CHAPTER 9

BALLISTICS, FIRE CONTROL, AND ALIGNMENT

INTRODUCTION

If you looked up the definition of ballistics in the older dictionary-not very old, at that-you would find that missiles are not included in the definition. A 1958 definition of ballistics says that it is "the science which studies the laws governing the motion of projectiles shot from artillery or firearms, or (ballistics of bombs) of bombs dropped from aircraft." Later definitions include missiles.

The science of ballistics studies the effects of various factors on the speed, course, range, and other behavior of the projectile, bomb, or missile. The factors include initial velocity, force of gravity, atmospheric conditions (wind, moisture, clouds, etc.), earth's rotation, earth's curvature, and drift. Ever since the invention of guns, men have studied how to use them with greater accuracy. The pioneer hunter learned from trial and error how to allow for the wind and how to "lead" his target. The scientific principles as they applied to projectiles shot from guns were formulated and applied long before the era of guided missiles. In *Gunner's Mate M (Missiles) 3&2*, NAVTRA 10199, you learned how ballistic principles apply to guided missiles. The effects of gravity, air density, wind, coriolis effect, stabilization (of the ship and the missile), trunnion tilt, and parallax on the trajectory of a guided missile were explained and illustrated. The missile design is planned to take advantage of these effects as much as possible, or to offset their disadvantages.

The principles of missile flight as affected by missile aerodynamics also were explained in the preceding course. The density of air decreases as the altitude increases. This reduces the air pressure and the drag on the missile passing through it. The layers of the atmosphere were defined as the troposphere, the stratosphere, and the ionosphere. The ionosphere begins about 25 miles above the surface of the earth. The air particles in it are ionized by the ultraviolet rays from the sun and to a less extent by the charged particles from the sun. The low air density at this height makes increases in speed possible; the effects of ionization on missile electronic systems and nuclear material are still being studied.

Most long-range missile flights will be made in the stratosphere, which extends between the troposphere (the layer of air next to the earth's surface) and the ionosphere. The constant temperature and lack of winds are advantageous to missile flight, but the low temperature and the lack of oxygen are disadvantageous. By carrying out flights in the stratosphere, the advantages of low drag, high speed, low fuel consumption, and greater range are obtained. The shape of the missile and the shape and arrangement of the fins are designed to take advantage of the lift of air, and also to provide stability to the missile. Fixed fins contribute primarily to stability; control is achieved by movable fins. Design and arrangement of fins differ for subsonic and supersonic missiles.

The speed of missiles is often stated as a Mach number, which represents the ratio of the speed of the missile to the speed of sound in the surrounding atmosphere. At subsonic speeds, the Mach number is less than one, as 0.80; at supersonic speeds it is greater than one, as 1:31. Talos and Terrier have a speed in the range of Mach 2.5; Tartar speed in Mach 2; Asroc speed is Mach 1.

All the principles of missile flight are important in missile fire control. You need the background knowledge given you in the preceding course, and barely touched on here, to help you understand how the weapons system operates and enable you to see why certain things must be done in certain ways in the operation and maintenance of the system.

EQUIPMENT OF A MISSILE WEAPONS SYSTEM

A missile weapons system consists of a weapons direction system, one or more fire control systems, the launching system, and the missiles. The weapons direction system and the fire control systems and their related equipments comprise the weapons control system. The system described in this section is installed aboard the DLG-9 class frigates. It consists of a weapons direction system, two Terrier missile fire control systems (Mk 76), a Mk 10 guided missile launching system, and BT and HT missiles. However, for the sake of clarity and to conserve space, we have generally limited our discussion to one fire control system. On the basis of their fundamentals of operation, fire control systems may be divided into two main classes: linear rate and relative rate. Figure 9-1 illustrates the equipments in the groups of equipments, and the two basic methods of solving the fire control problem.

LINEAR RATE SYSTEMS

Linear rate systems are used for both surface and air targets, for gun and missile systems Linear rate systems measure changes in target position in knots, like the surface fire control systems used in main battery installations. Because it has both magnitude and direction, relative target motion is a VECTOR quantity. And, like any vector, it can be separated into two or more components.

In figure 9-1B (1) relative target motion has been separated into three components. The component along the line of sight is range rate (dR). The component at right angles to the LOS in a horizontal plane is the linear bearing rate (RdBS). And the component at right angles to the LOS in a vertical plane is the linear elevation rate (RdE).

The director measures target range, bearing, and elevation, and transmits their values to the computer. The computer solves the vector problem and calculates the future position of the target at the end of the missile's time of flight, allowing for the effect of relative motion during the time the missile is in the air. It then determines from the predicted target position how the missile launcher must be positioned for the missile to hit the target, allowing for wind, gravity, drift, and initial missile velocity.

The computer solves the problem continuously and continuous orders are sent to the guns or missiles. The rates are calculated in the computer from three groups of inputs:

1. Ship motion inputs of own ship's course and speed.
2. Target motion inputs of target course and speed; in an AA problem, target speed is resolved into two components-horizontal speed and rate of climb (vertical speed).
3. Target position inputs of target elevation, bearing, and range.

Three rates are computed relative to the LOS: in the LOS (range), across it in the horizontal plane (bearing), and perpendicular to it in the vertical plane (elevation). These rates are based on the position of the LOS at the instant of their computation. The velocity of the LOS is not used directly to determine the rates. This is a disadvantage of the system. However, when aided tracking is used by the director, the velocity of the LOS furnishes a check on rate accuracy. (The linear rates are converted to angular rates for aided tracking.) The calculated linear rates correspond to the computer's coordinate system.

Relative Rate

Many publications use the term relative rate rather than angular rate. For our purposes the two terms have the same meaning.

There are many different types of relative rate directors used in the Navy. One common feature is that they use gyros to measure the angular tracking rate.

The lead-computing sight determines changes in target position by measuring the ANGULAR VELOCITY of the line of sight. (If you keep your finger pointed at a moving airplane, the rate at which your arm and finger move to follow the plane's flight is a rough measure of the angular velocity of your line of sight.) Angular rate systems measure this angular velocity, and correct for time of flight and curvature of trajectory. As the director operator keeps his sights on the target, and introduces range, the equipment automatically computes the elevation and bearing lead angles required to compensate for target motion. The launchers are then automatically and continuously moved through these angles.

Figure 9-1B (2) shows how this method works. Here the target is flying a circular course about the gun, so that elevation is the only problem we need to worry about. (The same procedure would be used if the plane were flying in a horizontal circular course.)

The range is such that the time of flight to any position on the target course is three seconds, and the target is changing its elevation it the rate of 5° per second. During the three seconds of projectile flight, the target elevation will increase by 15°. If the gun is fired at this future position (that is, with a 15° lead angle), the times of flight of the projectile and target will be equal, and the projectile will strike the target.

The major difference then, between the linear rate and angular rate systems, is that the former measures components of target motion linearly In three planes, and the latter measures the angular velocity of the line of sight, to predict changes in target position.

SEARCH RADARS

Outside the weapon system but supplying the target data needed for its use are the search radars (fig. 9-1). The search radars look for and detect targets on the surface of the sea, and in the air. These radars keep a large volume of space about the ship under constant surveillance, and they stand watch in all kinds of weather. Their beams can penetrate fog, rain, snow, and the dark of night, as they constantly sweep the sky and earth's surface in their search for the enemy. When a target is found, the radars measure its position with respect to own ship or some other reference point. To determine a target's position, we must know its range, bearing, and, in the case of an air target, its elevation. Search radars can usually give all three of these coordinates, but some radars specialize. Some radars are designed to search for aircraft and others for objects on the surface of the sea. Air search radars are used primarily to detect aircraft and missiles. Surface search radars are used mostly for detecting targets on the surface of the sea. Most of the low-flying aircraft are detected by surface search radars. FC radars can pick out prominent shore targets such as a tower, a high mountain peak, or protruding rocks.

In the typical weapons systems shown in figure 9-1, there are three search radars: the AN/SPS-10, AN/SPS-39, and AN/SPS-37. Working together as a group of detecting equipments, these three radar sets can cover all the sky and surface about a ship.

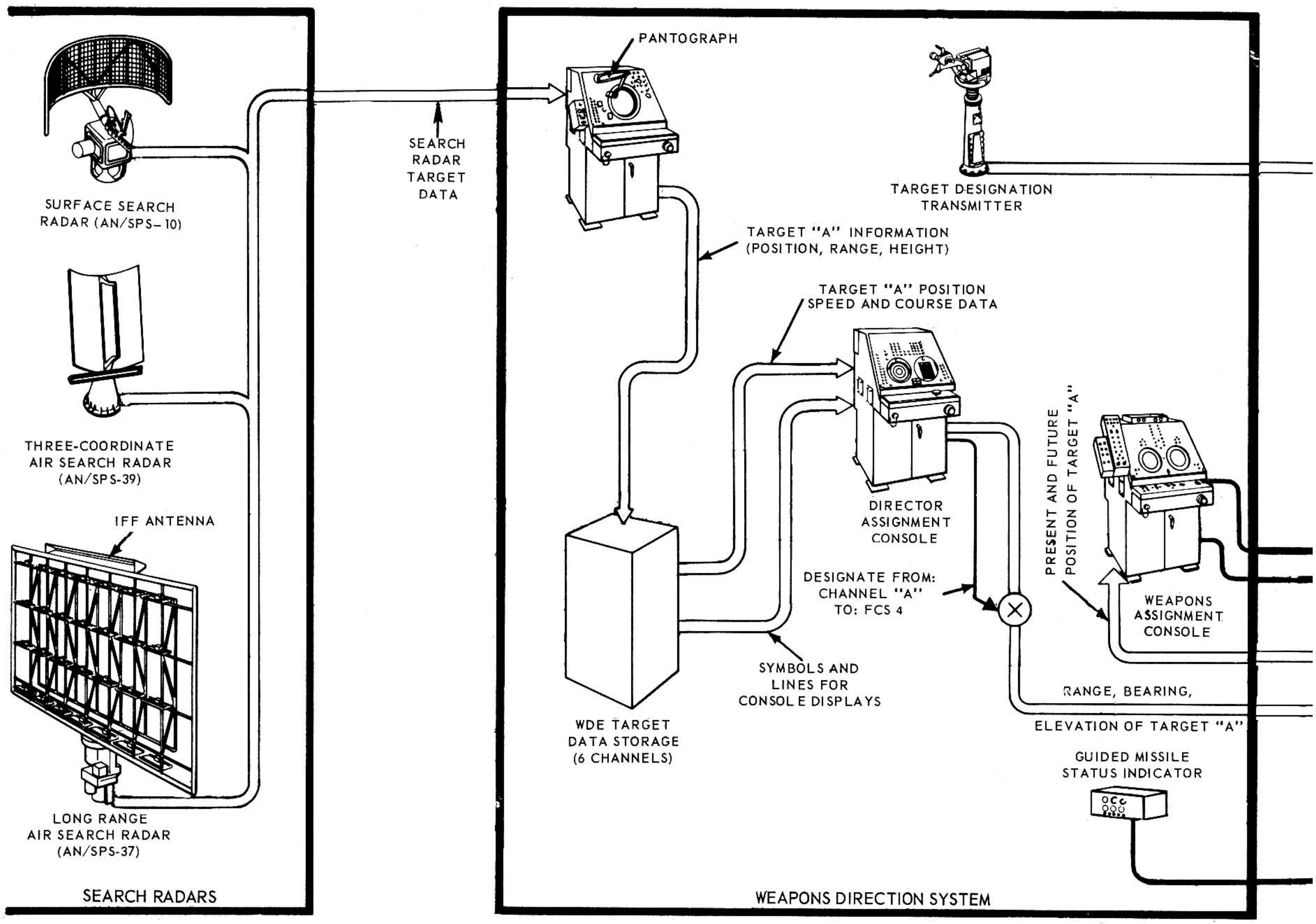
AN/SPS-10

The AN/SPS-10 is a surface search radar. It detects surface targets in excess of 15 miles. The radar transmits a beam that looks like a fan set edgewise on the surface of the sea. The beam is rotated continuously through 360 degrees. The spread of the fan is about 22 degrees, and therefore the radar can pick up air targets. But its primary purpose is to detect targets on the surface and to keep them under constant observation

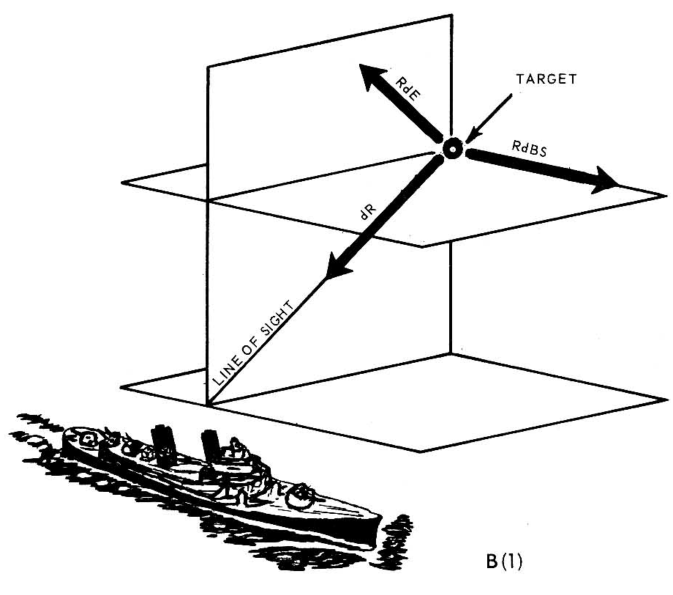
You can classify the AN/SPS-10 as a two coordinate radar. It can measure only the range and bearing of targets. To find the position of any object on a plane (and that is what the surface of the earth or sea is usually considered to be), all you need is range and bearing. But to find the position of an object in the air you must have three pieces of information-range, bearing, and elevation.

AN/SPS-39

Radar Set AN/SPS-39 is an air search radar; it can measure the elevation, as well as range and


PANTOGRAPH
SEARCH
RADAR
TARGET
DATA
SURFACE SEARCH
RADAR (AN/SPS-10)
TARGET DESIGNATION
TRANSMITTER
TARGET "A" INFORMATION
(POSITION, RANGE, HEIGHT)
TARGET "A" POSITION
SPEED AND COURSE DATA
THREE-COORDINATE
AIR SEARCH RADAR
(AN/SPS-39)
PRESENT AND FUTURE
POSITION OF TARGET "A"
IFF ANTENNA
DIRECTOR
ASSIGNMENT
CONSOLE
DESIGNATE FROM:
CHANNEL "A"
TO: FCS 4
WEAPONS
ASSIGNMENT
CONSOLE
SYMBOLS AND
LINES FOR
CONSOLE DISPLAYS
RANGE, BEARING,
ELEVATION OF TARGET "A"
WDE TARGET
DATA STORAGE
(6 CHANNELS)
GUIDED MISSILE
STATUS INDICATOR
LONG RANGE
AIR SEARCH RADAR
(AN/SPS-37)
SEARCH RADARS
WEAPONS DIRECTION SYSTEM

A


TARGET
RdE
RdBS
dR
LINE OF SIGHT

B(1)

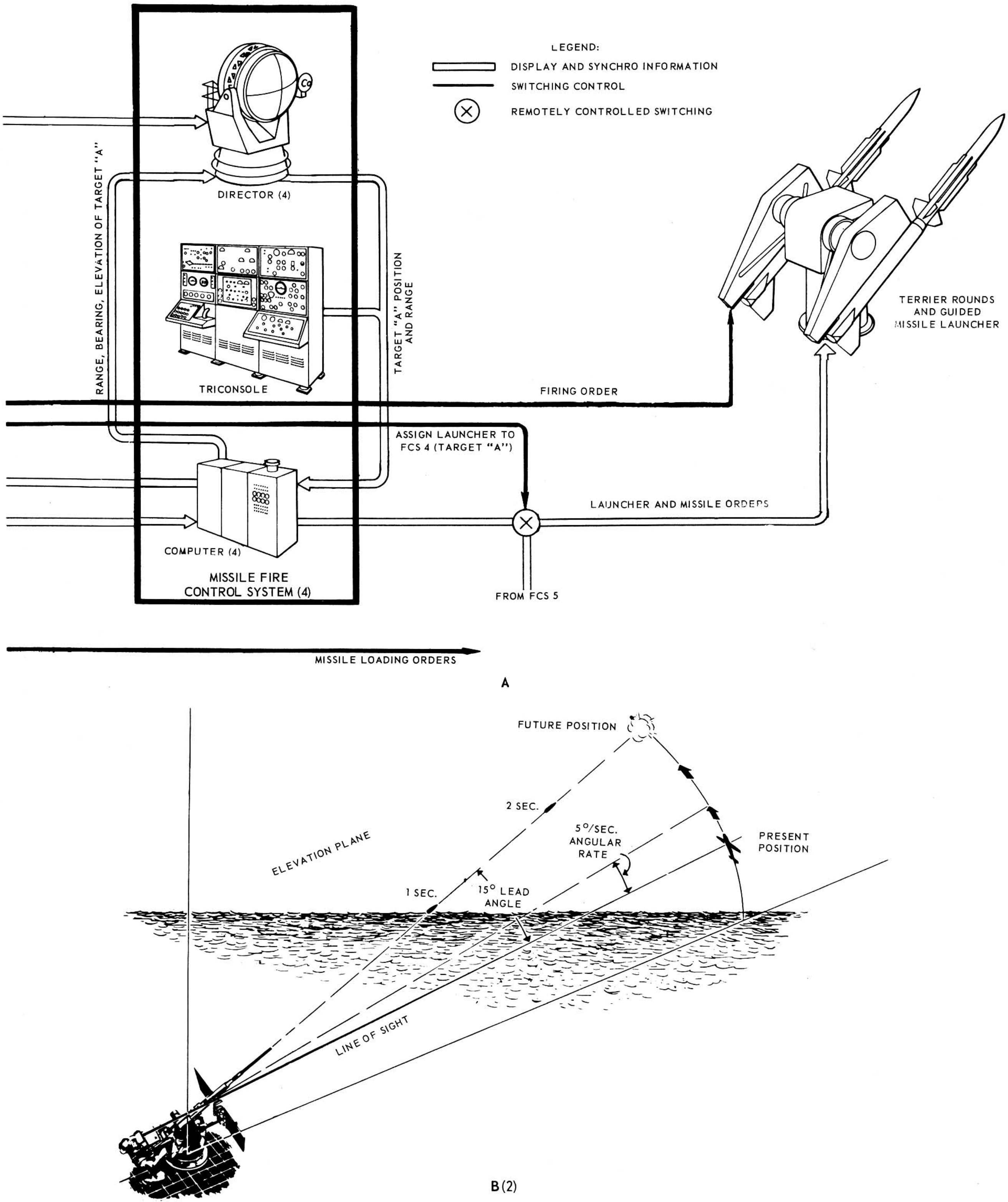


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Figure 9-1.—Typical missile weapons system. A. Components of the system, by groups; B. Using the components to solve the fire control problem; (1) Linear rate method; (2) Relative (angular) rate method.

bearing, of air targets. The set can pick up aircraft at an altitude in excess of 35,000 feet out to a range in excess of 100 miles. This radar transmits a narrow, pencil-shaped beam and scans it up and down as the antenna rotates.

AN/SPS-37

Compared with gun weapons systems, missile weapons systems are petty "slow on the draw." It takes almost a minute to select and then load missiles on a launcher. Even the trigger action is slow. Once the firing key is closed, it takes slightly over a second for-a missile to leave the launcher. So the more warning a ship has of the approach of an enemy, the more time there is to prepare the missile battery for action. Another radar, the AN/SPS-37, gives this advance preparation time. It is a long range radar. Like the AN/SPS-10, it has a fan beam and can measure only the range and bearing of air and surface targets.

IDENTIFICATION OF FRIEND OR FOE (IFF). - Look at the top of the AN/SPS-37's antenna (figure 9-1). The small antenna you see there is for the Identification of Friend or Foe (IFF) equipment. In modern warfare the identification of friend or enemy is very important. A missile cannot tell an enemy target from a friendly one. Therefore, we must make sure that we launch a weapon at a curious or unaware friend. How can we identify a target that may be several hundred miles from our ship? The answer is: IFF equipment. The equipment consists of two major units-a challenging unit and a transponder. The challenging unit is aboard ship arid electronically asks the question, "Are you a friend or foe?" The transponder is located on board friendly ships and aircraft and answers the question put by the challenging unit. The challenging unit sends out a pulse of low-power radio energy toward the target. If the target is friendly it will transmit back a series of coded pulses. If there is no answer to the challenge, the target is classified as hostile.

Target Designation Transmitter (TDT)

Optical device called target designation transmitters (fig. 9-1) are used as supplementary target detection equipment. Their use is limited to short-range, visible targets. The speed of missiles and jet aircraft is so great that such targets must be engaged while they are still well beyond the range of our present optical instruments.

