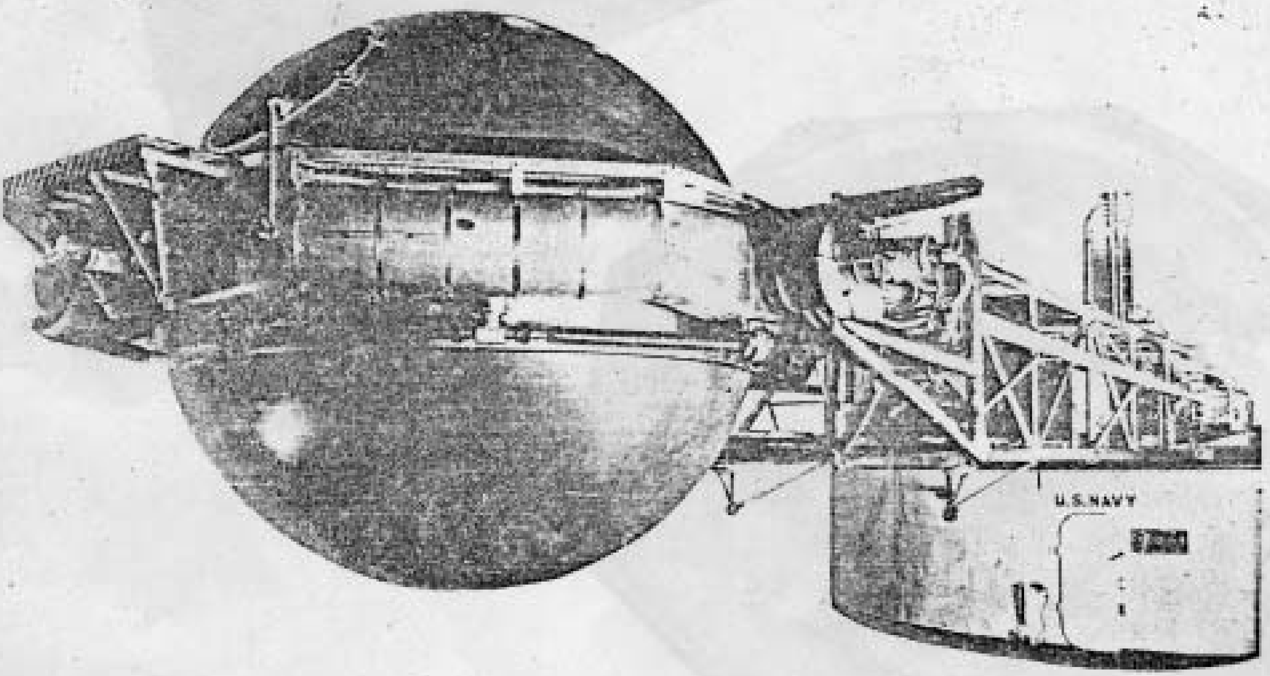
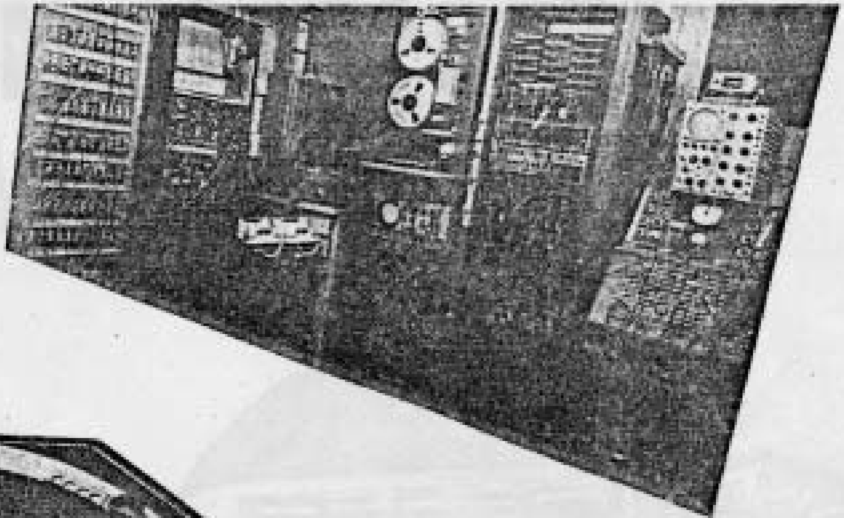
AEROSPACE MEDICAL RESEARCH DEPARTMENT

