N62-14485

SIMULATION EQUIPMENT USED IN THE TRAINING OF ASTRONAUTS AND FLIGHT CONTROL CREWS IN PROJECT MERCURY

Stanley Faber
Head, Flight Simulation Section
NASA - Manned Spacecraft Center

At the beginning of the Mercury Program it was realized that the entire preparation of the man for piloting the spacecraft would have to be done by use of simulation techniques. It was also realized that no single all-inclusive flight simulator could provide the astronaut with practice in all phases of the mission in a sufficiently realistic environment. To determine the simulation needs, the Mercury-Atlas flight was broken down into areas of astronaut mission responsibility and into areas of physiological and psychological factors affecting the astronaut. A study was made of existing and proposed devices to determine requirements, suitability, feasibility, and availability of these devices. The simulators and devices finally selected are listed in Figure 1. Omitted from this list are several devices that are not actually simulators, such as mockups and visual devices, disorientation devices such as the one at Pensacola, and airplane 0 g familiarization flights. The listings in Figure 1 are not by order of importance or time availability but rather in groupings of fixed-based and dynamic or moving-based simulators.

The first two devices, Control Simulators No. 1 and No. 2, were part-task trainers consisting of a pilot support, a hand controller, a simplified display panel, and an analog computer programmed with six-degree-of-freedom equations of motion. In Trainer No. 1, the pilot was upright in a chair and used a research type three-axis hand controller. In Trainer No. 2, the pilot used a couch support and a Mercury type hand controller. Both of these training devices were used for initial indoctrination and training in the manual control of the spacecraft attitudes during orbit, retrofire, and reentry. Control techniques, display configurations, and manual control with inflated pressure suit were all evaluated on these devices. The devices were retired upon receipt of the Mercury Procedures Trainers.

The Mercury Procedures Trainers are complete flight trainers that allow practice and evaluation of all procedural and inflight tasks. Figure 2 shows the trainer, the instructor's station in the foreground and the capsule in the background. Two trainers were produced by the McDonnell Aircraft Corporation, one for Langley and one for Cape Canaveral. The trainers are nearly identical with the exception of the computing equipment used to define the vehicle motions. The Langley equipment is capable of solving for all motions including those caused by the aerodynamic effects during reentry. The Cape equipment, however, can only reproduce the vehicle rotary motions of space flight. The trainers are relatively high-fidelity simulators of the operation of most of the onboard systems, especially those that involve direct astronaut activity. The major items not simulated are the spacecraft noises and the view out of the capsule through the window and the periscope. The periscope display in the Langley Trainer has been animated to allow some attitude control practice using this reference system. The instructor from his station can introudce directly approximately 275 separate vehicle failures and indirectly, countless more.

The design of these trainers follows that of most airplane flight trainers in the limited use of actual vehicle hardware and to the use of electronic techniques to animate all displays. The use of actual or pseudo-actual vehicle hardware is limited to that required to produce the physical environment, that is, the enclosure, the panel, the hand controller and associated linkages, the couch, the switches, and so forth. System hardware such as for the Automatic Stabilization and Control System or for the Life Support System is not used. The operation of these systems is duplicated through techniques making use of timers and diode function generators and analog computing amplifiers, integrators, and servos.

The next group of devices listed in Figure 1 are those in which physical motion is involved. These motions were used either to subject the astronaut to an inhospitable environment, reference the centrifuge or Multiple-Axis Spin Test Inertial Facility; or where motion cues are considered to be important; or where a moving base was the simplest method of generating satisfactory displays.

The first of these moving-based devices was the Pilot Egress Trainer. This trainer is a boiler-plate mockup of the spacecraft with similar hydrodynamic characteristics and similar escape path obstructions. The trainer was used in both tanks and open seas to develop the preferred recovery and egress procedures. Procedures were formulated for egress from all probable vehicle conditions including very rough seas and a completely submerged spacecraft. The trainer is also used to train ground teams supporting the flight. Helicoptor and ship retrievals were made in which the communications and recovery procedures were practiced.

