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THE VERTICAL MOTION SIMULATOR

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Flight simulation has progressed greatly in the past twenty-five years. The first immobile flight simulators pale in the presence of contemporary technological advances in flight simulation. Today's flight simulators, such as NASA's multimillion dollar Vertical Motion Simulator (VMS), recreate an authentic aircraft environment, and reproduce the sensations of flight by mechanically generating true physical events. A pilot trainee may receive practice and experience without the risk of actual flight test activities. Therefore, there are very few surprises when he/she takes his/her first real flight. New aircraft design concepts may also be tested. For instance, simulation was used to examine the Space Shuttle idea in its early stages.

In the Vertical Motion Simulator, the pilot sits in a cockpit that is a realistic replica of the aircraft being studied. It is used primarily to simulate the Space Shuttle, helicopters, tilt-rotor aircraft, Harrier jets and other aircraft that take off and land vertically. Cathode ray tubes, which are mounted on the cab where windows would normally be found, show computer-generated imagery to the pilot. This provides the visual aspect of the simulation. Computer-generated flight sounds are piped into the cockpit via speakers placed in the cab, bringing audible reality to the simulation. In addition, a powerful electrohydraulic motion drive system moves the cab through simulation maneuvers. This motion system can move the cab through six axes. These three systems, in conjunction with flight controls and instrumentation in the cab that respond realistically, duplicate flight conditions accurately. Digital computers have also been incorporated into the VMS facility. They compute the pilot's control inputs and produce signals which command the visual, audio, and motion generators to provide various cues to the simulator pilot. In addition to managing the current maneuver, the computer system must keep the cab near the center of the simulator chamber to allow for maximum mobility on each successive maneuver. The cab is programmed to assume a more neutral position in the chamber in movements that are inconspicuous to the pilot.

The visual display systems of the Vertical Motion Simulator are paramount to the consummation of realistic simulations. Before the introduction of computer-generated imagery (CGI), a closed-circuit television system was used. Television cameras, mounted on mobile scaffolding, filmed two large three-dimensional terrain models at various angles. The terrain models have features that range from cornfields to an aircraft carrier at sea. The recent computer-generated imagery system displays terrestrial features as well as runways, ships, and other aircraft. It can also simulate changing weather and visibility conditions on a panoramic windshield scene.

The audio component of the VMS is comparable to the synthesizers used by many of today's musicians. This system can create engine noises and the rumble of wheels, and is so precise that it can reproduce the changing sounds of air flow outside of the cockpit.

Though visual and aural cues are sufficient for many flight simulations, many aircraft simulations require a motion drive system that can reproduce the movements felt by a pilot during an actual flight. The VMS motion generator consists of a synergistic electrohydraulic motion system mounted on a moving platform with large lateral and vertical capabilities. It duplicates the physical sensations of actual flight and guides the cab over a wide range of motion. Vertical motion is the primary degree of freedom and all other modes are ancillary, yet quite essential. The VMS is specially designed to provide a six-degree-of-freedom motion capability, including sixty feet of vertical motion, forty feet of lateral motion, and eight feet of longitudinal motion. This unique facility can also roll plus or minus twenty-two degrees, pitch plus or minus twenty-five degrees, and yaw plus or minus twenty-nine degrees.

In the last few years, three major revisions have been made on the Vertical Motion Simulator here at NASA Ames Research Center. The new Control Data Corporation (CDC) 7600 Computer has proven to be much more effective than its predecessors, the Sigma 7 and PDP 11/55 digital computers. The Interchangeable Cab System (ICAB) enables the simulator cabs of various aircraft to be mounted on the main platform. Lastly, computer-generated imagery has been substituted in place of television scenes, allowing for a wider range of visual images.

The Vertical Motion Simulator is managed completely by a network of computers, the nucleus of that network being the Control Data Corporation (CDC) 7600 Computer. This system offers a notable increase in computing speed over previous computers, and can be programmed to simulate various aircraft such as a 747 airplane, a Harrier jet, an F-14 jet, a helicopter, or a Space Shuttle. It is used primarily, however, to simulate aircraft that take off or land vertically or on a short runway. This large scale computer also has the capability to simulate several aircraft on different simulators, simultaneously. The flight simulation program for the CDC 7600 includes mathematical equations which are associated with the aircraft's position in space, flight characteristics, and the specifications of the aircraft being simulated. As the pilot operates the cockpit controls, signals are sent to the computer. The computer interprets these signals and calculates the proper response of the aircraft instantaneously. The computer then issues the appropriate commands to the motion drive system, the flight instrumentation, the audio system, and the video system, to provide the pilot with representative aircraft responses and flight environment. The entire process, which includes the generation of sound, motion, visual effects, and instrumentation response, occurs in mere milliseconds.

