Progress Report

E.S.A.
on
Cockpit Design & Flight
Control Integration

Phase I

by: John P. Dunn
John P. Dunn
Advanced Design

At the present time, there is some doubt as to the future of this E.S.A. Because of this, and the possibility that in the future the basic E.S.A. concept may be altered to fit a specific project, I have decided to prepare a semi-summary report entitled PHASE I. This summary defines and outlines our progress through 21 August 1959.

## PHOTOGRAPHS

1. NAVY GOODRICH MARK II FULL PRESSURE SUIT. THE SUIT SHOWN IS COMPLETE, INCLUDING THE EMERGENCY BACK PACK, INTEGRATED HARNESS, AND FLOTATION GARMENT. SUIT PRESSURE IS 3.4 PSI.

2. COMPLETE INSTRUMENT PANEL MOCK-UP FOR A TWO-MAN VEHICLE.

3. INDIVIDUAL PHOTOGRAPH OF LEFT ARM CONSOLE, SHOWING CONTROLS, EMERGENCY SYSTEMS, AND LIQUID ENGINE THROTTLE CONTROL.

4. INDIVIDUAL PHOTOGRAPH OF RIGHT ARM CONSOLE, SHOWING CONTROLS, EMERGENCY SYSTEMS, AND REACTION CONTROL STICK.

5. OCCUPANT WEARING COMPLETE FULL PRESSURE SUIT AND SEATED IN THE TEST MOCK-UP SEAT. SUIT PRESSURE IS 3.4 PSI.

6. COMPOSITE VIEW SHOWING ENTIRE SYSTEM. SUIT PRESSURE IS 3.4 PSI.

Total engineering hours expended through 21 August 1959 = 790 hours.

PROGRESS

1. E.S.A. approved by: R. Pratt, L. Adams, W. Clohessy.

2. Received one Navy Goodrich Mark II Full Pressure Suit on loan from the U.S. Navy.

3. Received indoctrination and training on the use of full pressure suits.

4. Made visits to the following in conjunction with the E.S.A.:

   A. WADC, Dayton, Ohio.
   B. Full Pressure Suit Training Unit, North Island, San Diego.
   C. Martin-Baltimore Space Flight and Human Factors Sections.
   D. Eclipse-Pioneer Instrument Corporation.
   E. Sperry Gyroscope Company.
   F. Kollsman Instrument Corporation.

5. Designed and constructed the following:

   Occupant Support (Seat) for Full Pressure Suit.
   Complete Instrument Panel for a Two-Man Space Vehicle.
   Consoles and Controls Necessary for Two-Man Space Vehicle.

6. Construction of a small laboratory on fifth floor of VTF used to make pressure tests with mock-ups.

In order to keep this report reasonably short, the exact dimensions of the component parts have been omitted. Also, the report only explains what instruments, controls, etc., have been used, not why or how they were selected. Exact information is contained in a number of drawing, data sheets, and reports, which are available from the writer.

A total of 23 pressure tests have been made since the pressure suit was obtained. These 23 pressure tests represent some 12 hours spent with the suit donned in the pressurized condition. In addition, many hours were spent in the unpressurized condition to obtain additional information.

All dimensions were obtained from one subject, which is undesirable. However, this particular subject is a 90th percentile man (where 95th is maximum) which means that for all practical purposes, the dimensions represent the largest systems required. This has obvious advantages when using the dimensions in conjunction with the layouts of future proposals. Dimensions were obtained with suit pressure ranging from 0 to 3.6 psi.

PHASE I

INSTRUMENT PANEL — DATE: 31 August 1959

FINAL CONCEPT — REFER TO PHOTO NO. 2

The instrument panel is designed to display the information needed to enable a pilot or co-pilot to navigate, control, land and take-off a space vehicle. Each is to have the capability to take over complete control of the vehicle in the event that one becomes incapacitated. This panel concept shows a right and left hand display panel which are exact duplicates. Instruments which are not duplicated are contained in the central part of the panel, between the occupants, for common viewing.

