DESIGN PARAMETERS FOR A LIGHTWEIGHT HANDHELD RADAR SYSTEM – AN/PPS-6( )

U. S. ARMY SIGNAL RESEARCH AND DEVELOPMENT LABORATORY
FORT MONMOUTH, NEW JERSEY
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FINAL REPORT ON TASK ORDER .18F

DUNLAP AND ASSOCIATES, INC.
STAMFORD, CONNECTICUT

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FOR A
LIGHTWEIGHT HANDHELD RADAR SYSTEM

AN/PPS-6 ( )

Prepared for

U. S. Army Signal Research and Development Laboratory
Fort Monmouth, New Jersey

Contract No. DA-36-039 SC-78921
D/A Task No. 3A95 20 001 01
Final Report on Task .18F

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January 1962

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CONFERENCES

1. DATE: 30 June 1961

   PLACE: Fort Monmouth, New Jersey

   ORGANIZATIONS REPRESENTED: USASRDL and Dunlap and Associates, Inc.

   PURPOSE: To discuss plans for the human factors study of a lightweight handheld radar.

   SUMMARY: Since the operational use of an equipment will influence its design requirements, it was decided that the Infantry should be contacted regarding the use of this radar. Plans were made for the investigation of human factors problems associated with the design of this set.

2. DATE: 8 August 1961

   PLACE: Fort Monmouth, New Jersey

   ORGANIZATIONS REPRESENTED: USASRDL and Dunlap and Associates, Inc.

   PURPOSE: To review the mission of a lightweight handheld radar, to present data on steadiness, and to discuss some preliminary design concepts.

   SUMMARY: Interest in this set had been evidenced by Special Warfare Center. Correspondence between the mission as developed by Dunlap and Associates, Inc., and the QMR issued by Special Warfare was noted. USASRDL had been requested to manufacture a number of copies of the prototype of this set. Dunlap and Associates, Inc., was requested to provide quick-reaction design assistance for this effort.

3. DATE: 23 August 1961

PLACE: Fort Monmouth, New Jersey

ORGANIZATIONS REPRESENTED: USASRDL and Dunlap and Associates, Inc.

PURPOSE: To present and discuss preliminary design recommendations as well as additional steadiness data.

SUMMARY: Steadiness data presented indicated that a neck-suspended design would be preferable to a handheld one. Three versions of such a design were presented and agreement was reached upon the most preferable and most feasible of these. Plans to incorporate this design into the prototypical copies being made were indicated.

4. DATE: 17 October 1961

PLACE: Fort Monmouth, New Jersey

ORGANIZATIONS REPRESENTED: USASRDL and Dunlap and Associates, Inc.

PURPOSE: To review the preliminary design prepared by USASRDL mechanical engineering personnel.

SUMMARY: Plans indicated a proposed weight of 10 pounds including batteries, A-scope and tripod. The design being presented was compared with Dunlap and Associates, Inc., preliminary recommendations and similarities and differences were discussed. A further conference was anticipated.

5. DATE: 31 October 1961

PLACE: Fort Monmouth, New Jersey

ORGANIZATIONS REPRESENTED: USASRDL and Dunlap and Associates, Inc.

PURPOSE: To review and confer upon design of the radar set.

SUMMARY: The design of the set being planned at that time was reviewed and agreement on future plans was reached. Future panel designs are to be reviewed by Dunlap and Associates, Inc.

ABSTRACT

A developmental, lightweight, handheld radar set, AN/PPS-6 ( ), is described; the projected mission of the system is summarized; and relevant human capabilities are reviewed. Based upon these factors, an allocation of function between the operator and his equipment is presented. The original prototype model of the equipment is reviewed from the human factors viewpoint, and an alternative design concept presented. Details of the system mission analysis are presented in Appendix A, and a report of three laboratory studies of aiming steadiness is given in Appendix B.

PURPOSE

The purpose of the work being reported was the development of design recommendations for a lightweight, handheld radar based upon operational requirements for such a system and human capabilities relevant to its operation.

DESIGN PARAMETERS
FOR A LIGHTWEIGHT HANDHELD RADAR SYSTEM

I. Introduction

A lightweight, handheld radar system AN/PPS-6( ), hereafter referred to as ALHR, under development at the United States Army Signal Research and Development Laboratory, is in concept an extremely lightweight, ground-to-ground surveillance unit employing doppler-based, auditory moving target representation and range video presentation. The present report summarizes design recommendations for a preliminary model of this equipment based upon a system and mission analysis, consideration of human abilities and limitations, and restrictions imposed by current electronic state-of-the-art and limited development time.

It seems necessary in these introductory paragraphs to describe briefly the history or chronology of the task being reported upon. Such a chronology will indicate a change of focus which occurred part way through the task and will show logical development of the work. This chronology is shown schematically in Figure 1.

Initially, the Contractor was requested to provide assistance in development of design parameters for ALHR system, to evaluate the current design concepts, both verbalized and as embodied in the Prototype Model, and to propose a configuration which would meet the operational needs of the Army for such a system.

While work was being done on these tasks, an increased interest in ALHR was revealed by operational units, and USASRDL was requested to provide quickly a number of operational sets for demonstration and evaluation. The Contractor in turn was requested to reorient his efforts to this end and to suspend his work on ultimate design of the system.

This report is a documentary follow-up to the quick-reaction design assistance rendered. The substance of the material contained has already been presented in briefing form to cognizant project personnel at USASRDL. Also included in this report is a summary of the work to date on ultimate design parameters for the system.

The primary mode of attack on the original problem of establishing design parameters for ALHR was based upon the concept of a man-machine system, the requirements for which could be stated without having already established

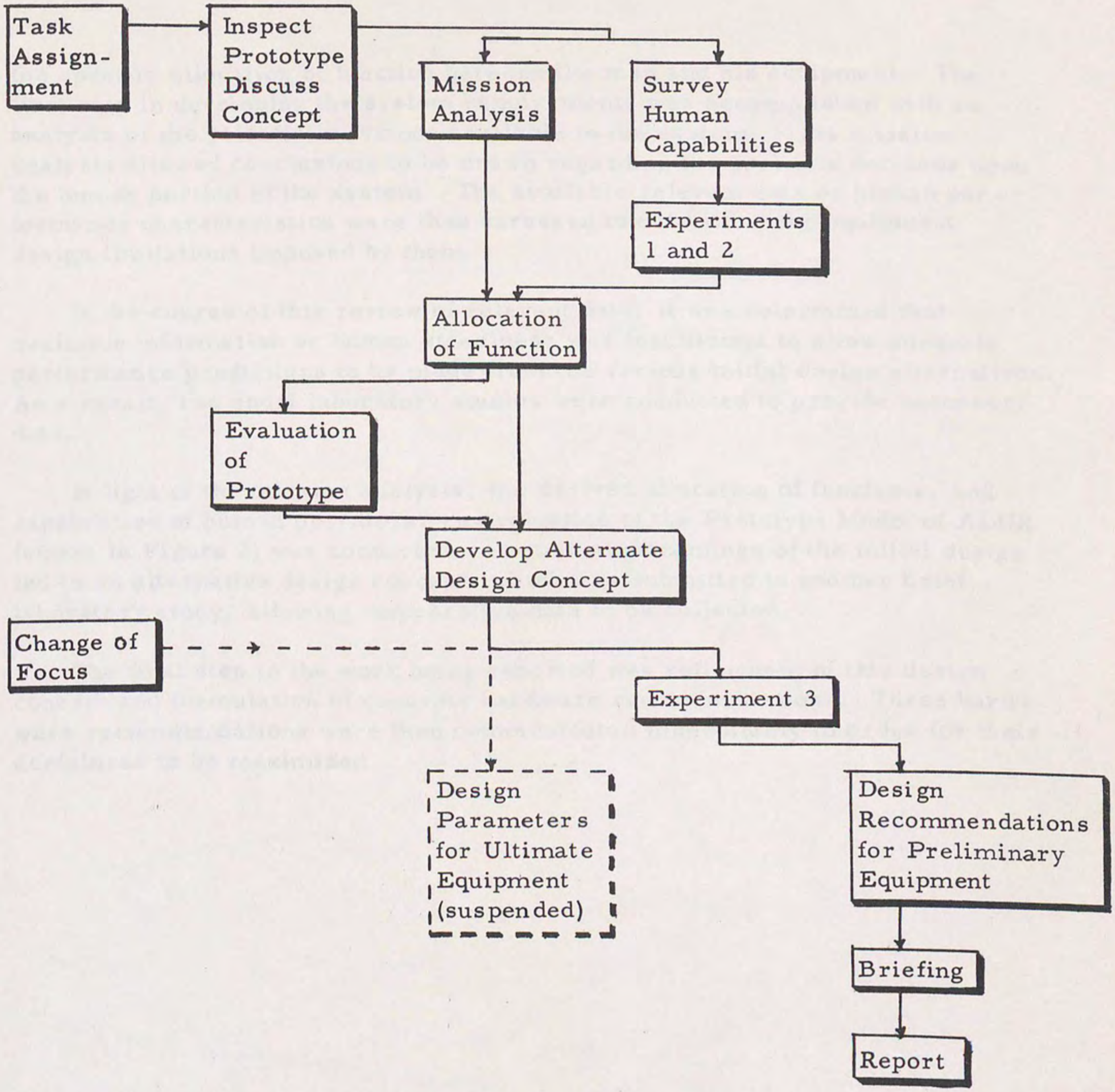


Figure 1. Schematic of Task Organization

the specific allocation of function between the man and his equipment. The first step in developing the system requirements was accomplished with an analysis of the potential missions available to the system. This mission analysis allowed conclusions to be drawn regarding the probable demands upon the human portion of the system. The available relevant data on human performance characteristics were then surveyed to determine the equipment design limitations imposed by them.

In the course of this review of relevant data, it was determined that available information on human steadiness was insufficient to allow adequate performance predictions to be made from the various initial design alternatives. As a result, two short laboratory studies were conducted to provide necessary data.

In light of the mission analysis, the derived allocation of functions, and capabilities of human operators, an evaluation of the Prototype Model of ALHR (shown in Figure 2) was conducted. Certain shortcomings of the initial design led to an alternative design concept, which was submitted to another brief laboratory study, allowing comparative data to be collected.

The final step in the work being reported was refinement of this design concept and formulation of concrete hardware recommendations. These hardware recommendations were then communicated immediately in order for their usefulness to be maximized.

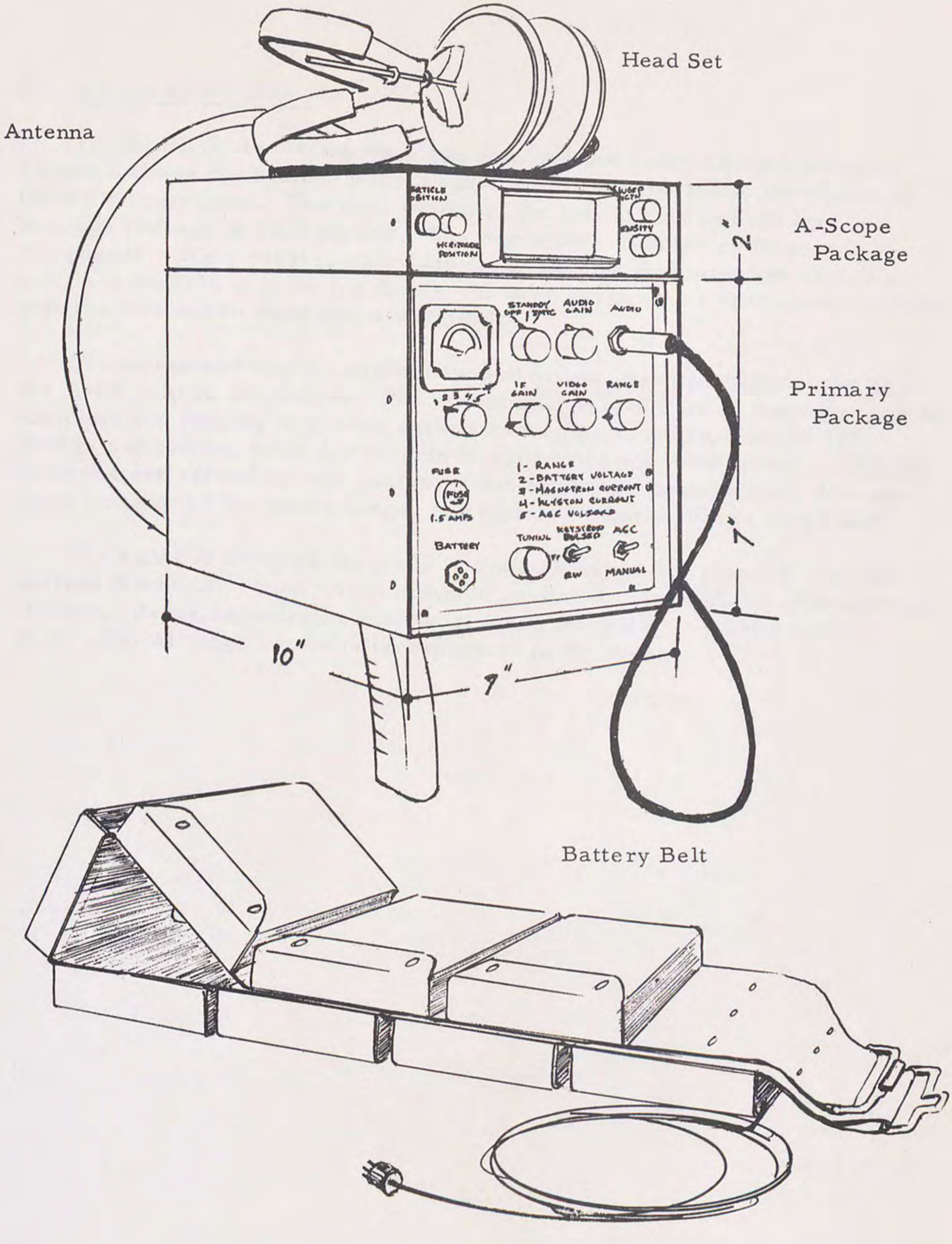


Figure 2. Representation of Prototype Model of ALHR

II. System Description

The ALHR System comprises one man and the radar equipment itself. Figure 2 shows the basic configuration of the Prototype Model developed by USASRDL personnel. The total weight of the set, including batteries and A-scope package is 15.3 pounds. The removable A-scope package weighs 2.3 pounds. Eight rechargeable batteries, carried in a modified cartridge belt, are capable of powering the set for over seven hours continuous operation with the A-scope or eight hours without it.

