RESTRICTED OP 1064

COMPUTER MARK I AND MODS.

DESCRIPTION AND OPERATION

A BUREAU OF ORDNANCE PUBLICATION 29 JUNE 1945

Change No. 1 made 3/18/54
Hamby, YNSN

COMPUTER MARK I AND MODS

DESCRIPTION AND OPERATION

29 JUNE 1945

NAVY DEPARTMENT

BUREAU OF ORDNANCE

WASHINGTON 25, D. C.

RESTRICTED 29 JUNE 1945

ORDNANCE PAMPHLET 1064

COMPUTER MARK 1 AND MODS

1. Ordnance Pamphlet 1064 describes the theory and operation of the Computer Mark 1 and Mods. A companion publication, Ordnance Pamphlet 1064A which is now in preparation, will cover care and maintenance of these equipments.

2. This publication is to be used by: operating personnel, both during instruction and while on actual duty; personnel of installing activities; and inspectors and other officers of the Bureau of Ordnance.

3. This pamphlet supersedes NAVORD OD 4184 (Revision B) which should be destroyed.

4. The following NAVORD OD'S which will be superseded when Ordnance Pamphlet 1064A has been completed contain additional information on Computers Mark 1 and Mods:

NAVORD OD 4174 (Revision C)
NAVORD OD 3133 (Revision A)
NAVORD OD 3137
NAVORD OD 3139
NAVORD OD 3140 (Revision B)
NAVORD OD 3180
NAVORD OD 3181
NAVORD OD 3183
NAVORD OD 3184 (Revision A)
NAVORD OD 3185 (Preliminary)
NAVORD OD 4186
NAVORD OD 5157
ORDNANCE PAMPHLET 1453 (Preliminary)

5. This publication is RESTRICTED and should be handled in accordance with Article 76, U.S. Navy Regulations, 1920.

G. F. HUSSEY, JR.
Rear Admiral, U.S. Navy
Chief of the Bureau of Ordnance

Prepared For
THE BUREAU OF ORDNANCE
by the
FORD INSTRUMENT COMPANY, INC.
Long Island City, New York

QUICK REFERENCE INDEX

CONTENTS

There is a detailed ALPHABETICAL INDEX on page 421

There are schematic diagrams of the entire Computer Mark 1 at the end of this pamphlet

INTRODUCTION

Ordnance Pamphlet 1064 describes the Computer Mark 1 and tells how to operate it. All maintenance information is covered in a continuation of this pamphlet which is bound separately and designated as Ordnance Pamphlet 1064A.

Ordnance Pamphlets 1064 and 1064A are written for beginners on the Computer Mark 1, but they are not intended for beginners in fire control. These pamphlets assume that although the reader knows very little about the Computer Mark 1, he is already acquainted with some of the simpler mechanical computers, and with the fire control problem.

The reader is assumed to be thoroughly familiar with the basic fire control mechanisms described in OP 1140.

The reader is also assumed to be familiar with the general nature of the fire control problem. Many of the fundamentals of fire control are discussed in this pamphlet, but usually on the assumption that they are already fairly well understood and need only a brief review.

All diagrams in this OP are presented in such a way that little or no previous experience in reading schematic diagrams is necessary.

NOTE: Since the majority of the Computers Mark 1 in service are Mark 1 Mod 7, and since the other Computers Mark 1 are very similar to the Mod 7, all references to the Computer Mark 1 in this OP apply to a Computer Mark 1 Mod 7 equipped with a Star Shell Computer Mark 1, a Selector Drive Mark 1, and a Target Course Indicator Mark 1.

The chapter on Modification Differences describes how other modifications differ from the Mod 7.

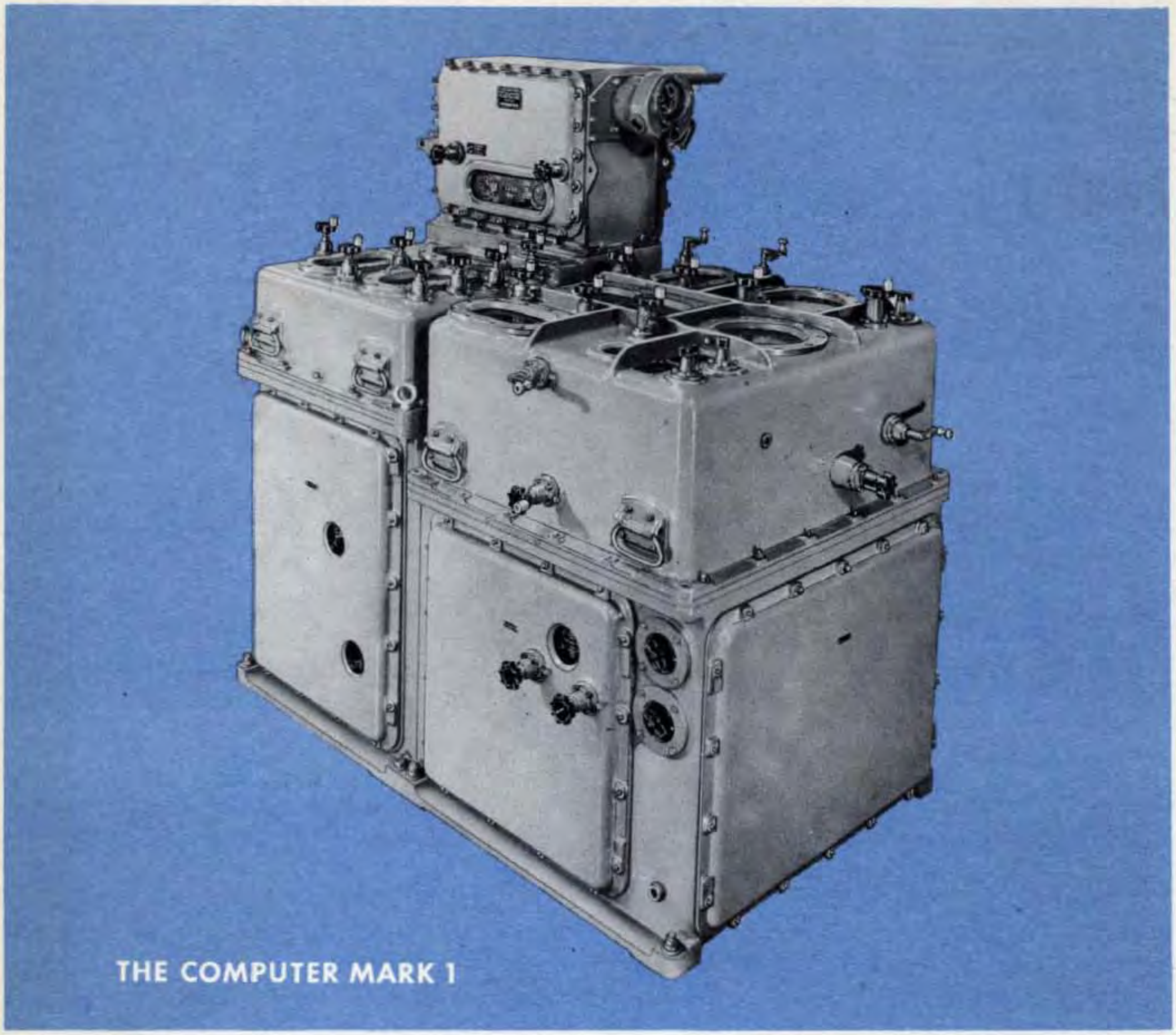
PART 1

GENERAL DESCRIPTION

The General Description is intended to give an over-all picture of the Computer Mark 1, and its place in the Gun Director Mark 37 System of fire control. The General Description familiarizes the reader with the main features of the Computer, and the fire control problem it solves, before he tackles the Detailed Description.

Those readers whose interest in the Computer Mark 1 is only general, and does not extend into the details of operation and maintenance, will probably find that the General Description contains most of the information they need.

The General Description includes the following subjects:

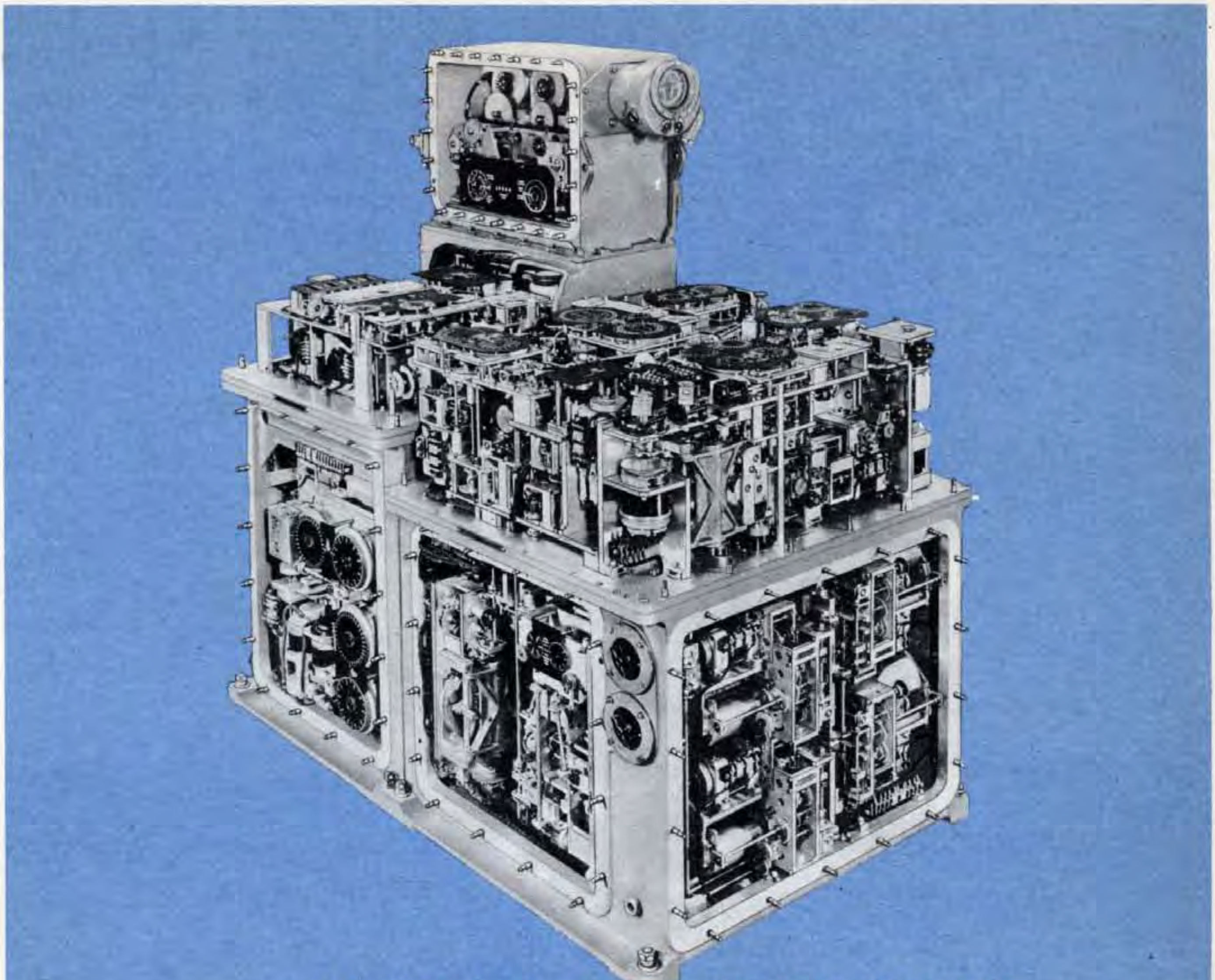


THE COMPUTER MARK 1

The Computer Mark 1 is the mechanical brain of the Gun Director Mark 37 System of Automatic Fire Control. This system controls the fire of the 5″/38 cal. dual-purpose guns against both air and surface targets. The system is also used to control 40-mm. guns at short ranges and main battery guns in barrage fire. Later modifications of the Computer Mark 1 calculate gun orders for 5″/54, 6″/47, and 8″/55 cal. batteries.

The Computer Mark 1 computes continuous gun orders containing corrections for all the significant factors affecting anti-aircraft and surface fire. The corrections allow for the motion of Ship and Target during the time the projectile is in flight; for the curvature of the projectile path caused by gravity, drift, and wind; for pitch and roll of the Ship; and for a number of other factors.

These gun orders, a fuze setting order, and parallax corrections, are continuously transmitted from the Computer to the gun mounts. At the mounts, these orders are used to point the guns continuously and to time the fuzes so that the projectiles will explode at the predicted position of the target.



COMPUTER MARK 1 WITHOUT ITS COVERS

At first the Computer Mark 1 looks like a chaotic maze of gearing and motors, but actually it is an orderly collection of connected basic mechanisms. The important thing to realize is that the thousands of gears and shafts which look so complicated do one of the simplest jobs in the Computer. Most of them just connect one mechanism to another. The mechanisms themselves—component solvers, integrators, multipliers, differentials and so on—do the computing. The gears and shafts merely transmit motion from one mechanism to another so that all the mechanisms in the Computer work together as a big network. The gearing is fairly intricate in construction, but the job it does is simple.

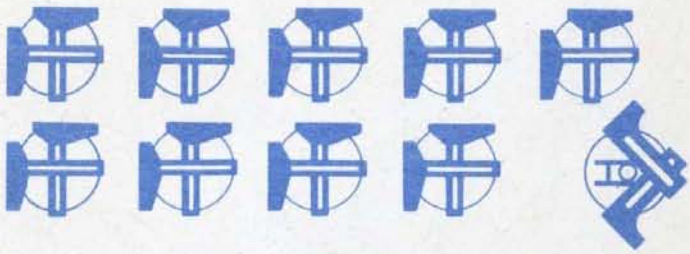
One does not have to be a mechanical engineer to understand the Computer Mark 1. The detailed description of the Computer breaks it down into about four sections which can be understood one at a time without too much difficulty. It is a good idea to become very familiar with this material because it contains information that will be useful in operating, testing, setting, and maintaining the Computer.

Here are the BASIC MECHANISMS

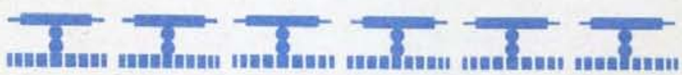
The Computer Mark 1 is made up almost entirely of the Basic Fire Control Mechanisms described in OP 1140. If the Basic Mechanisms were taken out of the Computer there would be nothing left but the case, a few special mechanisms, the shaft assemblies, and the wiring. Anyone who knows the Basic Mechanisms described in OP 1140 already knows a lot about the Computer Mark 1.

The Computer Mk 1 Mod 7 contains the following Basic Mechanisms:

9 COMPONENT SOLVERS AND 1 VECTOR SOLVER

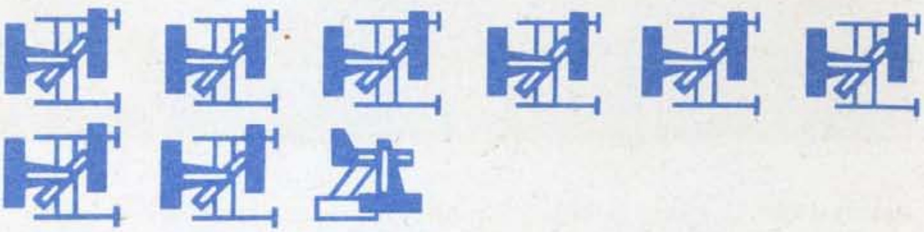


6 DISK INTEGRATORS



4 COMPONENT INTEGRATORS

9 MULTIPLIERS

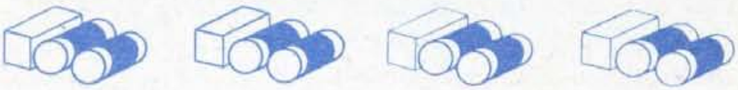


6 COMPUTING MULTIPLIERS

8 CAMS IN ADDITION TO THE CAMS IN THE COMPONENT SOLVERS AND MULTIPLIERS.

5 SINGLE-SPEED RECEIVERS

4 DOUBLE-SPEED RECEIVERS



in the COMPUTER MARK 1

10 SINGLE-SPEED TRANSMITTERS

10 DOUBLE-SPEED TRANSMITTERS

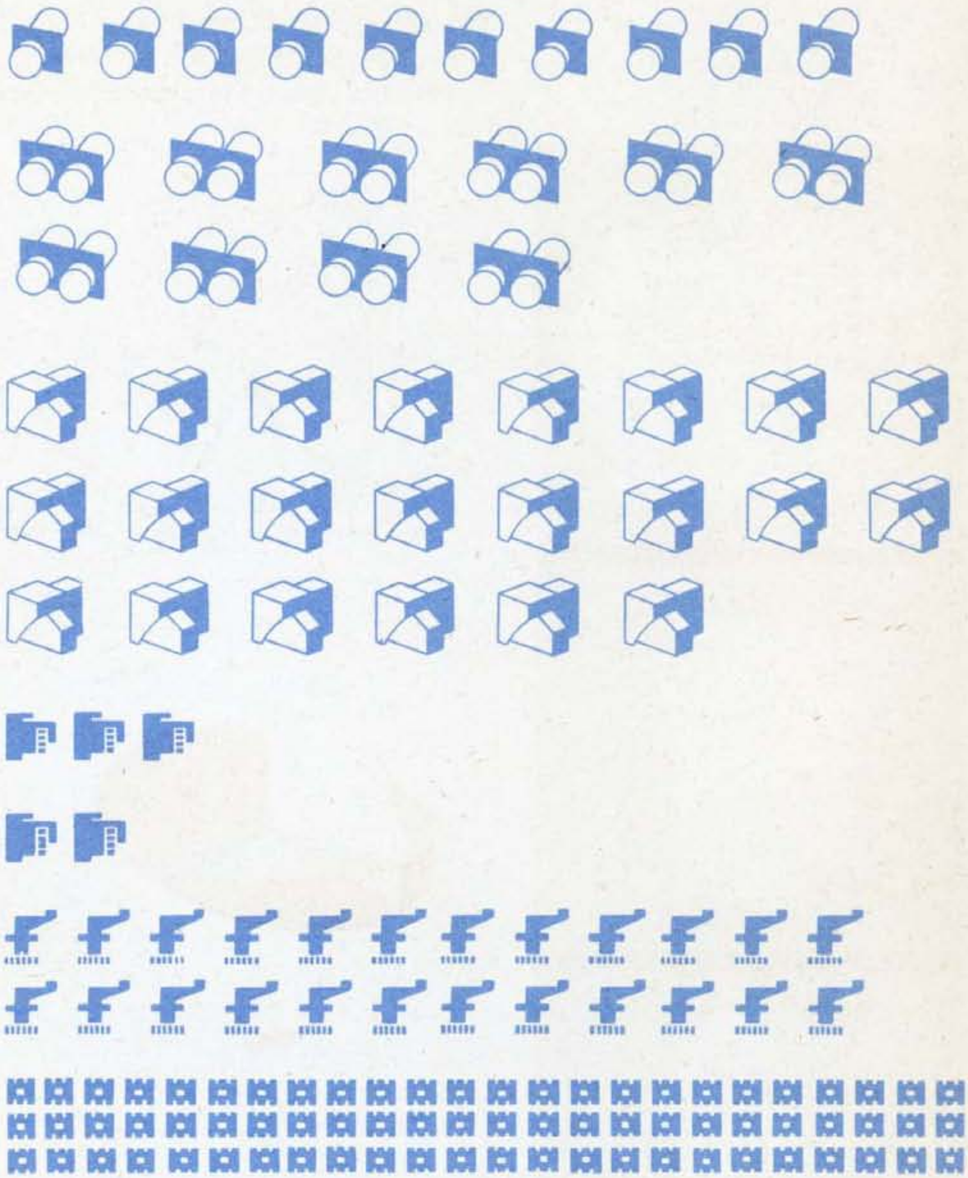
22 FOLLOW-UP CONTROLS

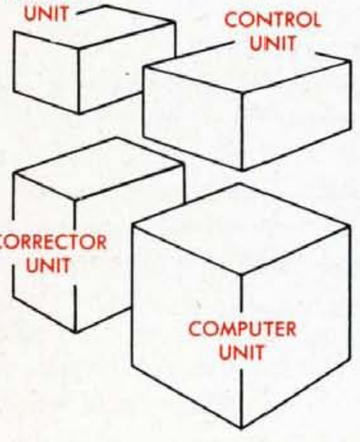
3 SOLENOID CLUTCHES

2 SOLENOID LOCKS

24 HANDCRANKS

MORE THAN 150 DIFFERENTIALS





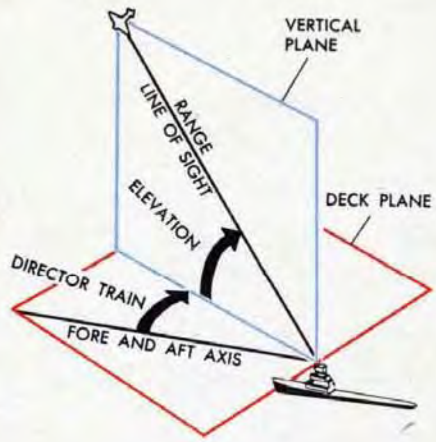
In order that the Computer Mark 1 may be installed more easily in certain types of ships, it is so constructed that it can be separated into four installation units.

Thousands of man-hours of skilled labor are required to make and assemble the parts of this Computer.

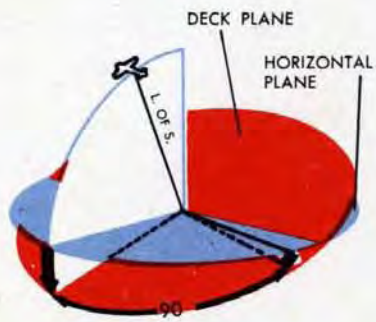
The finished instrument costs about $75,000. It should be treated with care.

COMPANION INSTRUMENTS of

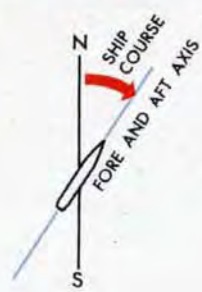
The Computer Mark 1 is one of a group of instruments which are connected together to form a system of anti-aircraft and surface fire control known as the Gun Director Mark 37 System.



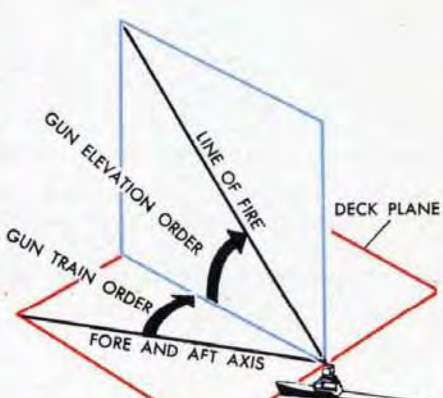
The Gun Director Mark 37 is the eyes of the system. After picking up the Target, the Director observes its location in relation to Own Ship. The Director measures the Target's Range and Elevation in relation to the deck plane. It also measures the Bearing in the deck plane clockwise from the bow of Own Ship to the vertical plane through the Line of Sight. This angle is called Director Train.



The Stable Element Mark 6 measures the inclination of the deck in relation to the horizontal plane and the Line of Sight.



The Gyro Compass measures Own Ship Course.

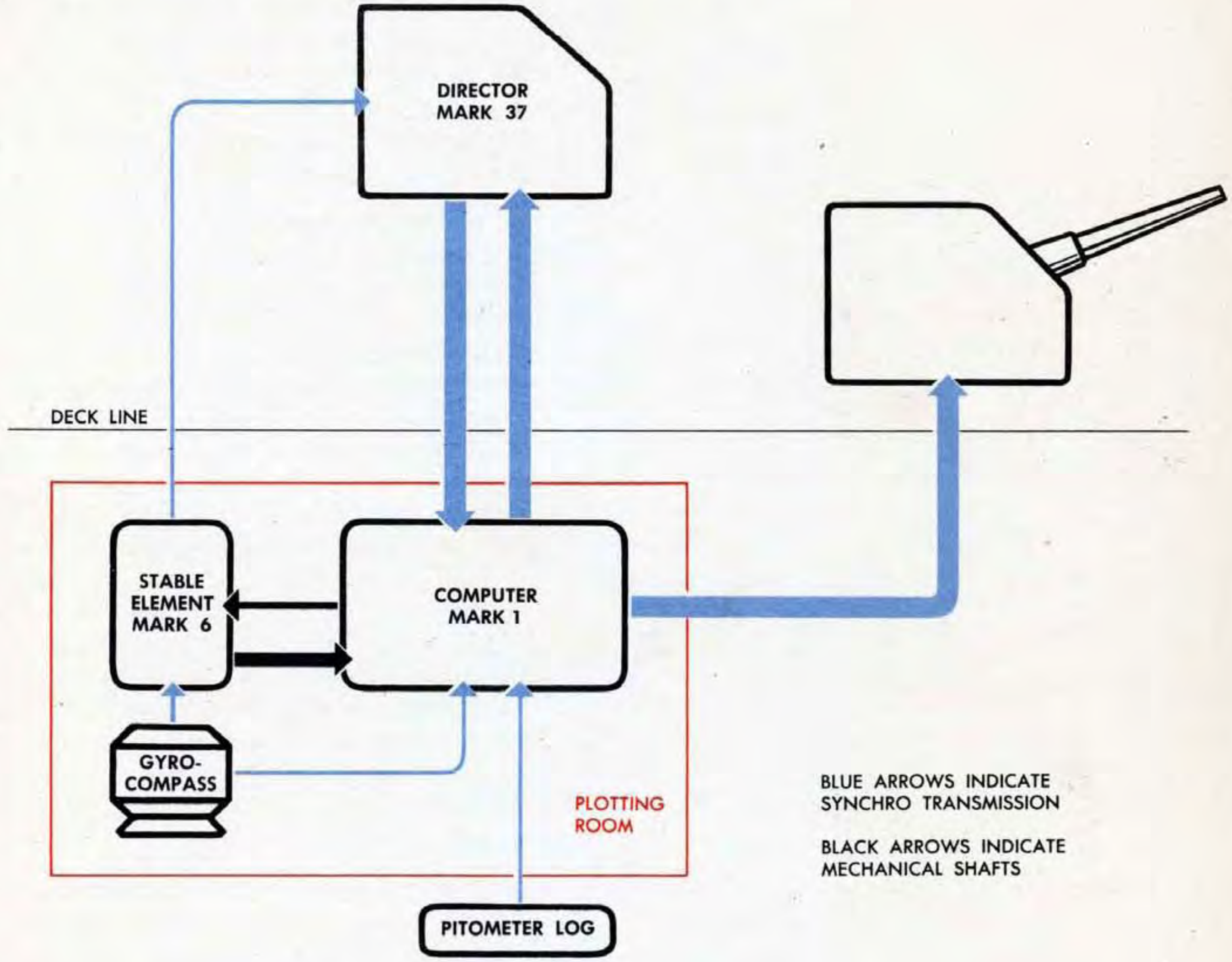


In the mounts, there are mechanical, electrical, or electrohydraulic mechanisms which keep the guns pointed and the fuzes set to agree with the gun and fuze order signals from the Computer. There are also provisions for introducing parallax corrections where necessary.

the COMPUTER MARK 1

There are a number of other elements in the Gun Director Mark 37 System, including the Pitometer Log which measures Own Ship Speed, a switchboard, and intercommunication telephones.

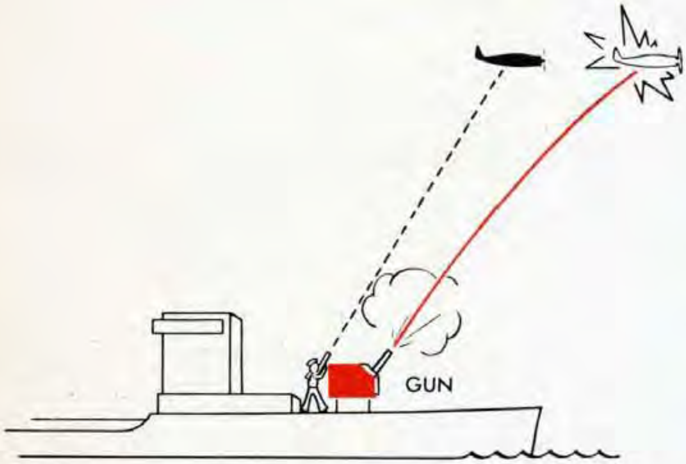
The various instruments are related to one another like this:



The Director is usually about 30 feet or more above the deck. The guns are located in various places on the deck depending on the type of ship.

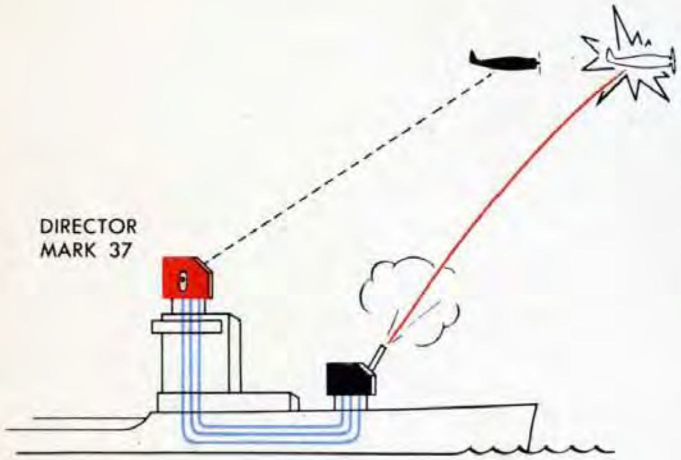
The Computer and the Stable Element stand together in the plotting room of the ship and are connected mechanically by shafts. The Gyro Compass and the switchboard are also in the plotting room. Most of the instruments in the system are connected electrically by synchro transmission.

The place of the COMPUTER MARK 1 in the GUN DIRECTOR MARK 37 SYSTEM



Since the Computer Mark 1 is part of the Gun Director Mark 37 System, it is essential to know the function of each unit of this system in order to understand the Computer itself. The Mark 37 System can best be built up by starting with the guns alone.

It would be possible to direct the fire of the guns from each gun mount, independently of other mounts or observation stations. But fire control from the mounts alone has several disadvantages. Visibility from the mount is often bad because of the smoke. Observation of surface targets is restricted by the relatively small height of the mounts above the water line. Also, it is difficult to coordinate the fire of several gun mounts when each is separately controlled.

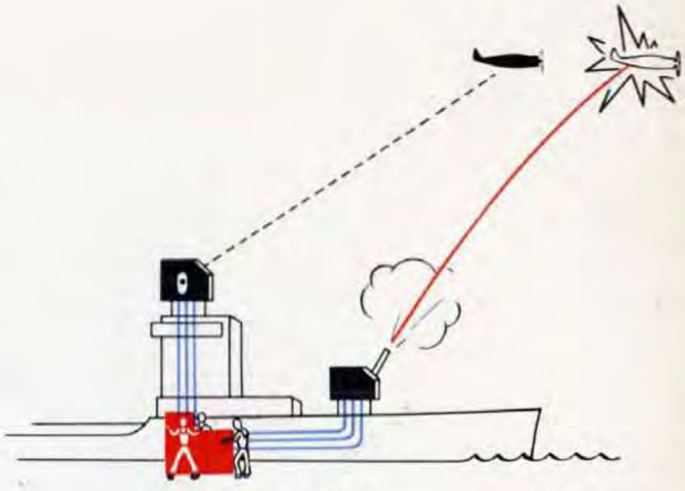


These difficulties are overcome by having a Gun Director aloft, high enough for the Director Crew to see above the smoke and to observe surface targets at great distances. With a Gun Director, the fire of all the gun mounts can be coordinated.

Firing with the combination of mounts and a Gun Director is better than firing from the gun mounts alone. In such a simple fire control system, however, all corrections for motion of Ship and Target, curvature of the projectile path, and the pitch and roll of the Ship would have to be made by guess work.

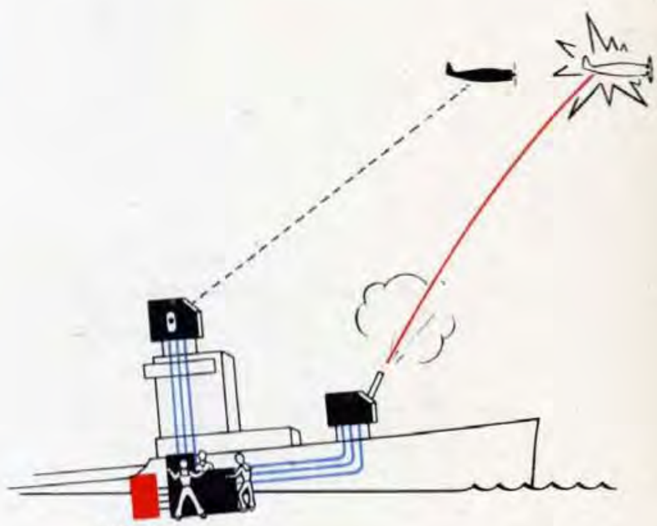
An instrument is needed to compute all these corrections instantaneously and continuously. In the Gun Director Mark 37 System of fire control, the instrument that fills this need is the Computer Mark 1.

The Computer Mark 1 is located in the plotting room. In the plotting room the Computer is better protected than it would be in the Director or at the gun mount. If the Director is put out of action, the Computer can still continue to function. In fact, one of the features of the Computer Mark 1 is that, without any Director inputs, it can generate enough of the values normally received from the Director to track a surface target.

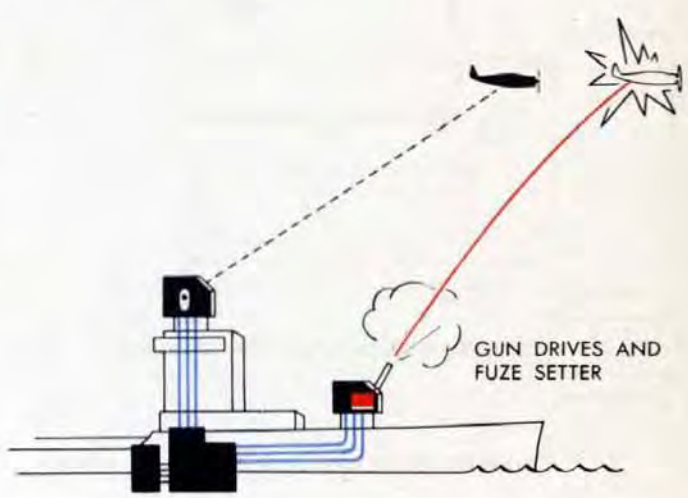


The Director and Computer in the Gun Director Mark 37 System are able to track the Target and compute predictions for relative motion and for curvature of the projectile path, but by themselves they cannot allow for pitch and roll of Own Ship.

In order to fire continuously during pitch and roll, the Director, Computer, and guns must be corrected continuously for the effects of deck inclination. To measure deck inclination, the Gun Director Mark 37 System uses the gyro mechanism called the Stable Element Mark 6. The Stable Element measures the amount of deck inclination from the horizontal plane with reference to the Line of Sight.



Because of the number and variety of the factors which enter into the fire control problem, the outputs of the Computer Mark 1 are continually changing. In order to keep the guns pointed in accordance with these varying orders from the Computer, there are electrical or electrohydraulic mechanisms at the gun mounts which receive the changing signals and control power drives. The power drives point the guns continuously by turning the whole mount in train, and moving the guns themselves in elevation. Another electrical mechanism, the Fuze Setter, receives the fuze order from the Computer Mark 1 and automatically sets the fuzes of the projectiles as they wait to be loaded.



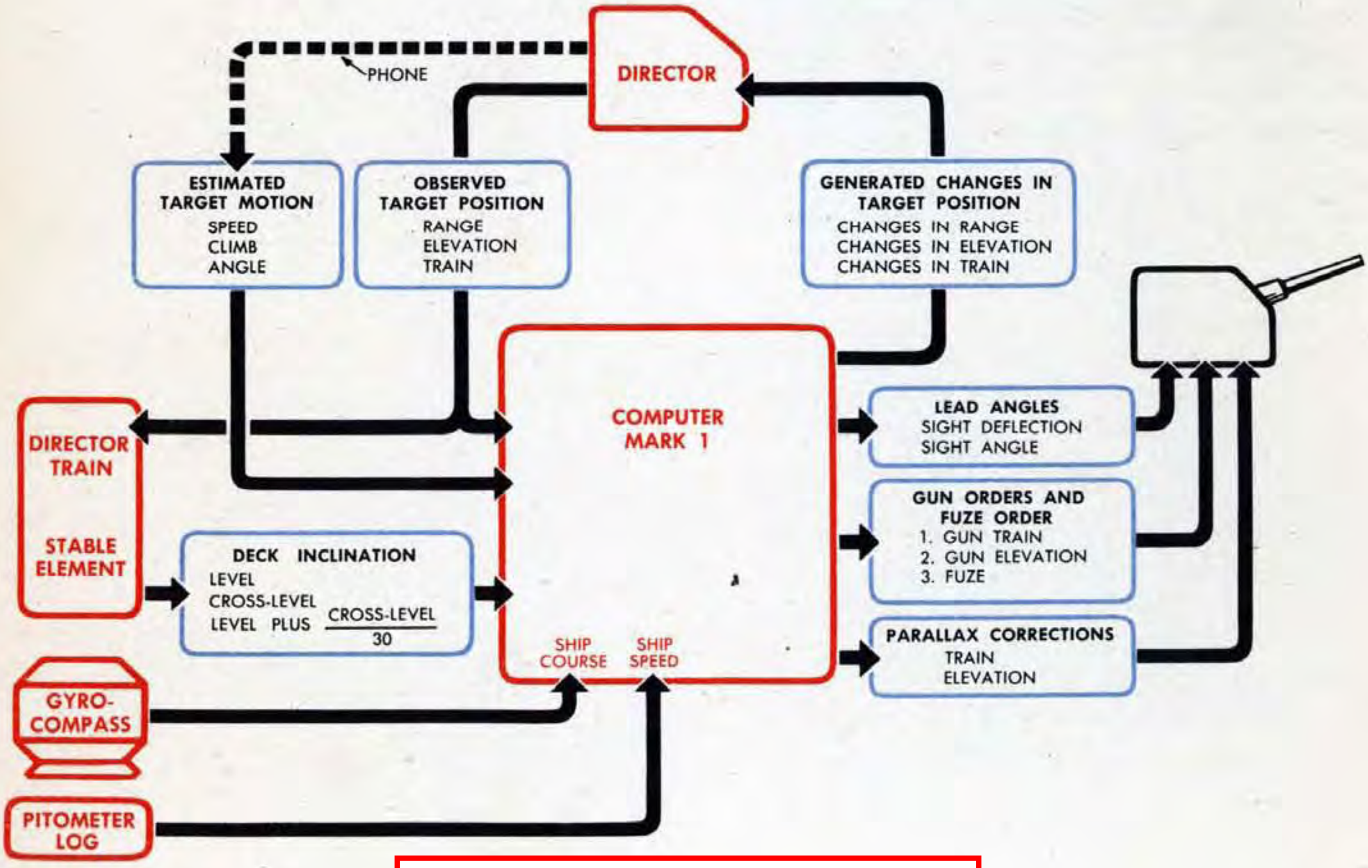
What the COMPUTER MARK 1 does in the

In the Gun Director Mark 37 System, all the instruments except those at the gun mounts are used to furnish inputs to the Computer Mark 1.

The Director Crew "pick up" a target with the telescopes and Range Finder. By turning their handwheels and the Range Knob, they keep their crosshairs continuously on the target, and transmit values of Range, Director Elevation, and Director Train to the Computer.

The Stable Element receives the value of Director Train from the Computer, and continuously measures the angles of Level and Cross-level, which are the vertical components of deck inclination from the horizontal, in and at right angles to the plane of sight. Level, Cross-level, and Level plus a function of Cross-level, are transmitted mechanically from the Stable Element to the Computer.

Besides the inputs from the Director and the Stable Element, the Computer receives the values of Ship Speed from the Pitometer Log, Ship Course from the Gyro Compass, and *estimates* of Horizontal Target Speed, Target Course, and Rate of Climb, by phone from the Control Officer in the Director.



GUN DIRECTOR MARK 37 SYSTEM

Using these inputs together with some other hand inputs, the Computer goes to work. Briefly, this is what it does:

1 The Computer Mark 1 computes and transmits to the gun mounts continuous Gun and Fuze Orders containing:

  a Corrections for movement of Ship and Target during the time of flight of the projectile.

  b Corrections for curvature of the projectile path caused by gravity, drift, wind, and changes in initial velocity.

  c Corrections for the effects on the gun of roll and pitch of the Ship.

2 The Computer computes continuous values of the Lead Angles in elevation and deflection. These Lead Angles are called Sight Angle and Sight Deflection. They are transmitted electrically to the gun mounts to offset the gun sights.

3 The Computer Mark 1 computes and transmits two Parallax Corrections, which may be applied at the individual gun mounts to compensate for differences in location of guns and Directors.

4 Through the Star Shell Computer, gun and fuze orders are computed for firing star shells to illuminate surface targets which the Computer Mark 1 is tracking.

5 The Computer corrects the estimated Target Motion inputs. It does this by generating changes of Range, Director Elevation, and Director Train which are transmitted electrically to the Director to drive the Director sights. By comparing the generated Computer values with the observed Director values of Range, Elevation, and Train, the Computer checks and corrects the original estimates of Target Horizontal Speed, Course, and Rate of Climb, and puts accurate values of these three quantities into the computing mechanism. When the estimated values are correct, the generated quantities keep the Director sights on Target. This process of correcting the Target Motion estimates is called Rate Control.

NOTE:
Unless the Target goes into a dive attack, Rate of Climb usually has a value close to zero. For this reason it is seldom necessary for an estimate of Rate of Climb to be phoned down from the Director. Instead, Rate of Climb can simply be set at zero, unless dive attack is indicated. The correct value of Rate of Climb will be computed during Rate Control.

For convenience, this special characteristic of the Rate of Climb estimate has been ignored throughout the General Description.

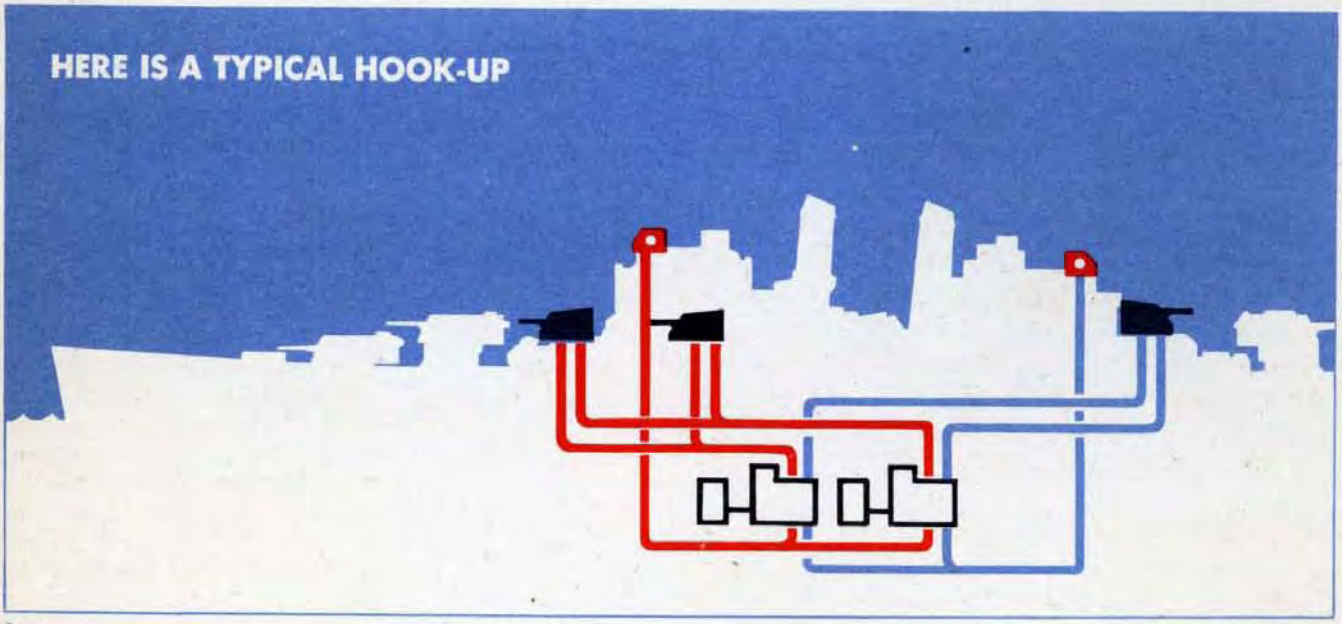
The ships using the COMPUTER MARK 1

The Computer Mark 1 and the other elements of the Gun Director Mark 37 System are used on the following types of ships:

Destroyers, all types after DD409 and some earlier
Light and heavy cruisers, after CL51 and CA68
Battleships, after BB55 and some earlier
Aircraft carriers of the types CV9 and CVB41
Some auxiliary vessels

Sometimes the computers are installed singly, sometimes in pairs, sometimes in groups of four, depending mainly on the type of ship.

On ships having more than one computer, each computer has a gun director. The installation is usually designed so that any director can be connected to any computer, and any computer can be used with any gun or group of guns. The limits of the possible cross-connection of directors, computers and guns are the limitation of shipboard wiring, and the fact that a director can control only those guns training in about the same arc of bearing as the director.



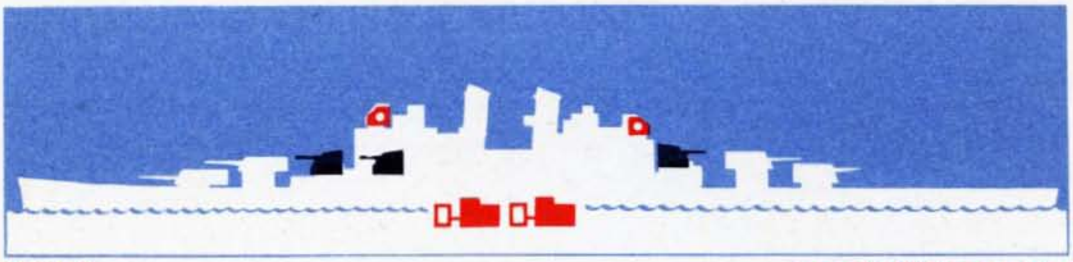
Here are typical locations of the Gun Director Mark 37 System on various kinds of ships. There are other variations. These are only a few examples.

AIRCRAFT CARRIER

2 COMPUTERS MARK 1

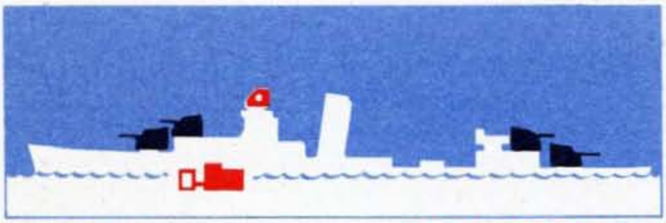
BATTLESHIP

4 COMPUTERS MARK 1



CRUISER

2 COMPUTERS MARK 1



DESTROYER

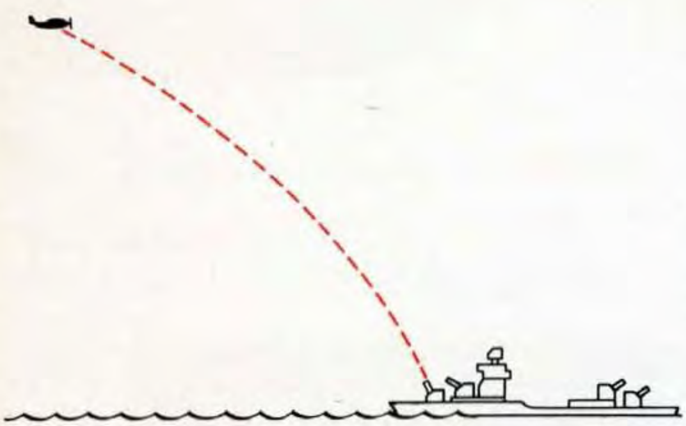
1 COMPUTER MARK 1

Types of TARGETS and ATTACK

Air targets

The Computer Mark 1 is primarily designed for use against air targets.

It computes accurate gun orders for Continuous Fire against nearly all types of air targets, such as:



1 High-level Horizontal Bombers

2 Low-level Torpedo Planes

3 Dive Bombers attacking Own Ship

4 Dive Bombers attacking other ships (when the vertical component of Target Speed does not exceed −250 knots).

The Computer may also be used for anti-aircraft barrage fire by the 5″ guns, or by the main battery guns.

Surface and land targets

The Computer also computes accurate gun orders for Continuous or Selected Fire against all types of surface targets:

1 Other ships, destroyers, cruisers, etc.

2 High-speed torpedo boats which travel at speeds outside the limits of the main battery computers.

3 Stationary land targets such as shore installations, and moving land targets such as tanks.

The Computer may also be used for barrage fire against a surface target both by the 5″ guns and the main battery guns.

Types of SELECTED FIRE

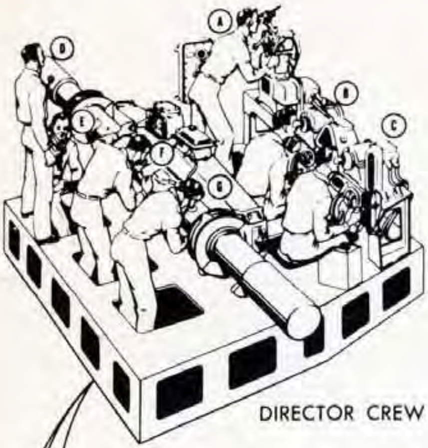
Two kinds of Selected Fire are possible in this system:

1 Selected Level Fire, in which the value of Level may be selected at either the Director or the Stable Element.

2 Selected Cross-level Fire, in which the value of Cross-level is always selected at the Stable Element.

In Selected Level Fire against a surface target the Computer Mark 1 can produce gun orders without Director inputs.

AUTOMATIC FIRE CONTROL in the



The Gun Director Mark 37 System is referred to as a system of Automatic Fire Control for continuous fire. However, it is important to realize that it falls considerably short of completely automatic fire control. It falls short in ways which require skill in operation. The role of the operating personnel in the Mark 37 System is not predominantly stand-by or in any sense auxiliary. Their functions are vitally important just because the System does leave gaps which must be filled in by the operating personnel.

Here is a list of the main functions of a fire control system, showing which functions are accomplished automatically in the Gun Director Mark 37 System, and which require manual operation by the crews.

1 Locating the target

There are two methods of locating targets in the Gun Director Mark 37 System, optical and radar. Neither of these is automatic. Both systems depend on observation by the operating personnel. The use of either system is a matter of discretion on the part of the officer in charge of the Director.

2 Tracking the target

Tracking is far from automatic. The sights must be kept on the Target by the Pointer, Trainer and Range Finder Operator, aided by some outputs from the Computer.

3 Communicating information

In the Gun Director Mark 37 System most information is communicated automatically by synchro transmission. Estimated values, however, are transmitted by phone.

4 Correcting the target motion estimates

The Mark 37 System has no way of measuring Target Motion directly. The Computer crew puts the *estimates* of Target Motion into the Computer, as values of the Horizontal Target Speed, Target Angle, and Rate of Climb. The Computer computes Relative Motion Rates and uses them to generate changes of Range, Elevation, and Bearing, which it compares with the Observed Changes of these three quantities. The differences between the Generated and the Observed Changes of each of these quantities are used by the Computer to correct the estimated values of Target Motion.

GUN DIRECTOR MARK 37 SYSTEM

When the Target Motion values are correct, the Computer will automatically generate Changes of Range, Elevation, and Bearing which will be equal to the Observed Changes.

The process of using the difference between the Generated and the Observed Changes of Range, Elevation, and Bearing to correct estimated Target Motion is called Rate Control. It is the main job in operating the Computer. Correcting these estimates requires skill on the part of Computer Operators, and knowledge of how the fire control problem is solved in the Computer Mark 1.

After Rate Control is completed, the target values are correct and the Computer automatically computes correct Relative Motion Rates and generates correct Changes of Range, Elevation, and Bearing, which keep the Director sights on Target AS LONG AS THE TARGET CONTINUES IN THE SAME DIRECTION AT THE SAME SPEED.

As soon as the Target changes its course or speed, Rate Control must be started all over again.

5 Predicting

Prediction is automatic in the Computer Mark 1 except for two hand inputs. These two inputs are the value of Initial Velocity, and the value of Dead Time. Dead Time is time between the setting of the fuze and the firing of the gun.

6 Stabilizing the guns and the director

The stabilizing of both the Director sights and the guns is fully automatic in the Director Mark 37 System.

7 Pointing the guns

Pointing the guns in response to signals from the Computer can be fully automatic.

8 Setting the fuzes

Fuzes are set automatically by the Automatic Fuze Setter.

9 Loading the guns

The projectiles must be taken from the setter and loaded into the gun by hand.

The sections of the COMPUTER MARK 1

The Computer Mark 1 has three main jobs. The first is to correct the estimated inputs of Horizontal Target Speed, Target Angle, and Rate of Climb and so establish three correct Relative Motion Rates. This job can be called *establishing the correct Relative Motion Rates* and is done in the Tracking Section.

The second main job is to compute two lead angles and a fuze order which will keep the guns pointed so that the projectile and Target will meet at the end of the Time of Flight. These computations may be called *establishing the Line of Fire* from a horizontal deck. This second job is done by the Prediction Section.

The third main job is to *stabilize the Line of Fire*. This is done by the Trunnion Tilt Section, which computes corrections to offset the effect of tilt of the gun trunnions on the Line of Fire.

There are four sections in the Computer Mark 1:

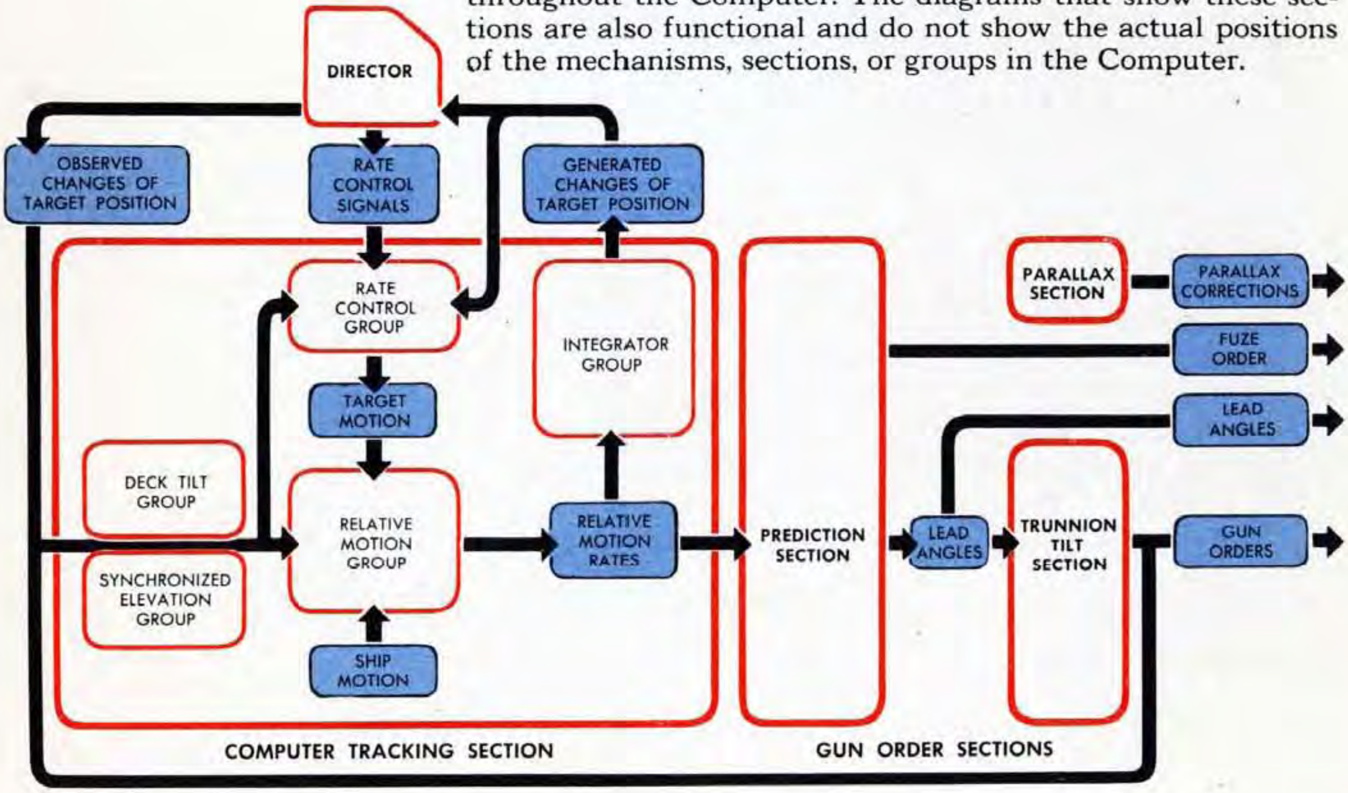
1 THE TRACKING SECTION
2 THE PREDICTION SECTION
3 THE TRUNNION TILT SECTION
4 THE PARALLAX SECTION

The Tracking Section can be divided into five groups:

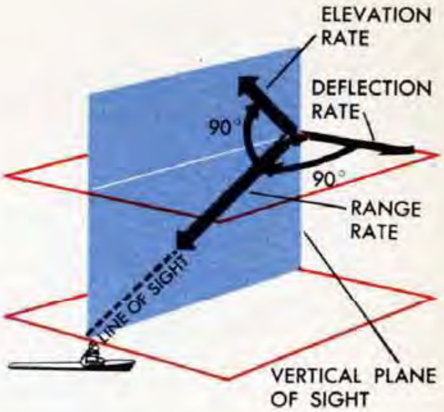
1 The Deck Tilt Group
2 The Relative Motion Group
3 The Integrator Group
4 The Rate Control Group
5 The Synchronize Elevation Group

The Parallax Corrections are not included in the Gun Orders but are transmitted separately to the guns.

This grouping of the sections is merely a functional grouping. The mechanisms that form each section are actually scattered throughout the Computer. The diagrams that show these sections are also functional and do not show the actual positions of the mechanisms, sections, or groups in the Computer.



THE TRACKING SECTION

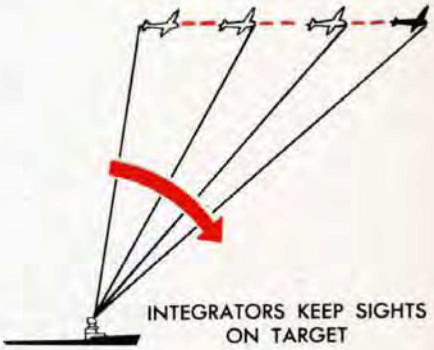


The Relative Motion Group of the Computer Mark 1 combines the motions of Own Ship and the Target into three rates of Relative Motion in relation to the Line of Sight.

The Integrator Group uses these rates to generate changes of Target Position in Range, Elevation, and Bearing. These changes are continuously transmitted to the Director to position the telescopes and the Range Finder.

If the generated values of Target Position do not keep the sights on the Target, the operators in the Director press their Rate Control keys and turn their handwheels to keep the sights on the Target.

The turning of the handwheels in the Director with the Rate Control keys closed sends Rate Control corrections to the RATE CONTROL GROUP in the Computer.



The Rate Control Group converts these Range, Elevation, and Bearing rate corrections into corrections to the values of Target Motion, and puts the corrected values of Target Motion into the Relative Motion Group. The values of Target Motion in the Relative Motion Group initially were estimates made by the Control Officer.

The Deck Tilt and Synchronize Elevation Groups are each used to refer one value from the deck plane to the horizontal plane. The Deck Tilt Group computes the correction necessary to convert Director Train in the deck plane to Relative Target Bearing in the horizontal plane. The Synchronize Elevation Group converts Director Elevation above the deck to Target Elevation above the horizontal.

THE PREDICTION SECTION uses the three Relative Motion Rates to compute the amount the guns must lead the Target. It computes two lead angles and a fuze setting order.

The Lead Angles include computations for the change in Target Position while the projectile is in the air and for the projectile's curved path. To obtain the Lead Angles, the Prediction Section computes the Target Position at the end of the Time of Flight and corrections for the effect of gravity, drift, wind, and changes in initial velocity on the projectile path.

The Fuze Setting Order includes a correction for the change in Range during the time the projectile is being loaded.

THE TRUNNION TILT SECTION computes corrections for the effects of pitch and roll on the gun trunnions. The lead angles and the Trunnion Tilt Corrections are combined with Director Elevation and Train to form the two Gun Orders.

THE PARALLAX SECTION computes Train and Elevation Parallax Corrections for a horizontal distance of 100 yards along the fore and aft axis. These two Parallax Corrections may be transmitted separately to the guns and Directors. Each gun or Director may use a fraction of each correction according to its distance from the Reference Point.

A SIMPLIFIED ACCOUNT OF TRACKING, PREDICTION, AND STABILIZATION

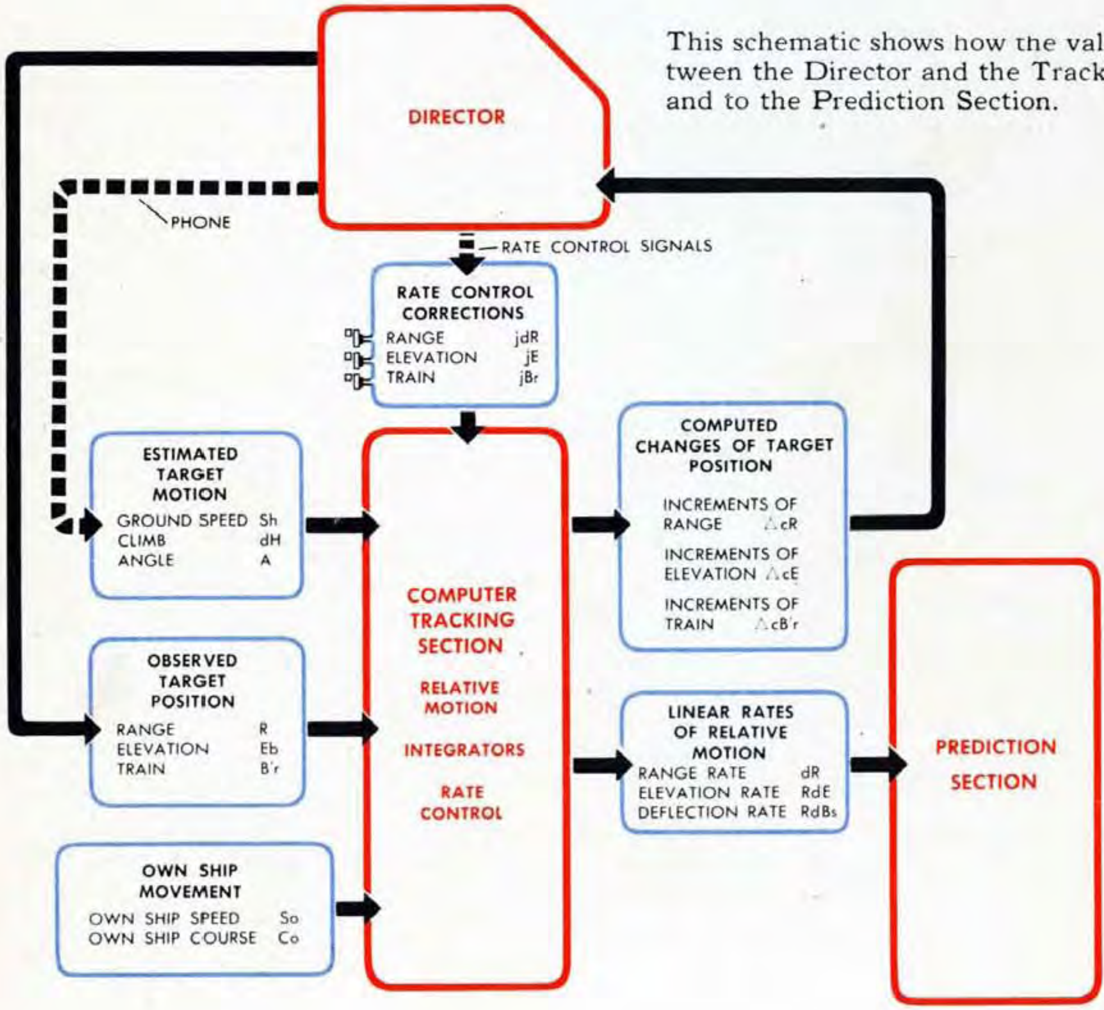
TRACKING the TARGET

It is easier to understand how the Computer tracks a Target and computes gun orders if Own Ship is first considered as being steady, that is, as if Own Ship were neither pitching nor rolling but had its deck horizontal all the time.

On a steady horizontal ship, the Deck Tilt Group, Trunnion Tilt Section, and the Stable Element may be disregarded. Since Parallax Corrections are not included in the Gun Orders, the Parallax Section may also be left out for the moment. With the deck horizontal, only two sections are needed in order to go through tracking and the computation of Gun and Fuze Orders.

The two sections needed are the Tracking and Prediction Sections. In the Tracking Section the Deck Tilt and Synchronize Elevation Groups may be disregarded at this time.

This schematic shows how the values flow between the Director and the Tracking Section, and to the Prediction Section.



1 When a Target is sighted, the Trainer, Pointer and Range Operator in the Director immediately pick it up and continuously measure its *Position* in Range, *R*, Elevation, *Eb*, and Director Train, *B'r*. These three quantities, *R*, *Eb*, and *B'r*, are transmitted electrically to the Computer.

2 The values of Target *Motion* are estimated by the Control Officer and phoned down to the plotting room, where they are set into the Tracking Section by hand by the Computer Crew. The Target Motion values are: Target Horizontal (Ground) Speed, *Sh*, Target Angle, *A*, and Rate of Climb, *dH*.

In addition to the Target Position values and Target Motion values, the Tracking Section receives the values of Ship Speed, *So*, and Ship Course, *Co*.

3 With these three groups of inputs the Tracking Section goes to work. The Relative Motion Group combines Ship and Target Motion into three linear Relative Motion Rates: Range Rate, *dR*, along the Line of Sight, Elevation Rate, *RdE*, perpendicular to the Line of Sight in the vertical plane, and Deflection Rate, *RdBs*, at right angles to the Line of Sight in the horizontal plane.

The Integrator Group uses these Relative Motion Rates to generate continuous Changes of Target Position: Generated Changes of Range, ΔcR, Generated Changes of Director Elevation, ΔcEb, and Generated Changes of Director Train, $\Delta cB'r$. These three quantities are continuously transmitted to the Director. If they keep the sights on the Target, the Relative Motion Rates are correct and the estimates of Target Motion are correct.

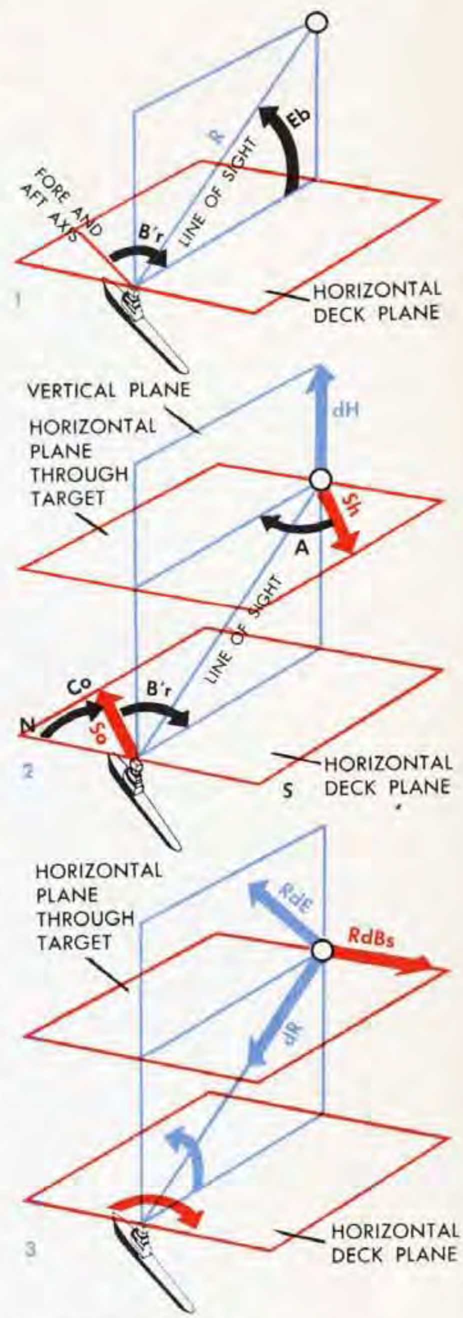
It is impossible to estimate the exact speed and direction of a plane. At the beginning of tracking, the generated quantities, which are based on these estimates, seldom keep the sights on Target.

If the sights do not stay on the Target, the estimates of Target Motion need correction. The Trainer, Pointer, and Range Operator turn their handwheels to bring the sights back on the Target.

By pressing their Rate Control keys as they turn the handwheels, the Director Crew automatically transmit Rate Control signals down to the Computer. These signals allow corrections to go into the Rate Control Group.

The Rate Control Group analyzes these Rate Control Corrections and decides how much the Target Motion estimates must have been wrong to have caused the errors in the generated values. The Rate Control Group then computes a set of more nearly correct Target Motion values.

When the Generated Changes of Target Position, ΔcR, ΔcEb, and $\Delta cB'r$, keep the sights on Target, a tracking solution is reached, and the Computer Crew know that the Target Motion values are correct. The Relative Motion Rates going into the Prediction Section are also correct and will result in accurate predictions.



GENERATED VALUES CONTINUALLY POSITION SIGHTS

NOTE:
In the *General Description*, the Pointer's and Trainer's Handwheels and Range Operator's Range Knob are all referred to as "handwheels." Similarly, the Pointer's and Trainer's Signal Keys and Range Operator's Signal Button are referred to as "signal keys."

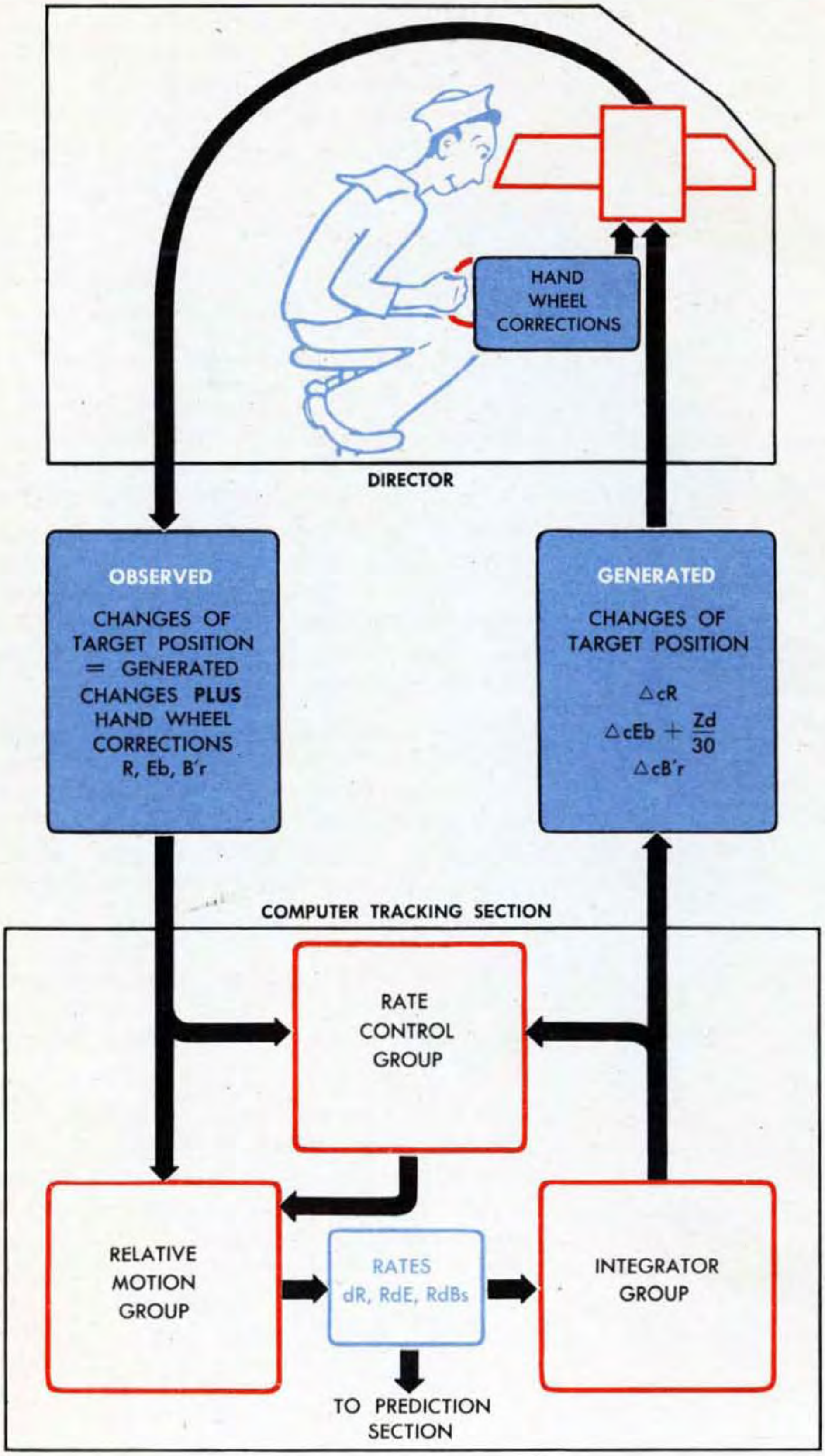
A summary of the tracking cycle for a horizontal deck

In the Gun Director Mark 37 System, tracking on a horizontal deck can be divided into the following operations:

1. Locating a Target and keeping the Director sights on it in order to measure Target Position and transmit this position continuously to the Computer.
2. Estimating the speeds and direction of Target Motion and using these estimates along with other quantities, to compute approximate Rates of Relative Motion.
3. Using the approximate Rates of Relative Motion and other quantities to generate continuous Changes of Target Position.
4. Using the Generated Changes of Target Position to position the Director sights.
5. Comparing the *Observed* Changes of Target Position, from the Director, with the *Generated* Changes of Target Position from the Computer.
6. Using the difference between the *generated* and *observed* values in the Computer to correct the estimates of Target Motion.

When a solution has been reached and the estimates of Target Motion are correct, the Generated Changes of Target Position drive the sights and Range Finder automatically. The Director sights then remain on Target even though the Target is temporarily out of sight. The guns can be fired accurately even though the Target is obscured. As long as the Target continues at the same speed and in the same straight line, the sights will be on the Target when it reappears.

The regeneration of quantities between the Director and Computer is such that, before a solution is reached, the Observed Changes of Range, Elevation, and Director Train, going to the Computer consist of the Generated Changes of those three quantities, plus any corrections the Director Crew put in by hand to keep the sights on Target. After a solution has been reached, the Observed Changes consist entirely of the Generated Changes, no handwheel corrections being necessary.



WHEN TRACKING ON
A HORIZONTAL DECK

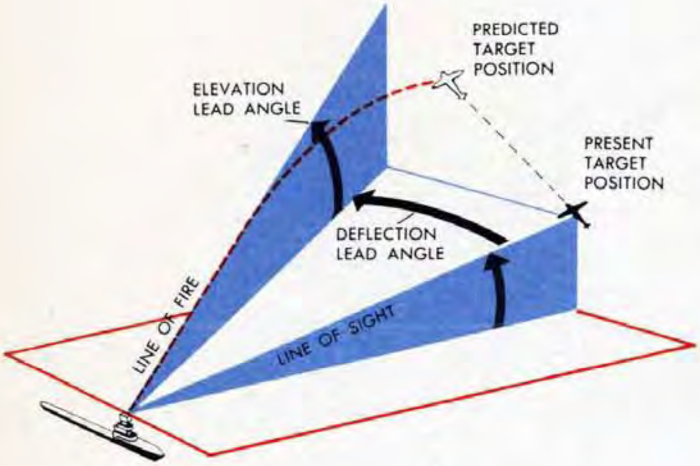
$Eb = E$

$B'r = Br$

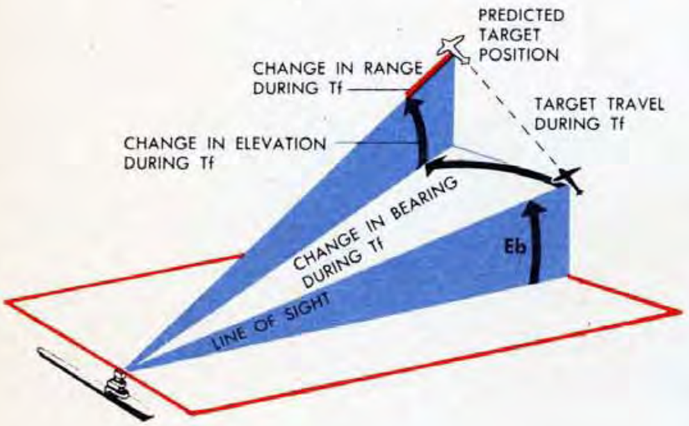
$\triangle cEb = \triangle cE$

$\triangle cB'r = \triangle cBr$

Establishing the LINE OF FIRE



The Relative Motion Rates from the Tracking Section are used in the Prediction Section to compute the Lead Angles. The Lead Angles are the angles in Elevation and Deflection by which the gun must lead the Target in order to make a hit. The Line of Fire is the line along which the gun must be pointed.

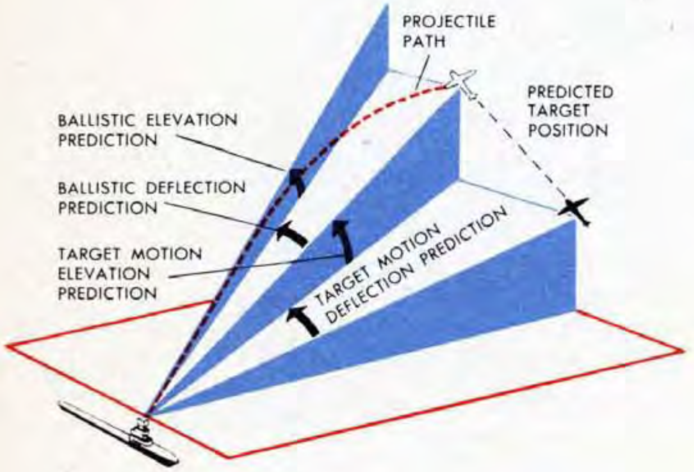


The Prediction Section computes two types of predictions to obtain the Lead Angles:

1 Relative Motion Predictions
2 Ballistic Predictions

The Relative Motion Predictions determine the Target's position relative to Own Ship at the end of the Time of Flight by computing Target travel during the time the projectile is on its way. The Prediction Section uses the three Relative Motion Rates and a computed Time of Flight, *Tf*, to obtain the Predicted Target Position in Range, Elevation, and Bearing.

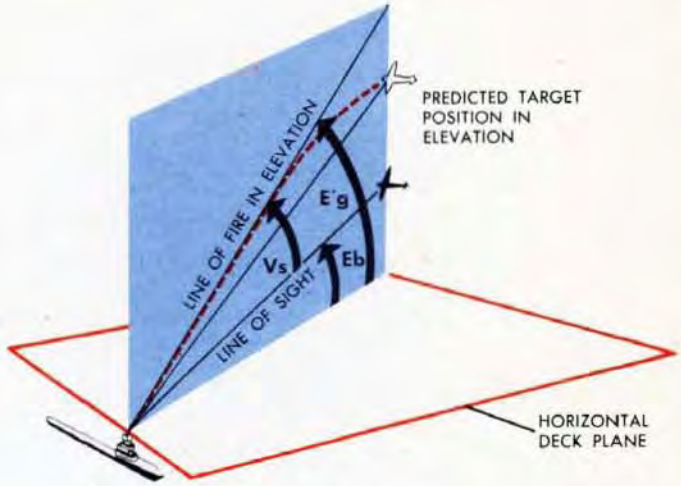
The gun cannot be aimed at this Predicted Target Position because the projectile follows a curved path. The projectile curves downward and over to one side as a result of the combined effects of gravity, drift, wind, and initial velocity. Therefore additional corrections are needed, which are called Ballistic Predictions. The Ballistic Predictions determine the amount the guns must be offset from the Predicted Target Position to allow for the curvature of the projectile path.



By combining the Relative Motion and Ballistic Predictions, the Prediction Section establishes two Lead Angles which determine a Line of Fire. Projectiles fired along this Predicted Line of Fire will hit the Target at the end of the time of projectile flight.

The Relative Motion Prediction in Elevation combined with the Ballistic Prediction in Elevation gives the Elevation lead angle, called Sight Angle, *Vs.*

On a steady horizontal deck, Sight Angle *Vs,* plus Director Elevation, *Eb,* is the Gun Elevation Order, *E′g.*



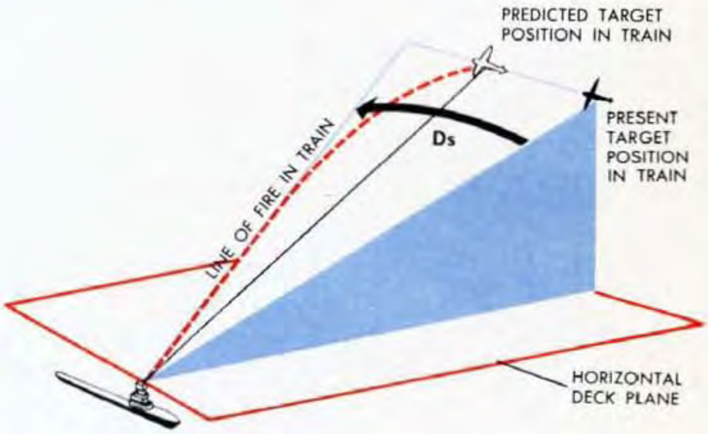
The Relative Motion Prediction in Train combined with the Ballistic Prediction in Train is the Deflection lead angle, called Sight Deflection, *Ds.*

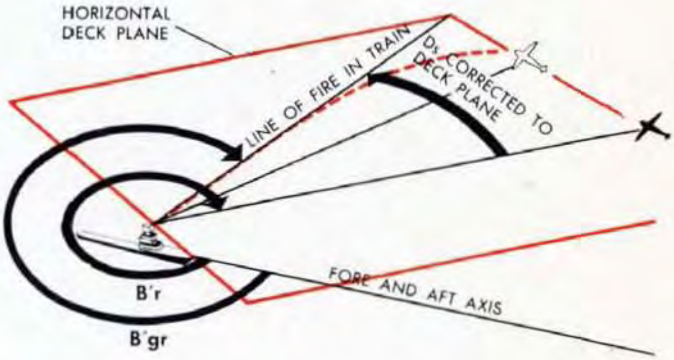
Since *Ds* is computed in a slant plane it must be corrected to the deck plane before it can be used in the Gun Train Order.

On a steady horizontal deck, Gun Train Order, *B′gr,* is made up of Sight Deflection, *Ds,* corrected to the deck plane, plus Director Train, *B′r.*

Ds is actually measured in a slant plane somewhat above or below the elevation of the Line of Sight.

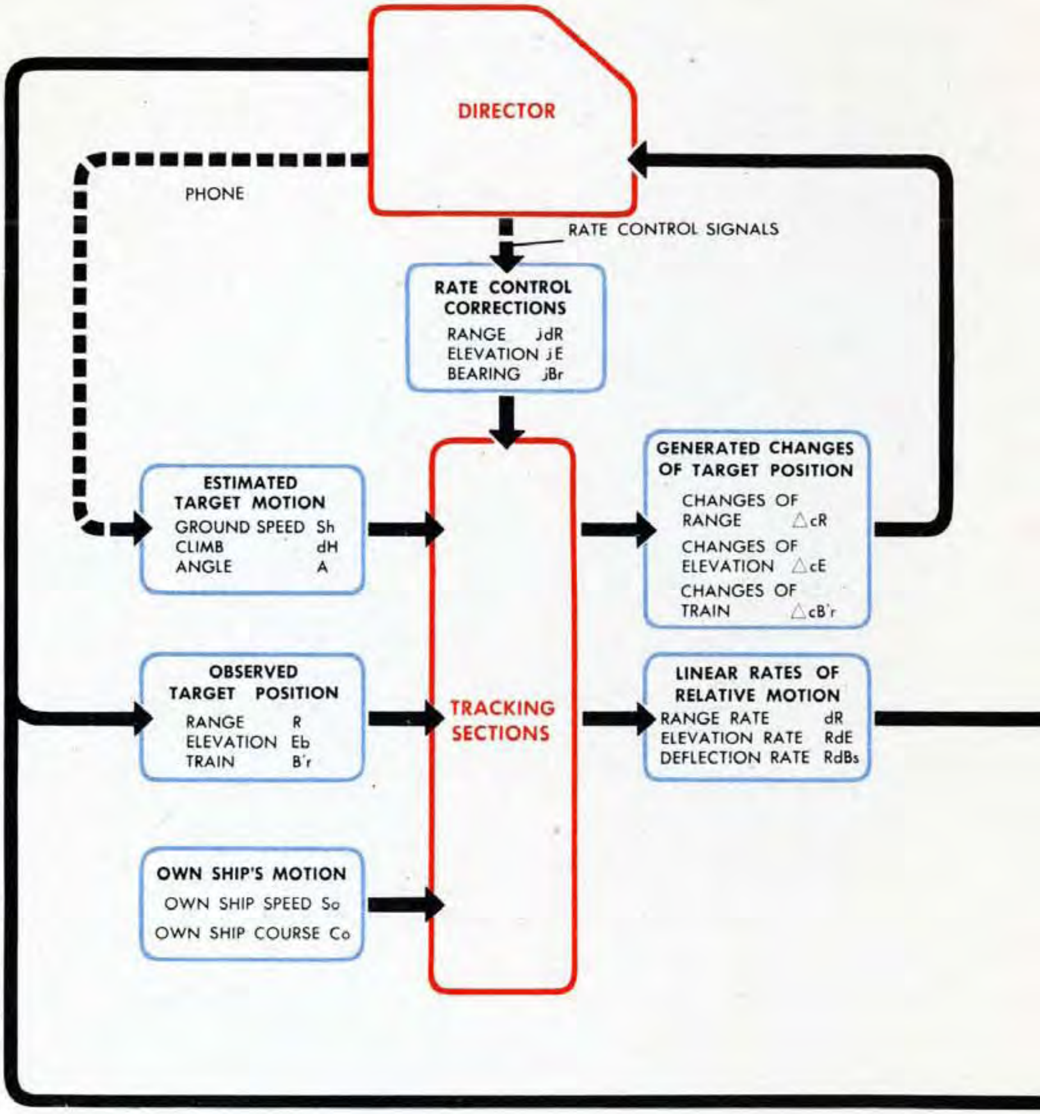
The Computer Mark 1 does not compute the Target Motion and Ballistic Predictions separately and add them. Instead, to save mechanisms, it computes them together.



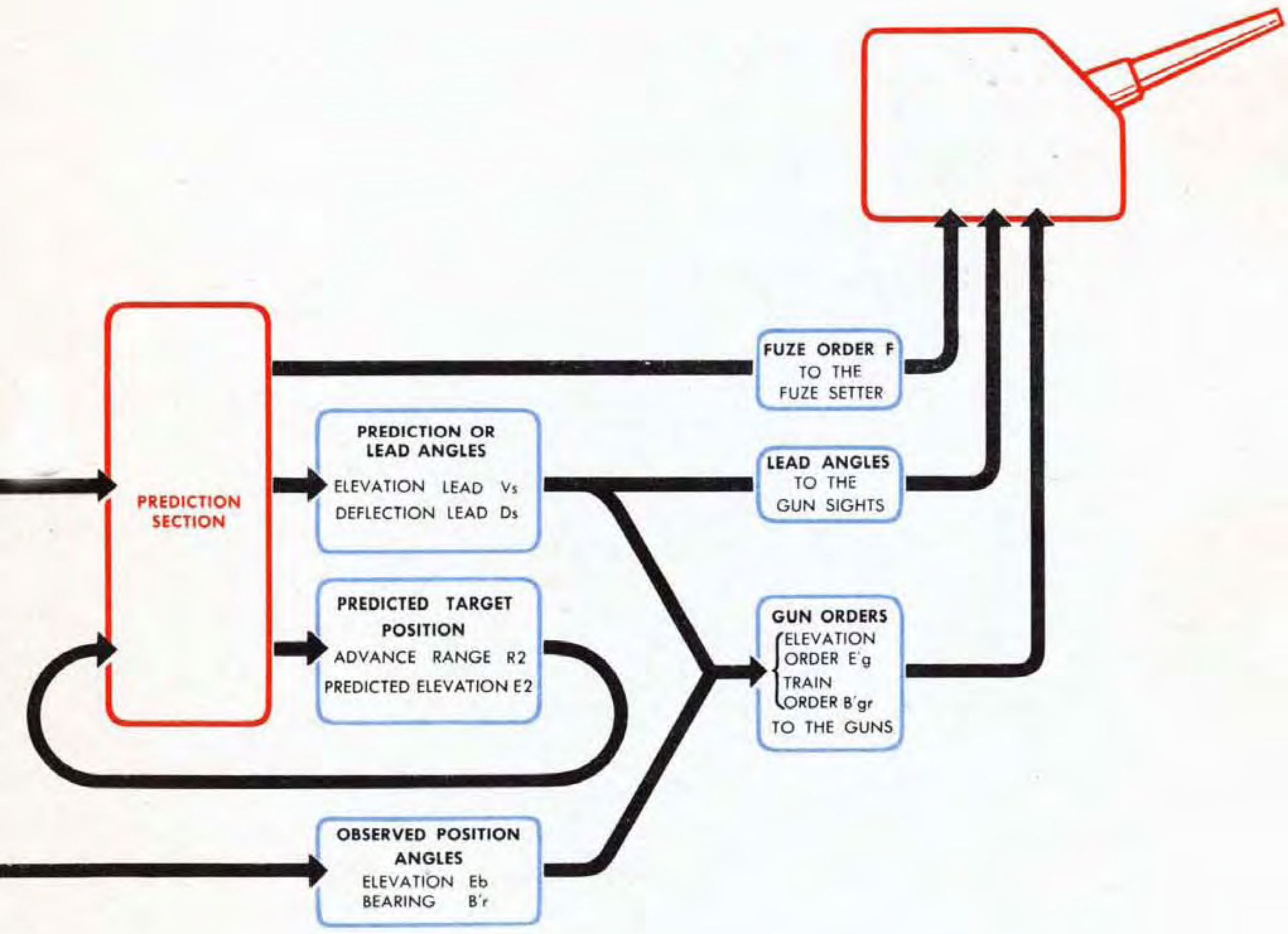


How the sections work together

This schematic shows how the Tracking and Prediction Sections of the Computer are connected to one another and to the Director and guns. Only the sections used in the computation from a horizontal deck are shown in this diagram.



The value of Time of Flight, *Tf*, which is used in these predictions is the time the projectile will take to reach the Predicted Target Position. Advance Range, *R2*, is approximately the Range to the predicted position of the Target. Predicted Elevation, *E2*, is approximately the Elevation to the predicted position of the Target. To compute a value of Time of Flight, *Tf*, both *R2* and *E2* must be used. After *R2* and *E2* have been approximately computed in the Prediction Section, they are used again as INPUTS to this section to compute values of Time of Flight and other ballistic quantities.

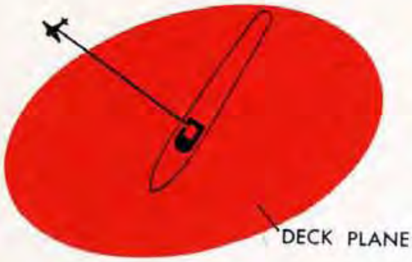


Because they are both outputs from and inputs to the Prediction Section, $R2$ and $E2$ are called *regenerative* quantities.

$R2$ and $E2$ are quantities used only for computations within the Computer. They are not outputs to the guns or the Fuze Setter.

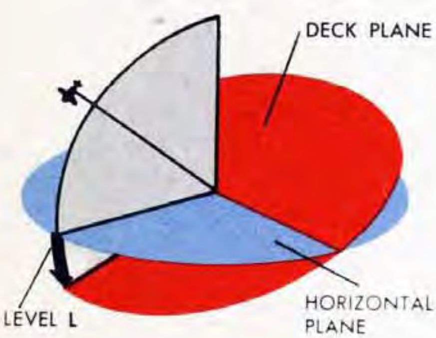
The Fuze Setting Order, F, is computed by a ballistic cam in the Prediction Section and is transmitted electrically to the automatic Fuze Setter Indicator Regulator at the gun mounts. Gun Orders are transmitted electrically to the Indicator Regulators in the mounts. The Lead Angles go to the gun sights.

STABILIZATION

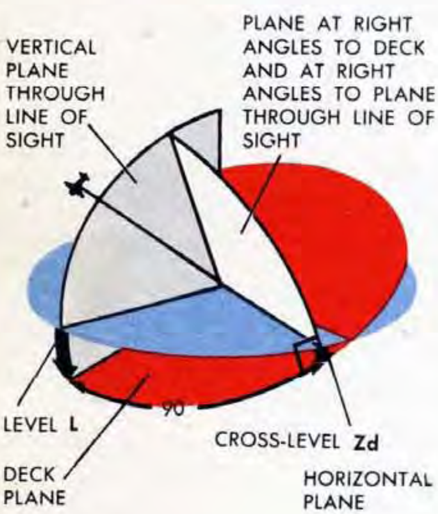


So far the Trunnion Tilt Section and the Deck Tilt and Synchronize Elevation Groups have not entered the discussion because the Ship was assumed to be steady and horizontal. Now they must be fitted into the pattern of Computer Mark 1 computations.

On a pitching and rolling ship there are three main needs for stabilization:



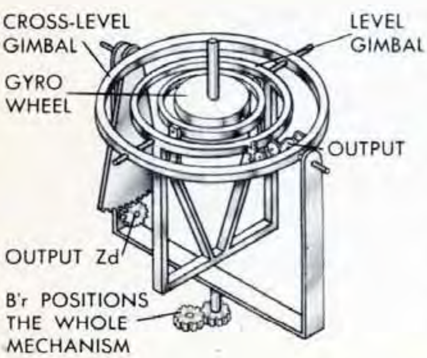
1. The values of Director Elevation and Director Train from the Director must be stabilized, or corrected for the inclination of the deck, before they can be used by the Tracking Section of the Computer. The pitching and rolling of the deck cause the values of Director Elevation and Train to vary, since they are measured from the tilting deck plane. These values have to be referred to the horizontal plane before they can be used for computations, since the Tracking and Prediction Sections of the Computer compute for the horizontal plane.
2. The generated values sent by the Computer to the Director to keep the Director sights on Target must also be corrected to allow for the inclination of the deck.
3. The Gun Orders must include corrections to allow for the tilt of the gun trunnions due to inclination of the deck.



The quantities used in stabilizing are Level, *L*, and Cross-Level, *Zd*. These quantities are the measurements of deck inclination in and at right angles to the plane through the Line of Sight.

Level, *L*, is the angle between the deck and the horizontal plane, measured in the vertical plane through the Line of Sight.

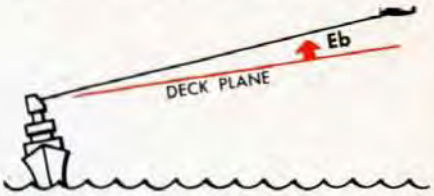
Cross-level, *Zd*, is the angle between the deck plane and the horizontal plane measured in a plane at right angles to the vertical plane through the Line of Sight and at right angles to the deck.



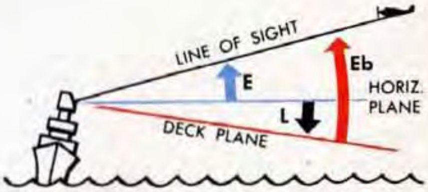
Both Level and Cross-level are measured by the Stable Element. The Stable Element mechanism is positioned by the value of Director Train, *B'r*, from the Computer, so that the Stable Element can always make its measurements in relation to the vertical plane through the Line of Sight.

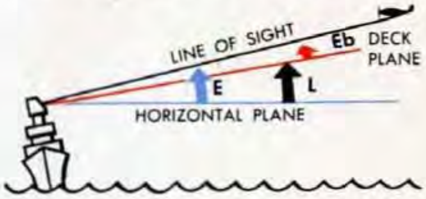
Stabilizing elevation

Since the base of the Director is always parallel to the deck, the whole Director rolls and pitches with the deck, and the measurements made from the Director sights are in or from the deck plane.



Director Elevation, *Eb*, is the elevation of the Line of Sight above the deck. *Eb* is continuously increasing and decreasing as the deck pitches and rolls. For computation, Target Elevation, *E*, above the HORIZONTAL is needed. *E* varies only as the actual elevation of the Target changes. *E* is used in computing Relative Motion Rates, since these rates are computed in relation to the horizontal plane.





To obtain Target Elevation, *E*, the changing value of Level, *L*, is continuously subtracted from Director Elevation, *Eb*. $Eb - L = E$. This subtraction takes place in the Synchronize Elevation Group. *Eb* from the Director and *L* from the Stable Element are the inputs to this group. The output is *E*, which goes to the Relative Motion Group.

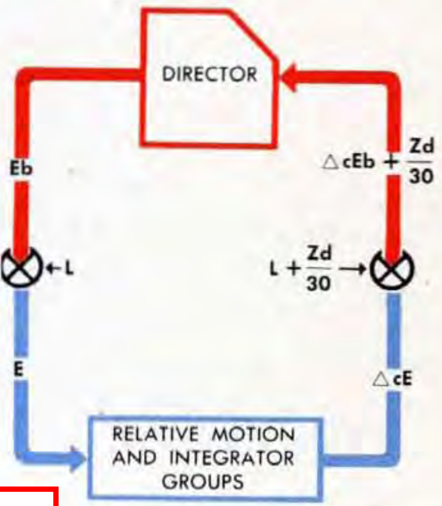
Zd is used to stabilize the Director sights in Cross-level and is always sent directly from the Stable Element to the Director. Therefore, the Director measures *Eb* in the vertical plane through the Line of Sight.

Changes of Target Elevation, $\triangle cE$, are generated by the Integrator Group, using the Linear Elevation Rate, *RdE*, obtained from the Relative Motion Group. $\triangle cE$ positions the Director sights to follow the changing elevation of the Target, but $\triangle cE$ alone cannot keep the sights on Target because of the rolling and pitching of the deck. The value of Level, *L*, which was subtracted from *Eb* to obtain a value of *E* must now be continuously added to $\triangle cE$ to compensate the sights for the motion of the deck. $\triangle cE + L = \triangle cEb$. $\triangle cEb$ is the Generated Changes of Director Elevation.