The panel is designed to display the instruments necessary for the occupants to make an earth based lunar landing and return.

## CENTRALLY LOCATED, COMMON VIEWING, DISPLAYS

### T.V. RECEIVER

Located on the top and in the center of the panel is the 7" T.V. receiver. The receiver is activated by two T.V. cameras; one forward looking, and one downward looking camera. Along the bottom edge of the receiver are two small windows which indicate which camera is being used. The cameras, coupled with the receiver will enable the pilots to monitor proposed landing areas and view their progress along the flight path. In addition, it will contribute to relieve some of the psychological stress placed on the pilots by allowing them to "see" outside the vehicle and observe the earth.

## CABIN ENVIRONMENTAL DISPLAYS

The cabin environment is shown by five instruments located at the top center of the panel, in a horizontal row. These instruments are 3 1/8" dia. semi-clock type. Reading from left to right, they display the following information:

Cabin Pressure
$CO_2$ Partial Pressure
$O_2$ Partial Pressure
$N_2$ Supply Pressure
$O_2$ Supply Pressure

The pilots maintain an emergency control over these five functions and may increase or decrease the pressure. Each of these instruments contains a warning light system.

ENGINE, BATTERY, AND REACTION CONTROL DISPLAYS

These five instruments are located directly below the cabin environment instruments, in a horizontal row. Reading from left to right, they are:

Liquid Engine rpm, (3 1/8 dia. full clock type instrument)
Liquid Engine Fuel Supply, (2 1/4" dia. semi-clock type instrument)
Battery Life, (2 1/4" dia. semi-clock type instrument)
Reaction Control Fuel Supply, (2 1/4" dia. semi-clock type instrument)
Liquid Engine Fuel Pressure (3 1/8" dia. full clock type instrument)

The pilot maintains direct control over the engine rpm and fuel pressure. The other three instruments give him an indication of the useful time remaining for the monitored functions. Each of these instruments also contains a small warning light.

Directly below these instruments are three 3/8" dia. lights and a digital readout. The three lights are used as warning lights, to indicate an immediate malfunction. From left to right the lights are:

Oxygen flow stopped
Ozone concentration present
$CO_2$ concentration present

The digital readout is used to monitor radiation accumulation.

BOOSTER SEQUENCE, INDICATOR CHECK LIST, AND RADIO, TELEMETRY AND RECORDING SYSTEMS INDICATORS

The above displays consist of four rectangular indicators located in the lower center of the panel. From left to right they are:

Indicator check list
Booster sequence
Booster engine status
Radio, Telemetry and Recording Systems Indicators

The indicator check list is simply a column of rectangular lights which are activated to indicate the following functions:

Engine Fire
Auto-pilot off
Re-entry expected

Entrance hatch unlocked
Infrared scanners extended
Landing gear down and locked
Gyro platform stabilized

The booster sequence display again consists of a column of lights which are activated to indicate the following functions:

Second Stage Separation
Second Stage Cut-off
First Stage Separation
Second Stage Fire
First Stage Cut-off
First Stage Fire

To the immediate right of these lights are a column of digital readouts, which indicate the time-to-go for each particular function.

Next is the Booster Engine Status display. Again, this is a column of lights. The functions monitored are:

First Stage Chamber Pressure (1 thru 4 engines)
Second Stage Chamber Pressure (2 engines)
First Stage Thrust (4 engines)
Second Stage Thrust (2 engines)
First Stage Turbine RPM (4 engines)
Second Stage Turbine RPM (2 engines)

ASTRO-TRACKER, AUTO-PILOT AND TEMPERATURE DISPLAYS

Located in the center-bottom of the panel is the astro-tracker system. To the immediate left of the astro-tracker is a column of three horizontal, linear, temperature instruments. Each of the three temperature instruments is equipped with a warning light system. Reading from top to bottom, they are:

Structure Temperature
Inside Wall Temperature
Cabin Temperature

INDIVIDUAL PILOT AND CO-PILOT DISPLAYS

These displays consist of a group of twelve instruments located on the right hand side of the panel and a set of twelve duplicate instruments located on the left hand side.

