NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594

October 3, 2002

Human Performance

STUDY REPORT
VERTICAL MOTION SIMULATOR ACTIVITIES
PHASE I: BACKDRIVE OF ACCIDENT FLIGHT

A. ACCIDENT

Operator: American Airlines (flight 587)
Location: Belle Harbor, New York
Date: November 12, 2001
Time: 0916 eastern standard time[1]
Aircraft: Airbus A300-600, N14053
NTSB Number: DCA02MA001

B. HUMAN PERFORMANCE GROUP

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[1] Unless otherwise indicated, all times are eastern standard time, based on a 24-hour clock.

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C. ACCIDENT SUMMARY

On November 12, 2001, about 0916 eastern standard time, American Airlines flight 587, an Airbus A300-600, was destroyed when it crashed into a residential area of Belle Harbor, New York, shortly after takeoff from the John F. Kennedy International Airport (JFK), Jamaica, New York. Two pilots, 7 flight attendants, 251 passengers, and 5 persons on the ground were fatally injured. Visual meteorological conditions prevailed and an instrument flight rules flight plan had been filed for the flight destined for Santo Domingo, Dominican Republic. The scheduled passenger flight was conducted under Title 14 Code of Federal Regulations (CFR) Part 121.

D. DETAILS OF THE INVESTIGATION

On August 12, 2002 the Human Performance group convened at the National Aeronautical and Space Administration (NASA) Ames Research Center, Moffett Field, California to conduct observations and tests using the NASA Vertical Motion Simulator (VMS). The observations and findings of the initial phase (Phase I) of these activities are presented in this study report. Additional observations and findings of the second phase (Phase II) of this activity will be presented in separate report to be released pending completion of data reduction and analysis. The Human Performance group activities at the VMS facility concluded on August 22, 2002.

E. VERTICAL MOTION SIMULATOR ACTIVITIES

E.1. VERTICAL MOTION SIMULATOR (VMS) FACILITY

The Human Performance group activities described in this report were conducted using the VMS. The VMS is a unique research facility that offers unparalleled capabilities for replicating large amplitude motion cues. The VMS cab is mounted on a six-degree-of-freedom motion platform that provides the following motion capabilities, making it the world's largest motion based simulator:

Table 1. VMS Nominal Motion Limits

Motion	Range of Motion	Velocity	Acceleration
Vertical	±30 ft	16 ft/sec	24 ft/sec/sec
Lateral	±20 ft	8 ft/sec	16 ft/sec/sec
Longitudinal	±4 ft	4 ft/sec	10 ft/sec/sec
Roll	±18 deg	40 deg/sec	115 deg/sec/sec
Pitch	±18 deg	40 deg/sec	115 deg/sec/sec
Yaw	±24 deg	46 deg/sec	115 deg/sec/sec

A photograph of the VMS facility is presented in Figure 1. A more detailed description of the VMS facility is provided in Attachment 1.

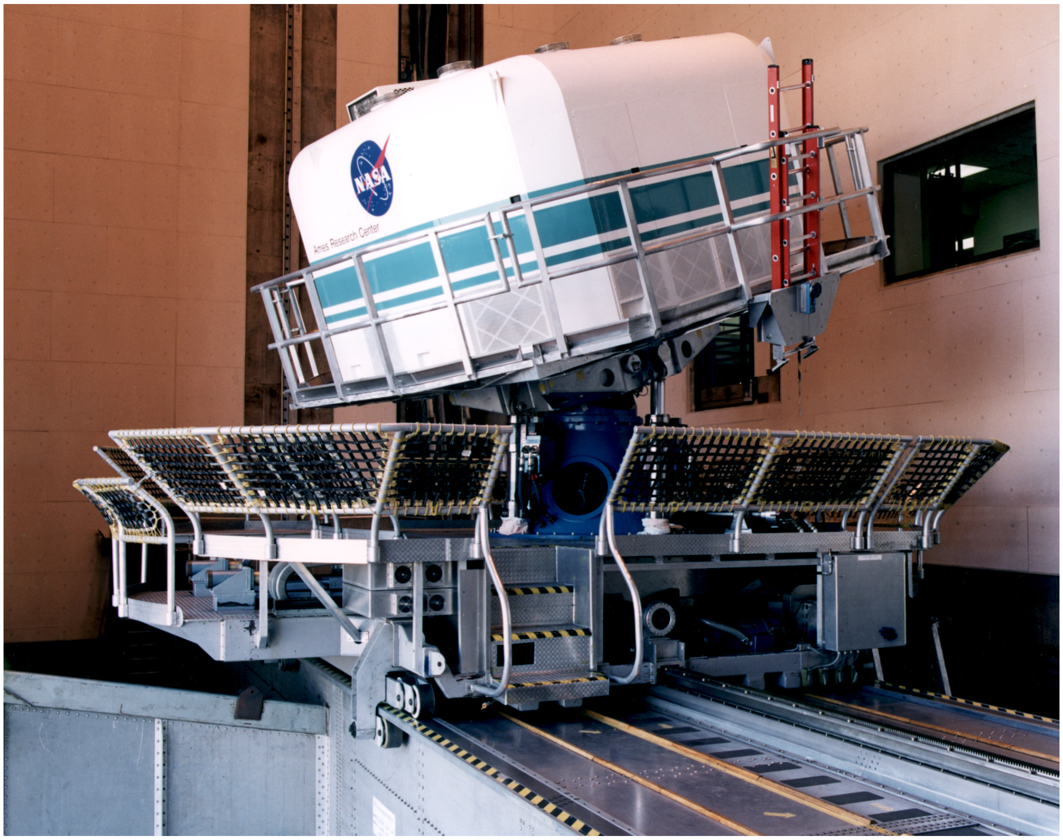

Figure 1. The NASA VMS cab and motion platform.

PHASE I: BACKDRIVE OF ACCIDENT FLIGHT

E.1.1. OBJECTIVES

The objectives for creating and observing a backdrive[2] of the American Airlines flight 587 accident sequence using the NASA VMS were:

1. To evaluate accelerations and angular motions similar to those experienced by the flight crew during the accident event; and

2. To evaluate cockpit displays, visual cues, and flight control motions similar to those experienced during the accident event.

E.1.2. SIMULATION

E.1.2.1. SIMULATOR CONFIGURATION

The VMS backdrive was based on the data recorded on the accident aircraft's digital flight data recorder (DFDR) and calculations made by the NTSB Aircraft Performance Group Chairman.[3] Audio segments of the accident aircraft's cockpit voice recorder (CVR) were used in conjunction with the VMS backdrive.[4] Both the audio segment and the VMS backdrive began just prior to the departure from runway 31L and continued until the final recorded data on the DFDR.