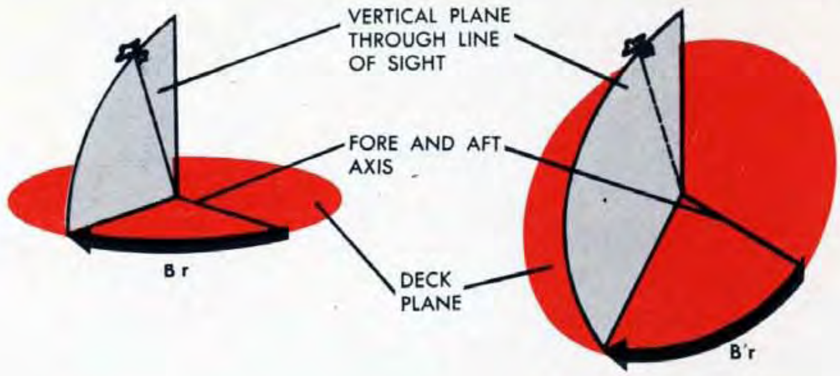
A function of Cross-level, $Zd/30$, is also added. $Zd/30$ permits Cross-level Corrections to be made without affecting Director Elevation.

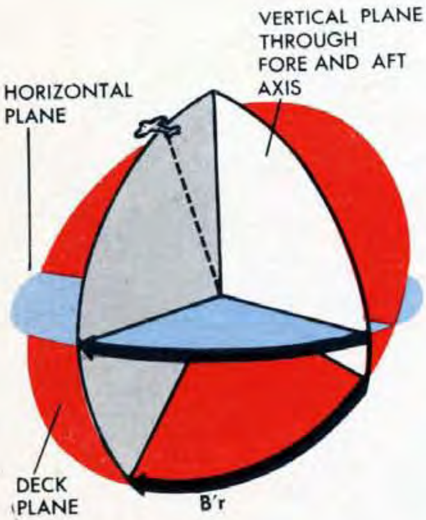
$L + Zd/30$ is usually added to $\triangle cE$ in the Computer and the whole value of $\triangle cEb + Zd/30$ is transmitted to the Director by one transmitter.

In some installations $L + Zd/30$ goes up directly from the Stable Element. $\triangle cE$ goes up alone from the Computer and is added to $L + Zd/30$ in the Director.



Stabilizing relative bearing

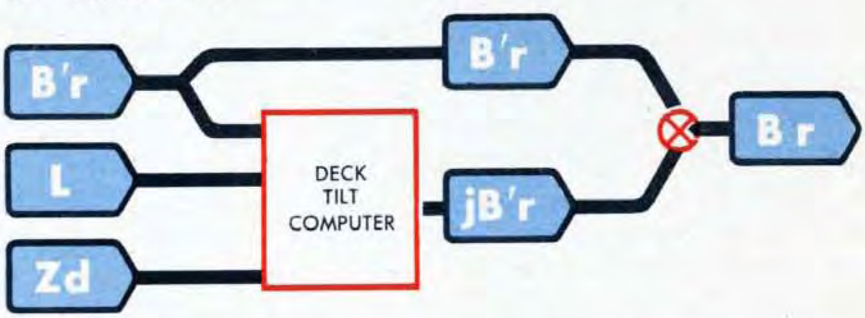


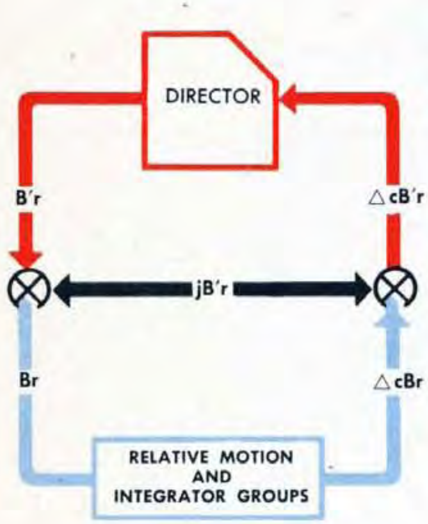


Director Train, $B'r$, is the angle measured in the deck plane from the bow of Own Ship clockwise to the vertical plane of the Line of Sight. When the deck is tilting, the Director must be continuously trained back and forth in order to keep the Line of Sight on the Target. Therefore $B'r$ is continuously increasing and decreasing as the Ship rolls and pitches. This change in $B'r$ due to deck tilt is difficult to visualize. It will be described in detail later in the chapter on Deck Tilt.

For computation in the Tracking Section, the value of Relative Target Bearing in the horizontal plane, Br, is needed. The calculated difference between Br and $B'r$ is a Deck Tilt Correction called $jB'r$. Br is produced by adding $jB'r$ to the measured value of Director Train, $B'r$.

$$B'r + jB'r = Br$$





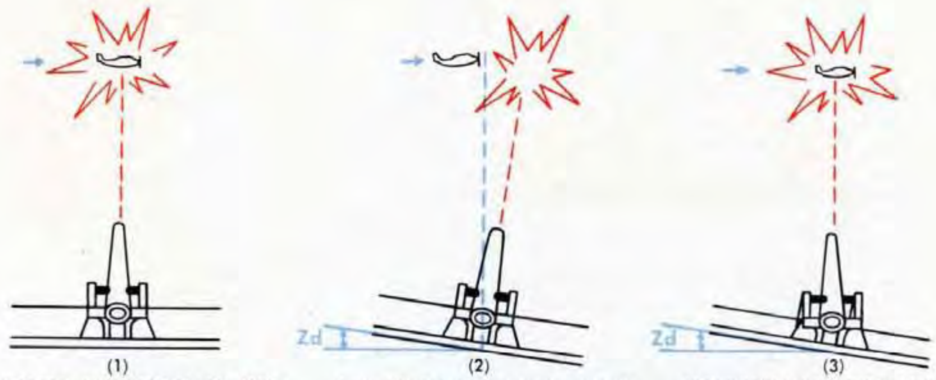
Deck Tilt Correction, $jB'r$, is computed by the Deck Tilt Group. The job of the Deck Tilt Group is to use L, Zd, and $B'r$ to produce this one correction, $jB'r$.

$jB'r$ is also used to convert the Generated Changes of Relative Target Bearing, $\triangle cBr$, computed by the Integrator Group, to Generated Changes of Director Train, $\triangle cB'r$. The Deck Tilt Correction, $jB'r$, is continually subtracted from $\triangle cBr$ to obtain $\triangle cB'r$.

$$\triangle cBr - jB'r = \triangle cB'r$$

$\triangle cB'r$ is the quantity required to keep the Director sights trained on the Target.

Stabilizing the guns



(1)
GUN ORDERS ARE CORRECT SO THAT PROJECTILE BURSTS ON TARGET. GUN TRUNNIONS ARE HORIZONTAL.

(2)
GUN ORDERS HAVE SAME VALUES AS IN (1) BUT TRUNNIONS ARE TILTED. PROJECTILE BURSTS LOW AND TO RIGHT OF TARGET.

(3)
TRUNNIONS ARE TILTED BUT GUN ORDERS ARE CORRECTED BY TRUNNION TILT CORRECTIONS. PROJECTILE BURSTS ON TARGET.

To prevent the guns being thrown off Target by the pitch and roll of the deck, continuous corrections are made to the Gun Orders, in Elevation and in Train.

These corrections are included in the two outputs from the Trunnion Tilt Section, *Vz* and *Dd*.

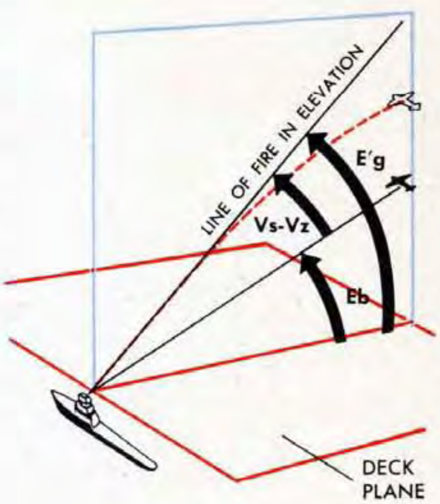
Vz is a correction to gun elevation to offset the tilting of the trunnions. *Vz* is subtracted from Director Elevation, *Eb*, plus Sight Angle, *Vs*, to give Gun Elevation Order, *E'g*.

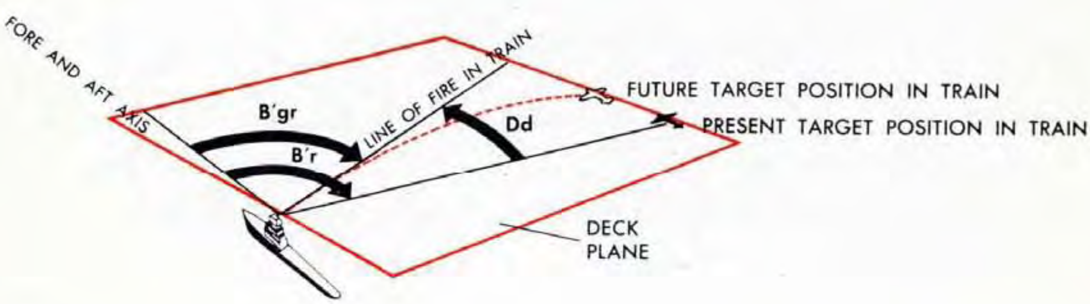
$Eb + Vs - Vz = E'g$

Dd is different from *Vz*. Instead of just correcting the Gun Train Order for Trunnion Tilt, *Dd* includes the whole Deflection Prediction, *Ds*, brought down to the deck plane, plus a train correction for Trunnion Tilt. *Dd* is the total deflection in the deck plane.

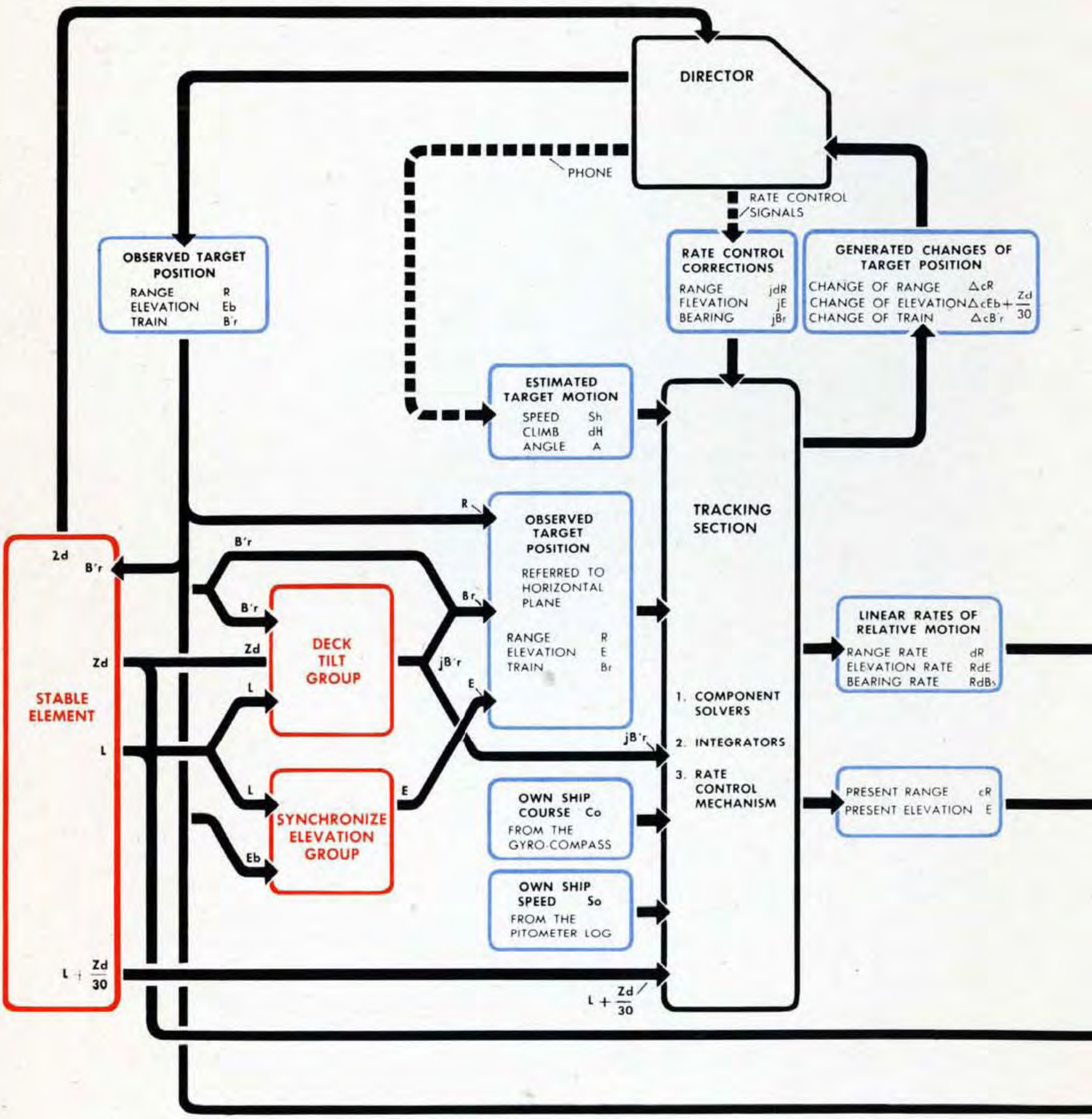
Dd is added directly to Director Train, *B'r*, to obtain Gun Train Order, *B'gr*.

$B'r + Dd = B'gr$

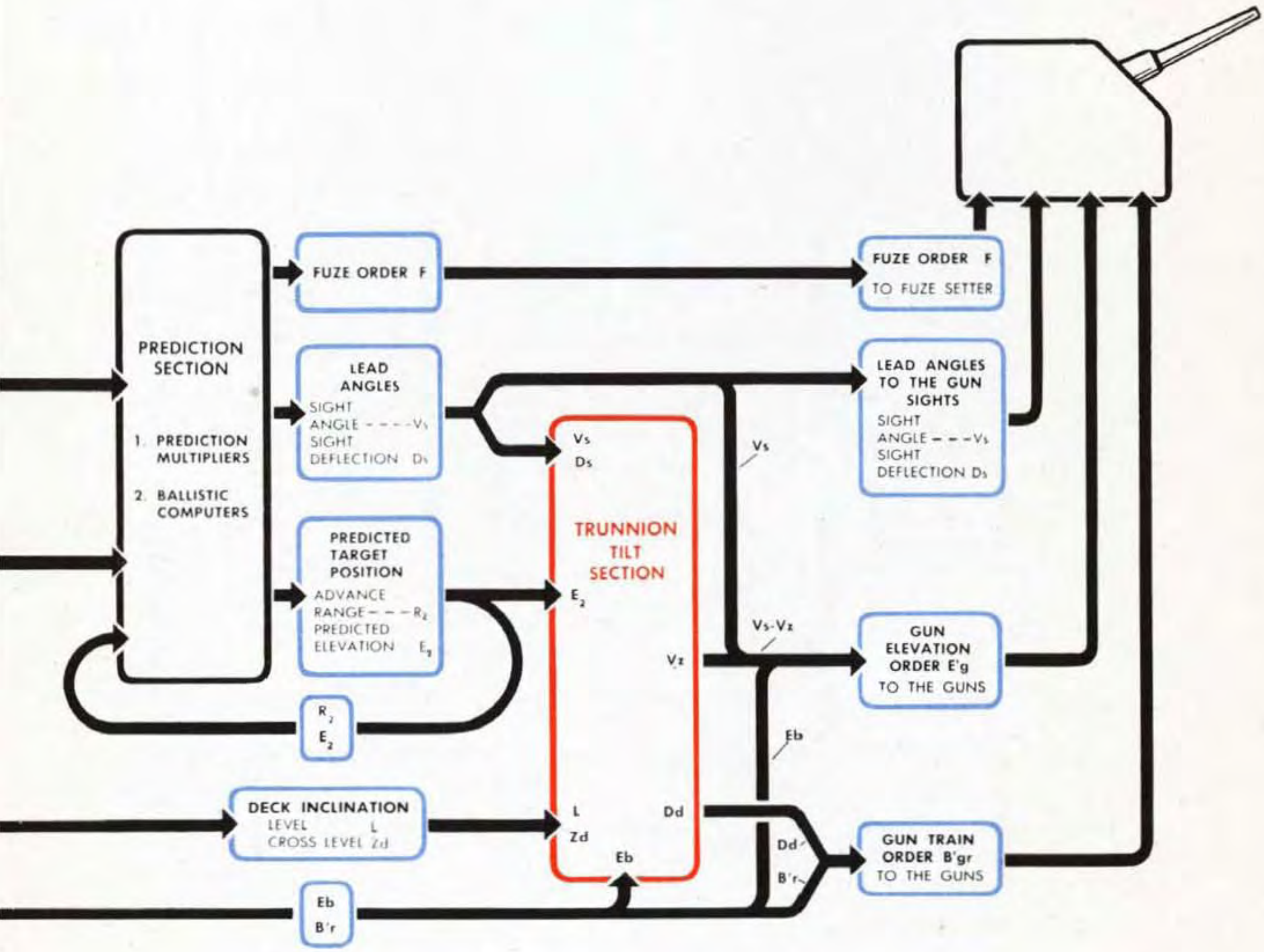




This schematic shows how the stabilizing sections



are connected with the other sections



The tracking cycle for a tilting deck

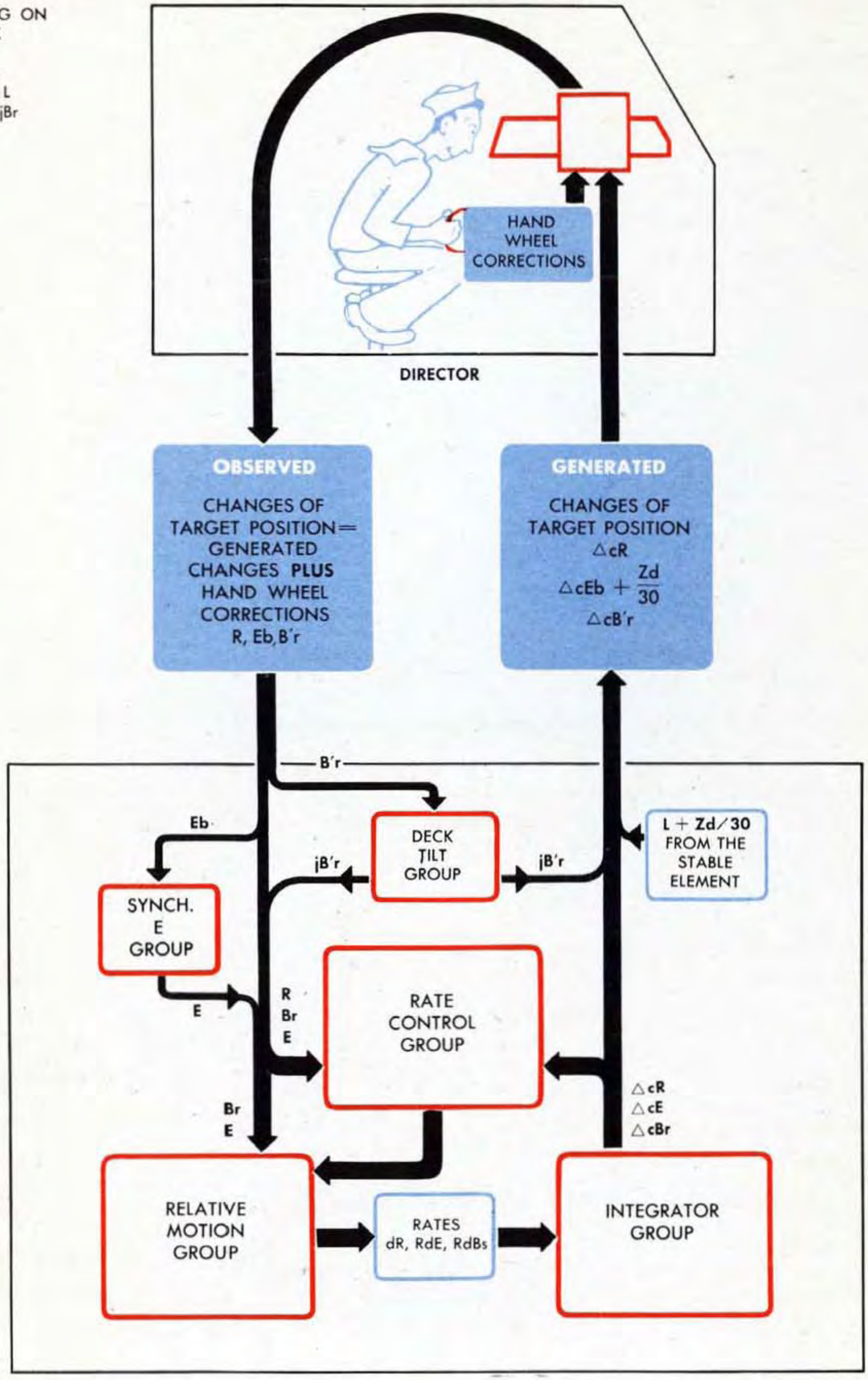
WHEN TRACKING ON A TILTING DECK

$Eb = E + L$

$B'r = Br - jB'r$

$\Delta cEb = \Delta cE + L$

$\Delta cB'r = \Delta cBr - jBr$

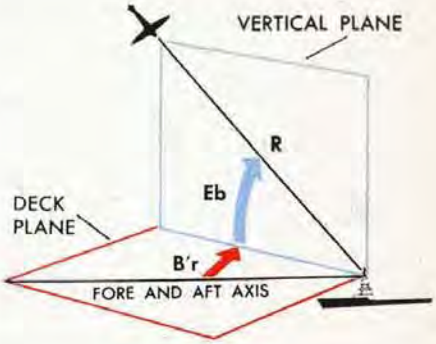


A MORE DETAILED ACCOUNT OF TRACKING, PREDICTION, AND STABILIZATION

In the simplified account of tracking, prediction, and stabilization, the mechanisms were handled in groups and only the quantities comprising the inputs and outputs of the sections and groups were discussed.

In the more detailed account which follows, each mechanism is shown separately and most of the intermediate quantities computed inside the sections are introduced.

The quantities not covered in this account are included in the Detailed Description of the Computer Mark 1 in Part 3 of this OP.



The inputs to the tracking section

When a target is sighted, the Director Crew puts the telescopes and Range Finder on it, and the values of Range, *R*, Director Train in the deck plane, *B'r*, and Director Elevation above the deck plane, *Eb*, are transmitted automatically to the Computer.

Observed Range, *R*, goes to the Range Receiver in the Rate Control Group and will be discussed later.

Director Train, *B'r*, is transmitted to the *B'r* Receiver in the Computer. Director Train is needed in the Relative Motion Group, but first it must be converted to the horizontal plane. *B'r* therefore goes from the *B'r* Receiver to the Deck Tilt Group.

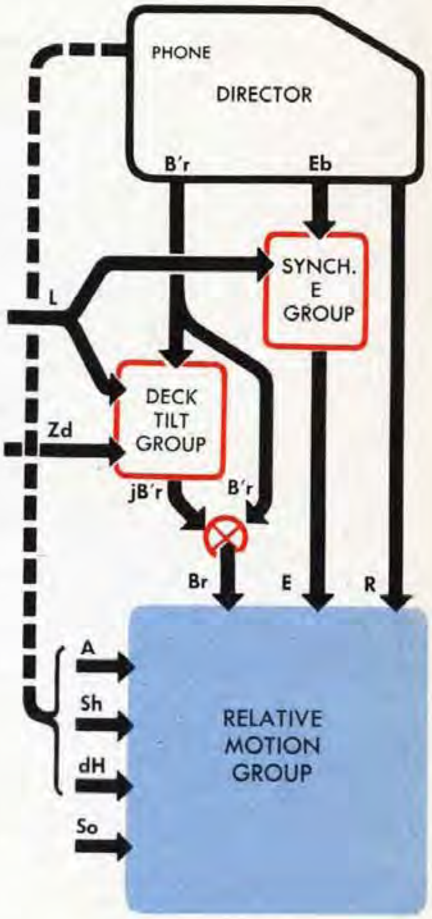
In the Deck Tilt Group, *B'r*, *L*, and *Zd* are used to compute the Deck Tilt Correction, *jB'r*. The Deck Tilt Group consists of a component solver and two multipliers. These three mechanisms are needed to produce the one output, *jB'r*, which is added to *B'r* to obtain *Br*, Relative Target Bearing in the horizontal plane.

Br then goes to the Relative Motion Group.

Eb from the Director goes to the *Eb* Receiver in the Computer, and from there to the Synchronize Elevation Group, where *L* is subtracted from *Eb*, giving *E*. The Synchronize Elevation Group, which consists of an arrangement of differentials and brakes, sends the value *E* to the Relative Motion Group, and also to other sections of the Computer.

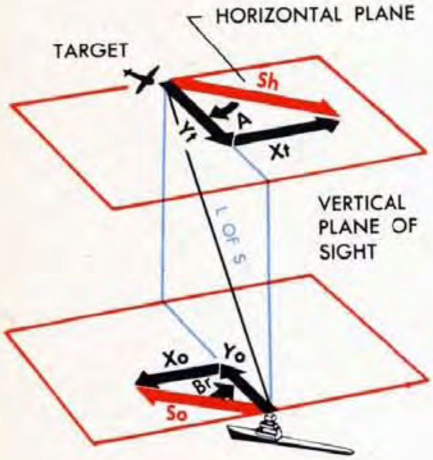
The values of Target Speed, *Sh*, Target Course, *Ct*, and Rate of Climb, *dH*, are estimated by the Control Officer in the Director, phoned down to the plotting room and cranked into the Relative Motion Group as *Sh*, *A*, and *dH*.

The remaining inputs to the Tracking Section are Ship Speed, *So*, and Ship Course, *Co*. *So* is transmitted electrically from the Pitometer Log to the *So* Receiver in the Relative Motion Group. *Co* is transmitted electrically from the Gyro Compass to the *Co* Receiver.



Computing RELATIVE MOTION rates

The Relative Motion Group contains a bank of four component solvers.

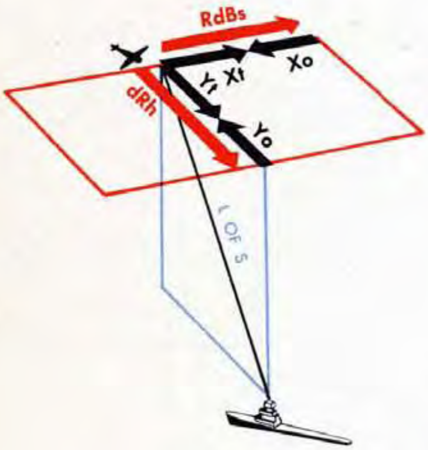


The Ship Component Solver takes Ship Speed, *So*, and Relative Bearing, *Br*, and computes the horizontal components of Ship Motion in and at right angles to the plane of sight.

The components are called *Xo* and *Yo*.

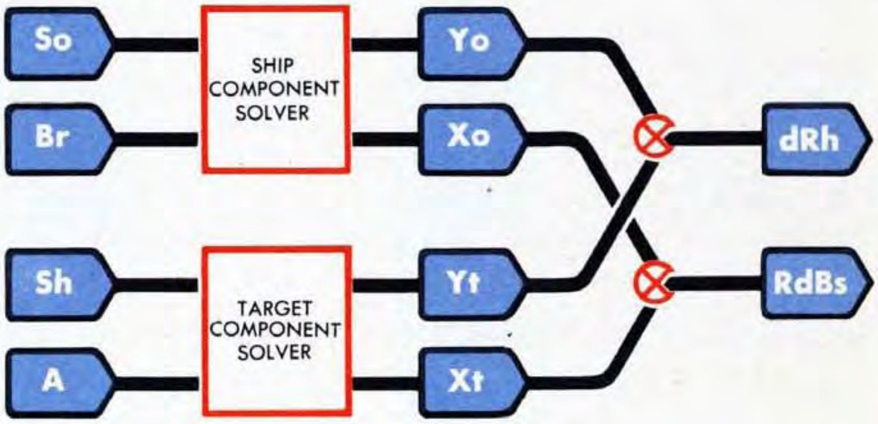
The Target Component Solver breaks down Target Speed, *Sh*, using Target Angle, *A*.

The Target Motion components are called *Xt* and *Yt*.



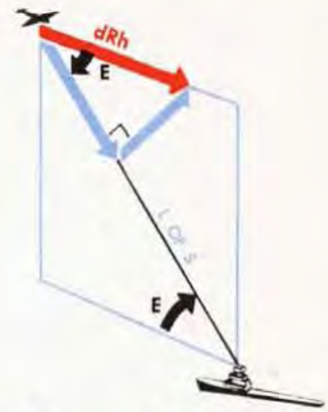
The Component of Ship Motion, *Yo*, is added to the Component of Target Motion, *Yt*, to give the linear Horizontal Range Rate, *dRh*. *dRh* is the combined motion of Ship and Target along a horizontal projection of the Line of Sight.

The two horizontal components, *Xo* and *Xt*, at right angles to the vertical plane through the Line of Sight are added to give total linear Deflection Rate, *RdBs*.

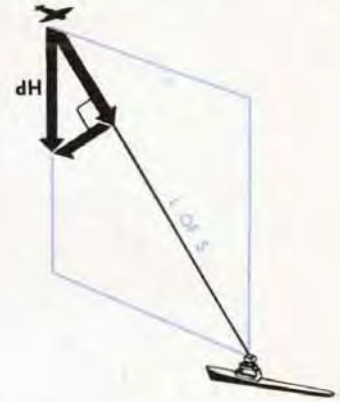


Direct Range Rate, *dR*, and Linear Elevation Rate, *RdE*, are computed from components of Horizontal Range Rate, *dRh*, and Rate of Climb, *dH*.

dRh and Target Elevation, *E*, go into the *dRh* Component Solver. The outputs of this solver are the components of *dRh* along and at right angles to the Line of Sight in the vertical plane through the Line of Sight.

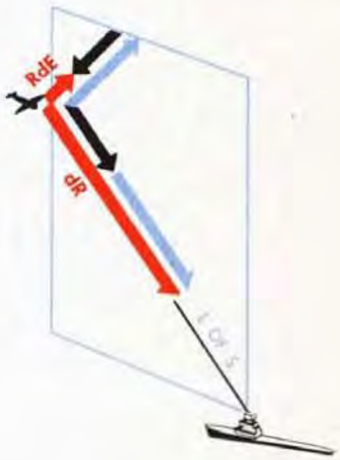


The *dH* Component Solver breaks up *dH* and angle *E* into components, also along and at right angles to the Line of Sight in the vertical plane through the Line of Sight.

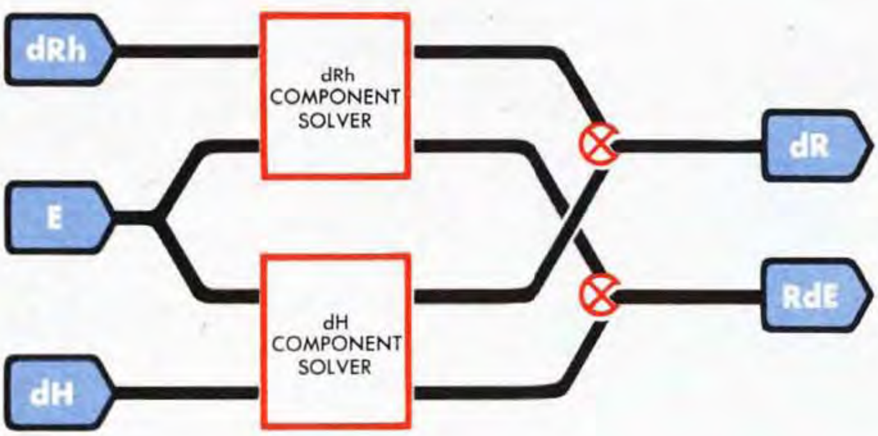


The components from each of these solvers lying along the Line of Sight are then added to give Direct Range Rate, *dR*. Direct Range Rate, *dR*, is the rate at which the Ship and Target are approaching or going apart from each other along the Line of Sight. It is the rate at which the Range is changing.

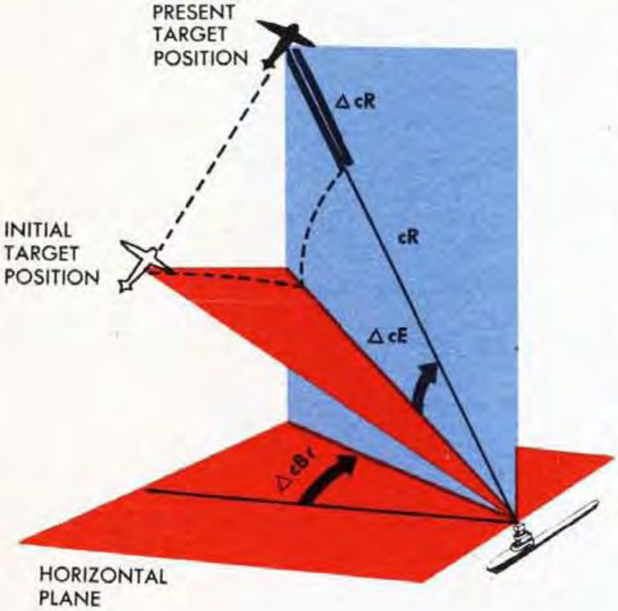
The two components at right angles to the Line of Sight make up Linear Elevation Rate, *RdE*, the combined Ship and Target speed at right angles to the Line of Sight in the vertical plane.



The Relative Motion Group computes these three Relative Motion Rates: *dR*, *RdE*, and *RdBs*.



THE INTEGRATOR GROUP



The Integrator Group has the job of generating continuous changes of Target Position. It computes Generated Changes of Range, $\triangle cR$, to drive the Generated Range Dials in the Computer and the Range Finder in the Director.

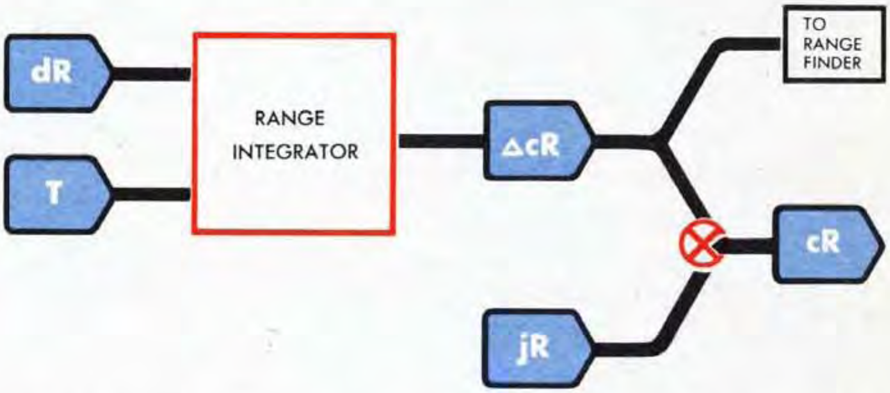
To drive the Generated Elevation and Bearing Dials the Integrator Group computes the Generated Changes of Target Elevation, $\triangle cE$, and Generated Changes of Relative Target Bearing, $\triangle cBr$.

To position the Director sights the Group also computes Generated Changes of Director Elevation, $\triangle cEb + Zd/30$, and Generated Changes of Director Train, $\triangle cB'r$.

The Integrator Group contains five disk integrators and two computing cam units.

Generating changes of range

The calculation of Range changes is fairly simple and is explained in detail in OP 1140.



The Range Integrator continuously multiplies the Range Rate, dR, by Time, T, to produce a continuous flow of increases or decreases in Range during the periods of Time, T. These changes in Range, $\triangle cR$, are continuously added to the Initial Range Setting, jR, to produce the Present Generated Range, cR, at any moment.

$\triangle cR$ positions the Range Finder in the Director.

Generating changes of elevation

Generating changes of Elevation and Bearing is a little more complicated than generating changes of Range, because the changes of Elevation and Bearing are ANGULAR changes. They are the changes that the sights must make in Elevation and Train to stay on the Target.

The Generated Changes of Elevation, $\triangle cE$, are calculated as follows:

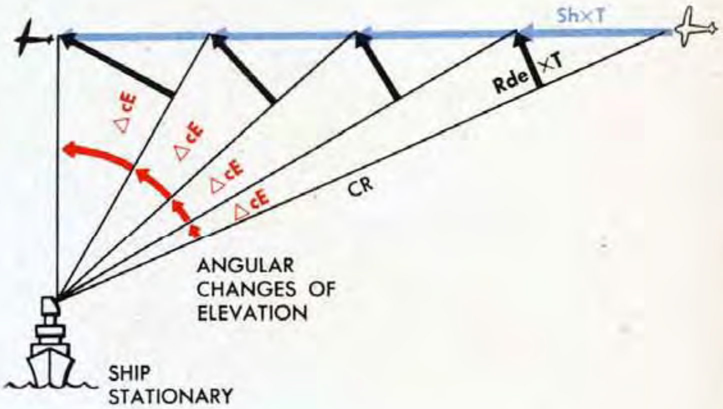
Elevation Rate, *RdE*, multiplied by Time, *T*, gives the linear Elevation change during the Time, *T*. $RdE \times T$ divided by the Range, *cR*, gives angular change in Elevation in radians.

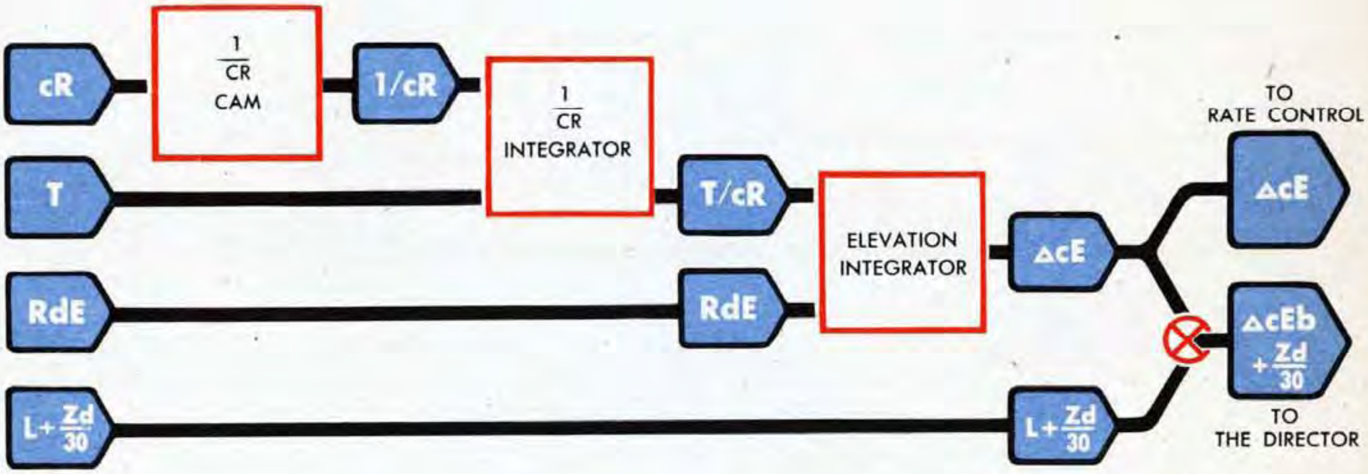
The Generated Angular Elevation Change, $\triangle cE$, is therefore computed for each successive instant of Time as $RdE \times T/cR$

$\triangle cE$ is computed in three mechanisms.

A reciprocal cam computes continuous values of $1/cR$. The changing values of $1/cR$ are multiplied by Time, *T*, in the $1/cR$ Integrator to give continuous values of T/cR. Then the values of T/cR are multiplied by the Elevation Rate, *RdE*, in the Elevation Integrator, to give continuous values of $RdE \times T/cR$, which are the Generated Changes of Elevation, $\triangle cE$.

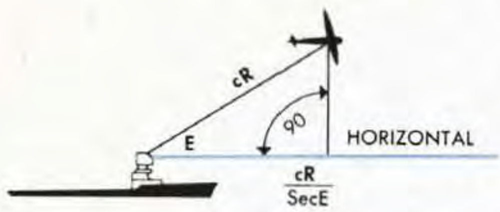
$\triangle cE$ continuously positions the Generated Elevation Dials in the Rate Control Group.



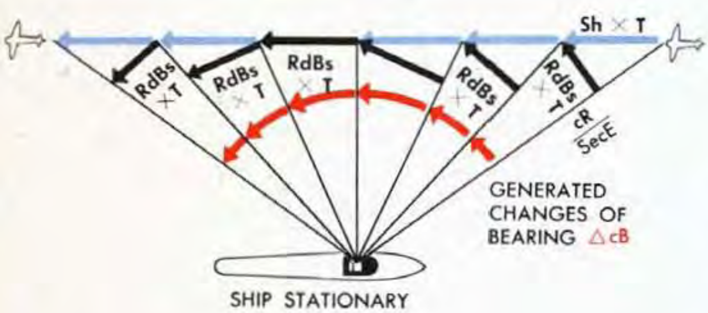


$L + Zd/30$ is added to $\triangle cE$, giving $\triangle cEb + Zd/30$. $\triangle cEb + Zd/30$ is continuously transmitted to the Director sights. The value of *L* compensates the sights for the effect of Level. The value $Zd/30$ permits Cross-level Corrections to be made at the Director without affecting Director Elevation.

Generating changes of director train



Computing the Generated Changes of Director Train requires more mechanisms than computing Generated Changes of Elevation. These Director Train increments must not only be ANGULAR increments but they must also be converted to the deck plane. Since the Director trains in the deck plane, Generated Changes of True Bearing in the horizontal plane, $\triangle cB$, are computed and then converted, first to Generated Changes of Relative Bearing, $\triangle cBr$, and then to Generated Changes of Director Train, $\triangle cB'r$.

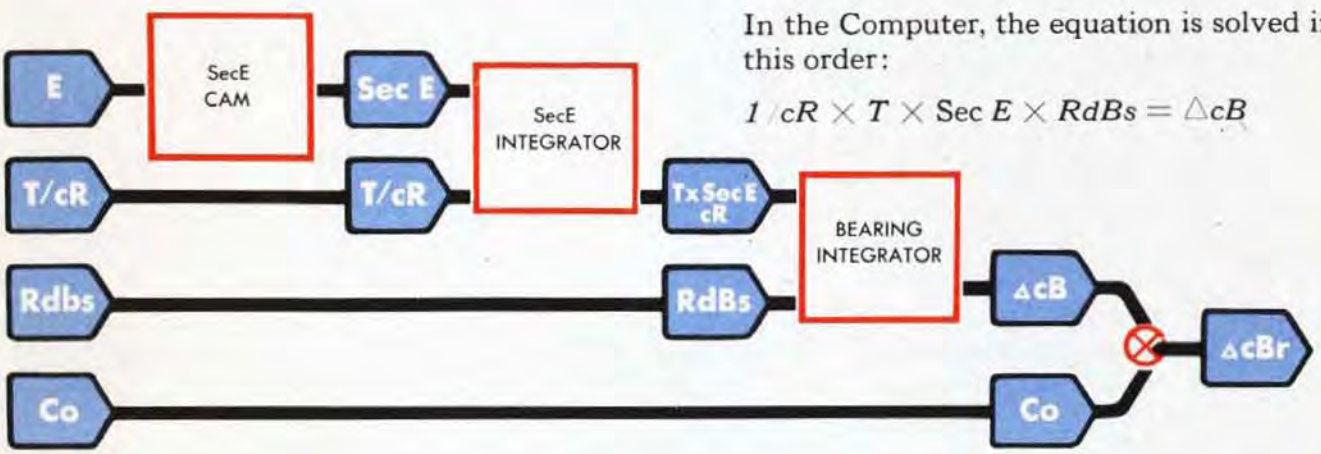


The Generated Angular Changes of True Bearing in the horizontal plane, $\triangle cB$, are computed like $\triangle cE$ except that $cR/\text{Sec } E$ is used instead of cR. This is necessary to convert from the slant plane of the Line of Sight to the horizontal plane.

$$\triangle cB = \frac{RdBs \times T}{\text{Horizontal Range}} = \frac{RdBs \times T}{cR/\text{Sec } E} = \frac{RdBs \times T \times \text{Sec } E}{cR}$$

In the Computer, the equation is solved in this order:

$$1/cR \times T \times \text{Sec } E \times RdBs = \triangle cB$$

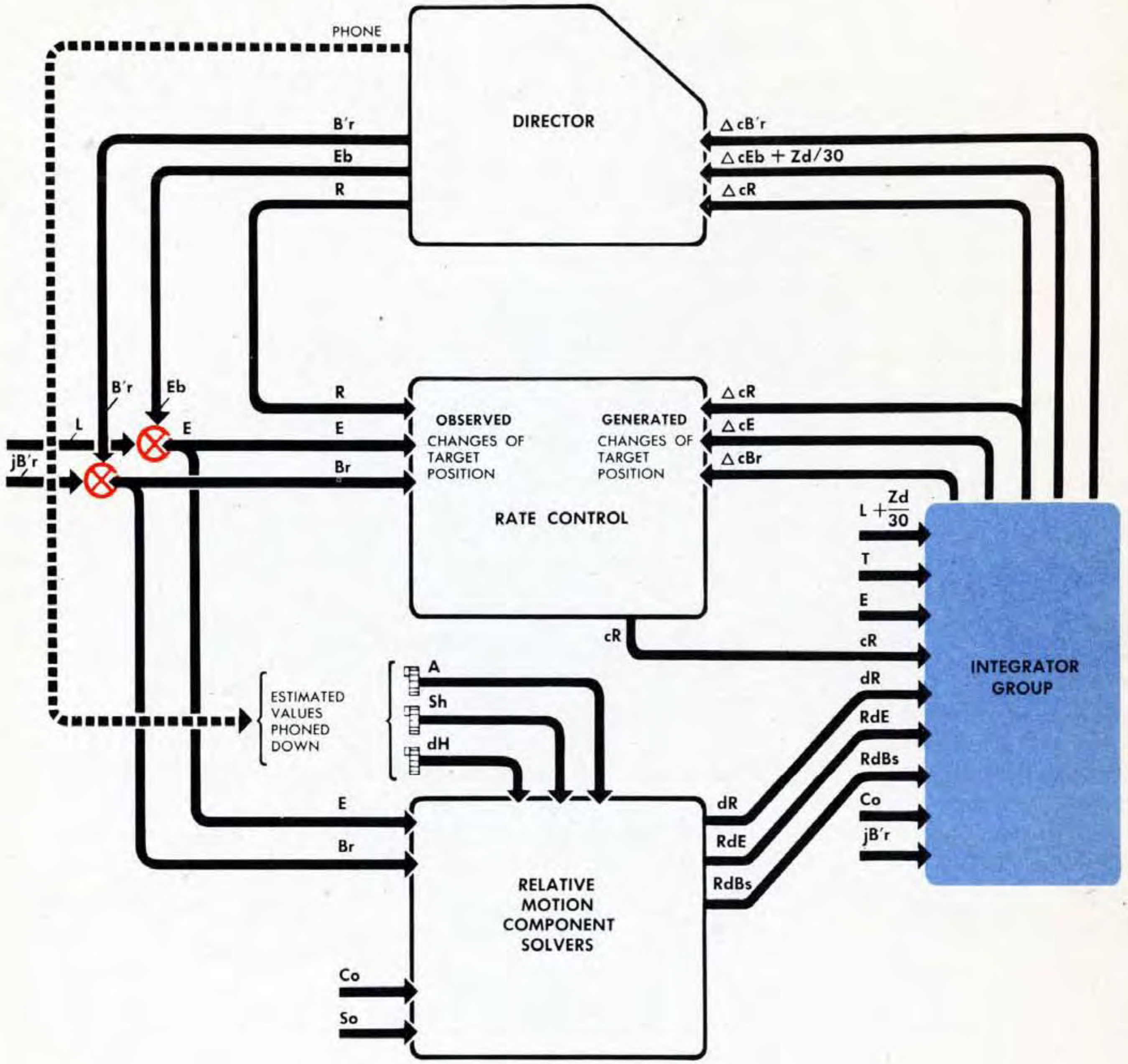


Own Ship Course, Co, is subtracted from $\triangle cB$ to take out the effect of a change in Own Ship Course. The new quantity obtained is the Generated Changes of Relative Bearing in the horizontal plane, $\triangle cBr$.

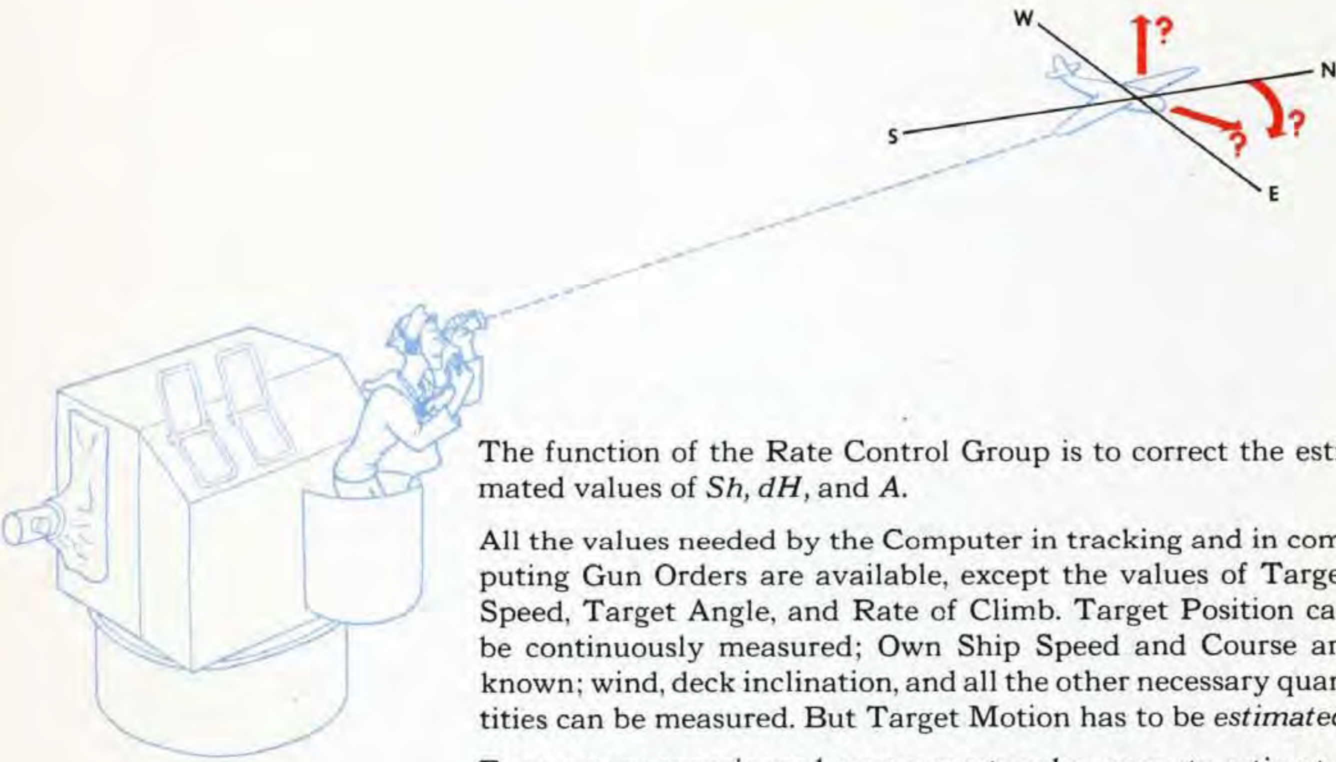
$$\triangle cB - Co = \triangle cBr$$

Deck Tilt Correction, $jB'r$, is subtracted from $\triangle cBr$ to correct it for the effect of deck inclination. The new quantity is the Generated Changes of Director Train, $\triangle cB'r$. $\triangle cB'r$ keeps the Director sights on Target in train regardless of changes in Own Ship Course and deck inclination.

Here are all the inputs and outputs of the integrator group



The RATE CONTROL GROUP



The function of the Rate Control Group is to correct the estimated values of *Sh, dH,* and *A*.

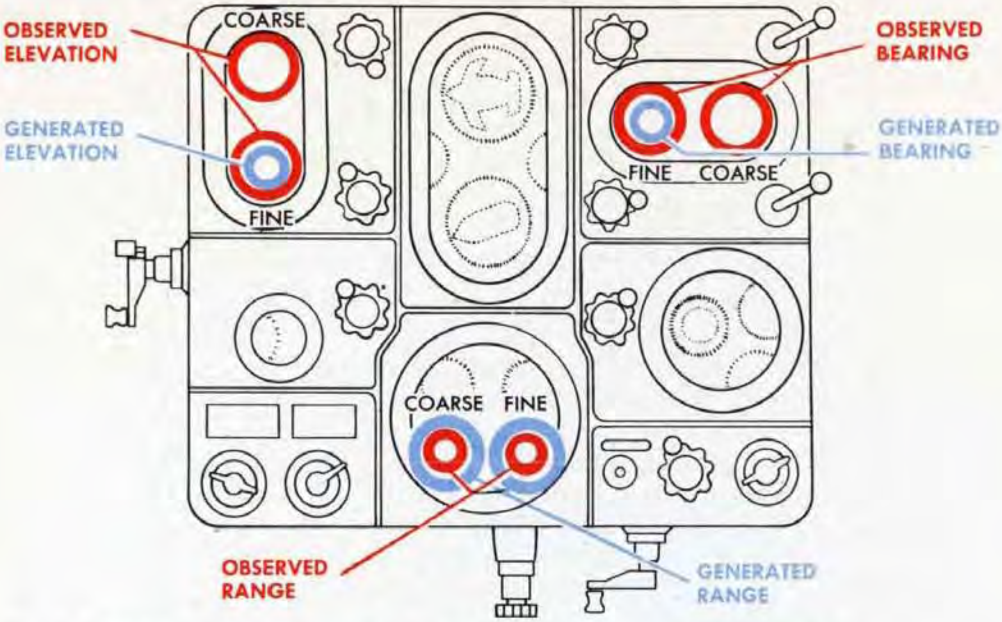
All the values needed by the Computer in tracking and in computing Gun Orders are available, except the values of Target Speed, Target Angle, and Rate of Climb. Target Position can be continuously measured; Own Ship Speed and Course are known; wind, deck inclination, and all the other necessary quantities can be measured. But Target Motion has to be *estimated*.

Even a very experienced man cannot make accurate estimates at long ranges, and the estimates, therefore, always have to be checked and corrected.

The Relative Motion Rates are computed from known values of Own Ship Motion, known values of Target Position, and *estimates* of Target Motion. When the Target Motion estimates are correct, the Relative Motion *Rates* will also be correct. The process of correcting Target Speed, Target Angle and Rate of Climb is therefore called "*Rate Control*."

The method of correcting the Target Motion estimates is this: First the Relative Motion Group computes Relative Motion Rates based on the estimates. Then the Integrator Group uses these rates to generate continuous changes of Target Position. These generated changes are compared with observed changes, and the differences between generated and observed changes are used to correct the estimates.

The job of the Rate Control Computing Mechanism is to analyze the differences between Observed Range and Generated Range, between Observed Elevation and Generated Elevation, and between Observed Target Bearing and Generated Target Bearing, to determine what errors in Target Speed, *Sh*, Target Angle, *A*, and Rate of Climb, *dH*, were responsible for the differences, and to correct these errors.



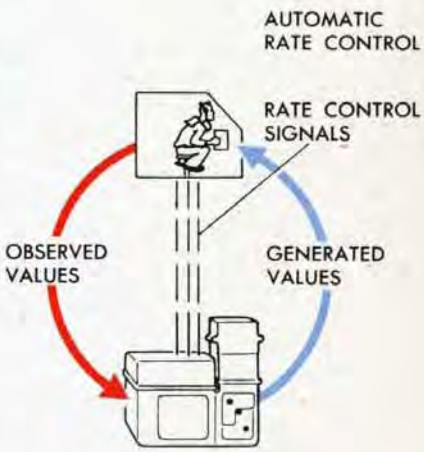
Both GENERATED and OBSERVED changes of Range, Bearing and Elevation show on dials on the top front section of the Computer Mark 1.

In Elevation and Bearing, the outer dials, fine and coarse, are positioned by the observed quantities in the horizontal plane, *E* and *Br*. The inner fine dials are positioned by the generated values, $\triangle cE$ and $\triangle cBr$.

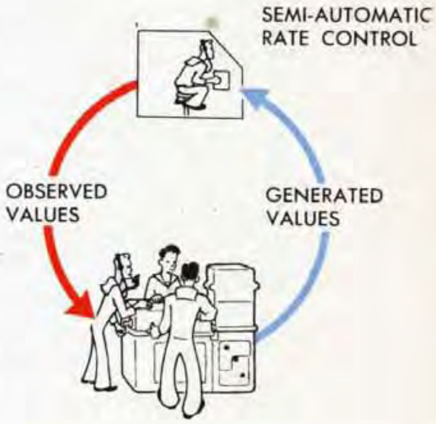
In Range the dials are arranged in the opposite way. The INNER dials are positioned by Observed Range, *R*, the outer dials by Generated Range, *cR*.

The Rate Control Group consists of the Range, Elevation, and Bearing Dials, a system of locks, clutches, and follow-ups, and the Rate Control Computing Mechanism. The Rate Control Computing Mechanism consists of four component integrators and a vector solver.

There are several ways of rate-controlling. The two methods which make use of the Rate Control Computing Mechanism are Automatic and Semi-automatic Rate Control.



In Automatic Rate Control, corrections are put into the Rate Control Computing Mechanism automatically on signals from the Director.



In Semi-automatic Rate Control, corrections are put into the Rate Control Computing Mechanism by handcranks at the Computer.

AUTOMATIC and SEMI-AUTOMATIC RATE CONTROL

Since Elevation and Bearing Rate Control are identical, and Range Rate Control is similar to these two, an error in just ONE of these quantities will serve to show how a Rate Control correction is put into the Rate Control Computing Mechanism.

Suppose the sights begin to move off in elevation. The Pointer turns his handwheels to bring them on. By turning his handwheels, he changes the value of Observed Elevation, *E*, in the Computer. The introduction of this change throws the Observed and Generated Dials out of synchronism.

What happens after this depends on the type of operation being used.

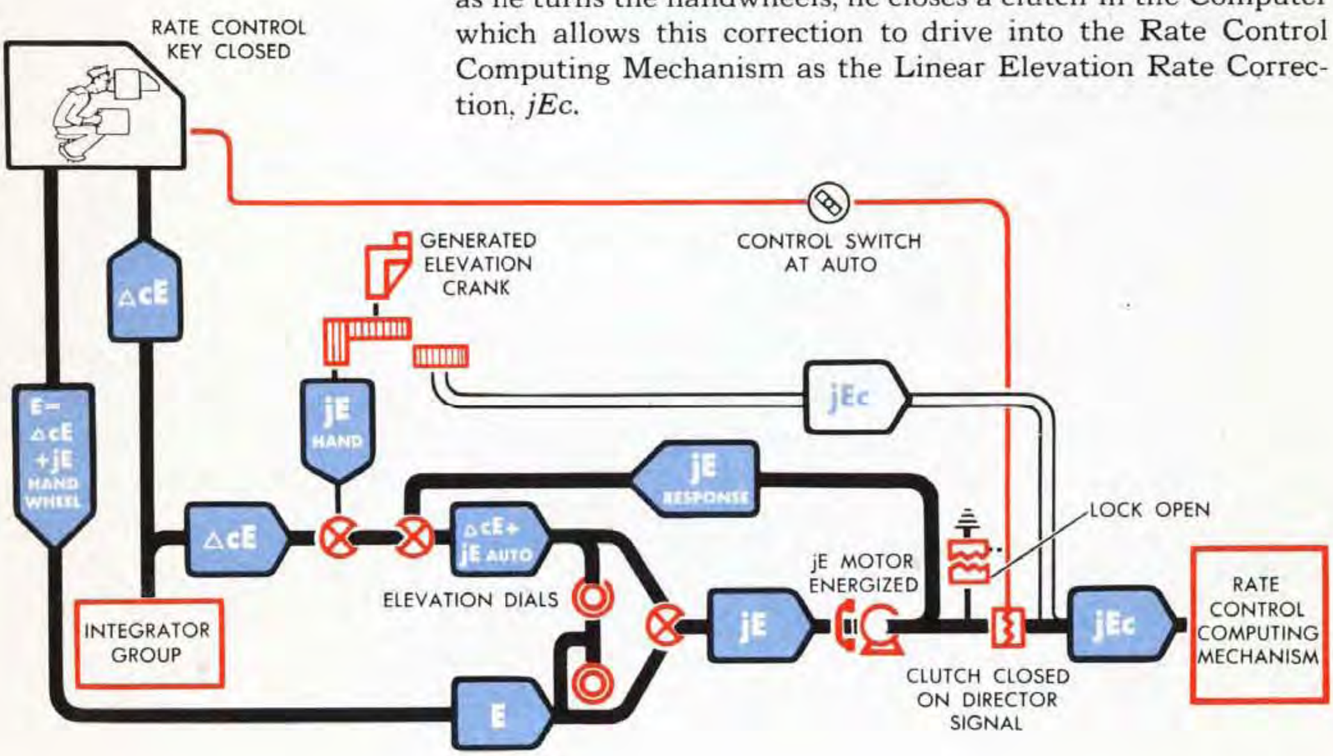
In Automatic Operation, the Generated and Observed Changes of Elevation are continuously fed into a differential which compares them.

As long as the Generated Changes equal the Observed Changes, the output of the differential is at zero.

When the Pointer turns his handwheels, making a change in Observed Elevation, the two sides of the differential no longer match. The difference between the two sides, *jE*, controls a follow-up motor which drives the Generated Elevation line until it matches the value on the Observed Elevation line.

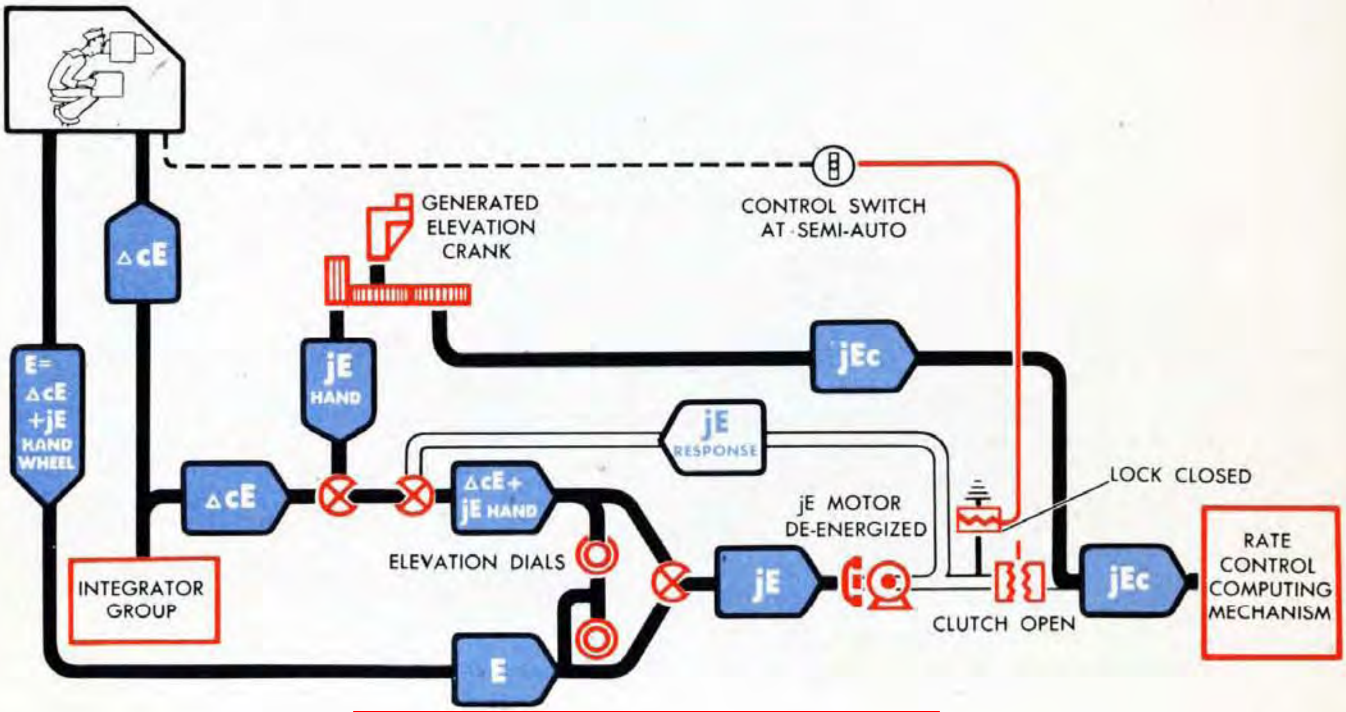
The amount the follow-up drives represents the Angular Correction in Elevation, *jE*.

If the Pointer in the Director has his Rate Control Key closed as he turns the handwheels, he closes a clutch in the Computer which allows this correction to drive into the Rate Control Computing Mechanism as the Linear Elevation Rate Correction, *jEc*.



In Semi-automatic Operation, the Pointer in the Director does not control the Elevation Rate Correction input line to the Rate Control Computing Mechanism. This line is controlled by the Elevation Operator at the Computer. The Elevation Operator watches the Elevation Dials, and as soon as he sees that the Generated Elevation Dial is turning faster or slower than the Observed Elevation Dial, he turns the Generated Elevation Crank in its IN position until the dials turn together. By turning the crank in the IN position he is not only matching the Elevation Dials but is also putting Elevation Rate Correction, *jEc*, into the Rate Control Computing Mechanism.

NOTE: In describing Rate Control, the quantities coming from and going to the Director have been referred to the horizontal plane. The stabilizing quantities, *L* and *Zd/30*, have been omitted.



Putting in range rate control corrections

Deflection Rate Control Corrections are put into the Rate Control Computing Mechanism in exactly the same way as Elevation Rate Control Corrections.

Range Rate Control Corrections are put in a little differently. All Elevation and Bearing lines in the Computer are driven by OBSERVED Elevation and Bearing, but the Range lines in the Computer are driven by GENERATED Range. The reason for this is that while Elevation and Bearing can be measured continuously, the Range Finder can only be focused intermittently. Generated Range is therefore a more smoothly and continuously changing quantity than Observed Range.

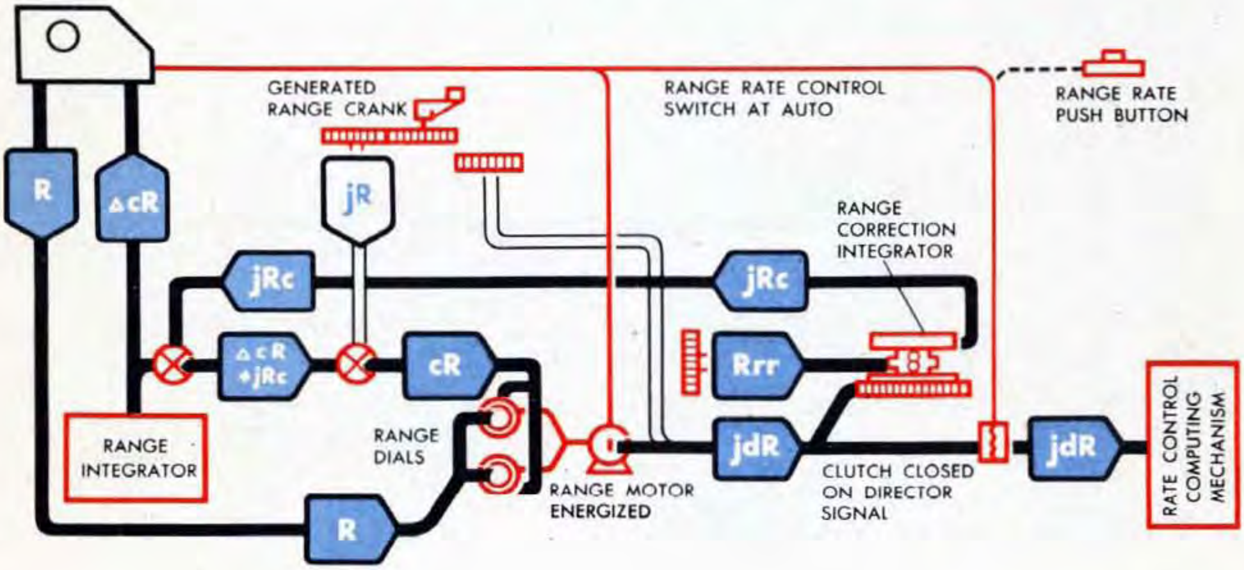
Because it positions all the Range lines, *cR* has to be very accurate. Generated Elevation and Bearing must change at the same rates as Observed Elevation and Bearing. *cR* must not only change at the same rate as *R, but also must be exactly equal to R whenever R is correct.*

When Generated Range, *cR*, changes at a different rate from Observed Range, *R*, Range Rate Control is needed.

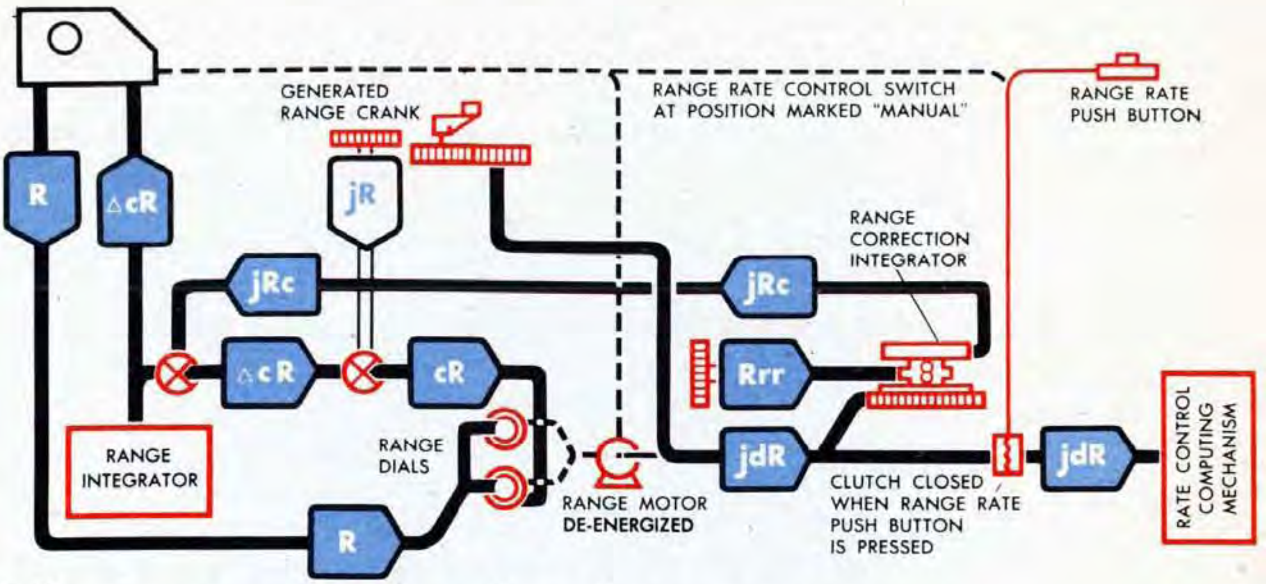
Range Rate Corrections going into the Rate Control Computing Mechanism are controlled through a mechanism called the Range Correction Integrator.

In Automatic Operation, *R* and *cR* are compared at the Range Dials. A special contact arrangement between the dials controls a motor which drives the difference between *R* and *cR* through the Range Correction Integrator into the *cR* line whenever the Signal Key in the Director is closed. This linear correction to *cR* is called *jRc*.

On the same signal from the Range Operator in the Director, a value proportional to the difference between *R* and *cR* is also driven through a clutch into the Rate Control Computing Mechanism, as Range Rate Correction, *jdR*.



In Semi-automatic Operation both the Linear Range Correction, *jRc*, and the Range Rate Correction, *jdR*, are put in manually by the Generated Range Crank in its IN position. The clutch through which *jdR* goes to the Rate Control Computing Mechanism is controlled by the Range Rate Manual Pushbutton.



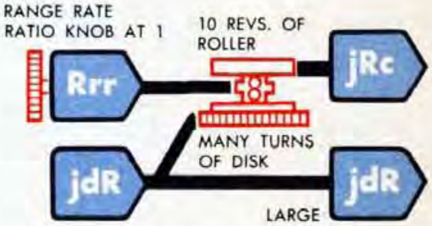
The range correction integrator

The function of the Range Correction Integrator is to control the amount of Range Rate Correction going into the Rate Control Computing Mechanism for any given amount of linear Range Correction.

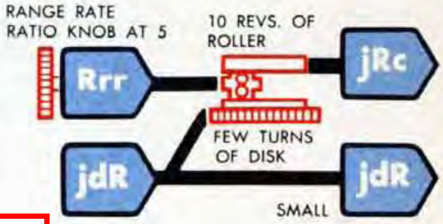
The disk of the Range Rate Integrator is turned by Range Rate Correction, *jdR*. The carriage is positioned directly by the Range Rate Ratio Knob on the front of the Computer. The roller drives Linear Range Correction, *jRc*, into the Generated Range Line.

The Range Rate Ratio Knob has a drum numbered from 1 to 5. The setting of this knob determines the amount of Range Rate Correction introduced for each linear correction to Generated Range.

Suppose Generated Range needs a correction *jRc* which requires ten turns of the integrator roller. If the Range Rate Ratio Knob is at 1, a relatively large Range Rate Correction, *jdR*, goes into the Rate Control Computing Mechanism for each Range Correction, *jRc*, because the integrator carriage is positioned near the center of the disk. With the carriage near the center, relatively many turns of the disk are needed to turn the roller ten revolutions. A relatively large *jdR* is therefore put in for the *jRc* needed to match the Range Dials.



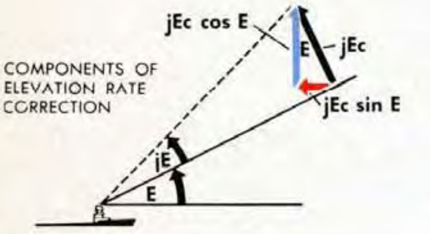
With the Range Rate Ratio Knob positioned near 5, a small Range Rate Correction, *jdR*, goes in for each Range Correction, *jRc*, because the carriage is positioned near the edge of the disk. With the carriage near the edge, fewer turns of the disk will produce the ten revolutions of the roller needed to match *cR* and *R*. *jdR* will be relatively small.



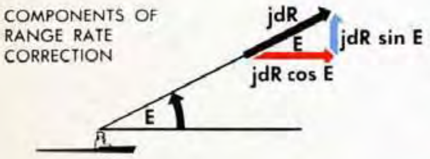
How rate control corrects RATE OF CLIMB TARGET SPEED and TARGET ANGLE

So far, the method has been shown by which the three Rate Control Corrections, Range Rate Control Correction, *jdR,* Elevation Rate Control Correction, *jEc,* and Bearing Rate Control Correction, *jBc,* go into the Rate Control Computing Mechanism.

Inside that mechanism, four Component Integrators and the Vector Solver use these corrections to correct the Target Motion values, *dH, Sh,* and *A.*

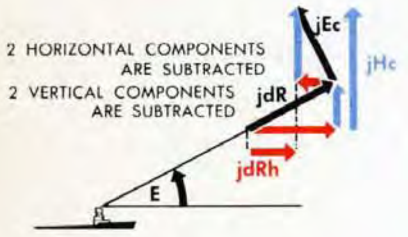


The Elevation Rate Correction, *jEc,* and Target Elevation, *E,* are the inputs to the first component integrator. The outputs are the horizontal and vertical components of *jEc: jEc* sin *E* and *jEc* cos *E.*

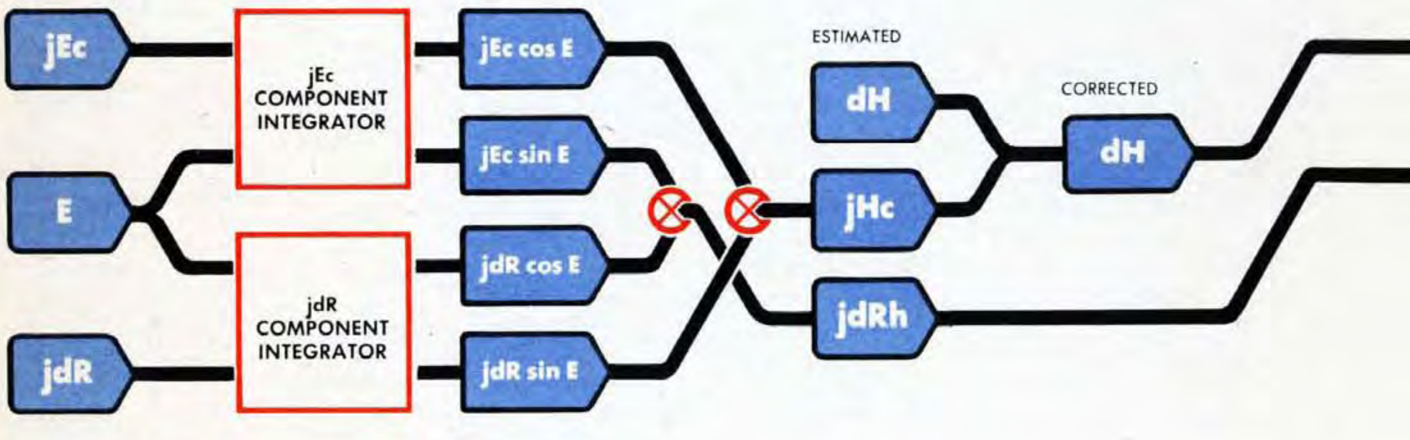


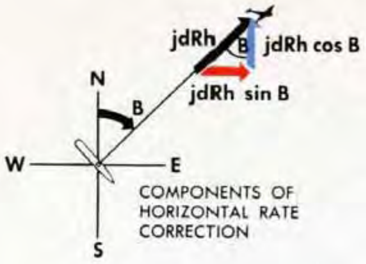
The inputs to the second component integrator are the Range Rate Correction, *jdR,* and Target Elevation, *E.*

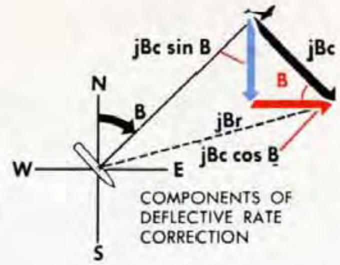
The outputs are the horizontal and vertical components of *jdR: jdR* cos *E* and *jdR* sin *E.*



The *horizontal* components from the two integrators are subtracted to obtain the Horizontal Range Rate Correction, *jdRh.* The *vertical* components from the two integrators are added to give the total vertical correction, *jHc. jHc* is used to correct Target Rate of Climb, *dH.*



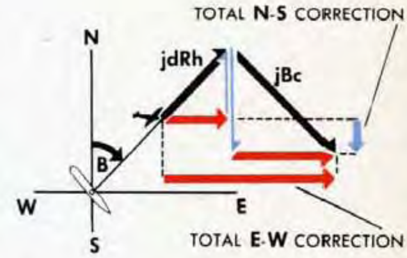




Two more component integrators break up the Horizontal Range Rate Correction, *jdRh*, and the Deflection Rate Correction, *jBc*, into their components along a North-South and East-West axis. The angular input to each of these component integrators is Target Bearing, *B*.

The N-S component of *jBc* is subtracted from the N-S component of *jdRh* to give the total N-S Horizontal Rate Correction.

The two E-W components are added to give the total E-W Horizontal Rate Correction.



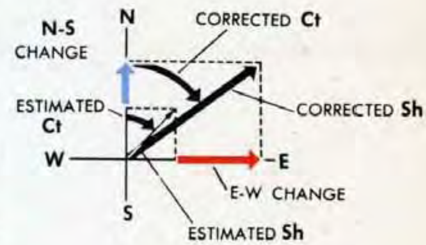
The Vector Solver corrects Sh and Ct

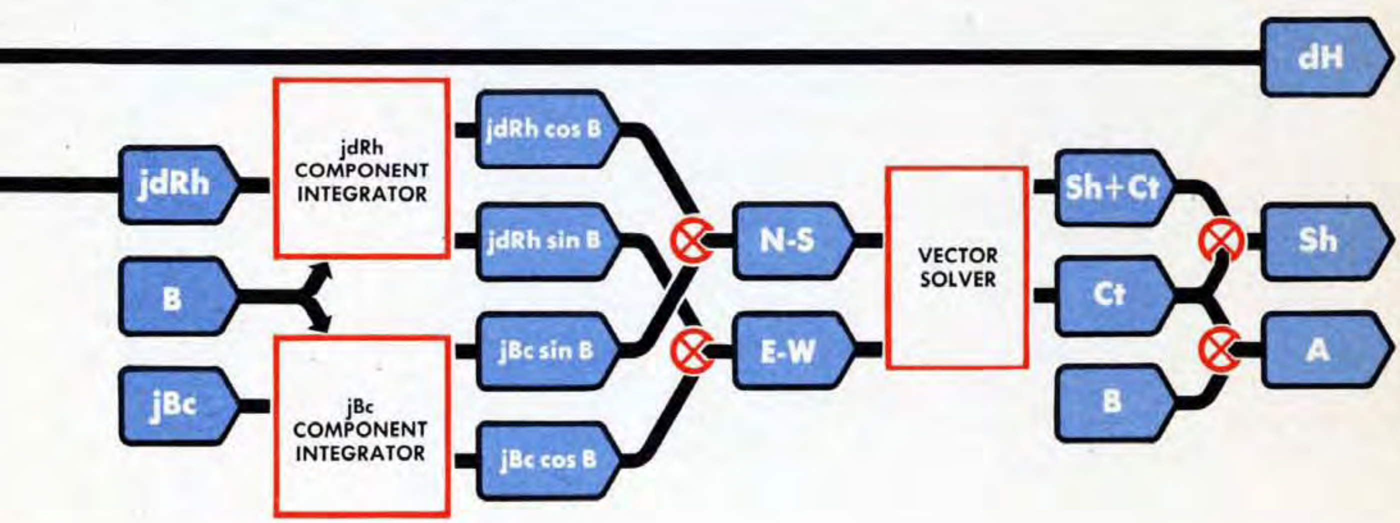
The N-S and the E-W Horizontal Rate Corrections go to the Vector Solver.

The Vector Solver was previously positioned by the estimated values of Target Speed, *Sh*, and Target Course, *Ct*. The corrections from the Rate Control Component Integrators are added to the values of *Sh* and *Ct* already in the Vector Solver. The Vector Solver's outputs are therefore *corrected values* of Target Speed and Target Course.

For mechanical reasons the two outputs of the Vector Solver are *(Sh + Ct)* and *Ct*. The *Ct* output is subtracted from the *Sh + Ct* output to obtain the corrected value of *Sh*. The *Ct* output is also subtracted from True Bearing, *B*, to obtain the corrected value of Target Angle, *A*.

The new values of *Sh* and *A* go to the Target Component Solver in the Relative Motion Group.





Another way to think about rate control

Suppose that the Control Officer can visualize his guesses of Target Motion by having a "ghost" plane that will fly according to his estimates.

Imagine that the ghost pilot will fly his ghost plane to any desired position in the sky and then fly at any speed and in any direction he is told. His plane will be visible to the Director Operators, but not to the enemy. The ghost pilot will agree not to be disturbed by anti-aircraft fire that hits his plane instead of the enemy plane. The obedient ghost is now ready to obey orders.

The ghost plane could be ordered to go to the target plane and then to fly according to the Control Officer's initial estimates of Target Angle, Target Speed, and Rate of Climb.

Suppose the ghost plane should drop below the target and fly off to its right. This would tell the Control Officer that his guesses were wrong. It would also help him correct them.

He would make corrections to his guesses of Target Course and Rate of Climb and order the ghost plane back to the target.

Suppose now that the ghost plane, flying according to these corrected values, remains on about the same course and level as the target but falls behind it.

The Control Officer would correct his Target Speed guess, order the ghost plane back to the target plane, and again instruct it to proceed at the corrected rates.

With each correction the Control Officer makes, the ghost plane flies closer and closer to the course and speed of the target.

Finally, when all three Target Motion values are corrected, the ghost plane flies right along with the target plane.

Parallel between the ghost plane story and rate control

The ghost plane represents in a general way what the Computer is thinking about the Target. More specifically, the movement of the ghost plane corresponds to the changes of Target position generated by the Computer.

1 Ordering the ghost plane initially to go up to the target corresponds to setting into the Computer the initial observed Target position inputs of Range, Elevation, and Relative Bearing.

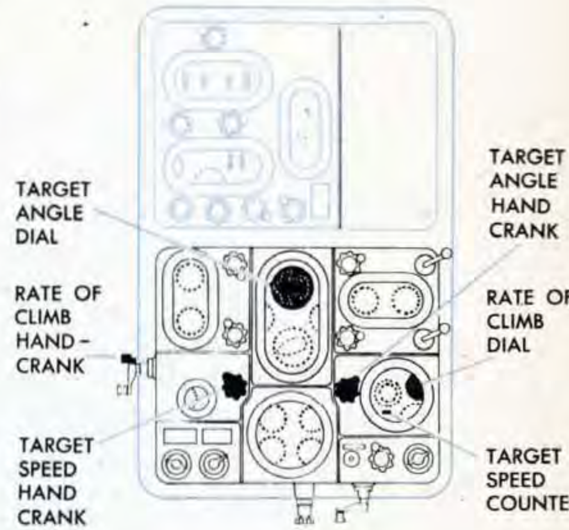
2 Ordering the ghost plane to fly at an estimated speed and direction corresponds to putting into the Computer the initial estimates of Target Speed, Target Angle, and Rate of Climb.

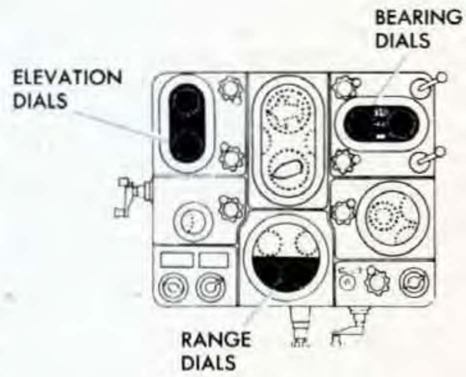
3 Watching the flight of the ghost plane vary from that of the real plane represents the comparison of the movements of the "generated dials" with the "observed dials." The movements of the Generated Elevation and Bearing Inner Dials, and the Generated Range Outer Dials, represent the behavior of the *ghost* plane. The movements of the Observed Elevation and Bearing Outer Dials, and the Observed Range Inner Dials, represent the observed movement of the *real* plane.

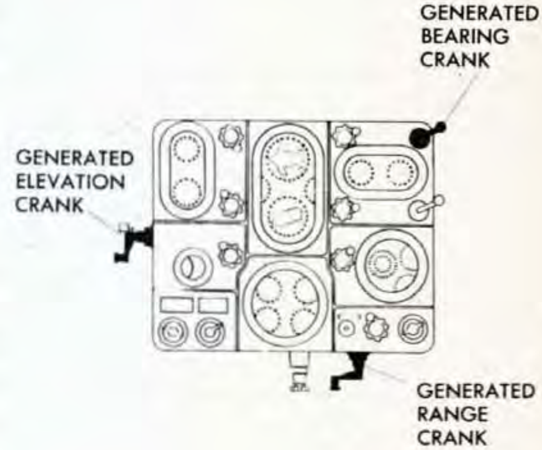
4 Ordering the ghost plane back to the Target corresponds to matching the Generated Range Dials with the Observed Range Dials. (This is not done with the Generated Elevation and Bearing Dials in the Computer Mark 1.)

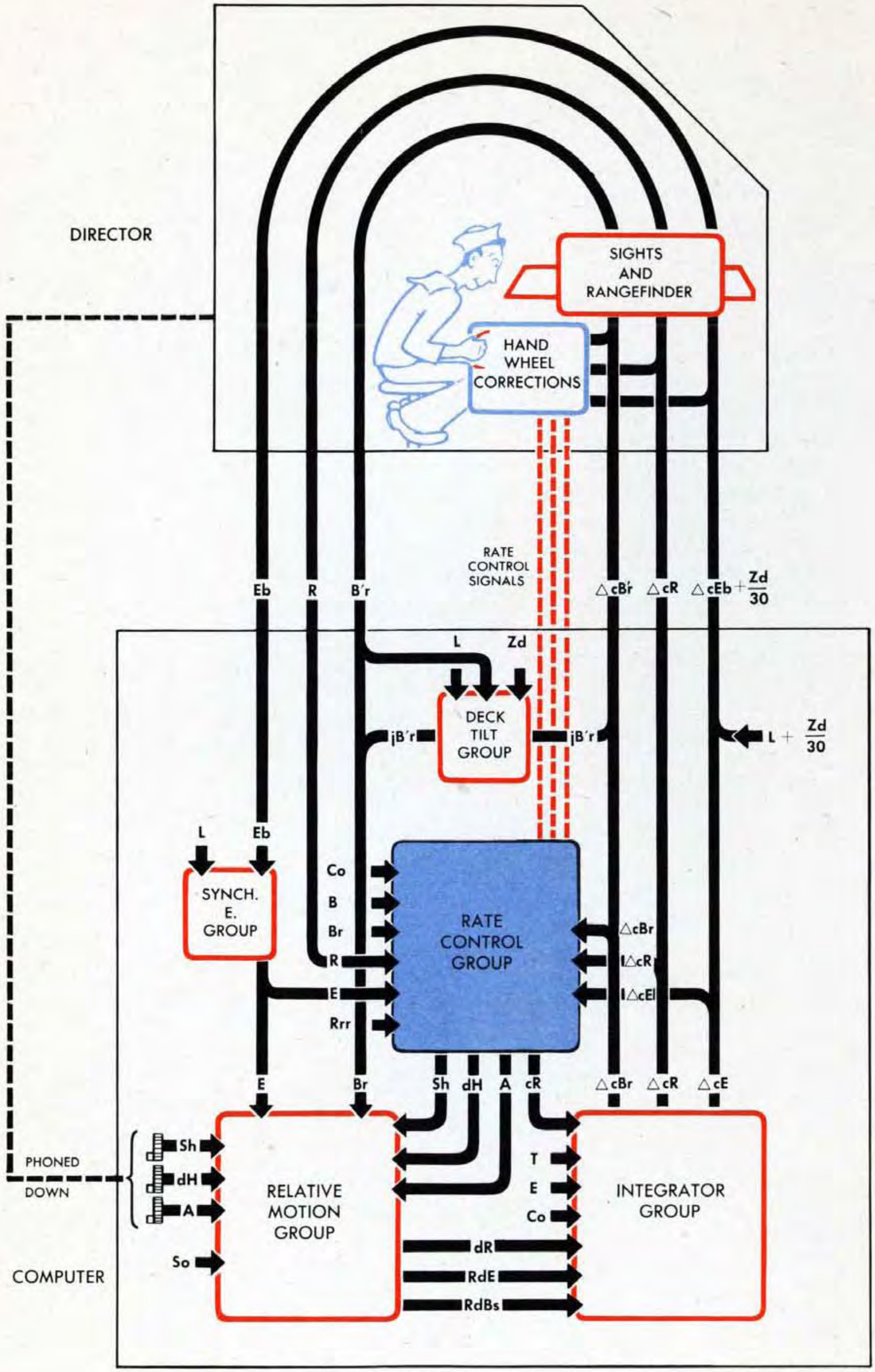
5 Ordering the ghost plane to fly at a corrected speed and direction corresponds to putting in *corrections* to Target Speed, Target Angle, and Rate of Climb. These corrections might be estimated and put in by hand, or they could be computed in the Rate Control Mechanism.

6 When the Target Motion values are correct, the ghost plane flies wing to wing with the Target and the generated dials will turn exactly with the observed dials. This is the same as saying that when the Target Motion estimates are correct, the Relative Motion Rates are correct, and the Generated Changes of Range, Elevation, and Bearing are correct. Since the generated changes continuously position the Director sights, the sights will now stay on the Target. The Relative Motion Rates on which predictions are based will be correct.








DIRECTOR
SIGHTS AND RANGEFINDER
HAND WHEEL CORRECTIONS
RATE CONTROL SIGNALS
Eb
R
B'r
△cB'r
△cR
△cEb + Zd/30
L
Zd
DECK TILT GROUP
jB'r
L + Zd/30
L
Eb
SYNCH. E. GROUP
Co
B
Br
R
E
Rrr
RATE CONTROL GROUP
△cBr
△cR
△cE
E
Br
Sh
dH
A
cR
△cBr
△cR
△cE
PHONED DOWN
Sh
dH
A
So
RELATIVE MOTION GROUP
T
E
Co
INTEGRATOR GROUP
dR
RdE
RdBs
COMPUTER

The RATE CONTROL GROUP completes the tracking section

Here is the whole Tracking Section of the Computer Mark 1, showing how the Rate Control Group fits in, how the corrected Target values go to the Relative Motion Group, and how the Relative Motion Rates are corrected.

Rate Control is a continuous process. One set of Rate Control corrections will not completely correct the Target values, but each time a set of corrections is put into the Rate Control group, the Target values become more nearly correct.

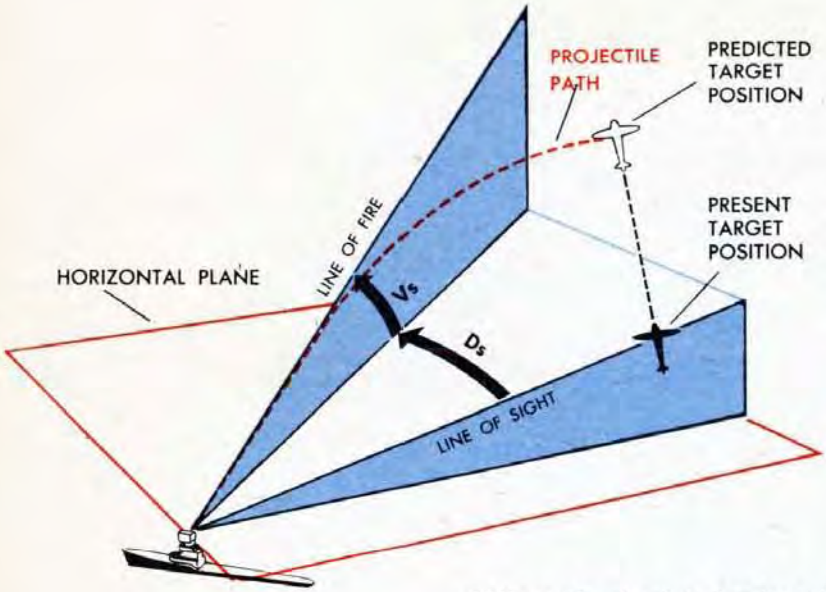
The corrected Target values are used to generate a new set of changes in Target Position which are continuously compared with the Observed Changes. The differences are again used for new Rate Control corrections, and so on, in a continuous regenerative cycle.

When the changes of Target Position generated by the Computer are equal to the Observed Changes of Target Position, a tracking solution is reached and no more Rate Control is necessary as long as the Target continues at the same speed and in the same direction.

Small variations in Target Speed and Direction can be put into the Computer by means of the Rate Control mechanism alone, but where the changes of Target Speed and Direction are large and sudden, the corrections to *Sh, A,* and *dH,* can be put into the Computer much faster by direct hand correction at the Target Speed, Target Angle, and Rate of Climb Knobs.

The new Target values are estimated at the Director and phoned down to the Computer. Then the Rate Control process starts all over again to correct these new estimates.

THE PREDICTION SECTION



The Prediction Section establishes the Line of Fire by computing two lead angles:

1 Sight Angle, *Vs*
2 Sight Deflection, *Ds*

When the deck is horizontal the two lead angles, *Vs* and *Ds*, are: the angle in Elevation, and the Deflection in the slant plane between the Line of Sight and the Line of Fire.

To aid in computing these two lead angles, two other prediction quantities must be computed:

1 Advance Range, *R2*
2 Predicted Elevation, *E2*

R2 and *E2* are also needed for computing quantities in other sections of the Computer.

The whole Prediction Section is based on calculations from a horizontal plane. Any corrections to the Line of Fire made necessary by tilting of the deck are computed in the Trunnion Tilt Section.

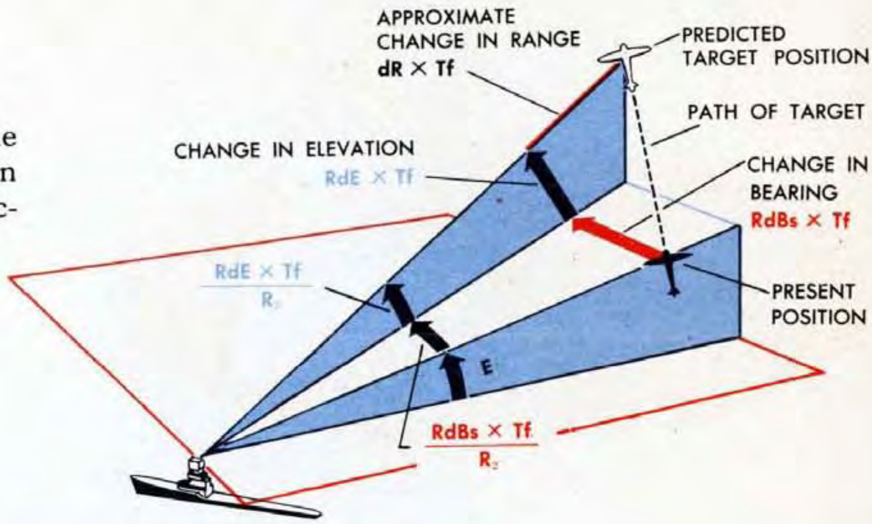
In establishing the Line of Fire, the Prediction Section makes two types of computations:

1 It computes the position of the Target at the end of the Time of Flight, allowing for the effect of Relative Motion during the time the projectile is in the air.

2 It computes how far away from this Predicted Target Position the guns must be positioned to allow for the curvature of the projectile path. Allowances are made for the effect of wind, drop of the projectile due to gravity, drift due to projectile rotation and changes in initial projectile velocity.

The prediction multipliers

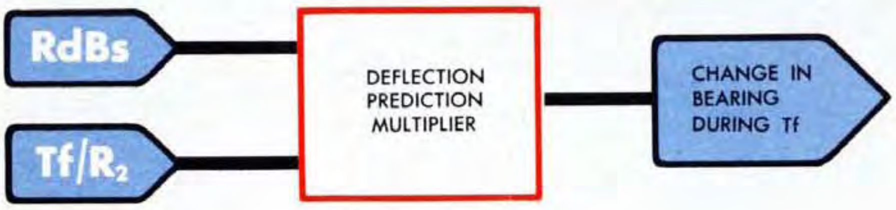
Target Position at the end of the Time of Flight is predicted in Range, in Elevation, and in Deflection.



The approximate change of Range during the Time of Flight is computed by multiplying Range Rate, *dR,* by Time of Flight, *Tf,* in the Range Prediction Multiplier.

