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TECHNICAL REPORT SDC 279-3-5

LAYOUT OF THE COMBAT INFORMATION CENTER IN THE PO-2W AIRCRAFT

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DEPARTMENT OF THE NAVY ★ OFFICE OF NAVAL RESEARCH ★

SPECIAL DEVICES CENTER

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LAYOUT OF THE COMBAT INFORMATION CENTER IN THE PO-2W AIRCRAFT

New York University
Human Engineering Project
April 1951

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1.0 SUMMARY

1.1 Purpose

This report represents the results of a study conducted to find the optimal layout of electronic equipment for the airborne Combat Information Center for the PO-2W aircraft.

1.2 Data

The information utilized for this study was derived from two sources:

a) A description of the available space in the Super-Constellation was obtained from the Lockheed Aircraft Corporation; information as to the equipment to be contained in the Combat Information Center was obtained from the Bureau of Aeronautics.

b) Information as to how the required equipment should be most efficiently arranged in the available space was provided by a group most familiar with the operation of an airborne Combat Information Center. This group was comprised of the Special Project Officers (Cadillac III) assigned to the Special Devices Center; Officers of the VX-4 Squadron engaged in operational evaluation of airborne radar equipment; and the professional men of the New York University Human Engineering Project. This group first determined the relative importance of a number of factors which contribute to the effective layout of an airborne CIC, and they then rated a series of suggested layouts (shown by means of three-dimensional models) to find that layout which best met the established criteria.

1.3 Conclusions

It was found that, in arranging equipment in an airborne CIC, there were four levels of importance into which the various considerations fell:

First Importance:	Availability of central displays
Second Importance:	Observation of the activities of certain personnel by the CIC Officer Ability of the CIC Officer to talk to certain personnel without phones Flight maintenance facility
Third Importance:	Ease of personnel traffic Crew comfort
Fourth Importance.	Ground maintenance facility.

Layout 1, which is contained in the Appendix, best met these and other more detailed criteria. It is characterized by division of the CIC personnel into three groups: the four Air Control Officers who face aft toward the Central Display; the control group (the CIC Officer, his Assistant, the Plotters for one Dead Reckoning Tracer, and the Talker) in the central portion of the CIC; and the auxiliary group forward (made up of the Height Finder, the Radar Operator, the RCM Operator, the Navigator, and the Radio Operator).

2.0 INTRODUCTION

This sect' is intended to give the reader an understanding of the basic problem with which this study deals and, to some extent, the history of Airborne Combat Information Centers, so that he may have a complete picture of the factors considered in arriving at the optimum layout.

2.1 The Problem

The basic problem may be stated briefly as follows: To design the most efficient layout of the CIC equipment to be used in the PO-2W aircraft, within the space provided for that purpose. The term "most efficient layout" as used above is intended to mean that arrangement which allows the best possible use of the equipment under the various operating procedures necessary to the accomplishment of the missions for which the PO-2W is intended.

2.2 Combat Information Centers - General

The Combat Information Center (CIC) is a space in a ship or aircraft specially configured and instrumented, and so organized and manned, as to provide for the collection, display, and dissemination of combat information and the performance of such combat control functions as are delegated by proper authority.

Information is received from various sources such as radar, sonar, visual lookouts, electronic counter measure equipment (ECM), radio, radio direction finders (RDF), intelligence reports, aerological data, operation orders, and other publications. This multitude of information must be sorted and displayed. It must then be analysed as to its tactical meaning. That requiring action must be acted upon; that requiring dissemination must be relayed to the necessary places.

It can be seen that the operation of CIC, owing to the complexity of its functions, requires the utmost in team effort for the successful accomplishment of these functions. This in turn requires that the CIC as a whole, and each component thereof, be so designed as to allow it to be used with a minimum of effort and a maximum of accuracy and efficiency.

Because of a rapid wartime expansion of the functions of CIC, and the attendent increases in equipment used, no time was available for the study of an optimal layout. New units of equipment, together with the personnel necessary to operate them, were placed in the most convenient position with little or no regard for their functional use. This resulted in a somewhat haphazard arrangement that was, to say the least, difficult to operate. The Bureau of Ships is presently engaged in rectifying this condition for shipboard CIC's, but it is a long and difficult undertaking. This study represents the efforts to lay out the airborne CIC for effective use.

2.3 History of Airborne Combat Information Centers

The airborne CIC had its beginning during the latter days of World War II and was a direct result of the Japanese Kamakazi attacks on our ships in the Pacific. Low-flying Japanese aircraft were able to approach to within twenty to twenty-five miles of our naval forces without being detected by radar on the surface ships. This situation was due to the line-of-sight characteristics of radar. With such short detection ranges it was impossible to destroy all of the attacking aircraft, either by intercepting them with fighters or by anti-aircraft gunfire from the surface ships, before they completed their attack.

The first attempt to solve this problem was the stationing of radar picket destroyers some distance from the task force. This tactic provided the needed early warning but resulted in unacceptable losses of destroyers as soon as the enemy discovered that he must eliminate these pickets if he were to reach his principal objective. An early solution to the problem of early warning of enemy aircraft approach, without this heavy loss of ships, became a necessity.

The next logical step in solving the problem was that of elevating the radar antenna, thereby extending the radar horizon. Since it was considered impractical to physically elevate the shipboard antenna to the necessary height, development of an airborne high-powered search radar, including the equipment necessary to relay the returning video picture back to the ship, was undertaken. This equipment had to be capable of being installed in a carrier-type air-craft and yet be rugged enough to withstand the rigors of carrier landings. In addition, equipment was needed aboard ship to receive and display the relayed picture. This program was given the code name Cadillac I and resulted in the development of the APS-20 "S" band radar, together with the necessary relay equipment, installed in the TBM-3W airplane. Necessary shipboard receiving and displaying equipment, called the PO, was also developed and installed on the base carrier.

Although this system was completed too late to be used during World War II and therefore could not be evaluated under wartime conditions, subsequent operational evaluation proved its worth in providing the early warning for which it was designed. In addition the system showed itself capable of detecting and tracking of snorkleing submarines and thus performed the added function of anti-submarine warfare.

Concurrent with the development of the Cadillac I system for carrier operations, the Cadillac II system was developed for land-based aircraft. Since the size of the aircraft was not restricted to single engine type, this system was designed with the necessary auxiliary

equipment so that it might to some extent operate independently of the surface CIC, thereby increasing its functions and radius of action. To provide the necessary additional space for the auxiliary equipment and personnel, the Navy chose the B-17G airplane for this installation, redesignating it the PB-1W.

The PB-1W had, in addition to the search radar and relay equipment, three-gound-stabilized radar repeat indicators, IFF, radio relay, a radar mapping unit, and the necessary VHF, MHF, and CW radio equipment. A large vertical plot and two status boards were also provided.

In addition to Air Early Warning (AEW) and Anti-submarine Warfare (ASW), this system was capable of limited Air Control, Weather Reconnisance, and Air-Sea Rescue (ASR). This was the beginning of the true Airborne CIC as it is visualized today.

Even with the limited facilities provided in the Cadillac II system, operational results obtained with this system indicated the desirability of a more complete Airborne CIC. In order to test the capabilities of such a system, it was decided to equip two Lockheed Constellations, Navy designation PO-1W, with the necessary equipment for operational evaluation. This program is known as the Cadillac III system.

Equipment of the Cadillac III system consists of a long-range search radar, the APS-20A; an altitude determining radar, APS-45; five repeat indicators, APA-56; a ground stabilization unit, APA-57; video insertion unit; grid insertion and radar mapping unit; an airborne dead-reckoning tracer; electronic counter-measure equipment; IFF; radio and radar relay; an elaborate plane crew and CIC crew interphone system; and the necessary VHF, MHF, and CW radio facilities.

The minimum CIC crew necessary to operate the Cadillac III system will be as follows: A CIC officer, an Assistant CIC Officer, four Air Control Officers, a Navigator, DRT Operator, Altitude Determining Radar Operator, Search Radar Operator, Radio Operator, Electronic Counter-Measures Operator, an Electronics Technician, and a Talker. This makes a total of fourteen, not including the Pilot and Co-pilot. It should be emphasized that this number does not allow for the necessary relief of personnel during long operational flights under heavy load.

With the equipment provided and the personnel required, the Cadillac III system has taken on the aspects of a shipboard CIC. The Bureau of Aeronautics, recognizing that this equipment must be operated at peak efficiency if the high hopes for an airborne CIC are to be realized, decided to contract for a human engineering evaluation of the system with a view to obtaining the optimum in layout and design of the CIC. It was hoped that such an evaluation would, in addition, produce certain

fundamental procedures as to how the system might be used under operational conditions.

The Special Devices Center, Office of Naval Research, was chosen to administer this contract, and, in January 1948, the contract was let to the New York University College of Engineering. A laboratory containing the Cadillac III equipment, radar target simulation equipment, and the necessary office spaces was set up at the Special Devices Center and the project got underway

Because of the delay in the early stages in receiving full Cadillac equipment, several studies of individual components of the Cadillac III system were initially undertaken. During this period, members of the project staff also gave increasing attention to considerations of layout and equipment dispositions. It was, therefore, natural for the Bureau of Aeronautics to turn to the project for aid in the design and layout of the CIC compartment in the PO-2W. The material that follows is based upon a human engineering evaluation of the factors which should be considered in layout of the PO-2W.

The airframe chosen for the operational Airborne CIC aircraft was the Lockheed Super-Constellation, Navy designation PO-2W. This is basically the same as the PO-1W with an additional eighteen feet of fuselage amidships. The extra eighteen feet will allow the CIC compartment to be larger and, at the same time, allow for provision or more and better facilities for crew comfort.

The CIC equipment proposed for this model is the same as in the PO-1W with some modifications and additions. The repeat indicators, for example, will allow the operators to see over the top of the console and will allow front-end maintenance. A central display and a new type (APX-6) IFF will be added. A Moving Target Indicator (MTI) system, which will allow targets to be tracked over land and possibly thru sea return, will be added when it becomes operationally available. Additional personnel will be needed to operate the display equipment.

2.4 Operational missions of Airborne CIC

The operational missions of an Airborne CIC, as promulgated by the Chief of Naval Operations, include the following:

Airborne Early Warning is that function of an airborne CIC concerned with searching, detecting, tracking, and reporting of targets within an area not covered by the radar of surface ships owing to the limitations imposed by the radar horizon. By performing this function the airborne CIC is able to furnish intelligence on the number and types of enemy crew operating in the area, together with their courses, speeds, altitudes, and compositions, to whatever Command Center is in need of this information. The Command Center then decides what action is necessary to combat these forces and initiates that action.

Air Control is that function of an airborne CIC concerned with the control of friendly aircraft, both offensive and defensive, within the CIC's area of responsibility. Offensively this would include such duties as providing friendly bombers with warning of the approach of enemy fighter groups, of acting as navigational director to friendly strike forces, and of directing mine laying aircraft to the point of release of their mines. Defensively it would include the duties of control of interceptor aircraft to a point of contact with enemy aircraft, vectoring of killer aircraft to submarine contacts, and aiding returning strikes and interceptors to effect rendezvous with their home base.

Weather Reconnisance is that function of an airborne CIC concerned with providing reports on weather in its area of operation. This function is usually combined with one or more of the other functions except when it is assigned to cover a hurricane or typhoon. In the latter case the aircraft finds the disturbance by radar and tracks it, sending reports on its progress back to a weather station.

Anti-Submarine Warfare is that function of an airborne CIC concerned with combating enemy submarines. In doing this it first detects and reports the position of submarines to the Command Center, then vectors friendly surface or aircraft to the position necessary for them to make an attack.

Other

In addition to the above primary missions, the following functions may be performed simultaneously.

Friendly Submarine Coordination
Radar Jamming
PO Link
Communications Relay
Radar Relay
Convoy Control and Coordination
Electronic Mapping
Air-Sea Rescue

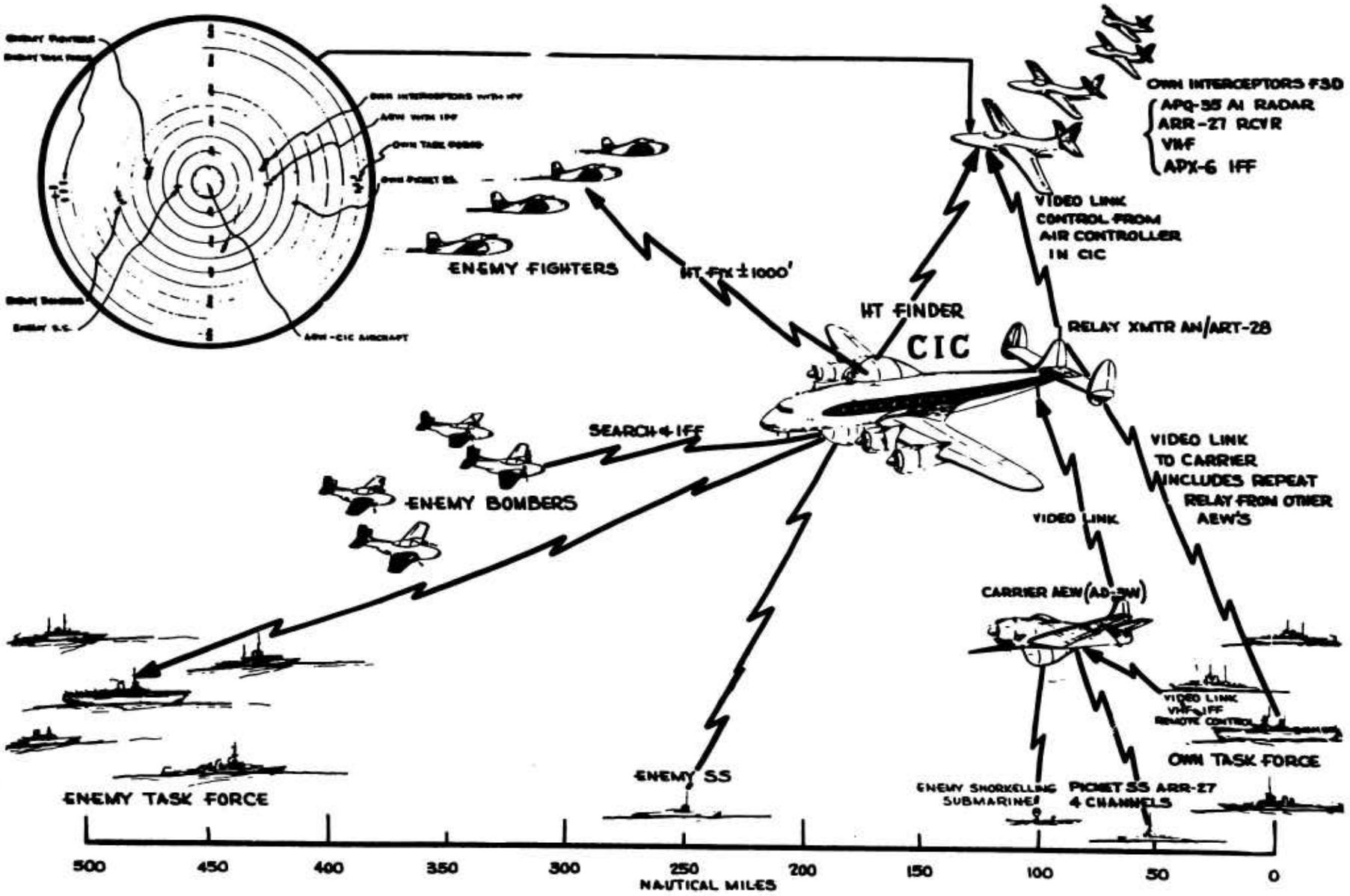
The above discussion, together with the drawings at the end of this report, will serve to give the reader an insight into the factors considered by the project in arriving at the optimal layout. Figure 1 graphically illustrates how the PO1W may be used tactically. For a much more detailed discussion of the operation of Airborne CIC, attention is invited to COMOPDEVFOR Reports on Project OP/V26/F42-1, Evaluation of the Capabilities and Limitations of Airborne Early Warning Equipment, and the Airborne Early Warning Operators Manual promulgated by Composite Squadron TWELVE dated 1 August 1949.

3.0 METHODS

This section is concerned with the description of the methods used by the New York University Human Engineering group to discover the most efficient arrangement of the electronics equipment aboard the PO-2W.

3.1 Background of the Study

Data on the size and design of the Constellation were submitted by



One of many tactical uses of PO-1W. Circle in upper left corner shows PPI presentation as viewed on all video link scopes.

FIG. 1

the Lockheed Corporation to NYU for familiarization of personnel with the aircraft. At the same time, a list of the electronics equipment to be included in the PO-2W was supplied by the Bureau of Aeronautics. The specifications for the PPI repeater scopes, designated the APA-56, are still not in final form. New York University is contributing its considerable experience in the laboratory operation of this gear in the design and packaging of this equipment.

Personnel engaged in the study have all had pertinent experience in airborne CIC. The group may be divided into three sub groups, all working together. The first would be special Naval Officers, experienced in CIC, assigned to the Special Devices Center to work with the New York University Human Engineering group. Second are the personnel of the VX-4 Squadron, Patuxent Naval Air Station, who are concerned with the operational testing of airborne CIC gear. The third group, the NYU Human Engineering staff, is composed of psychologists and engineers who have observed the laboratory operation of the airborne CIC. In addition, they are familiar with a good deal of the current thinking on the operational use of the airborne CIC through their contacts with the Bureau of Aeronautics, the Operational Development Force, the Naval Research Laboratory, the Naval Air Development Center, the Operational Evaluation Group, and the Office of the Chief of Naval Operations.

3.2 Techniques Used in the Study

With this background as a basis, a special study was made to determine the best layout of the electronics gear in the CIC of the PO-2W aircraft. This determination may be said to have been made in two major steps. The first was the recognition of the basic principles that should be used in arranging equipment in an airborne CIC, and the second was the degree to which a number of proposed layouts would satisfy these principles.

As a preliminary to the study, representatives of the VX-4 Squadron were given several familiarization exercises with the electronics equipment in the NYU laboratory at the Special Devices Center. The purpose of this orientation was to give the entire group participating in the study experience in the operation of the equipment to be arranged through operation using simulated targets. The other members of the group had had experience in this type of operation.

Following this orientation, the entire group was given a series of questions to answer, on printed forms, concerning the principles of layout of an airborne CIC. This series of questions will be referred to throughout the report as the "Questionnaire," to distinguish it from a second series of questions described later in the report, and designated the "Rating Sheet."

After the Questionnaire had been completed, the group was given a series of six different prepared layouts. Each of these six layouts was, in turn, represented by three-dimensional models. From these models each person filled out a "Rating Sheet," one sheet for each layout that was represented. In this manner each person was able to express in detail his reactions to each layout.

The construction and subsequent analysis of the Questionnaire and the Rating Sheets will be described inthe following sections, while a summary of the group's opinion, as expressed on boththe Questionnaire and the Rating Sheet, will follow in a separate section.

3.3 The Questionnaire

The questionnaire, a copy of which appears on pages 12, 13 and 14, was constructed to deal as much as possible with layout principles rather than operating procedures. This was donebecause the best operating procedures had not yet been determined. Criteria for operating procedures will be established on the basis of further experimental work and operational use, data on neither of which are presently available.

3.3.1 Contents of the Questionnaire

The Questionnaire was designed to help organize and determine the relative importance of the various factors to be considered in arriving at an efficient working layout for the PO-2W aircraft.

An airborne CIC, such as that contained in the PO-2W, functions to produce as much information as quickly as possible. This information must be accurate and of good quality. Here, quality implies evaluated information — information that best describes the tactical situation. Quality, as defined here, also involves the production of larger quantities of important information than less important information.

A great many factors contribute to effective performance, only some of which are influenced by the physical layout of equipment in the airborne CIC. It is obvious, for instance, that the effectiveness of radio or ICS communication is not affected substantially by physical layout. Placing one man ten feet nearer to another does not affect the amount of information that he can communicate via ICS or radio. However, the sharing of visual information is definitely influenced by the physical position of the viewers and the information.

The problem in constructing the Questionnaire was to deal with those factors of CIC performance influenced by physical layout of the equipment. The purpose of the first question in the Questionnaire, for example, was to discover the relative importance of seven major factors influencing CIC performance. These seven factors are the kind whose effectiveness was

determined, at least in part, by physical layout of the equipment.

Because of the importance of question 1 in determining principles of layout, a brief discussion of the nature of the seven factors is offered to demonstrate the necessity for consideration of each of them.

Flight Maintenance

The principal maintenance requirements include a convenient grouping of related equipment for purposes of calibration, sufficient space for repairing gear without removal of other gear, and sufficient clearance for removal of component equipment. There should be easily recognizable indicators, lights, and meters to indicate equipment malfunctioning.

Personnel Traffic in CIC

There should be room for CIC personnel to move about freely for changing of stations, for job rotation, and for a smooth traffic flow of personnel in supervisory and command positions.

An important traffic consideration in the airplane is the protection of the dark adaptation of members of the flight crew.

There should be definite ease of movement among the various stations in giving information, evaluation, and in dissemination of data. Any study of the flow of traffic in the CIC should include an analysis of man-machine and man-man links.

Easy Viewing of Displays

The most important points of display are the Status Boards, Air Summary Plot, Geographical (grid or polar) Display, and Dead Reckoning Trace. Of importance is the question of whether these displays should be placed vertical or horizontal, or aft, fore, port, or starboard.

Additional displays to be considered might be the Optical Projector and the Teleautograph. Of equal importance would be the number of display points that are used, their design, and the number and type of personnel using them.

Conversation Between the CIC Officer and Others Without Earphones

It has been felt among military personnel that the CIC Officer should be able to physically contact other members of his group. He might find it necessary to talk either to his assistant or his DRT operator, or even to get his attention by tapping him to give an oral command or hand signal. A situation of this type might arise if the normal channels of communication were overloaded or if there were a breakdown of communications. If communications should break down, the close grouping of personnel would permit some sort of partial operation of the system.

Observation of Activities by the CIC Officer in the CIC

The same would hold true for this consideration as for the previous one. In addition, the CIC Officer should be able to observe the

activities and data handled by this group without having to get their attention.

The CIC Officer should have access to all visual presentations aboard the aircraft

Ground Maintenance

An efficient layout should permit speedy ground maintenance. Equipment should be placed and connected in the plane with due consideration of the type and size of test equipment to be carried aboard during the ground maintenance. In addition, it should be easy to remove from the plane that equipment to be bench tested and repaired should it be necessary. Heavy gear should have connecting cranes, rollers, tracks, or some other appropriate method of removal. The aisle should be wide enough to permit even the largest piece of gear to be removed without interfering with any other equipment aboard the plane.

Crew Comfortization

Considerations of this type would include good seating design, a sufficient number of bunks, and adequate relaxation areas. There should be as good ventilation, air conditioning, and illumination as is possible under the circumstances.

The same detailed considerations were given to each of the other questions in the Questionnaire and to the manner in which they were presented.

The second question in the Questionnaire determines the display needs of each CIC crew member, the third and fourth questions deal with the CIC officer's specific display needs, the fifth question is concerned with the oral and/or manual links between the CIC officer and the other CIC crew members, with the exception of the Air Control Officers, and the sixth question takes into account the needs for oral links between the CIC officer and the other crew members.

The preliminary work on the construction of the Questionnaire was a group effort on the part of the members of Project Cadillac, utilizing all the experience and judgment accumulated during the life of the project. In this way the Questionnaire and Rating Sheet were devised.

Sample Questionnaire, Page 1

Questionnaire to Determine Principles to be Followed in Layout of PO-1W

1. Which of the following elements are the most important considerations in making a layout of the CIC gear? Rank the following items in order of their importance for airborne CIC, placing a "1" in front of the item you think most important, a "2" in front of the item you think second in importance and so on through the list.

   a) Excellent flight maintenance is provided. _____

   b) Layout makes for ease and convenience in CIC personnel traffic. _____

   c) All display boards are easily seen by the CIC personnel directly concerned. _____

   d) CICO's station permits him to talk to necessary individuals without using phones. _____

   e) CICO's station enables him to observe the activities and personnel anywhere in the CIC compartment. _____

   f) Excellent provision for ground maintenance. _____

   g) Full provision for physical comfort of CIC crew stationed at their posts. _____

2. Which displays are most important for which crew members? Below are listed certain members of the CIC crew. The three columns represent three kinds of displays. First, put an "X" in each column opposite the crew members who do not need to see the display at all. Second, do down column 1 and rank the importance of the permanent display to each crew member who needs to see it, putting a "1" opposite the crew member who needs it most, and so forth. Then go to Column 2 and do the same. Do the same for Column 3.

Crew	Column 1 Status Board with permanent information	Column 2 Status Board "hot" information	Column 3 DRT or Geographical plot
CICO			
ACICO			
ACO (doing AEW)			
ACO (doing intercept)			
Height Finder			
Talker			
Plotter			
Status Board Keeper			

3. Which of the following displays of information are most important for CICO? Rank the items in order of their importance for AEW only, putting a "1" opposite the most important item, a "2" opposite the next most important item, and so on.

a) Permanent status board. _____

b) Immediate status board. _____

c) Geographical plot. _____

d) Total plot on repeater scope (raw data) _____

4. Would question 3 be answered differently for an intercept mission? If so, rate it below.

a) Permanent status board. _____

b) Immediate status board. _____

c) Geographical plot. _____

d) Total plot of repeater scope. _____

5. Does CICO need to be able to talk to any of the following men without phones, or be able to watch them at work at their stations? Mark an "X" opposite any men he would not need to contact in this way, then rank the remaining men in order of their importance to CICO for this sort of contact.

a) Radar operator. _____

b) RCM operator. _____

c) Radio operator. _____

d) Navigator. _____

e) Height Finder operator. _____

Sample Questionnaire, Page 3

6. How often does CICO communicate (either listening or talking) with the following people by radio, ICS, or orally and/or visually. Indicate your judgments by making a check in one of the columns opposite each item. (No one column may have more than 7 checks, except the last.)

