National Aeronautics and
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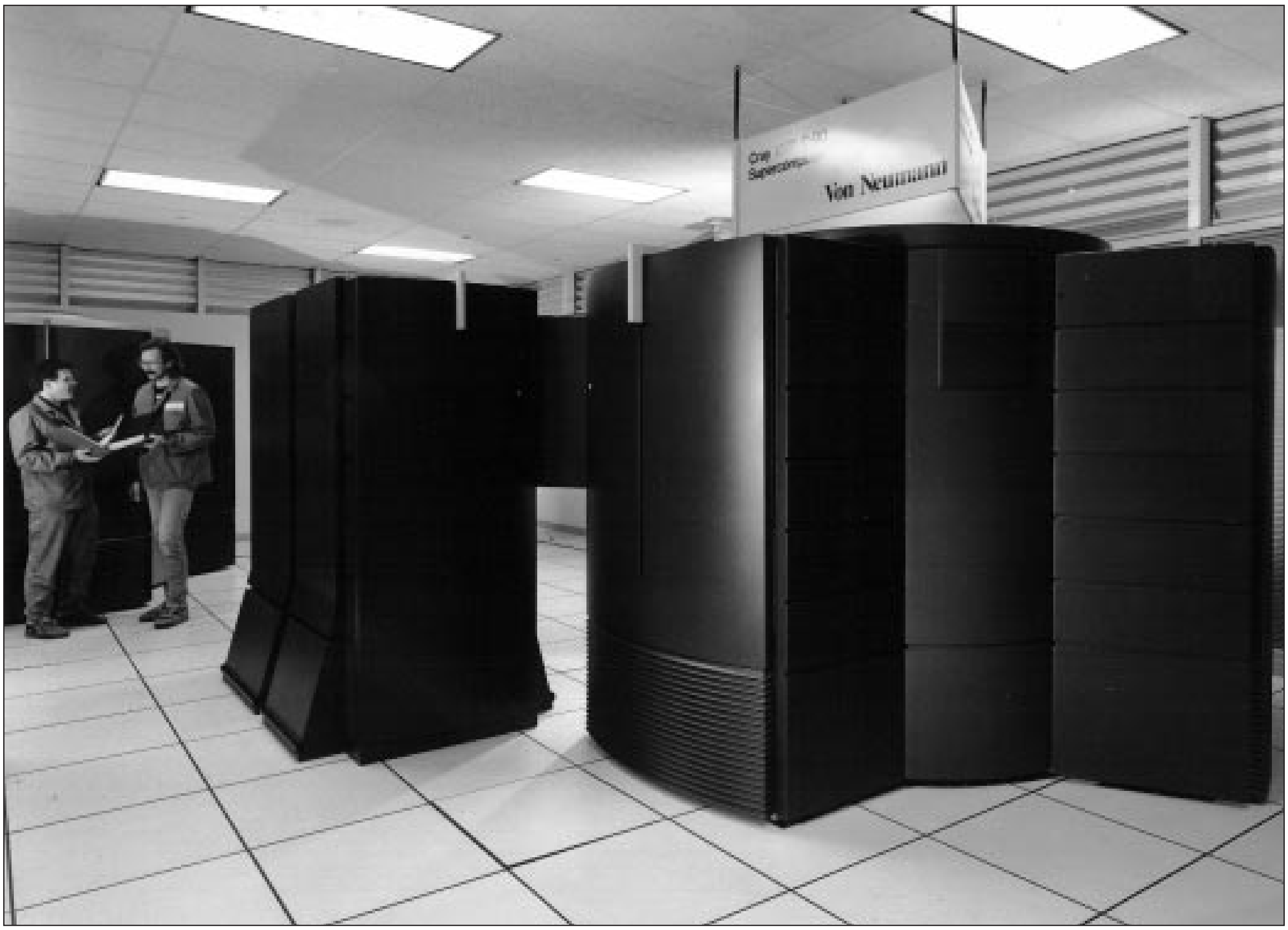
Information Summaries

Computers at NASA



NASA Photo

The world's fastest supercomputer, the Cray Y-MP C90, is located at NASA's Ames Research Center, Mountain View, Calif. Ames is NASA's lead center for supercomputer research and its supercomputers are the most advanced in the aerospace field. The $48 million supercomputer routinely performs 6 billion calculations per second. The C90 has a memory capacity of 1 billion words. It has 16 processors and a peak speed of 16 billion floating point operations per second (FLOPS). The C90 is one of several super-computers located in Ames' Numerical Aerodynamic Simulation (NAS) facility.

