect. Additionally, during certain weather conditions, runway use must be restricted, and the airport's capacity decreases by about one-third. The OMP proposes to reconfigure O'Hare's intersecting runways into a parallel layout. The changes would eliminate three, extend two, and add four new runways, dramatically improving airport efficiency, particularly during inclement weather.

The Federal Aviation Administration conducted real-time, HITL simulations at FFC of the proposed layout to enable O'Hare air traffic controllers to operate the future airport with traffic levels envisioned for 2018. The objectives of the simulation were to better define ground control operations, develop mitigation strategies for potential

traffic-flow problems, and evaluate the impact of the new configuration on controller workload.

Simulation

A high-fidelity visual database was created by FFC that represented the significant proposed changes to ORD. In addition, a new terminal building, two satellite towers, and other proposed additions were created for the visual scene. Plans are underway at O'Hare to reconfigure the tower such that the ground controllers will be in the center of the tower, elevated approximately 20 inches to better see the taxiways and ramp areas. Thus, for the simulation, a platform was constructed in the FFC tower to elevate the controllers the same 20 inches.

Twenty-five simulation pilots were hired and trained to manage the aircraft in the test scenarios. Simulation scenarios represented predicted peak traffic levels envisioned in the 2018 time frame: nearly 300 operations per hour. Both east-flow and west-flow scenarios were prepared, under both VFR and IFR conditions. The nine participating controllers from O'Hare took part in at least one week of pilot training in order to familiarize themselves with the new airport layout.

It is anticipated that eight controllers will be required to operate the increased traffic for the new airport layout: two Local Controllers (LC) and two Ground Controllers (GC) on both the north and south sides of the tower. For the simulation, two controller configurations were utilized: 1) four GC and two LC; 2) two GC and four LC.

The first two days of simulation were used to familiarize O'Hare controllers with the new operational procedures. An additional five days of data collection runs were conducted. At the end of each run, controllers rated various operational factors relative to their experience at O'Hare. In addition, the controllers were debriefed to discuss the operation in more detail. Transcripts of these sessions were delivered to the customer, as well as digital audio recordings of pilot/controller communications and video recordings of the simulations themselves. The data collection runs were webcast so that customer representatives could observe the simulation remotely in real time.

Results

During the course of the study, controllers proposed and tested new geographic definitions for the two inbound GC positions that ultimately reduced frequency congestion and better balanced ATC workload. Quantitative results are pending.

Investigative Team

Federal Aviation Administration
NASA Ames Research Center
Northrop Grumman Information Technology
Science Applications International Corporation

Research-Directed Projects at SimLabs

Virtual Airspace Simulation Technology-Real-Time

Principal Investigators: Debbi Ballinger, NASA Ames; Ronald Lehmer, SAIC

Summary

The Virtual Airspace Simulation Technology-Real-Time (VAST-RT) Project was established at NASA Ames Research Center as part of the Virtual Airspace Modeling and Simulation (VAMS) Project. The objective of VAST-RT is to provide new tools to simulate future air traffic management technologies and techniques, with the ultimate goal of increasing National Airspace System (NAS) capacity, efficiency, and safety. Through eight interim test phases, culminating in the achievement of a VAMS milestone, VAST-RT has developed an environment that integrates multiple existing simulation facilities, ATC simulation components developed by VAST-RT, and state-of-the-art decision support tools. The distributed environment allows human-in-the-loop simulations using combinations of all ATC domains in the NAS. VAST-RT provides revolutionary capabilities to evaluate the human factors aspects of air traffic management and control concepts, both system-wide and in localized segments of the NAS.

Introduction

Air transportation continues to grow at an unprecedented rate due to increasing demand for air travel and shipping. Without further advancements in air traffic management (ATM) and air traffic control (ATC), the NAS will not be able to safely meet rising air transportation requirements. In 2000, NASA—in partnership with the Federal Aviation Administration (FAA), academia, and industry—created the VAMS project to address this problem. The Virtual Airspace Simulation Technologies (VAST) part of the project is responsible for providing a simulation and modeling environment for testing and evaluating the new ATM/ATC concepts developed within VAMS.