Unlike other simulators with a single fixed cab, the Vertical Motion Simulator incorporates the newly developed Interchangeable Cab System (ICAB) to allow increased operational efficiency of the flight simulator. Testing and fixed-based checkout of the cabs can be performed at the development station while the motion system remains free for maximum use in simulation investigation. For maintenance purposes, all of the cabs have been constructed with removable canopies.

The Interchangeable Cab System consists of three operating interchangeable cabs and a development station with provision for two other cabs. Two more cabs are now in development. All of the cabs are designed facsimiles of original cockpits from different aircraft, and each is accoutred with a sound system which amplifies the sound of helicopter blades, landing gear, and touchdown, engine, and mechanical noises through four strategically placed speakers in each cab.

There are three ICABs currently in use at NASA Ames Research Center. The first has capabilities ranging from transport aircraft, such as the 747, to high performance vehicles such as the Space Shuttle. It has two seats, placed side by side. The second is an advanced helicopter cab, which is designed to look and handle like helicopters in the developmental or testing stages, such as Rotor Systems Research Aircraft (RSRA). The third ICAB in use is referred to as the "generic helicopter," and has the programming variability to be any rotorcraft. The two other ICABs now in development will be a single-place cockpit with fighter capabilities, and an Advanced Cab and Visual System (ACAVS).

The Flight Simulation Program at NASA Ames Research Center is one of the most advanced in the world. Ames aircraft simulators and human testing devices are used exclusively for research. About sixty percent of the operation time of the simulators is devoted to NASA's aeronautical research. The Ames facilities have been used to investigate most civilian aircraft as well as the Space Shuttle, tilt-rotor aircraft, and the Apollo lunar landing craft. Another thirty-five percent of Ames simulator operation time is used in cooperation with other governmental agencies. Experimental programs run by the Department of Defense occupy a large portion of this time. They have used the simulators extensively to investigate flight instrumentation which is superimposed on the windshield for easy visual access. This idea is also being tested by the Federal Aviation Administration for use in commercial aircraft. Also, the National Transportation Safety Board uses Ames facilities to determine the cause of aviation accidents. They do this by reconstructing crash scenarios using Ames simulators. The remaining five percent of Ames simulator operation time is devoted to the study and advancement of simulation technology.

In addition to their application as a training tool for pilots, simulators have become essential in the design, construction, and testing of new aircraft. Simulators allow engineers to study an aircraft's flight performance and characteristics without the cost or risk of an actual test flight. Because of their practicality, simulators will become more and more important in the development and design of new, safer aircraft.

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VERTICAL MOTION SIMULATOR (VMS)

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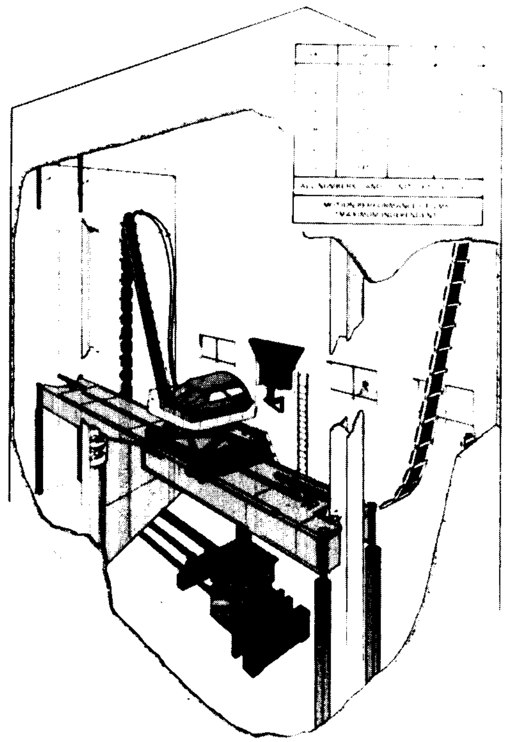

PRIMARY PURPOSE:

- EVALUATE/DESIGN OF
  - FLIGHT DYNAMICS
  - HANDLING QUALITIES
  - V/STOL FLIGHT SYSTEMS
  - CONTROLS

KEY CHARACTERISTICS

- 6 DEGREE OF FREEDOM
- ±30 FT VERTICAL TRAVEL
- DIGITAL/ANALOG DEVICES
- 2 MAN COCKPIT
- SPLITTER MIRROR DISPLAYS
- AURAL CUEING SYSTEM WITH ROTORCRAFT SOUNDS

Figure 1.- Vertical motion simulator (VMS).