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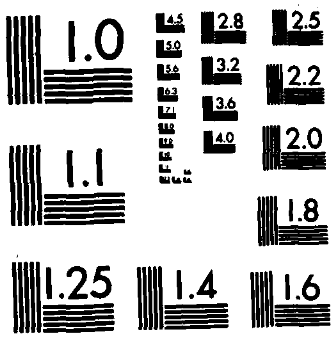

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COLLISION AVOIDANCE SYSTEM (CAS): HUMAN FACTORS ENGINEERING EVALUATION

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San Diego, California 92152

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COLLISION AVOIDANCE SYSTEM (CAS): HUMAN FACTORS ENGINEERING EVALUATION

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The Collision Avoidance System (CAS), a computerized navigational aid that was installed aboard a Navy ship for test and evaluation, provided senior bridge officers with reliable information that enabled them to make a rapid assessment of threatening situations and react accordingly. Although its effectiveness was impaired because of inadequate and inconsistent labeling of controls, inconsistent information display methods, and inefficient layout of controls CAS is considered to be a beneficial navigational aid. Operator training requirements are minimal and CAS has no impact on manpower

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) requirements. Proposed changes for redesigning CAS data display presentation, controls, and control panels were developed to eliminate the human engineering deficiencies identified to the extent possible. Also, a format for an operation manual and training guide for CAS was developed.

FOREWORD

In an attempt to improve the navigational safety of Navy ships, a computerized navigational aid, the Collision Avoidance System (CAS II), was installed in USS RANGER (CV 61) for test and evaluation. The Navy Personnel Research and Development Center was tasked by Commander Naval Air Force, U.S. Pacific Fleet (Code 73) to conduct the human factors engineering portion of the evaluation.

CAS is designed to serve as an aid in managing own ship's movements during hazardous and heavy sea traffic conditions. It provides bridge watch personnel with a visual presentation and computer-developed data that enables them to assess the entire navigation situation and resolve navigation problems. Although numerous human factor engineering deficiencies were noted, CAS was considered to be a desirable and beneficial navigation aid. However, CAS does not alter or decrease watch officers' decision-making responsibilities. Further, it does not replace any of the present navigation systems because it is totally dependent upon other shipboard sensing systems for data. Degradation or failure of any of the data input systems will adversely affect the results provided by CAS.

Appreciation is expressed to the Sperry Marine Division, Sperry Corporation for granting permission to reference and reproduce portions of their operation manual in this report. In addition, the cooperation and assistance of RANGER bridge watch personnel, expecially the Navigation Department headed by CAPT C. P. Downs, in providing information used in the analysis and evaluation are greatly appreciated.

JAMES F. KELLY, JR.
Commanding Officer

JAMES W. TWEEDDALE
Technical Director

SUMMARY

Problem

A computerized navigational aid, known as the Collision Avoidance System (CAS II), was installed in USS RANGER (CV 61) for test and evaluation. The Navy Personnel Research and Development Center was tasked by Commander Naval Air Force, U.S. Pacific Fleet (Code 73) to conduct the human factors engineering (HFE) portion of the evaluation.

Objective

The objectives of the evaluation were to determine (1) the effectiveness of CAS in predicting hazardous navigational conditions and its compatibility with other navigation systems, (2) the extent to which its displays, controls, and control panels conform to good HFE design practices, and (3) its immediate and long-range impact on manpower and training requirements.

Approach

1. During CAS installation, Center human factors engineers visited RANGER to gain familiarity with the system. After CAS became operational, they interviewed RANGER personnel to gain an insight into their initial experiences with using and operating the CAS.

2. Based on interview results and material included in the CAS operation manual, they analyzed CAS displays, controls, and control panels to determine whether they conformed with good HFE practices. Also, they developed guidelines for performing underway operational evaluation of CAS and an interview guide for conducting follow-up interviews.

3. During RANGER's Western Pacific deployment, a human factors engineer visited the ship to conduct a series of follow-up interviews and to observe and evaluate CAS's performance under actual operating conditions.

Results and Conclusions

1. CAS is considered to be a very effective and beneficial addition to a ship's navigation system because it accurately and rapidly provides a variety of target data. It is designed for use as a management tool by the commanding officer, navigator, and officer of the deck to assess the overall navigation situation. Targets that pose greatest threat to own ship can be quickly and readily identified, and the effects of proposed changes in course and speed to avoid hazardous conditions can be evaluated.

2. Numerous HFE design deficiencies were noted. The major deficiencies are the use of multipurpose controls whose functions and purposes are not always clear, inconsistent methods for displaying and identifying alphanumeric data presentations, poor construction of certain controls, improper location of numerous controls, and an ineffective alarm system.

3. Although the system is in continuous operation, it does not require a full-time operator. It is manned (by senior bridge watch officers) only when traffic conditions indicate that collision avoidance data are needed to evaluate threatening situations. Thus, there is no impact on manpower requirements.

4. CAS has a minimal impact on training. Formal training is not required because operators can learn to use CAS through on-the-job training and hands-on experience. However, the system, as designed, prolongs training time because operators must commit the functions of the multipurpose controls to memory. Also, its operating procedures are not designed to permit quick and easy reference during system operation.

Proposed Revision

A proposed revision for the CAS data display, controls, and control panels was developed to eliminate the HFE deficiencies identified to the extent possible. Also, a format for an operation manual and training guide was developed to enable operators to learn to use CAS with little difficulty.

Recommendations

1. If a decision is made to acquire CAS for installation on additional ships, it should be redesigned and modified with greater emphasis given to HFE design practices. The proposed changes for the data display presentations, controls, and control panels described herein should serve as a guide toward that objective.

2. A redesigned CAS for Navy use should include the vector display mode of operation as the primary mode of operation and, like the CAS tested in RANGER, should include (a) capabilities for providing alternate sources of radar and speed data input and (b) controls to maximize the definition and uniformity of targets displayed on the plan position indicator (PPI).

3. To simplify and reduce the amount of operator training necessary, the operating manual should be redesigned in the format presented herein.

CONTENTS

LIST OF FIGURES

INTRODUCTION

Problem

Various versions of computerized navigational aids have been developed to minimize or reduce the number of serious collisions at sea experienced by commercial ships. These navigational aids have been well accepted by navigation officers, and are now in widespread use throughout the commercial fleets of the United States and of numerous foreign countries.

Navy ships, of course, are not immune to collisions at sea. Over the years, such collisions have resulted in serious losses of physical and manpower assets. Thus, Commander Naval Air Force, U.S. Pacific Fleet (COMNAVAIRPAC), under the auspices of the Naval Sea Systems Command, was designated to evaluate the various computerized navigational aids available and select one for test and evaluation on a Navy ship. Subsequently, the collision avoidance system (CAS II),[1] which was designed, developed, and manufactured by the Sperry Corporation, was acquired by COMNAVAIRPAC and installed aboard USS RANGER (CV 61). The Navy Personnel Research and Development Center was tasked to conduct the human factors engineering (HFE) portion of the evaluation.

Purpose

The purposes of the evaluation were to determine:

1. The degree to which CAS, when manned and operated by the normal bridge watch team, facilitates the prediction and avoidance of potentially hazardous ship movements, and is compatible with other bridge equipments and functions associated with ship navigation.

2. The extent to which CAS conforms to good HFE design practices by examining operational characteristics and by analyzing and evaluating the features, design, and layout of the CAS displays, controls, and control panel.

3. Immediate and long-range manpower and training implications and requirements by identifying the magnitude of the operational tasks, assessing operator time and attention demands, and analyzing the extent and type of formal and informal training required to develop operator proficiency.

Background

CAS is a complete self-contained unit that is interfaced with shipboard radar, gyrocompass, and speed data generating systems. The CAS console, with its displays and controls, is illustrated in Figure 1. CAS performs two primary functions: (1) Based on data obtained from shipboard input systems, it computes and displays collision threat data, making bridge personnel aware of possible collision threats from other ships, and (2) it helps identify manuevers own ship can take to avoid such collisions.

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[1]CAS is a registered trademark of the Sperry Corporation. CAS II refers to the specific model that was acquired and evaluated. For simplicity, the system will be referred to as CAS throughout this report.

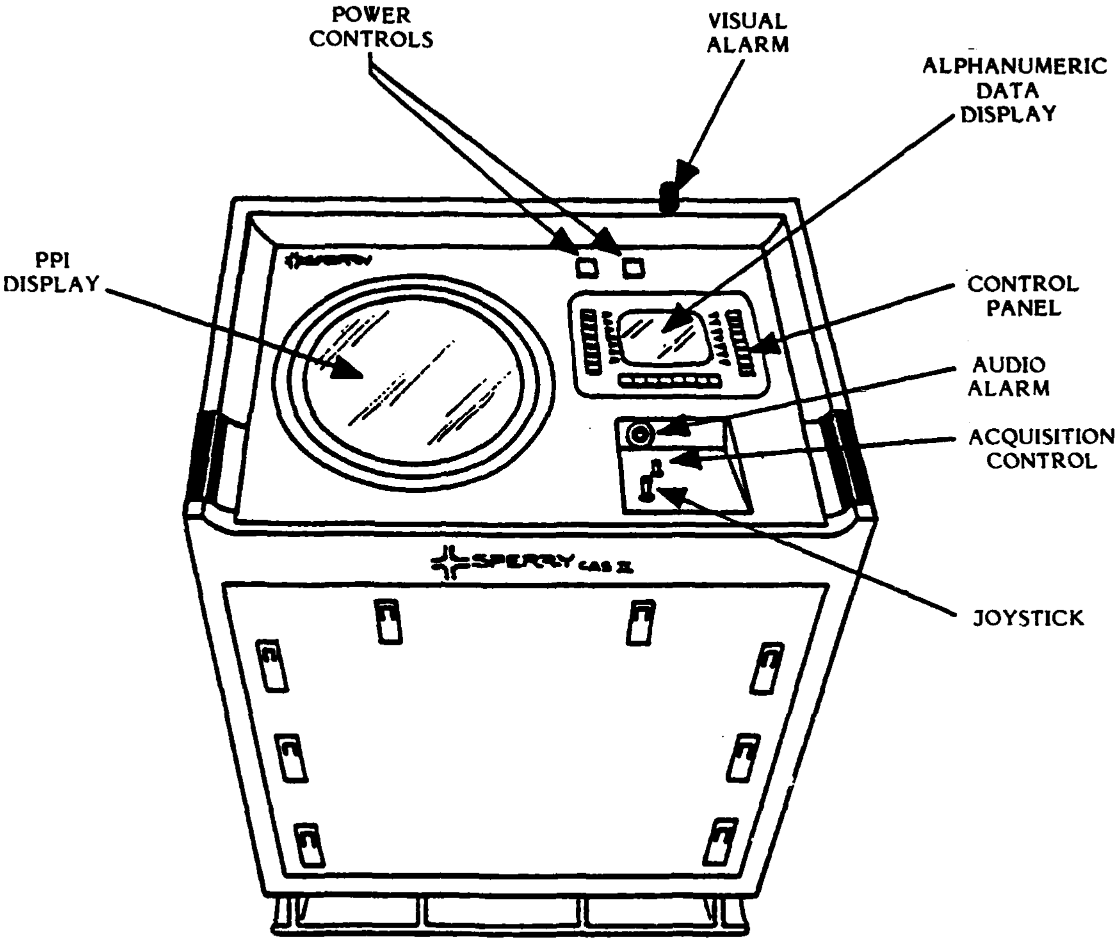
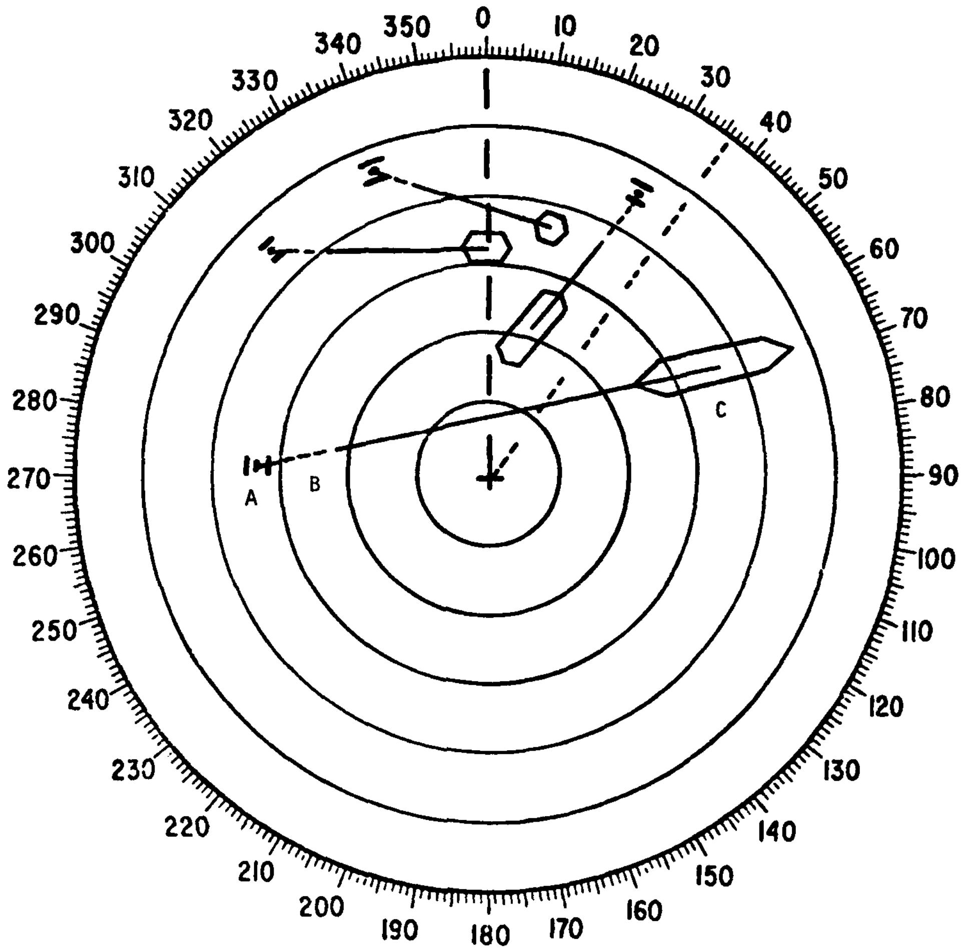


Figure 1. CAS console with displays and controls.

All targets detected by the radar are presented on the CAS plan position indicator (PPI). A sample PPI display presentation is presented in Figure 2. If the CAS operator considers a particular target to be of interest, he uses the joystick to place an acquisition symbol over the target and then presses the acquisition control. A short video line segment or tracking window appears on either side of the target, indicating that the target is being tracked (A on Figure 2).

After the newly acquired target has been initially evaluated by the CAS processsor, a segmented speed vector, which extends outward from the target in the direction of the target's present course, appears on the PPI (B on Figure 2). The length of the speed vector equals the distance the target will travel at its present speed in a fixed 6-minute time period.

After CAS has accumulated a sufficient amount of data on a newly acquired target (30 radar scans), it computes the area containing the closest point of approach (CPA) of the target to own ship's path. This computation considers all possible own ship's headings (i.e., it assumes that own ship can remain on its present course or change to any other course throughout a range of 360 degrees). If the calculations determine that an area exists where the target and own ship can come within a specified distance of each other, a six-sided PAD (for predicted area of danger) outlining this area will appear on the PPI (C on Figure 2), along with a solid track line extending from the center of the CPA to the target's speed vector. In heavy traffic areas and at times when a large number of targets are under track, the number of PADs and track lines displayed on the PPI can be confusing.