Tens of thousands of technical and administrative tasks related to America's space program are accomplished every day with the assistance of computers. Many of these machines perform functions unique to aeronautics research and space travel and to humanity's quest for knowledge of our universe. Since the 1950's, the computer has been the main tool that has enabled scientists and engineers to visualize the next frontier and then make it a reality.

Today, computers and computer applications at NASA vary from small microcomputers used for word processing, planning, and data management by clerical, professional, and management personnel to large mainframe computers for sophisticated management information and control systems.

Computer Applications

Microcomputers

- Electronic Mail
- Word Processing
- Data Base Management

Minicomputers

- Computer Aided Drafting
- Computer Aided Design and Engineering
- Computer Graphics and Word Processing

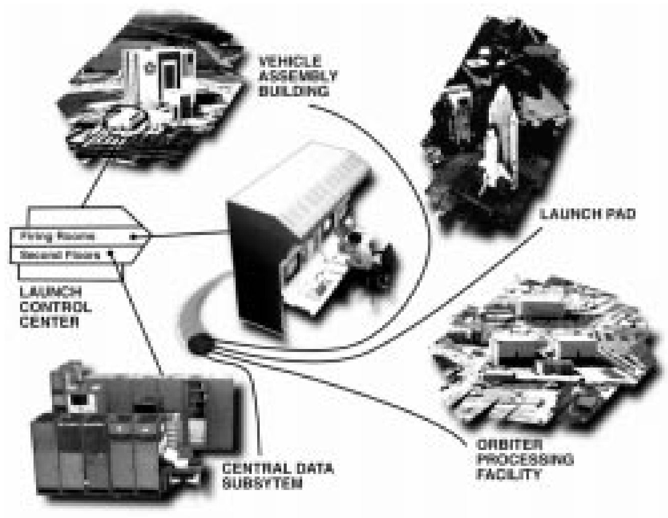
Mainframes

- Payroll
- Budgets
- Shuttle Operations (Configuration Management)
- Launch Control
- Software Development

Special Applications

- Electronic Printing
- Electronic Polishing
- Photographic Process Monitoring
- Modeling/Design
- Simulation
- Instrumentation/Data Logging
- Telemetry
- Virtual Reality

A good example of the technology used by NASA is contained in two computer-aided engineering graphics software packages. They are called PLAID and TEMPUS and they model objects like Space Station modules and the astronauts who will work in the Space Station environment. By studying the graphic models, specialists can find ways to ensure that the people in space interact efficiently and safely with machines. Unusable designs can be modified quickly and easily before scale models are ever built. PLAID is also useful for Space Shuttle mission planning and spacewalk simulation. The supporting hardware for these programs is a VAX 11/785 computer with a micro-VAX workstation networked to the main VAX.



The Launch Processing System operator at his console is the central point of contact for most checkout, assembly, and launch activities for the Space Shuttle.

Future planning is only part of the role of the computer in space travel. The astronauts, engineers, and technicians who operate the Space Shuttle rely on the launch processing system, onboard systems, and the Shuttle Data Processing Complex, all highly automated systems with programs using billions of calculations. These computerized systems are unique to space flight.

COMPUTERS RELATED TO THE SPACE SHUTTLE

Launch Processing System

At Kennedy Space Center in Florida, the launch processing system (LPS) is the computer-controlled overseer for prelaunch checkout and sequencing of the launch countdown of the Space Shuttle. The Space Shuttle, which carries people, equipment, laboratories, and satellites to and from Earth orbit, consists of an orbiter about the length and weight of a DC-9 jetliner, a huge external tank carrying propellants for the orbiter's main engines, and two solid rocket boosters. The external tank is the only component that is newly fabricated for each mission.

