

MERCURY OPERATIONAL EXPERIENCE

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Introduction

A number of papers have been given previously, both to the IAS and other scientific organizations, which deal with the operational planning for Project Mercury^{1,2}. This paper deals with the operational experience gained from the development of facilities to perform real-time flight control and the experience gained from using these facilities. The discussion of this experience is primarily limited to the Mercury-Atlas orbital flights leading up to and including the flight of Astronaut John H. Glenn, Jr. In addition, the over-all recovery operation is discussed.

Network Stations

The orbital track flown in the three-orbit Mercury flight and the location of the network tracking stations established around the world to maintain contact with the spacecraft are presented in figure 1. This orbit and the supporting network were chosen for a number of reasons but primarily on the basis of the following:

- (1) The desire to use the tracking facilities already available in the southern United States and the instrumentation on the Atlantic Missile Range
- (2) The desire to obtain continuous tracking and voice contact with the astronaut throughout the powered flight and the insertion into orbit and during the reentry and landing phases
- (3) The belief that radar tracking data should be available from a number of strategic locations around the world to establish the orbit properly
- (4) The desire to maintain voice contact with the astronaut as often as possible during the early phases of the flight and on the order of every 15 to 20 minutes thereafter
- (5) The need to remain within the temperate zones of the earth so that the design requirements on the spacecraft and the dangers of cold weather to the astronaut after landing could be reduced

All of these sites had voice and telemetry capabilities with the spacecraft. A large number of the sites had either C- or S-band radar tracking capability with teletype data facilities back to the Central Computing Center at Washington, D. C. The sites at Cape Canaveral; Bermuda; Muehea, Australia; Hawaii; Guaymas, Mexico; and California had facilities for radio command to the spacecraft. Teletype to and from the Control Center at Cape Canaveral was available to all the sites, and the capability of voice was provided from Hawaii through Bermuda and to the two sites in Australia. In addition, during John Glenn's flight, voice was provided to the Canary Islands and by single-sideband radio to the ships in the Indian Ocean and off the west coast of Africa.

The Communications and Computing Center is located at the NASA Goddard Space Flight Center, Greenbelt, Md., and high-speed data lines and voice and teletype lines were provided from this center to the Mercury Control Center at Cape Canaveral. All of these facilities were provided with the background of previous flight-test experience and on the basis of the safest operational concepts so that the safe recovery of the astronaut could be assured and to provide sufficient capability for controlling both unmanned and manned orbital flights. A great deal of experience has now been obtained from operating this complex network and should prove beneficial to future space-flight programs.

Based on the knowledge gained from the three Mercury-Atlas orbital flights flown to date, the following conclusions can be drawn:

The facilities provided by this network are, in most cases, more than adequate to provide both orbital information and data for performing flight control for unmanned and manned flights. Experience has shown that with the tracking and computing complex at Cape Canaveral and Washington, D. C., the orbital elements can be determined within a very few seconds after launch-vehicle cutoff with sufficient precision to assure control of the space vehicle should some abort condition present itself. Additional tracking obtained during the first half of the first orbit refines these computations to some extent and, together with the cutoff conditions, provides extremely accurate spacecraft positions for at least a three-orbit mission.

The computer program provided essentially real-time spacecraft position and, although complex, it has shown the capability of handling almost any trajectory problem which could exist. The radar tracking system has shown that low-altitude orbits can be acquired and tracked with a high degree of accuracy provided proper acquisition data and systems are available.

In all cases, horizon-to-horizon coverage on UHF, which provided excellent telemetry and voice contact with the spacecraft, was possible. The use of HF extended the contact times by about 2 minutes at each site and is considered an important adjunct to the spacecraft communications system. The command capabilities to the spacecraft proved to be adequate and useful and, of course, a necessity for unmanned operations. In this case, the coverage from a given site was more dependent upon antenna patterns than the other UHF systems, but with minor design changes horizon-to-horizon coverage is also believed to be possible with this system. As noted previously, either teletype or voice, or both, were available to all of the sites. However, experience has shown that voice facilities to all sites are highly desirable. The use of voice has proven to be very useful in providing real-time flight control, as evidenced by the rapid decisions required in the last two orbital flights. In conclusion, except for the voice requirements, the network facilities provided in

past flights appear to be in most cases more than adequate to support manned orbital flights.

In order to perform real-time flight control, the computing program and the computing complex provides the heart of this capability. Experience has shown that programs can be developed such that rapid decisions can be made within a few seconds of almost any foreseeable emergency situation. However, careful attention must be given to the data displays and the method in which these data are presented. The displays must be simple and the actual numbers of displays must be minimized. The point to be made here is that only the final decision-making processes should be displayed for human judgment, and that any processes involving arithmetic should be left for automatic computer decision. One of the most significant lessons to be gained from our experience is the need to bring the flight control personnel together with the computer programmers and the computing complex. These engineers and mathematicians must work together intimately to provide proper flight control. Also, the development and checkout of the programs and displays require that all of these elements be together in one location on a continuous basis. It might be pointed out that the computers were used in Project Mercury for making only those computations associated with trajectory information. Future space programs will require computer programs and equipment to aid in making decisions regarding spacecraft systems performance and other tasks which may require rapid decision-making processes.

Flight Simulation

The most powerful tool developed in conjunction with the Mercury network was the capability of simulating all phases of the flight. The simulation provided training for both the astronaut and the flight control team in all aspects of the flight operation. In addition to training, the simulation facilities provided an excellent means of checking all of the network facilities and allowed development of operating procedures well in advance of an actual flight test. This flight simulation proved to be an important adjunct to the training of the maintenance and operating people at all of the sites in that it provided realistic problems in many phases of network operations.

The flight simulation was accomplished with the use of two facilities, both of which were provided with a Mercury spacecraft procedures trainer. One of these facilities utilized a complete simulation of a remote-site flight-control facility. The second and most beneficial facility was the one developed in conjunction with the Mercury Control Center. With this facility, not only could the astronaut and the procedures trainer be realistically tied in with the control center to simulate the powered phase of the flight, but a complete trajectory simulation was possible by using the actual launch and orbit computer programmers. Also, by using taped procedures trainer outputs, each of the sites around the network was able to simulate in the proper sequence an entire three-orbit flight. A complete description of this system is not presented in this paper, but the importance of this equipment to the success of the mission cannot be too strongly emphasized. Although the flight-control procedures and ground

rules were thoroughly thought out through paper studies, the simulation facilities provided the best means of proving and improving these procedures and rules. In fact, a great deal of the success of the Mercury flights can be directly attributed to these simulations.

