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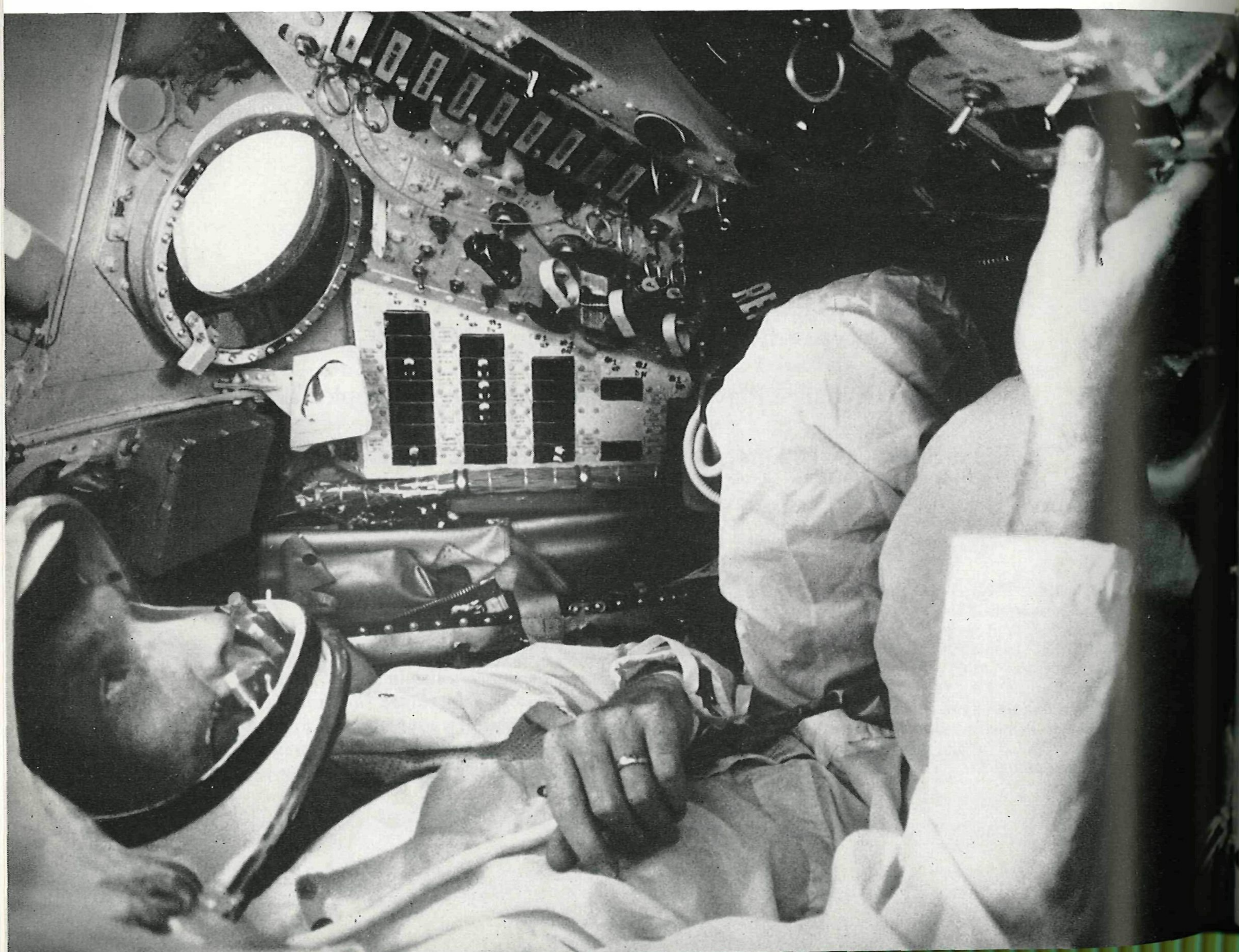
Cover