Starting at the top of the group are two master warning lights. They are tied in directly with the individual instrument warning lights and are explained later in the section of this paper entitled Warning Lights.

Directly below the warning lights is a horizontal row of three 3 1/8" dia. full clock type instruments. Reading from left to right, these are:

Acceleration (fore and aft)
Rate of Turn (deviation from programmed flight path)
Velocity (along programmed flight path)

Directly below the Rate of Turn Indicator, is the attitude gyro. To the immediate left of the attitude gyro is a composite linear indicator. This indicator displays Mach number in relation to desired position. For example, if the vehicle had slowed down to an indicated .3 Mach number, shown on the right side of the instrument, the left hand part would show that the vehicle should be on final approach for a landing. Cruise or space flight desired velocity may be set up in the digital readout portion of the instrument. When the desired velocity is obtained, the double and single bars will come together to form a large solid bar, which is on the same plane as the horizon of the attitude gyro. This enables the pilot to read the instrument at a glance.

To the immediate right of the attitude gyro is another composite linear instrument. It works in the same manner as the composite velocity indicator and displays the following information:

Vehicle Altitude
Program of Command Altitude
Target Altitude
Rate of Climb and Descent
Barometric Pressure

To the immediate right of the composite altitude indicator is a column of three instruments consisting of two 2 1/4" dia. full clock type instruments and a digital readout. From top to bottom, these are:

Greenwich Mean Time
Total Elapsed Time
Time-to-Re-entry

Directly below the attitude gyro is a 6" dia. Cathode-Ray-Tube Position Indicator.

To the left of the Position Indicator is a 2 1/4" full clock type, suit pressure indicator.

To the right of the Position Indicator is a 2 1/4" dia. full clock type, engine thrust indicator.

## ADDITIONAL PANEL DISPLAY SPACE

The display systems shown and described so far are necessary for any space vehicle. As you know, each space vehicle will be assigned a specific mission. To successfully complete the mission a number of additional displays will be required. Space has been provided on this panel to allow for the addition of these instruments. The instruments will be installed in the areas provided and shown by the white lines on the panel. These areas are located on the extreme right, left, and left and right top center portions of the panel.

As it is shown, the complete panel measures 27" x 64".

## INSTRUMENT SHAPE AND GROUP CODING

Wherever possible, the various instruments have been both shape and group coded. The use of different sized full and semi-clock, linear verticle and linear horizontal, type instruments has effectively shape coded the instruments. In addition, by grouping the instruments in horizontal and verticle rows, the displays themselves are group coded.

## WARNING LIGHT SYSTEM

### MASTER WARNING LIGHTS

#### Color

One bright red

One bright amber

Lights are to flash at approximately 100 times per minute.

The red warning light is to incorporate an auditory warning horn connected to the occupants earphones.

### GENERAL WARNING LIGHTS

#### Color

Red - indicates emergency with immediate action required.

Amber - malfunction warning, action required.

Green - indicator that action has been taken.

In the case of cockpit design the general warning lights will be used as follows:

Each instrument that requires monitoring by the occupants will contain a small light. The light will be red if a malfunction of the system monitored affects the occupant or mission immediately. Examples are cabin oxygen content, failure of retro-thrust rockets and etc. In addition, and at the same time, a red light will light in the switch or control used to monitor the situation. When the occupant pushes the switch to correct the malfunction, it will turn green (green light). However, the red instrument light will continue to stay on until the malfunction has been corrected, at which time both the green switch light and the instrument light will go off.

The same applies to the use of amber lights, except that amber lights will be used in place of red when the situation monitored does not immediately affect the occupant nor the mission. An example would be the humidity control.