As previously mentioned, mission rules for all phases of the operation beginning with the count-down and ending with recovery were established previous to each operation. The development of these rules and of the flight-control concepts began at the same time, which was a considerable length of time before any of the Mercury flight operations. The mission rules were established in an effort to provide for every conceivable situation which could occur onboard the spacecraft; that is, consideration of both the astronaut and the spacecraft systems and all of the conceivable ground equipment failures which could have a direct bearing on the flight operation. In addition, rules were established in an effort to handle a large number of launch-vehicle malfunctions. These rules of course, dealt primarily with the effects of a sudden cutoff condition and its effect on the spacecraft flight thereafter. As pointed out, these rules were established for the prelaunch, powered flight, and orbital flight phases of the mission.

Because of the complexity of the entire operation and the critical time element of powered flight, it was felt and borne out by flight experience that such a set of rules was an absolute necessity. Of course, it is impossible to think of everything that can happen; but if most of the contingencies have been anticipated, the rest of the time can be used to concentrate on the unexpected. Also, the simulated flights were an excellent test bed for all of these rules and many changes came about as a result of these tests. Furthermore, through simulations of the malfunctions covered by the mission rules, a much better understanding of all of the operating problems and spacecraft systems was achieved, and a number of problem areas was uncovered. Because of the many operating problems, the need for this type of operations analysis cannot be overemphasized. As a matter of fact, such a set of mission rules would be extremely useful to the conceptual design of any space flight program, and it would be beneficial to have these rules during the initial phases of the program as a set of design guidelines.

Flight Control

The organizational setup to perform control of the flight is presented in figure 2. This organization is limited to that group performing direct flight control from lift-off to landing. Within the Mercury Control Center the Operations Director was, of course, the over-all director of the entire flight operation with a Network Commander and a Recovery Commander supplying the necessary command-level support to the operation. The Flight Director had detailed flight-control responsibility for the flight following lift-off of the space vehicle. The organization used to perform the flight control activities is as shown by the block diagram. There was a Support Control Coordinator responsible for managing and operating the systems support to the Control Center. The Assistant Flight Directors, normally several people, provided necessary administrative and procedural support during both prelaunch

and the flight operation. The Network Status Monitor was responsible for the entire Mercury network during operating periods and for conducting the network countdown. The Launch-Vehicle Monitor was responsible for monitoring primarily the operation of the automatic abort system in the launch vehicle. In the bottom row of the diagram are the main flight-control elements who supported the Flight Director and actually performed the detailed control of the flight. The Flight Surgeon was responsible for all of the aeromedical aspects of the mission. The Environmental Control Monitor was responsible for the life-support system within the spacecraft. The Capsule Communicator maintained voice communications with the astronaut during the powered phase of the flight and when the spacecraft was over the Mercury Control Center. The Capsule Systems Monitor observed all of the spacecraft systems, such as, the reaction control system, attitude control system, and electrical control system. The Retrofire Controller was responsible for all of the times of retrofire associated with both the normal and aborted flights. The Flight Dynamics Officer had over-all control of the computing complex supporting the operation, monitored the various trajectory displays indicating launch-vehicle performance, and with the computer made the "go-no-go" decision at orbital insertion. All of these primary flight controllers had responsibility over their respective areas, not only during powered flight but during all of the orbital flight and reentry, and made recommendations to the Flight Director on their particular systems.

Figure 3 shows the organization of a typical remote site. The Capsule Communicator at the site acted as the Flight Director for a particular location and was responsible by voice and teletype to the Mercury Control Center. He was the engineer responsible for communicating with the astronaut and for making any decisions affecting the flight operation. He had a maintenance operations supervisor responsible for the detailed systems support at the site, a systems monitor who observed all of the major spacecraft systems, and, again, an aeromedical monitor responsible for the aeromedical aspects of the astronaut and the spacecraft.

Figures 4 and 5 present photographs of the Mercury Control Center and a typical remote site. The Mercury flight experience has shown that this size organization is about as big as can be coped with and still perform the flight control task. In the future, every effort must be made to automate as many of the systems outputs as possible so that only the final systems performance parameters are presented to the flight controllers and thereby limit the number of engineers required to analyze the flight performance.

Recovery Operations

The recovery operations for Project Mercury were, of course, one of the largest and more complex aspects of all of the operating plans required for the test. The following discussion is given as a description of the forces set up for the orbital flight of John Glenn. The recovery areas setup for this operation can be considered in two broad categories: Planned recovery areas in which the probability of landing was considered sufficiently high to require the positioning of location and retrieval units to assume recovery within a

specific time; and contingency recovery areas in which the probability of landing was considered sufficiently low to require only the utilization of specialized search and rescue procedures.

The planned recovery areas were all located in the North Atlantic Ocean as shown in figure 6, and table I is a summary of the support positioned in these areas at launch time for the MA-6 flight.

Special recovery teams utilizing helicopters, amphibious vehicles, and salvage ships were located at the launch site to provide rapid access to the spacecraft for landings resulting from possible aborts during the late countdown and the early phase of powered flight. Winds at the launch site were measured and the locus of probable landing positions for various abort times were computed to facilitate positioning of these recovery forces.

Areas A to E supported all probable landings in the event an abort was necessitated at any time during powered flight. Area A would contain landings for abort velocities up to about 24,000 feet per second, and Areas B, C, D, and E would support higher abort velocities where programed use of the retrorockets become effective in localizing the landing area. Forces as shown in table I were positioned in these areas to provide for location and retrieval within a maximum of 3 hours in the areas of higher landing probability and 6 hours in the area where the probability of landing was somewhat lower.

Once the spacecraft was in orbital flight, Areas F, G, and H were available for landing at the end of the first, second, or third orbits, respectively. Forces as shown in table I were available to assure location and retrieval within a maximum of 3 hours for most probable landing situations.

Thus, to assure short-time recovery for all probable aborts that could occur during powered flight and for landings at the end of each of the three orbits, a total of 21 ships, 12 helicopters, and 16 search aircraft were on station in the deep-water landing areas at the time of the MA-6 launch. Backup search aircraft were available at several staging locations to assure maintaining the airborne aircraft listed in table I. These forces in the planned recovery areas were all linked by communications with the recovery control center located within the Mercury Control Center at Cape Canaveral.

