ollo/Saturn Press Information

Note to Newsmen:

These are the facts about IBM's role as a NASA prime contractor in the Apollo/Saturn program. They are organized for quick reference. Computer terms are defined in a glossary. Glossy prints of photographs and illustrations are available from IBM information offices listed on the following page. Please order by photo number.

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IBM Apollo/Saturn Contracts

Real-Time Computer Complex
$186 million NASA prime contract for IBM System/360 Model 75 data processing systems; programming, simulation and maintenance.

Federal Systems Center
Houston

Goddard Real-Time System
$38 million NASA prime contract for two System/360 Model 75 computer systems; system engineering, programming, simulation and maintenance.

Federal Systems Center
Greenbelt, Md.

Instrument Unit
$233 million NASA prime contract for 12 production models for the uprated Saturn I and 15 production models for the Saturn V; system testing and inflight monitoring from remote sites.

Space Systems Center
Huntsville, Ala.

Computer and Data Adapter
$101 million NASA prime contract for seven prototypes of the computer, six prototypes of the data adapter and thirty-one production models of each.

Electronics Systems Center
Owego, N. Y.

Launch Support
$56 million NASA prime contract for engineering test support of the instrument unit; operating, maintaining and writing computer programs for the Saturn launch computer complex.

Space Systems Center
Cape Kennedy

The Real-Time Computer Complex (RTCC) is an IBM computing and data processing system at NASA's Manned Spacecraft Center in Houston. It collects, processes and sends to Mission Control the information needed to direct every phase of an Apollo/Saturn mission. It computes what the space vehicle is doing and compares that with what it should be doing. RTCC works in real-time—so fast, there is virtually no time between receiving and solving a computing problem.

Equipment

IBM System/360 Model 75J's*, plus peripheral storage and processing equipment. Two computers are used during a mission. One is primary. The other operates identically, but as standby. (For equipment specifications, see Goddard section.)

*System/360 replaces IBM 7094-II computers used during the Gemini program and on the first three Apollo/Saturn missions.

What RTCC Does

Computers work under the control of a program. A program is a list of coded instructions stored in computer memories. It enables computers to perform mathematical and logical operations to solve a problem. Each Apollo/Saturn mission requires its own RTCC program package. The lunar mission program package is one of the longest, most complex computer programs ever written. It has seven program subsystems, each with a mission specialty —from launch to reentry:

Wide-angle view of RTCC—one of the world's largest computer centers.

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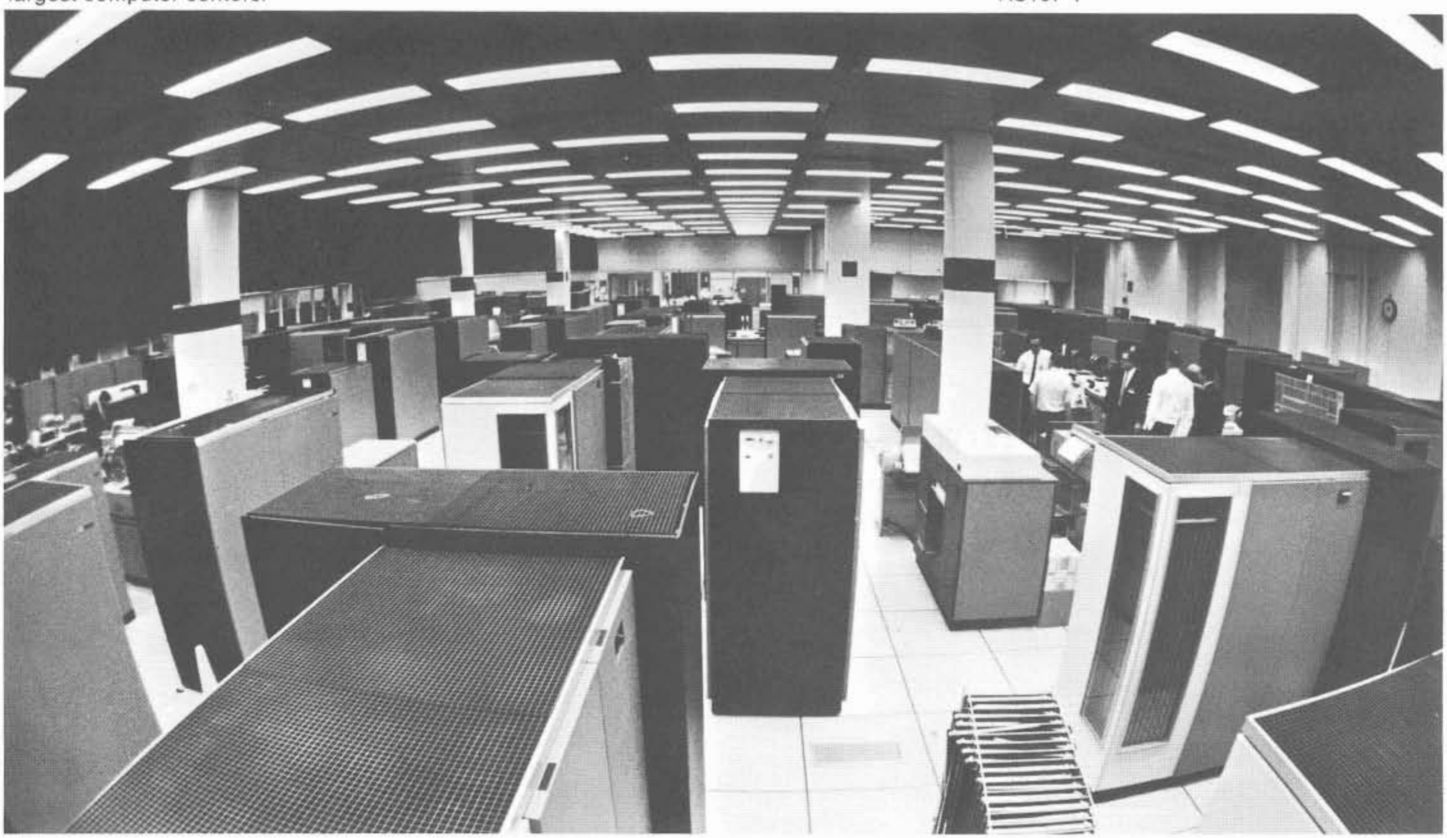


1. *Launch Program Subsystem:* updates position and velocity, using:

- Range and velocity values every half-second from the impact predictor computer at Cape Kennedy.
- Range, azimuth and elevation values every tenth of a second from radar at the eastern test range.
- Range and velocity values every second from the instrument unit.
- Range and velocity values every two seconds from the command module computer.
- Range and range rate values every tenth of a second from Unified S-Band radar sites.
- Range and velocity values every half-second from ships downrange.

A computer controller selects the sources of information to use and tells NASA flight controllers which ones he selected. Every half-second, RTCC computes and sends to flight controllers a position vector (vehicle's location) and a velocity vector (how fast and in what direction the position is changing).

After S-IVB engine cutoff and during the space vehicle's coast period, RTCC computes position, velocity and altitude and calculates whether the vehicle can achieve at least one and one-half orbits of the earth—a "go" condition. If the condition is "no-go," RTCC computes the maneuver and the S-IVB's extra burn time to achieve orbit. Or, should Mission Control elect to end the flight, RTCC computes the maneuver for reentry and splash-down in a preselected recovery area.

If an abort occurs . . .

. . . while the launch escape tower is still attached (during the first three minutes), RTCC predicts the splash-down point. (mode 1 abort)

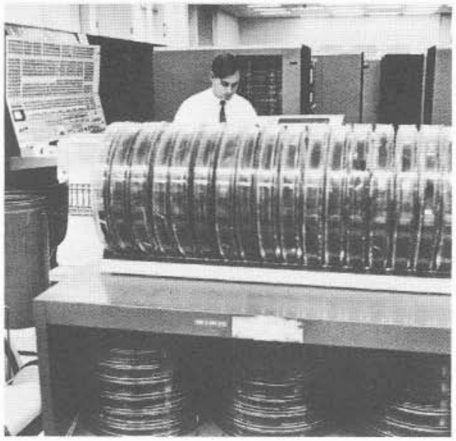
. . . after the tower is jettisoned, but before orbital velocity is reached, RTCC computes a ballistic trajectory and predicts the splashdown point. (mode 2 abort)

. . . after orbital velocity is reached, RTCC computes the maneuvers and service module engine burn for a controlled reentry downrange. (mode 3 abort)

During the lunar module descent to and ascent from the lunar surface, RTCC computes several values for flight controller monitoring, including present position of the LM and its velocity. Primary data source for these computations is telemetry information from the Primary Navigation and Guidance, and the Abort Guidance systems in the LM. In another display, information based on the on-board systems is compared with position data from the Unified S-Band radar sites. These position and velocity values are computed and displayed to flight controllers every two seconds.

