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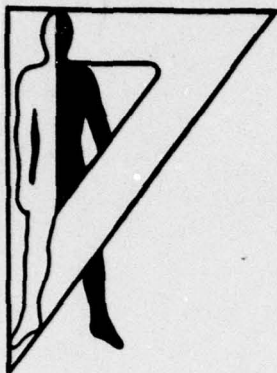
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HUMAN ENGINEERING EVALUATION OF THE SMALL-CALIBER  
AMMUNITION MODERNIZATION PROGRAM (SCAMP)/LOAD AND  
ASSEMBLE SUB-MODULE (LASM) CONTROL ROOM

HUMAN ENGINEERING LABORATORY  
ABERDEEN PROVING GROUND, MARYLAND

OCTOBER 1976

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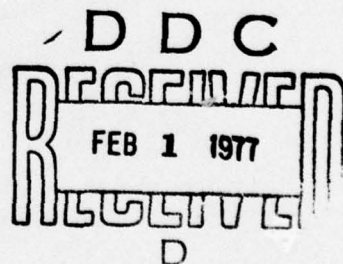
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Lester Jee

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Aberdeen Proving Ground, Maryland

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**HUMAN ENGINEERING EVALUATION OF  
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LOAD AND ASSEMBLE SUB-MODULE (LASM) CONTROL ROOM**

**INTRODUCTION**

This report's primary purpose is to present the human engineering recommendations for redesigning the Load and Assemble Sub-Module Control Room for the Small-Caliber Ammunition Modernization Program (SCAMP). The ultimate goal in this redesign is to increase the efficiency and effectiveness with which the operator performs his tasks. This is accomplished by (a) arranging and locating controls and displays in optimum positions for use by the operator, and (b) better utilizing the space allotted for personnel and equipment. Proper redesign of the sub-module control room will reduce downtime, increase safety, increase production, and provide better accessibility for maintaining the equipment.

**BACKGROUND-GUIDELINES**

Factors which were considered in the arrangement of controls and displays are:

- a. Priority of location
- b. Spacing
- c. Grouping by either function or sequence
- d. Sequence of operation

**Priority of Location**

Priority of location refers to placing the most important controls and displays in the optimum positions for use on a panel or console. The optimum positions are defined as those areas where controls and displays are most accessible to the operator. The criteria used to determine priority are:

- a. Frequency and duration of use.
- b. Accuracy and speed required in reading a display or operating a control.
- c. Consequences of an error or delay in using the control or display.
- d. Ease of manipulating a control in various possible locations, in terms of force, precision, and speed required.

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According to the Military Handbook for Human Factors Engineering Design for Army Materiel<sup>a</sup>, the priority of components is divided into three categories, which the designer should use for arranging components:

a. Primary (highest-priority) displays and controls, which should be placed in the optimum visual and manual workspaces.

b. Secondary controls and displays, which may not warrant the highest priority in location but still must be accessible when required. These should be placed within the operator's maximum viewing area and reach.

c. Least important controls and displays, which should be placed in the lowest-priority positions, include set-up and calibration controls and displays which are not used during operation.

### Spacing

Spacing refers to the relationship between controls and displays. The arrangement of controls and displays should assist the operator in associating each display with its related control. Military Handbook 759<sup>a</sup> states that "the spacing of controls should be based on:

"(a) Requirements for using controls simultaneously.

"(b) Requirements for using controls sequentially.

"(c) Body part used to operate a control.

"(d) Size of the control and amount of movement required (e.g., displacement or rotation).

"(e) Need for blind reaching (i.e., reaching for the control and grasping it without seeing it).

"(f) Effects on system performance if the operator inadvertently uses the wrong control."

### Grouping

Controls and displays should be grouped by function when there is no specific sequence of function, and they should be spatially arranged so the relationship between them is readily apparent to the operator.

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<sup>a</sup>U.S. Army Human Engineering Laboratory. Human factors engineering design for Army materiel. MIL-HDBK 759, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA, 12 March 1975.

## Sequence

When arranged horizontally, controls and displays which are used in sequence should be ordered from left to right by sequence of operation.

Controls and displays which are arranged vertically should be placed so their order of operation is from top to bottom.

## METHOD

During a visit to the SCAMP facilities at the Twin Cities Army Ammunition Plant, operation of the Load and Assemble Sub-Module was examined. By interviewing operators and observing actual Sub-Module operation, a list (Table 1) of the operator's tasks was derived as a basis for determining the priority, spacing, grouping, and sequence for the various pieces of equipment.

Two reference documents, Military Handbook 759<sup>a</sup> and Military Standard 1472B<sup>b</sup>, were used as guidelines for the redesign.

The following equipment is required for the Load and Assemble Sub-Module:

### Previous Components

- Honeywell 316 Computer
- Isotopic Detector System
- Battelle Monitor System
- Tektronix Rack Oscilloscope
- Tektronix Teletype (Paper)
- Tektronix Teletype (Display)
- Power Supply System
- Product Quality Control System (PQCS)
- TV Monitors (3)

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<sup>b</sup>U.S. Army Missile Command. Human engineering design criteria for military systems, equipment and facilities. MIL-STD-1472B, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA, 31 December 1974.