Summary on Search Radars

To summarize, you can see that search radars, in conjunction with IFF equipment, search for targets, find them, and. then identify them. As a hunter, you perform these same basic functions when you hunt for game. Your eyes probe the underbrush and other parts of the landscape in search of prey. When you sight some animal or bird, you fix your eyes on it and measure its position with respect to you, and then you identify it "Is this animal or bird in season?" you ask yourself. If it is, you raise your gun and prepare to fire; if it is not, you resume your search for legal game.

A basic idea to keep in mind is that the equipments in a weapons system simply extend man's senses and capabilities. Radar extends his vision by hundreds of miles and gives him the added capability of seeing in the dark, and in other conditions of poor visibility. The IFF equipment enables him to tell whether a target is friendly or not.

Target echoes and IFF pulses are sent from the radars through a radar switchboard to consoles in the weapons control system. Target position and range information follow a similar path. In figure, 9-1. all this information is labeled "search radar target data."

GMLS CAPABILITIES

Guided missile launching systems are capable of stowing, selecting, loading, and launching missiles which can be used against air, surface, shore, and underwater targets. The 3Ts, (Terrier, Talos and Tartar) are the three missile systems now found aboard ships. These systems have undergone many changes since their inception. A Standard missile has been developed which will be employed with either the Terrier (Standard extended range (ER) missile) or the Tartar (Standard medium range (MR) missile) missile systems. The ASROC missile has also been adapted for use with some Terrier systems.

A brief description of the capabilities of the three missile system follows.

A Terrier/ASROC GMLS system provides the fleet with a tactical air, shore, surface, and underwater defense. The Terrier missile used for air, surface, and shore defense can maintain a firing rate of two missiles every 30 seconds when launched from a dual arm launcher. When the launcher is in the ASW mode of operation, two ASROC missiles can be loaded simultaneously. They can only be fired singly with the B side firing first and can maintain a firing rate of approximately 80 seconds.

The Terrier missile is a guided weapon with a solid fuel rocket motor and sustainer. The missile uses either a beamriding (BT) or a semiactive homing (HT) guidance system.

The ASROC missile is a solid fuel, rocket propelled ballistic weapon with either a torpedo or a depth charge configuration. Both weapons are fired from the same dual arm missile launcher in which a Terrier weapon is launched in quick succession (a salvo) and an ASROC weapon launched singly. To make an ASROC missile compatible with a Terrier launching system, the ASROC missile must be equipped with an adapter rail mechanism so that the ASROC can be handled by the same equipment as the Terrier missiles. Both missiles have the capability of carrying either a conventional or nuclear warhead.

A Tartar/Standard GMLS provides the fleet with a tactical weapon for use against air and surface targets. Tartar/Standard missiles are launched from either a single or dual arm launcher with a load-to-fire rate of approximately 8 seconds for Tartar missiles and 10 seconds for Standard missiles.

The Tartar/Standard (MR) missiles are supersonic surface to air missiles with a solid fuel dual thrust rocket motor. They are guided by a semi-active homing system.

A Talos GMLS provides the fleet with a tactical weapon for use against air targets. The Talos missile booster combination is a ramjet propelled supersonic missile with a solid propellant rocket booster. The missile uses a beam riding control system during midcourse flight and a homing guidance system during the terminal phase of flight. Talos can carry either a nuclear warhead or a conventional warhead.

Modes of Operation

Based on information received from a ship's weapon system, a GMLS controls the movements and performance of each missile selected prior to missile firing. Target selection determines the missile type, whether a single or multi missile firing is desirable, and when to load a missile onto the launcher guide arm for firing. Missiles within a launching system can be assigned a code letter according to their purpose and design. An X, Y, or Z select code circuit can be used to identify each type of missile within a system. Missiles can be coded by their configuration, (whether they are used against surface, air or under water targets,) and also by the type of warheads they employ against a target. The coding circuit will provide a selected missile with the initial flight guidance prior to launch. The type of target selected, which would be the most threatening target, determines the mode of operation of a launcher system and also determines the type of target data received by a system. Figure 9-2 shows the flow and processing of target data through a Terrier weapons system and the inputs to the launching system. Most weapon systems operate in three basic modes of operation: surface, underwater, and air.

Surface and Shore Targets

During surface operations in a Terrier weapon system, the controlling Missile Fire Control System (MFCS) tracks the target in range and bearing while the radar guidance beam is programmed to a small elevation angle above the target. The MFCS receives designation orders, acquires targets, and tracks surface targets. Target tracking data from the fire control director, missile performance characteristics, and own ship's motion are computed to generate launcher train and elevation orders for an optimum firing position. When the launcher is assigned to a MFCS, it trains and elevates to synchronize to a computed position which aims the Terrier missile toward the correct capture point depending on the type of missile selected. The fire control systems computer continuously corrects the launcher aim point as the ship and target maneuver.

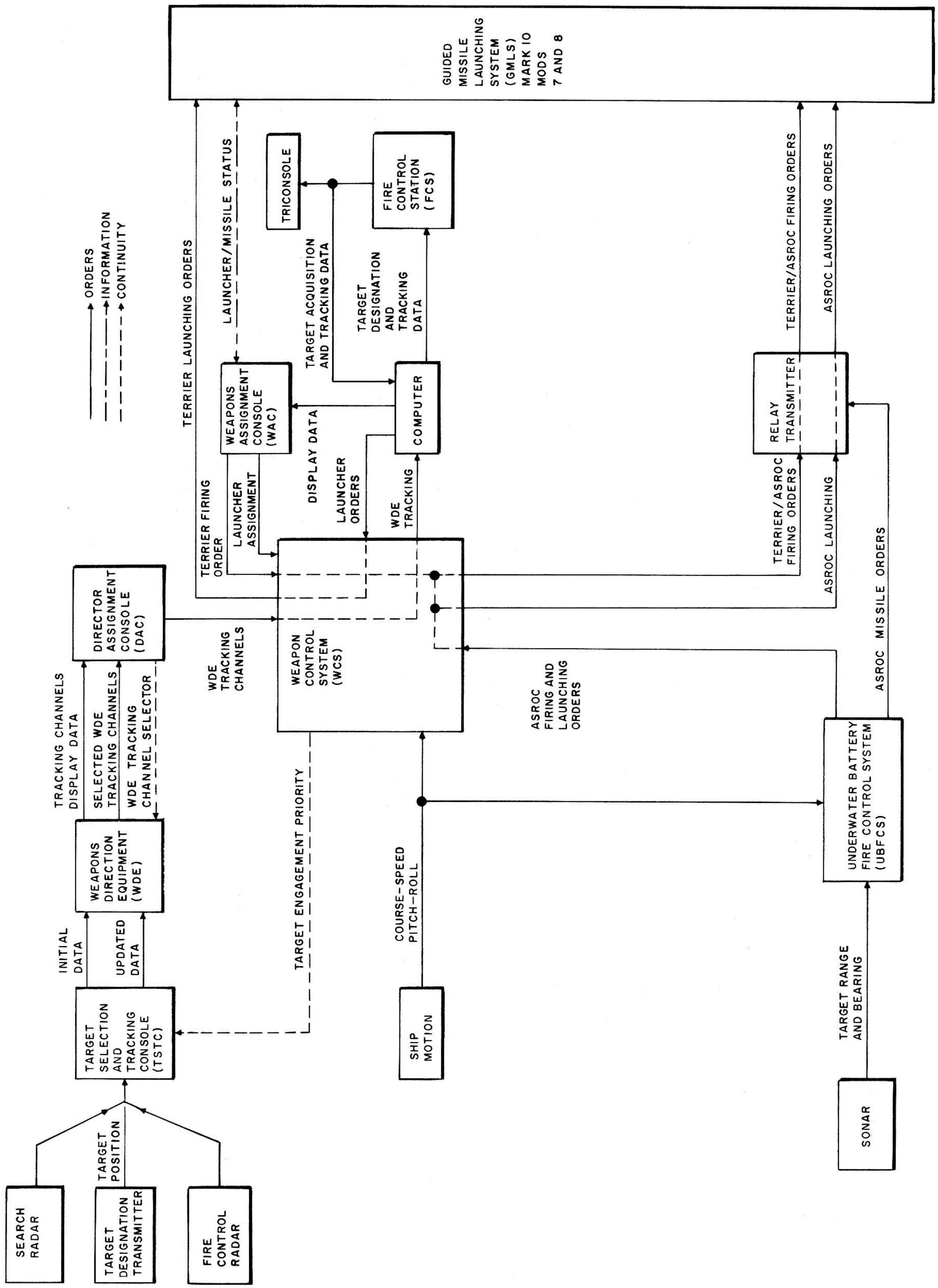

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Figure 9-2.—Flow and Processing of Target Data Through Terrier Weapons System.

For a shore target, a Terrier missile system follows a procedure similar to engagement of surface targets but the targets are not tracked. The missile is launched at a preselected point, and the missile warhead is detonated at a preselected height above the target. During shore firing operations, the MFCS radar director remains fixed in bearing as the ship holds a steady course. When launched, the missile follows the guidance beam toward the shore target, and the MFCS computer programs the beam down to the burst height as the missile-to-target range decreases to zero. Figure 9-3 illustrates a surface and shore fire control problem.

Underwater Targets

When underwater targets are encountered and identified as hostile, the ship's Underwater Battery Fire Control System (UBFCS) orders the Terrier missile system into an Antisubmarine Warfare (ASW) operation. When targets are to be engaged by ASROC missiles, the UBFCS controls the attack problem and the Weapon Direction System (WDS) implements the order for the launcher to shift to an ASROC mode. The UBFCS continues tracking the underwater target and continuously corrects the launcher aim point as the target and ship maneuver. When all indications are correct and the ASROC missile is launched, UBFCS designates a position is space where the Gun Fire Control System (GFCS) radar can acquire the ASROC missile and track it to its water entry point. This information is used by the UBFCS to evaluate the probable success of the firing. If the missile has a torpedo payload, a parachute deploys which slows the payload to a safe water entry velocity. The parachute detaches from the payload upon water impact. The torpedo sinks to a preset initial search depth and starts on a target search program. If the missile has a depth charge payload, the payload continues its trajectory to the water entry point and detonates at a preset depth.

Airborne Targets

Since GMLS are the ship's primary defense against air targets, we will discuss in some detail the components used during antiaircraft operations starting with a ship's weapons control system.

THE WEAPONS CONTROL SYSTEM

A weapons control system is comprised of two major subsystems: (1) a Weapons Direction System, and (2) one or more Fire Control Systems. The weapons control system contains equipment that makes decisions on its own or aids officers in making appropriate decisions. Information about targets is visually displayed and stored, and this displayed and stored information provides the basis for decision making. Commands are transmitted between equipments in the weapons control system and to units in other systems. Information is passed back and forth between equipments and individuals over data transmission circuits that are a part of the weapons control system. Computing equipment calculates lead angles which are sent to the launcher to aim it in the proper direction. Also, orders are sent to the missiles before they are launched. After the missiles are in flight, information is sent to them to direct their flight to the target.

The Weapons Control System serves the gun batteries as well as the missile batteries. A gun battery consists of a group of gun mounts of similar size, ballistic characteristics, and ammunition requirements. A missile battery has two or more missile launchers. Traditionally, the largest caliber of guns on board is the main battery, but the term "Main battery" may mean the weapon of the greatest potential effect, and therefore the missile battery may be the main battery.

Weapons Direction System

The typical missile weapons system shown in figure 9-1 includes Weapons Direction Equipment Mk 3. The WDS is made up of two groups of equipment: (1) Weapons Direction Equipment (WDE), and (2) related (ancillary or auxiliary) equipment.

WEAPONS DIRECTION EQUIPMENT. - This term is the one in current use. The same equipment has been called Designation Equipment

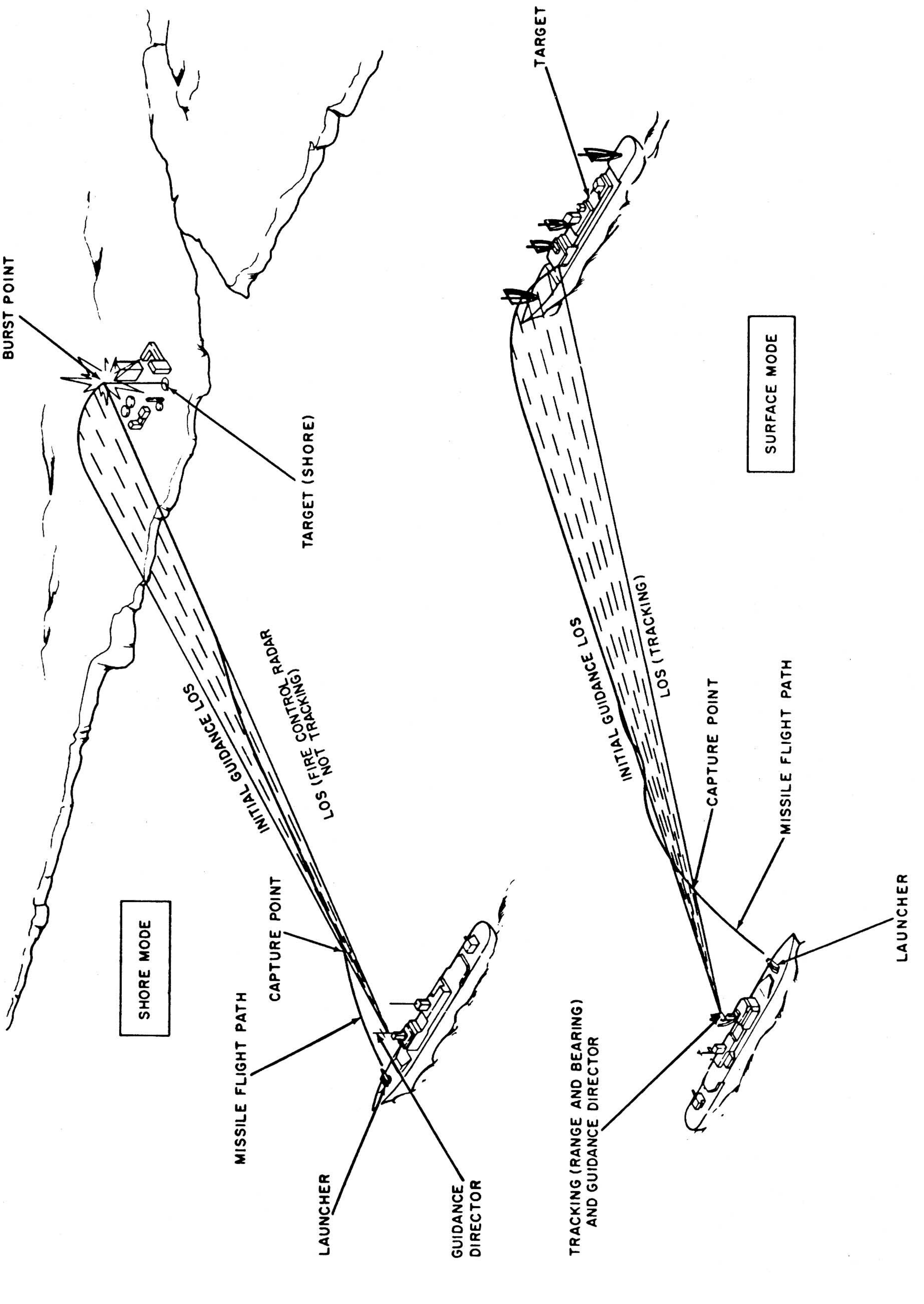

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Figure 9-3.—(U) Basic Fire Control Problem, Y Surface and Shore Modes.

(DE) or Target Designation Equipment (TDE), and you will find these terms still in use. In the system illustrated in figure 9-1, it is called Designation Equipment Mk 9. It consists primarily of three Target Selection and Tracking Consoles (TSTC), a Director Assignment Console (DAC) a Weapons Assignment Console (WAC), and a Guided Missile Status Indicator. The last two equipments are especially of interest to you because they originate many of the instructions sent to the launching system. They also receive much information in return.

The WDE, as a whole, selects targets from the video and target position information supplied by the search radars. This target information is electronically displayed on cathode-ray tubes in the various consoles. Selected search radar targets are manually tracked to determine course and speed. The WDE provides for the assignment of missile fire control radars to track the most threatening of these targets. Equipment is provided to assign the launcher to one of the missile fire control computers. Other equipment is used to let the launching system know what type of Terrier missile is to be launched. Also, a firing key is provided in the Designation Equipment to start the launching process. In short, the Designation Equipment coordinates and monitors the activities of the entire missile weapons system.

Target Selection and Tracking Console (TSTC). - The three TSTCs in our typical weapon system (fig. 9-1) can all be used for selecting and tracking targets. One TSTC is located in the Combat Information Center (CIC), and is normally used to select targets for tracking. The other two consoles are part of the Weapons Control Station, and they track the targets selected by the TSTC in CIC. All the consoles are wired in parallel; therefore, both functions (selection and tracking) can be performed by any console or combination of consoles. In figure 9-1 you can see the general outlines of a TSTC. Figure 9-4 shows the panel face.

The principal indicator on each console is a Planned Position Indicator (PPI). You studied this radar indicator in Basic Electronics, NAVTRA 10087 so we won't describe how it works. The cathode-ray tube displays the bearing and range of every target detected by a selected search radar. A control on each console can select a particular search radar to use as a target data source. The normal source is the AN/SPS-39.

The personnel in CIC and Weapons Control need this picture to evaluate the combat situation. Evaluation is concerned with answering the following questions:

1. What does the target intend to do? Is he going to make a run on the ship or simply stay at long range and observe?
2. How threatening to our ship's safety is the target? If it becomes obvious that his intent is to attack, how much time does our ship have to launch a counterattack? This raises another question.
3. What weapon shall the ship use to counter an attack?
4. What kind of weapons does the target carry?

Many other factors are involved in evaluating a target situation, but these sample questions should give you some idea of what the term "evaluate" means. The target selection and tracking consoles aid in the evaluation process by determining which targets to track, and then keeping them tracked. Each target assigned its own tracking and storage channel. The channels are lettered A through F. When a target has been selected for tracking and has been assigned a channel, the appropriate letter is electronically painted on the PPI-scope. Look at figure 9-5A. It shows a view of the air and sea space around your ship as seen from a position directly above it. Figure 9-5B is the TSTC display scope and it shows a symbolic reproduction of the actual combat picture. As the real targets maneuver, their electronic counterparts (blips) follow the same motions. Search radar target tracking consists of making the letter symbol associated with a target continuously follow the target blip. The operator uses the pantograph (fig. 9-4) as you would a gun sight. He lines up the pantograph ring sight with a target - let's say target A. Then he presses a button to measure the position of target A. This position information is put into a computer. The operator keeps his sight over the target for several seconds while he continually presses the tracking button. Meanwhile, the

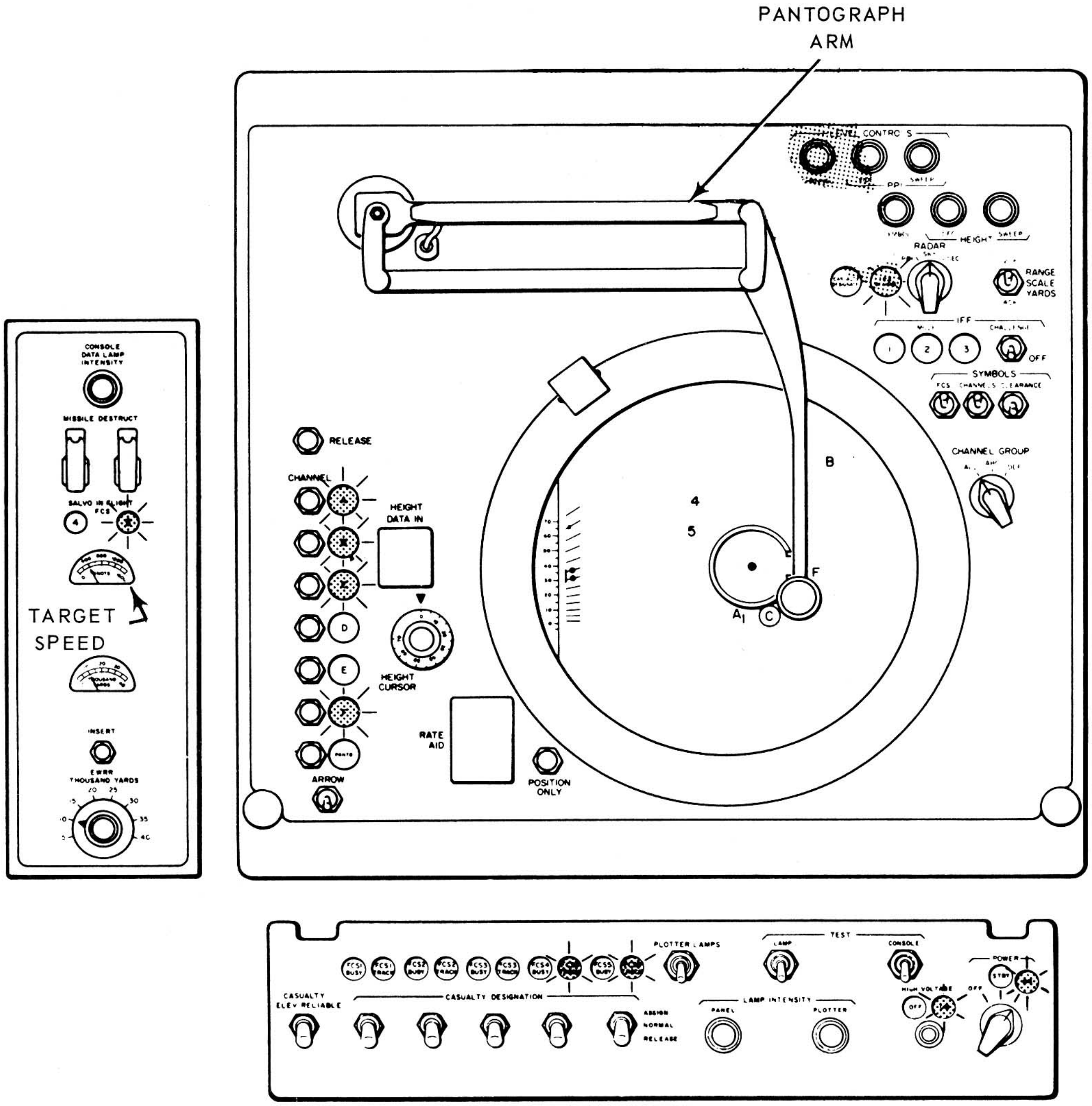

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Figure 9-4.—Panel face of target selection and tracking console (TSTC), Mk 9 Mod 0 Designation Equipment.

computer associated with target A is calculating the target's speed and course. When the computer has the correct course and speed of target A, the letter symbol, which is driven by the computer, will follow the target blip without the operator of. the console moving the pantograph. Target position, course, speed, and elevation are stored in the A channel computer for use by the TSTC and the DAC operators.