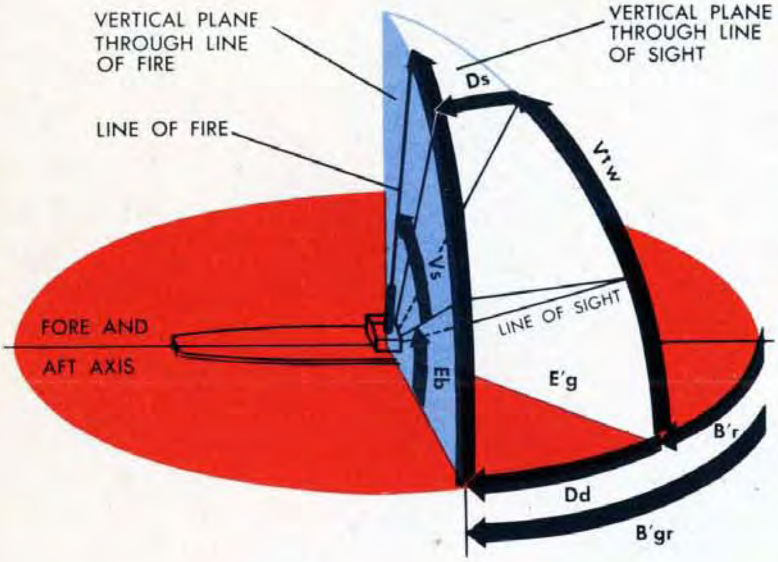
The change of Elevation during the Time of Flight is an ANGULAR quantity; therefore Elevation Rate, *RdE,* must be multiplied by *Tf* and then divided by *R2* to obtain the approximate angular Elevation changes. *RdE* is multiplied by *Tf/R2* in the Elevation Prediction Multiplier.

The change of Bearing during *Tf* is also an angular quantity, Deflection Rate, *RdBs,* is therefore multiplied by *Tf/R2* in the Deflection Prediction Multiplier.



NOTE:
Calculations needed to allow for curvature of the projectile path are more complex. They are explained in the Detailed Description chapter on *Prediction.*

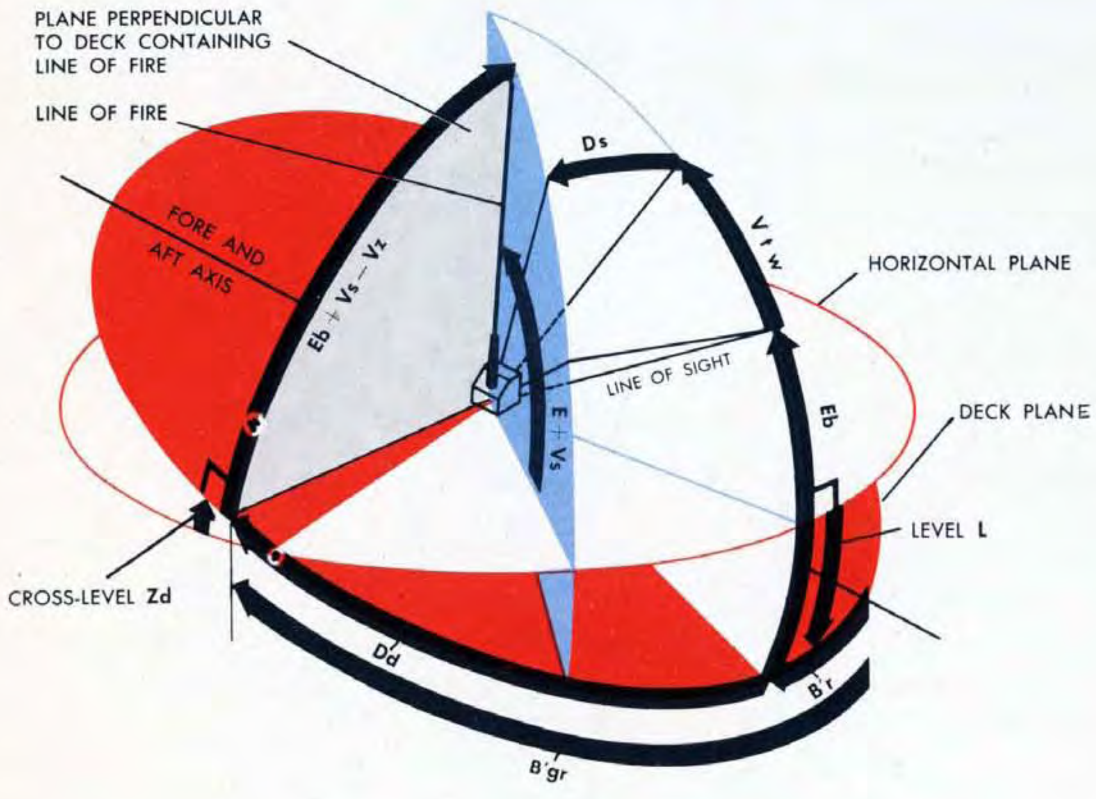
THE TRUNNION TILT SECTION



THIS IS HOW THE LINE OF FIRE IS ESTABLISHED ON A HORIZONTAL DECK

The Trunnion Tilt Section has two outputs. One is Vz, a correction to gun elevation to compensate for the effect on gun elevation of the tilting of the gun trunnions. The second output is Deck Deflection, *Dd*, which consists of *Ds* referred to the deck plane plus a train correction to compensate for the effect on gun train of the tilting of the gun trunnions.

The values of Vz and *Dd* increase and decrease continuously as Own Ship pitches and rolls. The function of these two corrections is to keep the gun aim steady in spite of the continuous tilting of the gun trunnions due to pitch and roll of the deck.



THIS IS HOW THE LINE OF FIRE IS ESTABLISHED ON A TILTED DECK

The Trunnion Tilt Elevation Correction, *Vz,* is computed in two multipliers. The values used to compute *Vz* are *Zd, Vs, Ds,* and *Eb.*

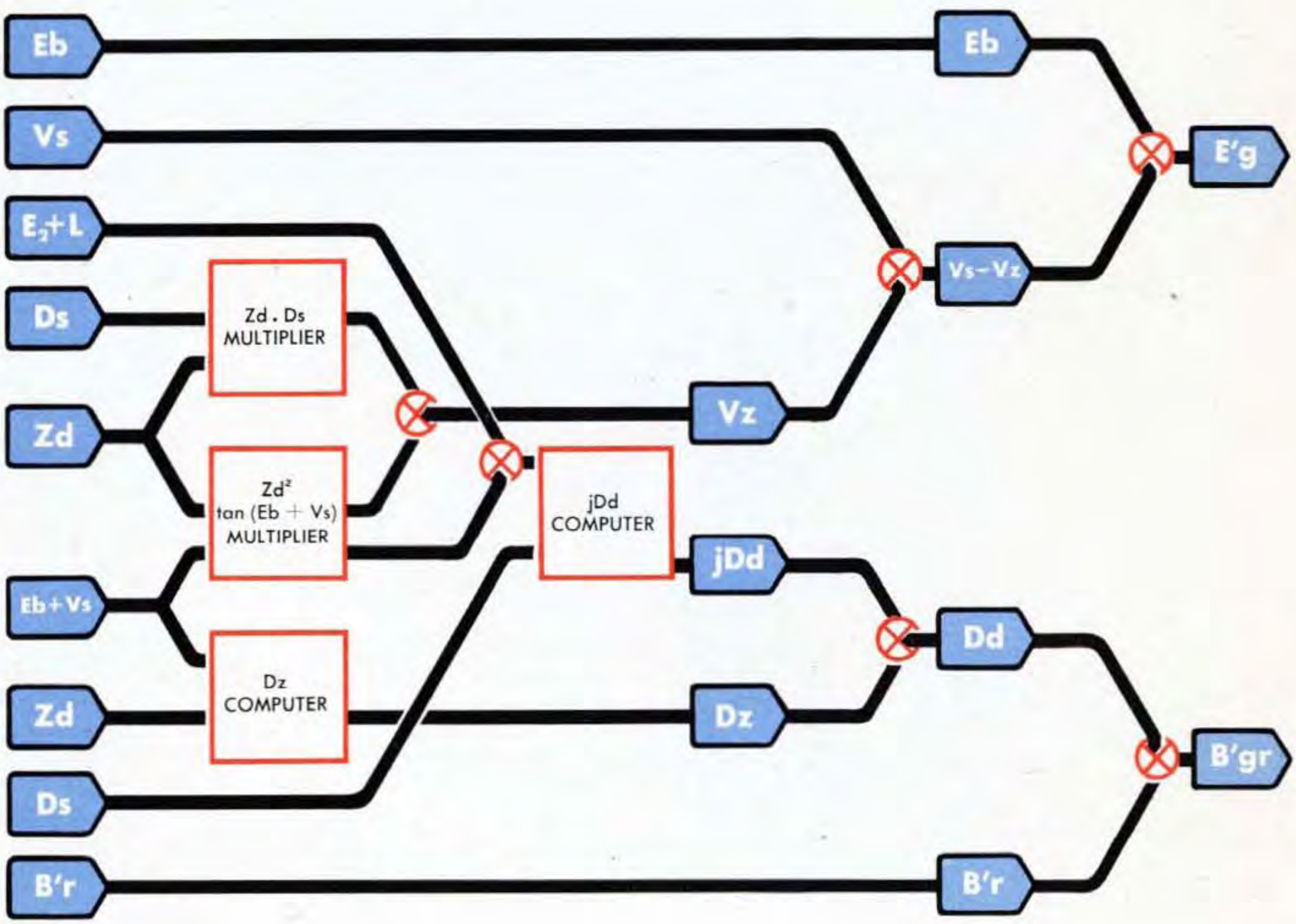
Vz is subtracted from *Eb* + *Vs* to produce the Gun Elevation Order, *E′g.*

The Trunnion Tilt Train Correction, *Dd,* consists of two quantities, *jDd* and *Dz. jDd* is roughly Sight Deflection, *Ds,* corrected to the deck plane and for the effect of Level. *Dz* is approximately the part of the Train Correction needed to compensate for the effect of Cross-level.

jDd and *Dz* are each computed in a special computer. The inputs are the same values as those used for *Vz* with the addition of *E2* + *L.* The outputs of the two computers are added to give Deck Deflection, *Dd.*

Deck Deflection, *Dd,* is added to *B′r* to give the Gun Train Order, *B′gr.*

Both gun orders, *E′g* and *B′gr,* are continuously and automatically transmitted to the gun mounts to operate the machinery controlling the actual pointing and training of the guns.



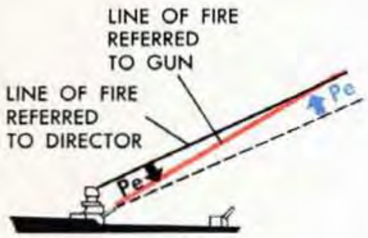
PARALLAX CORRECTIONS

The Line of Fire is established by the Computer from a certain reference point. The reference point is usually the Director when there is only one Director on board; if there are several Directors, the reference point may be either one of the Directors or a point chosen arbitrarily.

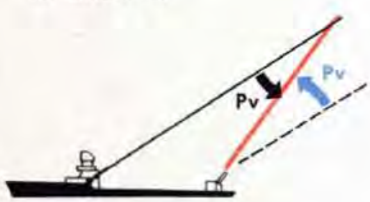
If a gun is at the reference point, it can use the Gun Orders without further correction. If a gun is anywhere else on the deck, its aim must be corrected to compensate for the horizontal distance between the reference point and that particular gun.

The corrections to compensate for this difference in location are the Parallax Corrections. The Parallax Section of the Computer Mark 1 computes two Parallax Corrections, one to Gun Elevation, called *Pv*, and one to Gun Train, called *Ph*. A third Parallax Correction, *Pe*, is computed on a ballistic cam along with Superelevation, *Vf*.

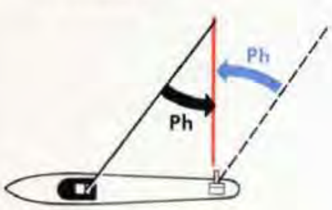
Pe compensates for the difference in height between the guns and reference point and is included in the Gun Elevation Order.



REFERENCE POINT AT DIRECTOR



REFERENCE POINT AT DIRECTOR



REFERENCE POINT AT DIRECTOR

Both *Pv* and *Ph* are corrections to compensate for a 100-yard horizontal distance between the guns or Director and the reference point.

The Parallax Elevation Correction, *Pv*, is largest when the Target is straight ahead or astern of Own Ship.

The Parallax Train Correction, *Ph*, is largest when the Target is abeam of Own Ship.

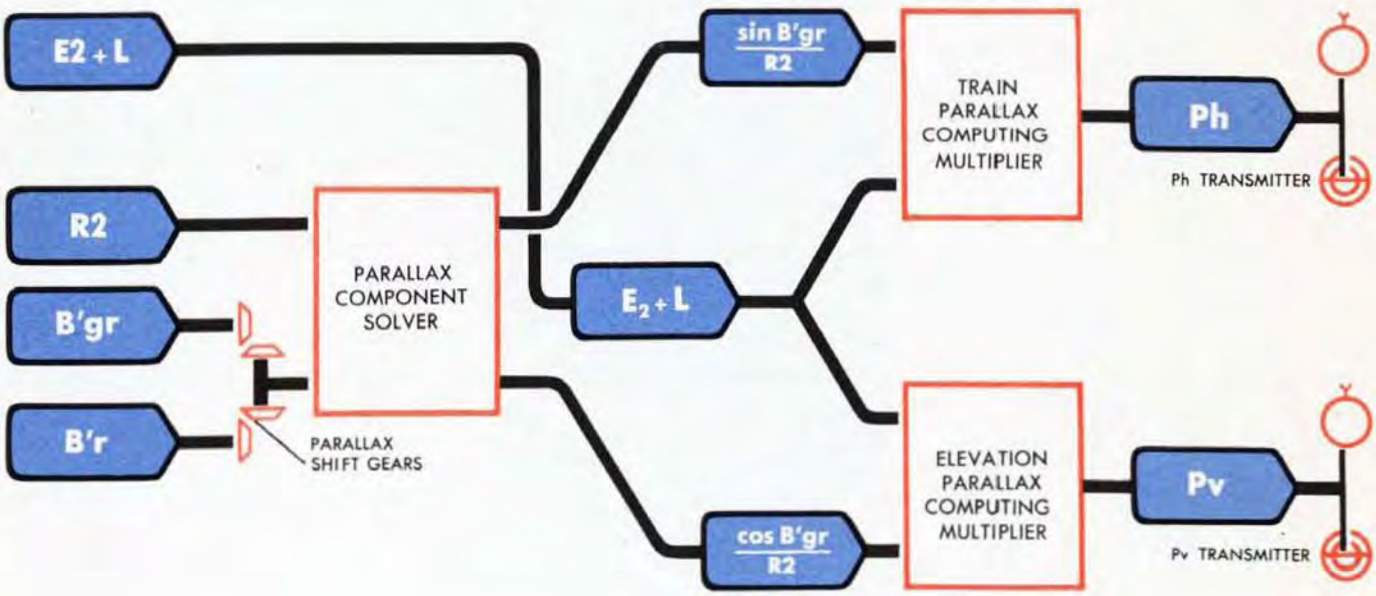
Pv and *Ph* are transmitted to the gun mounts separately from the Gun Orders. Each gun uses a fraction of each correction proportional to its own distance from the reference point. For example, a gun 50 yards from the reference point would use half of *Pv* and half of *Ph*. A gun 20 yards from the reference point would use one fifth of each correction, and so on.

The Parallax Section of the Computer Mark 1 contains a component solver, two single-cam computing multipliers, and two single-speed transmitters.

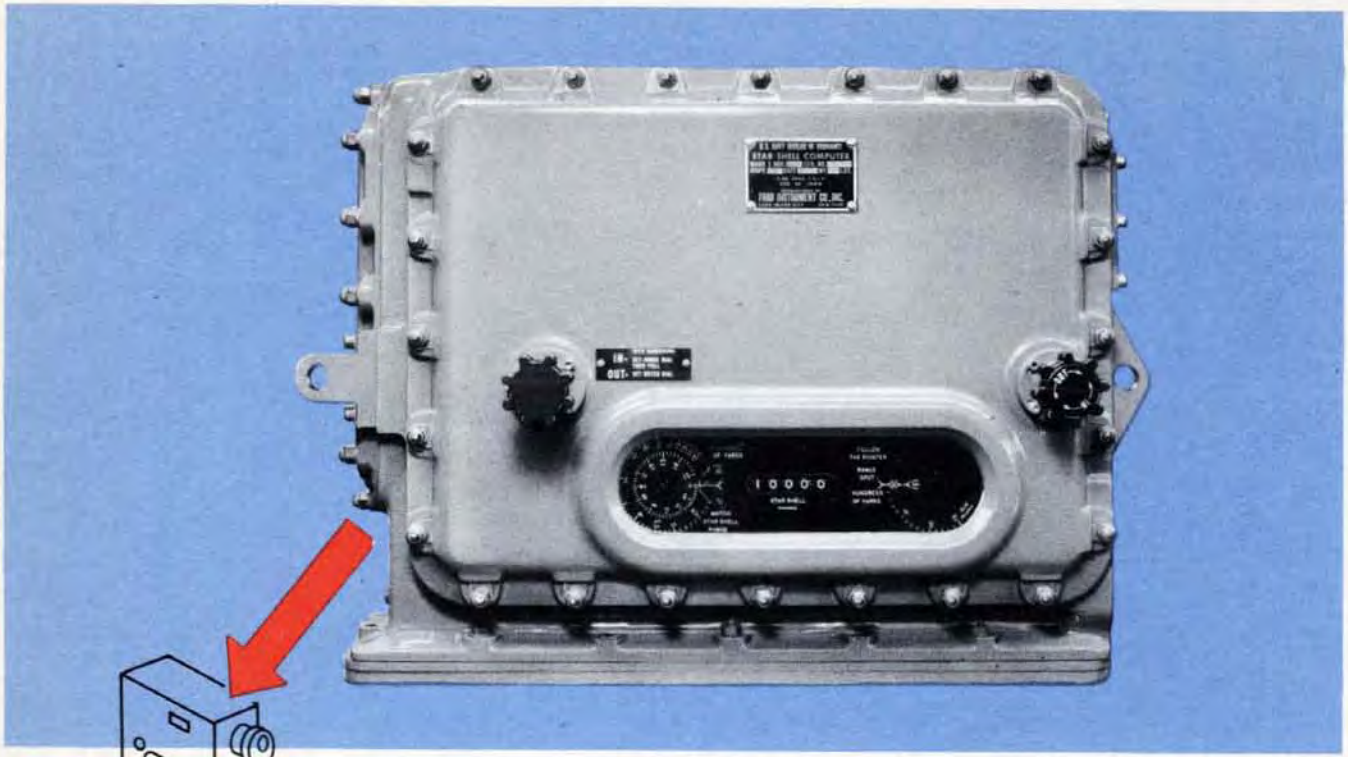
The values used in computing the Parallax Corrections are *E2 +L*, *R2*, and either *B'r* or *B'gr*. *B'r* is used on BB's, CA's, CV's, CBB's, and some CL's; *B'gr* is used on DD's, some AD's, AV's, and all ships having only one Director.

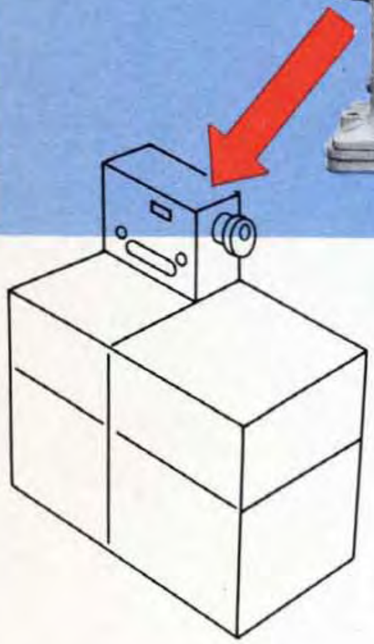
The outputs of the Parallax Section are *Pv* and *Ph*, which are transmitted electrically to the gun mounts. *Ph* is also transmitted to all Directors except those being used as a reference point. In the Directors, *Ph* is used to correct Director Train, *B'r*.

By correcting the Director Train for parallax, the values of *B'r* coming from all Directors on one ship are made uniform and the observations from any Director can be used for any or all guns aboard.



THE STAR SHELL COMPUTER MARK 1





This is the Star Shell Computer. Its job is to compute Gun and Fuze Orders for a 5″/38 cal. gun firing star shells to illuminate surface targets.

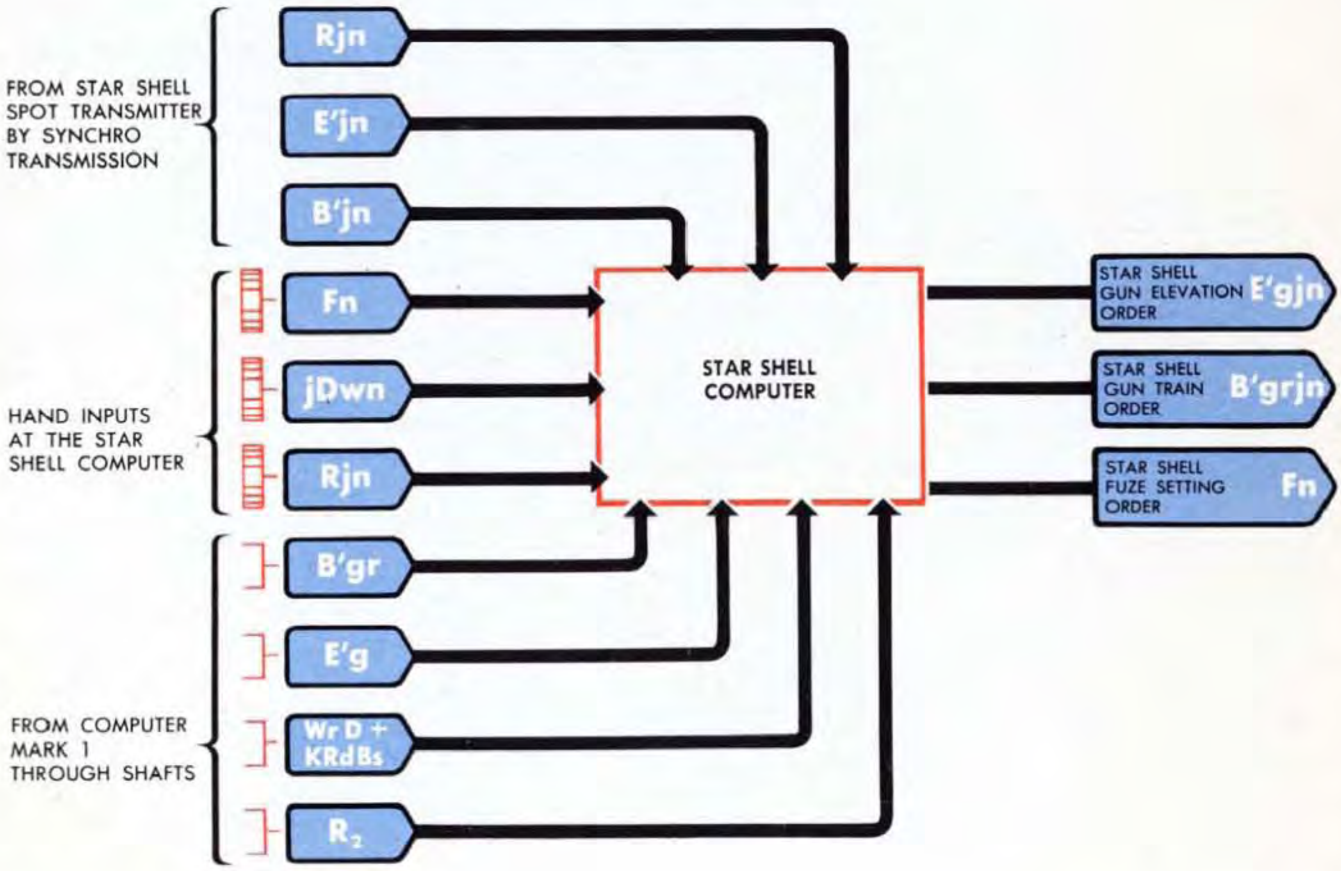
Star shells are projectiles containing a flare attached to a parachute. When the star shell bursts, the flare lights up and burns for about one minute as it floats down.

The star shells are fired at night to illuminate a given surface target or to search an area for possible targets.

When star shells are used for searching an area, the Star Shell Computer Mark 1 is NOT used. The guns are pointed according to ship's doctrine. Later mods of the Star Shell Computer provide for star shell search fire.

The Star Shell Computer receives the Gun Orders from the Computer Mark 1. These Gun Orders point the guns to HIT a given target. The Star Shell Computer adds corrections to these Gun Orders which point a gun to ILLUMINATE that same target. The Gun and Fuze Orders from the Star Shell Computer place a star 1000 yards beyond the target, 1500 feet above the target, and with a deflection such that it is directly beyond the moving target after it has been burning 30 seconds (half its life).

The inputs and outputs of the Star Shell Computer are shown in the schematic. The hand inputs need some explanation. Fuze Setting Order, *Fn*, and Angular Deflection, *jDwn*, are put in by matching the readings of the two Star Shell Range Dials with the reading on the Star Shell Range Counter. The matching is done with a two-position knob. *Rjn* is a hand input based on information received by synchro transmission. Star Shell Range Spot, *Rjn*, is sent by synchro transmission from the Star Shell Spot Transmitter to a synchro motor and dial in the Star Shell Computer. The value of *Rjn* which shows on the dial must be put into the Star Shell Computer mechanisms by hand. By turning a knob, the index on the Range Spot Ring Dial can be matched with the pointer on the receiver dial, thus putting in the value of *Rjn*



INPUTS and OUTPUTS of the COMPUTER MARK 1 and the

INPUTS

1 Inputs from the Director

Observed Target Position (By synchro transmission)	R	Observed Range
	Eb	Director Elevation
	B'r	Director Train
Estimated Target Motion (By phone to the Computer Operators, and initially set in manually)	Sh	Horizontal Target Speed
	dH	Rate of Climb
	A	Target Angle, or
	Ct	Target Course
Rate Control Signals (By electrical signal)	jdR	Range Rate Control Correction
	jE	Elevation Rate Control Correction
	jBr	Bearing Rate Control Correction
Spot Correction to the Computer Mark 1 (By synchro transmission)	Rj	Range Spot
	Vj	Elevation Spot
	Dj	Deflection Spot
Spot Corrections to the Star Shell Computer (By synchro transmission)	Rjn	Star Shell Range Spot
	E'jn	Star Shell Elevation Spot
	B'jn	Star Shell Deflection Spot

2 Inputs from the Stable Element (By shafts)	L	Level
	Zd	Cross-level
	L+Zd/30	Level plus function of Cross-level
3 Inputs from the Gyro Compass (By synchro transmission)	Co	Ship Course
4 Inputs from the Pitometer Log (By synchro transmission)	So	Ship Speed

5 Hand Inputs

Quantities that can be put in by hand only	Sw	Wind Speed
	Bw	Wind Direction
	I.V.	Initial Velocity
	Tg	Dead Time
	Rrr	Range Rate Ratio
	Dip	Dip Angle
Alternate hand inputs for quantities normally received electrically	cR	Range (Alternate input for *R*)
	E	Elevation (Alternate input for *Eb*)
	Br	Relative Bearing (Alternate input for *B'r*)
	Rj	Range Spot
	Vj	Elevation Spot
	Dj	Deflection Spot
	Co	Ship Course
	So	Ship Speed

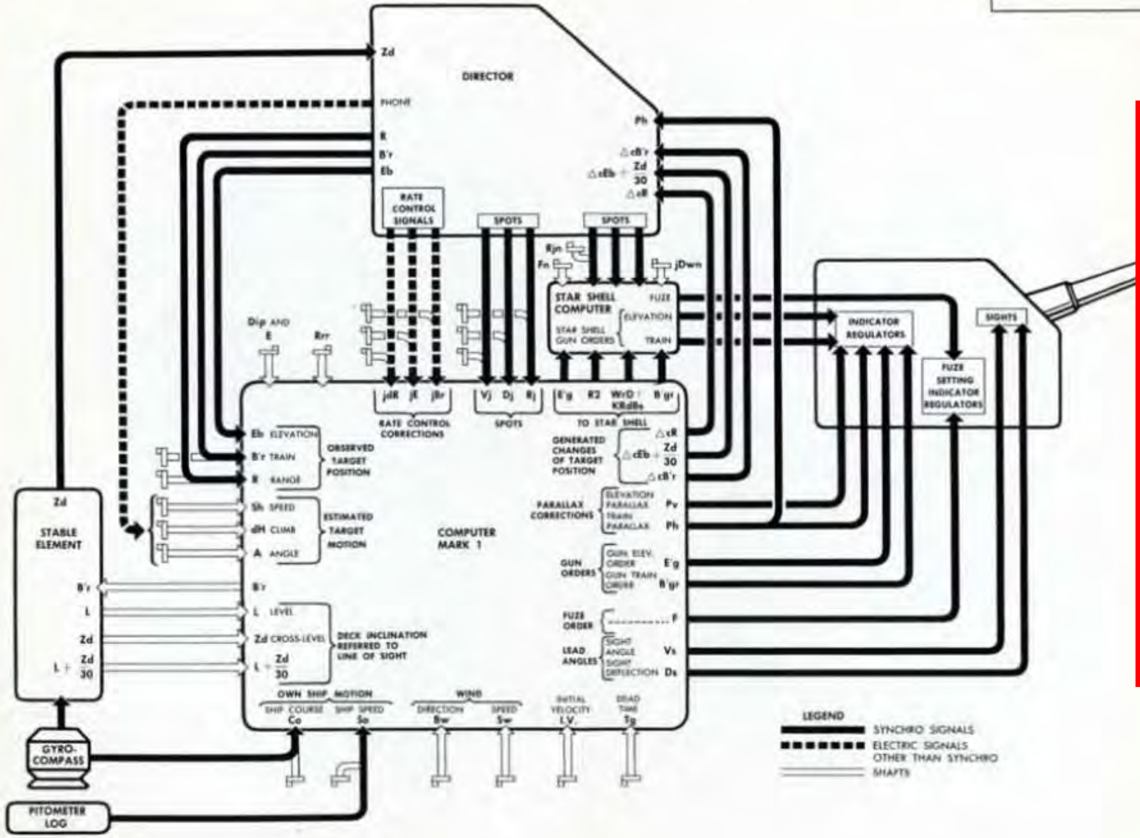
STAR SHELL COMPUTER MARK 1

Hand inputs that may be used during Rate Control	jdR	Rate Control Correction through Generated Range Crank
	jE	Rate Control Correction through Generated Elevation Crank
	jBr	Rate Control Correction through Generated Bearing Crank
	Sh	Horizontal Target Speed
	dH	Rate of Climb
	Ct	Target Course
	A	Target Angle
Hand inputs to the Star Shell Computer	Rjn	Star Shell Range Spot
	Fn	Star Shell Fuze Setting Order
	jDwn	Angular Deflection of Star

OUTPUTS

1 To the Gun Mounts (By synchro transmission)		
To the Train Indicator Regulator	B'gr	Gun Train Order
	B'grjn	Star Shell Gun Train Order
	Ph	Train Parallax Correction (also goes to some Directors)
To the Elevation Indicator Regulator	E'g	Gun Elevation Order
	E'gjn	Star Shell Gun Elevation Order
	Pv	Elevation Parallax Correction (also goes to some Directors)
To the Sights	Vs	Sight Angle
	Ds	Sight Deflection
To the Fuze Setting Indicator Regulator	F	Fuze Order
2 To the Director (By synchro transmission)		
To the Change of Range Receiver at the Range Finder	△cR	Generated Changes of Range
To the Elevation Receiver	△cEb + Zd 30	Generated Changes of Director Elevation plus Function of Cross-level
To the Train Receiver	△cB'r	Generated Changes of Director Train
3 To the Stable Element (By shaft)	B'r	Director Train
4 To the Star Shell Computer (By shafts)	E'g	Gun Elevation Order
	B'gr	Gun Train Order
	R2	Advance Range
	Wrd + KRdBs	Deflection Wind plus Function of Deflection Rate

COMPUTER MK 1, MOD 7
COMPUTER INPUTS and OUTPUTS



Summary of COMPUTER MARK 1 DATA

Size

Without handcranks the Computer Mark 1 measures approximately:

62 inches long
38 inches wide
45 inches high

With the Star Shell Computer Mark 1 in place the all-over height is 65 inches. The exact dimensions are shown below.

Weight

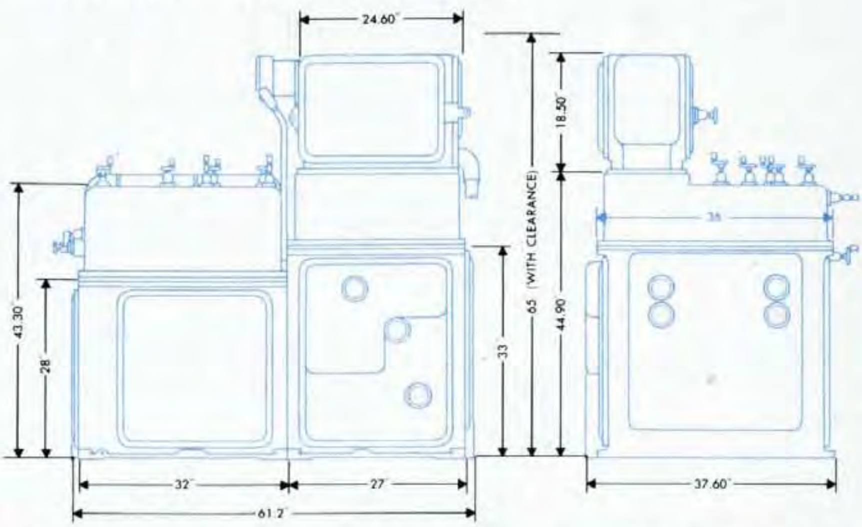
The Computer Mark 1 weighs about 3125 lbs.
The Star Shell Computer Mark 1 weighs about 215 lbs.

Power Supply

The Computer Mark 1 and the Star Shell Computer operate on 115-volt, 60-cycle, single-phase, alternating current.

The normal current, including excitation of the transmitters, is about 57½ amperes.

The maximum current, assuming the extremes in synchronization, could be as much as 140 amperes.



LIMITS OF OPERATION

INTERMITTENT DRIVES

COMPUTER MARK 1

Symbol	Lower Limit	Upper Limit
Ds	320 MILS	680 MILS
Vs	2,000′	3,800′
E2	0°	90°
Eb + Vs	1,640′	7,160′
dRs	− 450 KNOTS	+ 450 KNOTS
cR	750 YARDS	22,500 YARDS
E	− 2°	+ 85°

LIMIT STOPS

COMPUTER MARK 1

Stop No.	Symbol	Lower Limit	Upper Limit	
L-1	So	0 KNOTS	45 KNOTS	
L-2	Sh	0 KNOTS	400 KNOTS	
L-3	Sw	0 KNOTS	60 KNOTS	
L-4	dH	−250 KNOTS	+150 KNOTS	
L-5	dRh	−440 KNOTS	+440 KNOTS	
L-6	RdBs	−400 KNOTS	+400 KNOTS	
L-7	RdE	−400 KNOTS	+400 KNOTS	
L-8	dR	−450 KNOTS	+450 KNOTS	
L-9	Ywgr	−100 KNOTS	+100 KNOTS	
L-10	cR	0 YARDS	35,000 YARDS	
L-11	Eb	500′	8,600′	
L-12	E	−5°	+85°	Serial Numbers below 390
		−25°	+85°	Serial Numbers above 389
L-13	Rrr	1	5	
L-14	Tg	0 SECONDS	6 SECONDS	Serial Numbers below 781
	Tg + F − Tf	0 SECONDS	50 SECONDS	Serial Numbers above 780
L-15	I.V.	2,350 f.s.	2,600 f.s.	
L-16	L	480′	3,520′	
L-17	Zd	480′	3,520′	
L-18	jB′r	348° 20′	11° 40′	
L-19	R2	500 YARDS	18,000 YARDS	
L-20	Tf/R2	0.00122	0.00336	
L-21	R2	*300 YARDS	*18,200 YARDS	
L-22	Vf + Pe	0′	2,500′	
L-23	R2	*300 YARDS	*18,200 YARDS	
L-24	Tf	0.6 SECONDS	60.6 SECONDS	
L-25	R2	*300 YARDS	*18,200 YARDS	
L-27	R3	*−1,250 YARDS	*+19,750 YARDS	
L-28	Dtwj	−518 MILS	+518 MILS	
L-29	Rj	IN 12,000 YARDS	OUT 1,800 YARDS	
L-30	Dj	LEFT 180 MILS	RIGHT 180 MILS	
L-31	Vj	DOWN 180 MILS	UP 180 MILS	
L-32	Dd	−120°	+120°	
L-34	Vz	−2,940′	+1,860′	
L-35	F	0.6 SECONDS	55.0 SECONDS	
L-36	R3	*−1,250 YARDS	*+19,750 YARDS	
L-37	V	200′	3,800′	
L-38	Tg	0 SECONDS	6 SECONDS	Serial Numbers above 780

STAR SHELL COMPUTER

Stop No.	Symbol	Lower Limit	Upper Limit
L-1	WrD + KRdBs	−60 KNOTS (Read as 940 Knots on counter)	+60 KNOTS
L-2	Rjn	IN 1,500 YARDS	OUT 1,500 YARDS
L-3	Fn	8.20 SECONDS	41.55 SECONDS
L-4	jDwn	4,000 YARDS	15,000 YARDS

*Limit cannot be reached when ballistic unit containing limit stop is installed in Computer.

SYNCHROS in the COMPUTER MARK 1

Name		Location Section	Location Cover	Value per rev.	Size	Mods
Range Correction Transmitter		Control	1	1000 yds	5 G	All
Range Receiver	Coarse	Control	1	72,000 yds	5 F	
	Fine	Control	1	2000 yds	5 F	All
Target Course Transmitter		Control	1	360°	5 G	Except Mods 0, 1, 2, 9
Elevation Correction Transmitter		Computer	3	5°	6 DG	Mod 0
Bearing Correction Transmitter		Computer	3	5°	6 G	Mod 0
Elevation Correction Ind. Transmitter		Computer	3	10°	5 G	Except Mod 0
Elevation Correction Auto Transmitter		Computer	3	5°	6 G	Except Mod 0
Bearing Correction Ind. Transmitter		Computer	3	10°	5 G	Except Mod 0
Bearing Correction Auto Transmitter		Computer	3	5°	6 G	Except Mod 0
Ship Course Receiver	Coarse	Computer	5	360°	5 B	All
	Fine	Computer	5	10°	5 F	All
Deflection Spot Receiver		Indicator	2	360 mils	5 B	All
Elevation Spot Receiver		Indicator	2	360 mils	5 B	All
Range Spot Receiver		Indicator	2	4000 yds	5 B	All
Ship Speed Receiver		Indicator	2	Various	5 B	Except Mod 0
Fuze Setting Order Transmitter	Coarse	Indicator	2	100 sec	6 G	Mods 0, 1, 2, 9
					7 G	Except Mods 0, 1, 2, 9
	Fine	Indicator	2	2 sec	6 G	Mods 0, 1, 2, 9
					7 G	Except Mods 0, 1, 2, 9
Single Mount Sight Angle Transmitter		Indicator	2	2400 min	6 G	Mods 0, 2, 7, 11, 13
					7 G	Mods 9, 10, 5, 6
Single Mount Sight Deflection Transmitter		Indicator	2	442.24 mils	6 G	Mods 0, 2, 7, 11, 13
					7 G	Mods 9, 10, 5, 6
Twin Mount Sight Angle Transmitter	Coarse	Indicator	2	7200 min	6 G	Mods 1, 9, 7, 11, 13
					7 G	Mods 3, 10, 4, 8, 12

Twin Mount Sight Angle Transmitter	Fine	Indicator	2	200 min	6 G	Mods 1, 9, 7, 11, 13
					7 G	Mods 3, 10, 4, 8, 12
Twin Mount Sight Deflection Transmitter	Coarse	Indicator	2	4000 mils	6 G	Mods 1, 9, 7, 11, 13
					7 G	Mods 3, 10, 4, 8, 12
	Fine	Indicator	2	100 mils	6 G	Mods 1, 9, 7, 11, 13
					7 G	Mods 3, 10, 4, 8, 12
Gun Train Order Ind. Transmitter (No. 1)	Coarse	Corrector	8	360°	7 G	All
	Fine	Corrector	8	10°	7 G	All
Gun Train Order Auto Transmitter (No. 2)	Coarse	Corrector	8	360°	7 G	All
	Fine	Corrector	8	10°	7 G	All
Director Train Receiver	Coarse	Corrector	8	360°	5 B	All
	Fine	Corrector	8	10°	5 F	All
Gun Elev. Order Ind. Transmitter (No. 1)	Coarse	Corrector	6	10,800 min	7 G	All
	Fine	Corrector	6	600 min	7 G	All
Gun Elev. Order Auto Transmitter (No. 2)	Coarse	Corrector	6	10,800 min	7 G	All
	Fine	Corrector	6	600 min	7 G	All
Director Sight Elev. Receiver	Coarse	Corrector	6	180°	5 B	All
	Fine	Corrector	6	10°	5 F	All
Train Parallax Transmitter		Corrector	6	30°/100 yds	6 G	Mods 0, 1, 2, 9
					7 G	Except Mods 0, 1, 2, 9
Elevation Parallax		Corrector	6	10°/100 yds	7 G	Mods 5, 7, 11, 13, 8, 12
Star Shell Fuze Setting Order Transmitter	Coarse	Star Shell		100 sec	6 G	All
	Fine	Star Shell		2 sec	6 G	All
Star Shell Gun Elev. Order Transmitter	Coarse	Star Shell		10,800 min	6 DG	All
	Fine	Star Shell		600 min	6 DG	All
Star Shell Gun Train Order Transmitter	Coarse	Star Shell		360°	6 DG	All
	Fine	[illegible]		[illegible]	[illegible] DG	All
Star Shell Range Spot Receiver		[illegible]	[illegible]	[illegible]	[illegible] F	All

DESIGN FEATURES OF THE COMPUTER MARK 1

There are several important features of the Computer Mark 1 which must be grasped before the details of the Computer can be fully understood.

1 The Computer Mark 1 is designed to compute for a Target moving in a straight line at a constant speed.

The Rate Control Mechanism corrects the estimates of Target Motion set into the Computer. Once these have been corrected, the Computer will continue to compute correct Gun and Fuze Orders as long as the course and speed of the Target remain unchanged.

2 The inputs of Target Speed are Target Horizontal Speed, *Sh*, and Rate of Climb, *dH*. The air speed of the Target is NOT an input. Target Horizontal Speed, *Sh*, is the horizontal component of the Target's speed with respect to the ground. Rate of Climb, *dH*, is the vertical component of the Target's speed with respect to the ground.

Since both *Sh* and *dH* are measured with respect to the ground and not to the air, the effect of wind on the Target is already included in these speeds and need not be computed separately. For this reason the wind computations in the Computer Mark 1 are concerned only with the effect of wind on the projectiles.

3 The Range shaft lines in the Computer Mark 1 are positioned by Generated Range while the Elevation and Bearing shaft lines are positioned by Observed Elevation and Observed Bearing. One reason for this is that Elevation and Bearing are observed continuously in the Director, while Range if observed optically cannot be measured continuously.

Since Observed Range can be measured only intermittently, the motion of the Observed Range shaft line is not smooth. The Generated Range line on the other hand, moves smoothly since it is positioned by the Increments of Range from the Range Integrator. Using Generated Range to position the Range lines in the Computer therefore makes for smoother operation of all the mechanisms on this line.

Since Elevation and Bearing can be observed continuously, these observed quantities can be used to position the mechanisms in the Computer. Generated Elevation and Bearing could be used to position the mechanisms. However, the observed quantities are used in the Computer Mark 1 because they are more accurate than the generated quantities at the beginning of tracking, before the Rate Control Computing Mechanism has corrected the rates of change of the generated quantities.

4 The information stored on the ballistic cams in the Computer Mark 1 is based on trajectories which the projectile will follow when the Initial Velocity is 2550 feet per second and there is no Wind.

It is a feature of the Computer Mark 1 that it uses hand inputs of Wind Speed, Wind Direction, and actual Initial Velocity to alter the Advance Range and Advance Elevation inputs to these cams in such a way that the outputs from the cams include alterations for the effects of Wind and of variations in the Initial Velocity of the projectile.

Here is a table showing which of the variable factors in the fire control problem affect each of the outputs from the Computer Mark 1.

COMPUTED OUTPUTS

VARIABLES that affect the computed outputs	LEAD ANGLES		GUN ORDERS		FUZE SETTING ORDER
	GUN SIGHT POSITION		GUN POSITION		FUZE TIME
	Vs	Ds	E'g	B'gr	F
RELATIVE MOTION RATES	X	X	X	X	X
RANGE	X	X	X	X	X
ELEVATION	X	X	X	X	X
ROLL AND PITCH	—	—	X	X	—
DROP OF PROJECTILE	X	X	X	X	X
DRIFT OF PROJECTILE	X	X	X	X	X
TIME OF FLIGHT	X	X	X	X	X
INITIAL VELOCITY	X	X	X	X	X
WIND: RANGE WIND, ELEVATION WIND, DEFLECTION WIND	X	X	X	X	X
DEAD TIME	—	—	—	—	X
SPOTS: RANGE SPOT, ELEVATION SPOT, DEFLECTION SPOT	X	X	X	X	X

LEGEND: X indicates the output is affected by variable
— indicates the output is not affected by variable

PART 2

OPERATION

Part 2 identifies the operating controls, explains how the operating controls are used in various types of Computer operations, and traces through a typical operating cycle.

No explanations are given for the operating instructions. The reasons behind the operating instructions are supplied by Part 1, the *General Description,* and Part 3, the *Detailed Description.* Operation of the Computer Mark 1 is largely rate-controlling. For this reason, the chapters in the Detailed Description dealing with Relative Motion, Integrators, and Rate Control will be very useful to operators.

Part 2 is not intended to specify or supersede any *ship's doctrine.* It is not intended to imply when any particular type of operation is to be used. The four chapters in Part 2 will serve as a foundation for operating procedure when combined with the doctrine of a particular combat area and a particular ship.

The chapters in Part 2 are:

OPERATING CONTROLS

This chapter describes all of the dials, counters, handcranks, and switches which are used in operating the Computer Mark 1, the Target Course Indicator Mark 1, and the Star Shell Computer Mark 1. Dials and counters which are used only during tests are described in OP 1064A.

The dials and counters show the values of the various quantities on the Computer shaft lines. Some dials indicate the values of the quantities set in by handcranks or by automatic transmission. Other dials show the values of computed quantities. A knowledge of the location of all the dials and the quantities that can be read on them must be acquired in order to operate the Computer.

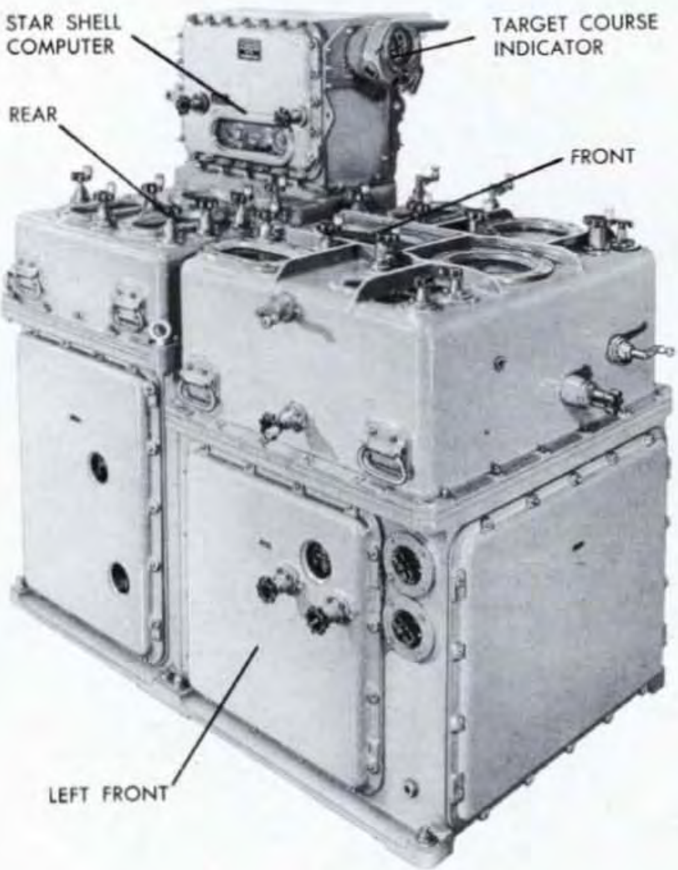
The handcranks provide a means of putting values into the Computer. In some cases a handcrank is the *only* means of putting a value into the Computer. More often the handcrank provides an *alternate* means of introducing a value when the normal automatic receivers fail. Such handcranks have a shift mechanism which allows them to be connected to or disconnected from the shaft lines, and to actuate switches to disconnect or connect the automatic receivers. A few of the handcranks are used only in the event of casualties in the fire control system.

The switches control electrical circuits in the Computer. Some of the switches are used to select a type of Computer operation, such as AUTO or SEMI-AUTO. The switches which are used for this purpose are especially important to identify because their several positions determine the ways in which various handcranks and dials are to be used.

The controls divide into five groups: the controls on the

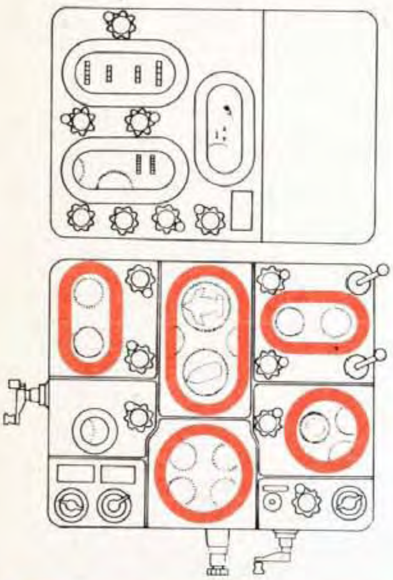
1 FRONT
2 LEFT FRONT
3 REAR
4 Target Course Indicator
5 Star Shell Computer

The front contains most of the controls used in operating the Computer and is therefore described first.



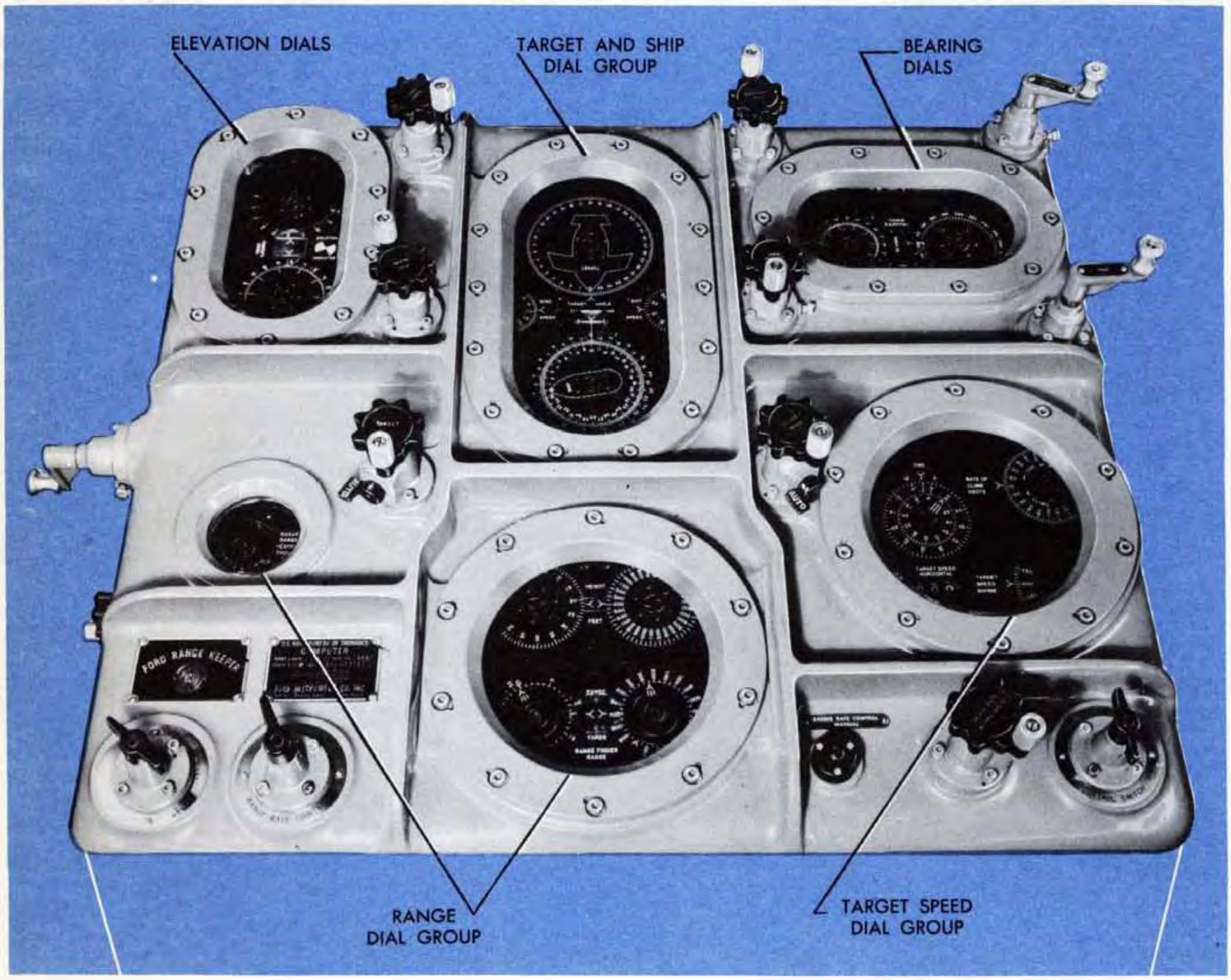
A large diagram of the Computer showing the locations and names of all the controls appears on page 109.

THE DIALS ON THE FRONT OF



The front of the Computer Mark 1 divides itself into five dial groups.

1 The TARGET AND SHIP Dial Group
2 The TARGET SPEED Dial Group
3 The RANGE Dial Group
4 The BEARING Dials
5 The ELEVATION Dials



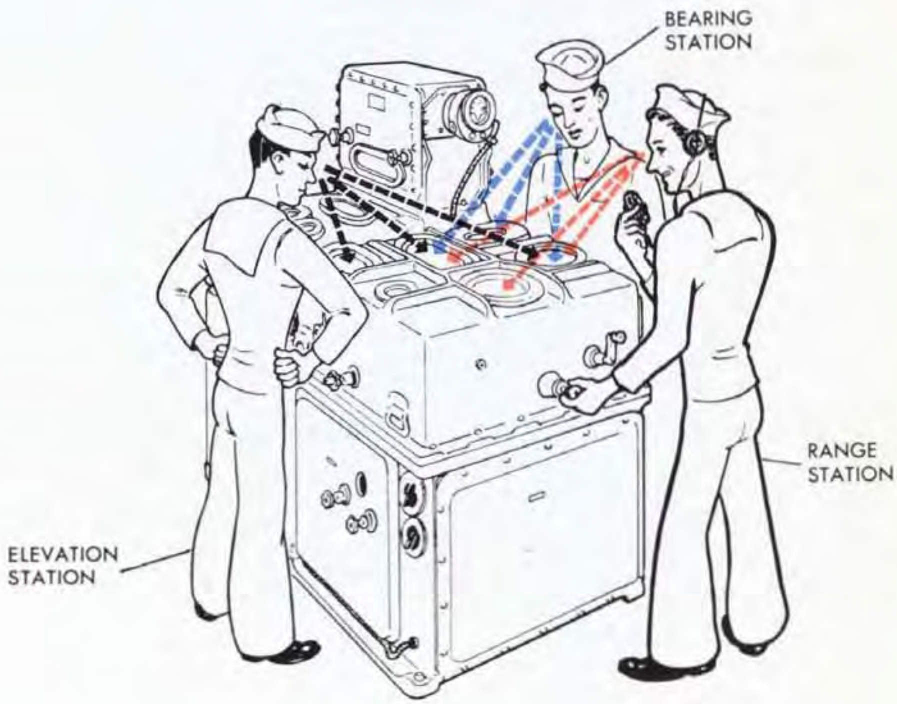
THE COMPUTER MARK 1

The five dial groups on the front of the Computer are used continuously in tracking a target. The front is operated from three operating stations: the Range Station in front of the Computer, the Bearing Station on the right side of the Computer, and the Elevation Station on the left side of the Computer. Each station may be manned by one or more operators, according to ship's doctrine.

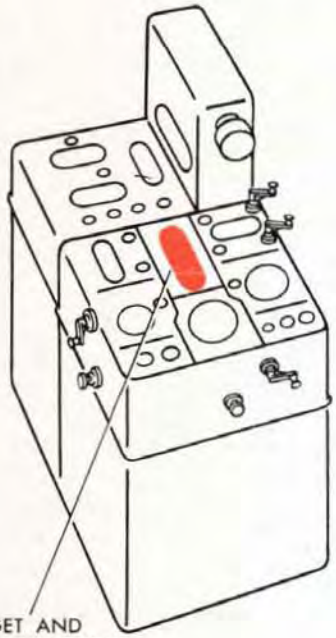
The Target and Ship Dial Group is watched by the men at all three operating stations. It is one of the most important sources of information for the operation of the Computer.

The Target Speed Dial Group is also watched by the men at all three operating stations.

Besides watching the Target and Ship Dial Group and the Target Speed Dial Group, the Range Station Operators watch the Range Dials, the Bearing Station Operators watch the Bearing Dials, and the Elevation Station Operators watch the Elevation Dials.

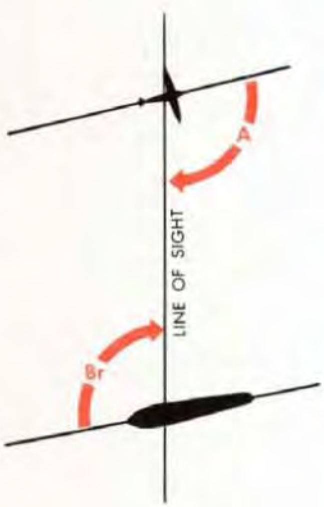


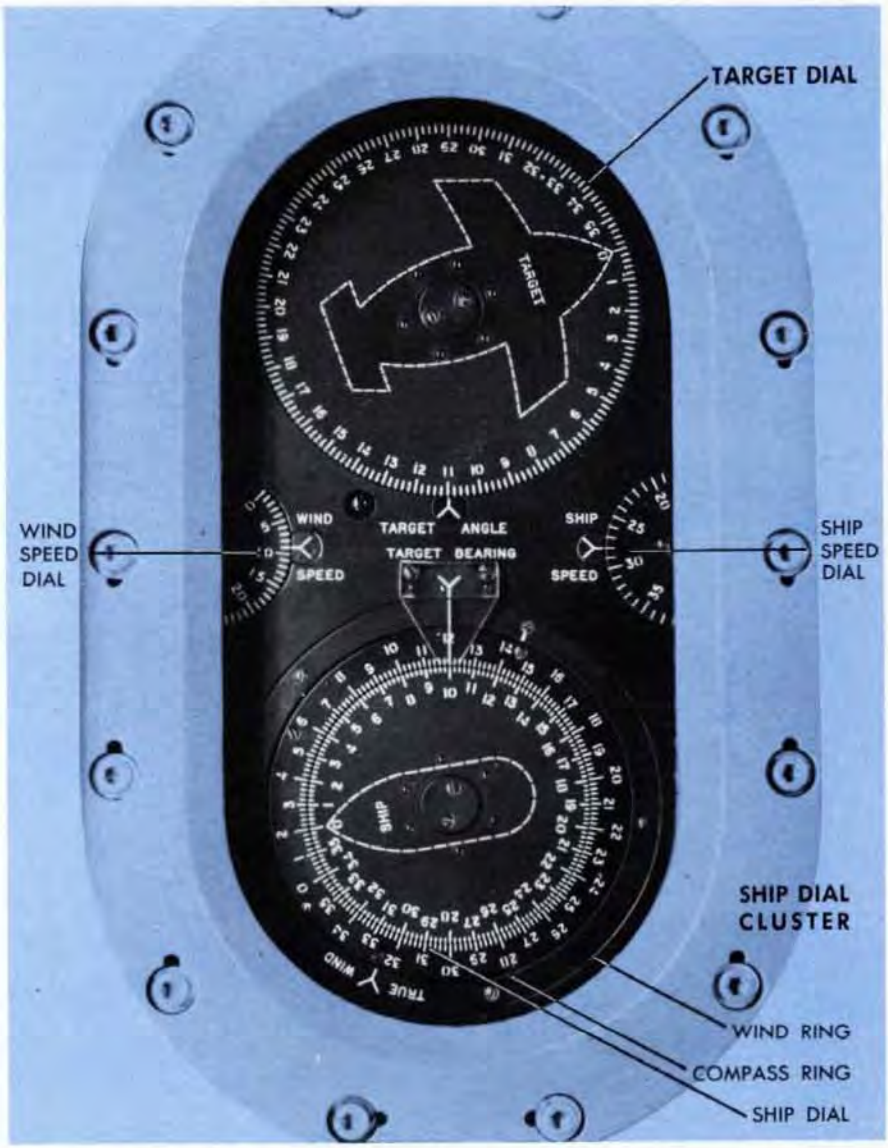
The TARGET and SHIP dial group



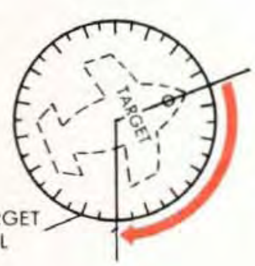
The Target and Ship Dial Group contains the Target Dial, the Ship Dial Cluster, the Wind Speed Dial, and the Ship Speed Dial.

The Target Dials and the dials in the Ship Dial Cluster indicate angles measured in the horizontal plane. A line drawn through the fixed indexes between the Target Dial and the Ship Dial Cluster represents the horizontal projection of the Line of Sight.





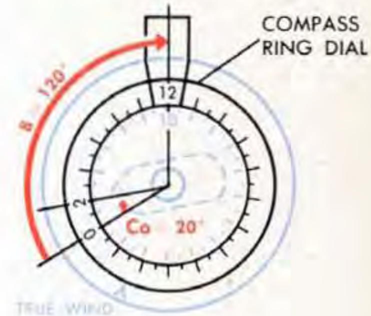
THE TARGET DIAL shows Target Angle, *A*. It is graduated every 2 degrees and numbered every 10 degrees from 0 to 360 degrees. One zero is omitted from each number to allow use of larger figures.



Target Angle is measured clockwise from the bow of the Target and is read at the fixed index representing the Line of Sight.

THE SHIP DIAL CLUSTER consists of three dials mounted one outside the other: the Ship Dial, the Compass Ring Dial, and the True Wind Ring Dial.

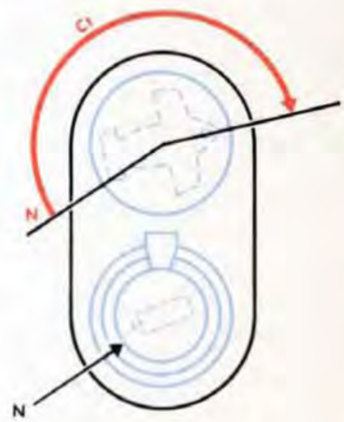
THE SHIP DIAL shows Relative Target Bearing, *Br*. *Br* is measured clockwise from the bow of the Ship and is read at the fixed index representing the Line of Sight.



THE COMPASS RING DIAL shows Ship Course, *Co*. The zero on this dial represents *North*. *Co* is measured clockwise from *North* and is read on the Compass Ring against the bow of the Ship. Changes in *Co* are recorded by movement of the Compass Dial around the Ship Dial.

The Compass Dial also shows True Target Bearing, *B*, the angle between *North* and the Line of Sight, measured clockwise from *North*. *B* is read on the Compass Ring against the fixed index. Both the Ship Dial and the Compass Ring are graduated every 2 degrees and numbered every 10 degrees from 0 to 360 degrees. The zeros are omitted to allow use of larger figures.

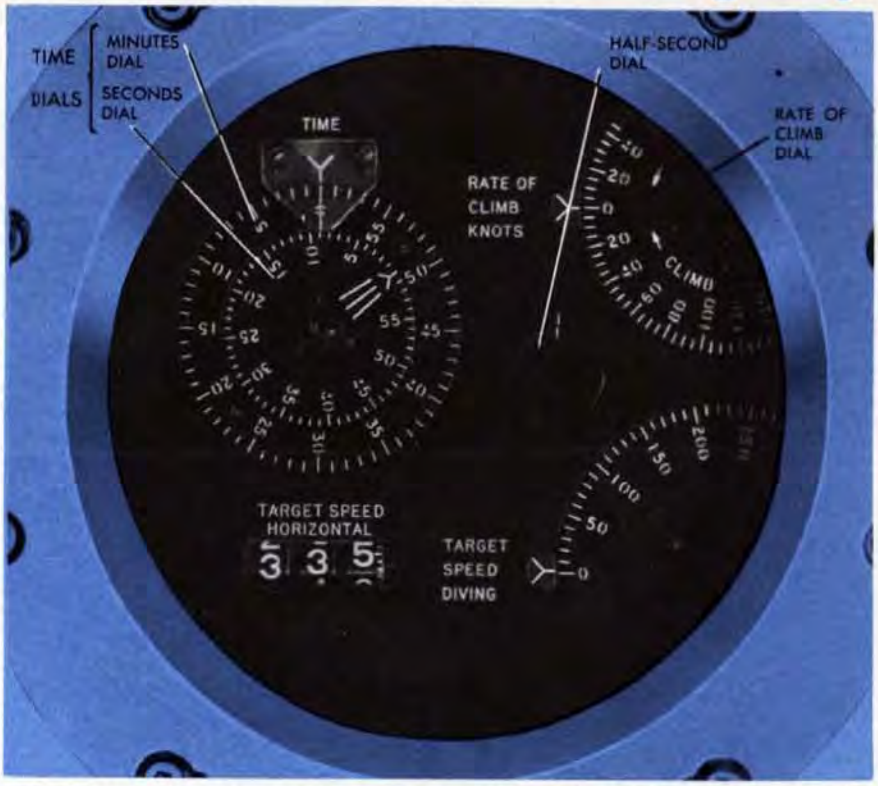
Target Course, *Ct*, is the angle measured clockwise from *North* to the bow of the Target. On the Target Dial it is possible to approximate *Ct* by observing the angle from *North*, as shown on the Compass Ring, clockwise to the bow of the Target. To obtain the exact value of *Ct*, read the value of *B* on the Compass Ring, add 180° and subtract the value of *A* as shown on the Target Dial. $Ct = B + 180° - A$.

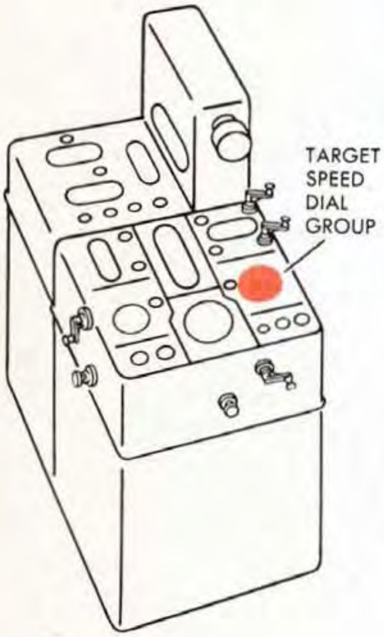


THE TRUE WIND RING DIAL has no graduations. Instead it has an index indicating the direction from which the wind is blowing. Wind Direction, *Bw*, is the angle between *North* and the direction from which the wind is blowing, measured clockwise from *North*. It is read on the Compass Ring against the True Wind Index. Wind Angle, *Bws*, is the angle between the direction from which the wind is blowing and the Line of Sight, measured clockwise on the Compass Ring from the True Wind Index to the fixed index. $Bws = B - Bw$.

The small dials on the Target and Ship Group show **WIND SPEED**, *Sw*, and **SHIP SPEED**, *So*. Each dial is read against its fixed index. The Wind Speed Dial is graduated from 0 to 60 knots, with numbers every 5 knots. The Ship Speed Dial is graduated from 0 to 45 knots, with numbers every 5 knots.

The TARGET SPEED dial group





The Target Speed Dial Group consists of the TARGET SPEED Counter, the TIME Dials, the RATE OF CLIMB Dial, and the TARGET SPEED DIVING Dial.

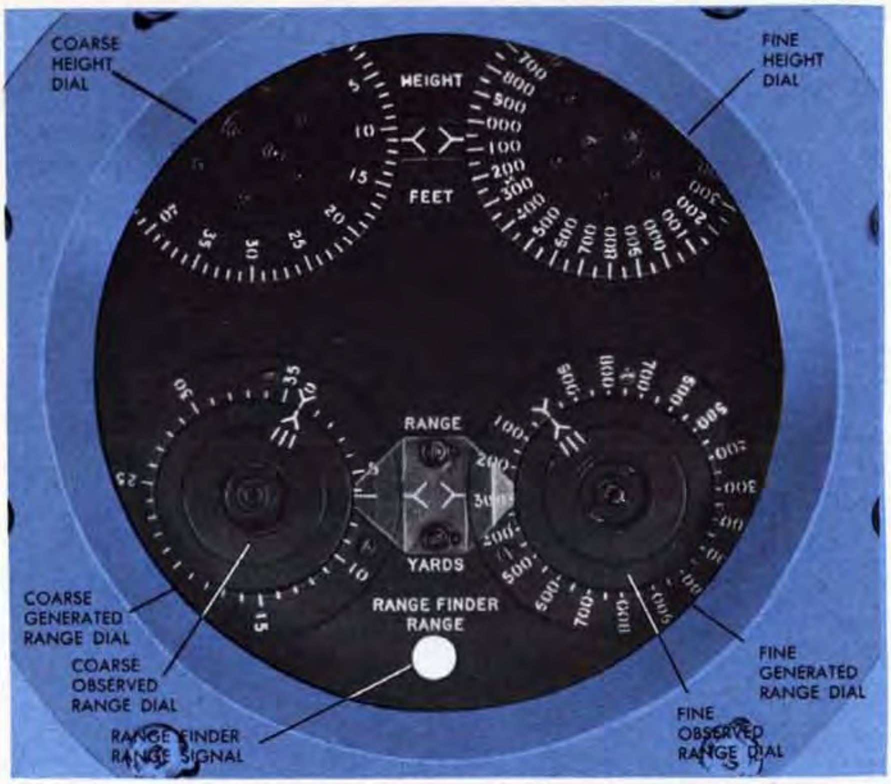
THE TARGET SPEED COUNTER shows Horizontal Ground Speed of Target, *Sh,* in knots, from 0 to 400 knots.

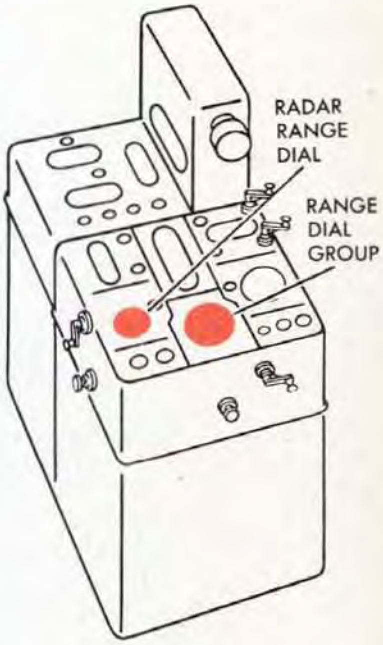
THE TIME DIALS are used principally in running tests. The ring dial is the Minutes Dial. It is graduated in minutes from 0 to 60, with numbers every 5 minutes. The inner dial is the Seconds Dial. It is graduated in seconds from 0 to 60, with numbers every 5 seconds. Both dials are read against the fixed index. The small dial is the Half-second Dial. It has one graduation and makes one revolution every half-second.

THE RATE OF CLIMB DIAL shows Rate of Climb, *dH,* in knots. It is graduated every 5 knots and numbered every 20 knots from 0 to CLIMB (plus) 150 knots, and from 0 to DIVE (minus) 250 knots.

THE TARGET SPEED DIVING DIAL is used only during certain dive attacks against Own Ship. It shows a substitute Range Rate, *dR,* for use when a special dive attack setup is ordered. This dial turns from minus 450 to plus 450 knots. It is graduated every 10 knots, numbered every 50 knots, and is read against the fixed index. To avoid confusion, only the DIVE (minus) side is graduated and numbered.

The RANGE dial group





The Range Dial Group contains the Generated and Observed Range Dials and the Height Dials. The coarse dials are on the left, and the fine dials are on the right.

GENERATED RANGE, *cR*, is shown on two ring dials, coarse and fine. The coarse *cR* Dial is graduated every 1,000 and numbered every 5,000 yards up to 35,000. Each dial has an index at its zero. The fine *cR* Dial is graduated every 50 and numbered every 100 yards. One revolution of the fine dial represents 2,000 yards. Each *cR* Dial is read against its fixed index.

OBSERVED RANGE, *R*, is indicated on two inner dials, coarse and fine. These inner dials have no graduations. When the indexes of the outer, *cR*, Range Dials are matched with the indexes on the inner, *R*, Range Dials, *R* equals *cR*. *R* can then be read indirectly by reading *cR* against the fixed index.

THE RANGE FINDER RANGE SIGNAL is in front of the Range Dials. A white signal appears here when the Range Operator in the Director presses his key to signal that Observed Range is correct. Otherwise this signal is black.

THE HEIGHT DIALS show the vertical height, *H*, of the Target. The coarse dial at the left is graduated every 1,000 feet and numbered every 5,000 feet up to 50,000. The fine dial is graduated every 50 feet and numbered every 100 feet. The Height Dials are read at their fixed indexes.

THE RADAR RANGE DIAL shows Radar Range. This dial is used chiefly to let the Range Operator follow the Radar tracking of a target before it comes within the operating limits of the Computer Tracking Section. The Radar Range Dial is graduated and numbered every 5,000 yards from 0 to 100,000 yards, and is read at the fixed index.

The BEARING dials

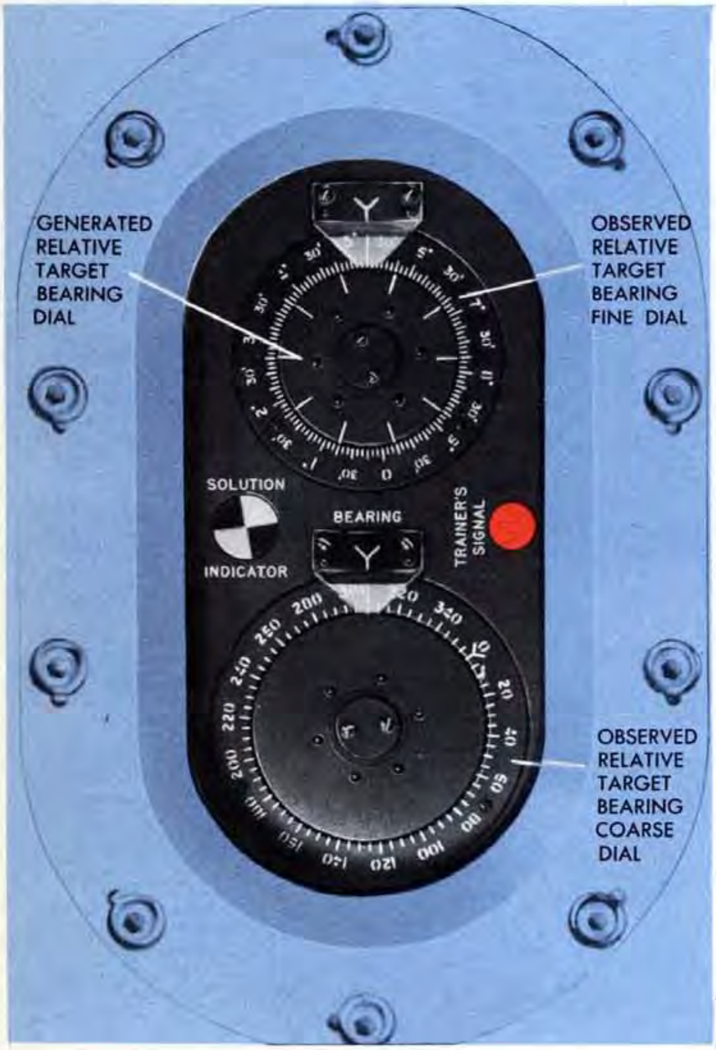
The Bearing Dials consist of a fine and a coarse ring dial, and an inner fine dial.

OBSERVED RELATIVE TARGET BEARING, *Br*, is shown on the two ring dials. Notice that the arrangement of the Bearing Dials is opposite to that of the Range Dials. In the Bearing Dial Group, the observed value is shown on the two *outer* dials. Generated Changes of Relative Target Bearing, △c*Br*, turn only the fine *inner* dial.

The coarse ring dial is graduated every 5 degrees and numbered every 20 degrees from 0 to 360 degrees.

The fine ring dial is graduated every 5 minutes and numbered every 30 minutes. One revolution represents 10 degrees.

Both ring dials are read at their fixed indexes.



THE GENERATED BEARING DIAL is not numbered but has ten equally spaced graduations. These graduations are used to show whether Generated Bearing is changing at the same RATE as Observed Bearing. When the inner and outer fine dials turn together, the Generated Bearing Rate is correct. The position of these graduations relative to the ring dial is immaterial.

THE TRAINER'S SIGNAL shows red when the Trainer in the Director has his signal key closed. Otherwise the signal is black.

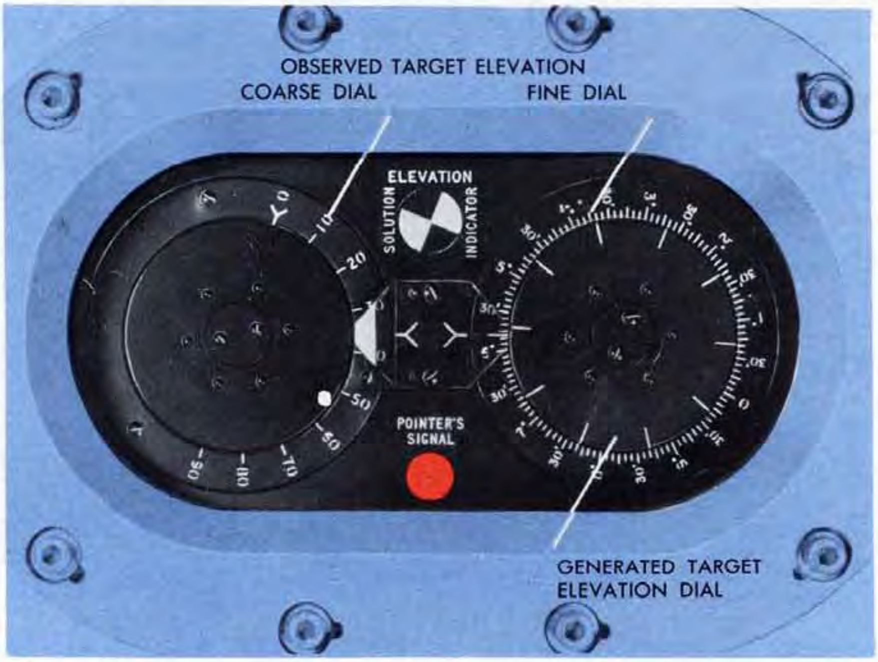
THE SOLUTION INDICATOR operates in Automatic Control only. It revolves when the Trainer in the Director is turning his handwheels.

If the Trainer's Signal shows red while the Solution Indicator turns, Bearing Rate Corrections are being put into the Rate Control Computing Mechanism automatically.

The ELEVATION dials

The Elevation Dials, like the Bearing Dials, consist of a fine and a coarse ring dial and a fine inner dial.

OBSERVED TARGET ELEVATION, *E* is shown on the two outer ring dials. Generated Changes of Target Elevation, $\triangle cE$, turn the fine inner dial.

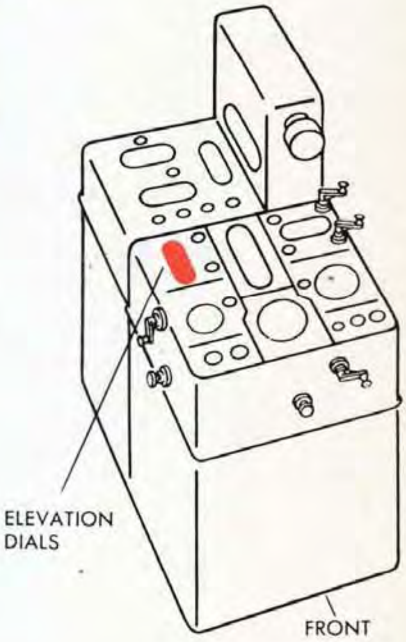


The coarse ring dial is graduated and numbered every 10 degrees, from 0 to 90 degrees.

The fine ring dial is graduated every 5 minutes and numbered every 30 minutes. One revolution of this dial represents 10 degrees.

Both ring dials are read at their fixed indexes.

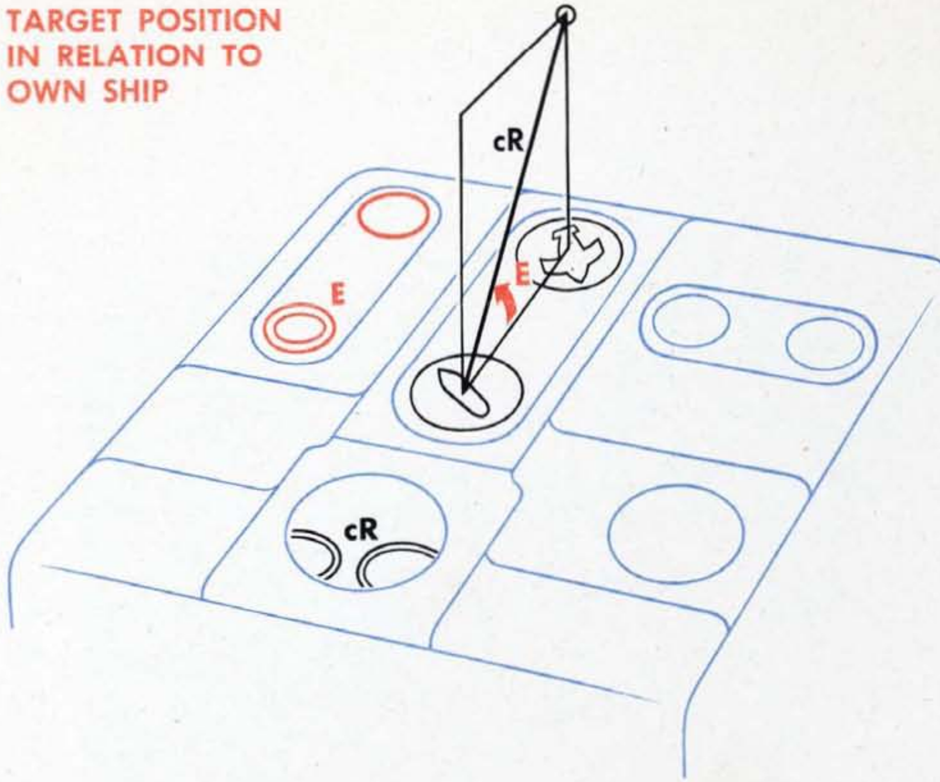
THE GENERATED ELEVATION DIAL has ten equally spaced graduations which are used to show whether Generated and Observed Elevation are changing at the same rate. The position of these graduations relative to the ring dial is immaterial.

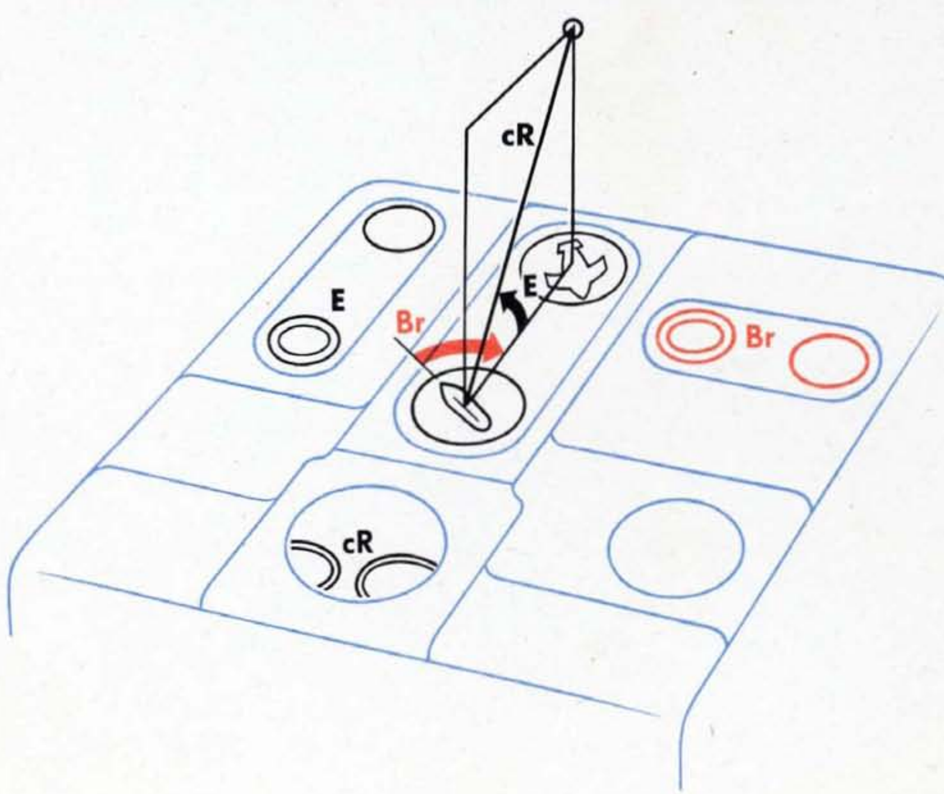


THE POINTER'S SIGNAL AND THE SOLUTION INDICATOR in the Elevation Dial Group work in exactly the same way as those in the Bearing Group.

The Pointer's Signal is red when the Pointer in the Director closes his key. Otherwise the signal is black. When the signal is red and the Solution Indicator turns, Elevation Rate Corrections are being put into the Rate Control Computing Mechanism automatically.

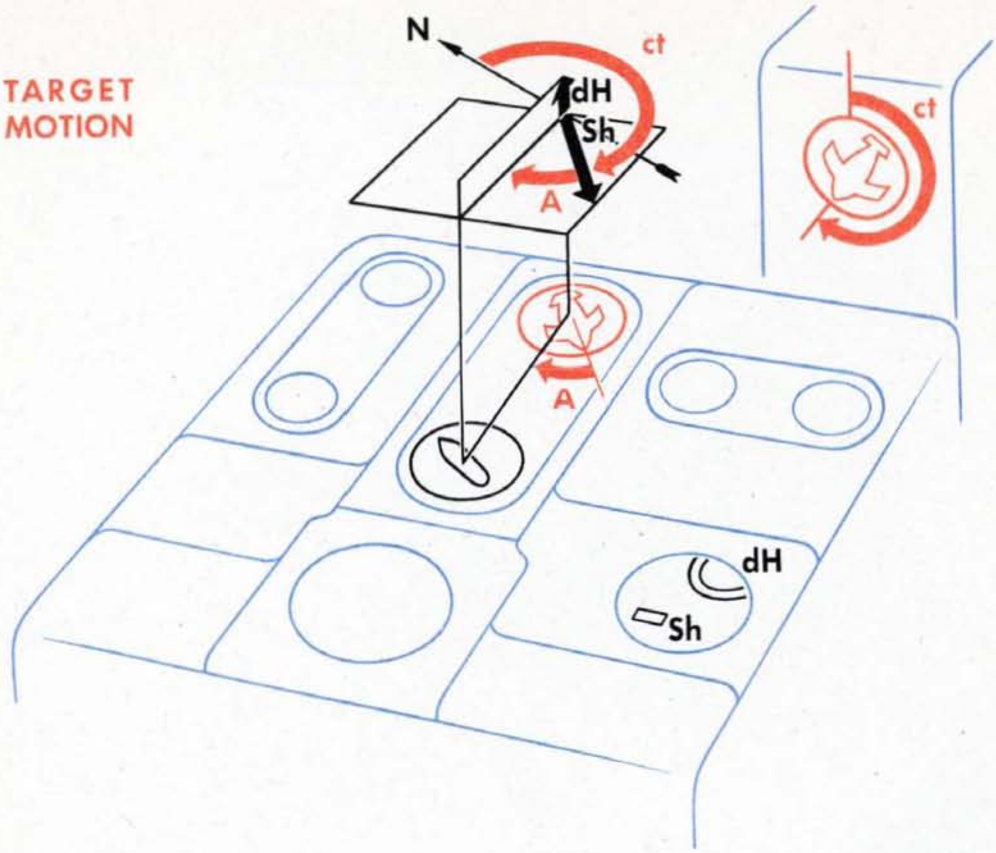
How the DIALS picture the



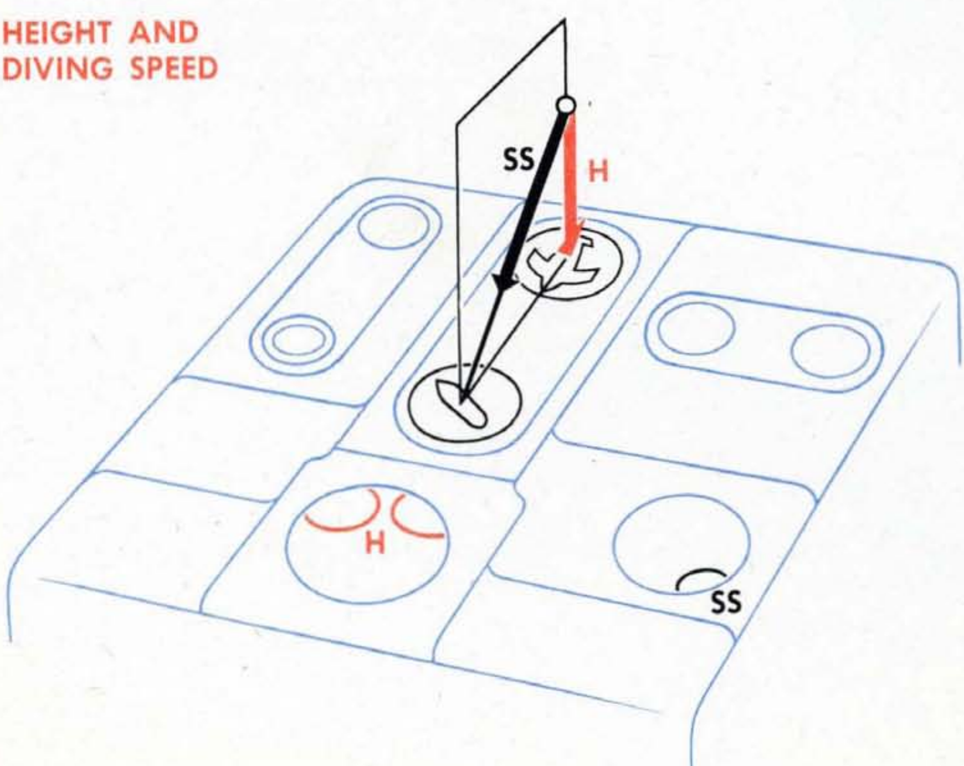


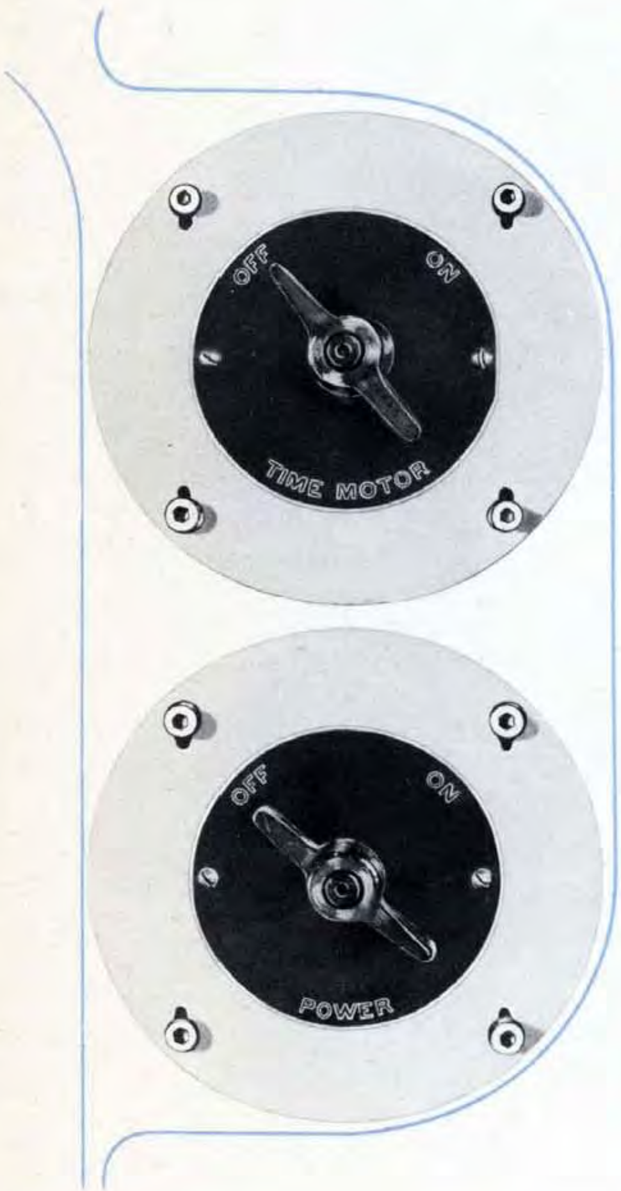
FIRE CONTROL PROBLEM

TARGET MOTION



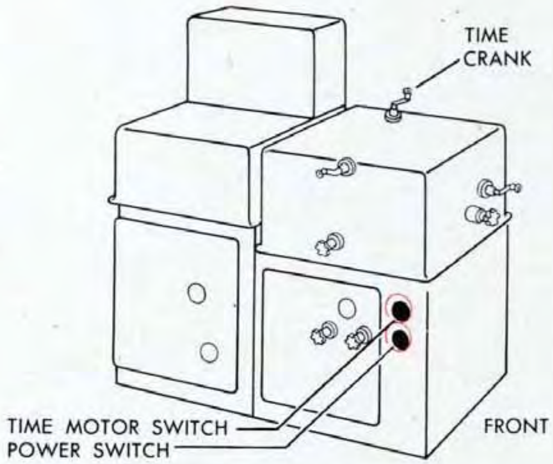
HEIGHT AND DIVING SPEED





The TIME MOTOR and POWER switches

The Time Motor and Power Switches are located on the lower left side of the Computer near the front. The station from which these switches are operated depends on ship's doctrine.



The TIME MOTOR SWITCH is the upper of the two switches. It has two positions: OFF and ON. Turning this switch to the ON position puts the Time Motor in operation when the Power Switch is ON.

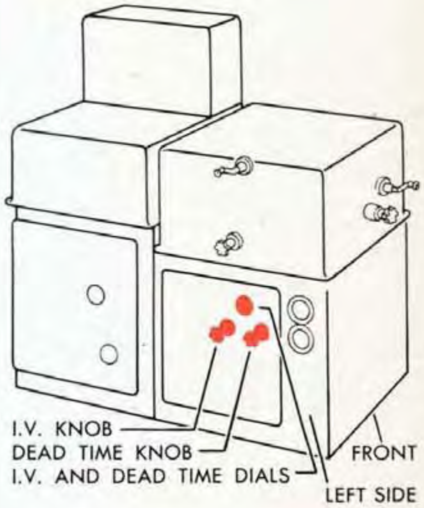
NOTE:
In the event that the Time Motor does not start, pull the Time Crank OUT and turn it clockwise.

The POWER SWITCH is the lower of the two switches. It has two positions: OFF and ON. Turning it to the ON position energizes the Computer.

CAUTION:
The Power Switch should be ON before any operating handcranks are turned.

INITIAL VELOCITY and DEAD TIME

The Initial Velocity and Dead Time Dials and Knobs are on the lower left side of the Computer, near the front and to the left of the Time Motor and Power Switches. The station from which these controls are operated depends on ship's doctrine.



The INITIAL VELOCITY DIAL shows Initial Velocity, *I.V.*, in feet per second. It is graduated every 5 feet per second and numbered every 50 feet per second from 2350 to 2600 feet per second. Making a setting of this dial puts into the Computer a correction for the difference between the *I.V.* which is ordered and 2550 feet per second. The *I.V.* shaft line is positioned by the Initial Velocity Knob.

The DEAD TIME DIAL shows Dead Time, Tg, the time in seconds between the setting of the fuze and the firing of the projectile. The dial is graduated from 0 to 6 seconds at half-second intervals. The Tg shaft line is positioned by the Dead Time Knob.

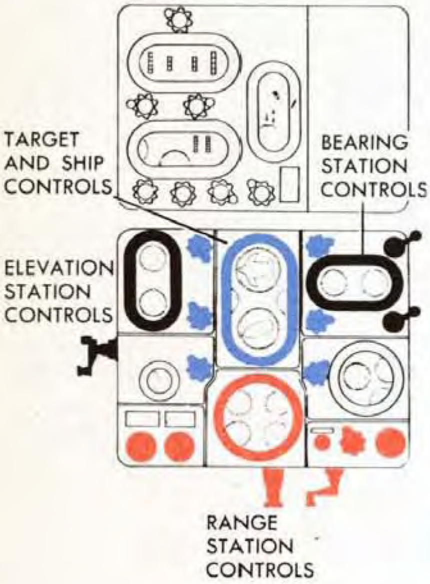
The INITIAL VELOCITY and DEAD TIME KNOBS each have two positions: IN and OUT. A pin holds each knob in the IN position. To make a setting to the dial, the pin must be lifted and the knob pulled OUT. When the knobs are released they spring back to their IN positions.

NOTE:

Set the Initial Velocity Dial at the computed Initial Velocity of the projectiles. For example, if the Initial Velocity for a given battery is determined to be 2590 feet per second, turn the Initial Velocity Knob until the Initial Velocity Dial reads 2590 at the fixed index.

Set the Initial Velocity Dial at 2550 only when the projectiles actually have this Initial Velocity, or when running tests and making settings which require Initial Velocity to be at this value.