A = Target and tracking window.
B = Segmented speed vector to show distance target will travel in 6 minutes.
C = Predicted area of danger (PAD).

Figure 2. Target tracking display on the CAS PPI--PADS mode of operation.

To obtain navigation data on an acquired target, the CAS operator positions the acquisition symbol over the target and presses the collision avoidance (C/A) data control. Data needed to evaluate the target, including target range, bearing, speed, course, CPA, and time to CPA (TCPA), then appear on the CAS alphanumeric data display. The readout for a typical target is displayed in Figure 3.

If CAS determines that own ship is on a collision course with a target, it activates both a visual and an audio alarm (see Figure 1). To avoid a collision, it may be necessary to change own ship's course and/or speed. Possible safe courses are represented on the PPI by the open areas that do not intersect a PAD. If the operator wishes to do so, he can enter a proposed or trial course and/or speed change into CAS and view the computed results on the PPI. If the change places own ship on a noncollision course, bridge personnel use the information to make the actual course and/or speed change.

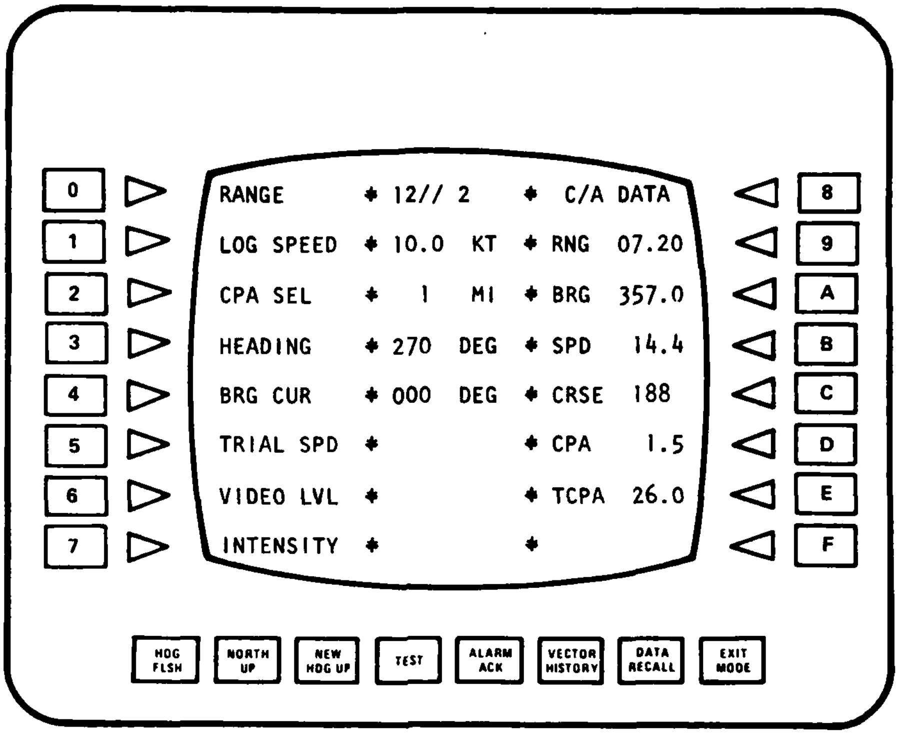


Figure 3. Collision avoidance (C/A) data for a typical target on the CAS alphanumeric data display.

The PAD display mode is CAS's primary mode of operation. The CAS model installed in RANGER was also equipped with an alternate or secondary mode of operation to provide for the display of true and relative motion vectors. In the vector display mode, the operator selects a true or relative motion vector display for all targets under track. The time-length (magnitude) of the motion vectors is operator-selectable (in contrast to the fixed 6-minute motion vectors displayed in the PAD mode). When CAS computes a possible point of collision in the vector mode, a symbol (flashing T) appears on the PPI next to the threatening target, rather than a PAD and a track line (see Figure 4). After the operator assesses the possible collision threat by adjusting the vector time-length, the point of possible collision is displayed on the PPI, and the time it will take own ship to reach that point is displayed on the data display.

Also, the CAS in RANGER was equipped with (1) guard rings to monitor and acquire targets automatically, and (2) two controls--labelled fast-time-constant (FTC) and sensitivity-time-control (STC)--to provide the operator with increased control over target uniformity and definition on the PPI display. The guard rings consist of two 3/8-nautical-mile-deep rings or ring segments that are scanned for untracked targets. The range and end bearings (relative to own ship) for each guard ring are operator-selectable. Untracked targets that penetrate a guard ring will either be acquired automatically or will activate the alarms, depending upon operator control settings.

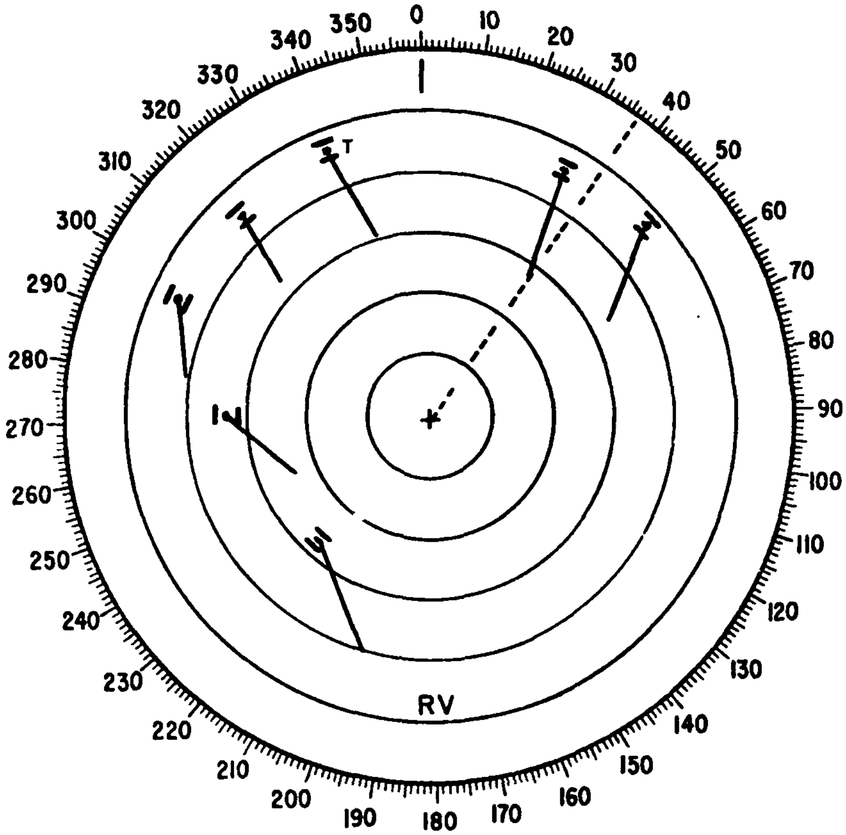


Figure 4. Target tracking display on the CAS PPI--relative vector (RV) display mode of operation.

The accuracy of the CAS PPI presentation and the generation of C/A data is totally dependent on the accuracy and consistency of data from the shipboard input systems. Thus, to offset or minimize the effects of failure or degradation of these system, the CAS model installed in RANGER was equipped with (1) a radar interswitching capability that allowed operators to select from three alternate sources of radar input (SPA-10, SPS-43, and LPN-66) for target detection and tracking, and (2) a dual-speed log interface, which provides an additional speed input source.

APPROACH

NAVPERSRANDCEN human factors engineers evaluated CAS in three phases, as described below.

1. During and following CAS installation, they visited RANGER on several occasions to develop a basic knowledge and understanding of the system. During these visits, they held informal interviews and discussions with CAS design engineers and other manufacturer's representatives. After RANGER's southern California operations, during which time CAS became operational, they interviewed RANGER personnel to obtain information on their initial reactions to and experiences with the CAS.

2. Based on data obtained during RANGER visits and material included in the CAS operating manual,[2] they analyzed CAS displays, controls, and control panels to determine whether design and layout characteristics conformed with good HFE practices. Also, they evaluated operating procedures to make a preliminary assessment of their potential impact on manpower and training requirements. Finally, based on RANGER personnel interview results, they developed (a) guidelines for performing underway operational observations of CAS, and (b) an interview guide for use in conducting follow-up interviews with user personnel.

3. During a Western Pacific cruise, after RANGER personnel had gained operational experience with CAS, one human factors engineer visited RANGER to observe CAS under actual operating conditions (including normal underway steaming and heavy traffic conditions during harbor entry). During the observation period, he evaluated CAS's operational characteristics, and conducted follow-up interviews with all personnel experienced in the use and operation of CAS.

RESULTS AND DISCUSSION

General Appraisal of CAS

Utility

RANGER personnel, including the commanding officer (CO) and the entire bridge watch team, consider CAS to be one of the more beneficial and effective navigational aids to have been added to any ship in recent years.

The target motion vectors displayed on the PPI for all targets under track and the threat assessment data available for each target on the data display allow watch officers to (1) view and assess the entire navigational situation quickly and (2) select targets that pose the greatest threat for close surveillance. The PPI target presentation and the C/A data computed for threatening targets enables them to make maneuvering decisions quickly when faced with a potential collision condition.

Also, CAS allows watch officers to compute closest point of approach (CPA) on targets much faster than they can with the maneuvering board (MANBOARD). When an officer is using MANBOARD to resolve a maneuvering problem, he may create several others. When he is using CAS to solve the same problem, he can avoid any movements that will create other problems, since the effects of a proposed change on all surrounding traffic are displayed on the PPI.

Interface with Other Navigation Systems

CAS does not alter or decrease any of the watch officer's decision-making responsibilities, nor does it replace current navigational systems. For example, even though using MANBOARD is a slower process than using CAS, MANBOARD is considered to be a more precise method for computing CPA on specific targets. Thus, CAS and MANBOARD are considered as complementary rather than redundant systems.

A senior member of the bridge watch team (the CO, the navigator, or the officer of the deck (OOD)) operates CAS, and other team members operate the radar repeaters. The surface watch team in the combat information center (CIC) continues to function in its

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[2]Sperry Marine Systems. CAS II Collision Avoidance System operation manual. November 1981.

normal manner by providing appropriate information to the bridge. Any apparent redundancies are considered highly desirable in assuring the ship's navigational safety.

Impact on Seamanship

Prior to and during installation of CAS, some RANGER personnel commented negatively as to its intended usefulness and its potential adverse impact on seamanship. However, after underway experiences with CAS, their reservations about the system disappeared. CAS is a management tool that is used primarily by senior bridge personnel to manage the entire traffic situation more effectively. Junior bridge personnel continue to use the standard navigational tools and aids such as the MANBOARD and radar repeaters. Because junior personnel continue to practice and develop fundamental navigational skills, CAS's impact on seamanship is expected to be minimal.

Modes of Operation

Although the PAD display is CAS's primary mode of operation, it was used very little by RANGER personnel during the normal course of operations. When using the vector display mode, watch officers selected relative motion vectors for display more often than they did true motion vectors because relative vectors provide a better concept of what other traffic is doing relative to own ship. Also, watch officers are trained to work with relative movement; for example, all MANBOARD plots are made using relative course and speed vectors.

Since watch officers consider the vector display mode to be more desirable than the PAD mode, it should be retained and considered as the primary mode of operation. However, there are some operating inconveniences that should be corrected. For example, two steps are required to change from true to relative motion vector displays (and reverse). This could be changed to a convenient single-step procedure by redesigning the operating controls. Other handling problems are discussed in Appendix A (p. A-2).

Guard Rings

The operation of the guard rings was not observed because they were not functioning during the underway portion of the evaluation. However, bridge personnel indicated that, although the rings had operated satisfactorily and were used on a limited number of occasions, their usefulness was minimal and resulted in reduced opportunities to interact with CAS. Although the guard rings were intended to reduce the human element in the target acquisition process, most officers agreed that, because of the relatively large number of bridge watch standers and the CIC surface watch team, there is little need for automatic target acquisition. With or without the guard rings, all targets detected within the selected scanning range are displayed on CAS's PPI (as well as on the surface watch radars and on the bridge radar repeaters). The only decision-making function performed by the guard rings is to place untracked targets in track.

The guard rings appear to be more suitable for commercial ships where few, if any, watch standers are on the bridge during normal steaming. On Navy ships, overreliance on the guard rings could result in reduced attentiveness and alertness on the part of the bridge watch team. For these reasons, the guard rings should not be included in a Navy model, unless they prove to be more useful on ships smaller than CVs.

Bridge Space Requirements

Prior to installation, ship's personnel indicated that the CAS console was much too big for the limited amount of space available on RANGER's bridge. The console is 40 inches wide and 25.2 inches deep, and requires about 7 square feet of deck space.

However, since the miniature electronic components inside the cabinet require a minimal amount of space (the cathode ray tube (CRT) and the power supply are the largest items), it appears that the size of the cabinet may have been dictated largely by the size of the power supply and the working surface for the displays and operating controls. This surface can be reduced in size by moving the displays closer together and the power supply can be physically separated from the console, thus enabling a reduction in the size of the console and in the amount of bridge deck space required.

Human Factors Engineering Evaluation

Displays, Controls, and Control Panels

In evaluating the displays, controls, and control panels, numerous deficiencies in HFE design practices were noted. These deficiencies are summarily described below and in detail, with illustrations, in Appendix A. All CAS controls and control panels are illustrated in Figure 5.

Many controls are inadequately labeled and inconsistent labeling procedures are used. For example, in many instances, the labels or legends that appear on the data display serve as status indicators, rather than as identifiers of the function or mode controlled. There is nothing on the data display to indicate to the operator the exact purpose of the control. In other instances, data display legends do indicate the function or mode controlled.

The alphanumeric data display presents various columnar data readouts in the right-hand column during varying operating conditions. However, the means used to identify the displayed information varies. For example, for CPA selection, a column label appears at the top of the column; for bearing cursor (BRG CUR) adjustment, it appears at the bottom. In two instances, no column label appears at all (see Appendix A, p. A-3).

The acquisition control and the joystick (Nos. 28 and 29 on Figure 5) are the two most frequently used controls. The acquisition control, which is used to acquire selected targets for tracking, is encased in a transparent dome made of a synthetic material that appears to contain a viscous substance. Because of the dome's construction, it is doubtful whether it could withstand frequent use over an extended period of time. In addition, when the acquisition control is depressed, there is no audible click or other means to indicate whether or not it has been activated. Neither the construction nor the operation of the switch meets military specifications.[3]

Although the joystick, used to select targets, is suitably located and performs the function for which designed, it appears to be somewhat delicate and fragile in construction and appearance. Whether it could withstand the rugged treatment to which it will be subjected over a prolonged period of time is unknown. Some officers indicated that a ball-type control similar to that used on most radar consoles might be sturdier and more durable.

Operator training and operator efficiency are adversely affected because of the control panel layout. For example, all of the operating controls are placed around or near the data display. Some of these controls are used to control the data display; others, the PPI display; and still others, the data display and PPI simultaneously. A separate panel containing all of the PPI controls located near the PPI display would not only make the controls easier to identify and locate but, also, more convenient to the operator.