The simulator cab used was the T-cab, which had a two-place side-by-side pilot station configuration typical of transport category airplanes, as shown in Figure 3. The cockpit displays were configured with three side-by-side monitors at each pilot station. At each station, the outboard monitor presented graphical strip charts of input and actual accelerations for longitudinal, lateral, and vertical (normal) axes and flight control positions; the inboard monitor displayed a centered compass rose navigation display of heading and track information, and a wind vector indicator with digital readouts of wind speed and direction in the lower left corner; and the center monitor was a primary flight display (PFD, see Figure 4) presenting altitude altitude, attitude, and airspeed information. A digital readout of event time was displayed in the upper left corner of the PFD. The PFD also contained an operable sideslip indicator (trapezoid below the sky

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[2] A simulation in which the accident flight sequence is simulated using data derived from the accident flight data recorder and other available sources to define cab motion, flight control positions, cockpit displays and the out-the-window visual scene in the simulator.

[3] Several limitations associated with the DFDR data and the simulator were identified by the group and are detailed below.

[4] Due to the sensitive nature of CVR audio recordings, all transmission of the CVR audio were through wired headsets, and only those authorized by the NTSB to listen to the CVR were issued headsets during Phase I sessions. The volume of the headset was set to ensure that it was not overheard or captured by any audio recording of the simulator session.

pointer) that presented lateral acceleration data based on Airbus Industrie specifications for the A300-600 sideslip indicator.

The cab was equipped with a transport category style control wheel and column, adjustable rudder pedals, and adjustable pilot seats. The cab was configured with four throttle levers. For this activity, throttle levers 1 and 2 indicated the throttle lever position from the throttle 1 parameter on the DFDR and throttle levers 3 and 4 indicated throttle lever position from the throttle 2 parameter on the DFDR. Control wheel, column, rudder pedal, and throttle positions were backdriven based on interpolated DFDR data during backdrive runs. Although the cab was equipped with gear, spoiler, and flaps levers, the positions of these controls were not backdriven and did not affect the activity.

Figure 3. The VMS cab configuration for Phase I.

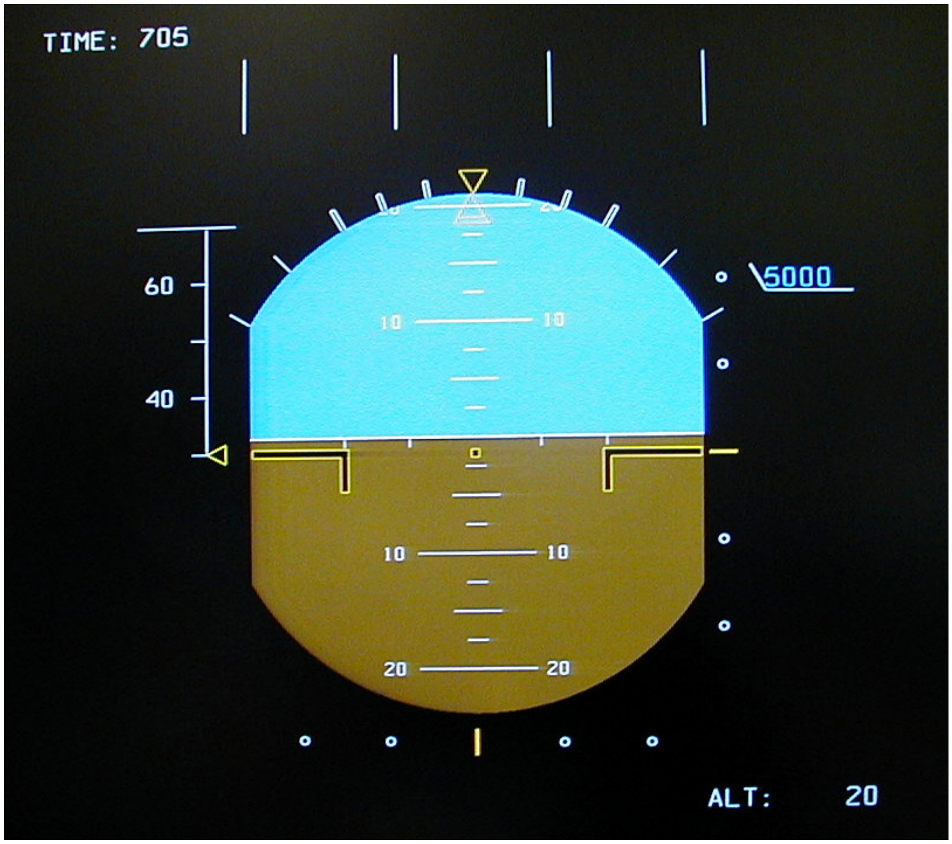

Figure 4. The primary flight display (PFD) implemented in Phase I.

During Phase I, the cab motion was backdriven by time histories of computed pilot station acceleration (Ax, Ay, Az) and angular position data based on the accident flight's DFDR accelerometer data and angular position data. Primary flight controls, including the rudder pedals, control wheel, control column, and throttles, were backdriven from interpolated DFDR data.[5] Heading, altitude, airspeed, aircraft attitude, and position data were backdriven and portrayed on replicas of the A300 primary flight display (PFD) and navigational display. An out-the-window visual scene based on a database of prominent visual features and coastline in the vicinity of JFK airport was presented during backdrive runs. During selected backdrive runs, a synchronized audio file containing a copy of the accident flight's CVR recording was played over headsets to those participants cleared to listen to the CVR. For each backdrive run, time histories of cab motion parameters including input data and measured VMS cab acceleration values (Ax, Ay, and Az) and flight control positions were recorded at

[5] DFDR parameters were sampled at a rate of between 1 and 8 Hz. The VMS simulator was backdriven with interpolated data for all parameters sampled at 50 Hz. See the Aircraft Performance Group Chairman's Aircraft Performance Study Report for detailed descriptions of the DFDR parameters used in the VMS simulation and the methods of interpolation implemented to create 50 Hz samples of these parameters.

a frequency of 50 Hz and visually displayed on monitors in the VMS control room. A picture of the control room layout is shown in Figure 5. In the control room, graphical strip charts of input and actual accelerations for longitudinal, lateral, and vertical (normal) axes and flight control positions, identical to those presented in the cab, were displayed on the upper left and right monitors. Additional montiors presented the out-the-window scene, the PFD display, the navigation display, and a "chase plane" view. Additionally, a flight control display was presented on two monitors and provided dynamic flight control position information and rudder travel limiter position information in a pictorial format (see Figure 6). All backdrive runs were videotaped and a video monitor displaying the overhead cab camera view was provided in the control room. A cockpit push-to-record button was implemented to allow participants to record verbal comments on the videotape as well as on a separate cassette recording.