The next device is the MASTIF (Multiple-Axis Spin Test Inertia Facility). This NASA-Lewis built simulator is shown in Figure 3. Very briefly it consists of three gimbals individually powered by compressed nitrogen gas thrusters. Angular rates from near zero to over 60 revolutions can readily be generated. The astronauts were whirled to rotational speeds above those where disorientation occurs to become familiar with this disorientation and to practice stopping the motions by use of the Mercury hand controller and angular rate instrument displays. The tests served mainly to build confidence that in the event of a gross Automatic Control System failure, the astronaut could regain control of the vehicle and stop all tumbling.

Next on our list of simulation devices is a facility considered one of the most important for the program. The Centrifuge at Johnsville has been used in astronaut training and in engineering evaluations of man and equipment. The gondola of the centrifuge was equipped with as much vehicle hardware as was required to support the astronaut in the launch and reentry phases of the mission. This vehicle equipment included the support couch, display panel, hand controller and linkages, Environment Control System, pressure suit, and the biomedical instrumentation. To further duplicate flight conditions, the gondola was evacuated to reduced cabin air pressure of the actual flight. Six-degree-of-freedom equations of motion were used to animate the display panel however the acceleration profiles were predefined. In the final training sessions man, equipment, and procedures were evaluated by simulation of the complete three-orbit mission starting with the preflight physical examination through countdown, launch, three orbits reentry, recovery, post mission debriefings and physicals. Base line medical data for comparison with the flight data was a very important byproduct of these astronaut training periods.

The last of the devices listed is the ALFA Trainer. Figure 4 shows the present form of this trainer. It is basically a pseudo-Mercury spacecraft mounted on a spherical air bearing. This nearly frictionless support coupled with a combined astronaut-plus-trainer center of gravity at the center of the ball, produces an almost perfect simulation of spaceflight, as far as attitude control is concerned. The structural support system and the effects of the 1 g field on the trainee limit the yaw and pitch motions to plus and minus 35 degrees. Roll is unlimited. All three attitude reference systems are available to the astronaut including the periscope, panel instruments, and the window. For the periscope display, a 10-foot diameter screen is viewed through optics simulating the wide-angle view of the vehicle periscope. A moving earth scene of the orbital track is back projected onto the screen . This display is relatively accurate for deviation angles up to 25 degrees. For the panel displays, actual vehicle hardware is used to measure the attitudes and rates and to display these to the astronaut. For the view through the window, a lighted horizon and a generalized star field are provided. Motion of the trainer is controlled by astronaut use of compressed air jets. Either the manual proportional jets or the manual low-level fly-by-wire jets can be used. Disturbances which can be produced by misalinment of the retrorockets are also simulated by compressed air jets.

This paper has thus far described the simulators developed for astronaut training. The astronaut, however, is but one member of the flight team. The operational plan for Project Mercury includes a network of telemetry, command, and tracking stations around the world directed by the Mercury Control Center at Cape Canaveral. As the design and construction of the network proceeded, it became evident that procedures to operate the network and facilities to test these procedures were required. This was especially true for the Control Center with its large staff who monitor many varied inputs. At the same time, it was evident that a need existed for verification of the readiness of the network to support a particular flight. The techniques of mission simulation were developed in order to supply the required facilities to exercise procedures and to verify readiness.

As in astronaut training, no one device or technique could supply all the required training and indoctrination to bring the Flight Controllers, the astronaut, and the entire Mercury Network into a well-integrated team. To accomplish this integration, two simulation facilities were constructed and a technique of world-wide simulation developed.

