A SIMULATION SYSTEM FOR THE MANNED SPACE-FLIGHT GROUND-SUPPORT NETWORK

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Introduction

Under construction at Houston, Texas, is the NASA Integrated Mission Control Center for ground control of manned spacecraft. A simulation system within this center will provide dynamic simulation of the ground network and in conjunction with spacecraft simulators, will permit integrated training for astronauts and flight controllers. The design is based on experience gained in the simulation system used in Project Mercury.

Ground Systems Simulation in Project Mercury

Prior to the first manned Mercury-Atlas mission in February 1962, a simulation system had been implemented at the Mercury Control Center (MCC) at Cape Canaveral, Fla., for the following purposes:

(1) To exercise mission rules and ground control procedures.

(2) To provide realistic training for flight controllers and for astronauts.

(3) To permit confidence testing of the systems of the Control Center and the tracking network.

The system, as installed and subsequently modified, used the Mercury Procedures Trainer (MPT) for its primary telemetry data source (fig. 1). An external means of introducing telemetry faults was added. Communications between the Mercury Control Room and the trainer were provide?, and provision was made within the simulation area in the MCC to simulate voice from the Mercury remote stations. Since the procedures trainer provided no position information, trajectory or orbit, data were generated for MCC and for NASA Goddard Space Flight Center by means of tapes played in MCC. Commands to the spacecraft were routed from MCC Flight Controller Consoles to the MPT with provision for introducing faults or spurious signals.

Three types of exercises were performed by using the Mercury Simulation System. They were flight dynamics exercises, Paunch simulations, and network simulations.

Flight dynamics exercises were specialized to exercise flight dynamics personnel in the critical powered-flight phase and to verify data transmission and programs of the computing center at Goddard. Only trajectory tape inputs were used. Data were transmitted from Cape Canaveral to Goddard via high-speed data lines. Display information computed at Goddard was returned to MCC for display to flight-dynamics personnel.

Launch simulations involved MCC, the Goddard Computing Center, and the Bermuda Tracking Station and covered the last 20 minutes of countdown through launch and injection into orbit until loss of signal between the spacecraft and the Bermuda station. The Mercury Procedures Trainer supplied telemetry and voice. Trajectory data were taken from tape. Launch simulations also permitted exercise of abort measures.

Network simulations were an extension of the launch simulation but continued through a period of orbital flight and the reentry phase. Simulation personnel at the actual remote stations provided scripted astronaut voice and taped spacecraft telemetry data to the tracking-station personnel at the appropriate times. These inputs were relayed to the MCC over operational voice and teletype lines to complete the simulation.

The Mercury simulation systen was used throughout the Mercury manned-spaceflight series with notable success. Its principal defects were its inability to operate in a closed-loop mode in vehicle dynamics (since it depended entirely on tape inputs) and a lack of adequate display and control devices for the simulation control personnel. The system was simple but effective.

The Future Ground Operational Support System

The manned space flight program is now in from the Mercury mission to the more complex Gemini and Apollo missions. Prior to the first Gemini rendezvous mission, ground control for manned flights will have been transferred to the Integrate? Mission Control Center (IMCC) now being equipped in Houston (fig. 2).

The IMCC, together with the launch control complex and the worldwide network of tracking ships and stations, is called the ground operational support system, or GOSS. The IMCC will provide a centralized control point for the GOSS by combining the mission control center with the real-time computing complex and supporting display, communications, telemetry, and command equipment. Ground control of the spacecraft in all mission phases will be exercised from IMCC.

Figure 3 shows the information flow between mission operations control room and spacecraft via the IMCC and the network. Each of the IMCC systems shown exists in duplicate to provide backup and simulation capability. Each link is described briefly.

Telemetry in pulse code modulation (PCM) form is transmitted from the spacecraft at 51.2 kilobits per second. When the information stream is received at the ground station, it is decommutated for local real-time display and reduced to a format compatible with transmission lines for transmission to the IMCC. Depending on the line capacity available, this format varies from 40.8 killobits per second in near real time (from Cape Canaveral only) to 60 word-per-minute teletype summaries (from overseas and shipboard stations). Telemetry information is converted in the mission operational computer (MOC) and the control and display system to television display format for viewing in the Mission Operational Computer Room (MOCR).