	Continuously or nearly so	Frequently	Occasionally	Rarely	Negligible or not at all
By radio					
1. Command channel					
2. Liaison channel					
3. VHF channels (intercept)					
By ICS					
4. ACICO					
5. ACO (AEW)					
6. ACO (intercept)					
7. Radio operator					
8. Radar operator					
9. RCM operator					
10. Plotter					
11. Height finder					
12. Talker					
13. Status board keeper					
14. Navigator					
15. Pilot					
Orally and/or visually					
16. ACICO					
17. ACO (AEW)					
18. ACO (intercept)					
19. Radio operator					
20. Radio operator					
21. RCM operator					
22. Plotter					
23. Height finder					
24. Talker					
25. Status board keeper					
26. Navigator					

3.3.2 Administration of the Questionnaire

The questionnaire was completed by the group of Naval officers, psychologists, and engineers in one sitting. The time required for the task was approximately one hour.

The individuals concerned realized that they were not able to answer the questions in terms of actual experience, since none of them had any great amount of experience with an airborne CIC of this scope and magnitude. For this reason each man had to draw on his general experience in CIC matters and make a projected estimate of CIC needs.

The Questionnaire was designed, using standard psychometric techniques, as a forced choice type. This method was chosen in order to get a "spread" of response because of the ambiguity of the situation.

However, once the situation had been explained, the individuals were able to proceed in answering the Questionnaire with some degree of confidence. The test of the suitability of the various questions, it was explained, was whether results could be obtained.

3.3.3 Analysis of the Questionnaire

The responses to the Questionnaire were summarized by a "scaling" method. The average rating for each item was found and plotted on a linear scale with each of the other items, in order to find the relative order of importance and the scale distance between items. This procedure can be illustrated by taking the first question as an example. In this case, the ratings for Item "f," dealing with ground maintenance, were as follows.

Rating	*Frequency*	*Product*
5th	1	5
6th	4	24
7th	8	56
	13	85

One man rated ground maintenance as being fifth in importance in Question No. 1, four men rated it sixth, and eight men rated it as seventh. By multiplying the rating by the number of men who gave it that rating and adding these resulting numbers, a value of 85 was obtained. Dividing this number by 13, the total number of raters, the average value of 6.5 was found. This is the relative value of the importance of ground maintenance, as found by the group as a whole, for Question No. 1. The average ratings of the other six times in Question No. 1 were found in a similar manner. These were plotted on the scale shown in Figure 2 on Page 16.

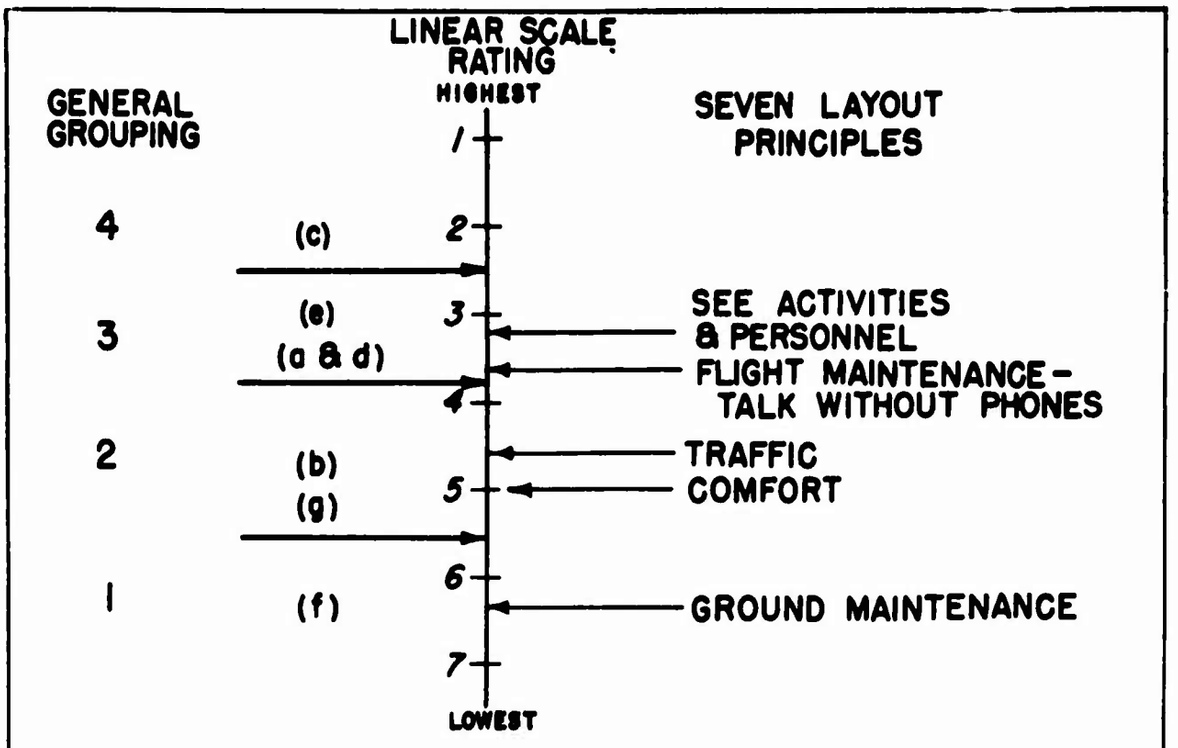


FIG. 2 RELATIVE IMPORTANCE OF LAYOUT PRINCIPLES

It will be noted that the order of importance of each item, from most to least important, runs as follows: "Displays," "CICO Sees Displays and Personnel," "Flight Maintenance" and "CICO talk without Phones" (equal in importance), "Traffic," "Crew Comfort," and "Ground Maintenance." However, the scale distance between items must not be ignored. It will further be noted that the seven items fall into four distinct groups, as marked at the left of Figure 2. The rate indicated at the left is arbitrary, that is valuing "Display" as being four times as important as "Ground Maintenance." In the indications of the data, "Display" could be valued as being twice as important as "Ground Maintenance," if the rates at the left read 6,5,4, and 3. The appropriateness of this result can be found only in the consistency of the results. In the section "Results of the Questionnaire" a check is made on the validity of these weighing values.

This example should clarify the method used in the analysis of all the data in the Questionnaire. These results will be found in Section 40.

3.4 The Rating Sheet

The Rating Sheet, a copy of which appears on pages 17 to 21, was

designed for the purpose of allowing an individual to rate systematically a particular equipment layout in all of its important details. The Questionnaire's results show which layout principles should be met, while the Rating Sheet shows how well each layout meets these principles.

EVALUATION OF AIRBORNE CIC LAYOUT #_____

Branch of Service:
Present Activity: Date:
Previous Activities:

Each of the statements below is concerned with a specific feature of airborne CIC operation which the layout you have studied permits or fulfills to a greater or lesser degree. To the right of each statement four columns are provided for your answers which are to be made in the form of an "X" in the appropriate column. The columns are labelled "excellent", "good", "fair", and "poor."

These adjectives are to be interpreted as follows:

Excellent - Does not seem to require any modification or improvement on the basis of present day standards or knowledge.

Good - - - Better than just adequate, but still merits some criticism.

Fair - - - Adequate, i.e., can fulfill its function, but improvements or changes would be desirable.

Poor - - - Inadequate.

Any item that you feel cannot be answered in this manner you may describe under "Comments", referring to the item number.

Definitions:

CICO - CIC officer, also represents top man in CIC plane.
ACICO - Qualified CIC officer, controls PPI for CICO.
ACO - Used to designate other CIC officers operating other consoles.

- a -

How well, in your opinion, does the layout provide for the following functions? Indicate this by placing an "X" in the appropriate column.

	Excellent	Good	Fair	Poor
1. Calibration and maintenance controls accessible (with no removal of other gear).....				
2. Special calibration possible with no disturbance of operators.....				
3. Repairs requiring more than one technician without disturbing CIC activities.....				
4. Convenient routine check-out.....				

	Excellent	Good	Fair	Poor
5. Instruments & indicators accessible to technician.....				
6. Technician's safety during in-flight maintenance.....				

Comments & Suggestions

- b -

How well, in your opinion, does the layout provide for the following functions? Indicate this by placing an "X" in the appropriate column.

	Excellent	Good	Fair	Poor
1. Passage of CICO to ACO's.....				
2. Aisle space in CIC (27" min).....				
3. Passage of CICO to DRT.....				
4. Path clearance around display boards.....				
5. Passage to forward head and rest area.....				
6. Passage for messenger in case communications break down.....				
7. Passage to rear head & bunks.....				
8. Clearance for technician to work.....				
9. Passage of CICO to radio station.....				
10. Passage of CICO to Radar.....				
11. Passage of CICO to Pilot.....				
12. Passage of CICO to RCM.....				
13. Passage of CICO to H.F.....				
14. Passage of CICO to Navigator.....				

Comments & Suggestions:

- c -

	Excellent	Good	Fair	Poor
1. ACO's view of display board.....				
2. Talker's view of display board.....				
3. DRT plotter's view of display boards.....				
4. RCM operator's view of display boards.....				
5. Qualified talker's view of DRT.....				

	Excellent	Good	Fair	Poor
6. Radio operator's view of display board.....				

Comments & Suggestions:

- d -

How well, in your opinion, does the layout provide for the following functions? Indicate this by placing an "X" in the appropriate column.

	Excellent	Good	Fair	Poor
1. CICO can contact ACICO without phones.....				
2. CICO can contact Radio Operator without phones.....				
3. CICO can contact Plotter without phones.....				
4. CICO can contact H.F. without phones.....				
5. CICO can contact Talker without phones.....				
6. CICO can contact Navigator without phones.....				
7. IP-49 Gear can be viewed.....				
8. Ease of relocation of consoles for other arrangements.....				
9. Space for additional CIC personnel.....				
10. Alternate locations & additions of display boards.....				
11. Alternate procedures possible.....				
12. Switching duties & functions quickly.....				

Comments & Suggestions:

- e -

	Excellent	Good	Fair	Poor
1. CICO's view of DRT.....				
2. CICO's view of Status Board.....				
3. CICO's view of Geographical Plot.....				
4. CICO's view of Other Displays.....				
5. CICO's view of ACICO.....				
6. CICO's view of ACO's.....				
7. CICO's view of APS-20 Scopes.....				

Excellent Good Fair Poor

8. CICO's view of I ACO scope in addition to ACICO's scope.....

Comments & Suggestions:

- f -

How well, in your opinion, does the layout provide for the following functions? Indicate this by placing an "X" in the appropriate column.

Excellent Good Fair Poor

1. Removing large gear for ground check without affecting other positions.....

2. Means of removing units for ground servicing.....

3. Space for setting up test equipment near gear being repaired.....

4. Cables for accessible for tracing and servicing.....

Power

1. Relationship of equipment to avoid interference due to electrical fields.....

2. Power requirements for position of equipment satisfactory.....

3. Cables, etc., installation satisfactory.....

4. Frequencies & voltages available where needed to operate gear.....

5. Same as above for technician.....

6. Central station for balancing and adjusting power loads.....

Comments & Suggestions:

- g -

Excellent Good Fair Poor

1. Seating for crew is comfortable using bucket seats.....

2. Seating for crew is comfortable using adjustable, spring-padded seats.....

3. Crowding conditions avoided.....

4. Air circulation at operators.....

~~CONFIDENTIAL~~

	Excellent	Good	Fair	Poor
5. Oxygen flow meter & mask connectors located at each station.....				
6. The idea of riding backward so that one can see display boards.....				
7. Men can vary their working positions.....				
8. General color schemes.....				
9. Comfortable mikes & earphones.....				
10. Men isolated from vibrations.....				
11. Dangerous electrical points protected to avoid accidental contact.....				
12. Fire hazards reduced.....				
13. All projections, sharp corners, padded.....				
14. Effective emergency warning system can be incorporated.....				
15. Minimum short-circuit hazards to operators.....				
16. Accessory gear around operator secure against normal changes in g.....				
17. Hatchways, doors, etc., available & sufficient.....				
18. Safety straps or stations for crash landing.....				
19. Scopes protected from direct light.....				
20. CIC ambient illumination satisfactory.....				
21. Light to permit visual links.....				
22. Light emitting equipment properly shielded.....				
23. Spot lighting available at necessary points.....				
24. Ability to light recesses.....				
25. Enough white light in CIC.....				
26. Enough red light in CIC.....				
27. Soundproofing in CIC.....				
28. High and Low Frequency vibrations away from operators.....				
29. Low noise levels at points where "oral" links may be used.....				
30. Controlled volume on ICS & Radio.....				

Comments & Suggestions:

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

Technical Requirements for

In-Flight Maintenance

1. Work Bench Details
2. Proper Outlets, Lights, etc.
3. Storage space for tools, meters, etc.
4. Storage space for spare parts
5. Permanent indicators & controls at technician's station
6. Convenient outlets near CIC equipment for technician's use
7. Central station for adjusting and balancing power loads
8. Suggestions:

3.4.1 Contents of the Rating Sheet

The Rating Sheet was developed from a number of items that could be applicable to any layout. The evaluator was to rate each item as Excellent, Good, Fair, or Poor, these terms being defined so that each rater would use them in the same way. Excellent, for instance, would be a rating for any item which "does not seem to require any modification or improvement on the basis of present day standards or knowledge."

As to the items themselves, the Questionnaire dealt with personnel traffic as a principle, whereas the Rating Sheet was concerned with specific aspects of traffic, such as "Passage of CICO to DRT." Items were constructed with the definite purpose of measuring how well the various principles were met in the layout.

3.4.2 Models

In order to consider the placement of a piece of electronic gear from all essential points of view, each item of equipment was first described on the form "Cadillac Component Data". A copy of this form will be found on pages 24 and 25.

These forms were completed by the military personnel on the basis of technical information available to the project. Using the information from these forms, a three dimensional model was made of each piece of gear. Figure 3, on Page 26, is a photograph of one of the layout of the models.

The models were made by the Special Devices Center model section to 1/5 actual size, and were painted in the following color code for presentation.

Grey	- Base color
Black	- Access door
Unpainted	- Bottom
Yellow	- Operating controls
Red	- Connections, cables, etc.

A 1/5 scale outline of the floor plan of the PO-2W was drawn and painted, with transparent plastic hull sections to indicate the space available due to curvature of the hull.

3.4.3 Development of the Proposed Layouts

One of the most important aspects of this study was the development of a number of proposed layouts Nine such layouts were developed, each of which represented a slightly different approach to the problem of laying out an airborne CIC. General industrial layout experience, modified for military applications, was utilized in making up these layouts. They were eventually reduced from nine to six, while minor details of each layout were varied in group conferences by the staff of the Project In brief, the six layouts can be described in Figure 4, on Page 27.

CADILLAC COMPONENT DATA

(for layout and model purposes)

Filled in by:_____

Date:_____

NYU Human Engineering Project
Contract No.: N6onr-279 TO III
Project No.: SDC 20-F-4

1. Military designation number and name:_____ Mfr.:_____

2. Previous titles or models:_____

3. General function of gear:_____

_____

_____

_____

_____

_____

4. Calibrating and adjusting Controls: ☐ Front ☐ Back ☐ Left side ☐ Right side ☐ Top

5. Maintenance access: ☐ Front ☐ Back ☐ Left side ☐ Right side ☐ Top

6. Does equipment have to be shut down for all maintenance:_____

7. Operated by: ☐ CICO ☐ ACO ☐ Radar Op. ☐ Radio Op. ☐ Technician ☐ Other

8. Operating controls (how many of each): Cranks_____ Knobs _____ Switches_____

9. Type of presentations and displays (how many of each): Counters_____ Dials_____ CRT_____ Lights_____ Other(_____)_____

10. Can operational controls be manipulated remotely?_____

If so, how is it done_____

_____

11. List, by title, publications (Handbooks, etc.) referring to gear and where they can be obtained:_____

_____

_____

Military designation number and name: _____

12. In put to gear from: _____

_____

☐ By switches ☐ Verbal ☐ Continuous(cables) ☐ By Signals ☐ Other

13. Output from gear to: _____

_____

☐ By switches ☐ Verbal ☐ Continuous(cables) ☐ By signals ☐ Other

14. Where located on plane at present:

a) Functionally _____

b) Physically _____

15. Overall dimensions, including controls and other projections:

Height _____ Width _____ Depth _____ Weight _____ #

16. Freehand sketch of gear, including dimensions:

Model color code: Grey - Base color
Black - Access doors
Unpainted - Bottom
Yellow - Operating controls surfaces
Red - connections (cables, etc.)

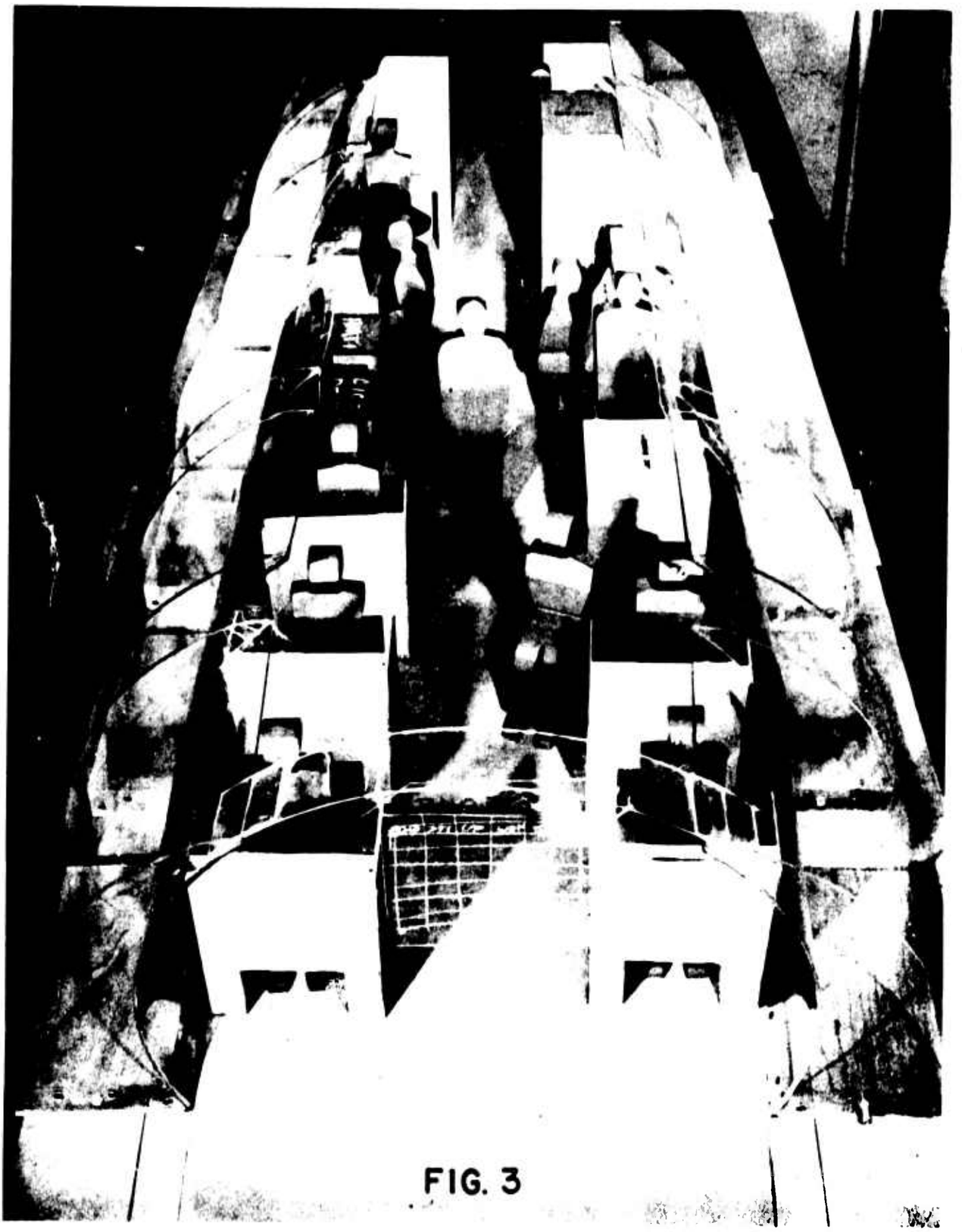


FIG. 3

LOCATION IN THE CIC	LAYOUT 1		LAYOUT 2		LAYOUT 3		LAYOUT 4		LAYOUT 5		LAYOUT 6	
	STARB'D	PORT	STARB'D	PORT	STARB'D	PORT	STARB'D	PORT	STARB'D	PORT	STARB'D	PORT
FORWARD	RCH NAVIGATOR	RADIO IP-49 RF	NAVIGATOR	RADIO IP-49 RF	CENTRAL DISPLAY BOARD NAVIGATOR IP-49	RF RADAR HEIGHT FINDER	CENTRAL DISPLAY BOARD RCM	NAVIGATOR	RADIO CENTER DISPLAY BOARD	NAVIGATOR	RF IP-49 RADAR RCM	
FORWARD OF CENTER	HEIGHT FINDER	RADAR ACICO	HEIGHT FINDER	RCM	ACO 1		RADIO IP-49	RF HEIGHT FINDER	RADAR	IP-49 RF ACICO	ACO 1 ACO 2 STATUS BOARD	
CENTER		AMTI CONTROLS	ACO 1	RADAR	ACO 2	DRT STATUS BOARL	CICO	ACICO	DRT STATUS BOARD		ACO 3 ACO 4 CENTRAL DISPLAY BOARD	
AFT OF CENTER	STATUS BOARD DRT	STATUS BOARD CICO	ACO 2 ACO 3	ACICO CICO STATUS BOARD	ACO 3 ACO 4	CICO STATUS BOARD ACICO	STATUS BOARD DRT	STATUS BOARD	ACO 1	ACO 3 CICO STATUS BOARD	DRT ACICO STATUS BOARD	CICO
AFT	ACO 1 ACO 2 CENTRAL DISPLAY BOARD	ACO 3 ACO 4	ACO 4 CENTRAL DISPLAY BOARD	DRT STATUS BOARD	RADIO	RCM	ACO 1 ACO 2	ACO 3 ACO 4	ACO 2 HEIGHT FINDER	ACO 4 RCM	HEIGHT FINDER RADIO	NAVIGATOR

FIG. 4

GENERAL DESCRIPTION OF THE SIX LAYOUTS RATED

3.4.4 Administration of the Rating Sheet

Each layout was presented in such a way that it could be easily visualized. In turn, familiarity with the actual gear was achieved in practice runs, and the proposed layouts themselves were set up as three dimensional scale models.

The ratings were accomplished, with considerable confidence on part of the personnel participating, over a period of one full day. However, before the Rating Sheet for each layout was filled out, the terms used in the Rating Sheet were carefully explained to the participants.

In filling out the Rating Sheet for each layout, the individual rated the adequacy of details rather than the adequacy of the layout as a whole. As a second step in the rating procedure, after completing the Rating Sheet, each member of the group indicated which layout received his overall preference, which he thought was second best, and which he thought was third best.

This latter step was an essential check on the procedure that was used. A comparison of the results is found in Section 4.

3.4.5 Analysis of the Rating Sheet

The analysis of the Rating Sheet was done in three steps. The first step was that of finding the average rate for an item in a particular layout, the second step that of finding the average rate for a factor in a layout (combining the items on personnel traffic, for instance), and the third step was that of finding the overall rating of a layout (combining the factor ratings).

To find an average rating for an item, take, for instance, the rating given to "Passage of CICO to ACO," in Layout No. 1.

Rating	*Numerical Equivalent*	*Frequency*	*Product*
Excellent	3	9	27
Good	2	3	6
Fair	1	0	0
Poor	0	0	0
		12	33

Nine men rated this item as Excellent and three men rated it as Good. The numerical equivalents used for the objective ratings are immaterial, so long as the assumption of equidistance between scale points is maintained. The sum of the product of the frequency and rating is 33. This figure, when divided by 12, the number of raters, gives 2.8, which is a rating between Excellent and Good, being closer to Excellent.

The items under section "b" of the Rating Sheet all pertain to personnel traffic, and the sum of the item values for the thirteen items used will give a factor rating for "traffic." This sum, 29.9, is divided

by 13, the number of items, to get 2.3. This means that traffic in Layout No. 1 is rated between Excellent and Good, being closer to Good. In a similar war, the factor ratings are combined, giving more weight to some factors than others (as determined by the results to the first question of the Questionnaire, illustrated previously). The overall rating of Layout No. 1 is 2.2, or somewhere between Excellent and Good, being closer to Good.

The rating of the layout which the rater preferred overall was also analyzed by the scaling method, illustrated by the two examples in this section.