Western Electric technician checks out airborne guidance units in TITAN *missile. The Laboratories developed the guidance system, and Western produced the ground-based radar and the airborne equipment for the first six* TITAN ICBM *squadrons (see page 374).*

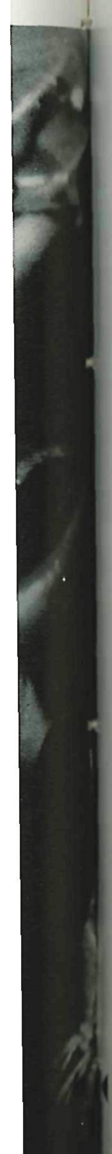
Though no astronaut will rocket aloft today, a group of men started working intensely at Cape Canaveral long before the dawn. These men are the Project Mercury flight controllers, continuing their vital training aimed at control of a manned space flight.

AROUND THE WORLD BY S



H. D. Irvin and W. L. Cowperthwait

BY SIMULATION



When Alan Shepard climbed into the Mercury capsule last spring, much of his confidence in the success of the mission necessarily rested on the capabilities of a conscientious group of men in the Project Mercury Control Center at Cape Canaveral. These were the flight controllers—men who make vital decisions during a Mercury mission and who issue or authorize commands affecting it.

These men did not learn their jobs overnight. In fact, the effectiveness of every person involved in the Mercury missions has been the result of countless hours of specialized training. Obviously, little of this training can be conducted "live"; it must be done through simulation.

When the Mercury program was initiated, the National Aeronautics and Space Administration recognized the need to train all participants before the missions began, and to continue this training between missions. Consequently, the NASA authorized the Western Electric Co. to provide specialized training facilities. The Training Simulation System for the Mercury Control Center at Cape Canaveral, Florida, is one of the installations designed for use during this training program.

Through the joint efforts of the NASA and Bell Laboratories, with their associated contractors and subcontractors, a NASA specification was issued early in 1960 which established the design philosophy for the simulation system. The other participating companies included Western Electric, McDonnell Aircraft Corporation, International Business Machines Corporation, Bendix Corporation and General Dynamics Corporation.

Technical direction and responsibility for coordinating the work on the simulation system were assigned to Bell Laboratories by Western Electric. The task included administering the system design and monitoring the various phases of equipment fabrication, installation, testing, and documentation.

To understand how the simulation system is used, it is helpful first to consider briefly the normal operation of the Mercury system during an actual mission. The more important elements of the operational system at Cape Canaveral include the Mercury Control Center Building, with its telemetry and communications facilities for direct contact with the capsule, the launch pad and its associated blockhouse for firing the booster, and the booster guidance facility, with its associated radars and computers. These elements are shown in the diagram on page 346.

This complex at "the Cape" is connected to computing and communications facilities of the Goddard Space Flight Center at Greenbelt, Maryland via high-speed data circuits, and teletypewriter and voice circuits. Goddard, in turn, is linked by teletypewriter and voice circuits to 16 remote tracking and voice-communications stations, strategically located around the world.