Search radar targets are tracked with the aid of pantograph arms, one on each TSTC. You can see a general outline of the arm in figure 9-SB. The arm is essentially a link between the search radars and the weapons control system. We can illustrate this point by showing, in a brief and general explanation, what happens when we start the WDE tracking process. You should have a general ideal of what is going on in Weapons Control so you can understand how you fit into the "big picture."

The weapons officer tells the operator of the tracking TSTC which target to follow. The operator places the pantograph arm, which has a ring sight, over the selected target blip. He then presses various buttons which open up a tracking channel. Assume that channel A is selected (for

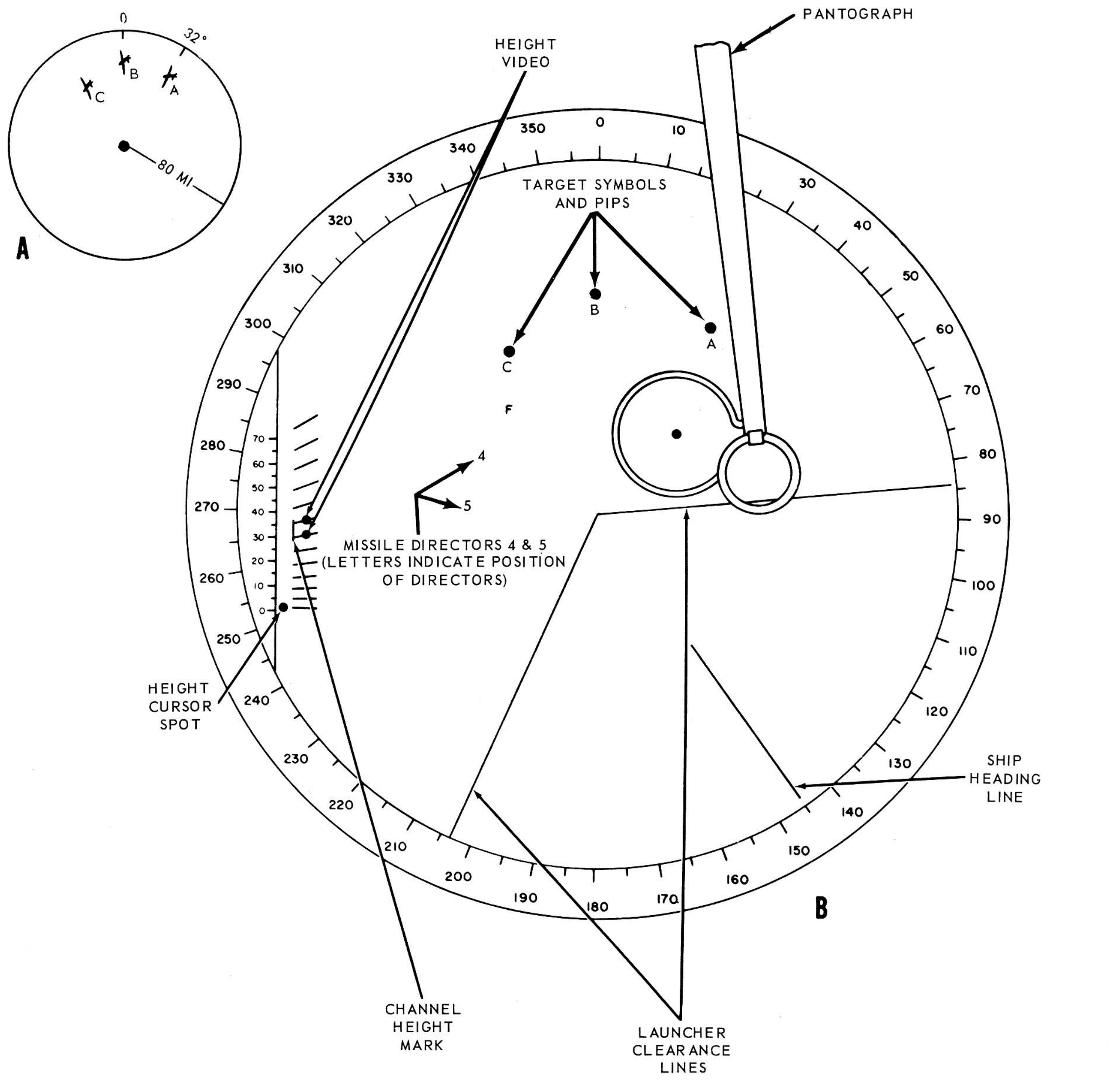

Figure 9-5.—How the combat picture looks on the TSTC display:
A. Targets A, B, and C; B. Display scope, Target Selection and Tracking Console.

target A). Target position and rate information are placed in the channel computer and storage unit, and stored. Also, if information about the height (elevation) of the target is available, this information is put into storage.

Let's follow this target through the weapons control system as the information passes from one equipment to another. We have already described the first leg where a selected target was passed from a search radar to tracking and storage channel A via the pantograph arm on one of the TSTCs. Target range, bearing, course, and speed are now stored in the A channel of the WDE Data Storage Unit (shown as a large box in fig. 9-1). Coming out of this unit is a line marked "Target A position. speed, and course data." The line ends at another piece of equipment in the WDE called the Director Assignment Console.

Director Assignment Console (DAC). - The Director Assignment Console (fig. 9-6) is located in the Weapons Control Station and is used to display target fife control information. Despite the console's name, its primary purpose is to assign a missile or gun fire control system rather than only a director to a particular target. The console contains two cathode-ray tube displays (fig. 9-6). The tube on the left shows the bearing and range of each target being tracked by the target selection and tracking console operators. Pushbutton controls are used by the console operator to assign fire control systems to targets and for releasing the systems after the targets are destroyed or if some other target becomes more threatening. Indicator lamps show the status of the fire control systems. For example, the track light shows that a fire control system is already tracking target A; the FCS NON-OP light indicates that its associated fire control system has a casualty in it and is therefore inoperative; the IND light indicates that some other designation source, such as a Target Designation Transmitter, is designating to a fire control system.

The multipurpose display on the right of the panel face (fig. 9-6) shows the target elevation and speed of any targets that are in tracking channels. This target information is determined by the tracking channel computers in the WDE target data storage unit (fig. 9-1). The DAC operator can tell from the information displayed on the multipurpose plot (vertical line) how much time he has to assign a fire control director to a target before the target reaches a range at which it can release its weapons. He can also determine from. the display how long a fire control system will be busy tracking a target and guiding a missile to it (horizontal line).

You can get a closeup view of the DAC displays in figure 9-7. You can learn quite a bit about a target by looking at these displays. The PPI tells us that target A is bearing 025°, and is about 75,000 yards from the ship. Missile fire control director 4 (symbolized by the numeral 4) is positioned at bearing 258° and its radar range measuring unit is sitting at 35,000 yards. As director 4 changes its train position, the numeral 4 will move correspondingly. Now figure out where director 5 is positioned in bearing and range. Notice the target course line extending from target A toward the center of the scope. The course line indicates that target A is heading for the ship.

The multipurpose display indicates how fast target A is traveling. It is making about 750 knots, and is flying at 35,000 feet. The multipurpose display also provides information about the length of time a director will be used to track and control missiles during the engagement.

According to the display in figure 9-7 target A is in position to launch an attack against the ship. Since he is within missile range (or soon will be), and beyond gun range, the DAC operator assigns a missile fire control system to engage the enemy. Assume that FCS 5 is busy controlling a missile salvo against another target. This means that all units in FCS 5 are at work; therefore, FCS 4 must be assigned to this target. The DAC operator assigns FCS 4 to target A by pressing appropriate control switches on the console. A selector switch in the missile FC switchboard automatically turns, connecting target A position information (as determined by the channel A tracking computer and storage unit) to the missile fire control computer in FCS 4.

The missile fire control computer (fig. 9-1) associated with director 4 changes the target A position information from tracking channel A into synchro signals that are proportional to the range, bearing, and elevation of target A. These target A position signals are then sent to the director's range, bearing, and elevation servos. The director slews onto the target, searches for it, and when it has found the target, begins to track it. Now the director and its radar accurately measure target A's position and range, and send this information down to the fire control computer. At about this time, the fire control system signals the DAC that it is tracking target A (the FCS 4 track light comes on), and the tracking channel A lights on the TSTC and DAC begin to flash, indicating that target A is being tracked by FCS 4.

The TSTC operator disconnects tracking channel A from the fire control system because

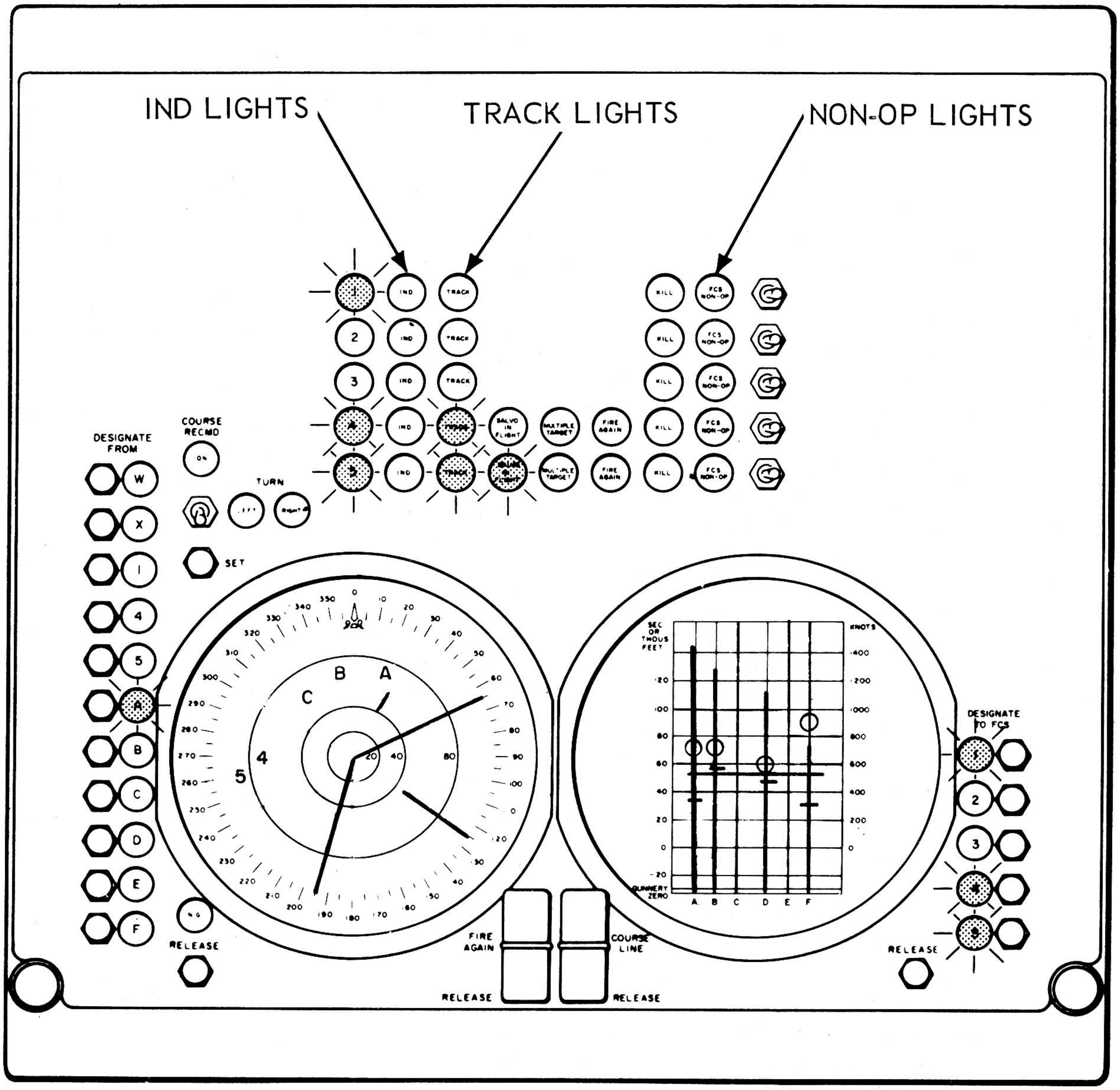

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Figure 9-6.—Panel face of Director Assignment Console (DAC).

there is no further need for it since the fire control system now has the target.

So far in this discussion, target A has been detected by a search radar, identified as a hostile target, selected out of a group of three targets, tracked by the TSTC operator to get a rough idea of the target's position and motion, passed on to a fire control system which then picked up target A. As the director and its radar track the target, they continuously and precisely measure target A's position and range. This very accurate information is sent to the computer, which predicts where the target will be some time in the future. The computer also makes up launcher train and elevation orders as well as information for use by the missile when it is in

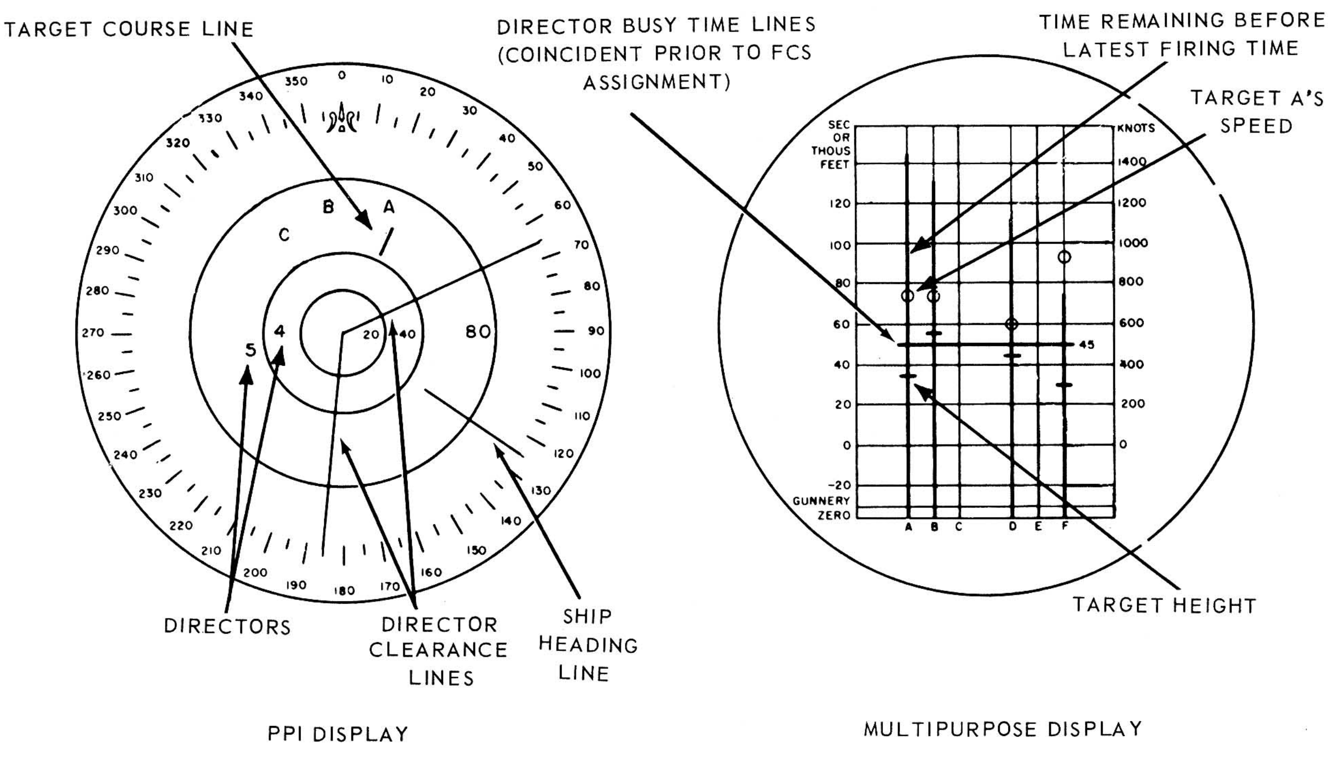

Figure 9-7.—Tactical displays on Director Assignment Console (DAC).

flight. We'll talk more about the fire control system later. But for the present, let us return to target A and take a look at the next step in its progress toward destruction.

Since our typical missile weapons systems has only one launching system, it must be shared with the two missile fire control systems. The operator of the next equipment we will discuss, the Weapons Assignment Console, has control of connecting the launcher with a selected fire control system, in this case, FCS 4.

Weapons Assignment Console (WAC). - Each of the PPI displays on the Weapons Assignment Console (WAC) presents target position information from a fire control system assigned to track a target. The PPI-scope on the left in figure 9-8 shows the target being tracked by radar set and director 4; the indicator on the right shows information about the target being tracked by system No. 5. A summary of conditions at the launching system also appears on the console. The last step in the evaluation process take place at the WAC. The WAC operator makes a final evaluation of the target in terms of: (l) Is the direction of the missile launcher clear of obstructions, such as the ship's superstructure? (2) Is the target within the range and altitude capability of Terrier type missiles? (3) Is the launcher synchronized with the computer order signals?

Each PPI (fig. 9-9) is a plot of range against bearing, with own-ship position at the center. The small circle at the center of the scope represents the minimum effective range of the missile. There is no point in firing a missile at a target within this range; you won't hit it.