THE CONTROLS ON THE FRONT OF THE COMPUTER MARK 1



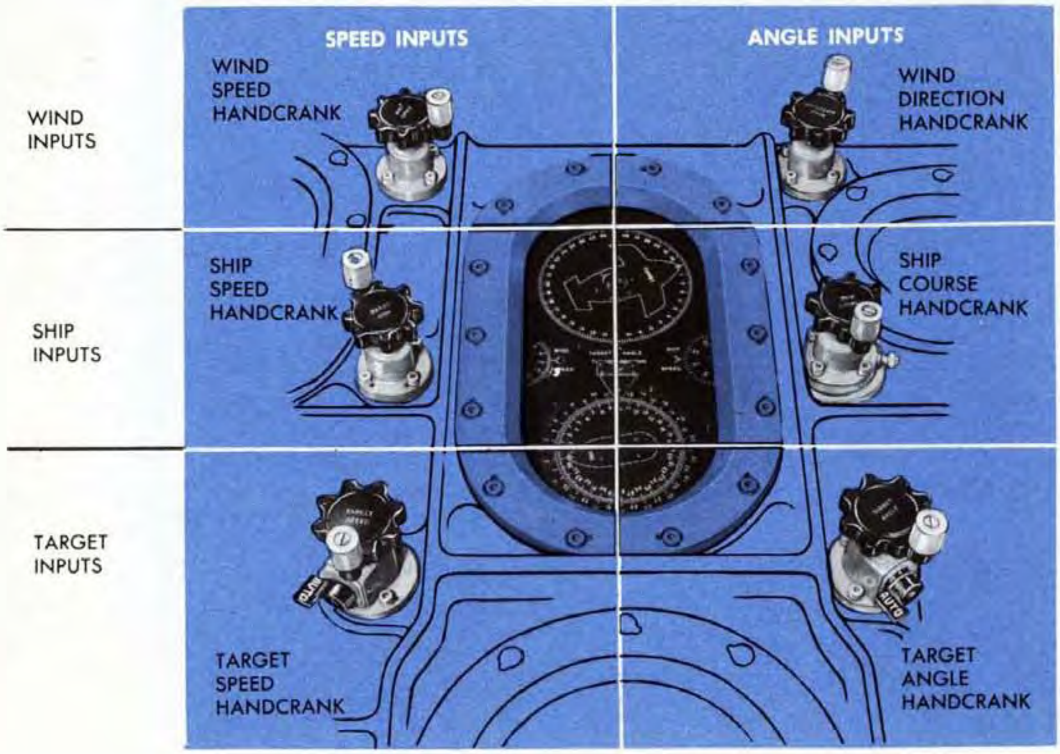
The simplest way to become familiar with the controls on the front of the Computer is to group them by operating stations.

The controls fall into four groups: the Target and Ship Dial Group Controls, the Range Station Controls, the Bearing Station Controls, and the Elevation Station Controls.

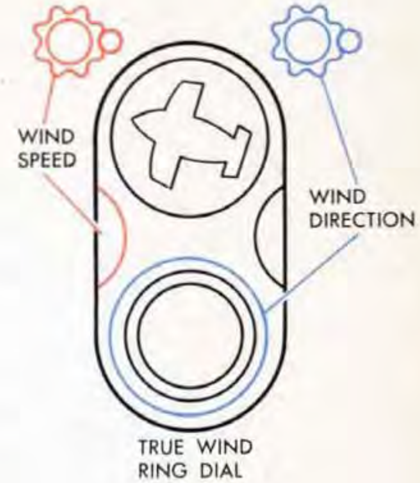
Operation of the controls in the Target and Ship Dial Group is divided among the operating stations according to ship's doctrine.

The controls in the target and ship group

There are six handcranks in this group. The three handcranks to the left of the dials are for SPEED INPUTS. Those on the right are for ANGLE INPUTS.



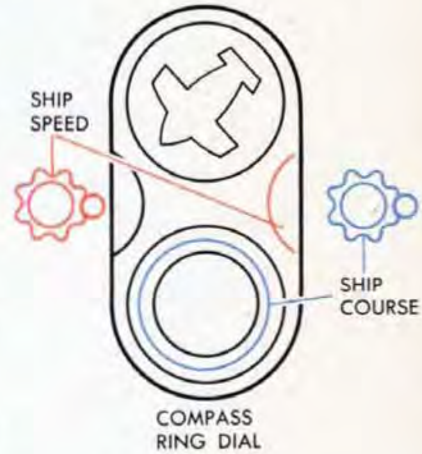
THE WIND SPEED HANDCRANK puts in values of Wind Speed, *Sw*, which show on the Wind Speed Dial.



THE WIND DIRECTION HANDCRANK puts in values of Wind Direction, *Bw*, which are read on the Wind Ring Dial.

Wind Speed and Wind Direction are always put in by hand, as ordered.

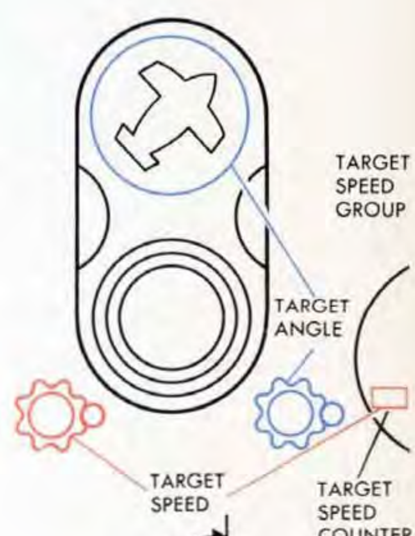
THE SHIP SPEED HANDCRANK has two positions: IN and OUT, with a pin to hold it in either position. When this handcrank is in the IN position, it puts in values of Ship Speed, *So*, which are read on the *So* Dial. When this handcrank is in the OUT position, the *So* Line and Dial are positioned automatically from the Pitometer Log through the Ship Speed Receiver.



When setting the Ship Speed Dial by hand, it is important to remember that 0 and 45 are at the same position on this dial.

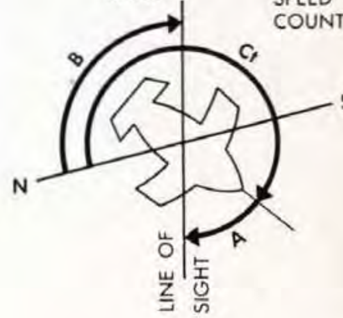
When Ship Speed is received by synchro transmission from the Pitometer Log, it is possible for the single-speed Ship Speed Receiver to be out of synchronism with the incoming signal. If the correct value does not appear on the dial, push the handcrank IN, set the dial by hand, and pull the handcrank OUT.

THE SHIP COURSE HANDCRANK has two positions: IN and OUT, with a pin to hold it in either position. When this handcrank is in the IN position, it puts in values of Ship Course, *Co*, which are read on the Compass Ring Dial. When this handcrank is in the OUT position, the *Co* Line and Dial are positioned automatically by the double-speed Ship Course Receiver which receives *Co* from the Gyro Compass.

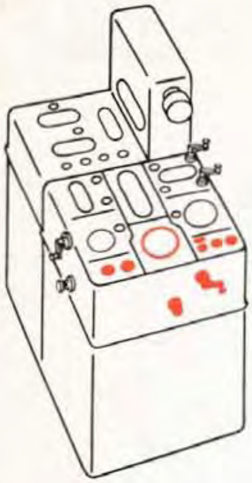


THE TARGET SPEED HANDCRANK puts in Target Horizontal Ground Speed, *Sh*, which shows on the Target Speed Counter in the Target Speed Dial Group.

THE TARGET ANGLE HANDCRANK positions the Target Course, *Ct*, shaft line and the Target Course Indicator Dial. *Ct* is subtracted from True Bearing, *B*, in the Computer, producing Target Angle, *A*, which appears on the Target Dial. $A = 180^\circ + B - Ct$.

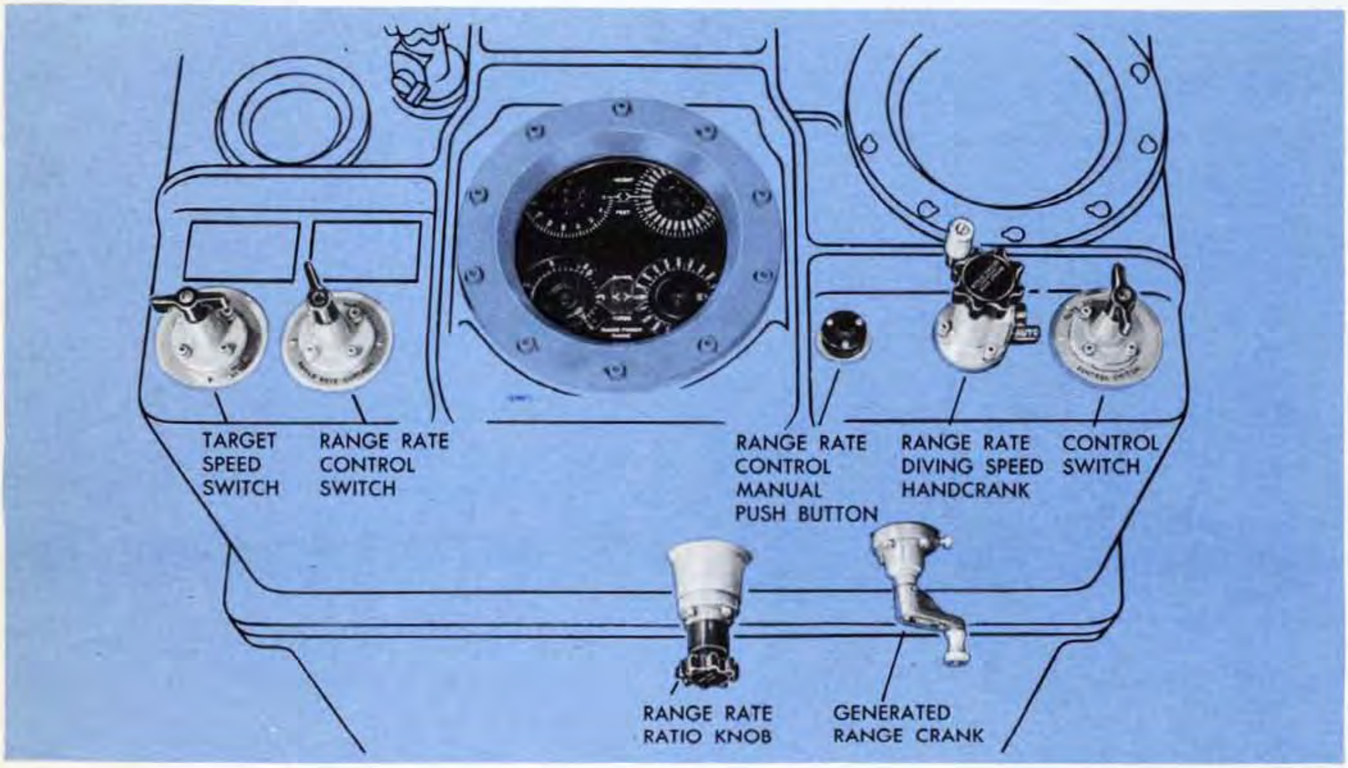


The Target Speed and Target Angle Handcranks have two positions: HAND and AUTO. Shift levers move them from one position to the other. With the levers at HAND position, these handcranks are connected to their shaft lines. With the levers at AUTO, the handcranks are disconnected, and the *Sh* and *Ct* shaft lines are positioned by the Rate Control Mechanism.



The controls at the range station

In addition to the dials, the controls at the Range Station include three switches: the Control Switch, the Range Rate Control Switch, and the Target Speed Switch. The controls also include the Generated Range Crank, the Range Rate Ratio Knob, the Range Rate/Diving Speed Handcrank, and the Range Rate Control Manual Push Button.

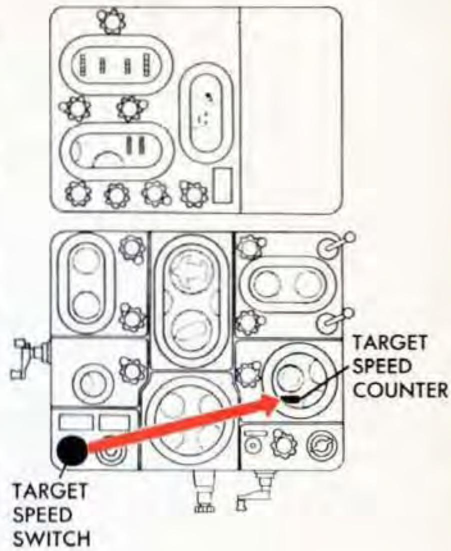


THE CONTROL SWITCH is on the right side of the top of the Computer near the front. This switch determines the method of rate-controlling Bearing and Elevation. The Control Switch has three positions: AUTO, SEMI-AUTO, and LOCAL.

With the Control Switch at AUTO, Bearing and Elevation Corrections are made automatically on signal from the Trainer and Pointer in the Director.

With the Control Switch at SEMI-AUTO, Bearing and Elevation Corrections are put into the Computer by the Computer Crew.

With the Control Switch at LOCAL, the Rate Control Mechanism is inoperative. This type of operation is used against surface targets when the Director is not operating.



THE TARGET SPEED SWITCH is connected to the Target Speed, *Sh*, Servo Motor. This switch has three positions: NORMAL, INCREASE, and DIVE ATTACK.

When the Target Speed Switch is at NORMAL, the *Sh* Follow-up controls the *Sh* Motor. This allows normal operation of the Rate Control Mechanism.

When the Target Speed Switch is at INCREASE, the "increase" side of the *Sh* Servo Motor is energized. This causes the *Sh* shaft line and counter to turn rapidly in an increasing direction. The switch has to be held at INCREASE since it springs back to NORMAL when released.

When the Target Speed Switch is at DIVE ATTACK, the "decrease" side of the *Sh* Servo Motor is energized. This causes the value on the Target Speed shaft line to decrease rapidly, running the Target Speed counter to zero. The switch stays at DIVE ATTACK until moved to another position.

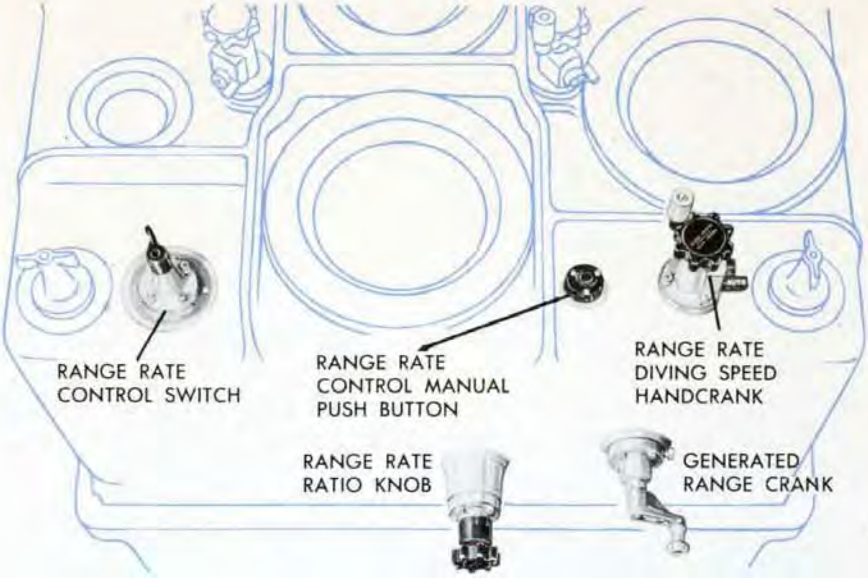
The Target Speed Switch functions only when the Target Speed and Target Angle Handcranks are at AUTO.

THE RANGE RATE CONTROL SWITCH is at the left side of the Computer, near the front. It has a one-wing handle. This switch controls the method by which Range Rate Corrections are put into the Rate Control Mechanism. The switch has two positions: AUTO and MANUAL.

With the Range Rate Control Switch at AUTO, Range and Range Rate Corrections are put in automatically on signal from the Range Operator in the Director or the Radar Operator.

With the Range Rate Control Switch at MANUAL, these corrections are put in bv a member of the Computer Crew.

The position of the Range Rate Control Switch is independent of the position of the Control Switch. RANGE MAY BE RATE-CONTROLLED EITHER AUTOMATICALLY OR SEMI-AUTOMATICALLY DURING AUTOMATIC OR SEMI-AUTOMATIC RATE CONTROL OF ELEVATION AND BEARING.

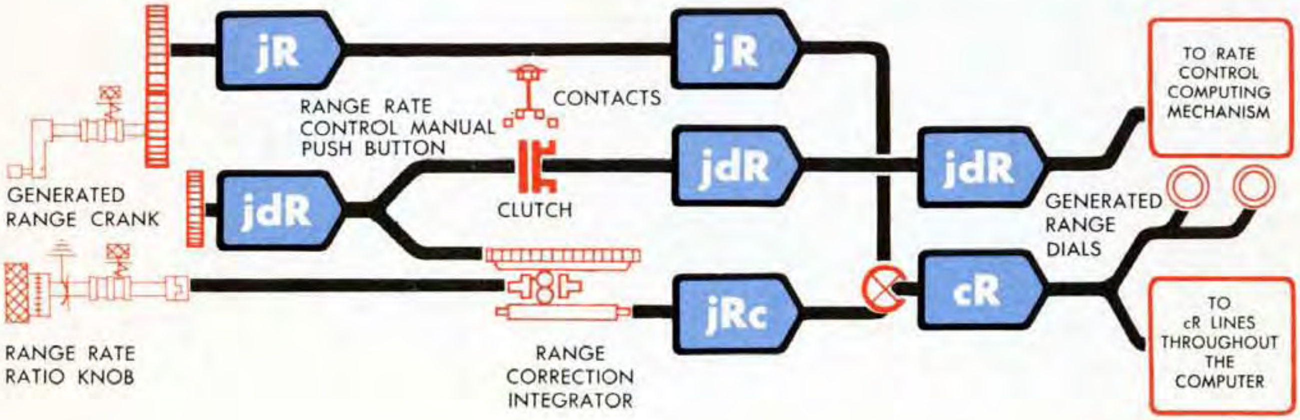


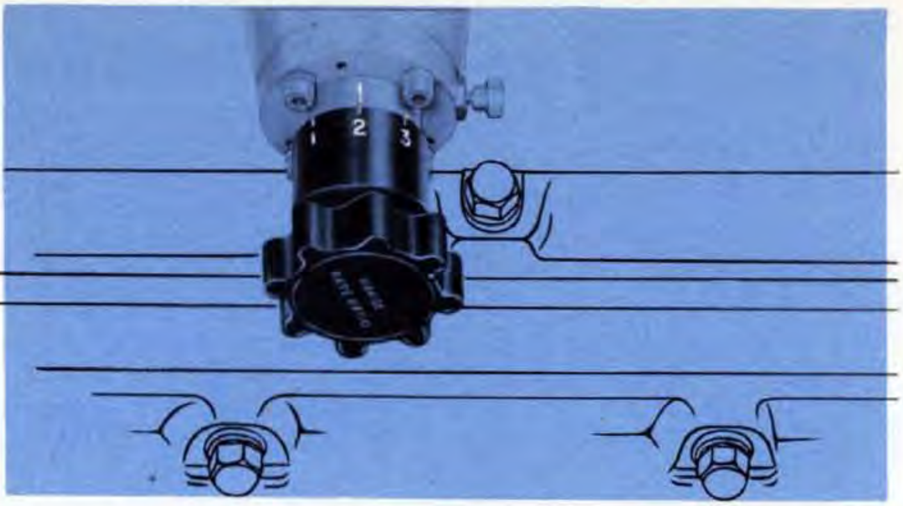
THE GENERATED RANGE CRANK turns the Generated Range line. It has two positions, IN and OUT, with a pin to hold it in the OUT position.

When the Range Rate Control Switch is at AUTO, Range Rate Control is handled automatically on signal from the Range Operator in the Director. The Generated Range Crank must be in its OUT position.

When the Range Rate Control Switch is at MANUAL, Range Rate Control is handled through the Generated Range Crank. In its OUT position the crank puts in linear Range Correction, *jR*, to match the indexes on the Generated Range Dials to the indexes on the Observed Range Dials. In its IN position the Generated Range Crank can make two kinds of corrections. It puts in linear Range Correction, *jRc*, to match *cR* to *R*, and if the Range Rate Control Manual Push Button is depressed, it also puts Range Rate Correction, *jdR*, into the Rate Control Computing Mechanism.

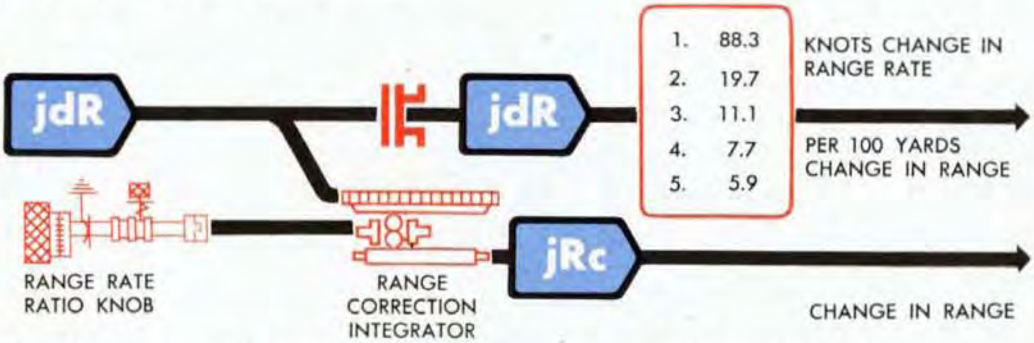
THE RANGE RATE CONTROL MANUAL PUSH BUTTON is located above the Generated Range Crank. When the Range Rate Control Switch is at MANUAL, pressing this push button closes a solenoid clutch which allows Range Rate Corrections to drive into the Rate Control Computing Mechanism.





THE RANGE RATE RATIO KNOB positions the carriage of the Range Correction Integrator. This integrator controls the ratio between linear Range Correction and the Range Rate Correction put into the Rate Control Computing Mechanism during Range Rate Control.

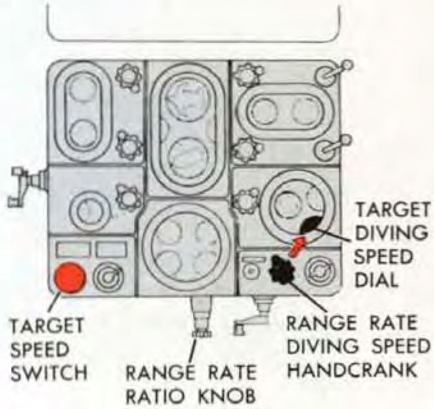
The sleeve of the Range Rate Ratio Knob is calibrated from 1 to 5. The largest Range Rate Correction for each linear Range Correction is made with the knob set at 1. As the knob is turned toward 5, the Range Rate Correction for each linear Range Correction becomes smaller. With the knob set at 1, a few revolutions of the Generated Range line will put in a large amount of Range Rate Correction. With the knob set at 5, an equal number of revolutions of the line results in a much smaller amount of Rate Correction.



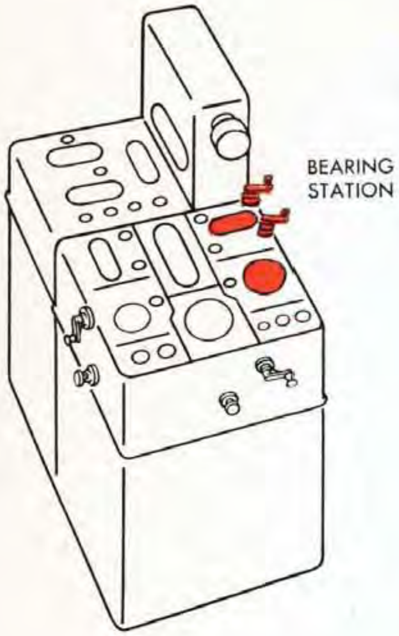
The Range Rate Ratio Knob has two positions: IN and OUT. It is always operated in the IN position. The OUT position is provided only to permit removal of the cover of the Computer for adjustment or repair.

The RANGE RATE DIVING SPEED HANDCRANK has two positions: HAND and AUTO. At HAND it positions the Target Diving Speed Dial and the *dR* shaft line .When this handcrank is at AUTO, it is disengaged, and the *dR* shaft line is positioned automatically by *dR* from the Relative Motion Group.

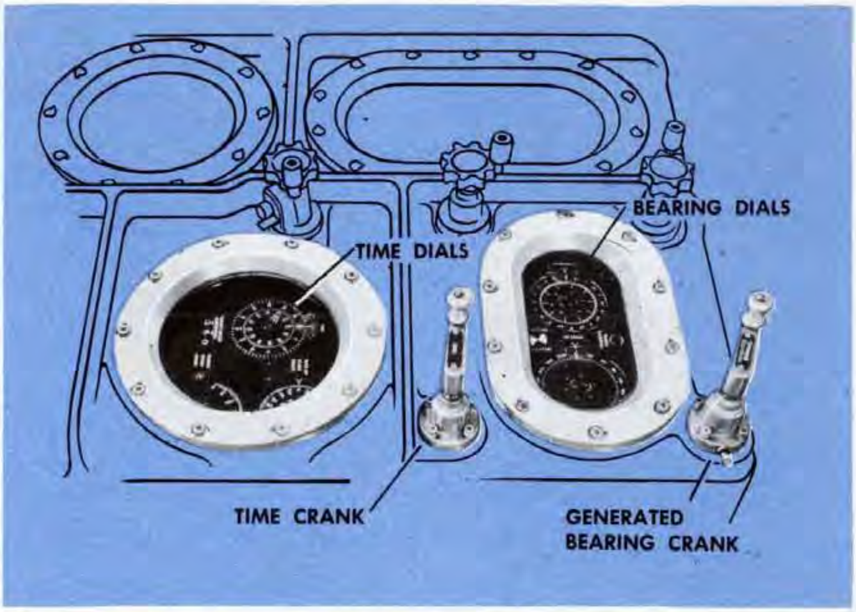
The Range Rate/Diving Speed Handcrank is used only when a DIVE ATTACK order is given and when the Target Speed Switch is at DIVE ATTACK. This handcrank must never be used when the Target is diving at other ships.

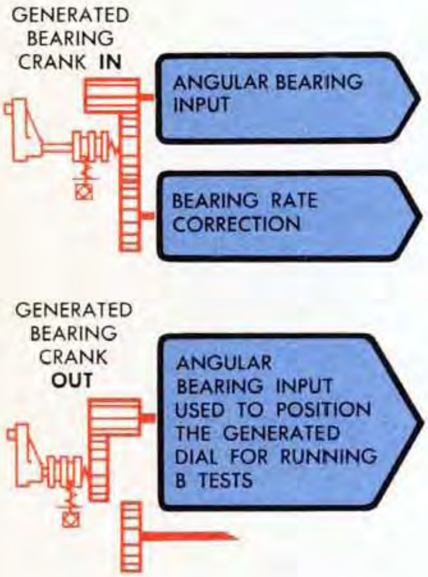


The controls at the bearing station



The controls at the Bearing Station consist of the Generated Bearing Crank and the Time Crank.





THE GENERATED BEARING CRANK has two positions: IN and OUT, with a pin to hold it in the OUT position.

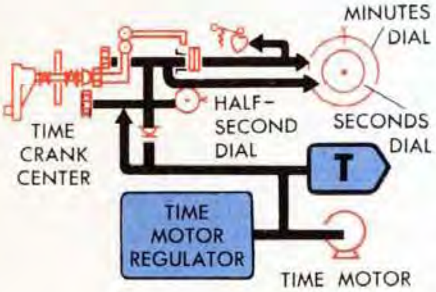
In Automatic Control, Bearing Rate Control is handled automatically on signal from the Trainer in the Director. The Generated Bearing Crank must be in its OUT position.

In Semi-automatic Control, the Generated Bearing Crank is put in its IN position to make Bearing Rate Control Corrections.

In its IN position, the Generated Bearing Crank puts in both angular inputs to Generated Bearing and *Bearing Rate Corrections* to keep the Generated Bearing Dial rotating at the same speed and in the same direction as the Observed Bearing Dial.

In its OUT position, the crank can be used to position the Generated Bearing Dial for running B Tests.

In Local Control, the Generated Bearing Crank in its OUT position is used to set the Relative Target Bearing Ring Dials to read the initial value of Generated Relative Target Bearing. Subsequent corrections to Generated Relative Target Bearing can also be introduced with this crank.

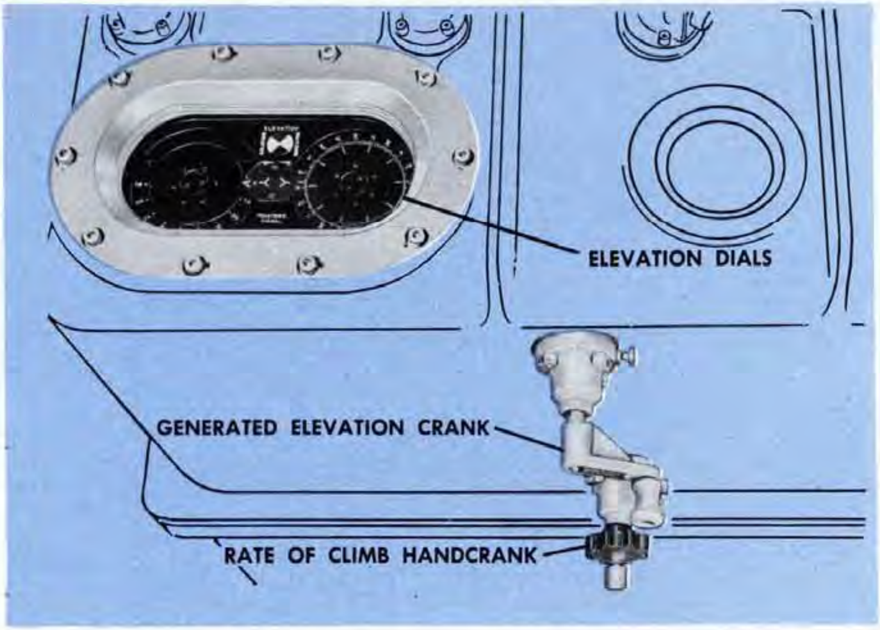


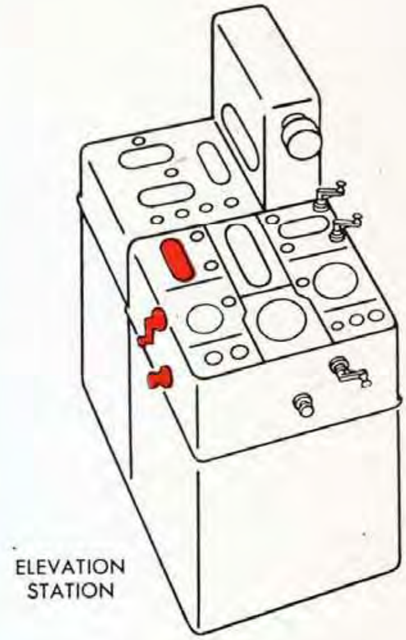
THE TIME CRANK has three positions: IN, CENTER, and OUT. It has to be held in the IN or OUT position, since it springs to CENTER when released. It is normally in the CENTER position, allowing the Time shaft line and dials to be positioned by the Time Motor. When the Time Crank is pushed IN, it zeros the Minute ring of the Time Dials. When turned in the IN position, this crank turns the Seconds Dial.

In its OUT position, the Time Crank is connected to the Time shafting. With the Time Motor Switch OFF, the Time shaft line may be rotated by the Time Crank for test purposes.

The controls at the elevation station

The controls at the Elevation Station consist of the Generated Elevation Crank and the Rate of Climb Handcrank.



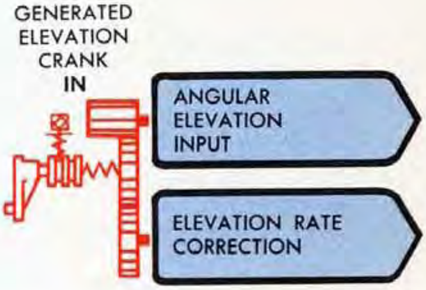


THE GENERATED ELEVATION CRANK has two positions: IN and OUT, with a pin to hold it in the OUT position.

In Automatic Control, Elevation Rate Control is handled automatically on signal from the Pointer in the Director. The Generated Elevation Crank must be in its OUT position.

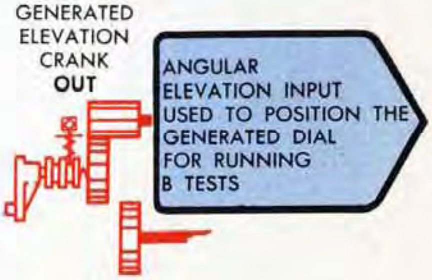
In Semi-automatic Control, Elevation Rate Control Corrections are put in through the Generated Elevation Crank. The Generated Elevation Crank must be in its IN position.

In its IN position the Generated Elevation Crank puts in both angular inputs to Generated Elevation and Elevation Rate Corrections, to keep the Generated Elevation Dial rotating at the same speed and in the same direction as the Observed Elevation Dial.



In its OUT position the crank can be used to position the Generated Elevation Dial for running B Tests.

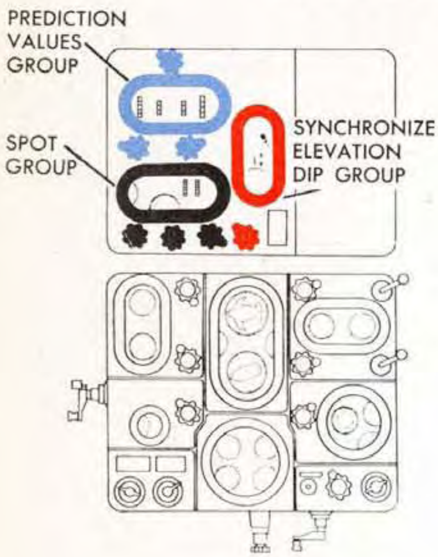
In Local Control, the Generated Elevation Crank is pulled OUT, since it is not used.



THE RATE OF CLIMB HANDCRANK is located below the Generated Elevation Crank. It has two positions: IN and OUT. In its IN position, it sets values of Rate of Climb, *dH*, into the Rate of Climb shaft line. The value on this shaft line can be read on the Rate of Climb Dial in the Target Speed Group.

When the Rate of Climb Handcrank is OUT, it is disconnected and the Rate Control Mechanism positions the *dH* shaft line automatically.

HANDCRANKS and DIALS on the REAR TOP of the COMPUTER

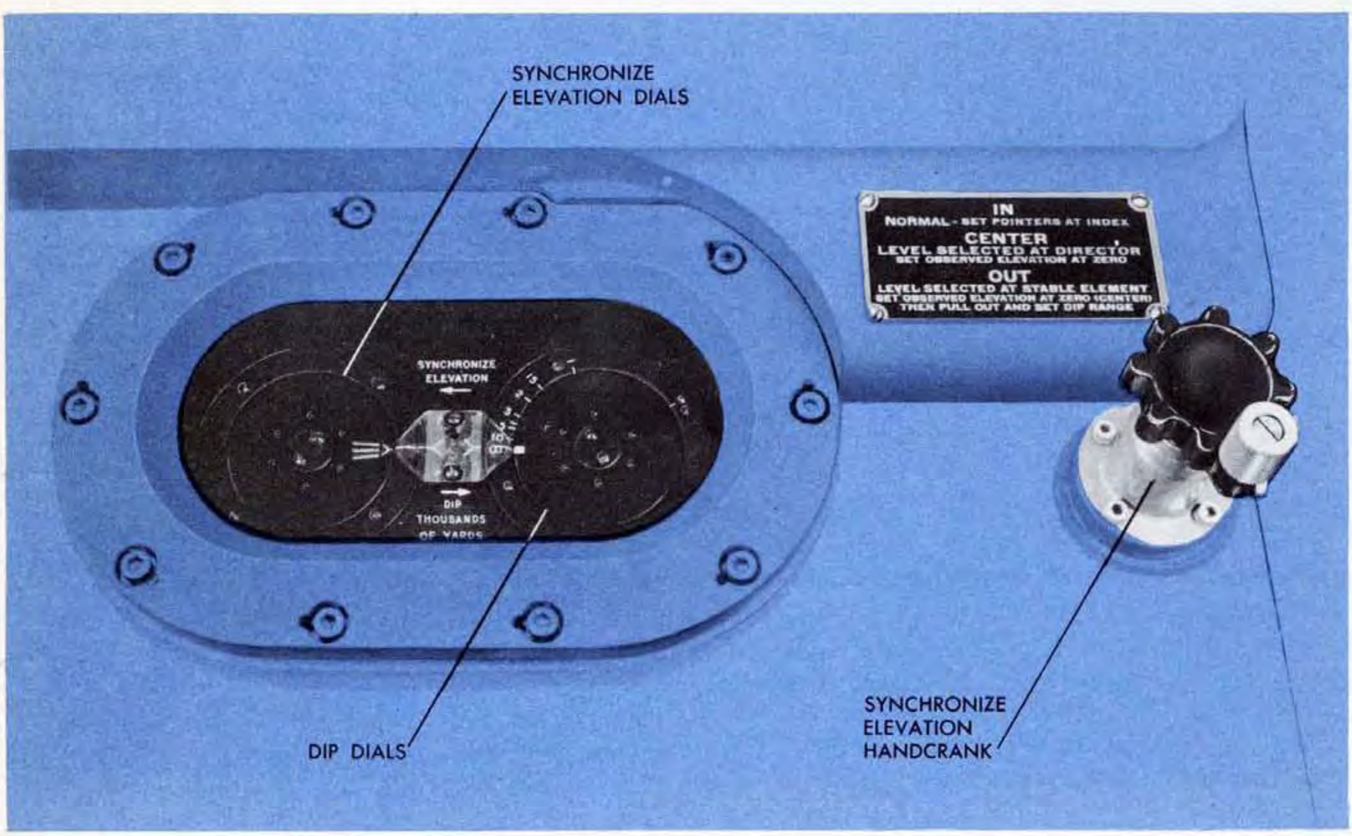


The rear top of the Computer Mark 1 is divided into three control groups:

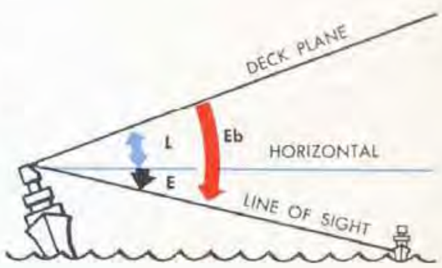
The Synchronize Elevation and Dip Group
The Spot Group
The Prediction Values Group

The synchronize elevation and dip dial group

This group consists of the Synchronize Elevation and Dip Dials and the Synchronize Elevation Handcrank.



THE SYNCHRONIZE ELEVATION DIALS consist of an inner dial and a ring dial. The index on the ring dial is a broken line. The index on the inner dial is an arrow. These markings are matched at the fixed index for Continuous Aim.

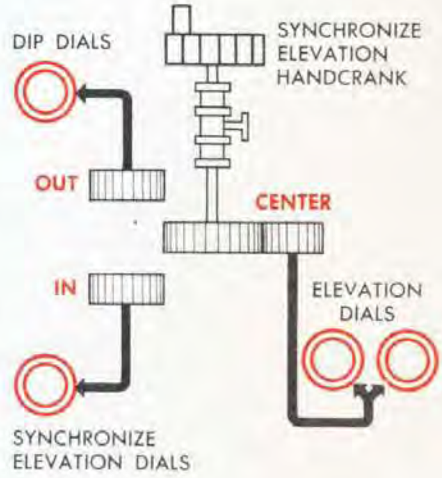


THE DIP DIALS consist of an inner dial with a wide index mark, and an outer ring with uneven graduations and numbers from 0.5 to infinity. The graduations on the outer dial represent thousands of yards of Range. The Dip Dials are used to obtain a substitute value for Target Elevation, *E*, when the Computer is operated without the Director. This substitute *E* is combined with Level Angle, *L*, to obtain a substitute value of Director Elevation, *Eb*, a value normally received from the Director.

THE SYNCHRONIZE ELEVATION HANDCRANK has three positions: IN, CENTER, and OUT, with a pin to lock it in each position.

In the IN position, the handcrank is connected to the Synchronize Elevation Dials. In preparing for Continuous Aim, this handcrank is turned in the IN position to match the Synchronize Elevation Dials at their fixed index.

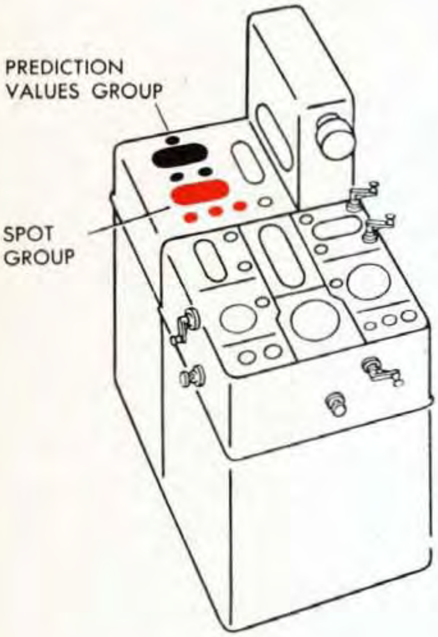
In the CENTER position, the Synchronize Elevation Handcrank is connected to the Observed Elevation shaft line and the Elevation Dials on the front of the Computer. When the Computer is being set up for Selected Level Fire, with Level Angle selected at the Director, against a surface target, this handcrank is turned in the CENTER position to zero the Elevation Dials. It should be left in the CENTER position.



In the OUT position the Synchronize Elevation Handcrank is connected to the Dip Dials. When the Computer is being set up to fire against a surface target without the Director Elevation input, that is, in Indirect Fire from the Stable Element, this handcrank is turned in the OUT position to put in a Dip value. The Dip value is set by matching the index on the inner Dip Dial to the fixed index and then setting the value of Advance Range on the ring dial to the same fixed index. Dip is set in after the Elevation Dials have been zeroed with the handcrank in the CENTER position. The graduations on the Dip Dial actually represent thousands of yards of Present Range. Advance Range is used to set the dials, however, because it is easily read on the adjacent *R2* Counter and is sufficiently accurate for this purpose.

When the handcrank is in the IN position, ignore any motion of the Dip Dials. When the handcrank is in the CENTER position, ignore any motion of both the Dip Dials and the Synchronize Elevation Dials. When the handcrank is in the OUT position, ignore any motion of the Synchronize Elevation Dials.

The spot group



The Spot Group consists of two Range Spot Counters, the Elevation Spot Dial, the Deflection Spot Dial, the Range Spot Handcrank, the Elevation Spot Knob, and the Deflection Spot Knob.

THE TWO RANGE SPOT COUNTERS show Range Spot, *Rj*, in yards. The upper counter reads from zero to 1,800 OUT. The lower counter reads from zero to 12,000 IN. One counter is always masked while the other shows a value of Range Spot. Both counters are uncovered at the zero position.

THE ELEVATION SPOT DIAL shows Elevation Spot, *Vj*, in mils from DOWN 180 mils to UP 180 mils. The dial is graduated every 5 mils, numbered every 20 mils, and read against its fixed index.

THE DEFLECTION SPOT DIAL shows Deflection Spot, *Dj*, in mils from RIGHT 180 mils to LEFT 180 mils. The dial is graduated every 5 mils, numbered every 20 mils, and read against its fixed index.

THE RANGE SPOT HANDCRANK puts Range Spot, *Rj*, into the Range Spot Counters and the *Rj* shaft line.

THE ELEVATION SPOT KNOB puts Elevation Spot, *Vj*, into the Elevation Spot Dial and the *Vj* shaft line.

THE DEFLECTION SPOT KNOB puts Deflection Spot, *Dj*, into the Deflection Spot Dial and the *Dj* shaft line.

The two knobs and the handcrank each have two positions: IN and OUT, with pins to hold them in either position. To introduce a spot manually, the knobs and handcrank must be in their IN positions. For automatic reception of spots from the Director, the knobs and handcrank must be OUT.

CAUTION:
The *Rj*, *Vj*, and *Dj* Receivers can get out of synchronism with the incoming signals. To prevent this, see that the Spot Dials indicate the correct value of the spot before pulling the handcranks OUT.

The prediction values group

The Prediction Values Group consists of the Sight Angle Counter and Handcrank, the Sight Deflection Counter and Handcrank, the Fuze Counter and Handcrank, and the Advance Range Counter.

THE SIGHT ANGLE COUNTER shows the computed value of Sight Angle, *Vs*, in minutes, with 2,000 minutes as the zero value.

THE SIGHT DEFLECTION COUNTER shows the computed value of Sight Deflection, *Ds*, in mils, with 500 mils as the zero value.

THE FUZE COUNTER shows the computed value of Fuze Setting Order, *F*, in seconds.

THE ADVANCE RANGE COUNTER shows the computed value of Advance Range, *R2*, in yards. There is no *R2* handcrank.

The handcranks in this group have two positions: IN and OUT, and each has a pin to hold it in either position.

THE SIGHT ANGLE HANDCRANK in its IN position is connected to the *Vs* shaft line and counter. When this knob is OUT, the *Vs* line is positioned by the Prediction Section of the Computer.

THE SIGHT DEFLECTION HANDCRANK in its IN position is connected to the *Ds* shaft line and counter. When this knob is OUT, the *Ds* line is positioned by the Prediction Section of the Computer.

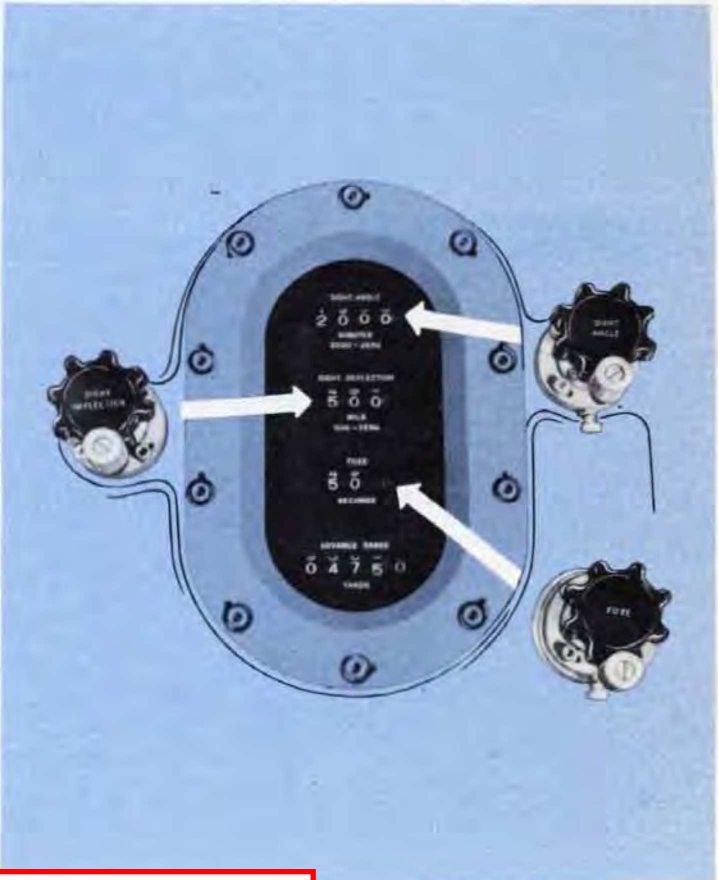
THE FUZE HANDCRANK in its IN position is connected to the *F* shaft line and counter. When this knob is OUT, the *F* line is positioned by the Prediction Section of the Computer.

If some of the power circuits should fail leaving the Sight Angle, Sight Deflection, and Fuze Transmitters energized, these transmitters can be set by hand through the handcranks to send values of *Vs*, *Ds* and *F* to the guns.

When no Star Shell Computer is supplied, the Fuze and Sight Angle Handcranks can be used in transmitting these values to the gun firing the star shells. The values to be used are obtained from a Star Shell Legend Plate.

THE FUZE COUNTER

Read the white figures to obtain the number of whole seconds. Read the red figure and graduations to obtain the tenths of a second. Only the numbers 0 and 5 appear on the tenth-seconds drum. Hundredths of a second can be approximated by observing the relation of the tenth-seconds graduations to the fixed index. The counter reading above is 14.65 seconds.



THE TARGET COURSE INDICATOR

The Target Course Indicator is mounted on the Star Shell Computer. It has a Target Course Dial, an INCREASE Button, and a DECREASE Button.

THE TARGET COURSE DIAL shows Target Course, *Ct*, which is the horizontal angle between *North* and the bow of the Target, measured clockwise from *North*.

An index plate around the dial is graduated in degrees from 0°, which represents *North*, to 360°, with graduations every 2 degrees and numbers every 10 degrees. Zeros are omitted so that the figures can be read more easily.

The dial has an airplane engraved on it. The bow of the Target is read against the index plate.

The dial is positioned by synchro transmission from the *Ct* Transmitter in the Computer.

TARGET AND SHIP GROUP

THE INCREASE AND DECREASE BUTTONS

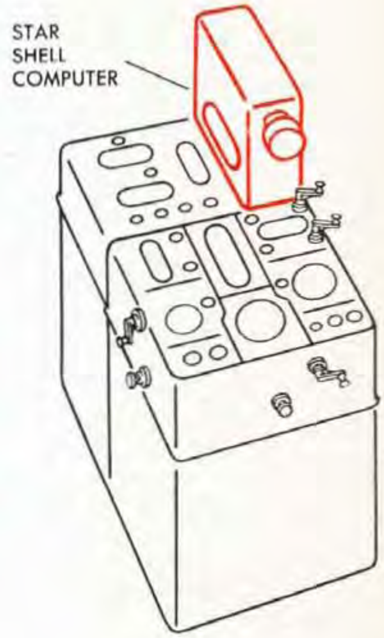
The *Ct* shaft line in the Computer may also be positioned manually by the push buttons on the Target Course Indicator. When the DECREASE Button is pressed, the value of *Ct* in the Computer decreases; when the INCREASE Button is pressed, the value of *Ct* in the Computer increases. The Target Course Indicator Dial shows the value of *Ct* in the Computer at all times. To make inputs at the Target Course Indicator, the Target Angle *and* Target Speed Handcranks must be positioned at AUTO.

THE TARGET SIGNAL LIGHT

On early modifications of the Computer Mark 1 there was a red signal light below the Target Dial. This signal light was ON only when a change in Target Angle was being put into the Computer through the Target Angle Repeater in the Director. This signal has been eliminated from later modifications of the Computer Mark 1.

THE STAR SHELL COMPUTER

The controls on the Star Shell Computer consist of the Star Shell Range Counter, the Star Shell Range Spot Dials and Knob, and the Star Shell Range Dials and Knob.

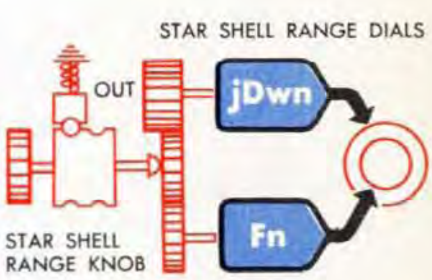


THE STAR SHELL RANGE COUNTER shows Star Shell Range, *R2n*. The reading of this counter, except as it may be modified by Star Shell Range Spot, *Rjn*, is 1000 yards higher than Advance Range, *R2*, which it receives from the Prediction Section of the Computer Mark 1. The 1000-yard offset, which is introduced at the time of adjustment, serves to cause star shells to burst beyond the Target.

THE STAR SHELL RANGE SPOT DIALS consist of an inner and an outer dial. The inner dial has an index on it and is positioned automatically by the Star Shell Spot Transmitter. The outer dial is graduated and numbered in hundreds of yards of Star Shell Range Spot, *Rjn*, from 1500 OUT to 1500 IN. The figures on the IN side are printed in red. This dial is positioned by the Star Shell Range Spot Knob.

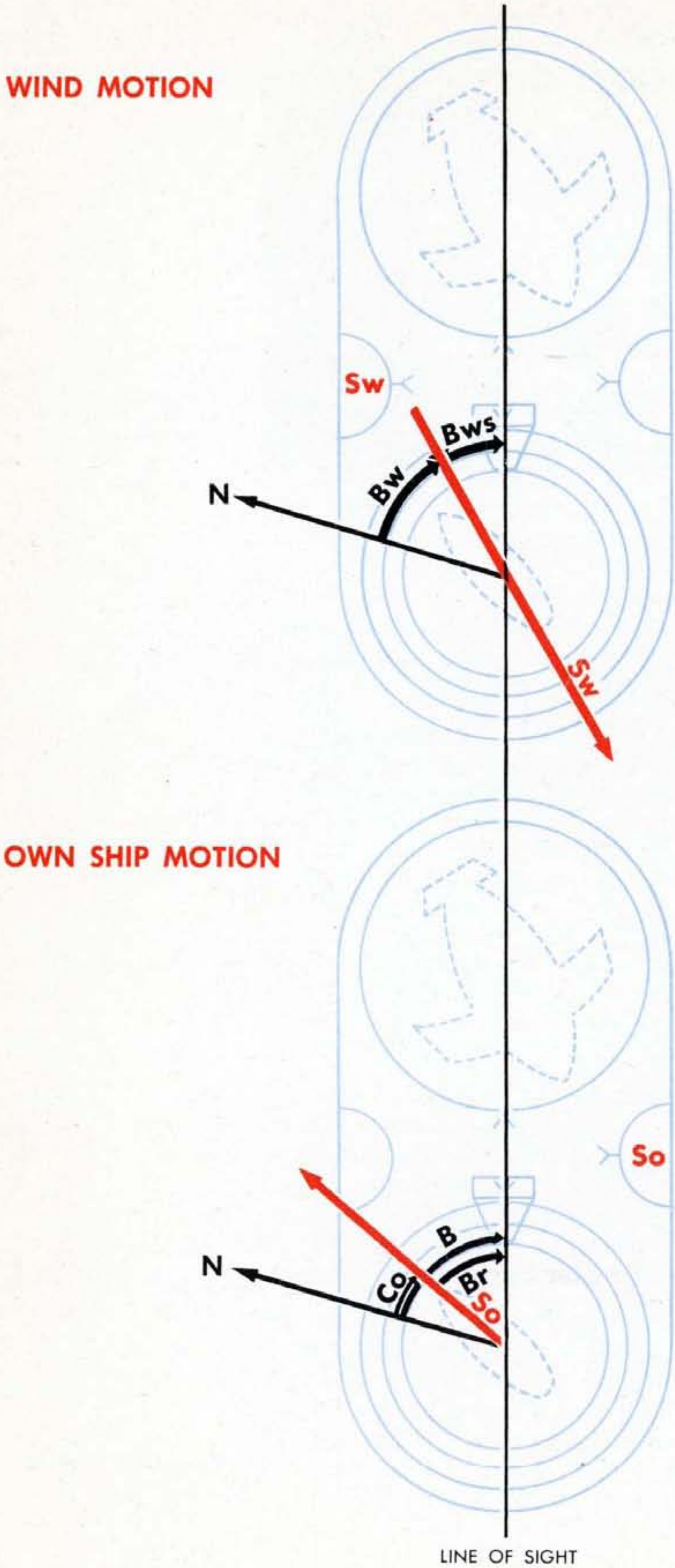
THE STAR SHELL RANGE SPOT KNOB sets Star Shell Range Spot, *Rjn*, into the outer Star Shell Range Spot Dial and the *Rjn* shaft line, when the outer *Rjn* Dial is matched to the inner *Rjn* Dial.

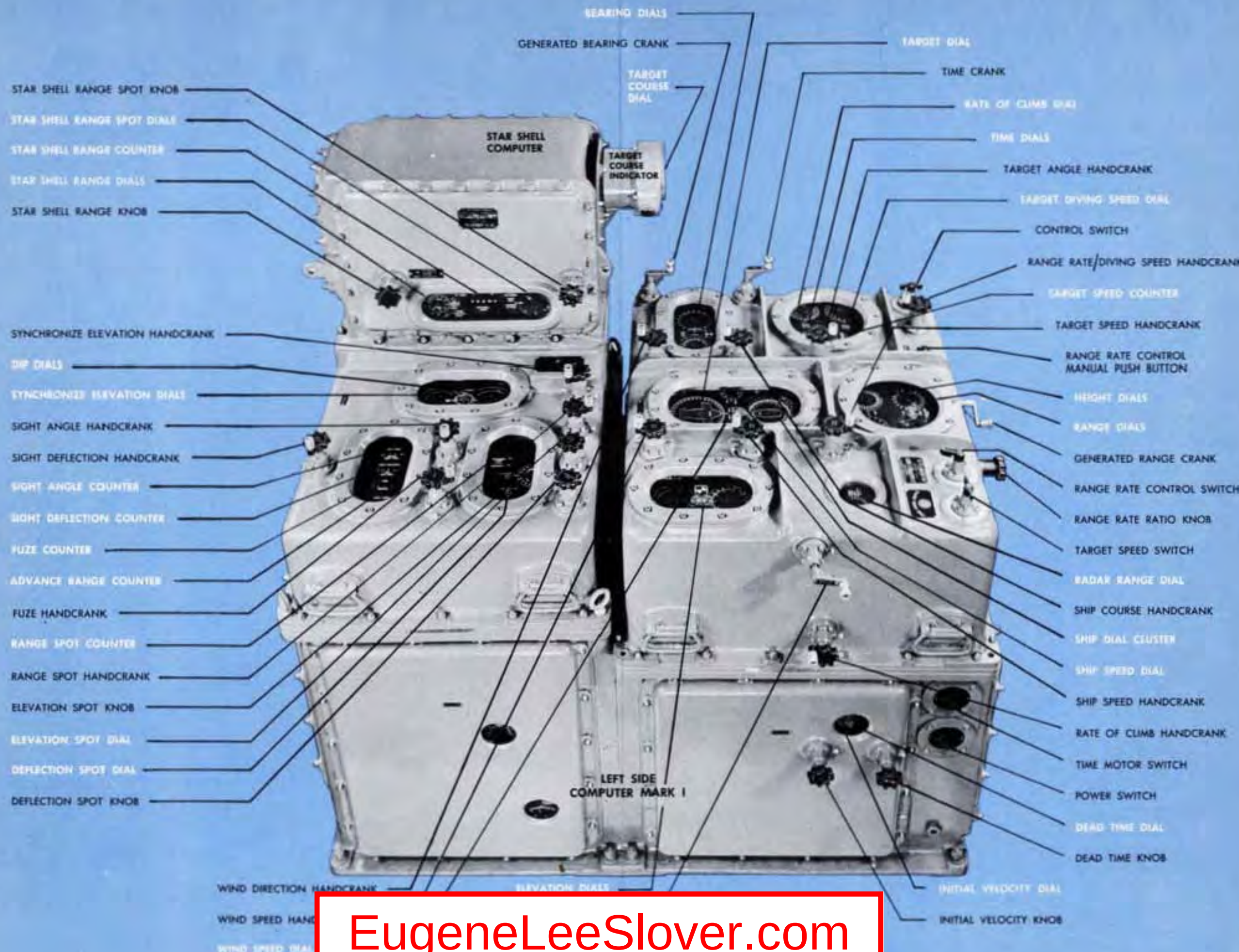
THE STAR SHELL RANGE DIALS consist of an inner and an outer dial. The inner Star Shell Range Dial is called the *Fn* Dial; the outer Star Shell Range Dial is called the *jDwn* Dial. Both dials have unevenly spaced graduations and are numbered in thousands of yards. These dials must be positioned by the Star Shell Range Knob so that the reading across their fixed index matches the reading on the Star Shell Range Counter.



THE STAR SHELL RANGE KNOB has two positions: IN and OUT, with a ball detent to hold it in either position. This knob is turned in its IN position to match the inner *Fn* Dial approximately to the Star Shell Range Counter reading. Then in its OUT position this knob is turned to move the outer *jDwn* Dial until the reading across the fixed index agrees exactly with the counter reading. In its IN position, the Star Shell Range Knob sets Star Shell Fuze Setting Order, *Fn*, into the Star Shell Computer. In its OUT position it sets in *jDwn*.

THE SHIP DIAL CLUSTER





BEARING DIALS
GENERATED BEARING CRANK
TARGET COURSE DIAL
TARGET DIAL
TIME CRANK
RATE OF CLIMB DIAL
TIME DIALS
TARGET ANGLE HANDCRANK
TARGET DIVING SPEED DIAL
CONTROL SWITCH
RANGE RATE/DIVING SPEED HANDCRANK
TARGET SPEED COUNTER
TARGET SPEED HANDCRANK
RANGE RATE CONTROL MANUAL PUSH BUTTON
HEIGHT DIALS
RANGE DIALS
GENERATED RANGE CRANK
RANGE RATE CONTROL SWITCH
RANGE RATE RATIO KNOB
TARGET SPEED SWITCH
RADAR RANGE DIAL
SHIP COURSE HANDCRANK
SHIP DIAL CLUSTER
SHIP SPEED DIAL
SHIP SPEED HANDCRANK
RATE OF CLIMB HANDCRANK
TIME MOTOR SWITCH
POWER SWITCH
DEAD TIME DIAL
DEAD TIME KNOB
INITIAL VELOCITY DIAL
INITIAL VELOCITY KNOB
STAR SHELL RANGE SPOT KNOB
STAR SHELL RANGE SPOT DIALS
STAR SHELL RANGE COUNTER
STAR SHELL RANGE DIALS
STAR SHELL RANGE KNOB
STAR SHELL COMPUTER
TARGET COURSE INDICATOR
SYNCHRONIZE ELEVATION HANDCRANK
DIP DIALS
SYNCHRONIZE ELEVATION DIALS
SIGHT ANGLE HANDCRANK
SIGHT DEFLECTION HANDCRANK
SIGHT ANGLE COUNTER
SIGHT DEFLECTION COUNTER
FUZE COUNTER
ADVANCE RANGE COUNTER
FUZE HANDCRANK
RANGE SPOT COUNTER
RANGE SPOT HANDCRANK
ELEVATION SPOT KNOB
ELEVATION SPOT DIAL
DEFLECTION SPOT DIAL
DEFLECTION SPOT KNOB
LEFT SIDE COMPUTER MARK I
WIND DIRECTION HANDCRANK
ELEVATION DIALS
WIND SPEED HAND
WIND SPEED DIAL

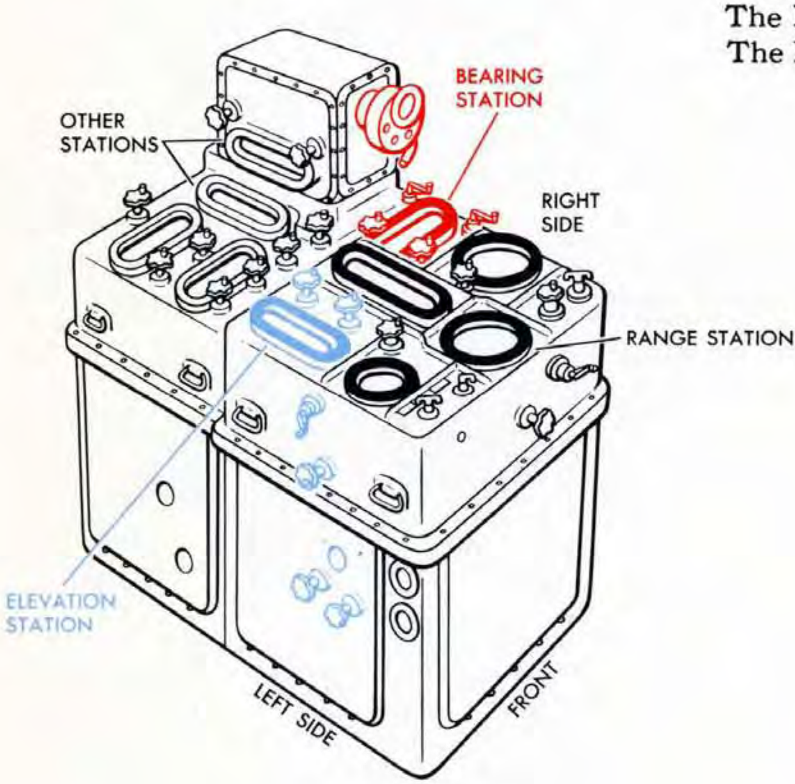
OPERATING INSTRUCTIONS

Operating Stations

The number of men operating the Computer Mark 1 and the duties assigned to each man are determined by ship's doctrine.

For convenience in describing operating procedures in this chapter, the principal controls of the Computer are divided among three operating stations:

The Range Station at the front
The Elevation Station at the left side
The Bearing Station at the right side



Each of these stations may be manned by one or more operators. If necessary one operator can man more than one station. For convenience it is assumed here that there is one operator at each of the three stations.

In the operating instructions that follow, the duties of the men at the three main stations are always given first. Additional duties are grouped under "Other Stations."

The Conditions of the Computer

The Computer controls must always be set in such a way that the Computer can be put into operation quickly. When no action is expected, the controls should be positioned to avoid needless wear of the Computer parts. The suggested settings for the Computer when it is not in use are grouped under the title, *Secured Condition of the Computer.*

When a search for a target begins, several changes may be made to these settings to prepare for action. When the type of target is not known, the Computer is put into the *Standby for Search* condition. When the type of target is known, the Computer may be put into *Standby for an Air Target* or *Standby for a Surface Target.*

When tracking a target, the Computer may be operated in several different ways. There are four basic types of operation: Automatic, Semi-automatic, Manual, and Local (without Director). In actual practice, features of two or more of these types are often combined.

The instructions which follow describe the steps required to change the Computer:

1 From *Secured* to *Standby for Search*

2 From *Standby for Search* to *Standby for an Air Target*

3 From *Standby for an Air Target* to each of the basic types of operation used for air targets. The basic types of operation for an air target are: Auto, Semi-auto, and Manual.

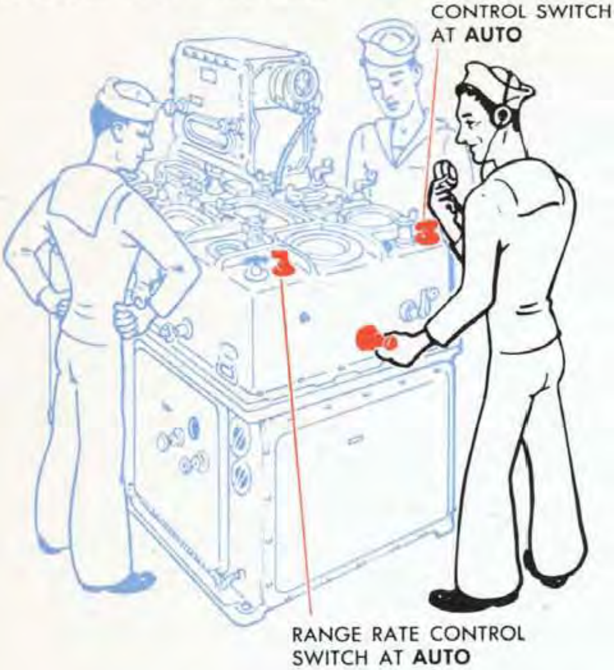
4 From *Standby for Search* to *Standby for a Surface Target.*

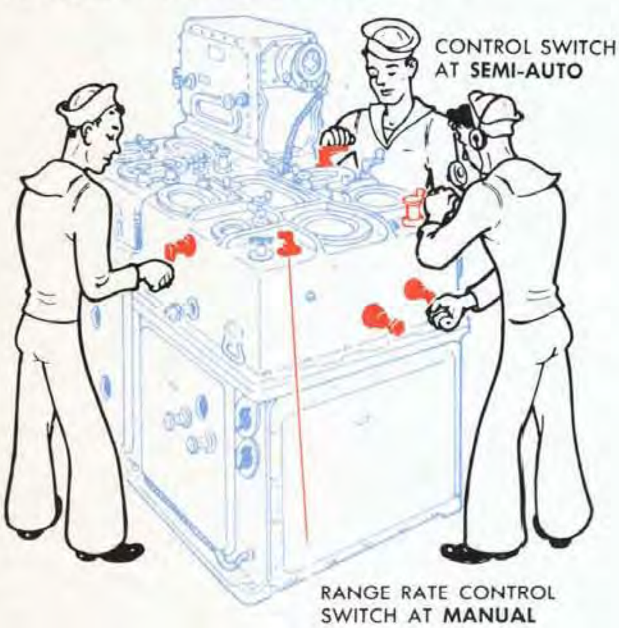
5 From *Standby for a Surface Target* to each of the basic types of operation used for surface targets. The basic types of operation for a surface target are: Manual and Local.

Operators who are familiar with these procedures will be able to change from any condition or type of operation to any other condition or type of operation

The Standby Conditions discussed on pages 116, 118, and 132, are a compromise between *speed* in shifting to full operation, and *prevention of wear.* There are other Standby setups which put greater emphasis on *speed* and less emphasis on *prevention of wear.* Samples of these faster setups are included on pages 146-147.

The FOUR TYPES of OPERATION





NOTE:
Range can be rate-controlled semi-automatically while Elevation and Bearing are being rate-controlled automatically. Likewise, Range can be rate-controlled automatically while Elevation and Bearing are being rate-controlled semi-automatically.

In Automatic and Semi-automatic Operation, the Rate Control Group computes corrected values of *Sh*, *dH*, and *A*.

AUTOMATIC OPERATION

In Automatic Operation the Rate Control Group computes the corrected values of *Sh*, *dH*, and *A*, on signal from the Director. When the Pointer and Trainer press their signal keys as they turn their handwheels, Elevation and Bearing Rate Control Corrections automatically feed into the Rate Control Group. When the Range Operator presses his Range Signal Button as he turns his Range Knob, Range Rate Control Corrections enter the Rate Control Group. The amount of Range Rate Control Correction is controlled manually by the Range Rate Ratio Knob at the Computer. A solution is reached when the Elevation and Bearing Solution Indicators cease turning.

Switch Positions:

Control Switch at AUTO
Range Rate Control Switch at AUTO

SEMI-AUTOMATIC OPERATION

In Semi-automatic Operation the Rate Control Group computes the corrected values of *Sh*, *dH*, and *A*, using Rate Control Corrections put in by hand by the Computer Crew. The Computer Crew makes rate corrections by turning the Generated Range, Generated Elevation, and Generated Bearing Cranks. These cranks are turned in their IN positions when the signals from the Director show that Observed Range, Observed Elevation, and Observed Bearing are correct. A solution is reached when sufficient corrections have been put in to keep the Generated Range, Generated Elevation, and Generated Bearing Dials rotating in the same directions and at the same rates as the Observed Range, Observed Elevation, and Observed Bearing Dials.

Switch Positions:

Control Switch at SEMI-AUTO
Range Rate Control Switch at MANUAL

In Manual and Local Operation, the Rate Control Group is not used. Instead, the operators correct *Sh, dH,* and *A* directly by means of the *Sh, dH,* and *A* Handcranks.

MANUAL OPERATION

In Manual Operation the Computer Crew makes rate corrections through the *Sh, dH,* and *A* Handcranks. A solution is reached when sufficient corrections have been made to the Target Motion values to keep the Generated Range, Generated Elevation, and Generated Bearing Dials rotating in the same directions and at the same rates as the Observed Range, Observed Elevation, and Observed Bearing Dials.

Switch Positions:

Control Switch at SEMI-AUTO
Range Rate Control Switch at MANUAL

LOCAL OPERATION

Local Operation is a type of operation used when Target Position is not being completely determined by the Gun Director Mark 37. Observed Range, *R*, Relative Target Bearing, *Br*, Target Angle, *A*, and Target Speed, *Sh*, are observed from some aloft station and continually phoned to the plotting room. The Computer Crew puts the values of these quantities into the Computer by hand at the Generated Range, Generated Bearing, Target Angle, and Target Speed Handcranks. The crew then corrects the values of *Sh* and *A* through the Target Speed and Target Angle Handcranks. The solution of the problem is reached when the readings on the Range and Bearing Dials stay in agreement with the phoned values.

Switch Positions:

Control Switch at LOCAL
Range Rate Control Switch at MANUAL

SECURED CONDITION

Securing the COMPUTER MARK 1

At the Range Station:

1 Turn the Time Motor Switch OFF.

At the Other Stations:

1 Set Level at a selected value of 2000 minutes at the Stable Element.

2 Disconnect Cross-level and set it at a selected value of 2000 minutes. On some ships this is done at the Selector Drive; on other ships it is done at the Stable Element.

Setting the handcranks and dials in Secured Condition

All handcranks, switches, and dials should be set at definite positions whenever the Computer is secured. Knowing the settings makes it possible to go into operation fast. If the same settings are used consistently, any changes from them can be recognized as evidence of tampering.

The settings used may vary according to ship's doctrine. The following settings are suggested:

At the Range Station:

1 Turn the Control Switch to LOCAL.

2 Put the Range Rate Diving Speed Handcrank to AUTO.

3 Turn the Range Rate Control Switch to MANUAL.

4 Turn the Target Speed Switch to NORMAL.

5 With the Target Speed Handcrank at HAND, set *Sh* at zero. Leave the handcrank at HAND.

6 Set the Range Rate Ratio Knob at 1.

7 With the Generated Range Crank OUT, set the Range Dials at 30,000 yards. Leave the crank OUT.

At the Elevation Station:

1 With the Rate of Climb Handcrank IN, set *dH* at zero. Leave the handcrank IN.

2 Set the Generated Elevation Crank at the OUT position.

3 With the Ship Speed Handcrank IN, set *So* at zero. Leave the handcrank IN.

4 With the Wind Speed Handcrank, set *Sw* at zero.

5 With the Synchronize Elevation Handcrank at CENTER, set *E* at zero. Leave the handcrank at CENTER.

6 Pull the Initial Velocity Knob OUT and set *I.V.* at 2600 f.s.

7 Pull the Dead Time Knob OUT and set *Tg* at the established value.

The Initial Velocity and Dead Time Knobs return to their IN positions when released.

At the Bearing Station:

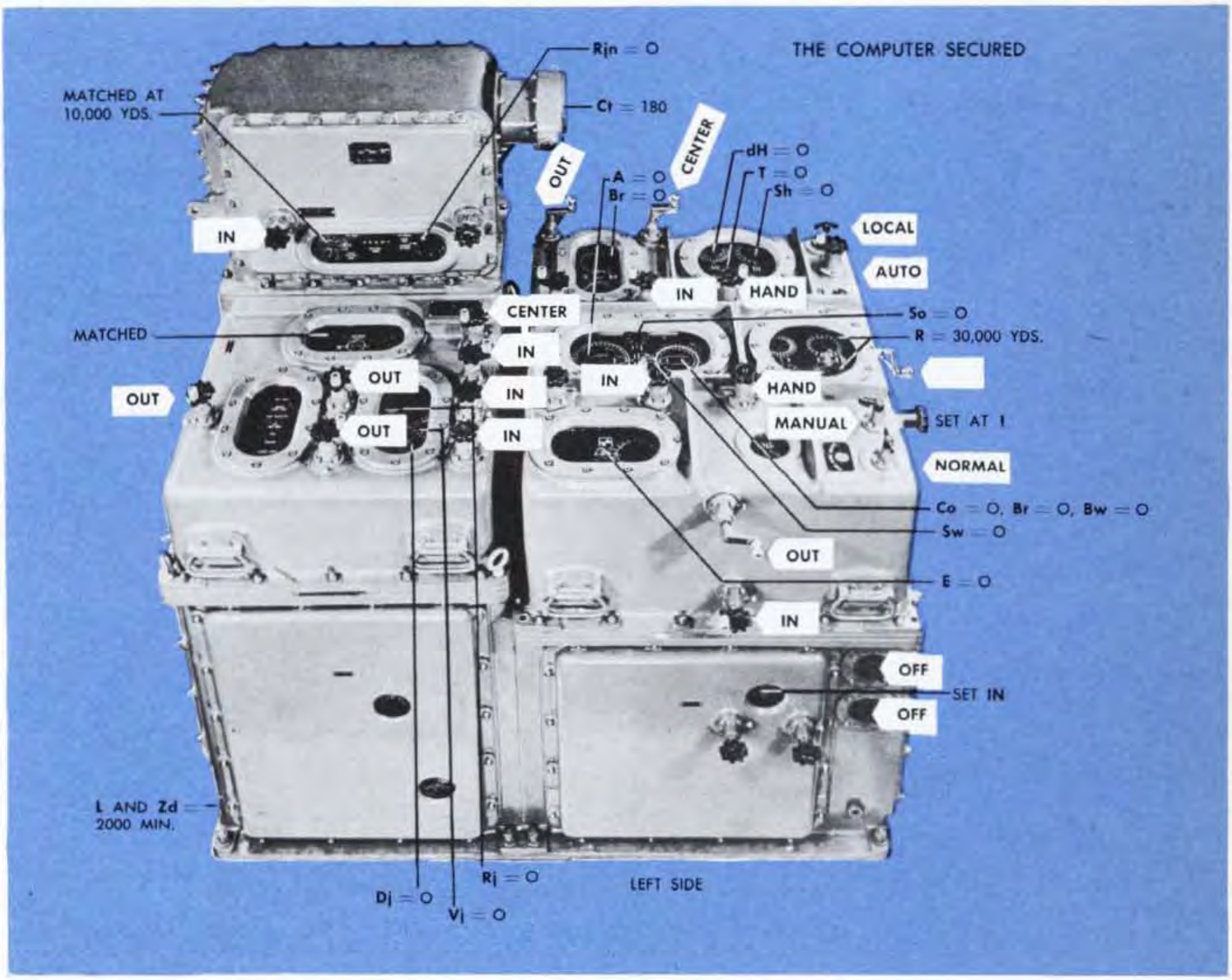
1 With the Ship Course Handcrank IN, set *Co* at zero. Leave the handcrank IN.
2 With the Wind Direction Handcrank, set *Bw* at zero.
3 With the Generated Bearing Crank OUT, set *Br* at zero. Leave the crank OUT.
4 With the Target Angle Handcrank at HAND, set *A* a zero. Leave the handcrank at HAND.
5 Push the Time Crank IN and zero the Time Dials. When the crank is released it returns to the CENTER position.

At the Other Stations:

1 With the Range Spot Handcrank and the Elevation and Deflection Spot Knobs IN, set *Rj, Vj,* and *Dj* at zero.
2 Leave the Sight Angle, Sight Deflection and Fuze Handcranks OUT.
3 With the Star Shell Range Spot Knob, set *Rjn* at zero.
4 With the Star Shell Range Knob IN, set the inner dial at 10,000 yards. Pull the knob OUT and set the outer dial at 10,000 yards. Push the knob IN.

After all settings are made:

1 Turn the Power Switch OFF.
2 Turn the Computer Power Supply Switch OFF at the Switchboard.



THE COMPUTER SECURED

STANDBY CONDITION

There are several Standby Conditions for the Gun Director Mark 37 System. These Standby Conditions and their names are determined by ship's doctrine. The Computer will be in one of the three following Standby Conditions, depending upon the System Standby Condition ordered.

Initial standby

Initial Standby is used only when there is little possibility of action.

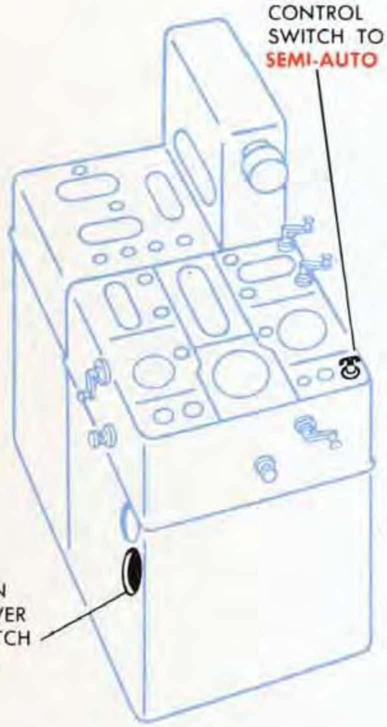
The Computer is in *Secured* Condition.

Only the Stable Element gyro is energized.

The Computer circuits and all other circuits are de-energized.

This condition keeps wear of the Computer at a minimum.

Standby for search



The Stable Element gyro and follow-ups are energized.

Level and Cross-level are set at selected values.

The Computer power circuit is energized.

The synchro circuits are not energized.

The *Standby for Search* Condition keeps the system in instant readiness to begin searching without causing needless wear of the Computer parts.

Standby during search

All circuits in the Stable Element and Computer are energized except the Director Elevation Transmission circuit to the *Eb* Receiver.

Level and Cross-level are set at selected values.

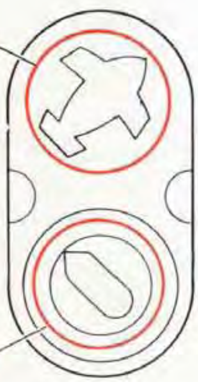
Changing from secured to standby for search and standby during search

At the Range Station:

1 Turn the Power Switch ON.
2 Turn the Control Switch to SEMI-AUTO.
3 Pull the Ship Course Handcrank OUT.
4 Set in ordered value of *I.V.*

The other Computer settings remain the same as for *Secured* Condition.

The Computer Dials During Search

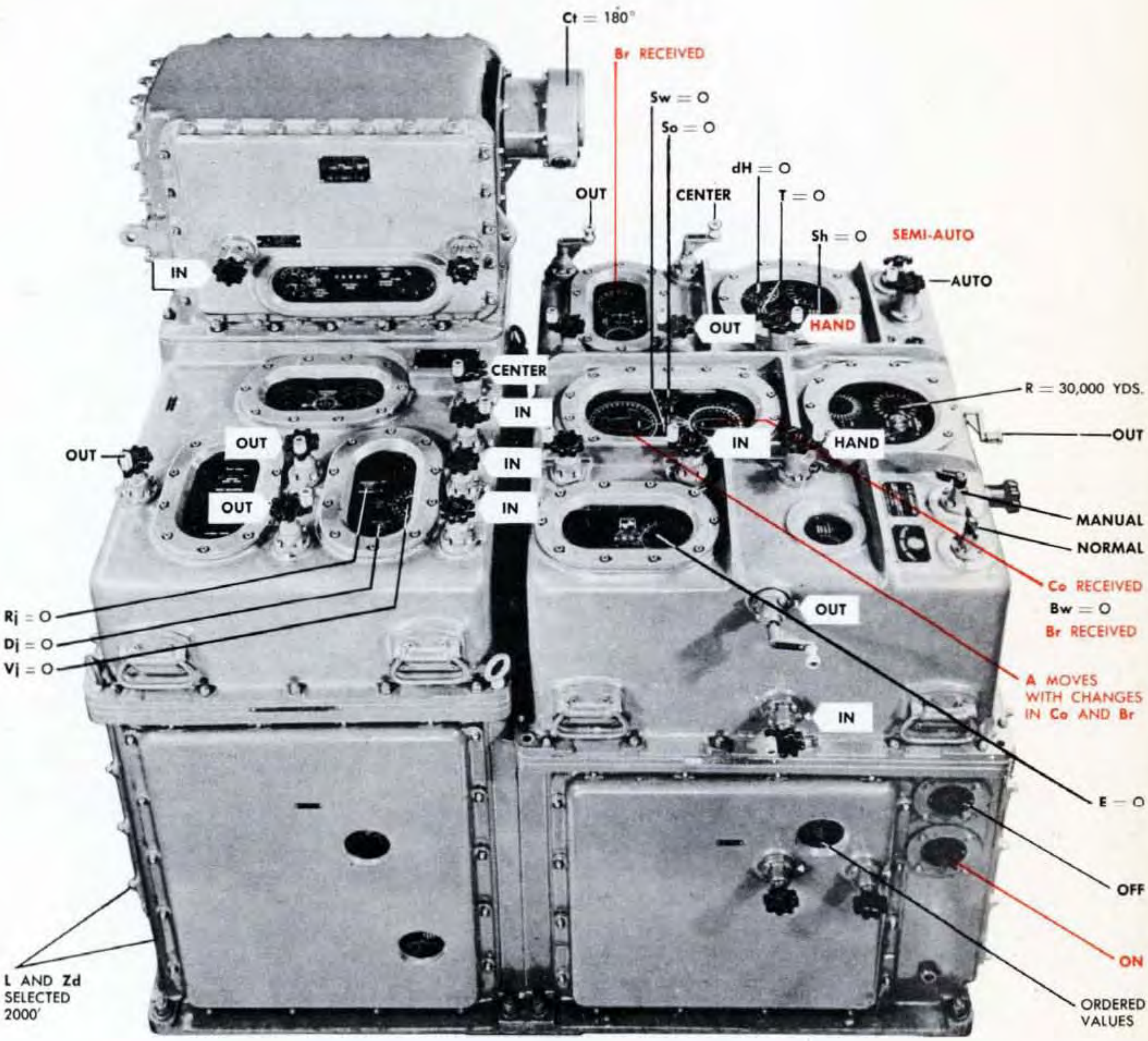


With the Power Switch ON, and the Switchboard positioned so that the Computer is in *Standby during Search*, the following dials move:

1 The Compass Ring Dial shows Ship Course, *Co*. This value is received from the Gyro Compass because the Ship Course Handcrank is OUT.
2 The Ship Dial turns and Relative Target Bearing, *Br*, changes as the Director trains in search of the target.
3 The Target Dial turns as Own Ship changes course and as Relative Target Bearing changes.

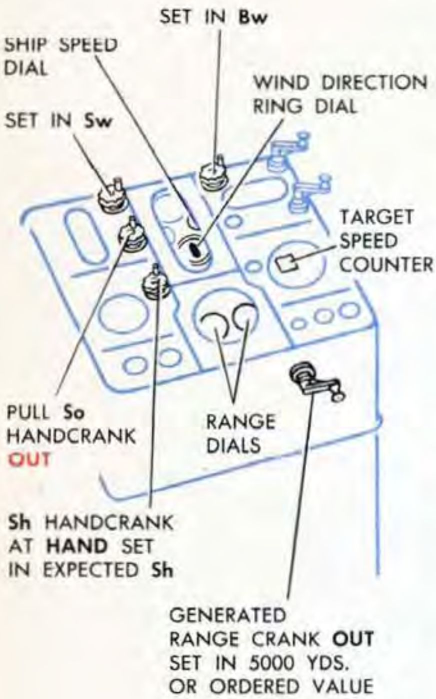
As soon as the type of target is known, additional settings may be made.

THE COMPUTER IN STANDBY DURING SEARCH



CHANGES FROM SECURED SHOWN IN RED

STANDBY FOR AN AIR TARGET



Changing from standby during search to standby for air target

At the Range Station:

1 With the Generated Range Crank OUT, match the "Y" indexes on the ring dials to the pointers on the inner dials. Set the ring dials at 5000 yards until an accurate range can be determined. Leave the crank OUT.

2 With the Target Speed Handcrank at HAND, set the estimated Target Speed into the Target Speed Counter. Leave the Handcrank at HAND.

At the Elevation Station:

1 With the Ship Speed Handcrank IN, set in the approximate *So;* then pull the handcrank OUT.

2 With the Wind Speed Handcrank, set in Wind Speed, *Sw*.

At the Bearing Station:

1 With the Wind Direction Handcrank, set in Wind Direction, *Bw*.

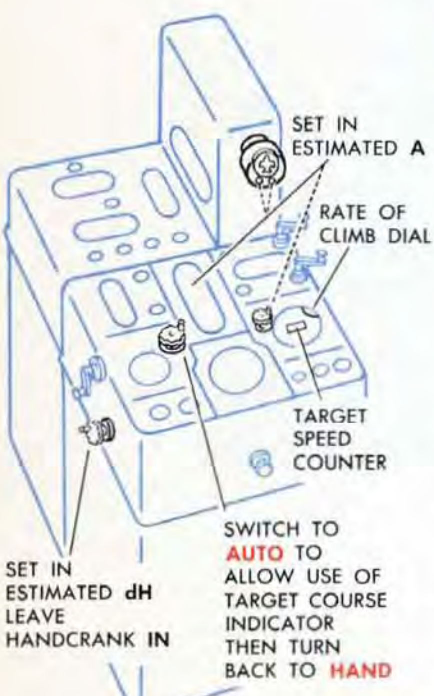
At the Other Stations:

1 Put the Stable Element at Continuous Aim.

2 Connect, synchronize, and lock the Selector Drive.

3 Make sure that all the switches connecting the Director, the Computer, the Stable Element, and the guns are ON at the Fire Control Switchboard.

4 Pull Spot Knobs OUT, noting that correct values of *Rj, Vj,* and *Dj* are indicated.



Setting in estimates of A, Sh, and dH

At the Range Station:

1 With the Target Angle Handcrank at HAND, set the estimated value of Target Angle, *A*, into the Target Dial. Leave the handcrank at HAND.

OR

Switch the Target Speed and Target Angle Handcrank to AUTO. At the Target Course Indicator press the INCREASE or DECREASE push-button until the estimated *A* is read on the Target Angle Dial. Return the handcranks to HAND position.

2 With the Target Speed Handcrank at HAND, set the estimated *Sh* into the Target Speed Counter.

3 With the Rate of Climb Handcrank in the IN position, set the estimated *dH* into the Rate of Climb Dial. Leave the handcrank IN.

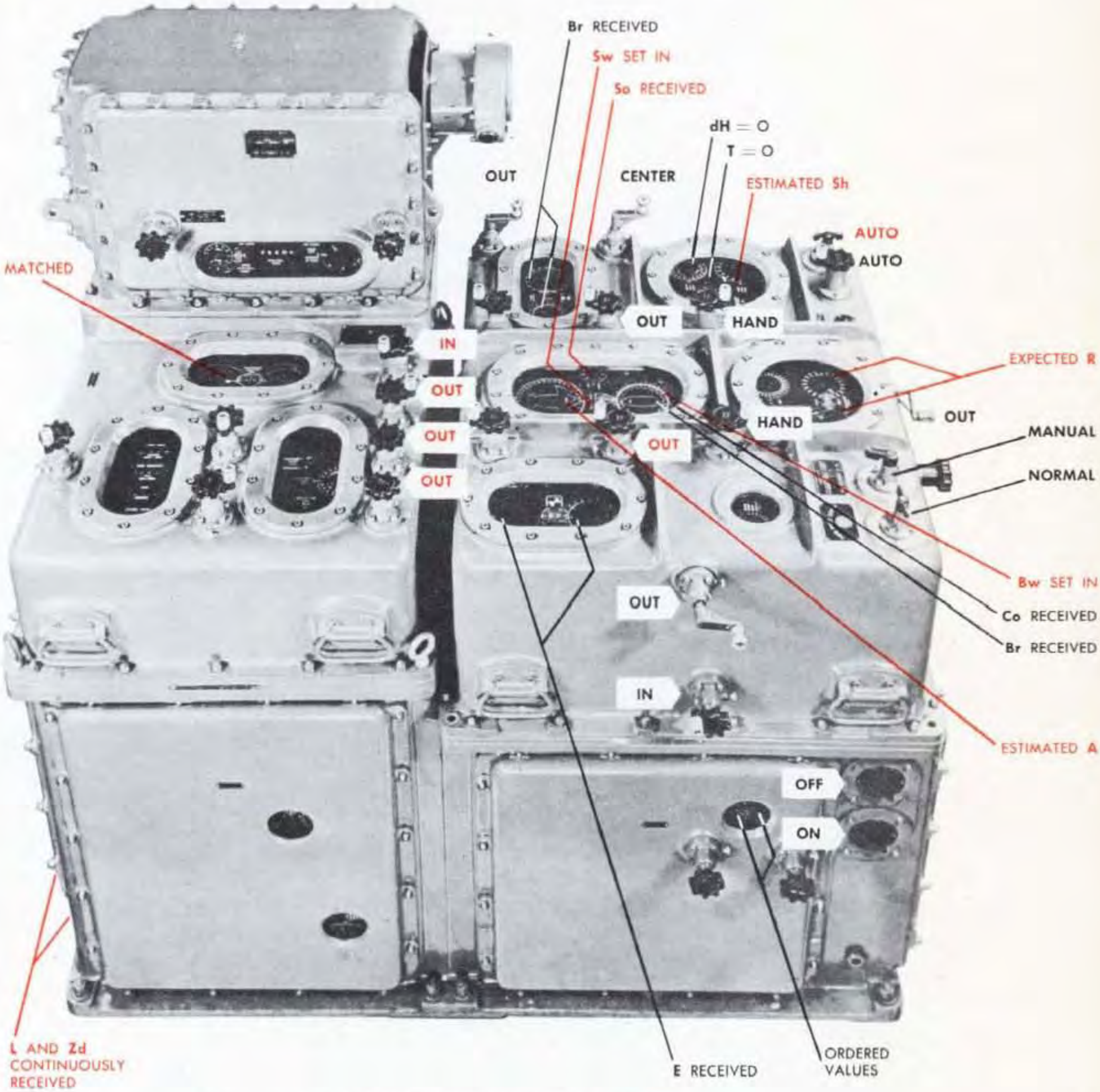
4 Turn the Control Switch to AUTO.

At the Elevation Station:

1 When the Director Sights are on the Target, push the Synchronize Elevation Handcrank IN and match the Synchronize Elevation Dials at the index.

2 See that Dead Time, *Tg*, and Initial Velocity, *I.V.*, are set at their ordered values.

THE COMPUTER IN STANDBY FOR AN AIR TARGET



CHANGES FROM STANDBY SHOWN IN RED

When the Director Sights are positioned on the Target, the Pointer, Trainer and Range Finder Operator in the Director indicate they are ready to start tracking by closing their signal keys. When the signal keys are closed, the Range Finder Signal on the Computer turns to white, and the Pointer's and Trainer's Signals turn to red.

AUTOMATIC OPERATION

NOTE:
Range Rate should be controlled in AUTO only when the Range input from the Director is smooth and accurate. Even when receiving Radar Range it is advisable to rate-control manually until the ranges smooth out. With optical ranging, Automatic Rate Control should not be used unless at least 40 accurate ranges per minute are received.

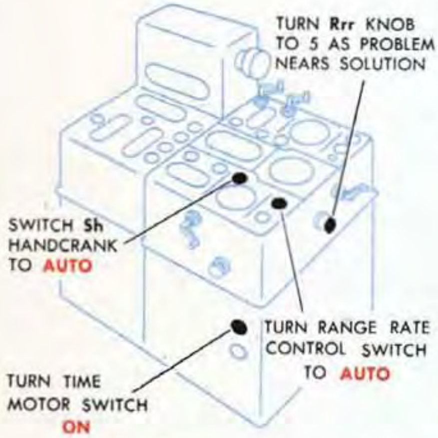
Changing from standby for an air target to automatic operation

At the Range Station:

1 Turn the Range Rate Control Switch to AUTO.
2 Turn the Time Motor Switch ON.
3 Shift the Target Speed and Target Angle Handcranks to AUTO.

At the Elevation Station:

1 Pull the Rate of Climb Handcrank OUT.



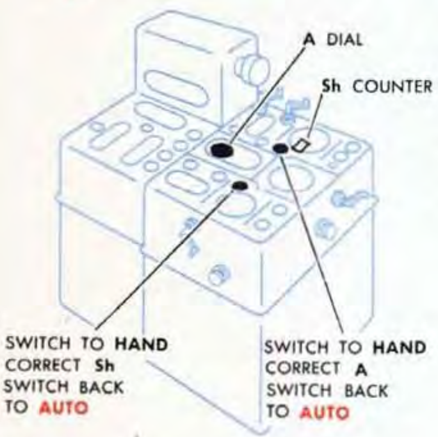
Tracking in automatic operation

At the Range Station:

1 Turn the Range Rate Ratio Knob toward 5 as the problem nears solution. When the rate corrections become small, the Generated Range Dials will oscillate if the Range Rate Ratio Knob is positioned at too low a figure.

Making target corrections during automatic operation

If a large correction to a Target value is needed, it is always advisable to assist the Rate Control Mechanism by quickly setting in the new value by hand.



At the Range Station:

1 When ordered, correct Target Speed with the lever on the handcrank at HAND. Switch the lever back to AUTO as soon as the correction has been made.

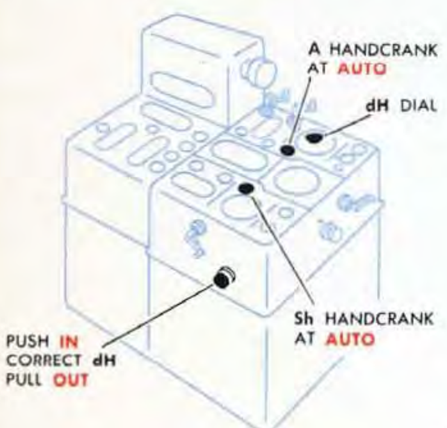
OR

Leave the Target Speed and Target Angle Handcranks at AUTO. Correct Target Speed by holding the Target Speed Switch at either INCREASE or DIVE ATTACK until the new value is read on the Target Speed Counter.

2 When ordered, correct Target Angle with the lever on the handcrank at HAND. Switch the lever back to AUTO as soon as the correction has been made.

OR

Leave the Target Angle and Target Speed Handcranks at AUTO. Correct Target Angle by pressing one of the push buttons on the Target Course Indicator until the new value is read on the *A* Dial.

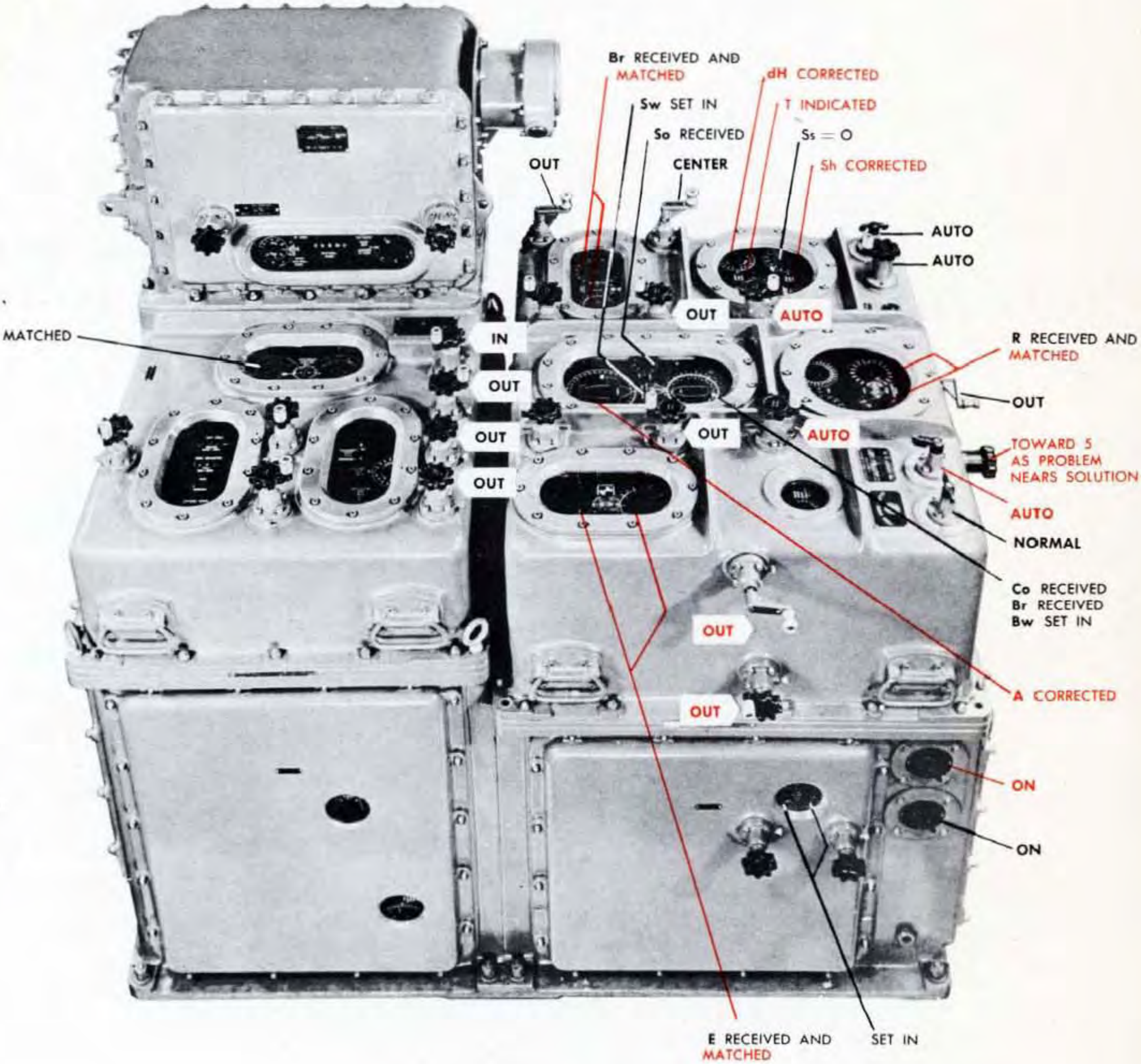


At the Elevation Station:

1 When ordered, make corrections to Rate of Climb with the *dH* Handcrank IN. Pull the handcrank OUT as soon as the correction has been made.