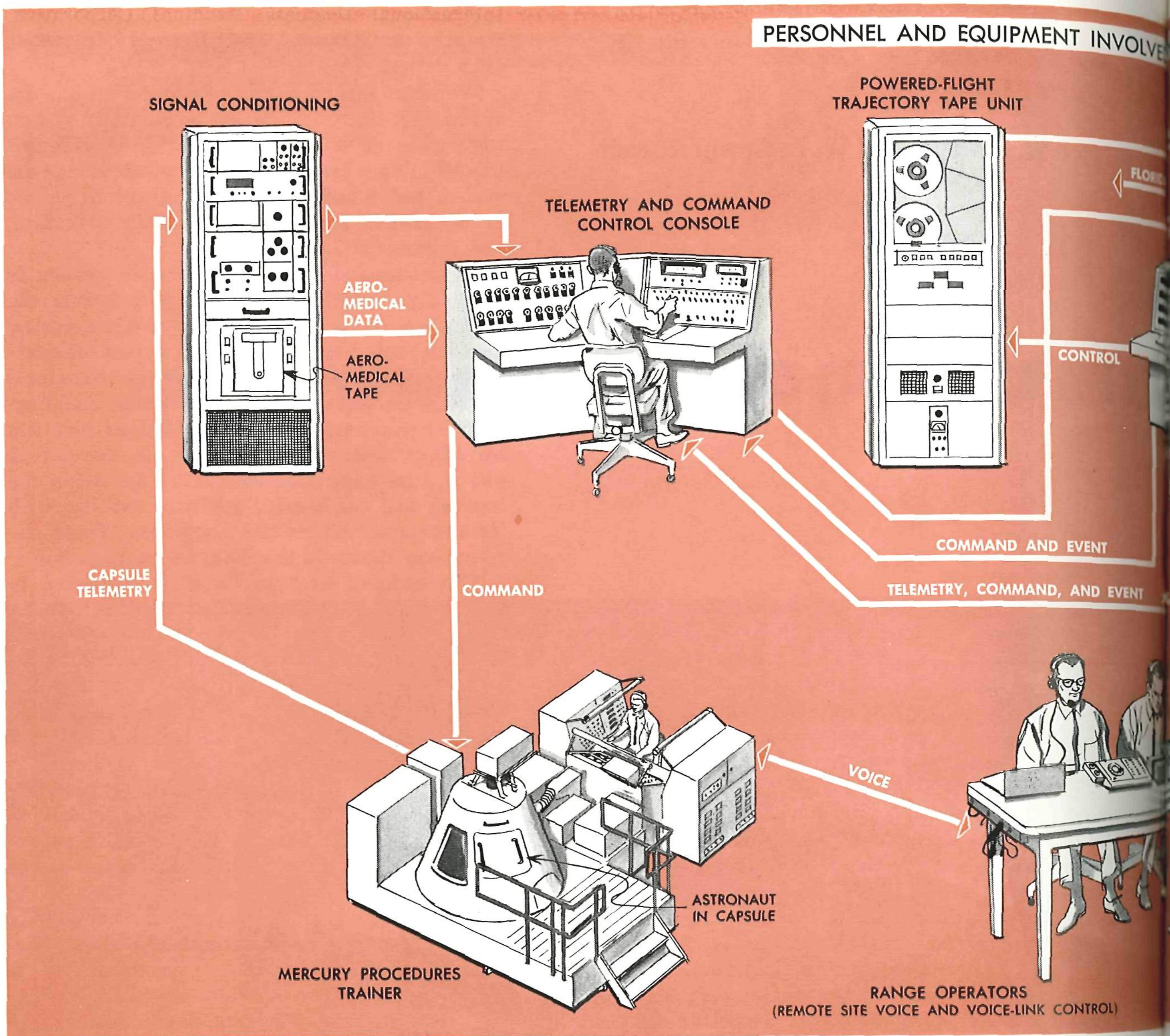
The Mercury Control Center controls the entire Mercury operation from before the rocket is launched through the time the capsule is recovered. During actual missions, the center serves in three capacities:

1. It monitors the launching of each booster and controls or commands the abort of a mission if such action is required.
2. It serves as one of the world-wide sites for tracking, telemetry receiving, command, and voice communications during orbital passes of the capsule.
3. It monitors normal re-entry of a capsule into the earth's atmosphere and directs the recovery operations.

During the prelaunch phases of a mission, the Control Center receives information on the state of readiness of each remote site via teletypewriter messages through Goddard. The center also receives information from the launch pad regarding the progress of the countdown and the condition of the astronaut.

