NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MCC
MISSION CONTROL CENTER
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS
FOREWORD

Manned Spacecraft Center (MSC) at Houston, Texas, has management responsibility for the design and development of spacecraft for manned space flights under the overall direction of the Office of Manned Space Flight, Headquarters, National Aeronautics and Space Administration, Washington, D. C. This management responsibility includes planning and execution of associated space flight missions.

First designated as the Space Task Group, MSC was formed at Langley Field, Virginia, in November, 1958, with specific management responsibilities for the design and development of a spacecraft for Project Mercury, selection and training of astronauts, and control of the flights from liftoff through recovery. In 1962, MSC was relocated to Houston. On May 15 and 16, 1965, the 22-orbit flight of Astronaut L. Gordon Cooper, Jr. in his “Faith 7” spacecraft successfully completed Project Mercury.

In the meantime, Manned Spacecraft Center had also been given similar responsibilities for the Gemini and Apollo programs, as well as for research and technology programs and necessary studies for advancing manned space flight as an outgrowth of the current programs.

The Gemini Program, using a two-man spacecraft, is providing added information on man’s capabilities during space flights of up to two weeks concerning weightlessness and physical effects on the flight crew; developing rendezvous and docking techniques with ‘orbiting’ spacecraft; experimenting with orbital flight maneuvering of manned spacecraft both before and after docking with a target vehicle; experimenting with extra-vehicular activity (the astronauts leaving the spacecraft while in space); and using the Gemini spacecraft as a manned vehicle for conducting scientific experiments.

Spacecraft development and testing for the Apollo program is being undertaken concurrently with the work on the Gemini program. Apollo, using a three-man spacecraft, will fly some earth-orbital missions to provide experience for the flight crews, further qualify the spacecraft systems, and permit additional experience in rendezvous and docking techniques. A lunar orbital and lunar landing mission is planned before the end of the decade. One of the three flight crew members will remain in the spacecraft in lunar orbit, while the other two will transfer to the Lunar Excursion Module (LEM) and descend to the lunar surface. After a period of exploration and scientific experiments on the lunar surface, they will lift off the moon and rendezvous with the orbiting Apollo spacecraft. They will then initiate action for the return trip to earth.

During Gemini and Apollo flights, from lift-off through recovery, control is exercised from the Mission Control Center-Houston. Operations personnel in the Mission Control Center maintain constant surveillance over vital spacecraft systems and, based on the performance of the inflight spacecraft as analyzed by a team of flight controllers deployed in a worldwide network, make key decisions necessary to accomplish flight objectives and assure mission success.

Thus the Mission Control Center plays a critical role in manned space flights of the United States.
MISSION CONTROL CENTER, CLEAR LAKE

Mission Control Center—Houston (MCC-H) is located in MSC Building 30, a three-story structure consisting of a Mission Operations Wing (MOW), an Operations Support Wing (OSW), and an interconnecting Lobby Wing. The MOW contains systems and equipment required to support the mission control function. The OSW contains office, laboratory and technical support areas for the Flight Operations Directorate. The Lobby Wing provides additional office space and dormitory facilities utilized by flight controllers during space flights of extended duration. The Mission Control Center is supported by an emergency power building which houses standby electrical power and air conditioning systems in the event of failure of primary sources.
INTRODUCTION

The basic function of mission control is to increase flight safety and mission performance by providing the flight crew with ground-based sources of information during normal or alternate missions and during mission emergencies.

Research and development testing of aircraft usually follows the pattern of a fixed flight plan with a predetermined set of tests followed by post-flight analysis. The flight-envelope boundaries are approached slowly because in-flight evaluation by the pilot and possible observers is limited by the available instrumentation and the ability to develop real-time solutions. The action in the event of emergencies is to return quickly to a more acceptable part of the flight envelope and, if necessary, abandon the aircraft.

The flight test phase of manned space flight programs is in many respects similar to comparable aspects of experimental programs of high performance aircraft. There are, however, very major differences. Principal among these differences are: (1) An essentially new and unknown flight environment, (2) A requirement for an early commitment to an ultimate design mission, (3) Limitations in ground-based flight simulation facilities, and (4) the scope and complexity of space flight operations.