2. *Telemetry Program Subsystem:* receives, processes and issues data on the space vehicle's position and velocity, and on the performance of its systems. It also processes and displays biomedical data on the astronaut crew. Data comes from:

- NASA's Manned Space Flight Network: radar tracking stations; remote communications and telemetry sites; tracking ships.



Magnetic tapes store instructions for RTCC computers.

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- Apollo onboard data system: Command Module computer; Apollo Command and Service Modules; Lunar Module; Lunar Module Computer; Instrument Unit; S-IVB stage; booster (S-IB on the uprated Saturn I, S-IC and S-II on the Saturn V).

Processing telemetry data includes:

- Unpacking: converting it to a form the computers can use.
- Calibrating: converting it to engineering units, such as volts and pounds per square inch.
- Limit-sensing: holding it back for display only when a condition deviates from operational limits.

Telemetry data is displayed at flight controller consoles by:

- Digital display drivers: banks of tiny lamps; a lighted lamp indicates, for example, on-time stage separation or engine cutoff.
- Strip chart recorders: linear plot of a system's value at specific times.
- Digital TV system: formats include:

tabular: numbers displayed against a table of nominal performance values.

graphic: lines representing system performance curves and the track of the spacecraft over the earth.

schematic: a drawing of an engine, for example, as a background for numeric performance values.

Flight controllers can use a special keyboard to convert telemetry data into teletype messages and transmit them to remote sites.

3. *Orbit Computation Program Subsystem:* calculates a table of predicted spacecraft positions and corresponding velocities along the predicted track of the vehicle. The track is projected with a mathematical model in the program subsystem. The model simulates the performance of the spacecraft, including the effects of any flight maneuvers planned during the prediction period. The table is called an ephemeris. Flight controllers use it to:

- Tell remote sites via teletype where and when to point their radar to acquire the spacecraft.
- Tell the astronauts which ground points should be visible to them; the duration of daylight and darkness; the times the sun and moon rise and set.
- Tell the astronauts when and how to orient their spacecraft for celestial navigation fixes.

4. *Trajectory Determination Program Subsystem:* processes radar data to determine spacecraft trajectory. This subsystem generates a correction to the current estimate of the spacecraft's position and velocity. It can also be used to spot radar errors. Corrected position and velocity values are displayed at flight controller consoles via the digital TV system. Data is also available to other program subsystems such as Orbit Computation and Mission Planning.

- Landing site determination: as the spacecraft orbits the moon and passes over a selected lunar landmark, optical sightings are taken on that landmark from the spacecraft and telemetered to the RTCC for processing. As a result of this process, a better estimate of the lunar landing site is obtained and made available to other subsystems for planning the lunar landing.

IBM System/360 Model 75J with magnetic disk storage units, input/output typewriters, central processor console and printer.

Once the Lunar Module is on the moon it tracks the spacecraft with its own radar system similar to an earth-based radar site. Tracking data is also telemetered to the RTCC for calculating more precise Lunar Module position. This is made available to other subsystems for planning the LM launch from the moon. Processing results are viewed on the digital TV displays.

5. *Mission Planning Program Subsystem:* computes spacecraft maneuvers at the request of flight controllers:

- In earth orbit:

  plane change: a modification of the spacecraft's trajectory that changes its track over the earth.

  phase change: a change in the shape of the orbit, either elliptical or circular.

- On a lunar mission:

  translunar injection: computes the spacecraft's heading toward the moon. The maneuver must meet the "free return constraint" so that if a propulsion system failure occurs, the trajectory will take the spacecraft around the moon and back to earth.

  midcourse correction: computes the spacecraft's point of lunar orbit insertion and aims the spacecraft at that point.

  lunar orbit insertion: computes the spacecraft's deceleration into a lunar parking orbit. A 68-mile orbit (60 nautical miles) of the lunar equatorial plane is optimum.

  Hohmann transfer: computes the lunar module's descent from lunar orbit to 50,000 feet above a preselected point on the moon.

  descent: computes the lunar module's descent to the moon.

  ascent: computes the lunar module's trajectory for ascent and rendezvous with the command and service modules parked in lunar orbit.

  transearth injection: computes the spacecraft's course for the earth after the lunar module completes rendezvous and docking with the command and service modules.

  midcourse correction: computes the spacecraft's heading toward the midpoint of a safe reentry corridor to earth.

6. *Digital Command Program Subsystem:* computes data to update the spacecraft. Data passed from the ground to the spacecraft:

- Tells the astronauts where to point their spacecraft and how long to thrust in a maneuver.
- Tells the astronauts the spacecraft's position and velocity.
- Signals the launch vehicle digital computer that events, such as stage separation and engine cutoff, have occurred.
- Synchronizes the spacecraft clock with the master clock at Mission Control.

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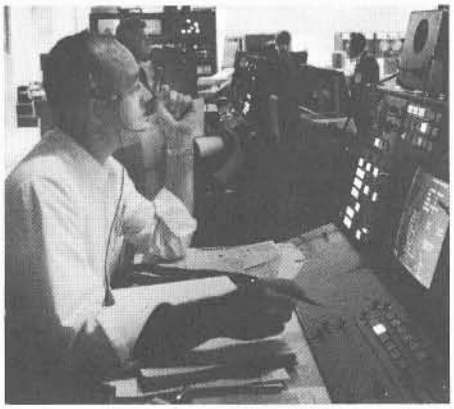


IBM computer controller monitors information display duplicated at Mission Control consoles.

Updated information, such as navigation and maneuvering data, is generated on command of flight controllers, transmitted to remote sites and relayed to the spacecraft as it passes overhead.

7. *Reentry Program Subsystem:*

- Computes the deorbit maneuver, which is the spacecraft's flight angle and the duration of engine burn for a reentry to earth.
- Predicts the reentry trajectory and splashdown point and the G-forces on the astronauts.
- Alerts remote sites to acquire the spacecraft on radar.
- Simulates the performance of the Command Module computer as backup for the spacecraft's automatic reentry system.

Control Programs

RTCC's seven program subsystems are coordinated by two control programs:

1. *Mission Control System:* decides where incoming data should be sent for processing.
2. *Real-Time Operating System:* routes data to RTCC program subsystems for processing; handles all information display. (The system is similar to Operating System/360, a control program for IBM System/360.)

The control programs act as traffic controllers for information flowing in and out of the computers. They assign priorities to requests for information and route the requests through the computers in order of priority. They maintain discipline within RTCC computers to insure real-time access to information.

Simulation

Preparing for emergencies—NASA calls it contingency training—takes up most of the time for mission simulation. Responses by flight controllers are checked during training exercises that simulate emergencies that could occur during a mission.

Exercises follow the flight plan of an upcoming mission. Besides training flight controllers, mission exercises train remote site crews and astronauts "flying" an Apollo crew trainer.

NASA's Apollo simulation checkout and training system uses an IBM System/360 Model 75J* and special simulation programs that match the realism of an actual mission. Simulated mission data is so realistic, RTCC detects no difference. Every source of information for RTCC that exists in a mission exists in simulation:

- All Manned Space Flight Network conditions.
- All radar, telemetry, command and communications operations.
- All thrusting maneuvers affecting the spacecraft's trajectory.
- All data displays to flight controllers.

*The simulation computer works with, but is not a part of, the RTCC system.

The Goddard Real-Time System (GRTS) is an IBM data processing system at NASA's Goddard Space Flight Center in Greenbelt, Md., near Washington, D.C. GRTS checks data communications with each of the Apollo ships and tracking sites in NASA's Manned Space Flight Network and evaluates data gathered by the network during Apollo missions.