As soon as the booster is fired and lifts off the launching pad, the guidance facilities start transmitting data to the Control Center on the performance and trajectory of the booster. From

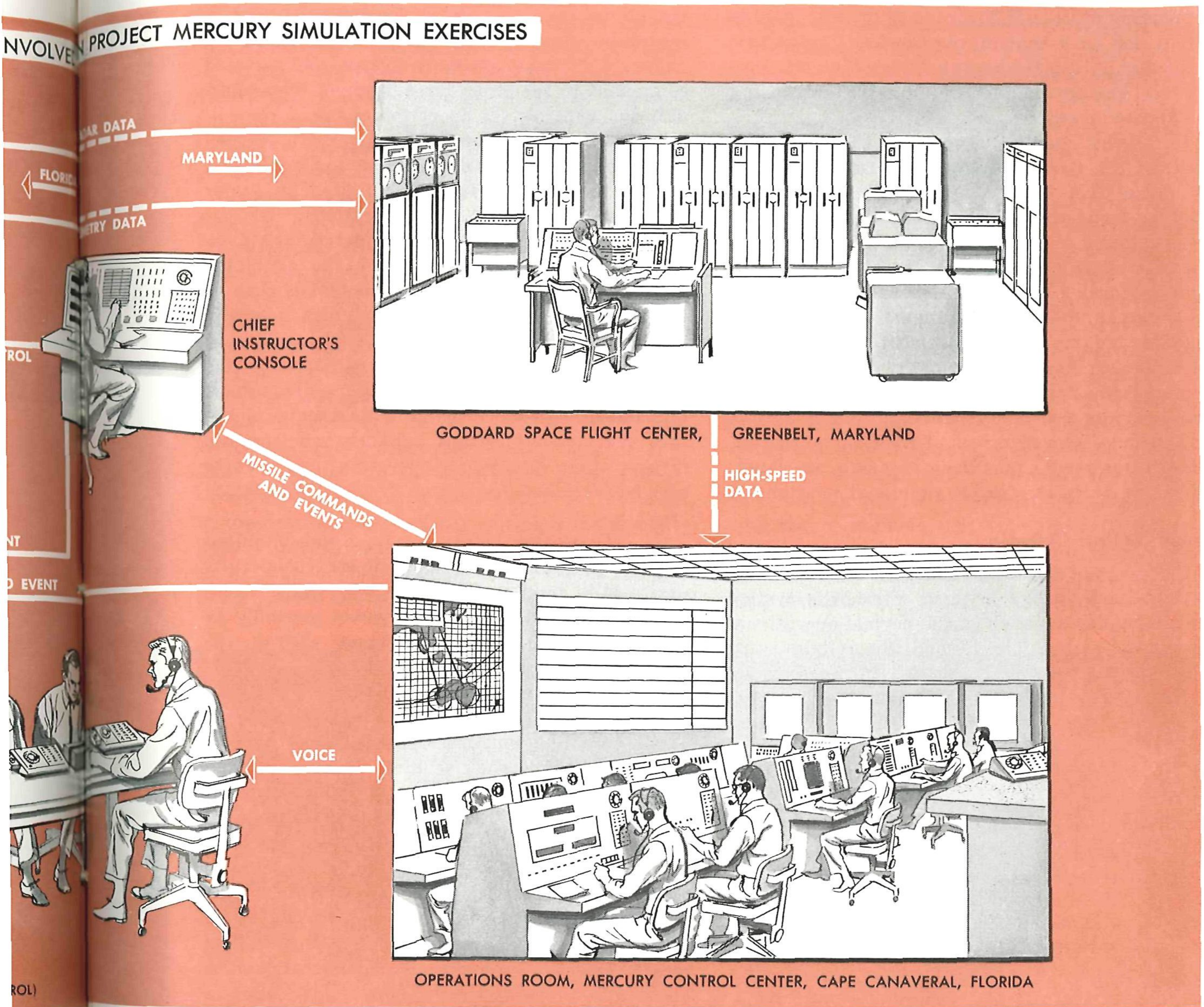
Astronaut John H. Glenn, Jr., maintains radio contact with Mercury flight controllers from his capsule simulator (NASA photo from UPI).



the center, these data are rerouted over high-speed transmission circuits to computers at Goddard. After being processed at Goddard, some of the resultant data go back to the Control Center at Cape Canaveral to be displayed on plot boards, meters, or similar equipment.