The equipment may be tripod-mounted or may be hand-held by means of the pistol grip on the bottom. The operational capabilities of the radar include detection and ranging of moving personnel targets to approximately 1000 meters and moving vehicular targets to approximately 2000 meters. Display functions are served by audio output of moving target information, A-scope video tracing for the entire range, and metered location of the range gate.

The radar is adjusted manually in azimuth by simply pointing it in the desired direction. When tripod mounted, azimuth rings indicate the direction of sight. Range adjustments may be attained manually or automatically, since optional range strobe is incorporated in the design.

III. Results of Mission Analysis

The primary mission of the ALHR System is short range, ground surveillance. In accomplishing this mission, it is apparent that the system must be as mobile as an infantryman, highly reliable and require a minimum of logistic support.

The over-all mission for which ALHR may be utilized will include two general situations. The first is the defensive situation where the set will be placed on some type of mount, will remain stationary for significant periods of time, and, with the aid of mil rings or other such device, will be used to derive reasonably accurate target location data for both fire direction and intelligence. In the second general situation, the set will be operated while supported by the operator himself. These activities are primarily concerned with offensive, patrol and guerrilla-type actions where troops will be on the move by foot. Under these conditions, time will not permit the operator to remove the set from its carrying position, mount it on a tripod and orient it against known terrain features. In addition, this procedure will probably not be necessary since precise azimuth determination would not be required. Hence, the set would basically be used for simple observation and gross location of either enemy or friendly elements. During these types of operations, once the enemy is detected and located, he may be either avoided or attacked depending upon the particular nature of the situation or mission. The enemy might merely be observed and his activities, along with his gross location, reported for use by intelligence. In regard to friendly elements, the equipment may be used for "joining up" or directing movement to some predetermined point.

A detailed analysis of the system mission (presented in Appendix A) and of probable combat environments provides bases for the establishment of certain design criteria, which are presented below in outline form. Some of these points will be dealt with in more detail in subsequent sections of this report.

1. System characteristics

    a. Capable of a high degree of mobility

    b. Capable of fixed installation

    c. Capable of effective surveillance in a very short time

    d. Capable of continuous surveillance

e. Capable of searching large areas quickly

f. Capable of reliable performance under extreme environmental conditions

g. Capable of being secured against light and noise while operating

2. Subsystem characteristics

a. Equipment characteristics

(1) General configuration

(a) Requires a detachable mount (e.g., tripod)

(b) Capable of operation while handheld by one man

(c) Easy to handle by one man walking, running, crawling, climbing, rolling over, etc.

(d) Capable of being transported without use of hands when not operating

(e) Transport position of equipment must not hamper effective maneuvering of operator

(f) Must not interfere unduly with carrying and use of operator's personal weapon

(2) Controls and Displays

(a) Must display adequate information for effective search, detection and identification

(b) Should be minimum number allowing effective operation

(c) Capable of being operated with gloved hand

(d) Capable of displaying entire range (as with A-scope)

(3) Maintainability

(a) Capable of withstanding normal field use

(b) Designed for ease of maintenance and repair

b. Personnel characteristics

(1) Trained in target identification

(2) Trained in target location (range and azimuth)

(3) Selected for normal hearing

(4) Trained in field maintenance of equipment

The above system and subsystem characteristics form one of the bases of design recommendations presented in a subsequent section of this report.

IV. Human Capabilities

Since the man is a substantial portion of the ALHR system, it is important to assure that the equipment compliments his capabilities. Care must be taken to prevent excessive demands being made upon the human. The design concept of ALHR includes man as both the transportation and the operator of the set. Therefore, the design must be such that he can, in fact, transport and operate it effectively. It appears that a number of human attributes are under question here. Can a man carry 15 or 16 pounds all day without difficulty? Can a man hold such a weight steady in one hand in order to operate it? Can a man determine the azimuth at which he has such a device pointed?

A review of data relevant to these questions showed that, given appropriate handles or straps, a man can carry a weight as great as that of the Prototype Model without much difficulty. The evidence on azimuth determination suggests that some aid, such as azimuth rings, or at least one or two known reference points are necessary for the degree of precision necessary in such activities as target spotting. However, it should be remembered that this degree of precision is necessary in only a small portion of the probable mission assignments of ALHR. On the question of steadiness in the handheld mode, little, if any, information was available.

To compensate for this lack of data, a small laboratory study was conducted. The details of this study (Experiment 1) are presented in Appendix B. Mockup Model A (Figure B-1) used in this study was a representation of the Prototype Model weighing five pounds. (Five pounds is an estimate of the minimum attainable weight for this equipment with full use of solid state electronics.)

Since it was not possible to hold this mockup steady with arm extended for more than a minute or two, it is readily apparent that such an operating technique with the much greater weight of the Prototype Model is not feasible.

A second study (Experiment 2 described in Appendix B) was conducted with the same mockup still held in one hand, but with the arm bent and with the elbow resting against the side. In this position, the mockup could be held steady for over eight minutes (certainly as long as one would be likely to try to hold the radar steady in operation); however, the subjects were near the limits of their endurance at that time, and a greater weight could not have been held nearly as long.

A clear implication of these studies was that the pistol grip on the bottom of the Prototype Model was not a satisfactory mode of support.

The additional design factors (e.g., control-display compatibility, design of controls, arrangement of controls and displays, etc.) which influence system effectiveness are the subject of many separate documents on Human Engineering (including chapters of the Joint Services Handbook, among others). Suffice it to say in connection with these several factors, that good Human Engineering practices have been considered and incorporated in the design recommendations presented in this report.

V. Allocation of Function

A number of differences are apparent between the talents of men and the capabilities of machines. It is these differences which make important the specific allocation of functions between men and machines in a system. Some functions are best served by machines. These include deductive reasoning, handling large quantities of data, responding quickly to control signals, performing routine or repetitive activities, and exerting large amounts of force smoothly and precisely.

Other functions can be most appropriately performed by men. Some of these are inductive reasoning, recognition of objects, signals, or patterns under adverse conditions of perception, sensing a wide variety of stimuli, and tracking under varying conditions.

Some functions can be handled equally by men or machines, in which case allocation decisions must be based upon size, weight, reliability, cost, loading, and so on. Still other functions require joint action by both man and machine.

The ALHR system is a relatively simple man-machine system in that it is composed of one man and one small piece of equipment. Even so, there are some functions which do not belong clearly to either the man or the machine, the allocation of which must be considered. An example is the extension and retraction of the range gate. When the assignment is to systematically search an area of significant size, the function is routine and repetitive and might well be assigned to the machine. When the assignment, on the other hand, is to track an already acquired target, the function may contain a wide range of conditions; the gate is to be moved conditionally upon loss of the target or in order to peak the target returns. In this case, the function should clearly be allocated to the man. The man could handle the search function as well, but if size, cost, and complexity allow, as they apparently do in the case of ALHR, then this function should be allocated to the machine. The automatic strobe feature must, of course, be optional since strobing is not desirable for tracking or static search (monitoring a single gate position).

An obvious example of a system function which requires joint action is the detection of a target. The machine portion of the system uses sensory modes not available to the man and is able to extend its sensing into darkness, fog or smoke. It then presents the obtained information, both signal and noise, to the operator for interpretation. Both portions of the system are vital to this function. The operator is not capable of the sensing required, but is better able to filter the signal from the noise and make interpretations.

In allocation of functions, the following questions must be answered: Is either portion of the system incapable of performing the function? Does one portion of the system perform the function more quickly or more accurately than the other? What is the relative cost (in time, weight, money, loading, etc.) of allocating this function to one portion of the system or to the other? When these questions have been answered, the utility of different allocations can be weighed and appropriate decisions made.

VI. Evaluation of the Prototype Model

The Prototype Model of ALHR was constructed primarily for experimental purposes at USASRDL. It was designed to demonstrate that the basic concept of a radar small enough for one man to carry and to hold during operation was feasible under current electronic state-of-the-art. This design was never intended for operational employment, but rather to serve as the first of a series of designs leading ultimately to operational equipment. The purpose of the following evaluation of the Prototype Model is to point out those features of the design which are, from a human factors viewpoint, either desirable or undesirable toward the end that future designs might be improved.

Many desirable characteristics are obvious in the Prototype Model. Most of these characteristics are related to the marked success its designers have shown in packing performance in a small box. The penalty paid for a video presentation is certainly nominal. 2.3 pounds and one hour decrease in battery life seem a small price to pay for the ability to view the entire range interval at one time as compared to sampling it aurally, one gate depth at a time.

Another outstandingly desirable feature is the option of strobing the range gate automatically. The strobe feature is of great value when the assignment is to search an area of significant size. It allocates to the equipment a routine function of systematically and uniformly advancing and retracting the range gate and, in the process, frees a certain portion of the operator's attention for the more difficult tasks of target detection and identification.

The observed shortcomings of the Prototype Model appear in two general areas: method of support and control-display configuration.

The original design concept includes two modes of operational support for ALHR. One is a small detachable tripod to be used in relatively static situations. The second is a pistol grip handle on the bottom of the case for use in more fluid situations. Use of this pistol grip handle is out of the question in view of the present weight of the equipment (13-15 pounds) and the probable weight of near-future models (10 pounds). Results of the studies cited earlier indicate that some alternative support mode for the fluid situation must be developed. One such mode (a neck strap on the order of that of a reflex camera) is described in Section VII of this report.

The second problem area lies in the number, type and arrangement of the operator's controls and displays. Since ALHR will probably be operated by personnel with little formal radar training, it is especially vital that operation of the set be as uncomplicated as possible without jeopardizing the capabilities inherent in the design concept. With this criterion in mind, it is evident that the control panel contains an excessive number of controls. Only primary controls and displays (those vital to mission accomplishment and/or used routinely by the operator) should be located within the optimum manual and visual areas. Maintenance and tune up controls should not be mixed with primary controls. In fact, unless the operator is trained to use them, they should not be easily accessible in the operating mode. Such controls might well be covered during operation to prevent their being moved out of adjustment.

It is suggested that three primary controls and one secondary control be given control panel space. These are:

1. A four-position selector switch for OFF, STANDBY, AUTOMATIC, and MANUAL.

2. A knurled knob for VOLUME.

3. A large knurled knob for RANGE.

4. A small pushbutton for BATTERY TEST (secondary control).

With proper separation, these controls would allow gloved operation and would offer minimum confusion to even the least experienced operator.

The A-scope and range meter are primary displays which must be located for convenient use. Assuming that the back of the set contains the control panel as in the Prototype Model, the present location of these displays is satisfactory. The design of the range meter itself makes it less than the optimum display. The thin pointer and increment marks, along with the rather short total scale length, make accurate reading and interpolation more difficult than necessary. A linear scaled meter mounted vertically or with its lowest value toward the operator would make a more easily read display. Such a meter should have a slightly larger pointer than that on the present meter, and low-level internal lighting should still be provided. A range meter of this type offers more scale per square inch of panel space than the one presently employed. Such a meter is shown in the design recommendations presented later in Section VIII of this report.

VII. An Alternate Design Concept

Inasmuch as mode of support was one of the most pressing problems observed in the Prototype Model of ALHR, first redesign consideration was oriented toward developing a more satisfactory personnel support mode. Although a detachable tripod remains desirable when in a fixed location, the mobility criterion prevents continuous utilization of a support aid. The weight of the Prototype Model and the probable weight of near-future models indicates that human support should be supplied by the large muscles of the legs and torso rather than the smaller, more readily fatigued muscles of the arms. This logic led directly to the idea of a neck strap, the set then being similar in principle to a reflex camera.