In several instances, the light warning system will be progressive; as the system being monitored begins to go out of the normal range, the amber light will come on. If the system continues to go out of tolerance, and no corrective action is taken, the red light will activate at the danger level.

PHASE I

CONTROL CONSOLES

FINAL CONFIGURATION REFER TO PHOTO. NOS. 3 & 4

To operate a vehicle of this type, each occupant must monitor 43 different controls. Of these 43 controls, 17 of them must be located and arranged so that they may be operated under an omni-directional 8 "G" load, with the pressure suit pressurized to 3.4 psi (emergency pressure).

The complete cockpit system has been designed so that during any phases of the program where "G" loads are applied, the occupants wear the full pressure suit, pressurized to 3.4 psi. In addition, during space flight, or orbit, one of the two occupants always wears a pressure suit, in the unpressurized condition. The reasons for this approach are extensive and will not be covered in this report. In the event that "G" loads are applied, the suit automatically pressurizes to 3.4 psi regardless of the cabin pressure. As part of the suit pressure system, the restraint harness is tightened and locked and the elbow retainers move to the full forward position. In doing this, the occupant is pressurized, locked in the seat, and the arms are moved forward until the liquid engine throttle and the reaction control stick are abreast of the occupant's hand. From this position the occupant may easily activate any one of the 17 emergency controls.

LEFT HAND CONSOLE

Starting with the left hand console and referring to the Photograph No. 4, you will see the liquid engine throttle. The button mounted on top of the throttle starts the liquid engine. The throttle is rotated to change fuel pressure and is moved fore and aft to change thrust. Above and to the right of the throttle is a horizontal row of four round buttons, and a column of three square buttons.

The four round buttons control the emergency initiation of the following functions:

DROGUE 'CHUTE #1
DROGUE 'CHUTE #2
MAIN 'CHUTE #1
RESERVE 'CHUTE

The three square buttons control the emergency initiation of the following:

RETRO 1 & 2
EMERGENCY EJECTION
RETRO 3 & 4

The emergency ejection button is red in color and is located to the immediate right of the left hand thumb. With this arrangement, emergency ejection may be manually initiated by either occupant in less than 0.5 seconds.

After the boost sequence is complete, the pressure suit depressurizes, the restraint system unlocks and the elbow retainers move to the full aft position. This allows the occupant's arm to move rearward approximately 5" and exposes a set of four toggle switches and six rheostat switches. From the unpressurized position, the occupant may activate any of these 10 controls in addition to the liquid engine throttle and emergency controls. The four toggle switches control the following systems:

Extention and retraction of the Infrared Scanners
Extention and retraction of the Landing Legs
Stabilization of the Inertial Gyro Platform
Increase or decrease the pressure suit ventilation air

The six rheostat switches control the following:

$O_2$ Partial Pressure
Cabin Temperature
Humidity Control
Cabin Pressure
$N_2$ Supply Pressure
$O_2$ Supply Pressure

RIGHT HAND CONSOLE

The right hand console is designed to be operated in the same manner as the left. In the pressurized position, the occupant's hand is pushed forward abreast of the reaction control stick. The control stick consists of a control handle mounted on a slender shaft which in turn is fastened to the housing which is movable in the verticle and horizontal planes. The control stick and handle are mounted in the horizontal plane and are spring loaded to remain in the neutral position. The vehicle is controlled in the pitch plane by up and down motions of the stick, controlled in the yaw plane by lateral stick movements and in the roll plane by rotating motions. It is felt, that at this time, these motions most closely duplicate the natural control motions of most pilots.

The handle of the control stick is designed so that the occupant inserts his first and index fingers into the holes at the top of the handle. The thumb is allowed to find a natural position either over the top of or along the side of the first finger. The ring and small fingers grip the lower part of the control handle in the finger grips provided. Small buttons have been placed where they may be activated by the thumb, ring, and small fingers.