The telemetry, voice, and command channels between the Control Center and the capsule are also activated as the booster lifts off the launch pad. Telemetered information from the capsule is displayed to the flight controllers by suitable equipment such as oscilloscopes, pen recorders, and meters. Simultaneously, and as long as the capsule remains within range of Cape Canaveral, certain of the telemetered events are sent to the Goddard computers.

As the Mercury capsule goes into orbit and recedes from radar view at Cape Canaveral, successive remote sites of the world-wide network pick it up and monitor its operation by voice and telemetry links and, at some sites, by radar tracking. During orbital passes, each site receives information from the capsule and from the astronaut. When this information is received at Goddard, some of the data are relayed to Cape Canaveral and to the other Mercury sites. Other data are "digested" by the Goddard computers for use in following and predicting the capsule's



flight, and the results of this analysis are passed to Canaveral.

In this way, a continuous flow of information to and from the Control Center is maintained throughout the entire mission. Even after the capsule has landed and the ships and aircraft of the recovery task force go into action, the Control Center coordinates the recovery operation until it is completed.

To accomplish such a mission, effective coordination between the many people involved is vital. The Training Simulation System for the Mercury Control Center has been designed to provide the facilities for training which will insure this coordination. The system feeds information to the operations room at the center to duplicate normal and abnormal conditions that may occur during an actual mission. It also accepts as inputs to the Mercury system the normal or emergency actions taken by the flight controllers, so that results of their actions can be noted, and necessary corrective training given.

Simulation system instructors devise a variety of missions to be simulated for training purposes. Switching arrangements allow simulation of either short suborbital or full orbital missions. These simulated missions give experience both to the flight controllers and to many of the supporting personnel. Training of the astronaut is integrated with that of the Control Center personnel by having the capsule of the Mercury Procedures Trainer manned by an astronaut during simulation exercises.

During an operational mission, the operations room at the Control Center is normally manned by more than twenty people. The flight controllers, each serving in a specific technical capacity, comprise about half of this group. Besides the controllers, there are the Operations Director, who has over-all mission responsibility, mission observers, and technical support personnel who operate and maintain equipment in the operations room. In addition, many technicians are required to operate and maintain equipment in the communications, telemetry, data-selection, and capsule-recovery areas of the Control Center. All of these people, plus the astronauts, are candidates for training during simulated missions.

Basic Design Criteria

Designers of the simulation system were guided by two basic design criteria. First, the system should employ as much of the normal operational equipment as possible. Second, the reliability of the operational system should in no way be jeopardized when switching between operational and simulation conditions. To comply with these requirements, the simulation system was divided into a group of functional subsystems, interconnected by suitable cables or switches. The major subsystems include the Mercury Procedures Trainer, the Telemetry and Command Control Console with its associated Aeromedical Tape-Drive Unit, the Chief Instructor's Console, the Trajectory Subsystem, and the Intercommunications Subsystem.

The Mercury Procedures Trainer, developed by McDonnell Aircraft and supplied by the NASA, is essentially a complete Mercury capsule with control consoles. During a simulated mission it serves as a source of telemetered signals and events and as a receiver for radioed commands. When manned by an astronaut, it can supply voice communication from the capsule. For a particular training exercise, the instructor at the trainer follows a mission "script" to operate the equipment as specified and to generate and accept signals or respond to commands from the other instructors or from trainees.

The operator of the Telemetry and Command Control Console controls the flow of information between the Procedures Trainer and the rest of the Mercury system used during a simulated mission. He can produce simulated telemetry signals independent of the Procedures Trainer, interrupt signals, introduce noise on telemetry channels, generate spurious signals, and forward commands to the Procedures Trainer. This operator also controls the operation of the Aeromedical Tape-Drive Unit, which supplies prerecorded heart and respiration data similar to those which would be received from an astronaut under unstressed or stressed flight conditions.