3.5 Layout Modifications

Once the major pieces of gear have been placed, as the procedure outlined above was designed to do, there remains the question of arranging the equipment at any one station so that the operator can use it to his best advantage.

The gear controls should be grouped within the operator's normal and full area of reach, and arranged according to frequency of use, their importance to the system, and the appropriateness of their location to the operator's sitting or standing position.

Since this study does not deal with such an important aspect of equipment layout, the layout of individual stations will be recommended in subsequent reports. The substance of these planned reports will be based on the acquisition of additional laboratory experience and observation of the operational use of the equipment.

The layout determined by this study should serve to establish the layout of major pieces of gear in the PO-2W. Minor modifications which implement rather than contradict the obtained layout principles will not invalidate the study results; changes of this kind will no doubt be found necessary in the light of additional facts that will come to light.

4.0 RESULTS

4.1 Results of the Questionnaire

The results of the Questionnaire, with an analysis of each question, are described in this section.

4.1.1 Question No. 1

This question deals with the relative importance of seven factors in the layout of an airborne CIC. By summarizing the responses of the members of the group to this question, it is possible to present Figure 5, which graphically illustrates the pooled opinion of the group. However, because of the small size of this group, necessarily so in sampling pertinent opinion, actual tests on the significance of the results were

found to be inappropriate.

It should be noted that in Figure 5 the seven layout principles fall into four general groups. In this picturization the first preference is well above the second, third, and fourth. The second, third, and fourth in importance are well above the fifth and sixth, which in turn are well above the last. This permits grouping the answers into four categories of importance.

This type of analysis will be continued throughout the remainder of the Questionnaire.

4.1.2 Question No. 2

Here the question of display was dealt with. In summarizing the importance of three types of displays, "Status Board with permanent information", "Status Board with hot information", and "Geographical Plot", to each member of the CIC crew, it was found that the CIC Officer was thought to have the greatest need of all for display boards.

The importance of each display to each crew member, as summarized by the group, was graded on a linear scale. In order of descending importance, they fell roughly into three groups. The first group found the CIC Officer having the greatest need for all displays. The next group found ACICO, ACO (engaged in intercept operation), ACO (engaged in AEW operation), the Talker, and the Plotter pretty well bunched. At the bottom of the listing are the Status Board Keeper and the Height Finder Operator, who were thought to have the least need for the displays mentioned.

A graphical presentation of this summary is presented, on a linear scale, in Figure 6.

4.1.3 Questions No. 3 and 4

These questions are concerned with the specific display needs of the CIC Officer. Here, the group rated the importance of four different displays to the CIC Officer. These displays are the "Permanent Status Board," and "Immediate Status Board (hot)," the "Geographical Plot," and the "Total Plot on the Repeater Scope (raw data)."

Figure 7 presents a summary of the findings of the group for both questions. It is interesting to note that the Permanent Status Board was rated, on a linear scale, far below any of the others. The Geographical Plot rated above the Raw Data, with the Hot Data being somewhere in the middle. Of further interest should be the variation in the importance of these displays to the CIC Officer when considered generally and then in a specific mission.

In this respect, Question 3 shows the Geographical Plot and the

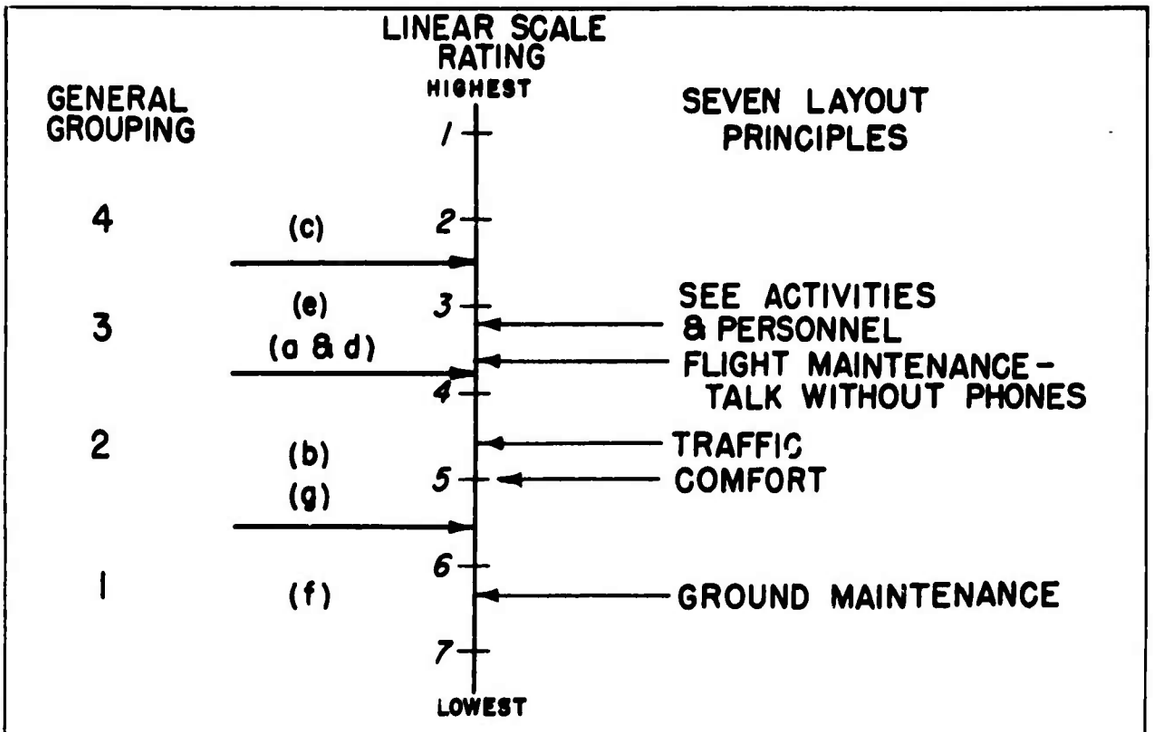


FIG. 5 RELATIVE IMPORTANCE OF LAYOUT PRINCIPLES

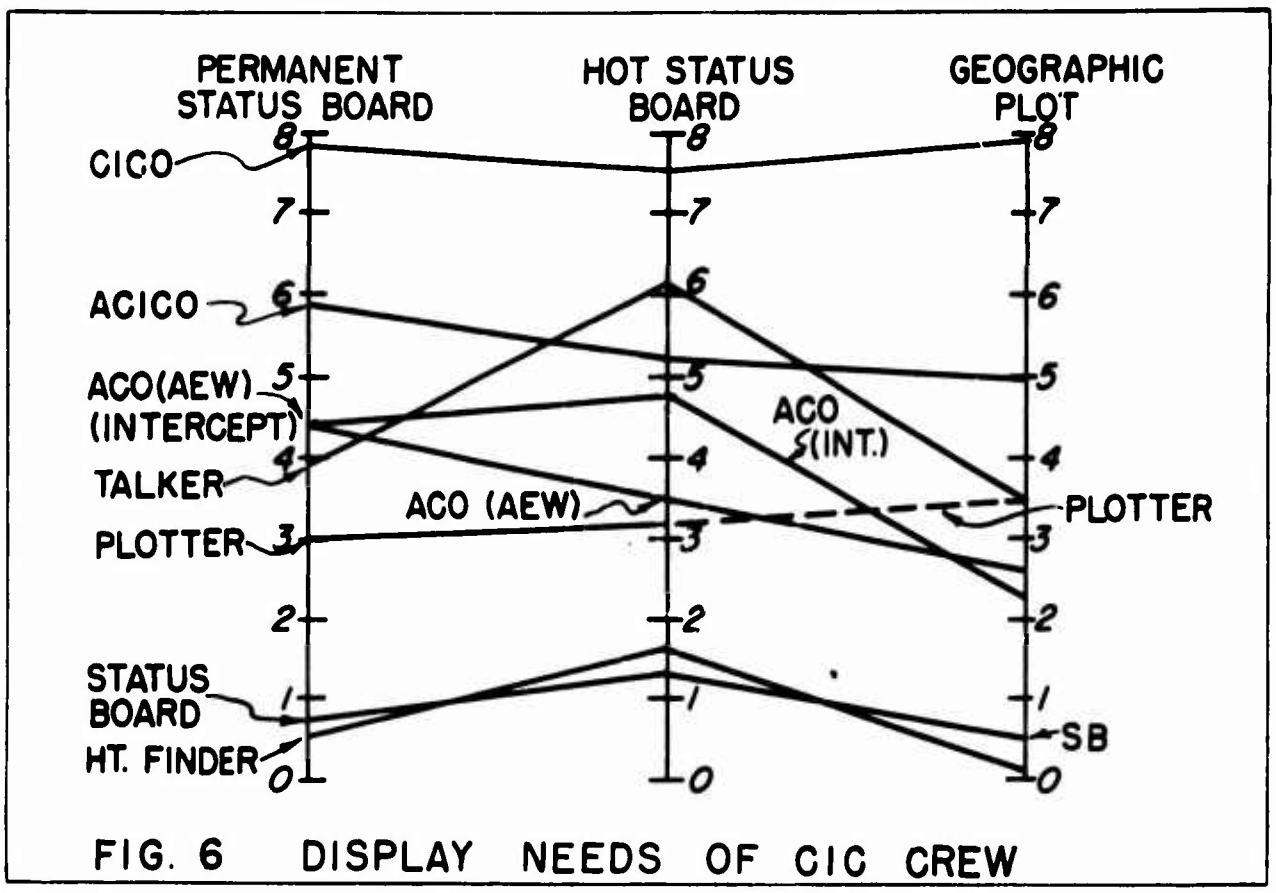


FIG. 6 DISPLAY NEEDS OF CIC CREW

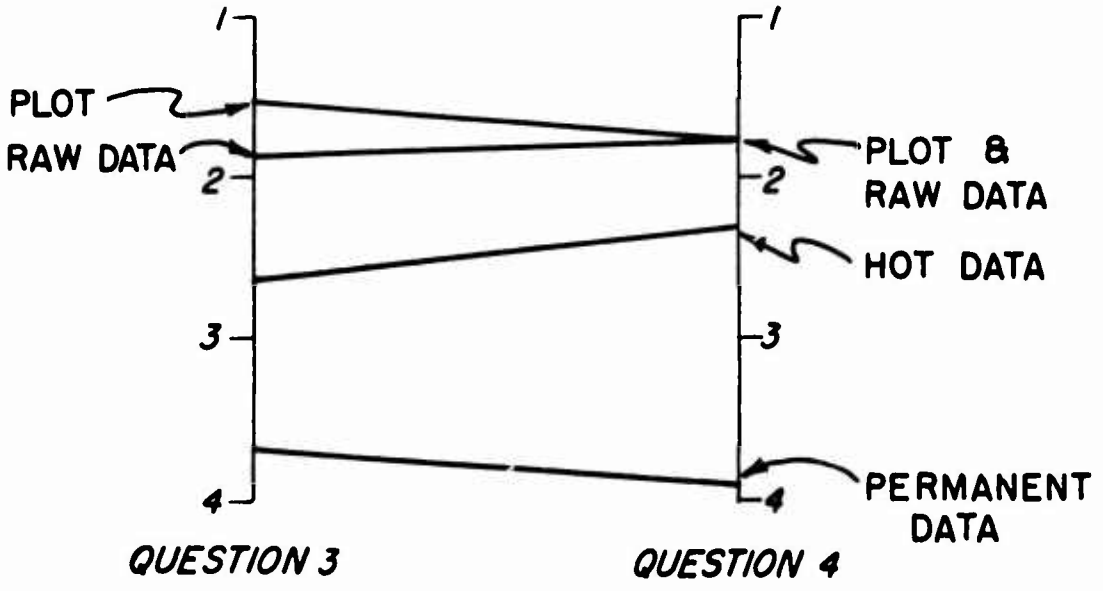


FIG. 7 DISPLAY NEEDS OF CIC OFFICER

Permanent Data being of lesser importance than in Question 4 (an intercept mission), and the inverse is true of the Raw Data and the Hot Data.

4.1.4 Question No. 5

The necessity of conversation between CICO and the Radar Operator, the RCM Operator, the Radio Operator, the Navigator, or the Height Finder Operator, without the use of phones, was examined in this question. Also taken into consideration at that time was the need of the CIC Officer to watch the aforementioned personnel at their work.

In summarizing the response to this question it may be said that there was little spread among the personnel, with the sole exception of the Navigator, whose oral contact with the CIC Officer was thought to be least important.

An interesting sidelight on this question is the fact that the Height Finder Operator was originally left out of this consideration. However, on his inclusion, he was graded, on the linear scale, as being the most important oral-visual link with the CIC Officer. He was closely followed by the Radar Operator, with the RCM Operator and the Radio Operator being rated a bit below him in importance. The oral-visual link between the CIC Officer and the Navigator was considerably below this. A graphical presentation of the summary of the response to this question is found in Figure 8.

4.1.5 Question No. 6

The summary of the responses to Question No. 6 is offered in Figure 9. This question deals with communications (radio, ICS, oral and visual) between the CIC Officer and each individual in the CIC, including the aircraft pilot.

The group answering the Questionnaire was asked to rate the frequency of communications between the CIC Officer and other members of the CIC under five column headings: "continuously or nearly so," "frequently," "occasionally," "rarely," and "very infrequently or not at all." They were further asked to check no more than seven items of the twenty six listed in any one of the first four columns. This limitation, providing for a better spread of response by discriminatory choices, forced each rater to choose only those items that he considered to be important and pertinent to the layout problem in the CIC.

The CIC Officer's use of the radio command channel was considered to be greater than any other means of communication available to him. However, his need for contacting the ACICO or the Plotter, either orally or visually, was thought to have as great a frequency as his ICS contact with the ACICO. The oral-visual link between the CIC Officer and the ACICO

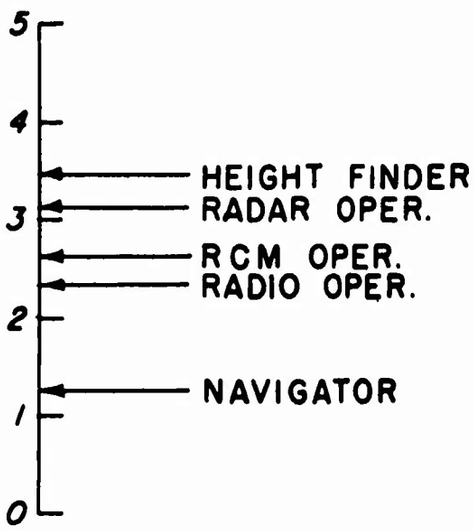


FIG. 8 ORAL LINKS FOR CIC OFFICER

or the Plotter, though, is more relevant to the problem of physical layout than any ICS-radio link from the CICO. In further consideration of the layout problem, with regard to communications by the CIC Officer, it is useful to see that he has a relatively small need for an oral-visual link with the ACO engaged in intercept work, the Radio Operator, the RCM and Radar Operators, the Navigator, or the Status Board Keeper.

The purpose of this question was not merely to present a comparison of the importance of oral-visual links to ICS-radio links available to the CIC Officer, but to establish the necessity of placing certain personnel nearer the CICO because of the frequency of communication between them and the CIC Officer. Thus, summarizing the response to the question, it was thought that the ACICO and the Plotter should be closest to the CIC Officer in any efficient CIC layout, with the Talker and the Height Finder Operator not too far off.

4.2 Results of the Rating Sheet

Prior to the analysis of the rating schedule it was necessary to develop a rating scheme that would give relative importance to the items rated in any particular layout. A particular layout could be judged as Excellent where ground maintenance is concerned and only Fair where flight maintenance is concerned. The importance of flight maintenance versus ground maintenance, for instance, as determined in the Questionnaire, indicated that flight maintenance is three times as important as ground maintenance in any layout. This does not mean that ground maintenance facilities should not be sought after. It does indicate, though, that if any compromise has to be made where both principles cannot be met, that the layout providing facility of flight maintenance is to be preferred. Thus, in order to get a meaningful overall rating of a particular layout, the items rated must be weighted according to the relative importance of the various principles, as determined by the Questionnaire.

The results of the group's rating of each layout were summarized according to the scheme that was derived from the Questionnaire results, as set forth, in general, above. These results are presented in Figure 10, in which it can be seen that ratings are found for each layout and for each of four factors that contribute to the overall rating.

4.3 Analysis of the Proposed Layouts

As a gross check on the adequacy of this systematized exploration of the value of each layout, each member of the group was asked to indicate which layout he preferred above all others, which he thought was second best, and which was third best. A summary of the overall ratings derived from the rating schedules is contained in the following

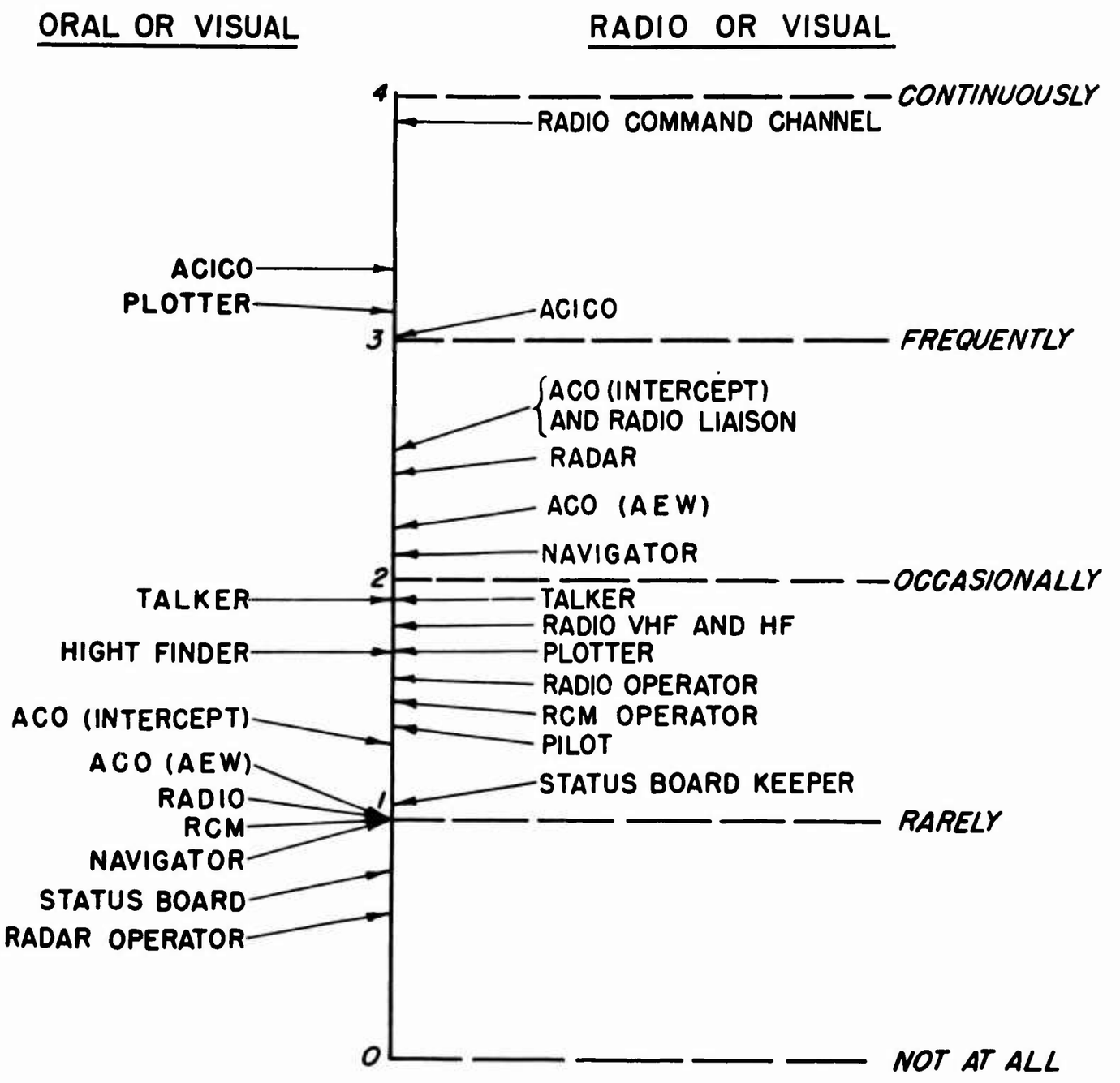


FIG. 9 COMMUNICATIONS LINKS FOR CIC OFFICER

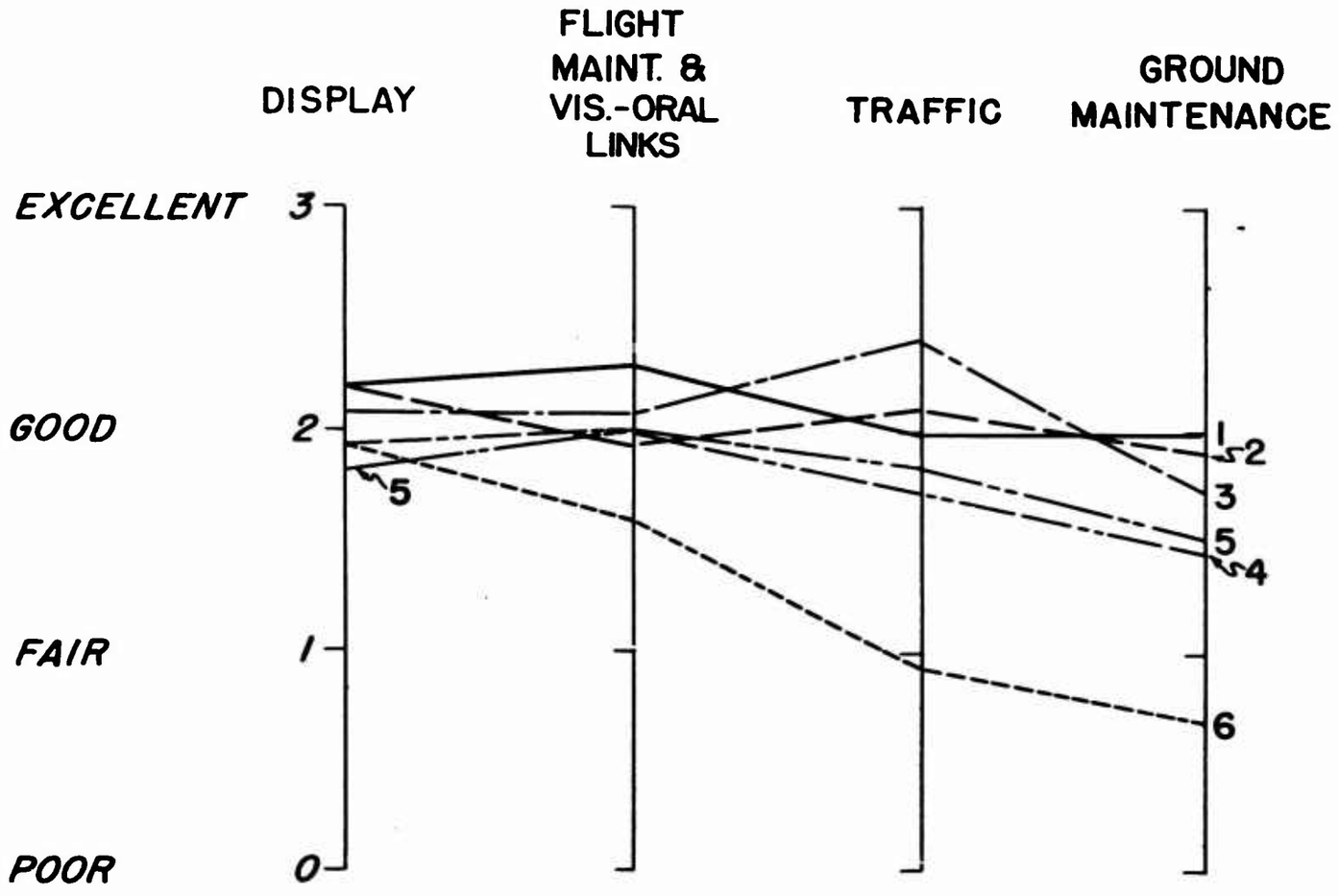


FIG. 10 SUMMARY OF RATINGS

tabulation.

Layout No.	Choice			Scale Value (based on 4 point scale)
	First	Second	Third	
1	12	1	0	2.9
2	0	10	3	2.3
3	1	2	10	2.0

Figure 11 represents graphically the layout ratings found by combining the factor scores compared with the results found by analyzing the overall ratings. It will be noted that the results obtained by the two rating methods check. (There is a difference in scale distances between items due to the rating methods.) This confirms the appropriateness of the weights used for combining the factor scores.

In filling out the rating schedule on each layout, the individual devoted himself to consideration of a number of items, and at no time was asked to summarize his opinions. Because of this, the check on the pertinence of the Questionnaire, in the rating scheme approach, represented an independent verification of the results obtained.

The balance of section 4 is devoted to a discussion of the results of the ratings. The layouts will be considered under six different headings. "Flight Maintenance," "Ground Maintenance," "Central Display," "Traffic," and "Communications Links," and "CICO's Visual Links."

The actual design of each layout will be found in Layouts 1-6 in the appendix of the report. It is recommended that these drawings be opened for reference while reading the balance of the report.

4.3.1 Flight Maintenance

Flight maintenance is difficult to rate if no operational repairs of in-flight breakdowns can be assessed. This was the case in the PO-2W layout study, since each evaluator made his rating without the benefit of any actual flight experience in the PO-2W.