**TABLE 1**  
**Sequence of Operator (Specific) Tasks**

---

---

1. Turn on water for hydraulic pump (outside).
2. Turn on Feeder Power (outside).
3. Reset Pushbuttons for Case and Bullet Feeder (outside).
4. Turn on Battelle current.
5. Turn on POWER ON button - button will light.
6. Turn on STAND-BY button - The AC voltage power-line meter will indicate a voltage reading. The indicators for fill level, vacuum, water, and air will light up (green).
7. Switch Computer Mainline Power on.
8. Turn on Fire Alarm System.
9. Turn on Counter and Oscilloscope.
10. Turn on Teletype (Commo).
11. Teletype Commo.
12. Turn MA/SI/RUN Switch to SI (Computer).
13. Press Master Clear (Computer).
14. Enter Octal 1000 in ply register (Computer).
15. Turn on MA/SI/RUN Switch to run (Computer).
16. Press START (Computer).
17. Check readings on the various gauges. They should be as follows: Line Press greater than 80PSI, Purge - 20 to 25PSI, By-Pass - 0.0 PSI (15 to 20PSI when in use), Dose - 5 to 6PSI, and Vacuum - above 20".
18. Turn on the Isotopic - The two blank, door open, and Isotopic Lights should remain out.
19. Re-initiate the Computer (Repeat steps 12 to 16).
20. Turn on the two Deluge Toggle Switches (Fire Alarm).
21. Turn on the Isotopic Gage Switches labeled Power, Source, and Air.
22. Check Headset Communications System with Wing personnel.

TABLE 1 - Continued

23. Turn on Battelle System.
24. Check emergency stop lamp and warning alarm function.
25. Turn Powder Switch on.
26. Feeder Control Switch on Auto.
27. Switch from Stand-by to Run.
28. Bring Sub-Module speed up to operating level by pushing the appropriate speed-control button.
29. Observe display panel to determine that all systems are operable.
30. Press Stand-by button.
31. Re-initialize Computer (Repeat steps 12 to 16).
32. Set Sense Switch 2 down (Computer).
33. Clear all data buffers (Computer).
34. Teletype Commo.
35. Teletype Commo (Check).
36. Reset Counter.
37. Run QC Isotopic Gage Check.
38. Monitor Burroughs Display.
39. Operate Display buttons.
40. QC7 - inspection.
41. Run.
42. Stops in Production (2 Types):
  - a. Control Stop.
  - b. Emergency Stop (E-Stop).

TABLE 1 - Continued

42a. Control Stop

1. Red light lights up on panel - stopped outside.
2. Stand-by (inside).
3. Teletype Commo.
4. Log Entry (wait for fault to be corrected).
5. Press Run Button.
6. Press Speed Controls.
7. Monitor Displays.

42b. Emergency Stop (2 types)

1. Case Did Not Transfer.
  - a. Light comes on.
  - b. Verbal Commo.
  - c. Teletype Commo.
  - d. Log Entry (wait for correction).
  - e. Reset Light.
  - f. Re-initialize Computer.
    - (1) Clock malfunction - reprogram computer.
    - (2) Program malfunction - reprogram computer.
    - (3) Teletype in parameters.
  - g. Press Run Switch.
  - h. Press Speed Controls.
  - i. Monitor Displays.

2. Stand-By

- a. Three Ways to Stop.
  - (1) Automatic (mechanically activated).

**TABLE 1 - Continued**

- (2) LASM operator - manual task.
- (3) WING Operator - manual task.
- b. If malfunction is for an extended time.
  - (1) Power Off (Optional).
  - (2) Isotopic Off.
- c. Teletype Commo.
- d. Log Entry.
- e. Re-start (Steps 5 to 41).

Shut-Down Procedures

1. Push Powder Off Button.
2. Monitor Display - reject bullets (powder).
3. Turn Off Feeders (bullet and case).  
Discs remain on.
4. Look out window - Verbal Commo.
5. Push Standby Button.
6. Push Powder On Button.
7. Allow Powder to Drain.
8. Push Powder Off Button.
9. Computer Printout.
10. Power Off.
11. Discs Off.
12. Main Feeder Off.
13. Water Off.
14. Computer Off.

TABLE 1 - Concluded

15. Turn Off:

a. Fire Alarm System.

b. Teletype.

c. Battelle System.

d. Counter.

e. Lights.

f. Isotopic Detector System.

16. Complete Sub-Module Daily Operating Log.

---

### Modified or Added Components

Burroughs Display System  
Control Section  
Air Gauge System  
Fault Detector System  
Power Supply Section  
Feeder Controls (Bullet and Case)  
Tachometer (Parts/Min)  
Voltmeter  
Clock (Digital)  
Elapsed—Time Clock (Digital)  
Parts Counter (Digital)

### RECOMMENDATIONS

The control room is very small in size and contains several non-movable components, so it permits only limited rearrangements of the equipment. The size of several components also restricts the areas where they can be located. Based on factors of priority and component size, the controls and displays have been divided into five basic groups or sections of equipment.