The instructor at the Chief Instructor's Console follows a master script of the simulated mission. His position supplies commands such as booster-firing and abort signals which normally originate from the launch pad blockhouse during the powered-flight phase of an actual mission. During the balance of the mission—the orbital and re-entry phases—the chief instructor monitors the communications channels, advises and directs other simulation operators, and accepts and relays messages to and from all simulation operators.

The Trajectory Subsystem is a special high-speed tape unit with associated control circuits designed to supply prerecorded tape data. These data simulates the data that would normally be associated with missile guidance during the powered-flight phase of a mission.

The Intercommunications Subsystem provides extensive voice communication and monitoring facilities throughout the Control Center by special telephone keyset equipment strategically located on all consoles in the various equipment operating areas and at a range conference table in the simulation room. Instructors at this table work from scripts to simulate voice communications to and from the remote world-wide sites.

To a visitor in the windowless operations room during a simulated mission, the effect of realism is striking. So strong does it sometimes become that he is almost compelled to go outside to see if there actually is a Mercury rocket standing on the pad, shrouded in frost and clouds of vapor, awaiting the firing signal.

The flight controllers man their positions in the operations room as they would for an actual mission and follow precisely the same rules of action. As the prelaunch countdown proceeds, and this may last for hours, operators in the simulation room talk to the flight controllers. During this period they simulate personnel at the launch pad, and the "voices" the controllers hear carry out the vast number of checks that must be made to assure the readiness of the capsule and the booster, and of the complex radars and guidance facilities at the Cape. Other voice operators "act" as talkers at the remote tracking sites around the world. They report in to the Mercury Control Center on the status of their sites; the wording is brief, the meaning precise:

"All systems condition green, except acquisition red. Estimate fix in 20 minutes. Over."

"Roger. Advise when status green. This is Canaveral. Out."

Messengers pass quickly among the rows of consoles, delivering simulated reports from the Mercury network to the flight controllers and taking outgoing messages for transmission. Periodically, as the countdown clock ticks off the seconds, a status announcement is made over the loudspeaker system.

"T minus 180 minutes and counting."

At the same moment in the countdown at which an astronaut would be scheduled to enter the Mercury capsule atop the booster, one of the "seven" walks into the simulation room and is assisted into the Procedures Trainer. He is sealed in the semi-darkness of the capsule's instrument lights; his only contact with the outside is by the simulation communications. As he begins the detailed tests of his vehicle, his voice is heard in the headsets of the flight controllers. A voice operator simulates the Capsule Test Conductor.

The simulation operator at the Telemetry and Command Control Console flips the ON switch of the Aeromedical Tape Unit. Out in the operations room, an oscilloscope on the Flight Surgeon's console comes alive, displaying a prerecorded electrocardiogram. Meters on this and other consoles show prerecorded respiration rates and temperatures typical of the astronaut's own, as well as the capsule's battery voltages and currents and a myriad of other telemetered quantities.

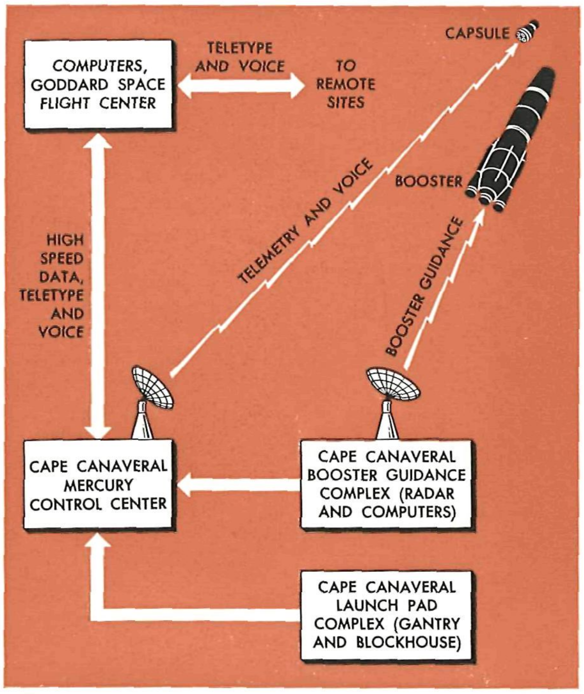
The simulation instructors critically monitor the operations of the flight controllers throughout the exercise, noting any procedural difficulties for discussion at the debriefing session which will follow. The script for today's exercise, whose contents are not known to the flight controllers, calls for the instructors to simulate several abnormal conditions aboard the capsule during both the countdown and the flight. These are conditions which conceivably might occur in a real Mercury mission, and they will require quick decisions by the Flight Director and his