Since it was recognized that certain low probability situations could lead to a spacecraft landing at essentially any point along the ground track over which the spacecraft flies, suitable recovery plans and support forces were provided to cover this unlikely contingency. In keeping with the low probabilities associated with remote landings, a minimum of support was planned for contingency recovery; however, a large force is required because of the extensive areas covered in three orbits around the earth. The location of contingency recovery units for the MA-6 flight is shown in figure 7. A typical unit consists basically of two search aircraft specially equipped for UHF/DF homing on spacecraft beacons, point-to-point and ground-to-air communications, and pararescue personnel equipped to provide on-scene assistance on both land and water. No retrieval forces were deployed in support of contingency landings;

however, procedures were available for retrieval support after the fact. These search and rescue units were stationed at the 16 locations shown in figure 7 and were all linked by communications with the recovery control center at Cape Canaveral. Throughout the MA-6 flight, the astronaut was continually provided with retrofiring times for landing in favorable contingency recovery areas. However, the contingency forces deployed had the capability of flying to any point along the orbital track if required.

Weather

As the whole world now knows, one of the most difficult operating problems encountered was the weather. Early in the project the NASA solicited the aid of the U.S. Weather Bureau in setting up an organization to supply pertinent weather information. This group developed means for obtaining fairly detailed weather data along the entire three-orbit track of the Mercury mission. This information was analyzed in many different ways to provide useful operational information. For instance, detailed analysis of the weather over the Atlantic Ocean for various periods of the year was made to provide a basis of planning the flight and to provide a background knowledge as to what could be expected to develop from day to day once a given weather pattern had been determined. As a guideline, weather ground rules were established on the basis of spacecraft structural limitations and recovery operating capabilities. These included such details as wind velocity, wave height, cloud cover, and visibility. During the days previous to and on the day of the operation, the U.S. Weather Bureau meteorologists provided weather information for all of the preselected recovery areas and the launching site. The other weather limitation was the result of the desire to obtain engineering photographic coverage in the launch area.

Flight Control and Recovery Operations for MA-6

In order to illustrate how the over-all operation is conducted, the MA-6 flight of John Glenn and the flight control and recovery operations utilized will be described starting with the initial countdown and ending with the final recovery operation.

The countdown for launching the Mercury-Atlas vehicle is conducted in two parts. The first part is conducted on the day before the launch and lasts approximately 4 hours. During this period detailed tests of all of the spacecraft systems are performed and those interface connections important to these systems are verified. This part of the countdown was conducted with no major problems or holds resulting. Approximately 17 1/2 hours separated the end of this count and the beginning of the final countdown, and during this period the spacecraft pyrotechnics were installed and connected and certain expendables such as fuel and oxygen were loaded.

At T-390 minutes the countdown was resumed and progressed without any unusual instance until T-120 minutes. During this period additional spacecraft systems checkouts were performed and the major portion of the launch vehicle countdown

was begun. At T-120 minutes a built-in hold of 90 minutes had been scheduled to assure that all systems had been given sufficient time for checkout before astronaut insertion. During this period a problem developed with the guidance system rate beacon in the launch vehicle causing an additional 45 minute hold, and an additional 10 minutes was required to repair a broken microphone bracket in the astronaut's helmet after the astronaut insertion procedure had been started. The countdown proceeded to T-60 minutes when a 40 minute hold was required to replace a broken bolt because of misalignment on the spacecraft's hatch attachment. At T-45 minutes, a 15 minute hold was required to add fuel to the launch vehicle; and at T-22 minutes an additional 25 minutes was required for filling the liquid-oxygen tanks as a result of a minor malfunction in the ground support equipment used to pump liquid oxygen into the launch vehicle. At T-6 minutes and 30 seconds, a 2 minute hold was required to make a quick check of the network computer at Bermuda. In general, the countdown was very smooth and extremely well executed. A feeling of confidence was noted in all concerned, including the astronaut, and it is probably more than significant that this feeling has existed on the last three Mercury-Atlas launches.

The launch occurred at 9:47:39 a.m. e.s.t. on February 20, 1962. The powered portion of the flight which lasted 5 minutes and 1 second was completely normal and the astronaut was able to make all of the planned communications and observations throughout this period. Throughout this portion of the flight no abnormalities were noted in either the spacecraft systems or in the astronaut's physical condition. The launch-vehicle guidance system performed almost perfectly, and 10 seconds after cutoff the computer gave a "go" recommendation. The cutoff conditions obtained were excellent.

Table II presents the actual cutoff conditions that were obtained. The altitude achieved was 528,381 feet and the spacecraft velocity achieved was 25,730 feet per second. The other significant quantity, flight-path angle, was -0.047° at cutoff. The other quantities shown in the table give more information on the flight parameters. These values include a perigee of 86.92 nautical miles, an apogee of 140.92 nautical miles, an orbit period of 88 minutes and 29 seconds, and an inclination angle of 32.54° . Also shown are the maximum accelerations achieved during exit from and entry into the earth's atmosphere, both of these values being 7.7g. All of these values were within the expected tolerances for the launch vehicle and its guidance system. The Mercury network computing system performed flawlessly throughout both the powered and orbital phases of the flight and provided complete information on the orbit, spacecraft position, and retrofire times necessary for all of the recovery areas. A comparison of the planned and actual times at which the major events occurred are given in table III and the times at which all of the network sites acquired and lost contact with the spacecraft are presented in table IV.

The flight test experience which had been achieved on the previous Mercury-Atlas orbital flights, that is, the MA-4 and MA-5, had given the flight control team an excellent opportunity to exercise control over the mission. These flights

were, of course, much more difficult to control and complete successfully because of the lack of an astronaut within the spacecraft. All of the analyses and decisions had to be made on the basis of telemetered information from the spacecraft. The presence of an astronaut made the flight test much more simple to complete, primarily on the basis of astronaut observations and his capability of systems management. A manned flight, however, makes the job of monitoring spacecraft performance more complex because of the large number of backup and alternate systems from which the astronaut could choose.

After separation of the spacecraft from the launch vehicle, the astronaut was given all the pertinent data involved with orbit parameters and the retrofire times necessary had immediate reentry been required. Following these transmissions, which were primarily from the Bermuda site, the astronaut made the planned checks of all of the spacecraft control modes using both the automatic and manual proportional systems. These checks indicated that all of the control systems were operating satisfactorily. Also, the astronaut reported that he felt no ill effects as a result of going from high accelerations to weightlessness, that he felt he was in excellent condition, and, as the two previous astronauts had commented, that he was greatly impressed with the view from this altitude.

