Mercury, it was necessary to design some specialized equipment. An example is the IBM 7281 Data Communications Channel (DCC) which automatically accepts inputs from a large number of data sources, places the information quantities directly at the disposal of the computer, automatically accepts calculated output data from the computer, and makes the information immediately available for transmission to many destinations.

For early missions, a duplexed configuration of IBM 7090 computers was connected by a DCC to radar stations, and sources comprising the real-time tracking and instrumentation system. For the MA–9 mission, a Triplex configuration of IBM 7094 computers, which were updated from the IBM 7090 configuration, was used.

Test and evaluation techniques.—Any system as complex as the Mercury network had to be thoroughly tested under conditions as close to actual operating conditions as possible. It had to be certain that the units and subsystems were functioning properly and that all elements were functioning together as a complete system. Thus, it was necessary to devise computer-controlled tests to check out all computer-related elements of the total system. Called CADFISS (Computation and Data Flow Integrated Subsystem) testing, this worldwide network test concept was employed in Mercury launch countdowns to determine final tracking and data processing system readiness.

Performance analysis.—A brief analysis of how the computing and data system performed during the manner orbital Mercury missions is presented.

Table 8–I shows FPS–16 and Verlort radar performance. Both radars approached their design limits while tracking an orbital target. The values were derived by fitting the data to the equations of motion. The data were far better than expected. Note that, up until the MA–9 mission, the standard deviation in elevation for the FPS–16 is twice that in azimuth, probably as a result of refraction errors. An improved correction for refraction was incorporated into the Mercury programs for MA–9. This is not apparent in the Verlort; apparently the much higher noise level concealed the refractive error. In many cases the data from certain FPS–16 and Verlort radars were better than the 0.1 mil and 1.0 mil criteria.

A comparison of the single-station FPS–16 orbital determination with the single-station Verlort solution shows that the FPS–16 is roughly four times as accurate in position and eight times as accurate in velocity determination.

The accuracy of the Mercury integration scheme, atmospheric model, and tracking data is demonstrated in table 8–II. The orbit, as determined by multiple station solution, was integrated forward to compare with newer tracking data. The vector changes in position and velocity were averaged and are presented in table 8–II.

The accuracy of the total system is demonstrated by the calculation of time-to-fire retrorockets. The spacecraft timing system is such that the rockets are fired at the integer second. With the spacecraft traveling at 5 miles per second, the landing point is known only to ±2.5

Table 8–I.—Radar Performance

Mission	Standard deviations—mission averages					
	FPS–16			Verlort		
	Range, yd	Azimuth, mils	Elevation, mils	Range, yd	Azimuth, mils	Elevation, mils
MA–6	8. 5	0. 23	0. 44	29. 0	1. 63	1. 35
MA–7	9. 8	. 22	. 40	33. 7	1. 62	1. 72
MA–8	8. 6	. 25	. 36	39. 6	1. 22	1. 34
MA–9	11. 2	. 27	. 26	20. 2	1. 36	1. 42

miles. The recovery forces are able to estimate their position to about ±2 miles. Thus, the total uncertainty may be approximately ±5 miles. Table 8-III shows the landing points predicted for the four manned missions. The center column shows the landing point established by radar tracking. The tracking information in MA-7 and MA-6 provided landing points within 15 to 20 miles of that reported by the recovery forces. This difference may have resulted from lift experienced by the spacecraft in reentry. The predictions for MA-8 and MA-9 are well within the area of uncertainty and show a nearly perfect retrofire and reentry.

Several years ago, a prediction such as that shown in table 8-III would have appeared very optimistic for the performance of the manned space-flight network. In considering performances as a whole, the network can be said to have performed considerably better than originally anticipated. The network tracking and computing system has successfully predicted the spacecraft landing points, and at all times has provided accurate information on the astronaut's position. For all of the Mercury missions, the network and computing system performed their basic functions normally and without exception.

Table 8-II.—Average Change in Position and Velocity

Mission	Change in position, yd	Change in velocity, ft/sec
MA-6	265	0. 9
MA-7	266	1. 1
MA-8	217	1. 0
MA-9	[a]220	[a]1. 6
	[b]1, 040	[b]4. 5

[a] First three passes
[b] Mission average—no data on 15 of 22 passes

Telemetry

Because the telemetry system has been described in reference 2, this section briefly describes only the design approach, modifications, and performance. To help orient the reader, a typical antenna installation at a telemetry station is presented in figure 8-8, and display and control consoles aboard a telemetry ship are presented in figure 8-9.

Table 8-III.—Results of Landing-Point Predictions Made by Computers

Mission	Predicted landing point	Reported pickup point of spacecraft
MA-6	21°31.2′	21°25.6′ N.
	68°52.9′	68°36.5′ W.
MA-7	19°24′ N.	19°30′
	63°52′ W.	64°15′.
MA-8	32°06′ N.	32°05.5′ N.
	174°31.8′ W.	174°28.5′ W.
MA-9	27°22′ N.	27°22.6′ N.
	176°29′ W.	176°35.3′ W.

Figure 8-8.—Antenna installations for the Telemetry and Control (T and C) Building Area, Guaymas, Mexico.

Figure 8-9.—Display and control consoles aboard the Rose Knot.

Design approach.—Obviously, the ground-station design requirements were established to be compatible with the spacecraft's telemetry characteristics. The basic type of telemetry system chosen early in Project Mercury was PAM/FM/FM. This system was chosen because it could provide the needed information and was a reasonably well proven state-of-the-art type which could be implemented on the ground stations with commercially available hardware. Implementation guidelines used are as follows:

(1) Two independent links were to be used to gain reliability. The equipment at each station was to provide independent receiving systems for the two links from the spacecraft. Separate preamplifiers, receivers, diversity combiners, filters, subcarrier discriminators, and the associated monitor and control equipment were to be provided. Separate monitoring of the data from the subcarrier discriminators of each system with commutated data not decoded was to be provided to permit the operator to select the telemetry system output to be displayed at a main control console.

(2) At the stations which were to have command transmitters, separate decoding and display equipment was to be provided for the two telemetry links. (This arrangement was necessary to provide reliability in determining that the proper commands were received at the spacecraft.) At all other sites, only one set of decommutation and output data display equipment was to be provided, with appropriate switching to the output of either receiving system.

(3) Provisions were to be made for separate magnetic tape recordings of the received outputs from each telemetry system to permit playback and reassessment of the data following a pass. These recordings also were to provide a permanent record of the data with an overall accuracy of 1 percent.

(4) Data-output display equipment was to be provided with the appropriate meters, lamp indicators, and direct writing records.

(5) Continuous data on IRIG channels 5, 6, and 7 were to be recorded and displayed on direct writing strip chart recorders with an accuracy of 2 percent of full scale. Each of these channels was also to be provided with a suitable events-per-unit time display. (This provision was needed by aeromedical personnel to monitor the astronaut's heart action and respiration.)

(6) Individual data outputs of the analog quantities handled on the commutated subcarrier (PAM) were to be displayed on meters with an accuracy of 2 percent of full scale. Display of the events data carried on the commutated subcarriers was to be in the form of lights. Appropriate translation equipment was to be provided to display the time measurements as in-line decimal digits in hours, minutes, and seconds.

(7) Monitor displays were to be provided to permit the operator to assess the outputs of both receiving systems at a station and to select the system to drive the final data output displays.

(8) A permanent recording system capable of rapid processing and display was to be provided to record all subcarrier discriminator outputs, all decommutated analog quantities, and received signal strength.

(9) The overall system-accuracy requirement was that system error not exceed 2 percent under field conditions.

System performance.—The telemetry and display system performance was outstanding throughout the project. During controlled flight, coverage time was generally horizon to horizon. Missions which had periods of drifting flight caused occasional signal dropouts due to nulls in the spacecraft antenna pattern. During reentry phases, both telemetry links were attenuated by the ionized sheath created by intense heat and ablation of the heat shield and reception was completely lost for periods of 3 to 5 minutes.

System accuracy (to the displays) of 2 percent, as originally implemented, was met satisfactorily. Summary data from remote sites which included the degradation factors of 2-percent meters, meter parallax, short mission meter scales (e.g., utilizing 50 percent of full-meter scale deflection), and reading error were generally within ±3 percent of full-scale meter deflection.

Air-Ground Communications

A system was required at each site to permit direct communications with the astronaut. This system, termed the air-ground system, would comprise all of the ground-based transmitting, receiving, control, and antenna equipment required to establish two-way voice communications with the Mercury spacecraft. General requirements included communications reliability, ease of rapidly restoring system operation in case of failure, and the use of proven off-the-shelf equipment to reduce both delivery time and costs. The following paragraphs describe the specific requirements for this system, the system modifications, and a summary of system performance.

Requirements.—To provide a highly reliable system of communications which would be able to overcome difficulties arising from spacecraft equipment failure, atmospheric disturbances, and ground-equipment breakdown, the following specific requirements were established:

(1) Complete voice transmission and reception facilities for both HF and UHF operation were to be provided, with the HF equipment to serve as a backup facility for the UHF.

(2) Standby UHF transmitters were required for backup purposes at all stations.

(3) Standby HF transmitters were required for backup use at certain critical stations.

(4) Remote and local transmitter control was required for all transmitters.

(5) The means for operating these transmitters on tone modulation as well as voice was required.

(6) At those sites equipped with command transmitters, a voice-modulation capability for the command transmitters was required as an emergency mode of operation.

(7) A means was required for individual operation of the UHF, HF, and emergency-voice modes, as well as simultaneous use of the UHF and HF or the UHF, HF, and emergency-voices modes.

(8) At sites where transmitting equipment was to be installed in vans, provisions for moving the van from the transmitting antenna to a receiving antenna were required in case of transmitting antenna or pedestal failure.

(9) To offset space-fading effects and also to provide built-in equipment backup facilities, dual space and polarization-diversity equipment was required for UHF reception, and dual-space diversity equipment was required for HF reception. This stipulation, then, required that two complete and identical sets of antennas, transmission lines, and receiver elements for both the HF and UHF equipment be furnished at each site.

(10) Circular polarization of UHF transmitting and receiving antennas was required to offset signal attenuation caused by any skew attitude of the spacecraft antenna with relation to the ground antennas.

(11) Recording facilities were required for all transmitted and received audio.

(12) Varied distribution of all received audio and transmitter sidetones was required through monitor speakers and the station intercom system in order to satisfy the site operating requirements.

Performance.—UHF was used for primary voice communication throughout the project with very satisfactory results.

Because of wave propagation, HF communication proved too intermittent to be used as more than backup communication and could not be considered as a reliable means of extending communication beyond station horizon. The HF quality improved somewhat, however, after a dipole antenna was installed on the MA–8 and MA–9 spacecraft.

A photograph of the air-ground antenna and transmitter van installed at Guaymas, Mexico, is shown in figure 8–10.

Command

Requirements.—The criteria for the command equipment followed the general guide lines for all Mercury equipment. The basic requirement was the transmission of commands from certain stations to the spacecraft in order to provide a command backup for the manually controlled or internally programed events in the spacecraft. The range coverage of the command system was to be limited only by line-of-sight conditions to the spacecraft. The minimum normal range of the systems was originally set at 700 nautical miles.

This equipment was to employ a suitable coding technique to provide high reliability with particular attention to prevention of incorrect commands because of noise, interference, or transmitting equipment failures. All command sites would have dual FRW–2, 500-watt transmitters. The command antenna was to have at least 18-db gain, circular polarization, and to be steerable.

Modifications.—Bermuda, having coverage of the critical insertion phase, required the ability to "brute force" command signals to the spacecraft regardless of the spacecraft an-

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tenna position. A 10-kw RF power amplifier was to be provided for that purpose. Likewise, monitoring facilities that would provide failure sensing of this power amplifier were required. If failure occurred, antenna transfer to the operational 500-watt transmitter would be done automatically. Three existing sites already had this high power and failure switching capability.

FIGURE 8-10.—Transmitter van and antenna installation at Guaymas, Mexico, for command and air-ground voice.

It was necessary to remove the standard coder controller of the FRW-2 and substitute coder control units designed to be compatible with the coding technique employed in the spacecraft equipment and the input requirements of the FRW-2 coder KY-171/URW coder which was part of the FRW-2. Furthermore, the coder controllers were to be capable of remote activation and rapid changeover to any one of several codes which might be desired.

During the implementation phase of the program, ancillary equipment consisting of control and monitoring facilities was designed and fabricated. This equipment was necessary to provide the desired fail-safe features and degrees of flexibility this program required. Furthermore, at sites equipped with command vans, provisions were made to allow the transmitter van to be moved to the receiver antenna pedestal in case the command antenna pedestal failed.

Mission requirements made major command equipment additions necessary. The need for additional command coverage became apparent when the program was expanded beyond three-orbital-pass missions. Consequently, dual 10-kw command facilities were installed on the Rose Knot Victor telemetry ship. The basic equipment furnished was identical to that furnished previously to the land-based stations. Temporary dual 500-watt command facilities were also added to the Coastal Sentry Quebec Ship. Here again, the basic equipment furnished was identical to existing land equipment.

Another major change in the command configuration was the MCC-Bermuda tone remoting system which became practical only after submarine cable circuits were available between Bermuda and Cape Canaveral.

Performance.—As with the other systems, the command equipment functioned as planned throughout the project.

Ground Communications

Introduction.—Operation of this system was discussed in reference 2; therefore, it is only briefly reviewed in the present paper. Again the basic design criteria were used: reliability, cost, and speed of implementation.

Requirements.—A primary requirement for the tracking network was that the stations be tied together with an adequate and reliable communications center. This center was to act as the heart of a communications system which would perform the following functions:

(1) Transmit acquisition information from the computing center to the tracking and telemetry stations.

(2) Transmit commands and instructions from the MCC to the stations.

(3) Transmit digital tracking data from the tracking stations to the computing center.

(4) Transmit telemetry summary messages from the stations to the MCC.

(5) Provide high-speed data transmission between the computing center and the MCC for display purposes.

(6) Provide voice communications capability between certain stations and the MCC.

(7) Transmit mission teletype traffic throughout the network.

Both teletype and voice circuits were required. The teletype circuits usually operated at 60 words per minute and provided for transmission of all of the required types of information except high-speed tracking data and, of course, voice communications. These two were handled by voice-quality circuits with a pass band of 280 to 2,800 cps.

The network that was established to meet these requirements is illustrated in reference 2.

Because these channels traverse extremely long distances and employ a variety of transmission media, such as land lines of various types, submarine cables, and HF radio, it was necessary that the design arrangement and operating technique preserve their transmission capability. The chief factors involved were overall attenuation, bandwidth, distortion, noise, return loss, and echo.

Modifications and Performance.—Following are some of the major changes made after the initial configuration was established:

(1) The HF link to Bermuda was dropped after the cable became available, and two high-speed data circuits from Bermuda to Goddard were added.

(2) The network was expanded to include the switching, conferencing, and monitoring (SCAMA) voice capability to Canary Island, Kano, Zanzibar, Canton Island, the Rose Knot Victor, and the Coastal Sentry Quebec.

(3) Zanzibar became a primary HF link for the Coastal Sentry Quebec.

(4) HF backup to Guaymas was added.

The Mercury communications network included 102,000 miles of teletype lines, 60,000 miles of telephone lines, and 15,000 miles of high-speed data lines.

The ground communication system operated very satisfactorily for all missions. Performance figures for the MA–7 and MA–8 missions are listed in table 8–IV.

Table 8–IV.—Messages Handled During MA–7 and MA–8

	MA–7	MA–8
Total number of messages	1, 814	5, 587
Information flow time, min	Messages	Messages
0 to 5	1, 597	4, 335
5 to 10	169	878
Over 10	24	334
Undetermined	24	40
Message transmission time, min		
0 to 1	526	1, 073
1 to 2	625	2, 087
2 to 3	410	1, 151
3 to 4	128	569
4 to 5	40	134
Over 5	75	515
Undetermined	10	58
Garbled messages	2	2
Lost messages	0	0

Timing

A timing system was required to provide timing signals for all recorders in a common format, binary-coded time signals for radar data, strobe pulses for radar interrogation, and outputs for driving wall clocks and displays. The system was to have the capability of synchronizing with WWV timing with a resolution accuracy to within 0.001 second. The stability of the timing system was to be such that the local timing oscillator drift would not exceed 0.001 second in 48 hours.

The timing system which had been developed for the scientific satellite tracking stations was selected since it had proved to be reliable and accurate under actual field operating conditions.

The timing system performed satisfactorily throughout the Mercury Project, and only minor modifications were necessary to correct component failures and increase reliability.

Intercom

It was apparent at the outset that rapid and flexible voice communications (intercom) would be needed within each station. Station personnel who would need such communications were (1) the flight controllers, who would monitor the flight status of the spacecraft and the overall conduct of the mission and who would advise and assist the astronaut in making decisions as required, and (2) the maintenance and operations personnel, who would provide technical support to the flight controllers in the operation of the various tracking, telemetry, and communications systems.

The intercom system had to have the capability of interconnecting several different consoles or positions in a conference type circuit (loop) whereby several people would be able to carry on a discussion, with others being able to "listen in" or be called on for comments or information. Also, because of the varied activities of different positions, there had to be several of these conference loops so that simultaneous conversations could be carried on with each loop usually isolated to one system or activity. The system also had to connect to outside lines so that the flight director could have immediate contact with any of the flight controllers at any station through the worldwide communications network.

After implementation by using standard components, only a few minor modifications to the intercom system were necessary to obtain proper, reliable operation. The system met the project requirements in a first-rate manner.

Control Centers

Mercury Control Center.—The primary function of MCC was to provide a means of centralizing control and coordination of all the activities associated with a Mercury mission. Figure 8–11 is a view of the operation room of MCC. Mission control and coordination were conducted from MCC beginning at approximately 10 to 12 days before lift-off and continuing through the launch, orbital, reentry, and recovery phases. Communication, display, and control capability for MCC operation was provided in the various consoles, which are shown in figure 8–12. Many of the positions contained duplicate displays and controls to provide redundancy which was considered essential to the Mercury Project.

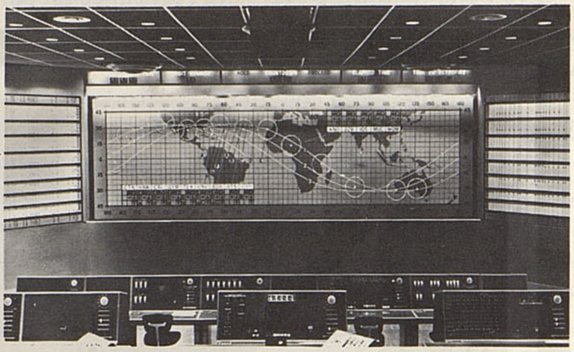

FIGURE 8–11.—Mercury Control Center as viewed from the observation room.

Bermuda Control Center.—In the earlier phases of the project, this secondary control center was required because the critical orbital insertion point of the spacecraft would be at a marginal distance and low-elevation angle from MCC, which might give unreliable data and would allow little time for MCC to determine go—no-go conditions. In addition, since Bermuda's vital tracking data needed for establishing insertion parameters had to be relayed by HF, a more fail-proof arrangement was needed. The Bermuda Control Center had the following basic functions:

(1) To command an abort in the event of critical spacecraft equipment failure or pilot difficulty late in the launch phase.

(2) To command an abort as directed by MCC in the event of certain propulsion or guidance system malfunctions.

(3) To control the mission independently in the event of communications failure with MCC.

Figures 8–13 and 8–14 show a view of the center and an equipment layout.

After the submarine cable to Bermuda was available, it was possible to remote the control data safely to MCC. The Bermuda station functioned as a remote station for the MA–9 mission with a minimum of flight-control staff.

Simulation Equipment

The development of a simulation system was established primarily to answer the need for an active training device for mission flight controllers. A secondary use for the simulation

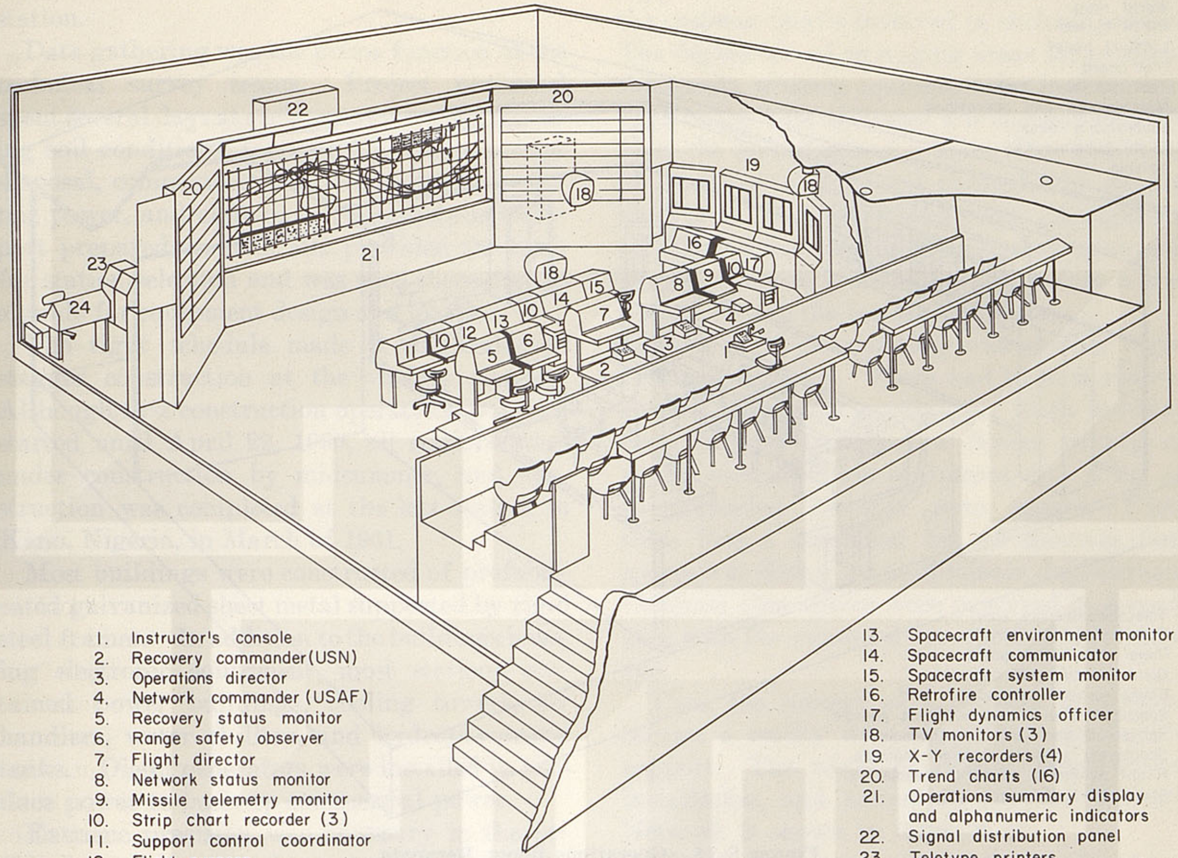

FIGURE 8-12.—Operations Room and Observation Room, Mercury Control Center.

FIGURE 8-13.—View of Bermuda Control Center.

system was the familiarization of the maintenance and operating personnel with the mission support required of them for a particular flight.

The simulation system was designed in two parts: the first and major part was the addition of specialized instrumentation and control consoles at MCC that could be used by instructors to provide the stimulus necessary to activate the MCC operational consoles; the second part was a separate remote-site simulator for the purpose of training flight controllers who would be ultimately assigned to stations other than the control center.