During assembly and checkout, the LPS monitors the solid rocket boosters, external tank, Space Shuttle main engines, and the complex systems of the orbiter through extensions called Hardware Interface Modules (HIM's). These are located in the Orbiter Processing Facility, Vehicle Assembly Building high bays, Hypergolic Maintenance Facility, launch pads, spacecraft checkout buildings, and various other sites supporting Space Shuttle maintenance and checkout. More than 20,000 parameters exist for just the ground-support equipment of the Space Shuttle. When all is ready, the boosters are stacked on a mobile launcher platform, the tank is attached to the boosters, and the orbiter to the tank. The entire assembly is then taken to the pad for launching.

The LPS consists of three major subsystems: checkout, control, and monitoring; central data; and record and playback. The large-scale host computers are Honeywell DPS 90's. The checkout, control, and monitoring subsystem hardware is provided by Martin Marietta. The distributed minicomputers are Model 245 machines produced by Modular Computer Systems, Inc.

Checkout, Control, and Monitoring Subsystem

The checkout, control, and monitoring subsystem consists of operator-manned consoles in the firing rooms, minicomputers, a data transmission system, a data recording area, HIM's, a common data buffer, and front-end processors.

Each subsystem operator position in the firing room has its own keyboard and visual display system. The information the human operator needs to make his/her decisions is displayed on screens resembling home color TV sets. Charts and diagrams are shown, pointing out where the unexpected condition exists, and using different colors to indicate the degree of urgency. A "red" signal means that immediate human attention is needed to prevent possibly serious consequences.

Each of three keyboards and display systems is considered as one "console," and operates as a unit. Two consoles, or six operator positions, are usually arranged in a quadrant or semicircle.

All consoles are orchestrated to work together on major tasks through an integration console at the front of the firing room. The small computer with each console has an online disk storage capacity of 5 million words to hold all the test procedures to be conducted by that operator and his/her assistants.

A master console in the firing room provides the controlling link for transfer of the real-time software from the central data subsystem, where it is compiled, to the network of up to 100 parallel minicomputers and micro-processors throughout the LPS. Approximately 430 minicomputers are used during a regular launch.

Central Data Subsystem

The central data subsystem consists of two large-scale computers that store test procedures, vehicle processing data, a master program library, historical data, pre-test and post-test data analysis, and other data. These computers make an immense amount of data immediately available to the smaller computers of the checkout, control, and monitor subsystem which have much less storage capacity.

The central data subsystem has two major interfaces. The real-time interface receives the vehicle and ground support equipment data from the checkout, control, and monitor subsystem. The video simulation interface provides simulated data to test real-time programs in the firing rooms without using the Space Shuttle.

Record and Playback Subsystem

The primary function of the record and playback subsystem is to record unprocessed Space Shuttle instrumentation data during tests and launch countdowns. These recordings can then be played back for post-test analysis when firing room personnel wish to troubleshoot Space Shuttle or LPS problems.

Computers Used on Board the Space Shuttle

The Space Shuttle contains five identical General Purpose Computers (GPC's). The hardware and software are redundant so that the avionics system which controls most of the Space Shuttle systems can withstand multiple failures. Four of the computers are designed to run the Primary Avionics System Software (PASS), and one computer contains the backup flight system (BFS) software.

The five computers are interconnected through digital data buses. During critical flight phases, such as ascent and entry, the PASS computers operate as a cooperative, redundant set to perform Guidance Navigation and Control (GNC) tasks. Critical GNC sensor data, available to all redundant set GPC's, are independently verified by each GPC.

Each of the computers operates in synchronized steps and cross-checks results of processing several hundred times per second. If a computer operating in a redundant set fails to meet the synchronization requirements of redundant set operations, it would be removed from the set by the other PASS computers.