The first orbit went exactly as planned and both the astronaut and the spacecraft performed perfectly. Over the Canary Islands' site, the astronaut's air-to-ground transmissions were patched to the voice network and in turn to the Mercury Control Center and provided the control center and all other voice sites the capability of monitoring the transmissions to and from the spacecraft in real-time. This condition existed throughout all three orbits from all sites having voice to the control center and provided the best tool for maintaining surveillance of the flight.

Except for the control systems checks which were made periodically, the astronaut remained on the automatic system with brief periods on the fly-by-wire system which utilizes the automatic control jets. This procedure was as planned so that a fixed attitude would be provided for radar tracking and so that the astronaut could make the necessary reports and observations during the first orbit. During the first orbit, it was obvious from the astronaut's reports that he could establish the pitch and yaw attitude of the spacecraft with precision by using the horizon on both the light and dark sides of the earth, and that he could also achieve a reasonable yaw reference. Aside from the xylose tablet taken over Kano, he had his first and only food (a tube of applesauce) over Canton Island during this orbit and reported no problems with eating nor any noticeable discomforts following the intake of this food.

During the first orbit, the network radar systems were able to obtain excellent tracking data and these data, together with the data obtained at cutoff, provided very accurate information on the spacecraft position and orbit. As an example, between the time the spacecraft was inserted into orbit and the data were received from the Australian sites, the retrosequence times changed a total of only 7 seconds for retrofire

at the end of 3 orbits. This indicated the accuracy of the orbit parameters. From this point to the end of the 3-orbit flight, using all of the available radar data, these times changed only 2 seconds. The final retrosequence time was 04:32:38 as compared with the time initially computed at cutoff of 04:32:47 and the time initially set into the clock on the ground before lift-off of 04:32:28. All of the network sites received data from the spacecraft and maintained communications with the astronaut from horizon to horizon, and everything progressed in a completely normal fashion. Because of the excellent condition of the astronaut and the spacecraft, there was no question about continuing into the second orbit, and a "go" decision was made among personnel at Guaymas, Mexico, and the Mercury Control Center and "foremost" the astronaut himself.

Shortly after the time that the "go" decision was made at Guaymas, the spacecraft began to drift in right yaw. After allowing the spacecraft to go through several cycles of drifting in yaw attitude and then being returned by the high thrust jets, the astronaut reported that he had no 1-pound jet action in left yaw. With an astronaut aboard the spacecraft, this malfunction was considered a minor problem, especially since he still had control over the spacecraft with a number of other available control systems. It should be pointed out, however, that without an astronaut aboard the spacecraft, this problem would have been very serious in that excessive amounts of fuel would have been used; and it may have been necessary to reenter the spacecraft in some contingency recovery area because of this high fuel-usage rate. From this point on the astronaut controlled the spacecraft attitude manually except for periodic checks of the automatic control system.

During the pass over the control center on the second orbit, it was noticed that the telemetry channel used to indicate that the landing bag was deployed was showing a read-out which, if true, indicated that the landing-bag deployment mechanism had been actuated. However, because there was no indication to the astronaut and he had not reported hearing any unusual noises or noticing any motions of the heat shield, it was felt that this signal, although a proper telemetry output, was false and probably had resulted from the failure of the sensing switch. Of course, this event caused a great deal of analysis to result and later required the most important decision of the mission to be made.

The flight continued with no further serious problems and the astronaut performed the planned 180° yaw maneuver over Africa to observe the earth and horizon while traveling in this direction and to determine his ability to control. Following this maneuver, the astronaut began to have what appeared to be trouble with the gyro reference system, that is, the attitudes as indicated by the spacecraft's instruments did not agree with the visual reference of the astronaut. However, the astronaut reported he had no trouble in maintaining the proper attitude of the spacecraft when he desired to do so by using the visual reference. Because of the problems with the automatic control system, previously mentioned, and the apparent gyro reference problem, the astronaut was forced to deviate from the flight plan to some extent, but he was able to continue all of the necessary control systems tasks and checks and to make a number of other prescribed tests which

allowed both the astronaut and the ground to evaluate his performance and the performance of the spacecraft systems. As observed by the ground and the astronaut, the horizon scanners appeared to deteriorate when on the dark side of the earth; but when the spacecraft again came into daylight, the reference system appeared to improve. However, analyses of the data subsequent to the flight proved that the horizon scanner system was functioning properly but the changes in spacecraft attitudes that resulted from the maneuvers performed by the astronaut caused the erroneous outputs which he noticed on the attitude instruments. It has been known that spurious attitude outputs would result if the gyro reference system were allowed to remain in effect during large deviations from the normal orbit attitude of 0° yaw, 0° roll, and -34° pitch, and this was apparently the case during the 180° yaw maneuver which was conducted over Africa. This condition will be alleviated in future flights by allowing the astronaut to disconnect the horizon scanner slaving system and the programed precession of the gyros which preserves the local horizon while he is maintaining attitudes other than the normal spacecraft orbit attitude.

As the "go-no-go" point at the end of the second and beginning of the third orbit approached, it was determined that although some spacecraft malfunctions had occurred, the astronaut continued to be in excellent condition and had complete control of the spacecraft. He was told by the Hawaiian site that the Mercury Control Center had made the decision to continue into the third orbit. The astronaut concurred, and the decision was made to complete the three-orbit mission.

One other problem which caused some minor concern was the increase in inverter temperatures to values somewhat above those desired. It appeared, and the flight test results confirmed, that the cooling system for these inverters was not functioning. However, recent tests made previous to the flight had shown that the inverters could withstand these and higher operating temperatures. The results of these tests caused the flight control people to minimize this problem, and it was decided that this minor malfunction was not of sufficient magnitude to terminate the flight after the second orbit. Furthermore, a backup inverter was still available for use had one of the main inverters failed during the third orbit.

During the third orbit, the apparent problems with the gyro reference system continued and the automatic stabilization and control system (ASCS) malfunctions in the yaw axis were still evident. However, these problems were not major and both the ground and the astronaut considered that the entire situation was well under control. This was primarily because of the excellent condition of the astronaut and his ability to use visual references on both the dark and light sides of the earth, and the fact that most of the control systems were still performing perfectly. The one problem which remained outstanding and unresolved was the determination of whether the heat-shield deployment mechanism had been actuated or whether the telemetry signal was false due to a sensing switch failure. During the pass over Hawaii on the third orbit, the astronaut was asked to perform some additional checks on the landing-bag deployment system. Although the test results were negative

and further indicated that the signal was false, they were not conclusive. There were still other possible malfunctions and the decision was made at the control center that the safest path to take was to leave the retropackage on following retrofire. This decision was made on the basis that the retropackage straps attached to the spacecraft and the spacecraft heat shield would maintain the heat shield in the closed position until sufficient aerodynamic force was exerted to keep the shield on the spacecraft. In addition, based on studies made in the past, it was felt that the retention of the package would not cause any serious damage to the heat shield or the spacecraft during the reentry and would burn off during the reentry heat pulse.