Operation of the set in this position (with the back of the equipment against the torso) requires extensive reorganization of the controls and displays in order for displays to be seen and controls operated. However, before this redesign effort was expended, another small laboratory study (Experiment 3 reported in Appendix B) was conducted to verify the effectiveness of the neck strap support concept.

In this study a mockup similar in size and weight (15 pounds) to the Prototype Model of ALHR was suspended from a web strap around the subject's neck (U. S. Army universal carrying strap). The back of the mockup rested against the subject's stomach, and use of both hands was allowed for controlling orientation. This mockup and support mode provided similar steadiness (three degrees or less unsteadiness) and less subjective fatigue than the five-pound handheld mockup with the elbow supported. These results indicated sufficient improvement to justify revision of the control-display configuration.

Design recommendations presented in the following section are a result of the knowledge gained to this point in the present work, the Contractor's considerable experience in human engineering, and a variety of constraints involved in the present effort. These constraints hinge primarily around the total lack of development time available. Off-the-shelf items had to be employed with minimum alteration. Volume, weight and configuration have all been influenced by this. The resulting design recommendations are a compromise, but a promising one.

VIII. Design Recommendations for Preliminary Equipment

In this section, three versions of a redesign for ALHR are suggested (see Figures 3, 4, and 5). The Proposed designs incorporate the outstanding features of the Prototype Model, upon which they are based, as well as the design parameters already discussed. These parameters were identified by examining requirements imposed by the mission, the operator, and available hardware. The limitations associated with the design of the Prototype Model are believed to be corrected in the proposed configuration.

The neck strap mode of support should allow the operator to carry and operate the set with minimal inconvenience and discomfort and with satisfactory effectiveness.

A radome is proposed to cover the antenna assembly, affording it maximum protection from dirt and damage, both in transport or in operation.

The batteries are contained within the set itself in order to provide a single complete package. This obviates the necessity of power wires running from the operator's battery belt, although the audio lead to the operator's headset is still required. The additional weight of the batteries is not expected to jeopardize performance under this support mode.

The two primary visual displays (A-scope and range meter) are mounted to the left in the top of the package within the optimum visual area. A mirror could be located on the inside of the top cover for indirect viewing from a prone or recessed (foxhole) position. Storage for the headset could be provided in the radome, or within the case if positioning of components will allow.

Control selection and arrangement is in general accord with good human engineering practices. The fact that several satisfactory arrangements are possible accounts for the three versions of the design presented in Figures 3, 4, and 5.

In Version A (Figure 3) the right handle includes the range control while the left contains the main function switch. These handle-switches allow range control and function changes without losing support or control of set orientation. These controls may not be feasible, however, in the short time available.

In Version B (Figure 4) all controls are located on the top of the set along with the visual displays. A cover is provided for protection. The primary controls are located on the right side and the secondary controls on the

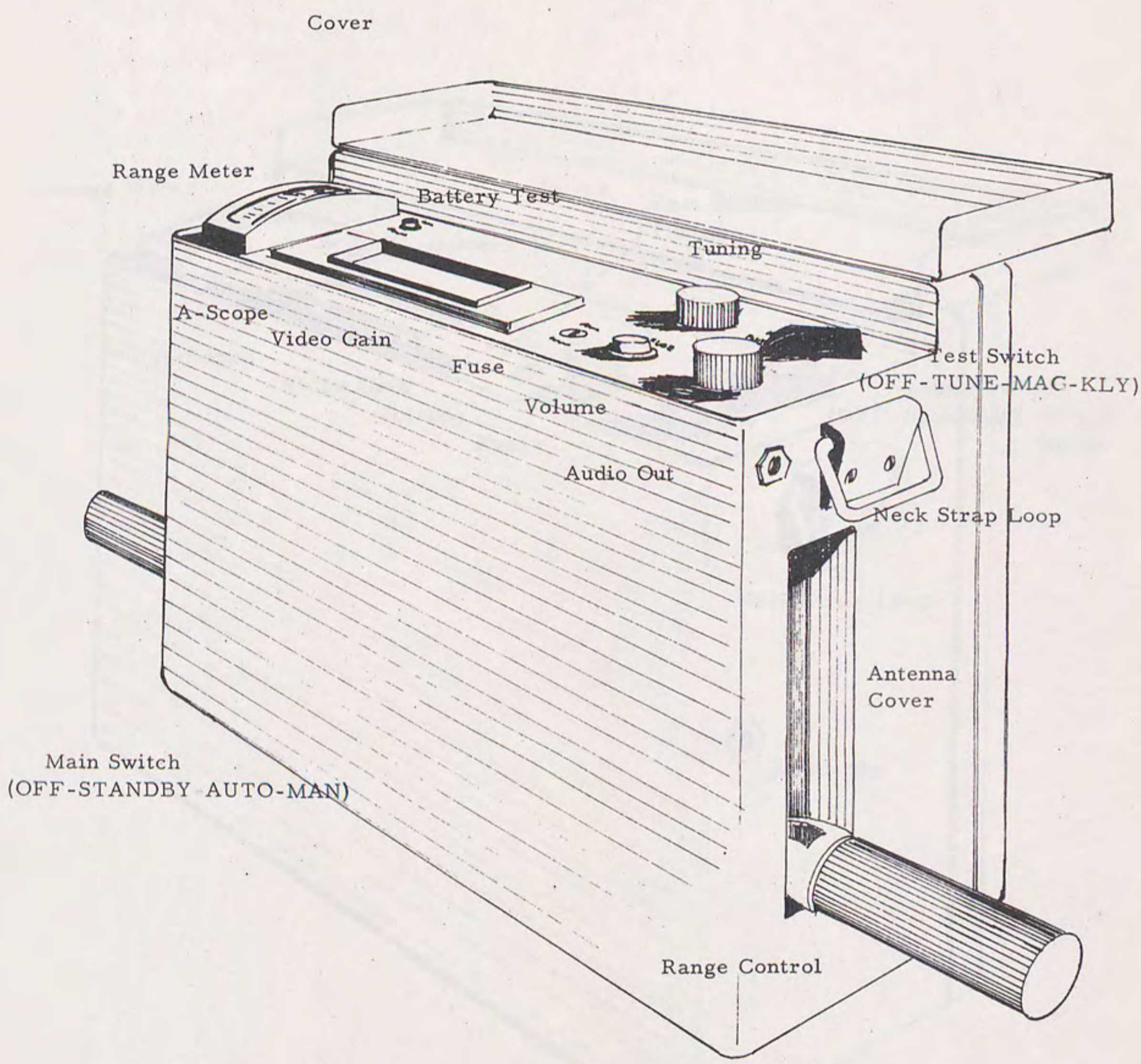


Figure 3. Recommended Design of ALHR, Version A.

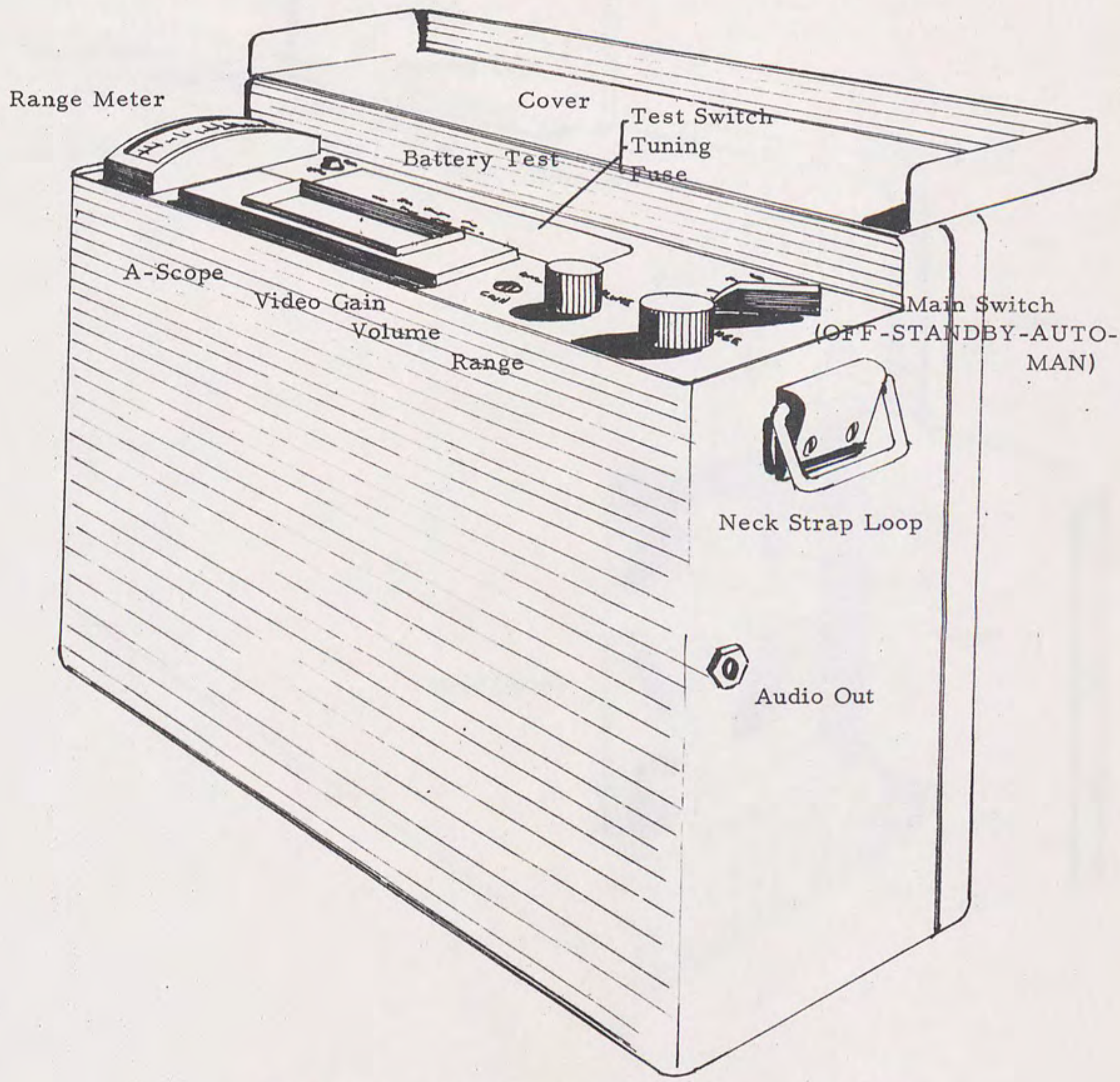


Figure 4. Recommended Design of ALHR, Version B.

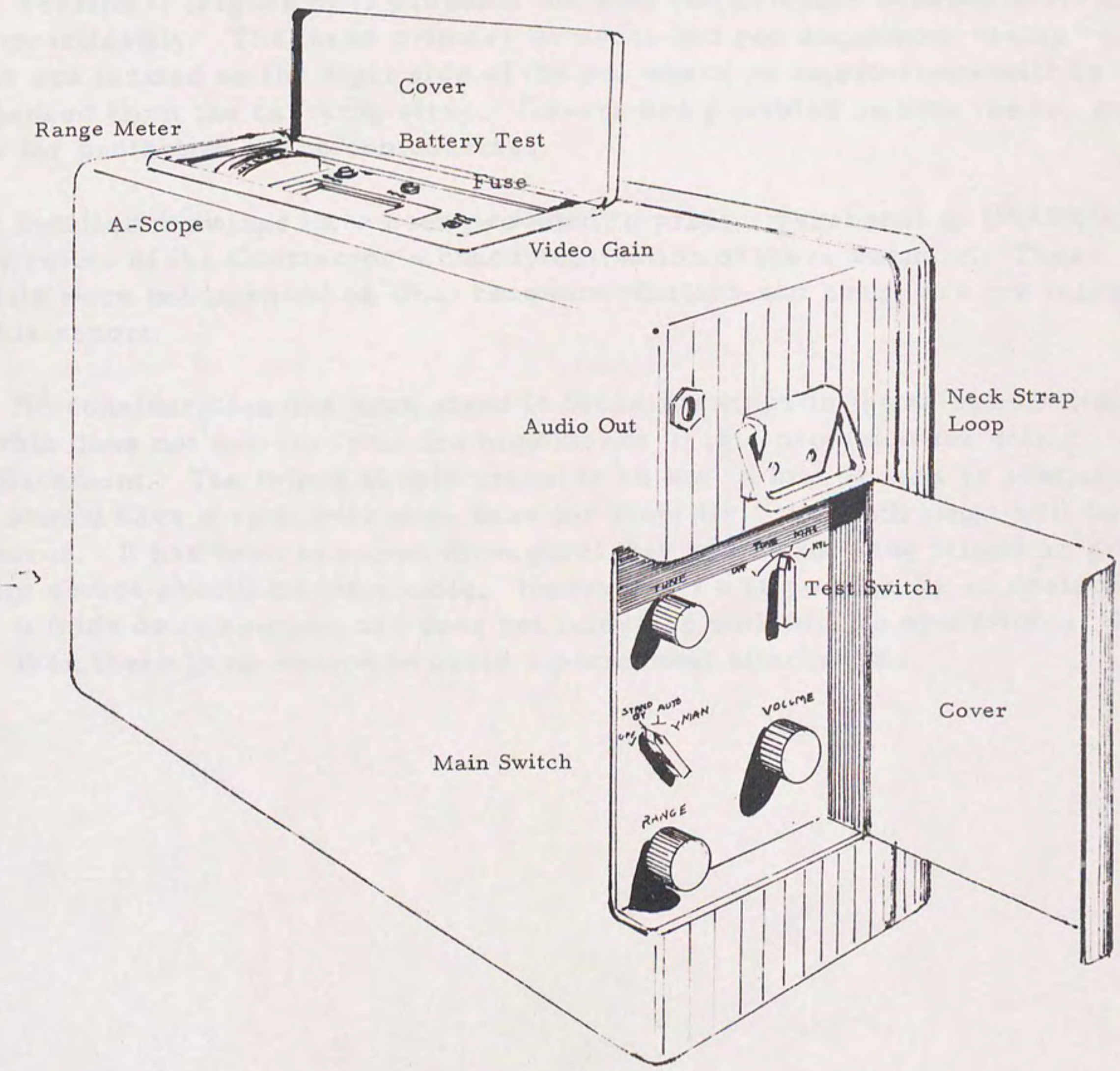


Figure 5. Recommended Design of ALHR,
Version C.

left. Most of the latter are under a second cover to eliminate any confusion of the operator which might arise from them. This version appears to be the easiest of the three to manufacture, but it is the least desirable due to interference of the carrying strap with control movements.