However, relative ratings of flight maintenance were gathered. Here, it is interesting to note, Layouts 5 and 6 rated slightly lower than the others (1.7 and 1.8 against 2.1, 2.2, and 2.1), although Layout 6, having the equipment in line, permits easy front and rear maintenance. It was probably thought by the raters that the availability of equipment (being accessible from all sides) for maintenance purposes should be directly proportional to the rating. For this reason, Layouts 5 and 6, which give a general impression of crowding, were probably rated as low as they were.

In general, the ratings on all layouts for this consideration centered around a value of 2, with the established range of rating being

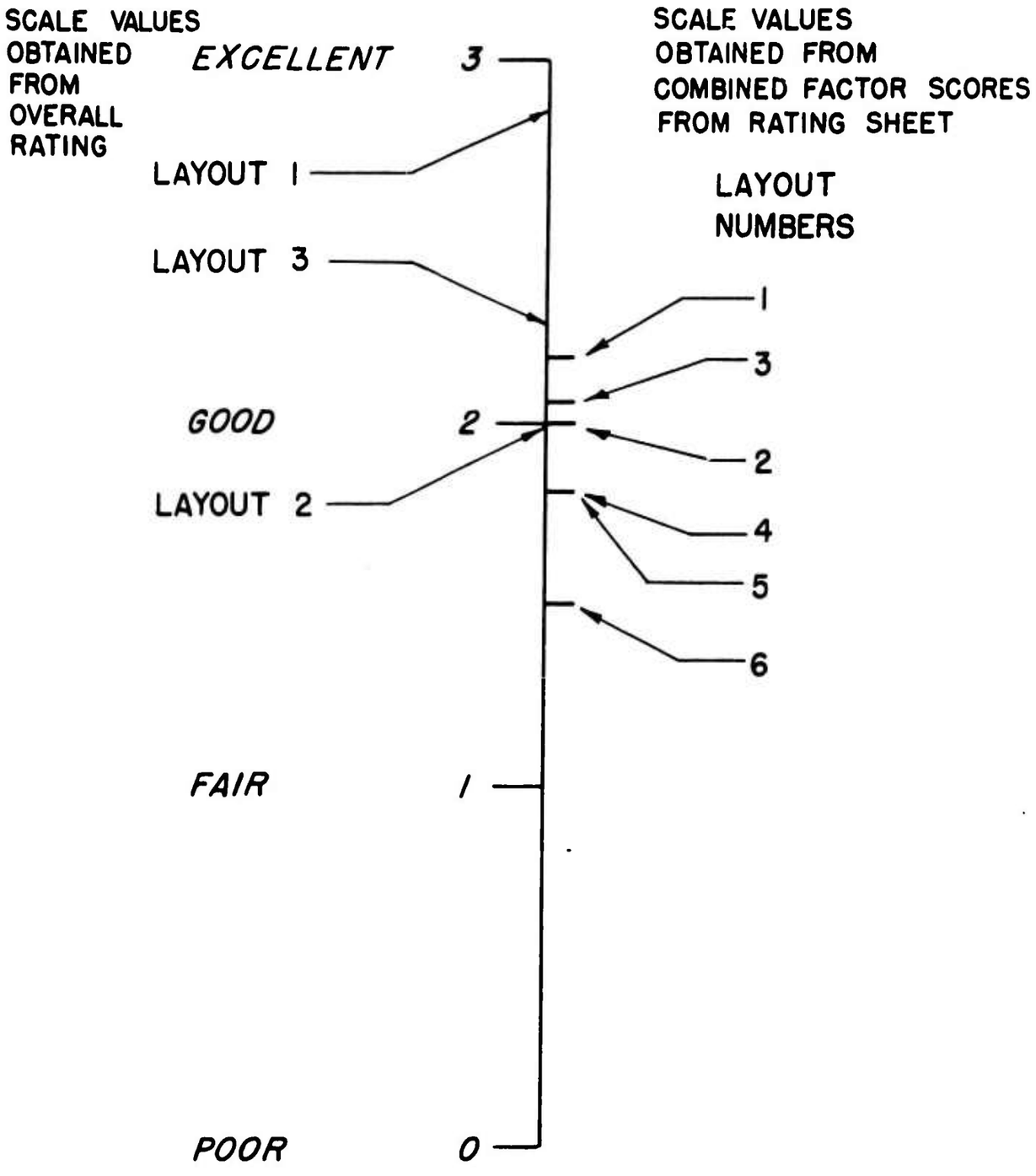


FIG. 11 OVERALL RATINGS ON SIX LAYOUTS

from 0 to 3.

4.3.2 Ground Maintenance

Layout 1 rated high in ground maintenance, chiefly because it received a high rating of 2.[illegible] on the item "space for setting up test equipment near gear being repaired." This high rating is the result of separating the cables to feed into consoles on both sides of the ship, and the particular distribution of other equipment port and starboard.

Because of the central location of the equipment in Layout 6, it was considered difficult to remove gear for purposes of ground maintenance.

4.3.3 Central Display

A most important comparison of the various layouts is made on the basis of the availability of the central display to all personnel.

It should be understood that a layout item rating giving a low value for the visual links of the Radio Operator may still be highly satisfactory in overall layout, particularly where the Radio Operator has no need to see the display.

In Layout 1 the display is well placed for the ACOs. They can observe it by merely looking up, over their consoles. This item was rated at 2.4.

Layout 2 permits the ACOs to see the Display Board if there is no aisle traffic. Here the four ACOs, located starboard, look ahead and, partially, up the aisle. ACICO can view the Board by looking to his left. Here the item of Display was given a rating of 2.3.

Layouts 3, 4, and 5 (with ratings of 1.7, 1.3, and 1.7), with the Display Board forward, tend to obstruct the view of the ACOs. In Layout 5 the Navigator and Radio Operator are in front of the Board. In Layout 4 the Navigator, Radar, RCM, Radio and Height Finder Operators are between ACICO and the Board; CICO and the DRT Operator are situated between the four ACOs and the Display.

The Talker is located in a central position in all layouts, to permit him to study the DRT and the Display Board as easily as possible. Layouts 1 and 2 are highest in this respect.

The Talker's view of the Display Board is very slightly better in Layout 2 because the DRT, where the Talker is expected to stand, is directly in front of the Display Board, providing the Talker with an unobstructed view. In Layout 1 his view is also excellent, since he stands in the aisle and faces aft.

Layout 3 provides a good view of the Board to the Talker who faces forward, while standing in the aisle. Layout 4 (rated 1.6) is poor in

this respect, causing a serious limitation in the use of the Board by the Talker. Layouts 5 and 6 (with ratings of 2 1 and 2 3) are also satisfactory, since no equipment or personnel are positioned between the Talker and the Board.

The DRT Plotter has a good view of the Display Board in Layouts 1, 2 and 4, but has his back to the Board in Layouts 3 and 6.

The RCM Operator has gear stacked in front of him higher than eye level and, therefore, cannot see the Board in Layouts 1, 2, 3, and 6. In Layout 5 he has an additional obstruction in having personnel in his way. In Layout 4, however, he has his best view of the Board, even though it is inconvenient.

The Radio Operator has the same problem as the RCM operator. A glance at the layouts will confirm this immediately.

An important item in which Layout 1 is deservedly high is the "flexibility in placing display boards at the number of different points." This characteristic allows the use of alternate procedures for different types of operational missions (AEW, fire control, fighter control, etc.), without a need to rearrange the layout each time there is such a change.

Layout 1, though not getting the high rating for all personnel, received a high enough rating for those who need the Display Board most. This was the basis for justification in rating Layout 1 as best in central display.

4.3.4 Traffic

The overall rating of traffic facilities, for all layouts, placed Layout 5 at the top, followed in order by Layouts 2, 1, 4, 3, and 6; the last three being much lower than the others.

The rating of "ease of traffic for CICO to the ACOs" placed Layout 3 highest, though not significantly higher than Layout 1 (ratings of 2.8 to 2.7). Layout 3 seems to have clearer aisle space, though more walking is involved for the CIC Officer to reach the four ACOs, situated in line, than in Layout 1, which has the four consoles grouped together near him.

Actually an analysis of the items making up the overall traffic rating shows that Layout 5 rated higher than Layout 1 on only three items, these being of less consequence than those in which Layout 1 was rated highest. This is satisfying, in a sense, becauses it minimizes a weak element in overall efficiency rating. The poorly rated items in Layout 1 are: Passage to rear head and bunks (1.7 for Layout 1 and 2.5 for Layout 3); Passage of CICO to Radio Station; Path clearance around Display Board.

On the plus side of the ratings, a perfect score is found for Layout 1 in "passage of CICO to DRT," in conjunction with the highest rating

for all layouts on "passage for messenger in case of communications breakdown." Layout 1 also rated highest in "room for technician to work on equipment" and for "ease of CIC Officer to reach the Height Finder and the Radar Station.A

All this indicates that Layout 1 could have been rated highest in every respect if the poorly rated items mentioned above had been eliminated or weighted low because of their relative unimportance.

4.3.5 Communications Links

The importance of rating the efficiency of communications links in arriving at an optimum layout may be seen in the fact that many electronic communication systems are known to be overloaded.

The layouts in this study were considered from the point of view of personal contact among the operators. For instance, it would occasionally be advantageous to have the ACOs in a location where they could be easily contacted by CIC Officer without the use of phones. At such times it might be faster and less confusing for CIC Officer to get the attention of an ACO by merely tapping him on the shoulder and then giving him a manual sign as to what he wants him to do.

In only four items of twelve were other layouts rated higher than Layout 1. Layout 4 rated high in the "relationship of CIC Officer to Radio Operator," even though there is some equipment between them, because he is the first man at the CIC Officer's left.

Layout 6 is higher than Layout 1 in the item "Navigator Station and CIC Officer." This is another reason for the superiority of Layout 1, however because the importance of having the Navigator close to the CIC Officer is questionable, and it also prevents the location of some more important station nearer to CICO.

Another important feature of Layout 1 is the amount of space for additional personnel and the ease of relocation of the consoles. Here it rated high again because of the functional grouping of the ACOs and the larger amount of floor space available around the DRT and CIC Officer Stations.

Other important links that should be given consideration are available in Layout 1. Thus, if the Radio Operator and ACICO have joint responsibilities, or overlapping duties, assigned by the CIC Officer on some mission, their close proximity to each other and the CIC Officer makes the accomplishment of the operation practical.

Layouts with men in line, such as Layouts 2, 3, and 5 tend to compartmentalize the personnel and limit the flexibility of communications links, while Layout 4 would provide many man-man links of relatively unknown importance, and neglect those that are presently considered highly

important.

4.3.6 CICO's Visual Links

If lines were drawn between the CIC Officer's Station and other stations to indicate visual links, it would be found that eight such links are possible in Layout 1. They join the CIC Officer with the Display Board, the four ACOs, the DRT, the ACICO, and the Height Finder. This layout allows for very little chance of any personnel blocking his view.

Layout 2 has five links between the CIC Officer and other stations. This includes viewing the Display Board, three ACOs, and the DRT. However, when he stands at the DRT, his links are reduced to two, the Display Board and one ACO.

Layout 5 allows for five links between the CIC Officer and the others. His view of the Display Board may be hindered at times by the Radar Operator or the Navigator, both of whom are situated in front of the Display Board.

In Layout 4 the CIC Officer has four links, with a limited and poor view of the Display Board. Here five operators are situated between him and the board.

In Layout 3 the CIC Officer has five links. These include the Display Board, two ACOs, the DRT, and the Radar Operator. Here, however, he loses contact with one ACO when he stands at the DRT. Also, the Display Board blocks his visual communications with the Navigator and the Radio Operator.

In Layout 6 he has more links than in any other, a total of six. These links include visual contact with the Status Board, three ACOs, the Height Finder, and the DRT. This layout is unique in that it permits procedures requiring a number of central displays to be viewed by all personnel, except the Radio Operator.

The links in Layout 1, however, seem to be the most useful and widely varied, as evidenced by the overlay found on the drawing of Layout 1.

5.0 CONCLUSION

Layout No. 1 has the electronics equipment of the PO-2W CIC arranged, as determined by methods described, in such a way as to allow for optimal performance of most CIC functions.

An important feature of this layout is the relationship of the CIC personnel to alternate or multiple viewing positions. Thus, as more operational and laboratory experience is accumulated in reference to the positioning and design of display boards, there will be available a choice

of positions that will still permit observation by the CICO and the DRT Operator.

Functionally, this layout permits the CIC Officer to direct all activities by ICS or personal contact. He has available, directly to his right, the latest raw data. This is on a console, used by the ACICO, under his supervision. By standing and turning he may study the DRT and the status boards located slightly aft of center, in addition to the Central Display Board located aft. An extra convenience for the CIC Officer is the fact that he can have a clear view of the Height Finder while he is at the DRT.

The four APA-56 consoles are available as a group to the CIC Officer without occupying desirable space around him. This is an acknowledgement of the heavy load placed on the CIC Officer, with recognition of the necessity for delegating duties, in order that he be free to act as a supervisor or commanding officer. However, this will not be possible if he has so many routine duties that he could not study and act on new situations as they arise.

This layout further permits the CIC Officer to contact any member of the CIC crew, either orally or physically. With one step he can contact either of two ACOs or the DRT Operator, by means of a turn of his head and he can observe activities of the ACICO or the Height Finder, with three steps forward he can contact the Radar Operator or the RCM Operator, or by an extra step forward he can observe the Navigator or the Radio Operator.

The IP-49, and the RF are stacked and placed near the Radar Operator while, at the same time, the IP-49 is available to the RCM Operator and the Navigator.

Maintenance facilities in this layout are excellent because of the positioning of the gear and the large amount of aisle clearance in the CIC, providing, of course, that the gear is designed for front-end maintenance.

Although the four ACOs face aft, toward the Central Display Board in this layout, detailed study indicates that this has advantages as well as disadvantages.

There is the added asset of permitting the scopes to be viewed by the CIC Officer. The Central Display Board is easily accessible and safely out of the paths of CIC traffic.

Layout No. 1 satisfies all the factors necessary for highly efficient CIC performance to a greater degree than any other proposed layout of the electronics equipment. However, there are likely to be minor changes in this layout as more laboratory and operational experience in the PO-2W is acquired. These changes will be almost entirely confined to rearranging the equipment at individual stations, and will probably not affect the general

layout to any great degree. This important aspect of the PO-2W will be described in future reports, to be released whenever such changes are indicated and substantiated by operational observations.

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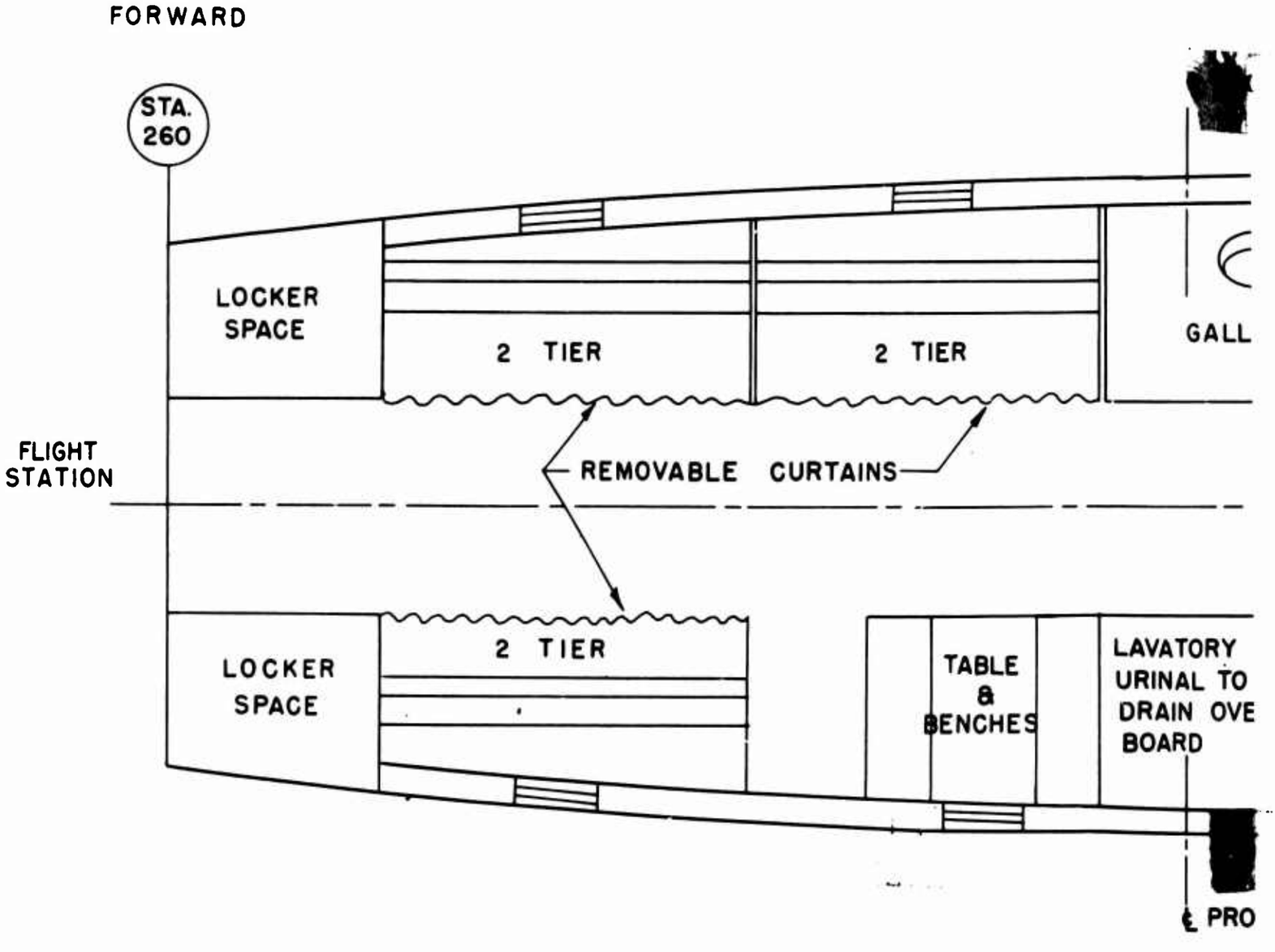
APPENDIX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2 TIER
2 TIER
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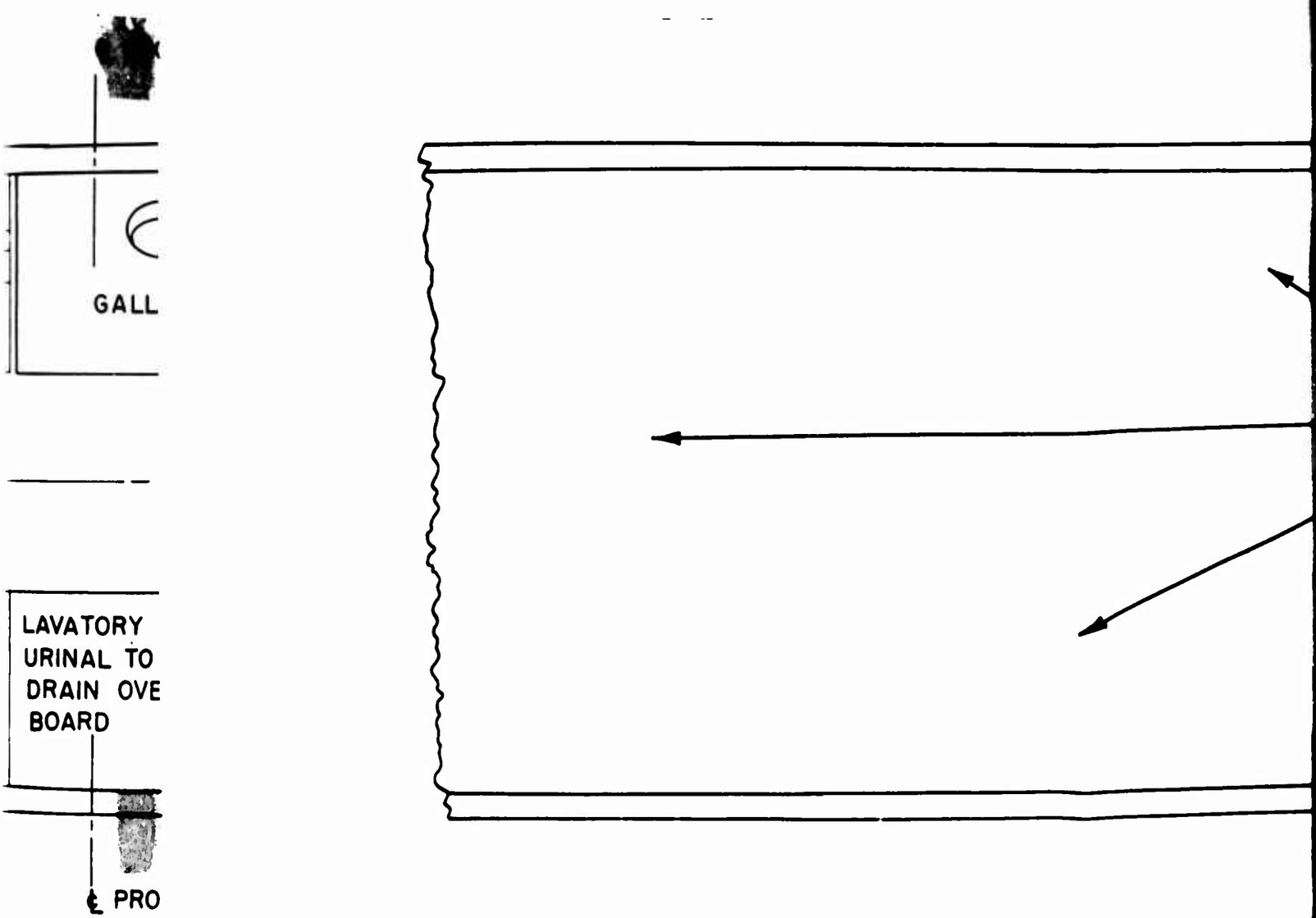
2 TIER
TABLE & BENCHES
LAVATORY URINAL TO DRAIN OVE BOARD
℄ PRO

A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URINAL TO
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BOARD
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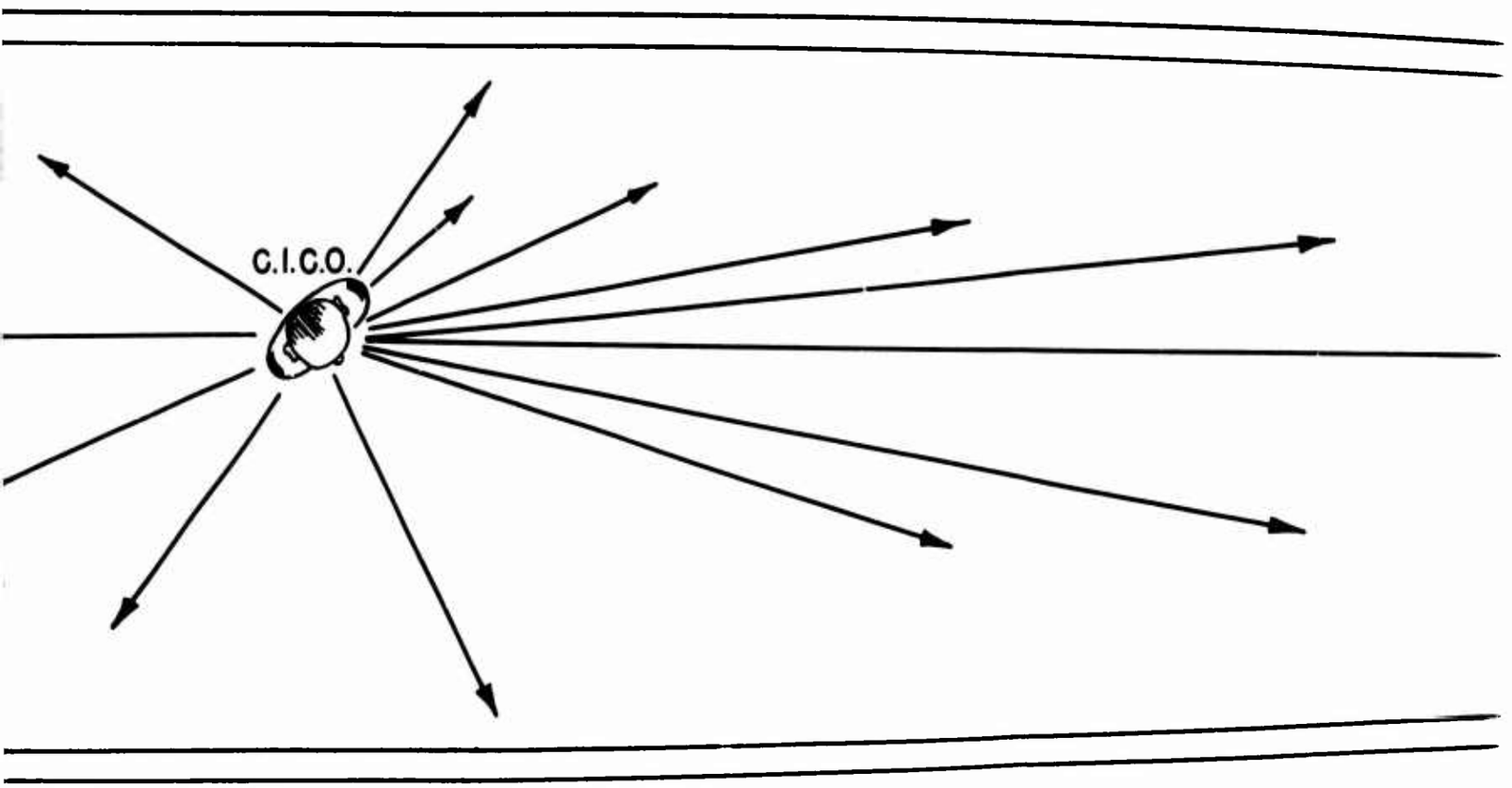
—EMERGENCY EXIT OVER THE WING



