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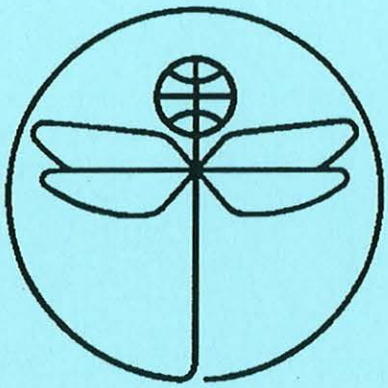

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INTEGRATED BENCH FACILITY FOR THE SIKORSKY S-92 FLIGHT CONTROL AND COCKPIT DISPLAY SYSTEM

BY

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Integrated Bench Facility for the Sikorsky S-92 Flight Control and Cockpit Display System.

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INTEGRATED BENCH FACILITY FOR THE SIKORSKY S-92™ FLIGHT CONTROL AND COCKPIT DISPLAY SYSTEM

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Abstract

The S-92™ System Integration Facility is a modular, rapidly adaptable system designed to support multiple users of different disciplines in the design and development of Sikorsky's newest commercial aircraft. The facility consists of a two station cockpit, out-the-window visual system, electronics racks, simulation environment, and control and monitoring stations. All aircraft sensors, actuators, and processors can be actual hardware or simulated, in any combination. This provides the capability to design, develop, integrate, and test a complex system whose individual components range from off-the-shelf devices to subsystems existing only as preliminary specifications.

Background

This paper describes a laboratory System Integration Facility (SIF) for the development and test of flight control and Avionic systems for the Sikorsky S-92™ helicopter. The S-92™ will provide a full-featured, integrated Flight Control/Cockpit system to satisfy the requirements of a sophisticated customer base. To meet functionality and certification requirements with minimal schedule risk and low delivered cost, the majority of the flight control development, system integration testing, and certification testing and documentation will be done before roll-out of the first flight article.

Besides providing an industry-leading feature set, the integrated cockpit system must be delivered at a competitive price and with minimal schedule risk. To this end, the majority of design problems and integration discontinuities must be uncovered early in the design cycle, where they are cheaper and easier to correct. Implementation of a realistic integration reduces the schedule risk allow for the minimum amount of expensive development flight hours.

System Overview

The S-92™ system development focuses on the integration of the Automatic Flight Control

System (AFCS) and Flight Director control laws with sensors, cockpit displays, aircraft electrical systems, and mechanical controls. The SIF consists of actual production and pre-production hardware built to existing S-92™ design. This hardware integrates with a simulation environment consisting of a GENHEL aircraft model, Out-The-Window displays, and Civil Navigation database. Computer control of the facility permits running of automated test cases, providing repeatable data for evaluating the effects of subsystem changes on the entire aircraft.

A block diagram of the SIF is shown in figure 2. The facility has a two station cockpit with actuator assembly. Color monitors provide the pilots with out-the-window views. Displays in the instrument panel provide the pilots with aircraft instruments and navigation information. At the rear of the cockpit are Inner and Outer Loop AFCS actuators.

All aircraft sensors, actuators, FCCs, and subsystems can be actual hardware or simulated, in any combination. Sensor models have extensive fault-insertion to test system failure response. This provides the capability to perform a range of test maneuvers with excellent repeatability. Data bus traffic, airframe body variables, and selected parameters from Flight Control and Avionic processors are available for display and are recorded for analysis.

The Civil Navigation environment enables realistic development and testing of coupled navigation algorithms and pilot display strategies. The environment contains airports and radio navigation sources and couples to the Out-The-Window-Display database to allow complete, realistic mission scenarios. The display shows terrain, runways, buildings, and other visual cues, and is user-adjustable for a variety of atmospheric conditions.

The facility is a highly effective tool for users from a broad range of disciplines to design the aircraft as an integrated system, rather than a series of subsystems sharing a common airframe.

Physical Configuration

Cockpit

The SIF is located on the raised-floor section of Sikorsky's Electronic Flight Controls Laboratory. Figure 1 shows a photo of the cockpit portion of the facility. The cockpit's pilot and copilot stations are equipped with conventional control sticks connected to Inner and Outer Loop AFCS actuators at the rear of the cockpit. Displays in the instrument panel provide the pilots with aircraft instruments and navigation information.