The first of these facilities, and by far the simpler, was constructed at Langley and was used to give the remote site Flight Controllers their initial familiarization with the displays and with the team aspects of flight monitoring. The facility consists of the procedures trainer and the displays typical of a remote site. Figure 5 shows a schematic of the facility. Vehicle data is obtained from the trainer, conditioned, and sent directly to the Flight Controller displays. All intra and intersite communications are simulated. Before each Mercury mission, exercises are run to evaluate site procedures and to exercise the Flight Controller-astronaut interface in both normal and abnormal situations.

The second facility, the mission simulator, was constructed at the Control Center and consists of the Procedures Trainer, interface equipment, and of course the Control Center facilities. When operated to animate Control Center displays only, the simulation is considered to be operating closed loop. This means that any real time astronaut or Flight Controller action will affect the simulated mission exactly as it would an actual mission. The complex is also operated in an open loop mode in connection with world-wide simulations.

Figure 6 is a photograph of the simulation area and shows the data conditioning equipment, the data control panels, the trajectory displays, and controls in the foreground. The procedures trainer instructor's station, the trainer capsule, and the trainer analog computer are in the background. Figure 7 is a schematic detailing the simulation equipment and the tie-in to the Control Center. Spacecraft data, approximately 50 functions, are taken from the trainer, conditioned to look like telemetry, and transmitted to the operational telemetry receiving equipment in the form of the telemetry composite before conversion to radio frequency. The reverse path, commands to the spacecraft, are simulated be sensing switch closures in the Control Center and using these closures to effect changes in trainer operation. The UHF and HF air-ground voice communications are also simulated. The intermediary equipment can modify, interrupt, or cause false readings on any of the channels. This equipment also generates the remaining 40 telemetry parameters (including the biomedical parameters) which come from the vehicle during flight.

The voice aspects of the vehicle countdown and the range operations are simulated so that prelaunch and launch procedures involving these communications paths could be exercised.

The trajectory--and at this time we will speak only of the powered flight phase--was generated by either of two methods. Both methods make use of the high speed operational data transmission systems and the Goddard Computing Complex. The first method which utilizes the "B" Simulator was used during most of the simulations. This machine uses magnetic tapes containing all necessary data to simulate the launch area tracking. These data include the outputs of the Atlas Guidance System, the outputs of the Impact Predictor Computer, and raw radar data. Also on the tapes are the discrete commands of booster and sustainer burnout which control the procedures trainer operation. The tapes used on the "B" Simulator can and have been made to produce both normal and problem launches and orbits. A typical problem might be an overspeed cutoff which restricts the possible landing areas.

The second method of powered flight trajectory simulation is used on launch day to verify the complete launch area trajectory data flow subsystem. Taped inputs to the guidance and to the impact computers are used to exercise the computers, the launch area data conversion and transmission system, as well as the high speed data lines to Goddard. With this second system, the discrete launch events can only be sent to the trainer via manual action of the trainer operators.

Simulation of radar tracking after capsule separation was not necessary from the flight control procedures standpoint as the operational programs of the Goddard Computer can define the entire flight path and generate all Control Center displays from just the insertion vector. Remote site radar tracking was simulated however to exercise the teletype system which is used to transmit this data to Goddard. The teletype tapes were generated by Goddard for replay at the remote sites during simulations.

The above system details the closed loop mission simulation capability at the Control Center. However one of the requirements of true mission simulation was to simulate world wide. To extend the capability to the remote sites, a method of animating the site displays was needed. Referring to Figure 7, it can be seen that the simulated vehicle data was displayed at the Control Center via operational ground station telemetry equipment, equipment that is an integral part of every remote site. Therefore all that was required was to record the data from the trainer on magnetic tapes and play these tapes at the remote sites. The tapes are made prior to each mission so that the format and calibration of the data would be relatively similar to the flight configuration. The other spacecraft data input to a site, the astronaut's voice, was simulated on the site by an individual scripted to make the standard reports and answer any expected querries from the Flight Control Teams. Both individual site exercises and integrated network mission simulations were conducted using this technique.