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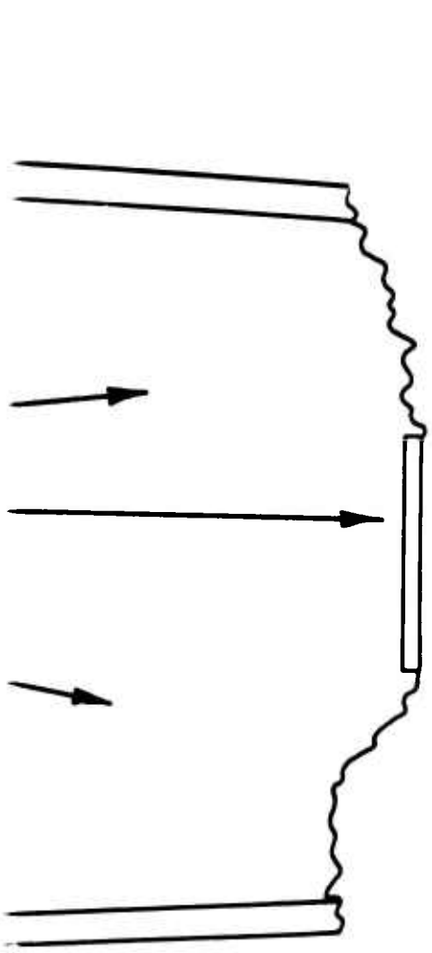

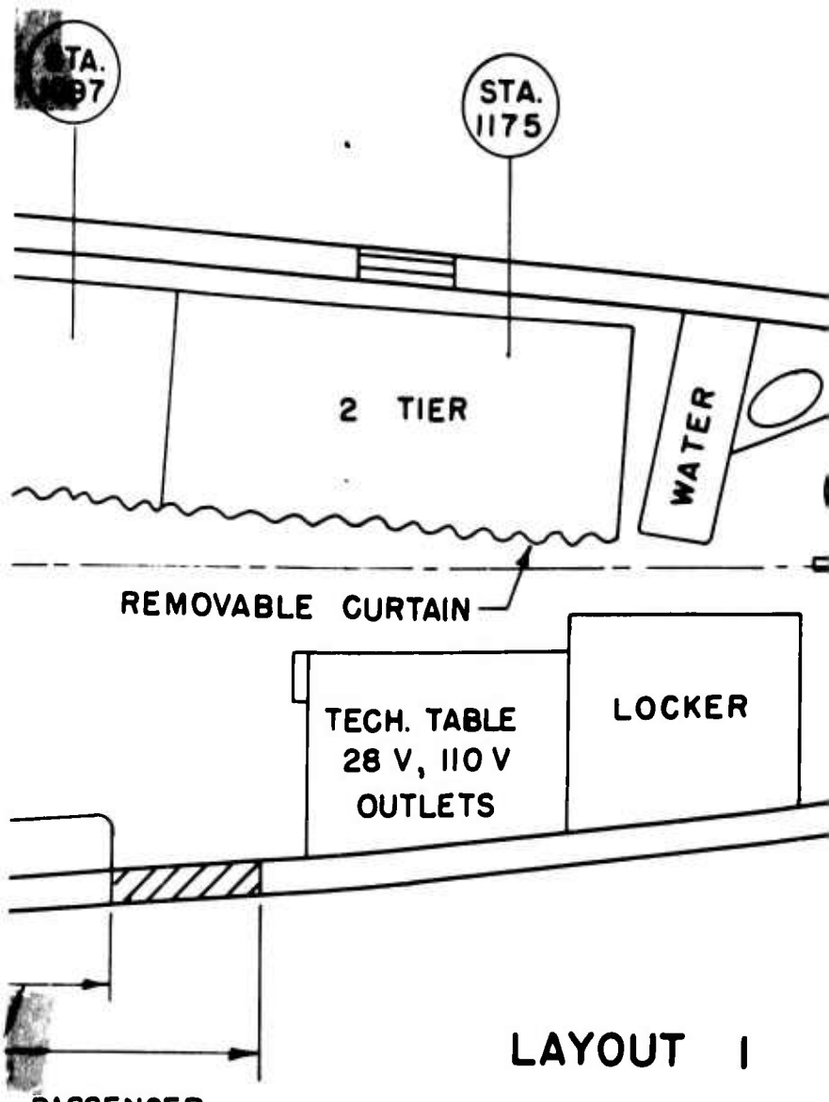

LAYOUT 1

[redacted]

BRACKETS FOR COFFEE
AND WATER CONTAINERS

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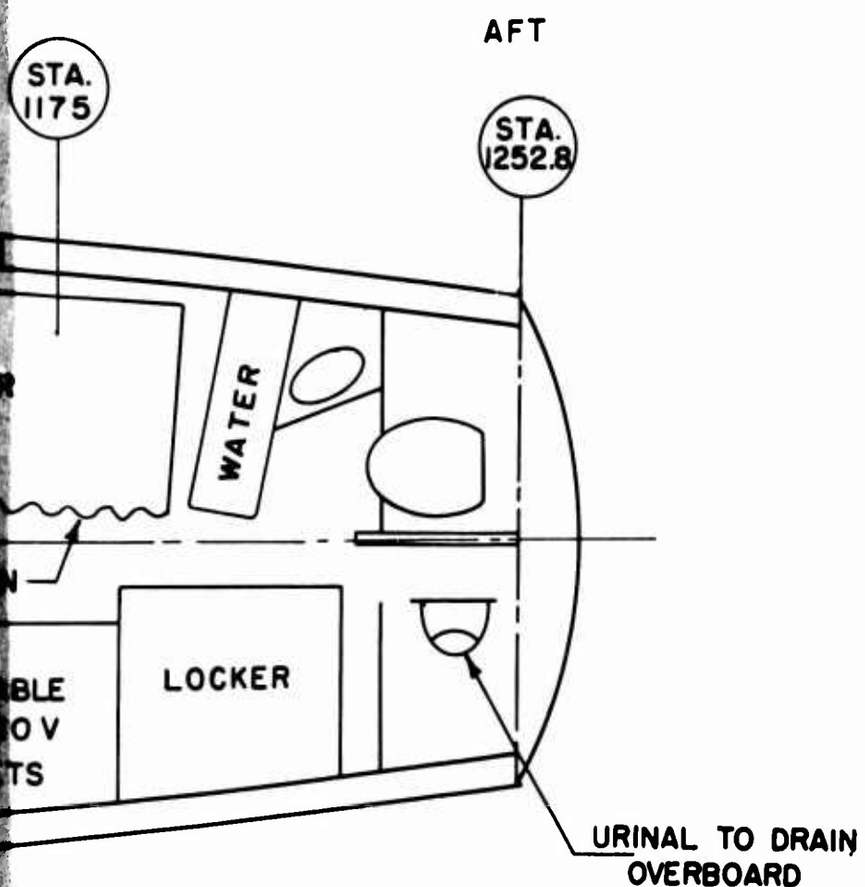
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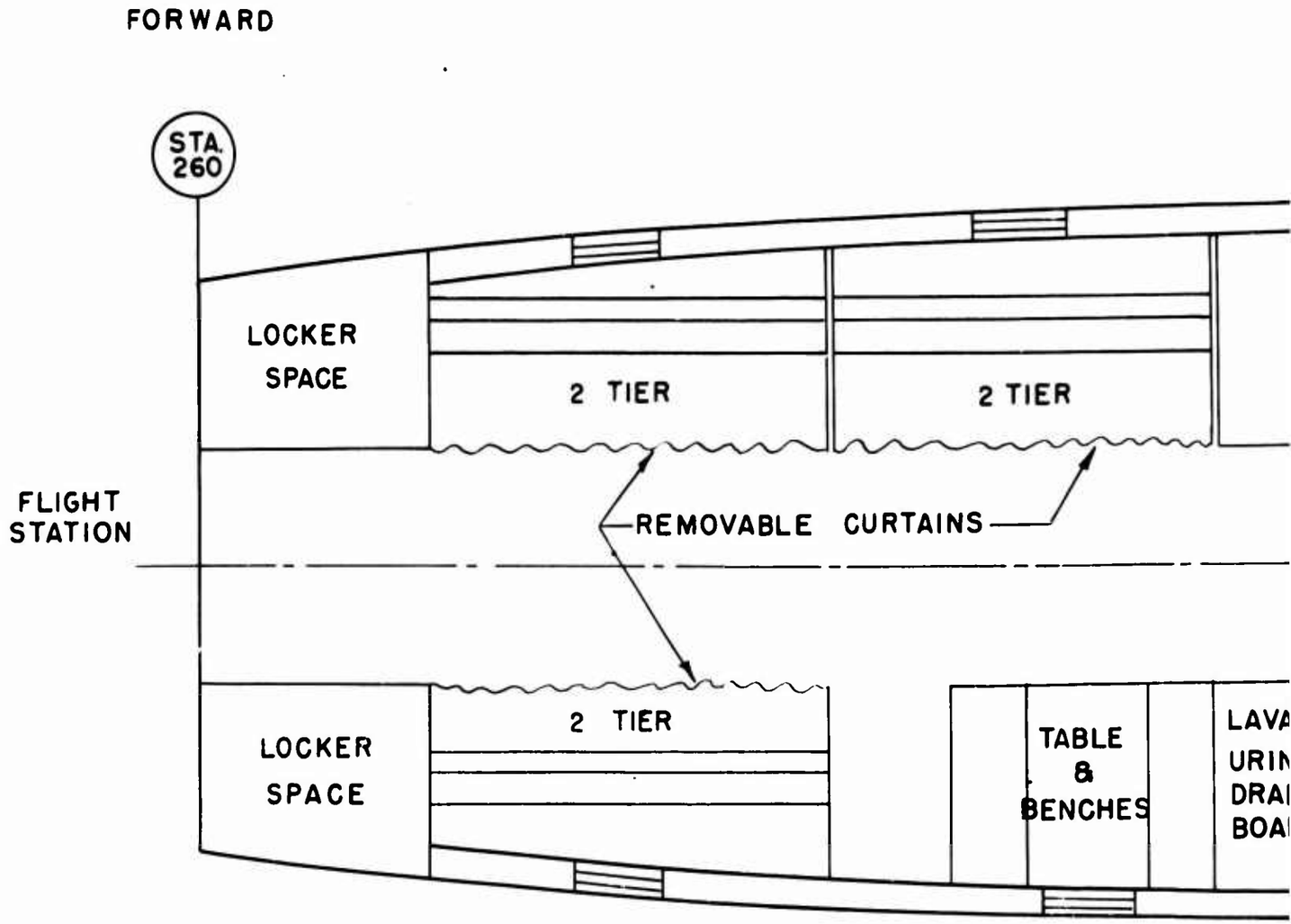
STA. 1252.8
WATER
LOCKER
URINAL TO DRAIN OVERBOARD

LAYOUT 1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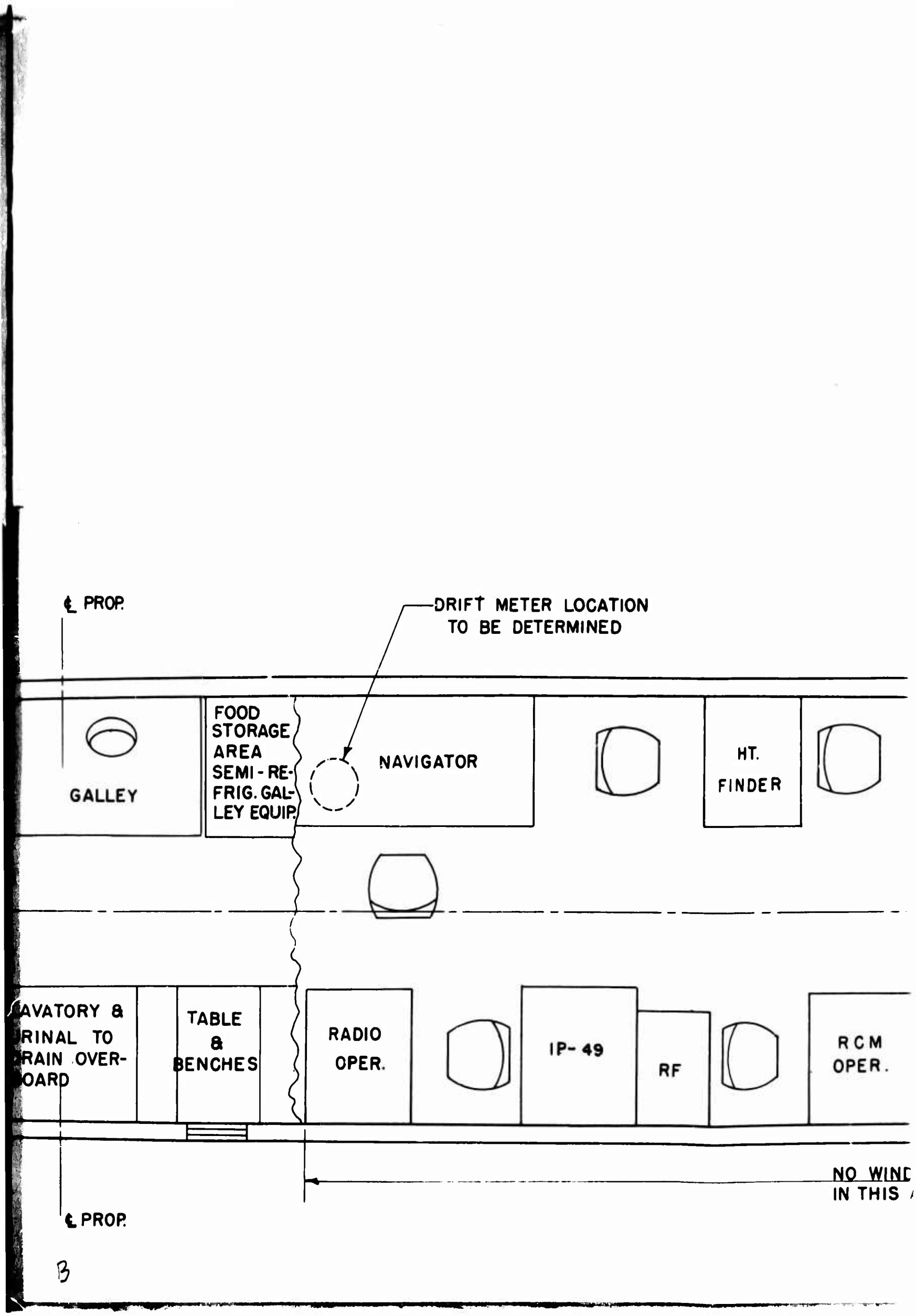
STA. 260
LOCKER SPACE
2 TIER
2 TIER
FLIGHT STATION
REMOVABLE CURTAINS
LOCKER SPACE
2 TIER
TABLE & BENCHES
LAVA
URIN
DRAI
BOA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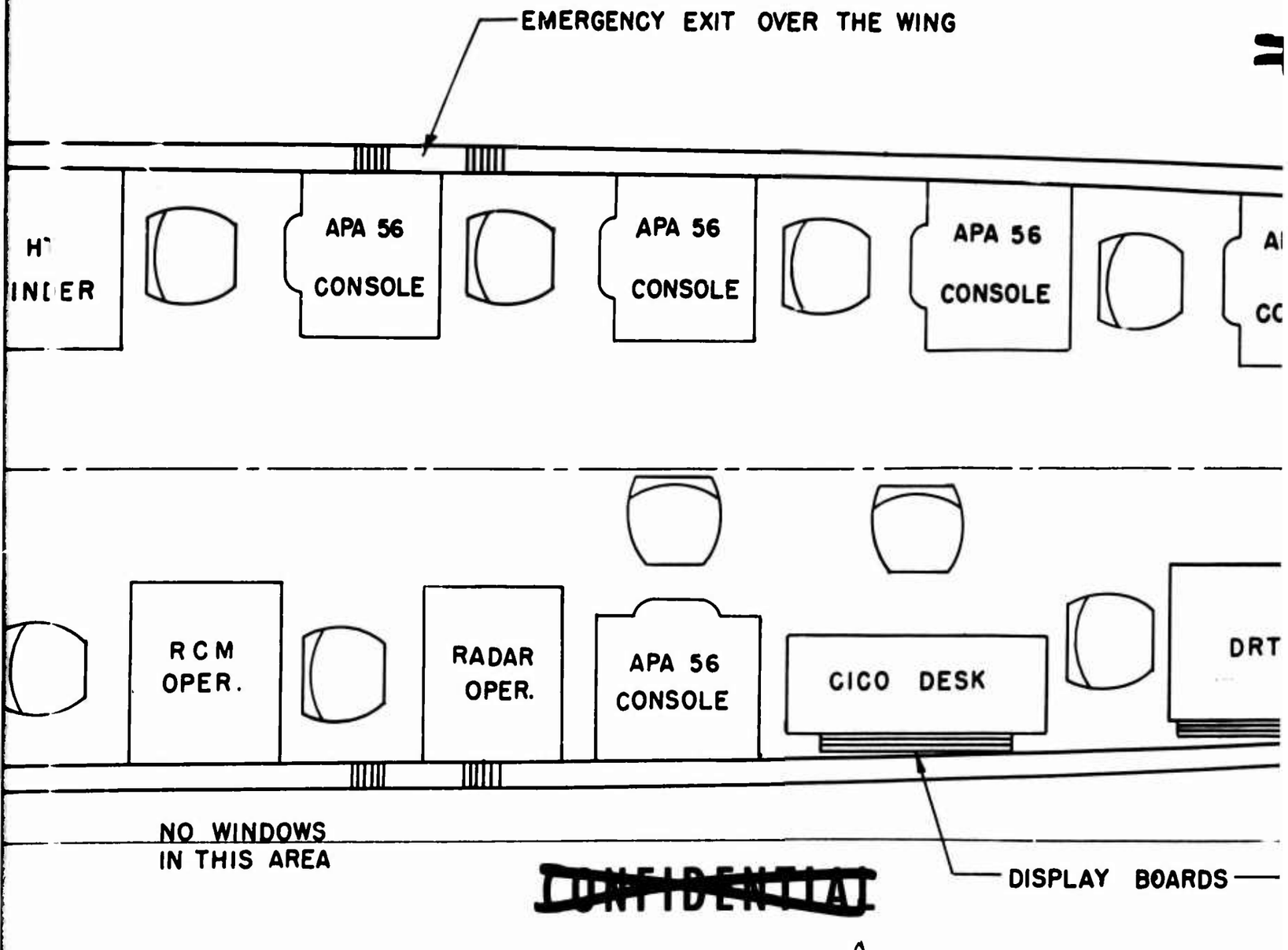
DRIFT METER LOCATION
TO BE DETERMINED
GALLEY
FOOD
STORAGE
AREA
SEMI - RE-
FRIG. GAL-
LEY EQUIP.
NAVIGATOR
HT.
FINDER
AVATORY &
RINAL TO
RAIN OVER-
OARD
TABLE
&
BENCHES
RADIO
OPER.
IP- 49
RF
RCM
OPER.
NO WIND
IN THIS
℄ PROP.

B



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C

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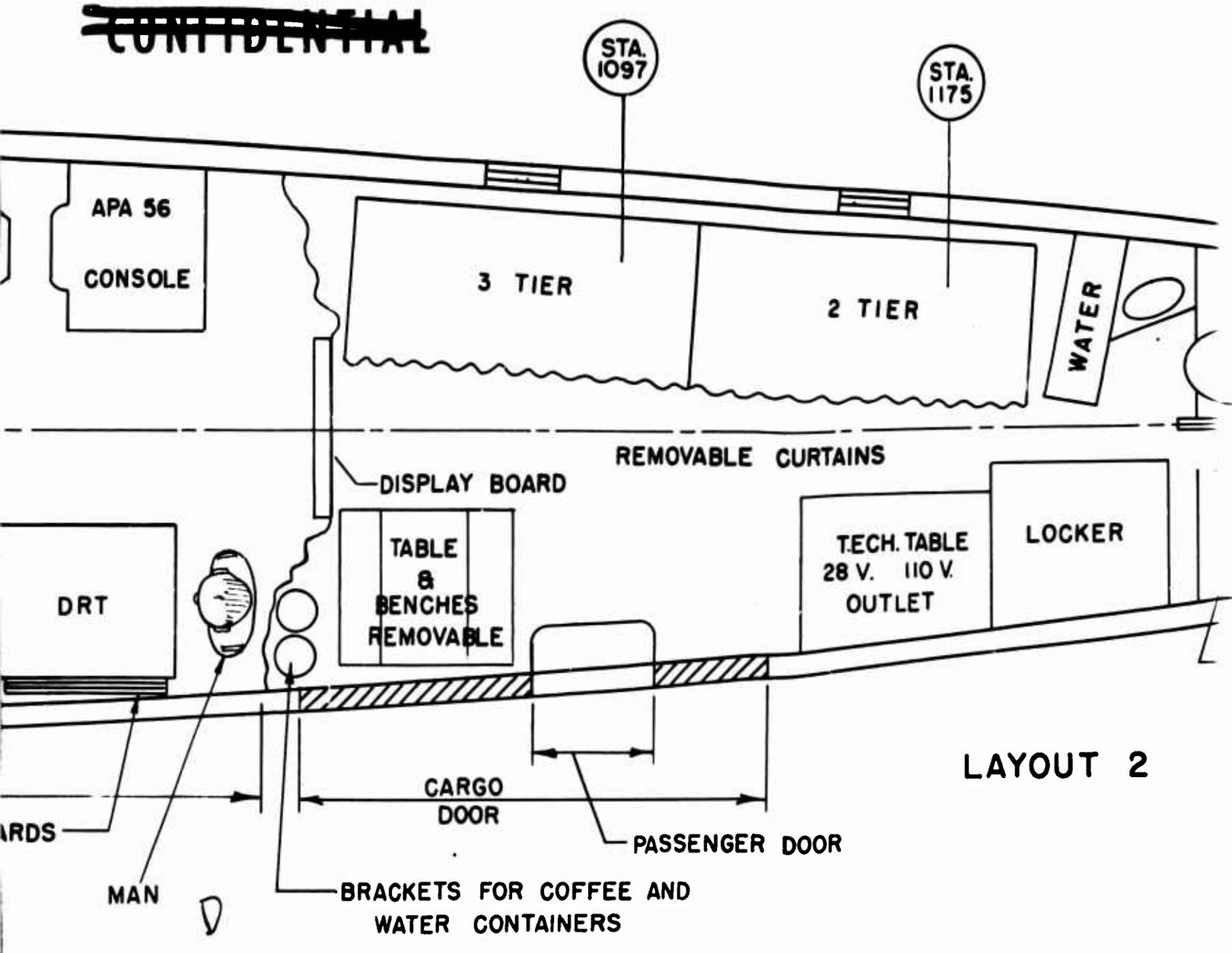