During simulation: two consoles (center) are the Telemetry and Command Subsystem and Chief Instructor's position. Range conference table is in foreground, Procedures Trainer in background.

flight controllers to take corrective actions. One possible corrective action might be to bring into service spare facilities which have been provided for just such eventualities. The instructors carefully observe the performance of the flight-controller team under these conditions.

At a signal from the Chief Instructor, the first abnormal condition called for in today's script is simulated. The operator of the Telemetry and Command Console adjusts a small knob. In the operations room, the Capsule Systems Monitor sees the telemetered temperature of a small unit in the capsule begin to rise. Over the voice circuits he can be heard informing the Flight Director that there may be a problem. Then, as the temperature ceases to rise and remains below a dangerous level, the decision is made that the mission is still in a "go" condition, with all systems functioning well enough to proceed.

As the countdown nears zero, a growing tension can be detected in the operations room, just as it would be during an actual Mercury mission. The same tension also is felt in the simulation room, where the instructors must work as a smooth team in operating the complex simulation system to provide a realistic set of signals to the operations room. The Chief Instructor watches the clock closely, with his hand resting on the



Important elements of the operational system for Project Mercury, including those at Cape Canaveral and Goddard Space Flight Center.

switch that will give the firing signal and start the simulation equipment into the dynamic phase of the exercise:

"Five . . . four . . . three . . . two . . . one . . . zero . . . LIFTOFF."

The powered-flight trajectory tape begins to roll, feeding simulated radar data over high-speed data lines to the computers at Goddard Space Flight Center eight hundred miles away. The computers analyze the data received and return the results to Cape Canaveral for display in the operations room. The Telemetry and Command Control Operator presses a button marked STRESS, and the heart and respiration rates displayed to the Flight Surgeon change to those of a man experiencing the stresses of rocket flight.

The pens on the trajectory plotboards crawl upwards, describing the arc of a booster's flight to the Flight Dynamics Officer. A voice-system operator in the simulation room adjusts controls so that the astronaut's voice is now heard through realistic static and fading as he maintains constant contact with the Capsule Communicator.

Now, just before the engines of the rocket booster are to be shut off to end the powered phase of the flight, the Chief Inspector throws a switch which keeps the signal indicating one of several significant events from being transmitted to the Mercury Control Center. When the event indication fails to occur at the scheduled time, the flight controllers can be heard questioning the astronaut over the simulated radio circuit. He assures them that all indications are "OK" in the capsule, and the Chief Instructor monitors the quick reactions to this situation by the flight controllers.

As the capsule's imaginary flight takes it over the horizon away from Cape Canaveral, the Voice-System Operator causes the radio link to fade. A few moments later, a range-station operator in the simulation room calls into the Control Center, as if from a remote site in the Atlantic Ocean, to report that the capsule is in a satisfactory orbit, and all is well aboard. During each ninety-minute orbit of the capsule, messages simulating those from each of the world-wide Mercury stations arrive in the operations room by voice and teletypewriter. Finally, word arrives that the retrorockets have been fired to slow the capsule from its 17,000 mph orbital speed, bringing it back to earth.

The capsule is scheduled to pass in radio "view" of Cape Canaveral during descent, and the simulation instructors re-establish voice and telemetry links to the center at the proper time.