Each section is a comprehensive unit of the system that allows easy maintenance, mobility, and accessibility for operation. Their arrangement, as specified later, presents a well-organized system that optimizes the controls and displays, within the constraints placed on the designer and operator. Each unit is mounted on rollers so it can be moved for maintenance or to change its location. Components of each section are mounted in roll-out racks where possible, to further facilitate maintenance. The following paragraphs describe the components of each section.

#### Section 1

This section includes only the Honeywell 316 Computer. Its dimensions are approximately 73" high, 30" wide, and 27" long. It is the largest single piece of hardware, and its size presents the biggest problem in integration into the new control-room layout.

Since the computer is essential to the Sub-Module's successful operation, it is a high-priority component. However, because of its size, it could not be located in the optimum position. Therefore, an attempt was made to locate it as close to the operator's normal operating position as possible, regardless of the position of the other high-priority components.

Re-initialization of the computer involves activating several buttons on the computer (steps 12 to 16, Table 1), and is the most time-consuming task the operator presently performs in his normal routine. The possibility of combining all the steps required for re-initializing the computer into one (if mechanically possible) should be investigated. This would reduce downtime and simplify the operator's task. If the clock or the program in the computer malfunctions, the computer must be reprogrammed—another timely task. An alternative method, to replace the present manual method of reentering a programming tape, would also be advantageous and should also be investigated.

## Section 2

Section 2 consists of the following components (Figure 1):

Tektronix Teletype	10"H	22"W	18"L
PQCS	7"H	20"W	25"L
Oscilloscope	9"H	9"W	20"L
Power Supplies	28"H	22"W	32"L

The teletype is the most-used piece of equipment in this section, because it must be used each time production stops. However, since it does not control the machinery directly, it cannot be considered a true high-priority component. Its frequency of use does, however, warrant locating it within the operator's viewing area and reach.

The Production Quality Control System (PQCS) and the Oscilloscope are low-priority components. The Oscilloscope is used for calibration and equipment checkout, and the PQCS is used for informational purposes. The importance of these pieces of equipment does not warrant locating them in an optimum position, but they should be located in an area where they are accessible to the operator.

The power supplies are also low priority, and need not be accessible during the operator's normal daily tasks. The power supplies should therefore be located in the area beneath the teletype.

## Section 3

The components contained in this section are (Figure 2):

Isotopic Detector	11"H	18"W	20"L
Air Gauge Panel	10"H	20"W	12"L
Battelle Monitor System	13"H	19"W	18"L

All of these components are secondary components, so they are not located in an optimum position. They should, however, be placed within the operator's maximum display area and reach. There is additional storage area beneath these components.