Launcher clearance lines represent the unclear area (because of ship superstructure or equipment) for the launcher, where it may not be trained (or elevated) for firing. Notice the tiny circle near the inside edge of the bearing scale at about 028°, at right PPI. This circle represents the position of the launcher. As the launcher trains, the circle moves to a position corresponding to launcher bearing. If the launcher were positioned between the V-shaped clearance

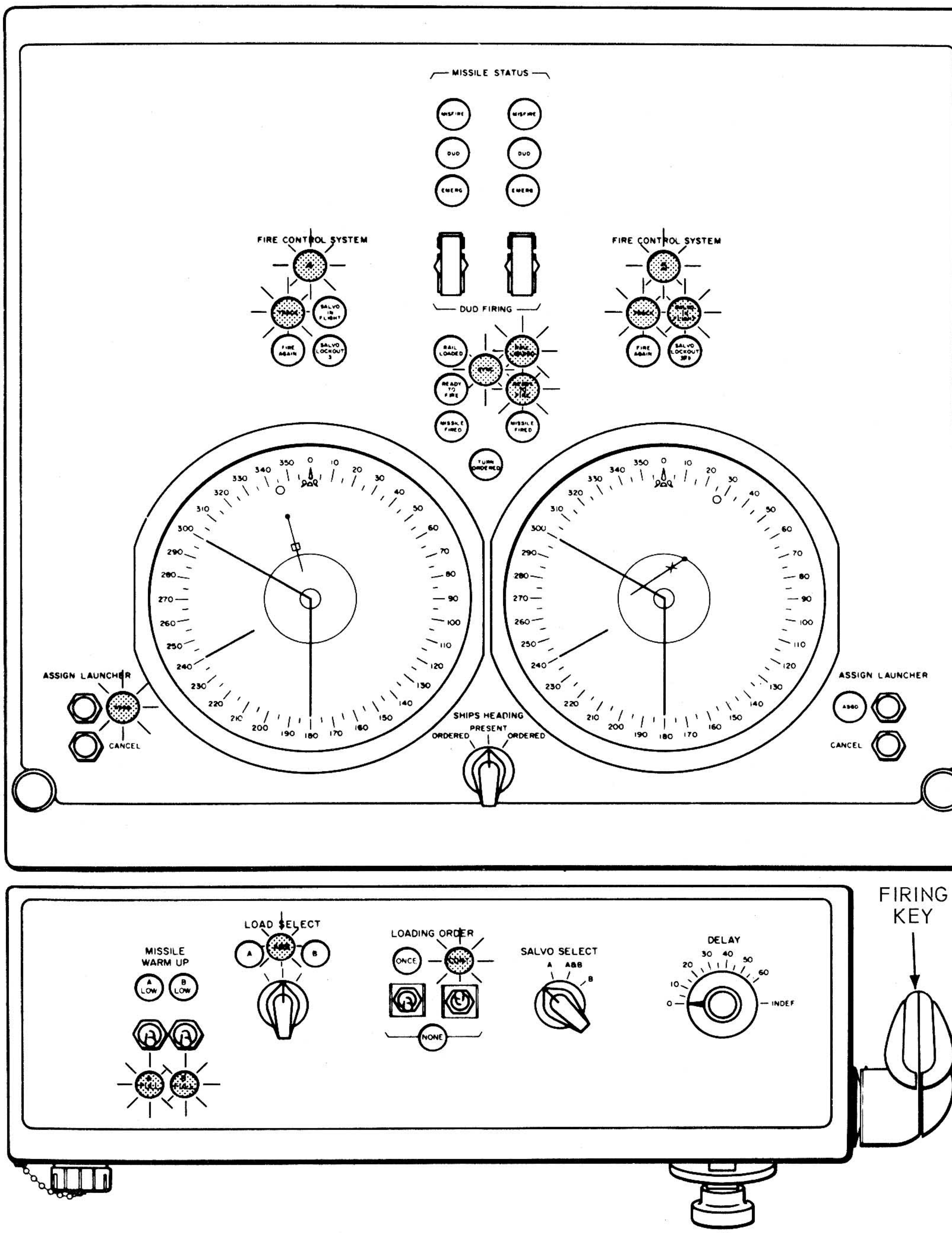

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Figure 9-8.—Panel face of Weapons Assignment Console (WAC).

lines, launching a missile would be prevented by the firing cutout cam and the automatic tracking cutout system.

To assign the launcher to one of the fire control systems, the operator of the console presses the appropriate pushbutton marked "ASSIGN LAUNCHER" (fig. 9-8). If the launcher is prepared for remote operation, it automatically synchronizes with the train and elevation orders transmitted from the assigned missile fire control computer. As soon as the launcher is synchronized with the order signals, the light labeled "SYNC" comes on.

When the fire control system has been assigned by the DAC operator to track a target, and the radar is automatically tracking the target, additional indications appear on the PPI display as shown in figure 9-9. An outer contour circle appears on the scope of interest. The outer contour represents the maximum capabilities of the Terrier missile; the inner contour circle represents the minimum area, which is too close to the ship for the missile to strike. A square appears for FCS 4 and a cross for FCS 5. These. geometrical figures represent target position at the time a missile would intercept it, if the missile were fired now. Notice that the square is outside the outer contour circle in the illustration. The WAC operator can see from the display that the missile is not capable of hitting this particular target because it is beyond the capabilities of the missile. If the target is headed toward the ship, firing the missile can be delayed until the target is within range; the computer will calculate the time accurately and speedily.

Two columns of lamps at the center of the WAC, just above the two display scopes (fig. 9-8), indicate missile status for the A and B rails of the launcher. These lamps are lighted by events that happen at the launcher. For instance, the RAIL LOADED lamp comes on when a missile is on the associated launcher rail. The SYNC lamp lights when the launcher is synchronized with the launcher train and elevation orders

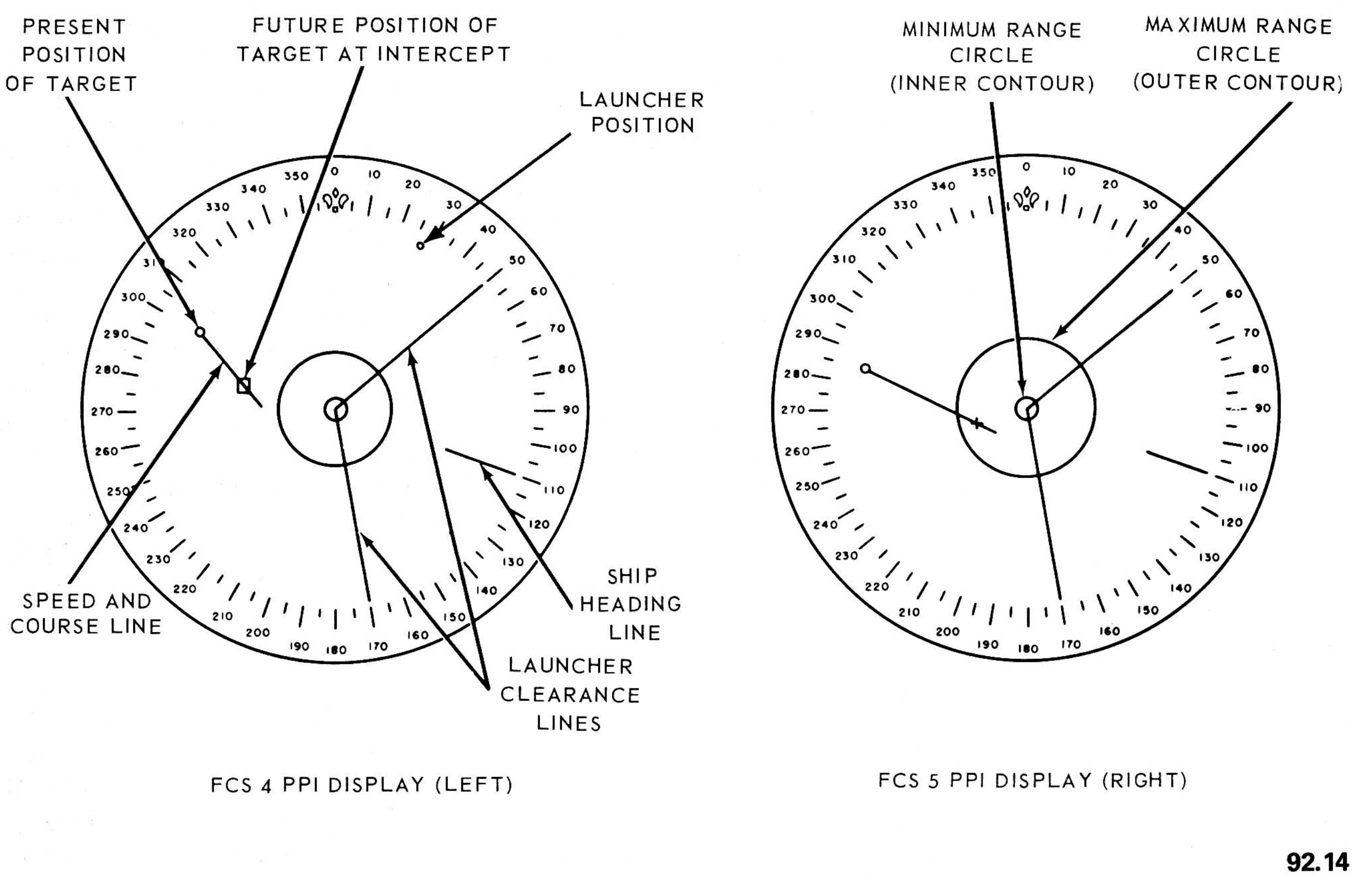

Figure 9-9.—Weapons assignment console (WAC) combat picture.

from the missile fire control computer. The READY TO FIRE lamp indicates that firing circuit interlocks are closed, the rail is loaded, the blast doors are closed, the firing zone is clear, the contactor is extended, the launcher is synchronized with computer orders, and the missile has received at least 20 seconds of warmup power and is ready to be fired. The weapons control officer makes the decision to fire when the READY TO FIRE lamp is on, and tells the WAC operator to close the firing key.

The MISSILE FIRED lamp is lighted after the missile has left the rail; this lamp remains on until both missiles have been fired, or the launcher has been released from the fire control system to which it was assigned.

The MISFIRE lamp is lighted when an attempt is made to fire a missile, the firing current flows through the booster squib, but the booster propellant does not ignite. A misfire is a dangerous failure. The DUD lamp lights when an attempt is made to fire but the firing current fails to flow through the booster squibs. Below each DUD lamp is an EMERG (emergency) lamp and a DUD FIRING switch. When the DUD FIRING switch is operated, it bypasses the normal firing circuits to the missile and connects firing current directly to the booster squibs. The EMERG lamp indicates that emergency firing circuits are energized.

The missile status information described above is also displayed on the Launcher Captain's panel (EP2). See figure 9-10.

Now let's shift Our attention to the group of five lamps that are above each PPI (fig. 9-8). The group on the left is associated with FCS 4 and the group on the right with FCS 5. When the director receives an assignment, the lamp at the top of the group lights. The TRACK lamp lights when the director starts to track an assigned target. The SALVO IN FLIGHT lamp is lighted during the time interval between launch and target intercept. When the DAC operator orders another salvo fired at the same target, the FIRE AGAIN lamp flashes. When two salvos have been fired at a target, the SALVO LOCKOUT 3RD lamp lights, which indicates that the director is not available for another assignment until the salvos already in flight have reached their target. The fire control systems can control a maximum of four missiles (two 2-missile salvos). Therefore, a third salvo (one or two missiles) cannot be fired.

At the lower left-hand corner of the main panel (fig. 9-8) are two pushbuttons and one lamp. The ASSIGN LAUNCHER pushbutton is used to assign the launcher to FCS 4. The ASSIGN (ASGD) lamp, alongside the pushbutton, lights to indicate that connection has been made between fire control system and the launcher. Also, on the EP2 panel (fig. 9-10) in the launching system, the LAUNCHER ASSIGNED lamp lights. As soon as two missiles have been fired and the firing key is released, assignment of the launcher to the fire control system is canceled automatically. When only one missile. is fired in the first salvo, launcher assignment is not canceled. If the WAC operator decides not to fire at a target after the launcher has been assigned, he may break the assignment by manually pressing the CANCEL pushbutton. When the assignment is canceled, the ASGD lamp goes out and so does the corresponding lamp on the EP2 panel.

The rectangular shaped panel at the bottom of the main display panel (fig. 9-8) is called the control-indicator auxiliary. It contains switches that send orders to the launching system concerning missile handling and firing. With the exception of the DELAY knob, you are familiar with all the functions in the launching system that are ordered by the controls on this panel.

The position of the LOAD SELECT switch indicates to the launching system personnel which launcher rails are to be loaded. You can see in figure 9-8 that the order is to load both A and B arms of the launcher. The LOAD A & B light just above the load select switch is burning, and this indicates that the launcher captain has acknowledged the order.

LOADING ORDER switches send orders to the launching system personnel to load the rails once, continuously, or not at all. The lamp associated with the operated switch shows the WAC operator that his order has been received and acknowledged. It does not mean, as you know, that the load order has been carried out. If you will look up at the main display panel, you can see that the B rail is loaded but the A rail is empty at this time. The RAIL LOADED lights are lit when the missiles are actually on the launcher and their shoes make contact with the interlock switches. This is positive proof

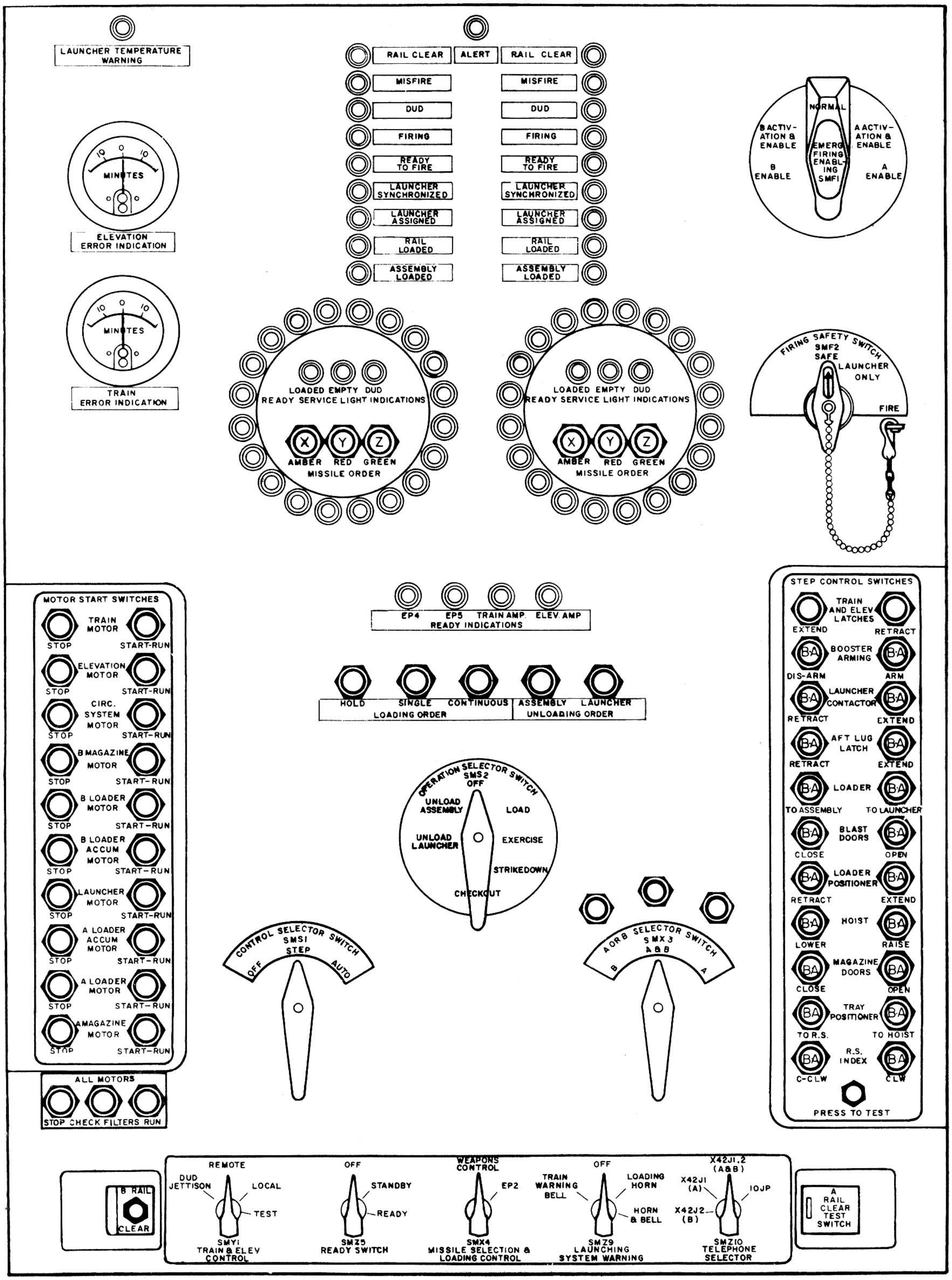

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Figure 9-10.—Launcher captain's panel (EP2), Mk 190 Mod 1.

that they are on the launcher and in firing position. No human opinion enters, into the picture.

The SALVO SELECT switch selects the rail or rails from which a missile is to be fired. When the switch is put in the position shown in figure 9-8, the missile officer wants a single missile fired at the target. He does not particularly care whether it leaves the A or the B rail. But he wants to make sure that one of them goes. If the A rail missile is ready first, and it normally is, that's fine. But if you get a NO-GO on the missile intended for rail A. then you load rail B. The salvo select switch (fig. 9-8) is positioned so a missile can be launched from the A arm only, the B arm only, or from the A and B arms (in succession, not simultaneously).

Operation of the DELAY control sends a synchro signal to the missile fire control computer to advance the fire control problem solution by whatever delay is selected. The term "delay" refers to the loading time of the launching system. If the approximate loading time of your system is forty seconds and you want to see what the fire control problem will look like 40 seconds from now, you turn the DELAY knob to 40 seconds. The computer uses this information to advance the present fire control problem by 40 seconds. Information about this future problem is sent back to the PPI-scope and the future position symbol will move to the position where the target will be 40 seconds from now. Being able to look into the future helps the WAC operator to evaluate more effectively.

Missiles must be warmed up before they are launched For Terrier missiles the minimum warmup time is 20 seconds. When MISSILE WARMUP switches are placed at the FULL position, warmup power is applied to the missile through the launcher-to-missile contactor, which mates with the warmup pad on the booster, and the FULL lamps light. Switches may be left in this position for a maximum of 15 minutes. If the missile is not fired during this period, the LOW lamps flash. This indicates that the operator should place the switches in the LOW position, which removes warmup power from the missiles so they can cool off.

When the DAC operator assigns a target to a fire control system, the BUSY lamp for the FCS (indicated by the FCS number) lights up on the WAC. Figure 9-8 shows that both fire control systems have been assigned a target. The lamp remains lighted until the assignment is canceled. The operator can tell if the fire control radar is automatically tracking the designated target because the TRACK lamp lights.

When the missile clears the launcher rail, the missile FC computer is notified by a SALVO IN FLIGHT signal from the launching system. The computer transmits the salvo-in-flight signal to the WAC SALVO IN FLIGHT lamp, which then lights. It remains on until the missile intercepts the target, or until its flight time runs out.

In case the DAC operator orders a second salvo to be fired against the same target, the FIRE AGAIN lamp begins flashing. When the second salvo is fired, the FIRE AGAIN lamp goes out, and the SALVO IN FLIGHT and the SALVO LOCKOUT 3RD lamps light. Interlock circuits prevent firing a third salvo and the lighted lamp shows that the lockout circuitry is working properly; the third salvo is automatically locked out, and overload of the missile system is prevented.

The TURN ORDERED lamp, before the SYNC lamp, is lighted from the pilot house when the captain or officer of the deck orders a change in ship's course. It is important that the WAC operator know of a proposed course change since it changes the area of launcher clearance. When the TURN ORDERED lamp lights, the operator can see what course change has been ordered by changing the SHIPS HEADING switch from PRESENT to either ORDERED position. All presentations on the WAC rotate to the proposed course. Target position may then be observed in relation to the new clear area.

Guided Missile Status Indicator. - Another unit in the Weapons Direction Equipment (fig. 9-1) that is closely associated with the launching system is the guided missile status indicator. Figure 9-11 shows the indicator's panel face. The indicator is mounted on a bulkhead in the Weapons Control Station. The primary function of the indicator is to order the type of missile to be loaded and to indicate the type and status of the missiles which have been selected for loading. Having ordered a particular type of missile, the indicator provides a means for checking that the launching system has elected the right type

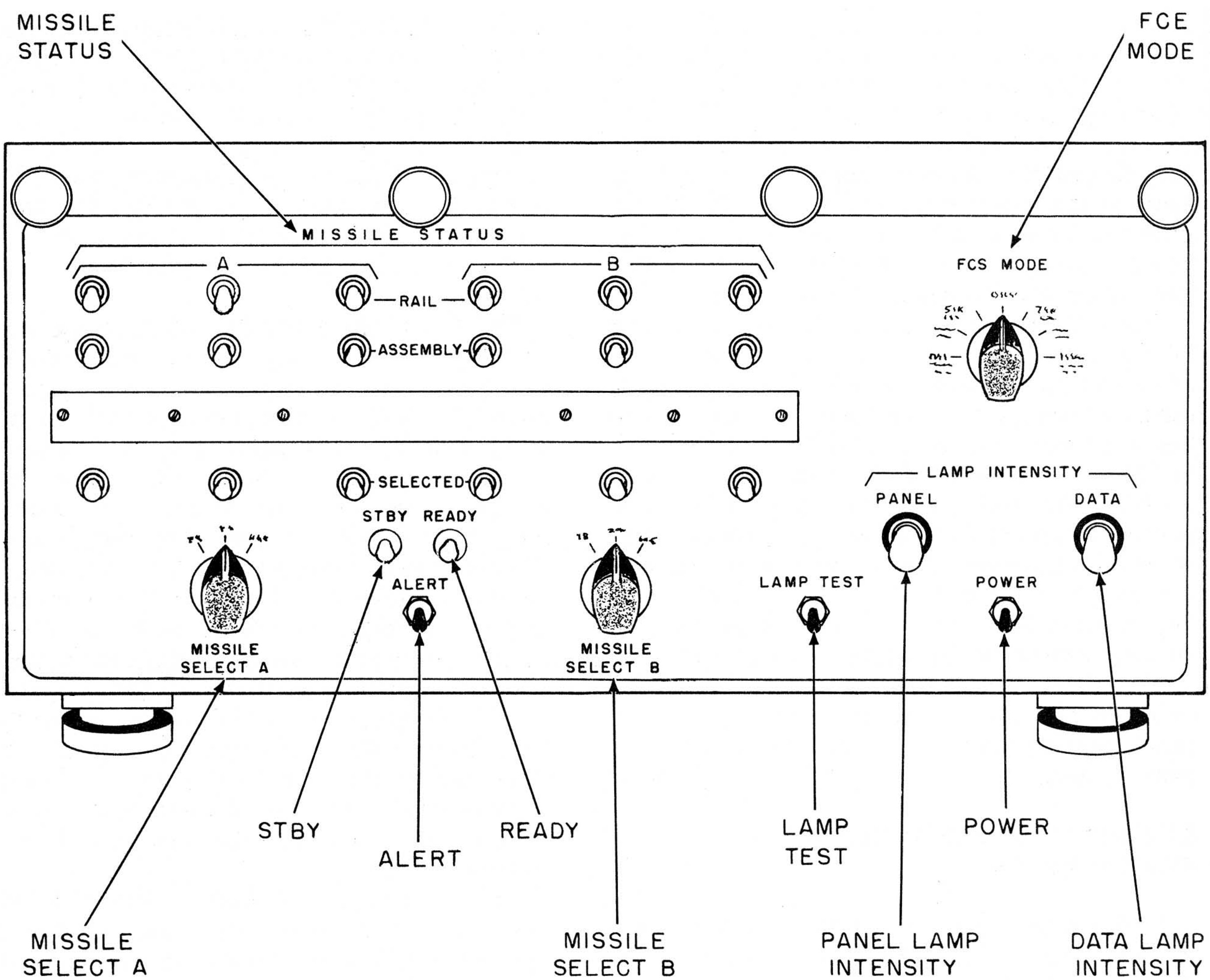

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Figure 9-11.—Guided Missile Status Indicator in the Weapons Control Station.

for loading, and, by watching lights, the WAC operator (who is usually the missile officer) can watch the progress of selected missiles as they pass from the magazine to the launcher arm during the loading process. At any time, he can tell where each missile is in the launching system. Also, the unit can provide signals to the fire control switchboard to order special modes of missile director operation.