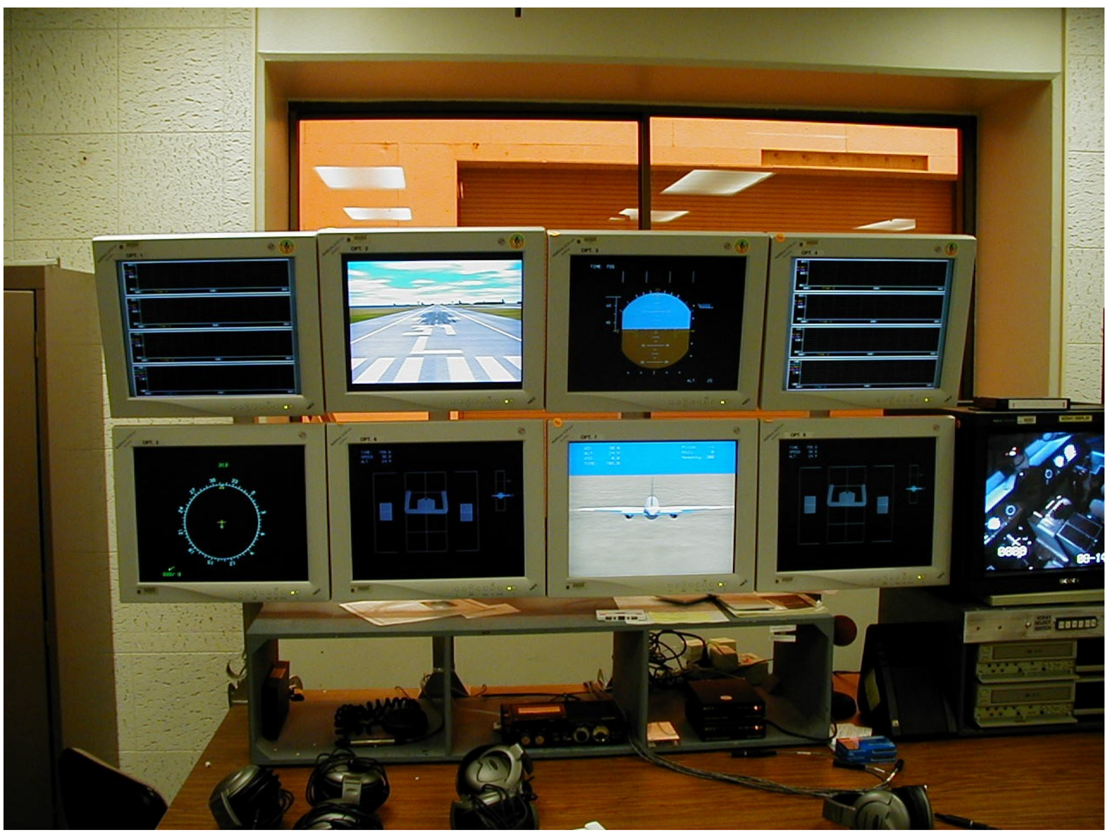

Figure 5. Control room layout.

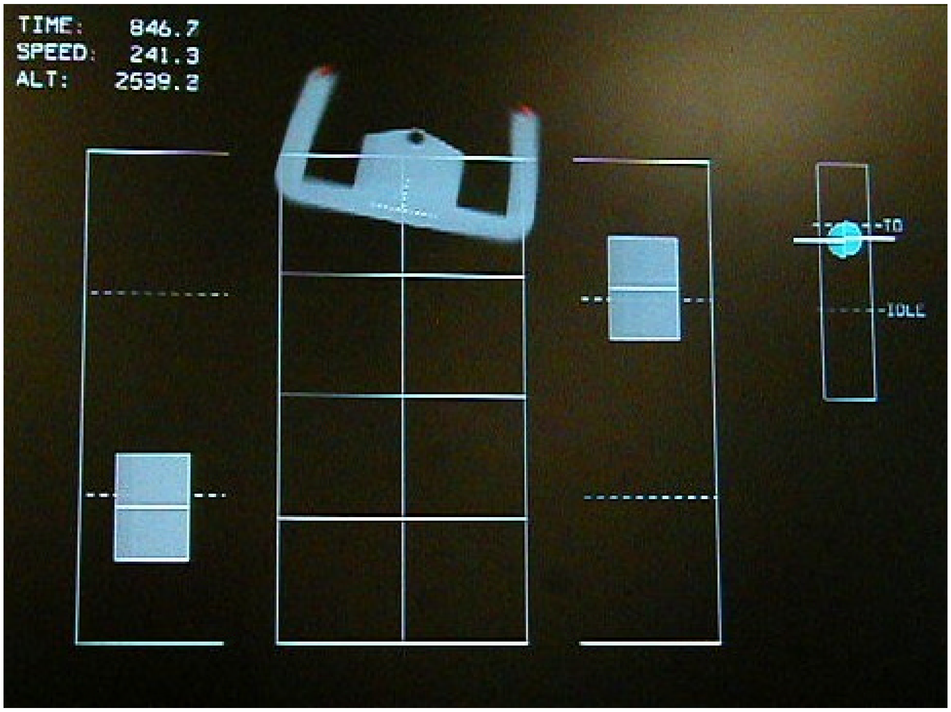

Figure 6. Flight control display used in the control room showing control wheel, column, rudder and throttle positions. (Note: dashed line on rudder position displays shows rudder travel limiter position that was updated dynamically during backdrive sessions.)

E.1.2.2. SIMULATOR LIMITATIONS

The Human Performance group identified the following limitations associated with the VMS backdrive based on DFDR derived data from the accident flight:

1. Motions generated by the VMS were constrained by the VMS nominal motion limits specified in Table 1.

2. DFDR Data: The data derived from the DFDR was provided by the Aircraft Performance group. This data was interpolated using a cubic spline fit applied to the DFDR data and over-sampled for input into the VMS control system at 50 Hz. On the DFDR, the sampling rate for the longitudinal and lateral axes was 4 Hz, and the sampling rate for vertical (normal axis) accelerations was 8 Hz. This limited the amount of high frequency acceleration data recorded. In addition, the longitudinal (pitch), lateral (roll), and directional (magnetic heading) flight angles were sampled at 1 Hz, resulting in increased uncertainty in the calculations of

the angular accelerations and load factors in the cockpit. Therefore, because high frequency data were not recorded on the DFDR and the VMS replicated the data from the DFDR, the potential high frequency accelerations could not be represented in the VMS backdrive. It was noted that on runway 31L at JFK considerable high frequency vibrations are typically felt during takeoff in an airplane. The DFDR and thus the VMS capture produced a gentler feel during takeoff than was expected.