Equipment Documentation

Within a general requirement to furnish adequate instruction manuals for the network equipment, detailed specifications for individual manuals were prepared and the overall organization of this family of documentation was developed. The detailed specification called for new manuals to be prepared in accordance with the best commercial practices and established minimum content requirements for the acceptance of existing, off-the-shelf manuals. The most notable feature of the overall organization of the manuals was the concept of system manuals and equipment manuals. Equipment manuals covered individual units and subsystems, such as communications receivers, audio line amplifiers, and radar sets; and system manuals

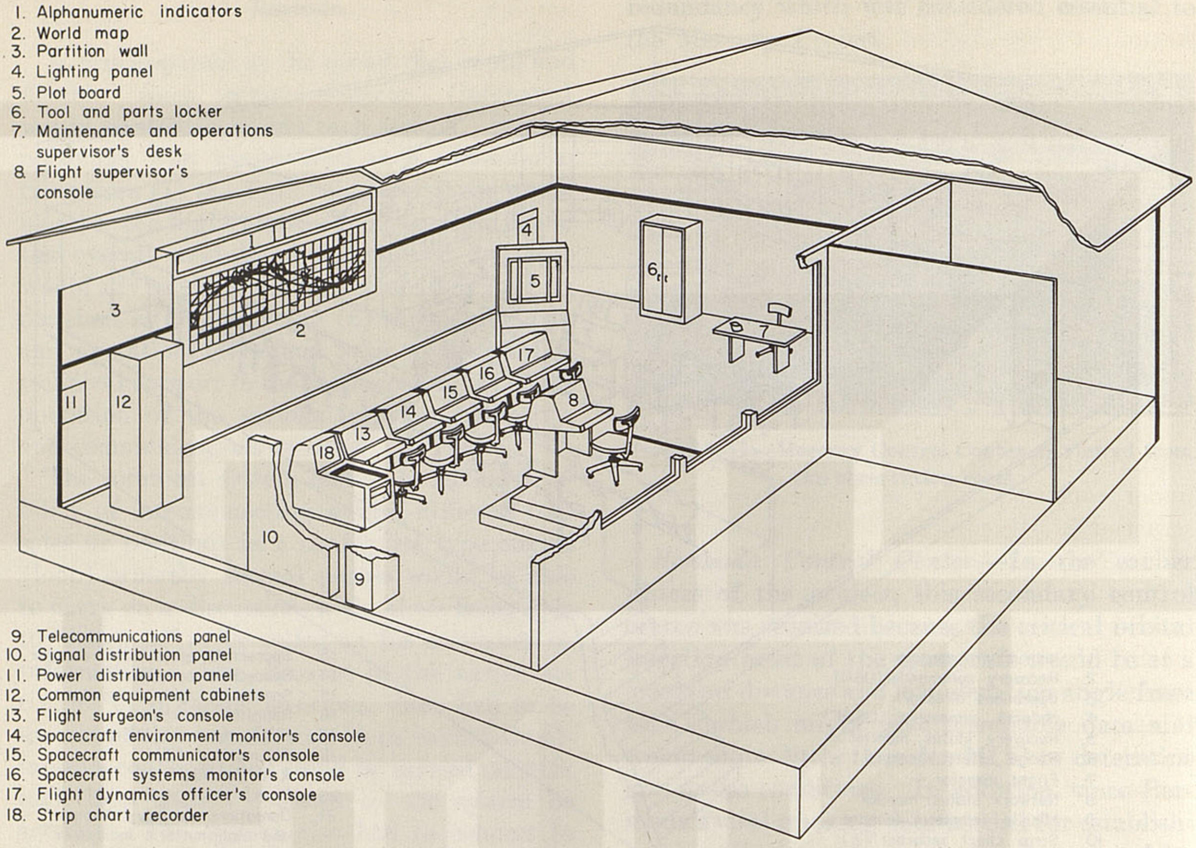

FIGURE 8–14.—Operations Room, Bermuda.

provided information on how the individual units and subsystems tied together to form the major network system. Altogether, approximately 450 separate manuals with copies totaling nearly 50,000 were supplied for use on the network.

Installation

The installation of ground instrumentation equipment actually began with the efforts of the teams who selected the sites for the remote stations. The general area for each station had been determined from the planned orbit charts, but selected areas required on-site inspection for the evaluation of local problems and land availability. Each station had to be considered from cost, adaptability, and accessability standpoints. Every attempt was made to use existing facilities, but where these were not available below the orbital paths, sites were chosen which presented the fewest problems while satisfying the necessary criteria.

The Project Mercury tracking stations required considerable land area to provide necessary isolation (separation) between transmitting and receiving antennas. The equipment covered a very wide range of frequencies and required specific terrain configurations to operate at maximum efficiency. It was determined that five of the stations and the control center could be located on national ranges where use could be made of existing facilities. One new station was to be located in Texas and two on shipboard. The remaining eight would have to be established on foreign or overseas territory.

Selection of the foreign locations was accomplished by two teams. The first, a management team which had representation from the U.S. Department of State, was to determine and resolve, if possible, all difficulties of a general nature such as political considerations, preference of local officials as to station location, and currency problems. In addition, contact was made with local contractors, material suppliers, and service companies. Labor sources were also investigated and data on living conditions were obtained. The management team selected a preferred and an alternate location for each station.

Data gathering was the prime function of the technical survey teams. Project personnel spent several days at each prospective site checking soil conditions, topography, water, sewage disposal, communications, transportation, electric power, and climate. A comprehensive report prepared on each site provided the basis for station selection and was used thereafter as a guide for equipment design and location.

The tight schedule made it impossible to stagger construction at the various stations. Although first construction operations were not started until April 29, 1960, all stations were under construction by midsummer, and construction was completed at the last station in Kano, Nigeria, in March of 1961.

Most buildings were constructed of prefabricated galvanized sheet metal supported by rigid steel frames. In addition to the buildings housing electronic equipment, most stations contained power buildings, cooling towers, air handlers, water chillers, and hydropneumatic tanks. Diesel generators were installed to produce power to back up commercial power.

Extreme precision was necessary in the positioning of every radar antenna. Each unit had to be surveyed to determine true latitude and longtitude with exact interrelation, and angles were established with a maximum allowable deviation of 6 seconds.

As construction of facilities was still underway at some stations, the equipment and the installation teams were arriving. The number of installers on a site team varied between 5 and 25, depending on the amount of equipment to be installed. A typical team consisted of the site manager, the team crew chief, a lead man for a subsystem or a combination of subsystems, several technicians, and one or two subcontractor advisors for specialized areas such as the acquisition system. Each team was also supported by a logistics man.

All installation team leaders were authorized to work with the local labor unions and utilize the local labor market to perform certain jobs beyond the capabilities of the installation team and its facilities.

Two depots—one on each coast of the United States—were established to provide logistics support for the overseas stations and to handle the customs details involved in such shipments. The depots served as staging areas for overseas shipments, whereas equipment destined for stations in the United States was shipped directly from the manufacturer. More than 1,000 tons of cargo were processed through the depots, most of it in preassembled units. A rigid receiving and inspecting system was set up at each station to check in all equipment before it was turned over to the installation team.

Spare parts provisioning was another logistics consideration. There had to be a reasonable on-site repair capability. Each industry team member supplied a 2-year supply of spares unique to his equipment and a list of recommended common item spares. From these lists a combined list of common item spares was drawn up to eliminate duplications. Common item spares were procured in accordance with the combined list and shipped to each site.

Thus, the concept of a network of stations became a reality with equipment and logistic support. The scope of design, construction, installation, and activation for the Mercury Network is shown in figure 8–15.

Figure 8–16 shows construction underway at Kano.

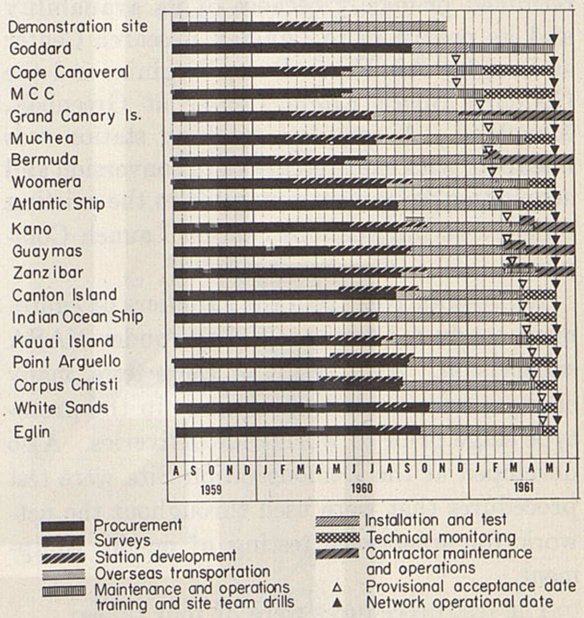

Figure 8–15.—Overall Mercury Network schedule.

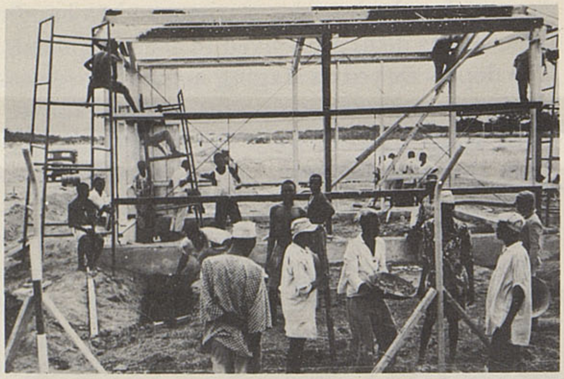

FIGURE 8–16.—Construction of the receiver building Kano, Nigeria.

Testing

Demonstration site.—The necessity of testing and evaluating the ground instrumentation equipment as a complete system prior to its installation on a worldwide basis was recognized in the early planning stages of the Mercury Project. Equipment from more than 10 major manufacturers plus numerous subcontractors was involved, and it had to be determined that all interrelated problems had been solved and that the equipment would perform as a system.

The selection of NASA Wallops Station, Wallops Island, Virginia, as a test site was determined primarily because of its availability and its proximity to Langley Research Center at Langley Air Force Base, Virginia, and the Goddard Space Flight Center at Greenbelt, Maryland. A complete tracking station was installed, with the Mercury data conversion and acquisition equipment connected to the existing FPS–16 at the Wallops Station Launch Complex.

Representatives from the suppliers of equipment conducted tests at Wallops under NASA supervision. As a result of these tests, many changes were made to equipment in the prototype stage prior to worldwide deliveries. Also developed at the Demonstration Site were test procedures that were used throughout the network for acceptance testing of on-site equipment.

The test procedures were of four types:

(1) Mercury Unit Tests (MUT) were developed to provide acceptance of self-contained equipment such as the R–390 HF voice receiver or the Ampex FR–100B tape recorder. The unit tests covered every measurable aspect that could influence the reliability of minimum performance expected of the unit.

(2) Mercury System Tests (MST) were developed to provide acceptance of a complete system. These tests checked the action of each interfaced relay as well as system performance.

(3) Mercury Integrated Tests (MIT) were developed to provide acceptance of the station as an integrated complex. These tests assured successful interface of systems. They also revealed RF interference problems.

(4) Mercury Dynamic Tests (MDT) were developed to test the equipment under simulated operating conditions. As ground station equipment was installed and evaluated at the Demonstration Site, the need for a method of closely simulating spacecraft tracking soon became apparent. Small leased aircraft were used to check the tracking accuracy of the new acquisition aid, and it was found that certain modifications were necessary for the equipment to meet specifications.

Instrumented aircraft.—As a result of these and other special aircraft tests, it was decided that aircraft would be obtained and completely instrumented with actual spacecraft electronics (see fig. 8–17) to serve three functions:

(1) To qualify each ground system prior to worldwide equipment delivery so that compatibility between ground and airborne systems was assured.

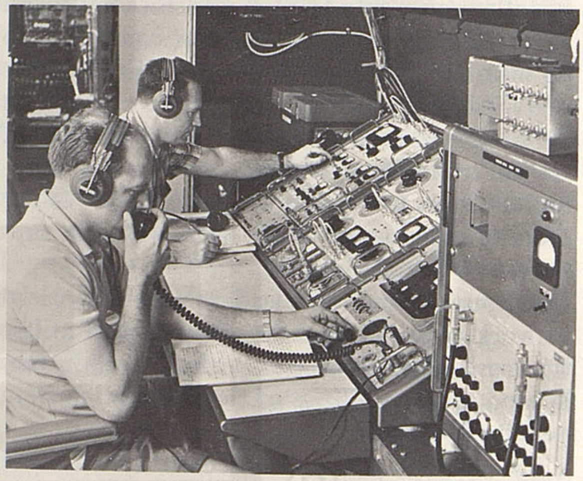

FIGURE 8–17.—Interior view of aircraft showing a small portion of the test equipment.

(2) To provide a complete checkout of each station in the network so that operational readiness was determined.

(3) To provide continual testing and training throughout the Mercury Project.

Training

Prior to station assignment, selected senior engineers received specialized equipment training and later helped to install the equipment at the Demonstration Site. After assignment, these senior engineers were responsible for making their equipment operational and for indoctrinating the other team members. Training was largely accomplished by working with the equipment during installation and by playing an active role in conducting acceptance tests. As time allowed, semiformal classes were held in theory and maintenance.

Formal training.—Installation technicians were technically capable of performing maintenance, but operational requirements posed the need for a refinement of the team concept and a regimented reaction to the demands of mission accomplishment. Transition from installer and maintenance technician to operator was accomplished by a rigorous training program that included: formal indoctrination lectures on space-flight matters and on Project Mercury; on-the-job training combined with classroom drills covering operation of the equipment; local-station simulated missions; and network simulations using countdowns, live communications, and telemetry tapes.

The maintenance and operation capability of station personnel had to be continually upgraded, and replacement personnel had to be provided. Likewise, the station had to be exercised as an entity to assure that it could work as a cohesive unit during a mission.

Training center.—To upgrade individual capabilities and to provide replacement personnel, a training center was established at the Demonstration Site. The primary long-term objective of the Engineering and Training Center was to sustain or improve the level of competence of the personnel manning the Mercury network stations through a comprehensive training program in each of the equipment subsystems making up the station. It was also designed to give the necessary high-level training to replacement personnel so that network proficiency would not suffer from personnel attrition.

To supplement the training received at the center, cross-training packages of lesson guides, equipment exercises, and examinations were developed for use at all the Mercury network stations. These were used for training of personnel in secondary areas of responsibility to enhance the overall capability of each team at the stations.

Network Configuration

Arrangement for MA–6

Up to this point, network requirements and systems development and implementation have been discussed. The types of systems available at each site are listed in table 8–V. To illustrate how a Mercury station was arranged, a line drawing of the Hawaii station layout is shown in figure 8–18.

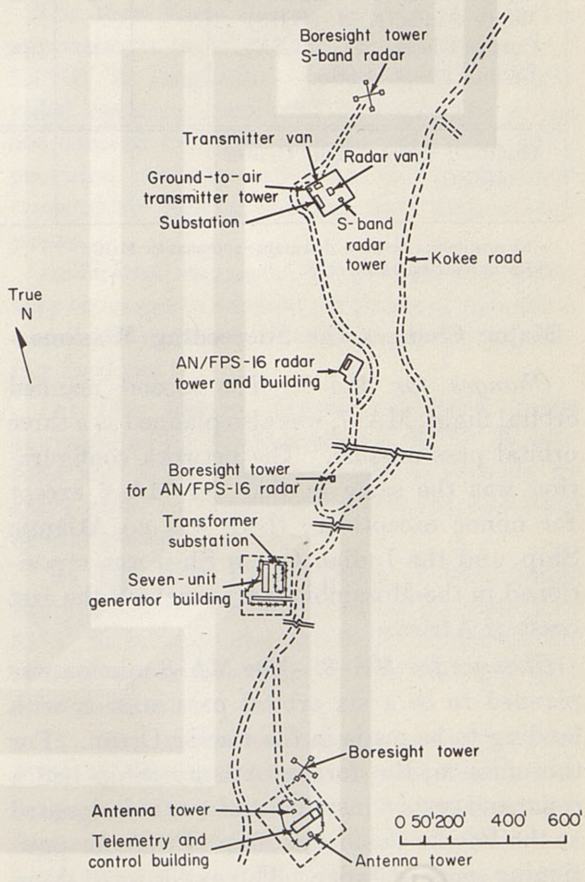

FIGURE 8–18.—Hawaii station layout.

Table 8-V.—Station Equipment

Station	Command control	Telemetry reception	Air-ground voice	FPS-16 radar	Verlort radar	Acquisition aid	Computer	Ground communications		Timing
								Voice	Telemetry	
Cape Canaveral (CNV-MCC)	x	x	x	x		x	B/GE IP7090	x	x	x
Grand Bahama Island (GBI)[a]	x	x	x	x				x	x	x
Grand Turk Island (GTI)[a]	x	x	x					x	x	x
Bermuda (BDA)	x	x	x	x	x	x	IBM-709	x	x	x
Atlantic Ship (ATS)		x	x			x		x	x	x
Grand Canary Island (CYI)		x	x		x	x		x	x	x
Kano, Nigeria (KNO)		x	x			x			x	x
Zanzibar (ZZB)		x	x			x			x	x
Indian Ocean Ship (IOS)		x	x			x			x	x
Muchea, Australia (MUC)	x	x	x		x	x		x	x	x
Woomera, Australia (WOM)		x	x	x		x		x	x	x
Canton Island (CTN)		x	x			x			x	x
Kauai Island, Hawaii (HAW)	x	x	x	x	x	x		x	x	x
Point Arguello, Calif. (CAL)	x	x	x	x	x	x		x	x	x
Guaymas, Mexico (GYM)	x	x	x		x	x		x	x	x
White Sands, N.M. (WHS)[b]				x		x		x	x	x
Corpus Christi, Tex. (TEX)		x	x		x	x		x	x	x
Eglin, Florida (EGL)[b]				x	MPQ-31	x		x	x	x
Goddard Space Flight Center (GSFC)							IBM-7090	Communications Center		

[a] No monitoring facilities; downrange antennas for MCC.
[b] Radar tracking station only.

Major Changes for Succeeding Missions

Changes for MA-7.—The second manned orbital flight, MA-7, was also planned as a three orbital pass mission. The network configuration was the same as that for MA-6 except for minor exceptions; there was no Atlantic Ship, and the Indian Ocean Ship was repositioned in the Mozambique Channel, off the east coast of Africa.

Changes for MA-8.—The MA-8 mission was planned to be a six orbital pass mission with landing to be made in the Pacific Ocean. For this mission, the former Atlantic Ship had a command system installed and was redesignated as the Pacific Command Ship (PCS) for positioning south of Japan. Three additional ships, the Huntsville, the Watertown, and the American Mariner, were made a part of the network and positioned near Midway to get reentry data.

Changes for MA-9.—Since it was decided to extend the length of the MA-9 mission to 22 orbital passes, it was necessary to modify the network so that adequate support could be provided. The following describes the changes that were required:

Equipment:

(1) All command sites were provided with additional command capabilities to give the site flight controllers the capability to turn on the spacecraft's telemetry transmitter, radar beacons, and an astronaut alarm. Other command changes included the addition of a complete system aboard the Coastal Sentry Quebec (CSQ) and an increase of the Rose Knot Victor (RKV) command power from 600 watts to

10 kilowatts. Figure 8–19 shows the two ships in the port of Baltimore for modifications.

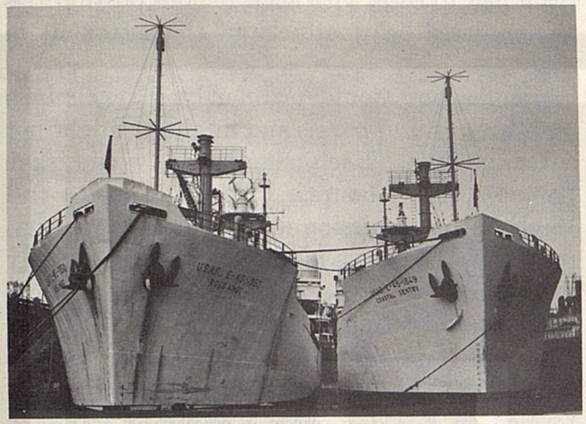

FIGURE 8–19.—Rose Knot Victor and Coastal Sentry Quebec in Port Baltimore for MA–9 modifications.

(2) Mercury tracking site clocks showing "spacecraft elapsed time" and "time to retrofire" were modified to extend their reading time.

(3) Additional equipment was installed at California and Bermuda, allowing biomedical data to be sent (over land lines) to MCC display consoles.

(4) A telemetry automatic processing system that used a small general purpose computer (AN/UYK–1) was installed at Bermuda. The system was designed to accept PAM/FM/FM frames of 88 parameters every 800 milliseconds in real-time and generate special and regular summary messages. The output data were in a format which represented selected parameters in engineering units. A running tolerance check of all parameters was included and selected data were stored for postpass analysis.

(5) Receivers were installed at MCC, Canary Island, and the CSQ for reception of the slow-scan TV picture from the spacecraft. The installation at MCC and on the CSQ included record and display capabilities, whereas the installation at CYI was for record only.

(6) An additional IBM computer was added to the computer complex at GSFC, and the two 7090's already in operation were converted to 7094's.

Communications:

(1) The radio links to BDA were discontinued since the submarine cable was now operational.

(2) Communications to the CSQ at the new location were handled through a radio link which could operate through either Honolulu or Bassendean and thence by the usual path.

(3) Communications to the RKV were handled by RF links to Honolulu and New York.

(4) A new circuit was added to relay the Range Tracker data through Honolulu.

(5) The mission message format was changed to improve circuit operation and to facilitate accumulation of more data.

(6) New equipment arrangements were instituted at Goddard to permit CADFISS and operational programs to be conducted simultaneously.

Relocation of ships: The Coastal Sentry Quebec was relocated to the approximate position of 28°30′ N. latitude and 130°00′ E. longitude. The primary purpose of this location was to provide adequate retrosequence command backup during the 6th, 7th, 21st, and 22nd orbital passes.

The Rose Knot Victor was relocated to the approximate position of 25°00′ S. latitude and 120°00′ W. longitude. In this position, it provided optimum command coverage for passes not covered by other network sites. The RKV provided coverage with its 10-kw command transmitter during the 8th and 13th orbital passes.

Additional support: To provide the necessary coverage to support a mission of this duration it was necessary to add the following tracking facilities:

(1) The Range Tracker (C-band radar equipped ship) was stationed at 31°30′ N. latitude and 173°00′ E. longitude to provide reentry radar coverage for the 4th, 7th, and 22nd orbital passes.

(2) The Twin Falls Victory (C-band radar equipped ship) was stationed in the vicinity of 31°3′ N. latitude and 75°00′ W. longitude for reentry radar coverage for the 2nd and 17th orbital passes.

(3) The Ascension Island station provided FPS–16 radar tracking during the fourth orbital pass. Also provided were telemetry recording, air-ground relay, and ECG remoting.

(4) The East Island, Puerto Rico, station provided FPS–16 radar tracking.

(5) The Antigua Island station provided telemetry recording, air-ground relay, and ECG relay.

(6) Air-ground voice facilities were provided at Wake Island, Kwajalein Island, and San Nicholas Island. The Wake and Kwajalein sites provided an extension for the Hawaii air-ground facilities. California had additional coverage provided by the San Nicholas installation.

Network Operations

Time at the tracking station is generally divided into mission periods and nonmission periods. The mission period for Mercury comprised some 10 days prior to launch and the actual flight time. The nonmission period was the time between missions used for personnel training, equipment modification, testing, and checkout. The operations activities during the mission period are explained in the following paragraphs, with the MA–9 mission used as an example.

Precountdown

The MA–9 precountdown period for all network stations was scheduled as follows:

- F–7 day—Orbital mission simulation and reentry simulation
- F–6 day—Orbital mission simulation and reentry simulation
- F–5 day—Two reentry simulations
- F–4 day—Detailed system tests
- F–3 day—Equipment maintenance
- F–2 day—Orbital mission simulation
- F–1 day—Patching check and equipment maintenance

These various activities are described in the following paragraphs.

Simulations.—To the station, the simulations were full-dress rehearsals for the missions. With the entire network participating and all onstation systems in operation, authentic dry runs were conducted, complete with builtin emergency situations which had to be detected, analyzed, and acted upon in "real time" by the flight controllers and station personnel. Authenticity was gained by the use of taped inputs to the telemetry displays and events recorders and by the use of a communicator reading from a prepared script over the intercom loop that would ordinarily carry the real astronaut's voice. In addition to anticipated problems of spacecraft equipment malfunctions, the ground team had to cope with such remote possibilities as simulated heart attacks of the astronaut in flight.

Simulations would ordinarily cover launch and three orbital passes and might or might not cover reentry. Each simulation would take from 4½ to 6½ hours. Prior to MA–8, a full 18-orbital-pass mission was simulated in anticipation of MA–9 as a means of pointing out any major problem areas in personnel scheduling, sleeping, and eating plans.