Commands for transmission to the spacecraft include real-time commands, which will cause a system action in the spacecraft upon receipt; stored program commands, which insert a word into the spacecraft onboard computer; and clocktime words, used to synchronize spacecraft clocks. Commands are assembled, addressed, checked for errors, sub-bit encoded, and routed from the IMCC digital command system via transmission lines to the remote tracking stations. At the remote station, they are again checked for errors and stored in core memory until the spacecraft is within effective air-to-ground range, at which time they are transmitted. When a command is received and verified in the spacecraft, a "validate" signal is returned to the ground via the telemetry downlink. The receipt of this signal at the station then causes the command system to step to the next command.

Acquisition information for the tracking stations originates from the ephemeris program in the MOC and is transmitted in teletype or high-speed data format to the remote sites. Radar tracking data are returned over the same lines and are used to update the computed ephemeris.

Direct voice and teletype communication is provided to all tracking stations. The spacecraft air-to-ground voice circuits can be patched into network voice lines for direct, IMCC-to-spacecraft communications.

The Real-Time Computing Complex of the IMCC, composed of four IBM-7094 digital computers and their peripheral equipment, performs the following principal operational functions:

(1) Computation of spacecraft trajectory and ephemeris.

(2) Computation of maneuvers required for rendezvous and controller reentry (Gemini) and translunar insertion (Apollo).

(3) Validation of spacecraft computer computations.

(4) Coding of commands for transmission to spacecraft.

(5) Generation of digital and digitally derived television display for MOCR and staff support areas based on telemetry, command, network, and other inputs.

A single computer carries the full operational program. A second operates continually on a standby basis with the capability of instantaneous switchover. The third and fourth computers are used in simulation, program development, premission readiness checks for the second MOCR, and maintenance time. Any computer may be assigned any of the several computer roles interchangeably.

The Mission Operations Control Room is the command post of the IMCC. There are two identical MOCR's, each having a configuration similar to that of the Mercury Control Center, and each supported by its own display and control system. It is not intended that two missions be conducted simultaneously from IMCC. The second MOCR will be used for simulation, training, and premission readiness tests during active mission periods.

The Mercury network, considerably modified by Mercury experience and in accordance with new mission needs, will be used for Apollo and Gemini tracking and data acquisition. Figure 4 shows the network now being implemented for Gemini and early Apollo flights. It should be noted here that there will be two types of remote stations, characterized by the data handling capacity of the lines linking them to Houston. The Cape Canaveral, Texas, and Bermuda stations, which have high-speed or wide-band data lines, are capable of returning selected telemetry to IMCC without significant delay; and inversely these stations can transmit directly to the spacecraft and the commands released at Houston. The more distant ships and stations, serviced by teletype, require reformatting of both telemetry and commands prior to relay to IMCC and to the spacecraft, respectively.

Simulation Requirements of the Ground Support System

The tasks of a simulation system for the new IMCC and the network are basically the same as those undertaken in Mercury, that is:

(1) To develop and exercise mission rules and procedures.

(2) To provide realistic training for flight controllers and for astronauts in the ground environment.

(3) To assist in checkout and confidence testing of equipment and personnel prior to mission.

Among the ground rules for design of the simulation system are the following:

(1) Maximum use of operational equipment and communication lines is required for economy and realism.

(2) Means of training remote-site flight-control teams must be provided both before and after deployment of these personnel to their stations.

(3) It must be possible to continue a simulation while an actual mission is in progress (except during the critical launch phase) without interference with the mission.

(4) The system must be able to operate either with or without connection to the Gemini or Apollo mission simulators, which will be installed at Houston and at Cape Canaveral. These simulators will be capable of dynamic performance.

(5) Since no "hardware" simulator is to be provided for the Agena-Atlas combination, the IMCC simulation system must provide a dynamic model of the Agena which is sufficiently detailed to permit realistic rendezvous mission simulation.

(6) Realistic faulting of all systems is required.

(7) The system will not extend to radio-frequency (RF) links either at IMCC or at the remote sites.

The significant new dimension of this simulation system is found not in the basic requirements or the ground rules just listed, but in the new complexity of the missions themselves. Unlike Mercury, the Gemini, Agena, and Apollo vehicles are capable of making appreciable changes in their orbits. In rendezvous operations, the positions of the vehicles must be computed not only with respect to earth but also relative to each other. Since the philosophy of their operation accords the astronaut discretionary control, the importance of dynamic simulation is greatly increased.

Simulation System

The simulation system now being assembled to meet these requirements of the preceding paragraphs is shown schematically in figure 5.

Based on the operational IMCC, including the MOCR, missions operational computer communications system, and control and display systems, the simulation system adds the following major simulation components:

(1) The Gemini and Apollo mission simulators at Houston and Cape Canaveral, simulating the spacecraft.