To conduct an integrated network simulation, special telemetry tapes and astronaut scripts were supplied to each site. Detailed instructions as to when to play the tapes (in terms of time from liftoff) and as to the setup of the telemetry receiving station were also sent to all sites.

Preparation of these simulations required careful and thorough planning and coordination. Since the simulations are basically open loop, the actions of the astronaut and the Flight Controllers had to be anticipated and these effects included in the prerecorded tapes. The missions were based on the flight plan and on the existing mission rules. A number of abnormalities or faults were included to exercise the astronaut and flight control procedures and to test the mission rules.

The special telemetry tapes were prepared by having an astronaut fly a complete mission with the trainer personnel simulating all ground stations. A master telemetry tape was recorded and the site tapes were prepared from this master by copying data for only those periods the spacecraft would be over that particular site. The recorded data was reviewed to evaluate the suitability of the data from the standpoints of calibration accuracy, conformity to last minute vehicle modifications, and adherence to the mission rules. If any of the data was not suitable, the telemetry ground station decommutators were repatched so that the flight control displays would be close to the desired readings. Repatchings were also used to produce further spacecraft failures. The use of this repatching technique allowed one telemetry tape to serve as the basis for several simulated missions. The scripts for the simulation of the air-to-ground voice were based on the astronaut's voice reports as recorded and on the objectives of the mission. As with telemetry repatchings, the voice scripts allowed considerable flexibility of operation.

Mission simulations are conducted in a manner similar to the actual launch. The entire network goes through a three-to six-hour countdown actually performing the equipment, communications, and data flow checkouts. At the Cape, most of the launch area checkouts such as the spacecraft and booster are only simulated; however, where tie-in to the network exists, the actual checkout is performed. After liftoff each site receives contact with the spacecraft in turn and transacts its voice and data collection tasks. As a standard mission operation, each site reports to the Control Center a summary of the telemetry readouts and a synopsis of the Flight Controller's opinions of the vehicle and astronaut status. These teletype messages are carefully monitored by the simulation group to insure that the desired displays and data were received by the site and that the anticipated actions were taken. If deviations are noted, the simulation group teletypes new instructions to the subsequent sites to attempt to get the "mission" back on track. The simulations normally terminate with splash; however recovery aspects have been exercised. Not to be forgotten in the simulations are the debriefings conducted by the Flight Director. These debriefings can and have lasted almost as long as the simulated flight itself and have lead to many improvements in procedures and equipment usage.

As may be evident from the preceding paragraphs, mission simulation is more "technique" than equipment. These paragraphs just brush the surface as to the many varied duties required before and during simulations to effect a successful world-wide simulated mission.

In conclusion, I might summarize the training routine that leads up to each flight. Sometime in the months preceding his flight, the flight astronaut participates in a centrifuge program. He re-acquaints himself with the techniques of increasing his acceleration tolerance and with the acceleration profile as it affects his mission sequencing. Approximately three months before a flight, he starts intensive use of the procedures trainer and the ALFA Trainer to plan the flight and to become proficient in the inflight duties.

The network schedule is somewhat more abridged. About three weeks before the flight, exercises are held on the remote site trainer with the flight astronaut participating if possible. After deployment to the remote sites, approximately F -7 days, the Control Center with an assist from Bermuda conducts launch abort exercises. The flight astronaut participates in these drills as much as possible. The closed loop mode of Control Center simulation is used so that the total effect of any decision can be evaluated. Between F -4 and F -2 days, full integrated network simulations are conducted around the world. The astronaut has already "flown" these missions and participates mostly as an interested spectator.

The above routine, in fact the entire simulation and training effort was developed by a process of evolution and continues to develop as the needs of the program grow.