Detailed system tests.—The detailed system tests (DST), mentioned earlier as being performed on F–4 day, were a group of standard procedures used to check and measure thoroughly the operational performance of each of the station subsystems. Since the same test was used for corresponding systems at all stations, and since results of previously run DST's were recorded, the current status of any subsystem could be easily evaluated by the DST performed just prior to the mission.

The DST procedures consisted of two parts: the instructions and the data sheets. Meter readings, voltage and current measurements, standing-wave ratios, and various other parameters were recorded on the data sheets which were returned to Goddard for analysis immediately after the mission. On the station, the cumulative results of the DST's were used in the determination of the station status, which was a factor in the decision to proceed with or delay the launch.

Maintenance day.—F–3 day and F–1 day were left open for last-minute maintenance details, particularly in correcting any equipment deficiencies detected during the DST's. Final briefings were also held to correct any procedural problems pointed up by the previous simulations.

Network Countdown

The network countdown began 5 hours and 50 minutes prior to the scheduled launch. This time was devoted to computer and data flow checks, teletype checks, voice checks, and brief system tests. The Network Countdown document specifically scheduled each of these activities, and designated the stations and equipment positions to which a particular operation was applicable. The brief system test was a shortened version of the DST and was designed to lend assurance that equipment performance had not significantly deteriorated since the DST was run 4 days previously. Whereas the DST may have taken 12 or more hours, most DST's could be performed in less than 2 hours.

The Network Countdown also contained the "plus-count," a scheduling of pertinent activities to be performed before acquisition of the spacecraft and during the pass.

Flight Activities

After launch of the spacecraft, a time period of from about 5 minutes (at Bermuda) to 90 minutes (at Eglin) would elapse before the spacecraft passed over the station. The actual pass, the time from which the spacecraft appeared above the horizon until it was lost below the horizon, averaged about 7 minutes. Average time between passes was about 85 minutes. This time was devoted to equipment calibrations—setting up known levels and annotating the recorders so that later analysis would have known standards—and preparation for the next pass.

Prepass calibrations were begun 45 minutes before the start of the next pass. Twenty-five minutes prior to the pass the first acquisition message would be received. This was a teletype message sent from the control center advising the station of the time and coordinates at which it could expect to acquire the spacecraft. These figures were derived by the computers at Goddard based on the real-time radar data from the last station passed over by the spacecraft. The information permitted the acquisition and and radar operators to train their antennas to the spot where the spacecraft would first be "sighted." A second acquisition message was received 5 minutes prior to the spacecraft passage to communicate any inflight deviations during the intervening 20 minutes.

Acquisition would ordinarily take place within a few seconds of horizon time. Because of the wide beamwidth of the antenna used by the active acquisition aid, this system ordinarily was the first to acquire the target. At radar sites, the S-band and C-band radars would nonetheless search independently. At contact, all antennas were immediately slaved to the system which acquired first.

As the radar locked on target, it would then be set to track automatically, and, at operator discretion, it could be made the controlling system for the other antennas. At dual radar sites, data from the C-band radar—the most accurate of the two systems—was fed to the teletype for transmission to the computers at Goddard. If this radar lost track, data from the S-band radar were put on the line.

As soon as possible after the last pass over the station, the postlaunch instrumentation message was teletyped to the control center. It contained a tabulation of the times of acquisition and loss of signal for the various systems, the modes of operation, and a summary status report.

It was obvious that the length of the MA–9 mission would preclude the manning of all station equipments from launch to termination. The flight path was such, however, that all stations had periods when the spacecraft would not pass over them for three or more orbital passes.

Documentation guides.—Three documents provided the major guideline for station personnel activities during the pass. The Network Operations Directive 61–1, was produced jointly by MSC, GSFC, and DOD and it set forth the general operating procedures for all systems so that a standard action would be used in a given circumstance at any station in the network.

The second document, the Data Acquisition Plan, gave detailed instructions for recorder setups, pen assignments, patching arrangements, and plotboard assignments, and gave information for disposition of data records after the mission. A new Data Acquisition Plan was published prior to each launch. It was prepared by MSC with inputs from GSFC.

The third document was the Communications Operations Plan, prepared by GSFC. This was a detailed account of how the communications network was to function.

Performance

The Mercury network, throughout all orbital flights of the Mercury spacecraft, has clearly demonstrated its capability to keep track of a manned spacecraft and remain in communication with the astronaut. These capabilities are the direct result of the many months of planning, instrumentation installation and checkout, training, and the highly efficient performance of the equipment and personnel at all network sites during the actual missions.

There were six orbital flights of the Mercury spacecraft, one unmanned (MA–4), one with a chimpanzee aboard (MA–5), and four manned (MA–6 through MA–9). The network performance continually improved during these missions as more and more experience was gained. This progress was typified by the peak performance demonstrated during the last Mercury mission, MA–9. It lasted for nearly 22 orbital passes (fig. 8–20) with the spacecraft landing in the planned landing area near Midway Island in the Pacific Ocean. There were some minor equipment failures associated with the Mercury network, but they did not materially affect mission support or detract from the excellent performance demonstrated by the network throughout the flight.

A summary of network performance for the MA–9 mission is presented in the following paragraphs.

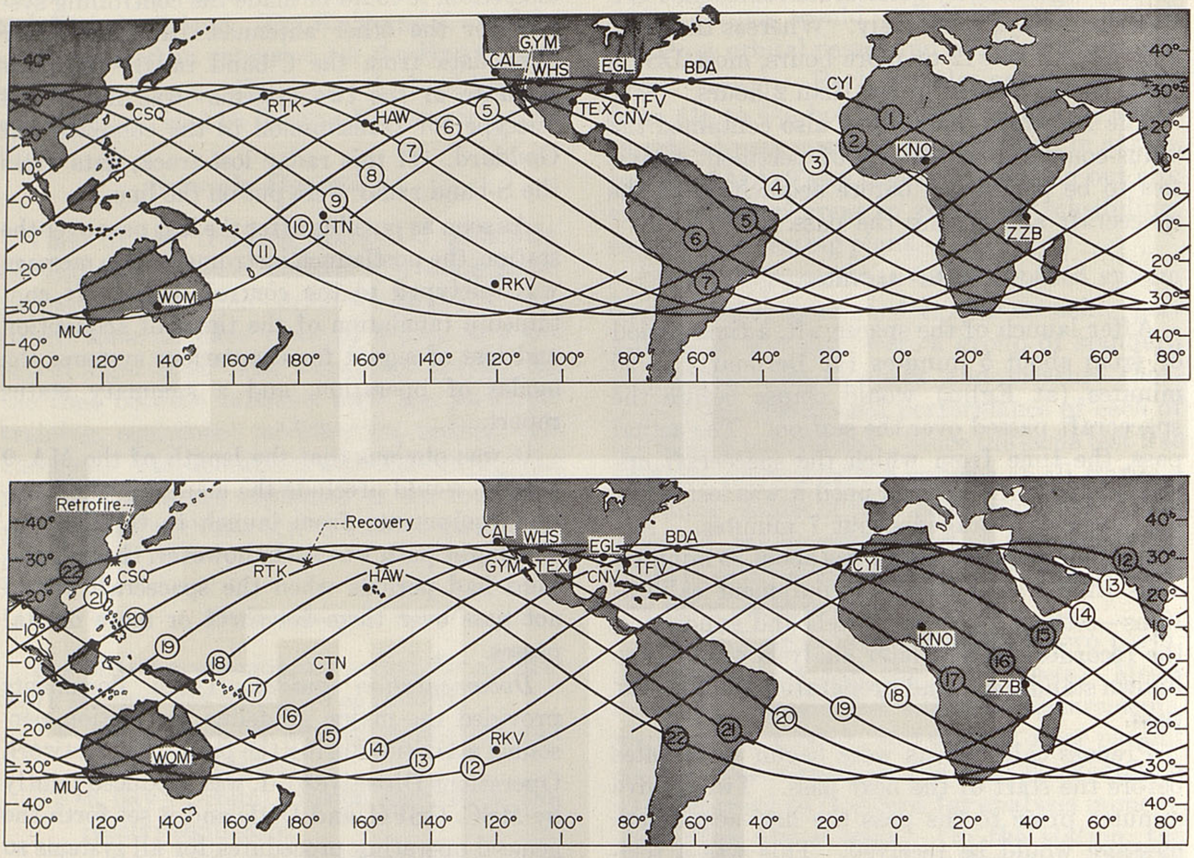

FIGURE 8–20.—MA–9 orbital charts.

Radar Tracking

During the countdown on May 14, 1963, the radar at Bermuda failed to pass the CADFISS slew tests. Digital data were intermittently of poor quality in both the azimuth and range channels. Efforts to locate the trouble were ineffective, and the quality of the data gradually decreased. At T–15 minutes, the range data error exceeded the tolerable limits, and at T–13 minutes the mission was postponed for 24 hours. Subsequent investigation revealed a faulty preamplifier in the azimuth digital-data channel and a faulty shift register in the range digital-data channel. The simultaneous failure of both components complicated the failure analysis.

On launch day there were no radar problems, and the C- and S-band beacon checks prior to launch indicated no beacon problems. The network C-band radars tracked approximately 10 percent of the total mission time, which is 80 percent of the total time that the C-band beacon was turned on. The network S-band radars tracked 1.7 percent of the total mission time, which is 36 percent of the total time that the S-band beacon was turned on. The amount of radar data furnished to the Goddard computers was of sufficient quality and quantity to update the trajectories, and it was determined that the orbital parameters did not decay an appreciable amount. Initial tracking reports indicated that the C-band beacon was not as good as it had been on previous missions because of the heavier than usual modulation on the beacon replies. The heavy modulation experienced by the MCC and Bermuda radars during launch seemed to lessen as the mission progressed.

In addition to the normal Mercury Network radar sites, the following sites were used for the MA–9 mission: Ascension Island, East Island, Puerto Rico, and the radar ships Twin Falls Victory and Range Tracker.

Acquisition Aid

In general, the performance of the acquisition-aid systems at all stations was satisfactory and comparable to that of previous missions. Low-angle elevation tracking, below approximately 15°, was accomplished manually because of multipath conditions at most stations. The only major acquisition-aid problem experienced during the mission was on the Coastal Sentry Quebec, where failure of the elevation antenna drive system occurred prior to the 6th orbital pass. However, the antenna was positioned manually from the 6th through the 8th passes, and the malfunction in the drive system was corrected in time for acquisition in the 9th pass.

Computing

The MA–9 countdown began at midnight on May 14, 1963. The Goddard computer, equipment, interface, CADFISS, and trajectory confidence tests were all satisfactory. During the countdown, while using the "B" computer, some dropout was observed at the MCC. The high-speed output subchannel on the "B" computer communication channel was interchanged with the plotboard high-speed subchannel.

At the request of the Flight Dynamics Officer, the powered flight phase was supported with the "A" and "C" computers, then switched to the "A" and "B" computers during orbital flight. The "B" computer gave no indication of dropout during the rest of the mission. Lift-off occurred at 08:04:13 a.m. e.s.t.

The Atlantic Missile Range (AMR) I.P. 7094 and the General Electric-Burroughs guidance computers provided excellent data throughout the launch. A "go" decision was indicated by all three data sources.

In the orbital phase, during the periods when the spacecraft C- and S-band beacons were on, the tracking data received from the network sites were excellent. During the mission, spacecraft weight change data resulting from fuel and coolant-water usage were manually put into the computers.

The retrofire time recommended by the Goddard computers was 33:59:30 ground-elapsed time (g.e.t.), and retrofire was manually initiated at this time. After retrofire, the predicted landing point transmitted to the MCC from the Goddard computer was 27°22′ N. latitude and 176°29′ W. longitude. An attempt to refine this prediction with six frames of data acquired by the Range Tracker ship during blackout failed to yield a converged solution. The computed time of the blackout was from 34:08:16 to 34:22:30 g.e.t. The actual time of initial blackout was reported by the Range Tracker to be 34:08:17 g.e.t. The actual landing point was reported by the recovery ship to be 27°22.6′ N. latitude and 176°35.3′ W. longitude.

Although several minor computer problems were encountered and corrected throughout the flight, at no time during the mission did the computers fail to drive the digital displays and plotboards at the MCC. In addition, performance of the high-speed lines between Goddard and the MCC was excellent.

For the first time, CADFISS tests were conducted during the mission to determine the operational status of major equipment subsystems at network sites. These tests were considered necessary since mandatory equipment at many sites did not operate for prolonged periods of time when the spacecraft was out of range. All of these tests were successfully supported by the third Goddard computer while the other two

Goddard computers continued the operational support of the mission.

Two range ships, the Range Tracker and the Twin Falls Victory, were used to provide tracking data to the computers. The Range Tracker provided good tracking data during the 7th, 20th, and 21st orbital passes. During reentry the Range Tracker was poorly positioned with respect to the blackout zone and provided only six frames of data for this phase of reentry. An analysis of these data indicated a landing point which was about 3° or 180 nautical miles away from the correct landing point. Twin Falls Victory data readout was good on three passes.

Ground Telemetry System

The telemetry coverage for the mission was excellent. There were no major ground system failures, although some coverage was lost because of the manual switching procedure used onboard the spacecraft. In general, any deviation from nominal coverage can be attributed to spacecraft attitude or to the transmitters being turned off. The telemetry relay circuits from Antigua, California, Bermuda, and Ascension were satisfactory in all respects. During all passes over these stations when telemetry antennas were radiating, data were remoted to the MCC. During the third orbital pass, the telemetry was switched to the high-frequency link prior to the spacecraft's passing over Hawaii and remained on until it was over the California site, at which time telemetry was switched back to the low-frequency link. At all other times, the telemetry remained on low frequency. No telemetry system anomalies were noted during this period.

Air-to-Ground Voice Communications

The air-to-ground communications were of good quality. The UHF system was used as the primary communications system except for the scheduled HF checks. During periods of communication, UHF coverage varied only slightly from predicted acquisition and loss times because of the nominal orbital trajectory. As expected, air-to-ground communications could not be established during the communications blackout period. An Instrumentation Support Instruction was transmitted to the network outlining the use of the UHF squelch circuit as defined in the network documentation. A premission checkout and the mission results indicated that proper use of the squelch circuit eliminated background noise from open UHF receivers during periods of silence. This change also resulted in a reduction of noise level on the Goddard circuit during air-to-ground transmissions.

Relay aircraft in the Atlantic Ocean area reported good UHF reception from the spacecraft and good relay transmissions to MCC on the 2nd, 3rd, and 17th orbital passes. A relay attempt on the 16th pass was unsuccessful because of a severe thunderstorm in the vicinity of the relay aircraft. Communications from the MCC to the spacecraft through the relay aircraft were not attempted on the 2nd pass, and they were unsuccessful on the 3rd pass because the spacecraft had passed out of range. However, the relay communications were successful on the 7th pass. Ascension and Antigua Islands in the Atlantic were also available for relaying communications between the spacecraft and the MCC. Relay through Ascension was successfully accomplished for a period of approximately 6 minutes during the third orbital pass. The Antigua voice relay was not used during the mission.

In the Pacific Ocean area, communications were successfully relayed from Hawaii through Kwajalein and Wake Islands on passes 3 and 19, respectively. A voice-operated relay from the MCC through the Range Tracker was attempted on the 20th orbital pass. However, this attempt was unsuccessful because the transmission was made on the MCC-Hawaii remote air-ground position instead of the Goddard Conference Loop. This error apparently placed a 1700-cps tone on the circuit to the Range Tracker and resulted in keeping the automatic voice relay continuously closed; however, several transmissions from the astronaut were received in the MCC. Another attempt to use the relay on the 22nd pass was ineffective. As in the MA–8 mission, satisfactory communications were established in the primary landing area between the spacecraft and Hawaii by using relay aircraft.

Command System

The reader is referred to appendix F for a transcript of the MA–9 air-to-ground voice communications.

The command system for the MA–9 mission operated in a satisfactory manner, and the command control plan was followed very closely throughout the mission. Several malfunctions were noted at various sites, but command capability was never lost by any site during the time in which the spacecraft was passing over that site. The command carrier "on" indication from the Bermuda station to the MCC was delayed approximately 32 seconds on the first pass; however, it had no net effect on the mission since the onboard command receiver signal strength remained above the receiver threshold setting.

A total of 19 functions were transmitted from the command stations. All of these functions were received onboard the spacecraft with the exception of one telemetry "on" function from Muchea and the clock change from the Coastal Sentry Quebec. The telemetry "on" command from Muchea was not received because it was transmitted when the spacecraft was out of range of the 600-watt ground transmitter. The clock change from the Coastal Sentry Quebec was not received because the command tone was also sent before the spacecraft was within range of the ground transmitter.

The following ground-system malfunctions were experienced:

(1) The Rose Knot Victor had an intermittent problem in the beam power supply of the backup power amplifier. It was detected before lift-off and the equipment remained inoperative throughout the mission. The prime transmitter was used to support the mission.

(2) Guaymas had a failure in the filament transformer of the standby transmitter at 29:40:47 g.e.t. which damaged the power amplifier tube. The filament transformer and the power amplifier tube were both replaced and the equipment was operational by 32:05:47 g.e.t. The prime transmitter remained operational during this time.

(3) The Bermuda high-power transmitter came on with a 3.6-kw output but did not come up to full power. The station automatically switched to low power, 600 watts, at 00:06:31 g.e.t.

Ground Communications

All regular, part-time, and alternate circuits of the network participated in the MA–9 mission. Critical coverage was continuously established on these circuits during preflight countdown until the end of the mission for Adelaide, Muchea, Honolulu, New York, Mercury Control Center, and GSFC. For other sites, critical coverage was dependent upon standby status (critical coverage being allowed to lapse when the station was on a standby basis.

Upon review of the SCAMA log for the mission, it is apparent that this phase of communications was quite reliable. The few instances of poor readability were mainly a result of the station operation techniques and excessive background noise inside and outside the station.

Communications during the mission were nearly perfect. Every communication patch performed properly when needed. As anticipated, outages occurred on a few occasions when a station did not have the spacecraft "in view" or during otherwise unimportant communications periods.

Average total message delays during MA–9 approximated 2 minutes, compared with 3 minutes and 15 seconds for MA–8. This difference can be accounted for by the heavier traffic concentration of MA–8.

The MA–9 mission occurred during a period of high solar activity. Unlike MA–8, however, there were no geomagnetic disturbances and the propagation conditions were favorable.

Timing

The timing system performed satisfactorily at all stations except California. On passes 3, 4, 5, 16, 17, and 18, the serial decimal timing was in error in tens-of-seconds readout. The problem was corrected after pass 18 by replacing all tubes in the timing counter units and adjusting the phanastron in the time-comparison unit. During pass 20, the timing system was again defective since it indicated 21 hours rather than 20 hours.

707–056 O—63——11

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9. OPERATIONAL SUPPORT FROM THE DEPARTMENT OF DEFENSE

By Major General Leighton I. Davis, *U.S. Air Force, Department of Defense Representative for Mercury Support Operations*

Summary

The Mercury–Atlas 9 mission marked the successful conclusion of the nation's first manned space flight program to which extensive operational support had been provided by the Department of Defense. This support covers many assets uniquely available within the broad scope of this nation's military structure and includes such areas as early wind-tunnel studies, astronaut training facilities, parachute development, launch vehicles and launch operations, aeromedical assistance crews, network facilities, recovery forces, and public information.

Early in the program a need was recognized for a more precise planning and control of the many areas of DOD support to the National Aeronautics and Space Administration. A Department of Defense Representative for Mercury Support Operations was designated by the Secretary of Defense and was the sole point-of-contact within the DOD for coordinating all NASA requirements with DOD resources. A coordinating organization, the Mercury Support Planning Office, was established to administer the plans, policies, and directives of the DOD Representative.

Both the Redstone and Atlas launch vehicles developed by the DOD for other programs were modified and together with launch operations provided support for the Mercury flight program. Military facilities and persons associated with tracking and telemetry stations within the DOD complex were made available to complete the Mercury Worldwide Network. By far the largest DOD support effort in terms of people, was the level of recovery forces deployed for the various Mercury missions. This manpower level was approximately 14,000 people for the manned orbital missions. For those missions where an occupant was included in the spacecraft, DOD medical teams were deployed to provide assistance to NASA medical specialists. The global DOD communications complex was activated for use during Mercury missions to lend support in a variety of areas where high-speed information flow was required. This communications complex, in addition to facilities of the Mercury Worldwide Network, was especially valuable in coordinating the deployment and operation of the recovery forces for an orbital mission. The DOD also supported the NASA in disseminating and controlling Mercury mission information for public consumption through its public information organization.

Providing support to Mercury flights has contributed greatly to the Department of Defense's knowledge and experience in areas of launch, network, recovery, communications, and medical space operations. Future space-flight operations can be effectively supported by applying the experience and procedures derived during Project Mercury.

Introduction

Throughout the Mercury Project, the Department of Defense (DOD) provided valuable and timely support in critical operational phases of the project. As the project progressed and the scope of its activities increased, a need for a centralized coordinating agency within the DOD was recognized. The person in charge of this agency was designated the DOD Representative who had the sole responsibility of coordinating the resources of the various military organizations to satisfy the project requirements of the National Aeronautics and Space Administration. In this regard the DOD Representative was the primary point-of-contact for the NASA Operations Director in conjunction with specific requests for Mercury support.

Prior to the designation of a DOD Representative for Mercury support operations, operational support for the project was handled on an official but somewhat informal basis. The intent of this paper is to describe the operational support that was provided after the designation in 1959 of a DOD Representative for Mercury support operations. This designation also provided NASA with a single point-of-contact for the submission of their DOD support needs.

Early in the Mercury Project wind tunnel facilities such as the Arnold Engineering and Development Center, Tullahoma, and the crew training devices such as the Centrifuge at Johnsville, Pa., were also made available; however, these support areas will not be discussed. The support areas which are discussed comprise launch vehicles and operations, worldwide tracking, recovery, communications, aeromedical, and public information. These areas are discussed separately as they pertain to Mercury-Redstone and Mercury-Atlas mission activities and are followed by a summary of DOD support provided for each specific mission. Although the DOD provided launch, range, and recovery support for the first Atlas launch, named Big Joe, and for the Little Joe spacecraft development flights, these are not presented. The Big Joe flight was conducted to provide early aerodynamic and thermodynamic data by reentering a boilerplate spacecraft. A greater emphasis is placed on describing the gradual build up of operational support from the relatively simple ballistic flights, requiring assistance primarily in the area designated the Atlantic Missile Range, to the worldwide orbital missions requiring DOD medical, network, and recovery forces stationed around the globe.

This paper is intended only as a summary of the concepts and techniques employed in the various support areas relating to the Department of Defense. The Aeromedical Activities, Network Development and Performance, Recovery, Redstone Development and Performance, and Atlas Development and Performance papers should be consulted for greater detail in the operational aspects of these subjects.

Planning and Organization

The National Aeronautics and Space Administration had sole responsibility for conducting the Mercury project. The NASA Operations Director was designated as the single point-of-contact with the Department of Defense. The talents, resources, and facilities of the Department of Defense were used to assist NASA in attaining the overall objectives of the project. The Secretary of Defense approved DOD support of Project Mercury in areas of launch, network, recovery and bioastronautics.

The Commander, Atlantic Missile Range Test Center (AFMTC), was designated as the Department of Defense Representative for Project Mercury support operations by the Secretary of Defense and was made responsible to coordinate the efforts of the many DOD elements involved and to provide a single point-of-contact for NASA for the Mercury Project. The DOD Representative was authorized such staff as he might need to accomplish his duties and was required to make maximum use of existing DOD organizations and procedures. Broad plans of DOD support for Project Mercury were developed by the DOD Representative and published in an Overall Plan on January 15, 1960.

The Mercury Support Planning Office, consisting of representatives from the major participants in DOD support of Project Mercury, was created to administer the plans and policies of the DOD Representative. This office coordinated NASA's support requirements for Mercury with the DOD elements to insure that needed support in the form of talent, facilities, organization and other resources, was timely and sufficient to the extent compatible with DOD's primary defense mission. The Mercury Support Planning Office was the final coordinating staff office for the DOD Representative in all matters relating to DOD support of Project Mercury operations.

Department of Defense support was originally divided into two stages: preoperational and operational. The operational stage included launch through recovery phases and the preoperational stage included all other times during which DOD supported Project Mercury. During each of these stages, control of DOD support differed, and a separate functional organization was required. In the preoperational stage, the DOD Representative had responsibility for coordinating the action of DOD forces in Project Mercury activities. In the operational stage, full decision-making responsibility was exercised by the NASA Operations Director. In either stage, additional guidance was provided by direct contact between the DOD Representative and the NASA.