3. Flight Control Force and Displacement Feedback: During the backdrive of the VMS, Human Performance group members only observed the displacement of the flight controls; they did not make control inputs. Therefore, an evaluation of required force to displace the controls could not be made during the backdrive.

4. Lack of Pilot in the Loop: The lack of having the pilot in the loop during the simulation was considered a limitation because input was not required for the control surfaces or the resultant cab motion. Human Performance group members were passive observers during backdrives in the sense that they were unable to make inputs to the flight controls and could only observe the response to backdriven inputs.

5. Lack of Sustained Accelerations: Due to the VMS nominal motion limits listed in Table 1, sustained accelerations beyond the motion limitations of the VMS were not possible. However, Human Performance group members noted that the VMS was far better in its capability to produce realistic motion cues as compared to a typical hexapod motion-based training simulator.

6. CVR: The playback of the CVR through the headsets in the cab did not provide a realistic presentation of the sounds in the cockpit synchronized with the backdrive. The cockpit area microphone on the accident aircraft captured sounds in the cockpit (within the capabilities of the microphone and recording device) while ATC transmissions and intra-cockpit communication were captured through the headsets. This presentation of sounds captured by the cockpit area microphone was not possible over loudspeakers in the VMS cab because of the need to protect the CVR content from unauthorized access. Some group members commented that playback of the cockpit area microphone over loudspeakers might have better created the impression that sounds captured by that microphone were more realistically heard as emanating from the cockpit environment rather than through the headsets. Group members also commented that the CVR playback was not capable of creating a sense of the spatial location of sound sources. Also, sounds generated by the motion of the VMS cab during backdrives provided cues regarding motion that were potentially distracting and misleading.

E.1.2.3. PROCEDURES

On Tuesday, August 13, 2002 the Human Performance group experienced the VMS backdrive with the accompanying audio segments of the CVR. Full motion, out-the-window visual scene graphics, the primary flight display (PFD) graphics, the compass rose navigation display, and the electronic strip chart displays were presented in the VMS cab. Two video recordings were made of each backdrive run, one showing an overhead view of the cab and the seated occupants, the other showing the graphical display of accelerations and flight control positions, the PFD and the "chase plane" view. Additionally verbal comments made by the group members at the conclusion of each run were recorded.

On the second day, the Human Performance group repeated the VMS backdrive. The group members also experienced three additional conditions on the second day. These conditions included:

1. Full VMS motion backdrive with the pedals simulated as a variable ratio limiter system,[6]
2. VMS backdrive with visuals and flight control movement but without the cab motions; and
3. VMS backdrive with visuals and cab motion but without control surface motion.

Upon conclusion of these backdrive runs, the Human Performance group met to review and summarize the VMS activities. A summary of the Human Performance group's observations is presented in Section E.1.4.

E.1.3. RECREATION OF DFDR ACCLERATIONS IN THE VMS

The following figures show the match between the computed pilot station accelerations based on the American Airlines flight 587 accident sequence DFDR recording and the measured accelerations during the Phase I backdrives in the VMS cab. In these figures, mean, minimum, and maximum measured acceleration values for Ax, Ay, and Az (corrected for pilot seated position) are presented along with computed pilot station accelerations based on DFDR data that was used as input to the VMS system during simulator backdrives.[7] The following nomenclature is used in these figures:

[6] The variable ratio limiter system allows full rudder pedal travel at all airspeeds but still limits the rudder surface travel. For this condition, the timing of rudder movements was presented as it was recorded by the DFDR, but the amplitude of motions was changed so that the pedals were displaced as a ratio of full rudder pedal travel rather than as a ratio of the limited pedal travel.
[7] Minimum and maximum acceleration values were determined for each time step. Therefore, the minimum and maximum acceleration curves do not represent a single backdrive.

Ax : x-axis (logitudinal) acceleration
Ay : y-axis (lateral) acceleration
Az : z-axis (vertical or normal axis) acceleration
NXPILOT: Computed pilot station x-axis acceleration based on DFDR data
NYPILOT: Computed pilot station y-axis acceleration based on DFDR data
NZPILOT: Computed pilot station z-axis acceleration based on DFDR data
Min: Minimum measured value for a given time sample
Max: Maximum measured value for a given time sample
Mean: Mean of acceleration values for a given time sample

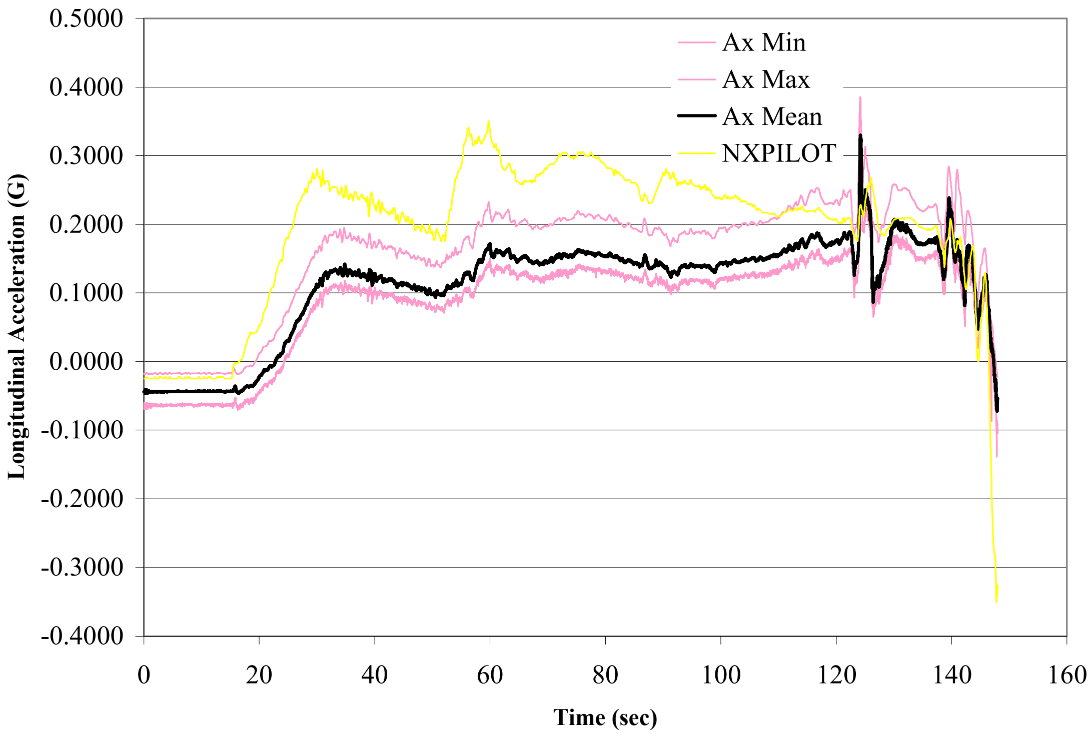

Figure 7. Input and measured longitudinal acceleration.