As you read the next few paragraphs, refer to figure 9-11. There are two MISSILE SELECT switches on the lower part of the panel, one for rail A and one for rail B. The switches have three positions and provide for ordering any of three types of missiles- BT, HT, or BT(N). To order a BT -3 missile, the switch for the desired rail is turned to the BT position. This sends a signal to the ready-service ring and it rotates to bring the nearest BT round to the load position. For BT-3A(N) or HT-3 missiles, the switch is set to the BTN - or HT position, respectively. A spring-loaded stop prevents accidental selection of a BT-(N) missile.

Directly above each switch are three columns of lamps which indicate missile status for each rail. Each vertical set of three lamps indicates a missile type. Each row of lamps shows the location of the missile during the loading process.

For example, if rail A is to be loaded with a BT missile, the switch is turned to that position. The three lamps above left are all marked BT. The lamp in the bottom row indicates the type of missile selected; the lamp in the middle row indicates that loading has started and the missile has reached the assembly area. When the lamp lights in the top row it indicates that the missile is on the launcher rail. Thus, the progress of the missile through the launching system can be followed from the Weapons Control Station.

The FCS MODE switch on the right hand side of the panel indicates to be fire control system when the missile fire control systems are to be used in a special type of operation. The switch has seven positions: BOTH 1-DIR SURF, 1-DIR SHORE, 2-DIR SHORE, NORM, 2-DIR SURF, 1-DIR SURF FCS 4, 1-DIR SURF FCS 5. For normal antiaircraft operation, the switch is left at NORM position. To engage a surface target, the switch is set at SURF, and for beach bombardment, at SHORE, the position depending on whether one or two directors are to be used. The lights and switches below the MODE switches are used to control the intensity of panel lighting and lamps, and to turn on the panel power.

GUIDED MISSILE FIRE CONTROL SYSTEM MK 76

Included in our representative missile weapon system are two missile fire control systems (no. 4 and no. 5). Each system consists of a Radar Set AN/SPG-55 (Fire Control Technicians pronounce it "speegee fifty-five.") and one Computer Mk 119. Since the systems are physically and functionally identical, we will describe only one system - number 4.

Radar Set AN/SPG-55

In general, the principal purpose of the Radar Set AN/SPG-55 (fig. 9-1) is to introduce into the computer the target's position and rate of motion in terms of range, bearing, and elevation (in the case of air targets), and to control the flight of the missiles. To do all these, the radar set must be able to find (search), to get on (acquire), and to track targets. The radar must be able to control all types of Terrier missiles. This presents a challenge to the radar set because, as you know, some Terriers are beam-riding missiles and others are semi-active homing missiles. However, the AN/SPG-55 can handle all Terrier types, but not simultaneously.

The radar has four radar transmitter: (1) track, (2) capture (3) guidance, and (4) an illumination transmitter. It also has two antennas: a main antenna (the large one in fig. 9-1), and the small capture antenna (fig. 9-12).

TRACK TRANSMITTER. - The track transmitter generates a very narrow beam which is used to search for, acquire, and then to track a target (fig. 9-12). Earlier you learn that the radar set is assigned (designated) a selected target by the DAC operator. Initially the targets were picked up by the search radars. There may be one, two, or many targets. The search radars measured their range and bearing, and, depending on the radar, the elevation. The search radar target information is fairly accurate, but it is not accurate enough to solve the fire control problem. Fire control radars are precise measuring devices. Target range and bearing measured by a fire control radar are extremely accurate. But these radars suffer from lack of power. They can detect targets only at relatively short ranges. Search radars are much more powerful than fire control radars.

To measure angles accurately, the track beam must be narrow. When the radar has the designated target in the track beam, and set automatically starts to follow the target and to measure its range and position. This information is transmitted over synchro circuits to the fire control computer.

CAPTURE TRANSMITTER. - The capture transmitter produces a wide, cone-shaped beam (fig. 9-12) for controlling the first moments of controlled flight of the beam-riding Terrier missiles. The capture beam is transmitted from the small antenna you see alongside the main antenna in figure 9-1. The capture problem and beam-riding guidance techniques were discussed in the preceding course. *Gunner's Mate M (Missiles) 3 & 2*, NAVTRA 10199, so we will not dwell on these subjects here. The basic capture holds for both Talos and Terrier beam rides. You might keep in mind that Talos beam riders

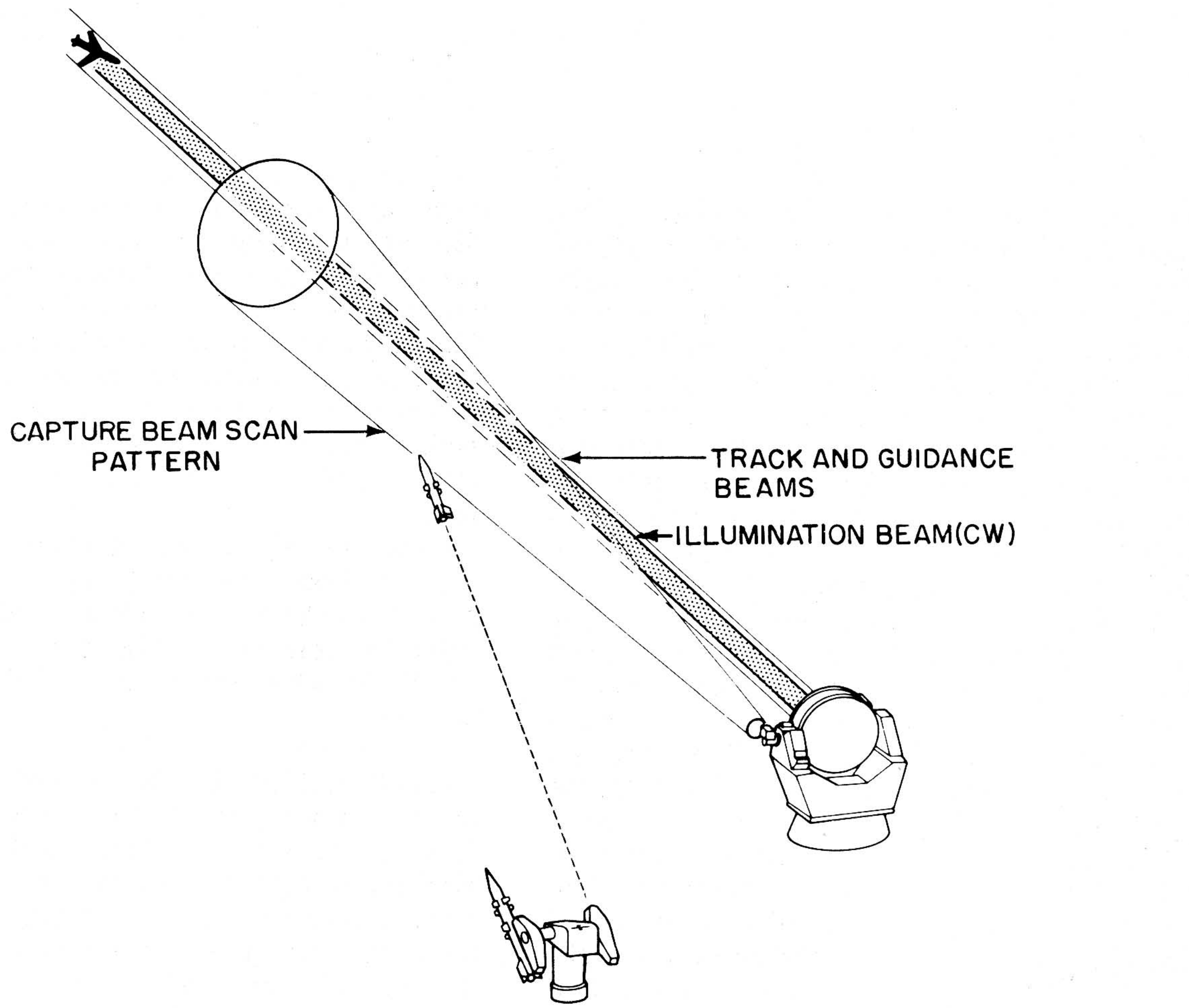

Figure 9-12.—Missile fire control radar.

are launched into a stationary capture beam from a momentarily stationary launcher. Then the beam is moved. Terrier beam riders are launched on the fly, so to speak. Both the capture beam and the missile launcher are moving at the moment of missile launch.

GUIDANCE TRANSMITTER. The guidance transmitter also generates a cone shaped beam (fig. 9-10) but it is much smaller than the capture beam. The small guidance beam enables the mile to fly a tighter course to the target. The large capture beam ensures that the radar set grabs the missile. Once the radar set has the missile in its electromagnetic grip, the missile puts itself into the small guidance beam and follows this beam to the target. The track, capture, and guidance beams are all coincident. Where one beam goes, they all go. As the track beam follows the target, the capture and guidance beams are dragged along.

ILLUMINATOR TRANSMITTER.-The flight sequence of the HT 3 missile is different, from that of the beam-rider Terrier. Homing Terriers carry a small radar receiver which picks up radar energy reflected from the target and homes in on this energy. The illuminator transmitter on the AN/SPG-55 generates a very narrow beam of radar energy. This beam is smaller than the tracking beam (fig. 9-12). After booster drop-off, and after the missile's guidance system is cut in, the homing missile seeker head receives r-f energy from the illumination beam that has bounced off the target.

The Mk 119 Computer

The computer is the "brains" of a fire control system; the Mk 119 is no exception. It makes the calculations that point the launcher in the right direction to put a beam-riding missile in the capture beam or to place a homing missile on its proper course. In other words, the computer solves the fire control problem. The solutions take the form of continuous outputs which control the movements of the launcher in train and elevation and introduce preflight information into beam-rider and homing missiles before they are launched. The lead angle information is called launcher orders; the missile preflight information is called missile orders.

There is a direct tie-in between the launching system and the missile fire control computers just as there is between the launching system and the Weapons Assignment Console in the Weapons Direction Equipment. Therefore, we need to consider the functions of Computer Mk 119. The reason for this emphasis on computer function is that many of the outputs of the computer flow through your launcher circuitry. You should know where the data comes from and the important part it plays in the operation of the missile system as a whole. Another reason is that you are expected to test computer outputs where they enter your launching system and also to see if the outputs get into the "birds." Remember that the outputs pass through the launcher-to-missile contactor.

LAUNCHER ORDERS. - There are two sections in the computer that generate launcher orders: the HT section and the BT section. The HT launcher order section determines the train and elevation angles which aim the launcher at a point in space so that the missile can intercept the target. The HT missile is not guided during the boosted phase of its flight. Consequently, the missile trajectory is affected by the forces of gravity and wind. Several other forces affect the missile's flight path at launch. As the missile leaves the launcher, its angular velocity will impart some motion to the missile, and a part of the straight line (linear) motion of the launcher will be added to the missile's motion. Corrections for all these ballistic factors are made in the HT launcher order section. Also, an additional elevation spot is added to the launcher elevation order so the missile will fly an up-and-over trajectory. The increased elevation spot is intended to put the missile above its intended target so it can swoop down on it. The beam-rider elevation launcher order does not have this increased elevation spot because the beam-rider. trajectory is along the line of sight. The beam-riding launcher section generates launcher orders that aim the launcher so the missile can intercept the capture beam. The orders contain corrections for wind, gravity, and the effects of launcher angular and linear motion on the missile.

Either homing or beam-riding launcher orders are fed from the computer to the missile through the launching system circuits. Switches in the fire control switchboard determine which set of launcher orders is passed on to the launcher.

MISSILE ORDERS. - While missiles are on the launcher, waiting to be fired, they receive pre-flight orders which are stored in the missile for later use in flight. BT missiles receive two orders proximity fuze setting (sometimes referred to as fuze time delay), and launcher cross traverse (often called missile roll order).

BT Missile Orders. - Figure 9-13 shows the general path of BT missile orders. They originate in the missile fire control computer and flow through the missile fire control switchboard to the launching system. Within the launching system, they flow through the launching system control circuits to the launcher-top round contactor (fig. 9-13) into the booster, and finally end up in the missile itself.

FUZE DELAY TIME determines when the warhead will detonate. This preflight order sets the proximity fuze (in the warhead) so it will detonate at a distance from the target calculated to get maximum destructive effect. The best distance to get maximum destructive effect from the warhead depends principally on the target size. Large targets, because the proximity fuze will detect them earlier (the large target has more reflecting area for electromagnetic waves),

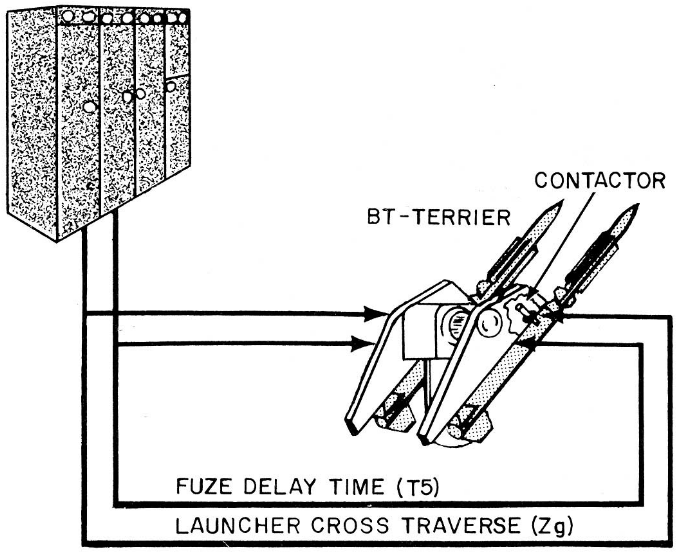

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Figure 9-13.—BT missile orders from fire control computer.

require relatively greater delay than do smaller targets. The effect of fuze delay time is illustrated in figure 9-14.

MISSILE ROLL ORDER is stored in the missile to provide a vertical reference. This order compensates for the roll of the missile while it is on the launcher (due to the roll and pitch of the ship). The missile roll gyro (fig. 9-15A) provides a reference system for guidance and roll stabilization. Before launch and during the boost phase of flight, the roll gyro is caged (locked). Therefore, the missile cannot tell which way is up. The fire control computer provides this vertical reference in the form of missile roll order. At the end of the boost period (about four seconds), the roll gyro is uncaged by a servomechanism device, the missile roll stabilizes, and its vertical reference is the reference that was supplied prior to launching. The net effect of missile roll order is to align the vertical axis of the missile guidance reference system with the guidance beam reference system.

The Terrier HT missile (fig. 9-15B) is a homing type missile. It also has a roll gyro for stabilization.

HT Missile orders. - Figure 9-16 shows the general path of HT missile orders. Preflight orders for the HT missiles are:

(1) Sweep selector signal
(2) N orders
(3) Seeker head orders
(4) Launcher cross traverse (roll order) orders

Like BT missile orders, the missile fire control computer is the common source of these pre- flight orders. All of these orders follow the same general path described for BT missile orders. Sweep Selector Signal. The HT missile looks for the target in much the same way that you would look for a program on the radio if you did not know on what station it was. You would probably start sweeping the turning knob from one end of the dial to the other while you listened for some identifying sound from the program. The HT missile seeker (fig. 9-15B) uses similar search technique. The seeker circuits (called a speed gate) sweep a narrow band of Doppler frequencies (fig. 9-17) that represent a narrow range of target speeds. To shorten the search time, the missile fire control computer determines where in the speed range the seeker should look. This sweep selection information is sent from the fire control computer to the missile before it is launched. Essentially, the sweep selector signal tells the missile receiver circuits to look for the target Doppler signal on the low end of the dial or the high end, depending on target speed. The Doppler frequency of a particular target, once acquired, should change very little unless the target executes violent evasive maneuvers which would change the missile-target range rate.

The Tartar missile also uses this method of seeking the target.

N Order. - For maximum maneuverability, the I missile is aimed and launched in such an attitude that it ascends to a high altitude and then plunges downward to intercept the target. This is sometimes called a hyperbolic trajectory. (No guided missile in current use follows a hyperbolic trajectory.) At target acquisition, however, the missile would normally perform a sharp turning maneuver and proceed in a straight line to intercept the target (fig. 9-18). Such a maneuver

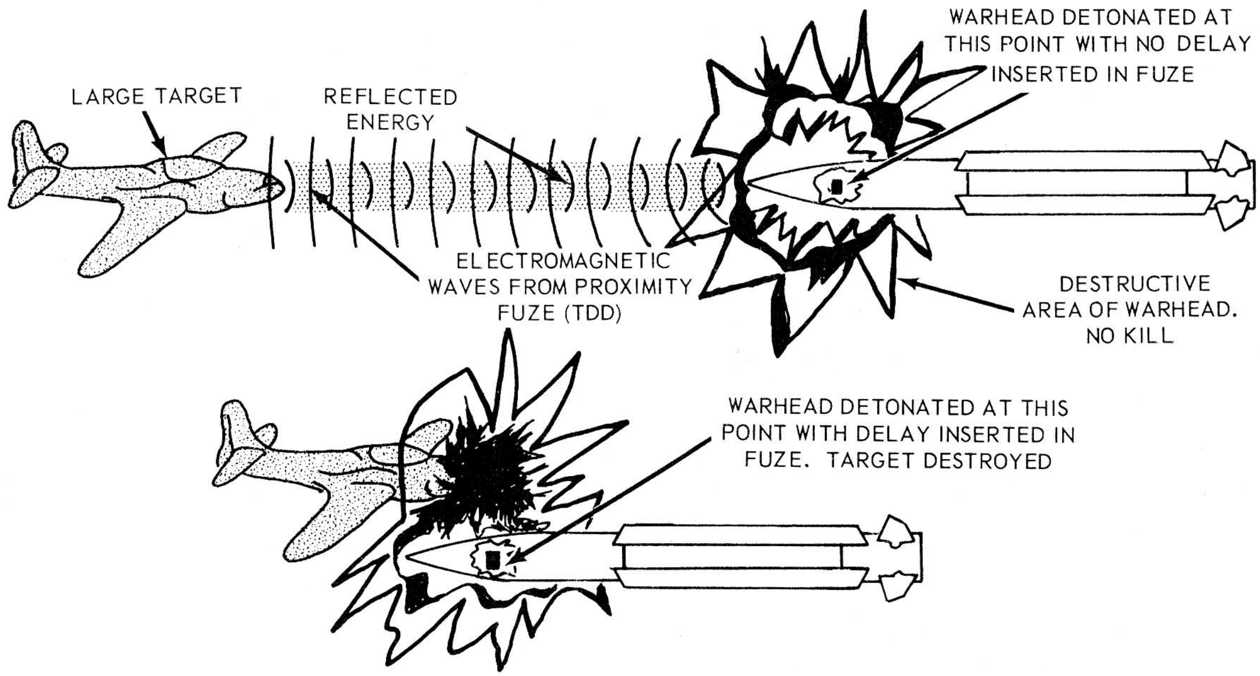

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Figure 9-14.—Effectiveness of warhead detonation: Above without fuze delay time; Below fuze delay time (T5) brings missile nearer target.