The VAST Project encompasses both real-time and non-real-time simulation. The Airspace Concept Evaluation System is the non-real-time simulation tool and focuses on modeling broad, system-level operational concepts. VAST-RT simulates gate-to-gate, real-time, human-in-the-loop scenarios and provides a customizable framework for connecting low- and medium-fidelity real-time components with high-fidelity human-in-the-loop facilities in a distributed simulation environment.

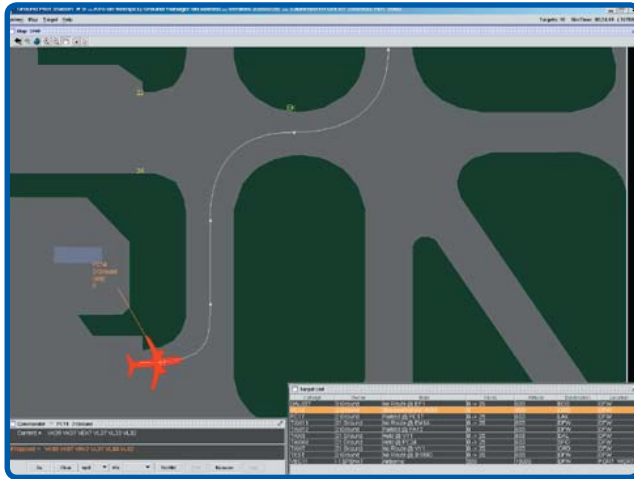
The VAST-RT architecture is the “backbone” that links the simulation together. It relies on High Level Architecture (HLA), a Department of Defense software suite that is used to connect applications and facilities in a real-time simulation. Typically, HLA works by combining disparate simulation systems (“federates”) into a larger, common “federation,” where information is exchanged in real-time between federates using Run-Time Infrastructure software. In the VAST-RT architecture, the HLA communications infrastructure is integrated with existing simulators using existing external interfaces where possible to minimize the cost and impact of connecting the simulators to the HLA federation.

The innovative interface design of VAST-RT allows for rapid and cost-effective integration of new and existing facilities, software models, and new ATC technology. The architecture and VAST-RT simulation components provide communications, control, and simulation support functions for widely distributed ATC simulations.

VAST-RT has completed a series of eight Interim Tests (IT) and a V&V simulation. The simulations were conducted in multiple NASA Ames facilities, including FutureFlight Central (FFC), the Crew-Vehicle Systems Research Facility (CVSRF), and the Vertical Motion



View from the FFC control tower. Because of HLA bridging technology, multiple simulators can participate in the same scenario in real-time.



A screenshot of the Airspace Traffic Generator interface.

Simulator (VMS). ITs #1-4 were conducted during 2003, ITs #5-6 occurred in 2004, and ITs #7-8 took place in 2005.

After the completion of IT #8, VAST-RT Capability 2a was released. Capability 2a is operational software and is available to the VAMS Project and other customers for their use. Several components of Capability 2a are also available as source code from the VAMS Project.

Simulation

The performance of the VAST-RT environment was measured quantitatively and qualitatively during the tests described below. Quantitative assessments were made of system and network loading, operational stability, and data integrity. Qualitative measurements of displays and usability were also made.

IT #7: The seventh test integrated a new decision support tool developed by the VAMS Surface Operation Automation Research (SOAR) concept called GoSAFE. GoSAFE delivers automated arrival, departure, and timed taxi clearances to aircraft via datalink in order to increase airport capacity. This interim test also included integrating VAST-RT's Airspace Traffic Generator (ATG) into FFC. The ATG can parse the datalink messages and drive aircraft in accordance with automated clearances. All tests for this iteration were conducted using the Dallas/Fort Worth airport database.

IT #8: The final IT demonstrated upgrades to numerous VAST-RT components. The ATG was upgraded to include improved ground simulation capability, datalink processing, air-to-ground dynamics transition, and an enhanced ground station user interface. Data collection

capabilities were significantly enhanced, and new tools for inspection and manipulation of simulation data were delivered. VAST-RT also demonstrated Airline Operations Center tools linked to the local simulation environment, which will ultimately permit inclusion of the business element of airport operations into real-time simulation of future ATM concepts and human factors research.