The four buttons located on the reaction control stick control the following:

Auto-pilot on and off
Emergency Astro-tracker System
Radio on - off
Arm retention lock and unlock

To the right of the reaction control stick is a panel containing two round and two square buttons. These are emergency buttons to control the following:

Second Stage Separation
Second Stage Cut-off
First Stage Separation
First Stage Cut-off

Directly below the reaction control stick is a red button, used to initiate automatic re-entry. As is the case with the left hand, the right hand moves aft 6" when the suit is depressurized. This exposes a duplicate panel containing four toggle and six rheostat switches.

The four toggle switches control the following:

T.V. Receiver On - Off, Forward and Downward Camera
Altitude Command on Digital Readout
Command Velocity
Time to Re-entry Digital Readout Re-set

The six rheostat switches control the following:

Radio Transmitter Frequency Selection
Radio Receiver Frequency Selection
Cathode Ray Tube On - Off Adjust
T.V. Receiver Adjust
Telemetry System Control
Recording System Control

In addition to the left and right hand console controls, there is a set of circuit breakers and the seat adjustment switches. These are all located on a small panel encased in the occupant's inside leg retainers. All of the arm consoles controls contain the warning light system explained in this report.

SPECIFIC MISSION CONTROLS

Additional controls that may be required to effect specific missions will be mounted on swing-out panels contained in the arm consoles.

PHASE I

OCCUPANT SUPPORT REFER TO PHOTO. NO. 5

FINAL CONCEPT

The occupant support system is the system which is concerned with the support and restraint of the pilot and co-pilot. This system includes the seat, restraint harness, emergency oxygen and suit pressure system, waste removal and food supply. A seat has been constructed which will contain an occupant wearing a full pressure suit in both the pressurized and unpressurized condition. The seat is of plywood construction so that it can be easily modified when necessary.

The system is designed so that any one of a number of different types and manufacture of full pressure suits may be utilized. The system is as flexible as possible so that it may also be adjusted to fit any particular individual. Movable or adjustable portions of the systems are: the seat back angle, the seat armrest angle, and height, the seat headrest height and angle, the seat pan, the foot rest height, the elbow retention system, and the restraint harness.

The control consoles are fitted directly to the ends of the armrests, and may be removed quite easily so that new or different consoles can be readily evaluated.