The Computer Crew now watches the Ship, Target, and Generated Dials, and stands ready either to make hand corrections, to change the method of operation, or to cease tracking.

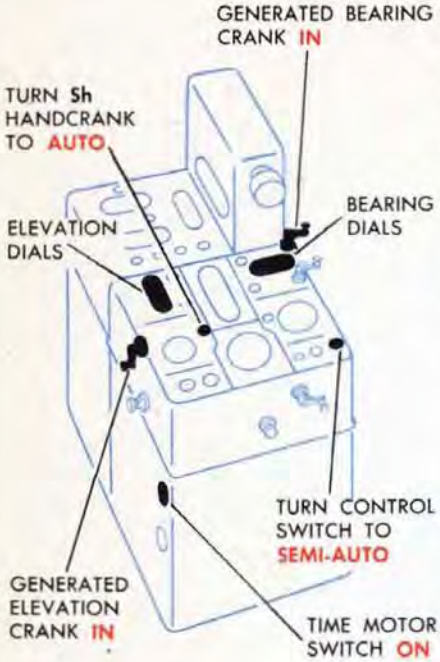
THE COMPUTER IN AUTOMATIC OPERATION



CHANGES FROM STANDBY FOR AN AIR TARGET SHOWN IN RED

SEMI-AUTOMATIC OPERATION

Changing from standby for an air target to semi-automatic operation



At the Range Station:

1 Turn the Control Switch to SEMI-AUTO.

2 Turn the Time Motor Switch ON.

3 Shift the lever on the Target Speed Handcrank to AUTO.

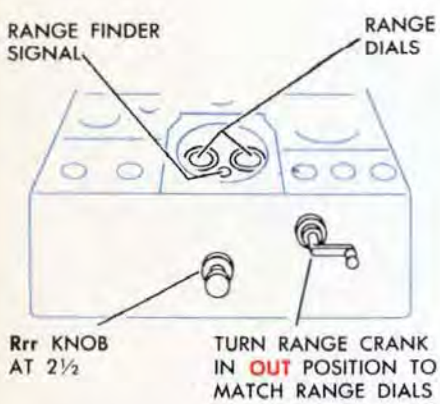
At the Elevation Station:

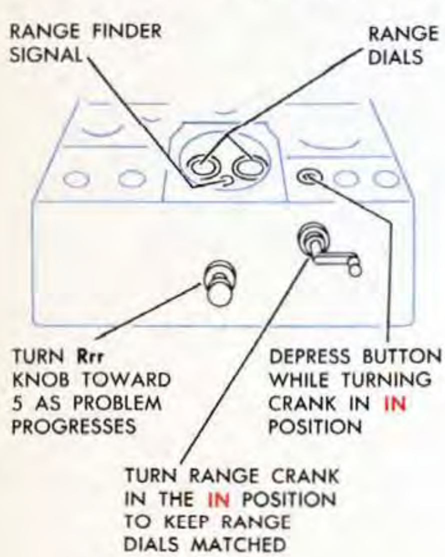
1 Put the Generated Elevation Crank IN.

At the Bearing Station:

1 Put the Generated Bearing Crank IN.

Rate control in semi-automatic operation





In Semi-automatic Operation, rate-controlling should be done at all stations at the same time.

At the Range Station:

1 Match the Range Dials.

To do this, put the Generated Range Crank in its IN position. When the Range Finder Signal shows white, pull the crank OUT against spring pressure and turn it until the indexes on the Generated Range Dials match the indexes on the Observed Range Dials. The dials may also be matched with the crank in its IN position. When the crank is turned in its IN position, the amount of dial change for a given crank rotation depends on the position of the Range Rate Ratio Knob. With this knob at 1, a large crank movement makes a small dial change. With the knob at 5, the same crank movement causes a much greater dial change. A good Range Rate Ratio Knob setting for beginners is 2½. Experienced operators will sense the proper setting.

2 Keep the Generated Range Dials rotating at such a rate and in such a direction that they match the Observed Range Dials whenever the Range Finder Signal is white.

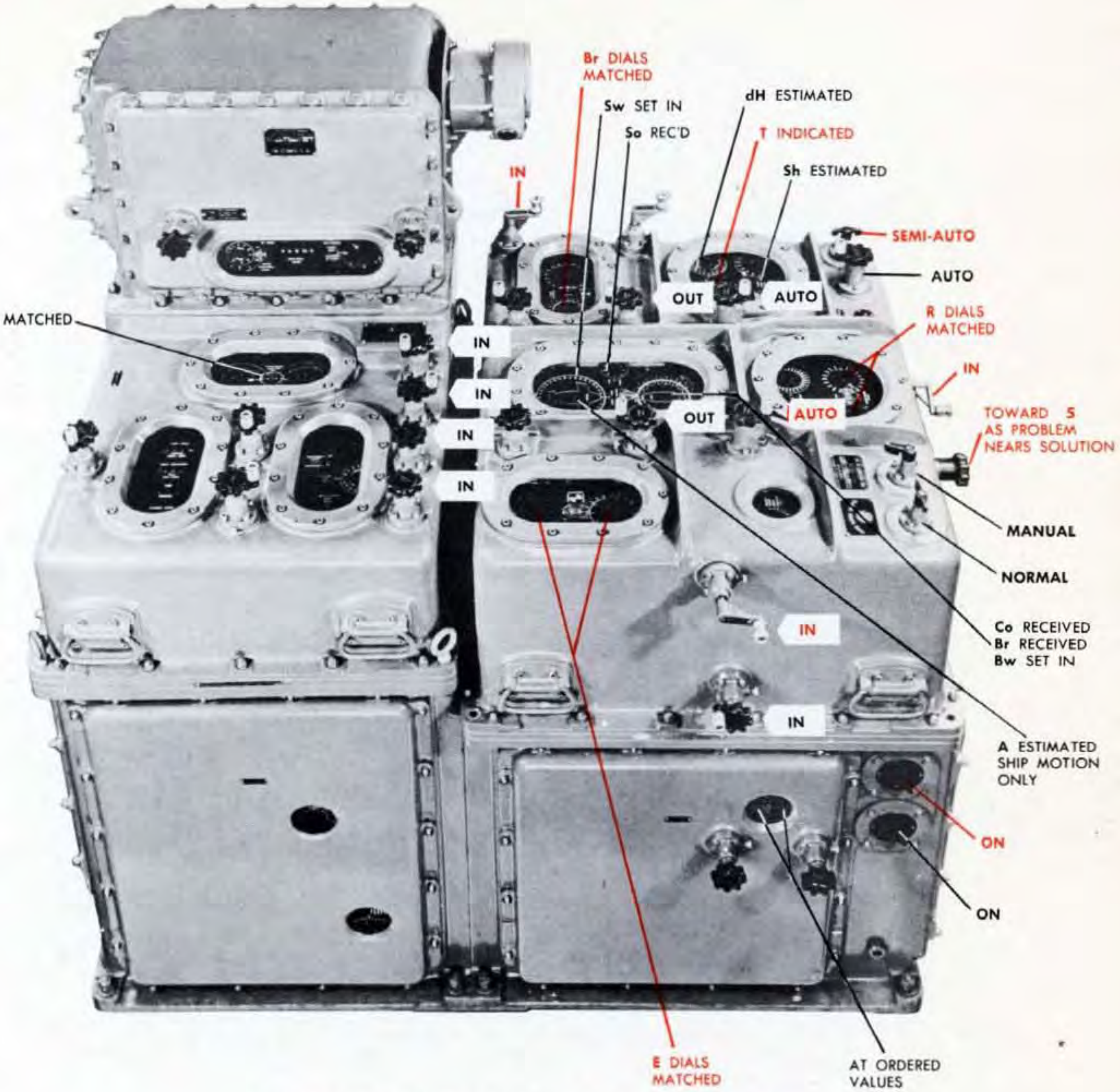
To do this, depress the Range Rate Control Manual Push-button and turn the Generated Range Crank in its IN position while the Range Finder Signal is white. Turn the crank until the dials match. Turning the crank in its IN position with the push-button depressed puts Range *Rate* Corrections into the Rate Control Mechanism.

The ratio of the *Rate* Corrections to the *Linear* Corrections is determined by the position of the Range Rate Ratio Knob.

If there is a great difference in rate of rotation between the Generated and Observed Range Dials, it is advisable to over-correct. To over-correct, depress the Range Rate Control Manual Push-button and turn the Generated Range Crank in its IN position until the index on the fine outer dial passes the index on the fine inner dial. Then release the push-button and turn the crank back to match the indexes on the dials.

THE COMPUTER IN SEMI-AUTOMATIC OPERATION

SETTINGS AT THE MOMENT THAT THE TIME MOTOR IS TURNED ON

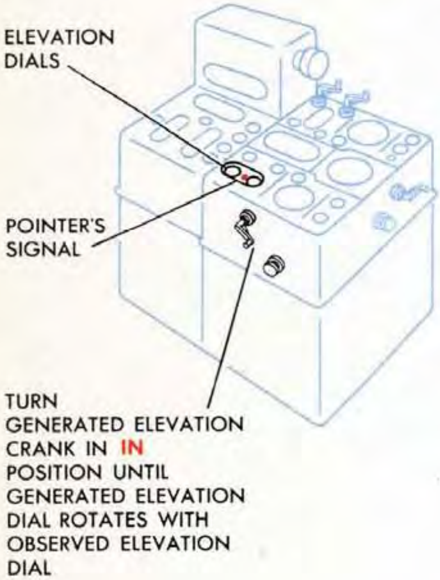


CHANGES FROM STANDBY FOR AN AIR TARGET SHOWN IN RED

The Range Rate Ratio Knob should be at the 1 position at the beginning of a problem or whenever large rate corrections are required. This knob should be turned to its next higher-numbered position whenever there is any oscillation of the Target Speed, *Sh*, Counter. As the problem progresses and the rate of rotation of the Generated Dials nears the rate of rotation of the Observed Dials, turn the Range Rate Ratio Knob toward its 5 position.

When the Generated Dials match the Observed Dials each time the Range Signal turns white, Generated Range and Range Rate are correct.

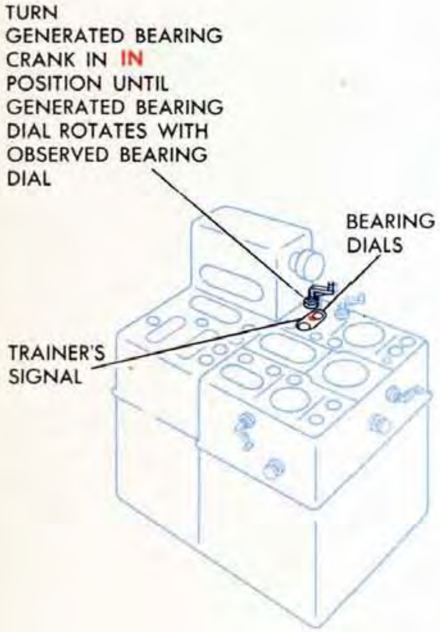
Rate-controlling at the elevation and bearing stations



At the Elevation Station:

1 With the Generated Elevation Crank in the IN position, turn it until the Generated Elevation Dial rotates with the fine Observed Elevation Dial. Over-correcting Elevation will cause false values of Rate of Climb and Range Rate to be computed.

When the Generated Elevation Dial and the fine Observed Elevation Dial rotate together, the Elevation Rate is correct.



At the Bearing Station:

1 With the Generated Bearing Crank in the IN position turn it until the Generated Bearing Dial rotates with the fine Observed Bearing Dial.

When the Generated Bearing Dial and the fine Observed Bearing Dial rotate together, the Bearing Rate is correct.

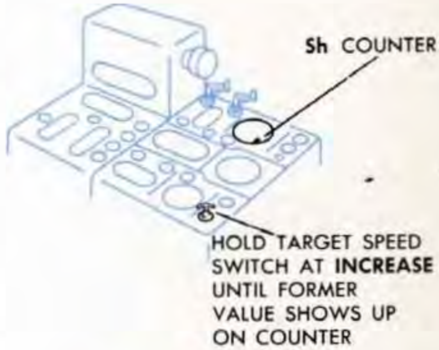
NOTE:
The speed with which rate corrections can be made will be determined by the skill of the operators. With experience the operators can judge the amount of crank rotation needed for any correction and make the whole correction quickly.

TARGET ANGLE

In Automatic or Semi-automatic Operation, a large fast change in Target Angle may cause the Rate Control Mechanism to compute a solution based on an incorrect Target Angle. Whenever this occurs, the reading on the Target Speed Counter drops rapidly to below 80 knots and all the dials showing generated values slow down. In Semi-automatic Operation, the Generated Bearing Dials rotate in the opposite direction to the Observed Bearing Dials. Finally the Target Angle Dial starts to vibrate.

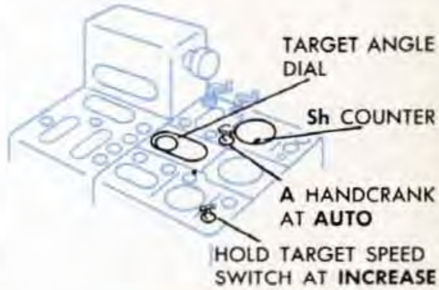
To avoid a false solution, watch the Target Speed Counter. As soon as the reading on this counter drops below 80 knots:

1 Hold the Target Speed Switch at INCREASE until the former value of Target Speed shows up on the counter. Let the switch spring back to NORMAL. The Computer will then compute the correct Target Angle.



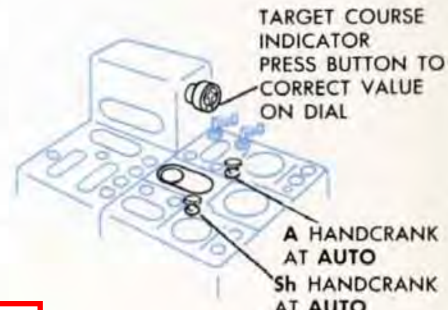
OR

2 When the report of a large change of Target Angle is received, switch the Target Angle Handcrank to HAND and make the correction to Target Angle while holding the Target Speed Switch at INCREASE. Hold the switch at INCREASE until the former value of Target Speed shows up on the counter. Switch the Target Angle Handcrank back to AUTO.



OR

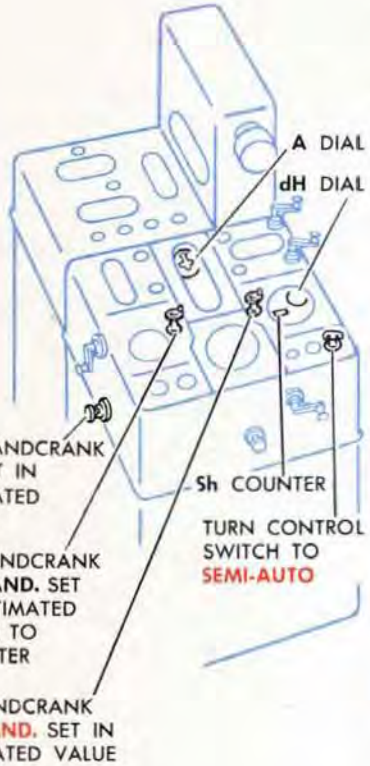
3 When a report of a large change of Target Course is received, leave the Target Angle Handcrank at AUTO. Press one of the buttons on the Target Course Indicator. It is not necessary to hold the Target Speed Switch at INCREASE, but a quicker solution will be obtained if this is done.



If the Target Angle Dial is vibrating, the Target Speed Switch must be held at INCREASE while the Target Angle is being corrected at the Target Course Indicator or after Target Angle is corrected by the Target Angle Handcrank.

MANUAL OPERATION against an Air Target

Changing from standby for an air target to manual operation against an air target



At the Range Station:

1 Turn the Control Switch to SEMI-AUTO.
2 With the Target Speed Handcrank at HAND, set the estimated Target Speed.

At the Elevation Station:

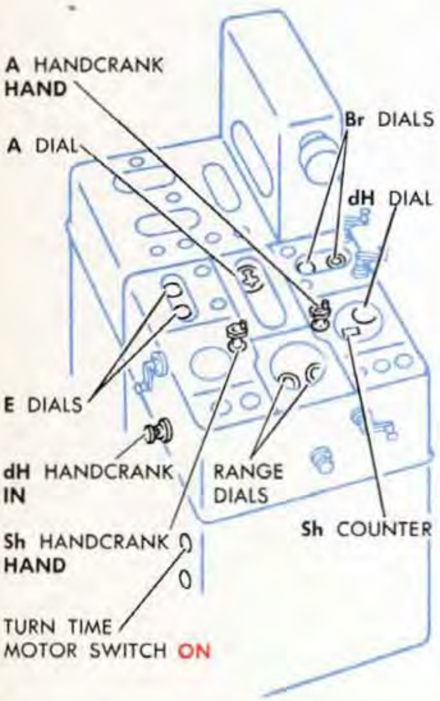
1 With the Rate of Climb Handcrank IN, set the estimated value for *dH* into the Rate of Climb Dial. Leave the handcrank IN.

At the Bearing Station:

1 With the Target Angle Handcrank at HAND, set the estimated Target Angle on the Target Dial. Leave the handcrank at HAND.

Manual control of rates against an air target

In Manual Operation for an air target, the Rate Control Mechanism is not used. Control of rates is handled from the Range and Elevation Stations. The Target Speed, Target Angle, and Rate of Climb Handcranks are used to correct the speed and direction of rotation of the Generated Dials.



At the Range Station:

1 Turn the Time Motor Switch ON.
2 With the Target Angle and Target Speed Handcranks at HAND, make corrections to these values until the Generated Range, Generated Elevation, and Generated Bearing Dials rotate at the same rates and in the same directions as the Observed Range, Observed Elevation, and Observed Bearing Dials.

At the Elevation Station:

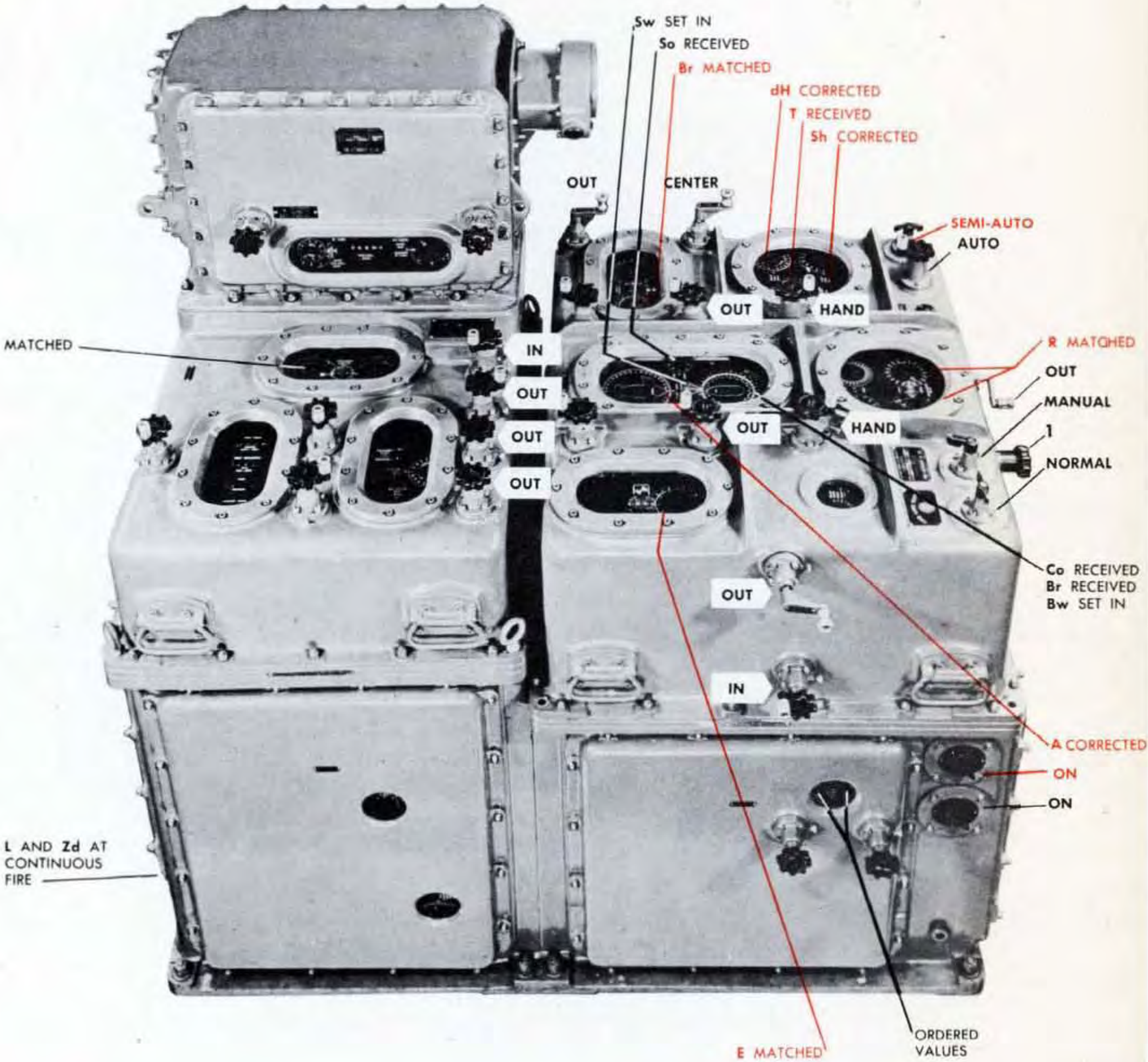
1 With the Rate of Climb Handcrank IN, make corrections to *dH* until the Generated Range and Generated Elevation Dials rotate at the same rates and in the same directions as the Observed Range and Observed Elevation Dials. Corrections to Rate of Climb have little effect on the Bearing Dials.

At the Bearing Station:

1 Stand by for instructions.

Target Elevation, *E*, and Target Angle, *A*, are used to determine which one of the three target values (*Sh*, *A*, or *dH*) to correct.

THE COMPUTER IN MANUAL OPERATION AGAINST AN AIR TARGET

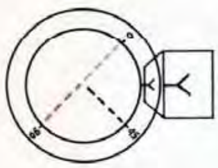


CHANGES FROM STANDBY FOR AN AIR TARGET SHOWN IN RED

CONTROLLING THE GENERATED DIALS IN MANUAL OPERATION

In general, Manual Control of rates against fast-moving air targets is difficult. Knowledge of the fire control problem and practice in Computer operation are necessary because any correction to *Sh, dH* or *A,* usually affects more than one of the generated quantities.

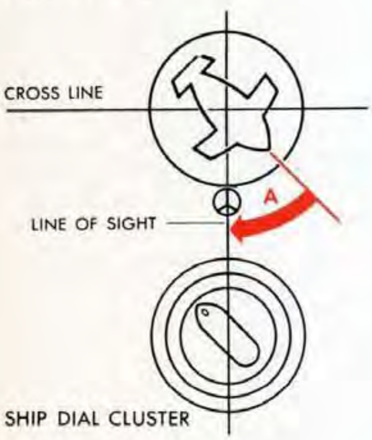
ELEVATION DIAL



While practicing, skill can be acquired by correcting each generated dial in turn, starting with the one showing the most error. In operation, a skilled operator can often correct two or more of the generated quantities at once.

The information which follows describes the correction of each generated quantity separately, by showing the changes in *Sh, dH* or *A* that will have the *greatest* effect on that quantity.

TARGET DIAL

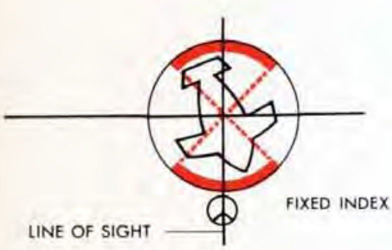


The effect of a change in *Sh, dH* or *A* on the generated dials depends on two things:

1. Target Elevation, *E,* the vertical angle between the Horizontal and the Line of Sight.
2. Target Angle, *A,* the horizontal angle between the direction in which the Target is moving and the Line of Sight.

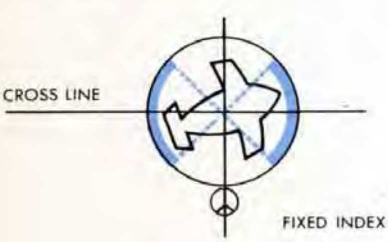
The Target Elevation Dial is divided by an imaginary line into two sections: one section containing values from zero to 45°, and the other section containing values from 45° to 90 degrees.

On the window of the Target Angle Dial, an imaginary line representing the Line of Sight is extended across the dial through the fixed index. Another imaginary line known as the Cross Line is drawn at right angles to the Line of Sight through the center of the Target.



The Target is said to be toward the Line of Sight when the bow of the Target is nearer the Line of Sight.

The Target is said to be toward the Cross Line when the bow of the Target is nearer the Cross Line.



The position of the Target on the Target Dial in relation to the Line of Sight and the Cross Line, together with the value of Target Elevation, determines which Target value has to be changed to control the generated dials in Manual Operation.

A generated dial may be turning in the same direction as the corresponding observed dial, but at a faster or slower speed, or it may be turning in the opposite direction to the observed dial. The instructions which follow give the correction for each of these conditions.

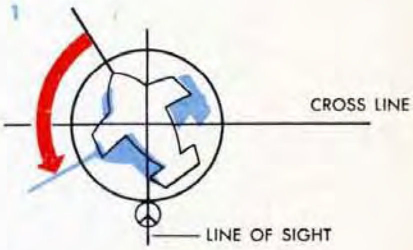
Controlling the generated range dials

When target elevation is below 45° and the target is toward the line of sight

To increase the speed of the Generated Range Dials, increase *Sh*.

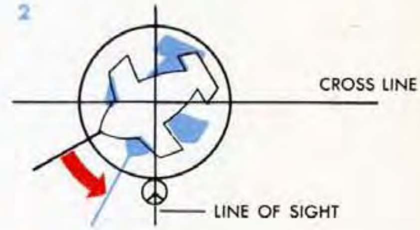
To decrease the speed of the Generated Range Dials, decrease *Sh*.

1 To reverse the direction of rotation of the Generated Range Dials, change *A* until the Target is on the other side of the Cross Line.

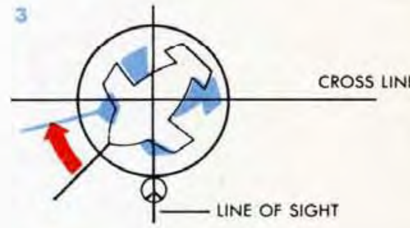
1


When target elevation is below 45° and the target is toward the cross line

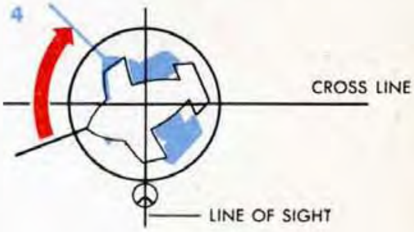
2 To increase the speed of the Generated Range Dials, move the Target away from the Cross Line.

2


3 To decrease the speed of the Generated Range Dials, move the Target closer to the Cross Line.

3


4 To reverse the direction of rotation of the Generated Range Dials, change *A* until the Target is on the other side of the Cross Line.

4


When target elevation is above 45°

To increase the speed of the Generated Range Dials, increase the numerical value of *dH*.

To decrease the speed of the Generated Range Dials, decrease the numerical value of *dH*.

To reverse the direction of rotation of the Generated Range Dials, change *dH* from a positive to a negative, or a negative to a positive value.

Controlling the generated elevation dial in manual operation

When target elevation is below 45°

To increase the speed of the Generated Elevation Dial, increase the numerical value of *dH*.

To decrease the speed of the Generated Elevation Dial, decrease the numerical value of *dH*.

To reverse the direction of rotation of the Generated Elevation Dial, change *dH* from a positive to a negative, or a negative to a positive value.

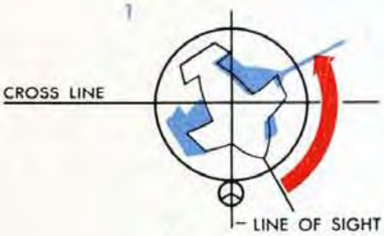
When target elevation is above 45° and the target is toward the **line of sight**

To increase the speed of the Generated Elevation Dial, increase *Sh*.

To decrease the speed of the Generated Elevation Dial, decrease *Sh*.

1 To reverse the direction of rotation of the Generated Elevation Dial, change *A* until the Target is on the other side of the Cross Line.

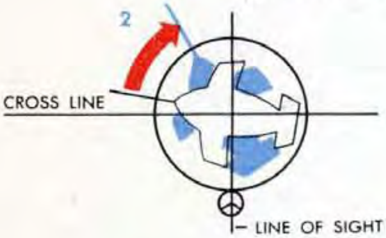
1



When target elevation is above 45° and the target is toward the **cross line**

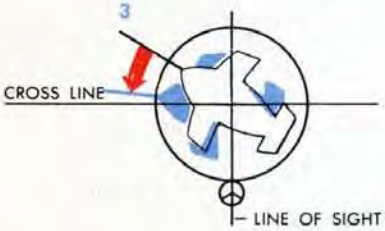
2 To increase the speed of the Generated Elevation Dial, change *A* to move the Target farther away from the Cross Line.

2



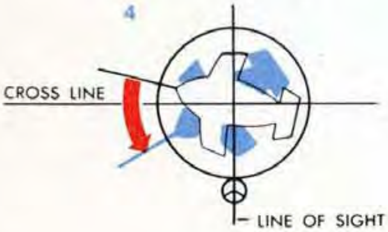
3 To decrease the speed of the Generated Elevation Dial, change *A* to move the Target closer to the Cross Line.

3



4 To reverse the direction of rotation of the Generated Elevation Dial, change *A* until the Target is on the other side of the Cross Line.

4

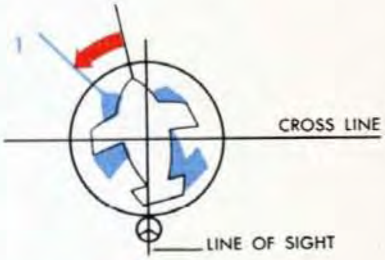


Controlling the generated bearing dial in manual operation

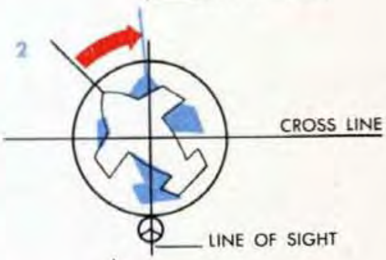
In making corrections to the Generated Bearing Dial, the value of Target Elevation may be disregarded.

When the target is toward the line of sight

1 To increase the speed of the Generated Bearing Dial, change *A* to move the Target farther away from the Line of Sight.

1


2 To decrease the speed of tne Generated Bearing Dial, change *A* to move the Target closer to the Line of Sight.

2


3 To reverse the direction of rotation of the Generated Bearing Dial, change *A* to move the Target to the other side of the Line of Sight.

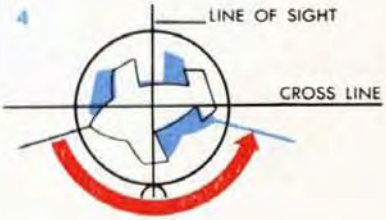
3


When the target is toward the cross line

To increase the speed of the Generated Bearing Dial, increase *Sh*.

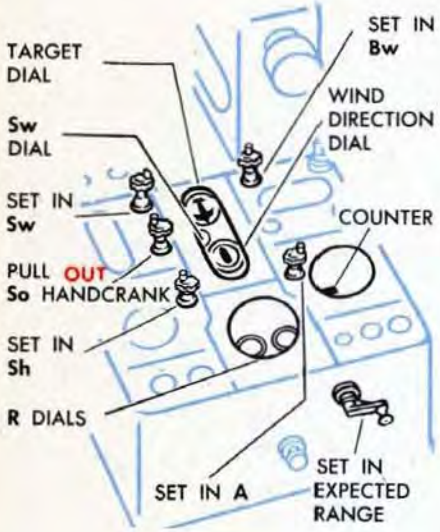
To decrease the speed of the Generated Bearing Dial, decrease *Sh*.

4 To reverse the direction of rotation of the Generated Bearing Dial, change *A* to move the Target to the other side of the Line of Sight.

4


STANDBY FOR A SURFACE TARGET

Changing from standby during search to standby for a surface target



At the Range Station:

1 With the Generated Range Crank OUT, set the expected Range into the Range Dials. Leave the crank OUT.

2 With the Target Speed Handcrank at HAND, set the estimated *Sh* into the Target Speed Counter. Leave the handcrank at HAND.

At the Elevation Station:

1 With the Rate of Climb Handcrank IN, check that the Rate of Climb Dial is at zero.

2 Set in Wind Speed by turning the Wind Speed Handcrank.

3 With the Ship Speed Handcrank IN, set the approximate speed; then pull the handcrank OUT.

At the Bearing Station:

1 Switch the Target Angle Handcrank to HAND and set in the estimated Target Course or Angle. Leave the handcrank at HAND.

2 Set in Wind Direction by turning the Wind Direction Handcrank.

At the Other Stations:

1 Put the Synchronize Elevation Handcrank IN and match the Synchronize Elevation Dials at the fixed index.

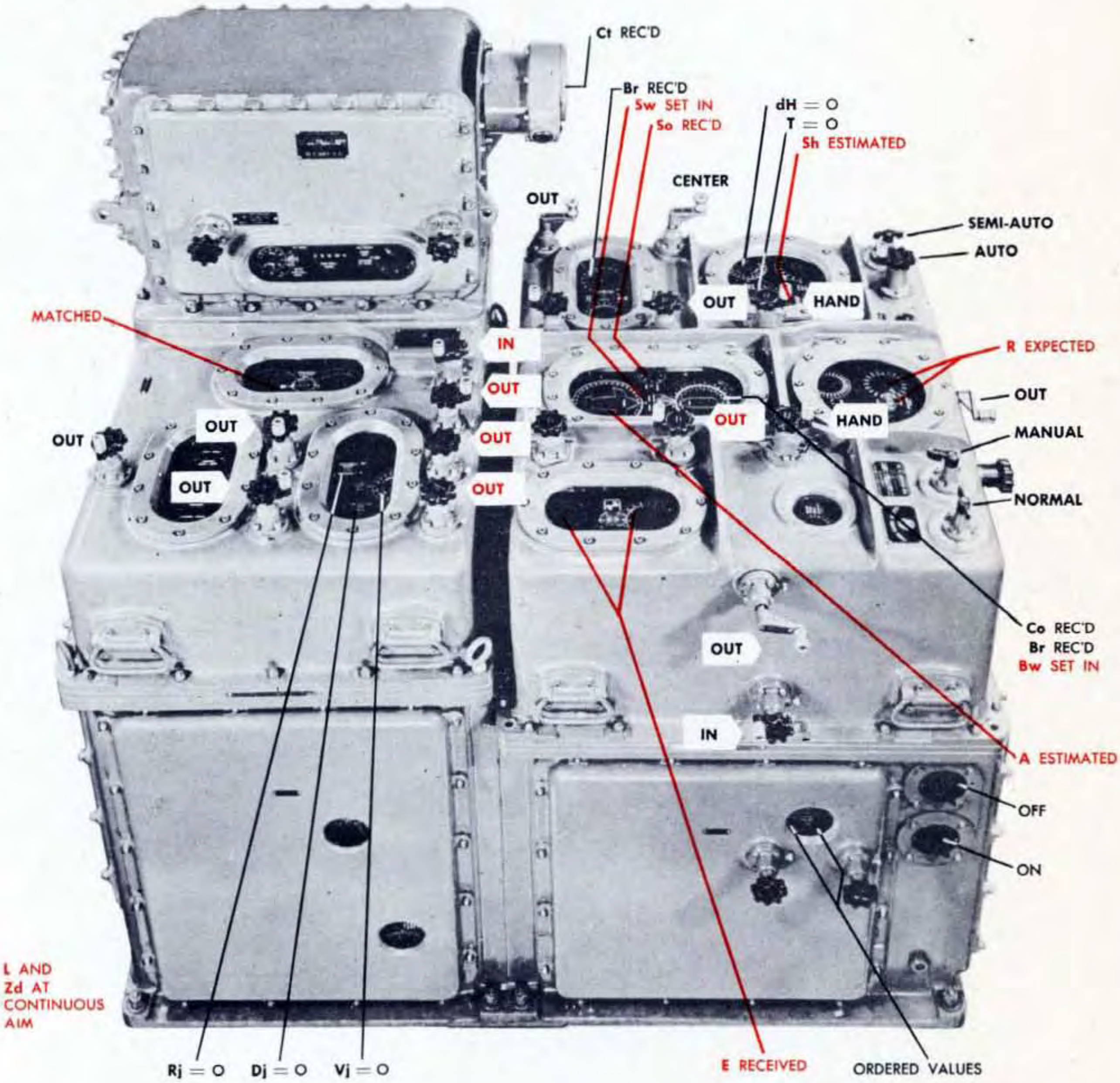
2 Pull the Spot Knobs OUT, noting that correct values of *Rj*, *Vj*, and *Dj* are indicated.

3 Put the Stable Element at Continuous Aim.

4 Make sure that all the switches connecting the Director, the Computer, the Stable Element, and the 5" guns are ON at the Fire Control Switchboard.

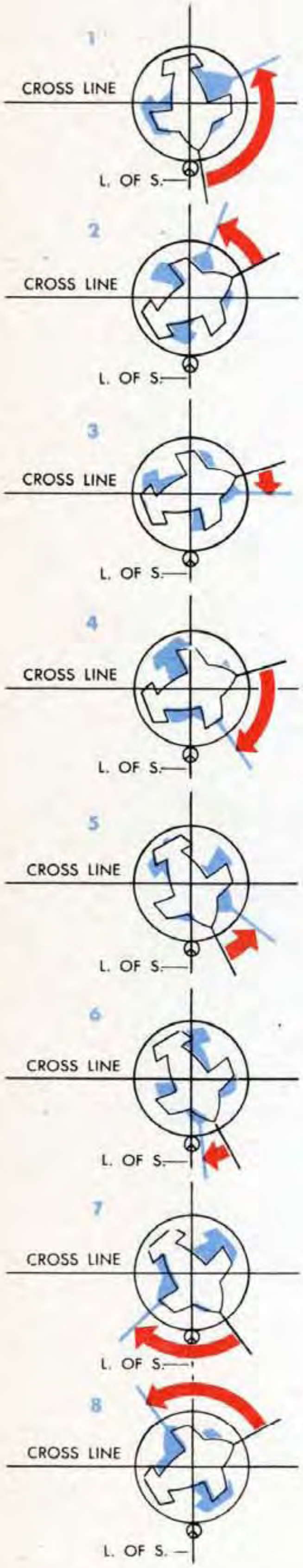
When the Range Finder, Pointer's, and Trainer's Signals indicate that the Director is tracking the Target, and the Target comes within tracking range, the Time Motor Switch is turned ON to commence tracking in Manual Operation.

COMPUTER IN STANDBY FOR A SURFACE TARGET



CHANGES FROM STANDBY SHOWN IN RED

MANUAL OPERATION AGAINST A SURFACE TARGET



Changing from standby for a surface target to manual operation against a surface target

At the Range Station:

1 Turn the Time Motor Switch ON.

Rate-controlling in manual operation against a surface target

When Observed Range is correct, the Generated Range Dials must be matched and kept rotating at the same speed. The Generated Bearing Dials must rotate at the same speed as the Observed Dials.

At the Range Station:

1 Use the Target Speed and Target Angle Handcranks to keep the Generated Range and Generated Bearing Dials rotating at the same rates and in the same directions as the Observed Range and Observed Bearing Dials.

Controlling the generated range dials

When the Target is toward the Line of Sight

To increase the speed of the dials, increase *Sh*.
To decrease the speed of the dials, decrease *Sh*.

1 To reverse the direction of rotation of the dials, move the Target to the other side of the Cross Line.

When the Target is toward the Cross Line

2 To increase the speed of the dials, move the Target farther from the Cross Line.

3 To decrease the speed of the dials, move the Target closer to the Cross Line.

4 To reverse the direction of rotation of the dials, move the Target to the other side of the Cross Line.

Controlling the generated bearing dial

When the Target is toward the Line of Sight

5 To increase the speed of the dial, move the Target away from the Line of Sight.

6 To decrease the speed of the dial, move the Target closer to the Line of Sight.

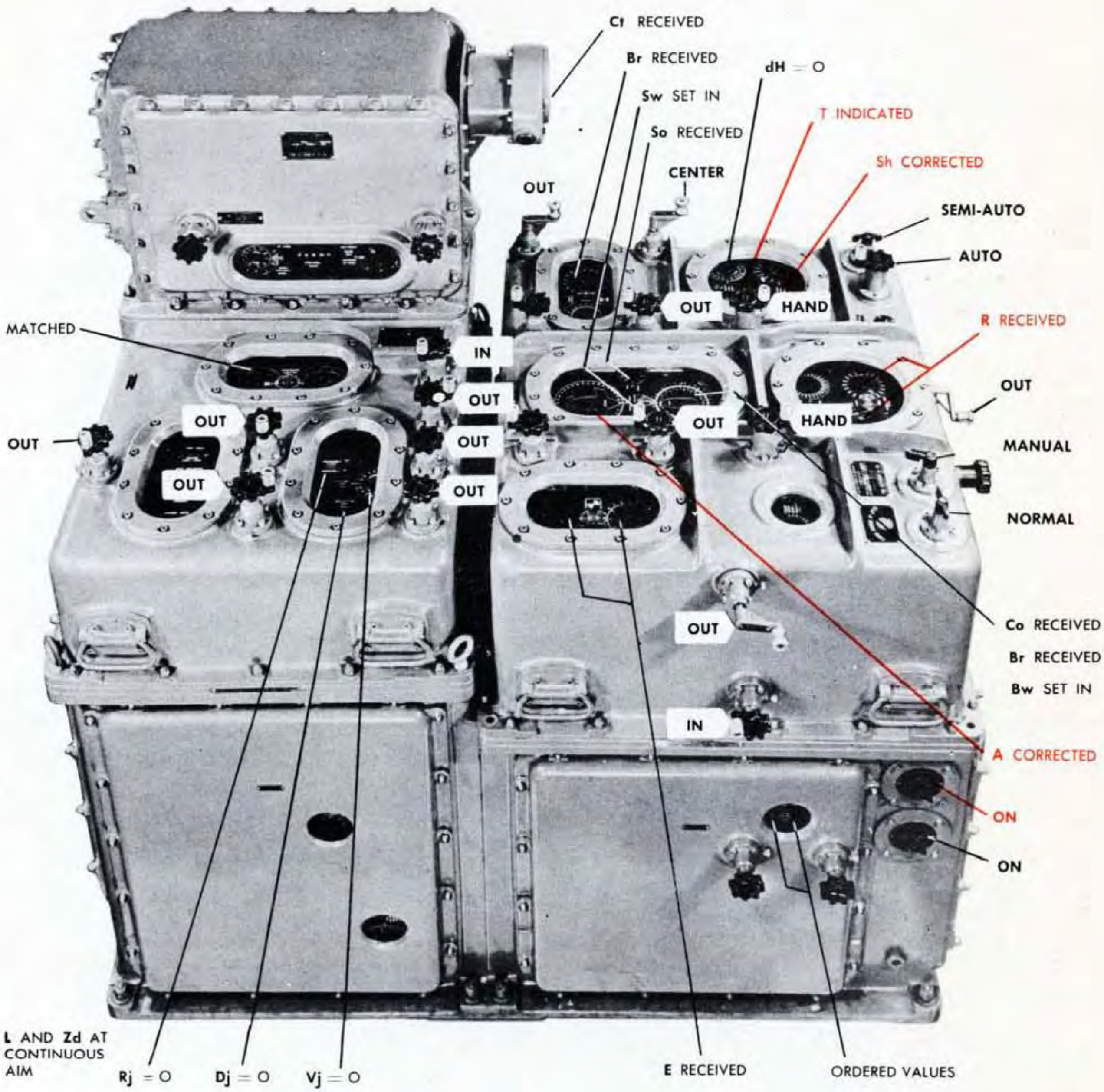
7 To reverse the direction of rotation of the dial, move the Target to the other side of the Line of Sight.

When the Target is toward the Cross Line

To increase the speed of the dial, increase *Sh*.
To decrease the speed of the dial, decrease *Sh*.

8 To reverse the direction of rotation of the dial, move the Target to the other side of the Line of Sight.

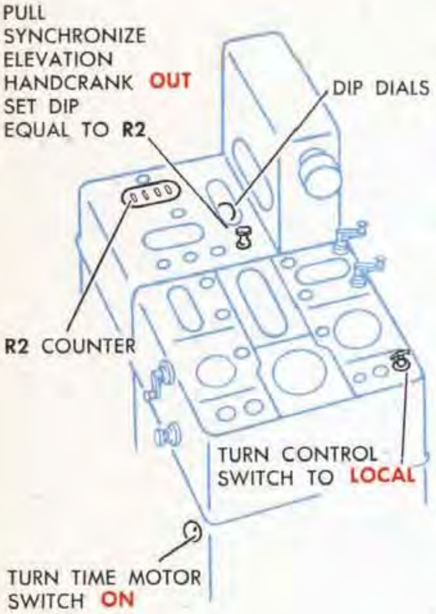
MANUAL OPERATION AGAINST A SURFACE TARGET



CHANGES FROM STANDBY FOR A SURFACE TARGET SHOWN IN RED

LOCAL OPERATION

Local Operation is used against surface targets only, when the Director is not operating, or when specified by ship's doctrine.



Changing from standby for a surface target to local operation

At the Range Station:

1 Turn the Control Switch to LOCAL.

At the Other Stations:

1 Put the Synchronize Elevation Handcrank at CENTER, set the *E* Dials at zero; then pull the Synchronize Elevation Handcrank OUT and set Dip Range into the Dip Dials.

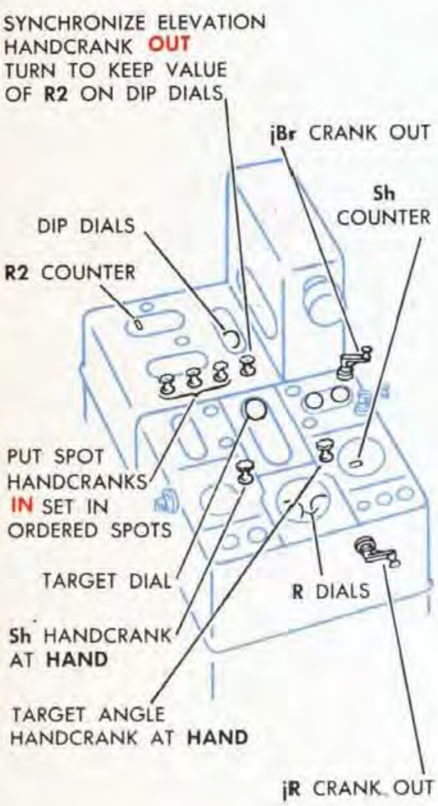
CAUTION: In setting Dip Range into the Dip Dials, be sure that the wide index on the coarse dial is set at the fixed index.

2 Put the Spot Handcranks IN.

To start tracking turn the Time Motor Switch ON.

Tracking in local operation

Range, *R*, Relative Target Bearing, *Br*, Target Angle, *A*, and Target Speed, *Sh*, are continually observed from some point on deck and phoned to the plotting room. The Computer Crew puts these values into the Computer. The Crew then corrects the Target estimates until no further corrections are needed to keep the computed values of Generated Range and Bearing shown on the dials equal to the phoned values of Range and Bearing.



At the Range Station:

1 With the Generated Range Crank OUT, set the phoned values of Range into the Generated Range Dials.

2 With the Target Speed and Target Angle Handcranks at HAND, correct *Sh* and *A* until the Range and Bearing Dials turn in agreement with the phoned values.

At the Bearing Station:

1 With the Generated Bearing Crank OUT, set the phoned values of Bearing into the Bearing Dials.

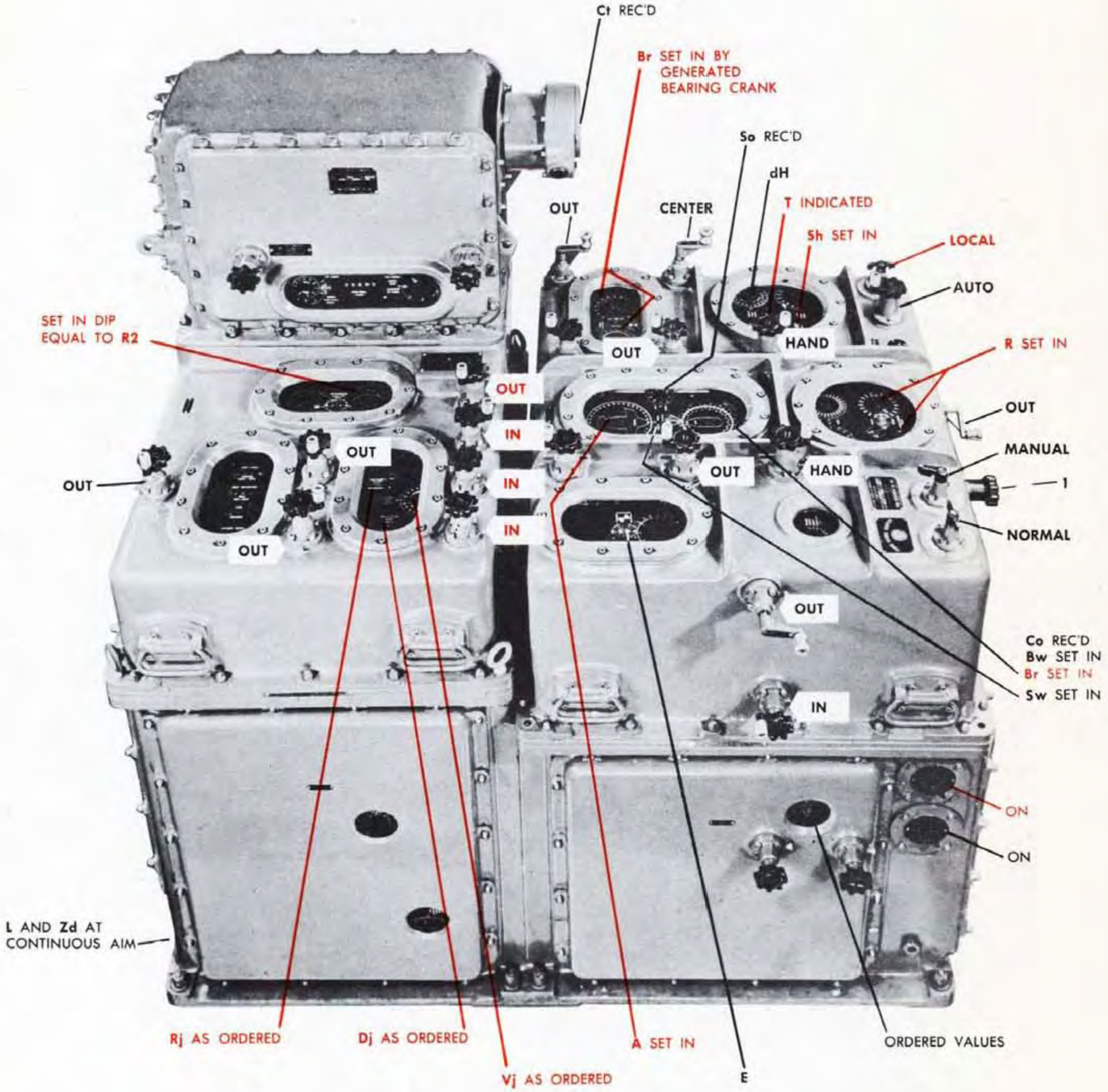
At the Other Stations:

1 Turn the Synchronize Elevation Handcrank in the OUT position to keep the value of Dip Range on the Dip Dials in agreement with the Advance Range reading on the *R2* Counter. (*R2* is used instead of *cR* for convenience in setting the Dip Range.)

2 With the Spot Handcranks IN, set in any Spot Corrections that are ordered.

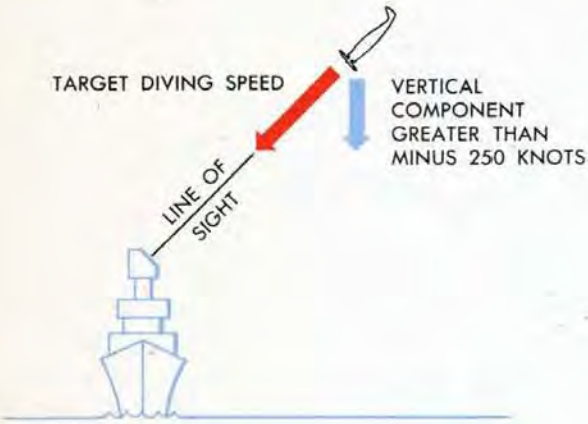
The problem is solved when no further Target value corrections are necessary to keep the values of Range and Bearing shown on the dials in agreement with the phoned values.

THE COMPUTER IN LOCAL OPERATION



CHANGES FROM STANDBY FOR A SURFACE TARGET SHOWN IN RED

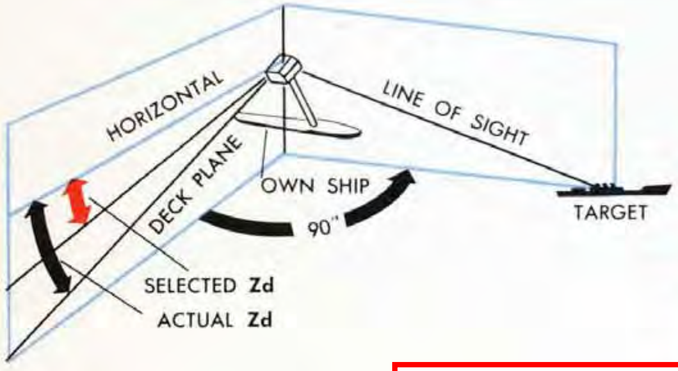
Summary of SPECIAL TYPES OF OPERATION

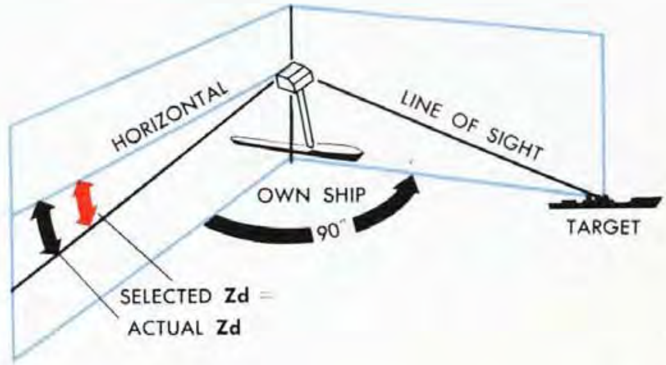


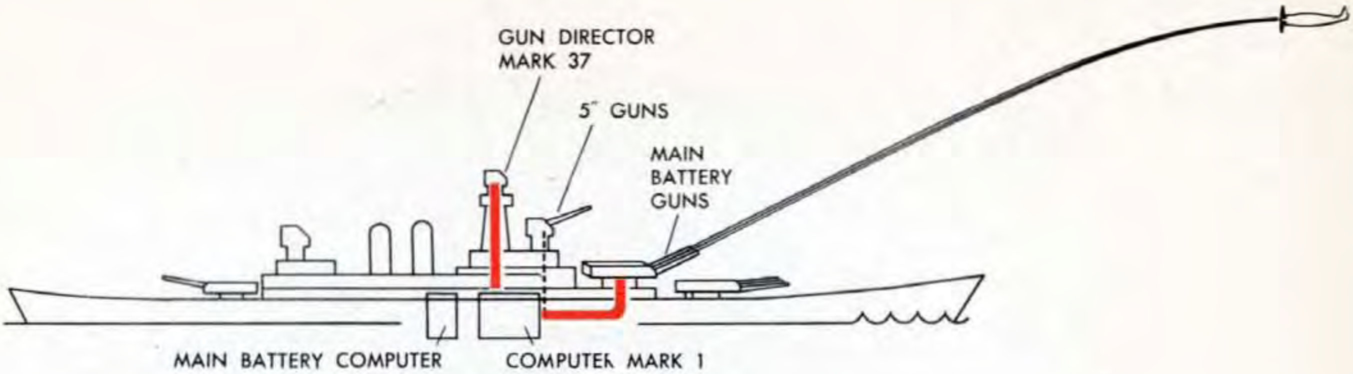
Special Dive Attack Procedure is a special type of operation used against air targets diving at Own Ship along the Line of Sight. Special Dive Attack Procedure is necessary only when the vertical component of dive is greater than −250 knots.

Selected Level Fire, Level Angle selected at the Director, is a method of operation used against surface targets when Continuous Aim cannot be used. The Pointer in the Director selects a fixed value of Level and fires the guns when actual Level equals the Selected Level. If the Director is not operating, the Selected Level is set at the Stable Element, and the firing of the guns is handled by the Stable Element Crew.

Selected Cross-level Fire also is used only against surface targets when Continuous Aim cannot be used. Selected Cross-level is always set at the Stable Element, and the firing of the guns is handled by the Stable Element Crew.







Main Battery Barrage Fire is a method of operation that permits the use of the main battery guns against on-coming aircraft. The normal outputs of the Computer Mark 1 are corrected by spots to compensate for the difference in ballistics between the 5" guns and the guns in the main battery.

Star Shell Fire is used at night to illuminate surface targets. A star shell bursts 1500 feet above and 1000 yards beyond the Target. When the shell bursts, it releases a parachute flare that burns for sixty seconds. A deflection correction is required to place the flare directly on the Line of Sight behind the Target after the flare has burned for thirty seconds.

A Star Shell Computer is mounted on the right side of the top of the Computer Mark 1. The Star Shell Computer receives data from the Computer and adds the corrections that are needed to place the star shell above and beyond the Target. The Star Shell Computer outputs are electrically transmitted to any one gun used to fire the star shells. The firing of the star shells does not interfere with the firing of service shells by the other guns. When a Star Shell Computer is not supplied, a Star Shell Legend Plate is mounted in its place. This legend plate gives the values of Sight Angle and Fuze Setting Order required for different values of Advance Range. These values are phoned to the gun used to fire the star shell.

DIVE ANGLE	DIVING SPEED FOR MAX. dH OF 250 KNOTS
90°	250
80°	254
70°	266
60°	289
50°	326
40°	389

DIVE ATTACK AGAINST OWN SHIP

The type of Computer operation used against diving aircraft depends on the nature of the dive attack.

In Auto or Semi-auto Operation

When Vertical Target Speed, *dH*, is numerically less than −250 knots, dive attacks against Own Ship can be handled by the Computer in Automatic or Semi-automatic Operation.

SPECIAL DIVE ATTACK PROCEDURE

When the *dH* Dial reaches −250 knots, SPECIAL DIVE ATTACK PROCEDURE must be used against Targets diving at Own Ship.

Changing to Special Dive Attack Procedure

At the Range Station:

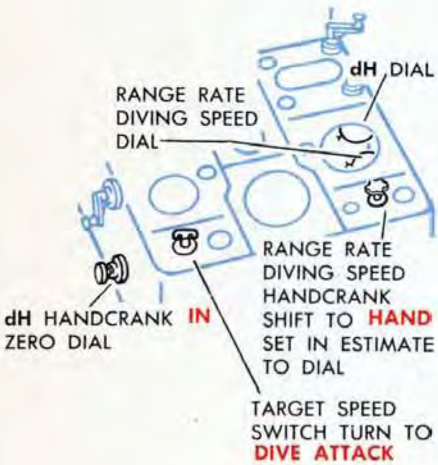
1 Turn the Target Speed Switch to DIVE ATTACK and leave it there.

2 Shift the Range Rate/Diving Speed Handcrank to HAND. Set the estimated Diving Speed into the Diving Speed Dial.

At the Elevation Station:

1 Put the Rate of Climb Handcrank IN. Zero the Rate of Climb Dial. Leave the handcrank IN.

Rate-controlling in Special Dive Attack Procedure



At the Range Station:

1 With the Range Rate/Diving Speed Handcrank at HAND, continue correcting the Diving Speed estimated until the Generated Range Dials turn at the same rate as the Observed Range Dials and remain matched at the same value.

At the Elevation Station:

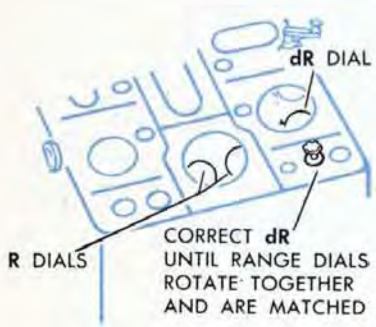
1 The Elevation Dials remain almost stationary because the Target is coming down the Line of Sight.

At the Bearing Station:

1 Any movement of the Bearing Dials is due to motion of Own Ship.

The solution is reached when the Generated Range, Elevation, and Bearing Dials rotate at the same rate as the Observed Range, Elevation, and Bearing Dials.

As soon as the Dive Attack order is over, turning the Target Speed Switch to NORMAL returns the Computer to Automatic Operation. Put the Range Rate/Diving Speed Handcrank at AUTO.



DIVE ATTACK AGAINST OTHER SHIPS

No special procedure is available for dive attack against other ships, regardless of the diving speed. The Computer should be placed in Automatic or Semi-automatic Operation.

SPECIAL DIVE ATTACK PROCEDURE CANNOT BE USED AGAINST PLANES DIVING AT OTHER SHIPS.

SELECTED LEVEL FIRE

Selected Level Fire is used only against surface targets. The guns can be fired only when the deck has tilted to the Selected Level Angle.

There are two types of Selected Level Fire: one in which the Selected Level is set by the Pointer in the Director, and another in which the Selected Level is set at the Stable Element. The second type is almost always used, and must be used when the Director is not operating.

WHEN LEVEL IS SELECTED AT THE DIRECTOR, the operation of the Computer is exactly the same as for regular Manual Operation against a surface target, except that the Synchronize Elevation Handcrank is put in the CENTER position and the Elevation Dials are set at zero.

The Pointer fires the guns whenever his crosshair is on the Target.

NOTE:

The Director Mark 37 is not well adapted to Selected Level Fire from the Director because the Trainer's and Range Finder Optics and the Radar Antenna cannot be elevated independently of the Pointer's Optics. When the Pointer's Line of Sight swings off the Target the Trainer's and Range Finder Optics and the Radar beams also swing off the Target. This makes ranging and training impossible under most conditions.

WHEN LEVEL IS SELECTED AT THE STABLE ELEMENT, the operation of the Computer is exactly the same as for either regular Manual or Local Operation, except that Dip is set in by the Synchronize Elevation Handcrank in the OUT position.

The Stable Element Crew puts the Stable Element firing selector lever at SELECTED LEVEL position and selects the value of Level desired. Either AUTO or HAND firing can be used. Whenever the deck tilts so that the actual Level equals the Selected Level, the firing contacts complete the firing circuit allowing the guns to be fired.

SELECTED CROSS-LEVEL FIRE

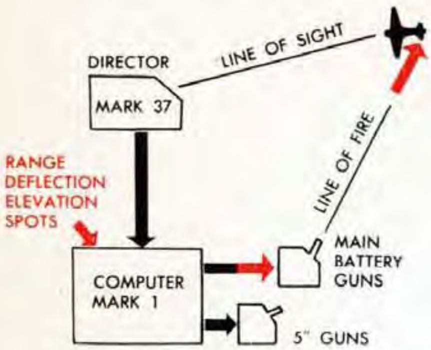
Selected Cross-level Fire is used only against surface targets. The guns can be fired only when the deck has tilted to the selected value of Cross-level.

Selected Cross-level Fire can be used with or without the Director. The Cross-level value is always selected at the Stable Element. The guns can be fired whenever the Stable Element firing contacts complete the firing circuit.

WITH THE DIRECTOR, the Computer is operated for Selected Cross-level Fire in Manual Operation.

WITHOUT THE DIRECTOR, the Computer is operated for Selected Cross-level Fire in Local Operation.

MAIN BATTERY OPERATION



Many of the Directors and Computers controlling main battery guns solve surface problems only. By using the Gun Director Mark 37 and the Computer Mark 1, the main battery guns can be adapted for barrage fire against on-coming aircraft.

The Computer Mark 1 normally computes solutions for the 5″ guns. These solutions can be adapted to main battery guns by the addition of the proper Range, Deflection, and Elevation Spot Corrections for each size of gun and projectile.

The spots that are required are given in a Table of Corrections for each size of gun. A Table of Corrections looks like this:

SAMPLE TABLE OF CORRECTIONS

4000 FEET
TARGET HEIGHT

MIN. OBS. RANGE	FUZE	RANGE SPOT IN	ELEV. SPOT DOWN	DEFL. SPOT RIGHT
12400	15	1080	16	0
12900	16	1140	17	1
13400	17	1190	18	1
13900	18	1250	20	1
14400	19	1310	21	1
14900	20	1370	23	1
15400	21	1421	25	1

OD 5102

This table is a sample and does not apply to any particular combination of gun and computer.

The Director Mark 37 and Computer Mark 1 track the Target by the same methods used when controlling the 5″ guns. The guns are elevated and trained continuously by the Mark 1 Gun Orders. The Parallax Corrections are not used.

When a solution is reached, the Spot Corrections that are shown on the Table are applied. A Fuze Setting Order is selected and phoned to the guns. The guns are fired when the computed Fuze Setting Order equals the Selected Fuze Setting Order.

When the Computer Mark 1 is used for main battery operation, its solution can be used by only one size of gun and projectile at any one firing. If the 5″ guns are to be fired in the same barrage as the main battery guns, a separate Computer Mark 1 is required to operate the 5″ guns, because the Spot Corrections made to suit the main battery guns would place the 5″ gunbursts short of the Target.

Using a TABLE OF CORRECTIONS

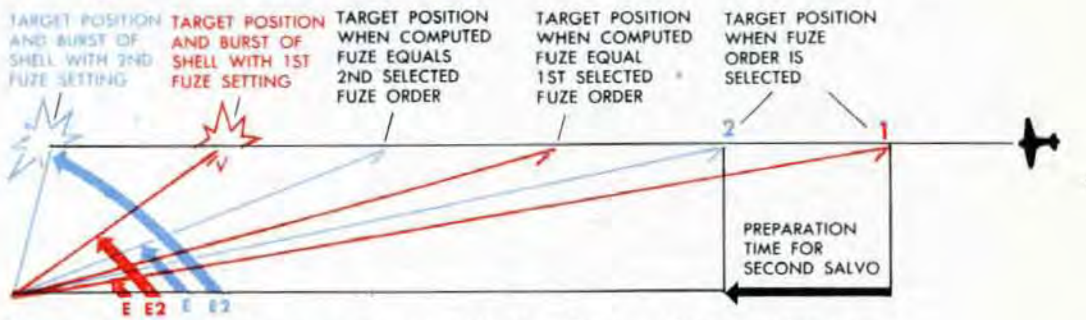
The Table of Corrections is based on one problem: a Target flying at a constant speed, at a constant height, directly toward Own Ship.

The guns are fired at a Selected Fuze Setting Order determined by the Target Height and Range. The Height of the Target is obtained from the Computer Height Dials. The Observed Present Range is obtained from the Generated Range Dials. After the Height and the Present Range are determined, a Minimum Observed Range is obtained from the table that is *less* than the Computer Range Dial reading. This allows for Target Motion between the time of selecting the Fuze Setting Order and the firing of the guns.

The Selected Fuze Setting Order depends on the Minimum Observed Range obtained from the table. In the column headed "Fuze," next to the column headed "Min. Obs. Range," is the value of the Selected Fuze Setting Order for the particular Height and Range of the Target. This Selected Fuze Setting Order is phoned to the guns.

The Range, Deflection, and Elevation Spots given in the table are set into the Computer to adapt its outputs to the ballistics of the main battery guns. With the Spots entered, the guns are fired as soon as the Fuze Setting Order transmitted from the Computer equals the Selected Fuze Setting Order previously phoned.

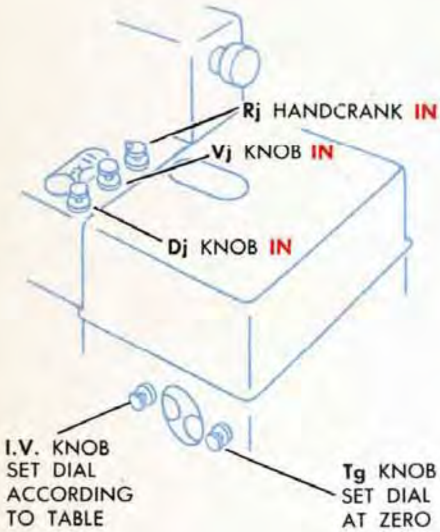
Using alternate tables



Two tables may be used to permit the firing of two salvos in close succession. Using this method, two Fuze Setting Orders are selected for two different ranges. The first range is longer than the second by a time sufficient to allow for the preparation of the guns for the second salvo.

THE MAIN BATTERY CONTROL

Changing from standby for an air target to main battery control



At the Range, Elevation, and Bearing Stations:

1 Make the changes required to go into Automatic, Semi-automatic, or Manual Operation.

At the Other Stations:

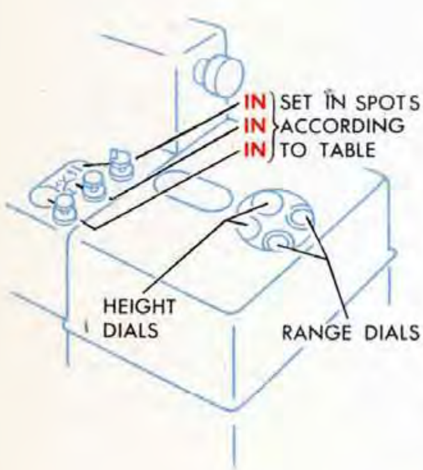
1 At the Fire Control Switchboard, connect the Gun Director Mark 37 and the Computer Mark 1 to the main battery guns.

2 Set the Dead Time Dial at zero.

3 Set the Initial Velocity Dial at a value that is equal to the actual *I.V.* of the main battery guns minus the value given on the Table of Corrections.

4 Put the Range Spot Handcrank and the Deflection and Elevation Spot Knobs IN.

The computer is then operated in automatic, semi-automatic or manual control until a solution is reached



After the solution is reached:

1 Read the Height Dials. Apply this value to the nearest thousand feet on the Table of Corrections.

2 Read the Range Dials. Select a Fuze Setting Order on the Table of Corrections for a shorter Range than is shown on the Range Dials.

3 Phone the Selected Fuze Setting Order to the guns, and at the same time,

4 Set in the Range, Deflection, and Elevation Spots given in the Table of Corrections for the Selected Fuze Setting Order.

At the Computer, the Fuze Setting Order Counter is watched carefully. The instant that the Fuze Setting Order Counter reading equals the phoned Selected Fuze Setting Order, the guns are fired.

STAR SHELL FIRE

Star Shell Fire is controlled in three ways:

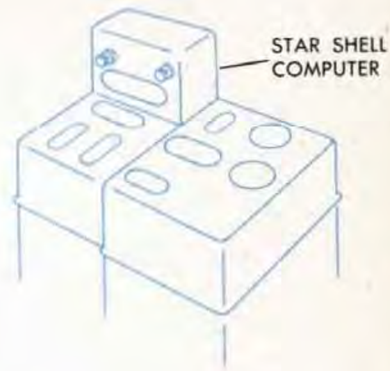
1 By the Star Shell Computer Mark 1.

2 By orders for Fuze and Sight Angle taken from the Star Shell Legend Plate and phoned to the guns.

3 By orders for Fuze and Sight Angle taken from the Star Shell Legend Plate and transmitted to the guns through the Computer Mark 1.

THE STAR SHELL COMPUTER

The Star Shell Computer is mounted on the top of the Computer Mark 1.



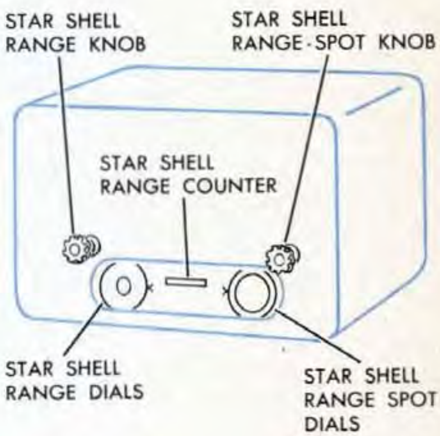
Operating the star shell computer

1 At the Fire Control Switchboard, connect the Star Shell Computer to the gun that is to fire the star shells.

2 Turn the Star Shell Range Spot Knob to match the index on the Range Spot Ring Dial with the arrow on the inner dial.

3 Push the Star Shell Range Knob IN and set the inner Star Shell Range Dial to the Star Shell Counter reading. Pull the knob OUT and set the ring dial to the counter reading. Return the knob to its IN position.

CAUTION: The transmission system of the Star Shell Computer is designed to control only one gun.



THE STAR SHELL LEGEND PLATE

When there is no Star Shell Computer, a Star Shell Legend Plate is attached to the Computer Mark 1 in its place.

The Legend Plate has four columns. The first column shows Advance Range at intervals of 2,000 yards, from 4,000 to 14,000 yards. The next two columns show the Fuze Setting Orders for powder and mechanical fuzes corresponding to the values of Advance Range given in the first column. The last column lists the values of Sight Angle corresponding to the values of Advance Range in the first column.

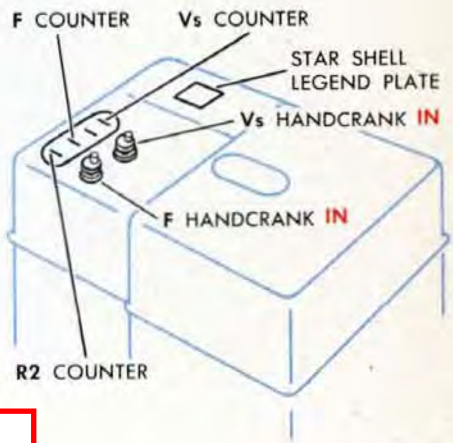
STAR SHELL DATA FOR 2500 F.S. I.V.

ADV. RANGE	FUZE PWDR.	FUZE MECH.	SIGHT ANGLE
4000	11	8	2570
6000	16	13	2630
8000	22	19	2800
10000	29	27	3050
12000	35	35	3400
14000	42	45	3880

Using the legend plate

1 Read the Advance Range Counter on the Computer. Apply this value to the Advance Range Column of the Star Shell Legend Plate.

2 Read the Fuze Setting Order and Sight Angle values appearing opposite the Advance Range selected, and phone these values to the gun firing the star shells, or if the 5″ battery is being used to fire star shells only, send the Fuze and Sight Angle data to the guns by setting the values into the Computer Mark 1. To do this, put the Fuze and Sight Angle Handcranks IN and turn them until the values designated on the Star Shell Legend Plate show on the Fuze and Sight Angle Counters on the Computer.



ALTERNATIVE STANDBY CONDITIONS

The following Standby Conditions may be used when great speed is needed in shifting to full operation.

Standby Condition

All the Computer, Stable Element, Director, and gun transmission circuits are energized.

The Stable Element Level and Cross-level Switches are at MANUAL.

The Selector Drive is in LOCK position.

At the Computer:
1 The Power Switch is ON.
2 The Ship Course Handcrank is IN.
3 The Control Switch is at SEMI-AUTO.
4 The Range Rate Control Switch is at MANUAL.
5 The Ship Speed Handcrank is OUT, with *So* synchronized.
6 The Time Motor is OFF.

NOTE:
To eliminate constant setting of fuzes in the bottom of the projectile hoist, the Fuze Handcrank on the Computer may be locked in its IN position with Fuze set at 2 seconds.

Standby during search

When Search begins, turn the Stable Element Level and Cross-level Switches to AUTO.

At the Computer:
1 Pull the Ship Course Handcrank OUT.
2 Pull the Fuze Handcrank OUT.

NOTE:
The only time the Selector Drive should be unlocked is when the equipment is in a Standby Condition and Own Ship is rolling more than 20 degrees. Under these conditions the Stable Element Level and Cross-level Switches must be at AUTO to prevent tumbling of the gyro. The plotting room crew must be alerted to shift to LOCK when Search begins.

Changing from standby during search to air target expected

At the Range Station:

1 Switch the Target Speed and Target Angle Handcranks to AUTO.
2 With the Target Speed Switch, set *Sh* at approximately 200 knots.
3 With the Generated Range Crank OUT, match Generated Range to Observed Range.
4 Turn the Time Switch ON.
5 Switch the Target Speed Handcrank to HAND.
6 Turn the Control Switch to AUTO.
7 After approximately 2 seconds, switch the Target Speed Handcrank back to AUTO. This may be done by the Elevation Operator while the Range Operator keeps the Range Dials matched.
8 Report "Plot set."
9 Push the Generated Range Crank IN. Press the Range Rate Manual Push-button and keep the Range Dials matched.

At the Elevation Station:

1 Put the Synchronize Elevation Handcrank IN and match the Synchronize Elevation Dials.
2 Set Rate of Climb on zero and pull the Rate of Climb Handcrank OUT.
3 Pull the Spot Knobs OUT.

At the Bearing Station:

1 At the Target Course Indicator, set Target Course as ordered.

A SAMPLE PROBLEM

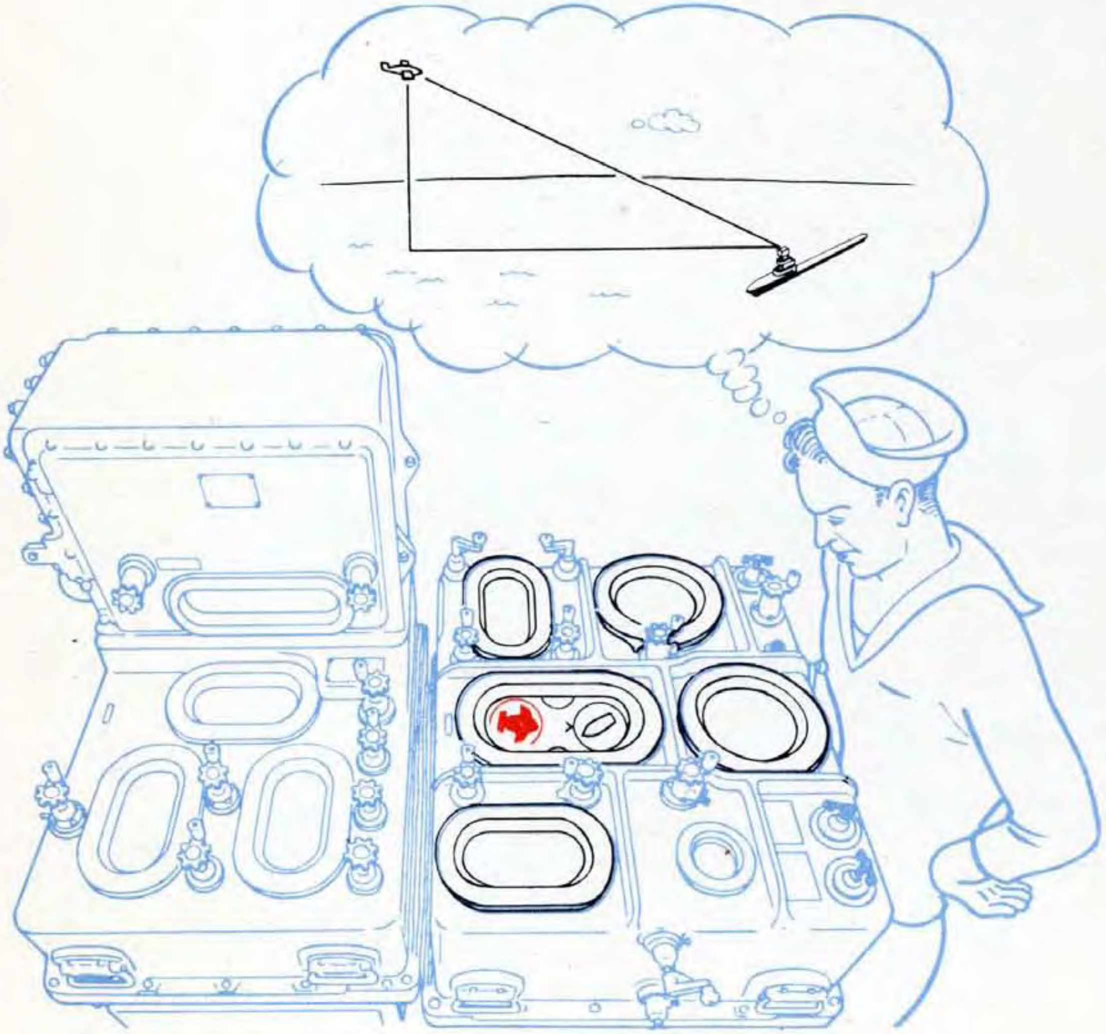
A man standing in the plotting room watching the Fire Control Switchboard and the Computer Mark 1 can obtain a very accurate picture of the fire control problem and of the activity throughout the Gun Director Mark 37 System.

The positions of the switches on the Fire Control Switchboard and the Computer show him the condition of the Computer relative to the other parts of the fire control system.

The positions and motion of the Computer dials give a good picture of the actual conditions existing between Own Ship and Target.

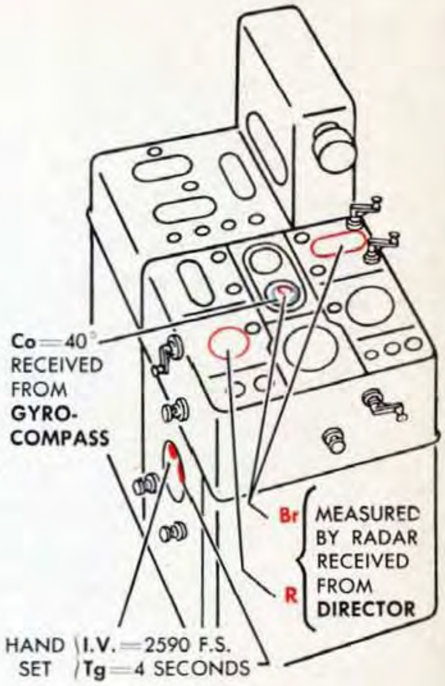
Indicating signals from various parts of the system show the action being taken there.

This chapter describes a sample fire control problem. It is not a typical combat problem but is designed to show how the action above deck can be visualized in the plotting room.



Action is expected

At the start of this problem, the switches on the Fire Control Switchboard and the Computer show that the Computer is in *Standby during Search. Standby during Search* usually indicates that action is expected.



At the Computer, Own Ship Course is being received from the Gyro Compass. The Compass Ring Dial reads 40° against the zero index of the Ship Dial. The only other dials showing actual values are the Initial Velocity Dial, which has been set at 2590 f.s., and the Dead Time Dial, which has been set at 4 seconds.

The Radar Range Dial and Relative Target Bearing Dials are moving, showing that the Director is searching for a target.

After a few moments the Radar Range Dial and Relative Target Bearing Dials steady down and move gradually, indicating that radar search has picked up a target. The Radar Range Dial shows a little under 75,000 yards.

The Bearing Dials steady down around 34 degrees.

There is no reading for Target Elevation because the Director Elevation Receiver is not yet energized at the Fire Control Switchboard.

The reading on the Radar Range Dial is decreasing, showing that the Target is approaching Own Ship. The high rate at which the reading is decreasing indicates an air target.

The problem so far can be visualized like this:

An air target is expected

The Computer is ordered to *Standby for an Air Target*. The Range Dials are set at 35,000 yards, the maximum Range at which the Computer can start tracking.

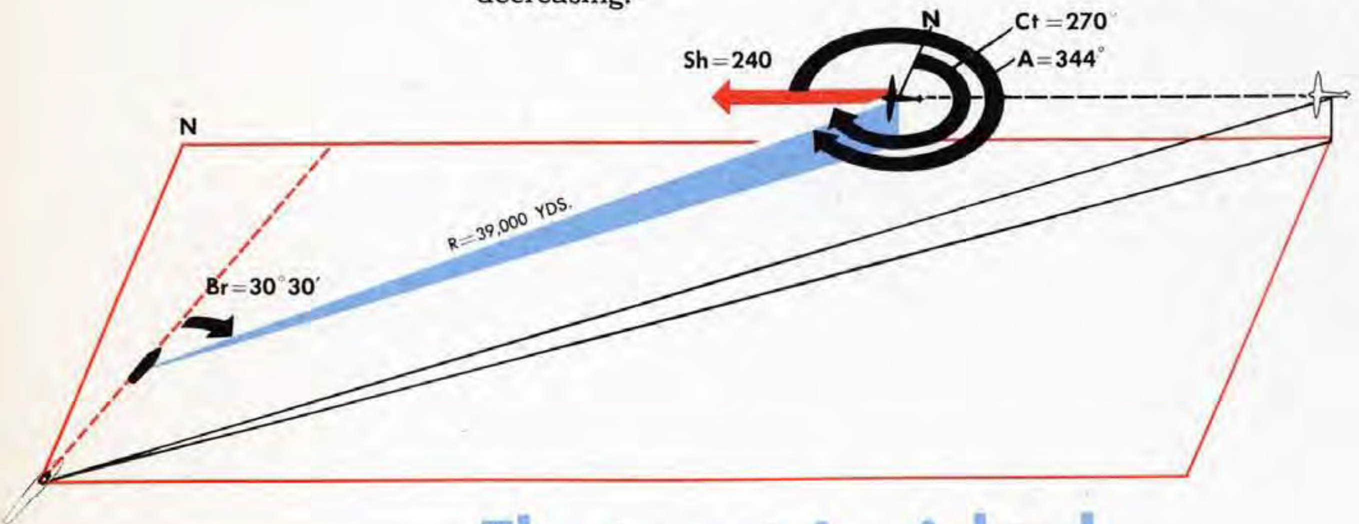
The Ship Speed Dial now shows 35 knots. The value of this quantity is being received from the Pitometer Log. Own Ship Course still reads 40 degrees.

Reports of Wind Direction and Wind Speed are now received. *Bw* is quickly set at 270°, *Sw* at 20 knots.

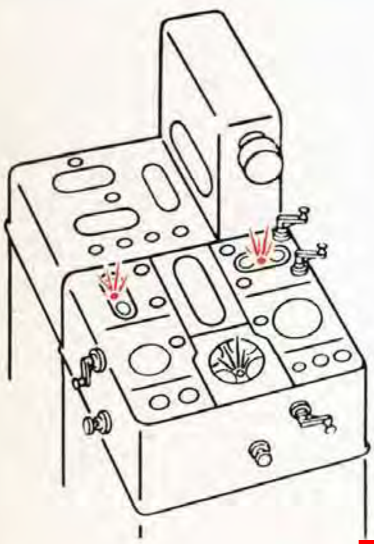
A moment later, estimates of Target Course and Target Speed are received by phone. *Ct* is set at 270° and *Sh* is set at 240 knots. *dH* is set at zero. According to these estimates, the Target is heading due West, flying at a steady altitude. The position of the Target in relation to Own Ship can now be seen on the Ship and Target Dials.

The Director Elevation Receiver is now energized and *E* can be read on the *E* Dials.

The Ship, Compass, and True Wind Dials, and the Observed Relative Target Bearing Dials turn slowly as Relative Target Bearing changes. The Radar Range Dial shows Range steadily decreasing.



The target is sighted



When Range has closed to less than 39,000 yards, and *Br* is 30° 30′, the Trainer's Signal turns to red. The Trainer now has his crosshair on the Target.

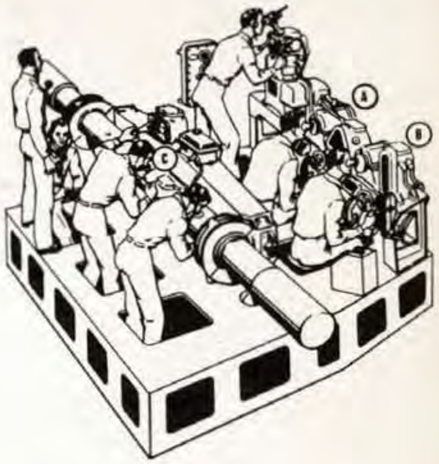
A few seconds later the Pointer's Signal also turns to red. Now the Pointer has his crosshair on the Target.

The Range Finder Signal turns to white, showing that the Range Operator in the Director has the Target in focus.

For a while all three signals from the Director continue to show these colors, indicating that the sights are being held on the Target by the Director Operators.

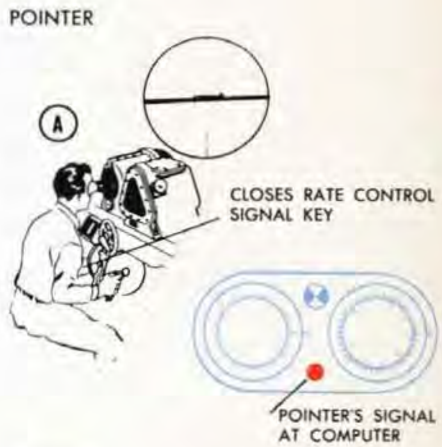
With the Director Sights and Range Finder on the Target, and all the necessary information available, tracking can be started at the Computer the moment that Range reaches 35,000 yards.

Reviewing the signals and indicators in automatic operation



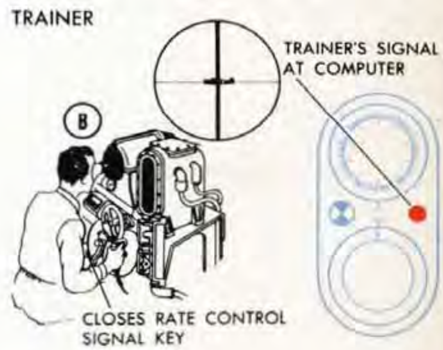
When the Computer is in Automatic Operation, the signals and solution indicators play a large part in visualizing the Gun Director operation. Because the Computer may be ordered into Automatic Operation when the maximum tracking range is reached, it is well to review the function of these controls.

Elevation



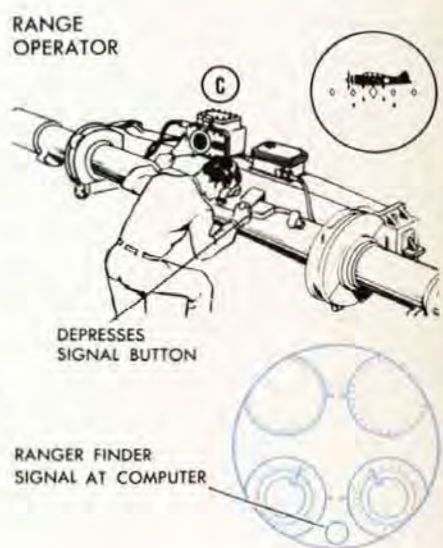
The Pointer closes his signal key and causes the Pointer's Signal at the Computer to show red whenever his crosshair is on the Target. If the Elevation Solution Indicator rotates while the Pointer's Signal is red, the Pointer is putting angular and rate corrections to Elevation into the Computer. If the Indicator rotates while the Signal is black, the Pointer is putting in angular corrections only.

Bearing



The Bearing Solution Indicator and the Trainer's Signal have the same relationship to Bearing corrections as the Elevation Solution Indicator and the Pointer's Signal have to Elevation corrections.

Range



The Range Operator depresses his signal button and causes the Range Finder Signal at the Computer to show white whenever the Range is correct. If the indexes on the Generated Range Dials are not matched to those on the Observed Range Dials at the time that the signal turns to white, the Generated Range Dials immediately turn until the indexes match. A linear and a rate correction to Range are made automatically.

If the indexes on the Range Dials are already matched at the time that the Range Finder Signal turns to white, no corrections are made to Range.

TRACKING BEGINS

When the Radar Range Dial reads 35,000 yards and Range is coming in smoothly and accurately, the Computer is ordered into Automatic Operation. The Control Switch and the Range Rate Control Switch are set at AUTO and the Time Switch is turned ON. The Generated Range, Elevation, and Bearing Dials spin and then synchronize with their Observed Dials.

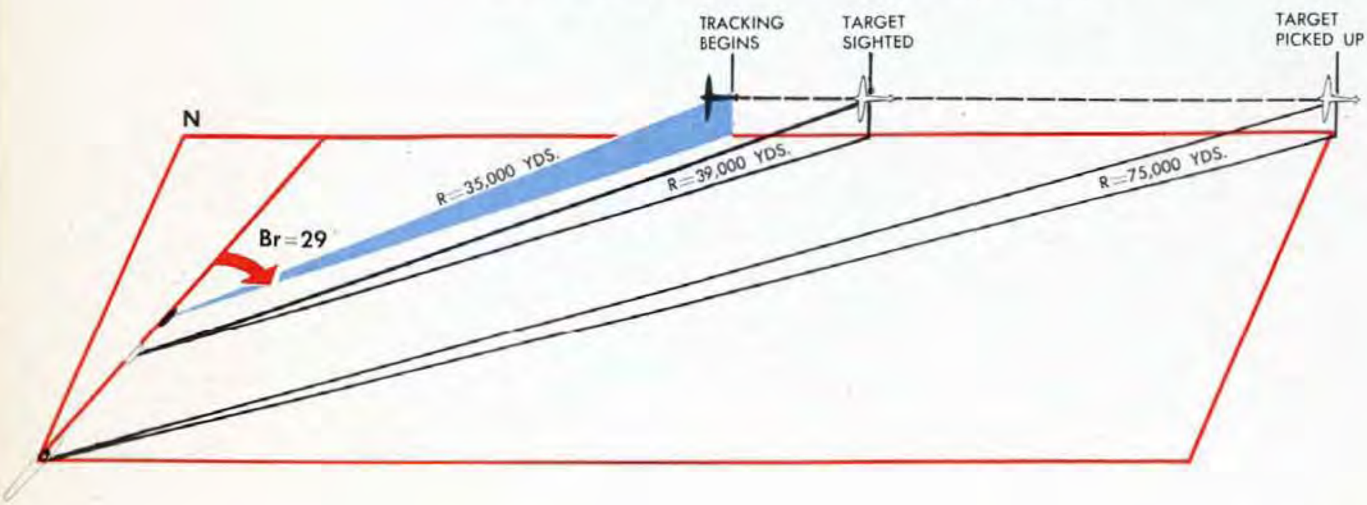
The sights are kept on target

As the Elevation Dials synchronize, the Pointer's Signal turns to black, showing that the Pointer's crosshair has moved off the Target. The Elevation Solution Indicator rotates as the Pointer turns his handwheels and sets in a correction to Elevation. The Pointer's Signal turns to red as the Indicator turns, showing that the Pointer is now setting in both angular and rate corrections to Elevation. After a moment the Indicator stops turning, and the Signal remains red. The Generated Changes of Elevation are now raising the Director sights at the correct rate to keep the Pointer's crosshair on the Target.

The Trainer's Signal remains red as the Computer is put into Automatic Operation. The Bearing Solution Indicator remains stationary, indicating that the Generated Changes of Director Train are training the Director correctly, and no rotation of the Trainer's handwheels is required to keep the Trainer's crosshair on the Target.

With Range just under 35,000 yards, Relative Bearing has decreased to 29°. The Elevation Dials now show less than 1°, Target Course is still 270°, and the Rate of Climb Dial still reads zero.

These dial readings show that the Target is flying low at a constant height and that it will pass ahead of Own Ship if both Ship and Target remain on their present courses.



A SOLUTION IS REACHED

At the time that the Computer is put into Automatic Operation, the Range Finder Signal is white, indicating that the Range Operator has the Target in focus. The Generated and Observed Range Dials turn together as the Generated Changes of Range from the Computer alter the Range Finder focus.

After a few seconds, the Range Finder Signal turns to black. The Target is now out of focus because the Generated Changes of Range are not correct. The Observed Range Dials turn faster than the Generated Range Dials and the indexes are no longer matched as the Range Operator turns his Range Knob to bring the Target into focus.

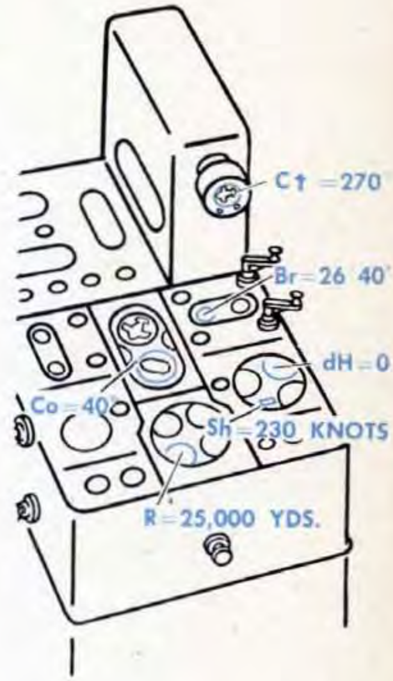
The Range Finder Signal turns to white again, and the dials jump to match at their indexes. The dials turn together as linear and rate corrections to Range are set into the Computer.