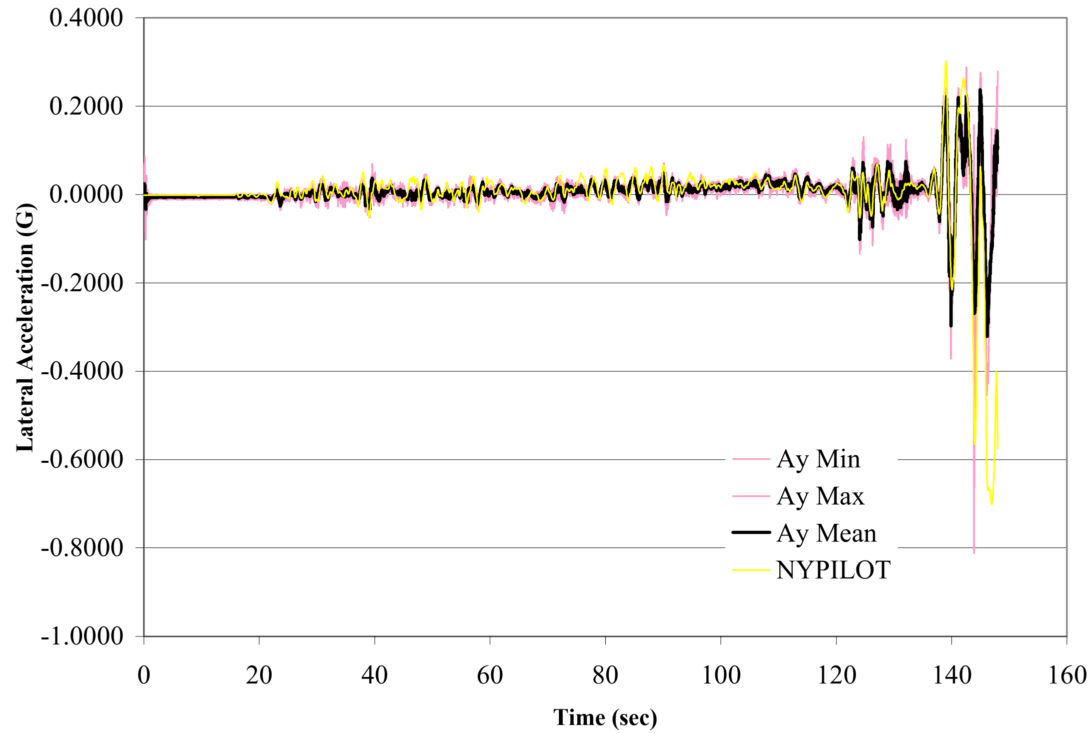

Figure 8. Input and measured lateral acceleration.

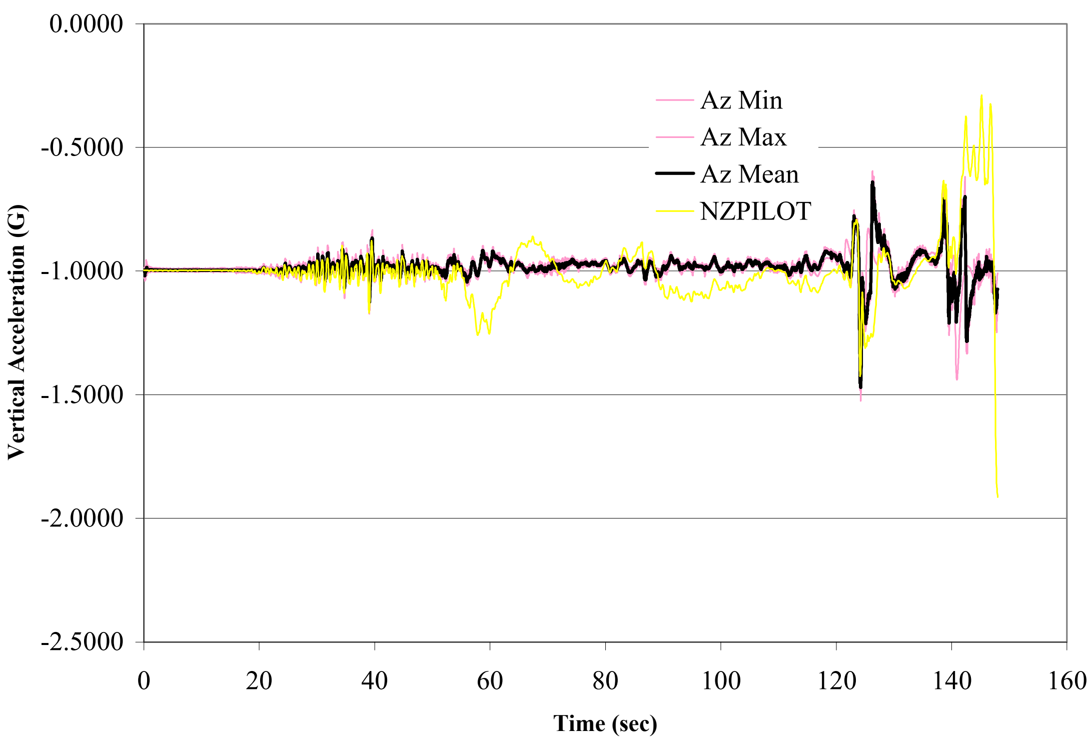

Figure 9. Input and measured vertical (normal axis) acceleration.