These planning, coordination and control procedures, set up in the early days of Project Mercury, remained basically unchanged until the end of the seventh Mercury-Atlas mission (MA–7). After MA–7, it was decided to amend the charter of the DOD Representative to insure a tighter control of the diverse DOD elements during mission operations, because of the expanding scope of the program, the need for a change in operational procedures and realinement of recovery communications. As a result, the duties and responsibilities of the DOD Representative were revised in June 1962. Significant changes were incorporated into the revised terms of reference for the DOD Representative which established two phases of operational support: the coordinating phase and the operational control phase which, at times, ran concurrently. The coordinating phase was that time during which plans were developed and resources arranged to support future operations. This phase was continuous and included training and simulation exercises preparatory to flight operations. The operational control phase included the launch through recovery aspects of the mission and began at 24 hours before the scheduled launch at which time the DOD Representative assumed operational control of the DOD forces, assets, and facilities used for support of Mercury operations. This phase terminated at the time the spacecraft and its occupant were recovered and turned over to NASA officials.

To provide for the centralization of overall operational control of the global recovery forces, the DOD Representative established the DOD Mercury Recovery Control Center at Cape Canaveral. Another method used by the DOD Representative for exercising operational control of the support forces was the publication of operations orders and directives prior to each mission. These orders proved to be an effective means for conducting these missions and contained a more detailed description of the procedures by which operational control would be exercised by the DOD Representative. Based on these orders, the supporting commanders prepared their individual directives for the control of their assigned forces.

Documentation

Several methods were used by the DOD Representative to evaluate DOD performance during the Mercury Project. Monthly status reports were submitted by the DOD Representative to the Secretary of Defense and Annual Reports summarized calendar year operations. Postmission reviews and preoperational conferences were held by the DOD Representative and attended by representatives from NASA, the National Ranges and DOD support forces.

Prior to each mission, the DOD Representative received readiness reports from the support forces and kept NASA informed as to the DOD's ability to support the mission. DOD forces were kept apprised of countdown status, lift-off time, flight progress, and landing information during an operation.

To consolidate and standardize the administrative and operational procedures for the DOD National Ranges, Operations Plan 60–1 was published in 1960. The procedures proved so effective for the early Mercury flights that a joint DOD/NASA document, Network Operations Directive 61–1, was published with a detailed description of the manner in which the DOD, NASA and the Australian Weapons Research Establishment (WRE) facilities would operate as an integrated global network in support of Project Mercury. The documentation flow which transferred information between NASA and DOD started with the NASA Program Requirements Document which requested specific items of support from the ranges. The ranges, in turn, replied with a Program Support Plan which specified how they would meet NASA's requirements.

Launch Support

Launch operations for Project Mercury were conducted at the Cape Canaveral Missile Test Annex of the Atlantic Missile Range. The Redstone vehicles were launched by NASA Marshall Space Flight Center assisted by members of the Army Ballistic Missile Agency. Other DOD participation in the Redstone launches was limited to standard launch complex and instrumentation support normally provided to missile programs by the AMR.

The DOD role in Atlas launches was extended to include the Atlas D launch vehicle, guidance system, and launch complex, and was provided by the Space Systems Division (SSD) of the Air Force Systems Command (AFSC). The 6555th Aerospace Test Wing of SSD located at Patrick AFB was given the responsibility for final installation, prelaunch checkouts, and actual launch of the Atlas launch vehicle to insert the Mercury spacecraft into a proper orbit.

Network Support

The mission of the Mercury Worldwide Network was to enable flight control people to monitor, by electronic means, the status and performance of the spacecraft, its systems, and its occupant and to communicate with the pilot. To accomplish this mission, NASA, with the assistance of the DOD, implemented a global tracking and telemetry network. This network required the use of certain existing DOD stations as well as the construction of additional facilities. As originally planned, the network consisted of 14 land-based stations, two DOD tracking ships, and a communications center.

A listing of the network stations is as follows:

Station number	*Station name*	*Operating agency*
1	Cape Canaveral	AMR
	Grand Bahama	AMR
	Grand Turk	AMR
2	Bermuda	NASA
3	Rose Knot	AMR
4	Canary Island	AMR
5	Kano	NASA
6	Zanzibar	NASA
7	Coastal Sentry	AMR
8	Muchea	WRE
9	Woomera	WRE
10	(Deleted)	
11	Canton Island	PMR
12	Hawaii	PMR
13	Pt. Arguello	PMR
14	Guaymas	NASA
15	White Sands	WSMR
16	Corpus Christi	WSMR
17	Eglin	APGC

The network was later modified on a mission-to-mission basis by other DOD facilities, including additional stations of the Atlantic Missile Range and two radar tracking ships. The DOD Communications Center was replaced by the NASA Communications and Computing Center at the Goddard Space Flight Center (GSFC) and some Mercury stations became identified by names more descriptive of their actual location.

During Mercury missions, the entire network was under operational control of the DOD Representative's network commander, assisted by the network status monitor, who advised the NASA Operations Director on the status of the network to perform its mission. Upon termination of the mission, operational control of the stations reverted to the respective range commanders or the NASA, as appropriate. After the network had been established, NASA provided the technical planning, augmentation, and modification of the network to complement the DOD operational control.

Instrumentation for the initial Mercury flights involved only the facilities of the AMR. The entire network, except for the Coastal Sentry, was first called up for support of MA–3.

The first time a Mercury network instrumented ship was used in support of a Mercury mission was during MR–3. The Coastal Sentry ship was located in the landing area for telemetry and communications between the spacecraft and the ground.

For the second manned flight, MR–4, the AMR Rose Knot ship, was deployed in the landing area. It was during MA–4 that most of the network stations had their first opportunity to attempt radar track. In general, radar track from the stations was poor and the Bermuda, White Sands, and Woomera data were not usable at Goddard. A postflight review was held at AMR and was attended by representatives from all of the radar sites. It was learned from this review that the antenna patterns for both the C- and S-band beacons were not good because of deep nulls in the antenna patterns. A decision was made to install an antenna pattern-phase shifting device on the spacecraft for the next mission. This device introduced a phase delay of 400 cycles per second to shift the antenna pattern and effectively smear over the deep nulls.

The installation of the phase shifter on the C-band antenna system for MA–5 proved successful. During the MA–5 postmission review, indications were that the radar coverage was much improved. This improvement was the result of the use of the phase shifter, the intensive training received by the radar operators between missions, and by the use of a radar controller on the handover net.

During the MA–7 flight, several stations reported amplitude modulation by the phase shifter on the C-band beacon; however, reentry data were smoother than on previous missions. The two relay aircraft obtained SARAH beacon bearings on the spacecraft and confirmed its location prior to sighting.

Failure of the magnetron driver unit on the Canary Islands Verlort radar caused a 15-minute hold in the MA–8 countdown. Some communications problems were encountered during periods of poor propagation conditions and aircraft relay was unsuccessful because the distance between spacecraft and aircraft was too great.

The launch for the Mercury-Atlas 9 (MA–9) mission was the first mission rescheduled because of network difficulties. Bermuda's C-band radar had unacceptable range data errors because of a faulty shift register in the range digital data channel and a faulty preamplifier in the azimuth digital data channel.

The network for MA–9 was augmented by the addition of the Twin Falls Victory Ship (AMR), the USNS Range Tracker (PMR), Antigua Island, Ascension Island, East Island, Wake Island, and Kwajalein Island.

Relay aircraft were equipped with high gain antennas and the spacecraft-to-ground voice relay was successful. Voice relay was also accomplished through Ascension, Wake, and Kwajalein. Radar aircraft of the Air Defense Command, used as part of the network for the first time, obtained a good skin track of the spacecraft during reentry, including blackout, and were able to obtain some contact during orbit. For the first time, stations were allowed to go on standby status during the orbital phase, and computer and data flow tests were conducted to confirm their return to operational status.

Recovery Support

During Project Mercury the DOD contribution to planned and contingency recovery operations expanded considerably. Starting with a concentration of all recovery efforts about a single planned landing area, recovery support multiplied until the DOD was supporting 32 planned landing areas and 51 contingency landing areas for the final Mercury mission. For MR–1A, the first unmanned ballistic flight, the recovery support forces consisted of 8 ships and 15 aircraft all located within 1,500 nautical miles of Cape Canaveral. Recovery support for the final MA–9 mission consisted of 28 ships and 171 aircraft.

Mercury-Redstone Series

The Mercury-Redstone series of four flights which required recovery support took place during the period December 1960 to July 1961. These missions all involved ballistic trajectory flights, with the primary planned landing area located directly downrange northeast of Grand Bahama Island. Naval ships and aircraft formed the recovery task force and were assigned stations within the designated recovery areas. Aircraft units from the Air Rescue Service (ARS) and the Air Force Missile Test Center (AFMTC) assisted the surface recovery forces. Contingency recovery commanders were designated and units of their commands were pre-positioned along the ballistic track to insure readiness should a contingency recovery situation have occurred.

Mercury-Atlas Series

Mercury-Atlas missions MA–3 to MA–9 were all planned as orbital flights varying from one orbital pass to the extensive 1-day, 22-orbit mission which concluded the Mercury program.

With the advancement from ballistic to orbital flight, the support provided by elements of the DOD substantially increased. No longer was it sufficient to consider only a downrange flight path, but now it was necessary to view the entire earth-circling orbital paths as potential contingency recovery operation areas. Although the number of planned landing areas increased from 1 to 32, the greatest expansion of DOD recovery effort occurred in the area of contingency recovery operations. The support of contingency recovery landing areas was primarily borne by aircraft, and in many instances by the same aircraft used in support of planned landing areas. The number of aircraft directly participating in recovery operations for this series increased from 22 located along the AMR ballistic track to 171 located at 30 land-based sites and onboard two aircraft carriers.

The unmanned flight of MA–3 was the first planned one orbital pass mission, but failure in the launch vehicle resulted in its destruction by the Range Safety Officer. The spacecraft escape system worked perfectly and the spacecraft was retrieved by a launch-site recovery-force helicopter, 200 yards off shore. This was the only time during the program that the launch-site recovery forces had to put into practice the many hours of training for just such an emergency.

Because of extensive slippages in the original scheduled dates for the orbital missions, two separate and distinct recovery-force deployments were required. The DOD recovery forces in support of these missions adjusted and substituted units as necessary to meet normal military commitments during the periods between recovery deployments. Despite these reorganizations, all recovery elements and units were ready and effectively performed their recovery missions.

The MA–7 mission of Astronaut Lieutenant Commander Carpenter, USN, terminated after a three-orbital flight with a 250 nautical mile overshoot of the primary landing area. Recovery was effected, however, about 3 hours after landing. A postmission review of this flight revealed the need for a change in recovery communications and operational procedures. This review led to the establishment of a DOD Mercury Recovery Control Center (MRCC) jointly staffed by Commander Cruiser-Destroyer Flotilla Four (CTF-140) and his deputy, Commander Air Rescue Service, who performed the recovery mission for the DOD representative. Furthermore, recovery communications equipment and procedures were changed for future missions so as to provide a more tightly controlled recovery organization capable of quick response to changing situations.

The last two missions of the Mercury Project, MA–8 and MA–9, constituted a culmination of all the lessons learned in previous missions, and reflected the flexibility of the recovery forces when the primary planned landing area was relocated from the Atlantic to the Pacific Ocean. The final flight had the greatest number of recovery forces providing support and required the closest coordination of effort. The Pacific recovery force trained intensively in preparation for these missions, and the smoothness with which the two operations were conducted reflected their efforts and refined procedures. In both flights the manned spacecraft landed within 4½ miles of the primary recovery ship and was recovered and on board within 45 minutes in each case.

Recovery forces supporting MA–8 were deployed with 19 surface units in the Atlantic and 7 in the Pacific. A total of 134 aircraft provided the planned and contingency recovery support for this mission. For MA–9, surface support forces in the planned landing areas numbered 15 ships in the Atlantic and 11 in the Pacific. Air support was provided by aircraft from the Army, Navy, Air Force, Marine Corps, and the U.S. Coast Guard. Commander, Middle East Force, provided a contingency surface recovery force of two ships for the north Indian Ocean areas.

Aeromedical Support

To fulfill the objectives of Project Mercury, the NASA requested the Department of Defense to provide certain medical support. The purpose of this support was to assure thorough on-scene medical care and a prompt and complete assessment of the astronaut's postflight condition.

On December 1, 1959, the Department of Defense Representative for Project Mercury Support Operations designated the Staff Surgeon, AFMTC, as his Assistant for Bioastronautics. The principal function of the Assistant was to plan, organize, and deploy worldwide medical support for Mercury flight operations in response to NASA medical requirements.

The Department of Defense provided medical support in the categories of administration, people, training, facilities, and equipment. The extent of this support is discussed to show the magnitude of such support.

Administrative Support

Administrative support included selection and deployment of medical resources and facilities and the formulation of medical support plans. The scope of this support included the following:

(1) Development of medical plans and programs.

(2) Acquisition, siting, and making operationally ready, the required medical facilities.

(3) Requisition, preparation, and deployment of all needed medical equipment.

(4) The preparation of plans to provide blood for an injured astronaut and procedures in case of non-survival of an astronaut.

(5) Medical staffing of a Forward Medical Station, an Operational Support Unit, and launch site recovery forces.

(6) Deployment of people and equipment to fleet recovery units.

(7) Establishment of specialty teams and alerting of specific DOD hospitals.

In addition, administrative actions were taken to procure medical specialists from Australia and the Public Health Service to support each mission. Arrangements were made for immunizations, distribution of publications to recovery medical forces, and training programs.

Training

For the later manned missions, 84 medical officers were trained by the AFMTC in June 1960 and in April 1963, 23 DOD medical officers were trained specifically for MA–9 by NASA.

People

During the program 233 medically trained people were made available by the DOD in support of Project Mercury flight operations. These people served in the following areas:

(1) As aeromedical monitors. The monitors were assigned to Mercury network tracking stations. Their functions were to monitor, using telemetry displays, the physiological condition of the astronaut.

(2) At Cape Canaveral, to provide emergency surgical support in the event of a launch site incident or disaster.

(3) On recovery vessels, to provide immediate on-scene medical assistance in the event of a medical emergency during recovery operations.

(4) At advanced medical units in high probability landing areas at Grand Bahama Island and Grand Turk Island.

(5) In the Bioastronautic Holding Facility in Hangar "S", Cape Canaveral, to assist in preflight preparations.

(6) A dietitian and food service supervisor were provided in the astronauts' dining facility to prepare and serve prescribed diets to the flight astronaut and his backup.

Facilities

The following medical facilities were provided:

(1) Cape Canaveral: Two blockhouses were modified to provide a forward Medical Station, a Medical Command Post, a Medical Communications Center, an astronauts' diet kitchen and dining room, and a ready room for the Medical Specialty Team.

(2) Downrange: Two prefabricated surgical hospitals and medical debriefing units were erected at Grand Bahama Island and Grand Turk Island.

(3) The Wilford Hall USAF Hospital, Lackland AFB, Texas; the US Navy Hospital, Portsmouth, Virginia; the Walter Reed Army Hospital, Washington, D.C.; the Tripler General Hospital, Honolulu, Hawaii; were designated as specialty team hospitals. Seven other DOD hospitals were alerted in high probability landing areas, to support the astronaut if needed.

Senior medical officers from the three armed services established the medical equipment needs in support of Project Mercury. The medical supplies and equipment were provided to NASA on a loan basis and will be available for support of future manned space flights.

The DOD medical participation in Project Mercury has been mutually beneficial in that the NASA received support otherwise unavailable to them and the Department of Defense medical services gained extensive experience in medical support operations. These trained experienced people represent a core of technically competent specialists to support future manned space programs.

Communications

The termination of Project Mercury was also the termination of an extensive communications complex used by the Department of Defense forces in support of this NASA project. This complex started with the early Mercury ballistic missile communications limited to that of radar and telemetry data needed within the confines of the Atlantic Missile Range (AMR).

As the project progressed to the orbital flights, communications grew in complexity to a point which involved the resources of the national ranges, Defense Communications Agency, and the equipment and facilities available to the separate commands, commercial agencies, and foreign governments.

Programs were initiated to provide communications that were uniquely required by the Mercury mission. Some of the equipment resulting from these programs was adopted by NASA for incorporation into future facilities support.

As Mercury missions advanced from unmanned suborbital to manned orbital flights, it became necessary for the DOD representative's staff to have communications specialists immediately available to assist in the overall DOD communications support as well as to participate actively in the operational phase of the missions. Beginning with the MA–7 mission, the function of the Communications Coordinator was performed for the DOD Representative by the Chief, Range Support Communications Division, AFMTC, assisted by other communications specialists in the AFMTC organization. The value of this group was fully realized during the course of the MA–9 mission. For this mission the most complex communications system employed in the support of the national space effort was implemented. From 48 hours before lift-off through test termination, this group of communicators supervised and maintained constant surveillance of the worldwide communications systems insuring that the best possible support and performance was afforded this Mercury mission.

Network Support

Communications for the Mercury suborbital flights consisted basically of the following:

(1) Launch pad intercommunications systems with associated circuitry to other Cape Canaveral instrumentation areas, such as command control, telemetry, radar, and central control. These systems were interfaced with those provided by NASA within the Mercury Control Center for internal communications.

(2) Voice, teletype, data, and timing circuits to Grand Bahama and Grand Turk Island tracking sites through the use of the AMR submarine cable.

(3) Ultra-high frequency (UHF) and high frequency (HF) communications between the spacecraft and ground with equipment provided by NASA and operated by the AMR at Cape Canaveral, Grand Bahama, and Grand Turk.

Additional communications support for the first manned suborbital flight consisted of a basic teletype and voice plan to provide for the passing of traffic to a recovery force consisting of 10 surface vessels and 11 aircraft in the Atlantic area. Teletype circuits connected the Mercury Recovery Control Center (MRCC) at Cape Canaveral to the three service communications centers, Andrews AFB, Ft. Detrick, and Cheltenham, in the Washington complex; the AMR submarine cable connected the MRCC with the recovery forces in Puerto Rico; and simple high-frequency single sideband (HF/SSB) voice communications connected the MRCC to the recovery ships and aircraft.

As the missions progressed into orbital flights, the NASA tracking network could not meet the need for expanded global tracking and communications requirements. The DOD augmented the existing NASA network by providing coverage at such stations as Antigua, Ascension, Pretoria, Kwajalein, Wake Island, and San Nicholas Island. DOD also provided range ships and aircraft specially configured for spacecraft voice relay.

During MA–8 and MA–9 the DOD provided communications support for the xenon flashing-light experiment being conducted at Durban, South Africa, by routing communications through the AMR station at Pretoria, South Africa.

The DOD Interrange tie line connecting Pt. Arguello, White Sands Missile Range, Eglin Air Force Base, and Cape Canaveral was widely used during the Mercury mission for radar handover and for intersite coordination. The value of this circuit was realized by both NASA and DOD elements for radar control. Beginning with the MA–6 and subsequent missions, modifications were made to include the sites at Guaymas, Mexico, and Corpus Christi, Texas. The line was extended to the Hawaii tracking site for MA–8 and MA–9.

To overcome problems associated with spacecraft-to-ground communications especially during the reentry period, the DOD initiated a developmental program on the use of airborne platforms as automatic relay stations. Special C–130 aircraft were configured with equipment capable of the receipt and automatic retransmission of the modes of communications, HF/UHF, available from the spacecraft or ground stations. Included in the program were various patterns by which the aircraft would fly so as to provide the best coverage and relay conditions. During MA–8 and MA–9 this system was also incorporated aboard the telemetry aircraft operated by the PMR in the Pacific area.

Shortly after MA–8, the AMR developed a technique for the relay of telemetry data by way of single-sideband radio. This system was successfully demonstrated in November 1962 from AMR stations Antigua and Ascension Islands to Cape Canaveral involving distances of 1,200 to 4,400 miles, respectively.

The system was offered to the NASA for use during MA–9 as a means of relaying real-time aeromedical data. The NASA accepted this proposal and the system performed successfully.

Recovery Support

In addition to the basic teletype and voice plan for passing communications traffic to the recovery force deployed in the Atlantic, provisions were also made for the handling of classified traffic by the installation of a secure teletype circuit between Patrick AFB and Cape Canaveral. The AMR submarine cable was used to interconnect the MRCC at Cape Canaveral with the recovery forces in Puerto Rico. High-frequency single-sideband (HF/SSB) voice communications were used between the recovery ships and aircraft in the Atlantic and MRCC.

For the MA–9 mission communications were needed to support 28 surface vessels, 171 aircraft, and various Recovery Control Centers and contingency forces deployed around the world. To tie this vast complex into an effective communications network, the communications resources of the DOD, with its inherent capability to interconnect with other governmental and commercial systems, were available to the DOD Representative's communications staff for support of MA–9.

The hub of the DOD recovery communications effort was the Mercury Control Center at Cape Canaveral. As missions progressed from suborbital to full orbital flights, the center was modified from one of limited communications support to an extensive and complex system which supported the 22-orbital flight (MA–9). This Center was designed to provide for the receipt of status information from worldwide deployed forces and for the passing of directions to the task force commanders. Desks were replaced by operational-type consoles equipped with communications systems capable of providing direct communications between the deployed forces and individuals on the recovery staff. Visual display equipment was provided for the rapid dissemination of information, as needed, within the MRCC and intercommunications links were installed for coordination between DOD and NASA elements.

General Support

As originally planned, the Mercury network communications system did not provide voice communications to network stations having an HF link connecting them with the Goddard Space Flight Center. In order to maintain voice communications with AMR range vessels operating under their control, the AMR established a voice circuit to two range vessels by using the unused sideband of the NASA SSB teletype circuit. This method of operation, commonly in use though not applied to the Mercury network, proved exceptionally useful to the flight controllers during early missions. This method of operation was extended to other Mercury stations so that during MA–9 voice communications were available to all sites.

Prior to MA–9, teletype communications from the Mercury Recovery Control Center were routed to the three military services communications stations in the Washington area complex. The basic service, although satisfactory, created delays when it became necessary to provide alternate routing or to correct technical difficulties and was also cumbersome in effecting coordination during the course of the mission. For MA–9, a plan was created which routed all teletype communications for the recovery forces through one station, Army East Coast Relay

Station at Ft. Detrick, for further dissemination by automatic means to the final destination. This new system proved very effective during MA–9 by providing a single point of contact for coordination purposes, a reduction of circuitry between Cape Canaveral and Washington, D.C., and an ability to react quickly to alternate routine requirements.

The Area Frequency Coordinator at AFMTC was given the responsibility for providing procedures and controls necessary to insure that the 11 spacecraft frequencies were protected from harmful interference. Critical times were established as being from 6 hours before lift-off through mission termination. The frequency protection plan, as developed, was applicable throughout a belt extending some 700 miles north and south of the predicted orbital paths. To provide the control agencies with timely information on implementation and termination of frequency protection, some 87 addressees were contacted by use of Address Indicator Group teletype messages. In addition to these actions, it was necessary during the course of Project Mercury to coordinate the assignment and use of 171 HF frequencies. Throughout the Mercury program a total of 43 cases of electronic radiation interference was reported and satisfactorily resolved or alleviated.

Public Information

Department of Defense support of the NASA public information effort on Project Mercury began with logistic support of news media covering the early launches. A press site which offered a direct view of the Redstone launch complex was built near the Mercury Control Center for the flights of Astronaut Commander Shepard, USN, and Astronaut Major Grissom, USAF (MR–3 and MR–4, respectively). A new, improved press site was constructed near the Cape Canaveral landing strip, near the Atlas launch complex, for the orbital flights.

Logistic support of the news media covering the Mercury activities developed into a general pattern with the greatest amount of support required at Cape Canaveral. The number of accredited news media representatives covering the flights increased with each launch until more than 700 covered the MA–9 flight. Support included transportation, escorts, communications lines (525 pairs of telephone lines and six wideband video lines from the Cape press site), shelter, and public-address systems. AFMTC had a full-time representative at the NASA news media center; and for MA–8 and MA–9, a DOD information officer was on duty at the Pacific News Center in Honolulu.