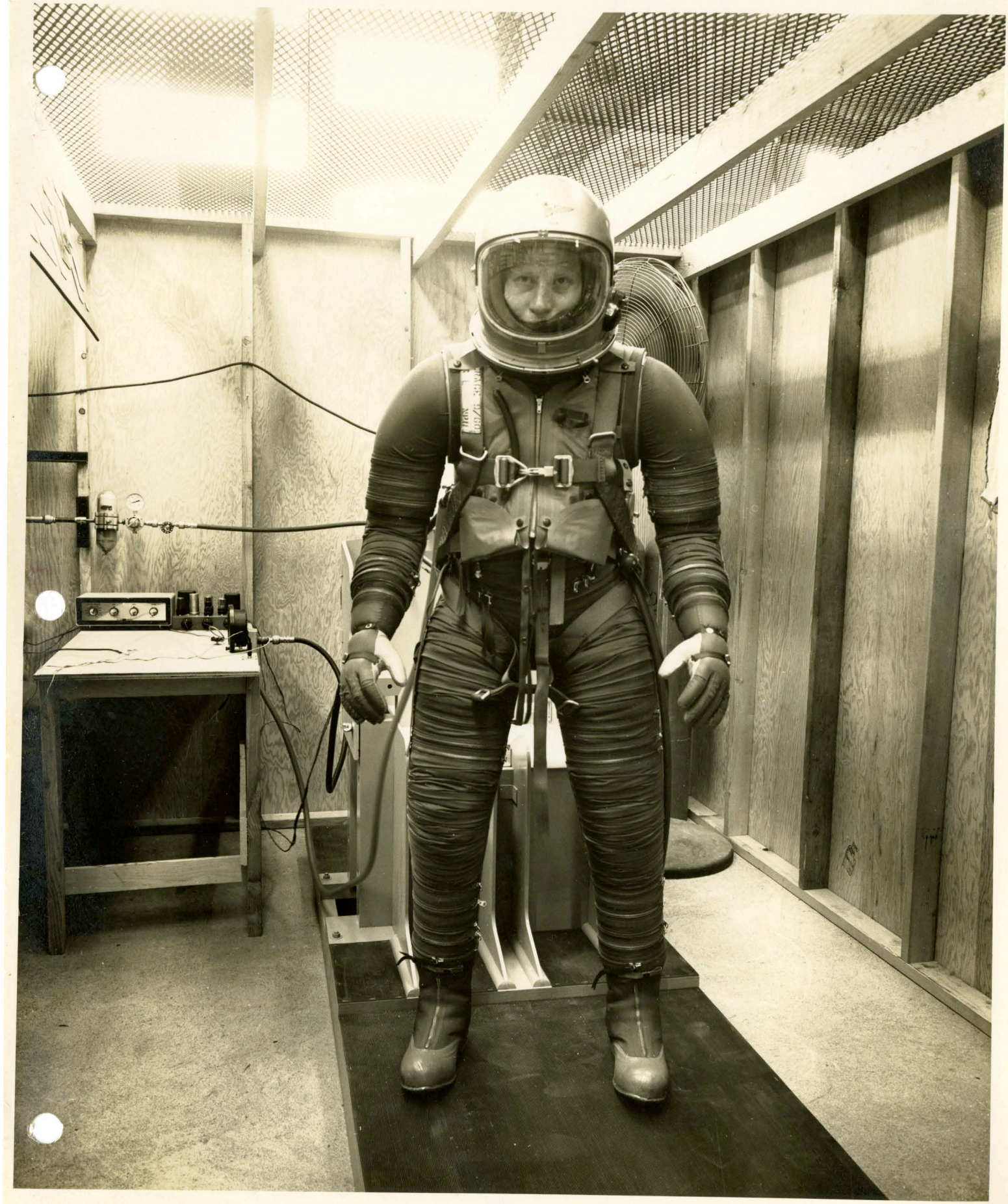
The seat itself provides protection and restraint to lateral and chest to back "G" loads by confining the shoulders, head, hips, arms and legs within the seat. "G" loads applied from back to chest are to be taken by the integrated restraint harness, the food and arm harness, as well as the lap belt. Knee restraint will be provided to prevent submarining.