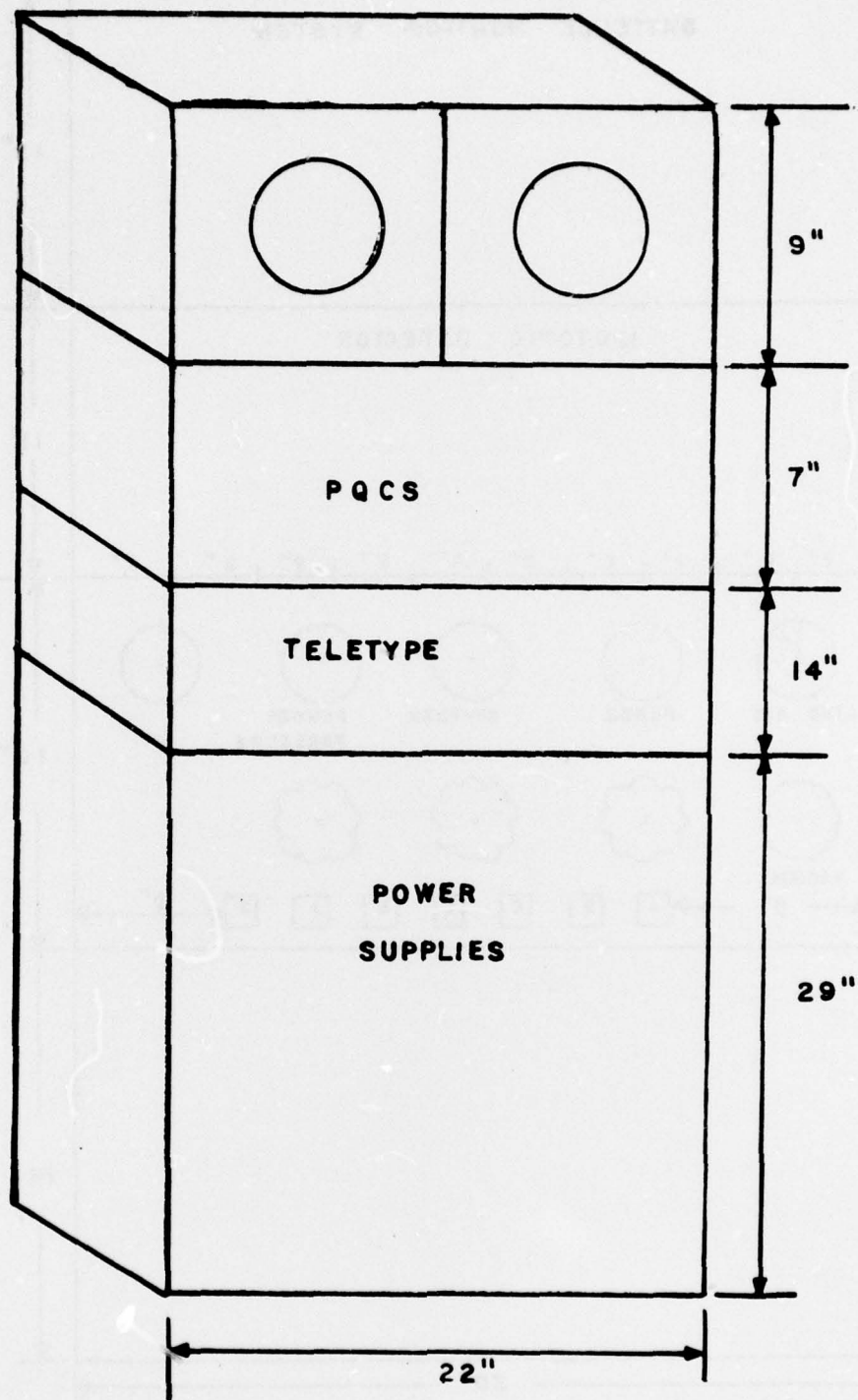


Figure 1. Section One.

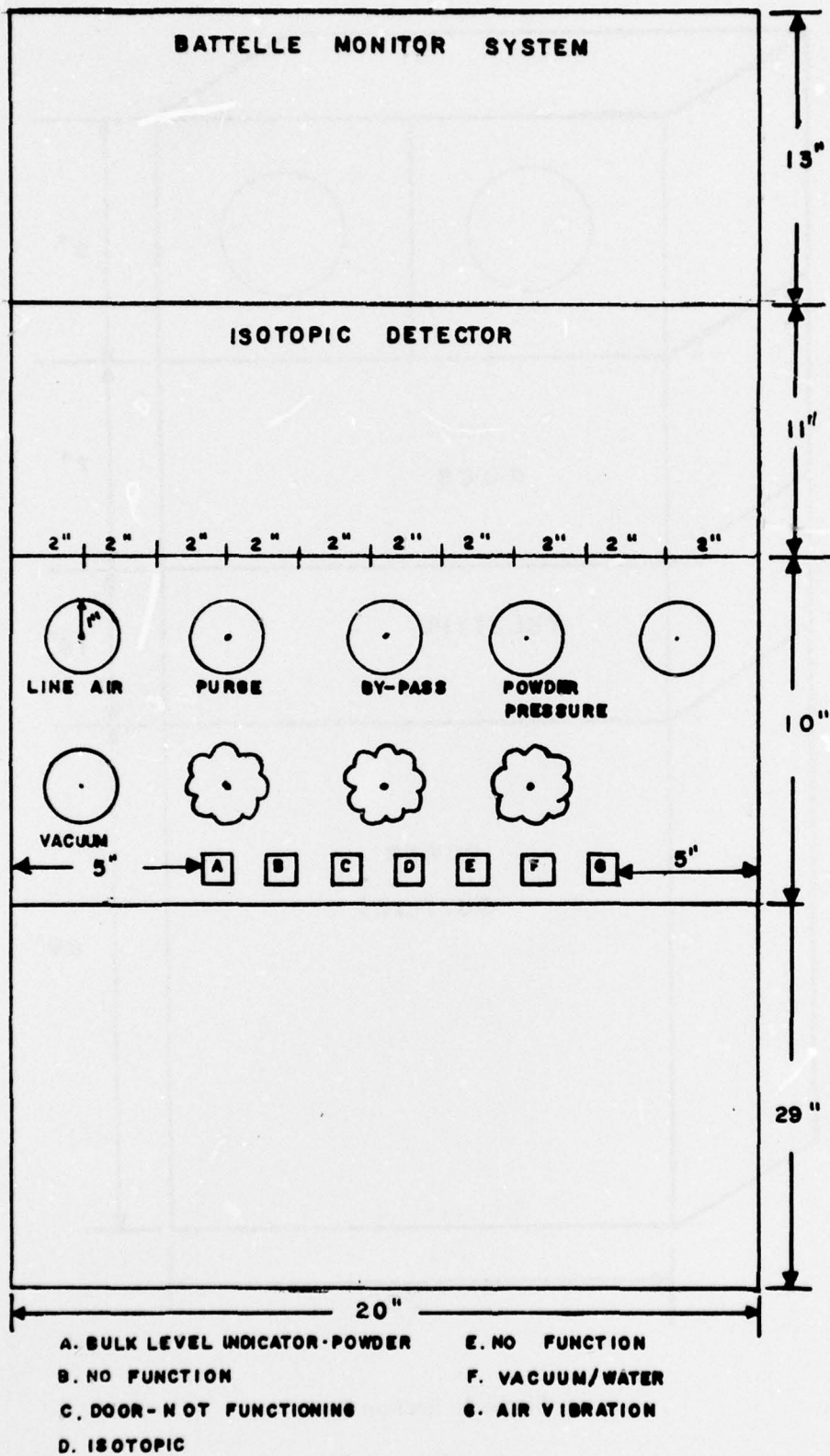


Figure 2. Section Two.