E.1.4. OBSERVATIONS OF THE HUMAN PERFORMANCE GROUP

Visual and Acceleration Cues and Flight Control Motions:

1. *Observations from the start of the takeoff roll until the time prior to first notable event: (705-823 seconds)*[8]
    a. While on the runway during takeoff, high frequency bouncing (vertical Gs) was not felt. Instead a slower, smoother, and less frequent bouncing feeling was experienced.
    b. There were some abrupt, ratcheting (i.e., seemingly mechanical) motions of the control wheel a few seconds after rotation.
    c. During the climb and after initiation of the first left turn, a slight lateral acceleration was felt. Human Performance group members familiar with the A300-600 felt that this was typical of the airplane response to roll commands and yaw damper compensation.

2. *The first notable event (824-834 seconds)*
    a. Many Human Performance group members described this event as typical of a crossing wake encounter. Prior to feeling a vertical acceleration, or bump, some Human Performance group members felt a slight yaw prior to the flight control motions but described the yaw as very small. This slight yaw motion, felt as a lateral acceleration in the cab, was described as a characteristic motion of an A300 flying through turbulence. This was followed by a vertical acceleration that was felt by most Human Performance group members and described as being similar to driving over a speed bump in a car. This bump seemed to result from the wake encounter rather than from the flight control motions.
    b. The group felt that these flight control motions seemed to occur either prior to or simultaneous with any significant motion experienced in the VMS. Human Performance group members observed that the flight control motions consisted of rapid, moderate amplitude wheel inputs without any corresponding rudder pedal movements.
    c. It was noted that the first encounter occurred with wings level.

3. *The second notable event (841-853 seconds)*
    a. The general consensus of the Human Performance group was that very slight simulator cab motions were felt prior to the first motion of the wheel and pedal to the right. These cab motions were described as a slight left lateral acceleration (i.e., an acceleration

[8] Reference times (in seconds) correspond to the elapsed time in DFDR Subframe Reference number provided in the VMS data input file. See the Aircraft Performance Group Chairman's Aircraft Performance Study Report for further details.

displacing the seated occupant to the left) and some Human Performance group members also experienced a concurrent feeling of being light in their seat (i.e., an unloading). In addition, the initial onset did not feel like a typical wake turbulence encounter. While rattling sounds from the CVR were heard during this time, the motion and visual cues experienced were not typical of a wake encounter. The precursor to the event was not as abrupt as the first notable event but the lateral acceleration, described as barely perceptible, was considered to be slightly stronger than that noted during the climb out and initial turn described earlier.

b. Most Human Performance group members observed that nothing was experienced until less than one second before the first wheel motion. The left lateral acceleration felt was described as being barely perceptible. Many Human Performance group members were able to only identify the left lateral acceleration when the flight controls were turned off but the motion of the cab was still enabled. Human Performance group members were uncertain whether the first wheel and pedal motion was in response to this left lateral acceleration since the magnitude of this acceleration was very small and did not seem sufficient to elicit a pilot response.

c. It was noted that the second encounter occurred with approximately 20 degrees stable left bank.

d. The first movements of the control wheel and rudder pedal to the right were large and abrupt. After the first motions of the wheel and pedal to the right, large lateral accelerations were felt and additional large, abrupt flight control motions in all three axes were observed. Human Performance group members felt a rapid succession of lateral accelerations but stated that it was difficult to sense if vertical and longitudinal accelerations were also present. The only sustained lateral acceleration was felt when the right pedal was deflected for approximately two seconds.

e. Human Performance group members also commented on the limited pedal system in the A300, as experienced in the VMS backdrive. Some Human Performance group members noted that the pedal motion was fast but thought the displacement was larger than anticipated with the pedal travel limiter system. During the backdrive runs where a variable ratio limiter system was simulated, some members stated that the motion of the pedals was so fast that it was hard to keep their feet on the pedals as they moved. The larger displacements at the same timing resulted in a much higher pedal velocity.

General Observations:

Human Performance group members:

- Did not observe a visual or acceleration cue that would lead a pilot to apply the observed initial magnitude of wheel and pedal in response to the second notable event.

- With A300 flight experience, noted that when turbulence is typically encountered, the first accelerations felt are in the lateral direction.

- Noted that the large magnitude and rapid speed of the first flight control movements during the second notable event were analogous to potential flight control inputs made during an avoidance maneuver.

- Concluded that the VMS, while constrained by the limitations previously noted, provided insight and was a beneficial tool for experiencing time synchronized motions, flight control motions, and displays as opposed to just looking at tabular or charted data.

Submitted By:

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Bartholomew Elias, Ph.D.
Senior Human Performance Investigator

ATTACHMENT 1: DESCRIPTION OF THE VERTICAL MOTION SIMULATOR (VMS)

4 pages

VMS Overview

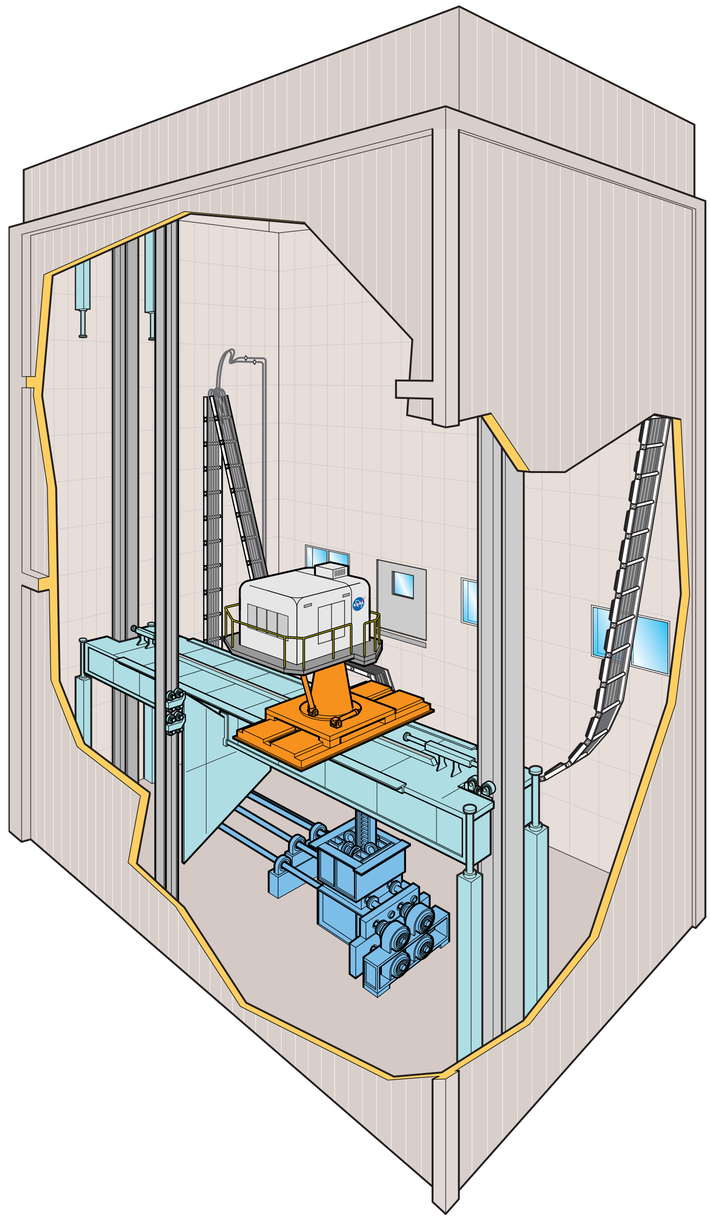
Aviation Systems Division
Simulation Planning Office
Aerospace Simulation Operations Branch