What GRTS Does

1. Uses an automated testing system called CADFISS (Computation and Data Flow Integrated Subsystem) to evaluate test data from the Apollo ships and tracking sites simultaneously.

   This system automatically generates and transmits notification to each site for test initiation and in return receives data which is compared with known values stored in the system. Status and analysis of received data is provided in real time. Tests include:

   - Verification of tracking system operations,
   - Verification of telemetry data formatting,
   - Verification of command system operation,
   - Verification of proper data flow between GRTS and the MSFN.

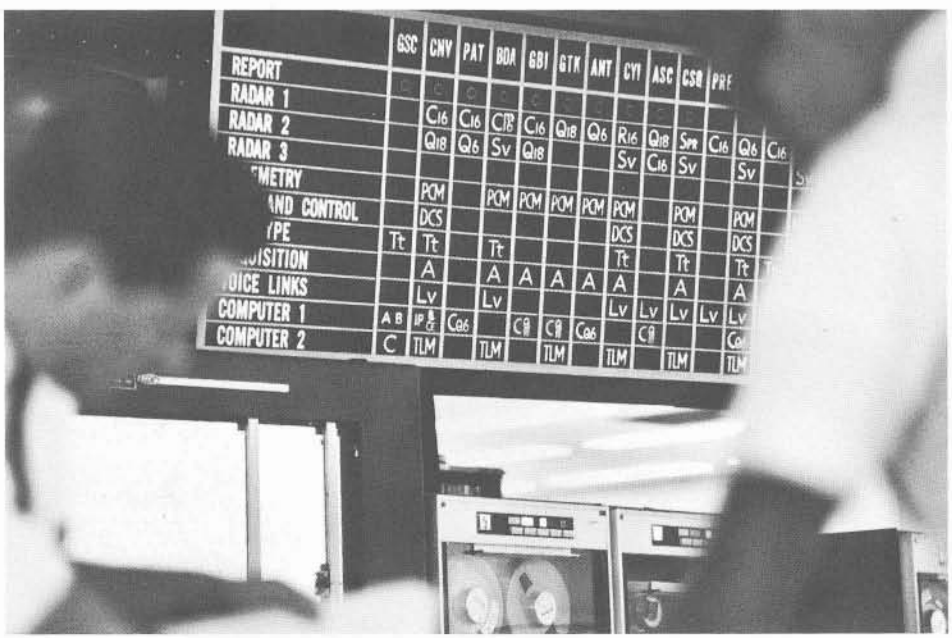
2. Evaluates tracking data received from the network during the mission and compares the results with nominal values established for the mission. The results are displayed in real time for monitoring by operations personnel.

3. Calculates and transmits to network sites data required to locate and track the Apollo spacecraft on each orbit.

Equipment

Two IBM System/360 Model 75 I's*, plus peripheral storage, data communications, manual input and display equipment comprise the Real Time System.

*System/360 replaces IBM 7094-11 computers used during the Gemini program and for early unmanned Apollo/Saturn missions.



Goddard uses IBM computers to test tracking and communications equipment at radar stations, remote sites and tracking ships that make up the Manned Space Flight Network.

IBM System/360 Model 75J and Model 75 I*

Type
Large-scale, general-purpose, high-performance: fixed-point, floating-point and decimal processing; micro-miniature solid logic technology

Storage
Main Processor: random access, core, 750-nanosecond cycle; storage protection (read and write), parity checking

Auxiliary: random access, core, eight-microsecond cycle; storage protection, parity checking

*Model J for RTCC and Model I for GRTS are identical, except where noted.

Storage Capacity
1,048,576 bytes for Model J; 524,288 bytes for Model I; four-way interleaving. With auxiliary core storage, 9,437,184 bytes for Model J; 8,388,608 bytes for Model I

Central Processing Unit
16 32-bit general-purpose registers; four 64-bit floating-point registers; basic machine cycle of 195 nanoseconds. Central processor has two sections: instruction unit, which processes instructions; execution unit, which executes them. Each operates independently

Data Word
32 bits, plus parity

Average Execution Times (Fixed-Point)
Add/Subtract: 0.4 microseconds (register to register); 0.7 microseconds (operand to register)

Multiply: 2.8 microseconds

Input/Output
Storage channel transfers information from core storage to the central processor and passes updated information back to core storage

Two high-speed (1.3 million bits a second) selector channels transmit information stored in eight disk drives

Two selector subchannels for Model J, three for Model I; channels transmit information stored in eight magnetic tape drives at a rate of up to 180,000 bytes a second

Multiplexor channel can attach up to 196 readout and display devices

Special communications channel connects RTCC and GRTS

The instrument unit is the control center of the Saturn launch vehicle. In it are 57 components—all the electronic, electrical and mechanical equipment required for guidance, navigation and control, and for measurement and telemetry of performance and environmental data—plus power supplies and environmental control equipment for cooling. The instrument unit was designed by NASA's George C. Marshall Space Flight Center in Huntsville, Ala. IBM manufactures and assembles the instrument unit at its Space Systems Center in Huntsville.

Structure
Located between the Saturn S-IVB stage and the space craft.

Diameter: 21.7 feet
Height: 3 feet
Weight: 500 pounds; 4,400 pounds assembled

The structure consists of three 120-degree sections of thin-wall aluminum alloy face sheets bonded over sections of aluminum honeycomb one inch thick.

Environmental Control
Heat from electronic components dissipates through 16 thermal conditioning panels* lining the interior wall of the instrument unit. An antifreeze-like coolant, 60 per cent methanol and 40 per cent water, circulates through the thermal conditioning panels.

Most of the components are mounted flush against the thermal conditioning panels. Certain components—the digital computer, data adapter, flight control computer and inertial guidance platform—are mounted directly to the interior wall of the instrument unit. Coolant is circulated through them.

Heat is removed from the coolant by a sublimator heat exchanger. It works this way: water from a reservoir in the instrument unit is supplied to the sublimator. The water is exposed through a porous plate to the low pressure of space. The water freezes and seals the pores. Heat in the coolant is absorbed by the ice, which is converted to water vapor—a process called sublimation. A sensor monitors the temperature of the coolant, activating the water supply to the sublimator as required.

A nitrogen gas system provides pressurization of the water and coolant reservoirs.

Guidance and Flight Control
1. *Major Components:* digital computer and data adapter; analog flight control computer; inertial guidance platform; emergency detection system control rate gyros and control accelerometers. Together, they measure acceleration and vehicle attitude, determine velocity and position and calculate and issue control commands to engine actuators.

The *inertial guidance platform* senses the vehicle's acceleration and flight attitude. It sends measurements to the *digital computer* through the *data adapter*. The *digital computer* uses the measurements to determine the vehicle's position and velocity. Any corrections required to keep the vehicle on course and at the proper velocity are calculated by the *digital computer*.

Correction signals, with outputs from *control rate gyros and control accelerometers*, go to the *flight control computer*. The *flight control computer* issues commands to steer the vehicle by gimbaling the engines. These correction signals are then passed to the *flight control computer* which issues the analog signals to gimbal the engines and steer the vehicle.

In addition, the digital computer controls vehicle sequencing by issuing coded digital information which is sent to the vehicle switch selectors. The switch selectors—one in the instrument unit and one in each propulsion stage—decode the input commands and issue the proper vehicle control functions.