#### Section 4

This section is the master control section which directly controls the machinery. Components in this section include (Figure 3):

- Burroughs Display and Controls
- Main Control Panel
- Fault Detector Panel
- Feeder Controls (Bullet and Case)
- Tool Inhibitor Panel
- Emergency Stop Button
- Voltmeter
- Tachometer (Parts/Min)
- Clock and Elapsed-Time Clock
- Parts Counter

While not all of these components have high priority, most of them are necessary either for safety reasons or for successful operation of the Sub-Module.

Figure 3 shows the arrangement of the Master Control Panel and its components. Most high-priority components, which are essential for successful operation of the Load and Assemble Sub-Module, are found in this panel. The most important component is the main control unit, which contains the controls that regulate the machinery. The button arrangement (Figure 4) has been modified from the original arrangement. The main control unit itself is located in the optimum control area, slightly to the right of the panel's center.

The Burroughs Display and Controls are components that must be continuously monitored during normal Sub-Module operation. The control button arrangement and displays were integrated, in their original configuration, into the new panel design. They are located in the optimum display and control area (Figure 3).

All other controls and displays are secondary components, but they are accessible to the operator during his normal daily tasks.

In locating these components, first consideration has been given to the safety controls, such as the emergency stop button and the fault-detector panel. The reason for this consideration for the safety controls is self-evident.

Since reducing the time it takes the operator to locate and react to a fault—which stops production—reduces downtime, the fault detector panel is situated in the operator's optimum viewing area or as near to it as possible.

This section also contains a desk top which serves as a writing surface (Figure 5).

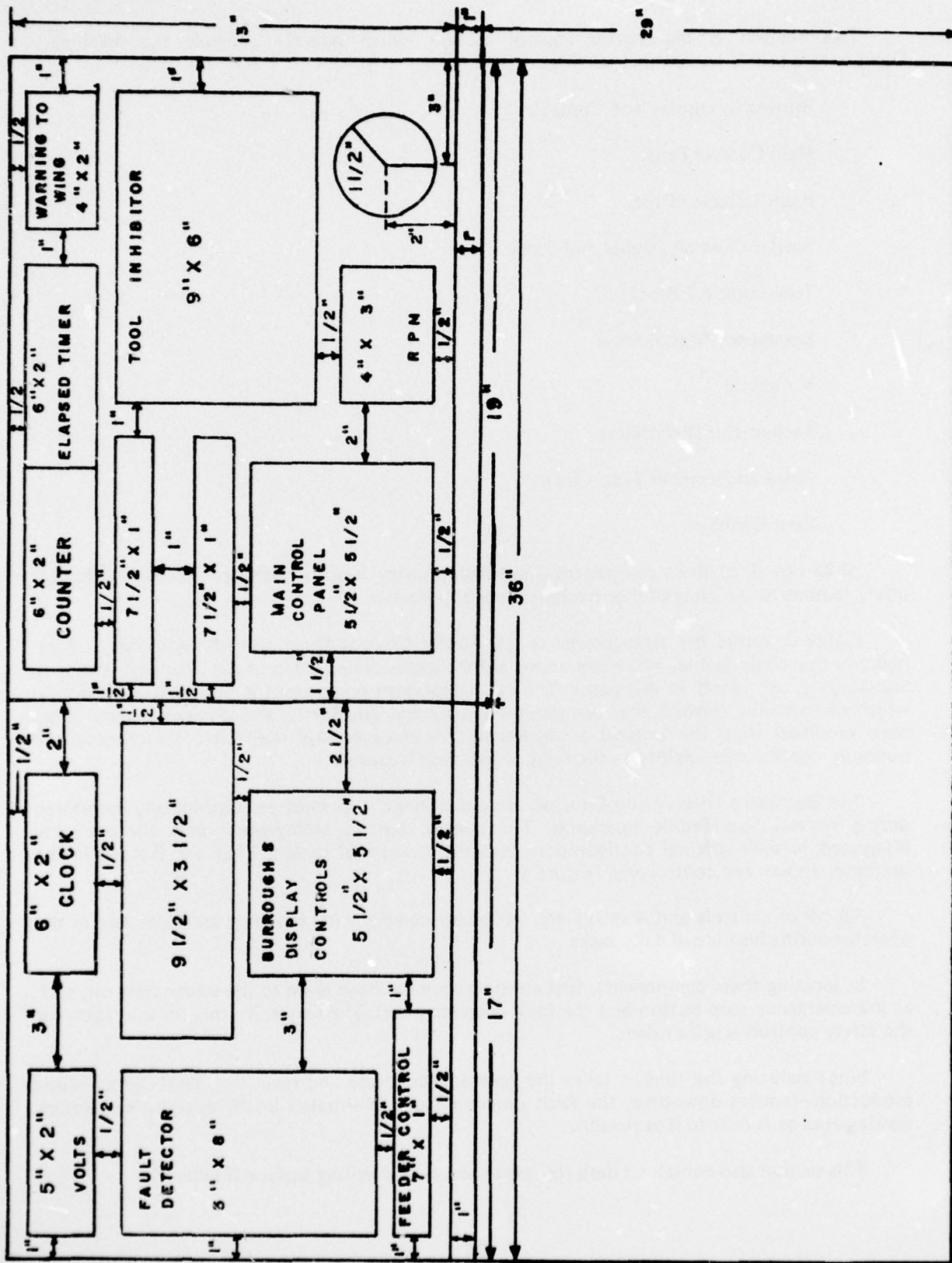


Figure 3. Master-Control Panel.