MERCURY ASTRONAUT TRAINING DEVICES

FIGURE 1

1. CONTROLS SIMULATORS NOS. 1 & 2 } FIXED BASE
2. MERCURY PROCEDURES TRAINER }
3. PILOT EGRESS TRAINER }
4. MASTIF SIMULATOR } MOVING BASE
5. JOHNSVILLE CENTRIFUGE }
6. ALFA TRAINER }

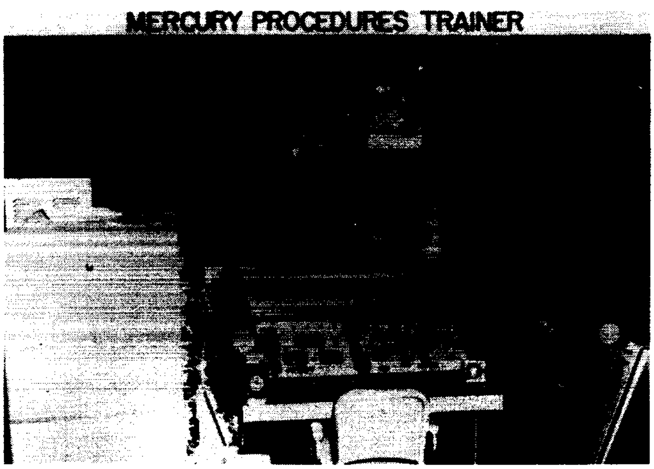


FIGURE 2

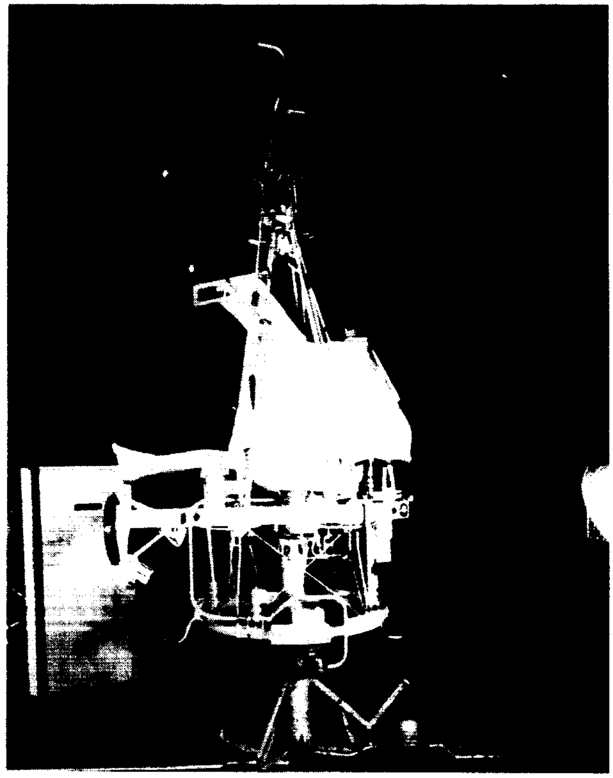
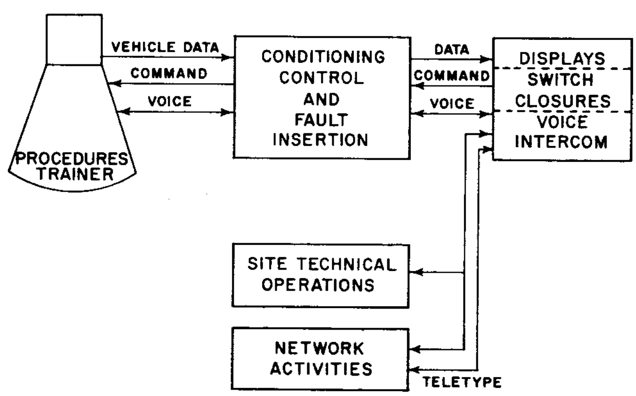


FIGURE 4 ALFA TRAINER

FIGURE 3

REMOTE SITE SIMULATOR, LANGLEY FIELD

FIGURE 5



This page is reproduced again at the back of this report by a different reproduction method so as to furnish the best possible detail to the user.