PLANS

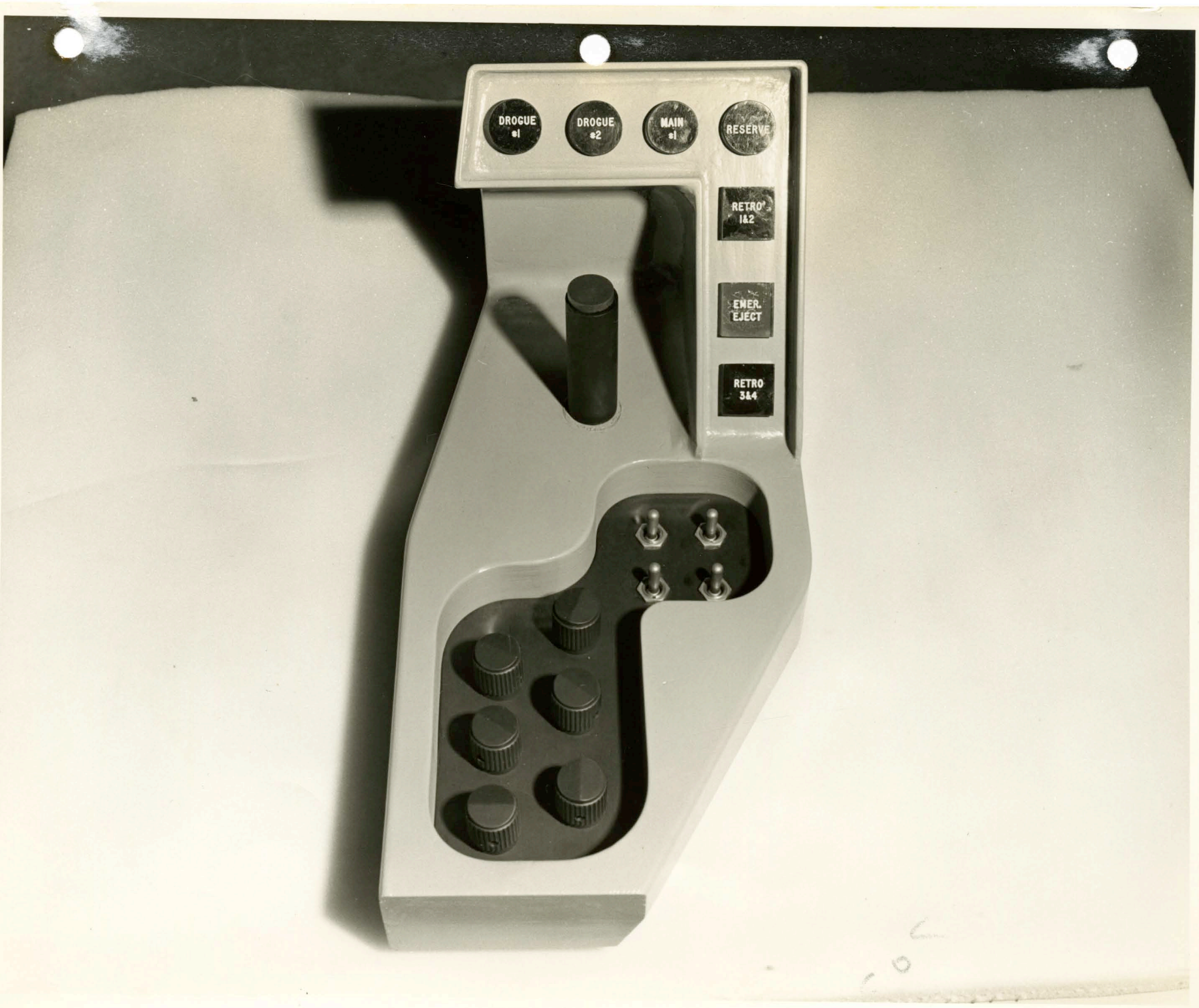
Phase I of this program was to layout and construct the basic test mock-up. Under the Phase II portion of the program, detail design of specific sections will be completed. During Phase II, it is planned to design and construct the instruments shown on the panel, detail design of the controls, the harness, food and water, and elimination systems of the occupant support system. When detail design of the instruments has been accomplished, they will be drawn by the Art Department, photographed, and attached to the panel. The harness system will be actual hardware, and the food, etc. systems will be mock-up. In addition, other types of pressure suits will be used to determine the flexibility of the systems. Tests will be conducted with the pressure suit in a vacuum chamber to determine what effect an actual altitude of approximately 125,000 ft. will have on the system.