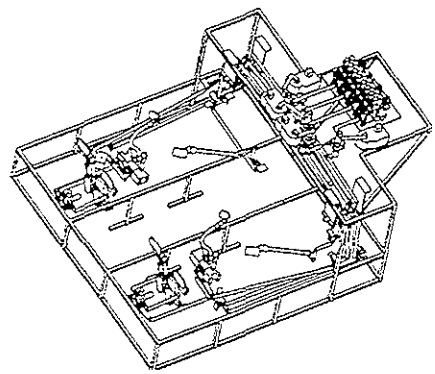

Figure 4
Cockpit Frame and Control Rods

The cockpit assembly was built using aircraft prints, which is a first step in validating the design. Even with the best CAD systems, the place to find interferences and print errors should not be the first flight article. Cyclic and Collective sticks and pedal assemblies are aircraft hardware, connected by control rods running under the cockpit floor. The cockpit is on a raised platform to allow access to the control rods. Figure 4 is a drawing of the cockpit frame and control rods. The pilot and co-pilot control rods run aft and join on a raised deck arrangement that represents the upper deck of the aircraft. Mounted on this deck are the Inner Loop Stability Augmentation System (SAS) actuators and the Outer Loop (Trim) actuators.

The S-92 ™ will have a "Glass Cockpit," and the Primary Function, Multi-Function, and Engine Instrument information is displayed on LCD displays in the instrument panel. The facility is configured to easily accept changes to the EFIS design. The display system provides Flight Management, Navigational Source Selection, and heads-down information. The center console houses navigation, radio, and display control panels.

Out-The-Window Visual system

Mounted directly in front of the cockpit are three, 37-inch color monitors that make up the display portion of the Out-The Window visual system. The three displays provide a panoramic, 180° X 80° field of view. The monitors are driven by a CompuScene IV display system that receives aircraft position and attitude from the simulation and maps that information into the visual database.

When the high-quality graphics of the CompuScene IV are not required, the center monitor is driven by a dedicated Silicon Graphics workstation. This frees up the CompuScene IV for use on other programs, and allows the S-92 ™ bench facility to operate without scheduling restrictions. The workstation's out-the-window display to the center monitor also drives a monitor at the Simulation Control station.

Electronics Racks

The Flight Control Computers (FCC), Avionic display generators, and sensors are on two electronics racks to fit with the aircraft Modular Rack concept. The racks are double-wide with pull-out shelves for access. Figure 3 is a photo of the rack assembly. Wiring runs from the equipment trays to connectors mounted on metal plates at the bottom of each rack. These connectors mate to an interconnect harness that comes up through a hole in the raised floor. Modularity permits the installation of actual aircraft wiring harnesses for design validation and interchange of equipment with the aircraft. In a matter of minutes the development equipment rack can be disconnected and replaced with an actual aircraft rack.

The Flight Control computers and all ARINC-429 busses have dedicated breakout and patch panels for monitoring and troubleshooting. Individual LRUs have breakout boxes that can be inserted on an as-needed basis.

The lab bench wiring harnesses were built from S-92 ™ aircraft drawings. These harnesses are not production units, but are electrically

identical. Errors discovered during checkout of the lab bench are used to correct the aircraft drawings.

Simulation computers

The simulation portion of the facility is distributed over a number of processors. The main simulation runs on multiple processors located in Sikorsky's central computing facility, and connect to the visual system and local processors at the lab bench.

The airframe and sensor models are provided by a GENHEL simulation running on a multi-processor Encore computer system. The number of processors varies with the complexity of the simulation. If a set of tests does not need a portion of the simulation, for example, Radio Navigation functions, those modules can be quickly disabled and the number of processors required reduced. This follows from the facility requirement of minimizing impact on shared resources.

The simulation processors are connected by a high-speed serial bus to a slave unit in the lab facility that handles all the analog and discrete Input/Output (I/O) processing. For specialized signals, such as thermocouple or Temperature Dependent Resistor (TDR) sensors, proprietary circuits convert the DC voltages provided by the I/O processor. The simulation processors also connect to the Silicon Graphics workstation, which is the host for ARINC-429 bus simulation and monitoring, and for local out-the-window visual generation.

Located behind the cockpit are the Control and Monitoring stations. The simulation control station has terminals to communicate with the simulation computers, and an auxiliary out-the-window display. Besides controlling the simulation, this station directs the data acquisition and display of ARINC-429 bus data and simulation parameters. The AFCS control station has a dedicated terminal to communicate with the Flight Control Computers.