SIMULATION AREA, CAPE CANAVERAL

FIGURE 6

MISSION SIMULATOR, CAPE CANAVERAL

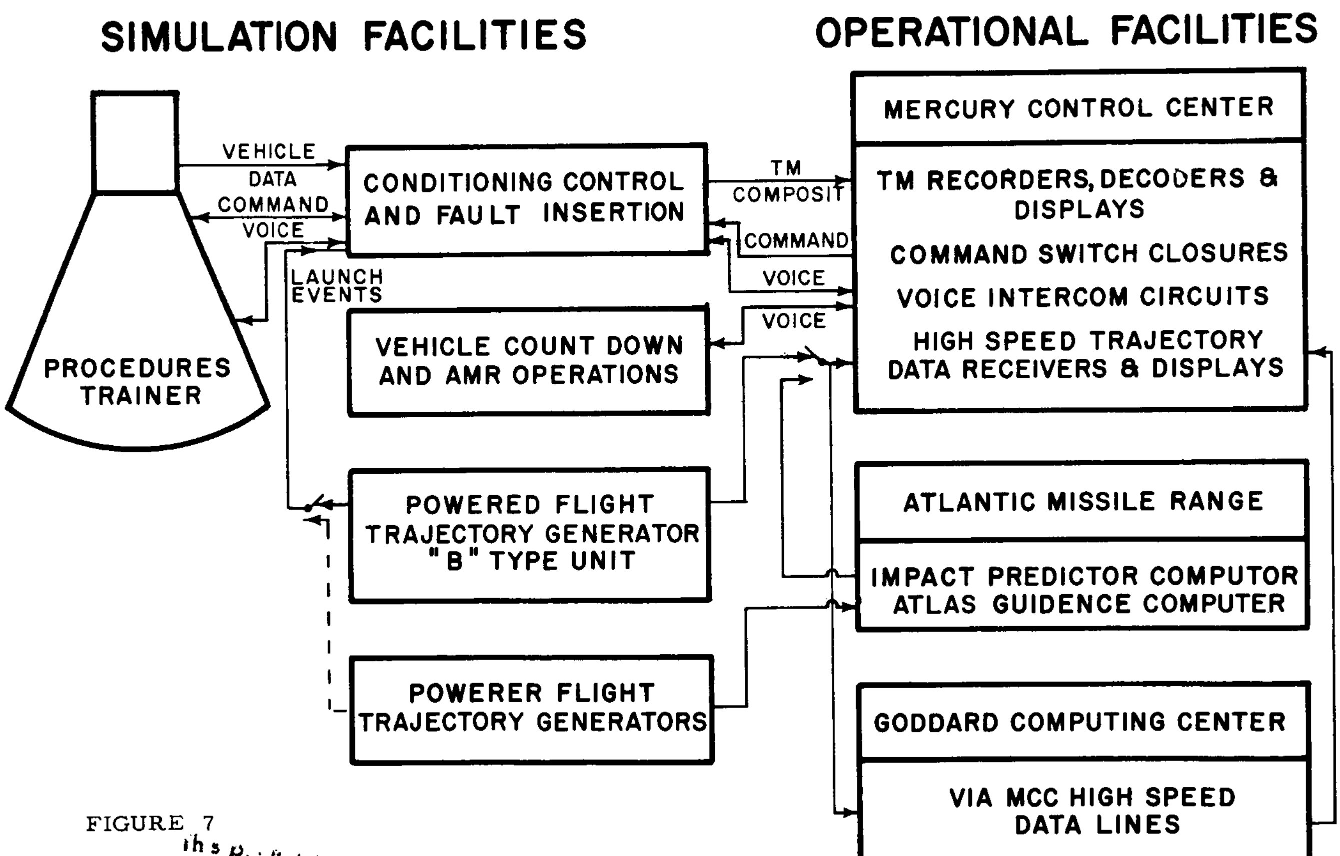


FIGURE 7

This page is reproduced again at the back of this report by a different reproduction method so as to furnish the best possible detail to the user.