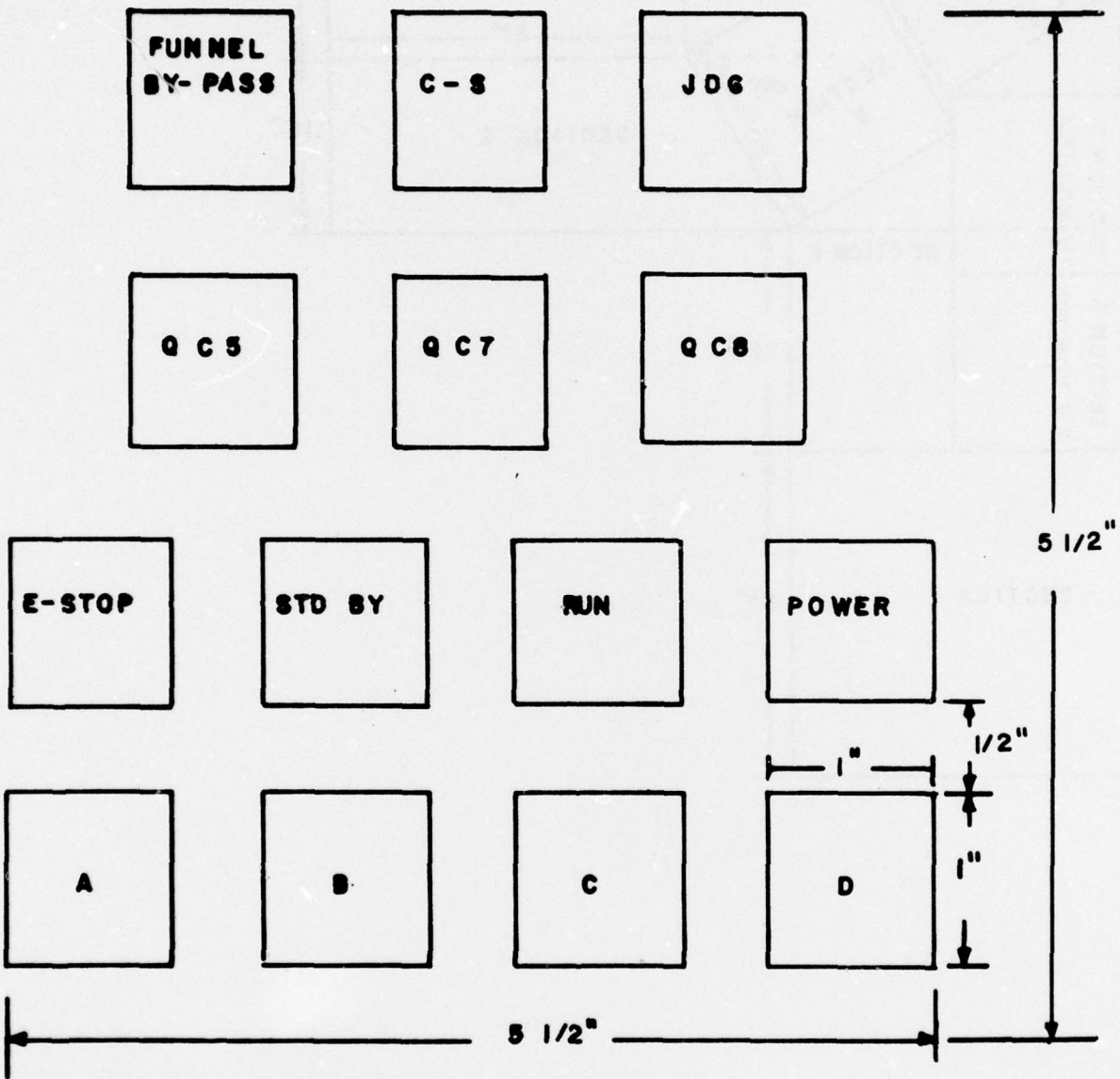


Figure 4. Main-Control-Panel button arrangement.