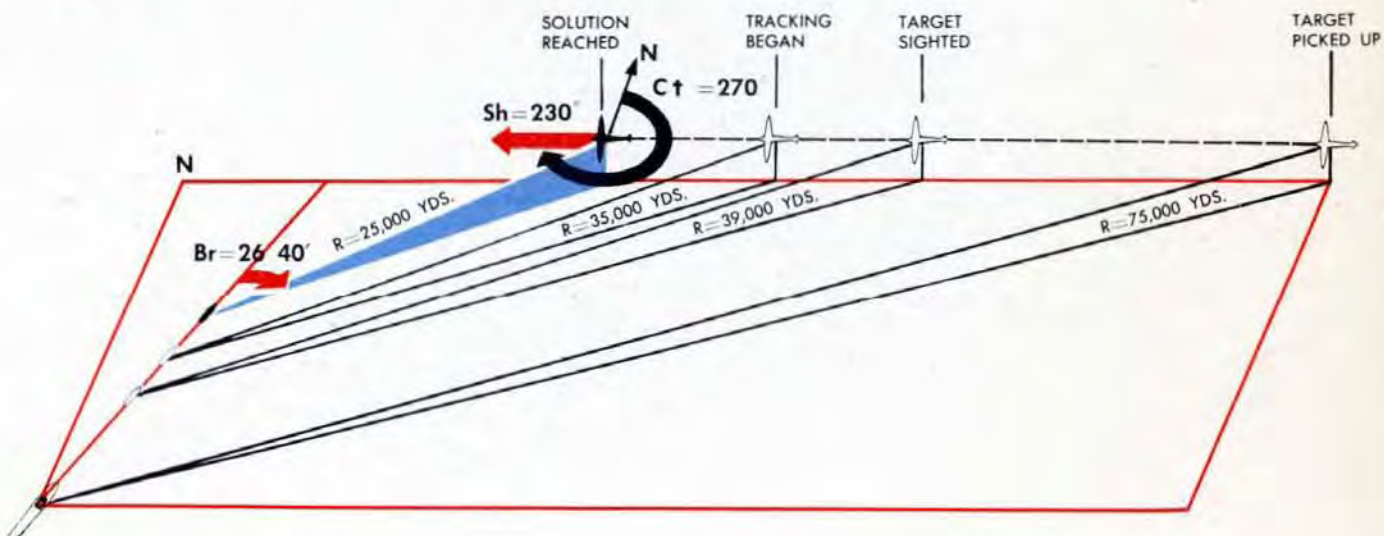
The Range Finder Signal now remains white. The Pointer's and Trainer's Signals remain red. All three operators in the Director are now on Target and the Generated Changes of Range, Elevation, and Bearing are keeping the sights on Target, and the Range Finder in focus. A solution has been reached, and the Computer is transmitting correct orders to the guns. Firing can begin as soon as the Target is within shooting Range.

At the time that the solution is reached, the Range Dials show that the Range has closed to 25,000 yards.

The Relative Target Bearing Dials, which showed 29° at the beginning of tracking, now show 26° 40′.

The Rate Corrections put in by the Trainer and Range Operator have been used by the Computer to correct the estimated value of Target Speed. The Target Speed Counter now reads 230 knots.





The PROBLEM PROGRESSES

The Range Finder Signal remains white and the Pointer's and Trainer's Signals remain red for several minutes after the solution is reached, indicating that the Target is continuing in a straight line at a constant speed.

When the Range Dials read 14,000 yards, the Relative Target Bearing Dials show 20° and Elevation is 2 degrees.

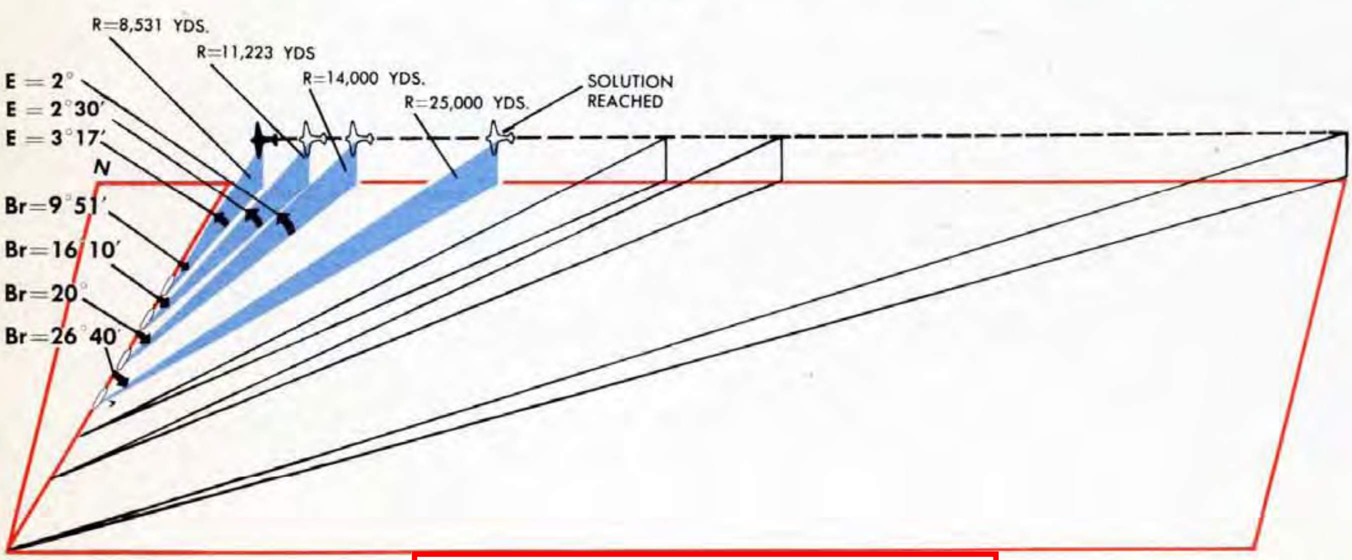
Twenty seconds later the dials are read again to check that the problem is progressing smoothly. At this reading, Range has decreased to 11,223 yards, Relative Target Bearing has decreased to 16° 10′, while Target Elevation has increased to 2° 30′.

The order *"Commence firing"* is given.

The Target is still approaching Own Ship and will cross in front of Own Ship if Target Course does not change. The dial on the Target Course Indicator is at present fairly steady at 220 degrees. The Target Speed Counter shows the Target to be flying at a steady speed of 230 knots.

The Range Finder Signal still remains white and the Pointer's and Trainer's Signals still remain red as the Target approaches, showing that the values generated by the Computer are keeping the Range Finder focused and the sights on the Target. Twenty seconds after the last dial reading, the dials show these new values:

> Range is down to 8 531 yards and Relative Target Bearing is only 9° 51′; Elevation continues to increase slowly and is now 3° 17′.



FIRING CEASES

When Range reaches 6038 yards, an order is received to "*Cease firing*." This is the usual order given when a Target is brought down. The Computer is ordered back to the original *Standby during Search,* indicating that further action is expected.

The moment that the "*Cease firing*" order is received in the Plotting Room, the dials show that the following changes have taken place:

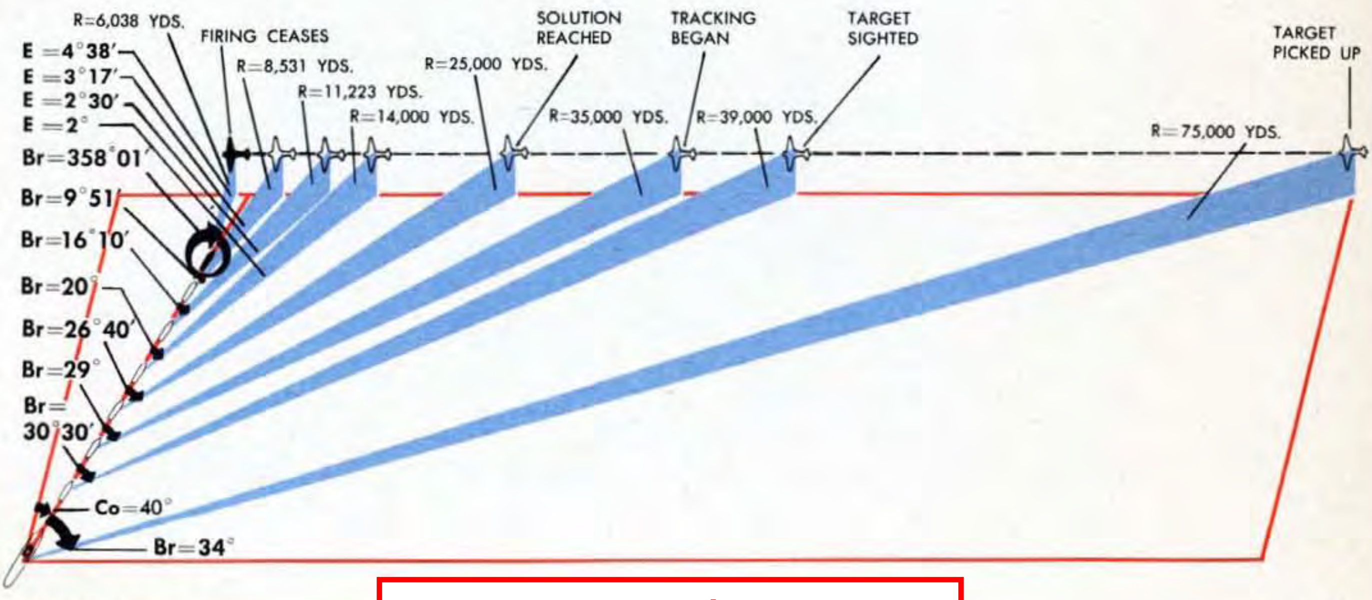
Range has decreased to 6038 yards.

The Target has now crossed in front of Own Ship, causing Relative Target Bearing to move to 358° 01′.

Target Elevation which has been increasing continuously, is now 4° 38′.

A SUMMARY OF THE PROBLEM

Here is a summary of the sample problem as it has been visualized from the Computer Dials:



OPERATING CAUTIONS

To avoid faulty operation of the Computer Mark 1, caution should be used in operating the instrument. Instructions are given here for avoiding some of the most usual sources of damage and faulty operation.

Use of the Time Crank

The Time Crank should never be turned counterclockwise in the OUT position. Although friction drive A-161 is adjusted to slip when the Time line is turned counterclockwise, this friction may be too tight and damage to the Time Motor Regulator may result if the Time line is turned backwards. In the IN position the Time Crank is connected to the Seconds Dial only and may be turned safely in either direction.

Elevation Limit Stops

Various units may slip out of adjustment if the Director Elevation Receiver drives at full speed against the end of the *Eb* limit stop, L-11, or the *E* limit stop, L-12.

Operating instructions are designed to avoid hitting L-11, which may cause clamp A-50 to slip in instruments having serial numbers 1 to 290. In changing from *Standby during Search* to *Standby for An Air or Surface Target,* make sure that the Director Pointer's sights are not at either limit of travel, because the operating limits of *Eb* in the Computer are narrower than in the Director. Then, when the *Eb* transmission circuit is completed, the servo motors will not drive into L-11.

One possible result of hitting the end of L-12 is slippage at assembly clamps A-56 and A-59 in instruments having serial numbers 1 to 290. Such slippage usually occurs when the Director Pointer's sights are slewed beyond the limits of the Computer, or while the Synch *E* Handcrank is being returned from the OUT position to the normal operating position at IN. Slippage due to the latter cause may be avoided by synchronizing as follows:

1. See that the correct value of Level is being received.
2. Put the Synch *E* Handcrank in the CENTER position. Wait until the *Eb* Receiver has synchronized on the signal.
3. Put the Synch *E* Handcrank IN and match the Synch *E* Dials.

Preventing faulty synchronization of Receivers

Due to the heart-shaped relief cams, synchro-receiver units will run toward synchronization in the direction of shorter travel. Under certain conditions, instead of driving to the desired synchronization point, certain receiver units may drive into the end of a limit stop in the opposite direction.

These units are:

The Range Spot Receiver (4000 yards per revolution)
The Elevation Spot Receiver (360 mils per revolution)
The Deflection Spot Receiver (360 mils per revolution)
The Ship Speed Receiver (40 knots per revolution, usually)
The Director Elevation Receiver (180° per revolution)

For an example of a condition under which a unit may drive into the end of a limit stop, consider the Elevation Spot Receiver. The limit stop travel is ± 180 mils, totaling 360 mils. This value, 360 mils, is equal to the value per revolution of the synchro motor. If the instrument setting were UP 150 mils and the transmitted value were DOWN 150 mils when the circuit was energized to receive the signal, the receiver unit would run into the UP 180 mils limit instead of driving back through zero to the desired DOWN 150 mils position.

The Ship Speed and Range Spot Receivers may synchronize a full revolution out. On most installations the *So* limit is 0 to 45 knots and the *So* Synchro has a value of 40 knots per revolution. When the Pitometer Log is on 0 knots, the *So* line in the instrument may therefore drive either to 0 or to 40 knots. In the same way, on modifications of the Computer Mark 1 having the IN 12,000-yard limit, when the Range Spot Transmitter is on 0, the Range Spot Receiver may synchronize on 0, IN 4000, IN 8000, or IN 12,000.

To prevent both faulty synchronization and running into limit stops, the units should be set at the approximate transmitted values, or held at zero position until after the transmission circuits have been completely energized.

Setting I.V.

The *I.V.* correction is actually three corrections: a powder temperature correction based on average magazine temperature, an erosion correction based on average erosion, and an air density correction based on air temperature and barometric pressure.

The standard *I.V.* value of 2550 f.s. for which zero correction is put into the Computer Mark 1 for 5"/38 cal. guns, is taken as an average *I.V.* for a rifle of average age and for average atmospheric conditions. It has no relationship to the standard *I.V.* of the particular ammunition being used. The *I.V.* setting, however, must allow for the standard *I.V.* of the projectile. For example, suppose the ammunition has a standard *I.V.* of 2600 f.s. If powder temperature and barometric pressure are such as to necessitate a +10 correction, and erosion necessitates a −20 correction, the *I.V.* setting will be 2600 + 10 − 20 = 2590. The Computer dial (or dials on Serial Nos. 811 up) must be set at 2590, NOT at 2550 + 10 − 20 = 2540.

The Range Rate/Diving Speed Handcrank

The handcrank labeled *Range Rate/Diving Speed* should be set at AUTO during normal operation of the Computer. It is used at HAND only during certain DIVE ATTACK problems. Since this handcrank is often set at HAND during testing, the operator should check to make sure that it is at AUTO during normal operation.

The Rrr Knob

The Range Rate Ratio Knob engages at only one position. To make sure that the knob is engaged, turn the knob in a decreasing direction to Ratio 1, and check that the limit of travel is reached.

Shifting from Semi-automatic Operation to Automatic or Local Operation

It is sometimes desirable to shift to Automatic Operation after reaching a solution of an air problem in Semi-automatic Operation. Since there is no definite matching point between Observed and Generated values of Bearing and Elevation in SEMI-AUTO, as there is in AUTO and LOCAL, the solution can easily be upset by shifting to AUTO without special care. If the Computer operator shifts to AUTO while the Pointer and Trainer have their signal keys closed, the *jE* and *jBr* Motors will drive the inner Elevation and Bearing Dials up to as much as 20° travel and will put in corresponding amounts of rate corrections. The solution will be considerably upset. If the Generated Elevation and Generated Bearing Cranks are left in the IN position when control is shifted to AUTO, the solution will be even more upset.

If a solution has been reached or even partially reached in SEMI-AUTO and it is desired to shift to AUTO, the following procedure should be followed:

1. Set the Generated Elevation and Generated Bearing Cranks in the OUT position.
2. Shift the Target Speed Handcrank to HAND.
3. Turn the Control Switch to AUTO.
4. Wait until the *jE* and *jBr* Motors drive the inner dials to synchronization; then shift the Target Speed Handcrank back to AUTO to resume Rate Control.

If it is desired to shift to LOCAL while tracking a surface target in SEMI-AUTO, synchronize Generated Bearing with Observed Bearing before making the shift to LOCAL.

Synchronize Generated Bearing with Observed Bearing as follows:

1. Shift to AUTO until the dials are synchronized.
2. Shift back through SEMI-AUTO to LOCAL.

If this is not done, Observed Bearing will run off the correct value by some amount up to 20 degrees.

Page 160 is blank

Part 3

DETAILED DESCRIPTION

The solution of the fire control problem can be divided among eight separate groups of mechanisms in the Computer Mark 1. Each of these groups forms a network which solves a portion of the problem. All eight networks in the Computer operate simultaneously, and a solution of the fire control problem is continuously transmitted to the guns all the time the Computer is in operation.

In this Detailed Description the first eight chapters describe the eight computing networks in the order in which the solution from each network builds toward the solution of the whole problem. Each computing mechanism is described in the order in which it solves its portion of the problem, without regard to its physical position in the Computer. The last two chapters describe the Star Shell Computer network and the Selector Drive.

An understanding of each network and of the interrelation between the various networks will give a complete picture of the method by which the Computer Mark 1 solves the fire control problem.

The Detailed Description is divided into the following chapters:

DETAILED KNOWLEDGE OF THE COMPUTER

The Detailed Description of the Computer Mark 1 may seem highly theoretical, but most of it is very useful information for anyone who is to operate the Computer, and indispensable to anyone who is to test, set, or maintain the Computer.

Why operators should read the detailed description

The operator who is familiar with what is going on under the covers of the Computer Mark 1 will have confidence in the instrument and in his own handling of it. He will be able to visualize the fire control problem and see more quickly what the Computer needs to reach a solution in any given situation. He will use the types of operation best suited to each problem and will not be tempted to avoid certain types because they may appear more complex.

An operator with a knowledge of the Detailed Description will understand and remember operating instructions more easily, he will be able to switch from one type of operation to another with greater speed and accuracy, and he will be equipped with the knowledge and confidence he needs to meet new situations and emergencies as they arise. For example: An operator may discover that a handcrank which should be in the AUTO position is in the HAND position. The man who is familiar with the Computer will know whether or not changing this handle to AUTO will introduce violent changes in the Computer outputs with consequent danger to either the Gun Crew or the Director Crew.

An informed operator will be much better able to prevent casualties. The operator who is merely following memorized instructions will be apt to overlook signs of trouble and to continue operation of the instrument until a casualty occurs.

Operators with detailed knowledge of the Computer will also be better able to detect faulty operation by the Director Crew and thus create a basis for better Director-Computer coordination.

HAS MANY PRACTICAL USES

Operation by a well-informed crew can save needless wear and tear on the Computer mechanisms. For instance, an understanding of the proper use of the Selector Drive will eliminate much needless wear in the Trunnion Tilt Section of the Computer.

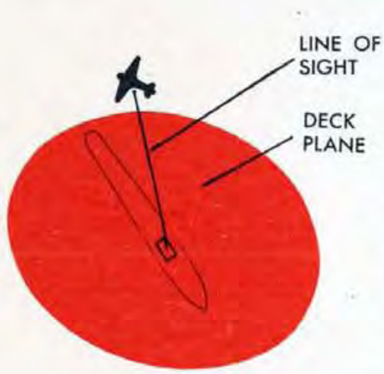
Another advantage of knowing the inside as well as the outside of the Computer is the background it provides for evaluating the word-of-mouth suggestions picked up from the fire control crews of other ships.

Why maintenance personnel must read the detailed description

The Detailed Description is required information for anyone who is going to test, set, or maintain the Computer Mark 1. The relationship of the mechanisms within each network, and the relationship of the networks to each other are explained here. The consequence of neglecting an upset clamp, a bent shaft, or a stuck gear cannot be appreciated fully without a thorough knowledge of the way in which the Computer mechanisms work together.

A man who has studied the Detailed Description will also realize the importance of finding the exact location of trouble in the Computer. He will know the interconnections between the networks and be able to locate trouble without difficulty.

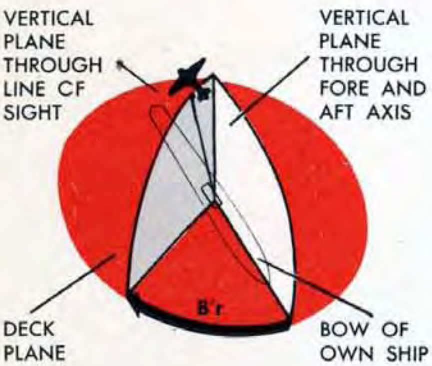
DECK TILT



The Deck Tilt Group computes a stabilizing quantity called Deck Tilt Correction, $jB'r$.

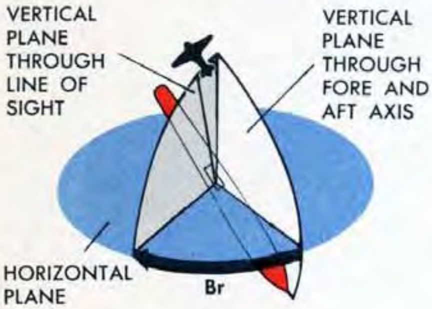
One of the input quantities which the Computer Mark 1 needs is a *horizontal* measure of the Target's bearing relative to the fore and aft axis of Own Ship. This horizontal measure of the Target's relative bearing is called Relative Target Bearing, *Br*. *Br* is the angle, *in the horizontal plane,* between the vertical plane through the fore and aft axis of Own Ship and the vertical plane through the Line of Sight, measured clockwise from the bow. *Br* is needed for computing Relative Motion Rates and Rate Control Corrections.

Br cannot be measured directly by the Gun Director Mark 37.



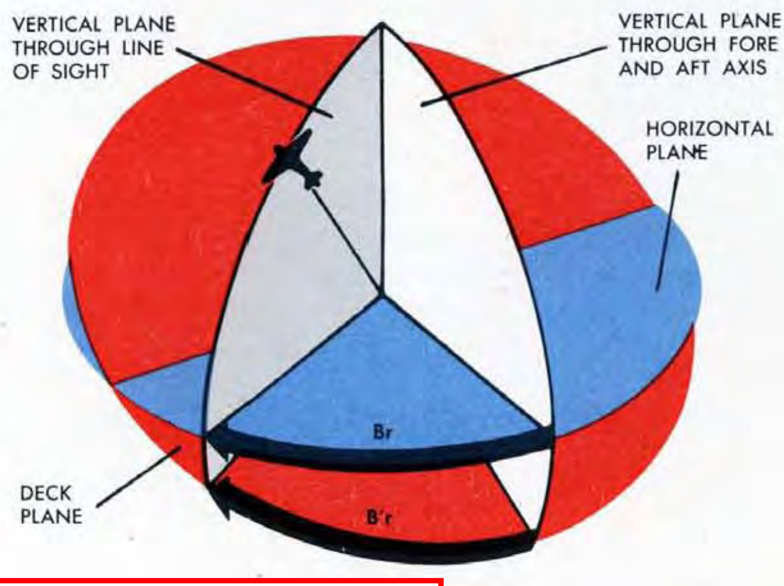
Since the Director is mounted on a roller path in the deck plane, the whole Director trains in the *deck* plane, and tilts with the deck as Own Ship rolls and pitches. When the sights are on the Target, the Director measures the Target's bearing relative to the fore and aft axis of Own Ship *in the deck plane*. This measure of the Target's relative bearing in the deck plane is called Director Train, *B'r*. *B'r* is the angle between a vertical plane through the fore and aft axis of Own Ship and a vertical plane through the Line of Sight, measured *in the deck plane,* clockwise from the bow of Own Ship.

In order to convert *B'r* to *Br*, the Computer Mark 1 must continuously compute the amount by which *B'r* differs from *Br*. This computed difference between *B'r* and *Br* is called Deck Tilt Correction, $jB'r$.



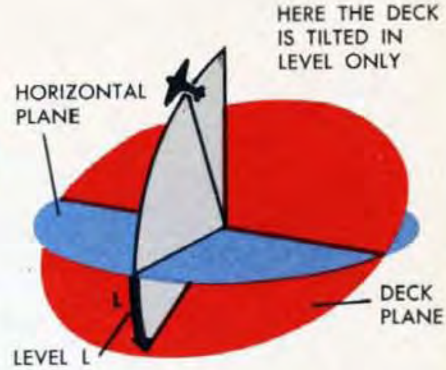
Br is obtained by continuously adding the computed Deck Tilt Correction, $jB'r$, to the measured value of Director Train, *B'r*.

$$Br = B'r + jB'r$$



NOTE:
Strictly speaking, the term "deck plane" does not mean a plane through the deck, but a plane through the Director sights parallel to the Director roller path.

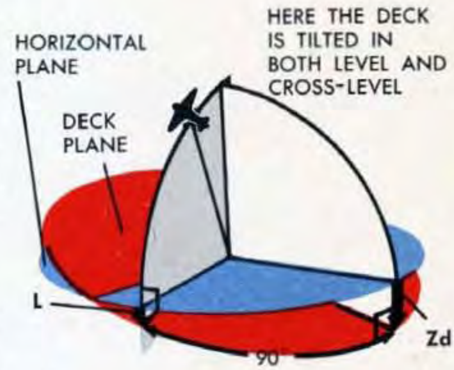
THE INPUTS
to the deck tilt group



The quantities used in computing Deck Tilt Correction, *jB′r*, are Director Train, *B′r*, Level, *L*, and Cross-level, *Zd*.

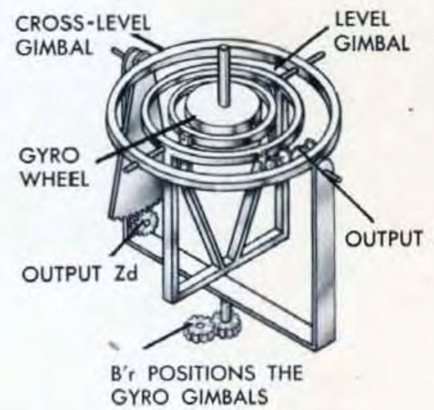
Level, *L*, and Cross-level, *Zd*, are measures of deck inclination.

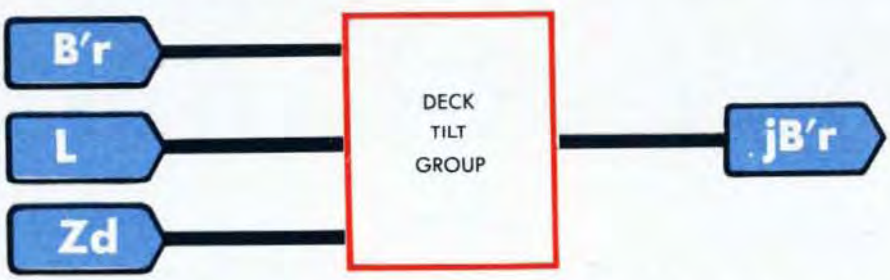
Level, *L*, is the angle between the horizontal plane and the tilted deck plane measured in the vertical plane through the Line of Sight. The correction for *L* is positive when the deck toward the Target tilts down.



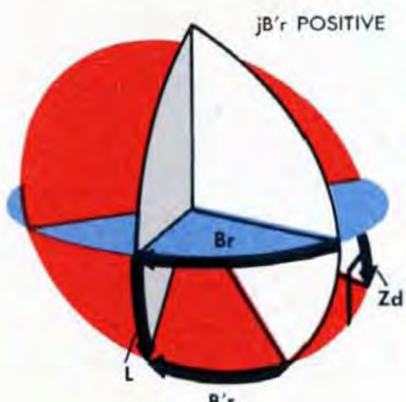
Cross-level, *Zd*, is the angle between the horizontal and the tilted deck measured in a plane at right angles to the deck plane, and at right angles to the vertical plane through the Line of Sight. The correction for *Zd* is positive if, when facing the Target, the deck to the left tilts down.

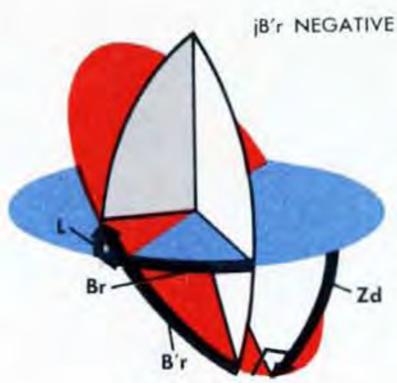
L and *Zd* are continuously measured by the Stable Element. The Stable Element contains a gyro which, within its limits of operation, always remains in the horizontal plane regardless of the inclination of the deck. The Computer transmits the value of Director Train, *B′r*, by a shaft line to the Stable Element. *B′r* positions the gyro gimbals so that measurements of deck inclination are made in relation to the Line of Sight. The measurements are the values of Level and Cross-level, and are transmitted by shafts to the Computer.



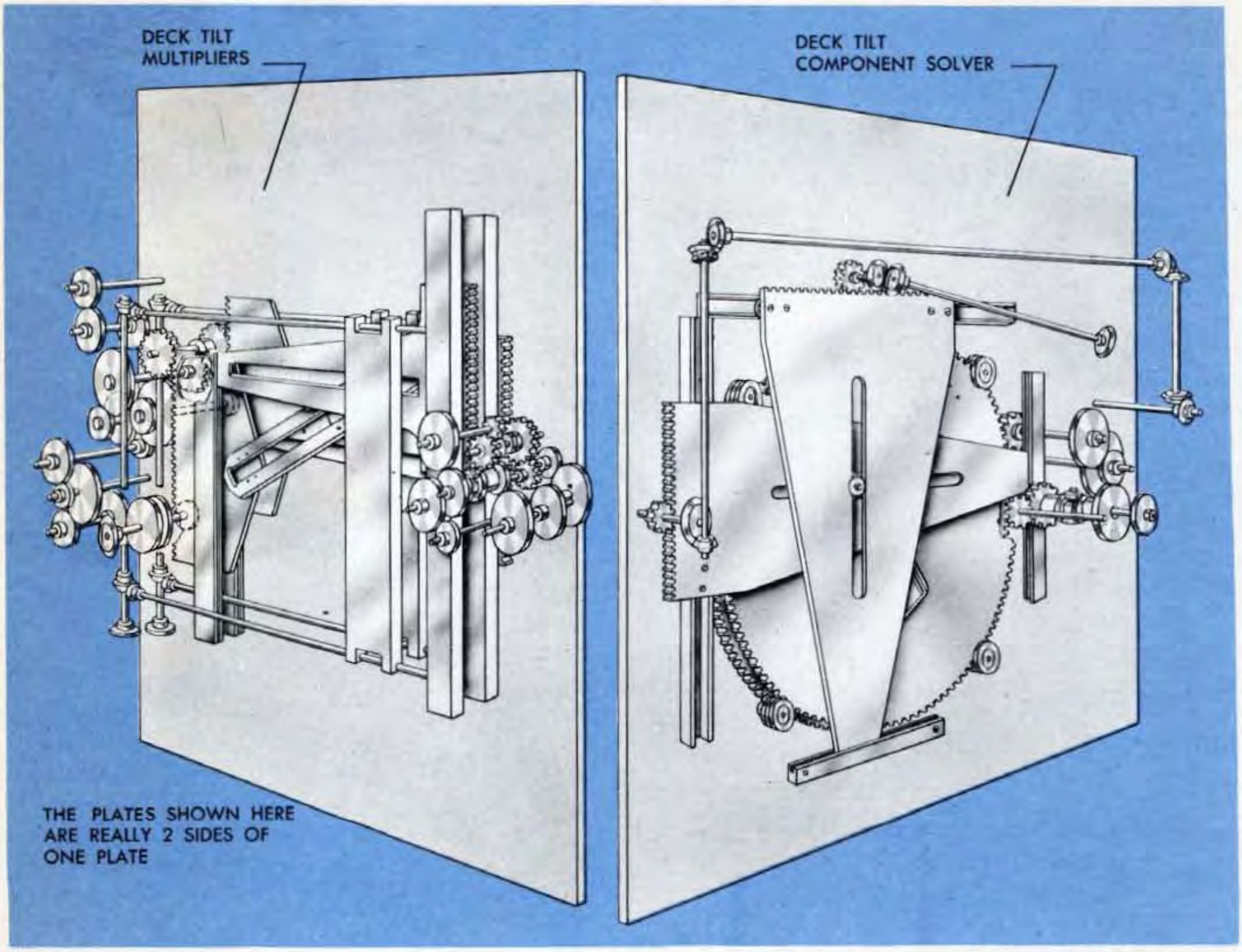


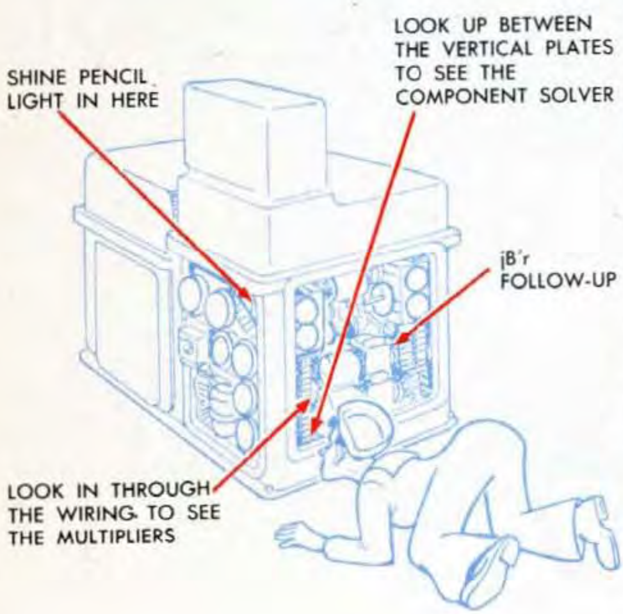
Deck Tilt Correction, *jB′r*, may be either positive or negative. When *Br* is larger than *B′r*, *jB′r* is positive. When *Br* is smaller than *B′r*, *jB′r* is negative.





The DECK TILT MECHANISM and the equation it solves





The Deck Tilt Mechanism consists of a component solver, two screw-type multipliers, a compensated follow-up control, and several differentials. The Deck Tilt Component Solver and Multipliers are mounted on a plate in the lower rear of the Computer Mark 1, between the Parallax and the Trunnion Tilt mechanisms.

The true equation for Deck Tilt Correction, $jB'r$, contains terms which would require a long network of mechanisms for their solution. To obtain a sufficiently correct value of $jB'r$ using only a few mechanisms, the true equation has been modified for use in the Computer Mark 1.

Here is the modified equation:

$$jB'r = K[Zd(L-L\cos 2B'r) + K_{l}L\cdot L\sin 2B'r]$$

This equation for $jB'r$ looks complicated but it is solved by only a few mechanisms: the component solver, the two multipliers, and the differentials.

The Deck Tilt COMPONENT SOLVER

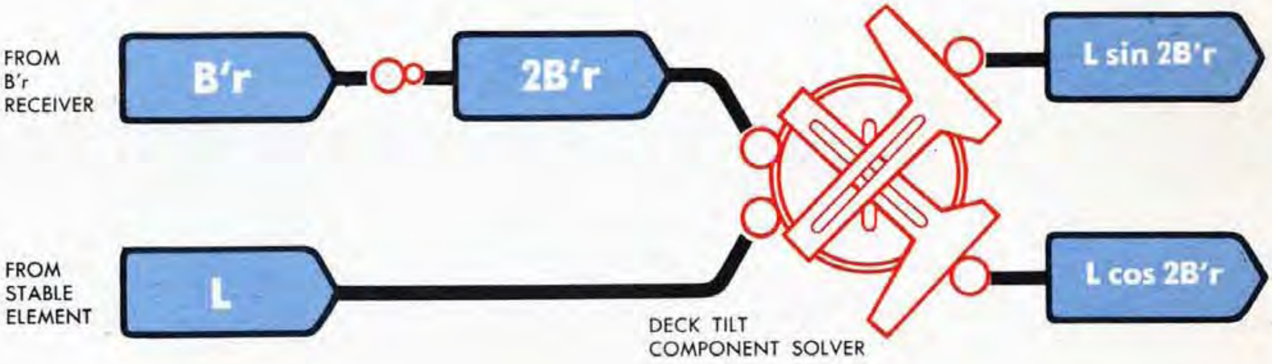
The first step in the solution of the *jB′r* equation is to compute the quantities *L* sin *2B′r* and *L* cos *2B′r*. These two quantities are computed in the Deck Tilt Component Solver.

The inputs to the component solver are *2B′r* and *L*.

The quantity *2B′r* is difficult to visualize and does not occur in the true equation for *jB′r*. It is used in the modified equation in approximating the value of certain other terms which would be difficult to compute mechanically.

The value of *2B′r* positions the vector gear in the Deck Tilt Component Solver. Since *2B′r* is twice the value of *B′r*, the vector gear makes two complete revolutions while the value of *B′r* changes from zero to 360 degrees. A cam-type component solver is used here because in this type the vector gear may turn through any number of revolutions.

Level, *L*, positions the cam. An offset pin is used in the component solver because the values of *L* are alternately positive and negative. This type of component solver is described in detail in OP 1140.



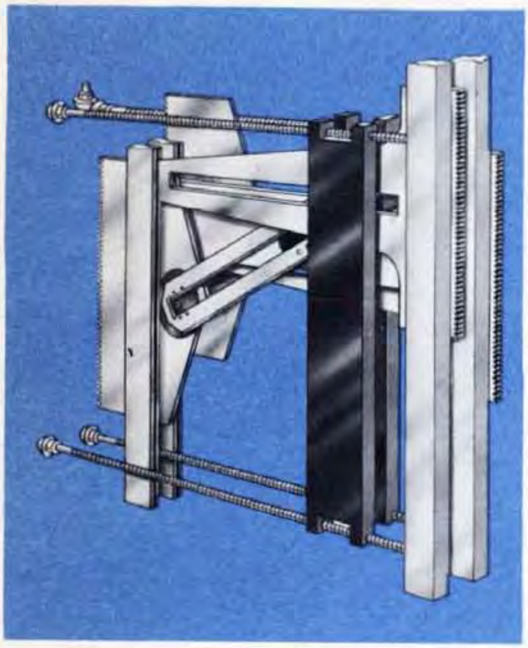
Director Train, *B′r*, from the *B′r* Receiver is multiplied by 2 in a gear ratio producing *2B′r*. The value of *2B′r* positions the vector gear. Level, *L*, from the Stable Element is the cam input.

The two outputs from the component solver are: *L* sin *2B′r* and *L* cos *2B′r*.

The use of *2B′r* in the Deck Tilt equation gives the same value of *jB′r* for given values of *L* and *Zd*, whether *B′r* is 90° or 270 degrees. With given values of *L* and *Zd*, the value of *jB′r* will be the same with a given *B′r* value as for a *B′r* value 180° greater or less.

NOTE:
It should be remembered that every component solver has a compensating differential. The function of the compensating differential is explained in OP 1140. For clarity this differential is omitted from the flow schematics in OP 1064.

The Deck Tilt MULTIPLIERS



The remaining quantities in the Deck Tilt equation are solved by two screw-type multipliers, two differentials, and some gearing.

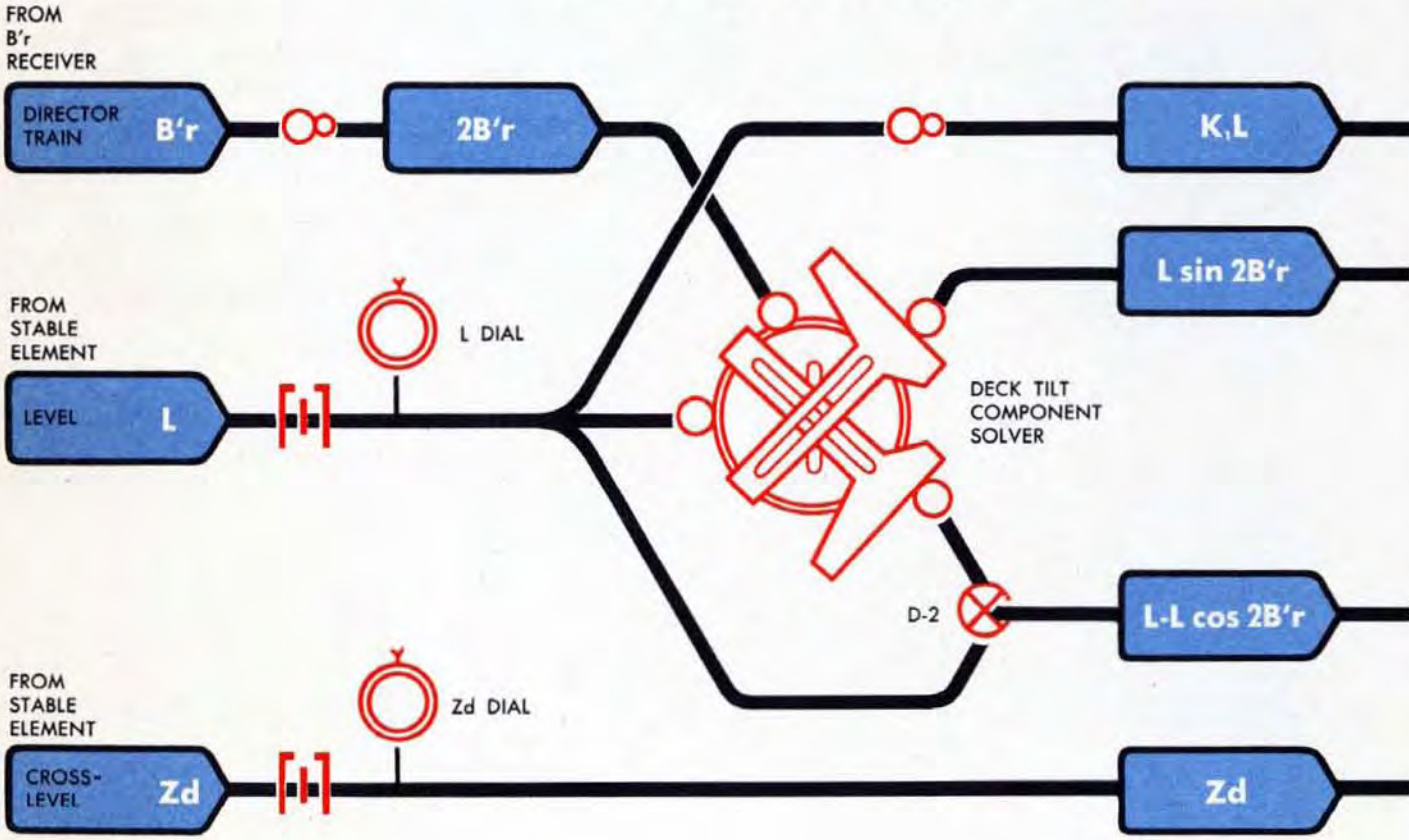
The $L \cos 2B'r$ output of the Deck Tilt Component Solver is subtracted from L at differential D-2. The result, $(L - L \cos 2B'r)$, positions the input rack of one of the multipliers. Zd positions the lead screw. The multiplier output is the first term of the Deck Tilt equation:

$$Zd\ (L - L \cos 2B'r).$$

The $L \sin 2B'r$ output of the component solver positions the input rack of the second multiplier. A gear ratio is used to multiply L by K_1 to obtain K_1L, which positions the lead screw. The output is the second term of the $jB'r$ equation:

$$K_1L \cdot L \sin 2B'r.$$

The inputs to each of the Deck Tilt Multipliers may have either positive or negative values. The fixed pin in each multiplier is therefore located at the center of travel of the inputs.



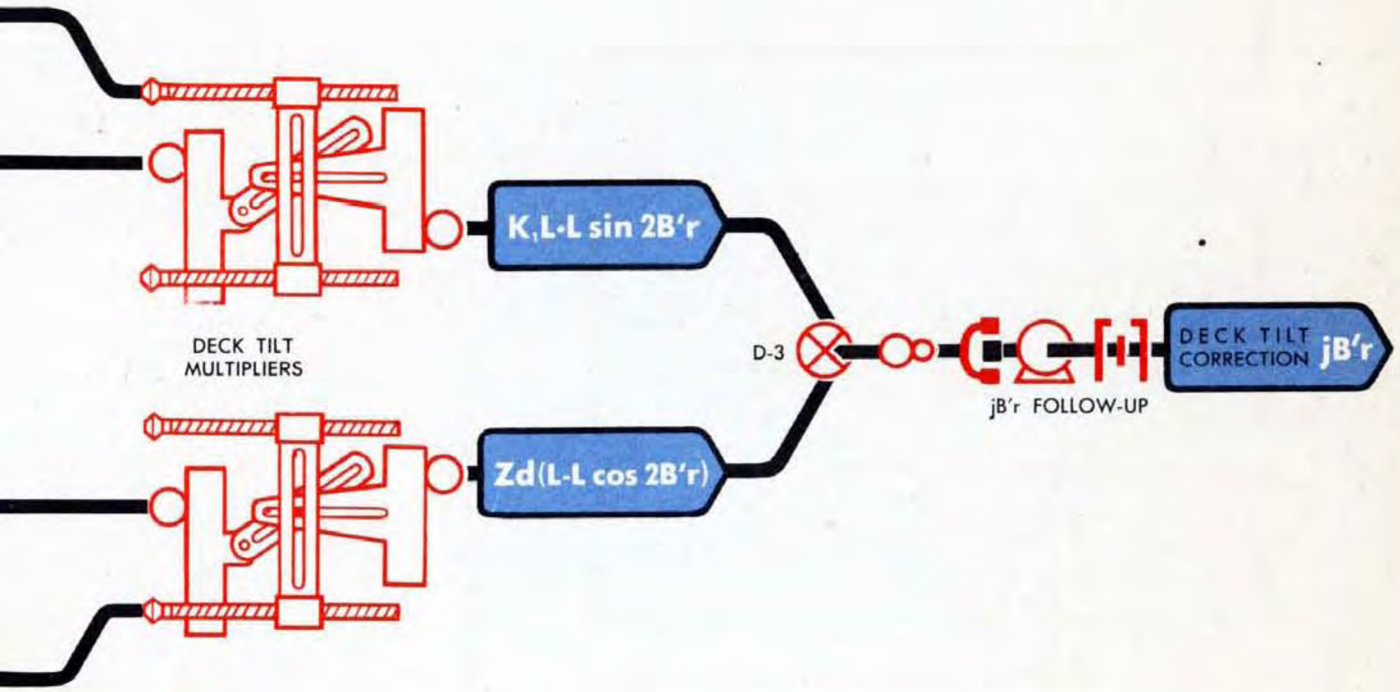
complete the equation

The outputs from the two Deck Tilt Multipliers are added together at differential D-3. The differential output is multiplied in gearing by a constant, K, to form the quantity:

$$K[Zd\,(L - L\cos 2B'r) + K_1 L \cdot L \sin 2B'r] \text{ which is } jB'r$$

A compensated follow-up amplifies the torque on the $jB'r$ line and drives $jB'r$ to the Relative Motion and the Integrator Groups.

Since the $jB'r$ Follow-up is always energized when the Power Switch is ON, the Deck Tilt Correction is continuously available in all types of operation.



How jB′r is used

Deck Tilt Correction, $jB'r$, is used to correct two different quantities:

1 Director Train, $B'r$, which is received in the Computer from the Director.

2 Generated Changes of Relative Target Bearing, $\triangle cBr$, which are transmitted from the Computer to the Director.

The quantity, $B'r$, received in the Computer is an angle in the deck plane. The Deck Tilt Correction, $jB'r$, is added to $B'r$ to obtain Relative Target Bearing, Br, the corresponding angle in the horizontal plane.

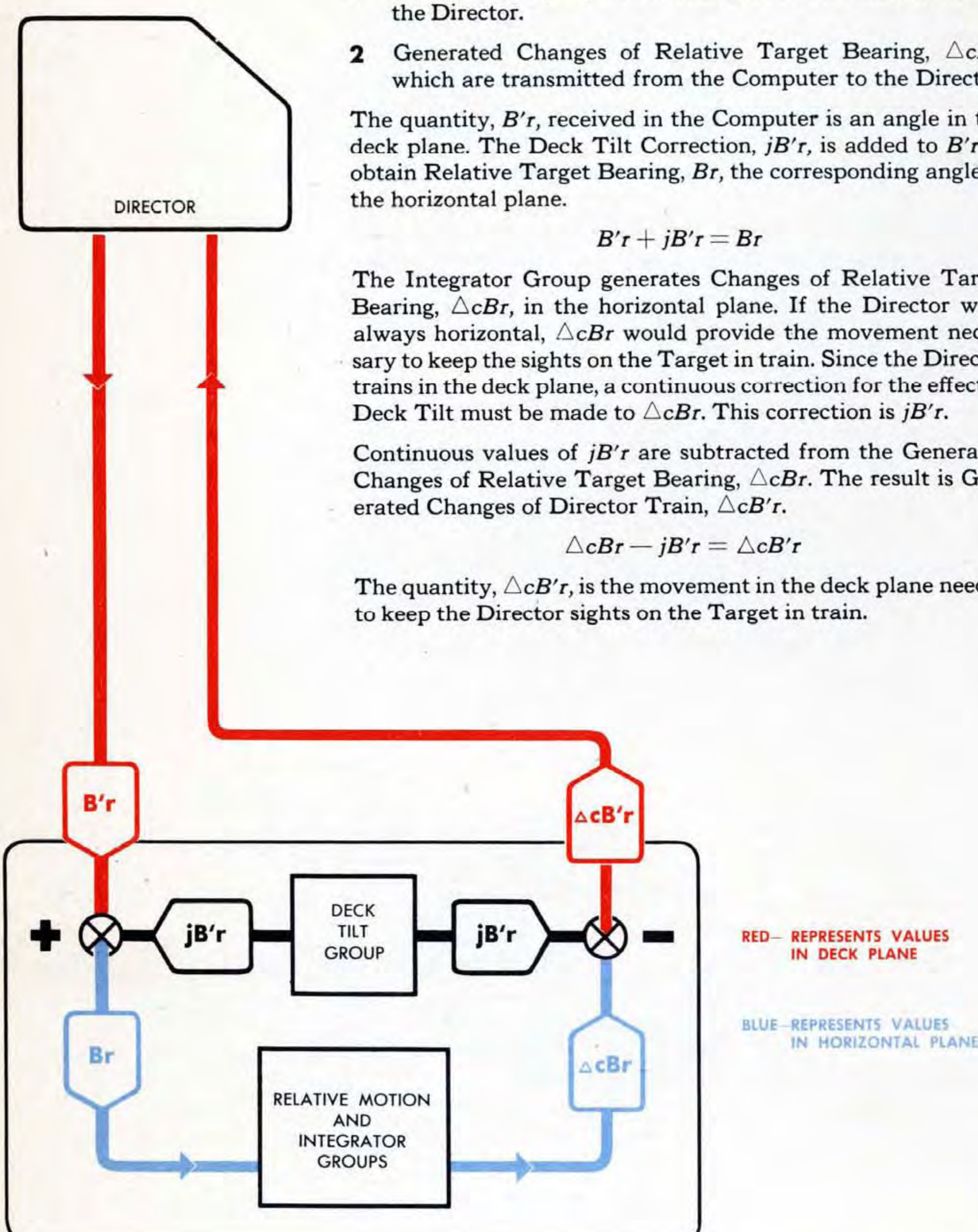
$$B'r + jB'r = Br$$

The Integrator Group generates Changes of Relative Target Bearing, $\triangle cBr$, in the horizontal plane. If the Director were always horizontal, $\triangle cBr$ would provide the movement necessary to keep the sights on the Target in train. Since the Director trains in the deck plane, a continuous correction for the effect of Deck Tilt must be made to $\triangle cBr$. This correction is $jB'r$.

Continuous values of $jB'r$ are subtracted from the Generated Changes of Relative Target Bearing, $\triangle cBr$. The result is Generated Changes of Director Train, $\triangle cB'r$.

$$\triangle cBr - jB'r = \triangle cB'r$$

The quantity, $\triangle cB'r$, is the movement in the deck plane needed to keep the Director sights on the Target in train.



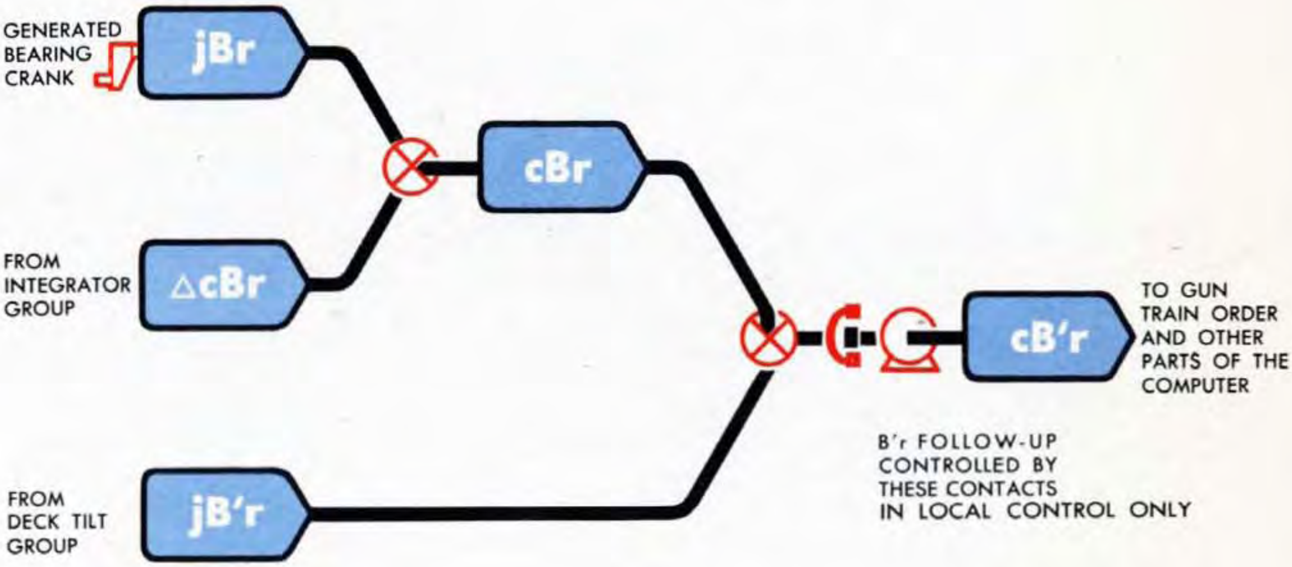
jB′r in Local Control

When, for any reason, no *B′r* signal is coming in from the Director, the Computer Mark 1 can compute a substitute value of Director Train, *B′r*. This substitute is Generated Director Train, *cB′r*.

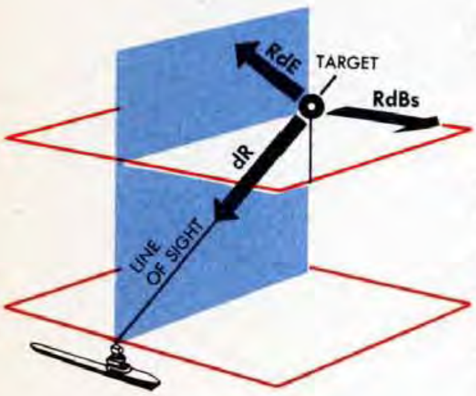
Generated Director Train, *cB′r*, consists of a manual setting of Relative Target Bearing, *jBr*, plus the Generated Changes of Bearing, △*cBr*, from the Integrator Group, plus the Deck Tilt Correction, *jB′r*.

The angle, *jBr* + △*cBr*, is the Generated Relative Bearing in the horizontal plane. The addition of Deck Tilt Correction, *jB′r*, produces an accurate value of *cB′r* in the deck plane.

The quantity *cB′r* is used to control the *B′r* Follow-ups in Local Control only. In Automatic and Semi-automatic Control, these follow-ups are positioned by the *B′r* Receiver. The operation of the *B′r* Follow-ups is described in detail in the chapter on Rate Control, pages 258-259.



RELATIVE MOTION



Relative Motion is the change of position of the Target as viewed from Own Ship. This change of position, or relative motion, may be the result of Target Motion only, Ship Motion only, or a combination of both Ship and Target Motion.

The job of the Relative Motion Group in the Tracking Section of the Computer Mark 1 is to compute the three Relative Motion Rates: Direct Range Rate, *dR,* Elevation Rate, *RdE,* and Deflection Rate, *RdBs.*

The RATES of Relative Motion are the speeds with which the Target is changing position in relation to Own Ship. For an air target, a Relative Motion Rate is computed in each of three directions in relation to the Line of Sight to the Target:

1. Directly along the Line of Sight
2. At right angles to the Line of Sight in the horizontal plane
3. At right angles to the Line of Sight in the vertical plane through the Line of Sight.

These three directions are chosen because the resulting rates can best be used for computing changes of Range, Elevation, and Bearing.

The Relative Motion Rate directly along the Line of Sight is Direct Range Rate, *dR*. Range Rate, *dR,* is the rate at which the Range is changing, and is needed by the Prediction Section to compute the change in Range that takes place during the time the projectile is in flight.

The Relative Motion Rate at right angles to the Line of Sight in the vertical plane is Elevation Rate, *RdE*. Elevation Rate, *RdE,* is the linear rate at which the Elevation of the Target is changing, as viewed from Own Ship. It is needed by the Prediction Section to compute the change in Elevation that takes place during the time the projectile is in flight.

The Relative Motion Rate at right angles to the Line of Sight in the horizontal plane is Deflection Rate, *RdBs*. The Deflection Rate is the linear rate at which Relative Target Bearing is changing. It is needed by the Prediction Section to compute the change in Bearing that takes place during the time the projectile is in flight.

The Height, *H,* of the Target is also computed by the Relative Motion Group.

The INPUTS to the Relative Motion Group

To compute the three Relative Motion Rates and Height, the Relative Motion Group needs three groups of inputs:

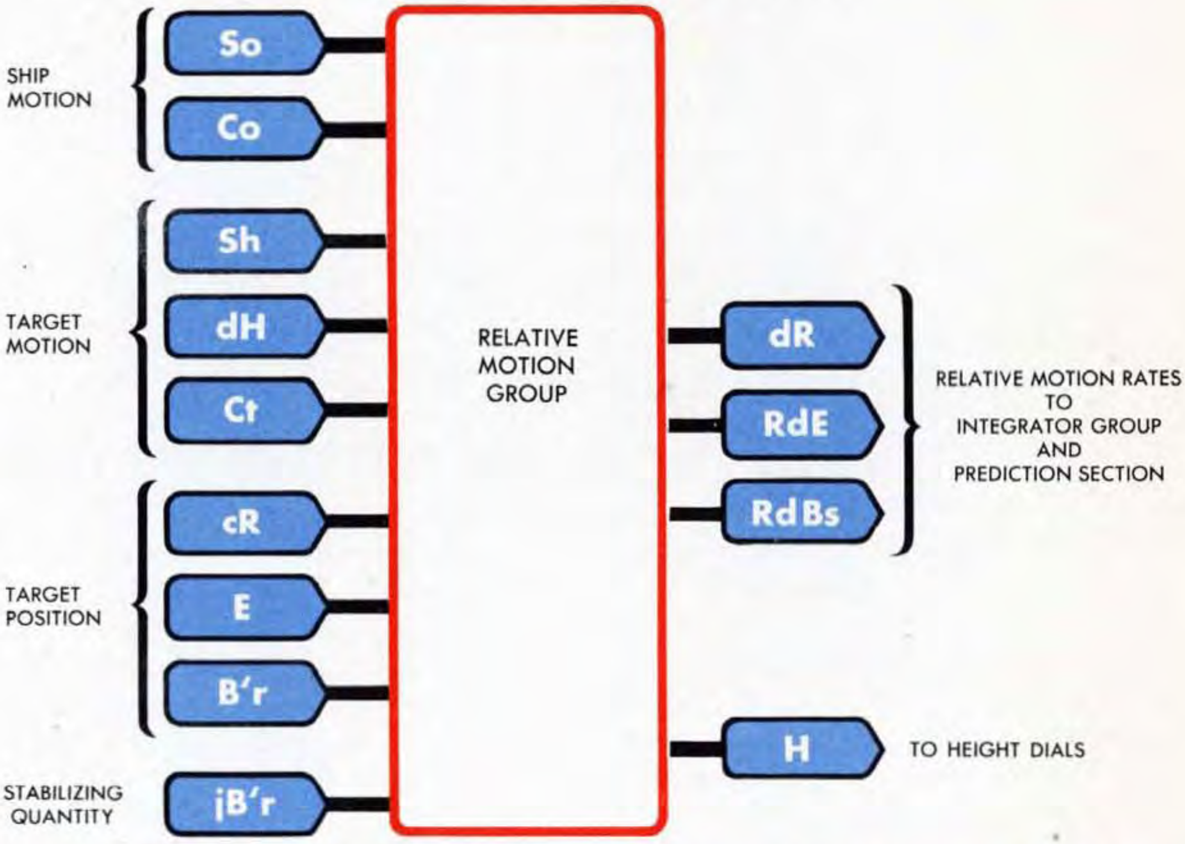
1. Ship Motion inputs
2. Target Motion inputs
3. Target Position inputs.

The Ship Motion inputs are Ship Speed, *So,* and Ship Course, *Co.*

The Target Motion inputs are Target Horizontal Speed, *Sh,* Target Course, *Ct,* and Rate of Climb, *dH.*

The Target Position inputs are Target Elevation, *E,* Director Train, *B′r,* and Present Range, *cR.*

In addition to these three groups, one stabilizing input is needed. This stabilizing input is Deck Tilt Correction, *jB′r.*



The OUTPUTS of the Relative Motion Group

Relative Motion Rates, *dR, RdE,* and *RdBs,* go to the Prediction Section and also to the Integrator Group in the Tracking Section.

The fourth output, Target Height, *H,* goes only to the Height Dials.

COMPONENTS

NOTE:
It will be remembered that Target *speed* and Target *direction*, taken together, are called Target Velocity. Velocity is *speed* in a given *direction*.

The Rates of Relative Motion depend on the speed and direction of motion of both Ship and Target. To compute these rates, the velocities of Ship and Target must be broken into components in the directions in which the rates are required. The components are necessary because the *direction* in which the Ship or Target is moving in relation to the Line of Sight determines how much of its velocity affects Range, Elevation, or Bearing.

The need for resolving velocities into their components is most easily shown in computing rates of Relative Motion between Own Ship and a surface target. With a surface target only two rates are needed: Range Rate and Deflection Rate.

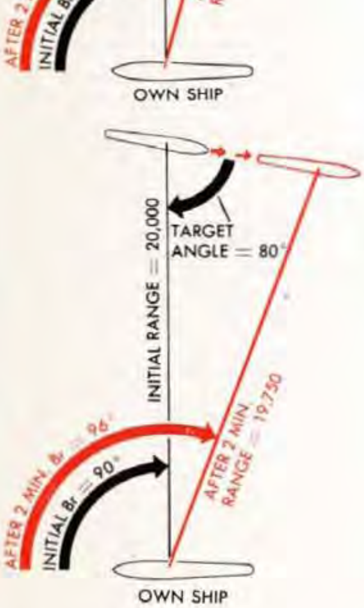
When own ship and a surface target are moving in the same straight line

When Own Ship and a surface target are moving in the same straight line, they are moving along the Line of Sight. Their speeds affect Range only. There is no motion at right angles to the Line of Sight; therefore the Deflection Rate is zero. The Range Rate is computed by adding or subtracting the speeds of Ship and Target depending on whether they are moving in opposite directions or in the same direction.

When they are moving in opposite directions, the sum of their speeds is the Range Rate. When they are moving in the same direction, the difference in their speeds is the Range Rate.

When own ship and a surface target are moving on different courses

When Own Ship and a surface target are moving on different courses, their speeds cannot be simply added or subtracted to obtain a Relative Motion Rate. The *direction* of their motion in relation to the Line of Sight must be considered.



Suppose that Own Ship is stationary and the Target is directly abeam of Own Ship with Relative Target Bearing, *Br*, at 90° and Range 20,000 yards. If Target Angle, *A*, is 20° and the Target moves in a straight line at 30 knots for two minutes, the Range will have decreased by about 1900 yards to 18,100 yards, and the Relative Bearing will have increased by approximately 2° to 92°.

If, however, with the same initial relative positions, Target Angle, *A*, had been 80° and the Target had moved at 30 knots for two minutes, the results would have been quite different. Range would have decreased only 250 yards, to 19,750 yards, while Relative Bearing would have increased approximately 6° to 96°.

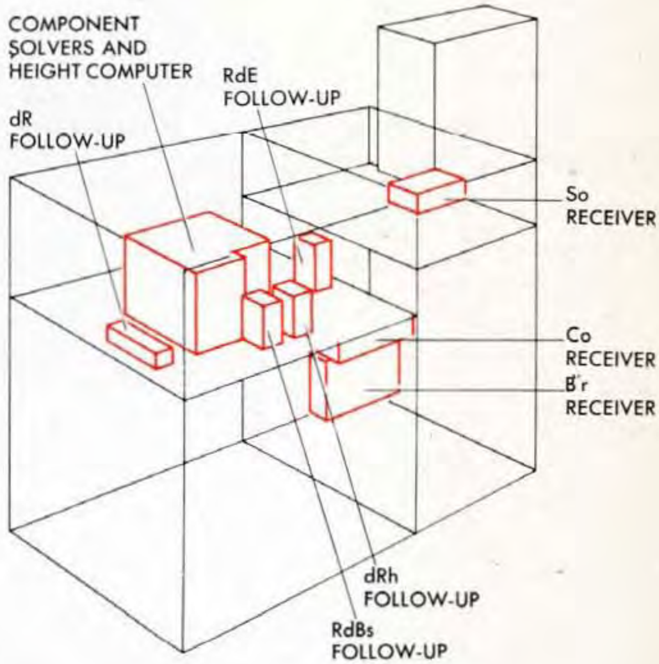
These examples demonstrate that usually only a fraction of the actual Target Speed affects Range, and only a fraction affects Bearing. These fractions are called components, and their sizes depend on the speed of the Target and the value of Target Angle, *A*.

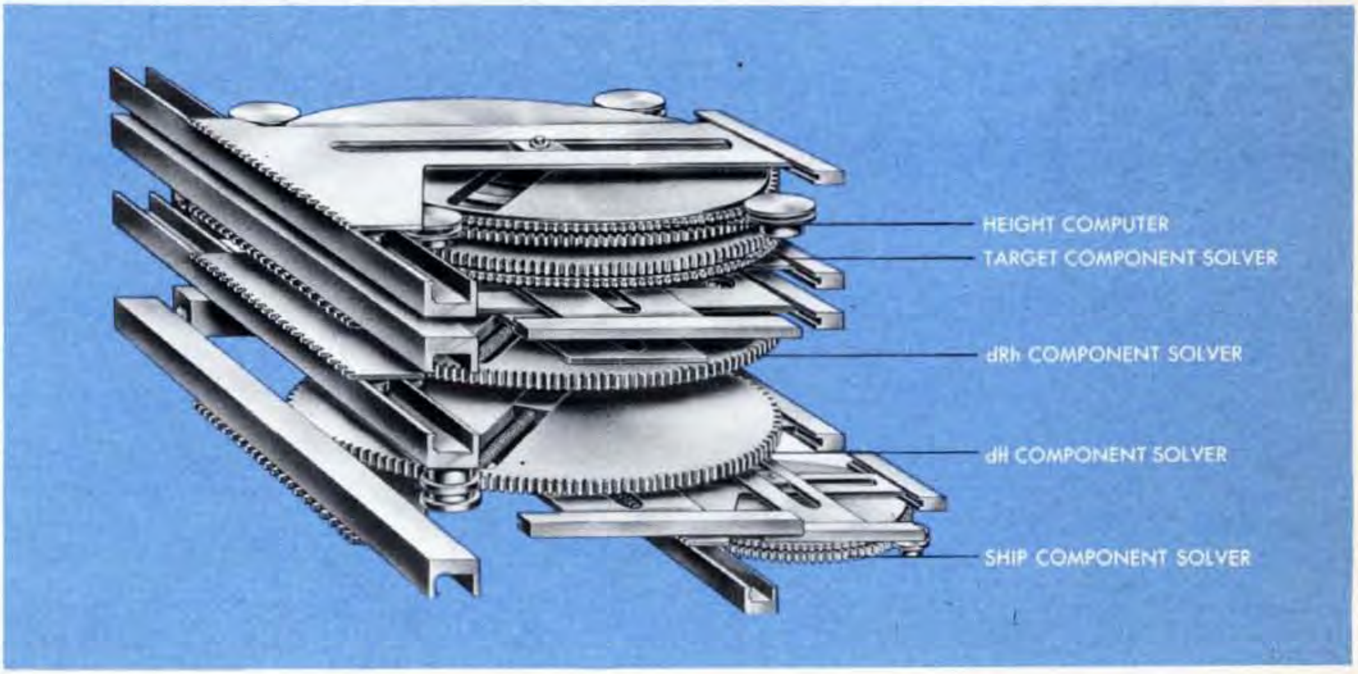
In the same way, the effect of Own Ship Speed on Range and Bearing depends on the value of Ship Speed, *So*, and Relative Target Bearing, *Br*.

The Components of Own Ship Velocity, Target Velocity, and the other velocity vectors needed for air targets are computed in the Relative Motion Group by the Relative Motion Component Solvers.

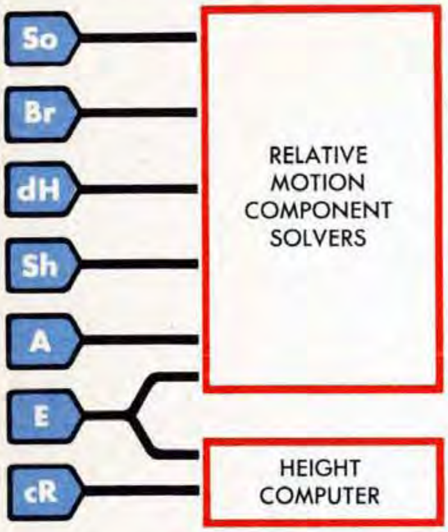
THE MECHANISM
in the relative motion group

The Relative Motion Group contains a bank of four component solvers and the Height Computer, the *B′r* and *Co* Double-speed Receivers, the *So* Single-speed Receiver, the follow-ups on the *dR*, *RdE*, *RdBs*, and *dRh* lines, and various differentials and dials. The component solvers and all the follow-ups are in the top front section of the Computer. The *Co* Receiver is in the lower front section. The *So* Receiver is in the top rear section, and the *B′r* Receiver is in the lower rear section.



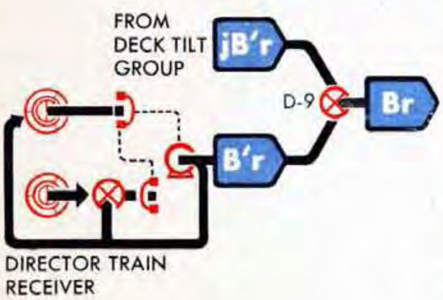


The inputs to the Component Solvers



The Relative Motion Rates are computed in relation to the horizontal plane and to the Line of Sight. Some of the inputs to the Computer are quantities measured from the deck plane or from *North*. These quantities cannot be used directly as inputs to the component solvers, but are used to compute the inputs needed by the component solvers.

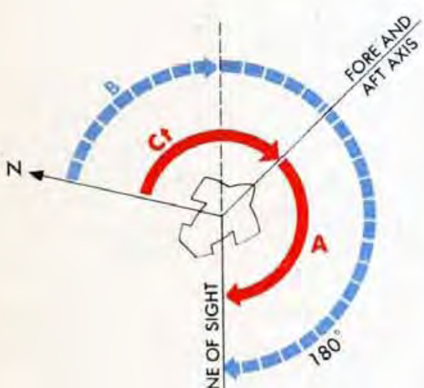
The quantities which must be computed for use by the component solvers are Relative Target Bearing, *Br*, Target Angle, *A*, and Target Elevation, *E*.



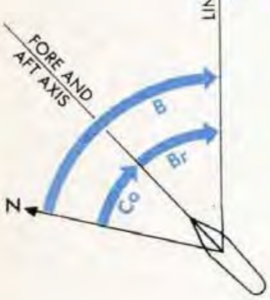
Relative Target Bearing, *Br*, is computed by adding Deck Tilt Correction, *jB′r*, to Director Train, *B′r*. Deck Tilt Correction, *jB′r*, is computed in the Deck Tilt Group. Director Train, *B′r*, is transmitted electrically from the Director to the *B′r* Receiver. Deck Tilt Correction, *jB′r*, is added to Director Train, *B′r*, at differential D-9, to obtain Relative Target Bearing, *Br*.

Target Angle, *A*, is the horizontal angle between a vertical plane through the fore and aft axis of the Target and a vertical plane through the Line of Sight, measured clockwise from the bow of the Target.

The value of *A* is computed as $B + 180^\circ - Ct$. *B* is True Target Bearing and *Ct* is Target Course.



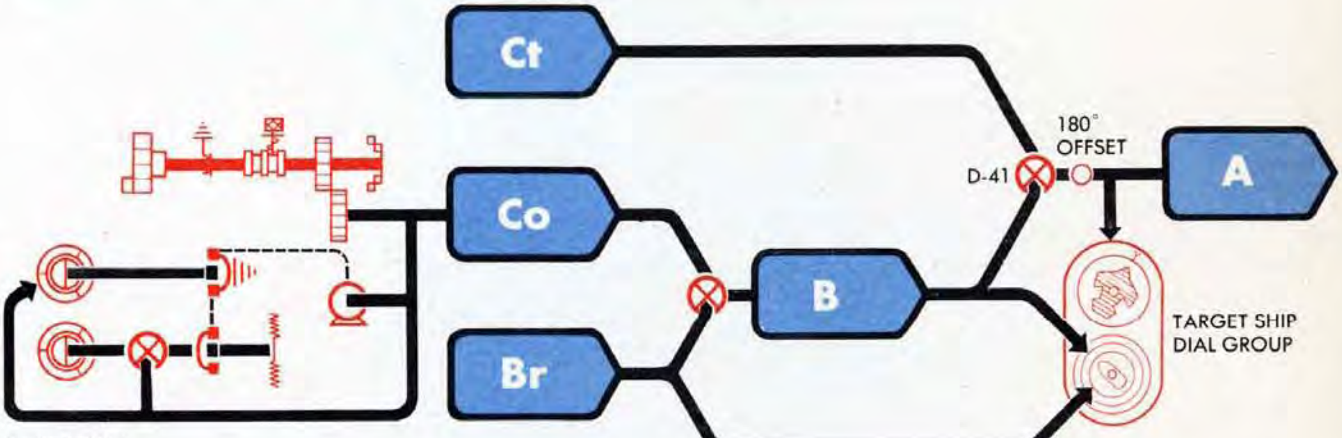
True Bearing, *B*, is the horizontal angle between a North-South vertical plane and the vertical plane through the Line of Sight, measured clockwise from North. The value of *B* is computed by adding Relative Target Bearing, *Br*, to Ship Course, *Co*.



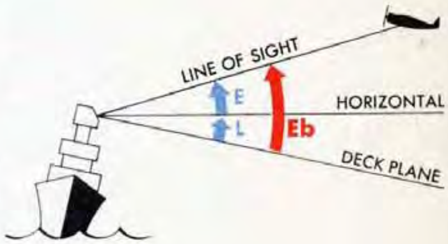
Ship Course, *Co*, is the horizontal angle between a North-South vertical plane and the vertical plane through the fore and aft axis of Own Ship, measured clockwise from North to the bow of Own Ship. The value of *Co* is either received electrically at the *Co* Receiver or is put in by hand at the Ship Course Handcrank.

Br is added to *Co* at differential D-26. The differential output is True Bearing, *B*.

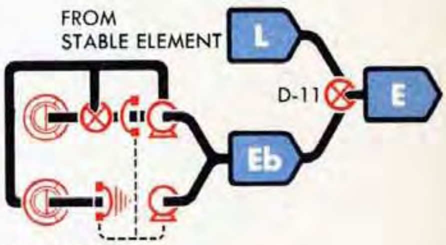
Target Course, *Ct*, is the horizontal angle between the North-South vertical plane and a vertical plane through the direction of motion of the Target, measured clockwise from North to the bow of the Target. *Ct* is estimated and set into the Computer through the Target Angle Handcrank. At differential D-41, the value of *Ct* is subtracted from *B*. The 180° is added to the differential output at a clamp offset. The result is Target Angle, *A*.



Target Elevation, *E*, is the last of the component solver inputs which need to be computed. *E* is the angle between the horizontal and the Line of Sight, measured in a vertical plane through the Line of Sight.



Director Elevation, *Eb*, is the angle between the deck plane and the Line of Sight, measured in a vertical plane through the Line of Sight. *Eb* is transmitted electrically from the Director to the *Eb* Receiver in the Synchronize Elevation Group. Level, *L*, is transmitted to the Computer by a shaft line from the Stable Element. *L* is subtracted from *Eb* at differential D-11 in the Synchronize Elevation Group to obtain Target Elevation, *E*.



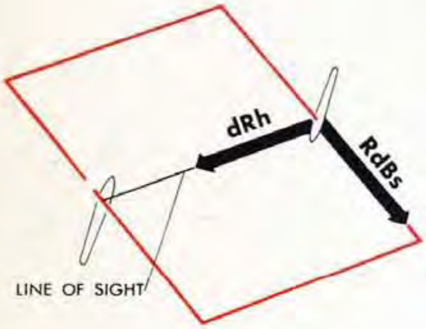
The speed inputs to the component solvers, *So*, *Sh*, and *dH*, need no initial computation inside the Computer.

Ship Speed, *So*, is transmitted electrically from the Pitometer Log to the *So* Receiver or set in by hand.

Target Horizontal Ground Speed, *Sh* is estimated and set into the Computer through the Target Speed Handcrank.

Rate of Climb, *dH*, the vertical speed of the Target, can also be estimated and is set into the Computer through the Rate of Climb Crank.

Relative motion for a SURFACE target



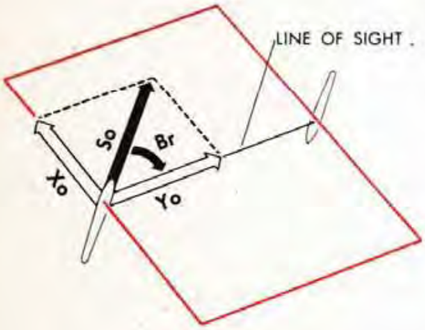
For the sake of clarity, this discussion of Relative Motion for a surface target assumes that the Line of Sight lies in a horizontal plane at the level of the Director. Actually the Line of Sight to a surface target is slightly depressed. If the Line of Sight is assumed to be horizontal, only two Relative Motion Rates are computed. They are:

Horizontal Range Rate, *dRh,* along the Line of Sight

Deflection Rate, *RdBs,* at right angles to the Line of Sight.

The Rates *dRh* and *RdBs* are obtained from Components of Ship Velocity and Target Velocity, computed by the Ship and Target Component Solvers.

The Ship Component Solver



The Ship Component Solver is a cam-type component solver. Component solvers are described in detail in OP 1140. The inputs are Own Ship Speed, *So,* and Relative Target Bearing, *Br. So* positions the cam and *Br* positions the vector gear.

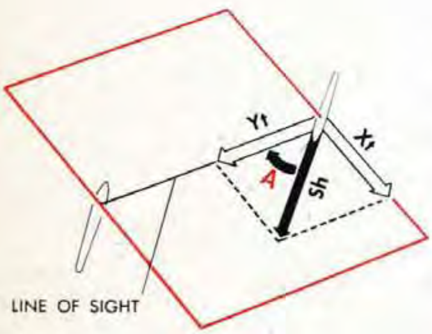
The outputs are:

1 The Component of Ship Velocity, *Yo,* along the horizontal Line of Sight, called the Range Component.

2 The Component of Ship Velocity, *Xo,* at right angles to the Line of Sight in the horizontal plane, called the Deflection Component.

SHIP COMPONENT SOLVER

The Target Component Solver



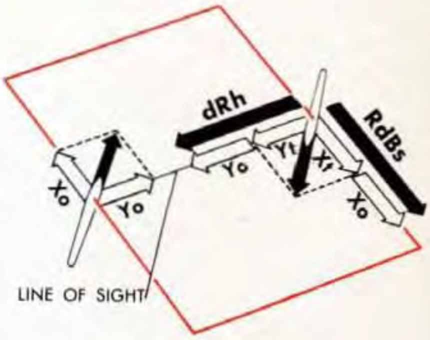
The Target Component Solver is also a cam-type component solver. The inputs are Horizontal Target Speed, *Sh,* and Target Angle, *A. Sh* positions the cam and *A* positions the vector gear.

The outputs are:

1 The Component of Horizontal Target Velocity, *Yt,* along the horizontal Line of Sight, called the Range Component.

2 The Component of Horizontal Target Velocity, *Xt,* at right angles to the Line of Sight in the horizontal plane, called the Deflection Component.

TARGET COMPONENT SOLVER



The Range Components, *Yo* and *Yt*, are now combined to obtain Horizontal Range Rate, *dRh*.

$$dRh = Yo + Yt$$

In this diagram, *Yo* and *Yt* are negative because the motion of both Own Ship and Target is decreasing the Range. The value of *dRh* is therefore negative, indicating a *closing* Range Rate.

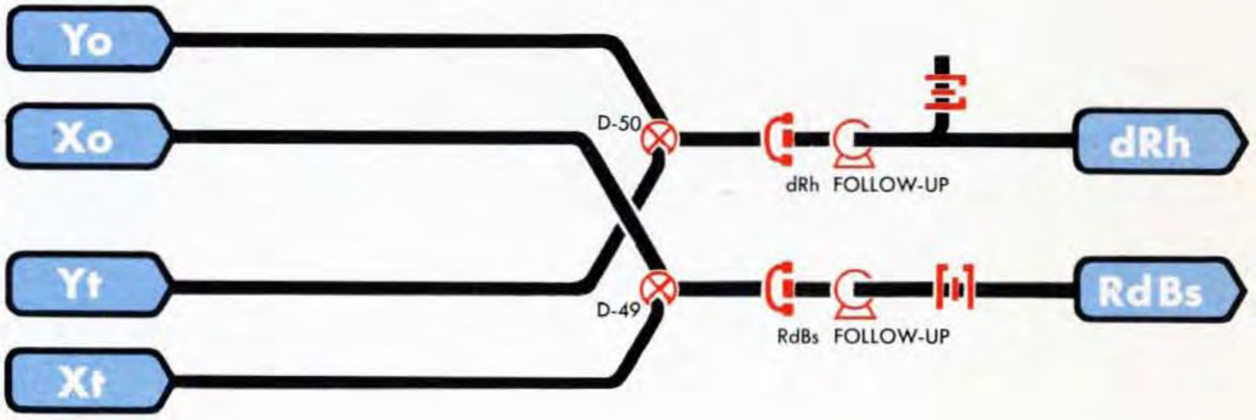
In the same way, the Deflection Components, *Xo* and *Xt*, are combined to obtain Deflection Rate, *RdBs*.

$$RdBs = Xo + Xt$$

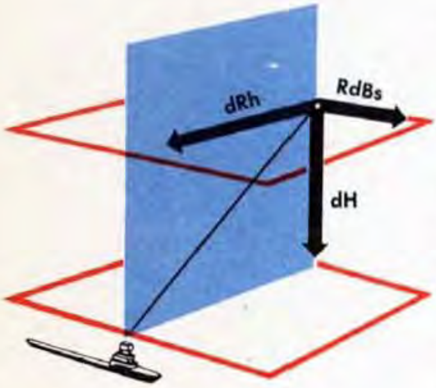
In the diagram, *Xo* and *Xt* are positive because the motion of both Own Ship and Target is causing the Line of Sight to deflect to the right. Deflection of the Line of Sight to the right is considered positive because it increases Bearing.

Both *dRh* and *RdBs* are amplified by follow-ups. These are energized whenever the Computer Power Switch is ON.

Since the Relative Motion Rates are rates of change of Target Position as viewed from Own Ship, the rates are usually drawn as though Own Ship were stationary and all the motion were at the Target.



Relative motion for an AIR target



Up to this point, Relative Motion Rates have been computed only in the horizontal plane at the level of Own Ship's Director.

For air targets, the Line of Sight is elevated above this horizontal plane. Calculations must be made in three planes:

1. The horizontal plane at the level of the Director of Own Ship.
2. The vertical plane through the Line of Sight.
3. The horizontal plane at the level of the air target.

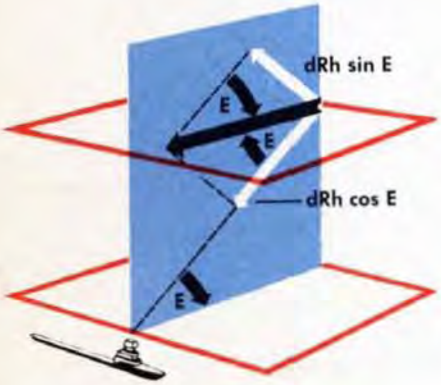
As in the case of the surface target, the Ship and Target Component Solvers are used to produce Horizontal Range Rate, *dRh*, and Deflection Rate, *RdBs*.

RdBs is one of the three final Relative Motion Rates needed for an air target.

Horizontal Range Rate, *dRh*, is used together with Rate of Climb, *dH*, to compute the other two rates needed:

1. Direct Range Rate, *dR*, the Relative Motion Rate along the Line of Sight between Own Ship and Target.
2. Elevation Rate, *RdE*, the Relative Motion Rate perpendicular to the Line of Sight in the vertical plane through the Line of Sight.

The dRh component solver



The Components of *dRh* are computed in the vertical plane through the Line of Sight.

Since *dRh* may be either positive or negative, a screw-type component solver is used. The input to the screw is *dRh*. The input to the vector gear is Target Elevation, *E*.

The outputs are:

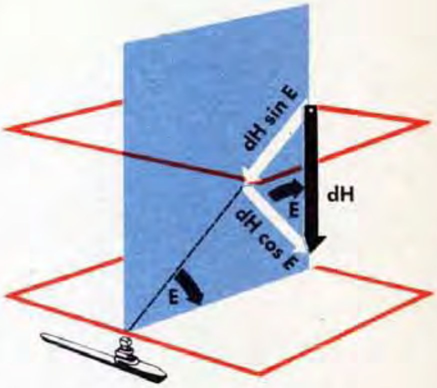
1. The Component of *dRh* directly along the Line of Sight, *dRh* cos *E*.
2. The Component of *dRh* perpendicular to the Line of Sight in the vertical plane through the Line of Sight, *dRh* sin *E*.

The dH component solver

Rate of Climb, *dH,* is the vertical component of the Target's actual speed. *dH* is positive when the Target is climbing, and negative when the Target is diving.

Since *dH,* like *dRh* can be either positive or negative, the *dH* Component Solver is a screw-type component solver.

The inputs to the *dH* Component Solver are Rate of Climb, *dH,* and Target Elevation, *E*. *dH* positions the screw and *E* positions the vector gear.



The outputs are:

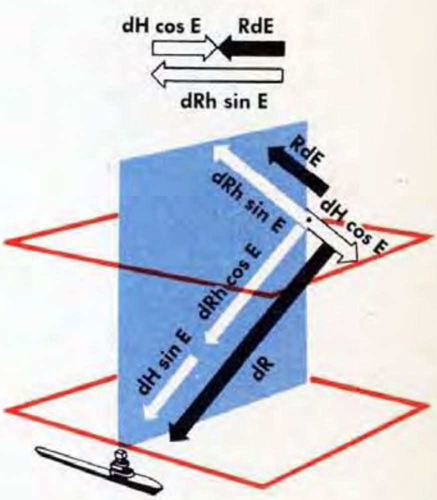
1. The component of *dH* along the Line of Sight, *dH* sin *E*.
2. The component of *dH* perpendicular to the Line of Sight, *dH* cos *E*.

Computing dR and RdE

The *dH* Component Solver and the *dRh* Component Solver produce two pairs of components.

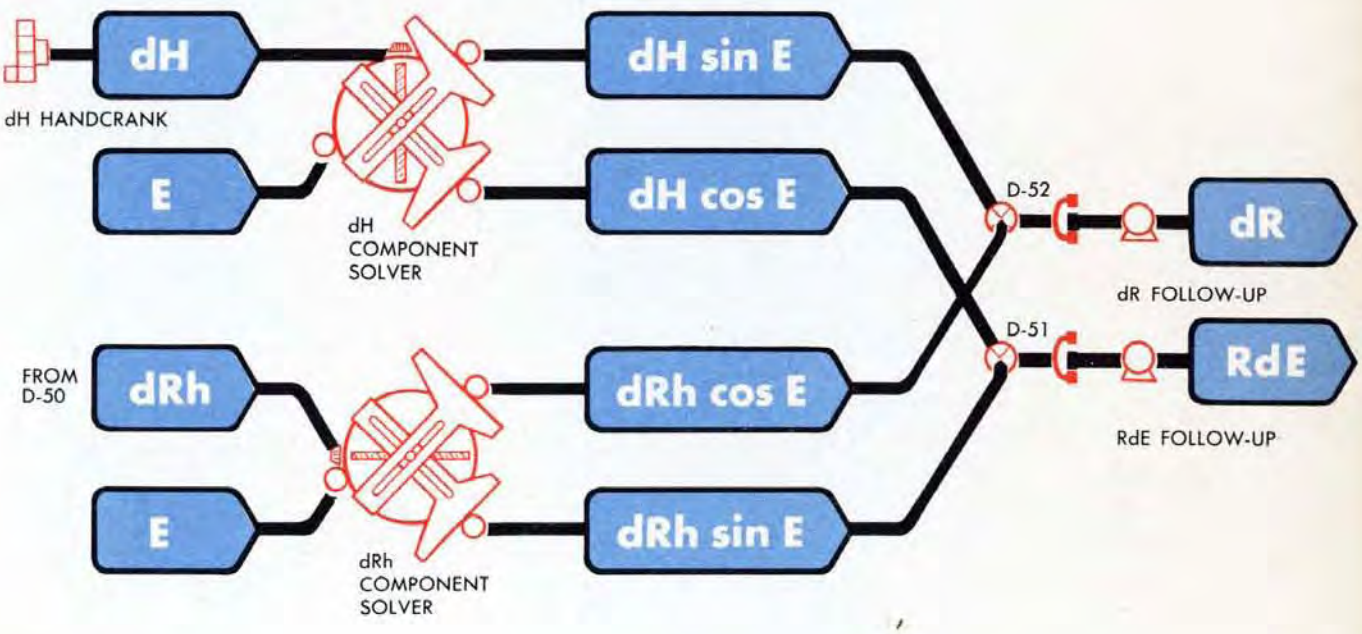
The Components along the Line of Sight are combined at differential D-52 to obtain Direct Range Rate, *dR*.

The Components perpendicular to the Line of Sight in the vertical plane are combined at differential D-51 to obtain Linear Elevation Rate, *RdE*.

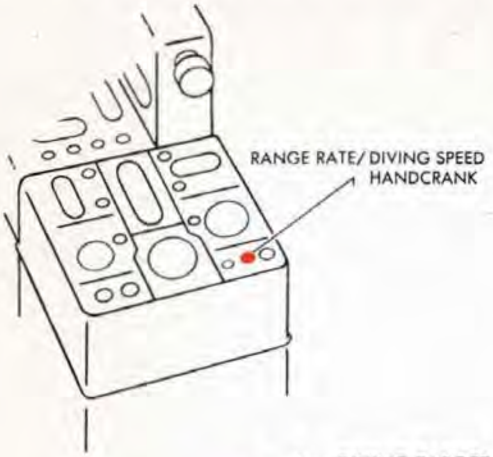


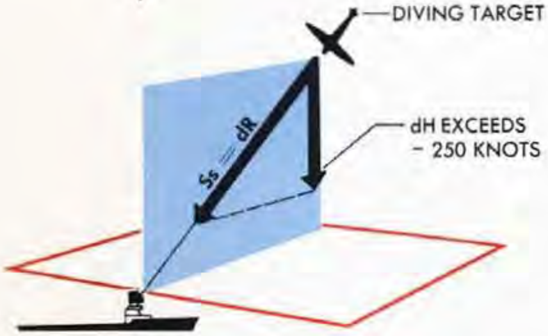
Direct Range Rate, *dR,* is positive when Range is increasing. Linear Elevation Rate, *RdE,* is positive when Elevation is increasing. In this diagram, *dR* is negative and *RdE* is positive.

Both *dR* and *RdE* are amplified by velocity-lag follow-ups.



THE RANGE RATE DIVING SPEED HANDCRANK





The Range Rate/Diving Speed Handcrank is located on top of the Computer Mark 1, to the right of the Range Dials. This handcrank can be used during a dive attack against Own Ship.

A Target diving at Own Ship is assumed to be diving almost along the Line of Sight. When a Target is diving along the Line of Sight, the actual Target Diving Speed, *Ss,* is approximately the same as Direct Range Rate, *dR*. Under these conditions *dR* will have a very high value, and *RdE* and *RdBs* will contain only very small Target Motion Components because most of the Target Motion is down the Line of Sight.

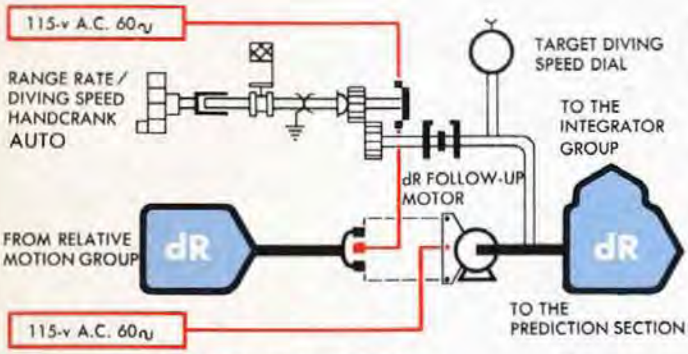
The Relative Motion Group cannot compute the full value of *dR* during this type of attack when both the Target Speed and Elevation are such that *dH* exceeds −250 knots. A limit stop on the *dH* line prevents the negative value of *dH* from exceeding −250 knots.

A Special Diving Attack Procedure is generally used when the Target Diving Speed along the Line of Sight causes Rate of Climb, *dH*, to exceed −250 knots. The Range Rate/Diving Speed Handcrank is then used to reposition the *dR* line quickly at the full value of Diving Speed, *Ss*.

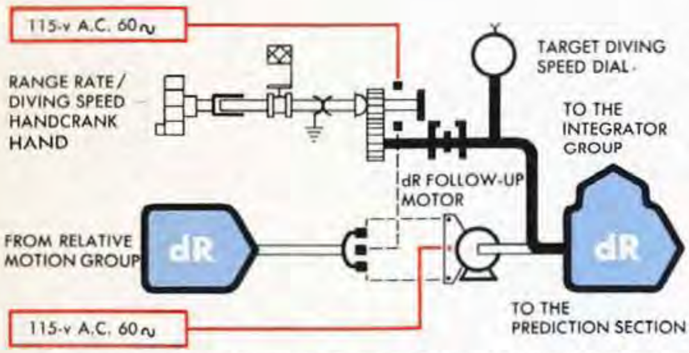
The Range Rate/Diving Speed Handcrank has two positions: AUTO and HAND.

In normal operation, the handcrank shift lever is at AUTO. The handcrank is disengaged from the *dR* shaft line and the *dR* line is driven by the values of *dR* computed in the Relative Motion Group.

During Special Dive Attack Procedure, the handcrank shift lever is switched to HAND. The handcrank drive gear is meshed with a gear on the *dR* shaft line. Shifting the lever to HAND also depresses a push-button switch which breaks the electrical circuit to the *dR* Follow-up Motor. With the handcrank at the HAND position, the *dR* Follow-up Motor is de-energized and the Range Rate/Diving Speed Handcrank is connected to the *dR* shaft line.



dR MOTOR DRIVES dR SHAFT LINE



RANGE RATE/DIVING SPEED HANDCRANK DRIVES dR SHAFT LINE

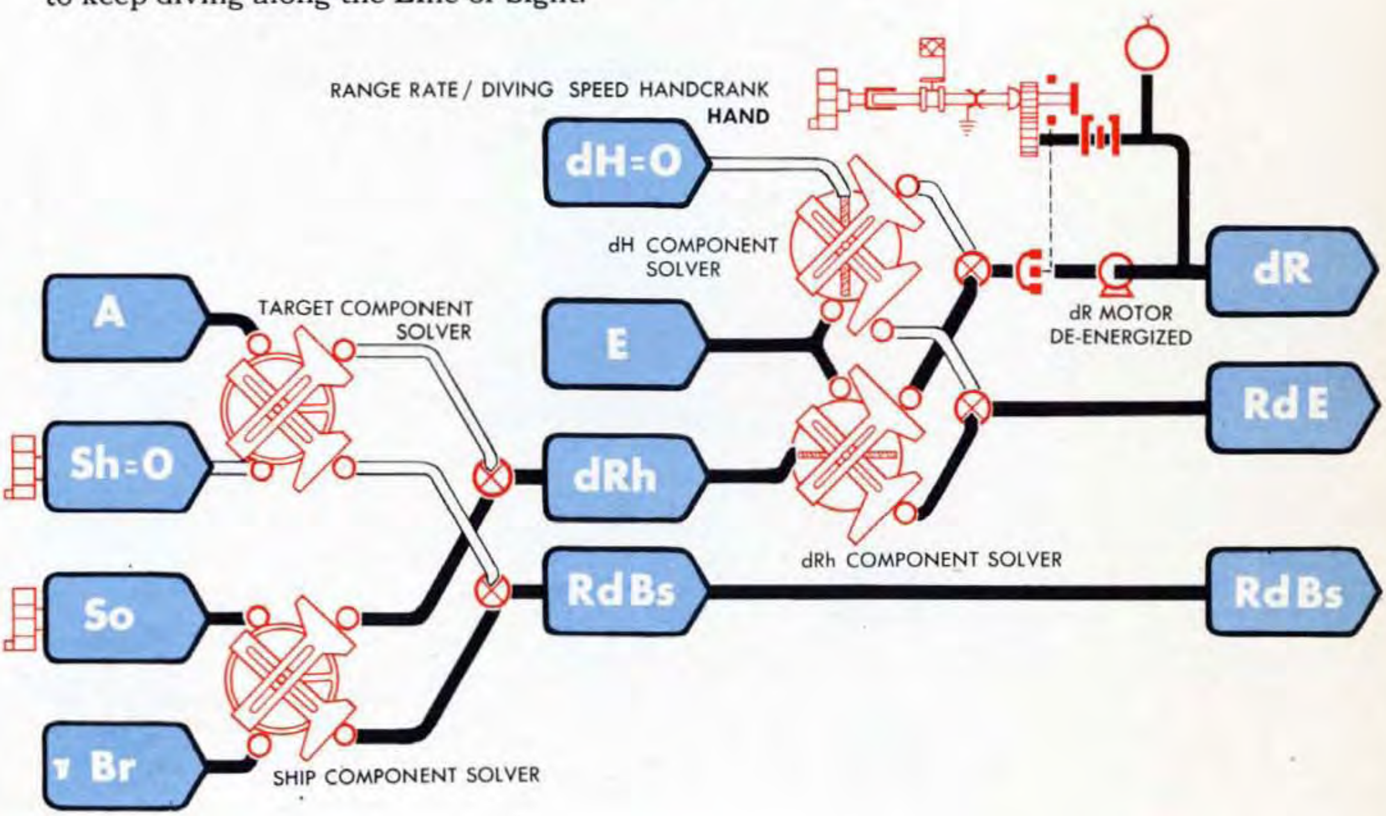
How the handcrank is used

As soon as a Target is observed to be diving at Own Ship with a vertical component of Diving Speed greater than −250 knots, the value of Target Diving Speed, *Ss*, is usually estimated at the Director and phoned to the Computer. At the Computer, Horizontal Target Ground Speed, *Sh*, and Rate of Climb are set at zero. The Range Rate/Diving Speed Handcrank is shifted to HAND to connect it to the *dR* shaft line, and the estimated value of Target Diving Speed, *Ss*, is set in on the Target Diving Speed Dial.