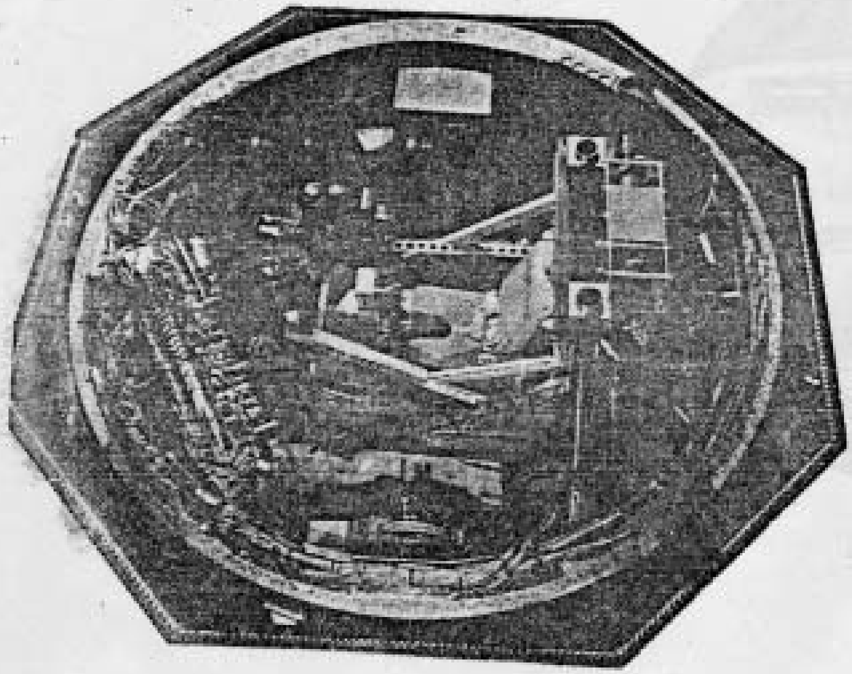


U. S. NAVAL AIR DEVELOPMENT CENTER

JOHNSVILLE, WARMINSTER
PENNSYLVANIA

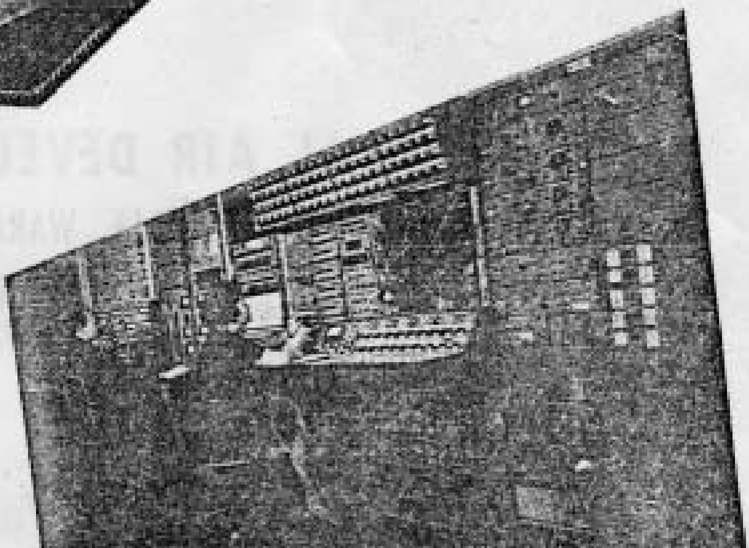
Instrumentation Station





Centrifuge Gondola

Centrifuge Control



AEROSPACE MEDICAL RESEARCH DEPARTMENT
U. S. NAVAL AIR DEVELOPMENT CENTER
JOHNSVILLE, WARMINSTER, PENNSYLVANIA
18974

THE UNITED STATES NAVY'S DYNAMIC FLIGHT SIMULATOR

The Aerospace Medical Research Department of the U.S. Naval Air Development Center houses the giant human centrifuge which is continually opening new avenues of investigation in the fields of acceleration stress as it affects man's behavior and physiological functions.

The history of aerospace medical research has demonstrated that the physiological evaluation of human performance in aircraft has always lagged behind aerodynamic engineering because of the lack of suitable research equipment. This lag was particularly evident at the onset of the Man in Space Program. The human centrifuge, however, has reversed this unusual situation, where in the past the physiological responses to G forces were based upon extrapolation and theorizing over and above the performance limitations of the centrifuges then in existence, it has now become possible to gather information on actual performance in these realms.