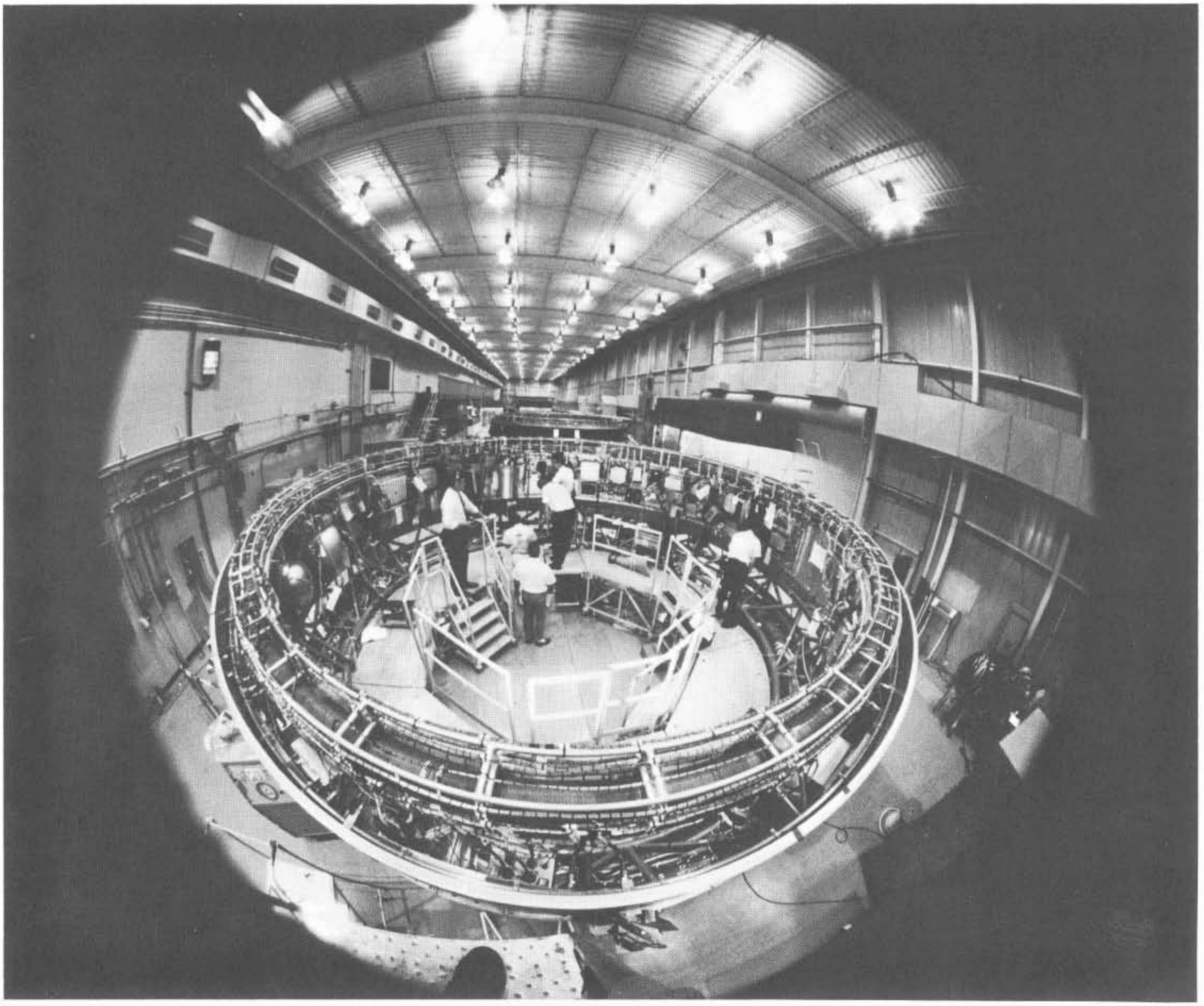
Instrumentation
1. *Measurements:* several hundred measurements are made by sensors to monitor performance and environmental data during flight. Results are telemetered to the nearest ground station. Measurements are taken of:

- Physical quantities, such as mechanical movements, atmospheric pressures, sound levels, temperatures and vibrations; all are transformed into electrical signals.
- Electrical values, such as voltage, current and frequency, which determine stage separation, engine cutoff and other flight control functions.

Signal conditioning modules convert sensor outputs to a range of 0-5 volts DC for telemetry.

2. *Telemetry:* measurements are routed to telemetry equipment for transmission to the ground. Multiplexing—transmitting messages one after another, but so fast that they appear to be transmitted simultaneously—is used on most channels. Multiplexing permits many transmissions on just a few channels.

*There are 16 additional thermal conditioning panels in the forward compartment of the instrument unit's environmental control system.



Instrument unit—the flight control center for the Saturn.

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3. *Tracking:* radar transponders increase the range and accuracy of ground-based tracking systems. Pulses of radar energy aimed at the space vehicle interrogate a transponder. The transponder replies with its own radar pulses. Ground stations fix the origin of the reply pulses and determine the vehicle's position.

4. *Radio Command:* receives and interprets data transmitted from the ground for the digital computer; follows a series of error control steps to verify that the message received agrees with the message transmitted:

- The message is decoded into its original pattern of digital bits. If a bit is missing, the entire message is rejected.
- The address is checked to verify that the message is intended for the computer in the instrument unit, not the guidance computer in the spacecraft. Both use similar radio command links.

If the message passes all the checks:

- It is sent to the data adapter to hold for the computer. At the same time, Radio Command sends a pulse signal to the ground to confirm that the message has been received and processed.
- The message is released by the data adapter to the digital computer.
- If the message contains update information (navigation positions, maneuvering instructions, etc.), it is stored in the computer, then read out to telemetry equipment. The message goes back to the ground station and is relayed to Mission Control. There, it is compared with the original message. If both messages agree, an "execute" command is transmitted to the ground station and relayed to the computer. The computer will not act on update information until it receives the "execute" command.

Electrical System

1. *Power Supplies:*

- Main supply:

twenty to thirty seconds before liftoff, the launch control center transfers power to four 28-volt alkaline silver-zinc batteries. Each battery has a life of 350 ampere hours. Loads distributed over the four batteries equalize drain and assure a redundant power source.

- Special supplies:

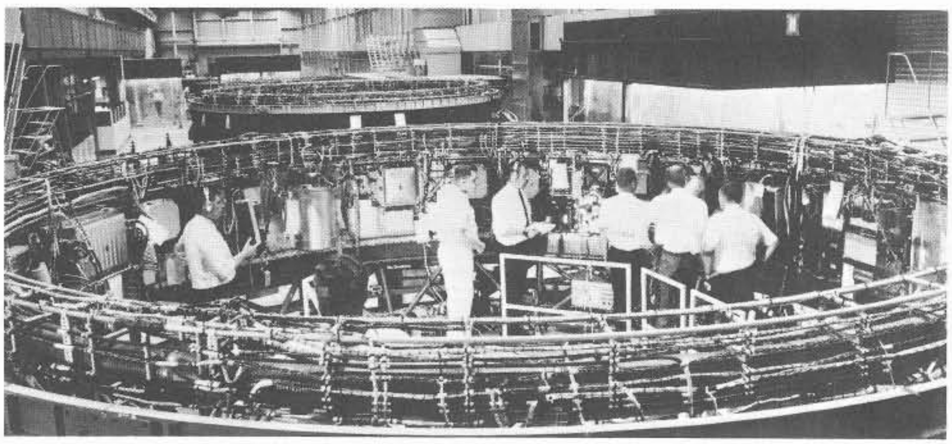
five-volt master power supply converts the main supply to a reference voltage for the measuring system's signal conditioning modules.

fifty-six-volt power supply provides the voltage for the guidance and control system's inertial guidance platform.

2. *Emergency Detection System:* detects any abnormal conditions in vehicle attitude and engine thrust during launch. Starts either an automatic abort or flashes a manual abort light in the cockpit—depending on how the crew positions a selector switch.

Testing

Each major component is tested individually and as part of its system (guidance and control, electrical, etc.) before the instrument unit is shipped to NASA's John F. Kennedy Space Center. After testing, the digital computer, data adapter, flight control computer, inertial guidance platform and the power supplies are removed and packaged separately for shipment. The other components remain in the instrument unit during shipment.



Components are tested individually, then tested again when combined in systems.

The programming system which controls the operation of the launch computer complex is designed by programmers at IBM-Huntsville's Space Systems Center. This programming system is divided into two major groups of programs: the operating system and the test programs.

Operating System

Operating system programs, containing 60,000 instructions, provide basic computer functions for the complex, such as communication routines that process the enormous flow of data. These programs enable one computer to communicate with another computer, with display consoles, with test equipment, and with the vehicle. In addition, they direct the complex flow of data within each computer.

The operating system also has programs to assess each request for service, assign it a priority, and service it in accordance with its assigned priority. There are programs, too, to control signals to the vehicle and to monitor and arrange for the display of signals from the vehicle. Execution of test programs is controlled by the operating system.