For coverage of recovery operations, news media representatives were positioned with DOD forces in the primary landing areas and communications channels were furnished so that real-time reporting was possible. Excellent cooperation was received from all DOD agencies in the preparation of information material and in the support of news media people by DOD forces.

After MA–8 and MA–9, NASA Headquarters convened in a meeting of the press pool representatives from all news media to critique the information aspects of the flights. The reports of the media personnel indicated that the logistic support furnished by DOD was sufficient and timely.

Review of Mercury Missions

The Department of Defense support discussed here is limited to that provided for the Mercury-Redstone (MR) missions and nine Mercury-Atlas (MA) missions during the Mercury Project. DOD support in the early phases of the Mercury Project was primarily in the areas of launch and network. As the project developed and missions became more complex in scope and objectives, DOD support expanded into the additional areas of recovery, communications and bioastronautics. The scope of this support, in terms of people, aircraft, and ships for the manned orbital flights is shown in tables 9–I and 9–II. A brief summary of each mission with regard to DOD support follows.

The first Mercury-Atlas vehicle (MA–1) was launched on July 29, 1960. The spacecraft was unmanned and was intended to land northeast of Antigua Island in the West Indies. Standard AMR tracking and data acquisition equipment was available and the recovery support consisted of units from the Atlantic Fleet (CINCLANT), Air Rescue Service (ARS), and AMR forces deployed as a task force. A structural failure occurred approxmiately 1

Table 9–I.—DOD Support for Project Mercury Manned Orbital Missions

Organization	People Activity	MA–6	MA–7	MA–8	MA–9
Commander in chief, Atlantic Fleet	Recovery forces in Atlantic	15, 000	10, 000	9, 000	6, 750
Commander in chief, Pacific Fleet	Recovery forces in Pacific	0	0	5, 000	6, 700
Atlantic Missile Range	Range support, three tracking stations, safety, telemetry aircraft, radar ships.	1, 300	1, 250	1, 250	6, 700
Base Support Division/Space Systems Division.	Booster, guidance, pad (Canaveral/West Coast)	500	480	455	430
European Command	Contingency recovery forces in Africa	215	265	215	300
Pacific Missile Range	Three tracking stations, telemetry aircraft, radar ship	195	165	310	345
Air Rescue Service	Contingency recovery inland area and Atlantic	160	210	210	485
Bioastronautics	Support of medical operations, Air Force, Army, Navy	160	130	95	100
White Sands Missile Range	2 tracking stations	80	80	85	75
Air Proving Ground Center	Tracking station	40	60	60	105
Communications	Air Force, Navy, Army Communications Centers	100	100	100	150
Commander Middle East Force	Contingency recovery (2 ships)	0	0	0	345
Pacific Command	Contingency recovery	160	160	100	100
Military Air Transport Service	Recovery aircraft (12 C–130's) Wx Recon	0	0	0	400
Caribbean Air Command	Contingency recovery	0	0	0	150
Miscellaneous	Radar aircraft, Air Photographic and Charting Service, Adm Aircraft, RF silence.	90	100	120	45
Total		18, 000	13, 000	17, 000	18, 000

Table 9-II.—DOD Aircraft and Ship Support for Project Mercury

Aircraft	MA-6	MA-7	MA-8	MA-9
Atlantic Area	82	74	65	65
Pacific Area [a]	12	12	41	58
EUCOM	16	16	16	27
Inland U.S.	4	2	4	4
CAIRC	0	0	2	5
Mauritius	4	2	0	0
Photo Recon	3	3	2	4
Weather Recon	1	1	1	4
Admin A/C	4	4	3	4
Total	126	114	134	171
Recovery ships	24	20	26	28

[a] Includes 4 aircraft from RAAF.

minute after lift-off. After a 2½ hour search by the launch-site recovery group, without success, activity reverted to regular salvage operations by AMR forces augmented by two Navy minesweepers. Approximately 98 percent of the spacecraft and some parts of the launch vehicle were ultimately recovered.

On November 21, 1960, the first Mercury-Redstone mission with an unmanned spacecraft using the Redstone launch vehicle was unsuccessful because premature engine cut-off activated the emergency escape system when the launch vehicle was a few inches off the pad. The launch vehicle settled back on the pad and was damaged slightly. The spacecraft was recovered for reuse.

The unmanned Mercury-Redstone 1–A mission (MR–1A) on December 19, 1960, was a reattempt of MR–1, and was successful. The recovery phase started with visual sighting by ship and aircraft lookouts and search and rescue and homing (SARAH) detection by search aircraft prior to spacecraft landing. A helicopter hoisted the spacecraft clear of the water 15 minutes after landing and deposited it onboard ship 17 minutes later.

The spacecraft for the Mercury-Redstone mission 2 (MR–2) was launched on January 31, 1961, and carried a 37-pound chimpanzee 420 statute miles downrange. The spacecraft was tracked by the AMR almost to landing, although it had overshot by about 100 miles. Ultra-high frequency (UHF) transmissions were detected by several recovery aircraft during the flight. Recovery aircraft located the spacecraft, and a helicopter returned it to a dock landing ship. Medical support people and materiel were provided on ships, at Cape Canaveral and at Grand Bahama Island to assist in medical operations.

The second Mercury-Atlas mission (MA–2) on February 21, 1961, was successful and the landing was northeast of Antigua Island. A recovery helicopter retrieved the spacecraft 42 minutes after launch and delivered it to a dock landing ship from which it was delivered to Roosevelt Roads, Puerto Rico.

The unmanned Mercury-Atlas 3 (MA–3) mission on April 25, 1961, was planned as a one-pass orbital flight with landing east of Bermuda. All network stations except the Coastal Sentry ship were called up to support the mission. The Recovery task force was deployed to cover the designated landing area. A recovery team from U.S. Commander in Chief, Europe (USCINCEUR) provided a contingency capability to 0° longitude. A failure in the launch vehicle resulted in the Range Safety Officer's aborting the mission 40 seconds after launching. The spacecraft was retrieved 200 yards off shore by a recovery helicopter which was deployed for this purpose.

The first manned Mercury flight, Mercury-Redstone 3 (MR–3) took place on May 5, 1961. After a successful reentry, the spacecraft, with Astronaut Commander Alan B. Shepard, Jr., USN, aboard, was sighted prior to its landing in the planned landing area by deployed helicopters. One of the helicopters delivered the Astronaut and spacecraft safely to the recovery aircraft carrier 26 minutes after landing. All phases of DOD support, including range, recovery, and medical, were excellent. For this mission the AMR Coastal Sentry ship was located in the landing area for telemetry and spacecraft-to-ground communications. Medical support consisted of aeromedical monitors aboard the Coastal Sentry Ship, emergency medical teams aboard recovery vessels and at the launch site, and a medical debriefing team at Grand Bahama Island. Aircraft of the ARS were on station to assist in search operations.

The second manned flight, Mercury-Redstone 4 (MR–4), was conducted on July 21, 1961. DOD support was comparable in scope to that of MR–3. For this mission the AMR Rose Knot ship was used in the landing area. The flight and landing phases were successful. After landing, premature actuation of the spacecraft side hatch resulted in an emergency situation in which the spacecraft filled rapidly with water and began to sink. Astronaut Major Virgil I. Grissom, USAF, egressed from the spacecraft, and, after a short but difficult period in the water lasting approximately 3 minutes, was hoisted aboard the recovery helicopter and delivered on board the recovery ship for medical examination 19 minutes after spacecraft landing. A second helicopter attempted to recover the sinking spacecraft. The weight of the flooded spacecraft exceeded the lift capability of the helicopter at full power and the pilot elected to release the spacecraft rather than to jeopardize further the safety of the helicopter and crew. The spacecraft sank in 2,800 fathoms of water.

A second attempt, to orbit an unmanned spacecraft, was scheduled for August 25, 1961. This mission was designated Mercury-Atlas 4 (MA–4). All network stations were scheduled to participate. Recovery forces were deployed similarly as had been for MA–3. Contingency support was increased in scope to include full deployment by forces from CINCLANT, and partial deployment by forces from USCINCEUR, CINCPACFLT, and ARS. Bioastronautic support included additional forces deployed for training in the launch-site area. Shortly prior to beginning the countdown, launch-vehicle problems were identified which resulted in a 3-week delay of the launch. All deployed forces were recalled, then redeployed for a September 12 launch. On September 13, the mission was successfully conducted with the spacecraft completing a one orbital pass and landing in the planned landing area. A C–54 search aircraft located the spacecraft and retrieval was accomplished by the USS *Decatur* and delivered to Bermuda Island. Network performance, with the exception of generally poor radar tracking, was good. The tracking problem was traced to the lack of operator training and poor spacecraft antenna patterns.

Mercury-Atlas 5 (MA–5) was scheduled for November 14, 1961, to carry a chimpanzee on a three-pass orbital flight. Recovery planning included the primary landing area at the end of the third pass, as well as the probable areas for landing at the end of the first and second orbital passes. Recovery forces were deployed accordingly and contingency recovery commanders planned for a full deployment. Additional medical forces included veterinary specialists for postflight care and examination of the chimpanzee, as well as a complete launch-site support team. On November 12, spacecraft problems resulted in a 2-week delay in the launch. During this period, recovery forces reverted to normal operational control, were reorganized, and redeployed for a November 29 launch date. The launch was successful and flight was normal until spacecraft problems prompted a decision to land the spacecraft at the end of the second orbital pass. Radar tracking was greatly improved through intensified training prior to the flight and better spacecraft antenna patterns as a result of a beacon modification. Reentry and landing proceeded normally and the spacecraft was sighted in the planned landing area by recovery aircraft about 260 miles south of Bermuda. It was retrieved within 80 minutes after sighting. The spacecraft and occupant were delivered to Bermuda.

Mercury-Atlas mission 6 (MA–6) on February 20, 1962, was the first manned orbital flight and involved three orbital passes. The spacecraft, with Astronaut Lieutenant Colonel John H. Glenn, USMC, aboard, landed about 166 miles due east of Grand Turk Island, approximately 4 miles from the recovery destroyer which retrieved the spacecraft 21 minutes after landing.

All network instrumentation remained operative and provided full coverage throughout the three orbital passes. Telemetry and communications were excellent in spite of some telemetry-recording and radio-propagation problems. Radar coverage was better than expected, exceeding the performance for MA–5. Although a 4-minute ionization blackout occurred during reentry, the C-band radars were able to maintain track of the spacecraft which resulted in an accurate prediction of the landing point.

The landing areas after passes 1, 2, and 3, were treated as primary recovery areas for this mission. The recovery task force comprising a total of 24 ships and 41 aircraft was stationed in the nine planned landing areas in the Atlantic Ocean. An additional 37 aircraft were standing by at Jacksonville, Florida; Bermuda, Lajes Air Force Base, Azores; BenGuerir, and Roosevelt Roads, Puerto Rico. Forces from USCINCEUR, CINCPAC, and USAF were deployed along the remaining orbital tracks for contingency recovery.

A full Bioastronautic Task Force, consisting of 159 medical people was provided by the DOD and deployed to support this mission. These people staffed or augmented 4 medical treatment facilities, 21 recovery ships, and 14 medical monitoring stations. The medical evaluation and debriefing of the astronaut was completed at the advanced medical treatment facility at Grand Turk Island on February 23, 1962.

The seventh Mercury-Atlas mission (MA–7) was launched on May 24, 1962. This mission was the second three-pass orbital flight. Astronaut Lieutenant Commander M. Scott Carpenter, USN, was the pilot for this mission. All network stations were scheduled to participate except the AMR Rose Knot ship which was undergoing modification for a command-control system. Only the landing area at the end of the third orbital pass was designated as primary for this mission, requiring support of only one aircraft carrier. The spacecraft was launched and inserted into a nominal orbit with exceptionally good precision. Just prior to retrofire, at the end of three passes, a failure in the automatic control system was noted. A manual retrofire maneuver was planned and the countdown was sent from the California site. Attitude errors at retrofire caused the spacecraft to overshoot the planned landing point by approximately 250 miles. A directional finding (D/F) bearing on the spacecraft was quickly obtained by search aircraft and a SC–54 arrived within 1 hour after spacecraft landing with an auxiliary flotation collar and other survival equipment. Helicopters were launched from the carrier U.S.S. *Intrepid* when the carrier was within flight range. Although an ARS SA–16 arrived on scene before the helicopters, the Task Force Commander decided to effect recovery by helicopter. The astronaut was retrieved 3 hours after landing and returned to the carrier. The spacecraft was retrieved by a recovery destroyer for delivery to Puerto Rico.

A postmission review held at Patrick Air Force Base, Florida, revealed the need for a more rapid flow of information between the Mercury Recovery Control Center (MRCC) at Cape Canaveral and the on-scene forces. Recovery communications equipment and procedures were changed for future missions so as to provide for a more tightly controlled recovery organization capable of quick response to changing situations.

On October 3, 1962, the eighth Mercury–Atlas mission (MA–8) was launched. This mission, planned for six passes, was successfully completed and the spacecraft, with Astronaut Commander Walter M. Schirra, USN, aboard, landed in the primary landing area approximately 4½ miles from the recovery aircraft carrier. For the first time in the Mercury Project, recovery forces were deployed in the Pacific Ocean for a primary landing northeast of Midway Island. The landing area in the Atlantic Ocean at the end of the third pass was also treated as a primary area in the event that a full six-orbital mission could not be completed. Contingency recovery forces were expanded to cover the additional ground tracks in the South Atlantic, Caribbean, and western Pacific Ocean. The AMR Coastal Sentry ship was positioned in the Pacific Ocean to monitor the planned retrofire maneuver. Two S-band radar ships from the Pacific Missile Range and an Army C-band radar ship were positioned uprange from the primary landing area for reentry tracking. The Bioastronautic Task Force consisted of 84 medical specialists assigned to the launch area, network stations, and recovery units. An additional 22 specialists were available on a standby basis.

Centralized operational control together with the cooperation of the DOD forces participating in MA–8 were instrumental in achieving an integrated and responsive organization.

The ninth Mercury–Atlas mission (MA–9) was launched on May 15, 1963. This manned 1-day mission was planned for 22 orbital passes with the primary landing area in the Pacific Ocean southeast of Midway Island. The MA–9 spacecraft, with Astronaut Major Gordon Cooper, USAF, aboard, was placed into a near-perfect orbit by the Atlas launch vehicle. After 33 hours of normal flight during which the major objectives were met, a malfunction in the spacecraft control system required manual control of the spacecraft during retrofire and reentry. This was accomplished successfully and precisely by the astronaut and the spacecraft landed in the primary landing area within 4½ miles of the recovery aircraft carrier.

There were a total of 26 planned landing areas in the Atlantic and Pacific Oceans for the MA–9 mission. These areas were selected so that the ships of the Atlantic and Pacific task forces could cover more than one area. A worldwide deployment of contingency recovery forces was required to cover the entire ground track of the spacecraft. All theater forces were augmented by long-range C–130 MATS airplanes. There were 98 aircraft deployed for contingency recovery by the Air Rescue Service (ARS), Caribbean Air Command (CAIRC), Pacific Air Forces (PACAF), and CINCUSAREUR. Two AMR network ships were positioned in the Pacific Ocean to give command-control coverage. Reentry tracking in the Atlantic and the Pacific was available from two C-band radar ships. The Bioastronautic Task Force included 78 medical people deployed, 32 specialty team members on standby, two specialty team hospitals, and 7 recovery support hospitals.

Support efforts of DOD also included the successful accomplishment of voice relays both in the Atlantic and Pacific. Relay to Mercury Control Center (MCC) of the astronaut's voice while in orbit was obtained by the AMR C–130's stationed near Bermuda. During reentry and after landing, voice communications were relayed through PMR aircraft to the Hawaii network site where it was patched through network voice circuits to MCC. Radar airplanes of the Air Defense Command stationed in the Atlantic and Pacific obtained skin track of the spacecraft. The network provided excellent tracking coverage throughout the flight, considering the lengthy operating period for the equipment and long working hours for site people. Thoroughness in planning and excellent performance of assigned missions by DOD forces were reflected in the success of the MA–9 mission.

Concluding Remarks

Many changes in procedures and techniques used in providing Department of Defense support were developed during the course of the Mercury Project. Many lessons were learned and put into effect during successive missions; however, only those significant items which may have possible application in supporting future manned space programs are described.

The organization for the coordination and control of the overall DOD participation in Project Mercury was highly satisfactory. The designation of a DOD Representative for coordination of DOD support for Project Mercury operations was effective in that NASA was provided with a single point-of-contact for the submission of their overall DOD support requirements.

The operation of the global Mercury network comprising DOD ranges, NASA stations, and two stations in Australia was a significant achievement in coordinated team effort and was only accomplished by the complete cooperation of all concerned. Network management and operational procedures were clearly defined and compiled in a comprehensive joint DOD–NASA Mercury Network Operations Directive which proved to be a very useful and effective document.

The demonstrated ability of several ranges to combine their collective resources effectively to support global missions proves the possibility of combining all such national missile tracking resources under a single management control for the support of all missile and space programs of all agencies.

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The integration of radar-tracking equipment into a tracking system at the DOD missile ranges increased the capability of each range to support future missions. Technological experience and achievements of each range were pooled to permit all ranges to take advantage of such advancements or modifications.

The application of relay techniques for transmitting remote telemetry data from the downrange stations, derived from AMR experience in data transmission, was reported to NASA for possible adaptation to the wire and radio circuits of the Mercury network. Subsequently NASA secured a telephone line for data transmission between Pt. Arguello and the Mercury Control Center. During the ninth Mercury-Atlas mission the Mercury Control Center was supplied with a real-time display of electrocardiograph functions from the DOD sites at California, Antigua, and at Ascension. In addition to increasing the potential at each site by such improvements, a considerable saving in research and development costs was also realized by virtue of this exchange of technical information.

The use of radar-tracking aircraft during Mercury missions and especially the results obtained during the reentry phase of the MA-9 mission added significantly to the flexibility of network operations.

The use of the vast communications resources within the DOD and their integration into existing NASA and commercial systems to support network and recovery operations contributed significantly to the operational success of the project.

One of the more important considerations for support of Mercury operational planning was to provide for the safe and rapid recovery of the astronaut. Plans made by the DOD elements provided for the deployment of forces in a large number of strategic locations to cover possible aborts during all phases of the mission. Much of the effort in training was expended by forces that were deployed to act in contingency situations which essentially never developed. Their efforts, nevertheless, contributed to the success of the recovery mission.

Providing support to Mercury flights has contributed greatly to DOD's knowledge and experience in areas of launch, network, recovery, communications, and medical space operations. Future space-flight operations can be effectively supported by applying the experience and procedures derived during Project Mercury.

10. ASTRONAUT TRAINING

By Robert B. Voas, Ph. D., *Asst. for Human Factors, Office of the Director, NASA Manned Spacecraft Center;* Harold I. Johnson, *Flight Crew Operations Division, NASA Manned Spacecraft Center; and* Raymond Zedekar, *Flight Crew Operations Division, NASA Manned Spacecraft Center*

Summary

Any training program must be based on three factors: the requirements of the job, the characteristics of the trainees, and the training facilities available. Each factor is briefly discussed and its effect upon the nature of the training program is indicated. Selection of the Mercury astronauts began in January 1959. They reported at the Manned Spacecraft Center in April of that year and took part in a group training program for the next 2 years. In April 1961, when the Mercury manned flight program began, a special preflight preparation program was conducted with each of the pilots and his backup designated for a flight. The remainder of the group took part in development and operational activities and did limited training to maintain the proficiency developed during the group training program.

The group training program consisted of five major areas: (1) basic astronautical science instruction, (2) systems training, (3) spacecraft control training, (4) environmental familiarization, and (5) egress and survival training. The specific preflight preparation programs involved: (1) integrating the pilot with the spacecraft, (2) specific systems training, (3) development and practice of the specific mission flight plan, (4) training with flight controllers, and (5) medical and physical preparation. All of the Mercury trainers and training facilities are briefly listed and discussed, and this section concludes with an evaluation of the training devices and of the various phases of the training program.

Overall, the Mercury training program appears to have been successful in providing experienced pilots with the detailed spacecraft operation and systems information and skills which were required for them to make the transition from airplanes to spacecraft. The program seems to have been well suited to the requirements of the Mercury Project and future programs will make use of the same basic techniques. In retrospect, some of the emphasis on environmental familiarization might have been reduced, and more complete simulation of the external view from the spacecraft should have been provided. However, the great majority of the trainers and training activities have been both beneficial and necessary to produce the level of readiness that was demonstrated in the flight program.

Introduction

The Mercury training program was the first opportunity to prepare individuals for space flight. In general, however, the techniques used were not basically new or unique to this project. Rather, standard training techniques and training equipment approaches which had been used for many years in aviation were adapted for preparing the astronauts for their flights. From the beginning, the role of the astronaut has been conceived as being active and highly similar to that of the test pilot who carries out the initial flights of new aircraft. While the Project Mercury drew heavily upon flight training methodology, there were certain specific requirements of this program which were significant in determining its basic form. It is perhaps worth keeping these requirements in mind in a review of the Mercury training procedures:

(1) The Mercury program was not a mass training program, only seven individuals were involved, and, therefore, it was possible to reduce the formality of the program and to use a number of shortcuts which would not have been

feasible in the larger aviation training programs.

(2) The participants in the training program were experienced individuals who were already well along in preparation for space flight. This not only greatly reduced the overall amount of training necessary, it was also possible to emphasize individual initiative and responsibility for their training status.

(3) The training program had to be flexible because the spacecraft which the astronaut was being trained to operate was under development and therefore was being modified according to mission requirements.

(4) The training program had to be designed to help feed back into the developmental process. The astronauts were expected to aid the development engineers by participating in the design and review of many of the spacecraft systems, and the training activities were frequently combined with systems tests to evaluate both onboard and crew equipment.

(5) Unlike flight training, actual training in space was not feasible. There was a complete dependence upon ground simulator training until the astronaut flew the mission for which he had been preparing.

(6) The training had to be designed to tie in with the training and preparation of other operational groups such as the flight controllers.

(7) The significance of the program to our national prestige, the very great interest of the public, and the large cost resulted in an unusually strong emphasis upon a very high level of reliability, perfection, and precision in the man's performance.

Training-Program Characteristics

Any training program must be based on three major factors: the job requirements, the characteristics of the trainees, and the training facilities which are available. These factors are discussed in the following paragraphs.

Characteristics of Mercury Astronaut's Job

While the Mercury spacecraft was designed to complete a limited preprogramed mission on a completely automatic basis, from the very beginning manual controls were also provided. It was recognized that the man could provide increased systems reliability and give flexibility to the mission by allowing for a greater variety of maneuvers and scientific observations. The decision to provide for complete manual operation was highly significant for the crew training program because it meant that there would be a requirement for an individual who could skillfully manage the vehicle, as well as merely tolerate the physical stresses of the flight.

The major tasks (refs. 1 and 2) which can be identified from an analysis of the Mercury vehicle and its mission, involve:

(1) Sequence monitoring—monitoring all of the critical phases of the space mission, such as lift-off, staging of the launch vehicle, the separation of the escape tower, the separation of the spacecraft from the launch vehicle, firing of the retrorockets, and deployment of the parachute.

(2) Systems management—operation of all of the onboard systems and the management of the critical consumable supplies to insure that any out-of-tolerance condition is recognized and corrected before an emergency situation develops.

(3) Attitude control—maneuvering the vehicle to the proper relationship to the earth or orbital path whenever it is required during the mission.

(4) Navigation—being able to determine the spacecraft's position in orbit at any time and determining the critical retrofire time.

(5) Communications—operating the radio links to keep the ground control center informed of his status.

(6) Research observations—carrying out the special activities related to research and the evaluation of spacecraft function under flight conditions. The difficulty of performing these tasks was increased by the presence of environmental conditions, such as high acceleration, reduced pressure, heat, noise, vibration, and weightlessness.

In addition to these tasks involved in the actual operation of spacecraft, the Mercury astronauts were expected to contribute to a number of areas in the Mercury program. These included four main areas:

(1) Design of the Mercury spacecraft.

(2) Development of operational procedures.

(3) Development of inflight test equipment. It was desired to carry out tests of the spacecraft function, of special advanced systems and components, and to do scientific research during

the space flight that required the astronauts' participation in the development of a number of specialized kinds of equipment.

(4) Contribution to public relations activities. The astronauts served as excellent spokesmen for the program and were an important aid in meeting the requirement set by Congress to keep the public informed on the space program.