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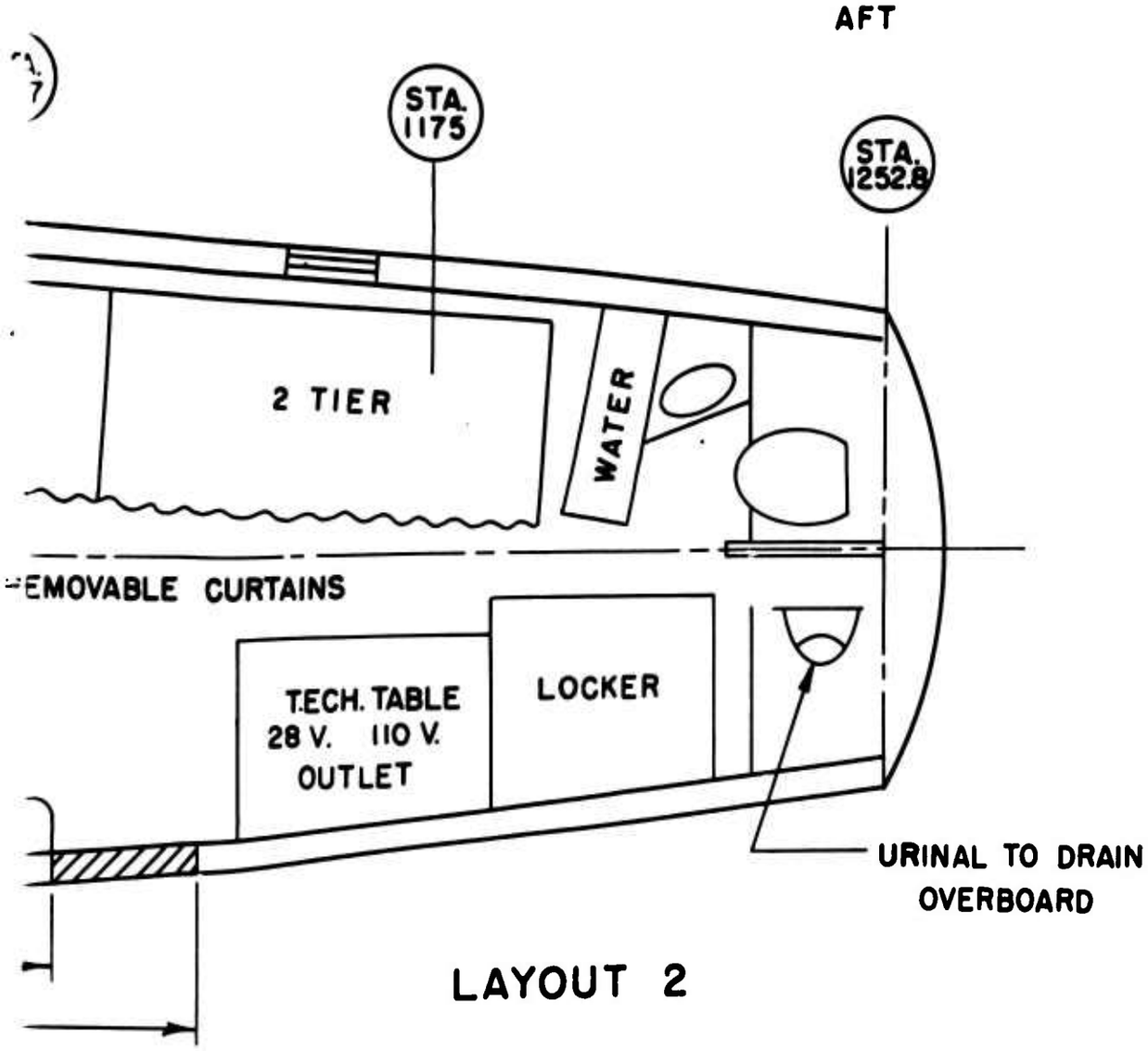

LAYOUT 2

PASSENGER DOOR

AND

FORWARD

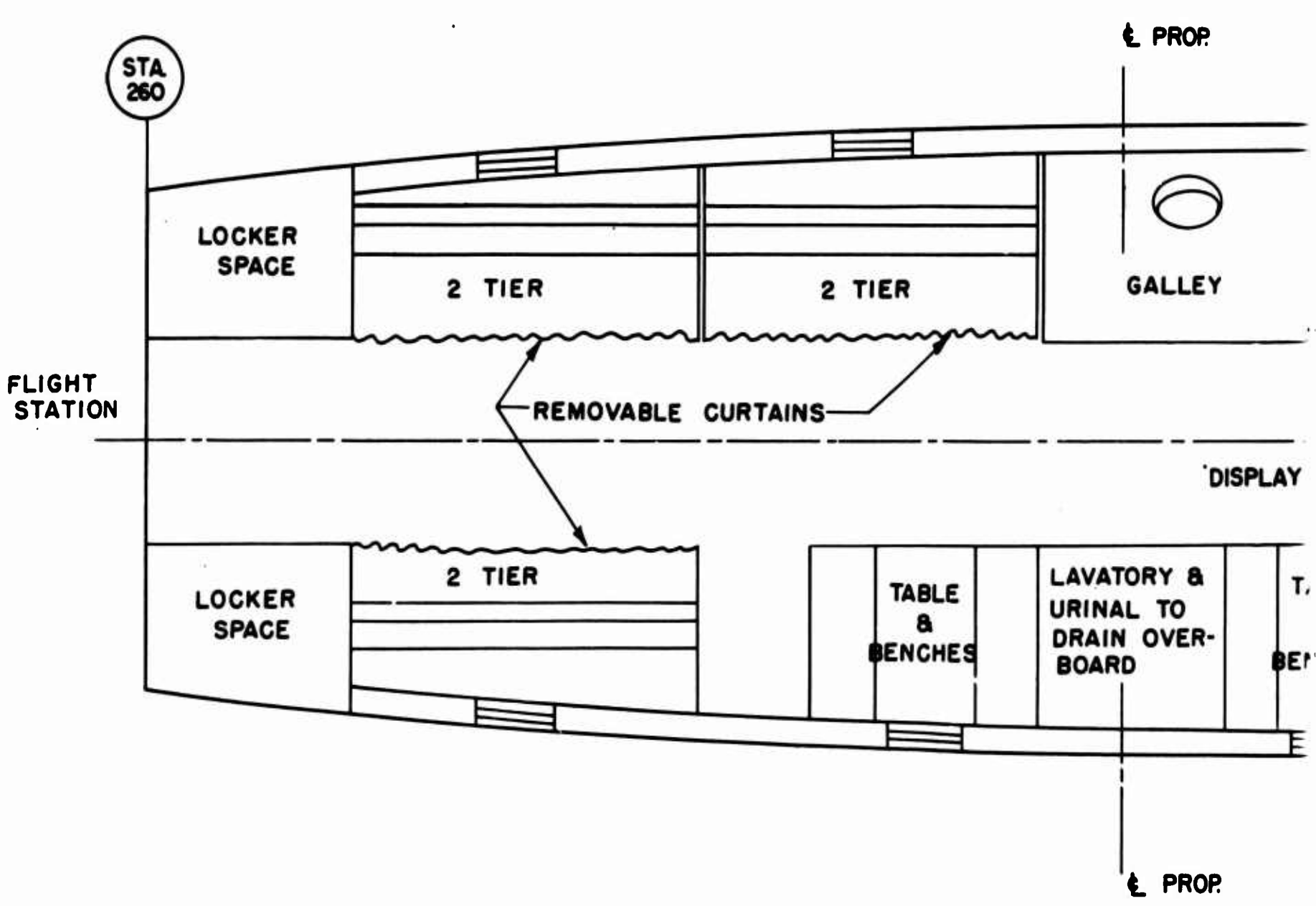
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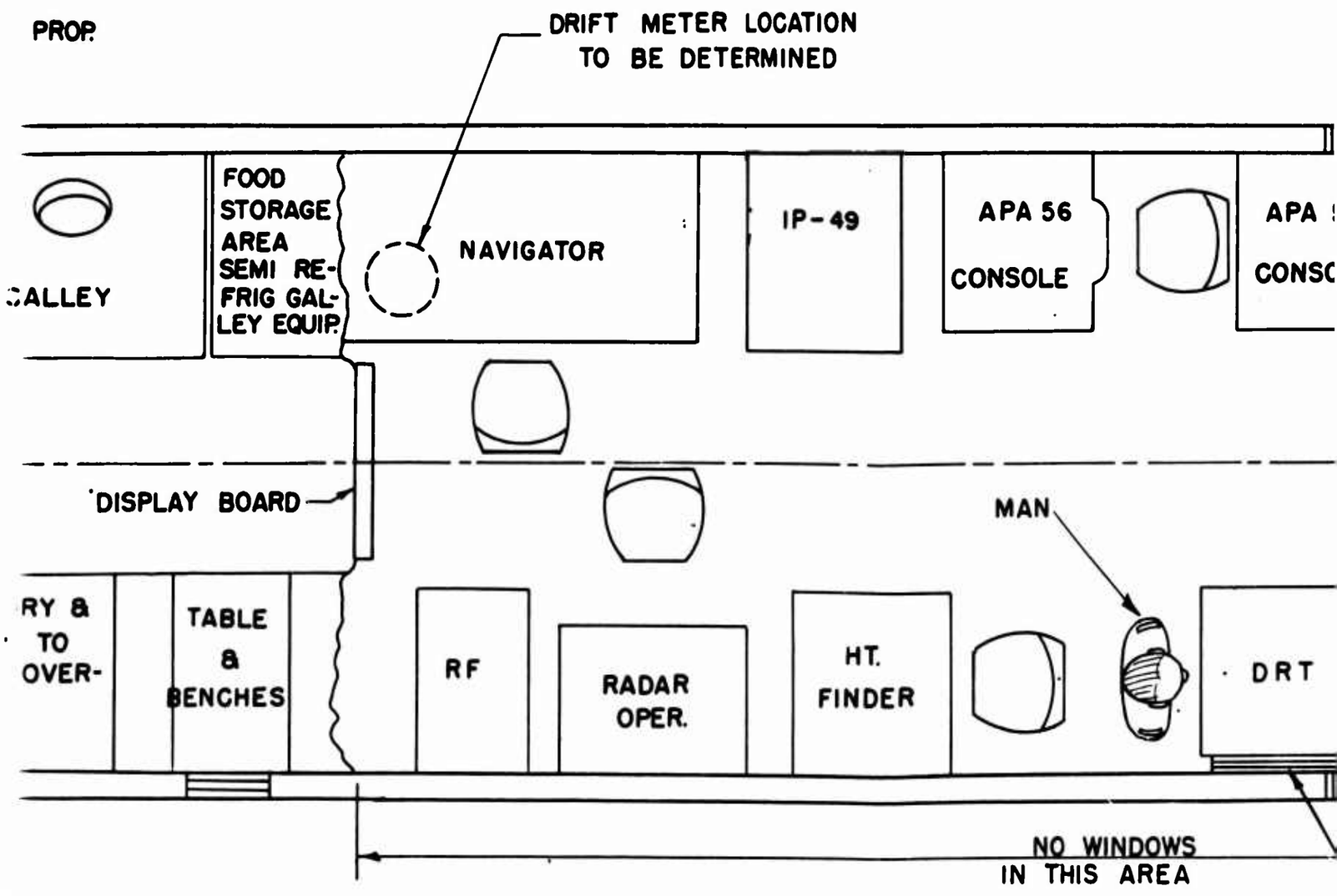
TABLE & BENCHES
LAVATORY & URINAL TO DRAIN OVER-BOARD
℄ PROP.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FOOD
STORAGE
AREA
SEMI RE-
FRIG GAL-
LEY EQUIP.
NAVIGATOR
IP-49
APA 56
CONSOLE
APA
CONSC
DISPLAY BOARD
MAN
RY &
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OVER-
TABLE
&
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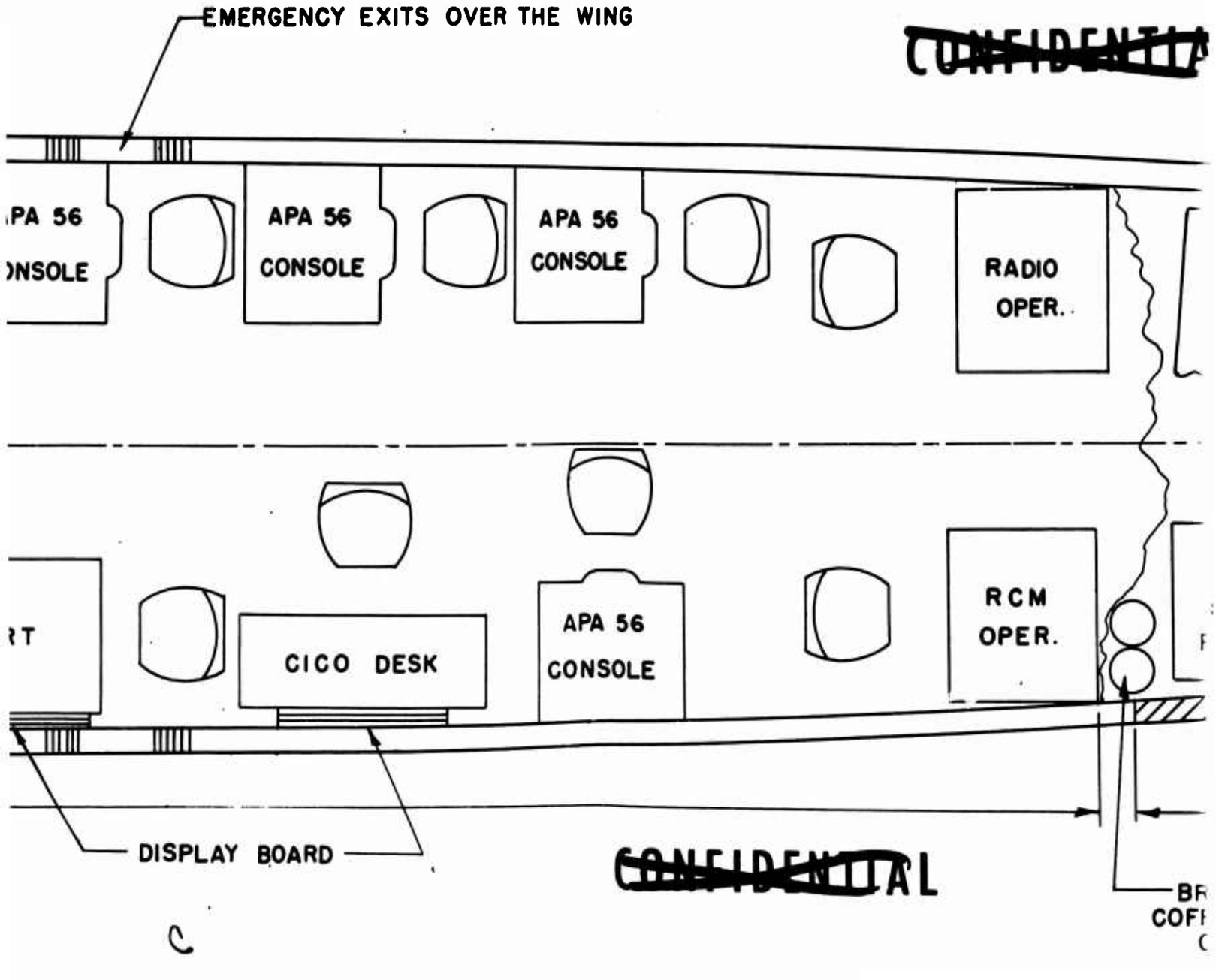
RADAR
OPER.
HT.
FINDER
DRT
NO WINDOWS
IN THIS AREA
PROP.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APA 56
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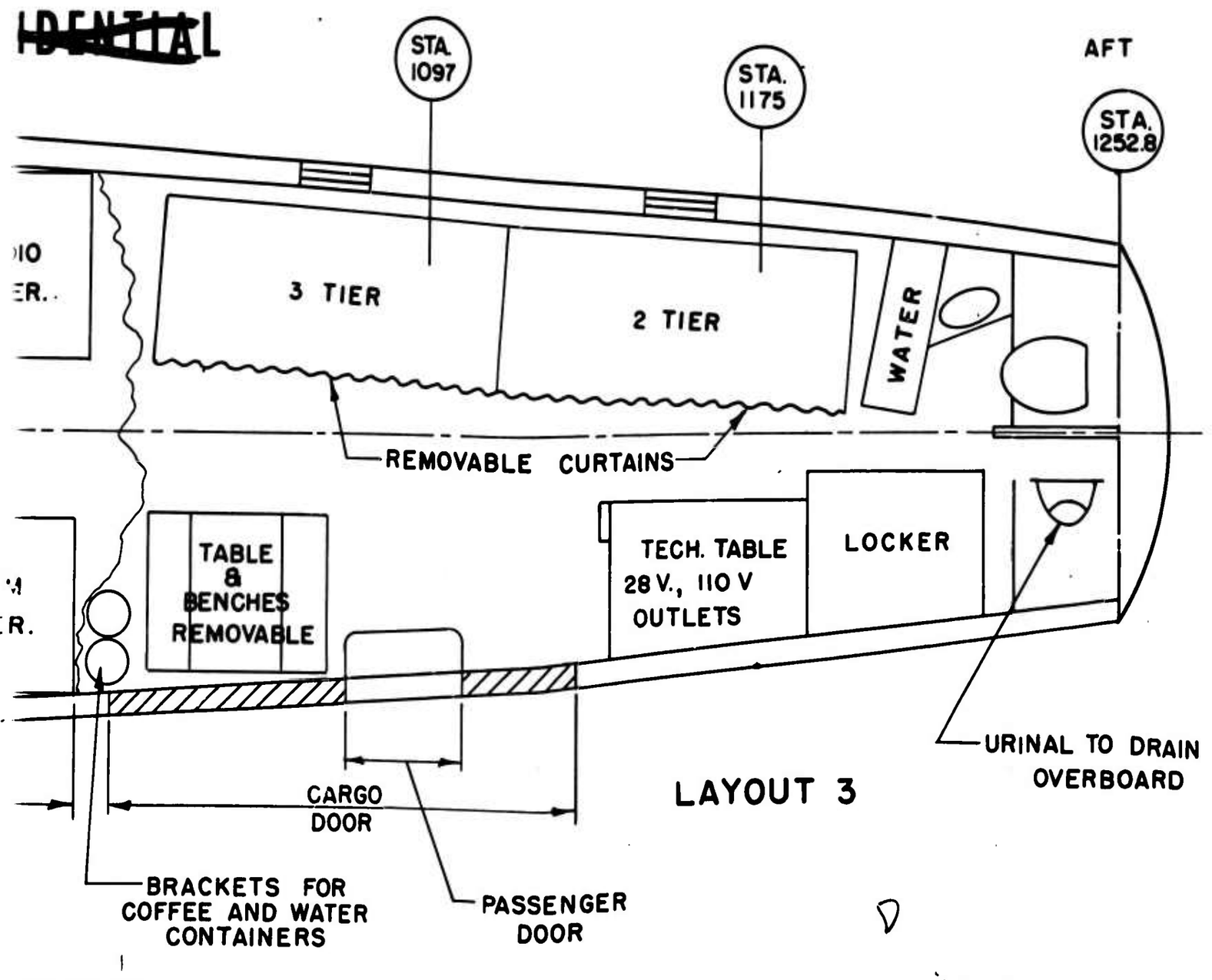
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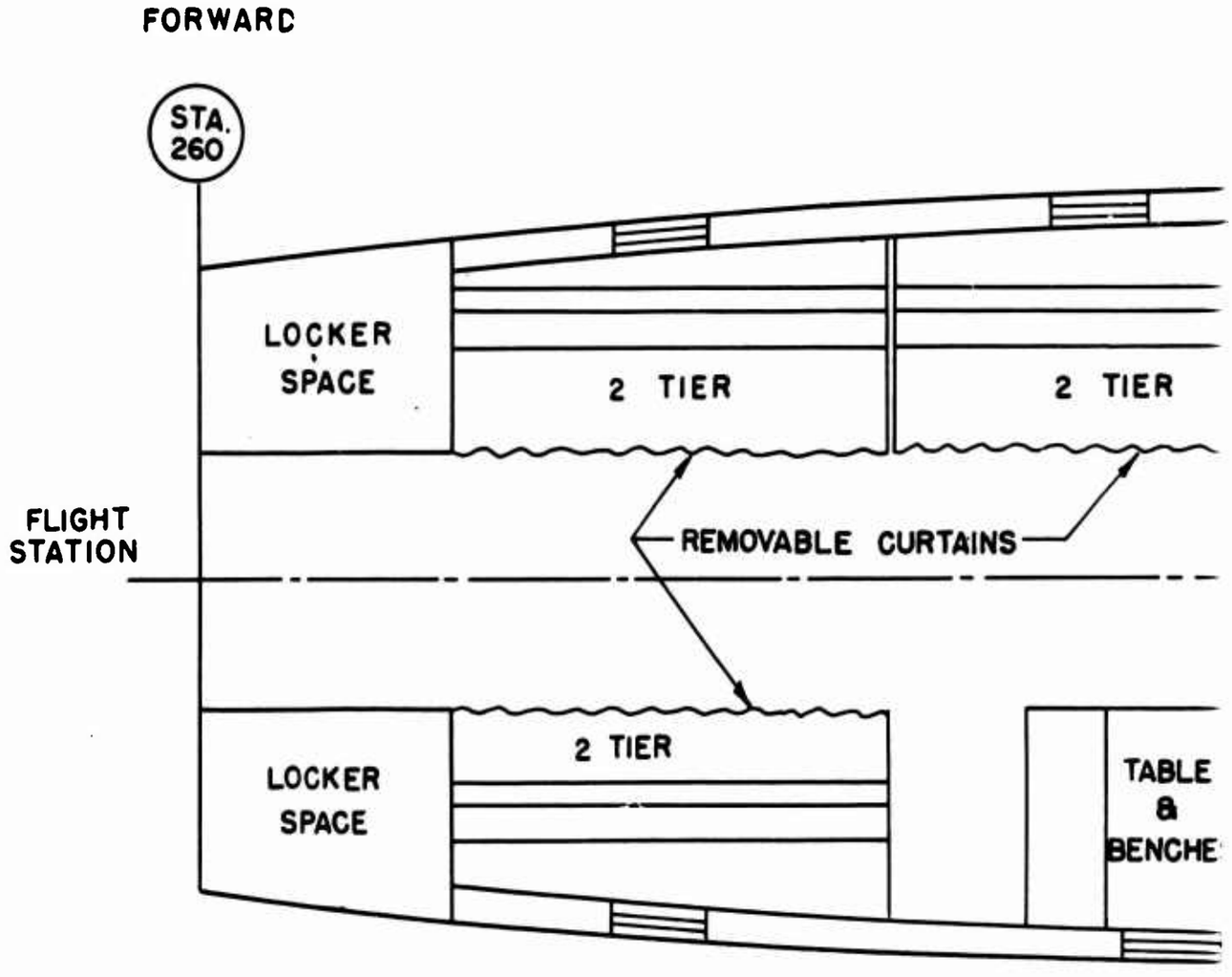
STA. 1175
AFT
STA. 1252.8
3 TIER
2 TIER
WATER
REMOVABLE CURTAINS
TABLE & BENCHES REMOVABLE
TECH. TABLE 28 V., 110 V OUTLETS
LOCKER
URINAL TO DRAIN OVERBOARD
CARGO DOOR
PASSENGER DOOR
BRACKETS FOR COFFEE AND WATER CONTAINERS
LAYOUT 3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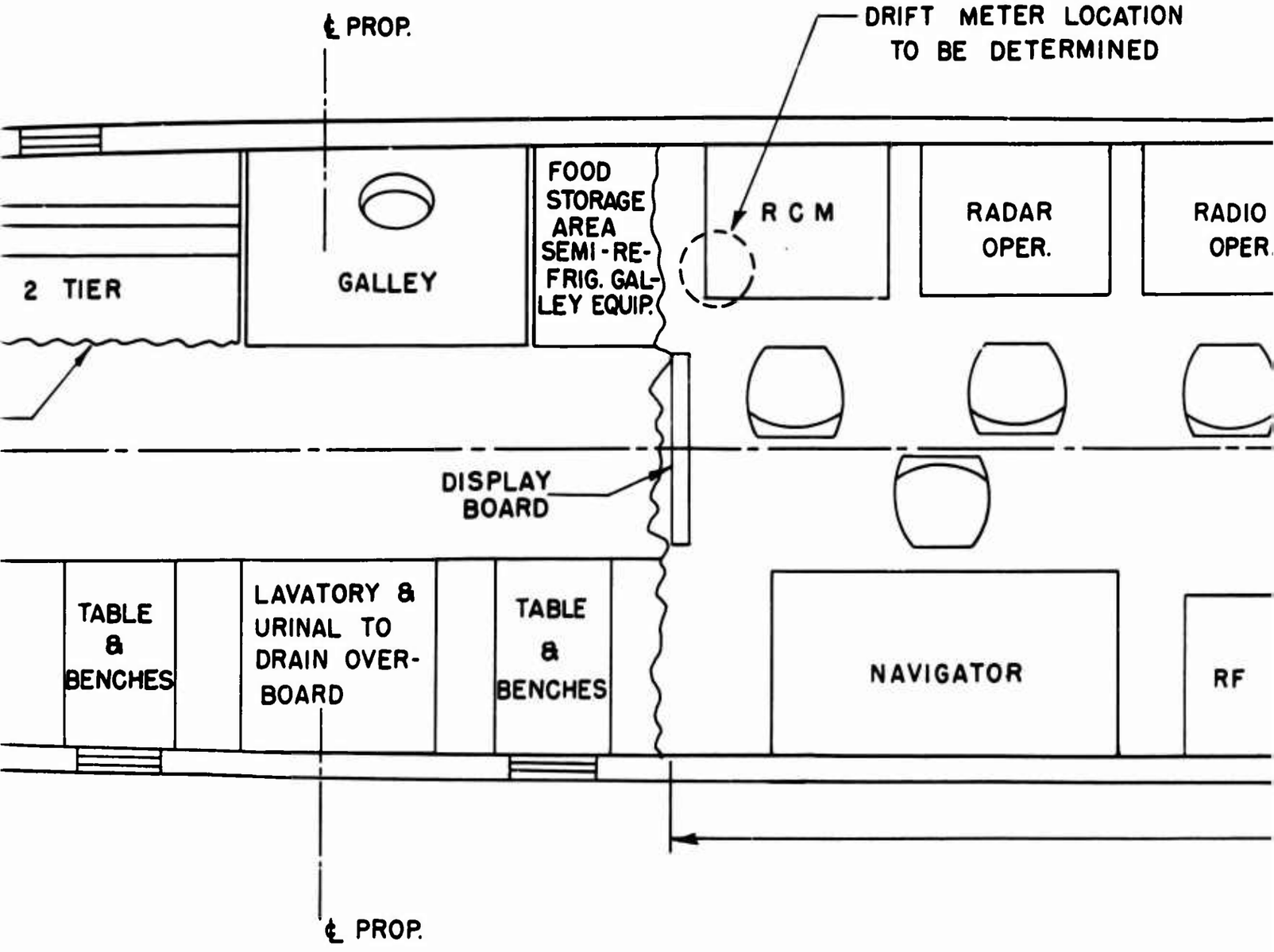
FLIGHT STATION
REMOVABLE CURTAINS
LOCKER SPACE
2 TIER
TABLE & BENCHE