Test Programs

These programs test operation of vehicle systems. They define signals for the vehicle and compare the vehicle response with predetermined requirements. During test processing, a running account of the progress of the test and the results is displayed at the test engineer's console.

For Saturn V vehicles, more than 58 test programs, comprising approximately 90,000 instructions, are provided in support of launch operations.

Contractors to NASA	Items
Bendix Corp. Teterboro, N.J.	ST124M inertial platform
General Dynamics/Astronautics San Diego, Calif.	Azusa radar tracking system
Gulton Industries Metuchen, N.J.	temperature gauge; microphone
IBM Federal Systems Division Owego, N.Y.	launch vehicle digital computer and data adapter
Pall Corp. Long Island, N.Y.	coolant pump

Subcontractors to IBM	Items
Aerodyne Controls Corp. Farmingdale, N.Y.	first-stage regulator; gas-bearing pressure regulator
Applied Microwave Laboratory, Inc. Andover, Mass.	CCS power divider
Astro Space Laboratories, Inc. Huntsville, Ala.	bleeder and union orifice assemblies
Automatic Metal Products Brooklyn, N.Y.	coaxial switch
AVCO Corp. Huntsville, Ala.	range cards; frequency measuring adapter
AVCO Corp. Nashville, Tenn.	cable trays; gas-bearing mounting panel; thermal conditioning panels
Avion Electronics, Inc. Paramus, N.J.	telemetry directional coupler; measuring assembly
Bourns, Inc. Riverside, Calif.	transducer pressure gauges
Brown Engineering Co., Inc. Huntsville, Ala.	component testing
Brown Engineering Company Lewisburg Division Lewisburg, Tenn.	measuring rack selector; measuring rack assembly; multiplexers; PCM digital data acquisition system; radio frequency systems; telemetry systems
Chrysler Corp. Huntsville, Ala.	Q-ball; vehicle plate assembly; directional antenna
Conic Corp. San Diego, Calif.	UHF transmitter
Crane Co., Hydro-Aire Division Burbank, Calif.	coolant pump
Eagle-Picher Industries, Inc. Joplin, Mo.	primary battery
Electro Development Corp. Seattle, Wash.	DC amplifier; channel selectors
Electronic Communications, Inc. St. Petersburg, Fla.	flight control computer
Fansteel, Inc. Compton, Calif.	two-cubic-foot bottle; 165-cubic-inch sphere; water/methanol accumulator
Fenwal Electronics, Inc. Framingham, Mass.	temperature probe
Flodyne Controls, Inc. Linden, N.J.	shutoff ball valve

Subcontractors to IBM	Items
The Foxboro Co. Foxboro, Mass.	gas temperature probe
Gulton Industries, Inc., Engineered Magnetics Division Hawthorne, Calif.	five-volt power supply; electrical cables; vibration accelerometers
Hayes International Corp. Huntsville, Ala.	network cables
IBM Federal Systems Division Owego, N.Y.	switch selectors
International Harvester Co., Solar Division San Diego, Calif.	gas-bearing heat exchanger; manifold assembly; water/methanol accumulator
Lockheed-Georgia Company Marietta, Ga.	water/methanol accumulator system
Lynch Corp., Cox Instruments Division Detroit, Mich.	flowmeters
Marotta Valve Corp. Boonton, N.J.	shutoff and solenoid valves
Martin Co. Orlando, Fla.	control signal processor
Melpar, Inc. Falls Church, Va.	antennas and power dividers
Motorola, Inc., Military Electronics Division Scottsdale, Ariz.	C-band transponder; command receiver; S-band transponder
North American Rockwell Corp. Tulsa, Okla.	structure segments
Northrop Corp., Nortronics Division Norwood, Mass.	rate gyro package
Perkin-Elmer Corp. Norwalk, Conn.	retro-reflector
Phelps Dodge North Haven, Conn.	foam-flex network cables
Philco-Ford Corp., Communications and Electronics Division Menlo Park, Calif.	coaxial termination
Potter Aeronautical Corp. Union, N.J.	flowmeters
Purolator Products, Inc. Newbury Park, Calif.	gas-bearing pressure regulator; quick disconnect coupling
Quantatron A Teledyne Company Santa Monica, Calif.	CCS coaxial switch
Rantec Corp. Calabasas, Calif.	telemetry RF coupler
Raytheon Co., Micro Wave Division Bristol, Tenn.	Azusa radar tracking antenna
Resistoflex Corp. Roseland, N.J.	flex hose assembly
Rosemount Engineering Co. Minneapolis, Minn.	temperature gauge
Servonic Instruments, Inc. Costa Mesa, Calif.	transducer pressure gauge

Subcontractors to IBM	Items
Space Craft, Inc. Huntsville, Ala.	command decoder; frequency converter; multiplexers; servo-accelerometer; antennas; computer interface unit
Spaco, Inc. Huntsville, Ala.	servo-accelerometer
Statham Instruments, Inc. Los Angeles, Calif.	control accelerometer
Systron-Donner Corp. Concord, Calif.	force balance accelerometer
Tavco, Inc. Santa Monica, Calif.	pressure switch
Teledyne Systems Co. Hawthorne, Calif.	thermal probes
Transco Products, Inc. Venice, Calif.	coaxial switch
TRW, Inc. Cleveland	coolant pump
United Aircraft Corp., Hamilton Standard Division Windsor Locks, Conn.	preflight heat exchanger; water accumulator assembly
United Control Corp. Redmond, Wash.	temperature control assembly
Vacco Valve Co. South El Monte, Calif.	quality test filter
Varian Associates, Eimac Division San Carlos, Calif.	UHF transmitter
Watkins-Johnson Co. Palo Alto, Calif.	power amplifier
Wyle Laboratories Huntsville, Ala.	component testing; structure testing

IBM integrates 57 components in the instrument unit—all the equipment required for guidance, navigation and control and for measurements, telemetry and cooling.

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Launch Vehicle Digital Computer and Data Adapter

The computer and data adapter are part of the Saturn guidance system. They are located one over the other and are connected by wire harness in the instrument unit. They were designed and are manufactured by IBM's Electronics Systems Center in Owego, N.Y.

What the Computer Does

1. *Prelaunch Checkout:* using a self-contained program, it tests itself and the rest of the launch vehicle's guidance and control system and its telemetry system. It also runs a mission simulation.
2. *Booster Guidance:* processes data on velocity, position, attitude and time. Twenty-five times a second, it issues steering signals controlling the direction of thrust of the gimbaled rocket engines to keep the launch vehicle on course to orbit.
3. *Saturn V Lunar Trajectory Injection:* issues signals to ignite the S-IVB engine and navigates the vehicle out of its earth orbit into a lunar trajectory.* It calculates the Apollo's escape velocity and signals engine cutoff. During the Apollo's turnaround and docking maneuver, it helps keep the S-IVB stage stable.

*RTCC calculates the time to reignite the S-IVB engine to begin the lunar trajectory injection.

The digital computer issues signals 25 times a second to keep the Saturn on course during launch.