Version C (Figure 5) is probably the best compromise between desirability and practicality. The three primary controls and two secondary "setup" controls are located on the right side of the set where no interference will be experienced from the carrying strap. Covers are provided on both the top and side for protection of the components.

Detailed drawings have been provided to project personnel at USASRDL as illustrative of the Contractor's conceptualization of these designs. These details were not intended as final recommendations and hence are not included in this report.

No consideration has been given in these drawings to the tripod or mount, but this does not detract from the importance of this provision for static emplacement. The tripod should probably be low (a foot or less is adequate) and should have a relatively wide base for stability. Azimuth rings will be required. It has been assumed throughout this report that any tripod or ground mount device should be detachable. However, if a tripod can be so designed that it folds or telescopes and does not interfere with mobile operation of the set, then there is no reason to avoid a permanent attachment.

APPENDIX A: MISSION ANALYSIS

APPENDIX A: MISSION ANALYSIS

A. Purpose

The following material will accomplish two purposes. First, it will describe the characteristics of the likely combat environment to which the radar will be exposed and discuss in some detail the kinds of tactical missions that a radar of this type should be able to perform. Second, the material will develop a statement of equipment characteristics which are required of the final system configuration to assure maximum operational effectiveness. This statement of equipment characteristics is based on knowledge of probable combat environment and tactical application of the equipment. Without first considering these factors, it would be difficult to specify equipment characteristics which would be responsive to actual operating conditions.

B. General

Basically the ALHR may be described as a lightweight, short-range doppler radar designed for use by front-line infantry soldiers. The equipment may be carried and operated by one man. A more detailed description of the equipment is provided in Section II of the main text.

The need for this type of equipment is fairly apparent in relation to our present concepts of ground warfare. Present requirements for mobility and the need for small numbers of troops covering large fronts will create gaps in our lines which are vulnerable to surprise attacks. Obviously, it is necessary to assure "at-will" surveillance of these gaps. Mobile and transportable ground surveillance radars presently provide necessary coverage for gaps between major units (e.g., between regiments, divisions, etc.). However, the same sort of requirement also exists for smaller units (e.g., squad, company, etc.). The function of the ALHR is to fulfill the surveillance requirements of the smaller, company level units. At this level the equipment could be employed in the following ways under conditions of restricted visibility:

- Sentry duty - general unit security
- Detection and identification of targets
- Location of targets for fire direction
- Detection, identification and location of targets for intelligence purposes

C. Characteristics of Infantry Operations

This section will describe briefly characteristics of the combat environment with which both men and equipment must cope.

1. Weather

Infantry operations are conducted under all kinds of weather conditions. One can expect operations to be conducted when temperatures vary between -20° F through 120° F. Precipitation (rain, snow and hail) and wind will not halt operations except possibly when violent major storms occur (e.g., hurricanes, etc.). In desert operations sand storms may force a temporary cessation of activity.

2. Terrain

Operations will be conducted on terrain of all descriptions. For the purposes of this document we can classify various terrain types in terms of mountains, flatlands, and swamps. Of course, these types of terrain may also have certain other characteristics, such as mud or rock, etc.

3. Vegetation

The vegetation encountered by infantry troops will be characteristic of that found in the desert, temperate climates and tropical jungles.

4. Personnel Activities

To characterize infantry operations in terms of weather, terrain and vegetation is not sufficient when one is concerned with the design of equipment to be employed by these troops. Consideration must also be given to the kinds of activities these men perform and to relating the implications of these activities to the equipment. In this regard we find that men will be engaged in the following kinds of activities: running, walking, crawling, jumping, climbing, falling, digging, throwing, etc. These activities will be accomplished under a wide variety of weather, terrain and vegetation conditions. All of this suggests that the handling of equipment will be rough and sometimes hasty, to say the least. Furthermore, the nature of an infantry soldier's existence is such that often he must be able to perform the above activities with a minimum of interference from the equipment he carries.

D. Tactical Missions for the ALHR

Considering the physical characteristics of the ALHR (e.g., size, weight, etc.), its operational capabilities, and the characteristics of its potential operational environment, one can specify a number of tactical missions that the equipment can perform. In general, infantry units can be expected to successfully employ ALHR equipments in a variety of offensive, defensive, and reconnaissance situations. The following paragraphs will describe those tactical missions where the equipment could be expected to provide our units with enhanced combat capability.

1. Defensive Missions

In general, we can say that the employment of the ALHR radar in defensive situations permits the equipment to be utilized in the greatest variety of ways. The equipment should be considered by unit commanders as an integral part of the Main Line of Resistance (MLR). In this context, the ALHR should be considered as a weapon, and, therefore, formal positions should be prepared (foxholes, etc.) and alternate positions should also be provided as part of the normal battle plan. Further, in this formal situation, provision should be made for the employment of a tripod or other supporting device. This device must provide some kind of mil circle to enable operators to orient the equipment with North or some known landmark, thus allowing operators to know the direction in which the equipment is "looking." Within the scope of the defensive deployment outlined above, the following paragraphs specify the missions within the equipment's capability.

a. Short-range Missions

For ranges up to 400 yards, this radar can perform duties of a sentry and guard against infiltration. The presence of patrols, both friendly and enemy, can be detected. The position of patrols can be located and tracked. This, of course, assumes the availability of communications and a plotting board capability in a platoon or company command post. The timeliness of such information will be of great value to commanders in maintaining the integrity of their positions. Preparations may be made to trap hostile patrols or fire may be directed on them and, of course, the enemy will have lost the advantage of surprise. On the other hand, information concerning the whereabouts of friendly patrols can be used to aid their safe return to friendly lines. For example, units could be notified as to the location of a friendly patrol so that they would not fire on the patrol when it entered their sector.

b. Long-range Missions

At ranges beyond 400 yards, the primary value of the equipment is that of intelligence of a more enduring type. For the short-range missions discussed above, the information is of immediate value -- the passage of only a few minutes (e.g., 5, 10, 20 minutes) will render the information obsolete. On the other hand, for long-range missions the information may not be obsolete for several hours, perhaps even a day. Granted, in some cases the information will also be obsolete in a matter of minutes. In any case, the equipment can be employed to detect, locate and track the movements of enemy troops, vehicles, and armor immediately to the rear of the enemy's forward positions. Warning of impending attacks through massing and movement of troops is possible. Fire may be directed on the targets detected by the equipment. However, this fire direction will be limited to determining the target's position (i.e., grid coordinates). It is not practical to attempt adjustment of fire on targets. It is suggested here that the greatest use of the radar for fire direction will be concerned with area targets and not point targets. This is because point targets are small and require precise location data which may be beyond the capability of the equipment.

c. Miscellaneous

An advantage that may accrue through the use of this radar is the possible reduction in the number of outposts required by a unit. Outposts also need not necessarily be located as far forward of the MLR as is the present practice. However, this is a decision for field commanders.

2. Offensive Missions

The character of the radar's missions changes sharply during offensive operations. During an attack the radar should be near the various unit commanders, especially during night attacks. The types of information the equipment can provide unit commanders are suggested below:

- Detect and generally locate the main body of enemy activity during the fluid phases of the attack and fire fight
- Provide a form of contact (similar to visual contact) with adjacent attacking units, especially important at night or when woods separate adjacent units
- Detect the approach of enemy armor and determine the precise direction from which an armored attack may be expected

- Provide warning of enemy counterattacks and their direction during the reorganization and consolidation phases of the attack once the objectives have been attained

As can be seen by the above "missions" the essential characteristic of the radar in offensive operations is its detection capability. There is no time to pinpoint targets by grid coordinates. It is sufficient to locate a target in terms of its relative direction (e.g., front, right front, left front, right flank, etc.) and its approximate range.

3. Patrolling Missions

Our primary concern here is with patrols which require penetration of enemy lines. Basically there are two types of patrols: reconnaissance and combat. The purpose of reconnaissance is to obtain information while avoiding combat contact. Combat patrols are aggressive actions for the purpose of neutralizing specific positions and/or capturing prisoners for interrogation. Both types of operations are conducted almost exclusively under cover of darkness. Since it is extremely difficult to operate at night over unfamiliar ground and know one's own location, it is suggested that the radar be used as a navigational aid. The following is a list of ways patrols might employ the radar:

- Friendly patrols could be aided in finding their way home through the use of corner reflectors -- the reflectors would mark the point where the patrol is expected to pass through the mine fields or barbed wire and into friendly lines.

- Reconnaissance patrols could use the radar to locate targets or areas to be investigated or avoided, depending on the situation.

- Combat patrols could utilize the equipment to locate their primary or alternate objectives -- depending on the nature of the objectives.

- Combat patrols could use the radar to detect and locate hostile intercepting patrols and thus avoid ambush.

The above "missions" indicate a requirement for detection and relative direction information. Precise location information is not required.

4. Miscellaneous Missions

During retrograde and relief operations it is expected that the radar will be employed primarily as a means of maintaining contact with both friendly and enemy units, especially when these operations take place at night.

Guerrilla units might employ the equipment in ambush situations to warn of the approach of the target. It might also be used to detect and locate hostile pursuing forces. In special cases the radar might be used to provide a warning against surprise attack.

Anti-guerrilla units will use this radar to detect, locate and track hostile guerrillas to facilitate trapping and destroying the guerrillas.

E. Design Considerations

1. General

The previous paragraphs have outlined a number of tactical applications or missions of the radar. We have also discussed the combat environment to which the radar will be exposed, in terms of terrain, weather, temperature and the handling of the equipment. To summarize these factors, we find that regular infantry units have many offensive and defensive uses for the radar. The equipment also has certain utility for patrol, retrograde and relief operations. Guerrilla and anti-guerrilla units can also effectively employ the radar. The combat environment is particularly harsh for electronic equipment, and the handling and care of the equipment will leave something to be desired.

Analysis of the radar's tactical missions and likely combat environment indicates that certain physical characteristics are required of the equipment to assure its maximum combat effectiveness when operated by a G.I. These characteristics may be called design requirements, specifications or criteria and should be given due consideration in the ultimate operational system configuration. The remainder of this appendix deals with specification of design criteria necessary for the optimum system configuration. It should be made clear at this point that it is not within the scope of this document to discuss design criteria that deal with the engineering performance of the radar. We are concerned with those criteria which in some way affect the operator, the manner in which he operates the equipment and the over-all man-machine "system" performance.

2. System Characteristics

Within the context of this document, system characteristics refer to the entire man-machine operating system as a whole. The following system characteristics are desirable:

a. High Degree of Mobility

The equipment must be small, lightweight, and capable of being transported rapidly and operated by one man. For offensive and patrol actions this is essential.

b. Fixed Installation

For defensive operations the equipment must be capable of providing target location information of sufficient accuracy to direct mortar or artillery fire. Azimuth is the important problem.

c. Sectors

Large sectors must be searched quickly. Detection by the enemy is a problem, but also during patrols, time will not permit a slow sector search.

d. Security

During night operations the equipment must be capable of being secured against self-generated light and noise.

e. Reliability

The equipment must be reliable under extreme environmental conditions.

f. Surveillance

The radar must be capable of long periods of surveillance should the need arise in defensive situations. It should also be capable of providing "short bursts" of surveillance immediately on demand. This is especially important for patrol operations where even short warm-up periods are intolerable.