Also over the Hawaiian site, the astronaut went over his retrosequence checklist and prepared for the retrofire maneuver. It was agreed that the flight plan would be followed and that the retrofire maneuver would take place using the automatic control system, with the astronaut prepared to take over manually should a malfunction occur. Additional time checks were also made over Hawaii to make sure that the retrofire clock was properly set and synchronized to provide retrofire at the proper moment. The astronaut himself continued to be in excellent condition and showed complete confidence in his ability to control any situation which might develop.

The retrofire maneuver took place at precisely the right time over the California site and, as a precautionary measure, the astronaut performed manual control along with the automatic control during this maneuver. The attitudes during retrofire were held within about 3° of the nominal attitudes as a result of this procedure, but large amounts of fuel were expended. Following this maneuver, the astronaut was instructed to retain the retropackage during reentry and was notified that he would have to retract the periscope manually and initiate the return to reentry attitude and the planned roll rate because of this interruption to the normal spacecraft sequence of events.

Following the firing of the retrorockets and with subsequent radar track, the real-time computers gave a predicted landing point. The predictions were within a small distance of where the spacecraft and astronaut were finally retrieved. As far as the ground was concerned, the reentry into the earth's atmosphere was entirely normal. The ionization blackout occurred within a few seconds of the expected time and although voice communications with the astronaut were lost for approximately 4 minutes and 20 seconds, the C-band radar units continued to track throughout this period and provided some confidence that all was well throughout the high heating period. As it might be expected, voice communications received from the astronaut following the ionization blackout period resulted in a great sigh of relief within the Mercury Control Center. The astronaut continued to report that he was in excellent condition after this time, and the reentry sequence from this point on was entirely normal.

A number of spacecraft control problems were experienced following peak reentry acceleration, primarily because of the method of control used during this period. In addition, large amounts of fuel from both the manual and automatic systems had been used and finally resulted in fuel depletion of

both systems just previous to the time that the drogue chute was deployed. The results of these flight tests have indicated that somewhat different control procedures be used during this period for the next flight.

The communications with the astronaut during the latter stages of descent on both the drogue and main parachutes were excellent and allowed communications with either the astronaut or the recovery forces throughout this entire descent phase and the recovery operations which took place following the landing. The landing occurred at 2:43 p.m. e.s.t. after 4 hours, 55 minutes, and 23 seconds of flight.

Recovery forces in all areas were notified of mission progress by the recovery control center. Based on mission progress, units located at the end of the third orbit knew they were to become involved, and figure 8 presents recovery details in the MA-6 landing area. An aircraft carrier with retrieval helicopters was located in the center of the planned landing area, one destroyer was located about 40 nautical miles downrange, and a second destroyer was located about 40 nautical miles uprange. Telemetry and search aircraft were airborne in the areas as shown. After the retro-rocket maneuver and about 15 minutes prior to the estimated time of landing, the recovery control center notified the recovery forces that according to calculations, the landing was predicted to occur near the uprange destroyer as shown in figure 8. The astronaut was also provided with this information by the Mercury Control Center as soon as communications were reestablished after the spacecraft emerged from the ionization blackout. Lookouts aboard the USS Noa, the destroyer in the uprange position, sighted the main parachute of the spacecraft as it descended below a broken cloud layer at an altitude of about 5,000 feet from a range of approximately 5 nautical miles. Communications were established between the spacecraft and the destroyer, and a continuous flow of information was passed throughout the remainder of the recovery operation.

In this case, location was very straightforward in that a retrieval ship gained visual contact during spacecraft landing. However, as a matter of interest for future operations since visual sightings are probably the exception rather than the rule, other spacecraft location information available soon after landing is also plotted in figure 8. The SOFAR fix was approximately 4 nautical miles from the landing point, and the first two HF/DF fixes were within approximately 25 miles of the actual spacecraft position. This landing information, along with the calculated landing position provided by the Mercury network, would have assured bringing search aircraft within UHF/DF range. In fact, the airborne search aircraft in the landing areas obtained UHF/DF contact with the spacecraft shortly after beacon activation at main parachute opening; however, it was the Noa's day and she was on her way to retrieve.

The Noa had the spacecraft aboard 20 minutes after landing. Figure 9 shows the spacecraft as it is being lowered to the deck. Astronaut Glenn remained in the spacecraft during pickup; and after it was positioned on the ship's deck, he egressed from the spacecraft through the side

hatch. Original plans had called for egress through the top at this time; however, the astronaut was becoming uncomfortably warm and decided to leave by the easier egress path.

In making the pickup, the Noa maneuvered alongside the spacecraft and engaged a hook into the spacecraft lifting loop. The hook is rigged on the end of a detachable pole to facilitate this engagement and the lifting line is rigged over one of the ship's regular boat davits as shown in figure 9. A deck winch is used for inhauling the lifting line, and when the spacecraft is properly positioned vertically, the davit is rotated inboard to position the spacecraft on deck. A brace attached to the davit is lowered over the top of the spacecraft to prevent swinging once the spacecraft is clear of the water.

Each ship in the recovery force had embarked a special medical team consisting of two doctors and one technician to provide medical care and/or initial postflight medical debriefing. For the MA-6 mission, postflight medical debriefing was the only requirement and was completed onboard the Noa in about 2 hours after pickup. The astronaut was then transferred to the aircraft carrier for further transfer to Grand Turk Island, and he arrived there approximately 5 hours after landing. Additional engineering and medical debriefings were conducted at Grand Turk.

References

1. Kraft, Christopher C., Jr.: Some Operational Aspects of Project Mercury. Presented at the Annual Meeting of Soc. of Experimental Test Pilots, Los Angeles, Calif., Oct. 9, 1959.
2. Mathews, Charles W.: Review of the Operational Plans for Mercury Orbital Mission. Presented at the Twenty-Eighth Annual Meeting of the Inst. of Aero. Sci., New York, N. Y., Jan. 25, 1960.

