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IBM

International Business Machines Corporation
Federal Systems Division
326 East Montgomery Avenue
Rockville, Maryland 20850

For further information contact:

In Rockville: E. B. Evans
301 424-6700

In Houston: A. J. Cella
713 HU 8-3300, Ext. 371

In Owego: F. C. Smith
607 MU 7-2121

FACT SHEET:
IBM COMPUTER WILL DIRECT SATURN ORBITAL TEST FLIGHT

An IBM digital computer will direct today's orbital mission of the Saturn IB, another step toward putting an American on the moon by 1970.

The computer will digest data on velocity, position, attitude and time and issue steering signals 25 times a second to keep the launch vehicle on course to orbit.

Then, through four orbits, the computer will control a series of tests designed to evaluate the Saturn's ability to stop and restart its second stage engines on future manned missions and maneuver into position as a launching platform for the manned Apollo spacecraft. After separation, the Apollo will continue on to the moon alone.

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In addition to the computer, the IBM Federal Systems Division's Electronics Systems Center in Owego, New York, under contract to the National Aeronautics and Space Administration's George C. Marshall Space Flight Center, has developed the factory-field test equipment called Aerospace System Test and Evaluation Complex (ASTEC).

IBM, through FSD's Space Systems Center at Huntsville, Alabama, also has the responsibility for the fabrication, assembly and test of the Saturn launch vehicle's instrument unit (IU). The IU is a three-foot, 21.7-foot diameter stage located between the S-IVB propulsion stage and the payload. The computer and data adapter are part of the IU's guidance system.

WHAT THE COMPUTER DOES

Before launch, the computer first checks out the entire guidance system, then runs a complete mission simulation. Once the 1.3-million-pound launch vehicle lifts off, the computer issues navigation commands for the two-stage booster.

During a typical launch-to-earth-orbit flight segment, changes in speed and attitude are sensed by such instruments as accelerometers and gyros. A data adapter gathers the signals and translates them into computer language.

The computer processes the data and, using information stored in its memory, issues steering correction signals. These signals are sent back through the data adapter to the flight control computer which directs the thrust of gimbaled rocket engines so that the launch vehicle stays on the most efficient course to earth orbit.

Even should one of the Saturn's engines fail, the computer would issue signals ordering the other engines to change their direction of thrust to compensate for the loss in power.

After navigating Saturn into orbit, the computer checks out the third stage propulsion system and sends test results to the ground for analysis. (On manned flights, the computer will calculate the transfer trajectory and issue signals restarting the third stage to send the Apollo on to the moon.)

UNIQUE SYSTEM FEATURES

There are four unique design concepts developed by IBM to meet the stringent weight and reliability requirements of the Saturn guidance system:

* Duplex Memory System - Two separate memory systems operating simultaneously during the most critical portions of the mission. This reduces the possibility of a system failure caused by transient errors in the memory. One memory corrects the other in the event of intermittent failure.

* Triple Modular Redundancy - The first computer application in which all circuits vital to the accurate operation of the computer (and data adapter) are triplicated, their output fed to "voting" circuits, and a two-out-of-three majority rule established.

* Unit Logic Devices - Microminiature circuit technology resulting in a small and light-weight computer that has seven times as many components and is three times faster, electronically, than many earlier computers.

* Magnesium-Lithium Structure - A light-weight, high-strength structure that serves as its own "cold-plate" to carry off potentially damaging heat generated by electronic circuits. It offers a 65-pound saving in weight over conventional aluminum structure designs.

DUPLEX MEMORY SYSTEM

The computer has a random access magnetic core memory system capable of storing 920,000 data bits in eight plug-in modules. Each memory module has self-contained electronics and toroid storage for 4096 28-bit computer words. Six of these modules, operating as pairs of duplex memories, are sufficient to hold the planned Saturn IB mission programs. The computer occupies only 2.2 cubic feet, weighs only 88 pounds, and requires 131 watts input power. However, two additional memory modules can be plugged into the computer for special mission requirements without increasing the computer's size.

The unusual aspect of the Saturn guidance computer memory system is that it is organized to operate either as a single memory or as two identical memories operating in parallel.

In the parallel, or duplex, mode the output of only one memory is used by the computer, although both operate simultaneously on the same program. Should a transient failure occur, the failure would be detected by special error detection circuitry built into the system. Automatically and instantaneously, the computer would switch to the memory that had not failed.

Should the second memory subsequently fail, the computer would switch back to the first. The mathematical probability that both memories would fail at the same memory word address at the same time is very small. Moreover, should a transient malfunction occur in either memory, the correct output from the working memory automatically corrects the failed memory, thus achieving a self-correcting system.

TRIPLE MODULAR REDUNDANCY

Besides the duplex memory design, IBM engineers utilized a triple modular redundancy (TMR) approach to achieve a high degree of reliability for the Saturn computer and data adapter. With TMR, the computer has three identical logic channels rather than the single channel of a conventional computer. Each of the three channels is subdivided into seven functional "modules" representing the most critical sections of the computer. This approach provides three identical modules for each vital function.

When a problem is presented to one module, the same problem is presented simultaneously to its triplets and all three act on the problem together. The results,

arrived at independently, are fed to a majority rule "voter" circuit. Any dissenting "vote" is discarded as an error, and only identical signals released by at least two of the modules are passed along by the voter circuit.

Since these critical areas of the computer (and data adapter) are not dependent upon single modules for correct data, the failure of one vital functional module cannot cause failure of the whole system. There are 98 voters in the computer checking an average of 13 output signals from each module. The voting procedure does not appreciably slow the computer. Worst-case delay is only 100 nanoseconds (billionths of a second).

UNIT LOGIC DEVICES

The microminiature circuit module for the IBM computer uses a hybrid integrated technology. Called unit logic devices, these modules comprise 90% of the Saturn guidance computer and data adapted.

There are more than 50 types of the ULD circuits and a total of 8918 ULD's in each computer and data adapter. The basic circuit contains up to 17 components. Passive components and electrical interconnection paths for each circuit are silk-screened onto both sides of wafer-like alumina substrates measuring 0.3-inch square by 0.028-inch thick. The active elements are attached by solder reflow.

Up to 35 of these ULD circuits are then mounted on a 2.5- by 3-inch multi-layer interconnection board containing all necessary signal and power connections.

Two boards interconnected back-to-back form a "page," the basic field replacement level for the system.

MAGNESIUM-LITHIUM CHASSIS

The structure in which ULD pages and the memory are housed is made of magnesium-lithium alloy — a metal with one of the best weight-to-strength ratios.

The structure also serves as its own cold-plate. Precision holes are gun-bored into the chassis through which a methanol-water coolant circulates to carry off heat generated by the electronic subassemblies. Using magnesium-lithium, and making the structure serve two functions, have saved 65 pounds compared with a conventional aluminum structure with a cold-plate.

DATA ADAPTER

The data adapter uses the same basic technology as the computer, including ULD circuits and TMR reliability concept. Within the 3.3-cubic foot, 190-pound package are duplex power supplies for the computer, memory and its own electrical requirements, plus registers and sampling circuits for 13 outputs and 32 inputs, buffers for all interrupt signals to the computer, digital-to-analog and analog-to-digital converters and glass ultrasonic delay lines to store digital data for the computer, also, timing circuits, and telemetry data converters.

In effect, the data adapter is the gateway to the computer for all elements of the complex Saturn guidance system.

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