3. Subsystem Characteristics

This section considers, for convenience, that this man-machine system has only two subsystems: the equipment subsystem and the personnel subsystem. The former refers to more detailed characteristics of the radar desirable for effective operation. The latter refers to those characteristics desirable in operators that can be attained through proper selection or training.

a. Equipment Characteristics

(1) General Configuration

- For defensive situations some kind of mount must be provided (e.g., tripod). Included as part of the mount must be some means of measuring the azimuth (relative or absolute) in which the equipment is "looking." On the other hand, during patrols, or attacks, the mount represents unnecessary weight and therefore might best be detachable.

- The equipment must be capable of operation while hand-held by a man for all operations other than defensive actions.

- The equipment must be easy to handle by one man whether walking, running, climbing, rolling over, etc. This is very important during attacks and patrolling.

- The equipment must be capable of being transported without the use of hands when not operating (e.g., a sling or carrying strap).

- The transport position must not hamper the effective maneuvering of the operator.

- The transport position must not interfere unduly with carrying and use of the operator's personal weapon.

(2) Controls and Displays

- Must display adequate information for effective search, detection, and identification.
- The number of controls and displays should be held to a minimum commensurate with effective operation.
- Controls should be capable of being operated with a gloved hand.
- For rapid search the equipment should be capable of displaying the entire range of the equipment simultaneously (e.g., as with an A-scope).

(3) Maintainability

- The equipment should be rugged and capable of withstanding the rough handling common to normal field use.
- Due to primitive field conditions the equipment should be designed for ease of maintenance and repair.

b. Personnel Characteristics

(1) Operating personnel should be selected for normal hearing.

(2) Personnel should be trained or practiced in the identification of targets.

(3) Training should be given in the techniques of target location (i.e., range and azimuth).

(4) Personnel require training in the field maintenance of the equipment.

The design characteristics specified above form the framework within which the final configuration will be developed. Some of these criteria are more important to over-all system effectiveness than others, but all should be weighed carefully before inclusion or exclusion. Undoubtedly some of them will conflict with engineering requirements or limitations, and some might appear to conflict with each other. Wherever conflicts exist, appropriate compromise solutions should be sought and resolved.

APPENDIX B: DETAILED LABORATORY STUDY REPORTS

APPENDIX B: DETAILED LABORATORY STUDY REPORTS

A. Introduction

A series of three studies was carried out in the laboratory of Dunlap and Associates, Inc., for the purpose of providing data on human capabilities in the realm of holding some type of aiming device steady on an obscure target. The need for such data was apparent in specifying the handle and support mode for a small handheld radar set. The original design of the Prototype Model of this radar weighed 15.3 pounds and was fitted with a pistol-grip handle under the main unit of the set. This led to two short experiments in which data were collected on the endurance and aiming steadiness capabilities of persons using a device of this type (i.e., held in one hand via a pistol-grip handle).

Two specific purposes of Experiment 1 were to determine whether this mode of support was feasible and what degree of unsteadiness could be expected. The implications of these questions are vital to the performance of the man-machine system involved. First, if the human were, in fact, not capable of holding a weight of this magnitude under control in an aiming situation, then the mobility aspects of the over-all system capability would be jeopardized. Second, if unsteadiness were large in relation to radar beam width, then system capabilities in search, identification, and target tracking would be severely limited. The specific purpose of Experiment 2 was to determine what, if any, improvement in endurance or aiming steadiness might be gained by allowing elbow support of the arm holding the device.

Evidence indicating the undesirability of supporting the entire weight of the set with the hands and arms led to an alternative design concept centered about suspending the set from a support strap around the neck. Experiment 3 was then conducted for the specific purpose of determining the effect of this mode of support upon endurance and aiming steadiness.

B. Method

The three studies being reported share many methodological features. Identical apparatus was used in Experiments 1 and 2, while that used in Experiment 3 differed only in design of the aiming device mockup. The procedure utilized differed from experiment to experiment only in the manner in which the aiming device was supported and controlled. Subjects and ambient illumination were common to all three experiments. The following paragraphs will describe the general case for each of these factors and will make explicit the variations from experiment to experiment.

1. Apparatus

a. Aiming Device Mockups

Drawings of the two aiming device mockups used are shown in Figure B-1. Model A was used in both Experiment 1 and Experiment 2, while Model B was used only in Experiment 3. The design of Model A incorporated the support features of the Prototype Model of the radar set, while that of Model B incorporated the support features of the alternate design concept resulting from the evaluations conducted.

The main component incorporated in mockup Model A was an Ednalite Electric Pointer. This pointer is designed to produce a small spot of intense light (32 foot-candles) at a relatively long distance. The size of the spot is no more than 1/2 inches or approximately 15 minutes of arc at 10-1/2 feet. The device averages 2-1/2 inches diameter and is 15 inches long. The pointer was mounted on a pistol-grip handle so that its center of gravity was positioned directly over the operator's hand. The weight of the mockup was increased to five pounds by the use of properly located molded lead. This appeared to be a realistic weight to which the existing Prototype Model of the radar might ultimately be decreased by full utilization of solid state electronic devices, new miniaturation techniques and a printed antenna array.

Mockup Model B also included as its main operating component the Ednalite Electric Pointer. A rectangular wooden box approximating the minimum dimensions necessary for packaging the components of the Recommended Design for the radar set formed the framework of this mockup. The pointer was mounted in approximately the same position as the antenna would be in a real radar set. Sufficient lead was mounted inside the box to make the total weight of the mockup equal 15 pounds, thus approximating the existing weight of the Prototype Model radar. An Army universal carrying strap attached to the sides of the mockup and passing behind the subject's neck supported the mockup in use. Since this mockup weighed ten pounds more than the mockup of the Prototype Model, a completely fair comparison between these two designs could not be made. Despite this fact, a comparison was made from the standpoint of operator unsteadiness and load- carrying ability.

The original experimental plan included experimentation with a five-pound "reflex camera" mockup which would be supported on a strap around the neck. Unfortunately, time could not be allotted for studying this design before steadiness data on the recommended model was needed.

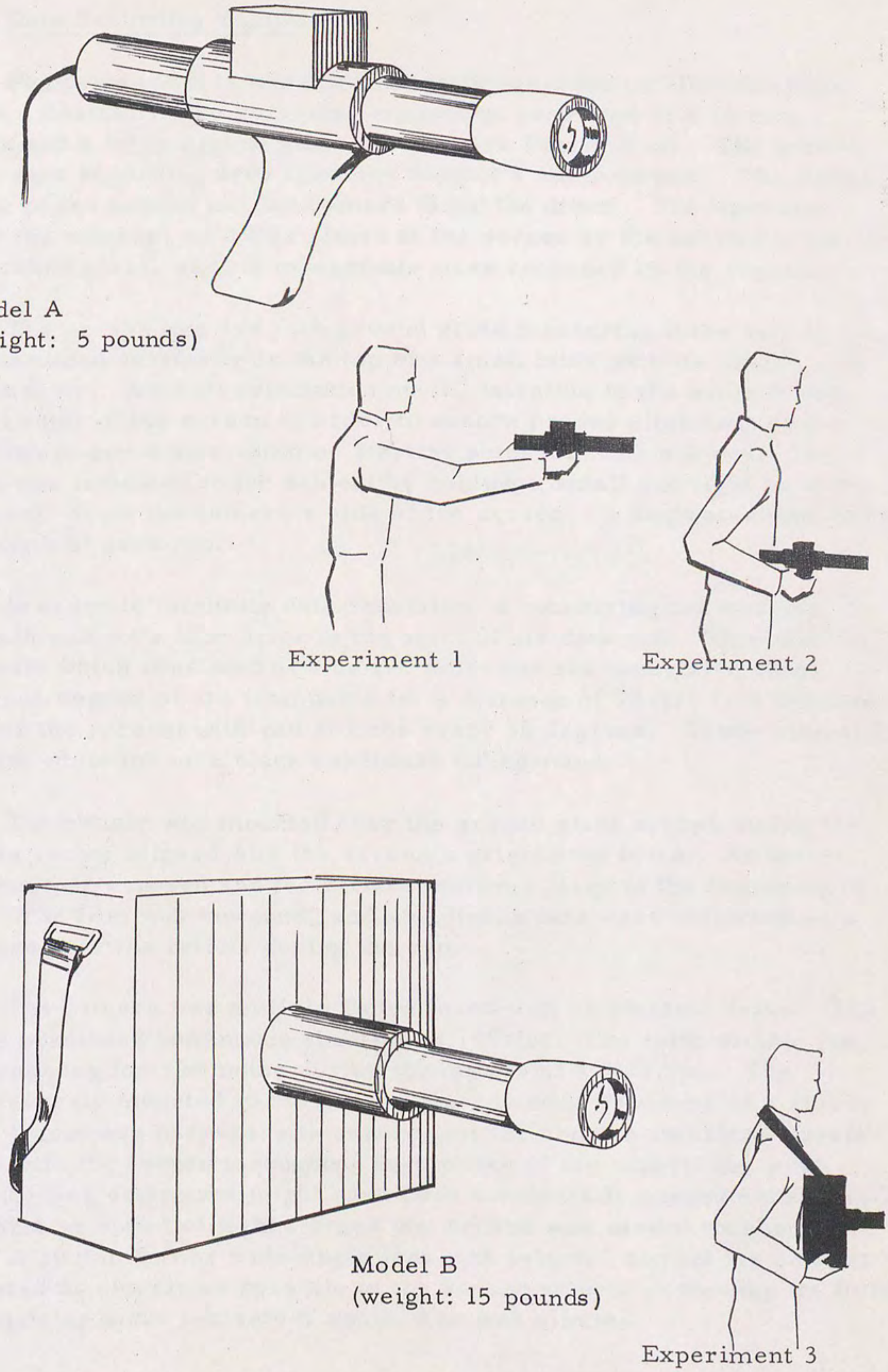


Figure B-1. Aiming Device Mockups.

b. <u>Data Recording Equipment</u>

Performance data were permanently recorded on 100-foot rolls of movie film. Basically, the recording equipment consisted of a 16 mm movie camera and a large ground glass screen (see Figure B-2). The screen separated the data recording area from the subject's environment. The subject faced one side of the screen and the camera faced the other. The light spot (generated by the mockup) as it was aimed at the screen by the subject projected through the ground glass, and its movements were recorded by the camera.

The screen was 1/4 inch ground glass measuring three feet by five feet. It was mounted vertically on the top of a small table with its longer side parallel to the floor. A small orientation mark, invisible to the subject was placed at the center of the screen in order to assure proper alignment of the camera and also to serve as a common starting point for each subject. The starting point was indicated to the subject by holding a small pen light over the orientation mark, from the camera's side of the screen. A stopwatch was used to time the length of each run.

In order to facilitate data reduction, a measuring aid was pre-exposed on each subject's film prior to the start of his data run. This measuring aid was a reticle which consisted of a center point and six concentric rings separated by one degree of arc (computed for a distance of 10-1/2 feet between the mockup and the screen) with radial lines every 30 degrees. These indications were made with white ink on a black cardboard background.

The reticle was mounted over the ground glass screen facing the camera and its center aligned with the screen's orientation mark. An entire roll of film was then exposed and the reticle removed prior to the beginning of the data run. The film was rewound, and steadiness data were collected as a double exposure over the reticle during the run.

The camera was an H-16 Bolex fitted with an electric drive. The electric drive permitted continuous shooting of 100-foot film rolls without the necessity of stopping for rewinding during the middle of a data run. The camera was securely mounted to the ground glass screen by means of a sturdy frame. This frame was necessary to assure that the camera remained consistently aligned with the screen throughout each phase of the experiment even though the recording equipment might have been accidentally nudged occasionally. The slowest shutter speed of eight frames per second was used throughout the experiment. A 10 mm Switar wide-angle lens was selected so that the camera could be situated as closely as possible to the screen without narrowing its field of view or requiring more laboratory space than was allotted.