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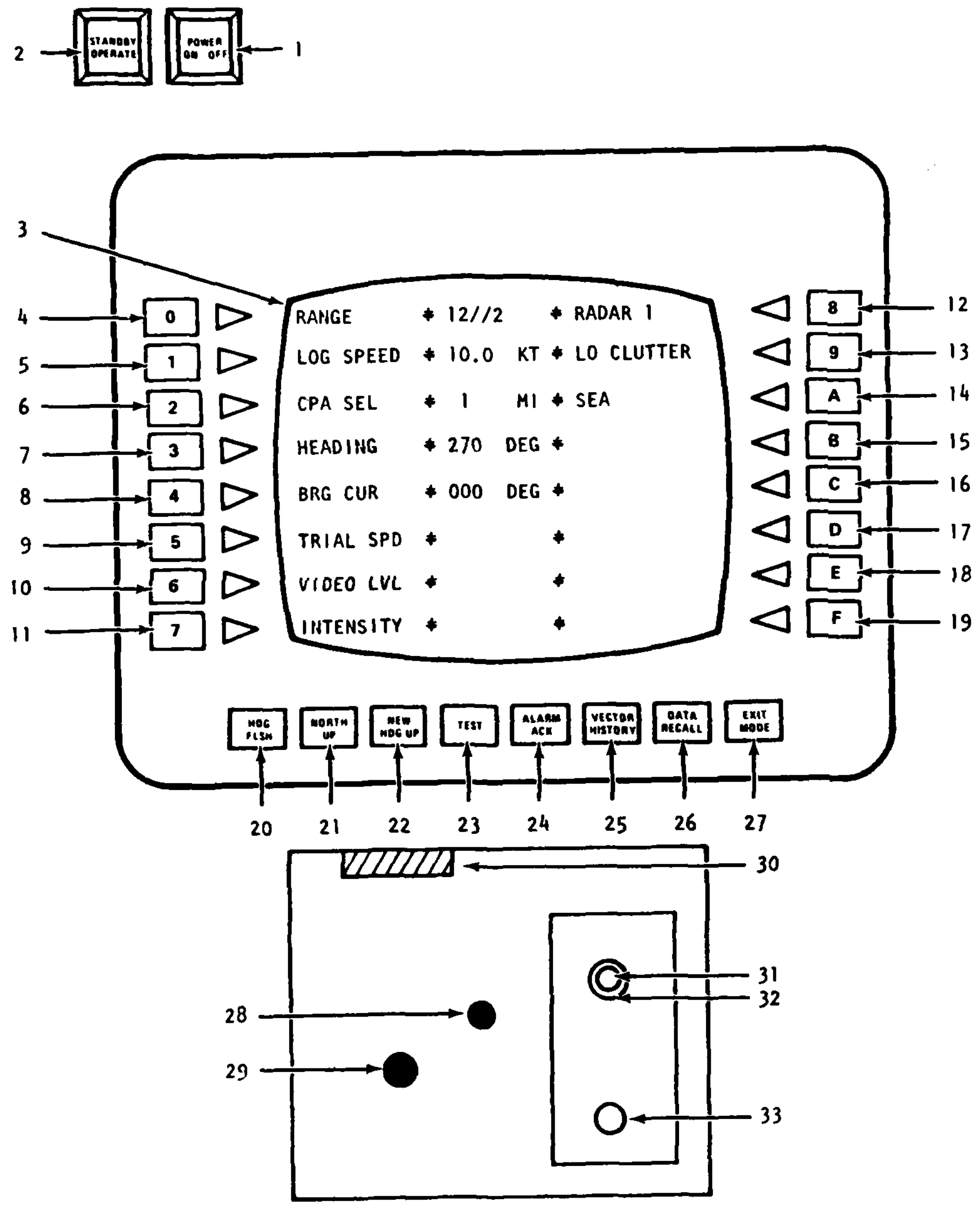
[3]Department of Defense. Military Standard: Human engineering design criteria for military systems, equipment, and facilities (MIL-STD-1472C). 2 May 1981.



1. Power on/off control
2. Standby/operate control
3. Data display
4. Range, control 0
5. Log/manual speed, control 1
6. CPA select, control 2
7. Heading, control 3
8. Bearing cursor, control 4
9. Trial speed, control 5
10. Video level, control 6
11. Intensity, control 7
12. Nondedicated, control 8
13. Nondedicated, control 9
14. Nondedicated, control A
15. Nondedicated, control B
16. Nondedicated, control C
17. Nondedicated, control D
18. Nondedicated, control E
19. Nondedicated, control F
20. Heading flasher control
21. North up control
22. New heading up control
23. Test control
24. Alarm acknowledgment control
25. Vector history control
26. Data recall control
27. Exit mode control
28. Acquisition control
29. Joystick
30. Audio alarm
31. Sensitivity-time control
32. Fast-time-constant control
33. Panel lamp

Figure 5. CAS alphanumeric data display, controls, and control panels.

Alarms

The CAS console includes two alarms to alert bridge personnel whenever it is determined that a threatening condition exists or that a target has been lost: (1) a visual alarm, a small red lamp located at the upper edge of the console, and (2) an audio alarm, a buzzer located beneath the data display (see Figure 1). Bridge personnel consider the alarms, particularly the audio one, to be more of a nuisance than a help. For this reason, they turned the audio alarm volume level to its minimum level (inaudible) most of the time, and disabled the remote audio alarm that was installed in the navigation office adjacent to the bridge. Since CAS was designed to compute areas of danger on all tracked targets for all possible own ship headings, some conditions that activate the alarms would be real threats only if the ship changed heading. The alarm system was not designed to discriminate between real and potential threats (the data display, however, does indicate the condition that caused the alarms to be activated). In any event, the alarm system is of little practical value if bridge personnel feel it causes too many false alerts and turn it off most of the time. An audible alarm with different sounds to distinguish degrees of threat would be more practical.

Although the visual alarm is considered less of a nuisance than the audio alarm, the lamp enclosure protrudes somewhat conspicuously from the console. Since the console does present somewhat of a barrier to the main traffic lane on the bridge, anyone passing too closely could catch clothing, equipment straps, etc. on the enclosure. The amount of abuse the lamp can withstand before it becomes loose or dislodged is not known. It would appear to be more suitable to build a lamp enclosure with a rounded durable dome into the console. A visual alarm with several colors of lamps to distinguish degrees of threat would be more suitable.

PPI Visibility

Although the PPI CRT is supposed to permit maximum daytime visibility, visibility was found to be inadequate during daylight underway operations. During the initial operation, the CRT was damaged because operators turned the brightness level to maximum to provide better visibility. To resolve the problem, the manufacturer provided and installed a detachable hood. While the hood does improve daytime visibility considerably, further improvement is needed. Also, the hood restricts the viewing angle and limits the number of people that can view the PPI display simultaneously.

Console Finish

After several months of operational use, the front or working side of the console was almost devoid of paint at waist-height level, undoubtedly because of the metal belt buckles and binoculars worn by operators. The console should be coated with a sturdier, more durable paint or those surfaces subject to high wear should be covered with suitable nonpainted material.

Impact on Manpower Requirements

As indicated previously, CAS is an additional or supplemental navigational aid used in conjunction with standard navigational systems and devices. Although CAS is in a continuous operating mode, it is manned only during heavy traffic conditions and during harbor entry and exit. Since manning and operation are performed primarily by the navigator or the OOD, who are part of the normal bridge watch team, additional personnel are not required.

CAS duplicates many of the functions performed by other navigational systems and devices. However, since CAS is an electronic device, it would be useless as a navigational aid in the event of failure or disruption in ship's power, failure or degradation in ship's interfaced data generating input systems, or failure of a major CAS component. Thus, normal bridge manning is required to continue operation of the standard navigation devices.

Since CAS does not increase or decrease the number of personnel required on the bridge watch team, it has no impact on manpower requirements.

Impact on Training Requirements

The overall impact of CAS on training requirements is minimal. CAS is a relatively simple system to operate; on-the-job training (OJT) under the guidance of an experienced operator is sufficient to develop operator skills. After the operator is given a basic orientation, including a demonstration of system setup and operating procedures, he can best gain proficiency by hands-on training. It should be noted, however, that an operator's learning process is hampered by inconsistent use and inadequate labeling of controls. The CAS operating manual[4] states that the number of operating controls was kept to a minimum to simplify operations. It is true that the number of operating controls was kept to a minimum, but only by using nondedicated, multipurpose controls, which turned out to be more of a handicap than an advantage. Before an operator can operate the system efficiently, he must commit to memory the operating functions of the various non-dedicated controls.

Operators can teach themselves to operate CAS by studying the operating manual and then using the system in conjunction with the manual. However, it was noted that, instead of studying the manual, operators learn to use the system by using the trial-and-error method, primarily because it is difficult to identify and locate specific items within the manual. If manuals are to be used in conjunction with system operation, they must be easy to use and well organized.

User Suggestions for Improving/Expanding CAS

A number of user suggestions for improving and expanding CAS are discussed below.

1. Status Recorder. Several users suggested that a recorder, with functions similar to those of recorders used on commercial aircraft, be incorporated into CAS. The recorder would be activated during serious collision-threatening conditions to record ship and target movements. In the event of a collision, a recording of the significant events and maneuvers prior to the collision would be of invaluable assistance during the subsequent investigation. The authors feel that this suggestion has sufficient merit to warrant a feasibility study.

2. Backlighted Glass Overlay. Another suggestion was that a backlighted glass overlay, similar to the glass overlay used on radar repeaters, be installed over the face of the PPI display to enable operators to record the identity of selected and specific targets. Although such a feature may be helpful, it does not appear to be essential for effective CAS operation and usage. Information on target identification is maintained on the status board and on the radar repeaters, and is readily available to all bridge personnel.

3. CPA Select. The maximum CPA distance that can be selected on CAS is 2 miles. However, because COs usually prefer to use and work with a 5-mile CPA limit, it was suggested that, if CAS were redesigned for Navy use, its capability be increased to accept a 5-mile CPA distance.

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[4]Op. cit. CAS operation manual.

4. Data Readout Sequence. Target range and bearing data are displayed in that order (see Figure 2, Appendix A), even though these data are customarily referred to in the inverse order. The same is true for course and speed data (not illustrated). It was suggested that these two sets of data be displayed in the same order in which they are customarily used and referenced.

5. Target Bearing Data. In providing collision avoidance data on a target, CPA range and time data are displayed. Since CAS apparently develops bearing data in computing collision avoidance data, it was suggested that such bearing data also be displayed in data sequence of bearing, range, and time.

PROPOSAL FOR IMPROVING CAS AND ITS OPERATION

Proposed Revision for CAS Data Display, Controls, and Control Panels

Specifications

If the Navy decides to include CAS in its shipboard navigational system, it is important that the HFE deficiencies identified be eliminated to the extent possible. Therefore, to demonstrate possible changes and improvements, a proposed revision of the CAS data display, controls, and control panels was developed to eliminate the majority of the deficiencies. During development, an attempt was made to minimize the need for operator training, while maximizing operational efficiency and effectiveness. In any revision of CAS, design engineers should attempt to satisfy the following criteria:

1. Initial steps for entering the data display should be similar to those currently used unless it can be demonstrated that a different approach is superior. The same is true for the follow-on steps after entry into the display.

2. To the extent possible, readouts on the data display after entry into an operational mode should indicate to the operator what to do when a follow-on operation is required.

3. Information that is no longer required to monitor system status or perform collision avoidance functions should not remain on the data display.

4. The number of steps required by an operator to achieve an end result should be reduced to a minimum.

5. Operating controls should be clearly identified as to their purpose and function. Controls should be grouped by purpose and function insofar as is practical. Further, they should be arranged within groups in a logical operational sequence and/or for convenience so that the more frequently used controls are easily identifiable and accessible.

Description

Figure 6 illustrates one way that the CAS displays, controls, and control panels could be revised to eliminate identified deficiencies.[5] The final version should be designed by a multidisciplinary team, including a human factors engineer.

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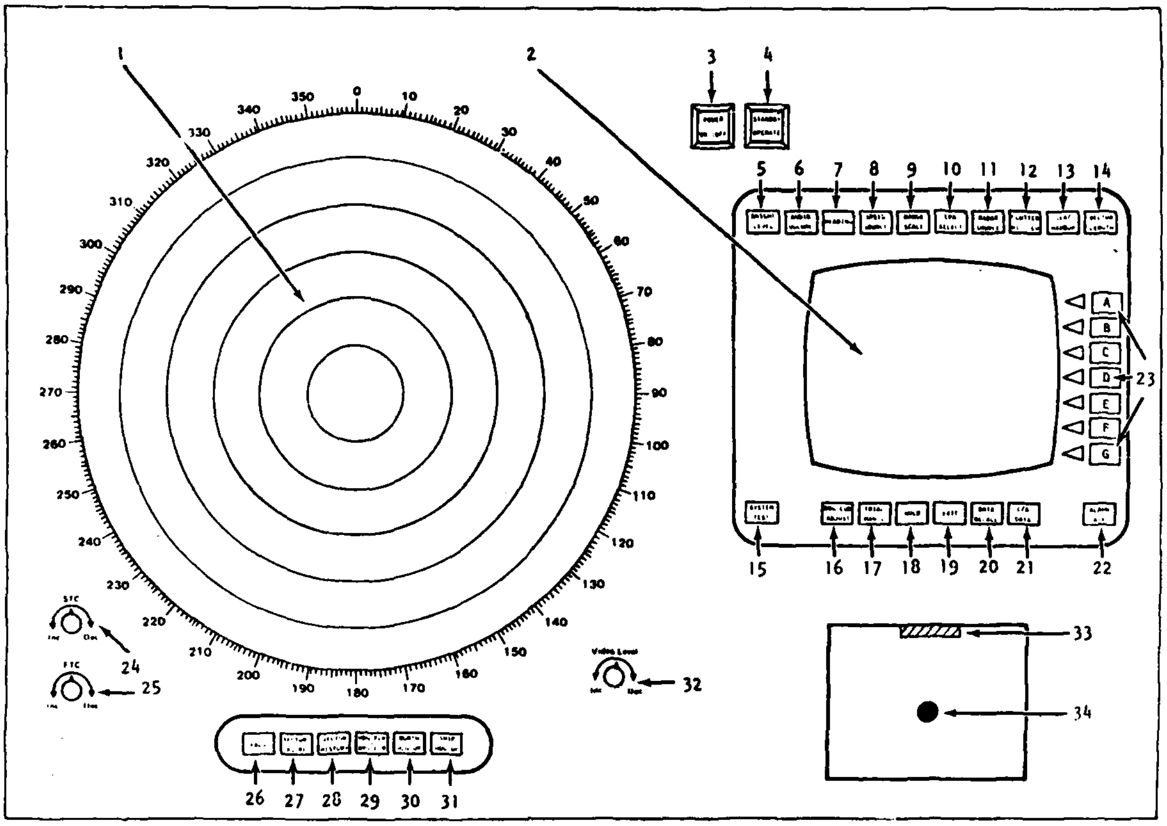
[5]User suggestions regarding CPA select, data readout sequence, and target bearing data were considered in developing the revised CAS.