Characteristics of Trainees

The job requirements discussed in the previous section required individuals with high skill levels, appropriate personality traits, and a high level of physical fitness. The requirements under each of these areas are summarized as follows:

(1) In the area of aptitude and ability factors, the individual needed:

(a) A good engineering knowledge

(b) A good knowledge of operational procedures typical of aircraft or missile systems

(c) General scientific knowledge and research skills.

(d) High intelligence.

(e) Psychomotor skills similar to those required to operate aircraft

(2) In the area of personality factors, the candidate had to demonstrate:

(a) Good stress tolerance

(b) A good ability to make decisions

(c) Ability to work with others

(d) Emotional maturity

(e) A strong motivation for the program

(3) The physical requirements included:

(a) Freedom from disease or disabilities

(b) A resistance to the physical stresses of space flight accelerations, reduced pressure, weightlessness, high temperatures, and so forth

(c) Medium size so that they could be adequately accommodated by the relatively small Mercury spacecraft.

Initial planning during the fall of 1958 resulted in the definition of five basic requirements for Mercury crew members: age, 39 or below; height, 5 feet 11 inches or below; graduate of a test pilot school; qualified to fly jet airplanes; with 1,500 hours of jet flying time; and a bachelor degree in science, engineering, or the equivalent. During the first weeks of January 1959, a selection board reviewed the records of 508 military test pilots and selected the 110 who met the above requirements. The 69 most highly qualified of these candidates were invited by the services to come to the Pentagon to receive a briefing on Project Mercury and to be interviewed by the NASA Space Task Group.

On the basis of these interviews, 32 were selected to proceed to the Lovelace Clinic for a week of detailed physiological examinations and then to the Wright Field Aeromedical Laboratory for a week of stress tests (refs. 3 to 6). Data from these two testing programs were summarized and reviewed at the Space Task Group during the first week of April 1959. In all, 18 men were found to be medically qualified without reservation and, of these, the seven most technically qualified were selected to enter training.

Training Facilities

Table 10–I summarizes all of the major training facilities used in the Mercury Astronaut Training Program. Included are training devices and other facilities used for significant areas of the training program. From the table, it can be seen that there were a large number of facilities used. This resulted from at least three factors.

(1) Since the program was a first effort of its kind, it seemed appropriate to try all facilities to get a better feel for the relative importance of various types of experiences to the training.

(2) It was generally impossible to simulate more than one or two of the environmental conditions at any given facility. Therefore, it was necessary to use many different devices to obtain experience with all aspects of the environment.

(3) Most of the training devices had to be simple and rudimentary because the simulation techniques for space flight were in their infancy, and the training program was based on an accelerated schedule.

Table 10–I also lists the availability, date, approximate training time per astronaut, estimates of cost, lead time, and support time for each of the major training devices. The scheduling of some types of training activities had to be held up pending delivery or completion of this equipment. Also as can be seen from the source or location of each device in table 10–I, these training facilities were spread out over

Table 10–I.—Trainer Summary

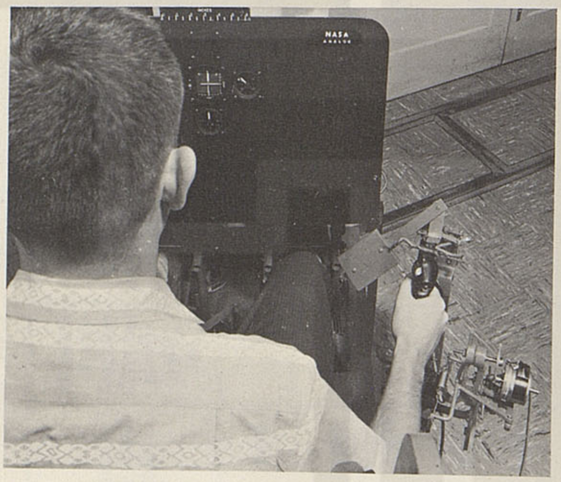
Identifying letter from fig. 10–1	Trainer	Primary purpose of trainer	Approximate date available	Approximate training time per astronaut, hr.	Approximate cost, dollars	Approximate lead time, months	Approximate support time, man-hours	Source	Assessment			
									Essential	Desirable	Early availability	Questionable value
a	Analog trainer no. 1.	Attitude control.	Apr. 1959	8	---------	0	200	NASA Langley Research Center.		x	x	
b	Proficiency airplane flights.	General performance proficiency.	May 1959	460	---------	0	60, 000	U.S. Air Force and inhouse.		x		
c	Centrifuge simulations.	Acceleration training; reentry control.	Aug. 1959	48	500, 000	4	15, 000	U.S. Navy, Johnsville, Pa.	x			
d	ALFA trainer	Attitude control.	Oct. 1959	12	50, 000	6	150	Inhouse	x			
e	Analog trainer no. 2.	Attitude control, pressure-suit training.	Oct. 1959	10	20, 000	3	200	Inhouse		x	x	
f	Navy slowly revolving room.	Disorientation familiarization.	Oct. 1959	1	---------	0	15	U.S. Navy, Pensacola, Fla.				x
g	Zero-g airplane flights.	Zero-g familiarization.	Dec. 1959	0. 7	---------	0	1, 000	U.S. Air Force		x		
h	Chapel Hill Planetarium	Star recognition training	Feb. 1960	28	---------	0	600	University of North Carolina	x			
i	MASTIF trainer	Disorientation familiarization	Feb. 1960	4	---------	0	300	NASA Lewis Research Center		x		
j	Egress trainer	Egress training	Feb. 1960	25	119, 000	10	1, 000	McDonnell Aircraft Corp.	x			
k	Procedures trainers (2)	Systems management, attitude control, mission training	June 1960	101	4, 000, 000	12	100, 000	McDonnell Aircraft Corp.	x			

l	ECS trainer	Environmental control system management	Nov. 1960	3	228, 000	12	1, 000	McDonnell Aircraft Corp.				x
m	Attitude instrument display mockup	Characteristics of attitude instruments	Jan. 1961	10	5, 000	4	50	Inhouse	x			
n	Ground recognition trainer	Periscope training and terrain familiarization	Apr. 1961	1	2, 000	3	5	Inhouse				x
o	Yaw recognition trainer	Out-the-window yaw angle recognition	Sept. 1962	2	1, 000	1	30	Inhouse	x			
p	Virtual image celestial display	Attitude control at night; star recognition training	May 1963	2	---------	12	75	Farrand Optical Co.	x			

the country. This resulted in a large amount of travel for the astronauts. As a result, their time was used somewhat less efficiently than if all the training facilities had been available from the beginning of the program at MSC. Most of these facilities are pictured in figures 10–1(a) to 10–1(p).

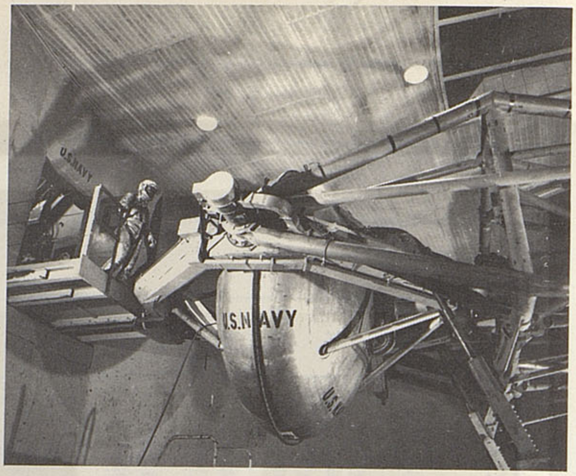
Training Chronology

Figure 10–2 presents a chronology of the Mercury training program. The astronaut selection program occupied the period from January to April 1959. The group training program ran for approximately 2 years, to April 1961. After April 1961, the manned flight program began. Prior to each flight, a preflight preparation program was conducted for the pilot and his backup. The length of this

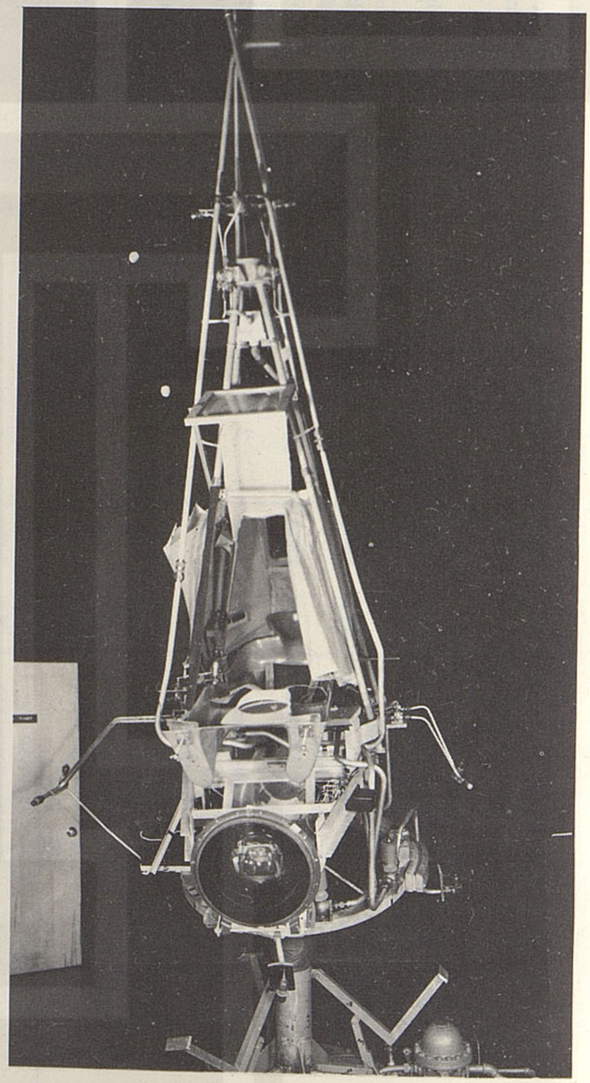


(a) Langley analog computer simulator.

(b) Aircraft used for proficiency flights.



(c) Centrifuge acceleration facility.



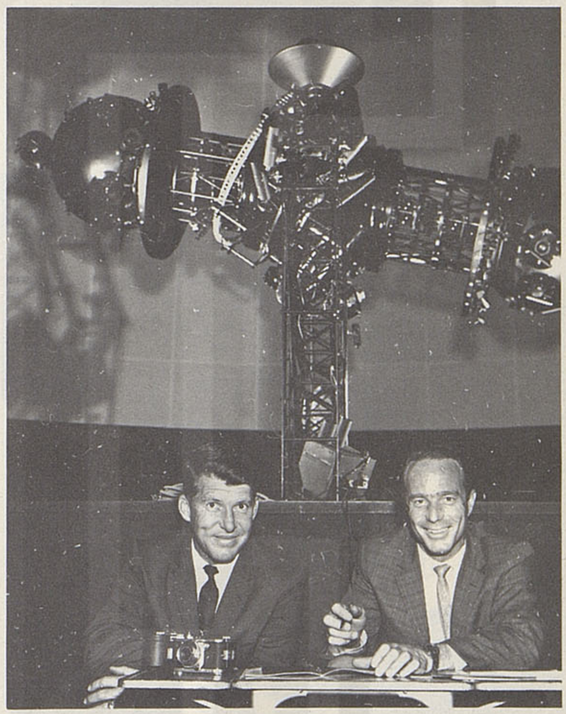
(d) ALFA trainer.

FIGURE 10–1.—Photographs of various training facilities.

(e) Analog computer trainer no. 2.

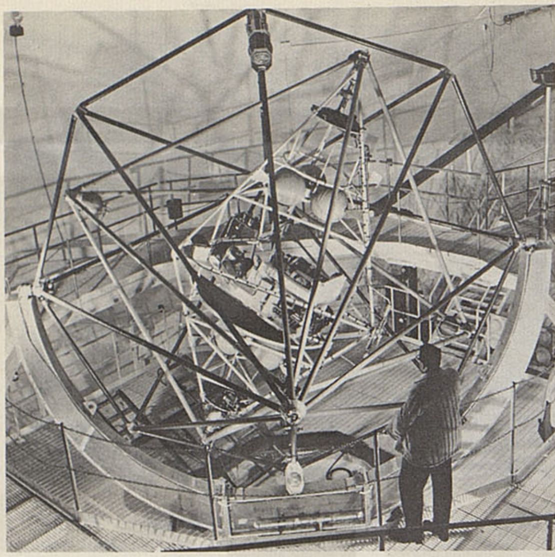
(g) Zero-g airplane flights.

(f) Slowly revolving room.

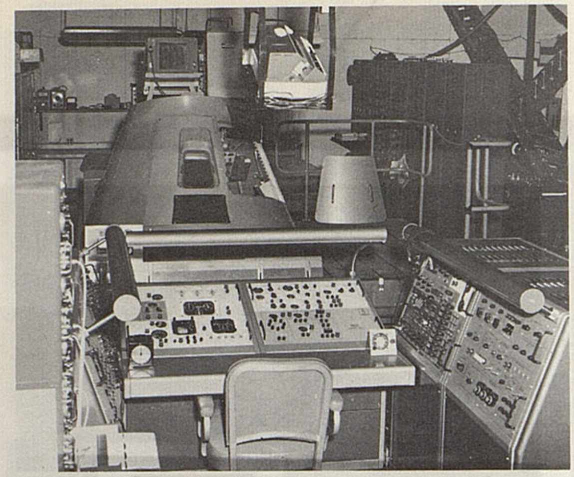


(h) Chapel Hill Planetarium.

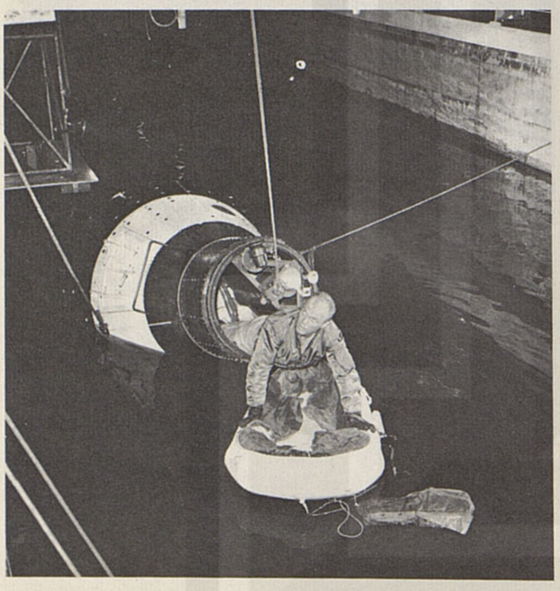
FIGURE 10–1.—Continued.



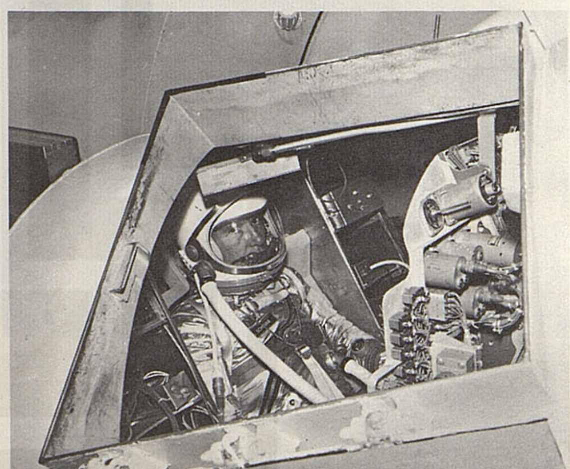
(i) MASTIF trainer.



(k) Procedures trainer.

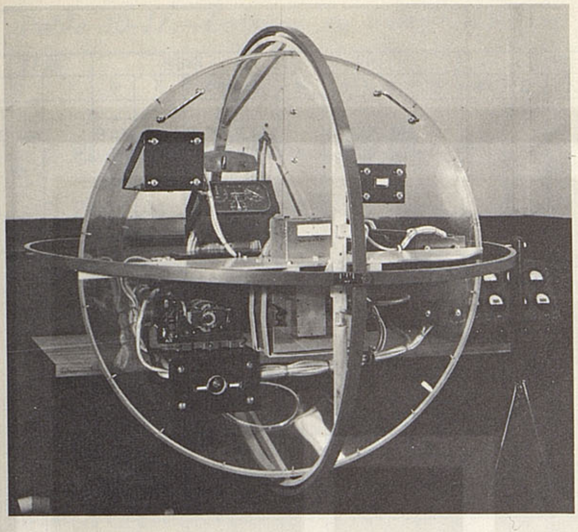


(j) Egress trainer.

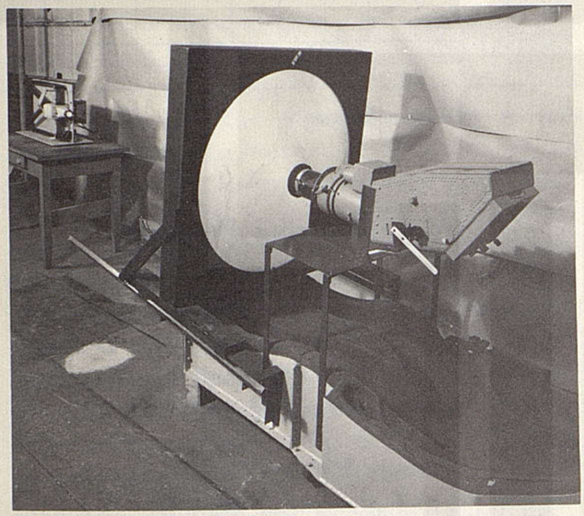


(l) ECS trainer.

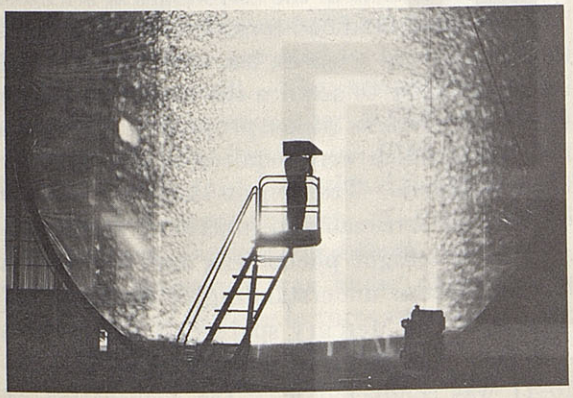
FIGURE 10-1.—Continued.



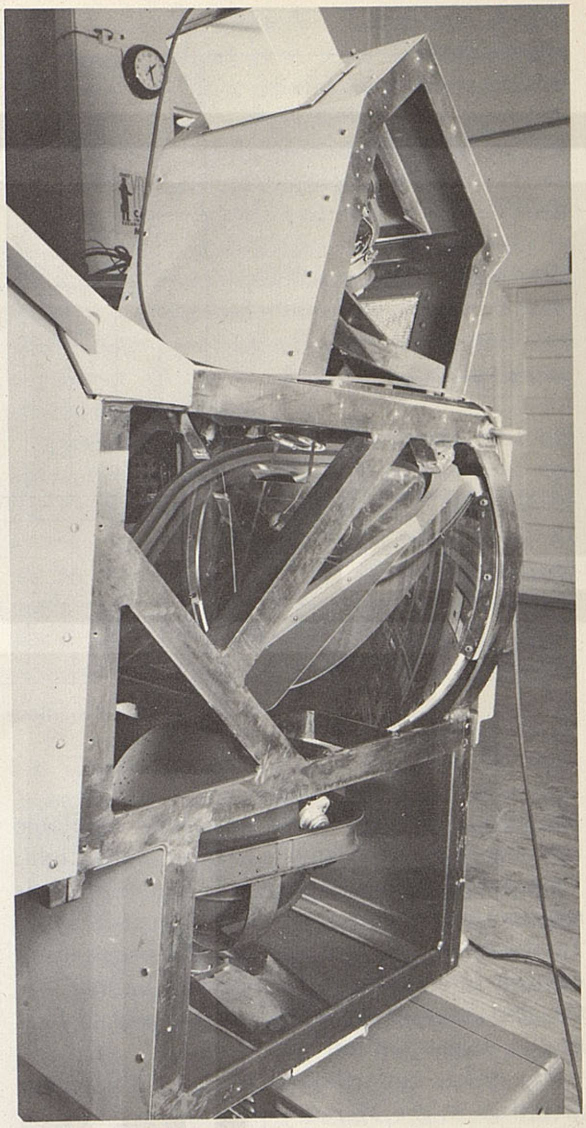
(m) Attitude instrument display mockup.



(n) Ground-features recognition trainer.



(o) Yaw recognition trainer.



(p) Virtual image celestial display.

FIGURE 10–1.—Concluded.

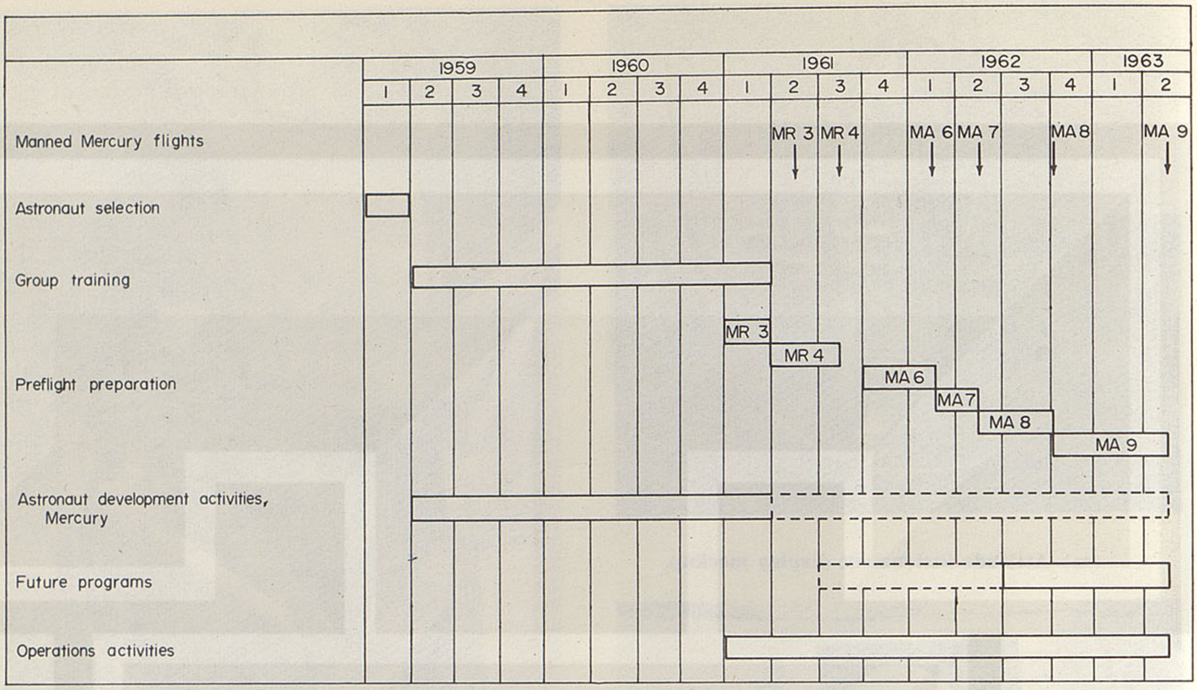


FIGURE 10–2.—Chronology of Mercury training program.

program depended upon the time available between flights and on the nature of the flight. In general, the backup pilot on one flight was selected as primary pilot for the next mission. In this way, the actual preflight preparation of each pilot encompassed close to 6 months—the first half as a backup and the second half as the primary pilot.

The pilots' contribution to the development activities in the Mercury program began soon after they reported to the NASA and had had sufficient indoctrination on the Mercury spacecraft systems. The astronauts participated in planning for the programs to follow Mercury which began in 1961 and became greatly accelerated in 1962.

Each man was assigned to a Mercury network station as voice communicator. Service in this capacity normally involved a minimum of 3, or more, weeks. This activity in connection with Mercury operations began with the manned Redstone flights in 1961 and became greatly amplified with the manned orbital flights in 1962 and 1963. After the termination of the group training program, they had to devote time to maintaining their proficiency, in addition to these operational requirements.

Group Training Program

The group training program consisted of five major areas which are described in the following paragraphs. Portions of this program have previously been described by Astronaut Slayton in ref. 7 and others (ref. 6 and 8).