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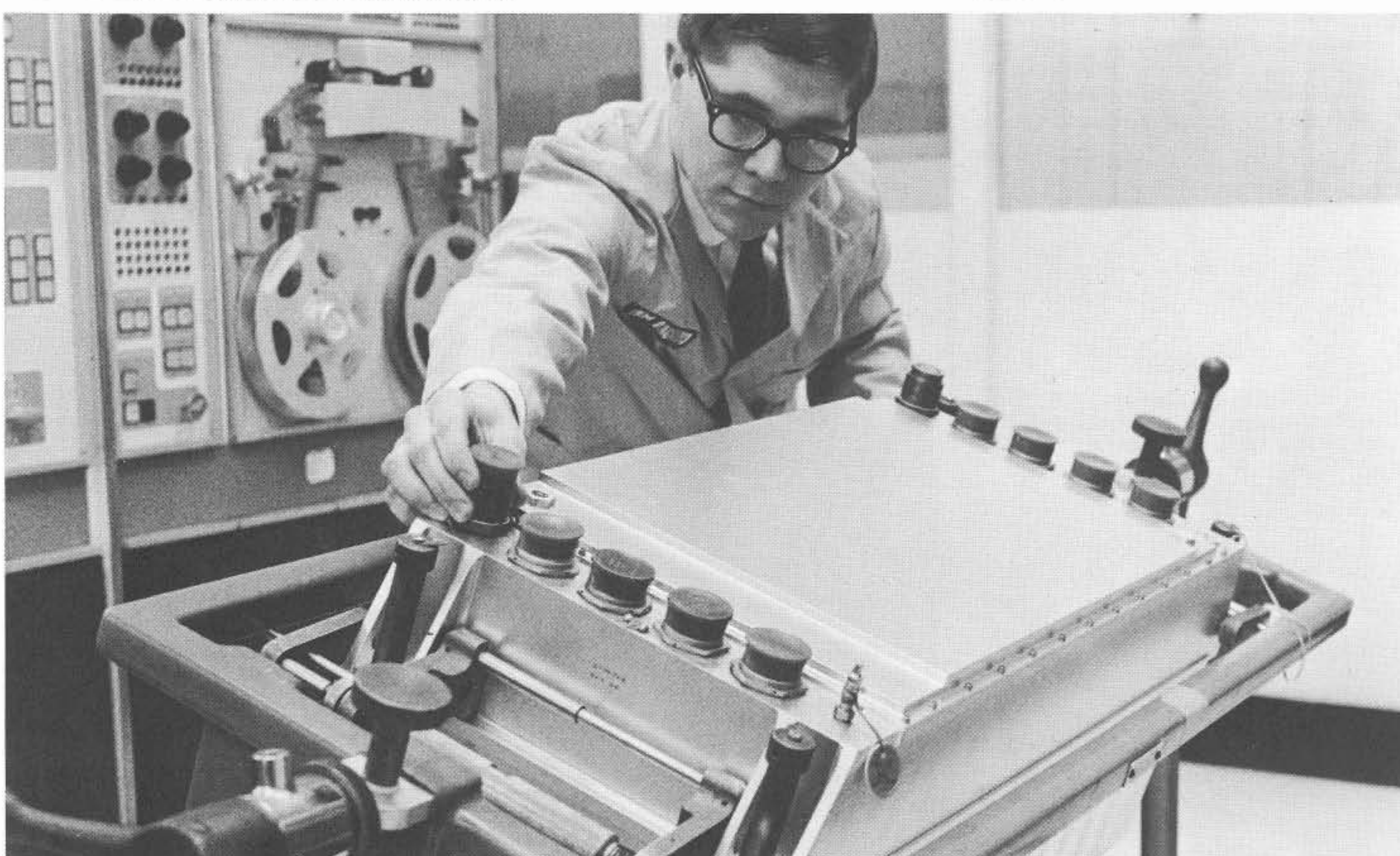


What the Data Adapter Does

Collects, stores, converts and transmits data. It is the communications link between the computer and the launch vehicle, the input/output clearing house of signal flow. It translates data into a form that can be used by receiving equipment. It converts inputs to the computer from analog to digital language. It converts digital outputs of the computer to the analog language of the rest of the guidance system.

Reliability

The computer and data adapter are classified by NASA as "man-rated."

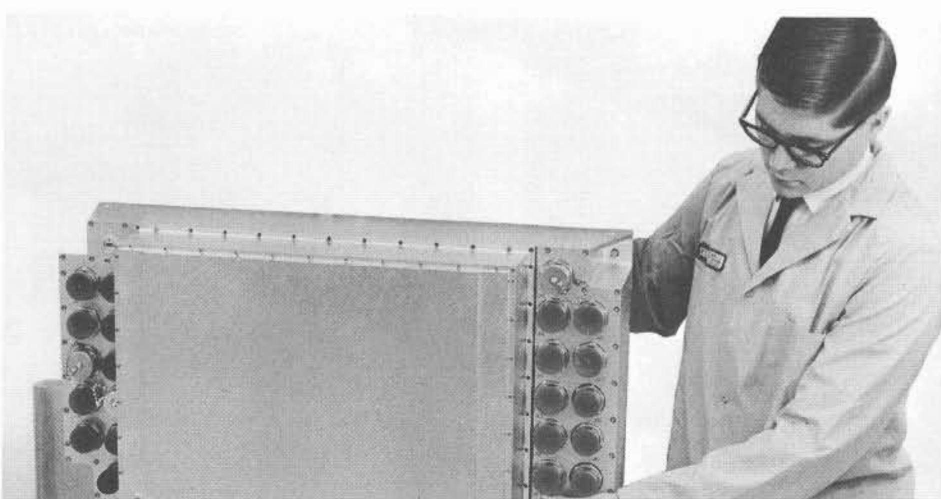
1. *Predicted Reliability:* 99 per cent.
2. *Mean-Time Between Failures:* 45,000 hours.
3. *Triple Modular Redundancy:* primary circuits in the computer and data adapter are triplicated. Their output signals are fed to voting circuits where a majority rule is established. If one signal differs from the other two, it is disregarded.

   The computer's logic system consists of three identical channels, each with seven modules. The outputs from one module are voted on, compiled and passed to the next module where the process is repeated. Results of each vote feed to a disagreement detector. Any 2-1 decision is reported via telemetry to the ground.
4. *Redundant Storage:* the computer's dual magnetic core memory can be operated as single storage (simplex) for increased capacity. Or it can be operated as two memories (duplex) with cross checking for increased reliability. In the duplex mode, identical information is stored in both memories. The contents of each are tested for error by parity, timing and current checking circuits. If an error is detected in one memory, the computer switches to the other. The correct memory refills the incorrect one.

Design and Construction

1. *Microminiature Electronics:* ninety per cent of the circuits in the computer and data adapter are microcircuit modules called unit logic devices. There are 9,337 in all. Each contains up to 17 components mounted on wafer-like ceramic substrates three-tenths of an inch square and twenty-three-thousandths of an inch thick.

   Resistors and electrical interconnection paths are silk-screened on both sides of the substrates. Transistor and diode chips are attached by solder reflow, a technique of soldering two parts, with one of the parts precoated with solder. The devices are mounted on multilayer interconnection boards with up to 12 conducting surfaces. Two boards interconnected back-to-back form a "page," the basic field replacement unit. There are 191 pages with 80,000 components in the computer and data adapter.
2. *Magnesium-Lithium Chassis:* the computer and data adapter make the first electronics structural use of magnesium-lithium alloy—a metal with one of the best weight-to-strength ratios. The structure also serves as its own cold plate to carry off heat from electronics subassemblies. Because the alloy does double duty as a structure and cold plate, there is a saving of 65 pounds over a conventional aluminum structure with a separate cold plate.



The data adapter is the communications link between the digital computer and the Saturn.

AS167-10

Computer Specifications

Type
General-purpose, serial, fixed-point, binary

Storage
Random access, destructive readout (DRO), core

Storage Capacity
32,768 28-bit words (including two parity bits), using any even multiple of up to eight plug-in modules, each containing 4,096 words

Arithmetic
Twos complement; separate elements for addition/subtraction and multiplication/division; both elements operate concurrently

Data Word
26 bits

Instruction Word
13 bits

Execution Times
Add/Subtract: 82 microseconds
Multiply: 328 microseconds
Divide: 656 microseconds

Operations a Second
9,600

Weight
90 pounds

Power
144 watts

Volume
2.2 cubic feet

Dimensions
Width: 29½ inches
Height: 12½ inches
Length: 10½ inches

Data Adapter Specifications

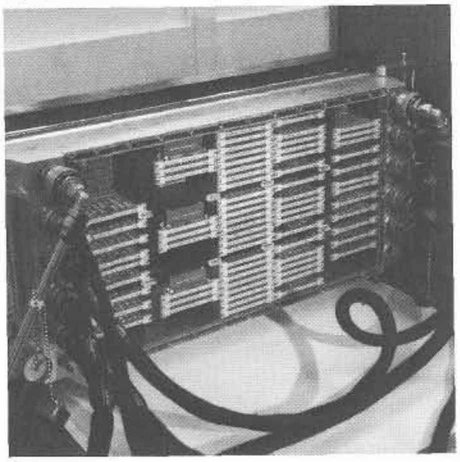
Weight
190 pounds

Power
400 watts

Volume
3.3 cubic feet

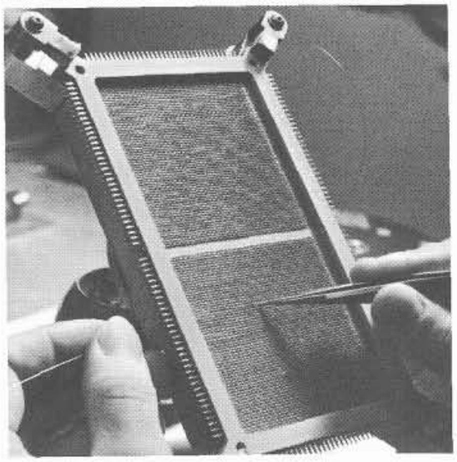
Dimensions
Width: 32 inches
Height: 16¼ inches
Length: 14¾ inches

Front view of digital computer and its replaceable circuit "pages."