NASA Ames Research Center

Vertical Motion Simulator Research Facility

The Vertical Motion Simulator (VMS) is a world-class research and development facility that offers unparalleled capabilities for conducting some of the most exciting and challenging studies and experiments involving aeronautics and aerospace disciplines. 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 the study of helicopter and vertical/ short take-off landing (V/STOL) issues specifically relating to research in controls, guidance, displays, automation, and handling qualities of existing or proposed aircraft. It is also an excellent tool for investigating issues relevant to nap-of-the-earth flight, and landing and rollout studies.

Recent simulation projects developed and conducted at the VMS include High Speed Research (High Speed Civil Transport), Advanced Subsonic Transport/ Short-Haul Civil Transport (Civil TiltRotor), Joint Strike Fighter (JSF) and Space Operations (Space Shuttle Orbiter).



Cut-away view of the Vertical Motion Simulator Facility

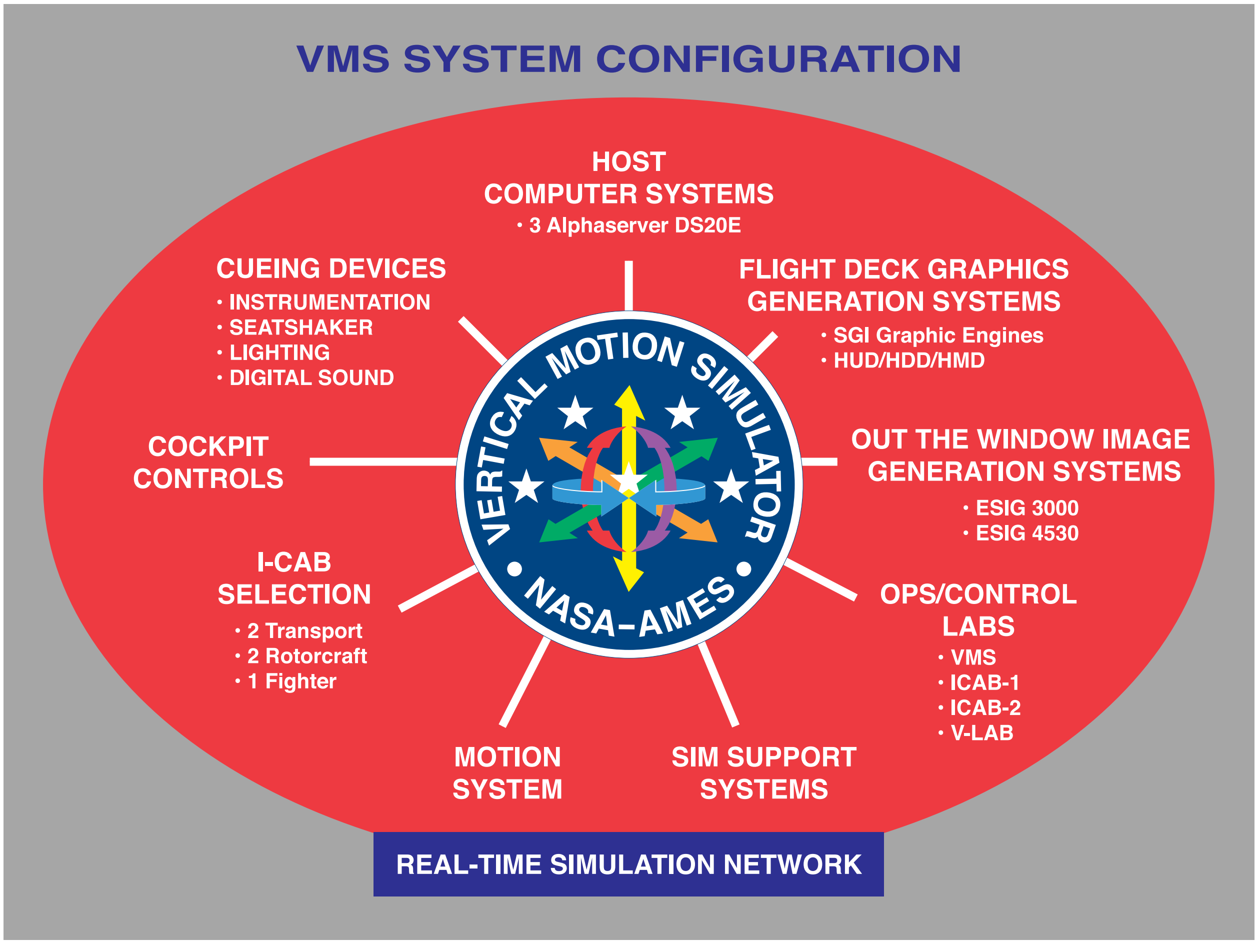


Figure 1

Simulation System Description

The VMS, which is located in the Aviation Systems Division at NASA Ames Research Center, is renowned for its efficient production of high-fidelity, fixed and moving base, real-time, piloted flight simulations of aerospace vehicles. The VMS offers researchers, from the government and private industry, unique and powerful capabilities to investigate and resolve issues related to current aircraft as well as advanced flight vehicles in their design stages. This national facility is also used to develop new techniques for flight simulation and to define the requirements and develop technology for both training and research simulators.

It is important to appreciate that the very prominent large motion base is only one part of the VMS. The complete system, as depicted in Figure 1 , consists of a collection of simulation subsystems working in concert via a real-time simulation network. Based on the VMS's operating philosophy of supporting the widest possible range of aeronautical research, the system can be configured by selecting and integrating the most appropriate of several interchangeable components to suit specific requirements of any simulation. This modular approach makes it easy to integrate specialized equipment for a particular simulation. Also, facility improvements can be implemented by upgrading individual components without disrupting operations of the entire simulator.