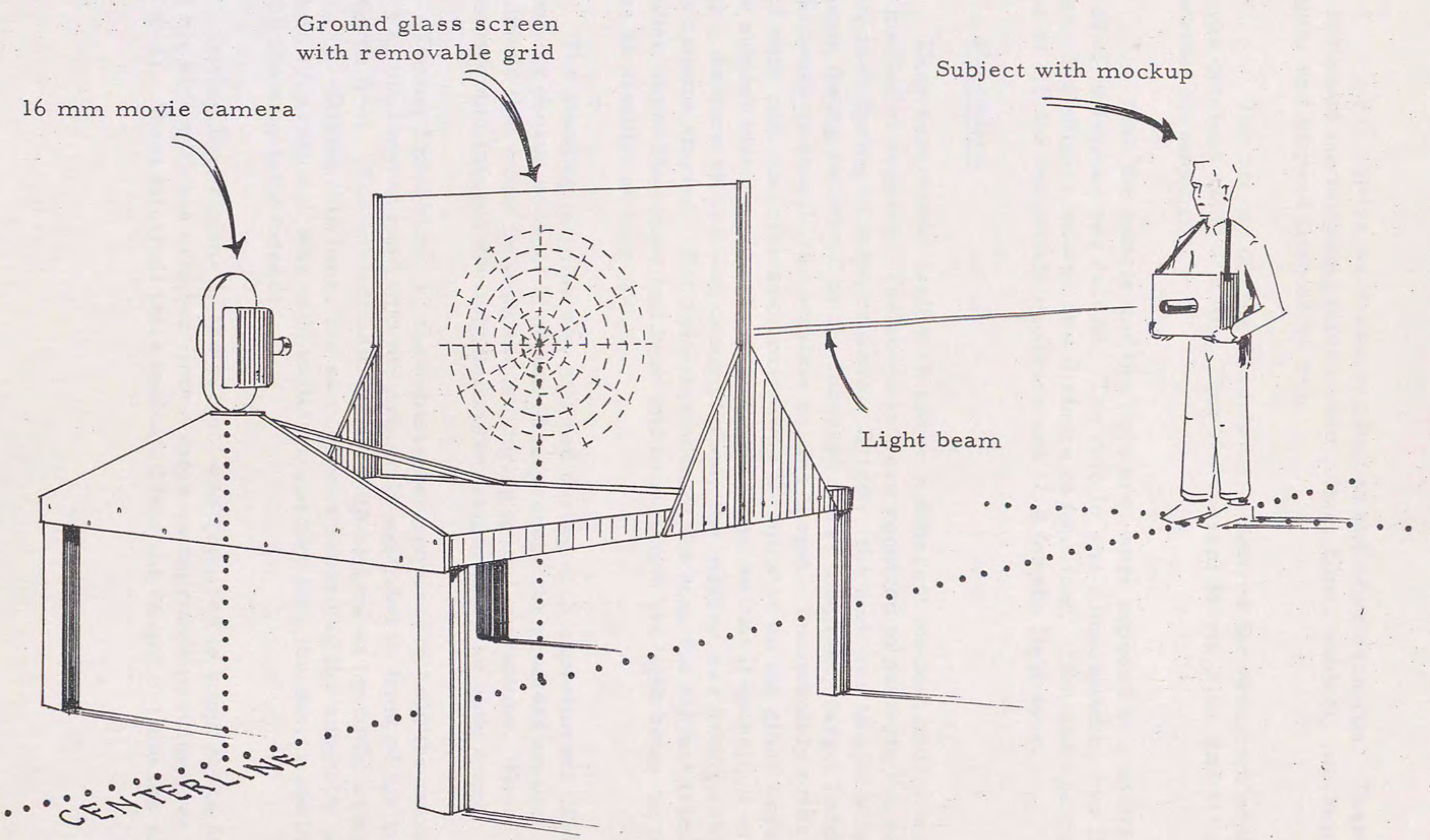


Figure B-2. Experimental Area Layout

Film titles were exposed before and after each run. These titles contained the following information: date, time, subject, mockup, condition, and elapsed time of the run.

The proper degree of contrast, required for reduction of the data, was obtained using a 16 mm Plus X Reversal Movie Film and standard commercial developing.

Both the reticle and the light spot were exposed at a shutter speed of eight frames per second. The reticle was illuminated by two RFL2 Reflector Floodlights located at a distance of four feet. The lens aperture was set at f16 for the reticle exposure and f2.8 for the light spot.

2. Procedure

Each experiment dealt with either a different mockup and/or a different method of support. The subjects were required to perform the same primary task during each experiment. Briefly, the task was to aim a narrow light beam (being generated by the mockup) at an "imaginary target" and to hold the beam as steadily as possible on this target. Immediately prior to the start of each run, an orientation mark was illuminated on the glass screen and the subject instructed to direct his light beam so that it coincided with the marker. As soon as this was accomplished, the marker was extinguished and the camera started. For the remainder of the run, the subject tried to remember where the target had been and to maintain his light beam on this location as steadily as he could.

The standing position was utilized during each experiment. This body position was chosen because it appeared to produce the greatest amount of unsteadiness that would be experienced during actual operations. Here, unsteadiness would involve not only muscular tremor but also body sway.

During Experiment 1, the subject was required to hold the mockup Model A in his favored hand with his arm fully extended in front of his body (see Figure B-1). The subject held the mockup as long as he could without dropping it. During this time, the camera was recording the subject's performance. A stopwatch was used to determine how long the device could be held with the arm fully extended.

During Experiment 2, the subject was required to support the device against his side with his arm bent into a more comfortable position (see Figure B-1). Short informal tests indicated that the length of time the subject was able to hold the device was not a critical factor here so that an entire 100-foot roll of film (approximately eight minutes) was taken of each subject's performance.

During Experiment 3, mockup Model B was suspended via its strap from the subject's neck as shown in Figure B-1. The subject's hands were placed on the sides of the mockup near the bottom to steady and aim the light beam. Again, endurance was not critical and an entire 100-foot roll of film was exposed with each subject's performance.

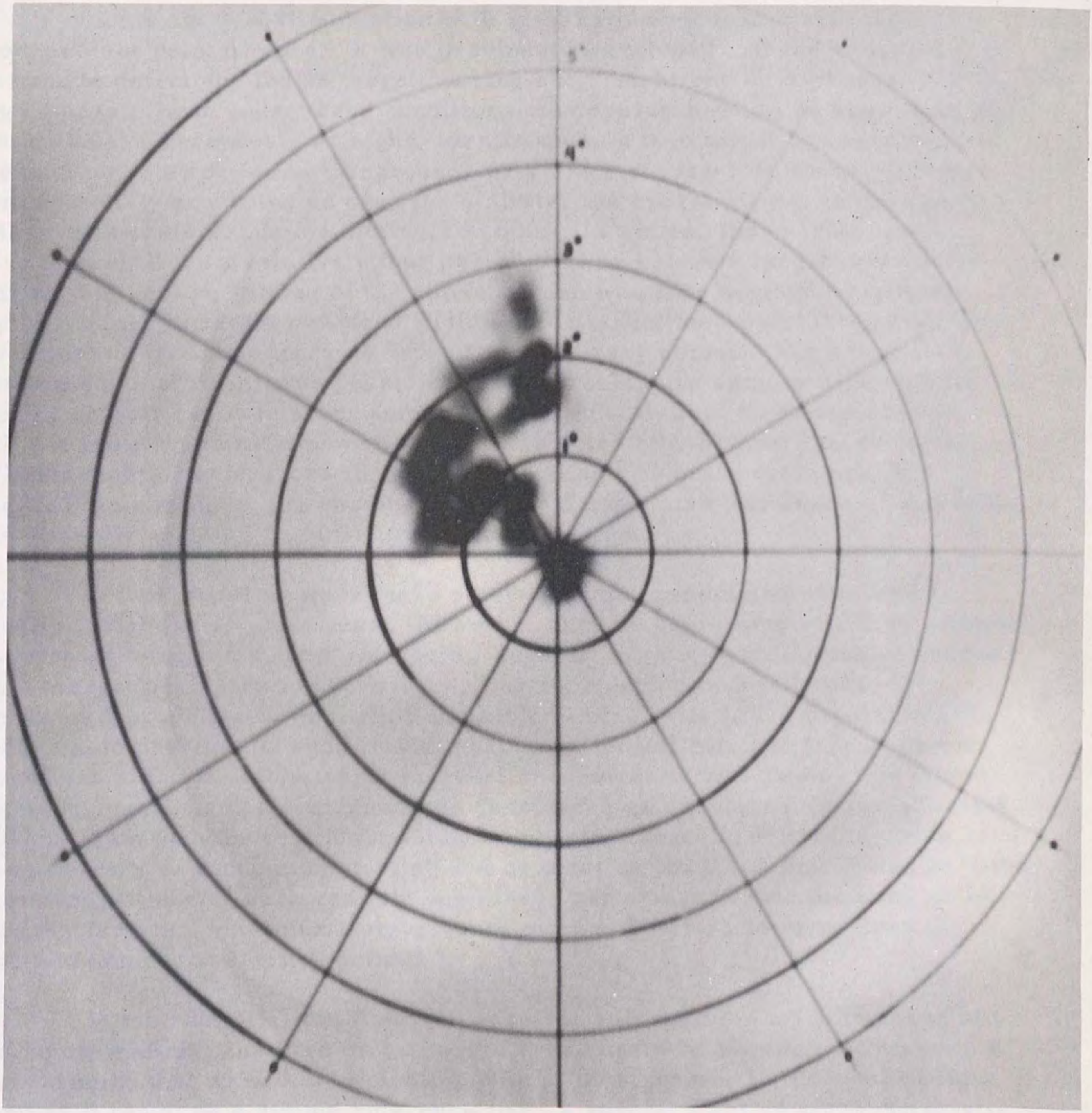
After the film was processed, it was reduced into a more useable form by preparing time reduction photographs. A sample of these photographs used during the analysis of these experiments is shown in Figure B-3. These photographs were made by exposing the desired number of film frames on photographic printing paper. A modified movie projector with a controllable lens diaphragm was constructed and used to make the exposures. This technique permitted the experimenter to view and analyze any interval of performance, starting at any time period during a run, without the necessity of plotting each frame by hand. By utilizing this technique, a substantial amount of time was saved without a loss in the accuracy required for analysis.

3. Subjects

The six subjects used were young, healthy males ranging in age from 18 to 28 years. All are members of the staff at Dunlap and Associates, Inc., and were selected primarily for their immediate availability. Each subject was right handed and possessed normal eyesight.

4. Ambient Illumination

Ambient illumination in the laboratory room was estimated to average less than one foot-candle. Some degree of illumination was necessary in order to provide the subject with some visual references; e.g., ceiling, wall and floor lines, screen frame, table outline, door frame, etc. If the room had been totally darkened, some subjects undoubtedly would have experienced a visual phenomenon known as autokinetic illusion. This illusion consists of an apparent movement of a point source light during complete darkness. Under the effects of this phenomenon, the subject would have attempted to compensate for the false movement by re-aiming his light beam in the opposite direction of apparent movement. Performance data would then have been compounded with an inconsistent factor which was of no interest in this experiment.



Subject #3 2 min. 14 sec. time interval

Figure B-3. A Sample Time Reduction Photograph

5. Procedural Note

Some ambient illumination with visual references was also desirable from another point of view. It was previously mentioned that the radar will be used to detect and locate targets during such conditions as darkness, smoke, fog or haze. Even under these conditions, the operator would be supplied with some visual references. At night, for instance, a tree might be observed on the skyline, a stone in the foreground, or a soldier a few feet ahead. While systematically searching an area for activity, the operator may be expected to utilize these references for aiming. In many instances, the operators will have to search for a relatively long period of time before a target is detected. During this period, aiming of the antenna beam would be performed without the assistance of target produced audio and/or visual feedback through the set. Even without these aiming aids, speed and accuracy demand that a search be performed as efficiently as possible without overlapping sectors already observed or completely missing potential areas of activity. Since the displays will not present information until a target is detected, the operator must turn to other sighting references immediately available in his environment for accuracy in aiming; e.g., various terrain features, his own "sense of direction" and whatever sighting features are built into his set.

It is doubtful whether these references are associated with what is usually thought of as steadiness. However, they do have some effect on antenna beam steadiness, as pointed out above, especially while systematically searching a "targetless" area for activity. After considering these factors, it appeared appropriate to include an invisible aiming point in the experimental setup and to provide the subject with peripheral visual references. Apparent movement of the invisible target marker, therefore, is included as one factor in the performance data and should be considered as one human factor affecting antenna beam steadiness. It should be emphasized that the visible target marker was used only as a common starting and orientation point and that it was invisible to the subject during each run. In summary, performance data includes three primary factors: muscular tremor, body sway and failure to remember the true location of the starting point.

In the real-life situation, the operator will not have a light spot to aid him in determining in which direction the radar beam is pointing. However, it was assumed that some aid to sighting will be incorporated in the final design; whether it would be a simple reference line, a special sight or a characteristic inherent in the design itself was undetermined at that time. The specific method depended too highly on the final configuration which would be selected to meet more important design requirements. The light beam, generated by the mockups, may be viewed as an extension of whatever aiming aid is ultimately incorporated in the final design. It is an extremely more accurate device than would be found on an operational set since it essentially extends the sight to the target area and forms a spot to indicate the antenna beam location. Nevertheless, the use of this method had major advantages over other conceivable methods during the experiments. For instance, it was a consistent method which could be incorporated in both mockups which otherwise would not have possessed identical aiming devices because of their radical dissimilarity in design and/or support. In addition, since subjects may be expected to vary in their ability to use different aiming methods, this variable did not become a major factor affecting the data. It should be mentioned that the light spot could also have been made invisible by the use of polarized light, prisms, or infra-red techniques, but the advantages of this course did not appear to be worth the time or effort involved. It is doubtful, for instance, whether the use of a rifle sight instead of a light spot would have made substantial differences in steadiness performance since there was no target to "shoot at." If the target were visible, performance data would have definitely been affected and would have little relevance to the real-life situation.

C. Results

1. Experiment 1

The total time each subject was able to hold the five-pound Model A mockup (endurance time) appears in the table below. These times also represent the total length of each subject's run during the first experiment.

Table of Endurance Times in Experiment 1.