Support Facilities

Electrical power for the lab bench is available from three sources: normal lab power, a programmable power supply, and a motor-generator system. Selection is made by a power switching panel. The programmable power supply is used for power transient testing. The motor-generators permit integration testing the electronics suite with the actual aircraft generation system.

A hydraulic pump is located adjacent to the lab bench in a sound-proof enclosure. Hydraulic lines run under the lab's raised floor and connect to electro-hydraulic and boost actuators on the rear deck of the cockpit assembly. The pressure and flow rate of the pump are adjustable to test proper operation of the actuators over a range of operating conditions.

System

Simulation

The GENHEL aircraft model provides a realistic simulation of the S-92™ airframe. This is necessary to provide a sound basis for flight control law development. When combined

with a detailed out-the-window visual display and realistic flight controls, the simulation allows the project pilots to evaluate the feel of the airframe. For example, a change in tail area can be evaluated over a range of CGs and Gross Weights in an afternoon, without the need for weeks of expensive flight testing and airframe modifications. The use of simulation cannot eliminate the need for flight testing, but is invaluable in narrowing the scope of the design and avoiding expensive 'dead ends.'

The simulation has a model of each sensor and actuator used in the system. The model definition is derived from the specification for the device. Simulation parameters (airframe attitudes, rates, accelerations, airspeed, etc.) pass through the sensor models and are output with the analog, discrete, and serial bus characteristics appropriate for that sensor.. Even self test modes are implemented. Sensor models have extensive fault-insertion capability to test system failure response.

Civil Navigation

The Civil Navigation database provides the basis for development and testing of the Coupled Flight Director with a variety of radio navigation sources. The database covers Metropolitan New York/New Jersey and Connecticut. It contains numerous airports and radio navigation sources covering VOR, ILS, ADF, and DME. The Civil Navigation database is coupled to the Out-The-Window-Display database to allow complete, realistic mission scenarios. Besides the Metropolitan New York area, additional databases can be accessed with oil rigs, heliports, etc., to cover a full range of aircraft missions.

The simulation includes the capability to "Snap-to." Upon command from the pilot, the simulation will be quick-trimmed to a predetermined altitude, attitude, airspeed, and location. This provides a quick way to perform repeatable maneuvers (e.g., approach, depart, ILS intercept) without having to manually fly the simulation back to a point. Different reference points are stored as files and recalled as necessary.

Operation

Simulation Environment

The S-92 ™ Avionics Simulation environment provides the operator the capability to execute Static and Real-Time testing and error insertion. The operator chooses parameters for recording and display, and can modify input parameters on the fly. The simulation also has extensive data reduction capability, and can perform a system self-test to verify the lab bench is fully operational. The operator selects between a piece of real or simulated hardware by plugging into the mounting tray with either the real equipment or a mating connector from the simulation. Figure 5 shows the selection of simulated or actual LRU by connector. The operator has the capability of setting flags in the simulation to enable or disable the simulation and stimulation functions.

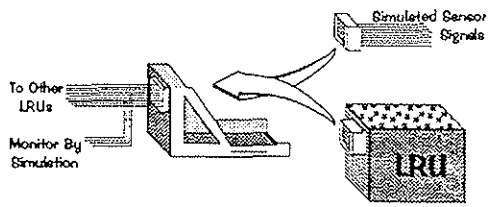

Figure 5
Selection of Simulated or Actual LRU

Static Testing enables the operator to preset the output value of simulated sensors from the Simulation Computer System. The preset value remains set throughout the simulation. Static Testing permits the operator to test the operation of the equipment over a pre-determined range of simulated values.

Static commands to the I/O and ARINC-429 bus interfaces can be set up and read without the need for real time support from the simulation processors. This allows continued testing when the full capabilities of the simulation are not available and conserves system resources. The operator can define the system configuration (real or simulated subsystems), and set specific static values for each of the simulated sensor inputs via menu or file inputs.

The Real-Time Simulation (Live Stick/Pre-Recorded Stick/Pre-Defined Operating Scenarios) allows the operator to execute simulated missions using a combination of simulated and actual equipment. The simulation is defined by the operator using either a pre-defined scenario or via interactive menu input. The Real-Time Simulation accepts inputs from, and provide outputs to the simulated equipment.