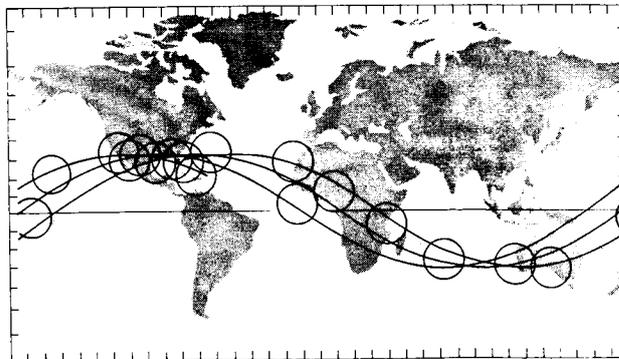


Figure 1.- Network station distribution.

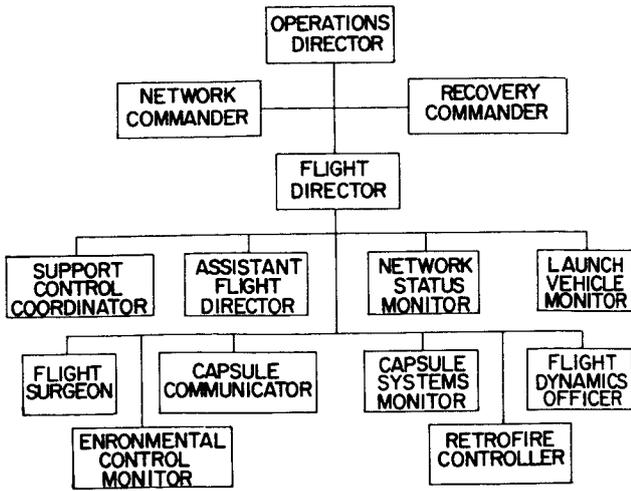


Figure 2.- Mercury Control Center organization.

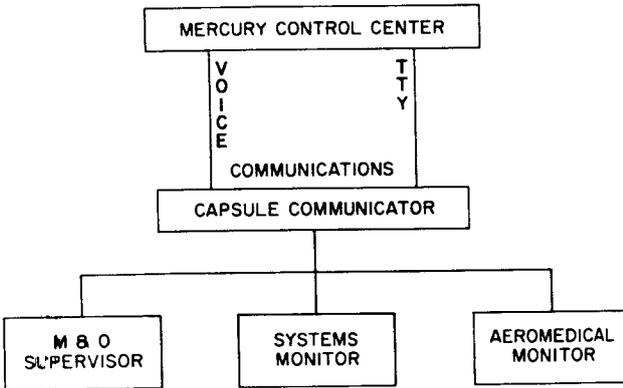


Figure 3.- Remote site organization.

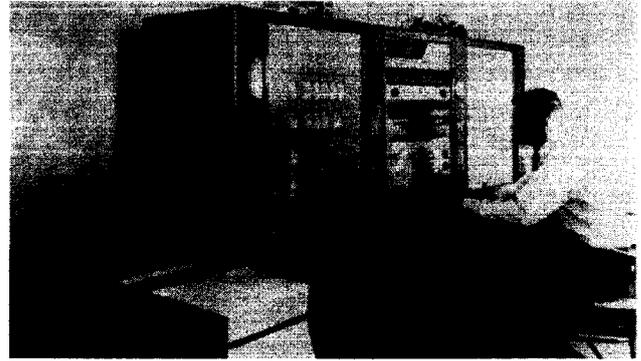


Figure 5.- Photograph of a typical remote site.

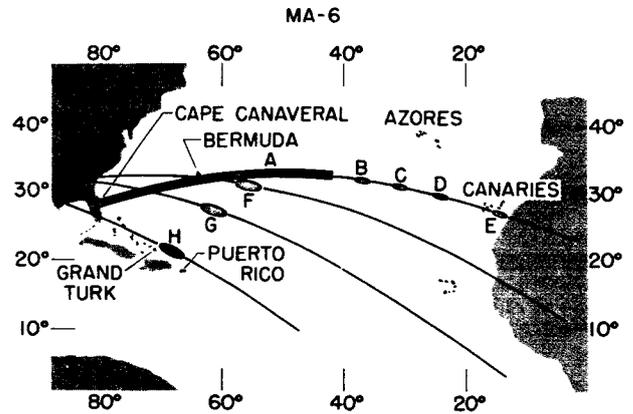


Figure 6.- Planned recovery areas.



Figure 4.- Photograph of the Mercury Control Center.

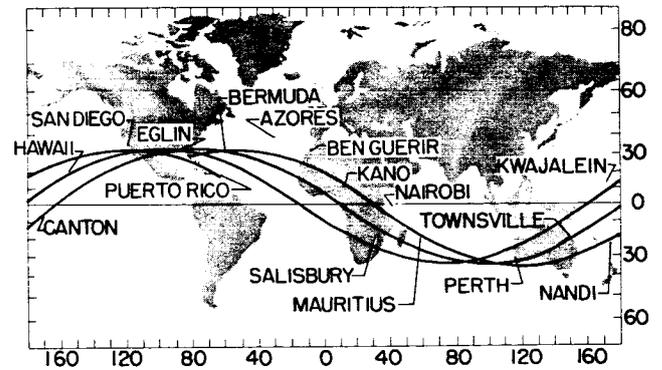


Figure 7.- MA-6 staging locations for contingency recovery.