1. Plan position indicator (PPI) display
2. Alphanumeric data display
3. Power on/off control
4. Standby/operate control
5. Data display, panel, symbols, and sweep brightness level primary control
6. Audio alarm volume primary control
7. Ship's heading input primary control
8. Ship's speed source selection primary control
9. Monitoring range scale selection primary control
10. Closest point of approach (CPA) range selection primary control
11. Tracking radar source selection primary control
12. PPI display visibility clutter control
13. Sea/harbor navigation selection control
14. Vector time-length adjustment primary control
15. Built-in test equipment activation control
16. Bearing cursor adjustment/setting primary control
17. Trial maneuver selection primary control
18. Hold control for retaining data display in a secondary display mode
19. Exit control for returning data display to initial display mode
20. Collision avoidance data recall control (for a previously selected target)
21. Initial collision avoidance data display control (for a newly selected target)
22. Collision alarm acknowledgment control
23. Nondedicated secondary controls used in conjunction with primary controls
24. PPI display sensitivity-time control
25. PPI display fast-time-constant control
26. PADS display mode selection control
27. True or relative motion vector display mode selection control
28. Vector history display selection control
29. Bearing cursor and heading flasher display on/off control
30. North heading up display selection control
31. Ship's heading up display selection control
32. PPI display video brightness level control
33. Audio alarm
34. Joystick

Not shown: Visual alarm lamp that is located on upper edge of the displays and control panel.

Figure 6. Proposed revision of CAS data display, controls, and control panels.

The revised version has 37 operating controls, compared to 30 in the original. By adding only 7 controls, the operation of CAS can be greatly simplified. The functions and operation of these controls are described in Appendix B.

Thirty-six of the controls (all but the joystick) are divided into five general groupings, as determined by function and frequency of use. These groupings are as follows:

1. The two controls at the upper-top center of the CAS console (Nos. 3 and 4) are used to apply power and place the system in operation. They are in the same location as before but their position is reversed, since the power control is used before the operation control.

2. The ten controls at the top of the data display (5-14) are used primarily during initial system turn-on to establish operating parameters and select data input sources. Each control is labeled to identify its specific purpose or function. In the original CAS, the functions of these controls were accomplished partially with dedicated controls at the bottom of the data display and partially with nondedicated controls.

3. The eight controls at the bottom of the data display (15-22) are used during the normal course of operation. Four (15, 19, 20, 22) are the same as on the present CAS but they have been repositioned to simplify location and identification during operation. Four (16, 17, 18, 21) are new controls that replace multipurpose controls.

4. The seven controls at the right side of the data display (23A-G) are nondedicated controls. (The original version had eight--8, 9, A-F.) These controls are operable only in conjunction with one of the labeled functional controls (5-11, 14, 16, 17). When the operator depresses a labeled functional control, appropriate labels and legends for the nondedicated controls will appear on the alphanumeric data display, indicating to the operator the settings and parameters of adjustment that are available to him. (Appendix B includes illustrated examples of how the nondedicated controls are used.)

5. Finally, nine controls appear at or near the bottom of the PPI display:

a. Three variable knob controls--24, 25, and 32--are used to define the quality, uniformity, and illumination level of the PPI video display. Controls 24 and 25 replace a concentric, or ganged, control and are relocated from the joystick control panel. Control 32 replaces a multipurpose control.

b. Six controls--26 to 31--are used to control the type of PPI display presentation. Controls 26 and 27 replace multipurpose controls, controls 28 and 30 are the same as on the present CAS, control 29 is changed to provide an on/off feature, and control 31 has been relabeled to clarify its function.

In addition to labeling, rearranging, and standardizing the use of operating controls, changes are proposed for the data display. Nonessential information will not appear on the data display--only that relevant to the immediate operation. Data that are displayed will be suitably labeled to provide appropriate identification to the user, the sequence of the displayed data will be changed to conform to Navy usage, and displays will be uniform to the extent possible. The revised display methods are fully explained in Appendix B.

Operation Manual and Training Guide

The extent to which operating procedures are used generally depends on the difficulty and organization of the material describing those procedures. Although the present CAS operation manual is complete, the organization of the material makes it somewhat difficult to understand. Information on specific operating procedures is difficult to locate. To correct these deficiencies, a format for an operator manual and training guide was developed and is presented in Appendix C. The proposed format is based on the proposed revision of CAS.

The proposed operation manual provides an illustration of the top panel or working surface of the CAS console. On this illustration, all controls are keyed to permit quick and easy reference to the descriptive material. The text provides, for each control, a description of its purpose and how it is used in the course of operations. Where appropriate, the text is accompanied by a figure demonstrating the control's operation.

Because CAS is relatively easy to operate, a separate training guide is not necessary. Instead, the detailed operating procedures can serve equally well in that capacity.

CONCLUSIONS

These conclusions were covered in the previous sections and are listed here for reader convenience.

1. CAS allows bridge watch officers to be more aware of and have more control over the entire navigational situation. CAS does not decrease or alter the watch officer's decision-making responsibilities; rather, it provides information that enables him to react more quickly in threatening situations.

2. CAS will have little or no impact on seamanship because it does not replace or substitute for any existing navigational systems. Instead, CAS is an additional aid that enables senior bridge watch officers to perform their navigational tasks more effectively and efficiently.

3. The guard rings included on RANGER's CAS to provide for automatic target acquisition are not considered essential for safe navigation; target acquisition can be accomplished easily by bridge watch standers.

4. Operators prefer the vector display mode of operation over the PAD mode because it enables them to view relative motion vectors on tracked targets. However, because it is a secondary mode of operation, there are some minor operating inconveniences.

5. Numerous HFE design deficiencies in the CAS displays, controls, and control panels detract from its overall operational effectiveness and efficiency.

6. The alarms, especially the audio alarm, are activated too frequently by situations that do not represent serious collision threats. Thus, they are turned off most of the time and do not serve the purpose for which intended.

7. CAS does not have an impact on manpower requirements. It requires continuous monitoring only during heavy traffic and threatening situations, when it is monitored and operated by senior bridge watch officers.

8. CAS will have a minimal impact on training requirements because operators can learn to operate the system through a relatively short period of on-the-job training. However, the use of nondedicated controls requires operators to memorize a variety of operating functions and procedures.

9. By redesigning CAS controls and control panel layouts and by improving the alphanumeric information display in accordance with good HFE design practices, CAS's operational effectiveness and efficiency can be improved.

RECOMMENDATIONS

1. If the Navy decides to acquire CAS for installation on additional ships, it should be revised and modified with greater emphasis given to HFE design practices. The proposed changes for the data display presentations, controls, and control panel described herein should serve as a guide toward that objective.

2. The revised CAS should use the vector display mode of operation as the primary mode of operation and, like the CAS tested on RANGER, should include capabilities for providing alternate sources of radar input, an additional source of speed input, and control over target definition and uniformity on the PPI. The guard rings are not considered necessary for ships of carrier size.

3. To simplify and reduce the amount of operator training necessary, the operating manual should be redesigned in the format presented in Appendix C.

APPENDIX A

HUMAN ENGINEERING DEFICIENCIES IN CAS

HUMAN ENGINEERING DEFICIENCIES

1. Incomplete labeling of the RANGE scale function. In the initial display, the RANGE legend adjacent to control 0 on the data display (Figure A-1), serves as a label for the adjacent range scale value in the center column of the display. Other elements in the center column are labeled with the appropriate units (i.e., knot, mile, or degree). The omission of the range scale unit label would be of little consequence were it not for the fact that an abbreviation of range, RNG, is used in the joystick mode to designate range from ship to a distant point or target (Figure A-2).

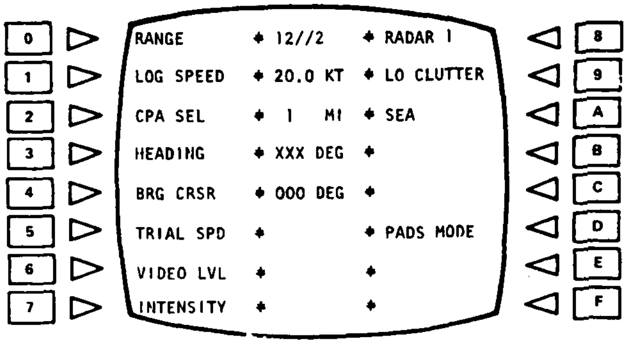


Figure A-1. Initial display in power-up condition (PADS mode of operation).

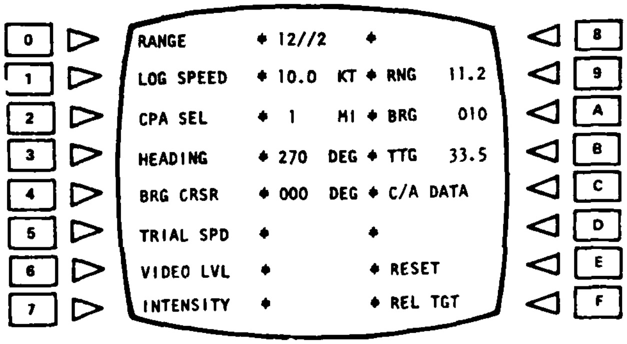


Figure A-2. Joystick mode with acquisition symbol position C/A data displayed.

2. Inadequate labeling of the SPEED mode of operation. The space on the data display immediately adjacent to control 1 (Figure A-1) identifies the particular speed source that has been selected by the operator. Depending upon the mode selected, the legend may read LOG SPEED, MAN (for manual) SPEED, or TRL (for trial) SPEED. Control 1 selects none of these; instead, it places the system in a speed source selection mode (i.e., in the mode where the log or manual speed source can be selected). Control 5 is used to select the trial speed adjust mode.

3. Inadequate labeling of CPA mode of operation. Control 2 is labeled CPA SEL. Actually, depressing control 2 places the system in the CPA SEL mode, as shown in Figure A-3. In this mode, the desired CPA can be selected.

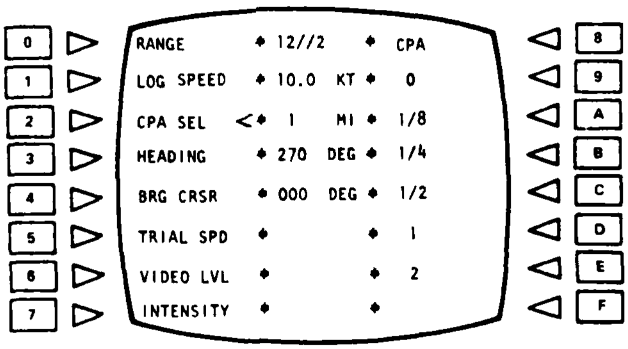


Figure A-3. CPA select mode.

4. Inadequate labeling of RADAR, CLUTTER, SEA/HARBOR, and PADS/VECTOR functions. Controls 8, 9, A, and D (Figure A-1) are used to place the system in the RADAR, CLUTTER, SEA/HARBOR, and PADS/VECTOR select modes respectively. The legends adjacent to these controls, however, do not identify the mode select functions; rather, they identify what has been selected (i.e., they are system status indicators). Nothing about the legends tell the operator what is "off" the display or what functions the controls serve.

5. Unnecessary clutter on the data display. The TRIAL SPD, VIDEO LVL, and INTENSITY legends identify the functions of controls 5, 6, and 7 respectively (Figure A-1). It appears that these labels should be displayed only when the functions controlled are in use--in the case of controls 6 and 7 particularly, this may be infrequent. At present, the legends constitute unnecessary clutter.

6. Inconsistent handling of the vector mode of operation. Deficiencies in the vector mode of operation start with the way it is selected. Figure A-1 shows the data display in the initial or power up condition with the system in the PADS mode of operation. The PADS MODE legend is positioned adjacent to control D. To change to the vector mode, the operator presses control D and the display changes to that shown in Figure A-4. The legend VECTOR TR, true vectors, has replaced the legend TRIAL SPD, adjacent to control 5. Control 5 now is assigned the vector control function, which is different from that appearing on the legend. Pressing control 5 causes the vector control function display to appear as shown in Figure A-5. (Note that TRIAL SPD appears adjacent to control D, whereas it is adjacent to control 5 in the PADS mode--Figure A-1.) A vector select, VECT SEL, function has been assigned to control B, and a vector length, VECT LG, function to control F. Pressing control B (Figure A-5) changes the legend adjacent to control 5 to either VECTOR TR (true) or VECTOR REL (relative), depending upon which was previously selected. The number in the center column adjacent to control 5 indicates vector length in minutes. The legend in the left-hand column does not adequately identify the data displayed in the adjacent center column. The VECT LG legend is adjacent to control F (A-5). When control F is pressed, vector length can be changed by pressing and holding either control 8 or 9.

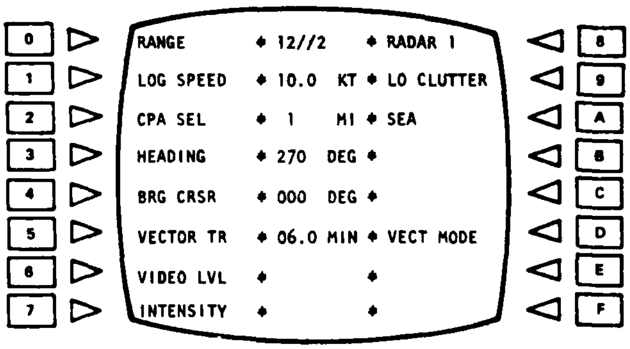


Figure A-4. Initial display for vector mode of operation.

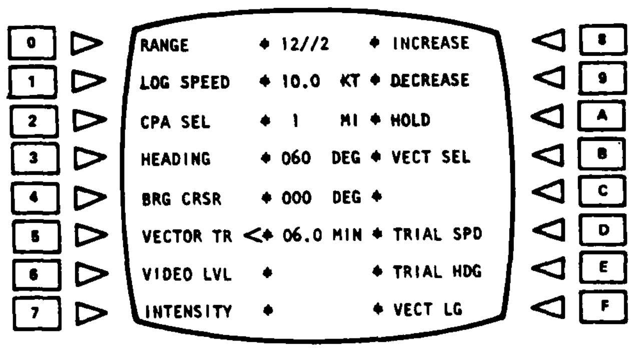


Figure A-5. Vector control mode (to enter trial speed and trial headings and to adjust vector time-length when in vector mode of operation).

The handling of the vector mode functions, as described above, is inconsistent in the following respects:

a. Legends/labels do not correctly identify control functions.

b. Controls on one side of the display are used to change legends adjacent to controls on the opposite side.

c. Vector mode functions displace the trial speed legend and cause it to be moved from one side of the display to the other.

d. The method of positioning legends is not consistent.

e. Functions identified by legends and functions assigned to controls are not consistent.

7. Inconsistent handling of TRIAL SPEED legends and functions. When the system is in the PADS configuration (Figure A-1), depressing control 5 places the data display in the trial speed adjust mode. As shown in Figure A-6, a second TRL SPEED legend is presented adjacent to control 1. Control 1 is inoperable in this mode. Adjacent to control 1 in the center column, the last value of trial speed set into the system is presented. This value may be adjusted by pressing and holding control 8 or 9.

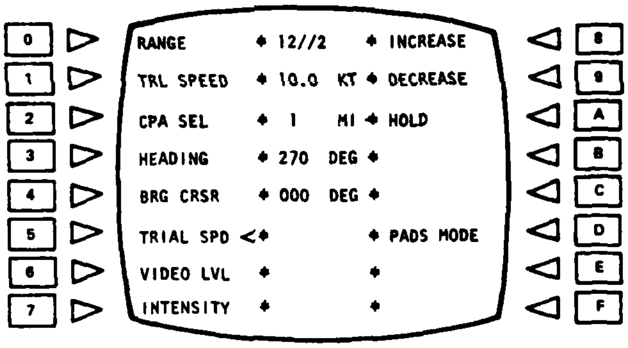


Figure A-6. Trial speed adjust mode.

