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Mission Control Center - Houston

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Introduction

General

The Mission Control Center - Houston (MCC-H) was designed to control all NASA manned space flights from the first Gemini rendezvous through the Apollo program. The MCC-H is a three-story building which contains 112,000 square feet, and which required 30 months to implement. It has a capability to control a live mission and a simulation simultaneously, or two simulations simultaneously. This capability was provided by locating duplicate operational areas on separate floors. The facility layout is shown in Figures 1, 2, and 3.

The MCC-H is comprised of five basic systems: the Display/Control System, the Real Time Computer Complex (RTCC), the Communications System, the Command System, and the Simulation, Checkout, and Training System (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 and at the same time either train another flight operations team or check out the other control area for an Apollo mission.

Principal systems located on the first floor are the RTCC and the Communications System. These 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 (MSFN) and the launch site.

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

Principal areas on the third floor are the MOCR, the SSR's, a Recovery Control Room (RCR), the Meteorological area, and the Display and Timing area. The MOCR and SSR's are exact duplications of the areas on the second floor. The RCR, the Meteorological area, and the Display and Timing areas support the dual mission facilities and systems on the second and third floors.

The MOCR is the principal command and decision area in the MCC-H. Critical information relating to spacecraft, launch vehicle, and ground systems, as well as aeromedical parameters are received from the worldwide stations, ships, and aircraft, and processed and displayed within the MOCR.

There are six SSR's 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 six SSR's are:

1. Flight Dynamics SSR: Monitors and evaluates all aspects of powered flight related to crew safety and orbital insertion, evaluates and recommends modification of trajectories to meet mission objectives, investigates and studies potential maneuver requirements and actual or potential contingency situations.

2. Vehicle Systems SSR: Monitors the detailed status of trends of flight systems and components of spacecraft. Is concerned with avoiding, correcting, or circumventing equipment failures onboard spacecraft.

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

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

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

6. Operations and Procedures SSR: Provides detailed technical and administrative support including administration of mission plans and procedures, mission control communication plans and procedures, and generates documentation change notices to networks and MCC-H flight controllers.

The RCR is the command and control center for all recovery operations. Its task is twofold; the Department of Defense 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 is provided at selected points throughout the world.

The weather conditions at the launch site and in the recovery areas play 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 Tiros 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.

Power System

Uninterruptible electrical power is assured by means of an emergency power building located adjacent to the MCC-H. Electrical power is divided into two categories: Category A and Category B. Category A is uninterruptible power generated within the emergency power building; it continually serves critical loads (e.g., data processing, critical displays, and timing equipment, plus certain lighting fixtures) during mission periods. Category B is 20-second interruptible power that supplies all MCC-H equipment not supplied by Category A power.

During normal operations, one-half of the Category A power and all of the Category B power is supplied by the commercial power system. During contingency situations, all required A and B power can be generated in the emergency power building.

Systems Description

Real Time Computer Complex

The RTCC consists of five IBM 7094 Mod II computer systems. Each system has a 524K auxiliary memory and a 64K main memory. The computers receive telemetry and trajectory data from the MSFN and perform such functions as data reduction, data computation, and conversion from percent full scale quantities to engineering units.

One 7094 has sufficient capability to control an operational mission; the computer assigned this function is called the Mission Operational Computer (MOC). However, when the MCC-H is supporting an operational mission a second 7094 is receiving live data inputs in parallel and is serving as a Dynamic Standby Computer (DSC) to the MOC.

At the same time a live mission is being controlled from one MOCR, a simulation can be conducted using the other MOCR. Simulations require two 7094's; a Simulation Operations Computer (SOC), which would function as an MOC, and a Ground Systems Support Computer (GSSC), which would generate for the SOC the data inputs that would normally be received from the worldwide tracking network. The fifth 7094 system could be used for periodic maintenance or job shop work. Thus, a typical RTCC functional configuration would be:

Computer A - MOC

Computer B - DSC

Computer C - SOC

Computer D - GSSC

Computer E - Periodic maintenance or job shop

A switching capability exists within the RTCC to assign any function to any computer system.

Display and Control

The Display/Control System provides mission control personnel with decision-oriented information concerning booster and vehicle systems, flight dynamics, life systems, the worldwide network, and recovery.

Computer derived data from the RTCC, 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 MOCR and the SSR's.

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.

A variety of information is available to the staff support and operation room personnel in many formats and combinations, including pictorials, meter-type displays, alpha-numerics (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, digital and analog data for group presentation.

Communications System

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 routes large quantities of data on a real-time basis.

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, MSFN, and the spacecraft.

The Facility Control System centralizes quality control and maintenance for all high-speed data, teletype, and audio frequency communications circuits that enter and leave MCC-H.

The Communications System is comprised of three separate subsystems, each of which has its own central switching or routing device.

The Pneumatic Tube Subsystem permits instantaneous transfer of hard copy materials between various points within the MCC-H. Each of two independent automatic routing devices is equipped to handle 22 send/receive stations. Any station can send to any other station handled by the same routing device. In addition to the automatic routing capability, five point-to-point tubes are provided to handle a large portion of the traffic and to back up the automatic devices.