Subject	Endurance Time (Seconds)
1	105
2	110
3	134
4	135
5	121
6	102
Mean	117.83

Figure B-4 shows the aiming steadiness dispersal pattern of data collected in Experiment 1. This figure, as well as all subsequent figures, was prepared by the time reduction method described in a previous section. Figure B-4 presents the total dispersion of aiming by all six subjects over the endurance times listed in the above table.

2. Experiment 2

Figures B-5 and B-6 present the aiming steadiness dispersal patterns obtained in Experiment 2, also using Mockup Model A. The endurance times from Experiment 1 (see above table) set the limits for the data included in Figure B-5. In other words, the "First Interval" for each subject was his endurance time in Experiment 1. Figure B-6 presents composite data from all subjects during the last 30 seconds of their respective runs. All subjects maintained control of the device throughout the approximately eight minutes of the run; hence no objective endurance measures were collected. There was, however, consistent reporting of fatigue and relief when the run ended.

3. Experiment 3

Figures B-7 and B-8 present the aiming steadiness dispersal patterns obtained in Experiment 3 using Mockup Model B. As with Experiment 2, the "First Interval" was defined for each subject by his endurance time in Experiment 1 (see above table). In this way, the data presented in Figure B-7 are comparable to those presented in Figure B-4 for Experiment 1 and in Figure B-5 for Experiment 2.

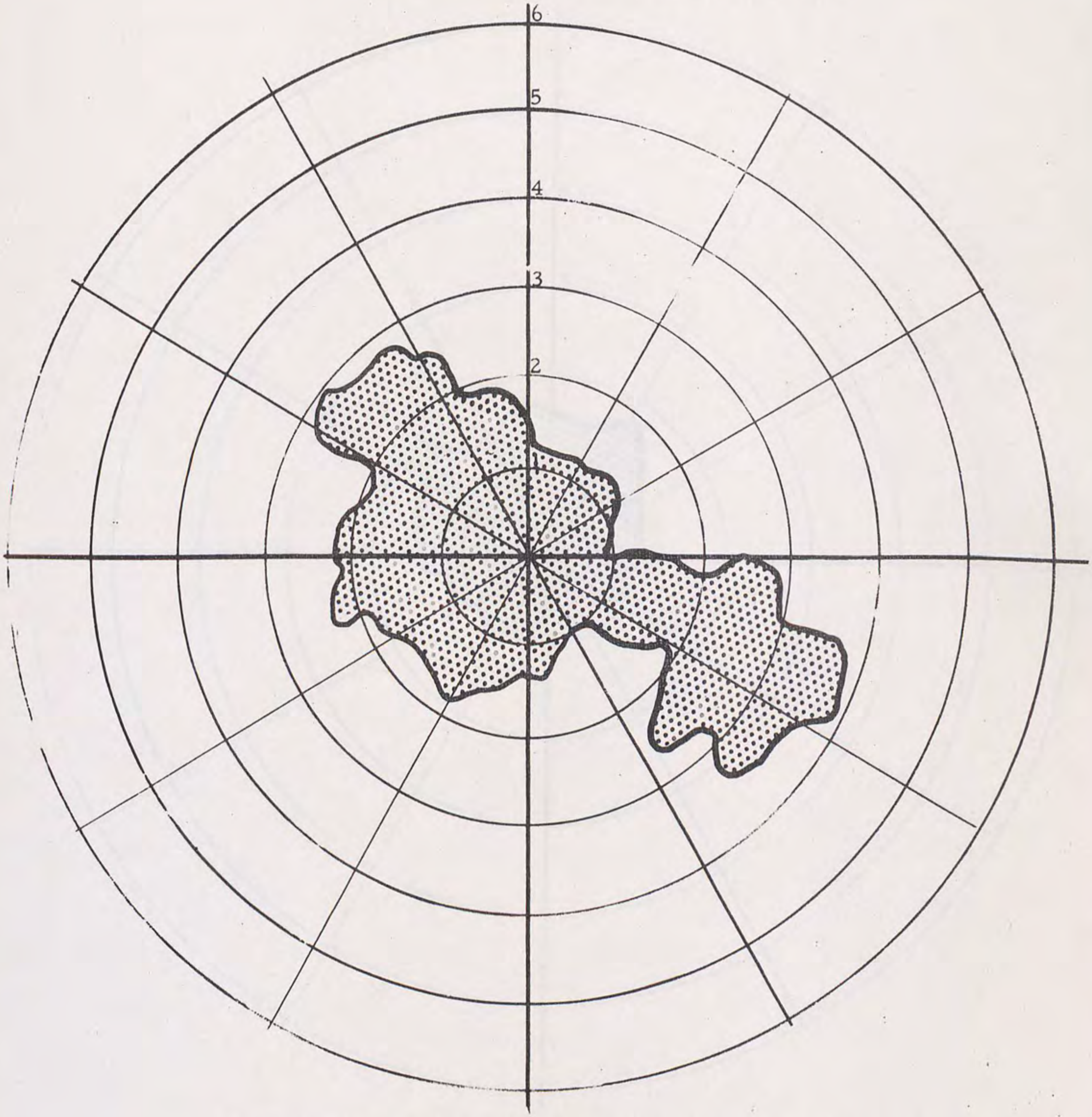
The data presented in Figure B-8 comprise the last 30 seconds of each subject's performance and are in this respect comparable to those presented in Figure B-6 for Experiment 2. No severe subjective fatigue was reported during this experiment. The separate, enclosed "islands" shown in Figure B-8 represent data from two subjects, neither of which overlapped the performance of the others.

D. Discussion and Conclusions

The table on page B-10 indicates the maximum time each subject was able to hold Mockup Model A with his arm extended. Mean time for the group was a few seconds less than two minutes. Based upon these data and the requirements of both the mission and the operator, it is appropriate to conclude that this method of support should be avoided unless the weight can be reduced far below five pounds. In addition, the dispersion pattern obtained during