The Space Shuttle computers are a modified IBM AP-101S model which IBM developed for aerospace applications. Each computer has 256,000 words of memory, with each half-word containing 25 bits. Each half-word of memory has 16 bits of data, with the remainder of the bits used for Error Correcting Code, parity checking, and code overwrite protection. Since the GPC's memory is composed of semi-conductor memory chips, cosmic radiation in space can corrupt its memory contents. Thus, the Error Correcting Code bits in each half-word are used to correct any memory errors introduced in this manner. In order to keep this system active, all five GPC's are left powered on while on orbit, but those not actively being used by the crew are configured to enter a power-conservation mode where little else but the error correction circuitry is operating.

The GPC's each employ separate Central Processing Unit (CPU) circuitry and Input/Output processor (IOP) circuitry. The CPU circuitry employs

Flight Director Chuck Shaw monitors operations on the Wake Shield Facility from his console in the flight control room in the Johnson Space Center's Mission Control Center. The Wake Shield Facility, seen on the large screen in the background, was on the end of Discovery's remote manipulator system. Most of the consoles supporting the mission are out of view in this image.

three separate processors in a "pipe-lined" array, allowing a processing speed of 1.2 million instructions per second. The CPU performs all the arithmetic and logic operations of the GPC; the IOP (under CPU control) connects the GPC to the network of data buses connecting to all the Data Processing System peripherals located throughout the Space Shuttle. The CPU, IOP, and all other circuitry of a GPC are housed in an enclosure measuring 7.5 by 10.1 by 19.5 inches, which protects the circuitry from electromagnetic interference. Each GPC weighs 60 pounds. The GPC's are located in the crew compartment mid-deck avionics bays and are cooled by fans. By today's standards, the computers would seem to be slow and lacking in memory. However, their key advantage is their ability to withstand the rigors of acceleration and vibration encountered in space flight.

Computers Used for Landing the Space Shuttle

The Microwave Landing System (MLS) provides highly accurate three-dimensional position information to the orbiter, which computes steering commands to maintain the spacecraft on the nominal flight trajectory during the landing phase, beginning approximately 15 kilometers (8 nautical miles) from the runway at the Kennedy Space Center in Florida or Edwards Air Force Base in California. The MLS is a specialized radio navigation system that provides range and angle information to the Shuttle navigation software during the final approach to the landing runway. It is important to note that the MLS is not a separate, distinct computer system. The computers used during the landing phase are the same computers used during all other phases of the mission. The computer software, however, is unique to the entry and landing phase.

The orbiter landing system is composed of three independent MLS sets. Each set consists of a Ku-band antenna, a radio frequency assembly, and a decoder assembly. Each Ku-band transmitter-receiver, with its decoder and data computation capabilities, determines the elevation angle, the azimuth angle, and the range of the orbiter with respect to the MLS ground station.

The orbiter MLS initially establishes a link to the ground station while the orbiter is on the heading alignment circle at an altitude of approximately 6,200 meters (20,000 feet). Angle and range data from the MLS are used by the Guidance, Navigation, and Control System from acquisition until the orbiter lands. From approximately 1,250 meters (5,000 feet) to touchdown, radar altitude provides altitude data to the pilots.

In 1983, a heads-up display (HUD) similar to the displays used on military aircraft was installed in the Space Shuttle Challenger and later incorporated into the Shuttle fleet. The HUD helps the crew fly to exactly the right spot for landing, which is particularly important when heavy payloads are aboard and braking and roll-out are important considerations.

The HUD is a set of two small glass screens and an optical combiner, positioned such that when the crew looks out the windows they see through the glass all essential instrument data and landing information without ever taking their eyes off the real world as they swoop down and glide in for their landing. This system eliminates the moment of “transition,” as pilots call it, when they shift their attention from the instruments which have guided them through poor visibility to the point in the approach where they can see the runway and use visual, out-the-window references for control to landing. Images are generated by a small cathode ray tube and passed through a series of lenses before being displayed to the crew on the combiner glasses as lighted symbology. The HUD computer also generates a simulated runway to which the crew can fly until the spacecraft breaks through any cloud layers, enabling the crew to see the real runway appear underneath the simulated one.