The Voice Subsystem provides the Flight Controllers with the capability of talking with other MCC-H mission participants, with remote site personnel, and directly with the flight crew. The intercom component consists primarily of 300 loops (party lines), each capable of connecting 180 "customers". The intercom component is interfaced to network voice circuits by the Communications Line Switch, a manually operated push-button switchboard. In additon to these "in-line" functions, the Voice Subsystem also provides a capability for recording simultaneously more than 60 voice circuits for post-mission analysis.

The heart of the Data Communications Subsystem is the Communications Processor, a dual UNIVAC 490 computer system. It receives data from various users (the RTCC, the Teletype Message Center, the Gemini Launch Data System, and the MSFN), performs message accountability functions, reformating, transmission rate conversion, and logging, and then routes the data to the proper user. In addition to these in-line functions, it also provides a means for data monitoring, communications circuit quality determination, and data retrieval. This dual computer system is arranged so that either computer is capable of handling two simultaneous operations with one computer on-line and the other in a standby mode.

Master Digital Command System

The MDCS in the MCC-H is the prime command point during operational missions; it provides a ground capability for updating and controlling functions in the spacecraft. In order to perform this function, the command system must receive, store, verify and route digital commands to transmitter sites such as Bermuda and Texas. It also relays pre-pass command messages to digital command system units at other remote sites. When the remote sites receive these data, the data are automatically checked for errors, and valid data are placed in memory cores for future use. Upon acceptance of the command relay 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 system provides real-time training for the flight controllers who support the MCC-H and the MSFN manned remote sites. The training consists primarily of simulated flights utilizing the operational hardware in the operational configuration. Typically, pre-planned data inputs are received into the SOC. The SOC treats the simulation data as if it were live data; thus, from the point on there exists total realism in the simulation. The pre-planned simulation scripts contain various anomalies, unknown to the flight controllers being trained, which occur throughout the simulated mission.

The SCATS is composed of the following four subsystems:

1. Simulated Remote Site Subsystem (SRSS)

The SRSS provides the capability of MSC training of flight controllers prior to deployment to remote sites. It consists of remote site console sets, telemetry ground stations and digital command units identical to those located at the actual remote sites. The SRSS can be employed for independent remote site controller familiarization exercises and for integrating the operations of these controllers with MCC-H controller operations; the latter function is accomplished through closed-loop integrated simulations involving the entire simulation system.

2. Simulation Control Subsystem (SCS)

The SCS provides simulation controllers with the maintenance and control capability required to analyze the simulation progress and control its environment. Display control equipment located in a Simulation Control Area (SCA) on each of the second and third floors is employed for this function. From these positions, simulation controllers monitor performance of the simulation systems and the controllers undergoing training, insert realistic faults in the generated simulation data, and, when appropriate, modify the environment simulated.

3. Simulation Data Subsystem (SDS)

The SDS performs the basic data processing, control, and distribution for the SCATS. Three units form the SDS, the Exchange Control Logic (ECL), Process Control Unit (PCU), and Control and Status Logic (CSL).

The ECL interfaces the PCU with the RTCC (GSSC) and with the SRSS PCM ground stations. The ECL multiplexes the incoming data bit streams and transfers them in sequence to the PCU. The PCU performs the PCM telemetry data formating, limit sensing, and time conversion along with all Remote Site Data Processor functions required for simulation support. The CSL interfaces control and display signals between the PCU, SRSS, and the rest of the facility.

4. Simulation Interface Subsystem (SIS)

The SIS provides the major interfacing

and patching between the SCATS Subsystems, and between these subsystems and the MSC Flight Crew Trainer (FCT), RTCC, Display/Control System and Communications System. The SIS performs the functions of simulation selection, data transmission, subsystem and FCT interfacing, and MCC-H interfacing.

Launch Data Systems

A Gemini Launch Data System (GLDS) and an Apollo Launch Data System (ALDS) were implemented at Cape Kennedy to permit transmission of real-time launch data to the MCC-H. The GLDS provides the capability to multiplex the inputs from three telemetry ground stations at Cape Kennedy with the down range telemetry from the Eastern Test Range, and to transmit the multiplexed data to the MCC-H at 40.8 kilobits/second. In addition, real-time trajectory data is sent to the MCC-H at 2.0 kilobits/second. Similarly, the ALDS provides to MCC-H the wideband telemetry and high-speed trajectory information required at MCC-H during the boost-powered flight phase of the mission.

Implementation Problems

The major problem involved scheduling the MCC-H facilities to support the integrated systems tests. The installation and checkout was phased as follows:

- Phase I - Equipment delivery
- Phase II - Equipment installation
- Phase III - Component checkout and subsystems test
- Phase IV - Equipment string tests (integrated systems tests)
- Phase V - Operational testing (flight controller exercises utilizing operational computer program)

The initial problem involved conflicts in scheduling the building construction activity and the equipment installation and component checkout. Frequently equipment installation and component checkout could not be scheduled due to previously scheduled building construction activity.