The main housing for the centrifuge is a cylindrical reinforced steel and concrete building, 124 feet in diameter. In the center of the 11,000 sq. ft. operating floor is a 180 ton 4000 horsepower motor built by the General Electric Company, the rotor of which is attached to a 50-foot tubular steel arm. Located at the terminal end of this arm is a two gimbal support system providing two degrees of freedom; a continuous 360 degrees of rotation about the pitch (backwards and forward rotation) and roll (left and right rotation) axes. Provisions are made for a third degree of freedom, yaw, with the yaw gimbal and its drive motor situated inside of the inner, or pitch gimbal. The roll and pitch gimbals are rotated by means of electric-hydraulic motors mounted on the counterweight of the arm. These gimbals permit a subject seated within the gondola to be continuously positioned with respect to the resultant of the radial, tangential and vertical components of acceleration when the arm is set in motion.

The 10-foot, 4-inch-diameter spherical gondola consists of three major components: (1) the center structural section; (2) the upper cap; (3) the lower cap. The upper and lower caps are spherical segments attached to and removable from the cylindrical center section. The center structural section supports all gondola payloads and is designed for external pressurization to one atmosphere. The caps serve as wind-screens only and are not capable of withstanding external pressurization. Special vacuum caps are required in order to evacuate the gondola for pressure-altitude simulation. The implementation of rotary joints permits the passage of hydraulic fluid (2000 psi), compressed air, vacuum, conditioned air, water and other elements that may be required for project operation within the gondola. The outer and inner gimbal control motors drive the gimbal rings through tubular steel shafts running the length of the arm. The gimbal motor control circuits are linked to the centrifuge control and observation stations by means of slip rings on the main motor rotor shaft. Additional sliprings at both axes of the gondola gimbal system transmit physiological, television, instrument control signals, etc., to and from the gondola. The entire centrifuge room is carefully shielded to protect the delicate physiological instrumentation circuits from magnetic and electrical interference. Floor, walls and ceiling of the centrifuge chamber are sheathed with 1/16 inch copper, Close study of the subject during operation of the centrifuge is effected through the use of television and movie cameras. As required, the recording of electrocardiogram, electroencephalogram, respiration, blood pressure, and other physiological parameters may be implemented.

The centrifuge arm, capsule, gimbals, counterweight, and gimbal control mechanism together weigh in excess of 45 tons. This tremendous mass must be rotated under close control to develop acceleration from a dead stop to approximately 180 mph (40 G's) in a little less than 7 seconds. In addition, by making minor changes in the main motor control circuitry, and removing the 28-foot outboard section of the arm including the gondola, radial acceleration up to 100 G's may be applied to a 5000 pound payload attached to the end of the remaining 22-foot inboard section.

In order to increase the utility of this centrifuge, free swinging carriages have been constructed to bear at the 37-1/2-foot suspension point on the arm. These carriages are used primarily for engineering testing of inanimate objects and equipment. Electronic devices and other aeronautical equipment, such as serial photographic cameras and G-suits, may be tested for their workability under prolonged G stress of magnitudes commensurate to those experienced in actual flight.