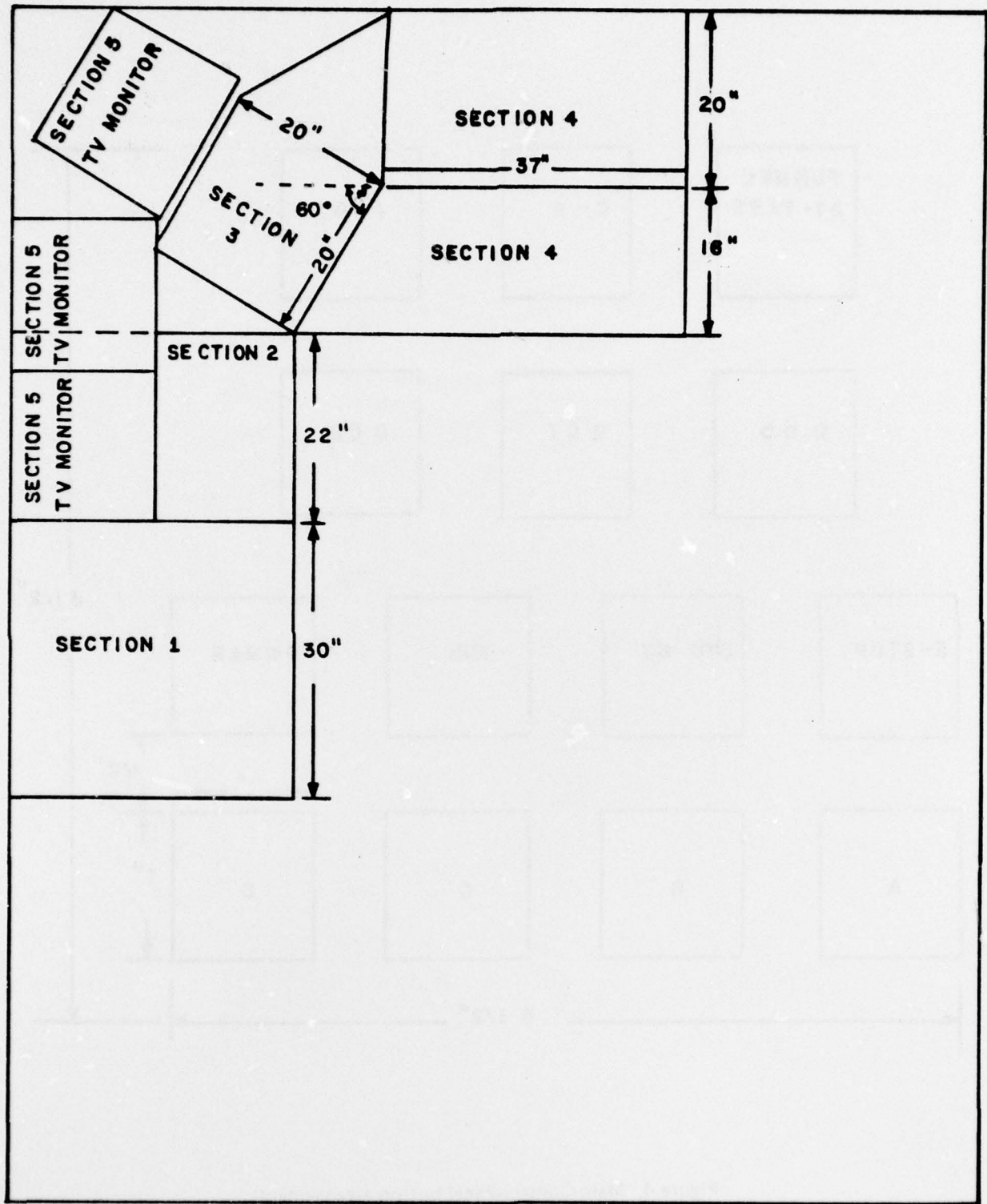


Figure 5. Contoured layout.

## Section 5

Section 5 consists of three TV monitors, 17"H 17"W 15"L, located in a rack directly below the ceiling. These televisions will be preset, and there will be no need to adjust them during Sub-Module operation.

In addition to all the equipment described previously, there is another Tektronix display teletype, which can be used in place of the continuous-paper-feed teletype, but which is ordinarily stored in the control room.

### Control Room Layout

The layout of the control room and the five sections is shown in Figure 5. The dimensions specified in all the figures are approximate, variable to the builder's preference. The telephone and the deluge (sprinkler) system are not shown in any of the figures, but they will remain in their present locations. As seen in Figure 5, the layout uses contoured sections to make the displays and controls more accessible to the operator. This enhances the operator's effectiveness by making it easier for him to monitor the displays in that section.

A second layout (Figure 6) is essentially the same as the first, except it is not contoured. Since it does not provide the benefits of the contoured section, it is less effective.

As previously mentioned, each section will be mounted on rollers to provide easy access, should it be necessary to move the equipment. In addition, the design of each section should have the components mounted in slide-out racks that can be pulled out for access to service the equipment. This would facilitate maintenance and reduce downtime. The location of the racks in each section is dictated by equipment requirements and dimensions, and will be subject to review for assurance of proper human engineering design.

### COMMENTS

Additional consideration should be given to such areas as (a) environmental conditions such as lighting, ventilation, noise and vibration, (b) coding of controls and displays, and (c) colors and markings used on the panels.

Because of the great number of displays in the control room, either the displays should have a shield to prevent glare, or the room should have an indirect lighting system. The illumination level, however, should still be adequate for the operator to perform all his tasks. Ventilation should be adequate for the maximum number of persons that would normally occupy the room at one time. There should be a circulating or exhaust fan, coupled with the present air-conditioning system, to allow sufficient air circulation. The effects of noise and vibration were not studied, but should be investigated.