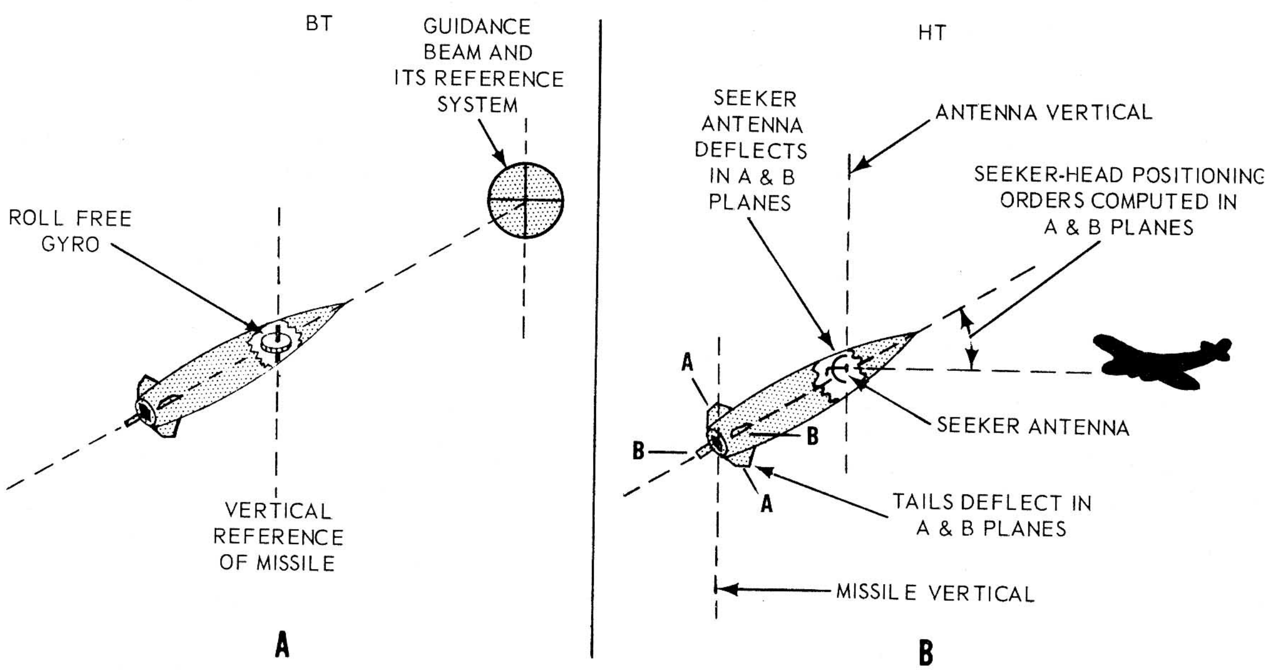

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Figure 9-15.—Missile roll order (cross-traverse): A. Terrier BT missile; B. Terrier HT missile.

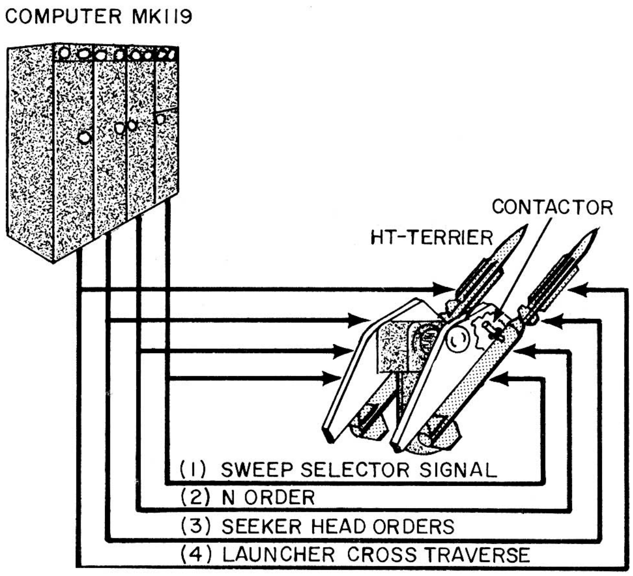

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Figure 9-16.—HT missile preflight orders.

would -cause a large loss in the velocity because of extreme control surface aerodynamic drag; and further loss of velocity because a large portion of the missile flight would occur in the denser air (with increased drag) of lower altitudes. So, to prevent straight-line intercept at target acquisition, the missile is made to turn gradually (fig. 9-18) toward the direction of target interception, thereby greatly conserving the boost velocity for the terminal phase of the missile flight and thus increasing the kill probability. The amount of turn required of the missile is calculated by the computer on shipboard and transmitted to the missile's guidance and control system, where it is stored until the homing phase. This type of missile: maneuver is also called proportional navigation, a type of homing guidance.

The rate at which the missile turns toward the intercept point for a given error signal from the seeker head is determined by a function called the variable navigation order, N.

Seeker Head Orders. - The homing Terrier missile is launched toward a point in space so it can intercept the target. The fire control computer predicts where the target will be with respect to the missile at booster burnout. This information is transmitted to and stored in the missile while it is on the launcher (fig. 9-19). The target position information is used later to position the seeker on the target. From launch until booster separation, the missile follows a ballistic trajectory. Except for maintaining the control surfaces streamlined, the missile steering system is inactive during the boost phase. Before launch and until a short time after booster separation, the seeker head is aligned with the fore and aft axis of the missile (fig. 9-15B). At booster separation, the missile is roll stabilized, for the missile must know which way is UP so it can determine the position of the target. Before launch, vertical reference information is put into the missile gyro system. Before the missile is launched, the fire control computer "tells" the missile where to look at booster dropoff. This prelaunch order is called seeker head order.

Missile Roll Orders.-Proper operation of the HT missile steering system depends on the correct missile roll attitude relative to the vertical position of the missile's roll gyro. (See part B of fig. 9-15). The vertical position of the roll gyro is established just before the missile is launched. Like the BT missile (or any guided missile for that matter), the HT missile must know which way is up if it is to be properly guided. The missile is launched in the correct flight attitude, but ship's motion is imparted to the missile at launch. So, while on the launcher, the missile is supplied with synchro information indicating roll error due to ship roll and pitch. At launch, the missile stores the existing roll error for later use. After booster separation, the roll stabilization system in the missile establishes and maintains correct roll attitude. The stored roll error signal causes the missile to rotate to the correct roll position.

Missile roll orders originate in the missile fire control computers and flow to the missile fire control switchboard. Automatic switching connects the launcher roll order circuits to either of the computers, depending on which fire control system your launcher is assigned to. Missile roll orders flow through the roll order switch and out the switchboard, then through the ship's wiring and connection boxes which are between the missile computer room and the launching

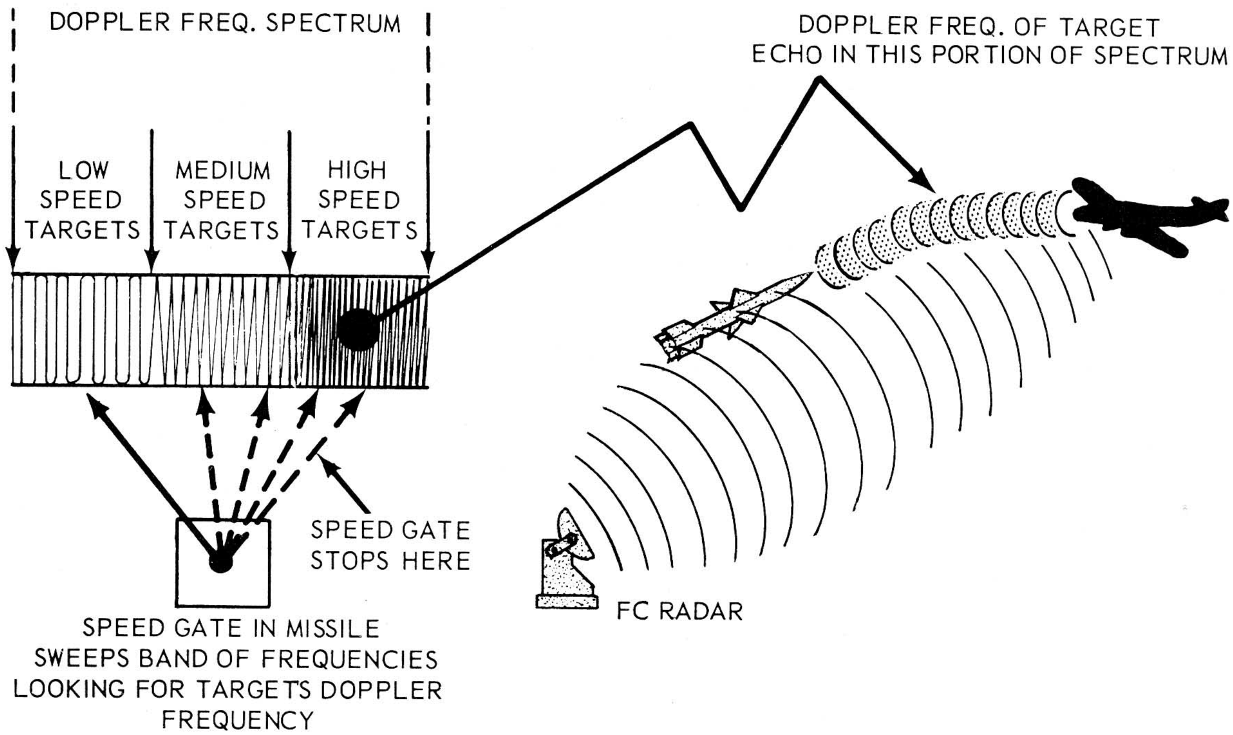

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Figure 9-17.—Sweep selection signal, used for homing missiles.

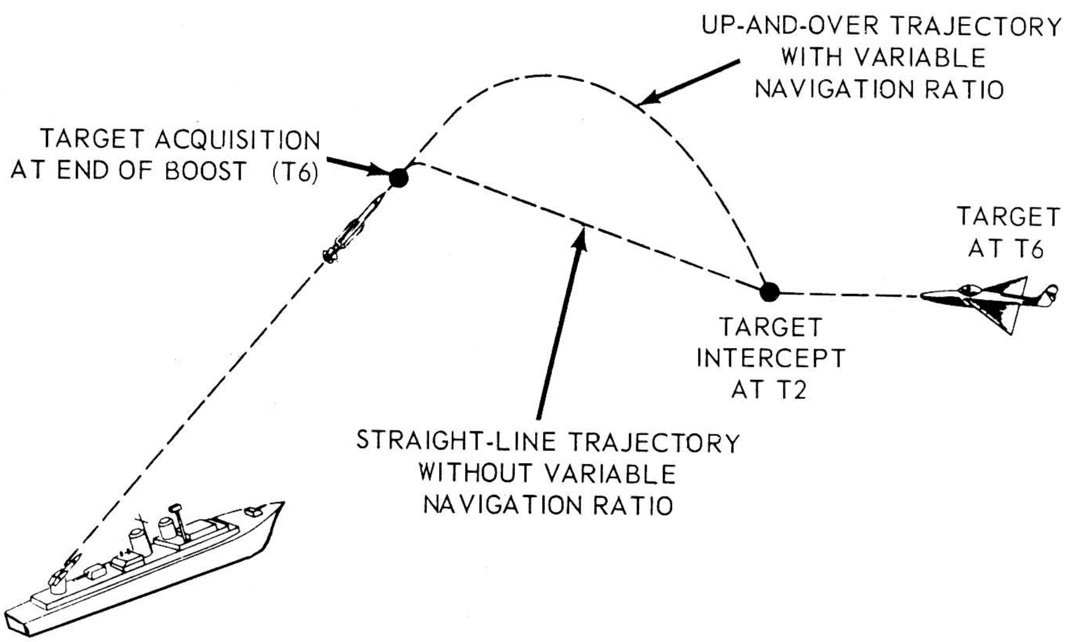

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Figure 9-18.—N order to missile.

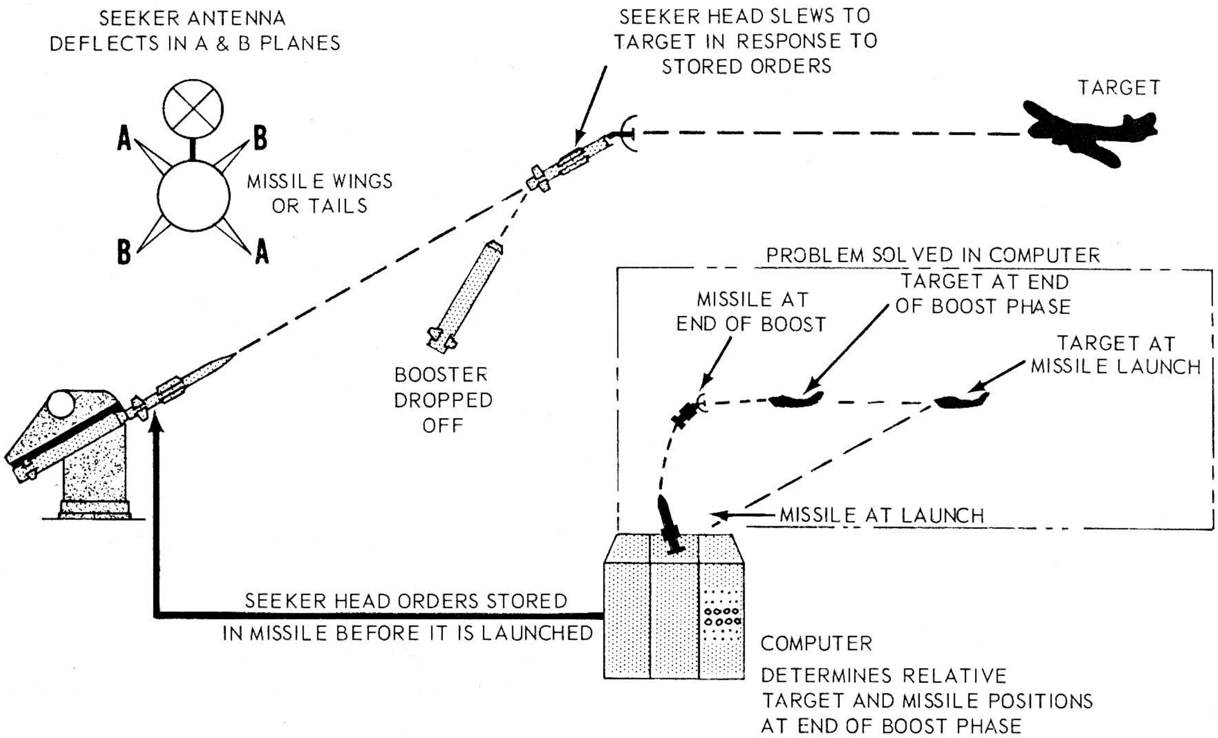

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Figure 9-19.—Seeker-head order to missile.

system. The launching system control circuits connect the missile roll order to the launcher, through the launcher-to-round contactor and booster pad, and then to the missile roll corrector. Figure 9-20 shows a one-function diagram of a missile roll order.

One of the many test in the Daily System Operability Test (DSOT) is to check for missile roll order. If the missile on test is not receiving the missile roll order (shown on the appropriate dial), you have to locate the point of trouble. Ask the Fire Control Technician in the missile computer room if roll order signals are coming but of the switchboard (fig. 9-20). If they are, then you know the trouble is in the circuits for which you are responsible, and you have to break out your one-function diagrams and begin troubleshooting.

The Director

As indicated in figure 9-1, there may be more than one director in the missile fire control system. A target is assigned to the director by the operator of the Director Assignment Console (DAC), and the director then begins tracking that target. When it has acquired the target, it goes into automatic tracking. It operates the TRACKING MODE switch, and this places the computer in the TRACKING mode. As soon as the computer has reached a solution, the symbols for target present position, target course line, point of intercept circle, outer range limit ellipse, and launcher bearing circle appear on the display scope of the WAC (fig. 9-9).

When the DAC operator is assured that the director is tracking the target satisfactorily, he releases the channel, and can assign it to another target if necessary. The launcher orders, missile roll orders, radar-phasing orders, and display data are now all valid. As soon as the WAC operator determines that range, clearance, and missile capability data are favorable, he assigns a launcher to the fire control system. The fire control switchboard connects the launcher to the computer. The computer determines the time to intercept for the weapons control system. The LAUNCHER ASSIGNED lamp lights on the

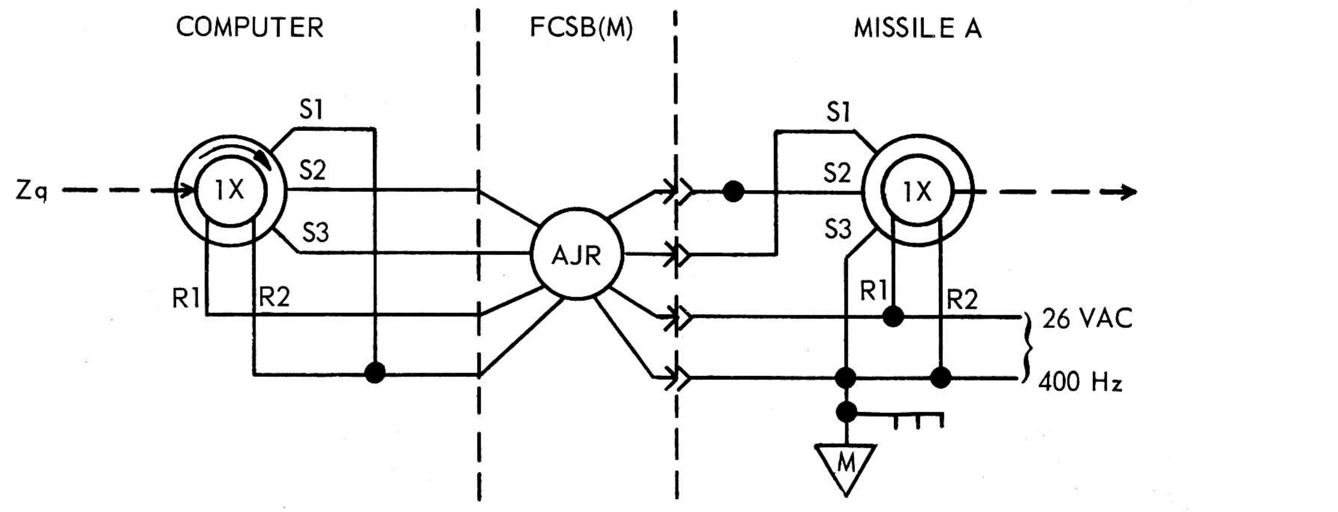

Figure 9-20.—One-function diagram of missile roll order for missile on A arm of launcher.

WAC, and at the director the CODE SELECT and ASSIGNED lamps light, and the warning bell sounds on the radar test set.

The code select circuits are enabled, the launcher slews to comply with the computer orders, and the missile receives correct roll orders and the DIRECTOR SELECTED signal, setting the missile code for the director selected. The launcher is now synchronized and ready to fire as soon as the weapons control officer gives the word and the WAC operator presses the firing key.

The director is also called the radar set. A gun director may contain a radar and/or optics for tracking and ranging. A missile director depends on the radar for tracking and is unmanned, though there is an operator in the radar control room, chiefly to monitor the equipment. The radar not only tracks the target, continuously transmitting target position to the computer, but it also transmits beams to control the missile (beam-riding or semiactive homing, or combination) and to guide it to its target.

The part of the director or radar set that is above deck is called the antenna group (fig. 9-21) and consists of a pedestal on which are mounted the antenna and the electrical and mechanical components required to stabilize and position the antenna. Inside the mechanical structure are the transmitting, receiving, and associated microwave circuits, and the gyroscopes needed to space-stabilize the antenna. The control and power group of the radar set is located below decks in the radar room.

Missile fire power is closely related to director activity. A missile director must stay on a target throughout missile flight to provide the necessary guidance. The assigned target time (director activity) of each director depends upon target range, therefore a ship's missile target handling capacity depends upon the amount of missile directors for each missile system installed.