Basic Science Program

An initial phase of the Mercury astronaut training program consisted of brief but comprehensive courses in the astronautical sciences. The astronauts had had considerable training in the aeronautical sciences, but most had not had an opportunity to acquire the basic knowledge in such subjects as rocket propulsion and space mechanics which were required in the Mercury flight program. Training in the space sciences enabled the astronauts to function better as observers of inflight phenomena and provided a basis for better understanding of the technical aspects of the Mercury spacecraft and vehicle systems. The series of courses listed in table 10–II was conducted with the cooperation of the NASA Langley Research Center. Time did not permit a more extensive program although it would have been desirable.

Table 10–II.—Lectures on Space Sciences

Subject	Hours
1. Elementary Mechanics and Aerodynamics	10
2. Principles of Guidance and Control	4
3. Navigation in Space	6
4. Elements of Communication	2
5. Space Physics	12
6. Basic Physiology	8

Systems Training

A large portion of the training program was devoted to familiarizing the astronauts with the Mercury systems. This knowledge was not only basic to all of their training activities but was the essential basis of their contribution to the development program. The primary requirements of this training were: to develop a basic understanding of the nature and characteristics of each system; to build on this understanding a knowledge of the system operation and function; and, finally, to develop, in the Mercury procedures trainers and the spacecraft, skill in managing the onboard systems.

Systems briefings.—The systems training began with a series of briefings given by specialists within the Space Task Group. The first set of lectures covered the Mercury systems and was followed by another group of lectures covering operational areas. These lectures were followed by a series of somewhat more detailed systems briefings by contractor personnel at the various contractor facilities. Periodically, throughout the 2 years of the group training program, systems lectures were repeated.

Contractor visits.—The astronauts visited contractor plants and other NASA centers in order to get a firsthand view of the developing hardware and of the operational facilities.

Manuals.—Documentation of the Mercury systems was a particularly difficult problem because the spacecraft was under development. The first set of systems lectures were used as the basis for the Mercury Familiarization Manual (ref. 9). This manual became the basic systems document used by the astronaut.

A second manual, which was developed later in the program and which emphasized the operational aspects of the systems management problem, was the Capsule (Spacecraft) Flight Operations Manual (ref. 10). This document was printed in a size small enough to be carried in the pocket of the flight jacket with the intention that it could be carried along on flights, if desired. In actual practice, it was not carried with the flight but was used during some trainer runs. A third publication used extensively in training was the Flight Controller's Handbook, which was developed within the Manned Spacecraft Center (see paper 15) and which provided a number of useful diagrams for analyzing system malfunctions.

Specialty Assignments.—To insure that the astronauts had available to them the most up-to-date information possible, they participated in the engineering reviews and other meetings on the spacecraft systems. Since no one man could cover all of these meetings, each astronaut was assigned to a specialty area (ref. 7). Each man attended meetings in his area and reported back to the group.

Mercury Procedures Trainers.—The bulk of the operational training in the Mercury systems was achieved on the Mercury Procedures Trainers (MPT). The name "procedures trainers" is actually a misnomer since these devices could better be classified as flight simulators. Initially, a very simple open-loop device had been considered for training in the basic launch procedures. This was to be supplemented later by a complete flight trainer. However, the time available for development and delivery of these training devices was so short that it was decided to combine the two into a single trainer. In this trainer, it was possible to simulate the operation of all of the Mercury systems and induce approximately 275 separate system failures (ref. 11). Provisions were made to pressurize the pressure suits. However, with the exception of the indicator readings, the actual environmental conditions in the cabin were not provided. Two of these units were procured in order to have one available at the launch site to be used in prelaunch training, while the other was used at the main training base at Langley Field, Va. These two procedures trainers differed slightly in their provisions for animating attitude control system, as is described later, but they were essentially identical in their capability to simulate the operation of onboard systems.

Initial training began by reviewing each system separately in the trainer. The normal operation of each system and all of the failures which could be simulated were demonstrated during this initial period. Following this, a series of both Redstone and Atlas simulated flights were made for each student, during which simulated emergencies were kept to a minimum in order to allow the astronauts to become familiar with the timing of the normal missions. Once they were generally familiar with the timing of the missions and the normal indications, the numbers and types of malfunctions were increased. By the end of the group training period, all the astronauts had made a large number of Atlas and Redstone runs and had had an opportunity to experience most of the major emergencies.

Environmental Control Systems Trainer.—Additional training in the operation of the environmental control system was provided by the environmental control systems trainer which was a heavy shell mock-up with a prototype spacecraft environmental system. The device used was delivered to NASA in November 1960 and installed in a man-rated vacuum chamber at the U.S. Naval Air Crew Equipment Laboratory in Philadelphia (fig. 10–1(l)). During December of 1960 and January of 1961, the astronauts participated in a program of system familiarization that included being exposed to a simulated reentry heat pulse and approximately 2 hours of the expected postlanding temperature. During these runs, the astronauts wore the pressure suits and became familiar with function of the suits when associated with the environmental control system. However, since a provision had been made for simulating the suit function in the procedures trainer, this type of training was not considered essential. This was particularly true since the astronauts received further first-hand familiarization to the environmental control system by participating in the preflight checkout of the spacecraft environmental control system at the launch site.

Attitude Control Training

A number of fixed and moving based simulators had to be employed because no single trainer was capable of simulating all of the tasks on all of the control systems under all environmental conditions (ref. 12). The function of each of the principal control attitude trainers is summarized in table 10–III. This table lists the attitude control trainers and the spacecraft control systems which could be simulated, the reference systems which were available to the pilots, tasks which could be practiced, environmental conditions simulated, and finally whether or not attitude tasks could be practiced in conjunction with other flight activities. Each of these trainers is briefly described in the following paragraphs.

Table 10–III.—Attitude Control Trainer Summary

Referenced to figure 10–1	Trainer	Control systems [a]				Reference systems				Types of tasks				Environmental conditions			Use while performing other tasks
		MP	FBW	RC	Mixed	Instruments	Window	Periscope	Mixed	Orbit attitude control	Retrofire	Reentry rate damping	Recovery from tumbling maneuvers	Linear acceleration	Angular acceleration	Pressure suit	
a	Analog trainer no. 1	x	x			x				x	x	x					
e	Analog trainer no. 2	x				x				x	x	x				x	
k	Procedures trainer no. 1	x	x	x	x	x	[b]	x	x	x	x	x				x	x
k	Procedures trainer no. 2	x	x	x	x	x				x	x	[c]					
o	Yaw recognition trainer						x										
m	Attitude Instrument display mock-up					x				x			x				
h	Ground recognition trainer							x									
d	ALFA	x	x			x	x	x	x	x	x				x		
i	MASTIF	x				x							x		x		
c	Centrifuge	x				x				x	x	x		x		x	x

[a] MP—Manual proportional.
FBW—Fly-by-wire.
RC—Rate command.

[b] Added to MPT no. 2 late in training program.

[c] Virtual image celestial display added to MPT no. 2 just prior to last flight.

Analog trainer.—The analog computer trainer provided the first simulation of the astronaut's manual flight-control task in Project Mercury. The simulator (fig. 10–1(a)) was set up by Langley Research Center personnel at the inception of Project Mercury and was used heavily during the first half of 1959, both for engineering feasibility tests and for introducing the Mercury flight control tasks to the astronauts.

Analog trainer no. 2.—The trainer was activated in the latter half of 1959. The simulator (fig. 10–1(e)) utilized a special-purpose a-c analog computer obtained from an obsolete F–100 gunnery trainer. Realism was enhanced by the use of an early type molded styrofoam couch and a prototype Mercury three-axis controller supplied by the contractor. Aside from providing the astronaut with his first opportunity to practice attitude control in the pressurized suit, this trainer was used to perform a number of engineering feasibility studies.

Mercury Procedures Trainers.—The Mercury procedures trainer no. 1, housed in the NASA Full-Scale Tunnel at Langley Air Force Base, Va., and trainer no. 2, housed in the Mercury Control Center (fig. 10–1(k)) at Cape Canaveral, Fla., were the most valuable flight-crew trainers used in the Mercury Project.

The decision to provide two trainers was found to be sound since, in addition to the astronauts' requirements, there were requirements to use both Mercury Procedures Trainers in conjunction with simulations in the flight controller training program. Trainer No. 1 was used in conjunction with the remote site simulator at Langley Air Force Base, Va.; and trainer no. 2, with the Control Center Mission Training Complex at the launch site. (See paper 15.)

Both trainers were delivered without analog computers for animating the rate-and-attitude flight instruments. Therefore, procedures trainer no. 1 was connected to the same computer used in the analog trainer no. 2. This computer allowed activation of all of the 22 possible combinations of manual and/or automatic attitude controls that were provided in the Mercury spacecraft. Three months after delivery, procedures trainer no. 2 was supplied with a small-capacity general-purpose analog computer which permitted activation of only the manual-control modes for the orbital phase of flight. Approximately 6 months prior to completion of Project Mercury, additional equipment was obtained to provide manual damping practice during reentry.

Trainer no. 1 had an active periscope display consisting of a moving dot on the face of a cathode ray tube which was activated by the hand controller and the analog computer. Very late in the project a new, versatile, virtual image display was also added to trainer no. 1. This display was used briefly for training prior to the last Mercury flight.

Virtual-image celestial display.—Because of the state-of-the-art of space flight external-view simulation at the outset of the Mercury project and the compressed time schedule, no external view other than that through the periscope was provided on MPT no. 1 at the time of delivery of the procedures trainers. However, considerable effort was expended in trying to develop new and versatile displays. One result of these efforts was the virtual-image viewing system (fig. 10–1(p)). The first working model of the system was delivered and installed on the MPT no. 1 in time for limited training prior to the MA–9 flight. This display could simultaneously accept inputs ranging from three-dimensional models to closed-circuit television or film strips. However, the only display available at the time of the MA–9 flight was a star view. The stars were produced by setting ball-bearings of various sizes into the surface of a 12-inch diameter, hollow magnesium sphere which was gimballed and driven by a computer. The ball bearings, upon illumination by a point light source, produce exceedingly realistic point sources of light of the desired brightness to represent the star fields.

Yaw-recognition trainer.—Prior to the MA–8 six-orbital-pass mission, there was considerable concern regarding whether or not the pilot would be able to detect his yaw position solely by use of the slow translation of terrain or clouds viewed out the window of his spacecraft. The pilot's ability to determine accurately yaw by using out-the-window references is all-important if his gyro altitude information was lacking during retrofire as in the MA–9 flight. In this case, Astronaut Cooper had to rely on his window scene to determine heading or yaw position accurately for retrofire. (See paper 17.)

In order to give the astronauts a preview of the out-the-window motion cues they would have in orbit, a yaw-recognition trainer (fig. 10–1(o)) was conceived, built, and activated in about 2 weeks. The trainer consisted of a 33-foot diameter convex-lens-shaped screen, one surface of which represented either the earth's surface or a constant-altitude cloud deck. This surface was made of polyethylene plastic and was used to display a real, moving image of simulated clouds produced by a film strip moving at the proper speed through a slide projector. The speed of the image movement duplicated the in-flight apparent movement between the spacecraft and the ground by having the observer view the scene from a point at the middle of the lens while standing 2 feet away from the surface. To heighten realism, the flight crews wore a box over their heads which had an opening which simulated the proper size and shape of the spacecraft window.

The MA–8 and MA–9 flight crews utilized the yaw recognition trainer prior to their flights. The other astronauts used the trainer subsequent to their flights. All of the pilots who had flown orbital flights reported that it duplicated almost exactly the visual yaw motion cues observed from the spacecraft.

Attitude instrument display mock-up.—The attitude instrument display mock-up (fig. 10–1(m)) consisted of a half-scale transparent model of the Mercury spacecraft mounted within a four-gimbal all-attitude support. The mock-up contained the actual Mercury rate and attitude indicators without horizon scanner or ASCS logic hardware. The exterior covers of the attitude gyroscopes were removed so that the trainee could observe the manner in which the attitude gyros tumbled during simulated motions of the spacecraft. The device illustrated how the attitude indicators can read incorrectly as a result of various spacecraft attitudes occurring at times when the floating gyroscope axes are not parallel to the spacecraft axes. The major purpose of this training device was to teach the astronauts how to regain use of the attitude gyros and attitude indicating system if correct reference were lost as a result of the tumbling of the gyros or the interference of the "repeater" stops. This conceptual trainer was very useful and each flight crew spent several hours studying the maneuvers planned for their flights.

Ground-recognition trainer.—The ground-recognition trainer (fig. 10–1(n)) consisted of a prototype molded couch, an actual Mercury periscope, a back-projection screen, and a motorized slide projector. The slide projector displayed a colored, moving image of the earth on the screen. No cloud cover was simulated. The image was viewed through the periscope, located at the proper distance from the screen to simulate the geometry of a periscope in a Mercury spacecraft at 110 nautical miles altitude and aimed at the earth's nadir.

The purpose of the trainer was to familiarize the astronauts with the wide-angle optics of the periscope which caused a compression of the images of coastlines, rivers, mountain ranges, and other topographical features. This trainer was not used extensively because, to a certain degree, the scenes viewed were very similar to those that were seen through the periscope simulation of the ALFA trainer.

Air-lubricated free-attitude trainer.—The air-lubricated free-attitude trainer (ALFA) (fig. 10–1(d)), was designed and developed by engineers of the NASA Manned Spacecraft Center. This trainer moved on an air-bearing and had 360° of freedom in roll and 35° of freedom in pitch and yaw. The astronaut operated compressed air jets through a Mercury hand controller. Retrofire disturbance torques were also simulated with compressed-air jets.

Two attitude-control systems were simulated on ALFA: manual proportional and fly-by-wire. In the fly-by-wire simulation, only the low-torque jets (used for attitude control in orbit when attempting to minimize fuel consumption) were simulated. All three reference systems are provided. The periscope was simulated through a wide-angle lens and a system of mirrors which presented a view of a circular screen on which a map of the earth was projected from a film strip. The actual Mercury gyro package and instrument display were mounted on the trainer. The window display was simulated schematically by an illuminated strip to represent the horizon and small bulbs to simulate the stars.

Multi-Axis Spin-Test Inertia Facility Trainer.—The Multi-Axis Spin-Test Inertia

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Facility (MASTIF) trainer, created in February 1960 by personnel of the NASA Lewis Research Center, was utilized for a simulation training program of recovery from tumbling flight in February 1960. The trainer (fig. 10–1 (i)) consisted of a couch mounted inside three gimbals, a three-axis hand controller, and a rate display. The astronauts were spun at rotational rates of about 30 rpm about all three spacecraft axes simultaneously. At a prearranged time, the astronauts assumed control of a three-axis compressed nitrogen fly-by-wire attitude control system and brought the couch to rest by reference to a Mercury rate-indicator instrument.

The purpose of the trainer was to provide the best technique and improved confidence level for stopping inadvertent tumbling of the Mercury spacecraft. The training was considered valuable even though the possibility of its application was thought to be fairly remote.

Centrifuge Training

Four formal centrifuge programs were conducted at the Aviation Medical Acceleration Laboratory's centrifuge at the Naval Air Development Center at Johnsville, Pa., as part of the group training program (fig. 10–1(c)). The first two programs were combined engineering-feasibility and preliminary astronaut-familiarization programs while the last two were intensive operational training programs for the Redstone and the Atlas flights. The configuration of the centrifuge gondola and the computer control system varied between programs. The gondola was configured to simulate spacecraft for either orbital or ballistic missions. The simulated attitude control system was run closed loop and the centrifuge was run open loop. The astronauts wore full pressure suits and some runs were made at a simulated altitude of 28,000 feet.

Overall, the astronauts experienced an average of 45 hours on the centrifuge. These programs appeared to be extremely valuable both for training and in providing an opportunity for checking out items of personal equipment and for demonstrating the adequacy of the spacecraft instrumentation for viewing under acceleration.

Environmental Familiarization

Despite the general familiarity of the astronauts with the space flight environment and their demonstrated capability of performing effectively under stress, an attempt was made during the training program to provide additional familiarity with this environment. The following five requirements were thought to be conducive to good performance under space-flight conditions:

(1) The astronauts required a detailed knowledge of and confidence in the equipment which they had to operate in space. This was primarily provided through the systems training described previously. However, the environmental familiarization involving pressure chamber and centrifuge runs provided an opportunity to become more fully acquainted with the pressure suit, the couch and restraint systems, the bioinstrumentation and other items of personal equipment and to develop confidence that these items would perform their functions adequately in the space-flight environment.

(2) The astronauts also required a familiarity with the environment itself. Familiarity with the conditions of space flight minimizes the number of novel and possibly distracting stimuli which will be encountered in flight. Experience with these conditions also permits the development of the specific techniques for minimizing these environmental effects. For example, under acceleration it is necessary for the astronauts to learn a special breathing technique to minimize the tendency of peripheral vision to become blurred because of reduced oxygenation of the blood. During early training, this breathing technique required some thought and distracted the astronauts from their control tasks. However, as training progressed, the breathing became automatic and full attention could be devoted to the task.

The accommodation of the pilot to the effects of acceleration can be seen in figure 10–3 which

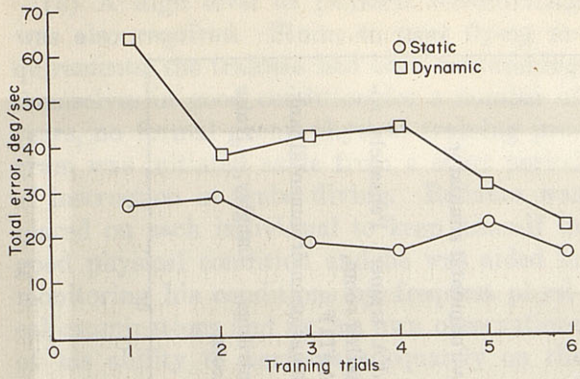

FIGURE 10-3.—Centrifuge retrofire training.

provides a comparison of the retrofire attitude control performance, under the simulated acceleration of the retrorockets and statically. The data presented are average values for all astronauts and show an increase in error with acceleration; however this initial effect tended to disappear with practice.

Table 10-IV summarizes the environmental conditions which were simulated during the group training program. The first column lists the various conditions experienced while the second gives the intensity of exposure encountered in suborbital and orbital flights. The third column summarizes the level experienced in training while the final column lists some of the trainers which were used to provide this experience. With the exception of weightlessness, all the environmental conditions were simulated during training at least to the level expected in a normal flight. Weightlessness condition cannot be simulated within the atmosphere for more than 60 seconds; however, the astronauts did, over several runs, build up an average of 40 minutes total weightlessness per man. In general, all of the environmental familiarization experiences were of value. However, with the exception of the linear acceleration experienced on the centrifuge and effects of suit pressurization, none of the environmental simulations were critical, including weightlessness.

Table 10–IV.—Flight and Trainer Environment Summary

Condition	Level in Flight: Normal (Redstone/Atlas)	Level in Flight: Emergency	Level Experienced in Training	Simulator
Weightlessness	Redstone, 5 min Atlas, 4½ hr		Up to 60 sec. Average of 40 min total weightlessness.	F–100F, C–131B, and C–135 aircraft.
Acceleration	Redstone, up to 11g Atlas, up to 7g	Up to 20g	All normal Atlas and Redstone Profiles and abort profiles up to 16g. Average of 70 dynamic runs per man.	Centrifuge.
Reduced pressure	5 psi for from 4½ hr to 34 hr	Pressurized 4.6 in suit.	Up to 6 hours in pressure suit; up to 3 hours in orbit condition; launch and reentry profiles have been experienced in at 5 psi and in pressurized suit.	Environmental simulator Centrifuge.
Heat	Capsule inner wall 275°, post-recovery period at 85°, 35 percent humidity.		Heat pulse up to 260° with normal recovery period.	Environmental simulator.
Rotation (Disorientation)	10°/sec		Up to 60 rpm	ALFA trainer; Pensacola rotating room.
Tumbling	None		Up to 54 rpm	MASTIF.
High Levels CO_2	Below 0.04 percent	Up to 3.5 percent.	Slow buildup to 3.5 percent	Submarine environmental tank.
Noise and Vibration	150 db outside spacecraft, 130 db inside spacedraft, 110 db at ear		90 to 110 db for normal Atlas launch period.	Centrifuge, Langley, Noise tests.

(3) A high level of physical conditioning was also required. Since, to meet flying requirements, the trainees had been maintaining themselves in good condition for a number of years, no formal group physical training program was initiated aside from a short period of instruction in scuba diving. Reliance was placed on each individual to keep himself in good physical condition and he was aided in monitoring his conditions by frequent physical examinations and by his own observations of his ability to perform adequately on the centrifuge and in other types of environmental training.

(4) A fourth requirement was the detailed planning and practice of emergency procedures until they could be rapidly and correctly executed. The majority of this type of training occurred on the procedures trainer, particularly during the period just prior to the flight.

(5) A final requirement for performing effectively under stress was to maintain their habits of altertness and their ability to react rapidly and think effectively in emergencies, which they had developed during their careers in flying. Since none of the training situations involved any significant amount of hazard, it was important that the astronauts have an opportunity to maintain their skills in meeting real emergencies. As a result they were provided with aircraft so they could maintain their flying skills (See fig. 10–1(b)).

Through these five steps, knowledge of the equipment available to their use, familiarity with the environment, physical conditioning, preplanning for emergencies, and the habit of constant alertness and readiness for action, the astronauts were provided with the basis for a high degree of effectiveness in performing well under the unusual environmental conditions associated with space flight.

In considering the problems of preparing individuals for performing effectively in a realistic environment, it is interesting to note that a number of programs, in which it was intended to use actual hardware in real environments in order to train the astronauts, were considered but were not put into practice because the training value appeared to be too small to justify the cost or safety hazards involved in their implementation. At the initiation of the Mercury program, it had been recommended that as part of the training program a series of balloon flights be undertaken in which the actual Mercury spacecraft would be carried to altitudes of from 80,000 to 100,000 feet. The plans for this program were carried for several months and the requirements studied in detail. The studies indicated that training value did not justify the risk or the cost involved in the program. Two other programs of a similar nature were also eliminated. One program involved placing the actual spacecraft on the Lewis MASTIF device for training in controlling attitude during retrofire. The MASTIF device was inside a full-scale wind tunnel, which could have been depressurized. Analysis also showed that it would be very difficult to reproduce the conditions of motion typical of space flight because of the very high inertia of the MASTIF gimbals. A final program of the same sort was a plan to place a flight Mercury spacecraft on top of the Redstone launch vehicle during static firing so that the astronaut could experience the actual noise and vibration typical of launch. Once again neither the risk nor the cost appeared justified in view of the limited training value. These three examples illustrate what seems to be a basic result of the Mercury training experience. Using actual flight equipment in simulated environments for training purposes alone generally involves too great an expense to be worthwhile. When only training is involved, mission simulators are most efficient. On the other hand, in the Mercury program, valuable training was achieved during the launch checkout of the actual flight vehicle in the pressure chamber at Cape Canaveral. In this case, however, the simulation benefited not only the training program but the checkout of the flight article.

Egress and Survival Training

The astronauts were provided with several training programs designed to prepare them to egress successfully, survive and be recovered under various contingency conditions. The egress and survival programs are summarized as follows.

Egress training, phase 1.—The first egress training program was conducted in February 1960, in which the egress trainer, spacecraft no. 5, (fig. 10–1(j)) and the NASA Langley Research Center Hydrodynamic Basin no. 1 were used. Each of the astronauts made several egresses through the top hatch with and without the pressure suits in calm water and in artificially generated waves up to 2 feet in height.

Egress training, phase 2.—The first full-scale open water egress program was conducted in the Gulf of Mexico near the Pensacola Naval Air Station in March and April of 1960. This program consisted of 1 day at sea, during which both top and side hatch egresses were accomplished, and a second day at the training tank for water-survival technique and drill.

Egress training, phase 3.—Underwater egress was accomplished at NASA Langley Research Center in August 1960, with the Langley Research Center Hydrodynamic Basin No. 1 again being used. Each astronaut made six egresses while the spacecraft was submerged. Half of these were accomplished while wearing the Mercury pressure suit.

Periodically, the astronauts were given refresher courses on proper egress and recovery procedures through briefings and participation in subsequent egress and recovery exercises.

In addition, each designated flight crew participated in a full-scale recovery exercise prior to each flight during which both top and side egress, survival equipment deployment, and helicopter pickup operations were accomplished.