The Mission Control Center-Houston provides centralized control of NASA manned space flight missions. It exercises full mission control from launch through recovery, and technical management in the areas of vehicle systems, flight dynamics, life systems, flight crew activities, recovery support and ground systems operations. In addition, flight controllers are also deployed to remote stations to aid in analyzing the data and, in certain instances, to make command decisions.
MSC Building 30 has been designed to give total support to NASA manned space flight missions. One of its wings has been designed to house the MCC-H; the other wing, the flight operations personnel and equipment required to develop the comprehensive operational planning and to train the flight operations team which will man the critical decision-making positions during mission periods.

The MCC-H is comprised of five basic systems: the Display/Control System (Page 11), the Real Time Computer Complex (RTCC) (Page 10), the Communications system (Page 12), the Command System (Page 13) and the Simulation, Checkout and Training System (Page 15) (SCATS).

These systems are designed to provide the flight operations team with the necessary real-time data and associated reference data for rapid assessment of mission progress, and for rapid decisions in the event of abnormal or emergency situations. The reference data are the result of the enormous effort that is spent prior to the mission in analyzing every possible contingency situation that may occur, and contains predicted trend data, mission rules and carefully planned, detailed operational procedures for regulating the mission.

The MCC-H has dual facilities and equipments, providing the capability to provide various combinations of simultaneous real-time missions, simulation exercises, or system checkout. For instance, it is possible to conduct an actual Gemini flight from one control area while at the same time, to either train another flight operations team or check out the other control area for an Apollo mission.
**Second Floor, MCC-H**

Principal areas on the second floor are the Mission Operations Control Room (MOCR), the staff support rooms (SSR), the simulation facilities and the Master Digital Command System. The MOCR is the principal command and control center, staffed with the key mission operations team responsible for overall management of the flight.

**First Floor, MCC-H**

Principal systems located on the first floor, MCC-H, are the Real Time Computer Complex and the Communications System. These systems support the dual mission facilities and systems located on the second and third floors. The Communications System provides the interface between MCC-H and both the Manned Space Flight Network and the launch site.
Third Floor, MCC-H

Principal areas on the third floor are the Mission Operations Control Room (MOCR), the staff support rooms (SSR), the Recovery Control Room (RCR), the Meteorological area and the Display and Timing area. The MOCR and SSR are exact duplications of the areas on the second floor. The Recovery Control Room, the meteorological area and the display and timing areas support the dual mission facilities and systems on the second and third floors.
The Mission Operations Control Room (MOCR) is the principal command and decision area in the MCC. Critical information relating to spacecraft, launch vehicle and ground systems, as well as aeromedical parameters, from the world-wide stations, ships and aircraft, is processed and displayed within the MOCR. Based on analysis of this continuous flow of information, personnel in this room must assess the spacecraft flight status and progress, and then, in time-critical periods, determine the continuation, alternation or termination of the space flight.

The 16 positions in the control room and the primary responsibilities are as follows. A graphic illustration shows the location of these consoles.
1. Mission Director — overall mission responsibility and control of flight test operations. In Project Mercury there were no alternative mission objectives that could be exercised other than early termination of the mission. The Gemini and Apollo missions, however, offer many possible alternatives which have to be decided in real time.
2. Department of Defense Representative — overall control of Department of Defense forces supporting the mission, including direction of the deployment of recovery forces, the operation of the recovery communications network, and the search, location and retrieval of the crew and spacecraft.
3. Public Affairs Officer — responsible for providing information on the mission status to the public.
4. Flight Director — responsible to the Operations Director for detailed control of the mission from liftoff until conclusion of the flight; assumes the duties of the Operations Director in his absence.
5. Assistant Flight Director — responsible to the Director for detailed control of the mission from liftoff through conclusion of the flight; assumes the duties of the Flight Director during his absence.
7. Operations and Procedures Officer — responsible to the Flight Director for the detailed implementation of the MCC/Ground Operational Support Systems mission control procedures.
8. Vehicle Systems Engineers — monitor and evaluate the performance of all electrical, mechanical and life support equipment aboard the spacecraft (this includes the Agena during rendezvous missions).
9. Flight Surgeon — directs all operational medical activities concerned with the mission, including the status of the flight crew.
10. Spacecraft Communicator — voice communications with the astronauts, exchanging information on the progress of the mission with them.
11. Flight Dynamics Officer — monitors and evaluates the flight parameters required to achieve a successful orbital flight; gives “GO” or “Abort” recommendations to the Flight Director.
12. Retrofire Officer — monitors impact prediction displays and is responsible for determination of retrofire times.
13. Guidance Officer — detects Stage I and Stage II slowrate deviations and other programmed events, verifies proper performance of the Gemini Inertial Guidance System and recommends action to the Flight Director.
14. Booster Systems Engineer — monitors propellant tank pressurization systems and advises the flight crew and/or Flight Director of systems abnormalities.
15. Assistant Flight Dynamics Officer — monitors and evaluates Gemini launch vehicle systems and reports any abnormalities to the Flight Director.
16. Maintenance and Operations Supervisor — responsible for the performance of MCC-H equipment and its ability to support the mission in progress.