This problem was alleviated by NASA's "buying-off" the building on a room-by-room and an area-by-area basis. When a given room or area was accepted by NASA, the brick and mortar contractor was relieved of further liability in that area.

The scheduling problem became more critical during the Phase IV equipment string tests. The primary reason for this is that the majority of these tests required one or more of the RTCC computers and major elements of the Display/Control System, as well as other common equipment items. The availability of the telemetry, command, communications, display/control, and simulation equipment had to be integrated with the schedule for debugging and testing of the real-time computer program. This schedule, in turn, was significantly influenced by the scheduled down times for maintenance.

Configuration Control

Control of configuration and engineering changes, while maintaining enough flexibility to accommodate last minute, and even real-time, changes, poses one of the difficult problems encountered in the management of large command and control systems.

In the MCC-H, these activities are keyed closely with mission phases and certain rules are observed to assure mission readiness. The NASA management is comprised of an engineering activity and an operations activity. The engineering group is responsible for engineering changes and non-mission systems support. All requests for changes to control center and Network systems are received by this group, the systems engineering is directed, and installation scheduled so that by a pre-determined cutoff date all work is completed. At this time, the operations group assumes control of the systems and pre-mission tests and necessary configurations of communication and display systems are carried out. Throughout the pre-mission and mission period, no engineering change work is permitted except that which is made necessary by equipment malfunction. This enhances the reliability and integrity of the particular mission support configuration.

Future Plans

Real Time Computer Complex Augmentation

A combination of known and predicted Apollo requirements indicates the need to replace the present IBM 7094 systems with systems which have greater capacity. The major areas of increased Apollo requirements are discussed below:

1. Telemetry

The volume of telemetry received from any single site is expected to increase by 30 percent over present Gemini requirements. The major factors which have contributed to the predicted increase are increased mission complexity, increased complexity of the launch vehicle, and the simultaneous operation of two manned vehicles. Display requirements are expected to increase in proportion to the increase in data flow, and in proportion to increased parameter size.

In addition to the 30 percent increase in the telemetry load from any one site, the number of sites transmitting high speed data over 2-kilobit lines is expected to increase. This will result in a significant increase in the total telemetry processing load for the RTCC.

2. Radar and Telemetry Trajectory Data

The additions of Unified S-Band and telemetered trajectory data from the launch vehicle and spacecraft guidance systems are the major factors causing an increased trajectory load on the RTCC.

3. Real-Time Mission Planning

The objective of this function is the

development of a real-time trajectory planning and evaluation capability which can assess a wide range of trajectory possibilities within specified performance, systems, and mission constraints. This capability would enable the ground systems to take into account contingency situations, including trajectory dispersions, vehicle systems failures, aeromed constraints, etc., and determine the trajectory and the flight plan which, for the existing situation, results in the attainment of the maximum number of mission objectives within the overall constraint of crew safety. Accommodation of these increasing data handling requirements will necessitate replacement of the existing RTCC computers with new-generation computing systems. The computer phaseover is planned for the calendar year 1966. Computer phasing must be staggered to allow continued support of missions during a high-density flight year. Present plans call for the new systems to be operational approximately January 1967.

The software systems are currently being developed, as is the optimum hardware configuration.

Other Future Plans

In addition to the RTCC augmentation, the problems of modifying the capability of the MCC-H to control dual missions simultaneously and to support Apollo SCATS are being studied. Also, studies are being conducted to determine how best to utilize the MCC-H to support the Apollo Applications Program. These studies will include areas specific to the Gemini program, which will become available at the conclusion of that program.

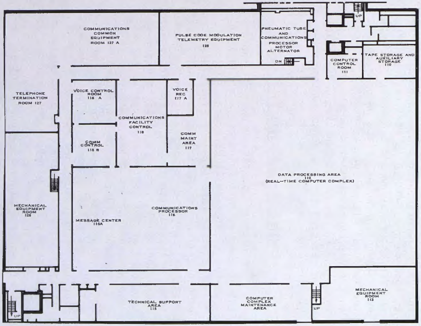

Figure 1.- First Floor - Mission Control Center - Houston

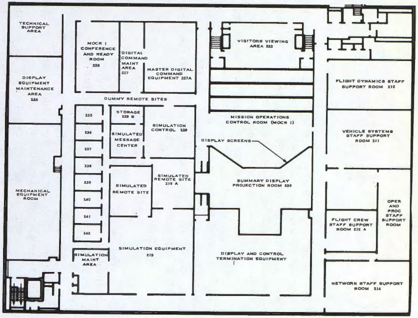

Figure 2.- Second Floor - Mission Control Center - Houston

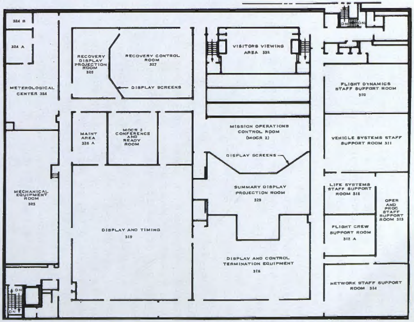

Figure 3.- Third Floor - Mission Control Center - Houston