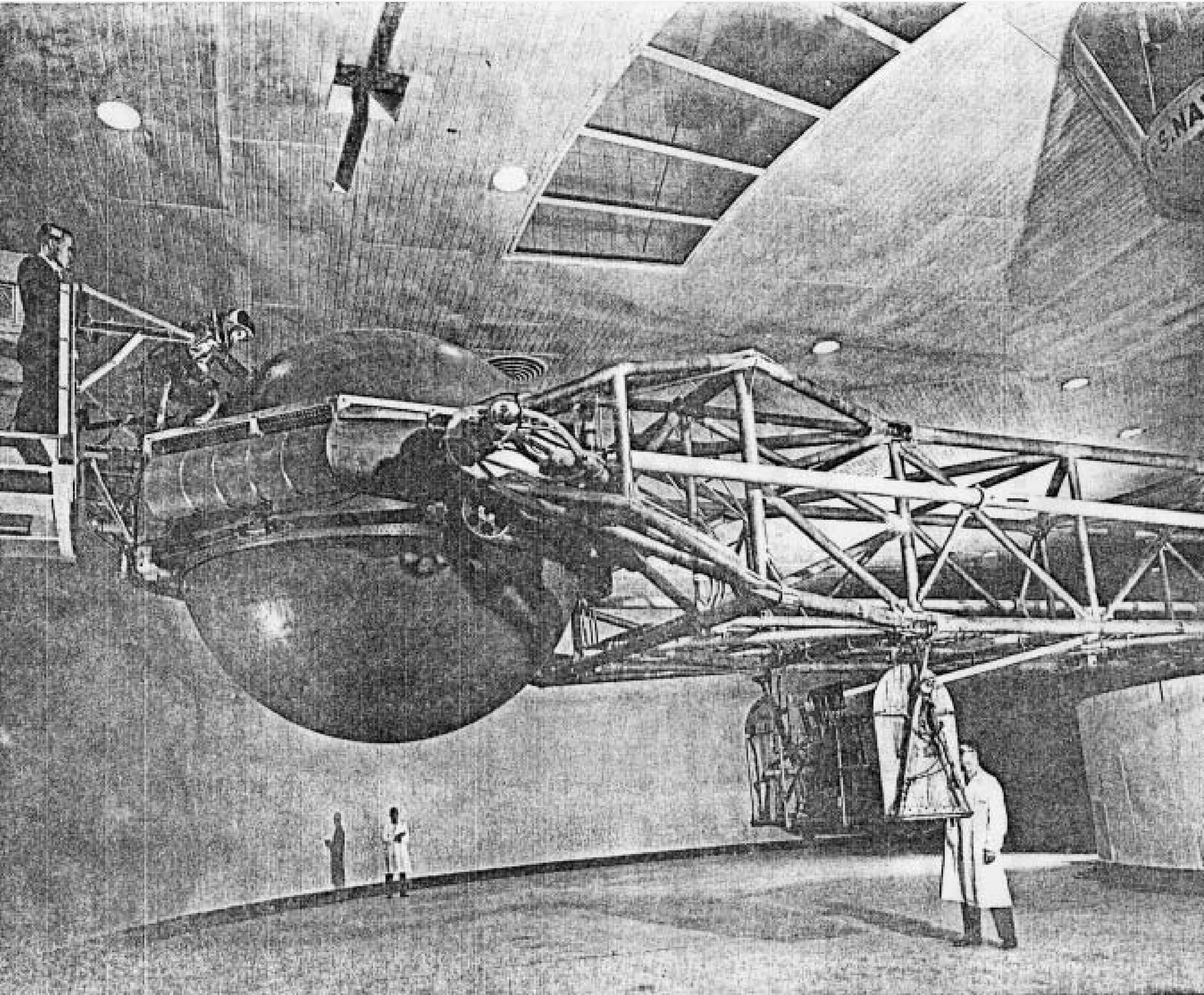
As a dynamic flight simulator the centrifuge is contributing to the solution of problems associated with high performance aircraft and space vehicles before they enter the more hazardous flight environment. Contributions are particularly significant in the areas of pilot tolerance, pilot restraint, cockpit instrumentation, control system design, controllability, flight techniques including emergency procedures, and pilot training.

To understand the dynamic flight simulator, consider briefly the following situation: The pilot in the gondola is facing the instrument display and operating the control system to execute a flight mission. The pilot's control motions are fed into a large general purpose computer which changes the instrument indications to show to the pilot his progress through a maneuver. This closed loop is, of course, that which is present in the usual fixed base flight simulator. The control motions of the pilot, together with the aerodynamic equations of the aircraft, are also used in computing accelerations. These signals are converted through a coordinate transformation system and compensating network into drive signals to the centrifuge. These signals drive the centrifuge in such a way that the pilot receives a good approximation of the acceleration he would receive in actual flight in this aircraft had he made the same control motions. Also, the fact that the position of the capsule is controlled in all planes provides means for exact investigation of any desired stress pattern under consideration.

In any simulation, the required compromises with the actual condition of flight place important restrictions on the usefulness of the simulation. No simulation can be more than an approximate reproduction of flight. The compromises that must be accepted are many. In a marginally stable aircraft, less compromise can be accepted, and, in particular, it is desirable to have acceleration inputs to the pilot, in addition to those afforded by indications of instruments. It is perhaps safe to say that, until the marginally stable aircraft became an important instrument of flight research, the necessity of presenting the pilot with acceleration forces was not clear. However, with the desire of man to go higher into space and at greater and greater speeds, the problem of acceleration became an increasingly important one.

The Aerospace Medical Research Department is affiliated with the University of Pennsylvania, and in accordance with this agreement is officially designated as an associate laboratory of the University. Under this arrangement, qualified civilian and military scientists working in this Department have faculty status with the University Graduate Schools. This Department accepts graduate students from the University and officer and civilian staff members may likewise be enrolled in the Graduate Schools.