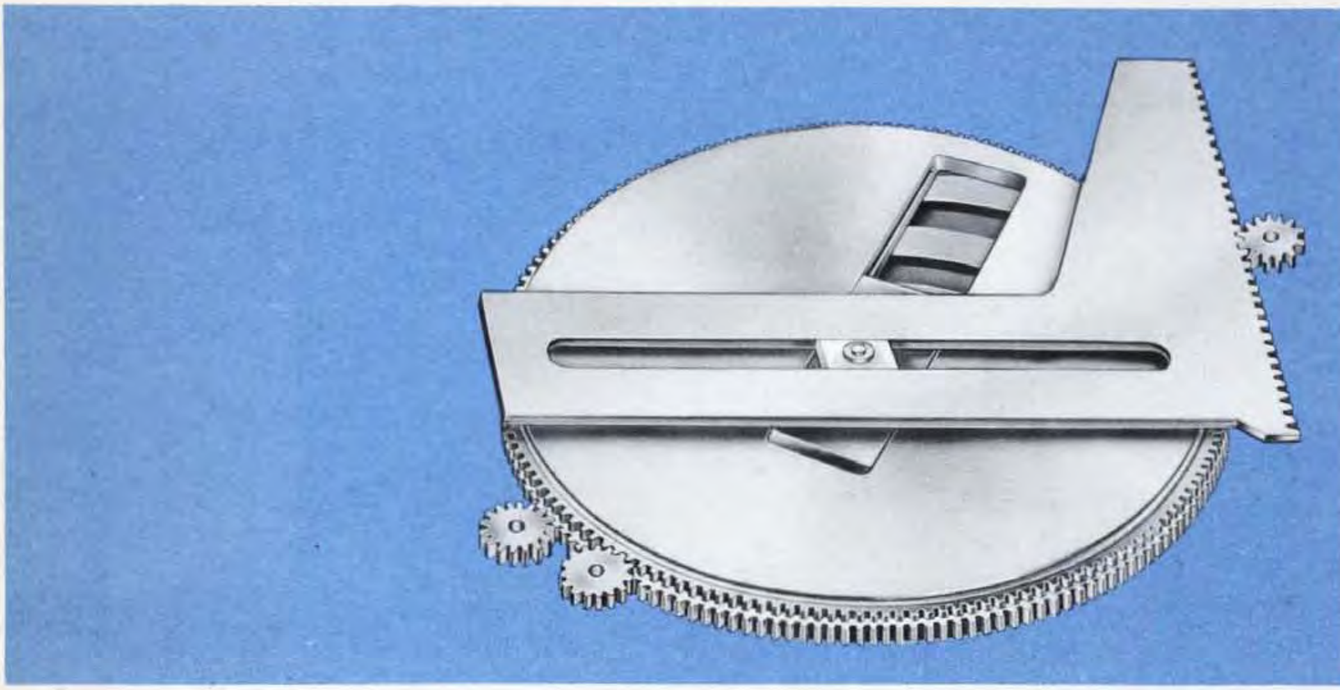
Why dH and Sh are turned to zero

In normal operation, components of Horizontal Target Speed, *Sh*, and of Own Ship Speed, *So*, are combined to obtain Horizontal Range Rate, *dRh*. Components of *dRh* and *dH* are combined to obtain *dR* and *RdE*. In Special Dive Attack Procedure, *dR* is put into the Computer by hand through the Range Rate/Diving Speed Handcrank, and components of *dH* and *dRh* are therefore not needed. For this reason, *dH* and *Sh* are turned to zero. *dRh*, then, contains only the component of Own Ship Speed.

The values of *RdE* and *RdBs* are usually close to zero because as Own Ship moves the Target continuously adjusts its course to keep diving along the Line of Sight.



The HEIGHT COMPUTER



The HEIGHT COMPUTER in the Computer Mark 1 is used to find the Height, *H*, of the Target.

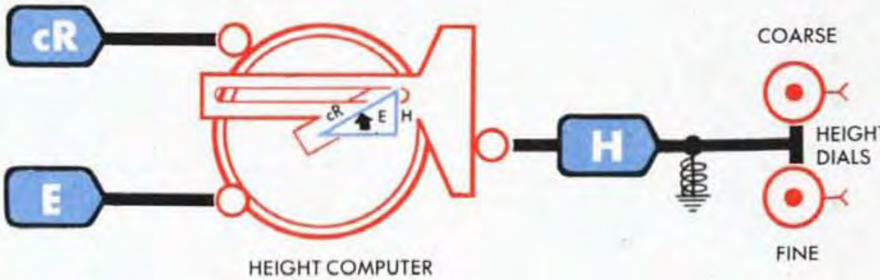
The Height Computer positions the Height Dials. Although Height is not actually used in computing Gun Orders, it is sometimes needed in finding *Present Range* or *Target Elevation.*

The Height Computer is a cam-type component solver with only one output rack. It is located on top of the Relative Motion Component Solvers.

The two inputs to the Height Computer are Generated Present Range, *cR*, which positions the cam, and Target Elevation, *E*, which positions the vector gear.

The output is *cR* sin *E*, which is equal to Target Height, *H*.

The output, *H*, goes directly to the Height Dials.



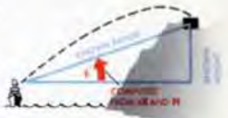
How height is used to find range

Suppose that a shore battery is being shelled. The height of the battery is known from a map, but the range is not known.

The angle of Elevation is easily found by putting the Pointer's crosshair on the Target.

The Computer Operator can now find the correct Range by turning the Generated Range Crank and watching the Height Dials. When the reading on the Height Dials is equal to the known height of the Target, the value of Present Range in the Computer is correct. The Range is correct because there is only one value of Range possible for each combination of Elevation and Height.

How height is used to find target elevation



If both the Height and the Range of a Target are known, the Target Elevation can be found from these two values.

Suppose a battery which is to be shelled is out of sight over a ridge of hills, but its range and height can be determined with the aid of a contour map. However the sights cannot be put on the Target because the Target is not visible.

Target Elevation can be found by the following method:

The Operator sets in the calculated value of Range and then reads the Height Dial.

If the Height reading does not correspond to the known height, the angle of Target Elevation must be wrong.

Target Elevation is adjusted until the correct Height reading shows on the Height Dials at the Computer.

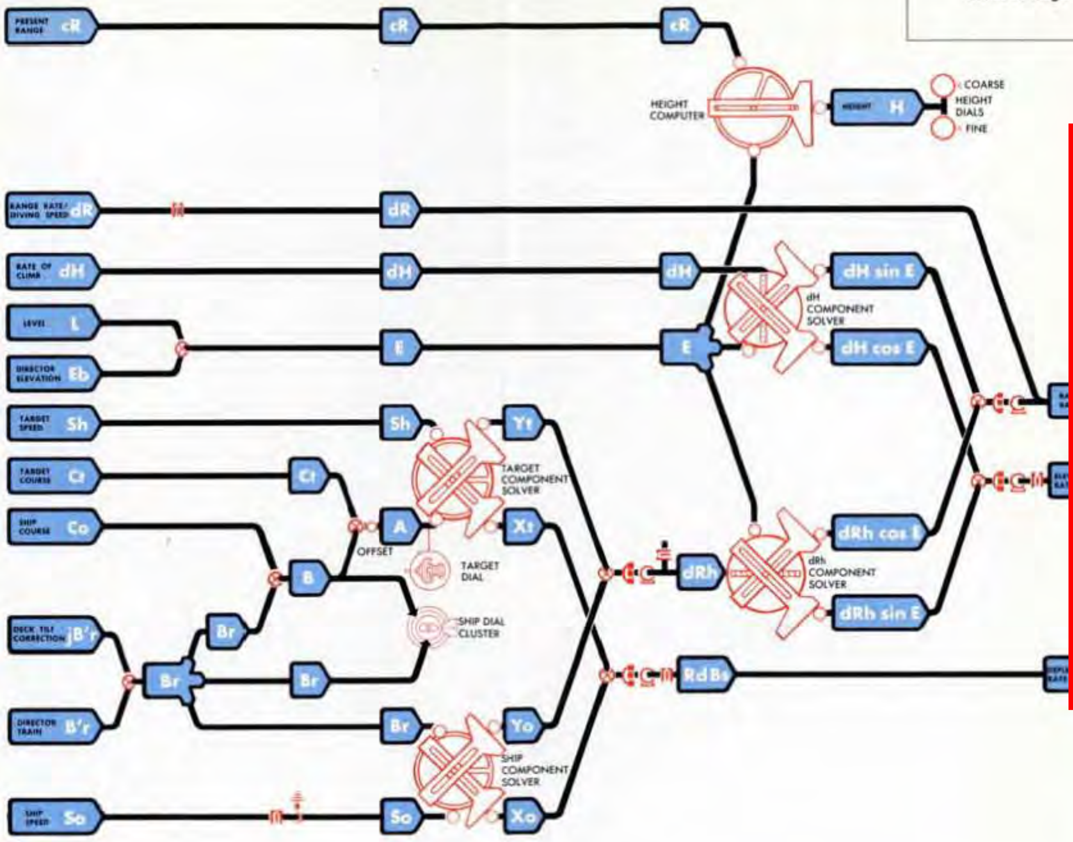
When both Range and Height readings are correct, the value of Target Elevation is also correct.

The Height Dials are also used for certain other purposes, as prescribed by *ship's doctrine*.

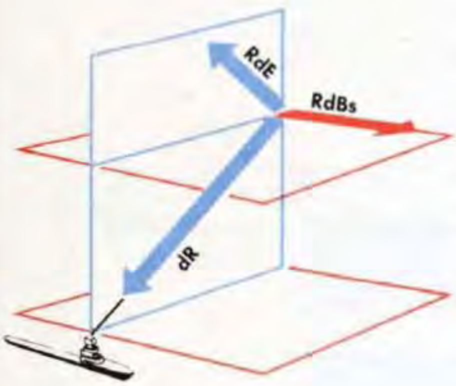
COMPUTER MK 1, MOD 7

RELATIVE MOTION GROUP

Schematic Diagram



THE INTEGRATOR GROUP

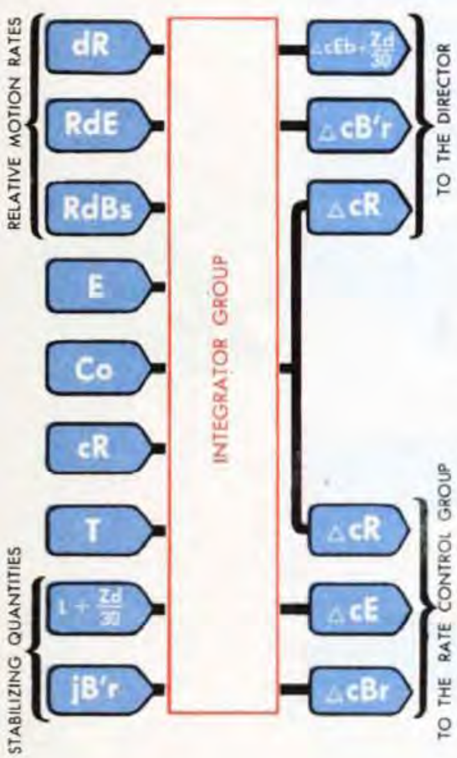


The Integrator Group computes *Linear* Changes of Generated Range, and *Angular* Changes of Generated Elevation and Relative Target Bearing, using the three Relative Motion Rates, *dR*, *RdE* and *RdBs*.

These continuously changing generated values are compared with the continuously changing observed values of Range, Elevation, and Bearing. Any differences between the generated and observed values may be corrected by means of the Rate Control Group.

To compute the Generated Changes of Range, Elevation, and Bearing, the Integrator Group receives the following inputs:

1 Range Rate, *dR*.
2 Linear Elevation Rate, *RdE*.
3 Linear Deflection Rate, *RdBs*.
4 Target Elevation, *E*.
5 Ship Course, *Co*.
6 Generated Present Range, *cR*.
7 Time, *T* (from the Time Motor within the Integrator Group).



Three outputs of the Integrator Group are used to turn the Generated Range, Elevation, and Relative Target Bearing Dials. These outputs are:

1 Generated Changes of Range, $\triangle cR$.
2 Generated Changes of Target Elevation, $\triangle cE$.
3 Generated Changes of Relative Target Bearing, $\triangle cBr$.

Similar generated quantities are also needed in the Director to position the Range Finder and the Pointer's and Trainer's sights.

Since the Generated Changes of Target Elevation and Relative Target Bearing are computed in relation to the horizontal plane, they must be corrected for deck inclination before being sent to the Director.

Stabilizing quantities added to the generated values at differentials in the Integrator Group are:

1 Level Angle plus a function of Cross-level, $L + Zd/30$.
2 Deck Tilt Correction, $jB'r$.

The generated quantities sent by synchro transmission to the Director are:

1 Generated Changes of Range, $\triangle cR$.
2 Generated Changes of Director Elevation, $\triangle cEb + Zd/30$.
3 Generated Changes of Director Train, $\triangle cB'r$.

The Mechanism in the Integrator Group

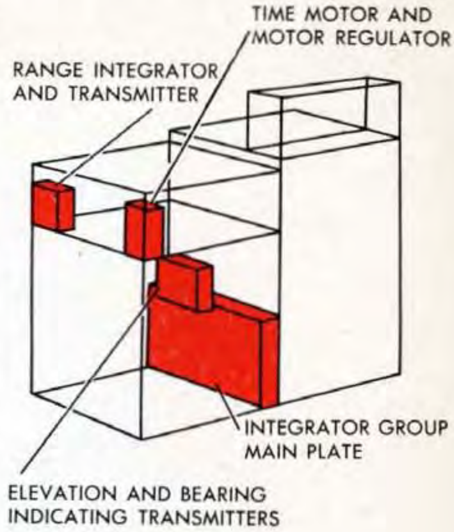
The mechanism in the Integrator Group includes five disk integrators, two cams, the Time Motor, the Time Motor Regulator, five single-speed transmitters, and various differentials.

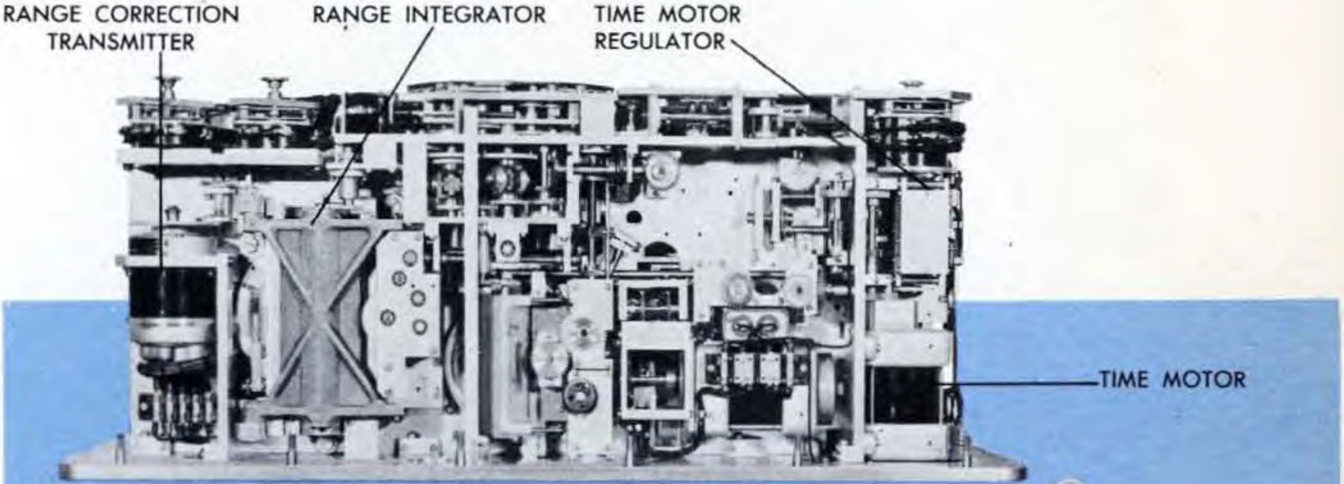
The Range Integrator, the Range Correction Transmitter, the Time Motor, and the Time Motor Regulator can be seen from the front of the Computer Mark 1.

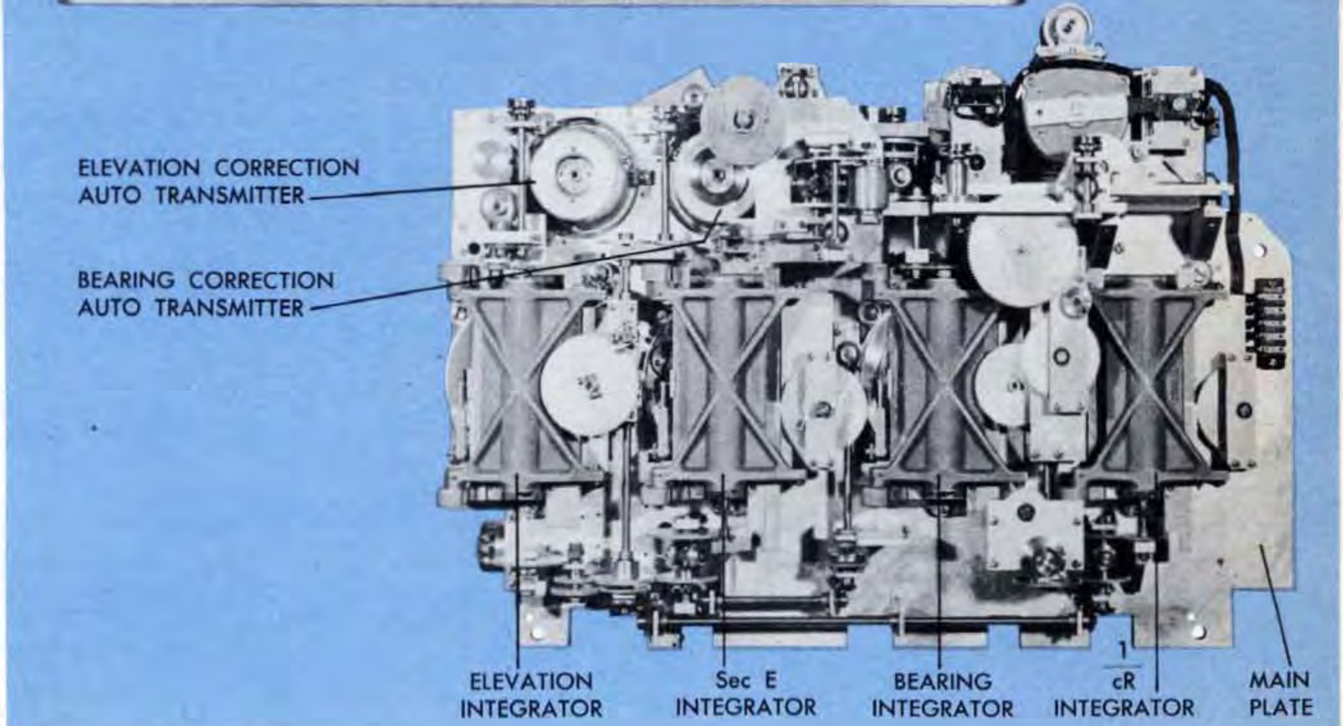
The other four disk integrators can be seen by looking into the lower righthand side of the Computer.

These four integrators, the two cams, and the two transmitters are mounted as a complete unit on a large plate.

The other two transmitters are mounted below the front top section of the Computer.



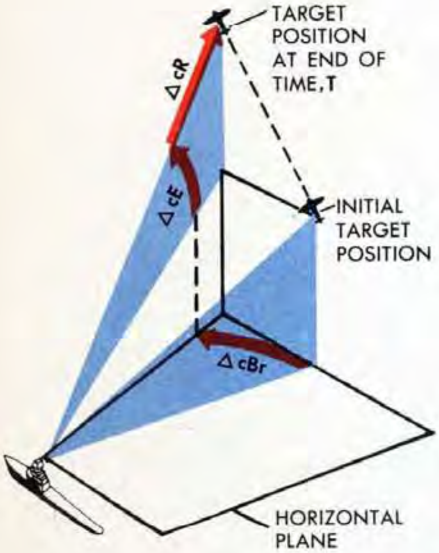




INCREMENTS

The main job of the Integrator Group is to compute continuous values of:

1. Generated Changes of Range, $\triangle cR$
2. Generated Changes of Elevation, $\triangle cE$
3. Generated Changes of Relative Target Bearing, $\triangle cBr$



The three Relative Motion Rates, *dR, RdE,* and *RdBs* are continuously multiplied by Time, *T,* in order to generate these three quantities.

Although the Relative Motion Rates change continuously as Own Ship and Target change their courses and speeds, the rates can be thought of as being CONSTANT at any instant.

If a linear rate is thought of as being constant during a short time interval, multiplying the rate by that time interval will give the linear change of Target Position during that time. The changes of Target Position which take place during very short intervals of time are called increments.

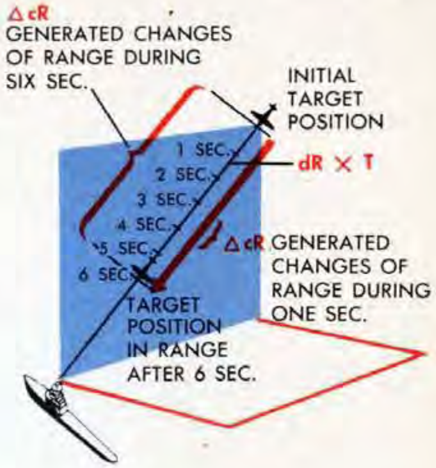
An integrator can be thought of as continuously multiplying a rate, which is constant during very short time intervals, by equally short intervals of time. The product for each time interval is added to the sum of the previous products to produce a total linear change of Target Position.

Increments of Range are *linear* and are generated by the Range Integrator.

Increments of Elevation and Bearing are *angular* and are generated by the Elevation and Bearing Integrators.

How these angular increments are generated from linear rates will be explained in detail later in this chapter.

GENERATED CHANGES OF RANGE



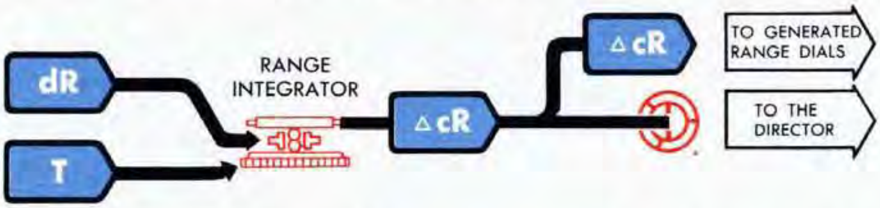
Direct Range Rate, *dR*, indicates the Rate at which Range is changing in yards per minute. To compute the linear Range change during a definite length of time, this equation is used:

LINEAR RATE × TIME = LINEAR DISTANCE

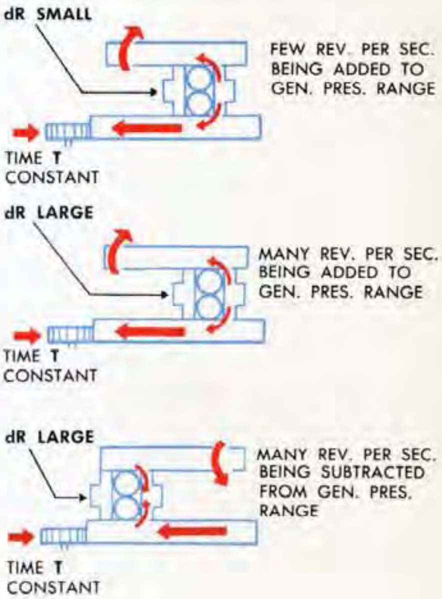
Range Rate, *dR*, × Time, *T*, = Changes of Range, △*cR*, generated during Time, *T*.

The range integrator

The Range Integrator continuously multiplies Range Rate, *dR*, by Time, *T*, to generate the Changes in Range during any time period. Direct Range Rate, *dR*, from the Relative Motion Group positions the carriage of the Range Integrator. Time, *T*, is supplied by the Time Motor. The Time Motor, controlled by the Time Motor Regulator, turns the disk of the Range Integrator at a constant speed. The output from the integrator roller is Generated Changes of Range, △*cR*.



From the moment that the integrator disk starts to rotate, the output roller is continually turning. Sometimes it turns quickly and sometimes it turns slowly. The number of turns of the output roller at any instant compared with the number of turns at any previous time indicates the *size* of the Range increment during that time period. The *speed* at which the roller turns determines *how fast* the increments are being added to or subtracted from previous values of Range. The *direction* in which the roller turns indicates whether Range is *increasing* or *decreasing*, that is, whether increments are being *added to* or *subtracted from* the present value of Generated Range.

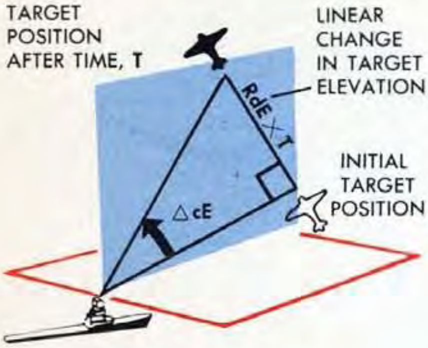


The value of △*cR* during a small time interval, such as 1/10 second, is the increment of Range Change during 1/10-second based on the value of *dR* during that 1/10-second interval. The value of △*cR* during a longer time period, such as 10 seconds, is the SUM of the increments generated during the 10-second period, each increment being based on the value of *dR* at the instant at which that increment was being generated. Over any period of time, △*cR* represents accurate Generated Changes of Range during that time period.

In the Computer, △*cR* is added to the Initial Range input, *jR*, to give continuous values of Generated Present Range, *cR*. *cR* positions the Generated Range Dials and the Generated Range lines throughout the Computer.

△*cR* is also transmitted by a single-speed synchro transmitter to the Change of Range Receiver in the Director, to position the Range Finder measuring wedges.

GENERATED CHANGES OF ELEVATION



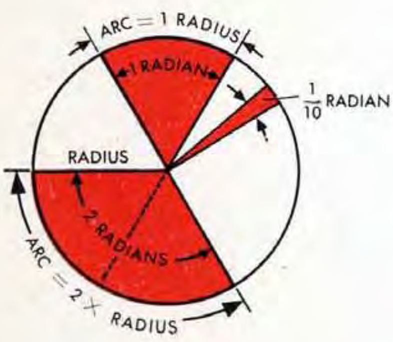
Generated Changes of Target Elevation, $\triangle cE$, are *angular* increments.

If the Linear Elevation Rate, RdE, from the Relative Motion Group were multiplied by Time, T, the product would be a *linear* change of Target Elevation, $RdE \times T$.

$\triangle cE$ is the angular change of Elevation caused by the Target moving the linear distance $RdE \times T$.

To understand how this *angular* change in Target Elevation is computed from the *linear* Elevation rate, RdE, the radian measure of the angles must be understood.

A RADIAN IS THE ANGLE FORMED BY TWO RADII OF A CIRCLE WHEN THE ARC THEY CUT OFF IS AS LONG AS THE RADIUS.

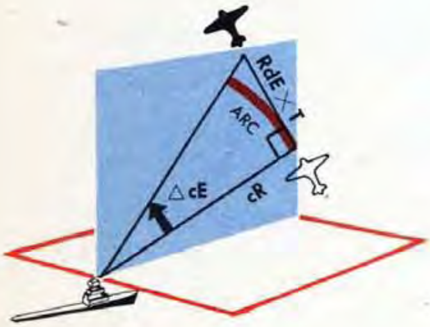


If the arc cut off is 1/10 the length of a radius, the angle equals 1/10 radian.

If the arc cut off is twice the length of a radius, the angle equals two radians.

Any angle may be measured in radians by dividing the length of the arc by the radius:

$$\frac{\text{arc}}{\text{radius}} = \text{angle in radians}$$



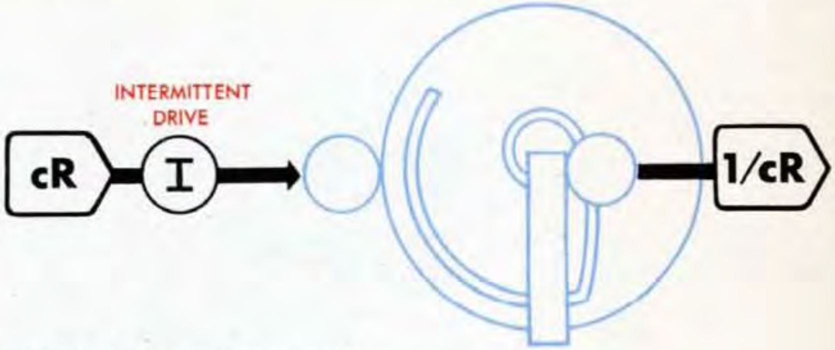
An arc of radius cR can be drawn in the vertical plane of sight from the initial Line of Sight to the Line of Sight at the end of Time, T.

The line representing the linear change in Target Elevation, $RdE \times T$, is tangent to this arc. If the Time, T, is very small, the line $RdE \times T$ can be considered equal in length to the arc.

Dividing the arc by the radius gives angle $\triangle cE$ in radians:

$$\frac{\text{arc}}{\text{radius}} = \frac{RdE \times T}{cR} = \triangle cE$$

This equation can also be written $1/cR \times T \times RdE = \triangle cE$. It is used in this form to compute Generated Changes of Target Elevation, $\triangle cE$, and is solved mechanically by a cam and two disk integrators.



The 1/cR cam

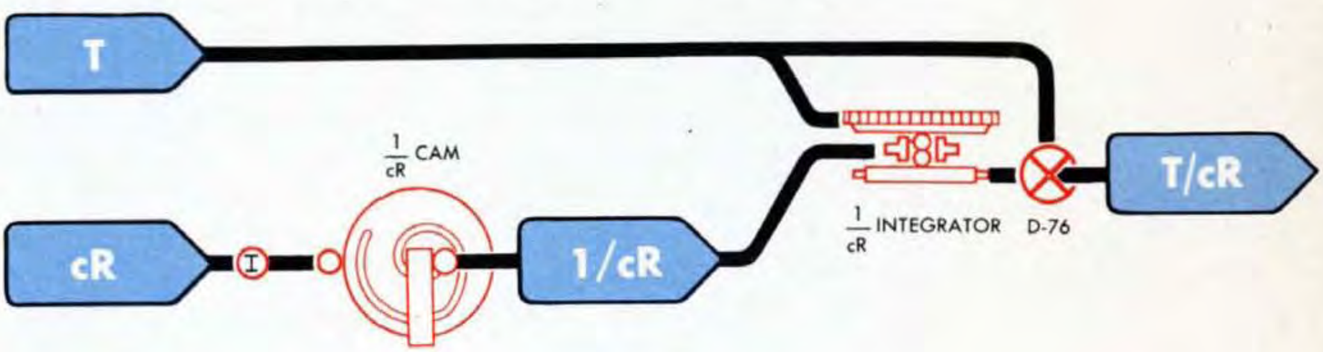
The first term in the $\triangle cE$ equation is obtained from a reciprocal cam. The $1/cR$ cam is grooved so that for every input of Generated Present Range, cR, the output is the reciprocal of cR, or $1/cR$. Multiplying by the reciprocal of cR instead of dividing by cR reduces the number of mechanisms needed to solve the equation.

The 1/cR integrator

The value $1/cR$, from the $1/cR$ cam, positions the carriage of the $1/cR$ Integrator. Time, T, from the Time Motor drives the integrator disk.

Since $1/cR$ is always a positive value, T also by-passes the integrator so that the whole width of the integrator disk can be used to obtain more accurate values. (See OP 1140, page 126.) This T by-pass is added to the output from the integrator roller at differential D-76 to obtain T/cR, the product of the two inputs.

The value of T/cR is sent to the Elevation Integrator to complete the computation of $\triangle cE$, and is also used in computing the Generated Changes of Relative Target Bearing, $\triangle cBr$.

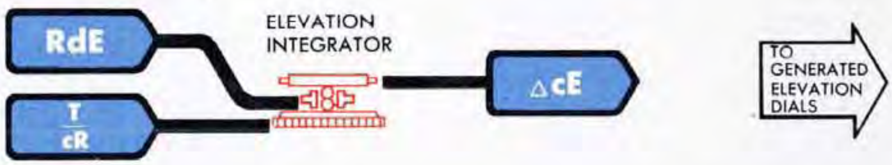


The ELEVATION integrator

With T/cR supplied by the $1/cR$ Integrator and RdE supplied by the Relative Motion Group, the equation $T/cR \times RdE = \triangle cE$ is solved by the Elevation Integrator.

The *inputs* to the Elevation Integrator are Linear Elevation Rate, RdE, which positions the integrator carriage, and T/cR, which turns the integrator disk.

The *output* of the integrator roller is Generated Changes of Target Elevation, $\triangle cE$.



$\triangle cE$ drives the Generated Elevation Dial on top of the Computer. Observed Elevation, E, turns the Observed Elevation Dials in the same dial group so that the Generated Changes of Elevation may be continuously compared with the Observed Changes of Elevation.

In the Director, $\triangle cE$ is used to position the Director Sights and the Range Finder. The Pointer continuously compares the Generated Changes of Elevation with Observed Changes of Elevation.

The Director Sights and Range Finder must also be positioned by the correction $L + Zd/30$. L compensates for the effect of Level; $Zd/30$ allows the Director Sights to be cross-leveled without affecting Director Elevation.

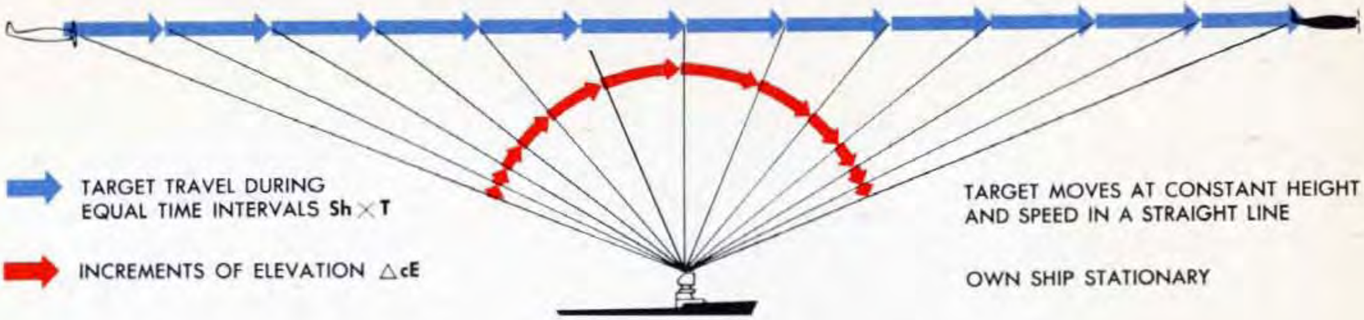
In most installations the value of $L + Zd/30$ is transmitted by shafting from the Stable Element to the Computer and is added to $\triangle cE$ at a differential in the Integrator Group, forming $\triangle cEb + Zd/30$. Then $\triangle cEb + Zd/30$ is transmitted as one quantity to the Director. Two single-speed synchro transmitters, one indicating and one automatic, are used to transmit $\triangle cEb + Zd/30$.

In some installations, $L + Zd/30$ is transmitted to the Director from the Stable Element, and $\triangle cE$ is transmitted from the Computer alone. The two quantities are added in the Director.

In either case, $\triangle cEb + Zd/30$ positions both the Director Sights and the Range Finder in elevation.

When $L + Zd/30$ is transmitted directly from the Stable Element to the Director, the $L + Zd/30$ shaft line going to the Integrator Group is locked by a locking gear.

How increments of elevation vary

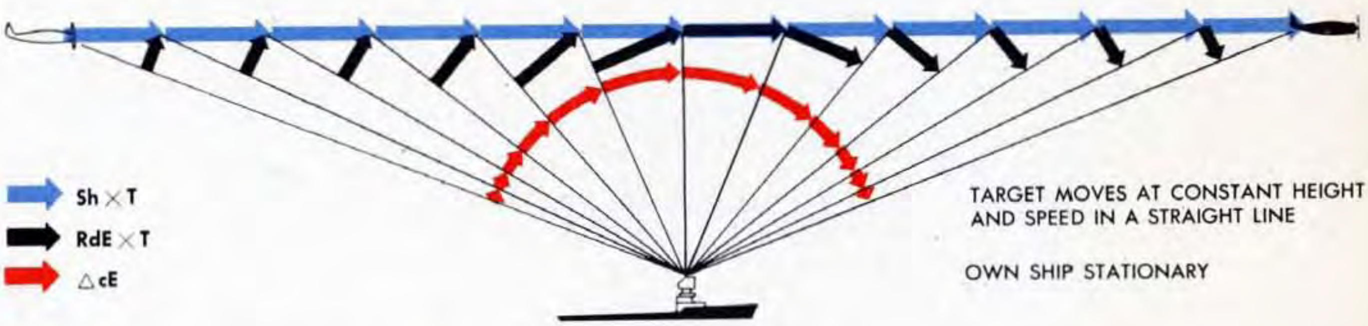


Suppose a Target is moving at a constant height and at a constant speed while Own Ship is stationary, as shown here.

The blue arrows represent linear Target travel during equal time intervals. These arrows are all the same length, since the linear rate is constant.

The red arrows represent the Angular Increments of Elevation needed to position the sights to keep them on the Target during each Time interval. Notice that these increments vary in size.

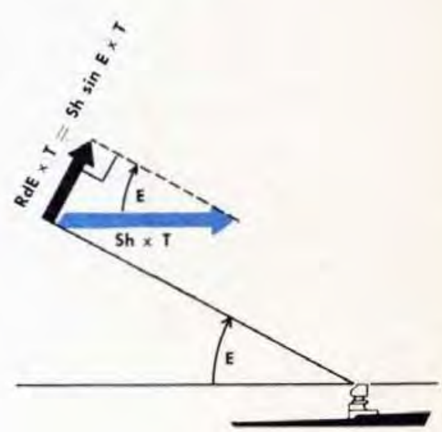
From the instant tracking begins until the Target is directly overhead, the Angular Increments of Elevation for equal Time intervals increase in size. As the Target moves away from Own Ship, the Angular Increments of Elevation begin to decrease for equal Time intervals.



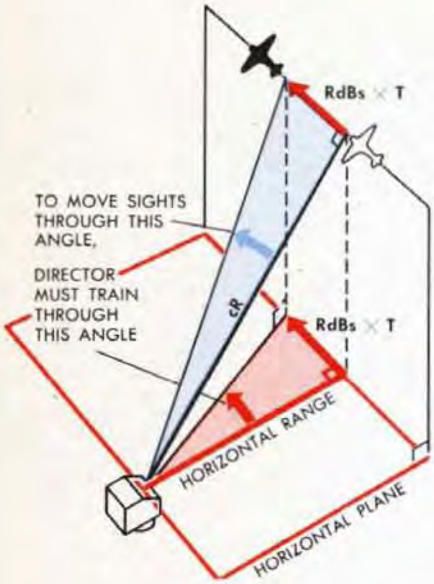
cR varies during the equal Time intervals because Range decreases as the Target approaches Own Ship and increases as soon as the Target has passed over Own Ship and is moving away. $\triangle cE$ varies inversely as *cR* or directly as $1/cR$.

Since Own Ship is stationary in this example, *RdE* consists only of the component of linear Target velocity lying at right angles to the Line of Sight in the vertical plane. For this special case, *RdE* equals *Sh* sin *E*. *Sh* is constant; therefore *RdE* varies as the sine of *E*. Since *E* increases as the Target approaches Own Ship, and decreases after the Target has passed over Own Ship, *RdE* also increases and then decreases. $\triangle cE$ varies as *RdE* varies.

Then, $\triangle cE = \dfrac{RdE \times T}{cR}$.



GENERATED CHANGES OF TRUE BEARING



The Generated Changes of True Bearing, $\triangle cB$, are angular increments measured in the horizontal plane.

Linear Deflection Rate, *RdBs*, multiplied by Time, *T*, is the *linear* increment of Deflection during Time, *T*.

$\frac{RdBs \times T}{cR}$ equals the *Angular* Increments of Bearing in the SLANT plane. In order to be used to train the Director, this angle must be converted to the horizontal plane.

The Angular Increments of Bearing in the horizontal plane, $\triangle cB$, are found by projecting the Lines of Sight and $RdBs \times T$ vertically onto the horizontal plane. One side of the triangle thus formed is the horizontal projection of *cR*, called Horizontal Range.

$$\triangle cB = \frac{RdBs \times T}{\text{Horizontal Range}}$$

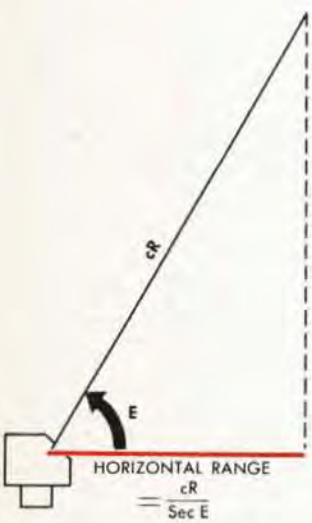
To compute Horizontal Range:

$$\text{Sec } E = \frac{cR}{\text{Horizontal Range}}$$

Therefore:

$$\text{Horizontal Range} = \frac{cR}{\text{Sec } E}$$

$\triangle cB$ is greater than the angle measured by $RdBs \times T$ in the slant plane, because the Horizontal Range is shorter than *cR*.

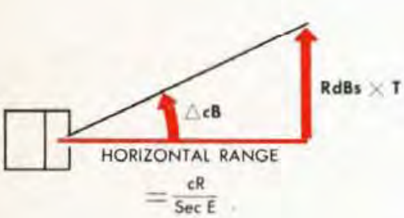


Dividing the linear increments, $RdBs \times T$, by Horizontal Range, $cR/\text{Sec } E$, gives the angular increments, $\triangle cB$ in radians. $\triangle cB$ is the Generated Changes of True Bearing in the HORIZONTAL plane.

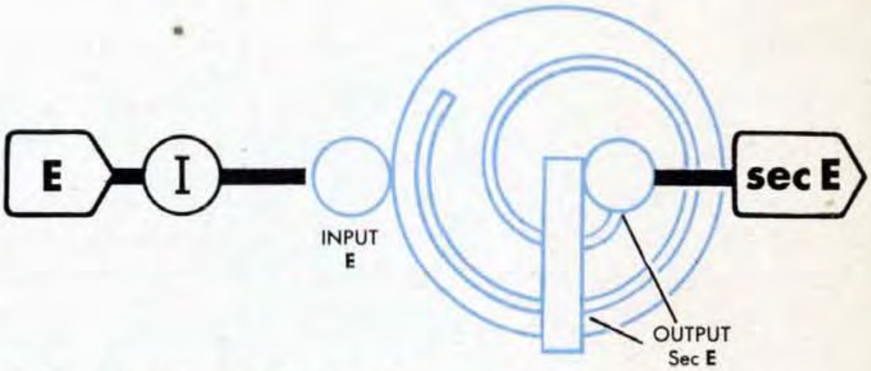
$$\frac{RdBs \times T}{cR/\text{Sec } E} = \triangle cB \text{ in radians}$$

This equation can also be written:

$$\frac{T}{cR} \times \text{Sec } E \times RdBs = \triangle cB$$



The quantity $T/cR \times \text{Sec } E$ is computed mechanically by a cam and an integrator.



The sec E cam

Sec *E* is computed by a secant cam mounted on the back of the main plate in the Integrator Group.

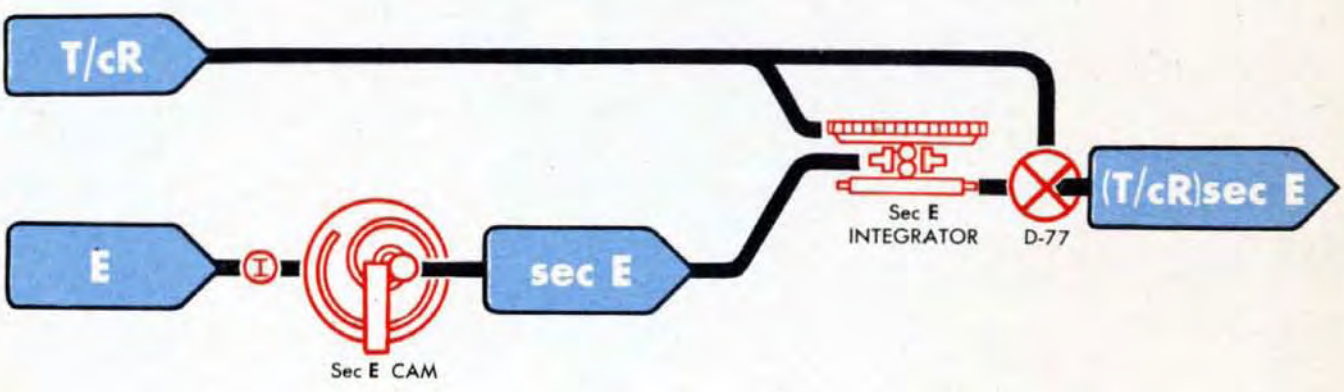
The sec E integrator

Sec *E* positions the carriage of the Sec *E* Integrator.

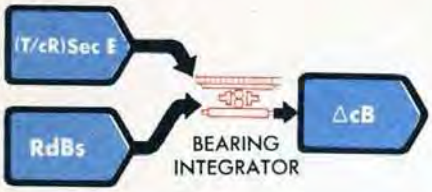
T/cR from the *1/cR* Integrator drives the disk.

T/cR also by-passes the Sec *E* Integrator and is added to the roller output at differential D-77. This is done so that the whole width of the integrator disk may be used for positive values of Sec *E*. The output from D-77 is (T/cR)Sec *E*, the first part of the equation: $T/cR \times \text{Sec } E \times RdBs = \triangle cB$.

The computation of $\triangle cB$ is completed by multiplying (T/cR) Sec *E* by *RdBs*. This is done in the Bearing Integrator.



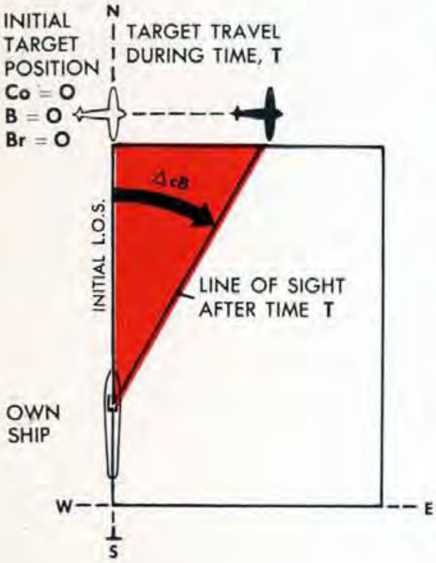
The BEARING integrator



$(T/cR)\sec E$ from the Sec E Integrator rotates the disk of the Bearing Integrator. Deflection Rate, $RdBs$, positions the integrator carriage. The output from the roller is Generated Changes of True Bearing, $\triangle cB$.

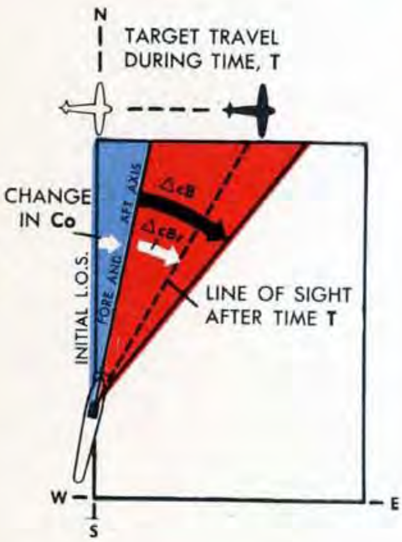
$\triangle cB$ represents the Changes in *True* Bearing caused by the changes in the position of the Line of Sight. But the Director Sights must be positioned by Changes in *Relative* Target Bearing, in order to keep the sights on Target when Own Ship changes course.

To convert Generated Changes of True Bearing, $\triangle cB$, into Generated Changes of Relative Target Bearing, $\triangle cBr$, the changes in Ship Course, Co, are subtracted from $\triangle cB$. $\triangle cB - Co = \triangle cBr$.



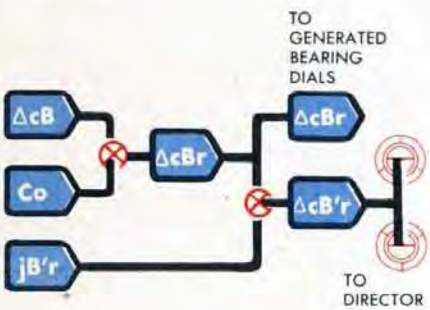
To understand why this is necessary, take a simple example in which Ship Course, Co, and True Target Bearing, B, are zero. Relative Target Bearing, Br, is also zero. The Target is tracked until it moves to the position shown. During this time, the Bearing Integrator computes a value of Generated Changes of True Bearing, $\triangle cB$, which in this case represents the total value of True Bearing, B. Co remains zero because Own Ship has not changed its course.

Suppose now that Own Ship Course had changed during the same amount of Target travel. The Bearing Integrator would still have computed $\triangle cB$ as the Bearing change between North and the Line of Sight. If the value of $\triangle cB$ were used to position the Director, the sights would be off the Target by the amount of change in Ship Course, Co. The angle by which the Director must be positioned is always Relative Target Bearing, the angle between the *fore and aft axis of Own Ship* and the Line of Sight.



To obtain Generated Changes of *Relative* Target Bearing, $\triangle cBr$, Ship Course, Co, must be subtracted from Generated Changes of *True* Bearing, $\triangle cB$.

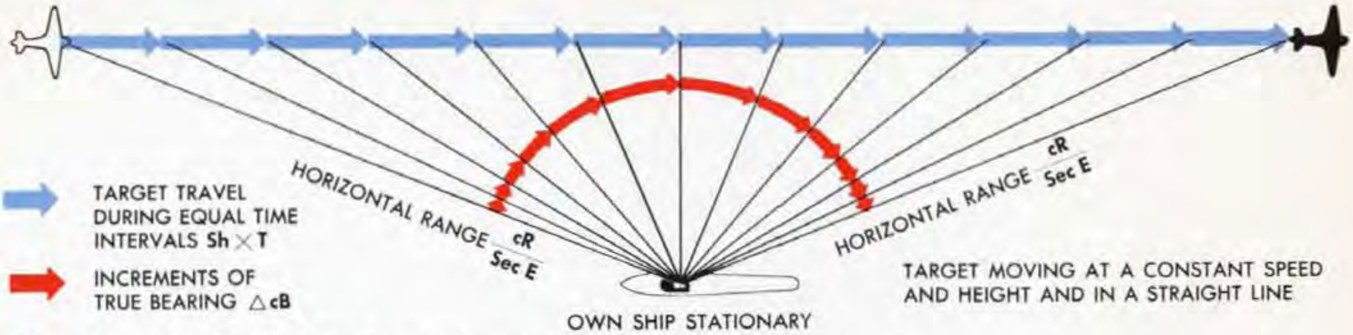
In the example shown, $\triangle cBr$ represents the total value of Relative Target Bearing, Br. $\triangle cBr$ positions the Generated Bearing Dial on top of the Computer.



Before $\triangle cBr$ is transmitted to the Director, it must be corrected to compensate for Deck Tilt, since the Director trains in the deck plane. The correction for Deck Tilt, $jB'r$, is computed by the Deck Tilt Group. Generated Changes of Relative Target Bearing in the horizontal plane, $\triangle cBr$, minus Deck Tilt Correction, $jB'r$, equal Generated Changes of Director Train, $\triangle cB'r$. $\triangle cBr - jB'r = \triangle cB'r$.

$\triangle cB'r$ is continuously transmitted to the Director to drive the whole Director in train. Two single-speed synchro transmitters, one indicating and one automatic, are used to transmit $\triangle cB'r$.

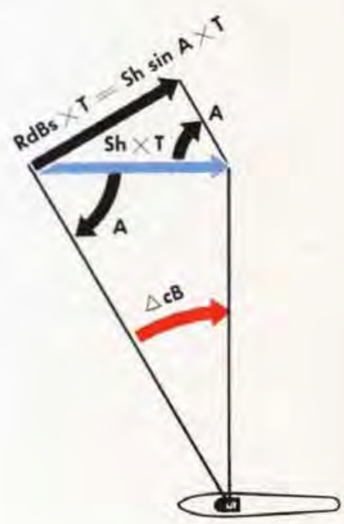
How the angular bearing increments vary



Suppose that Own Ship is stationary with the deck steady and horizontal. A Target is moving in a straight line at a constant height and at a constant speed as shown here. The blue arrows represent equal linear increments of Target Motion, $Sh \times T$, for equal intervals of Time. The red arrows represent the angular increments of Bearing, $\triangle cB$, needed to keep the sights on the Target during each time interval.

From the moment tracking begins until the Target is exactly abeam of Own Ship, the angular increments of Bearing, $\triangle cB$, increase in size, although the linear increments of Target Motion are equal. As the Target passes abeam of Own Ship and begins to move away, the angular increments begin to decrease in size.

The diagram shows that $\triangle cB$ varies *inversely* as Horizontal Range, $cR/\sec E$, varies, which is *directly* as the reciprocal of $cR/\sec E$ varies.



Since Own Ship is stationary in this example, *RdBs* consists only of the component of Horizontal Target Velocity lying horizontally at right angles to the Line of Sight.

$$RdBs = Sh \sin A$$

Since *Sh* is constant, *RdBs* varies as sin *A* varies. Although Target Angle, *A*, increases continuously during the flight of the Target, sin *A* increases only until *A* is 90° and then sin *A* decreases. *RdBs* varies as sin *A* varies. Therefore $\triangle cB$ varies directly as *RdBs* varies.

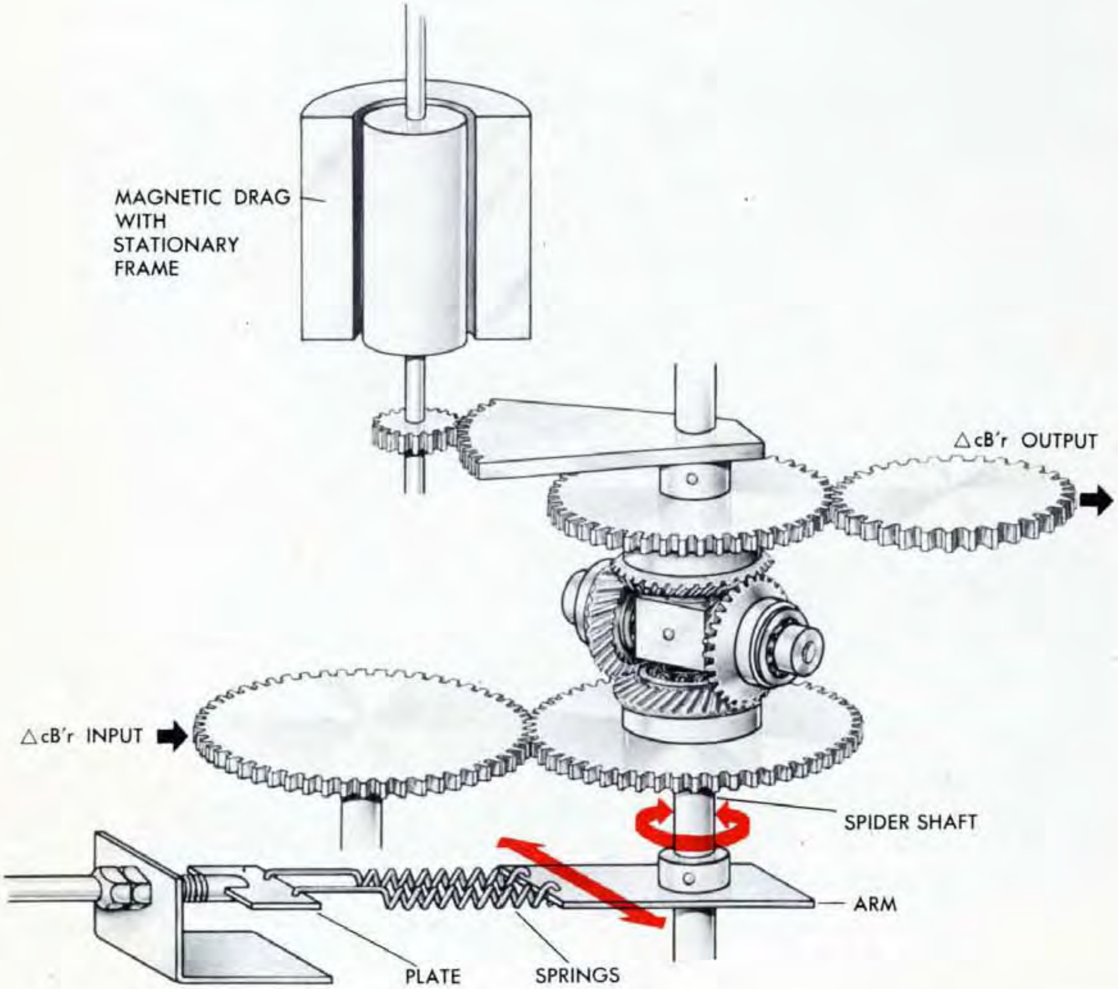
Then $\triangle cB = \dfrac{RdBs \times T \times \sec E}{cR}$

THE BEARING FILTER

The entire Director is trained by the quantity $\triangle cB'r$, transmitted from the Integrator Group in the Computer. The value of $\triangle cB'r$ must therefore change smoothly to avoid jerking the Director. The roughness on the $\triangle cB'r$ shaft line is likely to come from the value of Own Ship Course, *Co*. The Ship Course Receiver in the Computer Mark 1 is provided with a special damper to smooth out the *Co* signal. In addition, a special mechanism is installed on the $\triangle cB'r$ shaft line to prevent any possible roughness on the *Co* shaft line from affecting $\triangle cB'r$. This mechanism is called the Bearing Filter.

The parts of the bearing filter

The Bearing Filter consists of a differential, an arm assembly, and a magnetic drag. The magnetic drag is geared to the differential spider shaft. The arm assembly consists of an arm which is attached to the differential spider shaft, and two springs which connect the end of this arm to a small plate held by a threaded shaft. The threaded shaft is secured to a vertical plate.

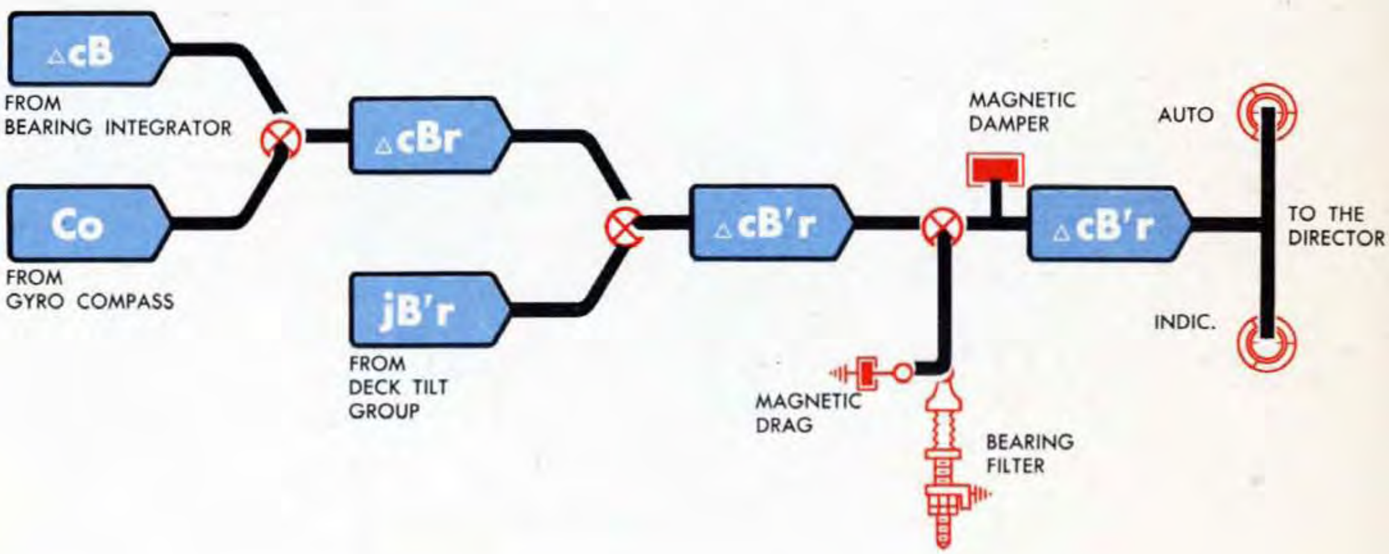


How the bearing filter works

$\triangle cB'r$ is both the input and the output of the differential. When the value of $\triangle cB'r$ changes smoothly, it feeds into one side of the differential and out of the other side while the spider shaft is held stationary by spring tension on the arm.

When the $\triangle cB'r$ input is rough or reverses direction suddenly, the normal inertia of the $\triangle cB'r$ output shaft line causes it to resist sudden changes of speed and to tend to continue turning at the old speed. An additional force is therefore exerted on the differential spider shaft, causing it to rotate, turning the arm and stretching the springs. In this way, the sudden change in $\triangle cB'r$ is absorbed by the rotation of the spider shaft. The increased pressure exerted by the stretched springs returns the spider slowly to its original position, changing the differential output to the new speed or direction. When the springs have returned the arm to its original position, the differential output again matches the input. The magnetic drag geared to the spider shaft damps or slows the spring action, eliminating any tendency of the arm and spider to oscillate.

A large part of the inertia of the $\triangle cB'r$ output line is provided by a heavy magnetic damper.



THE TIME LINE

The mechanisms on the Time line are the Time Motor, the Time Motor Regulator, the Time Motor Switch, the Time Crank, and the Time Dials.

When the Computer is being operated, the Time line is always driven by the Time Motor, which is controlled by the Time Motor Regulator.

The Time line is turned by hand only when it is necessary to zero the Time Dials and to bring the Time line up to speed during certain tests.

The Time Dials

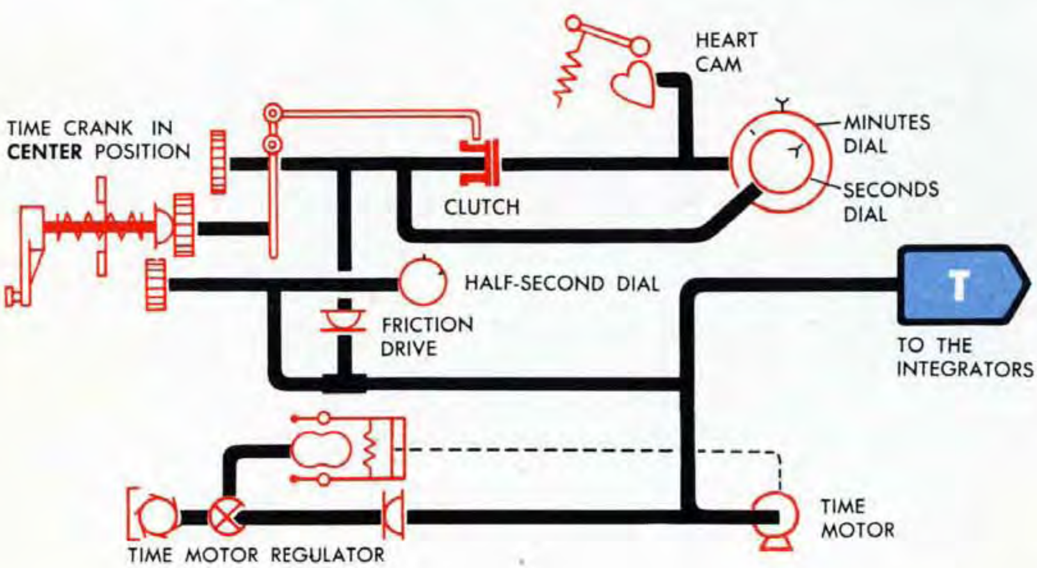
There are three Time Dials: a ring dial graduated in minutes, an inner dial graduated in seconds, and a small half-second dial with one graduation

The Time Crank

The Time Crank has three positions: CENTER, IN, and OUT. Centering springs keep the Time Crank in the CENTER position unless it is held in the IN or OUT position.

NORMAL OPERATION

When the Time Switch is turned ON and the Power Switch is ON, the Time Motor is energized and drives the Time line. The Time Crank is in CENTER position and is disengaged from the shaft line. Since Time, *T*, represents actual elapsed time by the clock, the Time Motor must be kept running at a definite constant speed under varying loads. This regulation is done by the Time Motor Regulator.



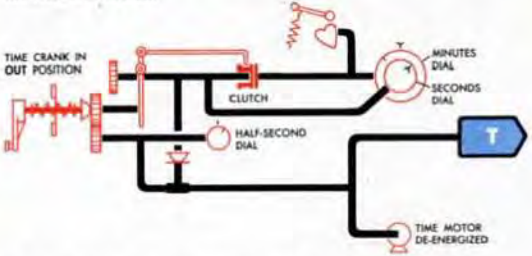
OPERATION DURING TESTS

The Time Crank is used to position all the Time Dials at zero before starting certain tests. The crank is also used at the start of each of these tests to bring the Time line up to speed.

This use of the Time Crank is described in detail in the chapter on B Tests in OP 1064A.

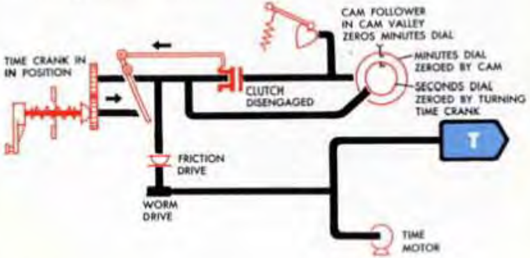
Zeroing the Time Dials

The Time Crank is first pulled OUT and turned clockwise to zero the Half-second Dial. In the OUT position, the crank is connected to the Time line and the entire line is turned to zero the Half-second Dial.



The Time Crank is then pushed to the IN position and turned to zero the Seconds Dial. Pushing the crank IN operates a clutch which disengages the Minutes Dial from the Time line. This allows the Minutes Dial to be returned to the zero position by a heart cam.

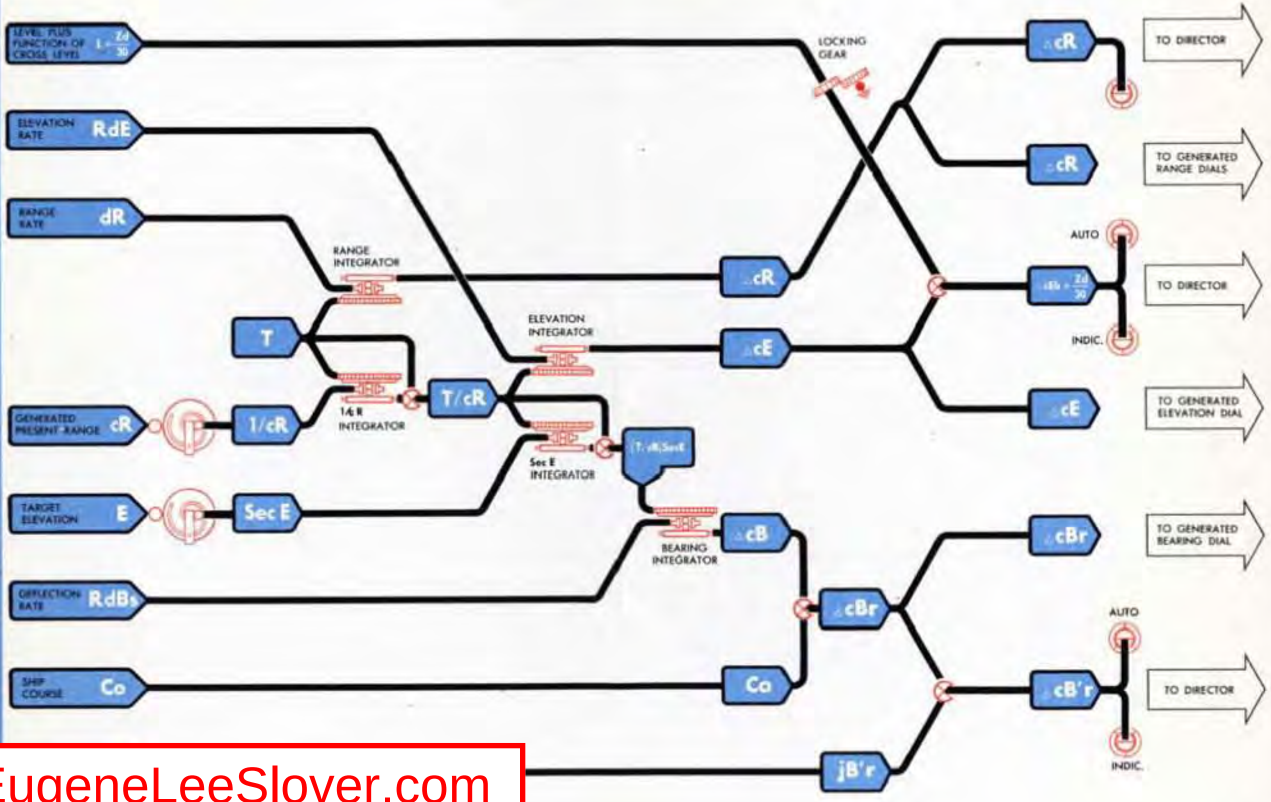
A friction drive on the line allows the Time Crank to be turned in the IN position to zero the Seconds Dial without disturbing the setting of the Half-second Dial.



COMPUTER MK 1, MOD 7

THE INTEGRATOR GROUP

SCHEMATIC DIAGRAM

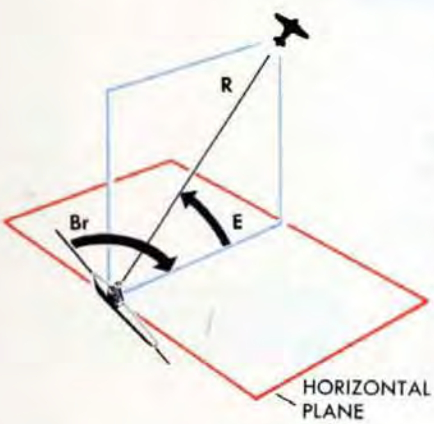


RATE CONTROL

The purpose of Rate Control is to correct the three Relative Motion Rates: *dR, RdE,* and *RdBs.*

All the necessary information for computing these three rates is available from the moment the Target is picked up, with the exception of accurate information about the speed and direction of Target Motion.

Information about the speed and direction of Own Ship Motion is always available and the position of the Target in relation to Own Ship is continuously measured from the moment the Target is picked up, but the speed and direction of the Target must first be estimated and then corrected. The process of correcting these estimates of Target speed and direction and thus correcting the Relative Motion Rates is called "*Rate Control.*"

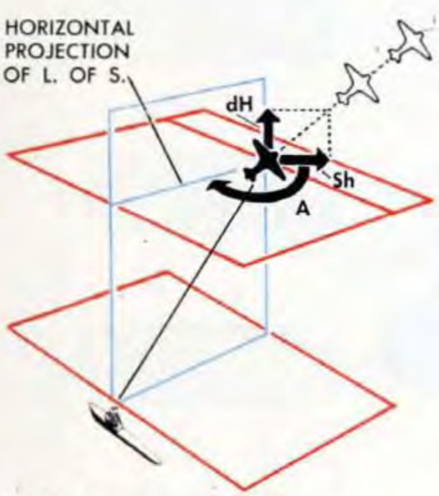


TARGET POSITION INPUTS TO THE RATE CONTROL MECHANISM

Information about the target

Target position

Information about the POSITION of the Target in relation to Own Ship is available whenever the Director sights are on Target. The Director continuously measures the Target Position in Range, *R,* Elevation, *Eb,* and Train, *B′r.* This information is continuously transmitted to the Computer. In the Computer, *Eb* and *B′r* are referred to the horizontal plane. Level, *L,* is subtracted from *Eb* to give *E,* in the Synchronize Elevation Mechanism. The Deck Tilt Correction, *jB′r,* is added to *B′r* to give *Br. R, E,* and *Br* are the Target Position inputs to the Rate Control Mechanism.



TARGET MOTION ESTIMATES

Target motion

The Director has no means of measuring the speed and direction of Target Motion directly. The values of Target Horizontal Speed, *Sh,* Rate of Climb, *dH,* and Target Angle, *A,* must be estimated first and corrected later by Rate Control. The initial estimates of Target Speed, Target Angle, and Rate of Climb may be called the Target Motion estimates.

The accuracy of the Target Motion estimates depends on the ability of the person doing the estimating. No matter how experienced he is, it is almost impossible for him to estimate *Sh, dH* and *A* with sufficient accuracy. These estimates must be checked and corrected.

Checking target motion estimates

Comparing observed and generated changes of target position

To check the Target Motion estimates, the Computer generates changes of Target Position on the basis of these Target Motion estimates. The *generated changes* are then compared with *observed changes* of Target Position. Using inputs of Own Ship Motion, Observed Target Position, and Estimated Target Motion, the Computer Mark 1 continuously generates changes of Range, Elevation, and Bearing. If these *Generated* Changes of Target Position go ahead of or fall behind the *Observed* Changes of Target Position, the estimated Target Motion values are wrong, since all the other inputs used are known to be correct.

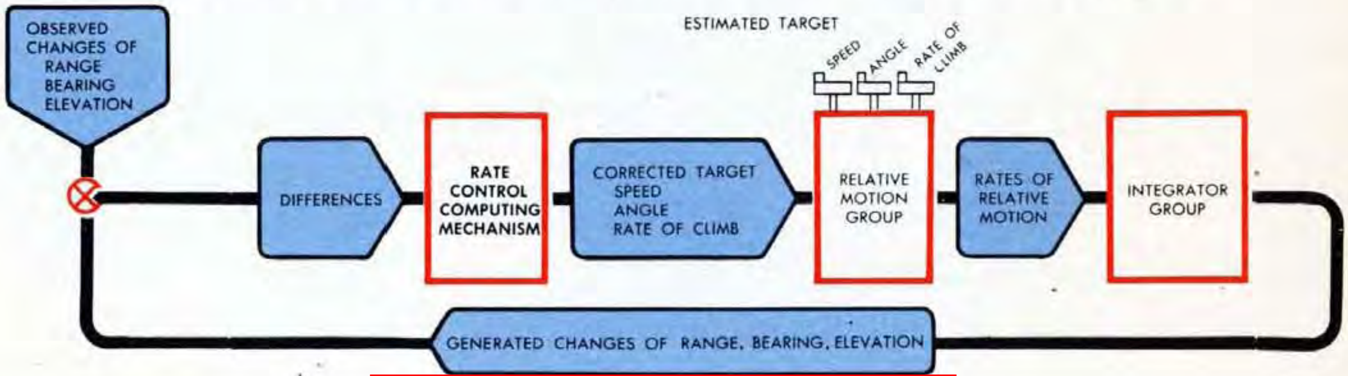
Correcting target motion estimates

The process of Rate Control consists in using the differences between the Generated and Observed Changes of Target Position to make corrections to Target Speed, Target Angle, and Rate of Climb.

These differences, or errors, are used as inputs to the Rate Control Computing Mechanism, which resolves them into corrections to the estimated values of Target Speed, Target Angle, and Rate of Climb. The corrected values of Target Speed, Target Angle, and Rate of Climb reposition the Relative Motion Component Solvers. The Component Solvers then compute more accurate Relative Motion Rates. These Relative Motion Rates are used to generate new changes of Target Position, which are again compared with the observed changes. When the Generated Changes vary in synchronism with the Observed Changes, the Relative Motion Rates are correct and will compute accurate predictions.

The term *"Rate Control"* is used in this OP to include all the methods of correcting the initial estimates of Target Speed, Target Angle and Rate of Climb, whether by the Rate Control Computing Mechanism, by direct hand alteration of the Target Motion inputs, or by a combination of the two.

This simplified schematic summarizes Rate Control through the Rate Control Computing Mechanism

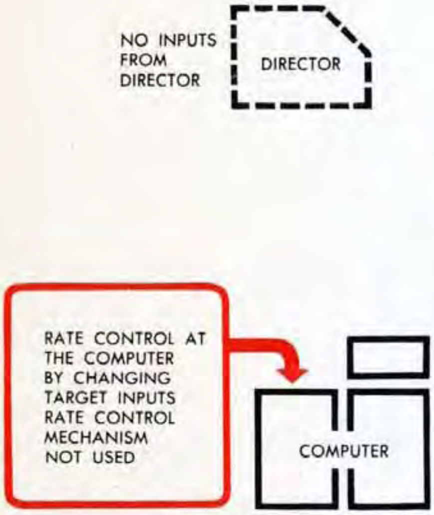


The FOUR MAIN METHODS of RATE CONTROL

Rate Control can be done in four distinct ways, or in combinations of these ways. These four main methods of Rate Control will be described in the order in which they are easiest to understand, beginning with the simplest method. This order is not intended to suggest any operating procedure.

Two methods DO NOT USE the rate control mechanism

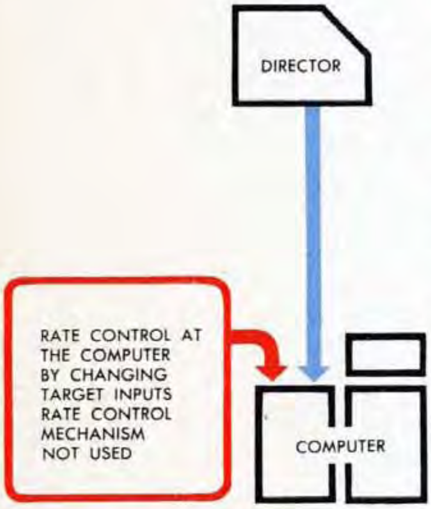
LOCAL CONTROL



FOR SURFACE TARGETS ONLY

LOCAL CONTROL may be thought of as an auxiliary form of Rate Control for surface firing. It consists of estimated hand corrections of Target Speed and Target Angle, based on intermittent reports of the Target's position. No Director inputs are received. The Computer Control Switch is at LOCAL. The Elevation input is hand-set at zero. Generated Range and Generated Bearing position all the Range and Bearing lines. Observed Range and Bearing are obtained and phoned to the plotting room. The Computer Operators compare the readings of the Range and Bearing Dials with the observed values received by phone. When the generated values begin to differ from the observed values, the Computer Operators estimate how much to correct Target Angle and Target Speed. They put these corrections into the Computer by turning the Target Speed and Target Angle Handcranks. They must also change the generated values of Range and Bearing to make them agree with the observed values received by phone.

MANUAL RATE CONTROL

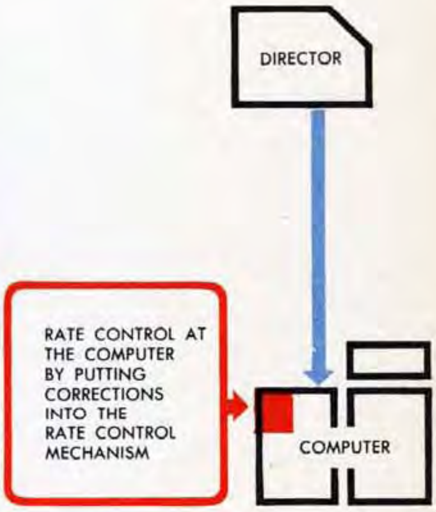


TARGET POSITION VALUES TRANSMITTED FROM DIRECTOR TO COMPUTER

MANUAL RATE CONTROL also consists of direct estimated hand corrections of Target Motion values, but instead of being based on intermittent reports, these corrections are made with the aid of dial movements which represent continuous observation of the Target from the Director. The Computer Control Switch is at SEMI-AUTO. Observed Range, Elevation, and Bearing are received electrically from the Director. Generated values of Range, Elevation, and Bearing come from the Integrator Group in the Computer. By comparing the dials which show Observed Changes, with the dials which show Generated Changes, the Computer Operators estimate how much to correct Target Speed, Target Angle, and Rate of Climb. They put these corrections into the Computer by turning the Target Speed, Target Angle, and Rate of Climb Handcranks. When the dials driven by the Generated Changes turn together with the dials driven by the Observed Changes, the Computer Operators know that the Target Motion inputs are correct.

Two methods USE the rate control mechanism

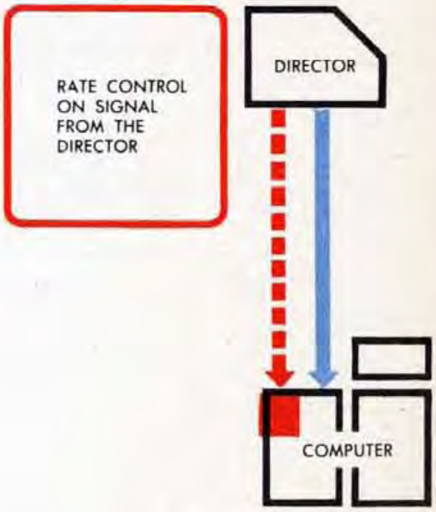
SEMI-AUTO
RATE CONTROL



TARGET POSITION VALUES TRANSMITTED FROM DIRECTOR TO COMPUTER

In SEMI-AUTOMATIC RATE CONTROL, the Rate Control Computing Mechanism does the work which in Manual Rate Control is done mentally by the operators. When the Generated Dials move out of synchronism with the Observed Dials, the Computer Operators put in Rate Corrections through the Generated Range, Generated Elevation and Generated Bearing Cranks. The Rate Control Computing Mechanism takes these Rate Corrections and translates them into corrections to Target Speed, Target Angle, and Rate of Climb. The Rate Control Computing Mechanism does most of the thinking necessary to correct the Target Motion estimates, and usually does it much faster and more accurately than the operators could. To summarize: The operators notice that the Generated Dials are moving either faster or slower than the Observed Dials. They make up this difference in rates of rotation by turning cranks which introduce Rate Corrections into the Rate Control Computing Mechanism. This mechanism then analyzes the three Rate Corrections. It determines what errors in *Sh*, *dH*, and *A* were responsible for the difference in rotation between the Generated and Observed Dials, and corrects these three Target Motion values.

AUTO
RATE CONTROL

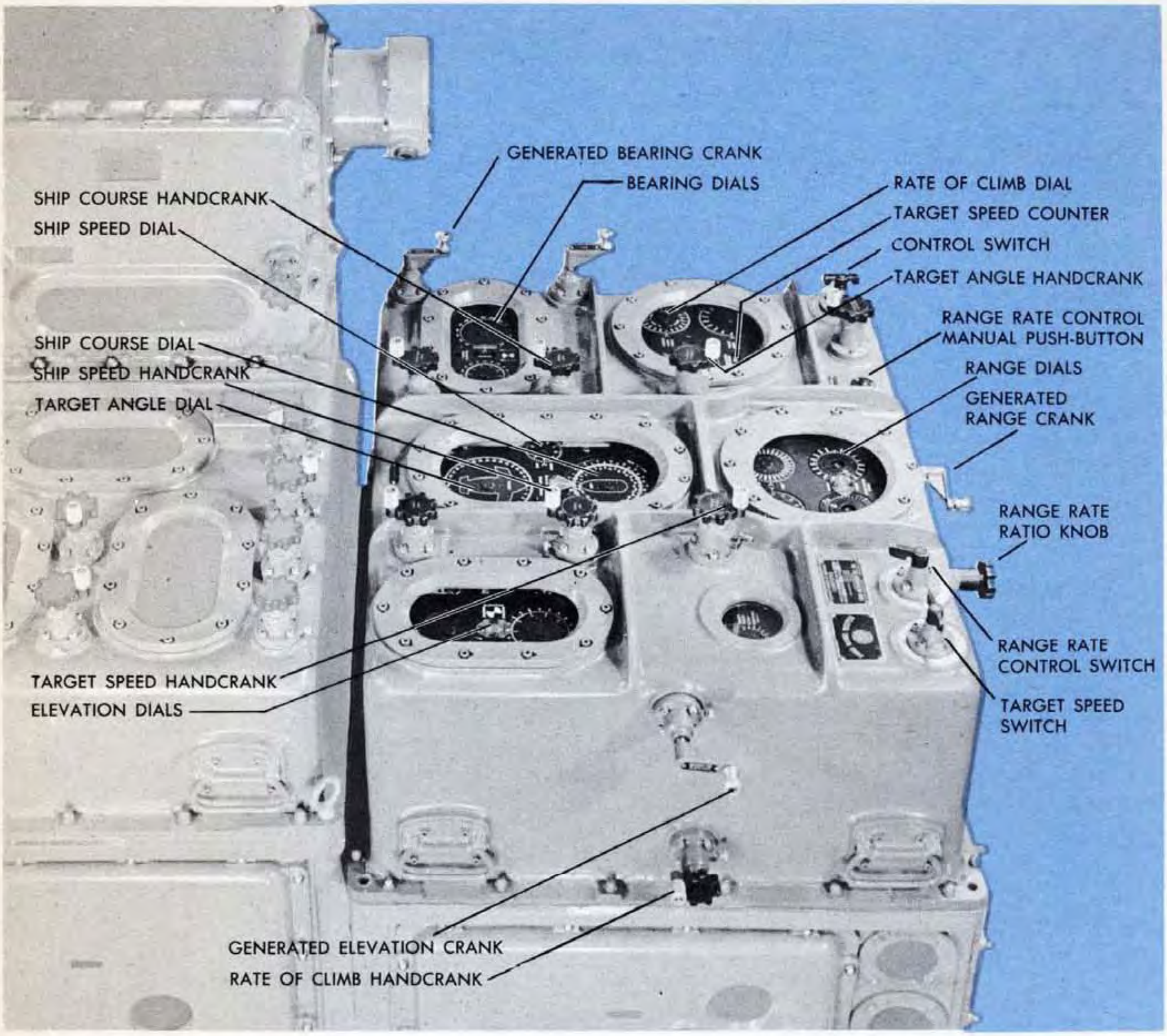


TARGET POSITION VALUES TRANSMITTED FROM DIRECTOR TO COMPUTER

In AUTOMATIC RATE CONTROL, as in Semi-automatic Rate Control, the Rate Control Computing Mechanism is used. But in Automatic, the matching of the Generated Changes with the Observed Changes is controlled from the Director by the Pointer, Trainer, and Range Operator instead of the Computer Crew. In full Automatic Rate Control, the Computer Operators have little to do. They watch the dials as the problem develops and see that everything goes smoothly.

Semi-automatic and Automatic Rate Control may be combined. For example, Elevation and Bearing could be in Automatic Control with Range in Semi-automatic Control.

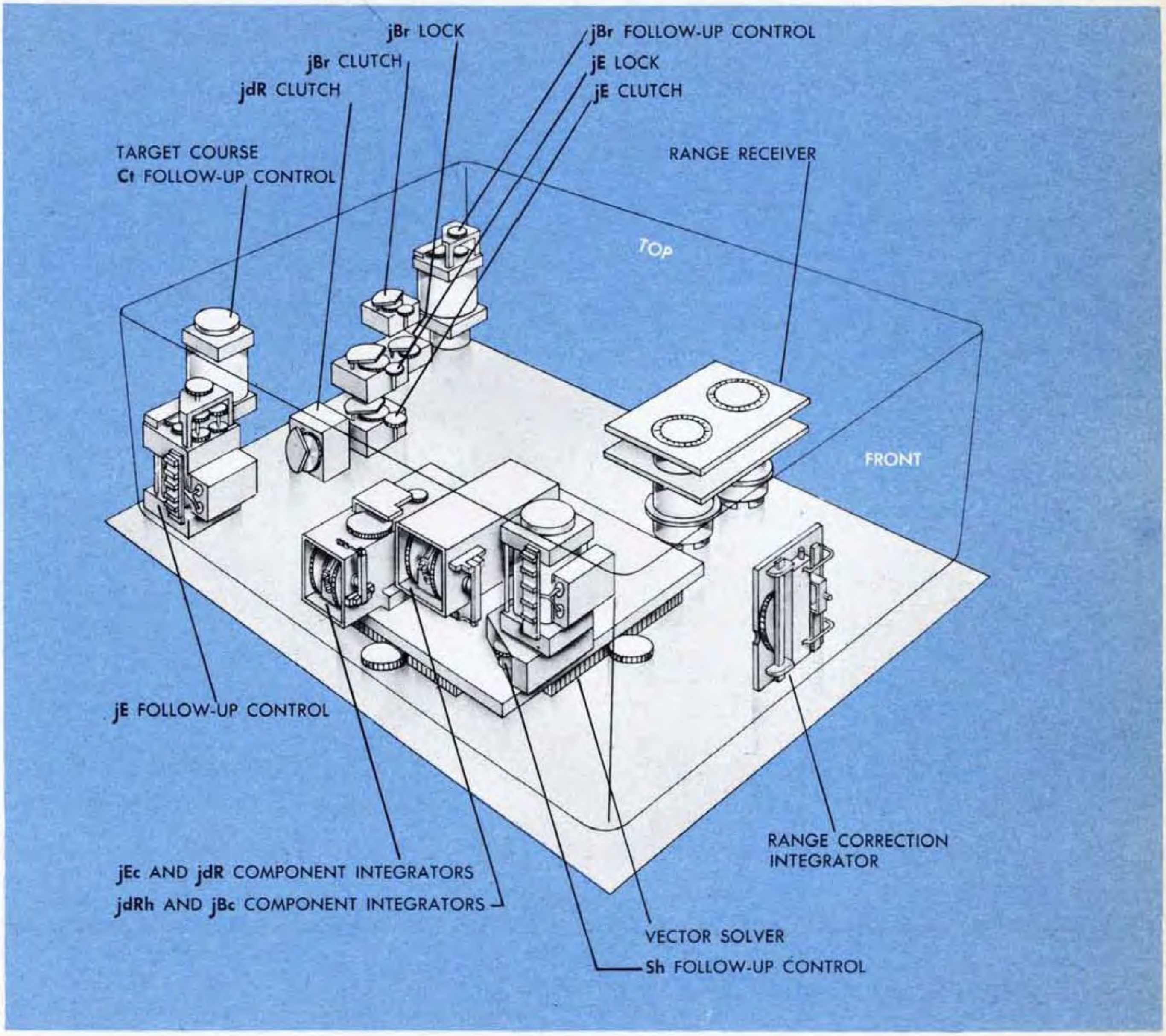
HANDCRANKS and DIALS used in RATE CONTROL



The dials, handcranks, and switches used in the various kinds of Rate Control are all mounted on the top front section of the Computer Mark 1.

In addition to these controls, the Rate Control Group contains the Range Receiver and the Rate Control Computing Mechanism.

The RATE CONTROL COMPUTING MECHANISM



The Rate Control Computing Mechanism is used in Automatic and Semi-automatic Rate Control. It consists mainly of:

- 4 Component Integrators
- 1 Vector Solver
- 1 4-inch Disk Integrator (Range Correction Integrator)
- 5 Follow-up Controls
- 3 Clutches
- 2 Locks

LOCAL CONTROL

Local Control is the direct hand correction of Target Speed and Target Angle on the basis of reports of Range and Relative Target Bearing from some source other than the Director. In most respects it is the simplest type of Rate Control, and for this reason it is described first.

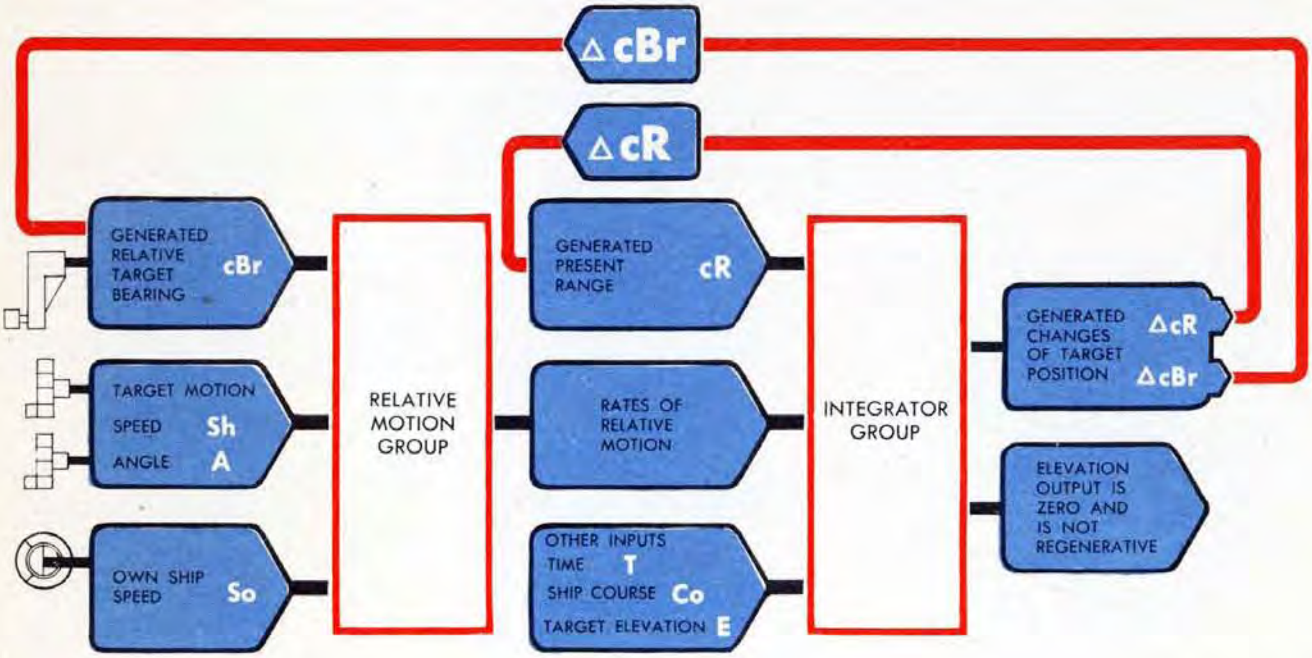
Used for surface targets only

In Local Control there are no Director inputs. Surface targets, which have no Rate of Climb, are the only moving targets for which the Computer Mark 1 is equipped to compute continuous Gun Orders *without the aid of Director inputs.* Operating in Local Control without the Director, the Computer keeps the Range and the Bearing. Generated Range and Generated Bearing continuously position all the Range and Bearing lines and dials. Elevation and Rate of Climb are hand-set at zero. The Elevation and Rate of Climb Dials remain at zero.

Target motion corrections are made by HAND

The values of Range and Relative Target Bearing generated by the Computer are compared by the Computer Crew with values received by phone. When the Generated Changes do not equal the Observed Changes, the inputs of Target Speed, *Sh,* and Target Angle, *A,* are corrected by hand with the *Sh* and *A* Handcranks.

This Schematic shows "Regeneration" in Local Control



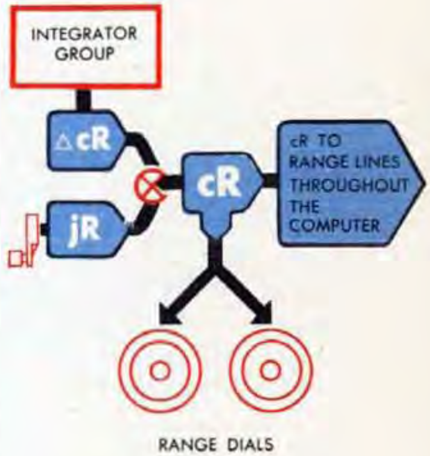
Range

When a Target is sighted, Observed Range, *R*, is phoned down to the Plotting Room and is put into the Computer through the Generated Range Crank in its OUT position. The hand input of Range is called *jR*.

The Generated Range line is then continuously positioned by the Generated Changes of Range, △*cR*, from the Integrator Group, giving a continuous value of Generated Range, *cR*.

Each time a value of Observed Range, *R*, is received by phone, it is compared with the generated value on the Range Dials. If the generated value is wrong, two kinds of corrections are made:

1. With the Generated Range Crank, a correction, *jR*, is put in to match Generated Range, *cR*, to Observed Range, *R*.
2. With the Target Speed and Target Angle Handcranks, corrections are made to *Sh* and *A*. These corrections go to the Relative Motion Group, where the Range Rate, *dR*, is corrected. The corrected *dR* is then used in generating Changes of Range, △*cR*, at a corrected rate. When *Sh* and *A* are correct, △*cR* will keep Generated Range, *cR*, equal to Observed Range, *R*.

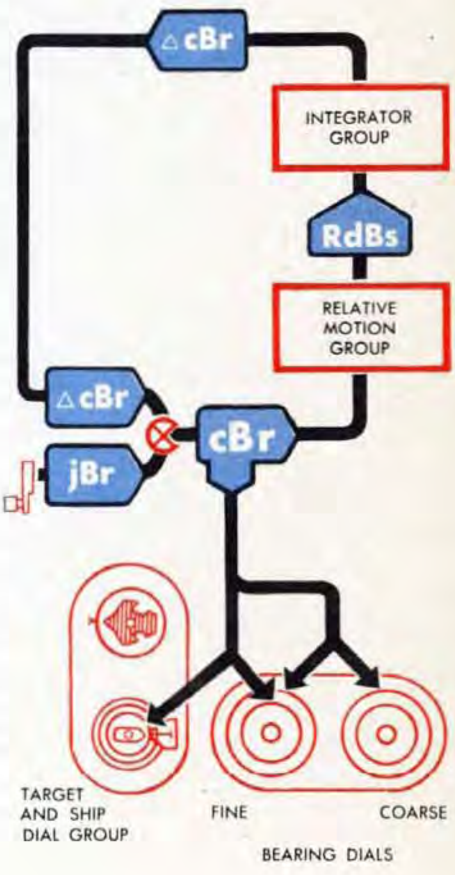


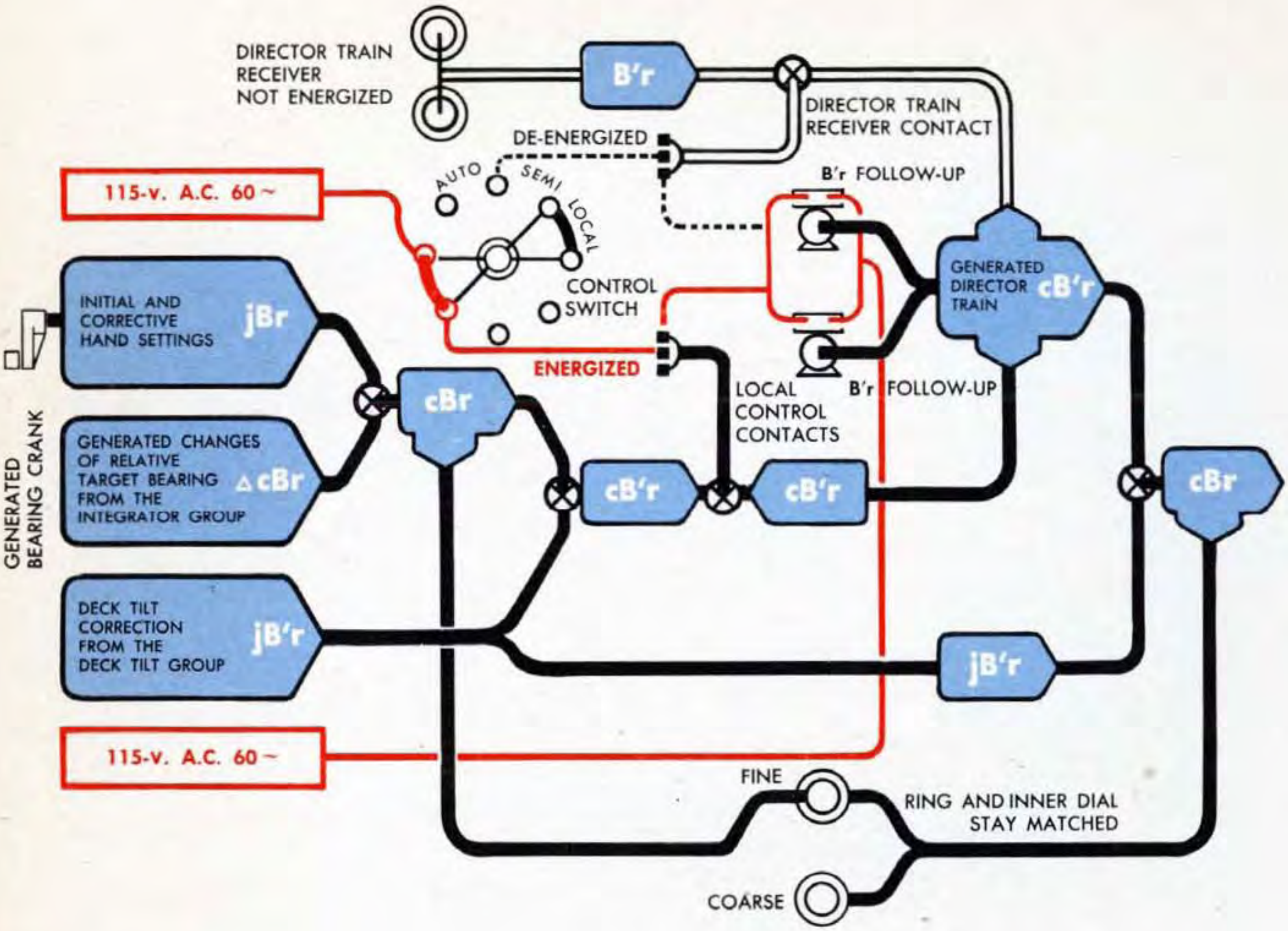
Bearing

Relative Target Bearing, *Br*, is phoned down from the observation station on deck and put into the Computer through the Generated Bearing Crank. After the initial Observed Bearing input, corrections to Generated Bearing called *jBr* are put into the Computer through the same Generated Bearing Crank. In the Computer, *jBr* is added to the Generated Changes of Relative Target Bearing, △*cBr*, from the Integrator Group, giving corrected Generated Bearing, *cBr*. Generated Bearing, *cBr*, positions all the Bearing Dials.