In the vector control mode (Figure A-5), the TRIAL SPD legend has been moved across the display to a position adjacent to control D. The legend VECTOR TR has been assigned the space adjacent to control 5 (replacing TRIAL SPD). Control 5 has been assigned the function of placing the system in the vector control mode. If control D is pressed, a TRIAL SPD legend appears adjacent to control 1, and as before, the trial speed value in the center column can be adjusted by pressing and holding control 8 or 9.

8. Inconsistent use and placement of column labels on the data display. Four different methods are used to identify information displayed in the right-hand column: (a) no column label at all, Figures A-5 and A-6, (b) column label (CPA) placed at top of column, Figure A-3, (c) column label (C/A DATA) placed within the column, Figure A-2, and (d) column label (BRG CRSR) placed beneath the displayed information, Figure A-7.

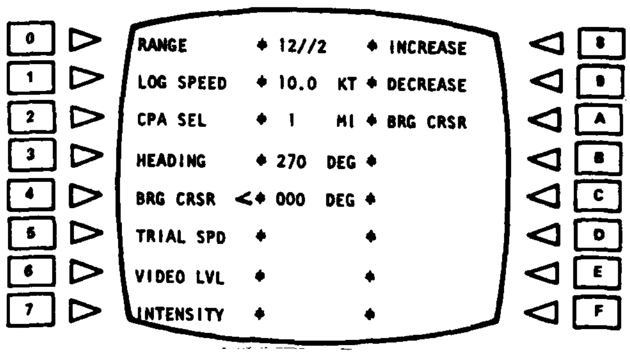


Figure A-7. Bearing cursor adjust mode.

9. Improper positioning and labeling of control HDG FLSH. The HDG FLSH (heading flasher) is a dedicated control and is located just below the data display, as shown in Figure A-8. Although labeled HDG FLSH, it also controls the bearing cursor on the PPI display. Pressing and holding the control down removes both the heading flasher and the bearing cursor from the PPI display for as long as the control is held down. Nothing about the label identifies the bearing cursor function. The control should be associated with the PPI display instead of the data display because it controls the PPI display rather than the data display.

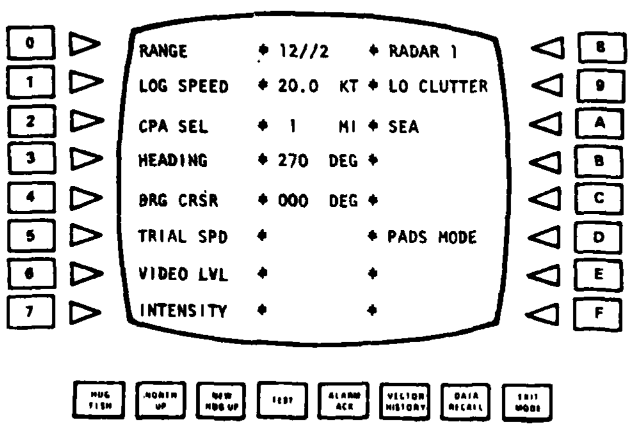


Figure A-8. Display with single function controls illustrated.

10. Improper placement of controls: NORTH UP, NEW HDG UP, and VECTOR HISTORY. These controls are located under the data display (Figure A-8) but have nothing to do with it. Instead, they control displays on the PPI. Therefore, they should be associated with the PPI display rather than the data display.

11. Poor positioning of the STC and FTC controls. The STC (sensitivity-time-control) and FTC (fast-time-constant) controls are located on the right-hand side of the joystick control panel (Figure A-9), but they are used to control PPI displays. Unlike the

joystick, these controls do not have to be positioned on the panel for right-hand operation. They are improperly placed and should be located near the PPI display to which they are related. The present concentric, or ganged, control can lead to operator error in selecting the correct control.

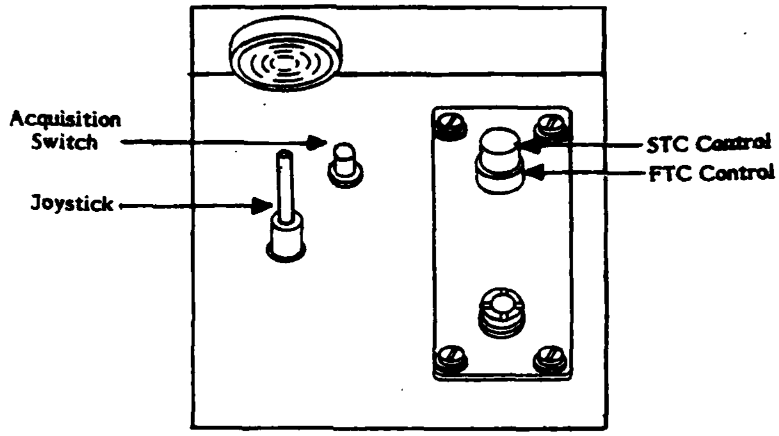


Figure 9. Joystick control panel: Acquisition switch, joystick, and STC and FTC controls.

12. Inadequate VIDEO LEVEL control. Control 6 is used to select the PPI display video level adjustment mode, as illustrated in Figure A-10. Controls 8 and 9 are used to adjust the video level of the PPI display, but they make adjustments too rapidly and thus precise and correct video level adjustment is difficult to achieve. However, correct video level is extremely important to assure adequate display and visibility of targets. A circular knob control (with a graduated scale) placed adjacent to the PPI display would enable precise setting of the correct video level.

13. Inadequate INTENSITY function. Control 7 is used to select the intensity adjustment mode, as shown in Figure A-11. In this mode, both the brightness level for controls and displays and the audio volume level for the alarm are adjusted. For easier operator identification, these diverse functions would be better understood if controlled from separate controls that are identified with labels that clearly identify purpose.

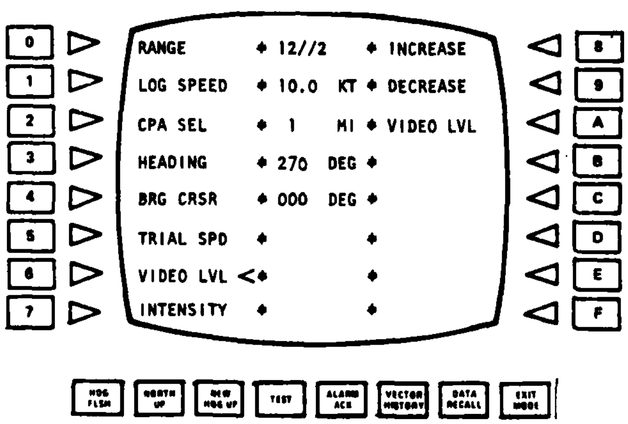


Figure A-10. Video level adjustment mode.

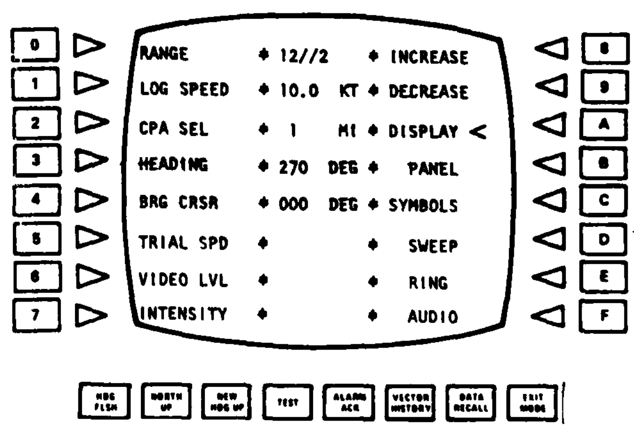


Figure A-11. Intensity level adjustment mode.

14. Diverse approaches used to enter the data display during system operation. Numerous and different approaches are used to enter the data display during operations:

a. Use of single function controls with permanent, unchanging labels on the data display. These controls are located on the left-hand side of the data display and include controls 0, 2, 4, 6, and 7 (Figure A-1).

b. Use of single function control in conjunction with multiple legends in the adjacent space on the data display. Control 1 (Figure A-1) is used only to select the log/manual speed source selection mode. However, different speed legends occupy the adjacent space at various times (i.e., LOG SPEED, MAN SPEED, and TRIAL SPD). In the trial speed mode, control 1 is inoperative. None of the labels identify the control function.

c. Use of a dual function control in a column of otherwise single function controls. Control 5 is used to select the trial speed mode when in the initial PADS or power-up configuration (Figure A-1). In the vector mode (Figure A-4), it is used to select the vector control mode.

d. Use of multifunction controls. Controls 8, 9, and A through F (Figure A-1) are used for varied and often dissimilar operations.

e. Use of single-function controls. The dedicated controls located at the bottom of the data display (Figure A-8) are labeled to identify their specific purpose.

f. Use of the joystick. Moving the joystick causes the data display to change to the presentation shown in Figure A-12. This mode and presentation allows the operator to identify targets/locations for retrieving collision avoidance (C/A) data.

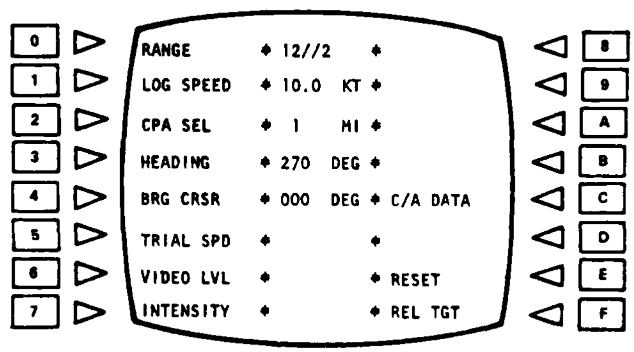


Figure A-12. Joystick control mode.

15. Different methods used to acquire and release targets. Two different types of controls are used to acquire and release targets even though the functions are related. Target acquisition is accomplished with a dedicated control, as shown in Figure A-9. Target release is accomplished with multipurpose control F, REL TGT, as shown in Figure A-12. The target acquisition switch does not meet the specifications set forth in MIL-STD-1472C.

APPENDIX B

PROPOSED REVISION OF COLLISION AVOIDANCE SYSTEM: DESCRIPTION OF CONTROLS AND DISPLAYS

This appendix describes a proposed version for redesigning and modifying the control panels, operating controls and associated data displays for the collision avoidance system (CAS). A visual concept of the general layout and location of all displays and controls is provided, followed by a description of the controls.

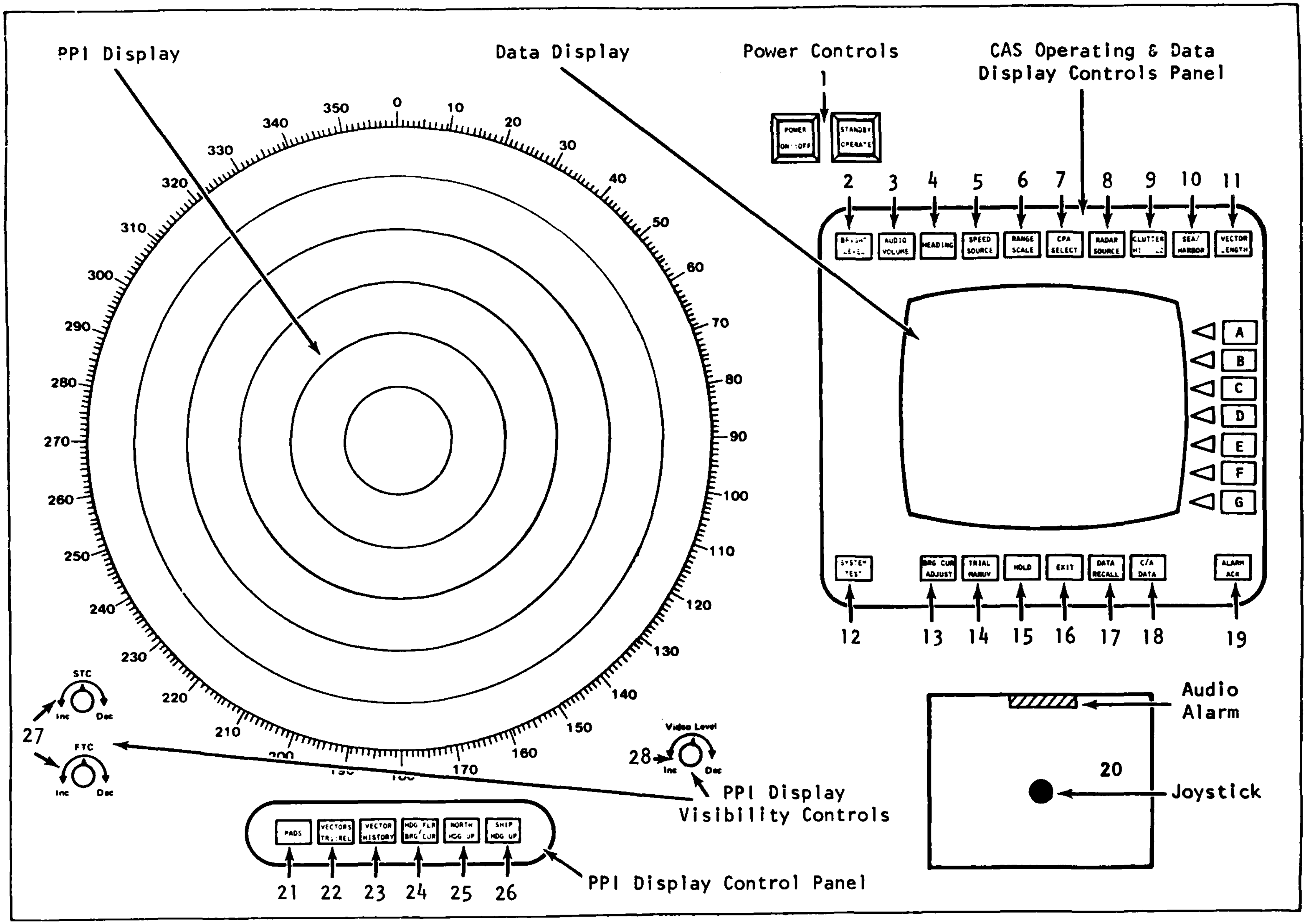


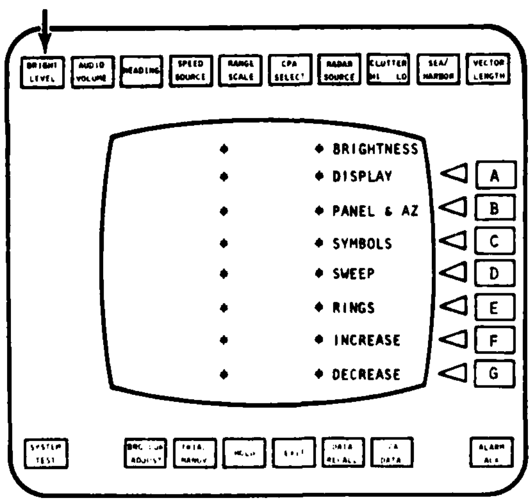
Figure B-1. Data displays and controls of revised CAS.

1. POWER ON::OFF and STANDBY/OPERATE

FUNCTION: The functions of these controls have not changed. However, their position is reversed since the POWER ON::OFF control is used before the STANDBY/OPERATE control.