Survival training, phase 1.—Water survival training was accomplished in conjunction with most of the water-egress programs and through briefings. The first water-survival training program was conducted at Pensacola, Florida, in March 1960. The training consisted of several briefings, a training film, and actual practice with the use of the survival equipment in the training tank and in the open sea during egress and recovery operations.

Survival training, phase 2.—In July 1960, the Mercury astronauts completed a 5½-day course in desert survival at the Air Force Survival School, Stead Air Force Base, Nevada. The course consisted of three phases: (1) 1½ days of academics oriented to survival operations in the North African or Australian desert; (2) 1 day of field demonstrations covering the utilization and care of available clothing and spacecraft and survival equipment; and (3) 3 days of remote-site training during which the astronauts applied the knowledge and techniques that they had learned during the briefings and demonstrations.

Preflight Preparation

Approximately 3 months prior to each flight, the designated pilot and his backup began specific preparations for the mission. The period of preparation was, however, somewhat variable depending upon the particular mission and the time between missions permitted by the flight schedules. Pilots participating in the earlier missions had the advantage that the training received in the group program was fresher and that less change had occurred in the vehicle configuration between the time of this program and their flight. Those participating in later flights experienced a lapse of intensive training from 1 to 2 years and had the problem that the spacecraft configuration had changed considerably in the interim, particularly as the mission length was extended. Thus, the preflight period of training became more and more significant. The final impression developing out of the Mercury experience was that on a day-for-day basis preflight preparation was the most valuable period of the training program. Experience indicated that the pilot was required to put in a 10- to 12-hour day for at least 6 days a week during this preflight period. Astronaut Cooper's activities during this time are shown in table 10–V. Since there were so many demands upon the pilot's time, a definite danger existed that important items of training would be pushed aside or overlooked unless care was taken to plan carefully in advance, and frequent training reviews were held to assure that all critical training items had been accomplished. During this period there are five major preparation activities for the flight crew. These activities have been described previously by Astronaut Carpenter (ref. 13).

Table 10–V—MA–9 Pilot Preflight Activities From January 1, 1963 to Launch Date

Date	Day	Activities
Jan. 2	Wed	Altitude Chamber Systems Test Review, blood-pressure checkout in altitude chamber, flying (TF–102A)
Jan. 4 to 7	Fri. to Tues	Altitude Chamber Systems Test
Jan. 10	Thurs	Flight-plan review, flying (TF–102A)
Jan. 12	Sat	TV systems test, flying (TF–102A)
Jan. 18 and 19	Fri. and Sat	Morehead Planetarium (celestial review)
Jan. 21	Mon	Weight and balance
Jan. 22	Tues	Systems briefings (ASCS and RCS)
Jan. 23	Wed	Systems briefings (communications and sequential)
Jan. 24	Thurs	Flight-plan and experiments review
Jan. 25	Fri	Systems briefings (electrical and ECS)
Jan. 30	Wed	Flying (F–102A)
Jan. 31	Thurs	Flying (T–33A)
Feb. 1	Fri	Launch vehicle rollout inspection
Feb. 2	Sat	Flying (T–33A)
Feb. 3	Sun	Flying (T–33A)
Feb. 4	Mon	Experiments status review
Feb. 5	Tues	Flight-plan review
Feb. 6	Wed	Couch fitting
Feb. 7	Thurs	Flying (T–33A)
Feb. 8	Fri	Observation of flashing beacon on T–33A
Feb. 11	Mon	Flight-plan briefing to Deputy Director for Mission Requirements
Feb. 12	Tues	Flying (F–102A)
Feb. 20	Wed	Flying (F–102A), flight-food testing
Feb. 21	Thurs	Experiments briefings
Feb. 23	Sat	Flying (T–33A)
Mar. 1	Fri	TV systems test
Mar. 4	Mon	Communication systems radiation test
Mar. 6	Wed	Weight and balance
Mar. 8	Fri	Flying (F–102A)
Mar. 12	Tues	Couch fitting
Mar. 13	Wed	Flying (T–33A, F–102A)
Mar. 14	Thurs	Communication systems radiation test
Mar. 15	Fri	Communication systems radiation test, Mercury Procedures Trainer
Mar. 19	Tues	Darkness and egress test
Mar. 20 to 24	Wed. to Sun	Simulated flight (Hangar)
Mar. 24	Sun	Flying (F–102A)
Mar. 26	Tues	Flying (T–33A)
Mar. 27	Wed	Flying (T–33A), Mercury Procedures Trainer
Mar. 28	Thurs	Flying (T–33A), Centrifuge—acceleration refamiliarization
Mar. 29	Fri	Mercury Procedures Trainer
Apr. 1 and 2	Mon. and Tues	Mercury Procedures Trainer
Apr. 4	Thurs	DOD–NASA MA–9 Review, Prepad RCS test
Apr. 5	Fri	Mercury Procedures Trainer, flying (TF–102A), Morehead Planetarium (Celestial review)
Apr. 6	Sat	Morehead Planetarium (Celestial review)
Apr. 7	Sun	Flying (F–102A)
Apr. 9	Tues	Flying (F–102A)
Apr. 10	Wed	Egress and recovery training
Apr. 11	Thurs	Egress and recovery training, survival pack exercise
Apr. 15	Mon	Flying (F–102A)
Apr. 16	Tues	Mercury Procedures Trainer, mission and flight controller briefing
Apr. 17	Wed	Mission and flight controller briefing
Apr. 18	Thurs	Alinement, weight, and balance; Mercury Procedures Trainer
Apr. 19	Fri	Mercury Procedures Trainer

Date	Day	Activities
Apr. 22	Mon	Mechanical mate
Apr. 23	Tues	Simulated flight no. 1
Apr. 24	Wed	Electrical mate
Apr. 25	Thurs	Mercury Procedures Trainer
Apr. 27	Sat	Mercury Procedures Trainer
Apr. 29	Mon	Yaw demonstration (AF Hangar)
Apr. 30	Tues	Systems briefings (review)
May 1	Wed	Systems and operations examination
May 2	Thurs	Launch simulation, Mission Rules review
May 3	Fri	Examination questionnaire review, marked spacecraft's normal and emergency instrument limits
May 4	Sat	Launch simulation
May 5	Sun	Flying (TF–102A)
May 6	Mon	Flight configuration sequence and aborts
May 7	Tues	Network simulation, Flight Plan Procedures training
May 8	Wed	Launch simulation and RF compatibility tests
May 9	Thurs	Network simulation
May 10	Fri	Simulated flight no. 3, flying (F–102A)
May 11	Sat	Mission Status Review, flight-plan and experiments briefings
May 12	Sun	Network simulation, physical examination
May 13	Mon	Mercury Procedures Trainer, mission review
May 14	Tues	Countdown (canceled)
May 15	Wed	Launch

Integration of the Pilot and the Spacecraft

After the spacecraft had been delivered to the launch site, a primary opportunity was provided for the pilot to operate the actual controls of the spacecraft. The participation of the MA–9 pilot with the checkout activities of the spacecraft is listed in table 10–VI(a) and a summary of the time spent in the actual spacecraft of all

Table 10–VI.—Pilot Time in Spacecraft During Hangar and Launch Complex

(*a*) *MA–9 Pilot Time in Spacecraft 20*

Date	Test description	Duration, hr:min
Oct. 11 to 19, 1962	Integrated systems tests	06:45
Nov. 11, 1962	RCS–hangar	03:15
Jan. 5, 1963	Altitude chamber	06:45
Jan. 12 and Mar. 1, 1963	TV systems test	07:00
Mar. 4, 14, 15, 1963	Communications systems radiation test	04:45
Mar. 19, 1963	Darkness and egress	01:20
Mar. 20, 21, 22, 1963	Simulated flight, hangar	12:10
April 4, 1963	Prepad RCS test	00:50
April 18, 1963	Alinement, weight, and balance	04:00
April 23, 1963	Systems test and simulated flight no. 1	04:00
April 24, 1963	Electrical mate	04:30
May 3, 1963	Mark instrument normal and emergency limits	00:45
May 6, 1963	Flight configuration sequence and abort	03:00
May 8, 1963	Launch simulation and RF compatibility	05:00
May 10, 1963	Systems test and simulated flight no. 3	03:45
May 14, 1963	Countdown (canceled)	06:00

Table 10-VI.—Concluded.

(b) Approximate Time in Flight Spacecraft During Preparation Periods for Each Orbital Flight

Flight	Time, hr
MA-6	25:55
MA-7	45:00
MA-8	31:27
MA-9	73:50
Average	44:03

the orbital pilots is given in table 10-VI(b). This activity is essential, since:

(1) An opportunity was provided to make final adjustments of personal equipment, such as the pressure suit, survival equipment, food items, and check lists to satisfy the special requirements of the flight spacecraft and the pilot.

(2) These tests provided an opportunity to check out the spacecraft system with the man in the loop; thus, for example, the adequacy of the environmental control system was checked with the pressure drop resulting from the pilot in his suit.

(3) The pilot became familiar with the specific configuration and performance of his spacecraft. The settings for the cooling system or the feel characteristics of the control systems vary slightly from spacecraft to spacecraft, and the pilot had an opportunity to become familiar with these features of the vehicle he would fly.

(4) The pilot had an opportunity to gain further familiarity with the prelaunch checkout procedures on the launch pad. During this time, he learned his role in the countdown and became familiar with the instrument indications and the lights and sounds that accompany the various tests as the vehicle is readied for flight.

Systems Training

A second major area of activity of the astronauts during this period was in systems training for his spacecraft. This systems training began with one or more series of lectures by the engineers involved in the checkout of the vehicle. Each lecture covered a specific system in great detail, emphasizing operational techniques and functional interrelationships. These systems lectures were then followed by extensive practice in emergency procedures on the Mercury procedures trainer. A problem was encountered in modifying the Mercury procedures trainer no. 2 to keep it as close as possible to the configuration of each spacecraft. It was, of course, impossible to make them completely identical. However, in general, it was possible to alter the trainer so that as the spacecraft systems were modified, the changed performance would be reflected to the pilot during simulations. When modifications could not be made, it was extremely important to make the pilot aware of the differences between the trainer's operation and the flight operation so that he could keep them clearly in mind.

Table 10-VII(a) summarizes the MA-9 pilot's training on Mercury Procedures Trainer no. 2 whereas table 10-VII(b) shows the total amount of time spent on the Mercury procedures trainer by the pilots of the four orbital missions during their preflight training program. Also indicated in table 10-VII(b) are the numbers and categories of malfunctions experienced. These data give some indication of the amount of time devoted to recognition and correction of the many malfunctions which could be programed into the trainer. The relative emphasis to be placed on emergency procedures in comparison with normal mission activities is difficult to assess. This seems to be a characteristic which may be increasingly true in the future, since a major function of the man may be to correct malfunctions of the vehicle's systems.

Table 10–VII.—Summary of Time Spent on MPT No. 2 During Preflight Preparation Period

(a) *MA–9 Pilot*

Date, 1963	Type of training	Time, hr:min	Number of simulated missions	Number and type of simulated missions						Special training activities ([a])
				ECS	RCS	Sequential	Electrical	Communications	Other	
Mar. 15	Flight checklist review	02:15	4							1, 3, 4
Mar. 27	Attitude control practice	01:45	1							1, 4
Mar. 29	Simulated systems failures	02:30	8	3	2	4	3	1	1	1, 2, 3, 4
Apr. 1	Simulated systems failures	02:30	5	2		5	2	1	1	1, 2, 3
Apr. 2	Simulated systems failures	02:00	3		2	5	1			2, 3
Apr. 5	Simulated systems failures	01:30	2	2		2		1		2, 3
Apr. 18	Simulated systems failures	02:15	4	2	1	4	4		1	1, 2, 3
Apr. 19	Simulated systems failures	03:45	6	1	1	4	3	1	1	2, 3, 5
Apr. 25	Flight-plan activities	02:00	2	1						1, 4
Apr. 27	Simulated systems failures	01:30	3		1	1	1	1		1, 2, 3
May 2	MCC–BDA simulation	01:30	2			2	1			2, 3
May 4	MCC–BDA simulation	01:30	2	2		1	1		1	2, 3
May 7	Network simulation and flight-plan activities.	05:00	2							1, 4, 5
May 9	Network simulation	01:00	2							1
May 12	Network simulation	01:00	1			1				1
May 13	Simulated systems failures	01:30	5		1	3	1		1	1, 2, 3
Total		33:30	52	13	8	32	17	5	6	

[a] The column numbers refer to the following activities:
1—Normal launches and reentries
2—Launch aborts
3—Orbital and reentry emergencies
4—Retrofire or reentry attitude control
5—Flight-plan activities

Table 10-VII.—Concluded

(b) Four Orbital Pilots

Flight	Number of Missions	Total Hours on MPT no. 2	Number and type of failures					
			ECS	RCS	Sequential	Electrical	Communication	Other
MA-6	80	59:45	30	24	57	35	11	25
MA-7	73	70:40	24	11	43	26	7	32
MA-8	37	29:15	10	5	22	15	5	11
MA-9	52	33:30	13	8	32	17	5	6
Average	60	48:35	19	12	38	23	7	18

Flight Plan Development and Training

The pilot also participated in the development and practice of a mission flight plan, which varied considerably in each mission. (See paper 17.) The astronaut participated in this process to help insure that he adequately understood the requirements and that the specific procedures could be carried out without compromising other mission requirements. The flight plan activities were tried out in the Mercury procedures trainer to determine the best procedures and equipment configurations. Since it was highly desirable to give the pilot ample opportunity to practice the flight plan and to get experience with the experimental equipment prior to the flight, it was essential to finalize the flight plan and have the experimental equipment ready well ahead of the launch date.

In addition to the practice of the specific mission activities in the Mercury procedures trainer, a number of special refresher training activities were conducted. Normally, each of the flight crews received a short refresher training program on the centrifuge. In this program no attempt was made to provide a complete simulation of the Mercury instrument panel or control tasks. The pilots normally experienced from six to eight launch or reentry profiles in the centrifuge to help refresh them in their breathing and straining techniques.

The flight crews also normally received a planetarium indoctrination (fig. 10–I(h)) to help them review the celestial sphere as seen from orbit. Since these programs were held close to the flight date, it was normally possible to simulate the appearance of the sky on the actual day of the launch and to simulate some of the special astronomical phenomena to be observed during the flight.

Combined Astronaut-Flight Controller Training

A fourth area of training conducted during the preflight period was the combined training of the astronaut with the flight control groups. For this training the Mercury procedures trainer no. 2 was tied into the Mercury Control Center's simulation equipment so that the astronaut could communicate directly with the flight controllers and the vehicle parameters from the Mercury procedures trainer no. 2 would be displayed to the flight controller in the same form as the vehicle data during the flight. Two types of training runs were made. The first was the launch-emergency training sessions in which only the launch portion of the mission was simulated. Various types of emergencies were simulated, some affected the astronaut but most involved information displayed to the controllers. During this time the astronaut and the ground flight controllers had an opportunity to become familiar with each other's procedures and to refine the launch communications and emergency procedures. Following each run, a debriefing session would be held to critique the run and to modify any procedures which did not appear adequate.

Following the launch abort simulations, network simulations were run with the flight controllers. On these simulations the pilot, through the hardline, could be in direct communication not only with the launch control center but with the other flight-control sites in the United States and Australia. In these simulations the pilot would frequently take part, thereby providing some of the stations with an opportunity to become familiar with his particular voice and communication patterns. This was particularly significant for the medical monitors since they made use of voice communications as one of their major monitoring aids. While these sessions were highly valuable for the flight controller, they were less valuable for the astronaut since much of his time would be spent with the spacecraft in the orbital configuration with little or no opportunity to practice emergency procedures. As a result, the astronaut frequently went through a launch and perhaps one-orbital pass with the network simulation and then spent the rest of his time in the simulator, carrying out emergency procedures and other special activities in which he particularly needed practice.

Medical and Physical Preparation

A final area of activity during this preflight period was in the medical and physical preparation of the astronaut. During this period, the final physical examinations, establishing the fitness of the pilot for the flight, were given and the majority of the baseline data with which the inflight results would be correlated was collected. It was also during this period that the astronaut was placed on a special diet in order to prevent possible solid waste problem during the flight. Medical preparations for the flight are described in greater detail in paper 11.

During this preflight period each of the astronauts intensified their physical fitness program, bringing it to a peak shortly before the launch date. This physical activity was important not only in insuring a high level of fitness at the time of launch but it also served the purpose of giving the pilot an opportunity to relax from the pressing technical problems which occupied the majority of his day. Overall, the problem of maintaining good physical fitness and avoiding excessive fatigue during this period was a serious one.

Concern was expressed in some quarters that the repeated delays which often occurred in the launch date would produce anxiety in the pilot or result in a letdown in proficiency due to "over training" or loss of motivation. No such effects were noted with any of the pilots. Astronaut Glenn experienced the longest delay following a launch attempt (30 days) with no undesirable effects either by his own account (ref. 14) or as indicated by his trainer performance. His performance on the retrofire control task for the month before and after the postponement of his flight is shown in figure 10–4. As

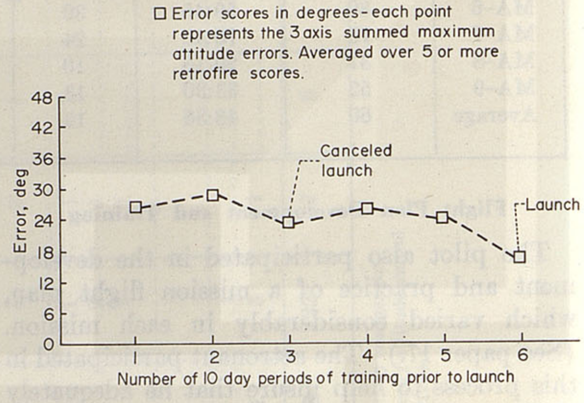

FIGURE 10–4.—Procedures trainer retrofire attitude control scores. MA–6 pilot.

can be seen there is no evidence of decrement in performance following the postponed launch.

Training Evaluation

The inflight performance of the pilot provides the best indication of the adequacy of the astronaut training program. Further verification was provided by comparing performance of specific maneuvers during flight with those on the trainers, and by having the pilots' comment on the value of the various training devices.

In those cases where specific flight maneuvers were practiced on the procedures trainer, comparisons can be made between the attitudes held in the trainer and those maintained in flight. This has been done in all previous flight reports in the sections on pilot performance (refs. 15 to 19). However, the number of these comparisons is limited since many periods of manual maneuvering could not be compared with ground data because the specific maneuver carried out during flight was not practiced under controlled conditions or because the maneuver involved attitudes outside the limits of the autopilot sensing system, in which case, attitude data would not be available from the gyro indicators.

A great deal of evaluative material was obtained from the astronauts during the debriefings following each mission. In general, the astronauts reported that while weightlessness was generally pleasant, there was a short period during the flight when they felt that they needed some time to adapt to both the weightless experience and to the novel view through the spacecraft window. (See paper 20.) Both of these features of the space flight were inadequately simulated during the training periods since the weightless condition could not be simulated for more than a minute and, until late in the program, there was no dynamic simulation of the view through the Mercury spacecraft window. This adaptation period, to the orbital flight condition, might have been reduced had it been possible to have a simulation of the external view and more prolonged weightless experience. In any case, this small adaptation period was not a serious problem for any of the astronauts.

The pilots were unanimous in indicating the importance of their participation in the checkout of the spacecraft during the period just prior to the flight. Many of them felt that this was the most valuable single portion of the training program. All of the pilots felt that the procedures trainer was the single, most useful training device. However, there were variations among them in the opinions of the amount of time required on the trainer prior to the flight. There was also general agreement that the centrifuge was the most critical environmental simulation device and that a short refamiliarization experience on the centrifuge prior to the flight was highly desirable.

The Mercury flight program was too limited to evaluate in detail all the many training devices and programs which were used in the astronaut training program. However, the best estimate of the authors as to the relative utility of the various trainers and programs are indicated in Table 10–I in the last column. In considering these ratings, the reader should note that they apply to programs with the special features of the Mercury training program listed in the introduction to this section. In addition to these ratings, the following general conclusions appear warranted:

(1) The devices and programs used in the Mercury astronaut training program were adequate to provide transition training for skilled pilots to the operation of a spacecraft.

(2) The program could have been shortened and made more efficient had adequate training facilities been available at the initiation of training and in one location.

(3) The most important environmental factors requiring simulation during the training were linear acceleration and the reduced mobility produced by the pressurized suit.

(4) Other environmental simulations were desirable but not critical to adequate flight preparation. This conclusion includes the weightless experience. However, it should be noted that training in weightlessness was relatively unimportant in the Mercury program because the astronaut was unable to move from the seat.

(5) Simulations involving actual flight hardware in realistic environments were studied and generally found to involve more cost and risk than could be justified by their training value, unless they were required for vehicle checkouts.

(6) Experience in the actual vehicle to be flown prior to the flight is a highly essential feature of the preflight preparation and is an exception to the foregoing generalization.

(7) Flight plans and all experimental and other movable equipment items which will be used within the spacecraft must be available and finalized well in advance of the launch date in order to permit adequate time for training in their use.

(8) A fixed-based simulator with dynamic displays is generally adequate for orbital flight training since angular and linear acceleration cues are relatively insignificant in the weightless condition. However, in certain cases motion may simplify the simulation problem.

(9) Two simulators are necessary in order to support both the general group training program at the central site and the preflight preparation program at the launch site.

(10) External view simulation on the full-mission simulator is essential since much of the orbital maneuvering will be done with the external view used as a reference.

(11) Integrated flight crew-flight controller training is essential to refine mission rules and communication procedures.

(12) Flexibility in the design of all trainer systems is essential in order to permit modification to fit the particular configuration of each flight vehicle.

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11. AEROMEDICAL PREPARATIONS

By Charles A. Berry, M.D., *Chief, Center Medical Operations Office, NASA Manned Spacecraft Center*

Summary

The lessons learned from the operational medical program conducted in Project Mercury are discussed in this paper.

The objectives of the medical portion of the crew selection program were met, and detailed physical examinations on even select test pilot groups have found rejectable defects. Stress-testing has been made part of a selection-in-depth training program.

Medical training given to the astronauts has been of great value during inflight monitoring and discussion of medical problems.

Medical maintenance has included routine medical care, and annual and special physical examinations. Close association of the flight surgeon and the astronaut in training has produced an excellent preventive medicine practice. The flight crew surgeon is best fitted to determine the astronaut's readiness for flight, but a specialist team conducts the examination for baseline data to compare with postflight data. Preflight examinations were conducted before each checkout procedure and more formally at 10 days and 3 days before flight, and on flight morning. Longer missions with Pacific recovery caused modification of the postflight examinations. The importance of practice runs of most of the medical procedures was shown and a medical countdown was developed and integrated with the Mercury Control Center (MCC) and blockhouse countdown.

Complete isolation of the crew is impractical and has depended on a reduction of stronger contacts in the immediate preflight period.

Drugs were provided in injectors, and pills were available in flight and in the survival kit. The only drug used was the dextro-amphetamine sulfate on the MA–9 mission. The astronaut must always be pre-tested to any drug he may use. Scheduling of rest, activities, and exercise periods is necessary. A method of obtaining separate urine samples was successfully used. Dietary control of defecation was successful. Inflight food and water ingestion must be scheduled.

Medical monitoring was performed for flight-safety reasons and for aiding the surgeons in making go–no–go recommendations to the operations director. The value of range flight simulations and of the medical flight controller has been shown. Parameters monitored included body temperature, respiration, electrocardiogram, blood pressure, and voice. The comparison and correlation of readings with environmental data are stressed. Correlation of inflight events and physiological responses is very meaningful. The space-flight environment, while exposing men to numerous stresses, has produced no unmanageable physiological overload. Postflight orthostatic hypotension has been noted for a period of several hours.

Recovery operations have been modified from taking medical care to the astronaut to taking the astronaut to medical care. The support has been trimmed to require fewer highly trained personnel to "wait it out" at the launch site.

Project Mercury gave the opportunity to define more closely the medical problem areas as the future is anticipated with great expectations and confidence in man's ability to adapt to and conquer this new frontier.

Introduction

The development of an operational medical program for Project Mercury posed a challenge to the national aerospace medical community in line with that which the orbiting of man posed to the national engineering community.

The purpose of this paper is to review briefly and necessarily incompletely the medical operations and findings from all our manned space flights and to emphasize the knowledge ac-