A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TO BE DETERMINED
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FOOD
STORAGE
AREA
SEMI-RE-
FRIG. GAL-
LEY EQUIP.
R C M
RADAR
OPER.
RADIO
OPER.
DISPLAY
BOARD
TABLE
&
BENCHES
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TABLE
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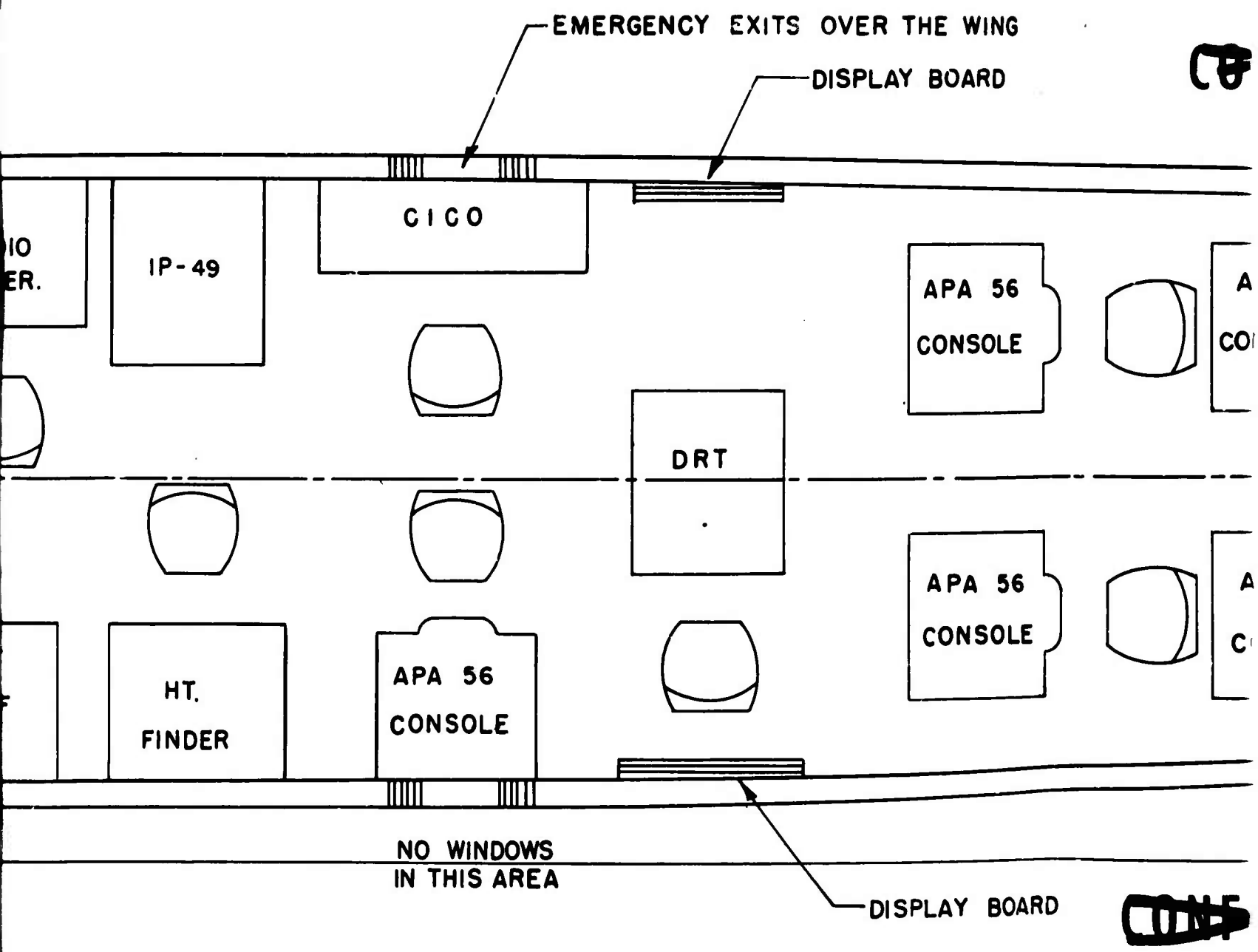
BENCHES
NAVIGATOR
RF
℄ PROP.

B.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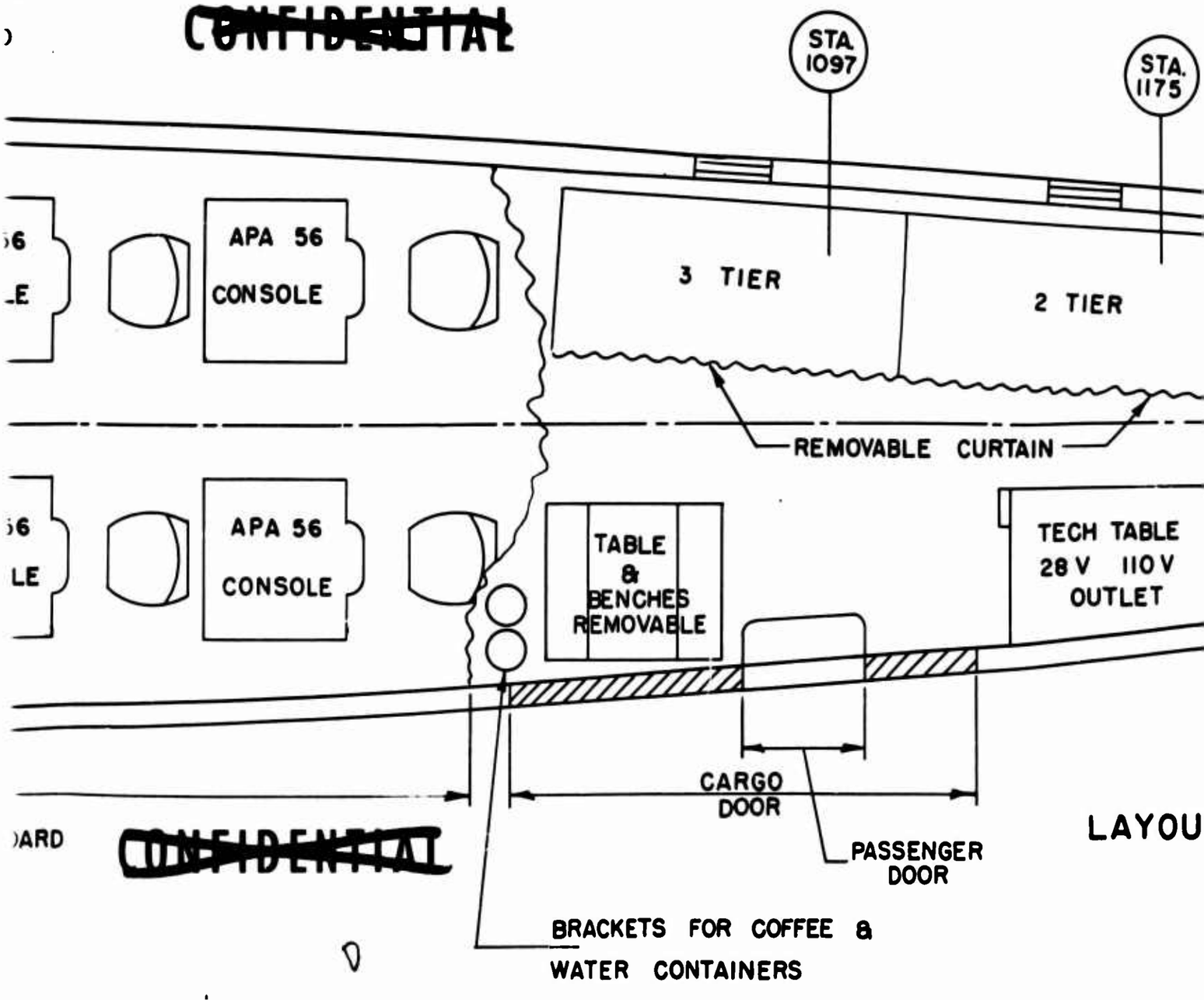
DISPLAY BOARD
IO
ER.
IP-49
CICO
APA 56
CONSOLE
DRT
APA 56
CONSOLE
HT.
FINDER
APA 56
CONSOLE
NO WINDOWS
IN THIS AREA
DISPLAY BOARD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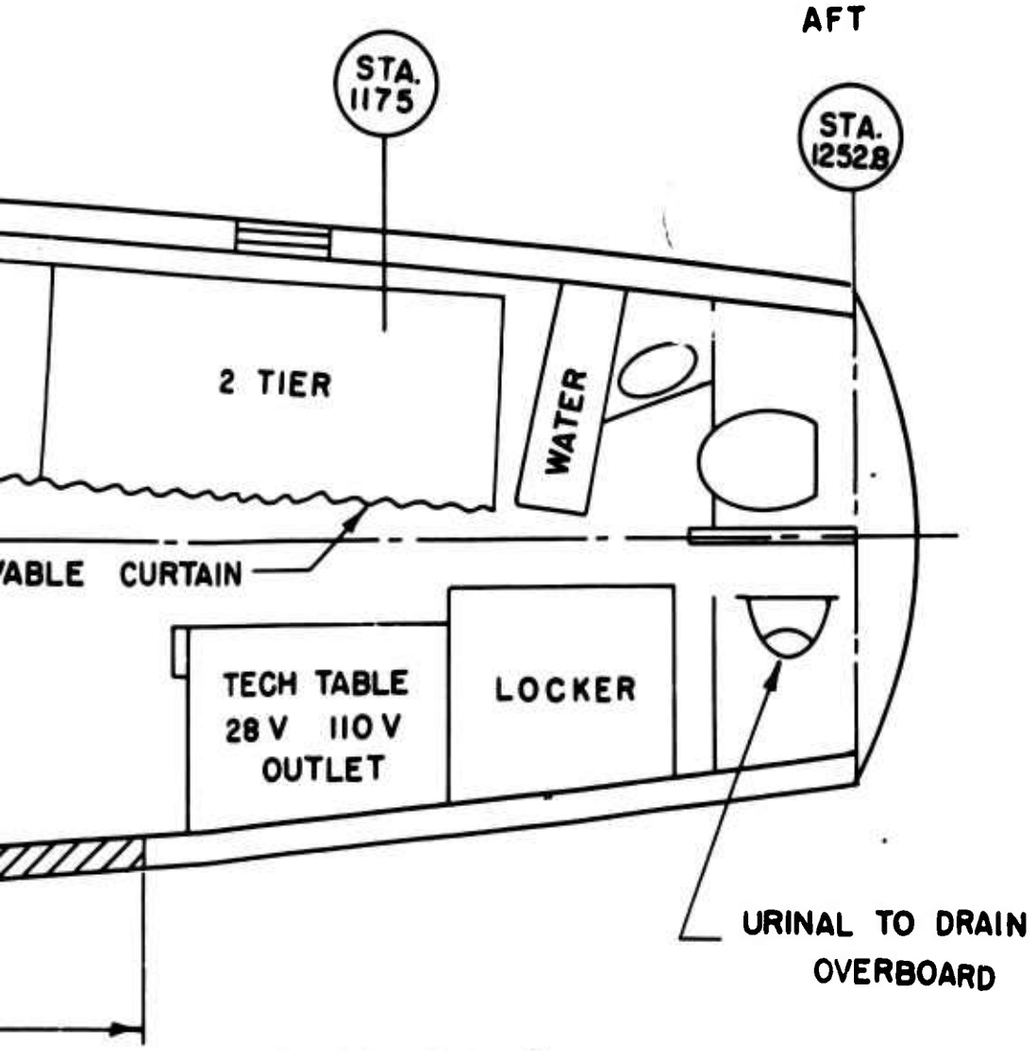
PASSENGER DOOR
BRACKETS FOR COFFEE & WATER CONTAINERS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WATER
VABLE CURTAIN
TECH TABLE
28 V 110 V
OUTLET
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URINAL TO DRAIN
OVERBOARD
ASSENGER
DOOR

LAYOUT 4

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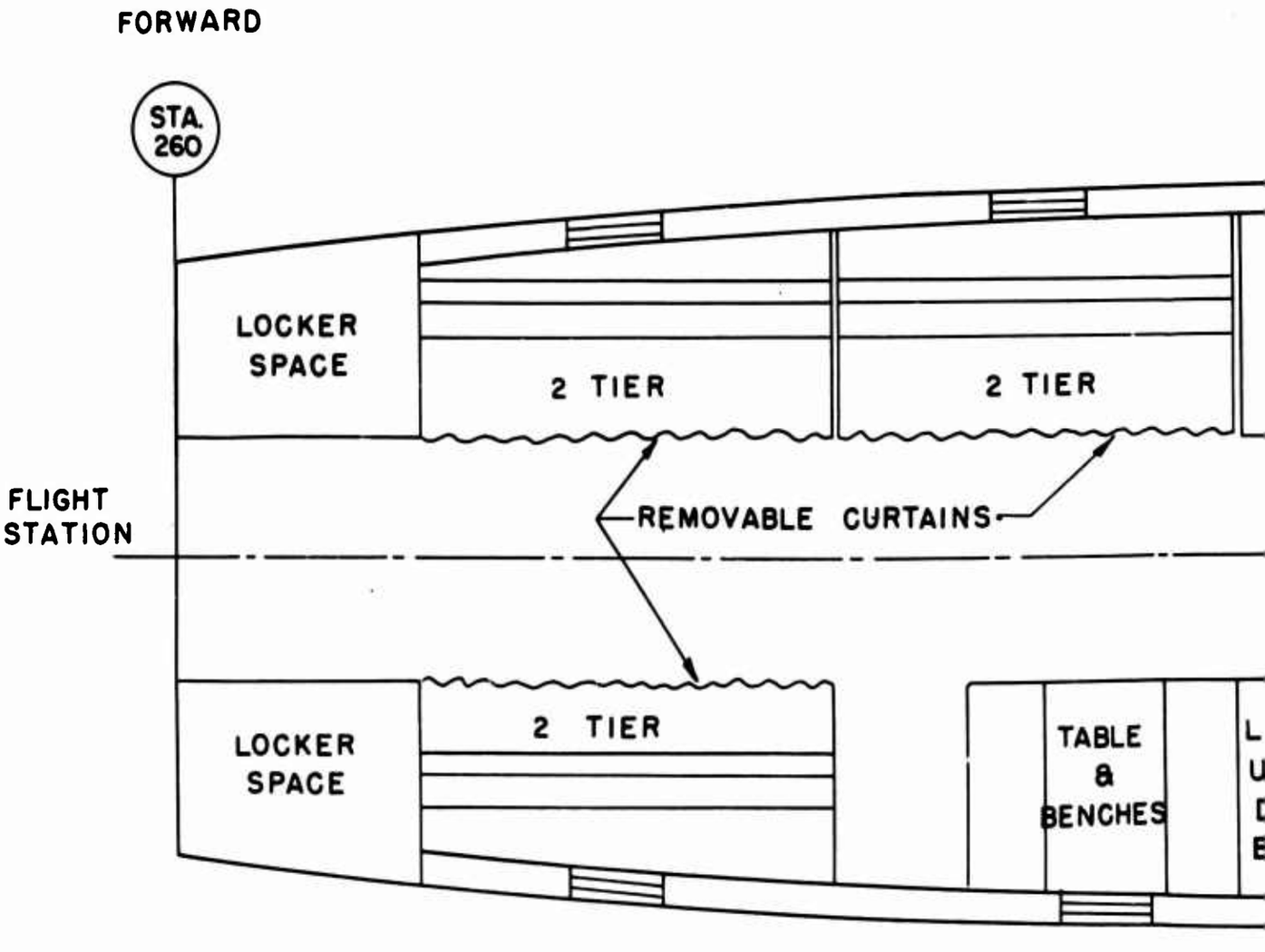
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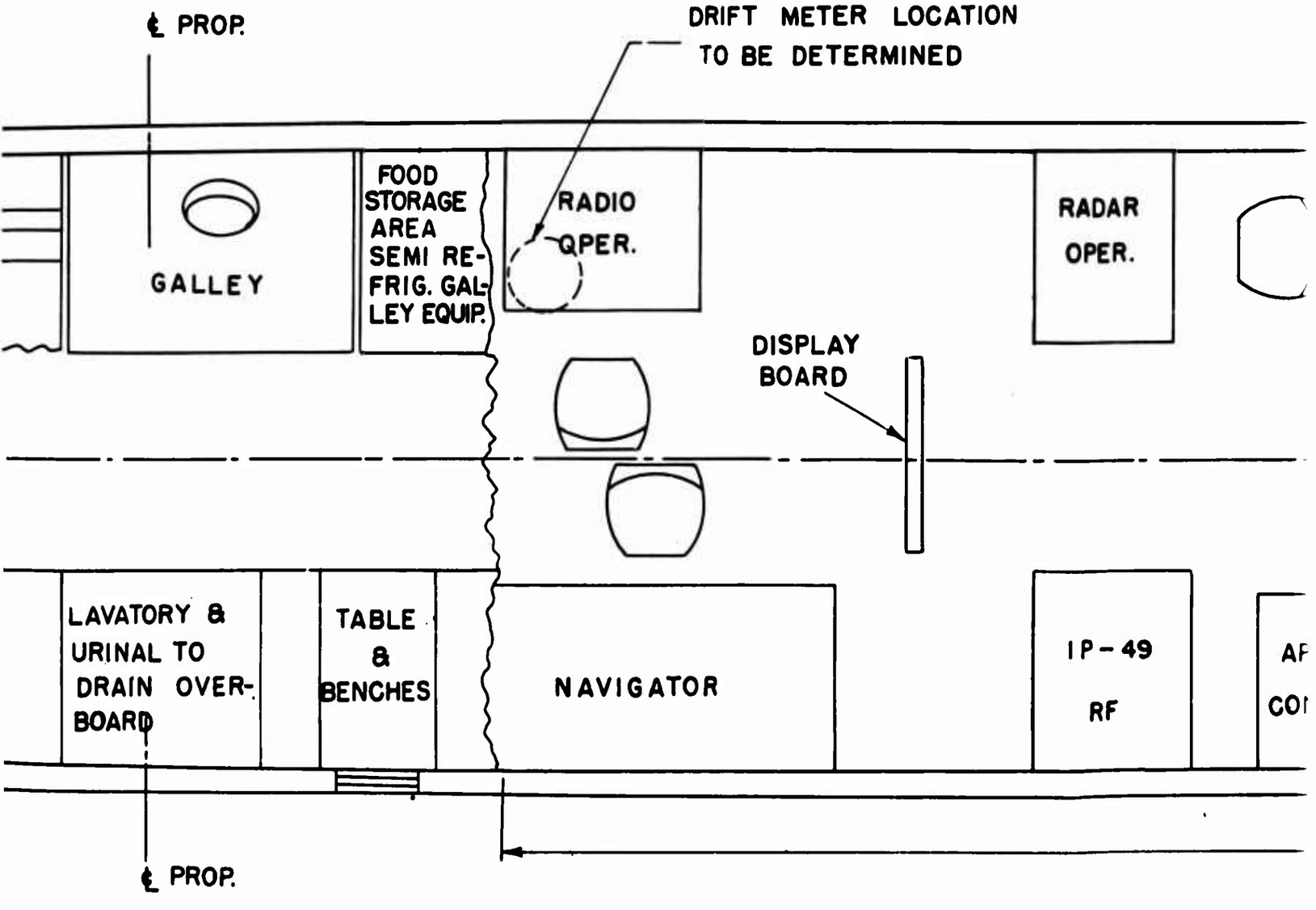
2 TIER
TABLE & BENCHES

A


℄ PROP.
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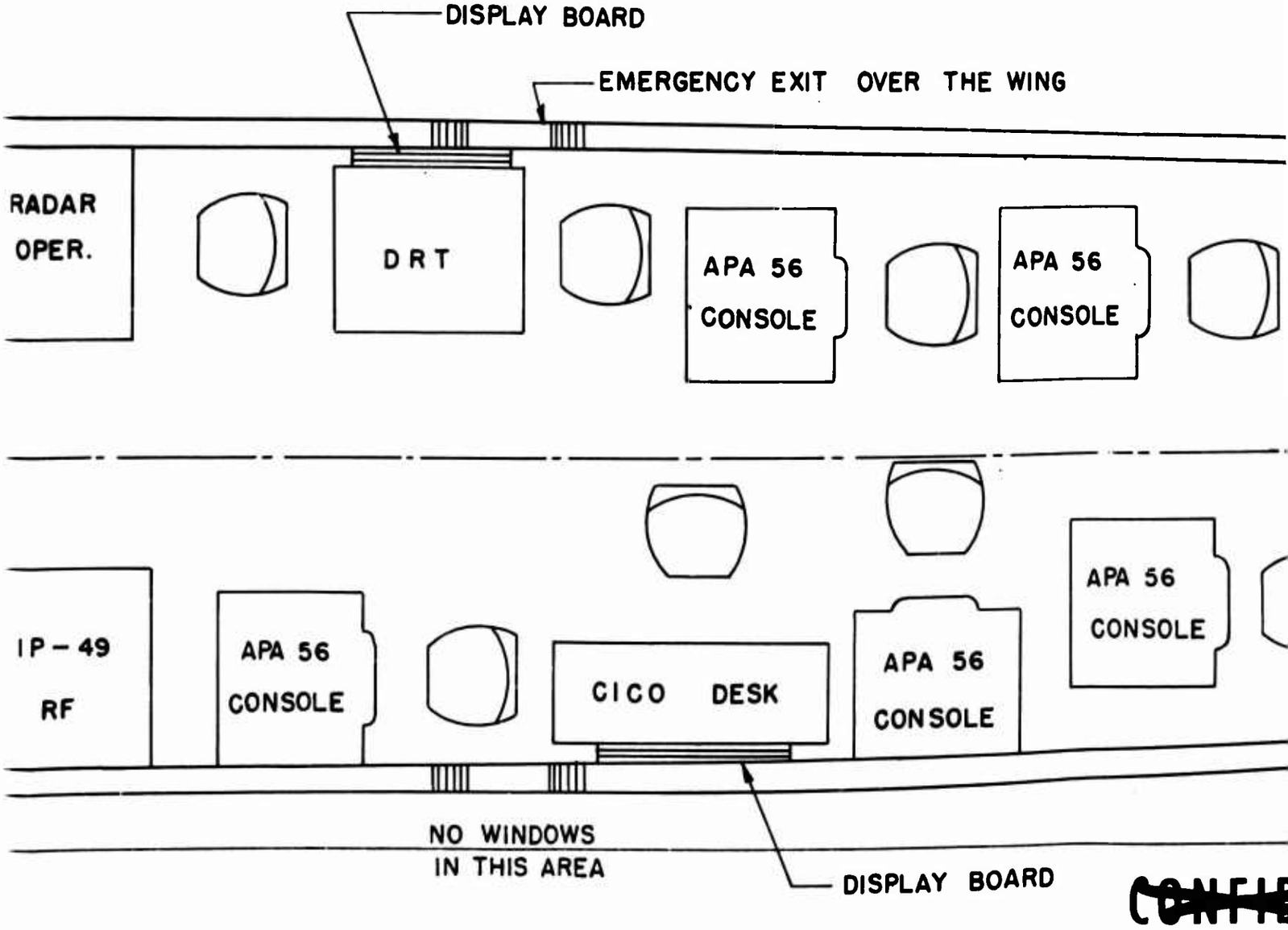
FOOD STORAGE AREA SEMI RE-FRIG. GAL-LEY EQUIP.
RADIO QPER.
RADAR OPER.
DISPLAY BOARD
LAVATORY & URINAL TO DRAIN OVER-BOARD
TABLE & BENCHES
NAVIGATOR
IP-49 RF
℄ PROP.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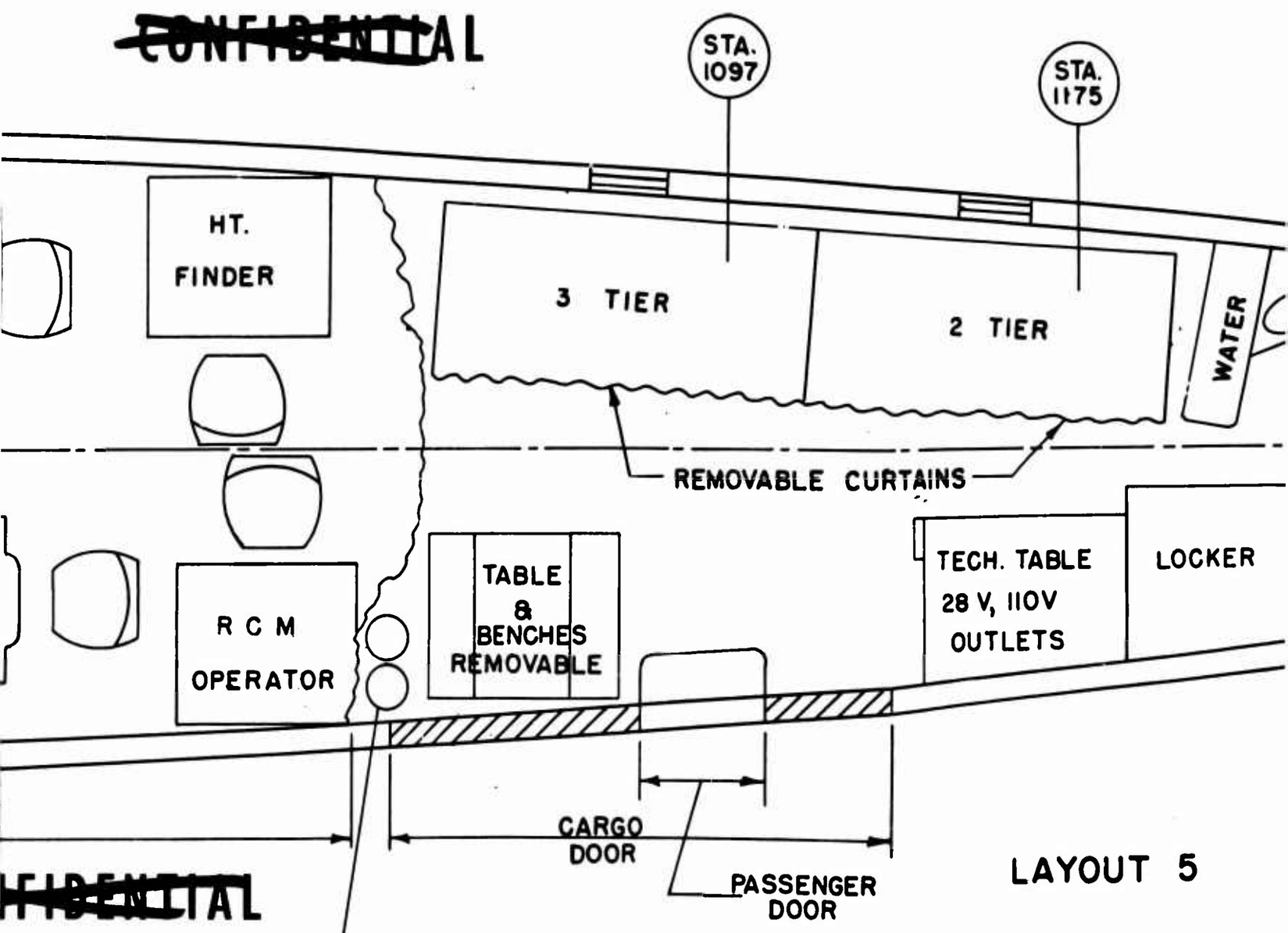
EMERGENCY EXIT OVER THE WING
RADAR OPER.
DRT
APA 56 CONSOLE
APA 56 CONSOLE
IP-49 RF
APA 56 CONSOLE
CICO DESK
APA 56 CONSOLE
APA 56 CONSOLE
NO WINDOWS IN THIS AREA
DISPLAY BOARD