The Real-Time Simulation enables the operator to execute the real-time simulation of the S-92™ Mission Equipment Package (MEP) and AFCS using live stick inputs from the flight control sticks, or predefined time-varying stick inputs. The simulation is capable of recording pilot stick inputs (pitch, roll, yaw, collective) and playing these signals back into the simulation and/or as stimulation into the stick transducers.

Prior to initiating any of the real-time simulations, the operator establishes initial set-up parameters (via menu-driven displays or pre-defined file) which will control the simulation. Set-up parameters include the following:

a. Environmental data - wind speed, wind heading, sea level air temperature, air temperature lapse rate, magnetic variation, local terrain altitude, and gravity

b. Helicopter profile data - initial helicopter position, altitude, true heading, true airspeed, segment times, mode, pitch and roll attitudes

c. Helicopter stores data - fuel tank levels /consumption rate

d. Nominal MEP data

e. Error functions data

f. Discrete failures data

Error Insertion The system has the capability to insert errors on all signal paths. With variable signals (airspeed, lateral acceleration, etc.) the errors are in the form of slope and bias changes (mx + B, where x is a variable, m is the slope and B is the bias). With discrete signals, the error is produced by forcing the output either to 'High'/'True'/'On' or 'Low'/'False'/'Off'. In both cases, the error coefficients (m, B, 'High and 'Low') can be programmed to vary with time.

Data Display / Data Recording The operator is capable of selecting Simulation software

variables (using variable names) to be recorded in an operator-selected output file or displayed on digital brush recorders during static test or real-time simulation. The simulation variables are entered by the operator via GENHEL Symbol set-up techniques or operator selectable pre-defined files. All recorded data is time-stamped and stored in a format compatible with existing Data Reduction tools.

Data Reduction The simulation facility provides the tools to reduce the captured data off-line following the simulation runs. Data reduction options include:

a. Reduction based on time intervals

b. Reduction based on change of discrete value(s)

c. Reduction based on the difference between pairs of parameters (e.g. second parameter subtracted from the first parameter, fourth parameter subtracted from the third parameter)

d. Reduction based on conditional event states

e. Statistical reduction (e.g., the calculation of the mean, minimum, maximum, and standard deviation of the processed parameters)

All data reduction files reside on the computer used for data reduction and plotting tasks.

Data Manipulation During real-time simulation, the operator has the capability to modify a simulation input parameter, including the injection of errors, without halting the simulation. The modification of these parameters allows the operator to select and observe the effect of a modification (e.g., proper output identification, output value, response and returned value). In addition, the operator has the capability to start and stop data recording and halt the simulation.

Wrap-Around Test The simulation has the capability of executing an operator-initiated wrap-around test that verifies the connectivity and integrity between the Simulation Host Computer System and the rest of the facility. This self-test is performed at the beginning of each simulation shift to insure the proper operation of the system.

Users

The main purpose for the SIF is to serve as a resource for the designers and engineers on the S-92 ™ program. The following is a list of just some of the in-house 'customers' for the SIF and their applications.

Avionics System Development

The modularity between the Simulation, Flight Controls, Avionics, and Electrical Systems allows complete flexibility and interchangeability of Avionic system designs. Various vendors and designs may be interfaced to the existing aircraft configuration and evaluated before the first aircraft is built. This enables rigorous risk reduction testing which can identify new integration ideas, resolve possible incompatibilities and, most importantly, identify the best design alternatives.

Electronic Flight Controls

Flight Control Law Development - The flight control laws are developed in the simulated FCCs using a high-level programming language. The control laws are processed through a Pictures-To-Code toolset to produce FCC source code. Ported code is validated by comparing the block diagrams against the operation of the code in the FCC, and by a side-by-side comparison with the simulation code over a range of automated test cases. The SIF's extensive simulated flight capability enables a considerable amount of integration certification testing to be completed in the lab, greatly reducing the amount of costly aircraft flight hours required to obtain FAA/CAA certification.

Mechanical Flight Controls

Since the cockpit has been built to actual aircraft drawings, the mechanical control design can be validated before the first aircraft is built. This allows pilot evaluation of control feel, throws, and possible interferences. Actuator vendors supply prototype hardware for evaluation that need not be flight certified, resulting in reduced prototype cost and faster turn-around.