OPERATION: While the basic sequence for operating these controls remains the same, the method of operation is changed. The POWER ON::OFF control is illuminated when the system is initially turned on to indicate that the system is energized. The STANDBY legend on the STANDBY/OPERATE control does not illuminate immediately as on the present CAS. Instead, the STANDBY legend illuminates when the 30-second warmup period has elapsed. This eliminates the need for the operator to determine when 30 seconds have elapsed. When the STANDBY legend illuminates, the system is placed in full operational status by depressing the STANDBY/OPERATE control. At such time, the OPERATE legend is illuminated.

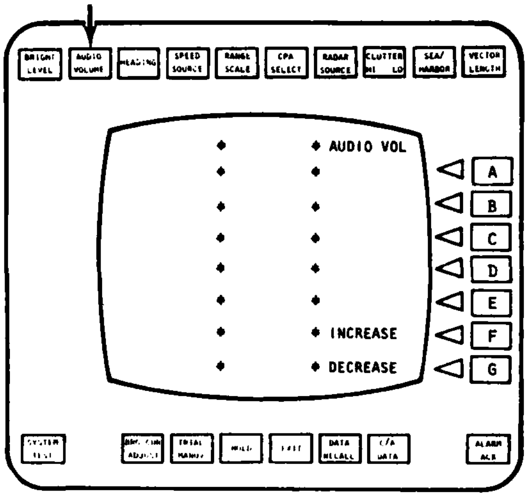
2. BRIGHT LEVEL



FUNCTION: Adjust the illumination of the data display, and the PPI panels, symbols, sweep, and rings.

OPERATION: Upon depressing the BRIGHT LEVEL control, the presentation on the data display will appear as shown. The brightness level of any of the elements listed may be adjusted by depressing the control adjacent to it. A small arrow will appear on the data display to indicate the element that is selected for adjustment. To increase or decrease the brightness level of that element, control F or G is depressed and held down until the desired brightness level is reached.

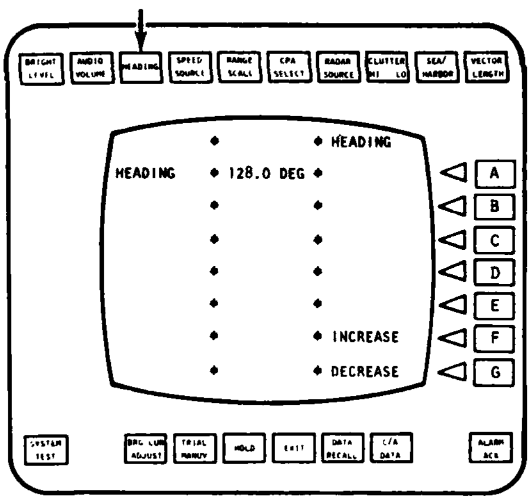
3. AUDIO VOLUME



FUNCTION: Adjust the volume level of the audio alarm.

OPERATION: Upon depressing the AUDIO VOLUME control, the presentation on the data display will appear as shown, and the audio alarm will sound. To increase or decrease the volume level, control F or G is depressed and held down until the desired volume level is reached.

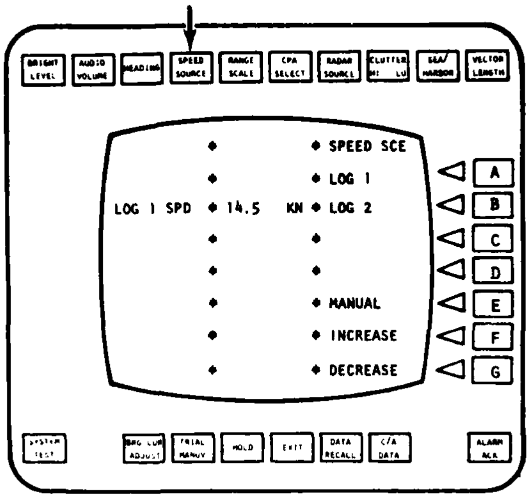
4. HEADING



FUNCTION: Manually enter ship's heading when gyrocompass malfunctions or fails to operate.

OPERATION: This control is not used unless the ship's gyrocompass fails. In such event, the system's built-in test equipment will identify the problem and provide an advisory on the data display indicting to the operator: GO TO STANDBY TO ENTER HEADING. After placing CAS in STANDBY by depressing the STANDBY/OPERATE control, the HEADING control is depressed to allow the operator to enter ship's heading manually. The presentation on the data display will appear as shown. Heading readout is increased or decreased by depressing and holding down control F or G until the correct heading appears. The STANDBY/OPERATE control is then depressed to return the system to operational status. When the gyro-compass returns on line, the input from it will keep the heading flasher aligned with own ship's heading; no further adjustment to heading is required.

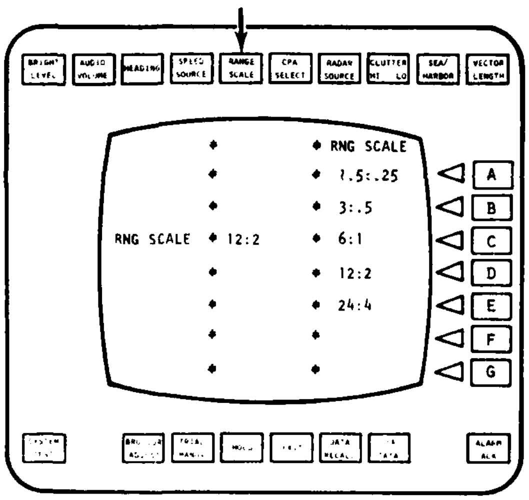
5. SPEED SOURCE



FUNCTION: Select speed data source input.

OPERATION: Upon depressing the SPEED SOURCE control, the presentation on the data display will appear as shown. Any one of three speed data sources may be selected by depressing control A, B, or E. The information appearing in the left-hand column of the data display will correspond to that of the control that is depressed. If control E (MANUAL) is selected, the initial value appearing in the center column for manual speed is that value last set into the system. The value of manual speed may be increased or decreased by depressing and holding down control F or G until the desired speed level appears.

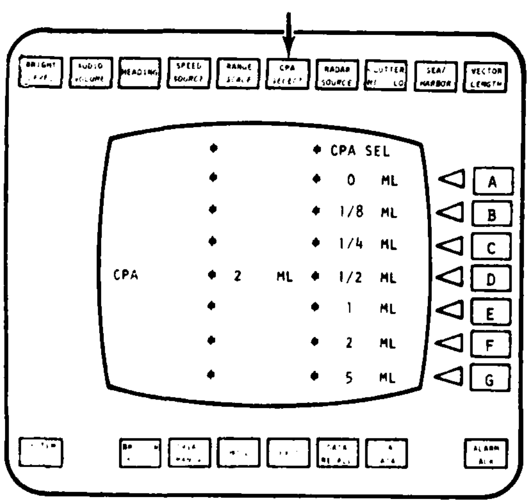
6. RANGE SCALE



FUNCTION: Select the range scale for PPI display presentation.

OPERATION: Upon depressing the RANGE SCALE control, the presentation on the data display will appear as shown. Any one of five range and range ring scales (in nautical miles) may be selected by depressing one of controls A through E. The RNG SCALE readout in the center column of the data display will change to reflect the range scale that is selected.

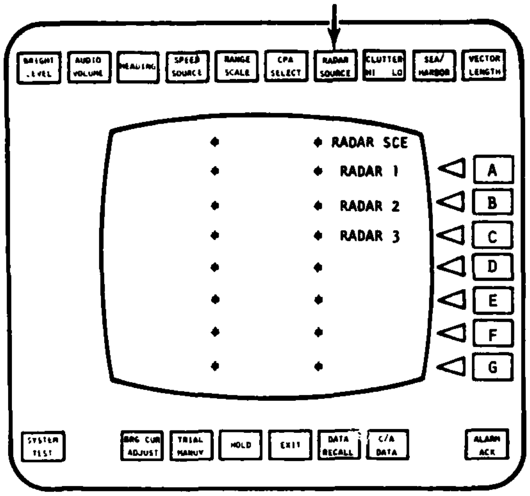
7. CPA SELECT



FUNCTION: Select closest point of approach (CPA) upon which collision avoidance data will be computed.

OPERATION: Upon depressing CPA SELECT control, the presentation on the data display will appear as shown. Any one of seven CPAs (in nautical miles) may be selected by depressing one of controls A through G. The selected CPA will appear in the center column of the data display adjacent to the CPA SEL legend. Control F was depressed to obtain the 2-mile CPA shown in the figure.

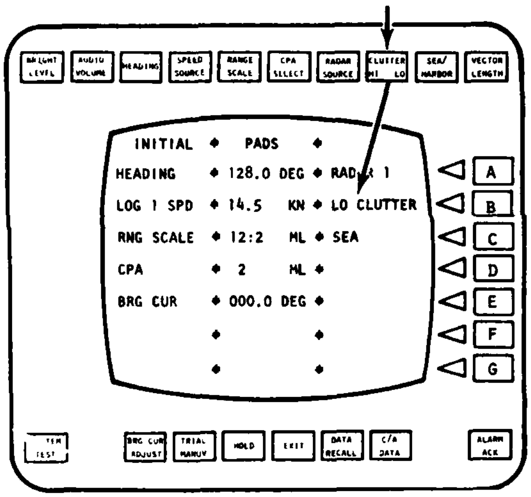
8. RADAR SOURCE



FUNCTION: Select radar data source input.

OPERATION: When the RADAR SOURCE control is depressed, the presentation on the data display will appear as shown. Any one of three radars may be selected to provide input to the CAS by depressing controls A, B, or C. When the data display returns to the initial mode of presentation, the radar selected and in use will appear in the right-hand column.

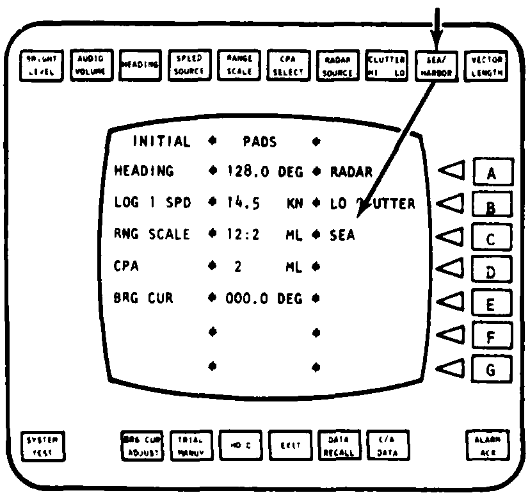
9. CLUTTER HI LO



FUNCTION: Suppress excessive clutter on the PPI display.

OPERATION: When CAS is energized, it will be in the LO CLUTTER mode as indicated. The lo clutter function is used under normal conditions. However, if a condition exists that results in excessive noise, the hi clutter function is selected by depressing CLUTTER HI LO. The legend in the right-hand column of the data display will change to read HI CLUTTER. When the excessive noise condition abates, the system is returned to the lo clutter function by depressing the CLUTTER HI LO control.

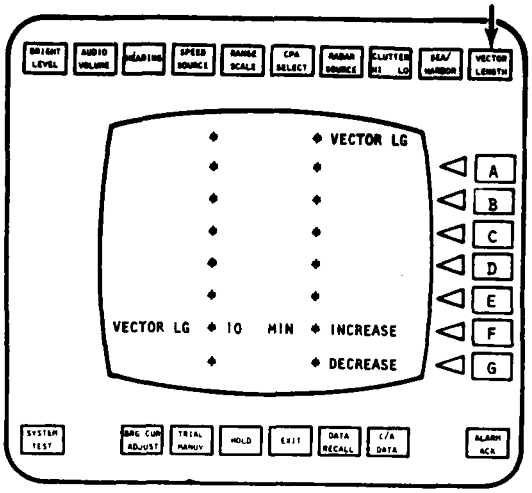
10. SEA/HARBOR



FUNCTION: Select range depths of the tracking window for open seas and close quarters navigation.

OPERATION: When CAS is energized, it will be in the SEA mode as indicated. When operating in close quarters, the SEA/HARBOR control is depressed and the legend on the data display presentation will change to HARBOR. When returning to open seas operation, the SEA/HARBOR control is depressed, and the legend on the data display presentation will change to SEA.

11. VECTOR LENGTH



FUNCTION: Select the time-length (magnitude) of the motion vectors displayed on the PPI when CAS is in the vector display mode of operation.

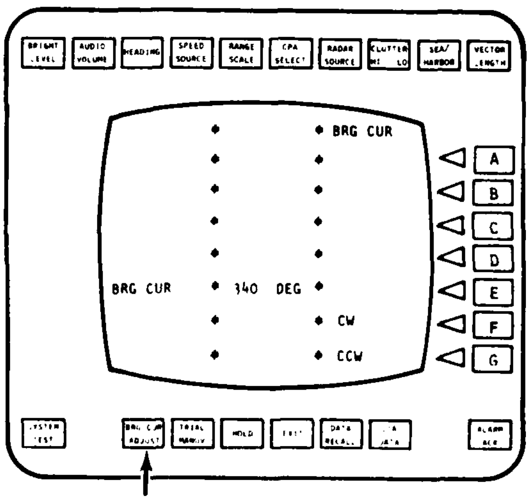
OPERATION: This control is operable only when CAS is set in the vector display mode of operation (selectable by a separate control, VECTORS TR::REL, located below the PPI display--see 22 below). In the vector display mode, when the VECTOR LENGTH control is depressed, the presentation on the data display will appear as shown. To increase or decrease the time-length vectors, depress and hold down control F or G until the desired time-length vector is reached.

12. SYSTEM TEST

FUNCTION: The function of the SYSTEM TEST control is the same as that of the TEST control on the present CAS.

OPERATION: The operation of this control remains the same as described in the present CAS operation manual.

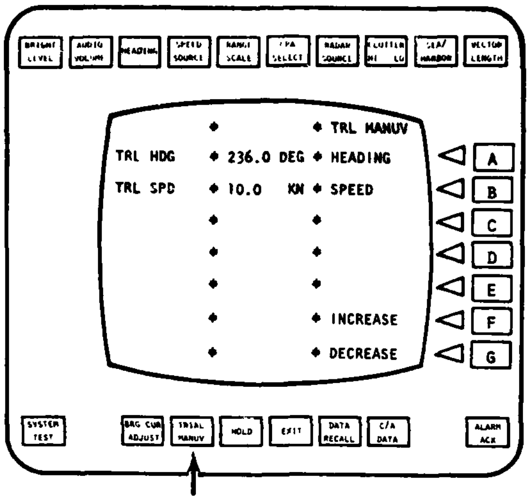
13. BRG CUR ADJUST



FUNCTION: Position the bearing cursor on the PPI display and corresponding value will appear on the data display.

OPERATION: Upon depressing the BRG CUR ADJUST control, the presentation on the data display will appear as shown. The bearing cursor, visible on the PPI display, may be moved in a clockwise (CW) direction by depressing control F or in a counterclockwise (CCW) direction by depressing control G and holding down either control until the bearing cursor reaches the desired position. The value of the bearing cursor setting will appear to the right of the BRG CUR legend on the data display (as illustrated in the figure).

14. TRIAL MANUV



FUNCTION: Enter trial speed in the PADS mode of operation, and enter trial speed and heading changes in the vector display mode of operation.