General practice for coding should be as follows:

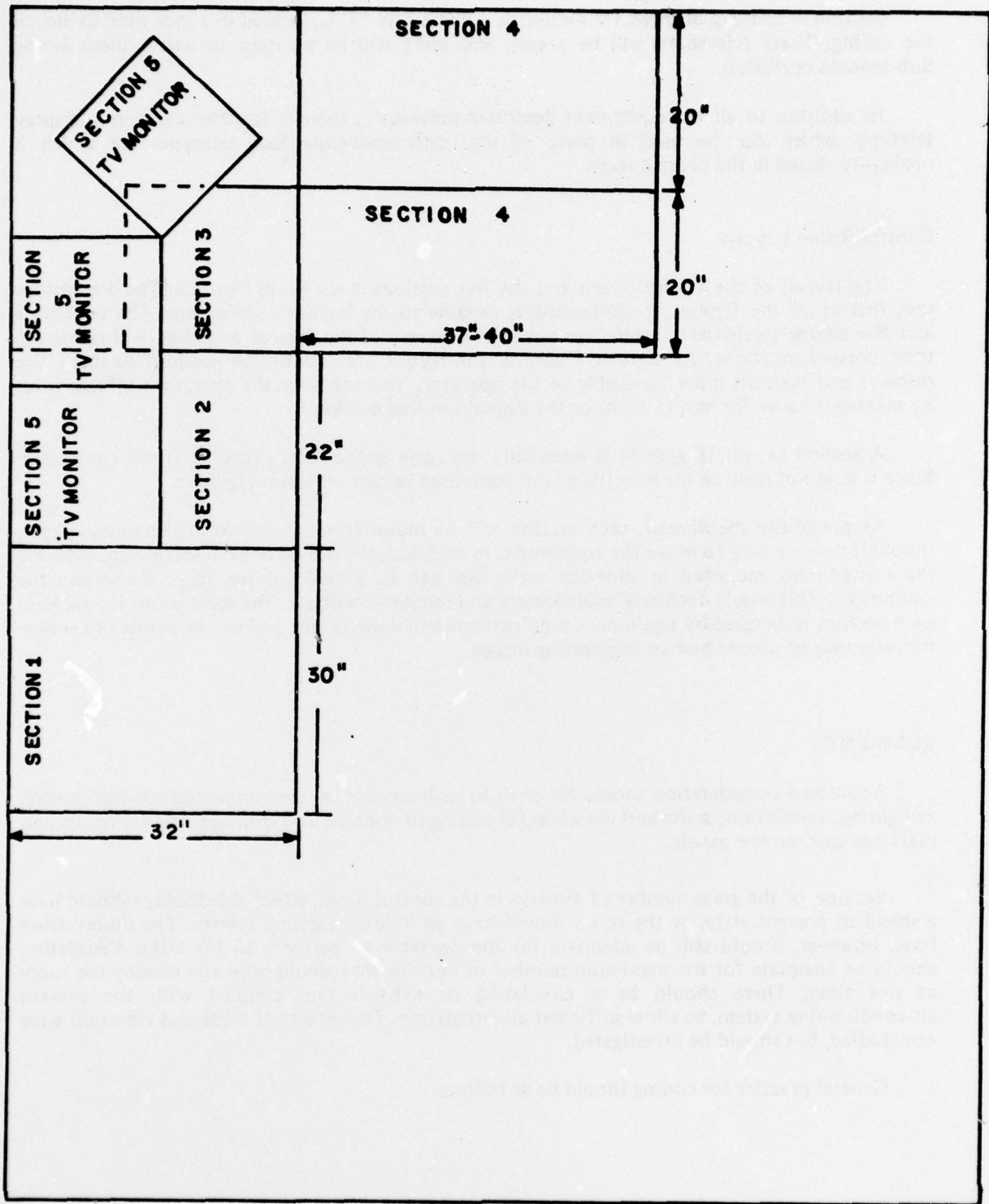


Figure 6. Non-contoured layout.

Controls - "All emergency controls should be coded, usually in red. To give the emergency controls the visual emphasis they demand, only a bare minimum of other, less important controls should be color coded. Colors used to code critical controls should contrast sharply with those used for noncritical controls"<sup>a</sup>.

Thus, following this practice, all emergency controls and controls which demand immediate attention should be color-coded in red. The present system already indicates the status of various control buttons by a green light, which shows that they are functioning in that mode. This coding should also be incorporated into the new system. All items and components on the panel, including all the buttons, should be labeled to clearly show their functions.

Displays - Colored codes, markings, and bands can help personnel read displays more effectively:

- a. By making it obvious at a glance whether the indication is within acceptable limits.
- b. By making it equally obvious when the indication is in a "danger" range that requires immediate corrective action.
- c. By keeping operators from misreading numbers or mistaking a desired numerical value.<sup>a</sup>

All displays in the Sub-Module should be studied to determine whether or not they are properly coded for the task they are required to perform.

## SUMMARY

The new design incorporates the basic principles of human engineering, but also takes the practical aspects into consideration. It allows easy access for maintenance, puts all the controls and displays into convenient locations, and reduces the time and effort the operator is required to use in performing his tasks.

Safety is also increased by making it easier for the operator to recognize an unsafe situation and react to it.

This report recommends desirable layouts, and control and display arrangements, for the Load and Assembly Sub-Module Control Room. These recommendations are intended as guides for redesign, and some modification may be required to incorporate them into the actual hardware. Any proposed modifications should be reviewed and approved by the Project Manager's human factors staff.