CONFI

~~CONFIDENTIAL~~



LAYOUT 5

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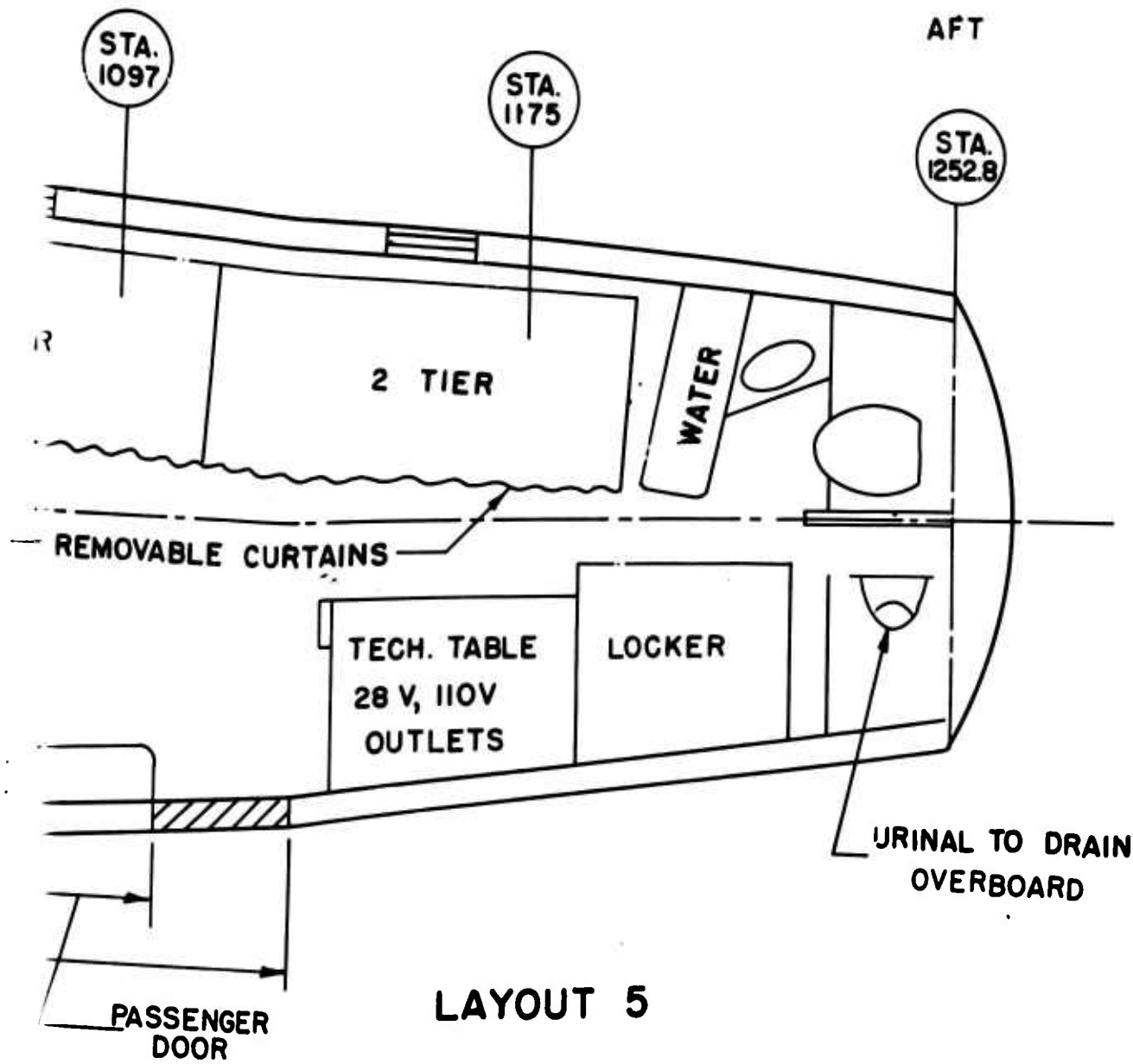
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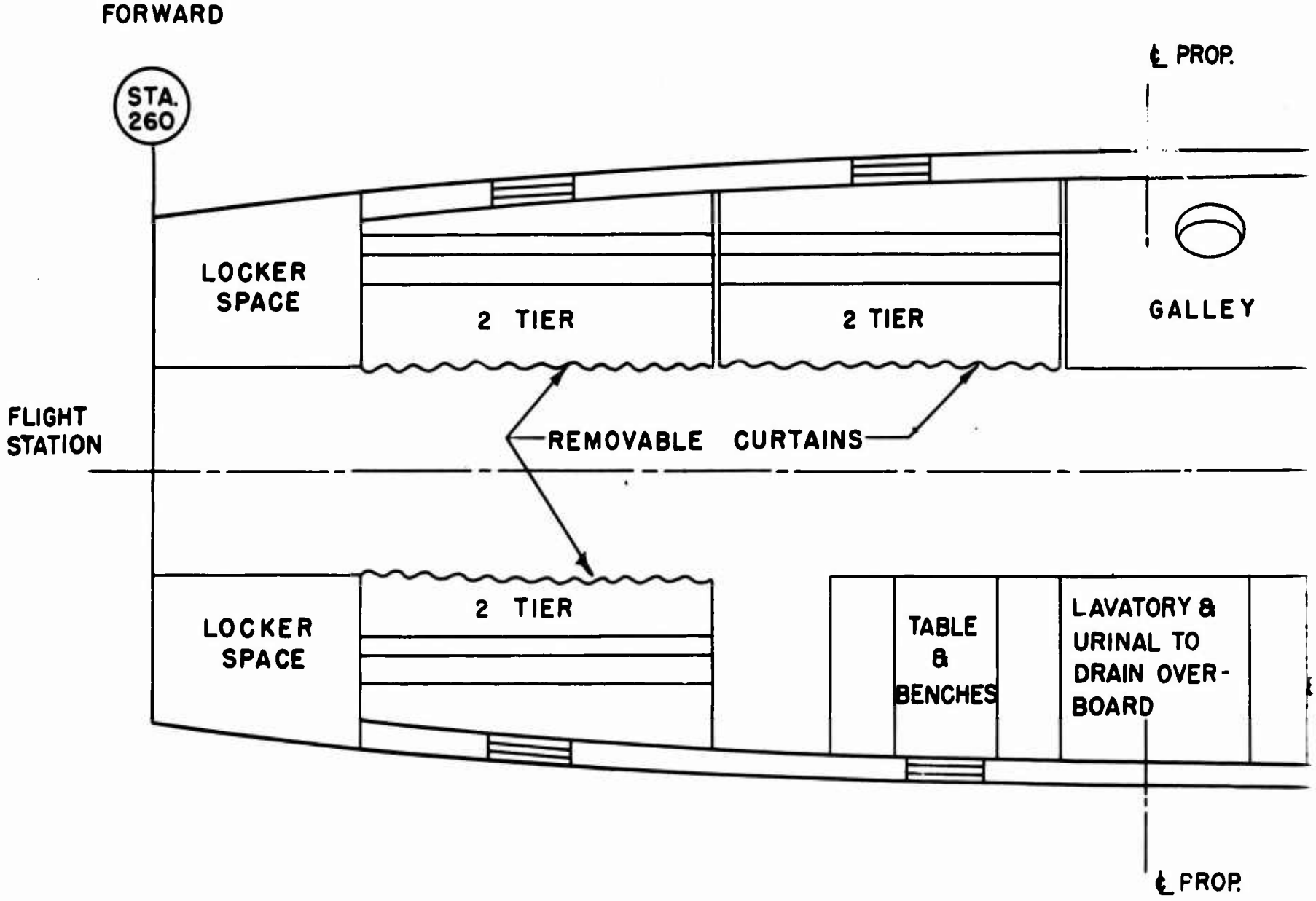
WATER
REMOVABLE CURTAINS
TECH. TABLE
28 V, 110V
OUTLETS
LOCKER
URINAL TO DRAIN OVERBOARD
PASSENGER DOOR

LAYOUT 5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LOCKER SPACE
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GALLEY
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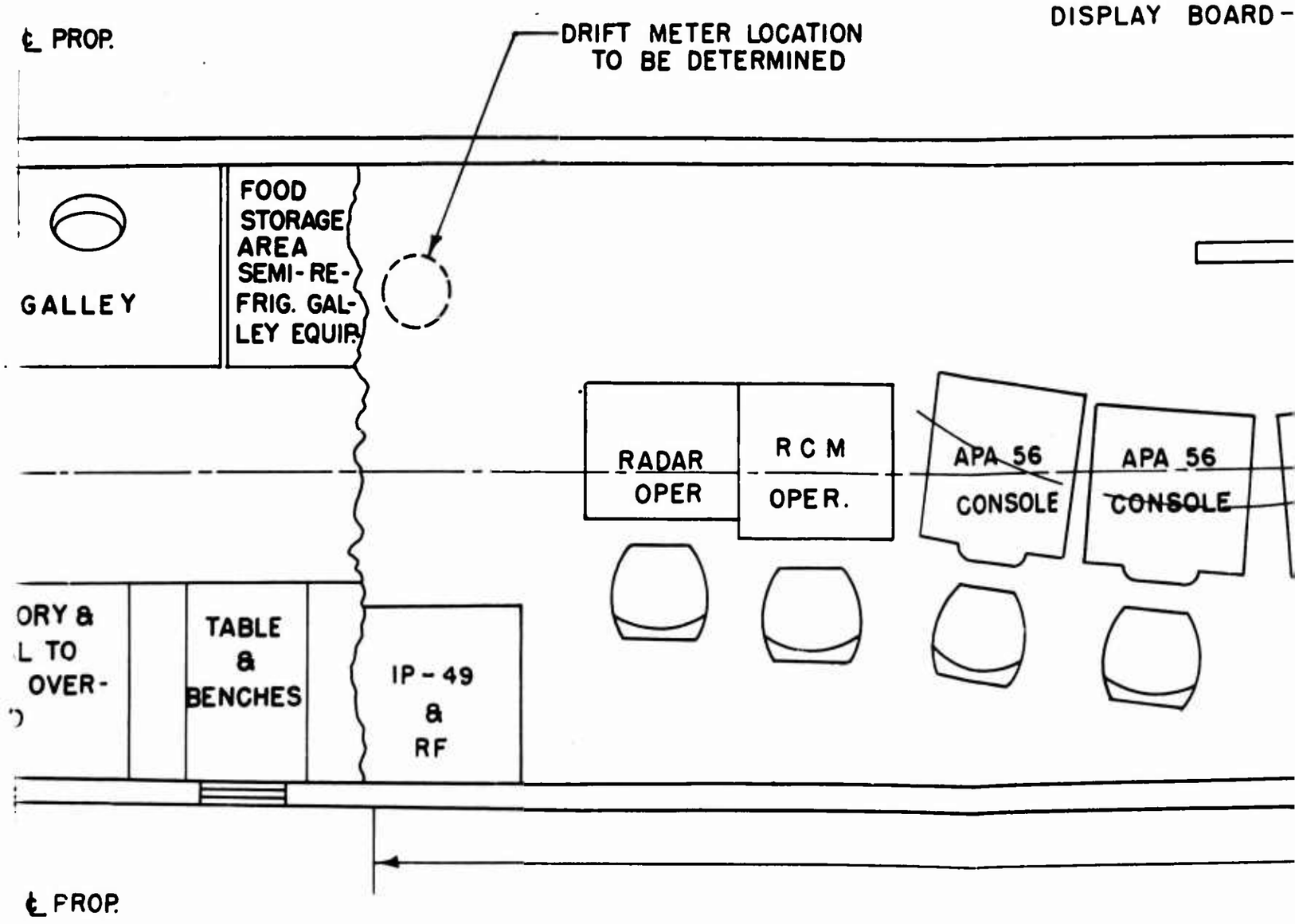
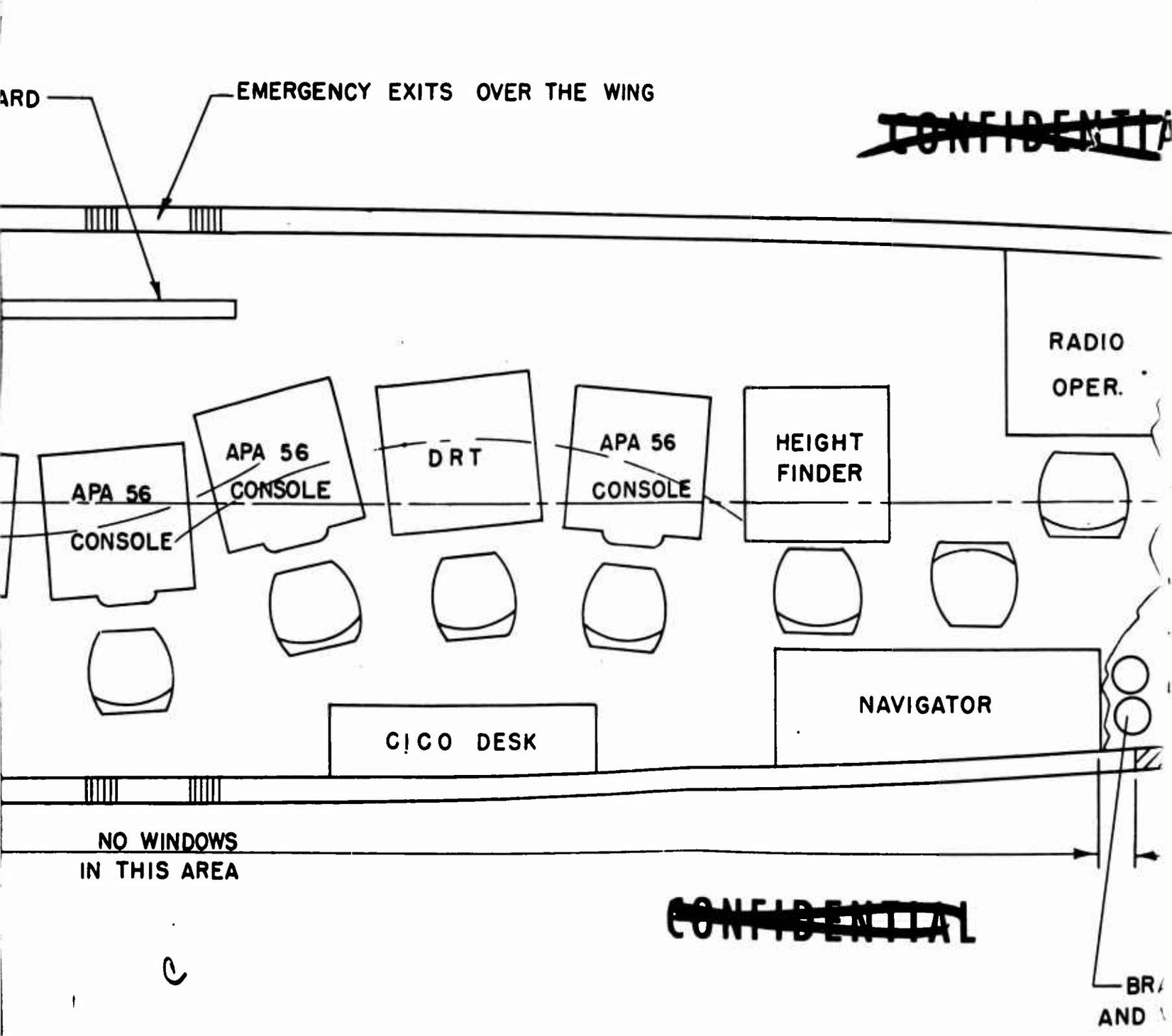
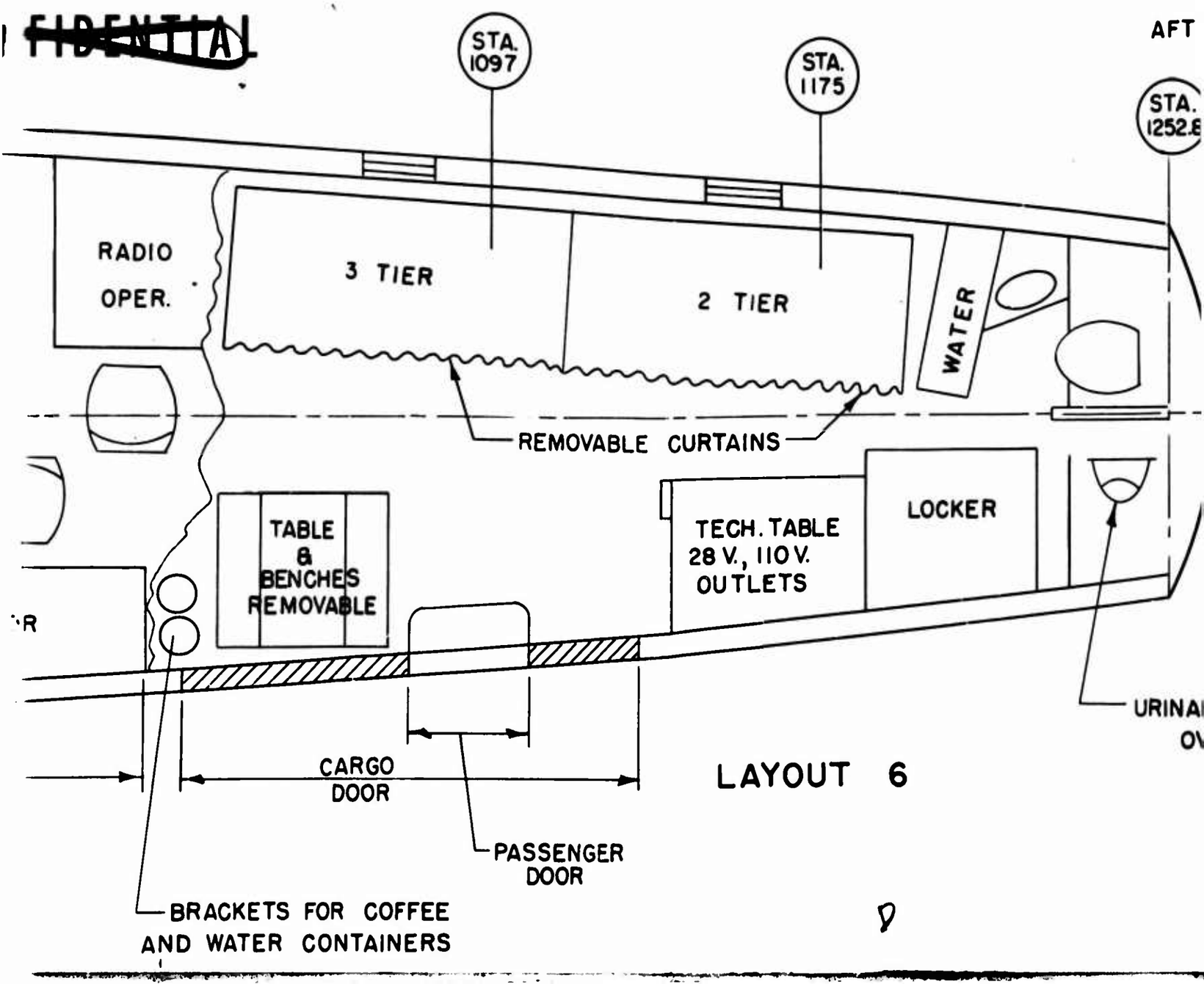
REMOVABLE CURTAINS
LOCKER SPACE
2 TIER
TABLE & BENCHES
LAVATORY & URINAL TO DRAIN OVER-BOARD
℄ PROP.

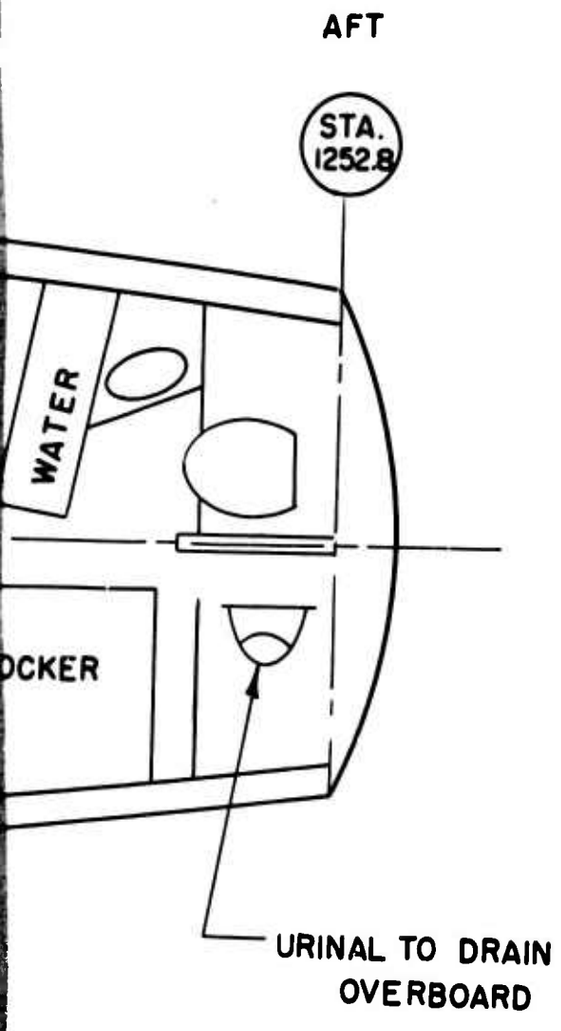
A


℄ PROP.
DRIFT METER LOCATION
TO BE DETERMINED
DISPLAY BOARD -
GALLEY
FOOD
STORAGE
AREA
SEMI-RE-
FRIG. GAL-
LEY EQUIP.
RADAR
OPER
R C M
OPER.
APA 56
CONSOLE
APA 56
CONSOLE
ORY &
L TO
OVER-
TABLE
&
BENCHES
IP-49
&
RF
℄ PROP.

B


ARD
EMERGENCY EXITS OVER THE WING
CONFIDENTIAL
RADIO
OPER.
APA 56
CONSOLE
APA 56
CONSOLE
DRT
APA 56
CONSOLE
HEIGHT
FINDER
NAVIGATOR
C!CO DESK
NO WINDOWS
IN THIS AREA
CONFIDENTIAL
BR
AND


STA. 1097
STA. 1175
AFT
RADIO OPER.
3 TIER
2 TIER
WATER
REMOVABLE CURTAINS
TABLE & BENCHES REMOVABLE
TECH. TABLE 28 V., 110 V. OUTLETS
LOCKER
CARGO DOOR
PASSENGER DOOR
BRACKETS FOR COFFEE AND WATER CONTAINERS
LAYOUT 6



E