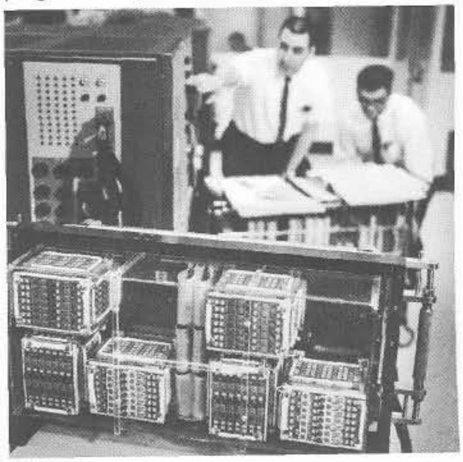
AS167-11

Eight thousand storage cores are strung by hand on computer memory planes.



AS167-12

Rear view of digital computer showing plug-in storage modules.



AS167-13

Launch Support

Instrument unit flight readiness

Saturn launch computer complex

IBM's facility at the John F. Kennedy Space Center has two main responsibilities: (1) prepare the instrument unit for flight; (2) operate, maintain and write computer programs for the Saturn launch computer complex.

Instrument Unit Flight Readiness

1. *Preliminary Checkout:*

- Checking for transit damage.
- Acceptance testing electronic systems.
- Mating the instrument unit with the launch vehicle.
- Testing the environmental control system.
- Checking electrical cables.

2. *Power-On Tests:*

- Radio frequency and telemetry subsystem tests: verify data quality and validity.
- Power transfer test: verifies that power can be switched from ground supplies to internal supplies.
- Propellant dispersion test: verifies that onboard systems receive arm and destruction signals in case of trouble in the fuel system.
- Switch selector test: verifies that switch selectors receive and decode computer flight control commands.
- Emergency detection system test: verifies that the system can detect loss of engine thrust and deviation from nominal flight attitude.
- Guidance and control systems tests: verify that all components operate individually and as systems.

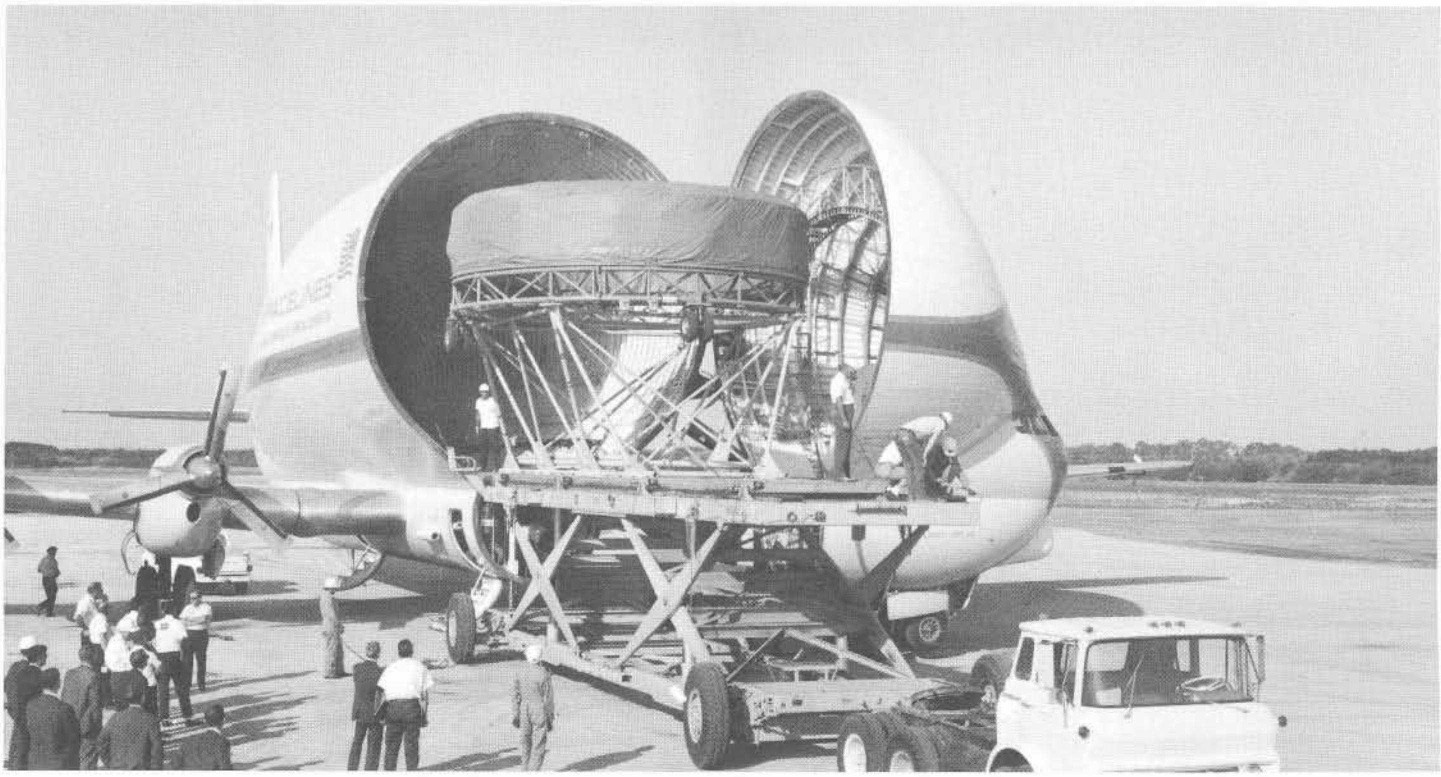
3. *Final Checkout:*

- Plugs-in and plugs-drop tests: verify compatibility of launch vehicle systems with ground support equipment. A launch environment—vibration, fuel flow in the vehicle, etc.—is simulated by computers.
- Countdown demonstration test: a "dress rehearsal" countdown to three seconds before ignition.