Information is displayed on television monitors, indicator lights and digital readout devices on the consoles. Information is also displayed on the large group display projection screens at the front of the control room.

A visitor viewing room, providing seating space for 74 persons, is located at the rear of each MOCR. This is a separate room with a glass front which permits authorized visitors to observe the functioning of the control room during a mission.
Staff Support Rooms (SSR)

There are six SSRs associated with each MOCR. The technical specialists located in these areas are responsible for supporting their counterparts in the MOCR. They perform data analysis, analyze long-term performance trends, compare these trends with base-line data and relay this information along with their recommendations to the MOCR personnel. The 6 SSRs are:

**Flight Dynamics SSR**: Monitors and evaluates all aspects of powered flight concerning crew safety and orbital insertion, evaluate and recommend modification of trajectories to meet mission objectives, investigate and study potential maneuver requirements and actual or potential contingency situations.

**Vehicle Systems SSR**: Monitors the detailed status of trends of flight systems and components of spacecraft. Concerned with avoiding, correcting or circumventing equipment failures on on-board spacecraft.

**Life Systems SSR**: Monitors and evaluates physiological and environmental data telemetered from spacecraft.

**Flight Crew SSR**: Coordinate non-medical flight crew activities involving effective control of spacecraft, as well as any scientific experiments attempted during the flight.

**Networks SSR**: Schedules, monitors and directs network activities and readiness checks. Verifies remote site pre-pass equipment checks and directs all network handover operations.

**Operations and Procedures SSR**: Provide detailed technical and administrative support including administration of mission plans and procedures, mission control communication plans and procedures, generate documentation changes notices to networks and MCC flight controllers.
Recovery Control Room

The Recovery Control Room is the command and control center for all recovery operations. Its task is twofold; the DOD personnel are responsible for detailed command and control of the recovery task forces, and the NASA personnel are responsible for coordination of recovery operations as required for mission support.

Recovery planning takes into consideration not only the nominal landing area but also all possible contingency landings. In view of the extensive worldwide areas involved, recovery support for contingency landings is based on a compromise between calculated risk and reasonable recovery force development.

Weather Room

The weather at the launch site and in the recovery areas plays an important part in the operation of manned space flight missions. Accurate up-to-date information on weather conditions is provided to the Flight Director and his operations team by meteorologists of the U. S. Weather Bureau from the weather room at MCC-H. This information is gathered from stations in the U. S. and around the world, and from Tyros satellite pictures, relayed to the weather room over special circuits and analyzed by the meteorologists. Predictions of weather conditions at the various recovery areas are made and updated periodically to provide a continuous flow of information to the flight control team.
REAL-TIME COMPUTER COMPLEX

The real-time computer complex (RTCC) provides the computation facilities in the MCC-H for flight dynamic analysis, telemetry processing, acquisition predictions, and flight controller display generation with call-up capability. This complex consists of five IBM 7094 computers, computer switching devices, computer room display equipment, and associated support equipment such as magnetic tape units and IBM 1460 computers.

The primary functions of this complex are to process incoming tracking and telemetry data for evaluation of overall mission conditions. Parameters critical to this evaluation are position and velocity of the spacecraft establishing the go/no go information for each powered flight phase.

To facilitate recovery operations, the computers predict where the spacecraft will be at any predetermined time throughout the mission. Also, the computers provide each tracking station with acquisition information which can be used for positioning antennas and advising station personnel of times they can expect to acquire the spacecraft. The computers are also used for monitoring and evaluating telemetry information received from spacecraft to determine if both personnel and equipment are performing satisfactorily within predetermined environmental and operational parameters.

Two computers are used for each live mission (one operating in dynamic standby) for the functions described above. Two computers are available for practice exercises to simulate a mission at the same time a live mission is in progress.
DISPLAY/CONTROL SYSTEM

The display/control system provides mission control personnel with information concerning booster and vehicle systems, flight dynamics, life systems, the worldwide network, and recovery. This information is necessary to make the decisions which assure mission success and to advise proper actions through the voice circuits and the digital command system.