The Aerospace Medical Research Department has as its integrated composite, complete and well equipped laboratories. These include a psychology Division, a Dynamic Simulation Division, a Physiology Division with associated surgical space, a Biophysics and Bioastronautics Division, a Biochemistry Division which includes facilities for the handling of radioactive isotopes, and a Medical Division.



SCHEDULE OF OPERATION - 50 FOOT CENTRIFUGE

Date: 31 July - September 1961

Investigation: Astronaut Acceleration Training Program IV

Principal Investigator:

Dr. Randall Chambers, AMAL
Mr. Helmut Kuehnel, NASA
Mr. Jeremy B. Jones, NASA
Dr. William S. Augerson, NASA

Subjects:

Astronaut Training - John Glenn, NASA
Malcolm Carpenter, NASA
Leroy Cooper, Jr., NASA
Virgil Grissom, NASA
Alan Shepard, NASA
Walter Schirra, Jr., NASA
Donald Slayton, NASA

Research Subjects - Dr. William Augerson, NASA
Dr. Gordon Benson, AMAL
Dr. Randall Chambers, AMAL
Dr. William Douglas, NASA
Mr. Richard Lathrop, AMAL
Mr. Jeremy Jones, NASA
Mr. Jim Savary, ACL
Mr. Art Guntner, AMAL
Mr. Warren North, NASA
Mr. Robert Kerr, AMAL

Fabrication Required:

Modify Mercury instrument panel to specifications in familiarization manual. Fabricate clock for panel as specified. Change color hoods for telelight panel lamps. Modify lamps for required specifications illumination levels. Fabricate as required for panel accelerometer. Fabricate as required for mounting of suit pressure gauge, cabin pressure gauge, and cabin temperature gauge in their required positions. Fabricate as required for installation of NASA cameras in gondola. Fabricate as required for modifications of side-arm controller. Complete construction of en-code — de-code device. Fabricate as required for installation of NASA environmental control systems for breathing oxygen and suit cooling. Construct necessary plumbing system for emergency oxygen control system. Fabricate as required for all biomedical instrumentation as indicated by Mr. Bush and Mr. Stewart. Fabricate as required for low pressurization of gondola. Fabricate auxiliary head restraint system for tumble runs.

Installation Required:

Install strong back, support box structure, contour couch system, accelerometers, Mercury side-arm controller, left-hand stick containing "stop-the-nun" switch, and Mercury instrument display panel, Also install data board, pressure gauge, speaker for rocket noise, fan, gondola bio-med cable connected to outside biopatch, two Mercury pulse cameras, T.V. camera, biomedical equipment controls for ECS system. communication system, equipment for visual research as required, Mercury capsule lighting. Also install, vacuum pumps and pressure control outside gondola. In Building #85, install Model 317 magnetic tape recorder, de-code device and auxiliary equipment as required.

Instrumentation:

Calibrate scale and check out pitch, roll and yaw, rate and attitude indicators, fuel indicator, clock, altimeter, all aspects of the telelight panel, cabin pressure instrument, temperature, suit pressure gauge, cabin pressure gauge, panel accelerometer, rate of descent indicator, key button, and control fuel handles. Tie in wfth ACL computers and tape programmer, check simulation profiles for normal Atlas Mercury mission runs. Instrument inter-communication system connecting Astronaut with the following duty stations: NASA Project Engineer, AMAL Project Officer, Medical Officer (2 head sets), Data Taker Station, Computer Director, Computer Operator, Centrifuge Operator, Performance Monitoring Station, Tape Programmer, Instrumentation Station, Voice Communicator, and the Environmental Control Systems Monitor. Instrument speaker in dressing room with volume control. Instrument Medical Monitoring Station with "push to restrict" switch, Instrument Project Engineer Station with "push to remove" button. Instrument voice disc recorders at Instrumentation Station, Instrument manual control task, Instrument the two NASA cameras and T.V. camera. Instrument all electronic and sensing equipment for medical and performance monitoring, Instrument cardiostimulator, spirometer, and oscilloscope for Medical Monitoring Station, Instrument Minneapolis-Honeywell 14-channel magnetic tape recorder. Wire from Instrumentation Station panel to patch board at Performance Monitoring Station. Instrument recorder at Project Engineer's window with the following: stick deflections in pitch, roll and yaw, attitude angles in pitch, roll and yaw, time, and G_x acceleration profile. Instrument two recorders at Performance Monitoring Station as required in Building 85. At the Instrumentation station, instrument the Heiland recorder for the following: manual control system on and off', angular acceleration in pitch, hand-controller position in pitch, roll and yaw, angular rate in pitch, roll and yaw, angular attitude In pitch, roll and yaw, and measured acceleration in G, G_y, and G_z, and retro fire events and IC stop initiated. Instrument sequence panel and panel monitoring system at Data Taker Station, instrument recorder of centrifuge performance at Punched Tape Operator Station, Instrument monitoring system for Environmental Control Station. Instrument the two Sanborn recorders at the Medical Monitoring Station wfth the following: mission acceleration, suit inlet pressure, suit outlet pressure, blood pressure, rectal body temperature and respiration rate, ECG #1, ECG #2, O_2 partial pressure in, O_2 partial pressure out, CO_2 as measured by infrared sensor, CO_2, cabin temperature 1 and cabin temperature 2. Instrument Capsule Communicator Station as indicated by NASA. Install, speaker, mike and pre-amplifier at Building 85. Instrument chest strap respiration and lip unit thermistor as required. Instrument and check out closed circuit environmental system. Obtain and instrument 4-channel recorder for Tape Programmer Station.