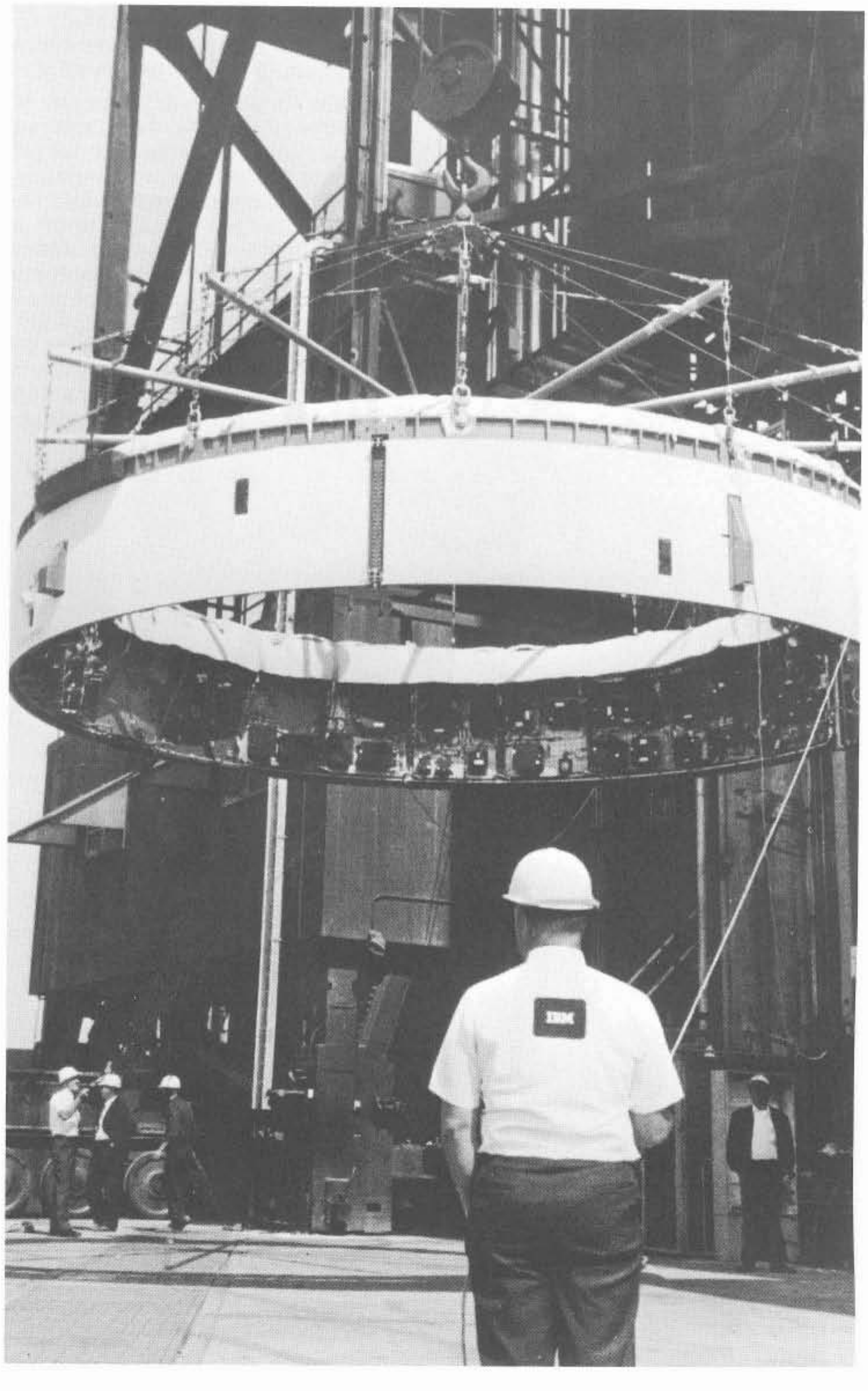
4. *Launch:* during countdown, the instrument unit transmits launch vehicle readiness data to launch control consoles manned by IBM engineers. After launch, IBM engineers help evaluate data on the instrument unit's flight performance.

Instrument unit arrives on Super Guppy aircraft at Kennedy Space Center.

NASA Photo 107-KSC-66C-3655



IBM test conductor with the instrument unit on the launch pad at Cape Kennedy.



NASA Photo 66-H-346

Saturn Launch Computer Complex
Operated and maintained by IBM and controlled by IBM computer programs during preflight tests, countdown, ignition and launch. The complex consists of:

- Two computers*: one in the firing room, the other at the launch pad.
- Console displays: carry telemetry data on vehicle performance during preflight tests, countdown and launch.
- Digital data acquisition systems: transfer output data from the computers to console displays.
- Electrical networks: cables connecting the computers, digital data acquisition systems and console displays.

*RCA Model 110A's.

IBM engineers monitor launch readiness tests from their consoles in the firing room. Pressing a button to activate a launch vehicle gyro, for example, generates a discrete command signal. The signal passes through electrical cables and a computer in the firing room to a computer at the launch pad, then through more electrical cables to the instrument unit. Activating the gyro generates a reply signal back through the system. The computers pass the reply signal to digital data acquisition systems, which convert the signal to console displays. Two computers and two digital data acquisition systems are required to handle the volume of data—an average of 150,000 signals every second.

Maintaining the launch complex includes:

- Calibrating and testing.
- Trouble-shooting and replacing parts.
- Modifications.
- Designing and building test equipment.
- Launch-testing spare parts.

IBM engineers man control consoles during Saturn preflight tests, countdown and launch.

AS167-14

Glossary of Computer Terms

Glossary of Computer Terms

Address: the location in a computer where information is stored.

Analog: translating physical conditions, such as voltages and resistances, into directly analogous mechanical or electrical quantities. An analog computer measures continuously, as opposed to a digital computer, which counts in individual pulses of voltage or current.

Binary: a numbering system which uses only the symbols zero and one.

Bit: a single symbol in a binary number; a unit of computer storage capacity expressed as a zero or one.

Buffer Register: a temporary computer storage device of small capacity that equalizes any difference in the rate and flow of data, and holds data until the computer is ready to use it.

Byte: a unit of computer storage, eight bits long.

Data Word: a group of bits treated by a computer as the basic unit of information for calculation.

Destructive Readout (DRO): a standard technique of computer storage operation whereby information read from memory is erased and replaced automatically in one step. DRO memories use fewer circuits and are less expensive than non-destructive readout memories.

Digital: the use of numbers to express all the quantities and variables of a problem or calculation. In a binary system, the numbers are combinations of zeros and ones, and are expressed by electrical impulses.

Discrete Signal: a separate, distinct, noncontinuous signal pulse, expressed singly or in a series; used by a computer to issue commands, e.g., to ignite rocket engines, to separate stages, to alter the direction of gimbaled engines for a change in course.

Fixed-Point Arithmetic: a method of computer calculation in which scaling for placement of a radix point in a number is provided in the computer program, rather than by internal machine operation.

Floating-Point Arithmetic: a method of computer calculation that automatically places the radix point in a number. Internal machine operation moves the point. Scaling in the program is not necessary.

Four-Way Interleaving: the organization of computer storage into four independent sections, all of which are accessible simultaneously for faster operation.

General-Purpose Computer: a computer designed for many types of data handling problems, rather than a single special purpose.

Instruction Word: a computer word consisting of at least two parts: one defining the type of operation, i.e., addition, subtraction, etc., and the other containing the address, or location, of one of the quantities needed to execute the operation.

Interrupt: a break in a computer's normal routine that temporarily diverts the attention of the computer to another, more immediate problem.

Magnetic Core: a small doughnut-shaped core, with on- or off-magnetization, used to store information in a computer. Saturn computer cores have an outside diameter of thirty-two-thousandths of an inch, an inside diameter of nineteen-thousandths of an inch.

Microsecond: one-millionth of a second.

Module: an incremental building block, usually an interchangeable plug-in item, for expanding capabiilty.

Multilayer Interconnection Board: a "sandwich" of alternating layers of paper-thin conducting and insulating materials. Holes are precision-drilled through the sandwich and plated to connect circuit paths etched on the conducting layers. Transistor, diode and resistor chips are soldered to the interconnecting boards.

Multiplexor Channel: input/output linkage that carries several messages, one after another, to and from a computer. Messages move so fast that they appear to be transmitted simultaneously.

Nanosecond: one-billionth of a second.

Operand: the contents of a computer address.

Parity Bit: a bit added to a group of bits making up a computer data word; the parity bit's sole purpose is to detect any inaccurate retrieval of the data word.

Program: a set of computer instructions, or steps, expressed in computer code, that tells a computer how to solve a problem.

Radix: the base of a number system. For example, the radix of the decimal system is ten; the radix of the binary system is two.

Random Access: a type of computer storage operation in which any data word can be fetched in precisely the same amount of time, regardless of its address, i.e., its location in storage.

Real-Time: a method of processing data so fast that there is virtually no time between receiving and solving a computing problem.

Register: a temporary storage location to facilitate arithmetic operations in a computer.

Selector Channel: a high-speed transmission channel that carries information from input/output devices; when the channel is connected with an input/output unit, all other units on that channel are locked out until information from the first unit is transmitted.

Serial: a type of internal computer organization with which data is handled one bit at a time, in a fixed time sequence, compared with a parallel organization, with which a computer can work with a whole data word at a time.

Storage Protection: a safeguard against accidentally writing over information stored in a computer.

Twos Complement: the radix complement in the binary numbering system of a computer.

Unit Logic Device: IBM's name for the microcircuit modules used in the Saturn digital computer and data adapter. The device contains up to 17 resistor, diode and transistor chips, all interconnected by a conductor pattern on a paper-thin substrate base.

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