Stable Element

Stabilization of missiles in flight has been mentioned several times in the discussion of missile orders, missile roll orders, and seeker head orders. All gun and missile systems must have means to correct for ship's roll and pitch; gyroscopes or stable elements are used by the ship, the missiles, and the fire control systems. The radar set shown in figure 9-21 uses Computer Mk 118 Mod 0 and associated stable elements. The gyros in the mechanical structure of the antenna group space-stabilize the antenna to compensate for the roll and pitch of the ship. Several installations of gun fire systems have Stable Element Mk 6 Mod 1 in the gunnery plotting room, and a Stable Element Control Panel, used to start and to monitor the stable element, in the missile plotting room. Under

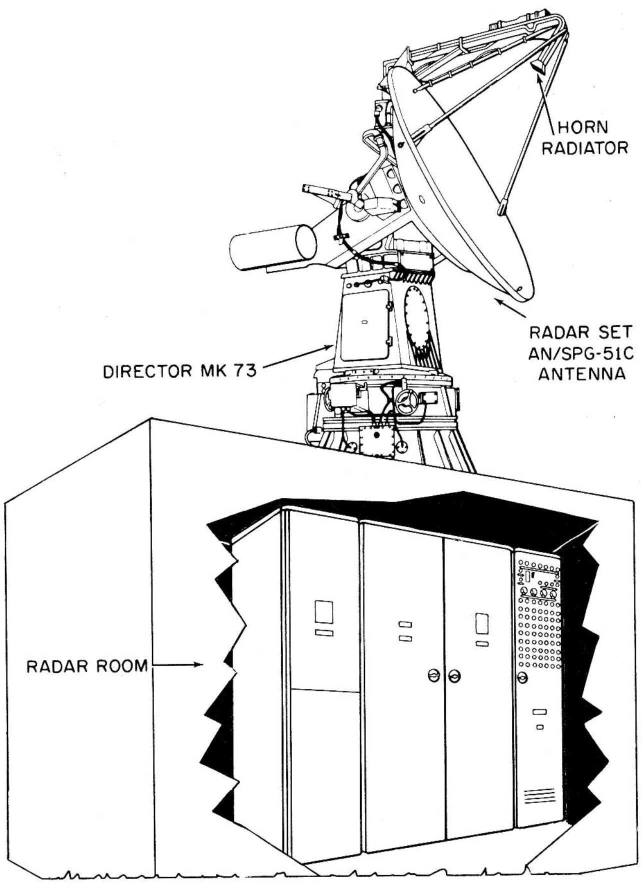

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Figure 9-21.—Fire Control System Mk 74: Radar AN/SPG-51C, Director Mk 73, and radar room with consoles.

certain conditions, target assignment and target position data may be transferred between the missile system and the gunnery system. The stable element measures the level and crosslevel angles caused by the variation in the position of the deck of the ship with respect to the horizontal. These angles are used to keep the line of sight of the director positioned automatically on the target while the ship rolls and pitches.

The principles of gyros and their use in missiles were described in the preceding course, Gunner's Mate M (Missiles) 3&2, NAVTRA 10199. Because the spin axis of a gyro is fixed in space, the gyro can provide stabilized reference planes from which various angles, lines, and motions in the fire control problem can be measured. The gyro in the stable element measures the amount of roll and pitch of the ship and sends correction angles to the computer.

A gyro that measures the rate of change is called a rate gyro. A single-degree-of-freedom gyro is used extensively in fire control systems both as a computing device and a stabilizing device. It can detect and measure an angular rate of change of position of an object. In fire control, we are most concerned with the angular rate of change of position of the target. The director-radar tracks the target, measuring the target's position and changes of position. The term relative rate is sometimes used instead of angular rate. The speed of the target plus change of trajectory due to ballistic factors must be measured to determine target position at a given moment.

ALIGNING THE MISSILE BATTERIES

Alignment may be considered as of two types-alignment of all parts of a component so it functions correctly and smoothly, and alignment of all the components of a weapons system so they function properly as a whole system. Most of the paragraphs and sections on alignment that you find scattered through OPs are of the first type-how to adjust and align the parts of a component. If the weapons system has been manufactured and installed properly, and it is functioning as intended, it is best not to tamper with it. Adjustments may need to be made to correct for wear or damage.

The alignment of all the components of a guided missile weapons system is done originally by the shipbuilder. Refinements and readjustments may be necessary as the system is "worn in." Some of these realignments are made on the shakedown cruise.

SOURCES OF ALIGNMENT INFORMATION

The basic text on alignment is OP 762 (Second Revision) Alignment of Ordnance Installations Aboard Ship. Although gun battery alignment is explained in the most detail, the basic principles and techniques of battery alignment are applicable to missile battery alignment.

Many of the procedures can be carried out only at a shipyard, but ship's personnel must work with shipyard personnel to do the job. On ship-board, the men from several ratings must cooperate to check the alignment of the missile systems and to make any adjustments. The quals require the GMM 1 & C to assist the fire control officer in the alignment of missile batteries. You learned about fire control principles in the course for GMM 3 & 2.

OP 2456, Battery Alignment, has a separate volume for each type of ship. For example, volume 8 is Battery Alignment, DLG Type. Ships. The description of procedures is written for guns, but the same methods are used for missile systems. ODs give specific instructions and drawings for each installation; these usually describe procedures to be used during installation of the weapons system and alignment after completion of installation and before the ship is seaborne. All information on the installation and alignment is kept on board to be used for reference when realigning or adjusting. The Publications Requirement List. names all the publications that should be aboard. OD 17425, for example, lists all the publications placed on guided missile frigates, DLG 26 class. From this list you can select the publications you need to study to do your part in aligning the weapons system. The ODs are revised from time to time, so be sure you have the latest one.

Alignment and adjustment of the components of a weapons system must be made with exacting care. Before attempting to do any of this work, make a check list that you can follow, and make yourself thoroughly familiar with the procedures to be followed. Since you will not be operating alone, work it out with the men who will be at different stations.

SYSTEM ALIGNMENT

Alignment work done while the ship is afloat consists principally of tests and adjustments required for keeping the weapon system in readiness to deliver with the maximum effectiveness. Realignment is necessary because the ship's hull is a flexible structure and is subject to small but significant changes in shape when it leaves the drydock. These changes in hull shape can cause appreciable changes in the alignment of a battery. The details of the alignment procedures afloat are considerably different from drydock alignment because the ship is in motion and the instruments and references on shore cannot be used.

System alignment requires orienting and adjusting the several components to each other so they function properly as a whole. No alignment work should ever be undertaken without first making careful tests to make certain that adjustment is necessary. Before changing any adjustment, make a careful analysis to determine alignment errors and calculate the adjustments necessary. An incorrect or unnecessary adjustment can cause serious trouble in the system.

Shipyard Alignment

Before any alignment can be done on a new ship, a reference frame must be established. First, a reference point is selected from which measurements are made. Then a reference direction and a reference plane are selected. These three references are the reference frame (fig. 9-22). Directions are expressed with respect to the reference frame. The horizontal plane is the one most commonly used, and the ship's deck is nominally the horizontal plane. When the ship is afloat, the deck cannot be used as the horizontal reference plane because of the constant movement of the ship. Bench marks are set and tram readings are made while the ship. is in drydock, and these are used as references when the ship is afloat.

During the construction of a ship, one or more base plates (fig. 9-23) are installed within the hull of the ship. These plates are referenced to a similar plate mounted on a fixed ground installation. The plates are leveled as accurately as possible before the ship is launched. An imaginary base plane is figured from the averaged readings taken from the base plates. The fire control reference plane is parallel to the construction base plane and is the reference from which all system elements are aligned. A. vertical plane perpendicular to the fire control reference plane and lying along the ship's centerline is the zero train reference for all system elements.

Zero train position is established during original alignment in the drydock.

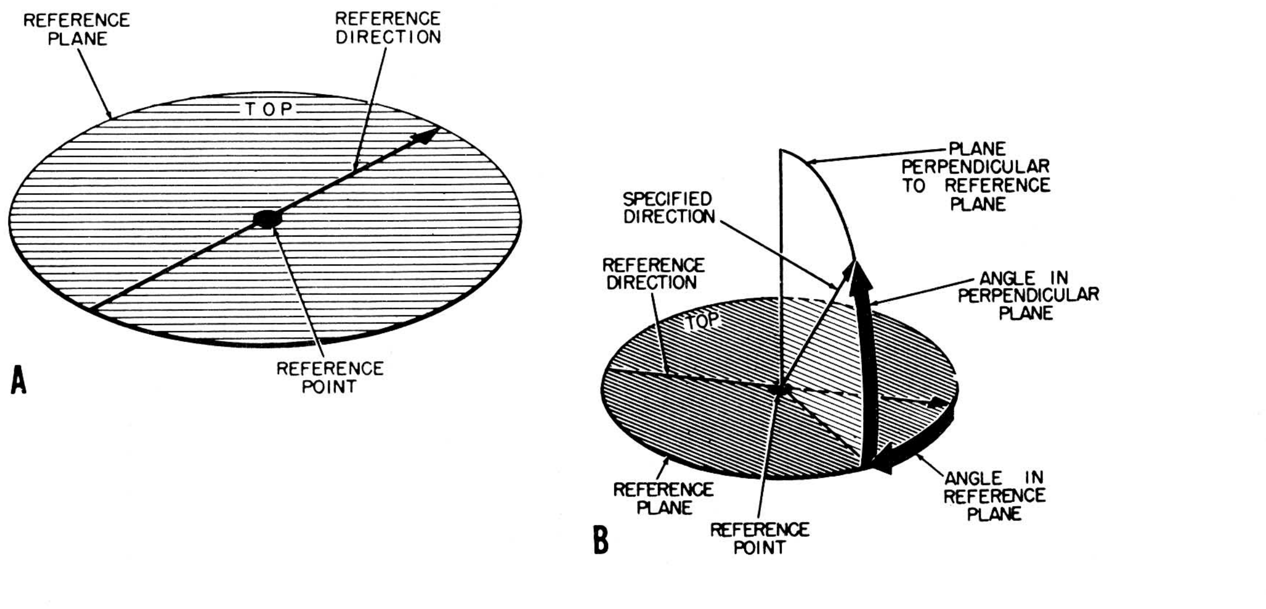

Figure 9-22.—Reference frames: A. Representation of reference frame; B. Expressing direction with respect to reference frame.

After battery alignment in train, comes alignment in elevation. The purpose of alignment in elevation is to set all elements so that when they are positioned in elevation with their pointing lines parallel to the reference plane (vertical parallax zero), the elevating dials of the elements will read zero and the elevation synchros will be at electrical zero.

So that guns and launchers can be realigned to the same position, bench marks and tram readings are provided.

BENCH MARK. - For purposes of checking director's zero train at sea, a bench mark and bench-mark reading are established. The bench mark usually is a small brass plate with crosslines etched on it. This plate (fig. 9-23) is welded to a secure part of the ship within vision of the director's sights. After zero director train has been established and the dials set, train the director and put the cross wires of the boresight or telescope on the bench mark, and read the train angle-read dials. This is the bench-mark reading which should be recorded, and which will remain the same until such time as new drydock data are obtained. The same telescope must be used for obtaining all settings and readings. The launcher is trained to position its rails parallel to the zero train reference plane and the train indicators are adjusted to the indicated zero train. Then the launcher is elevated to position its rails parallel to its roller path plane and all elevation indicators are adjusted to indicate zero elevation. The maximum amount of deviation permitted for each element is shown in figure 9-23.

TRAM READINGS. - A reference point for each turret, mount, or launcher must be established to check the accuracy of launcher or gun train dials at sea. The original tram readings are taken after zero mount or launcher train has been established and the dials set. However, unlike bench-mark readings, which never change, tram readings will change each time response is broken and any alignment correction is made to the mount or launcher. New tram readings must be taken and recorded after making any alignment correction between mount or launcher and director.

Shipboard Alignment Requirement

The alignment requirements for a weapons system include internal alignment of each of the components and system alignment of the different components or elements with each other.

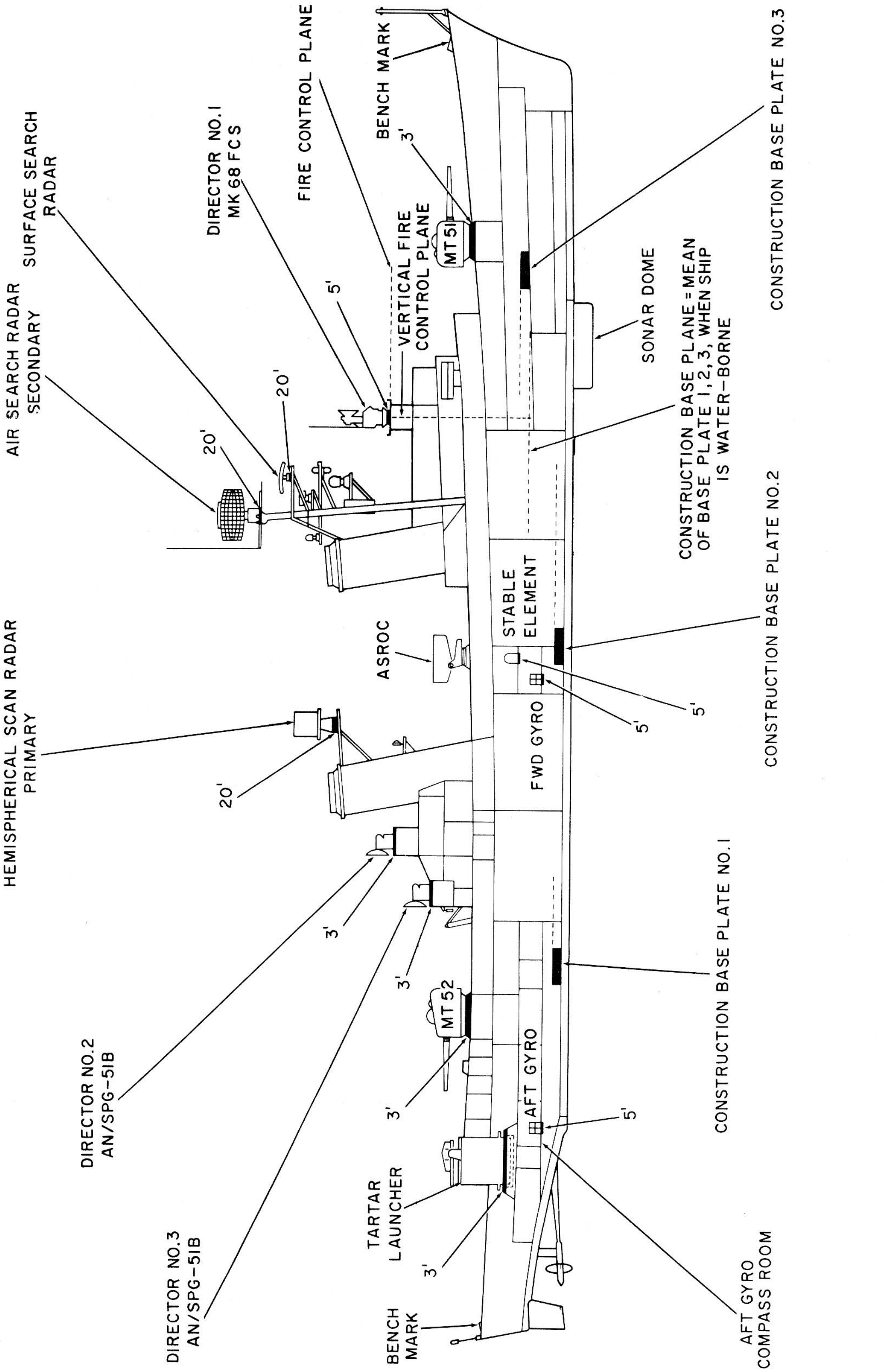

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Figure 9-23.—Mechanical Foundation Tolerances.

The internal alignment of an ordnance element is established at manufacture. A high degree of machining and fitting structural parts assures good internal alignment. If any basic alignment is necessary because of faulty manufacture, overhaul at a navy yard usually is necessary. Each director should be internally aligned with the ship's references (fig. 9-22). All parts of the weapons system are aligned to the reference while the ship is being outfitted or in dry dock, and the whole system is tested. When the ship is afloat, the operation of the system must be rechecked. If there are serious distortions, the ship is returned to the shipyard for adjustments.

The launchers and guns must be aligned to the directors in tin and elevation.

Alignment work done while the ship is afloat consists principally of tests and adjustments required for keeping the ship's ordnance equipment in readiness to deliver fire of maximum effectiveness.

We will not describe all the procedures of battery alignment that apply to the many different types of ships. However, if you understand the following procedures, which are based chiefly on procedures given for the Tartar system on DDG-2 class ships, you shouldn't have much difficulty on any other type of ship

On DDG-2 class ships, Gun Fire Control System Mk 68 is aligned first, and Missile Fire Control System Mk 74 is aligned to it. The Gun Fire Control Director Mk 68 is the reference director and the Missile Fire Control Director Mk 73 is aligned to it in train and elevation. Director Mk 68 is used to determine the alignment condition of all rotating elements with the exception of the missile launcher and the gyrocompass, which are aligned to Director Mk 73. The work of aligning the directors is not done by GMMs, but that work must be completed before the launchers can be aligned. Your alignment checks should be done soon after the directors have been aligned.

We should mention here a preliminary check which must be made before any alignment afloat work is undertaken. This is the transmission check. Synchro and dial errors corrected at this point will keep you from compounding the errors, or introducing errors to correct for errors in the ensuing alignment procedures. (Of course, these errors, even if initially undetected, would be revealed before you completed your alignment work. But by then you would be faced with the task of redoing one or more of the alignment phases.)

Do not proceed with synchro alignment unless the preliminary check shows a misalignment. If the synchro is close to zero, make only the fine adjustment. Be sure to use a power source of correct frequency and voltage since damage will result otherwise. Do not keep the synchro units energized any longer than necessary. If a synchro feels hot when touched, deenergize it and allow it to cool.

ALIGNMENT OF LAUNCHER

Precise alignment of the launcher requires extreme accuracy in the performance of alignment checks and adjustments. The manual train and elevation features of the Mk 11 launching system make checking very difficult when there is motion of the ship. It is suggested that the checks be made with the ship moored to a pier or at anchor in a calm sea. If the safety warnings are heeded, the checks and tests can be made without damage to the equipment or injury to personnel.

When ready to proceed with launcher and gyrocompass alignment, man the launcher and the gyrocompass, and establish telephone communications on the JCT phone circuit.

Alignment in Train

The train alignment check provided an accurate method or determining the degree of parallelism between the zero train lines of all elements of the system. When the director is trained to any point and the launcher dial pointers are matched with zero settings, the director and launcher lines of sight are parallel in train.

Since the ship is now afloat, it is impracticable to use multiple targets to obtain parallelism between the launcher and director. However, if the lines of sight of both director and launcher are aligned on a target at infinite range, for all practical purposes they will be parallel. This method, commonly called "shooting the moon," is the most accurate method of train alignment afloat. It is also called alignment on a celestial body.

When train alignment is performed simultaneously for several equipments, the train dial readings from all stations should be transmitted to a central station (such as the missile plotting room) for systematic recording. The recorders at the individual elements should cross check all readings to eliminate possible errors in recording the readings. Rotation of the earth and ship motion may cause the line of sight to drift from the target, but this drift is not detrimental as long as the line of sight is on the target when the reading is taken.

Install Boresight Telescope Mk 75 (modified) in Launcher Mk 8 (fig. 9-24) on the stationary guide, and insert a T-lug in the front guide of the B-rail. The T -lug prevents the front guide from tripping, and thus prevents personnel injury. Install the peepsight on the forward end of the guide arm.

Be sure the launcher is not energized when it is being manned for alignment and test purposes. Gear all unnecessary personnel from the area. An observer is stationed inside the launcher to read the train and elevation dials.

BENCH MARKING THE LAUNCHER. - The boresight operator should have the bench mark in his field of vision. The launcher is manually trained until the vertical crosshair of the borescope coincides with the vertical index on the bench mark. This should be done several times, training to the right and to the left of the bench mark to check on the first alignment. Do the same for elevation.

CORRECTING TRAIN ALIGNMENT ERRORS. - Before attempting to correct the error of equipments, carefully analyze the results of the train alignment check. Generally, a small deviation from zero (say, 2') is acceptable. A careful analysis of the launching system is required to determine whether the misalignment is caused by the components of the launching system or those of the fire control system. Misalignment within the launching system may cause serious casualties in the equipment. To isolate the cause of any misalignment, check the operation of the launching equipment to the fixed mechanical positions of STOW, DUD JET A, DUD JET B, LOAD, and TRANSFER. If the launching system operates correctly in those positions in train and elevation, the trouble is in the fire control system. Emergency adjustment can be made at the computer. Afterward, a transmission check must be made between the computer and the launcher. The launcher train dials should indicate launcher train order plus the correction applied. The results should be recorded in the Battery Alignment Log.

To correct the train dial, which is in the train receiver-regulator under the launcher shield, deenergize the launcher. Locate the adjustable (vernier) coupling on the B-end response shaft of the receiver-regulator, loosen the lockscrew of the coupling, and adjust the coupling to correct the train response dials by the amount of the TRAIN dial error. In other words, make the train dial reading equal director train dial reading when both are on target and in manual operation. Tighten the lockscrew on the adjustable coupling and recheck according to the previously described procedure. Continue to make adjustments until the error is within the allowable tolerance.