Photographic Coverage:

Two 2-3 pictures/second cameras will provide coverage of the head and trunk of the Astronaut and portions of the panel and controller. Closed circuit T.V. camera will also be used. Stills of all equipment and conditions are required. A documentary movie coverage of the simulation and test procedures of the project will be done jointly by NASA photographic personnel and AMAL personnel. All gondola films will be sent to NASA for development. Duplicates of NASA photographs and AMAL photographs will be provided as required.

Centrifuge Operator:

L. Passavanti, AMAL
R. Snyder, AMAL
J. Cunningham, AMAL

Power House Operator:

F. Strohacker, AMAL

Voice Communicator:

R. Voas, NASA
J. Van Bockel, NASA

Medical Officers:

Dr. Douglas, NASA
Dr. White, NASA
Dr. Augerson, NASA
Dr. Jackson, NASA
Dr. Henry, NASA
Dr. Laughlin, NASA
Dr. Morris, NASA
Dr. Benson, AMAL
Dr. Beckman, AMAL

ECS Monitor:

H. Stewart, NASA
M. Schler, NASA
R. Kerr, AMAL
E. Hays, NASA

Computer Director:

H. Doerfel, ACL
C. Brooks, ACL
F. Fenton, ACL

Performance Monitoring Station:

R. Lathrop, AMAL
B. Nelson, AMAL
R. Hall, AMAL
D. Morway, AMAL
R. Kerr, AMAL
R. Becktel, AMAL
W. Orrick, AMAL
J. Burki, AMAL

Computer Operator:

C. Blount, ACL
C. Brooks, ACL
T. Foley, ACL

Tape Programmer:

R. Hall, AMAL
F. Fenton, ACL
J. Dahms, ACL
R. Lathrop, AMAL

Remarks:

The primary objectives of this program are as follows:

1. To simulate as completely as possible a normal Mwrcury Atlas mission. This includes the pre-launch biomedical checkout and experience, the launch and re-entry accelerations, control task during orbital phase, and task performance including environmental control systems. certain aspects of the orbital phase, the re-entry and the post-run debriefing and biomedical checkouts.

2. To familiarize the Astronauts as thoroughly as possible with the longitudinal accelerations associated with the normal Atlas Mercury mission.

3. To provide procedural training to the Astronauts so that they may correlate mission events with acceleration trajectories during launch and re-entry.

4. To provide training on the attitude control task during retro fire

5. To provide training for the Astronauts in performing the re-entry rate [illegible]g task during re-entry accelerations.

6. To provide experience during tumble, aborts.

7. To evaluate the capsule lighting and study visual acuity under longitudinal accelerations expected in the Mercury Atlas mission.

8. To provide data showing the effects of acceleration on performance.

9. To provide physiological data concerning heart, blood pressure, temperature and respiration,

10. To evaluate modified protective and restraint equipment in conjunction with the environmental control system and biomedical instrumentation.

The acceleration training runs will be made at sea level, cabin altitude, and at 27,000 foot cabin altitude with the pressure suit uninflated for the majority of runs and inflated for a limited number of runs. There are five different tapes to be used in the programming of sequence functions for these runs. Run length varies from approximately 16 minutes to approximately 25 minutes. In addition to the acceleration training there will be some visual acuity studies and some physiological research, In addition, a tape is being prepared for tumble runs so that the effects of this acceleration stress may also be studied,