Computer derived data from the real-time computer complex, unprocessed data from the communications system, telemetry data, and stored reference material are displayed. Flexible and varied combinations of display data are provided by computer driven display generation equipment controlled from the consoles in the mission operation control room and the staff support rooms.

A video switching matrix provides each console operator with a selection of displays. A library of prepared reference slides is available to display static information on the TV precision monitor. In addition, digital-to-television display generators provide computer-generated data for dynamic information.

Thus a variety of information is available to the staff support and operation room personnel in many formats and combinations, including pictorials, meter-type displays, alphanumeric (a display of words and numerals updated simultaneously with receipt of data) and analog plots. Large wall displays in the MOCR and support rooms provide television and plotting data for group presentation.
The Communications System processes and distributes all signals, except television, entering and leaving MCC-H and provides internal communication capabilities for the MCC-H. The Communications Processor, the MCC-H message switching center, is a stored-program digital computer which processes large quantities of data on a real-time basis. Telemetry data is routed to a Pulse Code Modulated (PCM) telemetry system for data processing and display.

Teletype and facsimile traffic are routed through the teletype message center for distribution to printers for text and picture messages. The Voice Communication system enables voice communication between persons within MCC-H and between the MCC-H and flight crew training facilities, Manned Space Flight Network, and the spacecraft. The Facility Control systems centralizes quality control and maintenance for all high-speed data, teletype, and audio frequency communications circuits that enter and leave MCC-H.
The master digital command system (MDCS) in the MCC is the prime command point during operational missions and provides a capability for updating and controlling functions in the spacecraft from the ground. In order to perform this function, this command system must receive, store, verify and route digital commands to real-time sites such as Bermuda and Texas. It also relays prepass information to digital command system units at remote sites.

When the remote sites receive these data, they are automatically checked for errors and valid data are placed in memory cores for future use. Upon acceptance of the command, delayed by the digital command system unit, the spacecraft acknowledges receipt and validation by means of a telemetry signal referred to as a message acceptance pulse.
SIMULATION CHECKOUT AND TRAINING SYSTEM

The Simulation, Checkout and Training System (SCATS) provides realistic simulation of manned space flight missions for training both flight control personnel and the flight crew members.

The system has the capability of integrating the MCC-H simulation systems with flight crew trainers located at Manned Spacecraft Center and at Kennedy Space Center, Cape Kennedy, Florida.

The system includes simulated remote sites used for training remote site flight control personnel. These simulated stations are exercised by simulation control consoles, using source data from the flight trainers, SCATS special equipment, and the ground support simulation computer or any combination of these.

The simulation system also provides the capability of pretesting a mission, procedures, flight controllers and the crew members by purposely introducing "faults" into the information data streams. These faults may be introduced, at the option of the simulation team, into all forms of data such as telemetry, digital command and voice. By this technique potential weak points are detected and corrected. This training gives the astronauts and the flight controllers an opportunity to work together and build a mutual confidence and respect in the ability to successfully handle any contingency before the mission is actually flown.
WORLDWIDE NETWORK

The worldwide ground operational support systems network is controlled by MCC-H during Gemini and Apollo missions. The network is composed of facilities located at the launch site, remote land based sites, tracking ships and aircraft. This network performs four basic functions vital to mission success:

* Tracking
* Telemetry
* Command
* Spacecraft-to-ground voice communication.

The stations in this network have varying capabilities — for instance, some stations have both tracking and telemetry receiving capability, others only one; some stations can also transmit digital commands to the spacecraft and target vehicle; and some stations have direct voice communication capability with the spacecraft.

The data obtained by the network sites as the spacecraft passes over their respective areas is transmitted to MCC-H where it is evaluated and used to provide the operations control room with continuous mission information.

The information is transmitted from the stations by submarine cable, radio, and land-line. Telemetry data from the spacecraft provides information on which status of vehicle systems and the astronauts can be monitored. Continuous coverage is not possible since the spacecraft is out of range of network sites a portion of the time. Telemetry data is stored during such periods and periodically “dumped” over major receiving stations.

The command system provides MCC-H the capability to command either one or two spacecraft as required by the mission. Voice communication circuits provide necessary station-to-station communications as well as direct communications between the astronauts and flight controllers.