(2) Two simulated remote tracking stations, located in the IMCC building. These include PCM ground stations, digital command stations (DCS), flight controller consoles, and communications equipment, fully representative of the actual remote station configuration, except for acquisition and tracking systems.

(3) Eight dummy remote stations, equipped with communications equipment only, in which the crews of those stations not actually in contact with the simulated spacecraft can maintain their readiness until called into the instrumented stations.

(4) The ground Support Simulation Computer (GSSC), one of the four IBM-7094 digital computers, which has the following major duties:

(a) Produce simulated radar tracking data representatives of all actual tracking stations, including the launch data systems at Cape Canaveral and the Atlantic Missile Range stations.

(b) Simulate telemetry output of Agena and its Atlas launch vehicle, with the Agena telemetry and tracking data reflecting accurately the effects of commands received from GOSS.

(c) Control exercise sequence.

(d) Accept and reflect faults to PCM, DCS, and network functions.

(5) Simulation Control (Instructor) Consoles-one set for each MOCR and one set for the two simulated remote sites. The consoles have control of fault and sequence subroutines in the GSSC and of several other fault insertion devices. They also have enough displays to enable analysis of the mission and evaluation of flight controller performance.

(6) Simulation data and simulation interface subsystems which control routing of data and control words between operational and simulated components, according to the requirements of the simulation mode in use.

Operating Modes

The IMCC simulation system is required to support integrated training programs for at least two concurrent major mission programs: Gemini and Apollo. The frequency and duration of flights will be such that training must continue without serious interference in both programs during mission periods. In order to accomplish this objective, the system has been designed to operate in several modes. Since no major piece of equipment is common to all modes, it is possible to divide the system and thus operate two simple simulations simultaneously, provided that only one simulation requires the use of a mission simulator. When a mission simulator is not used, telemetry signals are played from prerecorded tape, and astronaut voices are simulated by instructors. When the Agena is used, it is simulated by the computer in all modes.

The following modes of operation are available:

Mission simulator - MOCR:

This mode (fig. 6) simulates ground contact with the spacecraft through one of the "real-time" stations: Cape Canaveral, Texas, or Bermuda. Flight controllers at the IMCC transmit voice and digital commands directly (via a real-time station) to the spacecraft. Near real-tine telemetry data are returned over land lines. There are, therefore, no decision-making or interpretive tasks at the real-time stations. In this mode, only the MOCR and spacecraft crews are trained.

Mission Simulator simulated remote station:

This represents a pass of the spacecraft over a single tracking ship or ground station (e. g. Canary Island, Rose Knot Victor, or Carnarvon), which does not have high-speed data links to the IMCC.

Real-time telemetry information is displayed at the station, but it is relayed to IMCC only in delayed summary. Commands for transmission to the spacecraft are received by teletype prior to acquisition and stored in memory for release during contact. Voice relay from IMCC through these stations to the spacecraft may be unavailable or unreliable. Flight controllers on duty at these stations may have tasks of varying complexity, as determined by mission rules and contingencies. In this mode remote station and spacecraft crews are trained, with the IMCC being simulated.

Network - Mission Simulator:

The third mode (fig. 8) combines the first two to represent the entire network. Up to eight remote station flight controller teams, each comprising five men, are assigned to the dummy remote stations where they receive realistic mission voice and teletype traffic. The teams rotate sequentially from the dummy stations to the instrumented simulated stations as the exercise develops the progress of the spacecraft over the network of tracking stations.

Actual Network:

Used only after final premission deployment of the flight controllers and ships to their tracking stations, this mode (fig. 9) exercises as much of the actual network as can be done realistically. A mission simulator at Cape Canaveral is used in closed-loop connection to the simulation checkout and training system (SCATS) during the launch and powered flight phases (through loss of signal between the spacecraft and the Bermuda station). Acquisition and tracking thereafter by nonreal time stat'rons are simulated at the stations by use of synchronized tape telemetry recording and simulated or recorded astronaut voices.

Proposed Employment

The IMCC, of which the simulation system described in this paper Is a part, is scheduled for completion in 1964. During acceptance testing of the installations,. the simulation system will be used as a signal source and display position for facility checkout. After readiness of the systems is established, the task of training flight controllers and developing mission rules for Gemini an5 Apollo will begin. According So present planning, the first mission supported by training in this new system will be a Gemini flight, launched in late 1964.