Elevation Alignment

The launcher is aligned in elevation to the director. It is elevated in manual control to bring its rails into position parallel to its roller path

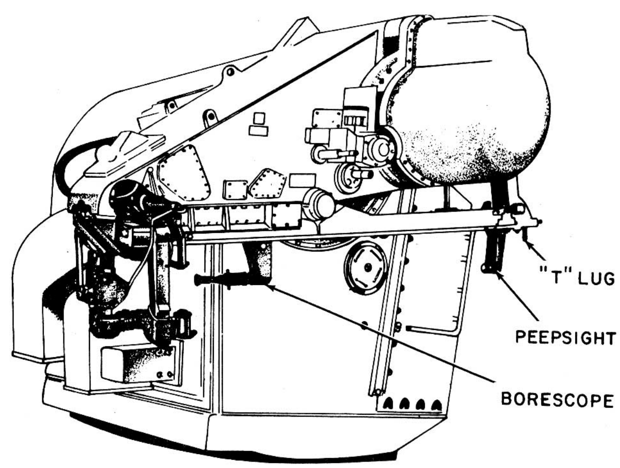

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Figure 9-24.—Boresight Telescope Mk 75 installed in Mk 8 launcher.

plane (at a point of known inclination) within 3' of arc. All elevation indicators are adjusted to indicate zero elevation.

The Mk 75 boresight telescope is installed on the stationary guide as for train alignment (fig. 9-24). The T-lug is inserted in the front guide of the launcher B rail. The peepsight assembly is installed on the forward end of the guide arm at a point about 5/8 inch from the rear of the front guide.

The launcher must not be energized for alignment or test; set the safety switch on the EP3 panel to SAFE and remove the handle. The train and elevation securing pins are released by turning the clamp screws, using handcranks. When the securing pins are fully retracted, they are locked in that position with the clamp screws. The train and elevation latches also have to be released, and hydraulic pressure is needed for. that. Energize the launcher elevation motor and retract the latches by depressing the latch retract buttons. Then deenergize the launcher. Hydraulic pressure is maintained by use of the hydraulic hand pump.

The launcher is then moved manually with the aid of a large crescent wrench. When the line of sight through the boresight is parallel to the director line of sight, release the hand drive. The man at the elevation receiver inside the launcher shield gives the elevation readings as the launcher is being moved. When the man at the director calls "mark," the dials should be at zero.

ELEVATION HORIZON CHECK. - The elevation horizon check provides an accurate method of determining elevation alignment errors between elements under normal operating conditions and a method of determining the relative inclination between the roller paths of the reference and nonreference elements while the ship is afloat. The aft missile director (no. 3, fig. 9-23) is used as the reference element for the Mk 11. Tartar missile launcher and he Mk 19 gyrocompass.

The horizon check is conducted by comparing the dial readings at the director and at the launcher as they are aimed at a series of points on the horizon. The ship should be underway, on a steady course, with a ship's speed of between 5 and 10 knots. A clear, clam day with a well-defined horizon is necessary.

The borescope should be installed in the launcher as for train and elevation check. All stations participating in the check should be manned.

Since the various elements of the missile battery are installed at different heights about the waterline, the dip angles of the elements will differ. The dip angle is the angle by which the line of sight of an element must be depressed before the horizontal to place the line of sight on the horizon. Figure 9-25 illustrates dip angles and dip differences. The dip angle is given in minutes and the height (H) is the height in feet of the element optics above the waterline at mean ship draft. The angle is computed by the formula:

$$\text{dip angle} = .98\sqrt{H}$$

Before the elevation horizon check is begun, record the dip angle of each element.

The director is trained to a suitable bearing and depressed to below 0° elevation. Each element that is being checked is trained to the same bearing and then depressed to the horizon. Then the director is positioned so the line of sight is on the horizon. As the line of sight approaches the horizon, the operator calls "Standby," to alert the operators at the other stations. When the line of sight is exactly on the horizon, he calls out "Mark." The operators of the elements being checked correct their elevation until the line of sight is exactly on the horizon. When all are aligned, the elevation dial readings are recorded.

These readings are taken throughout the full arc of launcher train, with readings at every 15° of bearing. All data are recorded on worksheets and the information is then plotted on graph paper for analysis.

There should always be a difference between the launcher and director elevation reading due to the difference in height of these elements aboard ship. The director, being higher, must always depress further to sight on the horizon than the launcher. This angle of depression onto the horizon is called "dip angle." The difference between dip angle of the director and dip angle of the launcher is called "dip difference." When the launcher and director are properly aligned in elevation, the zero axis of the horizon check curve should be above the zero axis of the graph by the amount of dip difference. If the zero axis of the horizon check curve fails at any other point on the graph, an elevation alignment error exists. This error is positive (high) when the zero axis of the curve is above the value of the dip difference, and negative (low) when below the value of dip difference.

To compute dip angle and dip difference consult ship's plans to obtain the height of the elements above the waterline. Enter table 9-1 at this height to obtain the dip angle to horizon. Subtract the dip angle of the launcher from the dip angle of the reference director. The difference is dip difference. It should be constant at all bearings.

All elevation readings are in minutes. On those elements having response dials graduated in degrees and minutes, the dial reading must be transposed to minutes, with 2000' representing zero elevation.

Generally, an error of ±3' is acceptable. Small errors may be the result of incorrect readings. For this and other reasons, it is better policy to do no adjusting of the dials unless large errors are found, after several readings have been taken that definitely indicate that adjustment is needed.

Since most missile system elements do not have roller path tilt correctors or leveling rings, no adjustments can be made to correct for errors in roller path tilt aboard ship. When roller path tilt errors are found to be excessive, correction is accomplished at a shipyard.

FIRING STOP MECHANISMS

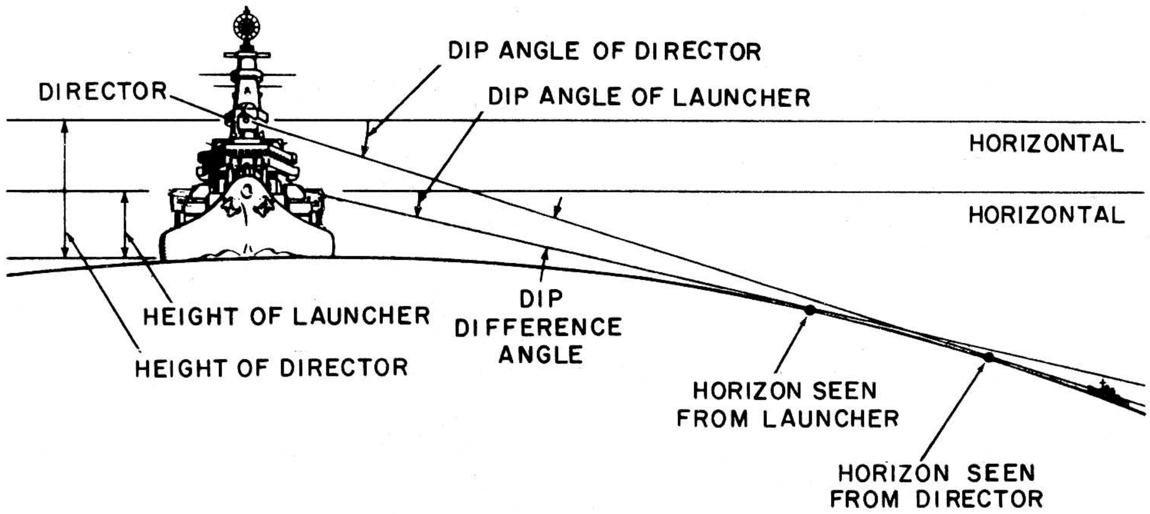
It's hard to overemphasize the importance of checking the firing stop mechanisms after making the original alignment, after doing any work or repair on the launchers that would disturb the firing stop mechanism, or in the course of routine checkups. Every casualty from ships firing into their own superstructures testifies to the seriousness of ANY misalignment. of the firing stop mechanisms Equally important: In EVERY case these casualties could have been prevented. They resulted from negligence on the part of the ship's personnel; or cams were cut improperly and in some cases misaligned; or the firing stop mechanisms were inoperative through lack of preventive maintenance.

As you remember, firing stop mechanisms are designed to interrupt electrical firing circuits and firing mechanism linkages whenever guns and launchers are trained or elevated to a position where firing the guns or launchers would endanger personnel or damage the ship. They should not be confused with the depression stop cams that are used occasionally to limit the movement of some guns and launchers to a safe zone of fire, or with train or elevation limit stops. Firing stop mechanisms do NOT interface with the free movement of the gun or launcher.

The Naval Ordnance Systems Command has issued definite instructions for the guidance of

Table 9-1.—Dip of the Sea Horizon

Height, ft	Dip '	Angle "	Height, ft	Dip '	Angle "
1	0	59	27	5	06
2	1	23	28	5	11
3	1	42	29	5	17
4	1	58	30	5	22
5	2	11	31	5	27
6	2	24	32	5	33
7	2	36	33	5	38
8	2	46	34	5	43
9	2	56	35	5	48
10	3	06	36	5	53
11	3	15	37	5	58
12	3	24	38	6	02
13	3	32	39	6	07
14	3	40	40	6	12
15	3	48	45	6	36
16	3	55	50	6	56
17	4	02	55	7	16
18	4	09	60	7	35
19	4	16	65	7	54
20	4	23	70	8	12
21	4	29	75	8	29
22	4	36	80	8	46
23	4	42	85	9	02
24	4	48	90	9	18
25	4	54	95	9	33
26	5	00	100	9	48



92.48

Figure 9-25.—Dip angle and dip difference.

the personnel responsible for plotting, cutting, installing, and checking firing cutout cams and mechanisms. These regulations apply strictly in all cases. In addition, special instructions govern particular installations.

The computations for the missile's trajectory and for the necessary safety clearances relative to the ship's structures and equipments are complicated and extensive. A high degree of precision and skill are required to make these computations, and to prepare and install the cutout cams in the launchers. The computations are now done with the electronic computers at the Naval Weapons Laboratory, and the cutout data prepared for the requesting ship. NWL also prepares the cutout cams and assists in installing and adjusting the cams. This was formerly done by the shipbuilding activities. OD 16581, "Method for Determining Pointing and Firing Cutout Zones for Shipboard Guided Missile Launching Systems," is the instruction followed. When a new cam is installed, it is essential that the two train reference points be reestablished. These are the train B-end stopped position and the non pointing zone cam arrested position. The nonpointing zone switches must be rest accordingly. NWL personnel will assist you in this.

The firing interrupter cams are plotted, scribed, and cut during the final stages of the initial installation or overhaul period and after I all installation and alterations to the topside, superstructure, masts, and rigging are completed.

New firing interrupter switch operating cams must be scribed, cut, and installed whenever changes in the topside arrangement of the ship affect existing areas of fire.

Procedures for scribing and matching the firing interrupter cams are given in the applicable OD. Performance of the cams should be checked before each firing, monthly, and whenever new cams are installed.

The Tartar system actually has four interrelated systems to ensure safe operation of the launcher. These are the (1 and 2) limit-stop system for train and elevation; (3) the automatic-pointing-cutout system; and (4) the automatic-firing-cutout system. The nonfiring zones are identical with the nonpointing zones. The train and elevation systems are physically and mechanically separate but are electrically connected through the automatic-pointing-cutout system and the automatic-firing-cutout system. The components of these systems - cams, levers, switches, brakes, etc. - are in the train and elevation receiver regulators. The pointing cutout system prevents movement of the launcher into zones in which firing would be hazardous. The firing cutout system opens the firing circuits so the missile cannot fire when the launcher is in a nonpointing zone or the strikedown gear is attached to the launcher. The train and elevation limit-stops restrict launcher movement under certain conditions. When activated, the limit-stop system neutralizes the associated power drive, thus limiting the movement of the launcher. The limit-stop cam controls the deceleration rate of the launcher power drive. Train and elevation require different rates of deceleration, and consequently their cams differ in contour. The actuating cams are identical. When the launcher approaches a nonpointing zone, they start the limit-stop system.

CAM ALIGNMENT

An adjustment screw is secured to the bottom of each limit-stop cam. To aid in alignment, scribe lines are scored into the cams. The position-plus-lead cam stacks, which indicate to the automatic-pointing-cutout and automatic-firing-cutout systems, have a vernier that permits simultaneous adjustment of all the cams in the stack, and each cam can be adjusted to a vernier in its base.

Firing interrupter cams, limit-stop cams, and associated shafts, switches, and components are present by the manufacturer and the installing activity. These cams do not require routine adjustment. They should be checked periodically and should be reset only if they are not within plus or minus 1° of actual launcher settings.

When the launcher is operated in TEST, the firing cutout system is checked. You will need checkout sheets for your system to indicate which lights will activate on the test panel for each condition.

RADAR ALIGNMENT

All elements of the guided missile battery are aligned in the same manner as a conventional weapons battery. There is, however, one additional step that must be accomplished before commencing the battery physical alignment. That is the alignment of the radar reference beam and the optical boresight telescope of the radar antenna. This is accomplished by use of a shore tower approximately 100 feet high and at least 1300 feet from the ship, on which is located an optical target and a tunable radar transmitter.

In some missile systems, the radar beam is used as the reference for this alignment. The radar beam is trained and elevated to the tunable transmitter and electrically aligned. The boresight telescope is then adjusted to the optical target and locked in place. In other missile systems the boresight telescope is the reference. The boresight telescope is trained and elevated to the optical target on the tower and then the radar beam is aligned to the tunable transmitter. This is the most critical alignment because in both cases the boresight telescope, after aligning, becomes the only reference line of sight for the director.

The above is drydock alignment, performed by shipyard personnel, perhaps assisted by FTs. When the ship is afloat, the radar reference beam is again checked (by FTs). While at the pier, the shore towers are used. At sea, all guided missile ships will use bow and/or stem towers, installed in accordance with current NAVORD instructions. Each tower will contain an optical boresight target, a capture antenna, and a track and guidance antenna.

In discussing the alignment of guided missile radar systems, we talked about the alignment of the reference beam to the boresight telescope. But there is more to guided missile radar beam alignment (collimation) than that. In some of our guided missile radar systems we have as many as four different radar beam: track, capture, guidance, and illumination. These must all be collimated to their own zero positions (beam zero indication) and to the reference beam. In some guided missile radar systems the guidance beam is used as the reference beam while in others the track beam is used. Whatever beam is. used, the problem is the same; all the other beams must be collimated to the reference beam. The role of the GMM in aligning the radars to the missile is to prepare the missile for testing, and to cooperate with the FTs who conduct the tests.

SONAR-TO-RADAR ALIGNMENT CHECKOUT

The sonar alignment check is performed to assure that the AN/SQS-23 sonar is accurate to the degree required by the ASROC weapon system. This check is accomplished by comparing sonar range and bearing with radar range and bearing of a surface target or a snorkeling submarine.

This check should be made monthly or whenever a target ship is available. Because the complete checkout requires considerable time, the entire check may be divided into sections so that at least one section of the check can be accomplished when a target ship is available. A different section of the check should be made each time. Fewer than the recommended bearing readings may be taken for each run when scheduled operations do not allow sufficient time for the complete check.

Selection of a fire control director to be used in this alignment check varies from one class of ship to another. In general, however, the director nearest the sonar transducer should be used. If the horizontal distance between the selected director and the sonar transducer exceeds 20 yards, compensation must be made for horizontal parallax.

The sonar alignment check consists of simultaneous sonar and radar determination of range and relative bearing of a target ship while both the target ship and own ship are on a parallel course at the same speed and at a predetermined range.

It is best to perform dial alignment in calm weather and sea conditions, with good visibility, while the ship is (1) underway in company with another ship to serve as a target at selected ranges, (2) anchored in quiet water, (3) moored to a buoy, or (4) tied up to a dock. A celestial body may also be used as a target.

General Requirements

Certain general requirements must be met before conducting the sonar alignment check.

1. The selected fire control director foundation must be in aliment with the first foundation machined, as specified in sections S78-1-f of General Specifications for Ships of the United States Navy.
2. Sonar AN/SQS-23 must be electronically adjusted and aligned as detailed in NAVSHIPS 93612. Technical Manual for Sonar Detecting Ranging Set AN/SQS-23. An improved version is the AN/SQS-26.
3. The sonar foundation must be in alignment with the first foundation machined in accordance with standard alignment procedures.
4. An operating area of open water at least 5 miles square with the least 40 to 50 fathom depth must be available (for submerged targets).
5. A surface (or submarine) target must be provided.
6. One man must be at each of the following stations to perform the tasks indicated.

a. One man at the selected fire-control director to optically sight the director on the target ship.

b. One man at the radar console to operate the radar and to read target range and relative bearing.

c. One man at the pelorus to make visual relative bearing checks of the target.

d. One man at the sonar indicator to act as data-taking coordinator and to receive and record data.

e. One man at the sonar indicator to operate the sonar and to read target range and relative bearing.

f. One man (ASW or sonar officer) to act as overall sonar alignment coordinate (in direct communications with the bridge).

Note that none of these stations is operated by a GMM. Your part in the alignment is that of aligning the launcher to the fire control director and other parts of the system before alignment to the sonar is begun.

WARNING: While equipment is energized, stay away from the front of the radar antenna.

FINAL ALIGNMENT ADJUSTMENT PROCEDURES

The success of missile flight will depend to a great extent upon the mechanical and electrical alignment of the system. Since guided missiles are used at relatively long ranges, the accuracy with which target angles and range are measured becomes increasingly important. A pointing error of 1/2 a mil at 30,000 yards will result in a miss distance of 45 feet at the target. The same pointing error at a range of 90,000 yards will result in a miss distance of 135 feet at the target.

If any error corrections were made to train or to elevation receiver-regulator dials, new alignment readings must be established. Obtain the detailed instructions for your launching system and follow them with care.

Upon completion of the train check and the horizon check, the elements of the system are rechecked on their respective benchmarks and new dial readings are recorded in the ship's battery alignment and smooth fire control logs.

Although both of the above tests can and should be conducted by ship's force, it is well to remember that any adjustment to either the train or elevation response requires an adjustment also to the load, stow, dud jettison, and transfer position synchros and cams. These adjustments are extremely critical and difficult to make. So before any adjusting is done to the system by ship's force it would be wise to ask for technical assistance from a repair facility.

FINAL OPERATIONAL CHECK

Modern ordnance installations are operated almost exclusively in automatic control, except under certain special conditions or in emergencies. Therefore, it is particularly important for an installation to be aligned accurately for automatic operation. If the alignment methods described in this chapter are employed so that the dials of each element are aligned accurately with the pointing line and the synchros are aligned with the dials, a good alignment should be obtained. However, it is advisable to check the results under conditions which approximate those under which the equipment will be operated.

Perform the check with the installation in automatic control, and with he parallax equipment functioning. A boresight telescope will be necessary.

If possible, select various targets at different bearings and at ranges which will be approximately equal to mean battle range for the equipment. For antiaircraft installations, try to use air targets which are at an elevation angle near 45°. The target should produce a slow bearing rate, so that accurate tracking is not difficult.

Train and elevate the director to track a target as accurately as possible, particularly in train. If the director trainer cannot stay on the target continuously, he should inform the operators at the weapons by telephone when he is on, by calling "Mark." The operator at each weapon observes the target through the sight telescope or the boresight, and makes a note of any train error present when the director is on the target. This is done for targets at various bearings, some moving to the right and some moving to the left. In this check, some small error is to be expected because there is always some lag and lost motion in the followup servomechanisms. However, the error observed when tracking to the left should be essentially equal to that observed when tracking to the right, and should be in the opposite direction. If the errors do not change direction when the direction of tracking is changed, or if they are considerably larger for one tracking direction than the other, a misalignment is indicated. This can be corrected by adjusting the train synchros; but before any adjustment is changed, a careful analysis should be made to be certain that the error is not caused by some other factor, For example, a misalignment of the sight telescope could cause an error. This should be corrected by boresighting the telescope-not by adjusting the synchros. In this case, adjusting the synchros would bring the sight telescope on, but would result in firing errors. If, after careful analysis, an adjustment is made to the synchros, a check should be made to see whether or not a corresponding adjustment must be made to the dials or any other part of the equipment.

SUMMARY

To operate and maintain launching systems effectively, you must know the relationship of the missile and the launching system to each other. Just as important, you must know their relationship to the rest of the weapon system. This "need to know" about the relationship of each part of a weapon system to the other parts of the system is clearly demonstrated by the Daily System Operability Test (DSOT). This daily test is designed to check the overall readiness and effectiveness of the entire weapon system. The DSOT will reveal almost any kind of trouble that may arise, especially in the interchange of information between systems and equipments in the weapon system. Although the entire test requires only about thirty minutes, the men of the associated ratings in each subsystem monitor the test, standing ready to find and correct the cause of any failure.

You can see that every component in a weapon system is linked directly or indirectly to the others and so are the operators and maintainers of the equipments. You must think and act in terms of the weapon system as a whole. What you do and what your equipment does affect the operation of the system as a unit.

Alignment of the Tartar system is given more coverage here than other systems. Although there are many areas of similarity, the alignment of each weapon system is specific for the ship on which it is installed. Data for your installation must be used when making any adjustments or alignments. The admonition stands: Don't tamper with it if it is working all right.