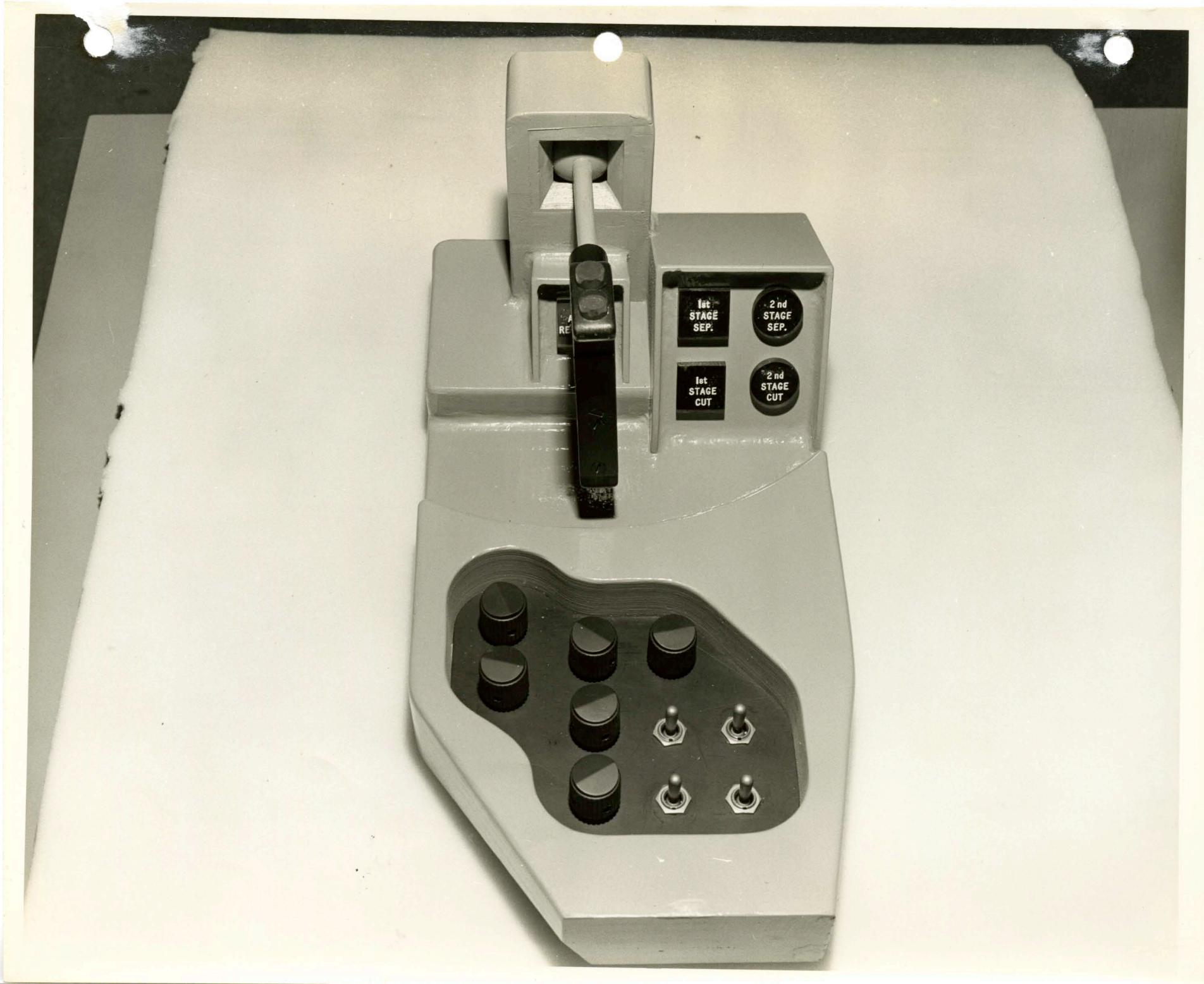
Phase III of the program is the actual construction of a finished mock-up. The finished mock-up will have the instrument faces mocked-up, replacing the photographs. In addition, some of the controls will be functional, all will have functional warning lights.

The finished mock-up will incorporate the analog computor and digital voltmeter to facilitate testing, plus an external testing console. Phase IV consists of the testing, demonstrations and future research on space vehicle cockpit design.




AUTOPILOT SYSTEM
STRUCTURE TEMP
CABIN TEMP


DROGUE #1
DROGUE #2
MAIN #1
RESERVE
RETRO 1&2
EMER. EJECT
RETRO 3&4


1st STAGE SEP.
2nd STAGE SEP.
1st STAGE CUT
2nd STAGE CUT