At the highest level, the simulation elements may be classified under the following functional categories: (i) Host computer, (ii) Interfaces, (iii) Test Operations and Control (Lab), (iv) Crew or Pilot Station (also known as the Cab), and (v) Cueing Systems. The basic concept of real-time man-in-the-loop flight simulation may be described as follows. The pilot executes control actions which are transmitted to the host computer which calculates the aircraft response variables (states) and the corresponding drive signals for the cue-producing devices. The devices generate cues (visual, motion, sound) that stimulate the pilot's various sensory organs in a manner similar to what would occur in actual flight. Hence, the pilot receives the sensation of actual flight, and can evaluate the flying qualities of the simulated aircraft. Researchers and engineers interact with the real-time simulation flow from the devices in the lab. Examples of this interaction are starting and stopping a run, introducing a simulated failure and monitoring test data. Communication between the functional elements is achieved via several interface computers, devices or data links.

Each of the functions described in the above paragraph is performed by one or more physical units.

The Simulation Host Computer is the nucleus of the simulation system because it solves the equations which represent the mathematical model of the aircraft and it generates the signals to command and control all the other devices in the system. Most importantly, it does all this in real-time. This means that the equations are solved fast enough to allow the computed variables that are output to the simulator to be synchronized with real-world (wall-clock) time,

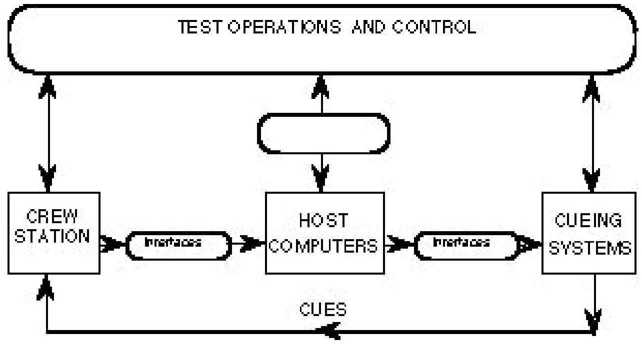


Figure 2 Simulator System Schematic Diagram

which allows the pilot to interact with the simulator as though it were the actual aircraft. SimLab's three production hosts are AlphaServer DS20E (667 mhz) computers manufactured by Compaq Computer Corporation. These powerful systems can operate the motion, laboratory and cockpit sub-systems at a 200 Hz update rate.

The Host Computer communicates with two other computer systems through a Real-Time Data Network :

1. The CGI (Computer Generated Imagery) System, which generates the out-the-window (OTW) visual scene. SimLab uses two multi-channel, full-color CGIs to provide a variety of realistic OTW scenery: The ESIG 3000 and ESIG 4530 which are built by Evans and Sutherland. A library of configurable terrain databases in each of the CGIs gives researchers considerable flexibility with their experiments. Figure 3 illustrates an ESIG 3000 generated OTW scene as viewed in a cab.

2. A suite of SGI (Silicon Graphics Inc.) graphics workstations, driven by the real-time host computer system, generate real-time avionics imagery for presentation on Head-Up (HUD), Head-Down (HDD) and Helmet Mounted (HMD) flight deck display systems.

Figure 3

The system description would be incomplete if there were no mention of the software running on the above mentioned hardware. On the Host Computer, the MicroTAU real-time operating system provides the backbone for all simulations. Also residing on the host are the application programs that represent the mathematical models of the aircraft and other auxiliary subsystems. On the CGI are the real-time image generation system software and the database for the OTW scenery. On the cockpit graphics systems reside the graphics generation programs for the cab and lab displays.

Interchangeable Cabs (I-Cabs)

The five I-CABs used with the VMS provide the capability to simulate the flight deck/ crewstation for almost any imaginable aerospace vehicle. R-CAB and N-CAB are used for rotorcraft simulations, while F-CAB is suited for fighter aircraft. The S-CAB and T-CAB, with their two-place side-by-side cockpit, are ideal for simulating transport vehicles. The cabs can be equipped with either conventional aircraft instruments or advanced avionics (glass cockpits) displays. Pilot controls are connected to electro-hydraulic loaders so that the control system parameters can be matched to those of the simulated aircraft. The cabs are configured, tested, and checked out at the fixed-base I-CAB development location before being moved to the motion platform. This pipeline approach provides maximum efficiency in the use of the motion system.

Other Cueing Devices

There are several other cueing devices besides the ones mentioned above. The sound-simulation system, provided by ASTi Digital Audio Communication System, can reproduce a wide variety of sounds associated with different types of aircraft, warning tones, and voice callouts. Seven speakers are mounted in the cab to provide the audio spatial effects. The vibration generator (or seat shaker) is a mechanism that provides high-frequency, low amplitude accelerations which are characteristic of aircraft vibrations. Motion cues of this type are beyond the frequency response of the VMS motion system. The seat shaker unit can be fitted in the F-CAB, N-CAB or R-CAB.

Examples of Research and Studies

Vehicles simulated at SimLab span the full spectrum of flight, ranging from the Shuttle orbiter and military fighters to various experimental fixed-wing, Vertical/Short Take-Off and Landing (V/STOL), Short Take-Off and Landing (STOL), Short Take-Off and Vertical Landing (STOVL), and rotorcraft designs. SimLab has contributed substantially to flight safety and aeronautical technology by refining and enhancing aircraft design, and improving handling qualities, reducing pilot workload, and providing information on advanced control laws and accident investigations.

For example, the VMS contributed to the U.S. Air Force C-17 Transport program by identifying design and performance issues before the aircraft was built. Also, the VMS is used twice a year to study landing and rollout of the Space Shuttle orbiter. SimLab gives the shuttle pilot-astronauts the opportunity to effectively practice landing scenarios or critical maneuver involving the orbiter. The simulator can provide worst-case scenarios for the pilot, such as blown tires, crosswinds, or failed auxiliary power units. The VMS has been critical for the study of drag-chute design and testing, tire wear, brakes, and crew evaluation and training.

For Further Information...

If you you have any questions please call Tom Alderete, Chief of the Simulation Planning Office at (650) 604-3271 or Barry Sullivan, Chief of the Aerospace Simulation Operations Branch at (650) 604-6756.

Or, visit us on the NASA Ames Homepage on the Internet. Our URL is:

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