Electrical Power Systems

Electrical system testing - Effects of bus switching transients and line voltage fluctuations (e.g., in-flight engine restart) are measured and used to validate analytical models. This is especially critical to determine load shedding for battery-only certification requirements.

Test Engineering

The SIF is used in the development of production Acceptance Test Procedures (ATP). It will give Test Engineering a working model of the aircraft to iron out any uncertainties while developing efficient and effective production test procedures ensuring a timely production schedule.

Summary

The S-92™ System Integration Facility is an excellent site to test the integration of Flight Control and Avionics hardware and software. The facility has been in operation for over a year, and has greatly reduced development costs compared to the cost of performing the same tests on an actual aircraft. The facility has also provided a place to try out new ideas and to test alternate LRUs.

The SIF will continue to grow as the S-92™ program develops, increasing functionality and expanding the list of users for this powerful resource. This facility is an excellent example of the high level of integration and demand for a quality product that marks the Sikorsky S-92™ helicopter.

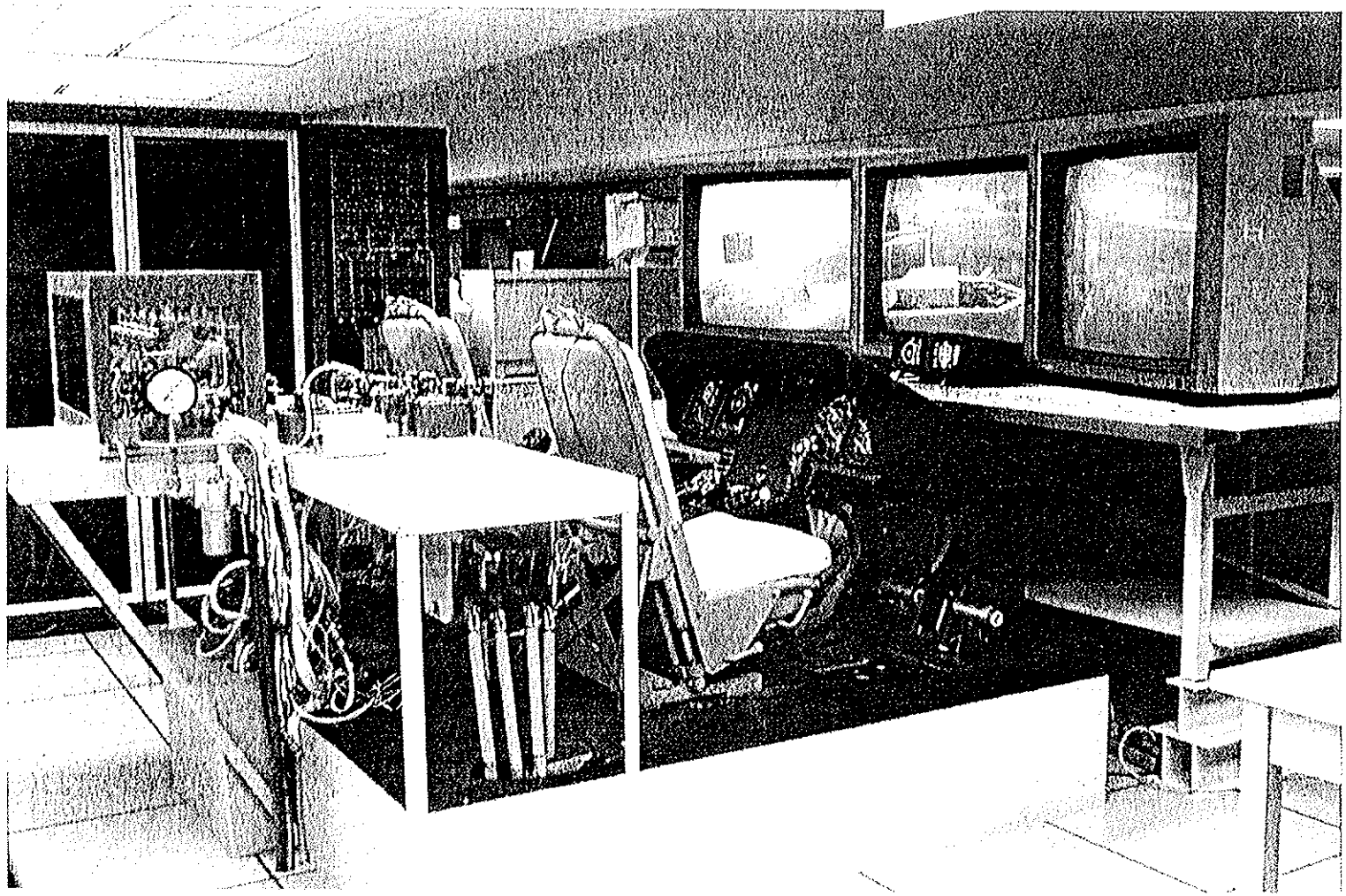

Figure 1
Cockpit Section Of Lab Facility

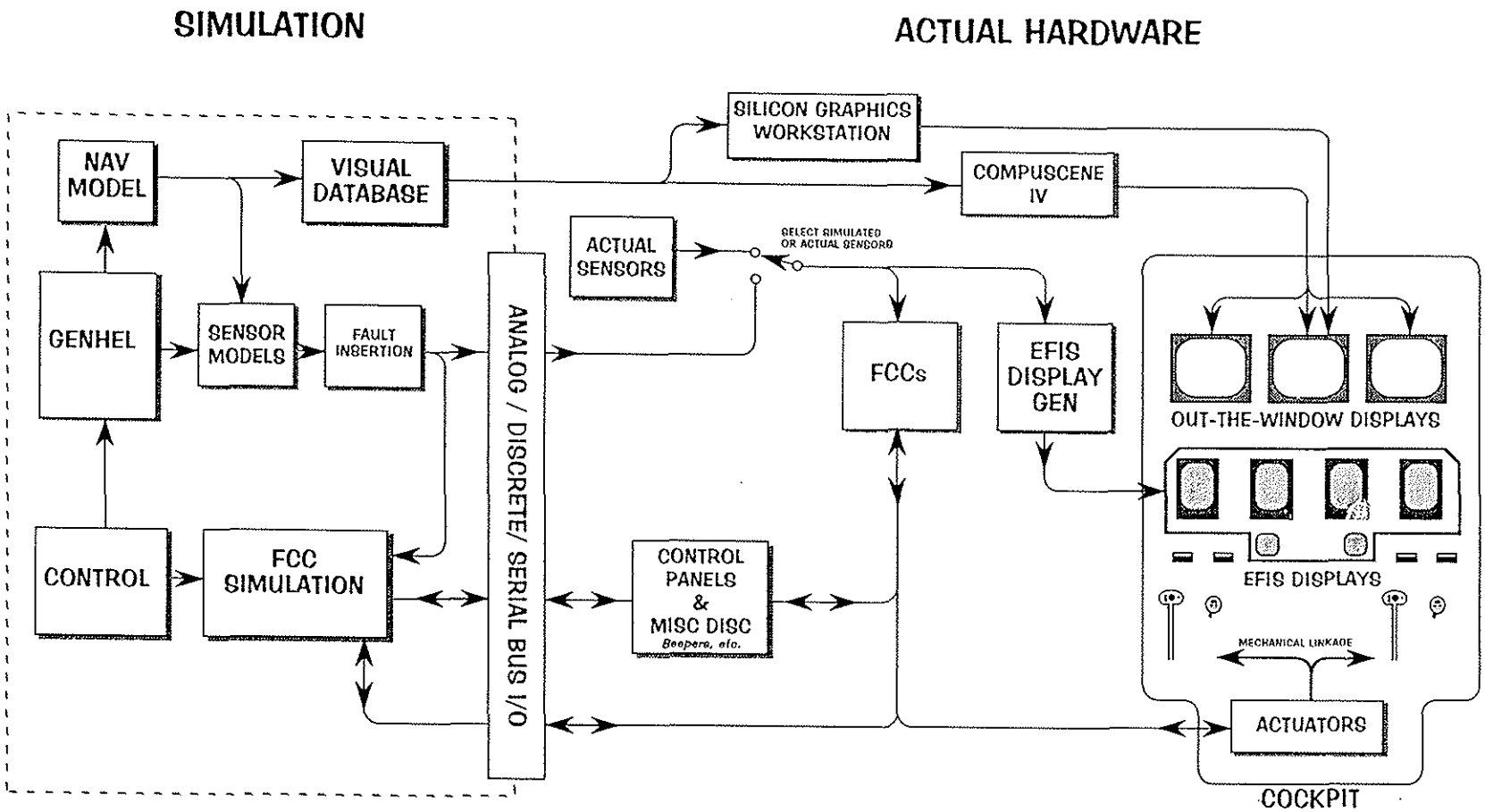

Figure 2
Facility Block Diagram

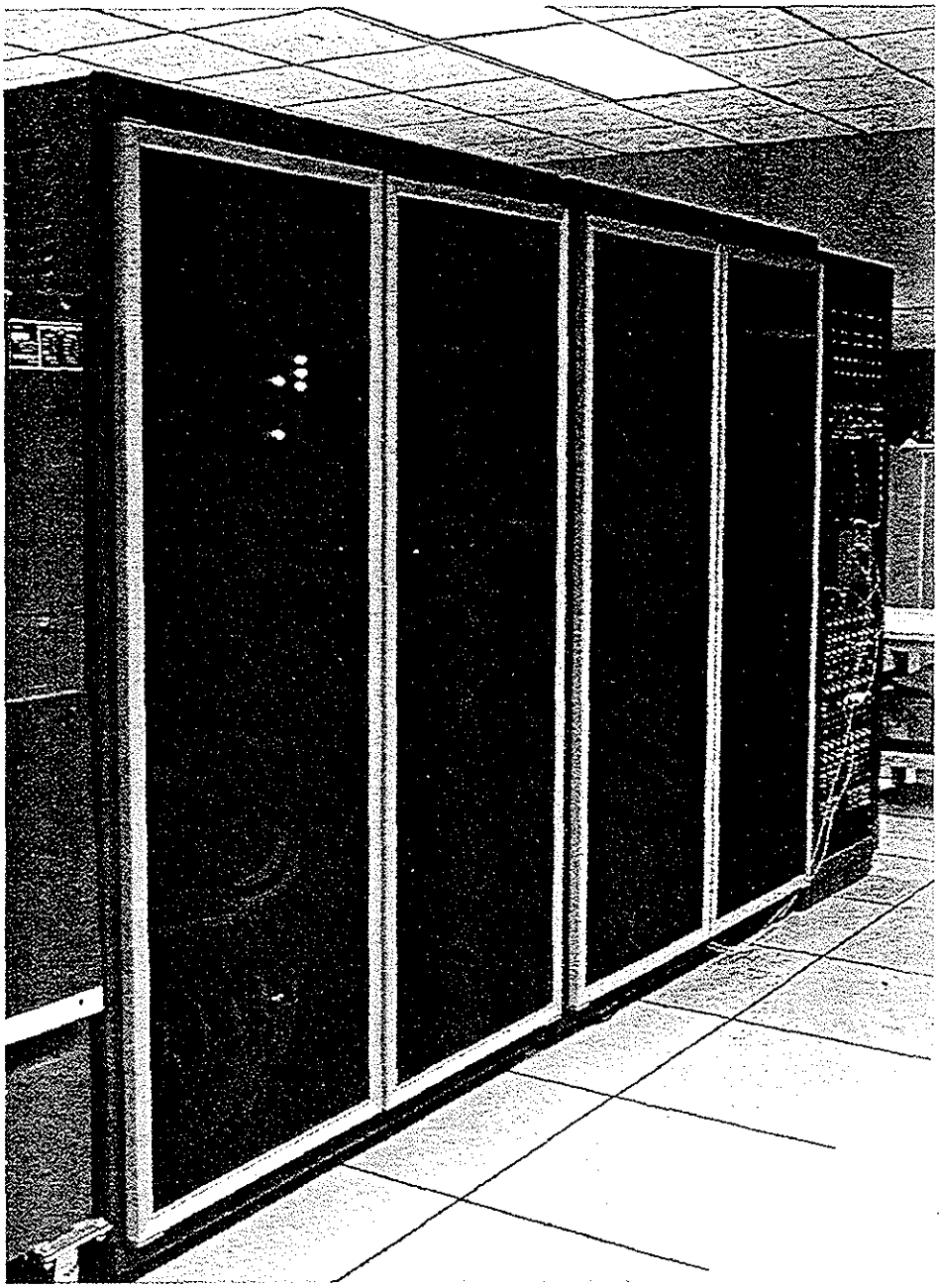

Figure 3
Electronic Rack Assembly