OPERATION: Upon depressing the TRIAL MANUV control, the presentation on the data display will appear as shown. The presentation in the figure is that which would appear when CAS is in the vector display mode of operation. When the system is in the PADS display mode of operation, only the TRL SPD and SPEED legends appear on the data display. To visualize on the PPI display the effects of possible changes in own ship's heading and/or speed, trial changes may be made in one or both. To enter a trial heading change, control A is depressed. A trial heading value then is entered by depressing and holding down control F or G until the desired heading change is reached. To enter a trial change in SPEED, control B, SPEED, is depressed, and the value of the speed is increased or decreased by following the above procedure for changing the heading value.

15. HOLD

FUNCTION: The function of the HOLD control is the same as that of a multipurpose control on the present CAS where the HOLD legend appears adjacent to control A during trial changes in speed and/or heading.

OPERATION: The operation of this control remains the same as described in the present CAS operation manual.

16. EXIT

FUNCTION: The function of the EXIT Control is the same as that of the EXIT MODE control on the present CAS.

OPERATION: The operation of this control remains the same as described in the present CAS operation manual.

17. DATA RECALL

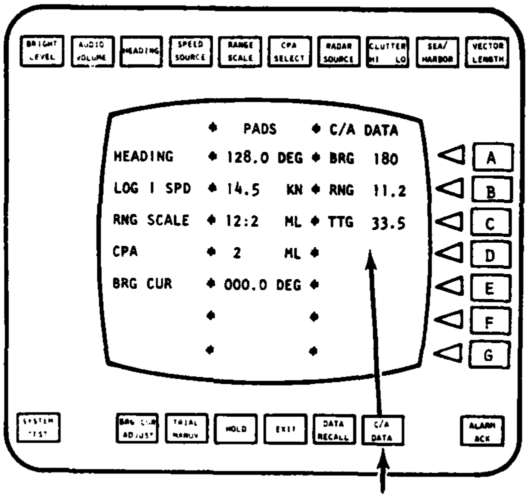
FUNCTION: The function of the DATA RECALL control is the same as that on the present CAS.

OPERATION: The operation of this control remains the same as described in the present CAS operation manual.

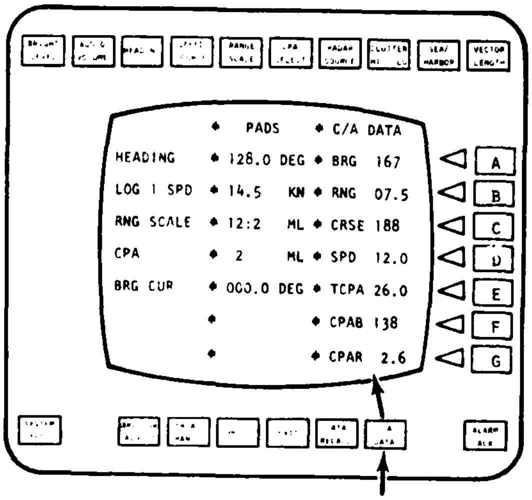
18. C/A DATA

FUNCTION: Obtain collision avoidance (C/A) data readout on selected targets or positions.

OPERATION: This control is operated in conjunction with the joystick. Two types of C/A data are available: acquisition symbol and tracked target.



<u>Acquisition symbol C/A data</u>: When the joystick is moved, the data display will appear as shown on the figure accompanying the discussion on the joystick (see 20 below). C/A data may be obtained for any point on the PPI display by moving the joystick to place the acquisition symbol over a target, object, or location. Upon depressing the C/A DATA control, the data display will provide a readout to show bearing (BRG), range (RNG), and time to go (TTG) for the position of the acquisition symbol. The data display will appear as shown in the figure to the left.



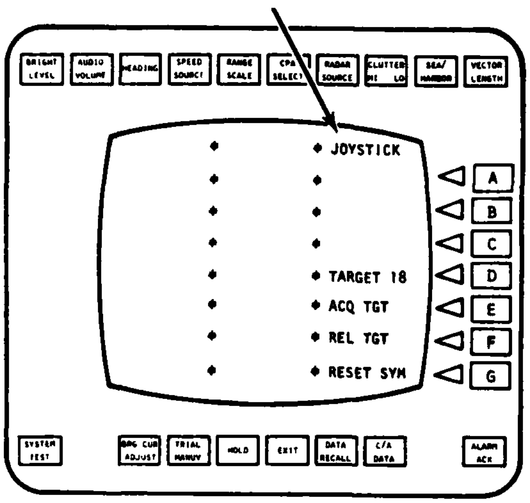
<u>Tracked target C/A data</u>: When the joystick is moved, the data display will appear as shown on the figure accompanying the discussion on the joystick. Detailed C/A data may be obtained for any target under track. The joystick is moved to place the acquisition symbol over the desired tracked target, and then the C/A DATA control is depressed. The C/A data readout will appear on the data display as shown in the figure to the left. Target's current bearing, range, course, and speed data are shown in the first four items in the right-hand column. The last three items indicate time to reach closest point of approach (TCPA), bearing of target at time of closest point of approach (CPAB), and range of target at time of closest point of approach (CPAR).

19. ALARM ACK

FUNCTION: The function of the ALARM ACK control is the same as that of the ALARM ACK control on the present CAS.

OPERATION: The operation of this control is the same as described in the present CAS operation manual.

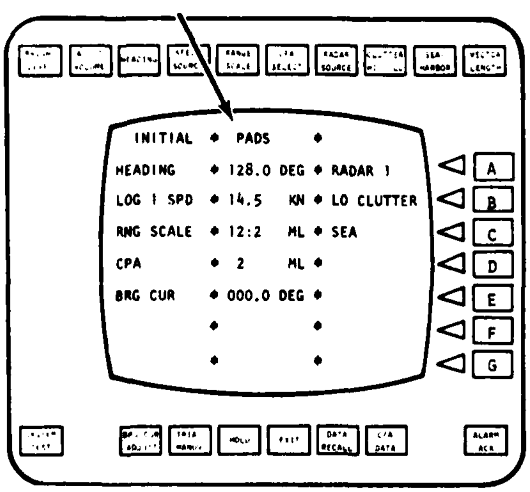
20. Joystick



FUNCTION: The function of the joystick remains the same as on the present CAS.

OPERATION: The general purpose of the joystick is not changed. However, the information that appears on the data display when the joystick is moved is changed to accommodate the deletion of the acquisition control from the joystick control panel. Upon moving the joystick (see Figure B-1 for location), the presentation on the data display will appear as shown. After the joystick is used to position the acquisition symbol over the desired target, control E (ACQ TGT) is depressed to place the target in track. Control F (REL TGT) is used to release a target from track, and control G (RESET SYM) is depressed to reset the acquisition symbol to the center of the PPI display. The legend adjacent to control D (TARGET) appears only when the number of targets being tracked (18) nears the 20-target capacity of CAS.

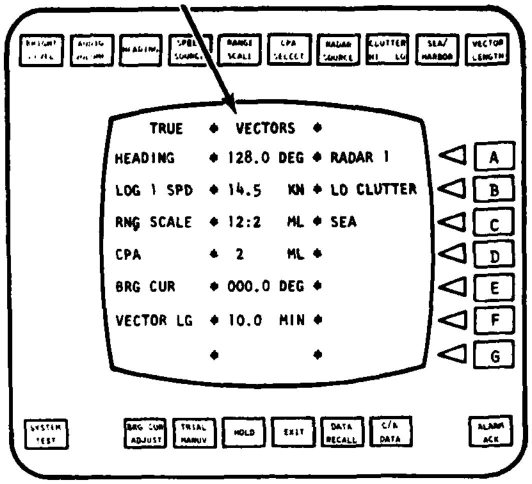
21. PADS



FUNCTION: Select PADS mode of operation for display on the PPI.

OPERATION: The PADS mode of operation and the applicable PPI display are the same as for the present CAS. However, a PADS control has been added and included on the PPI control panel to provide a readily identifiable means for changing the presentation on the PPI display to the PADS mode. When the PPI is set to display PADS, the data display will routinely appear as shown.

22. VECTORS TR::REL



FUNCTION: Select vectors display mode of operation for PPI presentation, and simultaneously provide for changing from true (TR) to relative (REL) motion vectors (and reverse).

OPERATION: The vectors display mode of operation and the associated PPI display are the same as for the present CAS. The VECTORS TR::REL control has been added and included on the PPI control panel to provide a readily identifiable means for changing to the vectors display mode from the PADS display mode. True motion vectors are displayed initially. The VECTORS TR::REL control is depressed to alternate between true and relative vector displays. When CAS is initially placed in the vector display mode, the data display will routinely appear as shown.

23. VECTOR HISTORY

FUNCTION: The function of the VECTOR HISTORY control is the same as that on the present CAS.

OPERATION: The operation of this control remains the sames as described in the present CAS manual. However, it has been relocated from the data display control panel to the PPI control panel.

24. HDG FLR/BRG CUR ON/OFF

FUNCTION The functions of the HDG FLR/BRG CUR ON/OFF control are the same as for the HDG FLSH control on the present CAS.

OPERATION: This control has been relocated from the data display control panel to the PPI control panel. Also, its operation has been altered. On the present CAS, the control must be depressed and held down for the duration of time that it is desired to delete the heading flasher and bearing cursor from the PPI display. The proposed function of the control will permit the operator to turn off the heading flasher and bearing cursor for as long as he does not want these indicators to appear on the PPI display.

25. NORTH HDG UP

FUNCTION: The functions of the NORTH HDG UP control remain the same as those of the NORTH UP control on the present CAS.

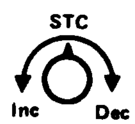
OPERATION: The operation of this control is the same as described in the present CAS manual. However, it has been relocated from the data display control panel to the PPI control panel.

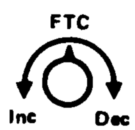
26. SHIP HDG UP

FUNCTION: The function of the SHIP HDG UP control is the same as that of the NEW HDG UP control on the present CAS.

OPERATION: This control, SHIP HDG UP, has been relabeled and moved from the data display control panel to the PPI control panel. When depressed, the PPI display is reoriented to show ship's heading as straight up. The control is depressed whenever it is desired to adjust and reorient the ship's heading on the PPI display.

27. STC and FTC





FUNCTION: The functions of the STC and FTC controls are the same as on the present CAS.

OPERATION: There is no change in the operation of these two controls, but two physical changes have been made. First, they have been moved from the joystick panel to the lower left of the PPI display (see Figure B-1), because they are used to control target uniformity and definition on the PPI display. Second, two separate controls replace the single concentric, or ganged, control. Separate controls enable the operator to readily identify the specific control that he wishes to use.

28. VIDEO LEVEL

FUNCTION: Control video level of targets and minimize clutter displayed on PPI.

OPERATION: A rotary knob provides the operator with a manual means to better control the fine tuning of the PPI video level. Figure B-1 shows location of the VIDEO LEVEL control knob.

APPENDIX C

FORMAT FOR OPERATION MANUAL AND TRAINING GUIDE FOR THE COLLISION AVOIDANCE SYSTEM

Note. This appendix provides an example of a proposed format for an operation manual and training guide for CAS. Although the proposed revised version of CAS described in Appendix B was used as the model for developing this format, the format can also be used for the present CAS.

OPERATING PROCEDURES AND TRAINING GUIDE FOR THE COLLISION AVOIDANCE SYSTEM

1. The material contained herein is intended to provide a working knowledge of the operating controls and functions of CAS. Figure C-1 shows the top panel or working surface of the CAS console on which all displays and controls are located. The major components of the panel are labeled to indicate their general purpose or function. In addition, all controls are keyed with numbers to provide a quick and easy reference to the descriptive procedural material in the following pages. Note that controls are not numbered in the order in which they appear on the panel. Instead, they are numbered in the order in which they normally are used when energizing the system and placing it in operation.

2. Thirty-six of the 37 controls (all but the joystick) are clustered in five general groups as determined by function and use frequency.

a. The two controls at the upper-top center of the console are used to apply power and place the system in operation (Nos. 1 and 2).

b. The ten controls at the top of the data display (3-11, 16) are used primarily during initial system turn on, setup, and adjustment. They establish CAS data input sources and operating parameters. Most of them are used infrequently during the normal course of operations.

c. The seven controls to the right of the data display (30A-G) are secondary or dependent controls. They can be used only in conjunction with one of the labeled functional controls located at the top and bottom of the data display.

d. The eight controls at the bottom of the data display (18-21, 25, 27-29) are used frequently during the course of operations. Some of them relate to overall system control; others control the information that appears on the data display.

e. The nine controls at the bottom of the PPI display (12-15, 22-24, 26) are used to control various aspects of the target/contact video presentation. Some of them are used primarily during initial setup of the system; others are used mainly during the normal course of operations.

3. Although most of the controls have broader operational applications, they can be classified into the following general categories:

a. Nos. 1 through 16--Initial turn-on, setup, and adjustment.

b. No. 17 (joystick)--Target selection.

c. Nos. 17-19--Collision avoidance data acquisition.

d. Nos. 20-24--Display threat assessment and trial maneuvers.

e. No. 25--Alarm acknowledgment.

f. Nos. 26-28--General utility.

g. No. 29--System test.

h. No. 30--Secondary controls.

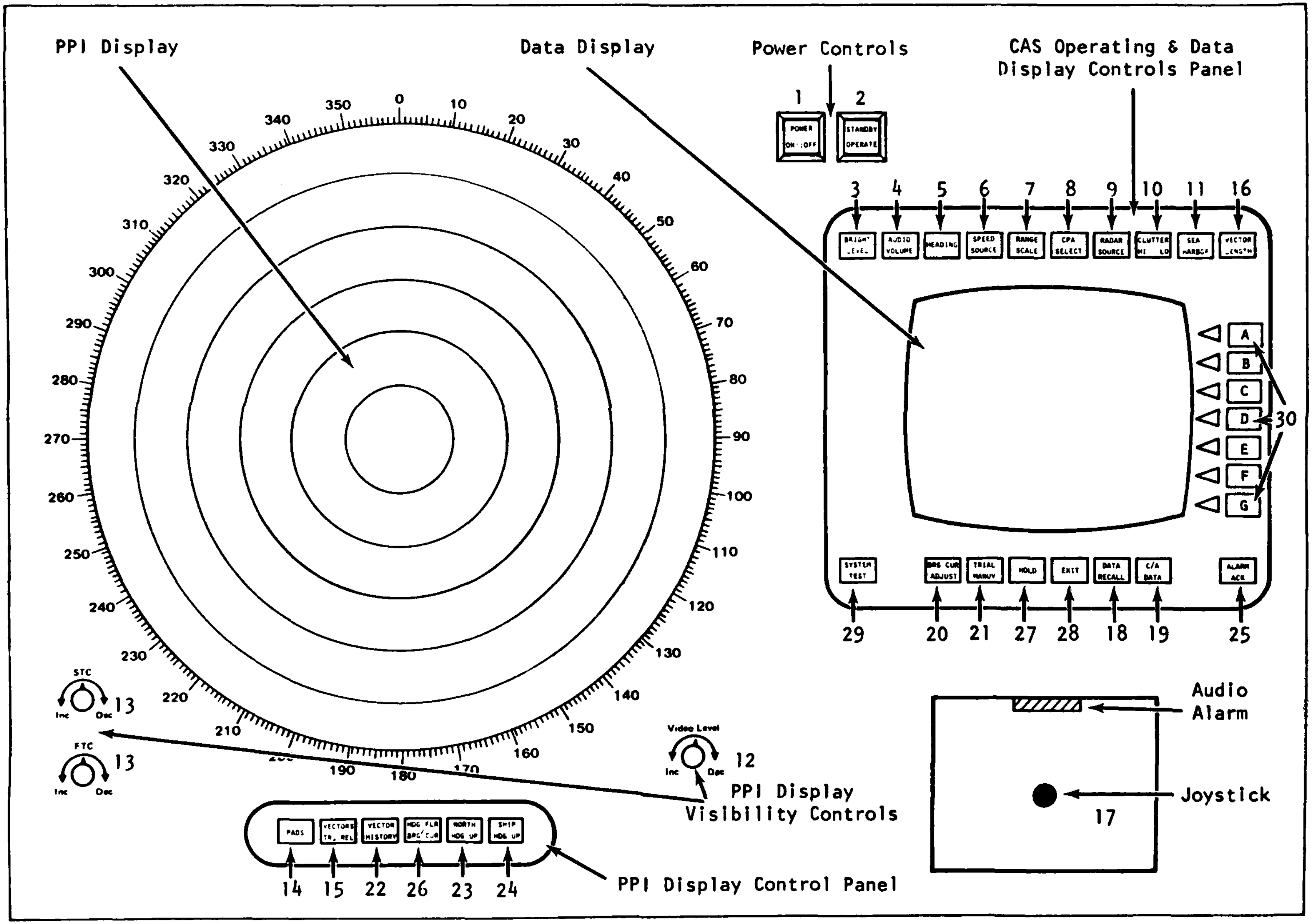
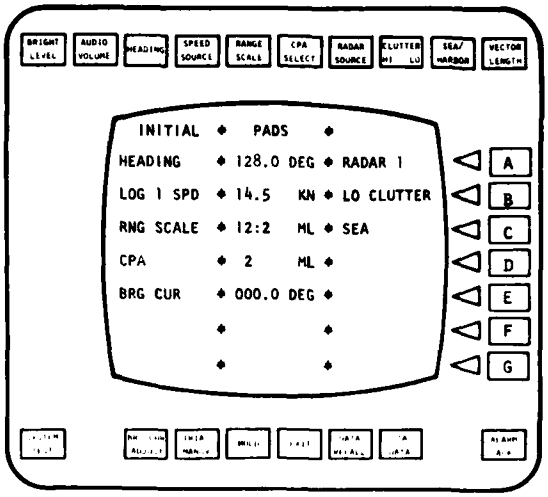


Figure C-1 Data displays and controls of revised CAS.