Summary

The Simulation System of the Integrated Mission Control Center will provide means to conduct training of ground control personnel for the Center itself and for the remote stations of the Network. When connected to a Spacecraft Flight Crew Trainer, it will permit realistic training of ground and spacecraft crews together. A number of training configurations are possible ranging from simple exercises involving a single site, to world wide simulation with the actual network.

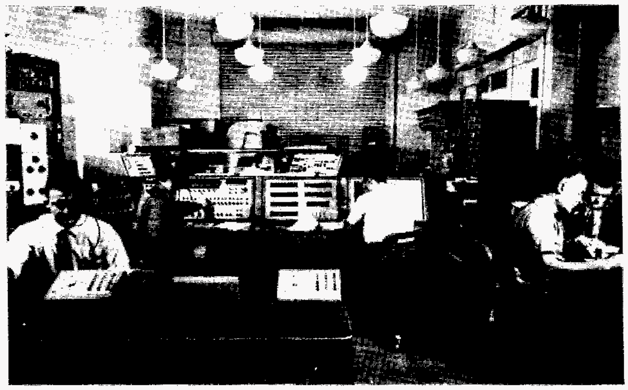

Figure 1. - Simulation Room at Mercury Control Center, Cape Canaveral

Figure 2. - Integrated Mission Control Center, Architect's Rendering

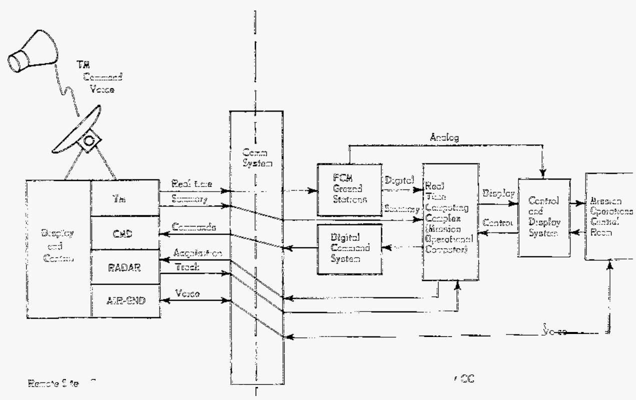

Figure 3. - IMCC to GOSS Data Flow

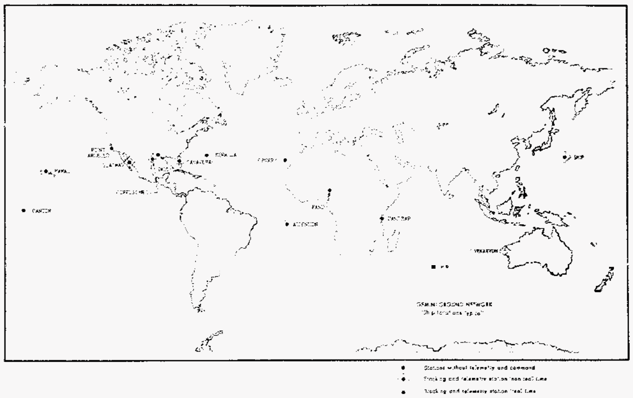

Figure 4. - World Map of Gemini Ground Network Stations

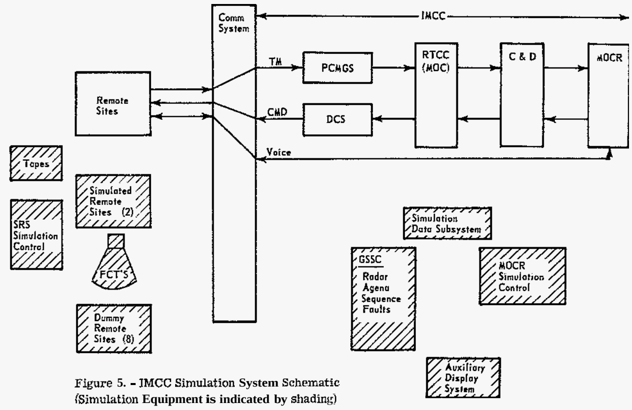

Figure 5. - IMCC Simulation System Schematic (Simulation Equipment is indicated by shading)