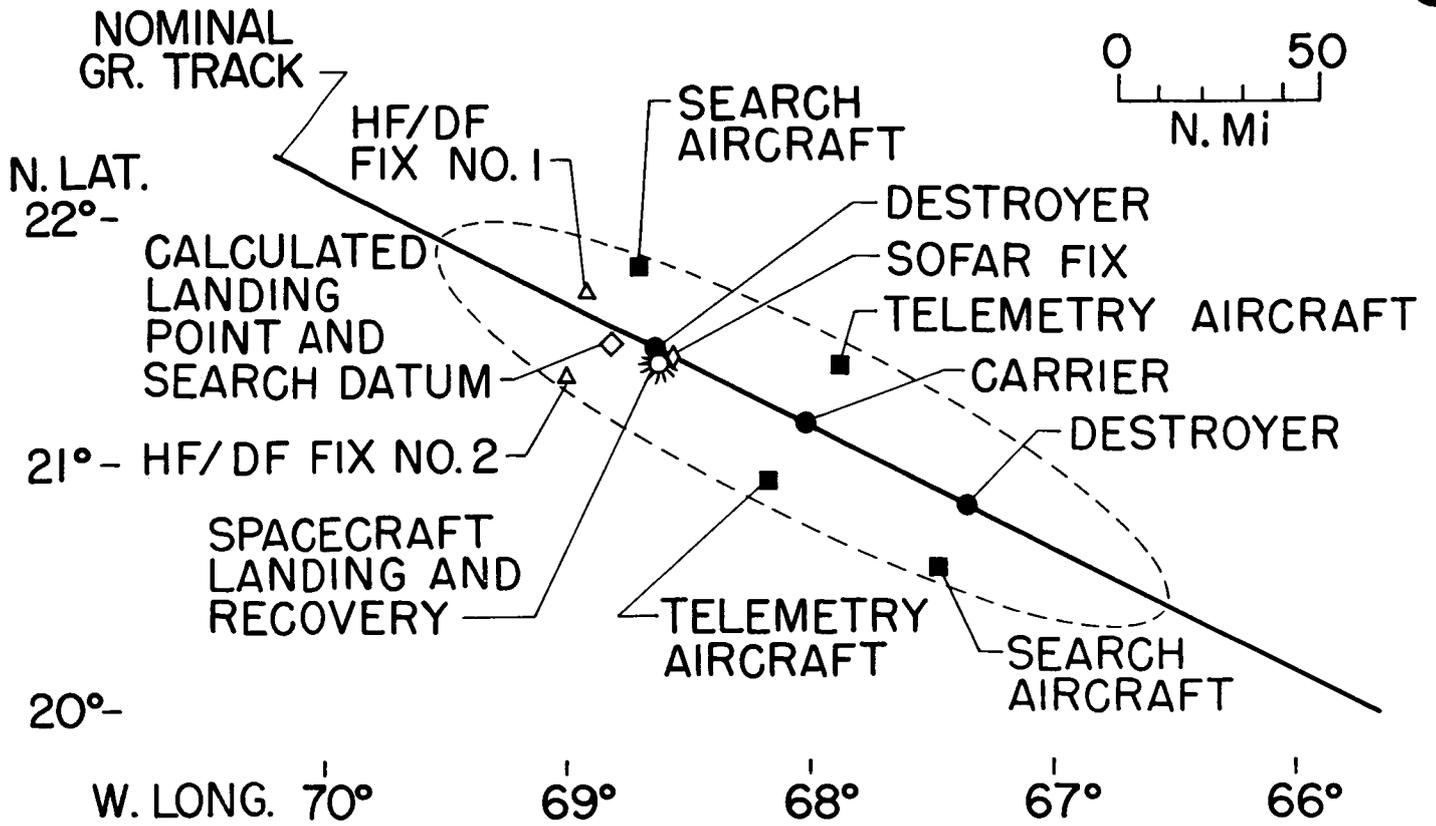


Figure 8.- MA-6 Landing area.

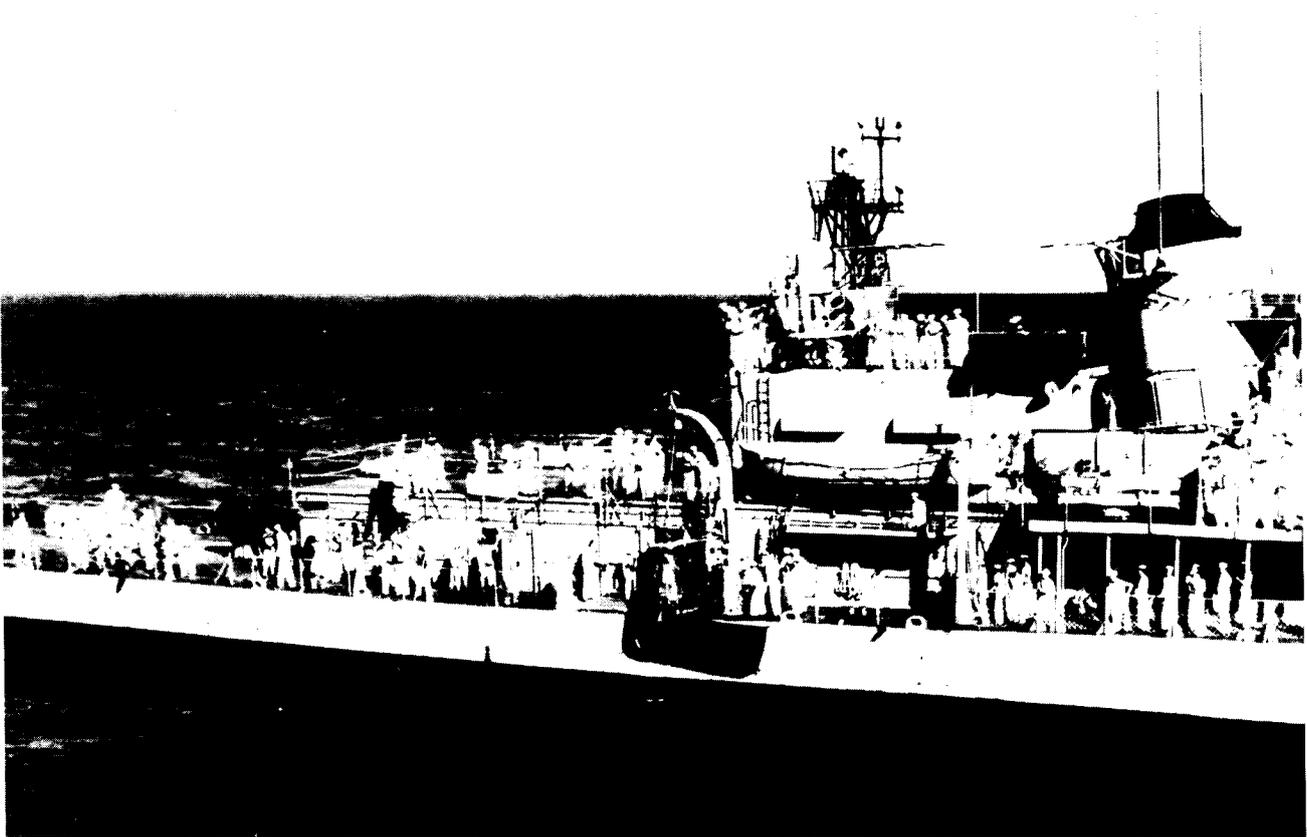


Figure 9.- MA-6 retrieval by destroyer Noa.