While the astronaut is resuming voice contact with Cape Canaveral, "event" displays before the flight controllers light up to show "Drogue Chute Deployed," then "Main Chute Deployed." Shortly afterward the announcement is heard on the intercom circuits that the capsule has landed safely in the ocean and is being retrieved.

As the hatch cover is removed and the astronaut climbs out of the Procedures Trainer capsule to join the simulation instructors in the operations room for a critique of the exercise, there is a visible relaxation among the flight controllers. This, as much as anything, attests to the realism of the simulation exercises.

The flight controllers call these exercises "playing the game," but it is a strict game, played seriously and well. For only through constant practice such as this do these men develop their skills, individually and as a team, ready to act with split-second timing when the day of the actual mission arrives.

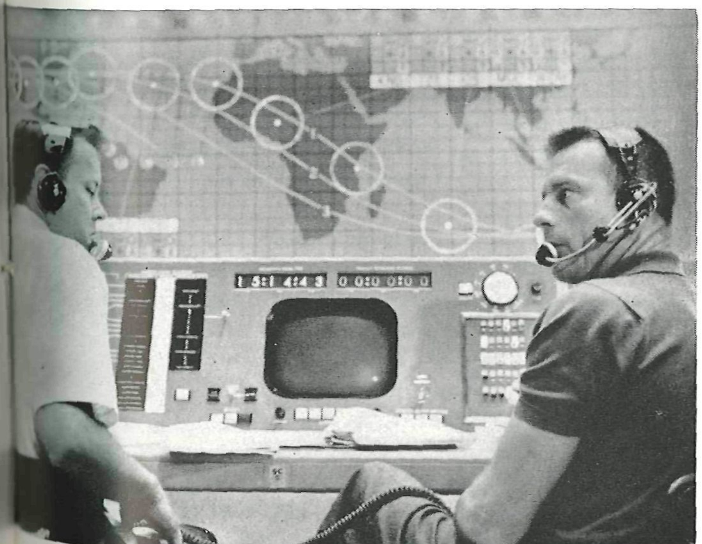
The first real "exam" came last May when the first American astronaut made his flight under the control of the dedicated group of flight controllers at the Mercury Control Center. And how did Astronaut Shepard feel about the preparations? Shortly after the flight he put it succinctly:

"Our training has been extremely thorough."

Mercury Spacecraft "Proves In" Ground Tracking Network

The most comprehensive test of Project Mercury to date—orbital flight and re-entry of an unmanned Mercury spacecraft on a completely automatic basis—was successfully completed last month. The flight of the spacecraft was tracked by a world-wide network of tracking and monitoring stations which Western Electric turned over to the National Aeronautics and Space Administration earlier this year. (RECORD, *June*, 1961.)

Through the 18-station network, which will track, monitor and provide communications with manned orbiting spacecraft in the future, came all the information necessary to monitor and control the unmanned orbital flight. NASA flight controllers at the Mercury Control Center at Cape Canaveral made all the vital decisions required for the flight in the operations room. The design and installation of this room was one of the responsibilities assigned to the Laboratories by Western. The Laboratories also implemented the operations at the Bermuda site, designed and installed a flight-controller training simulator, as described in the preceding article, served as consultant on technical phases of the project, was responsible for assessing the capability of equipment to fullfill operations plans and handled operational tests of the network.



Mercury's Control Center has a large animated map in the front of the room that displays the status of equipment at all tracking sites. It also shows the position of preferred recovery areas and indicates the position of the orbiting spacecraft. On each side of the map are "trend" plots which record conditions inside the spacecraft. When the manned spacecraft is launched into orbit these monitors will provide information concerning the astronauts heart rate, respiration rate and body temperature, as well as the oxygen supply, temperature and quantity of coolant in the spacecraft.

The complete communications network comprises a 60,000 mile route representing more than 140,000 circuit miles. Included are about 100,000 miles of teletypewriter circuits, 35,000 miles of telephone circuits and more than 5,000 miles of high-speed data circuits.

Astronaut Donald Slayton (right) discusses launching procedure with a flight controller (UPI photo).