Results

The capability of the VAST-RT system to simulate large segments of the NAS in real-time, utilize multiple simulation facilities, and integrate diverse existing and forward-looking tools and technologies was successfully demonstrated. The 2005 portion of VAST-RT marked the achievement of a VAMS milestone with the delivery of Capability 2a. Preparations for Capability 2b are underway. Because of the successes achieved in 2005, the VAST-RT team has been tasked with evaluating the VAMS SOAR concept in 2006, as well as demonstrating two VAMS concepts that cross multiple ATM domains blended into one simulation.



Many people have contributed to the success of the VAST-RT Project, and the team received a NASA Honor Award for its accomplishments.

Investigative Team

NASA Ames Research Center
Northrop Grumman Information Technology
Science Applications International Corporation

Mars Underground Mole and Mars Driller Fabrication and Integration at the Vertical Motion Simulator

Project Lead: Khoa Nguyen, NASA Ames Research Center

Summary

SimLabs supported the Mars Astrobiology Research and Technology Experiment (MARTE) by designing, fabricating, and providing mechanical integration of critical components of the Mars Underground Mole (MUM) and Drill Core Service Module (DCSM). SimLabs' expertise and efficiency allowed the project to be completed on time and under budget.

Introduction

The recent discovery of near-surface ground ice by Mars Orbiters supports theories of subsurface liquid water on Mars. Future searches for life on Mars will entail deep drilling to reach that subsurface water for extraction and sample analysis in order to detect biomarker compounds and validate life-on-Mars theories. The MARTE project involves simulation of a robotic mission to demonstrate drilling, sample handling, and instrument technologies relevant to the subsurface water extraction effort.

With experienced personnel that had efficiently developed numerous simulation hardware projects in the past, SimLabs was selected to help with the engineering and fabrication of the MUM and DCSM, both critical components of the MARTE driller. The task also required design verification and structural analysis, as well as support of all aspects of the final mechanical integration of the project.

Project Description

The MUM is a system that will hammer itself underground to a depth of five meters, then collect a soil sample and analyze the surrounding substrate with a dual spectral sensor before hammering itself back to the surface. SimLabs' engineers designed and fabricated an internal sliding weight mechanism that drives the artillery-shell-shaped MUM into the soil. Once buried, the MUM communicates via a tether to a Rover on the soil surface. The tether contains power and data wires, in addition to a fiber optic cable that transports spectral data collected underground to a spectrometer on the surface.

The DCSM is a hexagonal structure that consists of a main platform, a rotatable platform, and a roll cage. The main platform is a triangulated structure that has three adjustable legs braced by a system of tie rods that help station the structure firmly on the ground and a set of four retractable rollers on top that serve as a lifting-and-turning mechanism. The rotatable platform, which lies on top of the main platform, serves as the mounting surface for the Drill, the Core Sample Handling System, and the Bore Hole Inspection System; it is also used to support Remote Science Instruments, the Signs of Life Detector, and all related equipment. The roll cage was designed to stiffen

the overall structure and serve as the framework for the canopy that can be deployed at drill sites to protect equipment from severe weather. A special isolation platform made of honeycomb material was fabricated to help alleviate vibration and protect sensitive equipment.

Before the fabrication began, finite element models of the MUM and DCSM were constructed to examine the structures' modes, deflection, and stress. The analysis results were used to optimize the designs while meeting the required safety factors.



The MARTE project is developing robotic vehicles to aid in the search for life on Mars (depicted above in one of SimLabs' database views).

Results

The MUM working prototype can hammer to the bottom of a 50-gallon drum filled with Mars-like substrate. A field test is scheduled for the end of 2005 to investigate whether the MUM can hammer itself to the MARTE-required depth of five meters.

The DCSM was successfully designed and fabricated to meet two critical requirements: structural rigidity under operating loads and repeatability of positioning of the Drill and the Bore Hole Inspection System using the rotatable platform. The drill platform was integrated and tested in-house to demonstrate that the two requirements were met; results were later confirmed in the US field test in June 2005.

During the mechanical integration of both the MUM and the DCSM, SimLabs provided support in many other areas, including networking, electrical wiring, electrical engineering, and packaging. By finishing the project on time and under budget, SimLabs proved to be an efficient and flexible facility ready to meet challenges in many different fields.

Investigative Team

Allied Aerospace

NASA Ames Research Center

Northrop Grumman Information Technology

Science Applications International Corporation