1. POWER ON::OFF



PURPOSE: Used to apply initial power and place CAS in standby condition (or used to turn system off when no longer required for operation).

OPERATION: Depress the POWER ON::OFF control to energize all system voltages except the PPI high voltage. The POWER ON::OFF control is illuminated to indicate that the system has been energized. The initial data display readout will be similar to that shown. After 30 seconds, the STANDBY legend on the STANDBY/OPERATE control is illuminated to indicate that the system is ready to be placed in full operation (see 2 below).

Notes.

1. If there is a power failure lasting more than 30 seconds, the system will turn itself off automatically and this initial turn-on procedure must be followed.

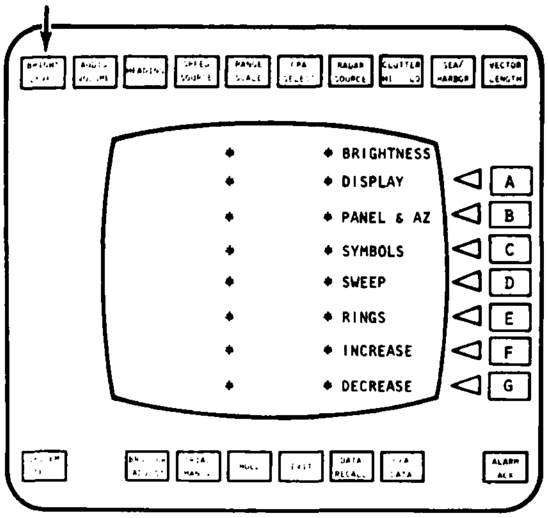
2. When the sysem is to be shut off, it must first be placed in the STANDBY mode--see 2 below.

2. STANDBY/OPERATE

PURPOSE: Used to apply power to the PPI display and place CAS in full operational status.

OPERATION: After applying initial power to the system with the POWER ON::OFF control, the STANDBY legend on the STANDBY/OPERATE control is illuminated following a 30-second warmup period. When the STANDBY legend illuminates, the system is ready for operation. Depress the STANDBY/OPERATE control. This applies high voltage to the PPI display. The OPERATE legend on the STANDBY/OPERATE control is illuminated to indicate that the system is in full operational status. Note. When the system is to be shut down, depress the STANDBY/OPERATE control to place the system in a STANDBY mode prior to depressing the POWER ON::OFF control.

3. BRIGHT LEVEL



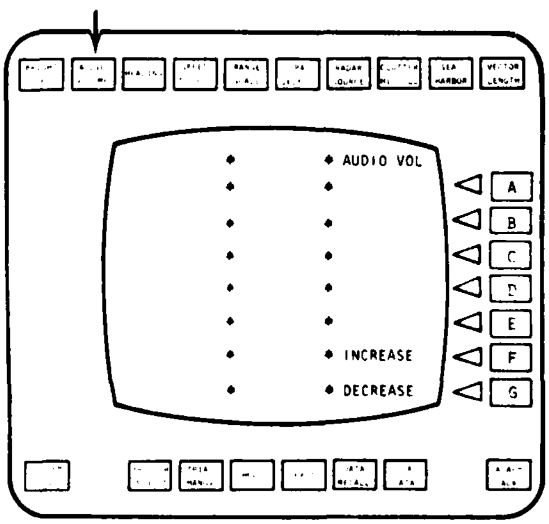
PURPOSE: Used to adjust the visibility levels of the panel controls and displays.

OPERATION: All brightness levels of the panel controls and displays are set at a predetermined level when the system is initially energized. If there is a need to adjust the brightness levels for improved visibility of the panel controls and/or displays, depress the BRIGHT LEVEL control. When the BRIGHT LEVEL control is depressed, the data display will change to appear as shown. One or more of the brightness levels may be adjusted as described below.

To adjust the brightness level of the data display, depress control A, located to the right of the DISPLAY legend. Next, depress and hold down control F (INCREASE) or control G (DECREASE) until the desired brightness level is reached.

[Note: Procedures for BRIGHT LEVEL controls B, C, D, and E would follow but are not included in this example.]

4. AUDIO VOLUME



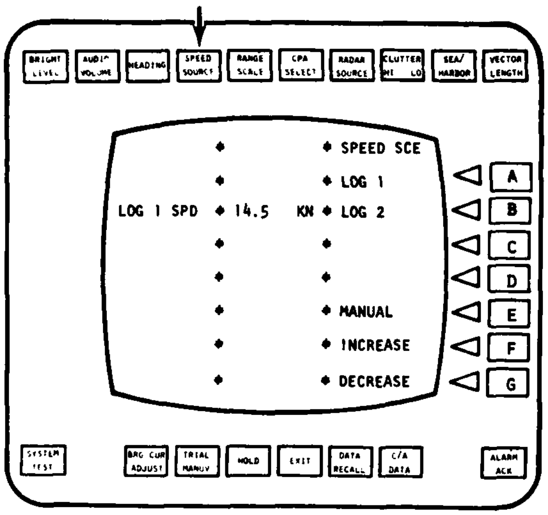
PURPOSE: Used to adjust the volume level of the audio alarm.

OPERATION: The audio alarm volume level is set to a predetermined level when the system is initially energized. If there is a need to raise or lower the volume level of the audio alarm, depress the AUDIO VOLUME control. When the AUDIO VOLUME control is depressed, the data display will appear as shown, and the alarm will sound. Depress and hold down control F (INCREASE) or control G (DECREASE) until the desired volume level is reached.

5. HEADING

[Note: The descriptive material for control 5, HEADING, was intentionally omitted from this operating procedures example.]

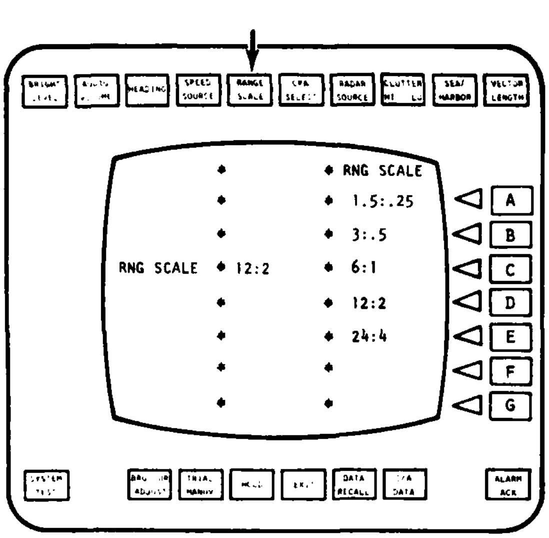
6. SPEED SOURCE



PURPOSE: Used to select the speed source input that the system will use in computing collision avoidance data.

OPERATION: The initial speed source input is set for LOG 1 when the system is initially energized. Two additional speed sources are available: LOG 2 and manual speed setting. If it is desired to change the speed source input, depress the SPEED SOURCE control. When the SPEED SOURCE control is depressed, the data display will change to appear as shown. If LOG 2 speed is selected, the legend on the left side of the data display will change to read LOG 2 SPD. Note: Ship's speed readout as calculated by the selected log speed source will appear in the center column to the right of the log speed legend. To manually enter a speed readout, depress control E to the right of the MANUAL legend. The legend in the left column of the data display will change to read MAN SPD. The initial value of the speed readout will be the last one that was entered when the system was last used in a manual speed mode. To change the value of the manual speed readout, depress and hold down control F (INCREASE) or control G (DECREASE) until the desired speed, in knots, is reached, as displayed in the center column of the data display to the right of the MAN SPD legend. To change back to a log speed source, depress the SPEED SOURCE control, and then select the desired speed log.

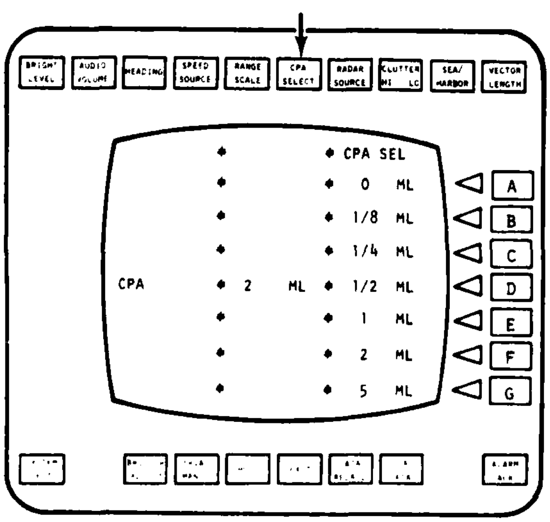
7. RANGE SCALE



PURPOSE: Used to select the range, in nautical miles, that will be displayed and visible on the PPI display. Simultaneously, the range ring spacing will be set for the six range rings that appear on the PPI display.

OPERATION: The system is preset to display a 12-nautical-mile range scale with 2-nautical-mile range ring spacing (12:2) when the system is initially energized. There are five range-scale settings available for display. To change the range scale, depress the RANGE SCALE control. When the RANGE SCALE control is depressed, the data display will appear as shown. The five range-scale settings that are available appear in the right hand column. They vary from 1.5:.25 to 24:4. A setting of 1.5:.25 means that the visibility range on the PPI display will be 1-1/2 nautical miles and the spacing between each range ring will be 1/4 nautical mile. Select the desired range scale by depressing the appropriate control to the right of the legend. The selected range scale will appear in the center column of the data display to the right of the RNG SCALE legend.

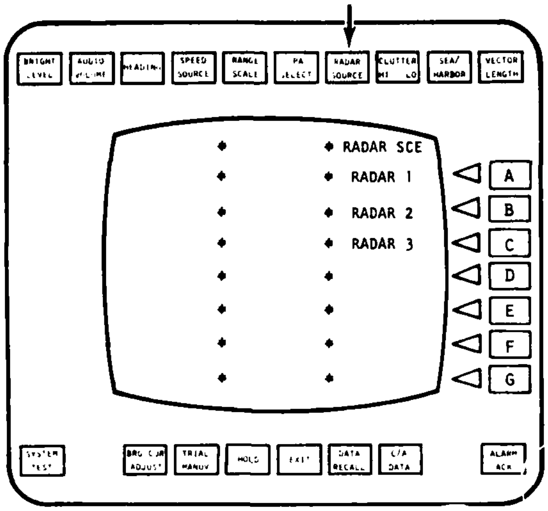
8. CPA SELECT



PURPOSE: Used to select the closest point of approach (CPA), in nautical miles, that will be used by CAS in computing collision avoidance data.

OPERATION: When the system is initially energized, it is preset to display a 1-nautical-mile CPA. There are seven CPAs from which to select. To change the CPA, depress the CPA SELECT control. When the CPA SELECT control is depressed, the data display will appear as shown. Select the desired CPA by depressing the appropriate control to the right of the CPA value that appears in the right- hand column of the data display. Note: Each CPA has an additional 300 yards added as a safety margin; therefore, when a "O" CPA is selected, the actual CPA can be as much as 300 yards.

9. RADAR SOURCE



PURPOSE: Used to select the radar system that will provide the video input to the CAS.

OPERATION: The system is preset to display video input from the radar system identified on the CAS as Radar 1 when the CAS is initially energized. Video input for the CAS is available from one of three radar systems. Alternate sources of video are available in the event of failure or malfunction in one of the units, when routine maintenance must be performed on one of the units, and when conditions are such that the quality of video return is better from one radar system than it is from the other two. To change and select a radar source other than Radar 1, depress the RADAR SOURCE control. When the RADAR SOURCE control is depressed, the data display will appear as shown. The radar source that is desired is selected by depressing the appropriate control to the right of the radar legend that appears on the data display. When the data display returns to its normal display mode, the radar system that is in use will be displayed in the right-hand column.

[Note: The above would be followed by a description of the three radar systems and the conditions under which each would provide the best video return such as weather, heavy traffic, and close-in or harbor navigation.]

The balance of the controls and controls shown in Figure C-1 would continue to be described in the above manner, accompanied by appropriate illustrations.

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Commander Naval Surface Force, U.S. Pacific Fleet
Commander Naval Air Development Center
Commander Naval Weapons Center
Commander David W. Taylor Naval Ship Research and Development Center
Commander Naval Surface Weapons Center
Commander Naval Ocean Systems Center
Commander Training Command, U.S. Atlantic Fleet
Commander Training Command, U.S. Pacific Fleet
Commanding Officer, Naval Coastal Systems Center
Commanding Officer, Naval Education and Training Program Development Center (Technical Library) (2)
Commanding Officer, Naval Education and Training Support Center, Pacific
Commanding Officer, Naval Technical Training Center, Corry Station (Code 101B)
Commanding Officer, Naval Training Equipment Center (Technical Library)
Director, Naval Education and Training Program Development Center Detachment, Memphis
Director, Training Analysis and Evaluation Group (TAEG)
Superintendent, Naval Postgraduate School
Secretary Treasurer, U.S. Naval Institute
Commandant Coast Guard Headquarters
Commanding Officer, U.S. Coast Guard Institute
Commanding Officer, U.S. Coast Guard Research and Development Center, Avery Point
Superintendent, U.S. Coast Guard Academy
Director, Science and Technology, Library of Congress
Defense Technical Information Center (DDA) (12)

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