EXPERIMENT NUMBER 1
MOCKUP MODEL A -- 5 lbs.
ARM EXTENDED

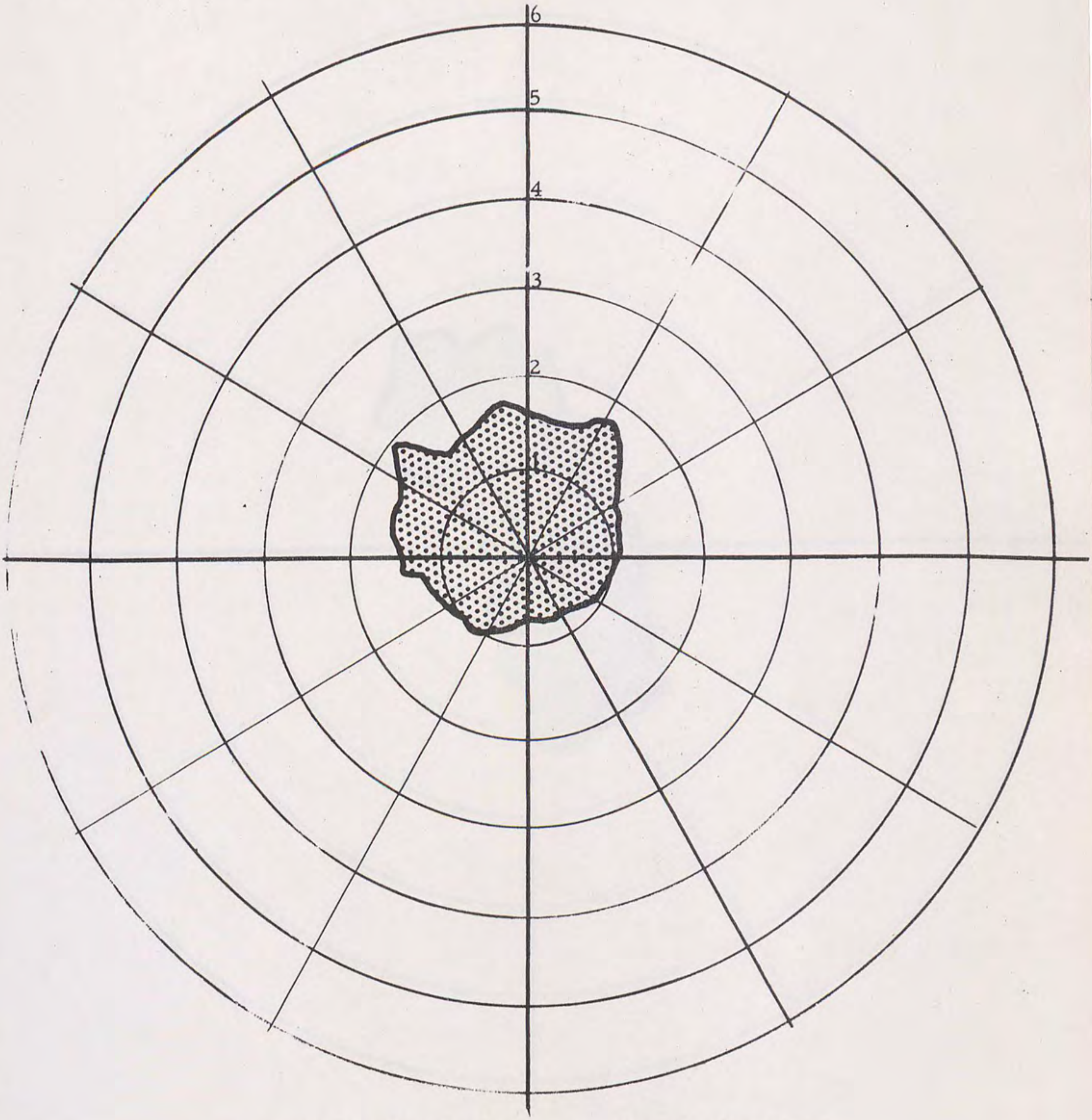
FIRST INTERVAL
ALL SIX SUBJECTS



AIMING STEADINESS DATA DISPERSAL PATTERN
Figure B-4

EXPERIMENT NUMBER 2
MOCKUP MODEL A -- 5 lbs.
ARM BENT -- SUPPORTED ON SIDE

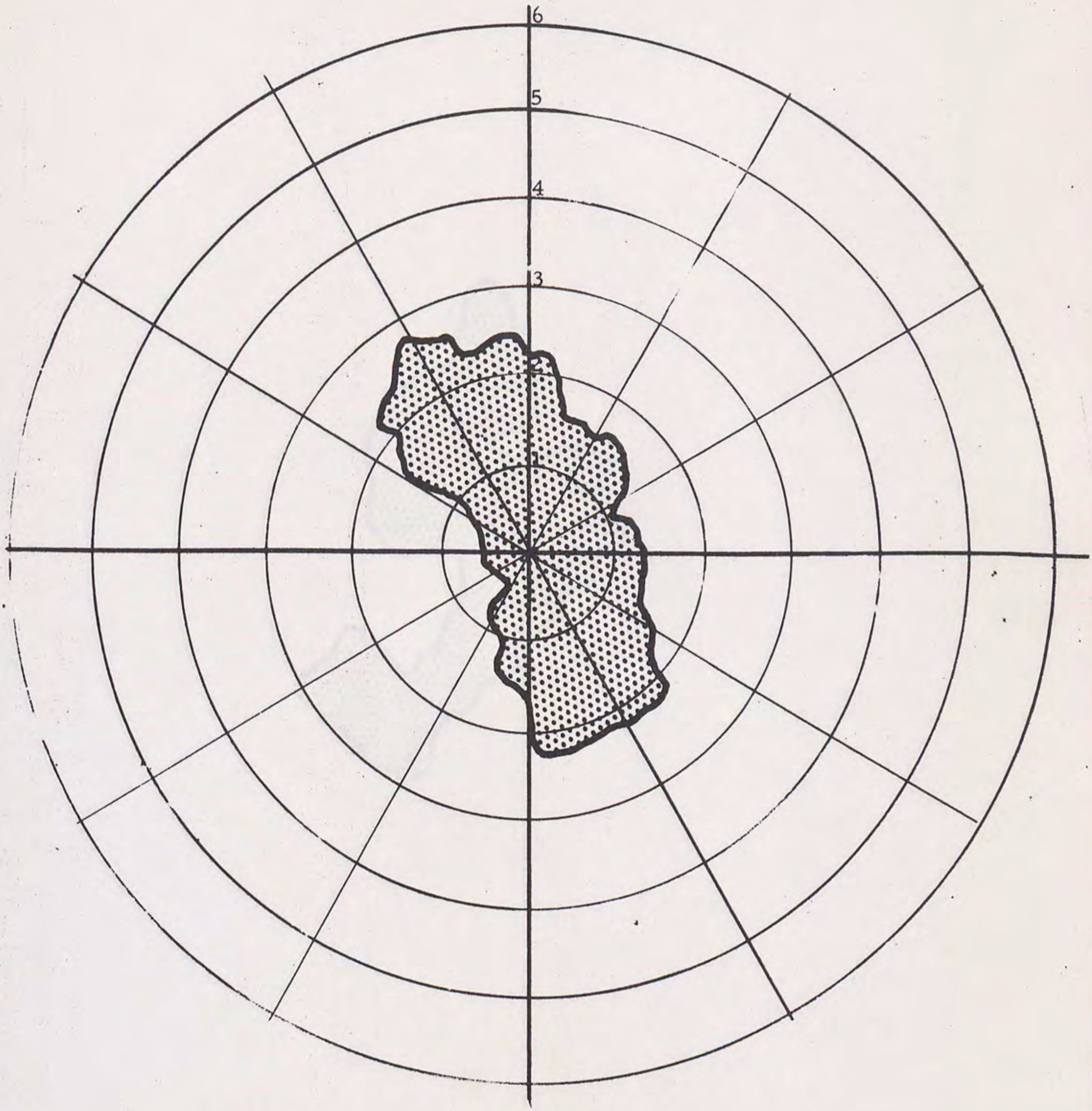
FIRST INTERVAL
ALL SIX SUBJECTS



AIMING STEADINESS DATA DISPERSAL PATTERN
Figure B-5

EXPERIMENT NUMBER 2
MOCKUP MODEL A -- 5 lbs.
ARM BENT -- SUPPORTED ON SIDE

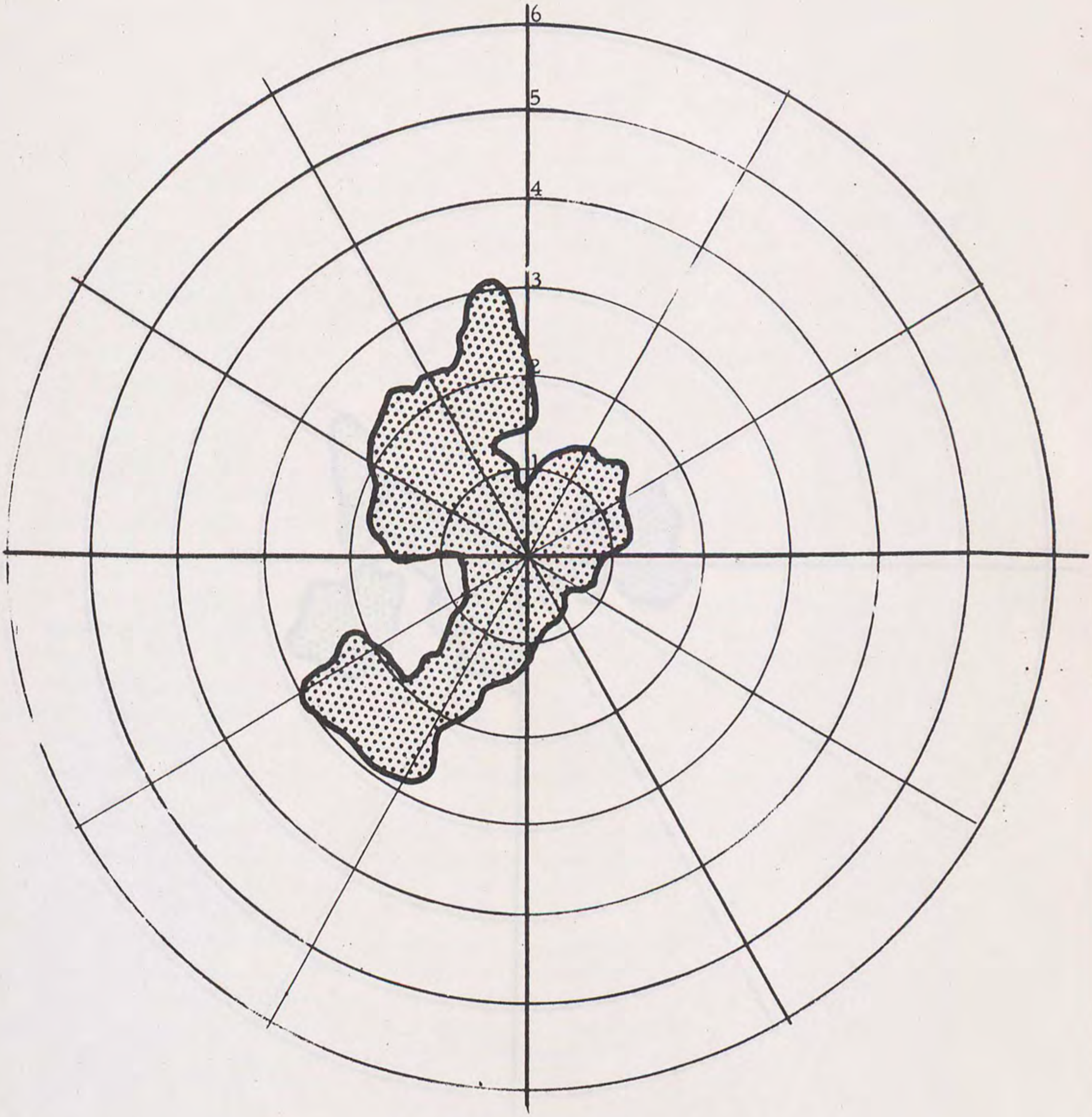
LAST 30 SECOND INTERVAL
ALL SIX SUBJECTS



AIMING STEADINESS DATA DISPERSAL PATTERN
Figure B-6

EXPERIMENT NUMBER 3
MOCKUP MODEL B -- 15 lbs.
NECK SUPPORTED

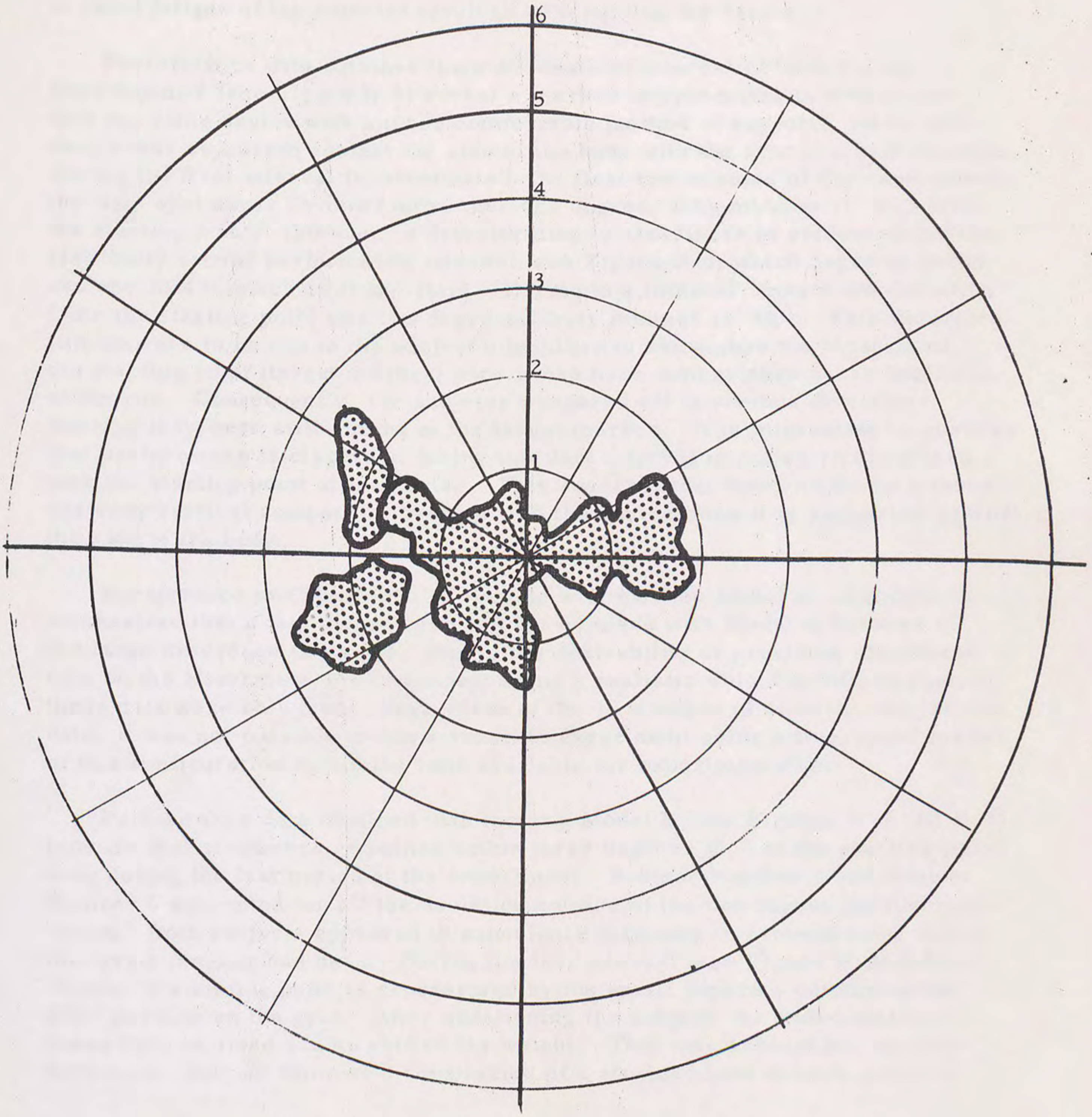
FIRST INTERVAL
ALL SIX SUBJECTS



AIMING STEADINESS DATA DISPERSAL PATTERN
Figure B-7

EXPERIMENT NUMBER 3
MOCKUP MODEL B -- 15 lbs.
NECK SUPPORTED

LAST 30 SECOND INTERVAL
ALL SIX SUBJECTS



AIMING STEADINESS DATA DISPERSAL PATTERN
Figure B-8

Experiment 1 (see Figure B-4) indicates rather gross unsteadiness for the combined subjects. Maximum deviation from the common starting point (center of reticle) is four degrees. This was the worst performance exhibited during the three experiments. Apparently, the unsteadiness experienced here is due to rapid fatigue of the muscles involved with holding the device.

Performance data obtained from an identical interval of time during Experiment 2 (see Figure B-5) reveal a marked improvement in steadiness with the same device with a more comfortable method of support. Here, the device was supported against the side of the body with the arm in a bent position. During the first interval (approximately the first two minutes of the experiment), the light spot never deviated more than one degree, fifty minutes (1° 50') from the starting point. However, a deterioration in steadiness is evidenced for the last thirty second performance interval (see Figure B-6) which began at seven and one-half minutes after the start. During this interval, maximum deviation from the starting point was two degrees, forty minutes (2° 40'). This deterioration appears to be due to the subject's inability to remember the location of the starting point (target marker) once it had been extinguished at the beginning of the run. Consequently, the subjects wandered off in various directions thinking they were still aiming at the target marker. It is interesting to observe that performance is dispersed during this last interval into a vertical pattern with the starting point at the center. This suggests that there might be a more unsteady vertical component involved with the device when it is supported against the side of the body.

In reference to Experiment 3, dealing with mockup Model B, it should be emphasized that a fair comparison can not be made with Model A because of the large difference in weight. Due to the desirability of providing steadiness data on the alternative design concept using a realistic weight of fifteen pounds, these data were collected. Regardless of the advantages of directly comparable data, it was not possible to run a separate experiment using a five-pound model of this configuration within the time available for experimentation.

Performance data obtained with mockup Model B (see Figures B-7 and B-8) indicate that steadiness remained within three degrees (3°) of the starting point even during the last period of the experiment. Subject Number 3 and Subject Number 6 accounted for all the deviation outside of the two degree performance circle. Both subjects appeared to experience difficulty in remembering where the target marker had been. During the last interval (see Figure B-8) Subject Number 3's aiming point is represented by the small separate pattern at the 250° position on the grid. After questioning the subject, he stated that his knees became tired and he shifted his weight. This may account for his performance. Subject Number 6 complained of a strained back muscle prior to the experiment but thought it would not make a difference in his performance. After completing his run he complained that the device felt heavy around his neck and that he had difficulty in remembering where the target marker had been.

As might be expected, examination of individual performance during the three experiments revealed a great degree of individual difference in performance. Some subjects did consistently better than others regardless of the device or the method of support. Even so, the combined evaluation of objective endurance data in Experiment 1, subjective fatigue reports in Experiments 2 and 3, and the aiming steadiness dispersal patterns in all three, provides basis for two, rather clear-cut conclusions. First, the neck strap support mode is preferable to the handheld mode, even when the elbow is supported. Second, with a six degree beam, as has been designated for the radar set and the neck strap support mode, unsteadiness does not appear to be a serious problem.

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DUNLAP AND ASSOCIATES, INC., Stamford, Connecticut
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AN/PPS-6 ( ) by L. L. Vallerie, R. T. McCay and J. Wm. Dunlap, January 62,
57 p. incl. illus. (Contract No. DA 36-039 SC-78921, D/A Task No. 3A95 20 001 01)
Final Report on Task Order . 18F — Unclassified report

A developmental, lightweight, handheld radar set, AN/PPS-6 ( ), is described; the projected mission of the system is summarized; and relevant human capabilities are reviewed. Based upon these factors, an allocation of function between the operator and his equipment is presented. The original prototype model of the equipment is reviewed from the human factors viewpoint, and an alternative design concept is presented. Details of the system mission analysis are presented in Appendix A, and a report of three laboratory studies of aiming steadiness is given in Appendix B.

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