TABLE I. - MA-6 RECOVERY FORCES FOR THE PLANNED RECOVERY AREAS

Area	Number of search aircraft	Number of helicopters	Number of ships	Maximum recovery time, hr
Launch site	---	3	---	short
A	6	---	8 destroyers	3 to 6
B,C,D,E	1 each	---	1 destroyer each	3 to 6
F,G,H	2 each	3 each.	1 carrier each 2 destroyers each	3
Total	16	12	21	---

TABLE II. - FLIGHT CONDITIONS

Cutoff conditions:

Altitude, ft	528,381
Velocity, ft/sec	25,730
Flight-path angle, deg	-0.047

Orbit parameters:

Perigee altitude, nautical miles	86.92
Apogee altitude, nautical miles	140.92
Period, min:sec	88:29
Inclination angle, deg	32.54

Maximum conditions:

Exit acceleration, g units	7.7
Exit dynamic pressure, lb/sq ft	982
Entry acceleration, g units	7.7
Entry dynamic pressure, lb/sq ft	472

TABLE III.- SEQUENCE OF EVENTS DURING MA-6 FLIGHT

Event	Planned Time ^a , hr:min:sec	Actual Time, hr:min:sec
Booster-engine cutoff	00:02:11.4	00:02:09.6
Tower release	00:02:34.2	00:02:33.3
Escape rocket firing	00:02:34.2	00:02:33.4
Sustainer-engine cutoff (SECO)		00:05:01.4
Tail-off complete	00:05:03.8	00:05:02
Spacecraft separation	00:05:03.8	00:05:03.6
Retrofire initiation	04:32:58	04:33:08
Retro (left) No. 1	04:32:58	04:33:08
Retro (bottom) No. 2	04:33:03	04:33:13
Retro (right) No. 3	04:33:08	04:33:18
Retro assembly jettison	04:33:58	(b)
0.05g relay	04:43:53	^c 04:43:31
Drogue parachute deployment	04:50:00	04:49:17.2
Main parachute deployment	04:50:36	04:50:11
Main parachute jettison (water impact)	04:55:22	04:55:23

^aPreflight calculated, based on nominal Atlas performance.

^bRetro assembly kept on during reentry.

^cThe 0.05g relay was actuated manually by astronaut when he was in a "small g field."

TABLE IV.- NETWORK ACQUISITION TIMES FOR MA-6 FLIGHT

Station	Telemetry Signal		Voice Reception	
	Acquisition, hr:min:sec	Loss, hr:min:sec	Frequency	Duration, hr:min:sec
Canaveral	00:00:00	00:06:20	UHF	00:00:00 to 00:05:30
Bermuda	00:03:02	00:10:26	UHF	00:03:30 to 00:09:30
			HF	00:11:00 to few sec
Canary Islands	00:14:15	00:21:23	UHF	00:15:00 to 00:23:00
			HF	00:12:00 to 00:14:00
Atlantic Ship	Not in range			
Kano	00:21:13	00:28:21	UHF	00:22:00 to 00:29:00
Zanzibar	00:29:51	00:37:51	UHF	00:29:00 to 00:38:00
Indian Ocean Ship	00:40:02	00:48:31	UHF	00:41:00 to 00:48:00
Muchea	00:49:21	00:57:55	UHF	00:50:00 to 00:58:30
Woomera	00:54:00	01:02:41	UHF	00:56:00 to 01:03:00
Canton	01:09:19	01:17:42	UHF	01:09:00 to 01:15:30
			HF	01:03:30 to 01:04:00
Hawaii	Not in range			
California	01:26:41	01:31:23	UHF	01:27:30 to 01:30:00
			HF	01:19:00 to 01:25:30
Guaymas	01:26:47	01:33:25	UHF	01:26:00 to 01:33:30
			HF	01:20:30 to 01:26:00
Texas	01:29:24	01:36:18	UHF	01:28:30 to 01:36:30
Eglin	01:32:00	01:37:05		
Canaveral	01:33:20	01:40:03	UHF	01:33:30 to 01:40:00
Bermuda	01:36:38	01:43:53	UHF	01:37:30 to 01:42:00
Canary Islands	01:47:55	01:53:58	UHF	01:48:00 to 01:55:30
Atlantic Ship	01:51:54	01:58:31	UHF	01:53:00 to 01:58:00
Kano	01:54:47	02:01:21	UHF	01:55:00 to 02:01:00
Zanzibar	02:04:05	02:10:51	UHF	02:04:00 to 02:11:00
Indian Ocean Ship	02:12:17	02:22:09	UHF	02:13:00 to 02:22:00
Muchea	02:22:51	02:31:23	UHF	02:25:00 to 02:32:30
			HF	02:23:30 to 02:24:30
Woomera	02:27:36	02:35:45	UHF	02:28:00 to 02:37:00
Canton	02:42:51	02:49:45	UHF	02:42:30 to 02:49:00
Hawaii	02:49:01	02:55:19	UHF	02:49:00 to 02:55:30
California	02:58:11	03:04:48	UHF	02:58:30 to 03:04:30
Guaymas	02:59:59	03:06:44	UHF	03:00:30 to 03:06:30
Texas	03:03:14	03:09:39	UHF	03:03:30 to 03:10:30
Eglin	03:05:35	03:12:07	UHF	03:07:30 to 03:12:30
Canaveral	03:06:51	03:13:46	UHF	03:07:00 to 03:14:00
Bermuda	03:09:56	03:17:03	UHF	03:09:00 to 03:16:30
			HF	03:16:30 to 03:18:00
Canary Islands	Not in range		HF	03:20:00 to 03:25:00
Atlantic Ship	03:24:44	03:32:25	UHF	03:26:30 to 03:30:00
			HF	03:25:00 to 03:26:30
			HF	03:30:30 to 03:32:30
Kano	Not in range			
Zanzibar	Not in range		HF	03:30:00 to 03:32:30
			HF	03:40:00 to 03:41:30
			HF	03:44:00 to 03:44:30
Indian Ocean Ship	03:46:55	03:56:49	HF	03:47:00 to 03:55:00
Muchea	03:56:31	04:04:12	UHF	03:58:30 to 04:04:00
			HF	03:57:00 to 03:58:00
Woomera	04:03:16	04:06:19	UHF	04:03:00 to 04:07:00
Canton	Not in range		HF	04:15:30 to 04:21:00
Hawaii	04:21:49	04:28:49	UHF	04:20:30 to 04:30:30
California	04:31:17	04:37:57	UHF	04:31:30 to 04:38:30
Guaymas	04:33:44	04:39:49	UHF	04:33:30 to 04:40:30
Texas	04:36:53	04:42:32	UHF	04:38:00 to 04:39:30
Eglin	04:39:00	04:42:52	UHF	04:39:00 to 04:43:30
Canaveral	04:40:52	04:42:55	UHF	04:40:30 to 04:43:30
(Canton)				