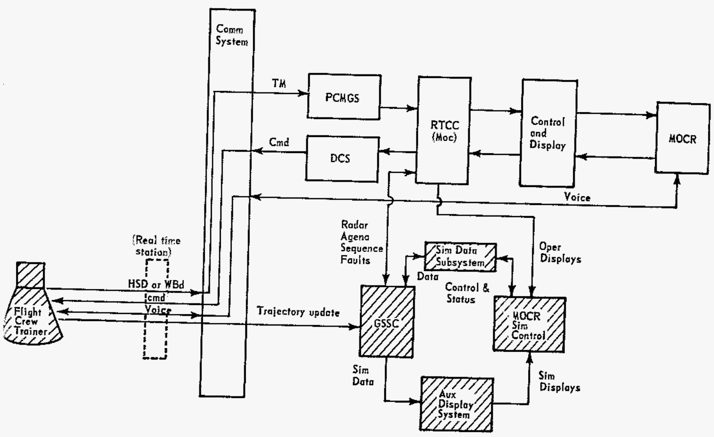

Figure 6. - Simulation System Mode 1 Schematic - Flight Crew Trainer - Mission Operations Control Room Exercise

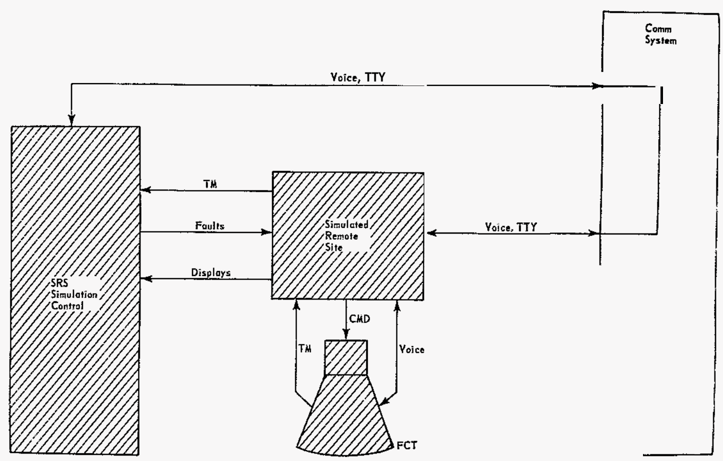

Figure 7. - Simulation System Mode 2 Schematic - Flight Crew Trainer - Simulated Remote Station Exercise

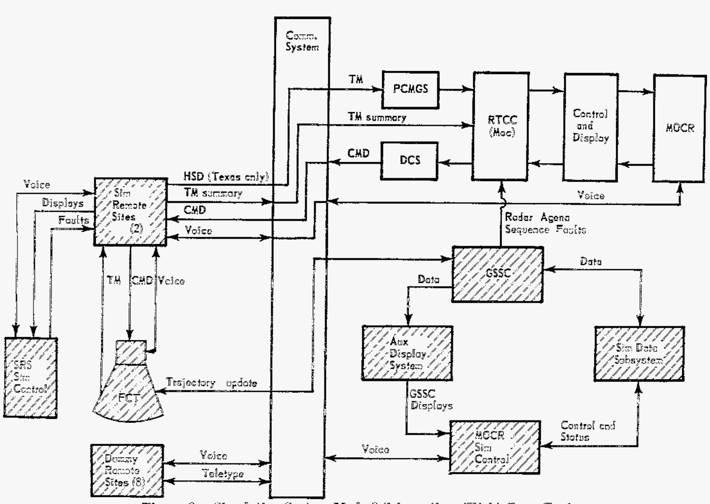

Figure 8. - Simulation System Mode 3 Schematic. Flight Crew Trainer - Simulated Remote Station - MOCR Exercise

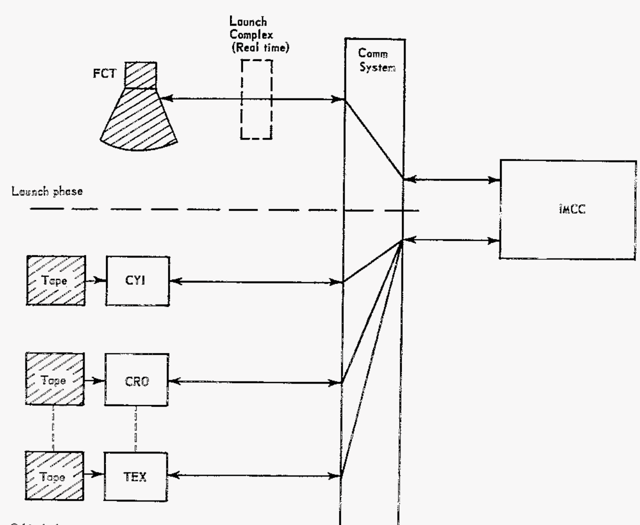

Figure 9. - Network Simulation Schematic