In order to return home, the Shuttle must be slowed down in a careful manner so that when its orbit encounters the atmosphere, the vehicle can maintain control and glide to its landing site. The Shuttle PASS and BFS computers described above are loaded by the crew with special entry software to provide Guidance, Navigation, and Control functions.

The purpose of the navigation software is to compute where the Shuttle is in relation to a specified reference system. During entry, the reference system is centered on the desired landing runway at the Kennedy Space Center or Edwards Air Force Base. The navigation software uses data provided by specialized navigation units to compute a very precise estimate of the position every few seconds. These include Inertial Measurement Units, Tactical Air Navigation, Air Data Transducer Assemblies, and MLS units. During the final approach to the runway, data from the radar altimeters are used by the crew to control the final touchdown rates.

The guidance software, armed with an accurate picture of where the Shuttle is with respect to where it will land, generates computer commands that allow the system to dissipate the tremendous amount of energy the Shuttle possesses when it enters the atmosphere, without skipping back into orbit or burning up. It also must ensure that just enough energy is maintained to reach the landing runway. This is accomplished by adjusting the vehicle drag acceleration using banking commands.

These commands to regulate energy, maintain stability, and keep the aerodynamic forces on the Shuttle within limits are carried out by the flight control software. These modules translate the guidance signals into actual instructions to the Shuttle’s Reaction Control System jets and the aerosurfaces, including the ailerons, speedbrake, and rudders.

Mission Control Center Computers

Space Shuttle flights are monitored and controlled from NASA’s Mission Control Center at the Johnson Space Center in Houston, Texas. The Shuttle Data Processing Complex provides the processing of command, trajectory, and telemetry functions. The complex includes five IBM 308X class machines, one dedicated to non-classified data processing, and three capable of supporting classified or non-classified data processing and associated support equipment. The two dedicated machines are designated as flight support hosts and the other three are designated as real-time hosts.

The host computers perform the following functions in support of the Shuttle data processing:

- Network communications — This subsystem sets up the interface controller to receive data from the worldwide tracking network and to separate and route telemetry and tracking data to the proper destination.
- Trajectory — During launch and landing procedures, radar tracking data samples are received and processed from remote tracking sites. The radar data are converted to vehicle position and velocity. Flight controllers can view the trajectory computed from radar data and that calculated by the onboard computers and telemetered down. Both are compared with nominal trajectory. If the predefined maneuver is inadequate, a new one is computed for uplink to the onboard computers.
- Telemetry — These programs can receive measurements from onboard sensors or onboard computers of orbiter telemetry data and from tracking site recorders. The subsystem converts these raw data to engineering data for viewing by the flight controllers. Each parameter can be checked against predefined limits and an out-of-limit condition is clearly shown on the displays. An audible alarm is triggered for critical conditions. Flight controllers can request several historical parameters at a time or a plot to represent trends.
- Telemetry data retrieval and reduction — Processed telemetry data are continuously stored both on magnetic tape and disk. Every 4 hours, a standard set of historical reports are generated and placed on microfiche.
- Command and control system — This subsystem formats and uplinks data to the onboard computer systems. Flight controllers use this subsystem to send real-time commands to onboard systems such as the ones configuring the communication system. In this way, flight controllers can back up the crew functions or relieve the crew of tasks more of concern to ground controllers.

Computers for Simulation

Every human space flight requires intensive preparation. Astronauts and flight controllers take part in “dress rehearsals” for each mission. A high-fidelity simulated mission environment provides training in the interaction between the crew and mission control personnel, responses to stressful situations, flight replanning, validation of flight procedures and plans, ground uplinks, and monitoring of system performance. This concept of integrating crew and flight control team simulations was first established during Project Mercury and has evolved through all human space flight programs since then.

In the Shuttle Mission Training Facility (SMTF), there are 14 computer systems which serve the Fixed

This facility plays an important role in the training of operational crew members for STS flights. In the foreground are computers, displays, and consoles supporting the Shuttle Mission Simulator seen in the backgraound. The fixed-base simulator is at left, while the motion-base facility is at right.