Each time a value of Observed Relative Bearing is phoned down, it is compared with the *generated* value on the Bearing Dials. If the generated value is wrong, the Computer Crew makes two kinds of corrections:

1. With the Generated Bearing Crank, a correction, *jBr*, is set in to make the reading on the Bearing Dials equal to the observed value of *Br*.
2. Corrections to *Sh* and *A* are put in with the Target Speed and Target Angle Handcranks. The corrected values of *Sh* and *A* in the Relative Motion Group then correct the Bearing Rate, *RdBs*, used in Generated Changes of Bearing, △*cBr*. When *Sh* and *A* are correct, the Generated Changes of Bearing, △*cBr*, will keep Generated Bearing equal to Observed Bearing.





This is a combined wiring diagram and schematic, showing the flow of quantities and the electrical circuits energized on the Bearing line *when the Control Switch is at LOCAL.*

This drawing also shows how, in Local Control, the Generated Bearing Crank and the Changes of Generated Relative Target Bearing from the Integrator Group position the Observed Relative Target Bearing line.

The *B'r* line is always positioned by two servo motors. In Local Control, both servos are controlled by the Local Control Contacts.

SOLVING A TRACKING PROBLEM IN LOCAL CONTROL

Here is a simple tracking problem which illustrates the general principles of Rate Control:

Assume that Own Ship is motionless.
The Control Switch is set at LOCAL.

The following information is phoned to the Computer Operators:

A Target has been observed at 9000 yards Range, moving away from Own Ship.

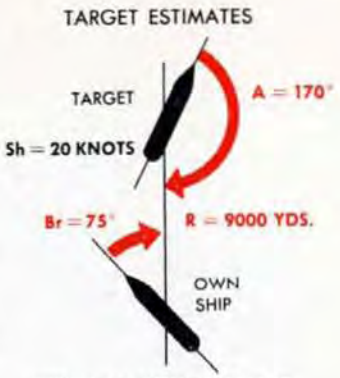
Observed Relative Target Bearing, *Br*, is 75 degrees.

Target Angle, *A*, is estimated at 170 degrees.

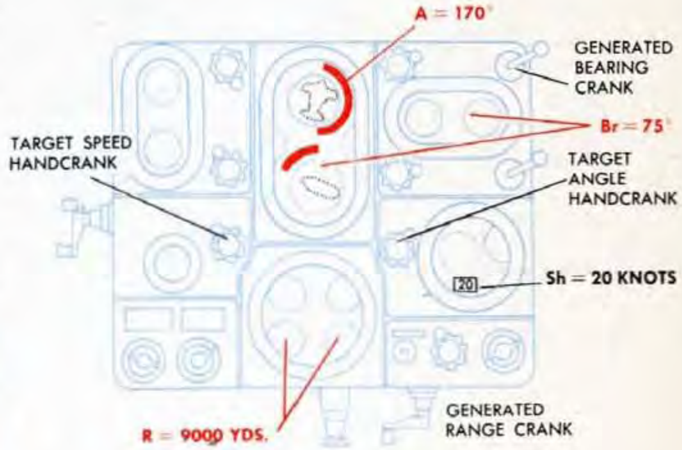
Target Speed, *Sh*, is estimated at 20 knots.

These values are set into the Computer by turning the Generated Range and Bearing Cranks, and the Target Speed and Target Angle Handcranks.

The Time Switch is turned ON and the Computer begins to generate Range and Bearing.



INITIAL OBSERVED RANGE AND BEARING



Comparing generated with observed range and bearing

About one minute after the initial inputs to the Computer are made, values of *R* and *Br* are received by the Computer Operators:

Observed Present Range, *R* = 10,000 yards

Relative Target Bearing, *Br* = 75 degrees.

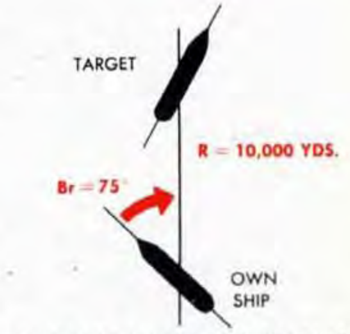
A quick reading of Range and Bearing generated by the Computer shows that:

Generated Present Range, *cR* = 9725 yards

Generated Relative Target Bearing, *cBr* = 75°40′.

A comparison of the observed and generated values shows that during the elapsed time of one minute, *cR* increased 275 yards less than *R*, and *cBr* increased 40 minutes more than *Br*.

Since *cR* became less than *R* but *cBr* became greater than *Br*, the comparison suggests that Range Rate must be increased and Bearing Rate decreased.



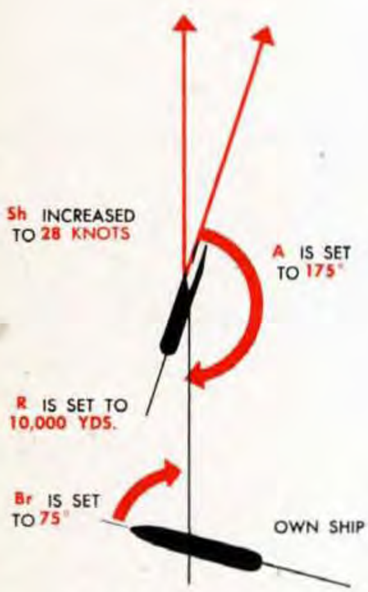
OBSERVED RANGE AND BEARING AFTER ONE MINUTE

GENERATED RANGE AND BEARING AFTER ONE MINUTE

Determining which quantities to correct

The direction of the Target Motion with respect to the Line of Sight makes it evident that any increase in Target Speed will cause an increase in Range Rate. This increase in Target Speed will also cause an increase in Bearing Rate, which is not desired in this case. The Bearing Rate can be decreased by increasing Target Angle.

The Computer Operators decide to increase Target Speed and Target Angle, but the sizes of these corrections must still be determined.



CORRECTED SETUP

Determining the size of the corrections

Comparison of Observed and Generated Range and Observed and Generated Bearing indicates that the Range Rate is more in error than the Bearing Rate.

The estimated direction of Target Motion relative to the Line of Sight is such that a change in Target Speed will cause an approximately corresponding change in Range Rate and will affect Bearing Rate only slightly.

The difference between observed and generated values of Range was 275 yards in 1 minute. Since one knot of Range Rate causes a Range change of 33.78 yards per minute, the Computer Operators decide to increase Target Speed by 8 knots. To compensate for the increase that this *Sh* change will cause in the Bearing Rate, Target Angle is increased to 175 degrees.

The Operators reset the Computer to the *observed* values:

Observed Present Range, *R,* to 10,000 yards
Relative Target Bearing, *Br,* to 75 degrees

They also correct the Target Motion estimates:

Target Speed, *Sh,* is changed to 28 knots
Target Angle, *A,* is changed to 175 degrees

NOTE:
Because the dials were read while in motion, the values will not necessarily agree with precise computations.

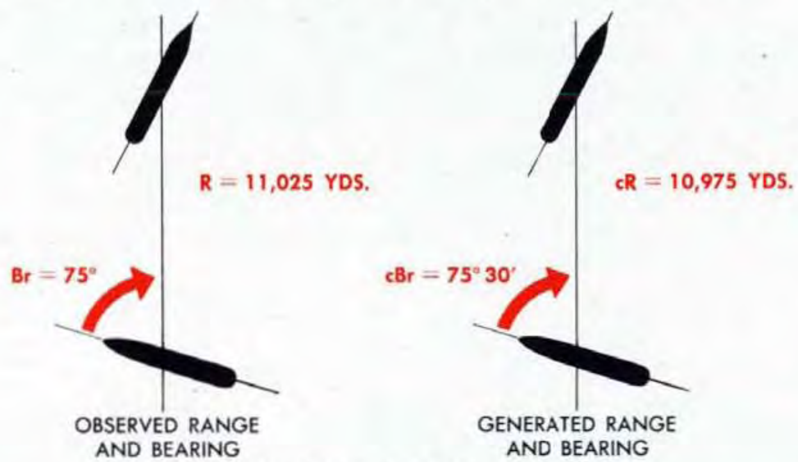
Completing the problem

At the end of the second minute, the Computer Operators receive these *observed* values:

Observed Present Range, $R = 11{,}025$ yards
Relative Target Bearing, $Br = 75$ degrees

The Computer readings are now:

Generated Present Range, $cR = 10{,}975$ yards
Generated Relative Target Bearing, $cBr = 75^\circ 30'$



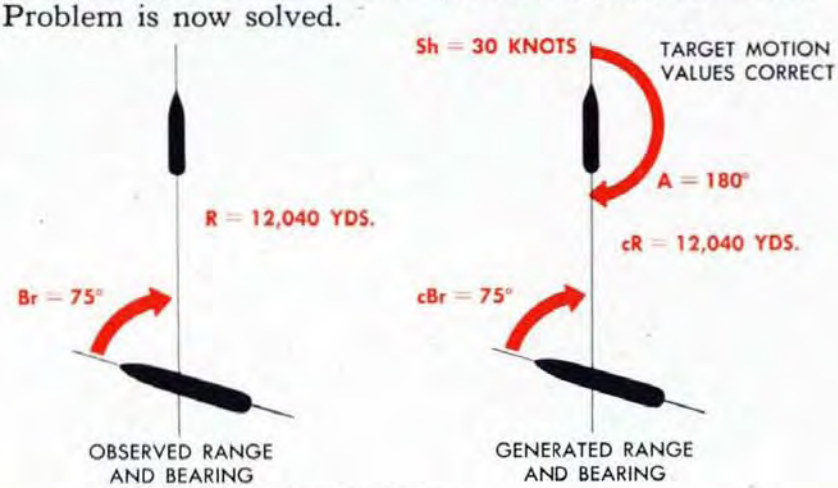
AFTER TWO MINUTES

A comparison of the Observed and Generated Range and Bearing values now shows that there is very little error.

Using the same reasoning as for the first set of corrections, these further corrections are made:

Target Speed is changed to 30 knots
Target Angle is changed to 180 degrees

After these corrections are made, and the Computer is reset to the observed values, the Computer generates a value of Genrated Present Range, cR, which is equal to Observed Present Range, R, and a value of Generated Relative Target Bearing, cBr, which is equal to Relative Target Bearing, Br. The Tracking Problem is now solved.



PROBLEM SOLVED

MANUAL CONTROL OF RATES

In Manual Control of rates, corrections to Target Speed and Target Angle and Rate of Climb are estimated by the Computer Crew with the aid of continuous Director observations of Target Position.

The Observed Changes of Target Position in relation to Own Ship in Range, Elevation, and Bearing are continuously sent from the Director to the Computer by synchro transmission. Observed Changes of Target Position show up on the Computer as rotation of three sets of dials: the outer Elevation Dials, the outer Bearing Dials, and the inner Range Dials. These are the *Observed Dials.*

Generated Changes of Target Position from the Integrator Group in the Computer turn the inner Elevation and Bearing Dials, and the outer Range Dials. These dials are the *Generated Dials.*

The Computer Crew watch the Observed and Generated Dials. They correct the values of *Sh, dH,* and *A* by hand at the *Sh, dH,* and *A* Handcranks until the Generated Dials turn in synchronism with the Observed Dials.

Manual rate control for surface and air targets

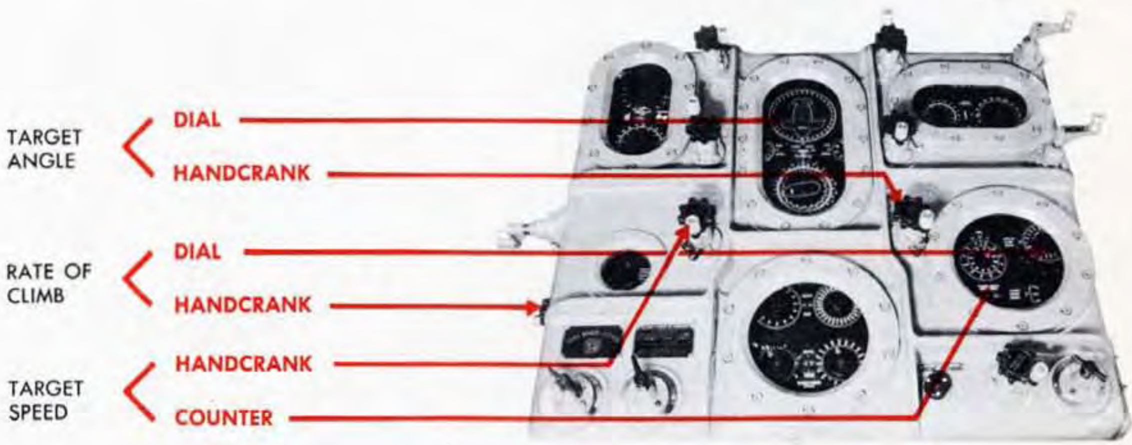
The Rate Control Computing Mechanism used in Automatic and Semi-automatic Rate Control is not designed to compute corrections to the Target Motion inputs when Target Speed is less than about 70 knots. For this reason, Local Control and Manual Rate Control are the only types of Rate Control which can be used against most surface targets.

Since Observed Elevation is continuously received in Manual Rate Control, Manual Rate Control may also be used against air targets. However, the short duration of air problems and the complexities of target movement in three dimensions make Manual Rate Control against air targets difficult. Manual Rate Control against air targets may be regarded as an auxiliary type of operation, while Manual Rate Control against surface targets is a normal type of operation.

Correcting the target motion quantities

To allow the Target Motion values to be corrected through the *Sh, dH,* and *A* Handcranks in Manual Rate Control, the Control Switch must be at SEMI-AUTO, and the Range Rate Control Switch at MANUAL. The circuits affected by these switches are described on pages 258-261. The levers on the Target Speed and Target Angle Handcranks must be in HAND position and the Rate of Climb Handcrank in its IN position, because these are the positions in which the handcranks are connected to the *Sh, dH,* and *A* shaft line.

Corrections are made to one or more of the Target Motion values, *Sh, dH,* and *A,* whenever any of the Generated Dials does not turn in synchronism with its corresponding Observed Dial.



The Computer Operators put in corrections to the Target Motion values until the corrected Relative Motion Rates cause the *generated* values of Range, Elevation, and Bearing to change at the same rates as the *observed* values of Range, Elevation, and Bearing are changing. Range dials must be matched.

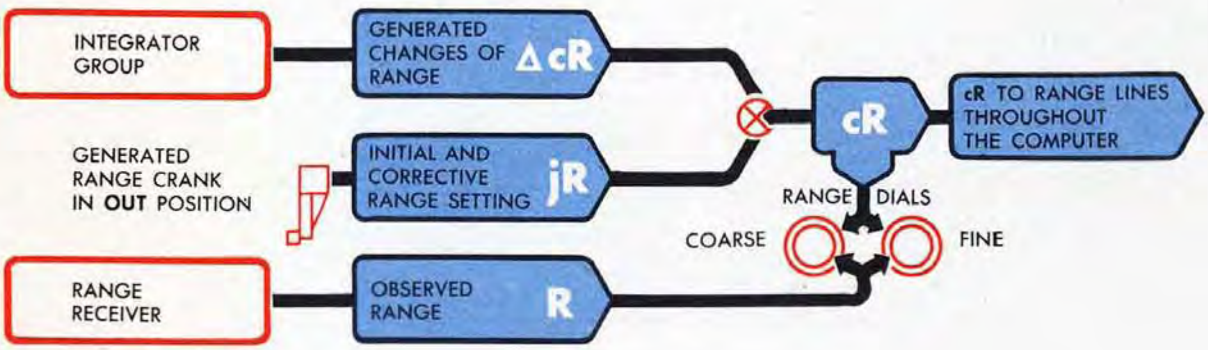
Information that will help the Operators determine which of the Target Motion quantities should be corrected is contained in the chapter on Operating Instructions, page 128.

How the dials receive observed and generated values

Range

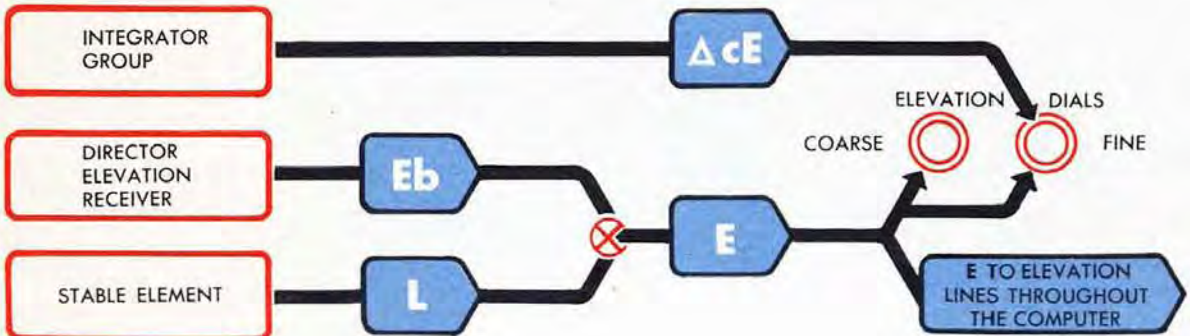
Observed Range is transmitted from the Director to the Range Receiver in the Computer. Observed Range positions the fine and coarse inner Range Dials. Generated Range, *cR,* positions all the other Range lines in the Computer, and the fine and and coarse outer Range Dials.

The reasons why *cR,* rather than *R,* is used to position the Range lines throughout the Computer have been mentioned in the General Description, page 54, and are explained in more detail on page 76.



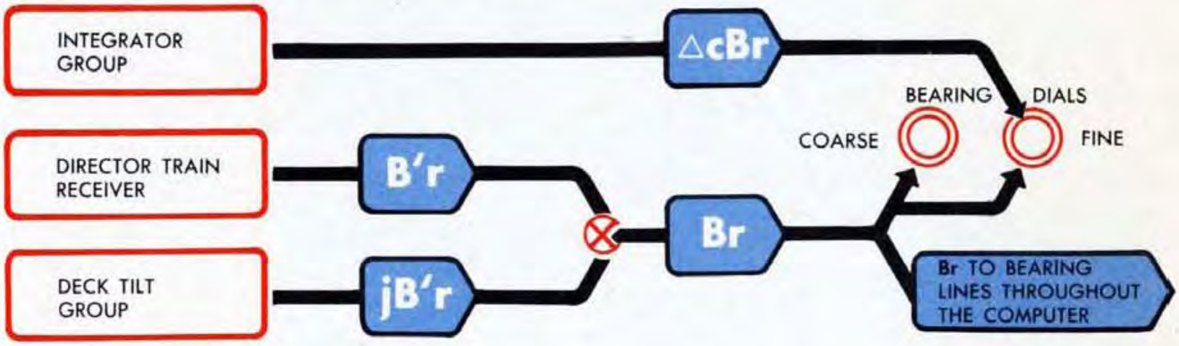
Elevation

Director Elevation, *Eb,* is continuously received by the Director Elevation Receiver. Level, *L,* is subtracted from *Eb* to obtain Target Elevation, *E,* which positions the fine and coarse Observed Elevation Dials. Generated Changes of Target Elevation, △*cE,* from the Integrator Group, turn the Generated Elevation Dial.

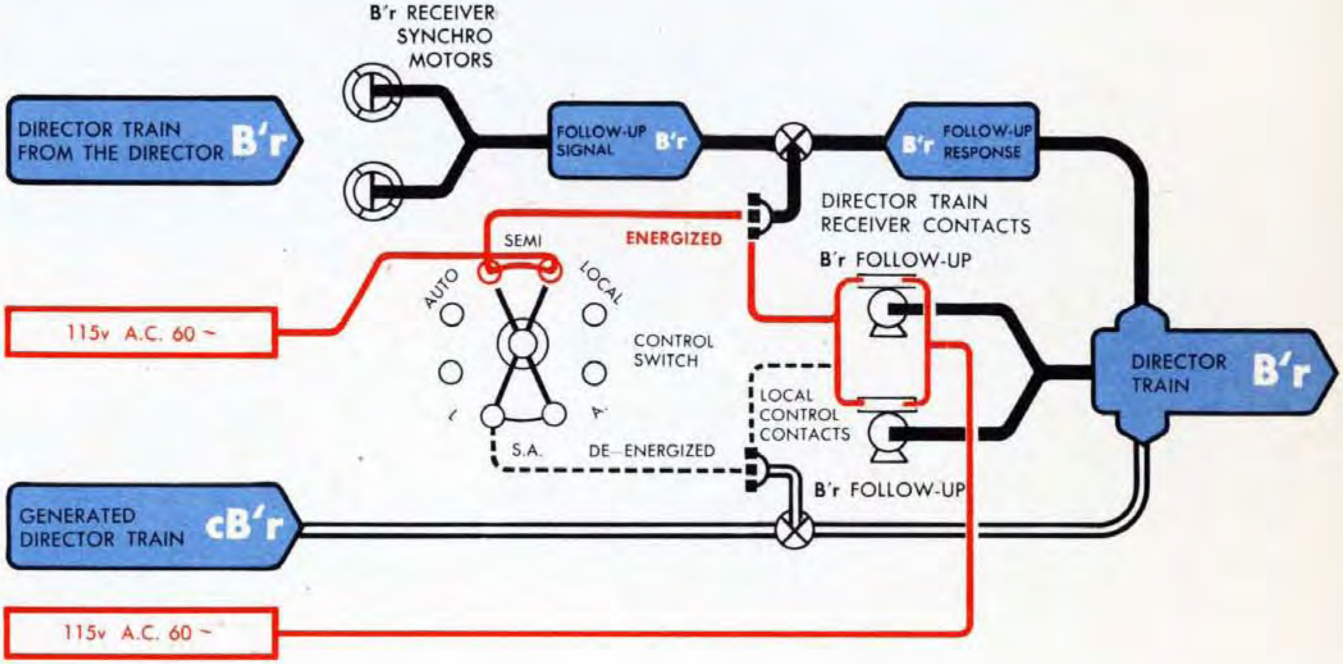


Bearing

In Manual Rate Control the Director transmits an input of Director Train, *B′r*, to the *B′r* Receiver in the Computer. Deck Tilt Correction, *jB′r*, is added to *B′r* to obtain Observed Relative Target Bearing, *Br*. *Br* positions all the Bearing lines in the Computer and the outer Bearing Dials, fine and coarse. Generated Changes of Relative Target Bearing, △*cBr*, from the Integrator Group, position the inner Bearing Dial. Generated Bearing does not regenerate in Manual Rate Control.



The diagram below shows the electric circuits energized in the Bearing network when the Control Switch is at SEMI-AUTO. Both *B′r* Servo Motors are now energized by the Director Train Receiver contacts. The contacts which were energized when the Control Switch was at LOCAL are now de-energized.



SEMI-AUTOMATIC RATE CONTROL

In Semi-automatic Rate Control, the Rate Control Computing Mechanism computes the necessary corrections to Target Speed, Target Angle, and Rate of Climb. Whenever the Computer Operators see that one or more of the Generated Dials are turning faster or slower than the corresponding Observed Dials, they put Rate Corrections into the Rate Control Computing Mechanism with the Generated Range, Generated Elevation, and Generated Bearing Cranks. These Rate Corrections are automatically converted into corrections to Target Motion values by the Rate Control Computing Mechanism.

The operators do not have to figure out what corrections to Sh, dH, and A are needed. They turn the Generated Cranks, thereby putting Rate Corrections into the Rate Control Computing Mechanism. The Rate Control Computing Mechanism automatically resolves these Rate Corrections into corrections to Sh, dH, and A.

If the Generated Range Dials begin to turn faster or slower than the Observed Range Dials, the Range Operator turns the Generated Range Crank to match the Range Dials, while depressing the Manual Range Push-button. By so doing, he also puts a Range Rate Correction, *jdR,* into the Rate Control Computing Mechanism.

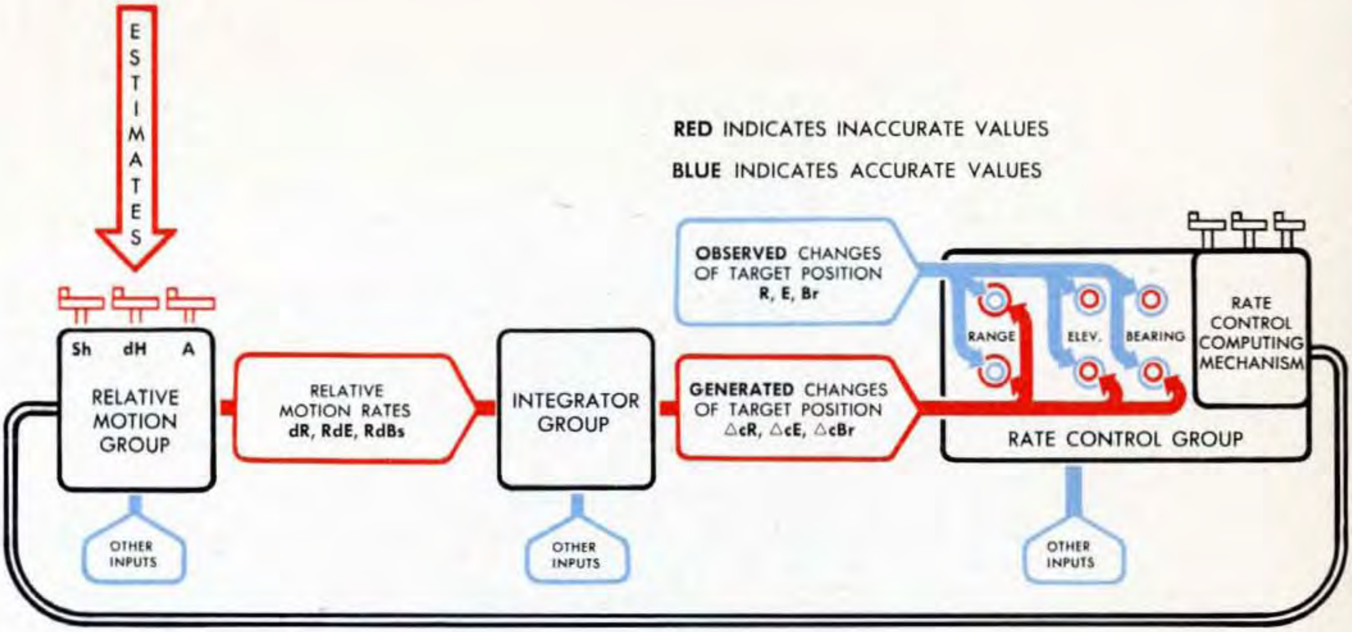
If the Generated Elevation Dial begins to turn faster or slower than the fine Observed Elevation Dial, the Elevation Operator uses the Generated Elevation Crank to put enough Elevation Rate Correction, *jEc,* into the Rate Control Computing Mechanism to make the Elevation Dials turn together.

In the same way, the Bearing Operator puts a Bearing Rate Correction, *jBc,* into the Rate Control Computing Mechanism to make the Bearing Dials turn together.

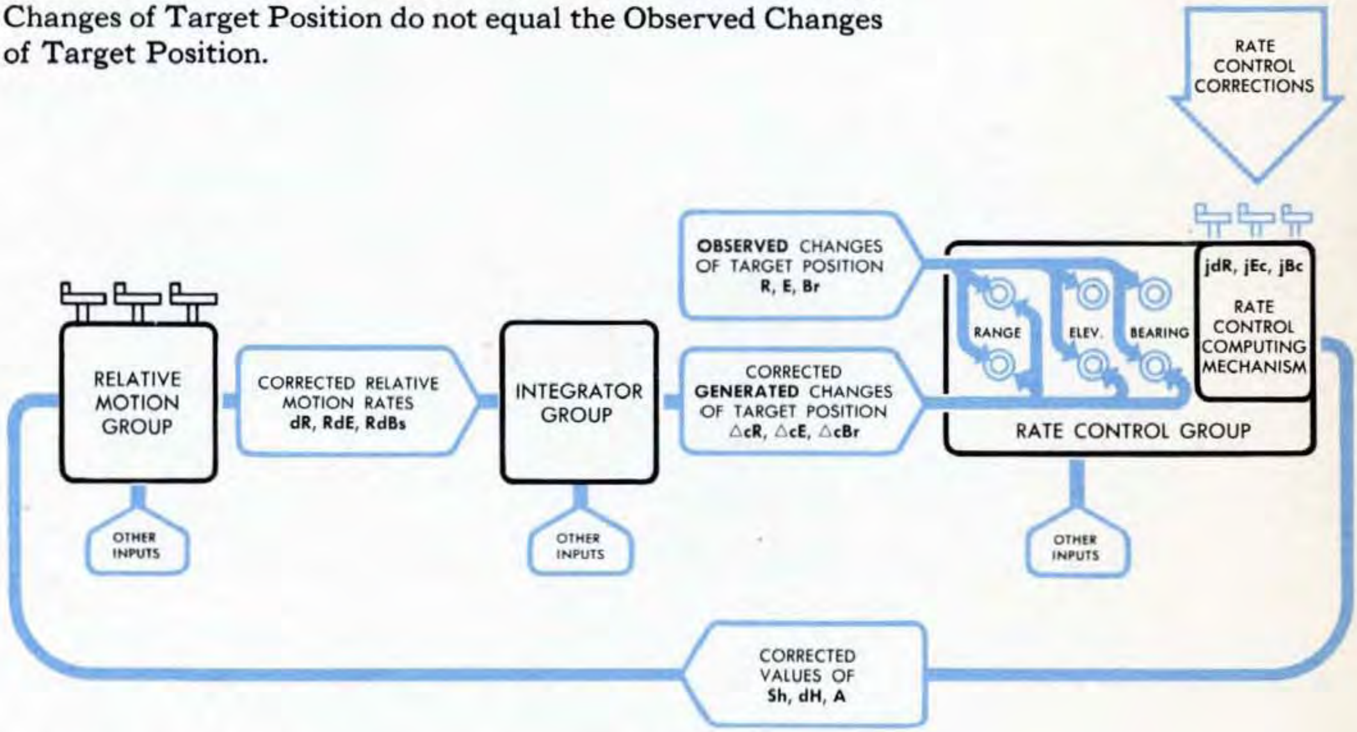
The Rate Control Computing Mechanism uses the three Rate Corrections, *jdR, jEc,* and *jBc* to compute a correction to *dH* and corrected values of *Sh* and *A*. These values are then transmitted mechanically to the Relative Motion Group.

The corrected values of *Sh, dH* and *A* cause the Relative Motion Group to compute corrected Relative Motion Rates. The corrected rates go to the Integrator Group and cause the changes of Range, Elevation, and Bearing to be generated at corrected rates.

After one or more sets of Rate Corrections have been put into the Rate Control Computing Mechanism, the Generated Dials will turn in synchronism with the Observed Dials, indicating that the Target Motion values and the Relative Motion Rates are correct. This is called a "solution."



This schematic shows the groups of quantities at the beginning of a fire control problem. The values of *Sh, dH* and *A*, are human estimates and therefore contain some error. The Generated Changes of Target Position do not equal the Observed Changes of Target Position.



This schematic shows the groups of quantities after the Operators have put Rate Corrections into the Rate Control Computing Mechanism. These corrections have been automatically converted into corrections to *Sh, dH*, and *A*. The corrected Target values have corrected the Relative Motion Rates which are now being used to generate changes of Range, Elevation and Bearing which keep the Generated Dials in synchronism with the Observed Dials.

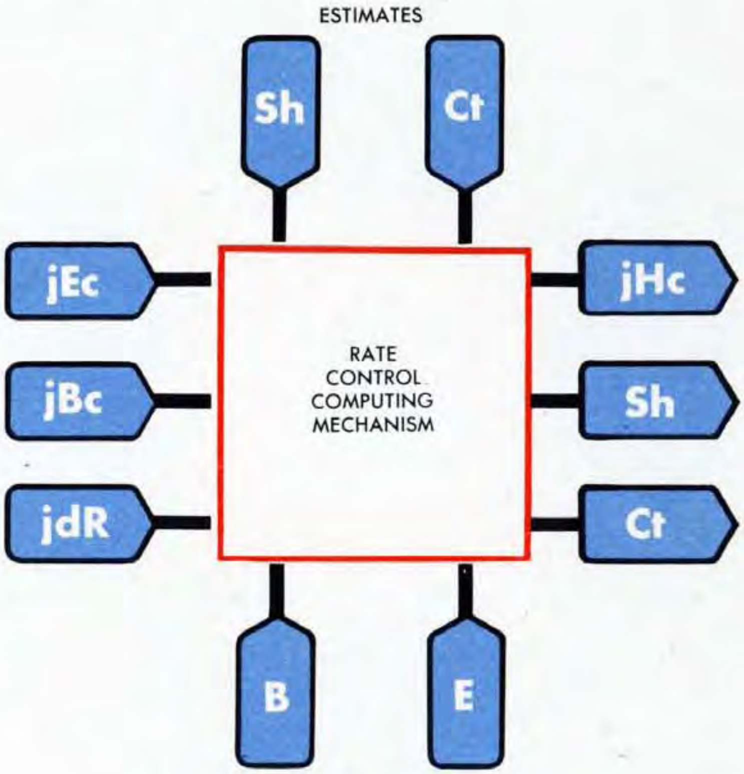
The RATE CONTROL COMPUTING MECHANISM

The Rate Control Computing Mechanism consists of these units:

Four component integrators, grouped in pairs
One vector solver
One four-inch disk integrator
Five follow-ups
Two solenoid locks and three solenoid clutches
Several differentials

There are seven *inputs* to the Rate Control Computing Mechanism:

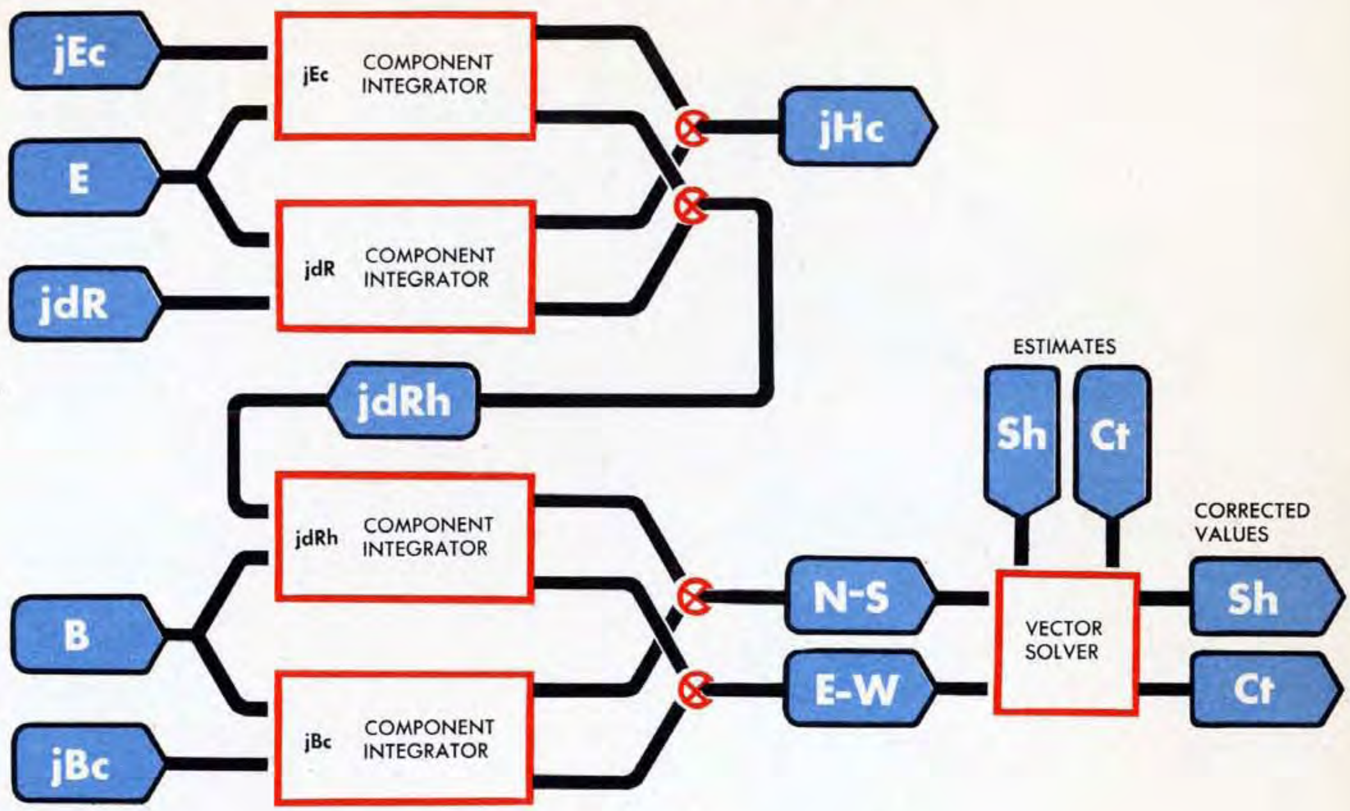
1. Linear Elevation Rate Correction, *jEc*
2. Linear Deflection Rate Correction, *jBc*
3. Direct Range Rate Correction, *jdR*
4. True Target Bearing, *B*
5. Observed Target Elevation, *E*
6. Horizontal Target Speed (estimated), *Sh*
7. Target Course (estimated), *Ct*



The *outputs* from the Rate Control Computing Mechanism are:

1. A Rate of Climb Correction, *jHc*, which is a correction to Rate of Climb, *dH*
2. A corrected value of Horizontal Target Speed, *Sh*
3. A corrected value of Target Course, *Ct*

How Sh, dH, and Ct are corrected



The three rate corrections, *jEc*, *jBc*, and *jdR* are used as inputs to three of the component integrators. Each component integrator has two outputs. These outputs are components of the inputs, at right angles to each other.

The outputs from the *jEc* and *jdR* Component Integrators are grouped to form two new values:

Rate of Climb Correction, *jHc*
Horizontal Range Rate Correction, *jdRh*

jHc is the required correction to Rate of Climb, *dH*.

jdRh becomes the input to the fourth component integrator.

The outputs of the *jdRh* and *jBc* Component Integrators are combined to obtain two values:

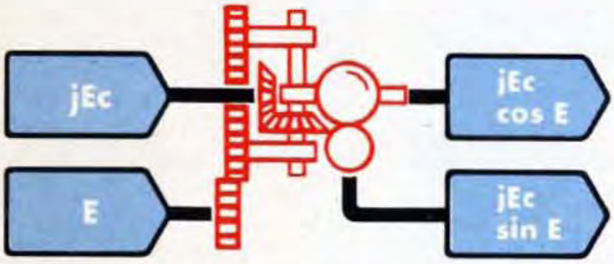
A North-South Correction to the Horizontal Target Speed Vector

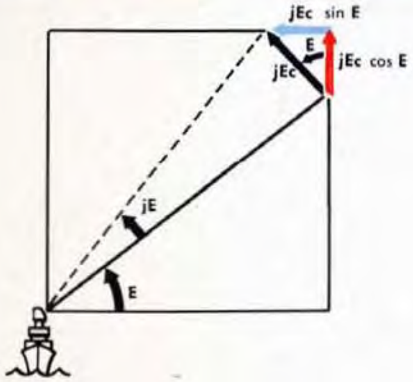
An East-West Correction to the Horizontal Target Speed Vector

The Vector Solver is initially positioned by the estimated values of Horizontal Target Speed, *Sh*, and Target Course, *Ct*. The *N-S* and *E-W* Speed Corrections reposition the Vector Solver racks. Moving these racks corrects the previous Vector Solver values of *Sh* and *Ct*. The outputs of the Vector Solver are the *corrected* values of *Sh* and *Ct*.

The ELEVATION COMPONENT INTEGRATORS

The four component integrators work in pairs. The first pair of component integrators of the Rate Control Computing Mechanisms consists of the *jEc* and the *jdR* Component Integrators. They work together to produce horizontal and vertical rate corrections.





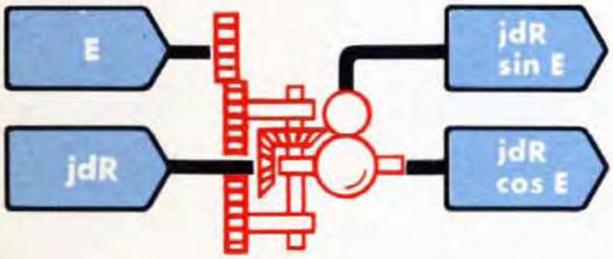
The jEc component integrator

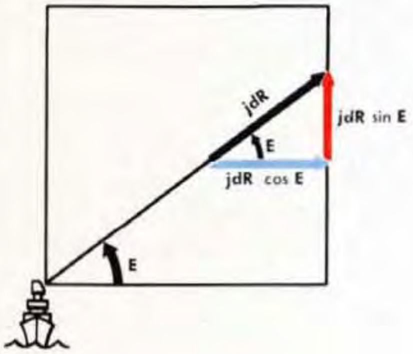
Elevation Rate Correction, *jEc*, is one input to the *jEc* Integrator. *jEc* turns the input roller. Target Elevation, *E*, is the other input. *E* positions the angular input gear.

The *jEc* Component Integrator breaks *jEc* into vertical and horizontal components:

1 The vertical component is *jEc* cos *E*.

2 The horizontal component is *jEc* sin *E*.





The jdR component integrator

Direct Range Rate Correction, *jdR*, turns the input roller of the *jdR* Component Integrator. Target Elevation, *E*, positions the angular input gear.

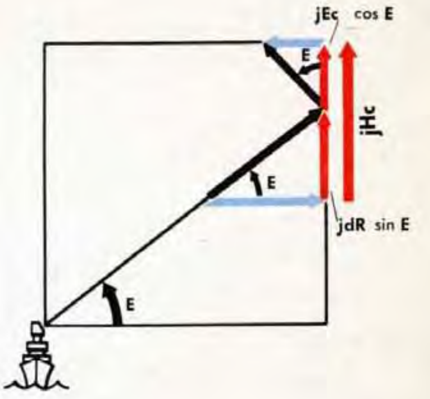
The *jdR* Component Integrator breaks *jdR* into vertical and horizontal components:

1 The vertical component is *jdR* sin *E*.

2 The horizontal component is *jdR* cos *E*.

The components of jEc and jdR are combined

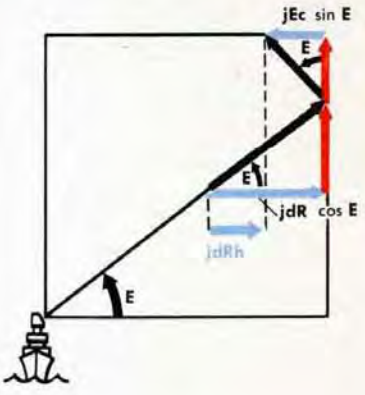
The *jEc* and *jdR* Component Integrators each produce one vertical and one horizontal component.



The two vertical components, one from each component integrator, are combined, giving *jHc*. Here the two vertical components are added because they are in the same direction.

$$jEc \cos E + jdR \sin E = jHc$$

jHc is a vertical correction, called the Rate of Climb Correction. jHc corrects dH by repositioning the dH lines.

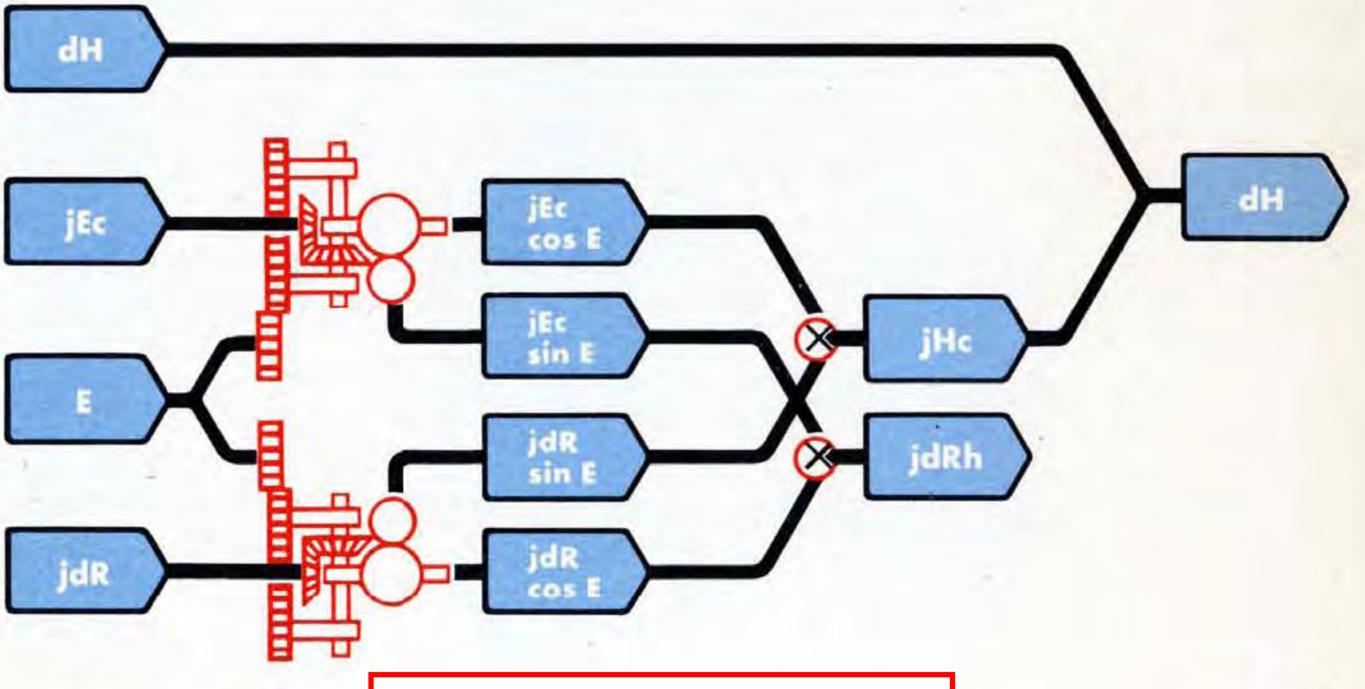


The two horizontal components, one from each component integrator, are combined, giving *jdRh*. In this example, one component is subtracted from the other because they are in opposite directions.

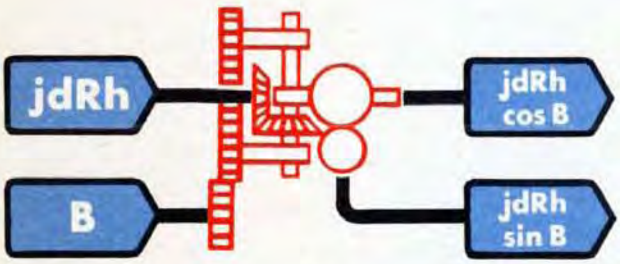
$$jdR \cos E - jEc \sin E = jdRh$$

jdRh is a horizontal correction in the plane containing the Line of Sight. It is not a correction to a Target value, but is used as an input to the jdRh Component Integrator. jdRh is called the Horizontal Range Rate Correction.

Remember that the job of the Rate Control Computing Mechanisms is to produce corrections to *Sh, dH,* and *Ct*. The first of these three corrections, *jHc*, is computed by the first pair of component integrators and is used to correct Rate of Climb, *dH*.

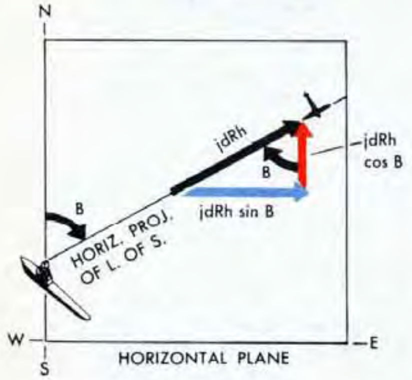


The BEARING COMPONENT INTEGRATORS



So far two corrections have been computed: the correction to *dH*, called *jHc*, and the Horizontal Range Rate Correction, *jdRh*.

A second pair of component integrators uses *jdRh* and the Deflection Rate Correction, *jBc*, to compute rate corrections along a North-South and East-West axis. These *N-S* and *E-W* Corrections are needed by the Vector Solver to compute corrections to Target Speed, *Sh*, and Target Course, *Ct*.



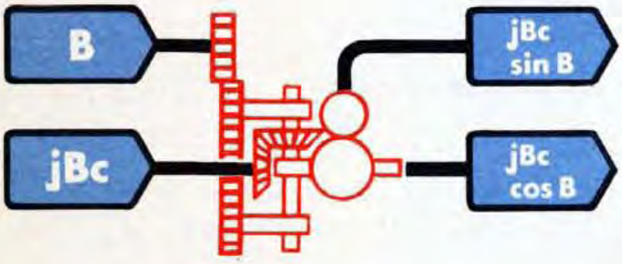
The jdRh component integrator

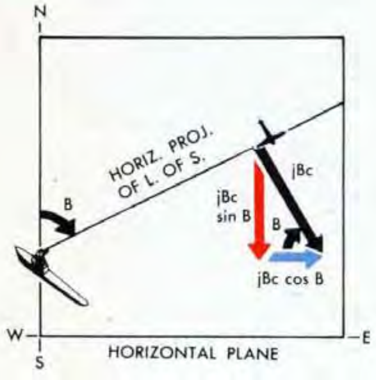
Direct Range Rate Correction, *jdRh*, and True Target Bearing, *B*, are the inputs to the *jdRh* Component Integrator. *B* is the angle between North and the horizontal projection of the Line of Sight measured in the horizontal plane. *jdRh* drives the input roller and *B* positions the angle input gear.

The outputs are two components at right angles to each other:

1 Along the *E-W* axis, *jdRh* sin *B*.

2 Along the *N-S* axis, *jdRh* cos *B*.





The jBc component integrator

Deflection Rate Correction, *jBc*, and True Target Bearing, *B*, are the inputs to the *jBc* Component Integrator. *jBc* drives the input roller and *B* positions the angle gear.

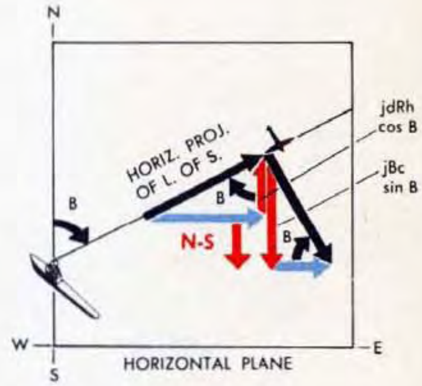
The outputs are two components at right angles to each other:

1 Along the *E-W* axis, *jBc* cos *B*.

2 Along the *N-S* axis, *jBc* sin *B*.

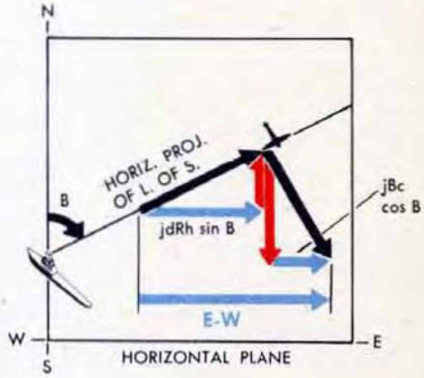
The components of jdRh and jBc are combined

The *jdRh* and *jBc* Integrators each produce one *N-S* and one *E-W* component.



The two *N-S* components, one from each component integrator, are combined to obtain the total *N-S* correction. Since they are in opposite directions in this example one component is subtracted from the other.

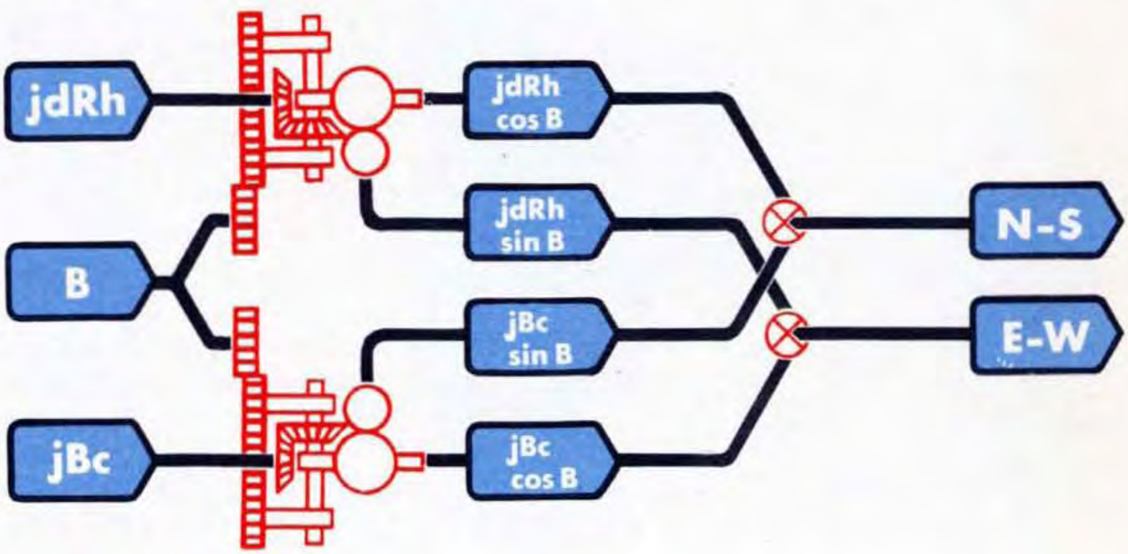
$$jBc \sin B - jdRh \cos B = \text{total } N\text{-}S \text{ correction.}$$



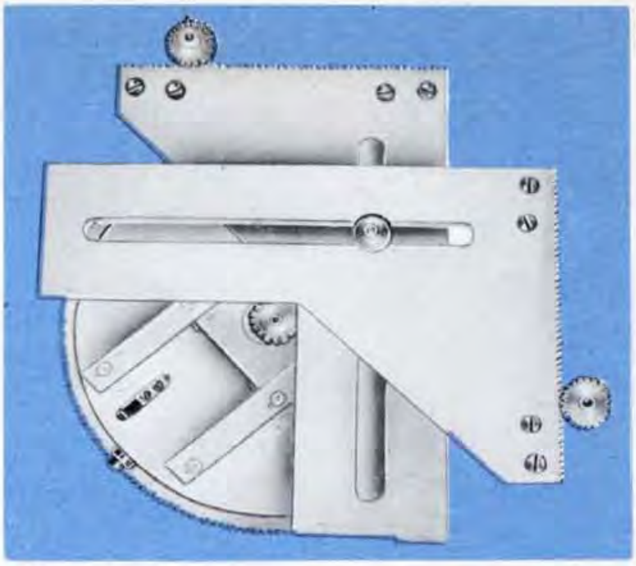
The two *E-W* components, one from each component integrator, are combined to obtain the total *E-W* correction. Since they are in the same direction in this example, the components are added.

$$jBc \cos B + jdRh \sin B = \text{total } E\text{-}W \text{ correction.}$$

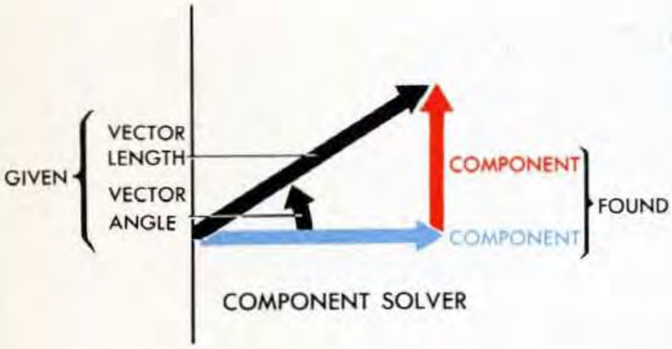
These *N-S* and *E-W* corrections are sent to the Vector Solver, where they correct the estimated values of Horizontal Target Speed, *Sh*, and Target Course, *Ct*.



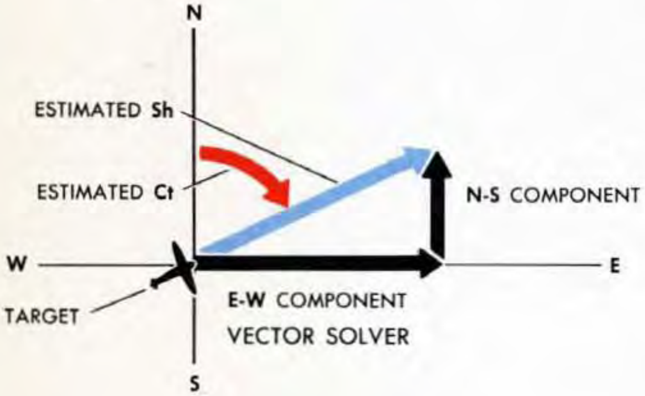
The VECTOR SOLVER



The Vector Solver is a component solver which can also work in reverse. For details, see OP 1140, page 106.

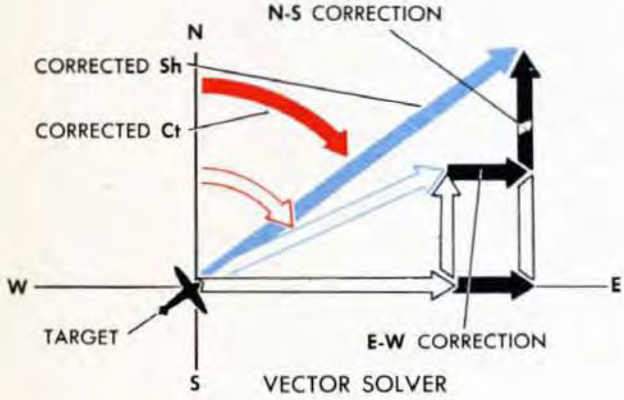


The estimated manual inputs of Horizontal Target Speed, *Sh*, and Target Course, *Ct*, set up a vector in the Vector Solver. This vector positions the Vector Solver racks at the values of the *N-S* and *E-W* components of this vector. During this operation, the Vector Solver acts as an ordinary component solver.

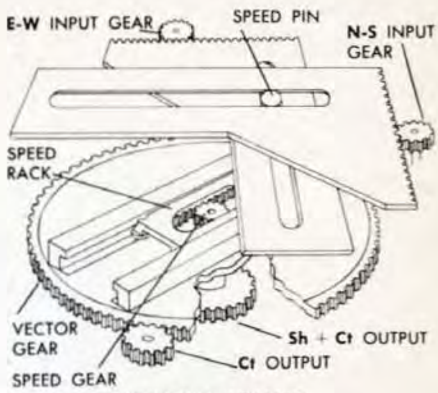


When the *N-S* and *E-W* Rate Corrections coming from the component integrators reposition these same racks, the racks change the length and direction of the vector and so correct the values of *Sh* and *Ct*.

During Rate Control, the *N-S* and *E-W* Corrections continuously position the Vector Solver. As the Relative Motion Rates become more nearly correct, each *N-S* and *E-W* Correction is smaller than the previous one until *Sh* and *Ct* are correct. When *Sh* and *Ct* are correct, the Relative Motion Rates and the Generated Changes of Target Position are correct, and no further Rate Control corrections are needed.



The vector solver outputs



VECTOR SOLVER

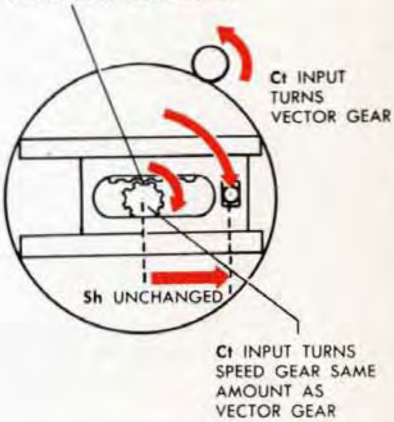
The output from the vector gear is *Ct*, and the output from the speed gear is $Sh + Ct$.

The distance between the speed pin and the center of the vector gear represents the length of the vector, *Sh*. The position of the vector gear represents the direction of the vector, *Ct*.

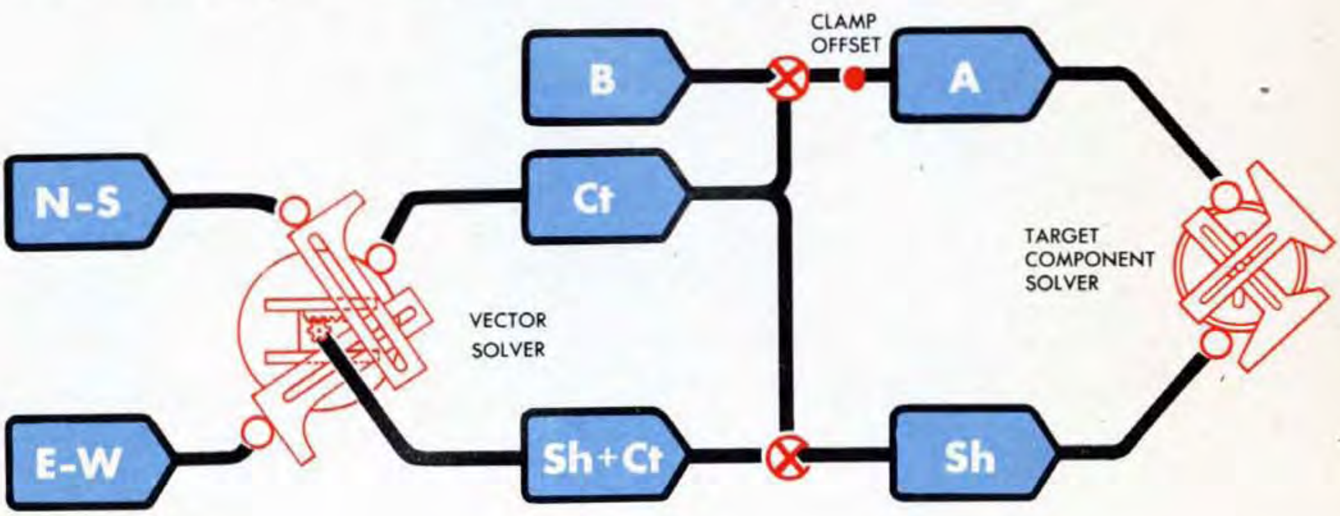
When there is a change in the *direction* of the vector only, both the vector gear AND THE SPEED OUTPUT GEAR must be turned together in order to keep the same vector length or speed. The speed gear is therefore turned for every input of *Ct* as well as for inputs of *Sh*, and the position of this speed gear always represents $Sh + Ct$. The Vector Solver output, *Ct*, is subtracted from the output, $Sh + Ct$, to keep Target Speed, *Sh*, correct.

A corrected value of Target Angle, *A*, is obtained by subtracting the Vector Solver output, *Ct*, from True Target Bearing, *B*, plus 180°.

$$B + 180^\circ - Ct = A$$



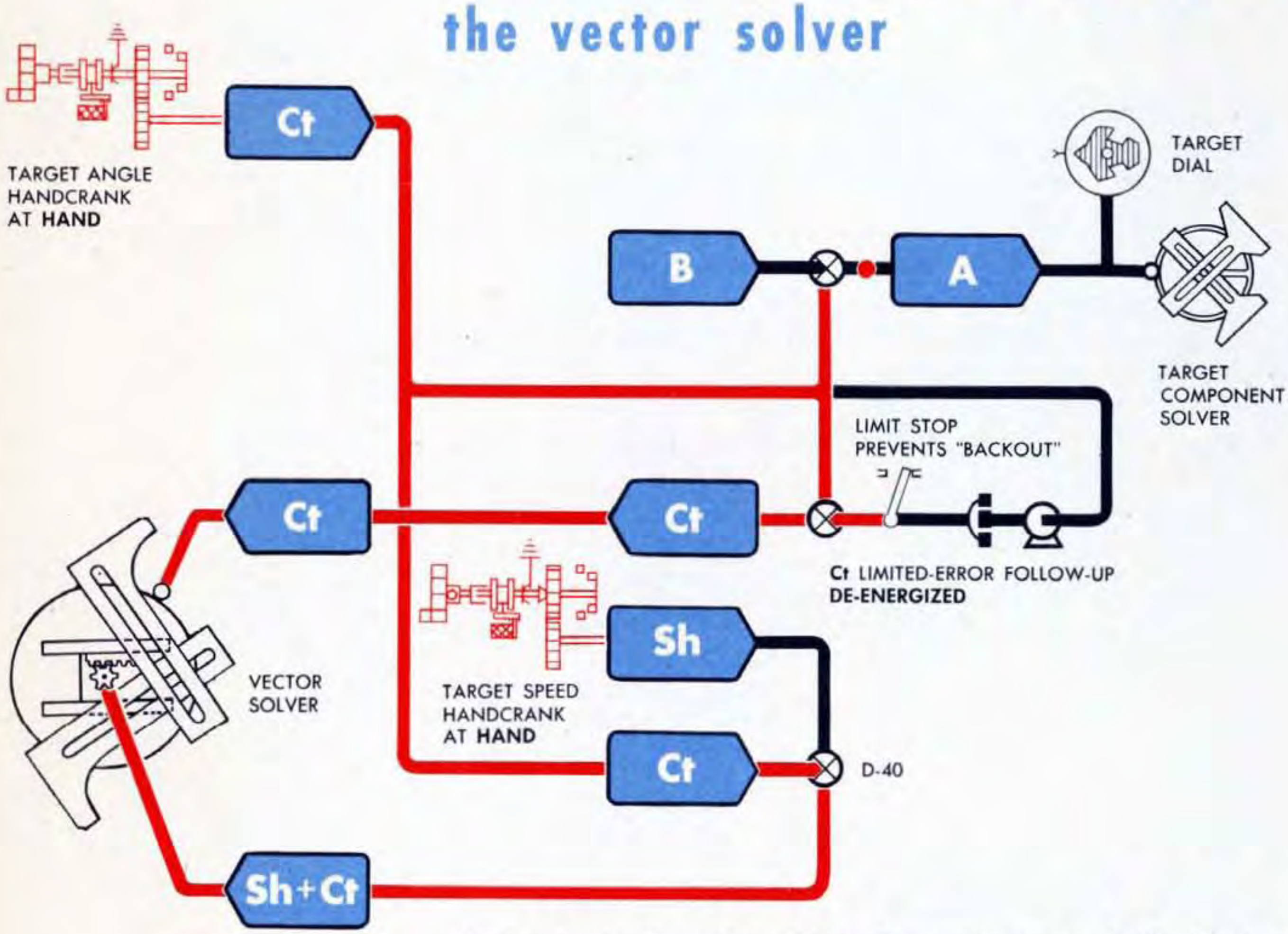
The corrected values of Target Angle, *A*, and Target Speed, *Sh*, go to the Target Component Solver in the Relative Motion Group. The Vector Solver is aided in positioning both the *Sh* and *Ct* lines by a special limited-error follow-up on each line.



Positioning the Ct line

The *Ct* line can be positioned *by hand* by turning the Target Angle Handcrank, and can be positioned *automatically* by using the *Ct* Limited-error Follow-up which amplifies the output of the Vector Solver.

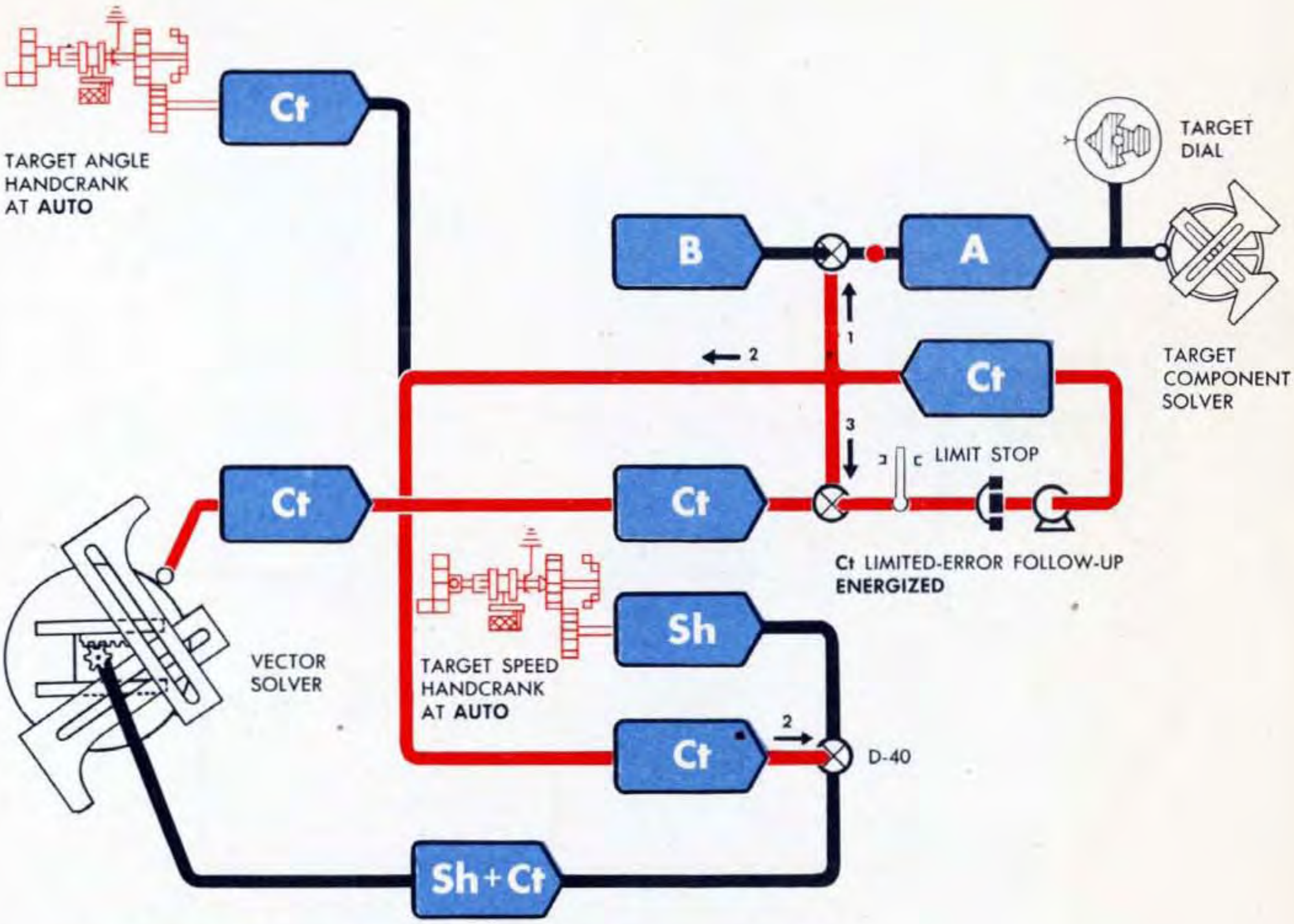
How manual Ct inputs position the vector solver



At the beginning of tracking, the vector gear of the Vector Solver is positioned by turning the Target Angle Handcrank with its lever at HAND position. The red line shows how *Ct* positions the vector gear and is subtracted from *B* to produce *A*. The value *A* positions the Target Dial and the Target Component Solver.

When the lever of the Target Angle Handcrank is at HAND, the *Ct* Follow-up Motor is de-energized. To prevent the hand input of *Ct* from throwing the follow-up out of synchronism, a limited-error follow-up control is used. A limit stop on this type of follow-up limits the motion of the differential spider which controls the contacts. Values of *Ct* coming from the Target Angle Handcrank feed into one side of this differential and out of the other side, since the motion of the spider is limited to about 3 degrees. The two sides of the differential are therefore always nearly matched, and the contacts remain approximately centralized at all times, whether the follow-up motor is energized or not.

How Ct from the vector solver positions the Ct line



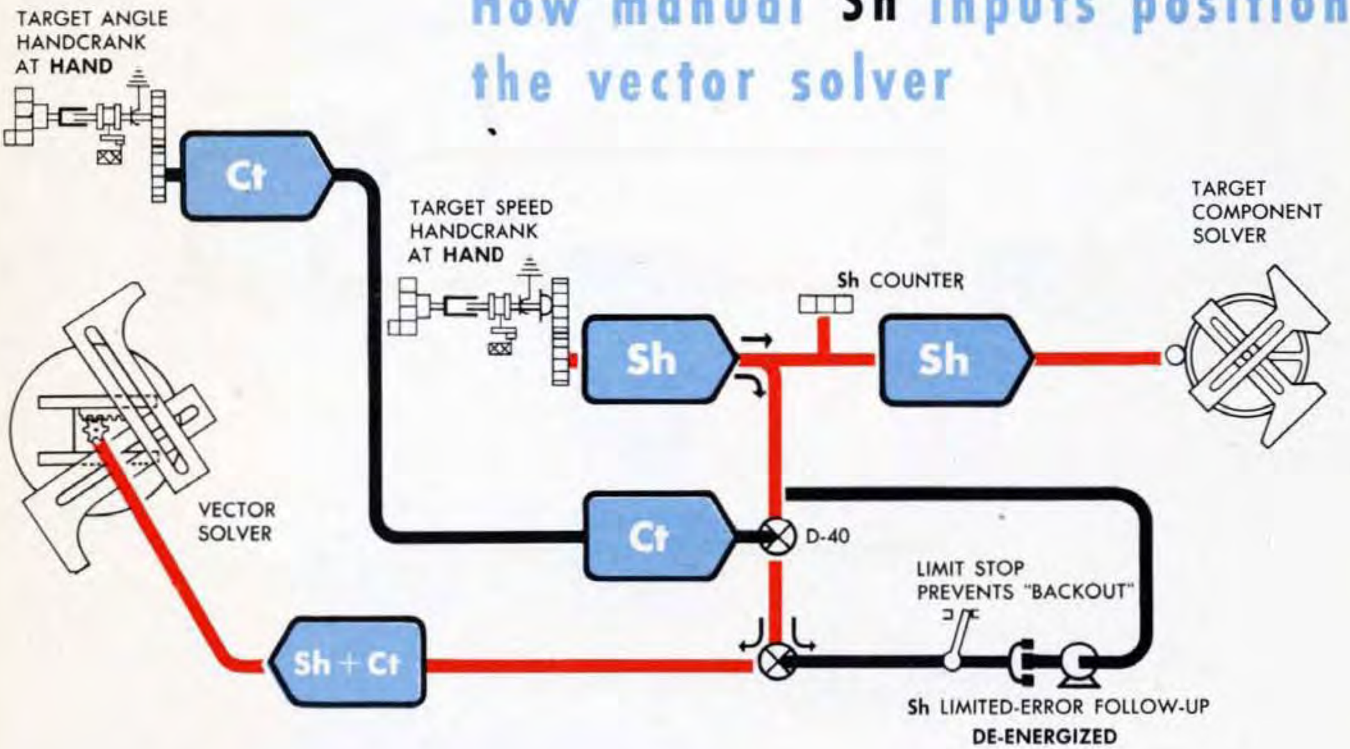
After the initial estimate of *A* is put into the Computer, the levers of the *A* and *Sh* Handcranks are turned to AUTO, energizing the *Ct* Follow-up. No time is wasted waiting for the *Ct* Follow-up to synchronize because the follow-up was kept close to synchronism during operation by hand. As soon as *N-S* and *E-W* Rate Corrections are computed by the Rate Control Computing Mechanism, the vector gear of the Vector Solver repositions the *Ct* line. This value of *Ct* feeds into one side of the follow-up differential, moves the spider, and offsets the follow-up contacts. The follow-up drives the *Ct* line to position three differentials:

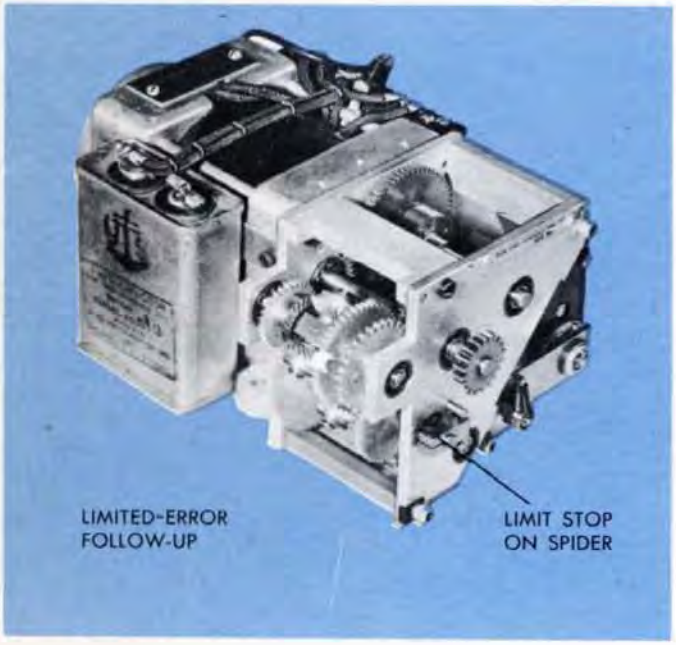
1. The differential at which *Ct* is subtracted from *B* to obtain *A*.
2. The differential at which *Ct* is subtracted from the *Sh* + *Ct* output of the Vector Solver to keep *Sh* at its proper value.
3. The differential of the *Ct* Follow-up, as the response to the signal from the Vector Solver.

Positioning the Sh line

The *Sh* line may be positioned by hand by turning the Target Speed Handcrank, or it may be positioned *automatically* by the *Sh* Limited-error Follow-up which amplifies the output of the Vector Solver.

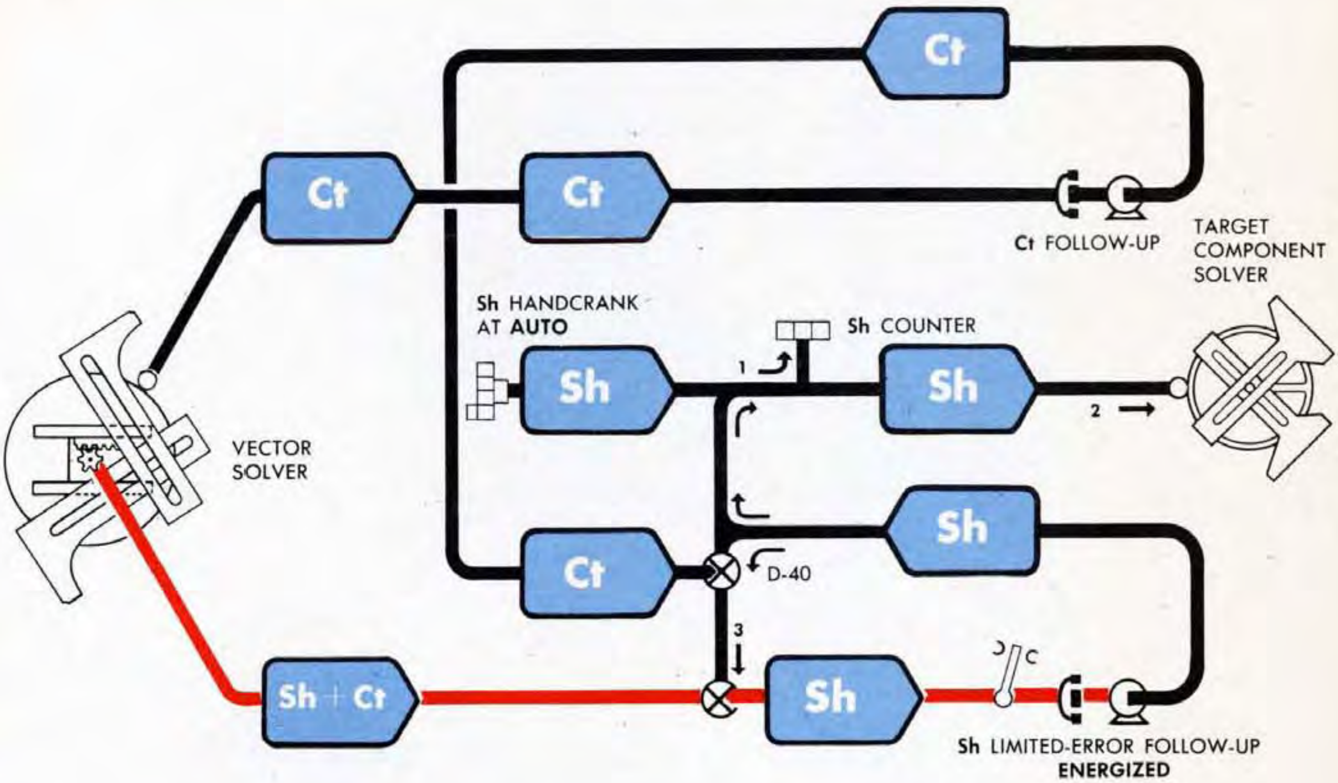
How manual Sh inputs position the vector solver





When tracking begins, the lever on the Target Speed Handcrank is switched to HAND position, de-energizing the *Sh* Follow-up. The initial *Sh* estimate can then be put into the Computer by hand. The red line shows how *Sh* positions the *Sh* Counter and the Target Component Solver. At differential D-40, *Sh* is added to *Ct*. *Sh* + *Ct* feeds into one side of the differential of the *Sh* Limited-error Follow-up. Since the spider is held by the limit stop, *Sh* + *Ct* drives out of the other side of the differential and positions the Vector Solver speed gear. The follow-up contacts remain approximately centralized at all times.

How Sh from the vector solver positions the Sh line



After the manual setting of *Sh*, the lever on the *Sh* and *A* Handcranks are switched to AUTO, energizing the *Sh* Follow-up. *N-S* and *E-W* Rate Corrections are computed by the Rate Control Computing Mechanism, and the Vector Solver speed gear positions the *Sh* + *Ct* line.

Sh + *Ct* from the Vector Solver drives into one side of the differential of the Limited-error Follow-up, where *Ct* is subtracted from *Sh* + *Ct*. *Sh* then offsets the contacts of the follow-up. The follow-up drives the *Sh* line to position three mechanisms:

1 The Target Speed Counter
2 The Target Component Solver
3 The differential of the *Sh* Follow-up, as response.

MAKING RATE CORRECTIONS IN SEMI-AUTO

After seeing how the Rate Corrections are turned into corrections to Target Motion values, it is necessary to know what determines the size of these corrections and how they are put into the Rate Control Computing Mechanism.

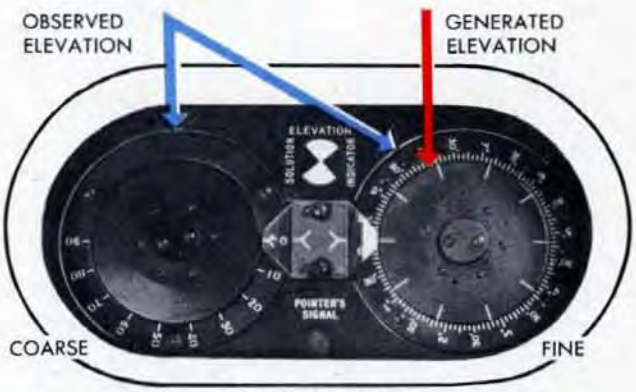
In Semi-automatic Operation, the Computer Operators turn the Generated Cranks to put Rate Corrections into the Rate Control Computing Mechanism to keep the Generated and Observed Dials turning together.

Turning the Generated Cranks when they are in their IN positions introduces the Rate Corrections into the Rate Control Mechanism.

Whenever the Generated Dials are rotating faster or slower than the respective Observed Dials, Rate Corrections are needed.

Turning the Generated Elevation and Bearing Cranks so as to cause the *fine* Generated Dials to turn with the respective Observed Dials introduces the necessary Elevation and Bearing Rate Corrections.

Turning the Generated Range Crank so as to match the Generated Range Dials with the Observed Range Dials introduces the Range Rate Correction.



ELEVATION DIALS

Keeping generated elevation matched with observed elevation

Observed Target Elevation, *E*, turns the outer Elevation Dials, both coarse and fine.

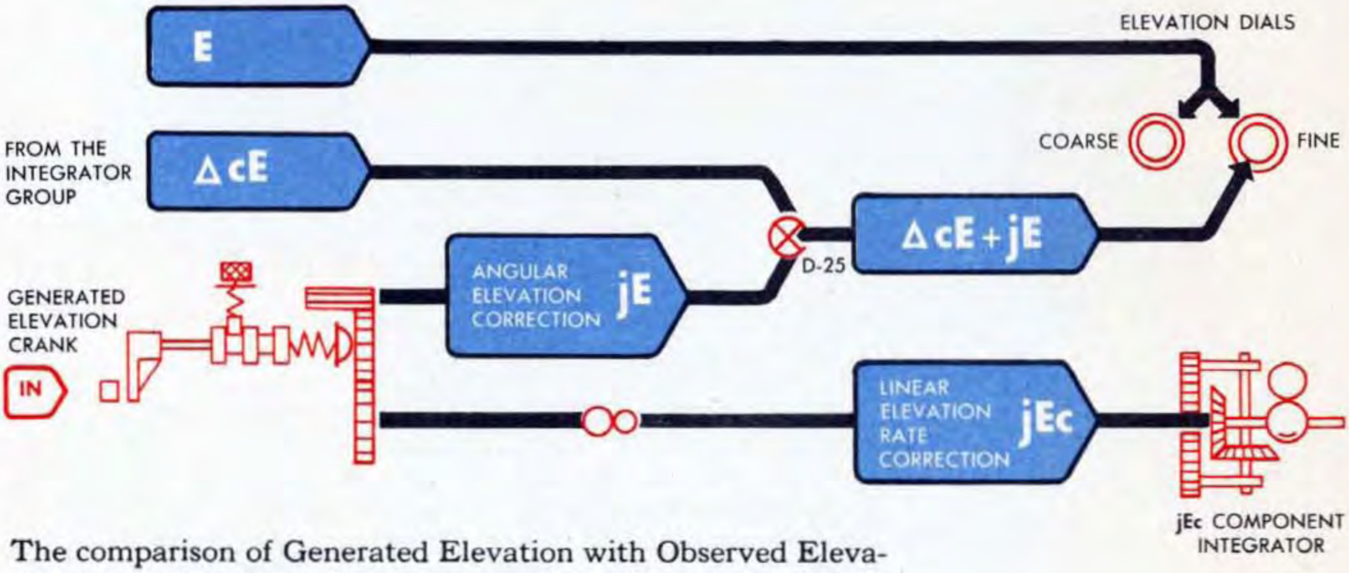
The Generated Changes of Elevation, $\triangle cE$, from the Integrator Group in the Computer, turn the Generated Elevation Dial.

If the Generated Elevation Dial turns faster or slower than the fine Observed Elevation Dial, and the Pointer's Signal is red indicating that the Pointer's sight is on the Target, the Elevation Operator turns the *jE* Crank in its IN position until the graduations on the dials rotate together.

The elevation rate correction jEc

When the Elevation Operator turns the *jE* Crank in its IN position, he does two things:

1. He puts *Angular* Elevation Correction, *jE,* into the Generated Elevation line.
2. He drives *Angular* Elevation Correction, *jE,* through ratio gearing to produce an approximate *Linear* Elevation Rate Correction, *jEc. jEc* drives into the *jEc* Component Integrator in the Rate Control Computing Mechanism.



The comparison of Generated Elevation with Observed Elevation is a comparison of *angular* quantities. The correction *jE* which is based on this comparison is also an angular quantity.

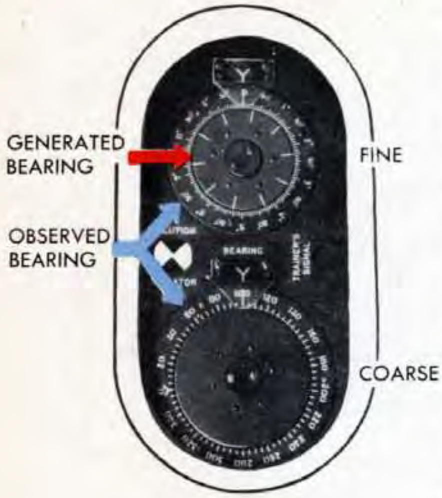
The job of the Rate Control Computing Mechanism is to correct *Sh, dH,* and *A.* Since *Sh* and *dH* are linear rates, *Angular* Elevation Correction, *jE,* must be converted into a *linear rate* correction before it can be used in correcting *Sh* and *dH*. The Linear Elevation Rate Correction, *jEc,* is obtained by driving *jE* through ratio gearing. This shortcut method of converting angular values into linear values is only approximate, but it produces values which are sufficiently accurate, and saves using extra mechanisms.

In the Rate Control Computing Mechanism, *jEc* is used together with Deflection Rate Correction, *jBc,* and Range Rate Correction, *jdR,* to compute corrections to Target Speed, Target Angle, and Rate of Climb. The corrected Target Motion values, *Sh, dH,* and *A,* feed into the Relative Motion Group where corrected Relative Motion Rates are computed. The corrected Elevation Rate, *RdE,* from this group goes to the Integrator Group and corrects the rate at which Changes of Elevation, △*cE,* are generated.

When Elevation Rate, *RdE,* is correct, △*cE* is being generated at the same rate that *E* is changing, and the inner and outer Elevation Dials turn together.

This solves the Elevation part of the Tracking Problem.

Making bearing rate corrections in SEMI-AUTO



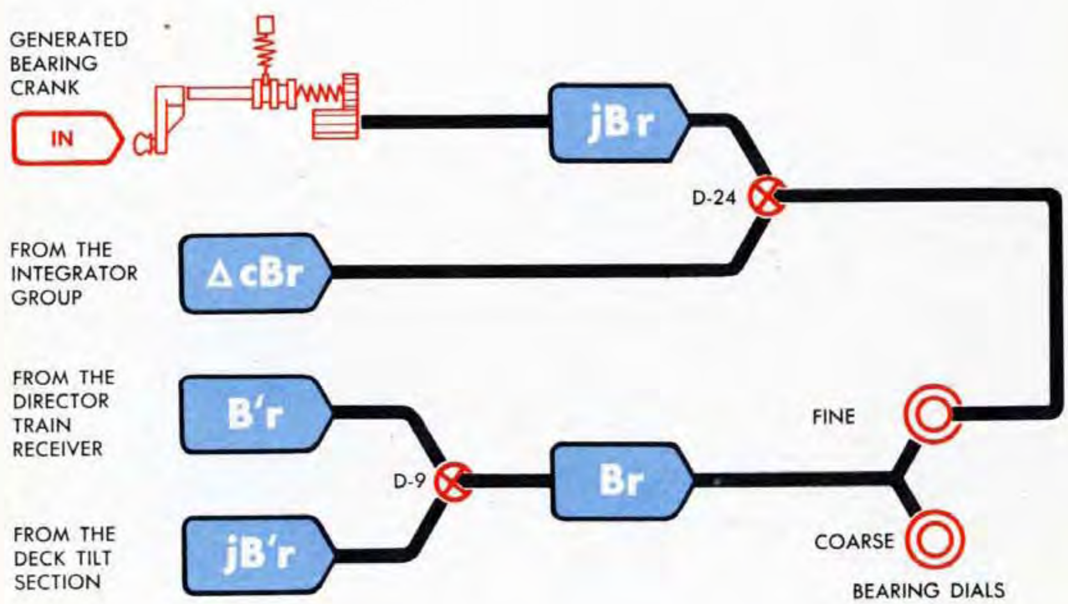
These are the Bearing Dials. They operate in the same way as the Elevation Dials.

Relative Target Bearing, *Br*, positions the outer Bearing Dials, both fine and coarse. Generated Changes of Relative Target Bearing, △c*Br*, from the Integrator Group position the Generated Bearing Dial, which is the inner dial of the fine pair.

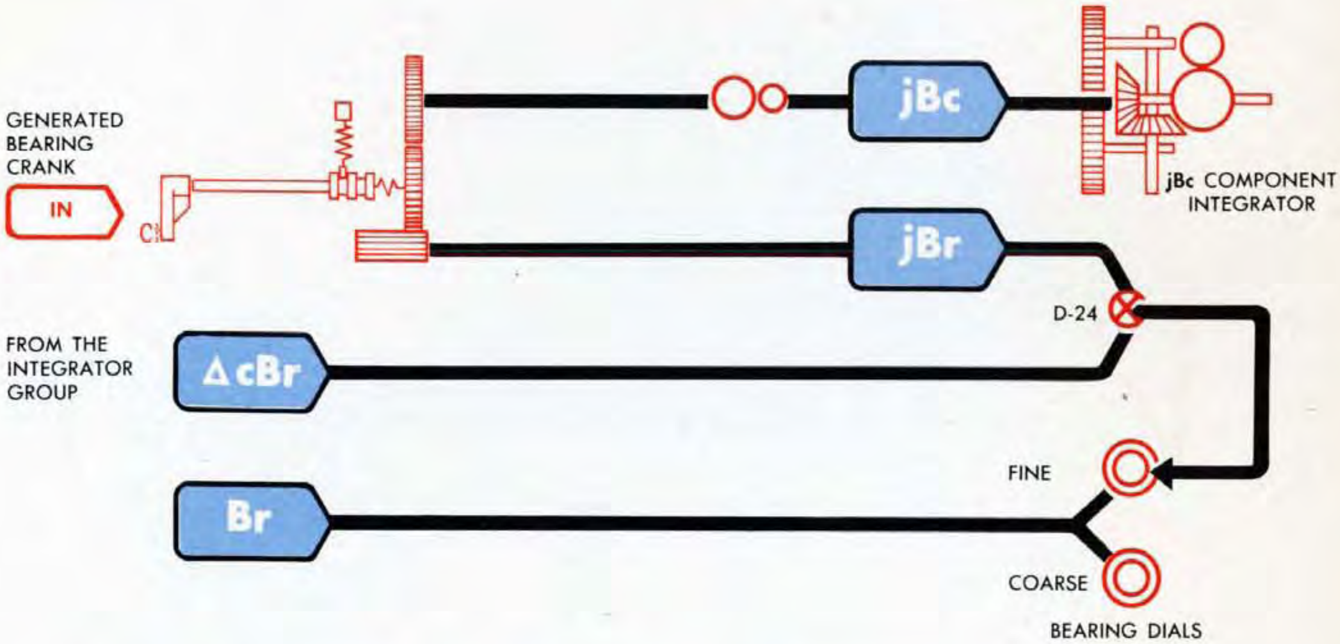
If the Generated Relative Target Bearing Dial turns faster or slower than the fine Observed Relative Target Bearing Dial, and if the Trainer's Signal is red indicating that the Trainer's sight is on the Target, the Bearing Operator corrects Generated Bearing by turning the *jBr* Crank in its IN position.

He continues to turn the crank until the Generated Dial revolves with the fine Observed Dial.

As in the case of Elevation, there are no numbers on the inner Bearing Dial since Generated Bearing is used to turn this dial only. The Bearing Operator is interested only in the *rate* at which Generated Bearing changes, not in its exact value at any moment.



Deflection rate correction jBc



When the Bearing Operator turns the *jBr* Crank in its IN position, he does two things:

1. He puts angular correction *jBr* into the Generated Bearing line.

2. He drives *angular* correction *jBr* through ratio gearing producing an approximate *linear* Deflection Rate Correction, *jBc*. *jBc* drives into the *jBc* Component Integrator in the Rate Control Computing Mechanism.

In the Rate Control Mechanism, Deflection Rate Correction, *jBc*, is used together with Elevation Rate Correction, *jEc*, and Range Rate Correction, *jdR*, to compute corrections to Target Speed, Target Angle, and Rate of Climb. The corrected Target Motion values, *Sh, dH*, and *A*, feed into the Relative Motion Group, where corrected Relative Motion Rates are computed. The corrected Deflection Rate, *RdBs*, goes to the Integrator Group and corrects the rate at which Changes of Relative Target Bearing, △*cBr*, are generated. △*cBr* drives the Generated Bearing Dial. *When RdBs is correct, △cBr is generated at the same rate as Br is changing, and the inner and outer Bearing Dials turn together*. The Bearing part of the problem is solved.

The GENERATED RANGE LINE IN SEMI-AUTO

It is important to understand why the Range lines used for computations in the Computer Mark 1 are positioned by Generated Range instead of Observed Range. Because the Range Finder can only be focused intermittently, the values of Observed Range, *R*, are only intermittently correct, and the positioning of the Range line by Observed Range would be jerky and often incorrect. In order to fire continuously, accurate values of Range must be available continuously. Intermittent values are not sufficient. Generated Range, *cR*, is computed continuously by adding $\triangle cR$ from the Range Integrator to Initial Range, *jR*. Generated Range therefore drives the numbered outer dials in the Range Dial Group. Observed Range drives the inner Range Dials, which are attached directly to the synchros of the Range Receiver.

In rate-controlling *Elevation* and *Bearing*, the Computer Operators put in Rate Corrections until the inner Elevation and Bearing Dials turn in synchronism with their respective outer dials.

In rate-controlling *Range*, the Operator puts in corrections, not only to keep the dials turning together, *but also to keep the indexes on the Generated Range Dials matched to the indexes on the Observed Range Dials.* When the indexes are matched and stay matched, *cR* and *R* are changing at the same rate, *and the value of cR is exactly equal to the value of R.*

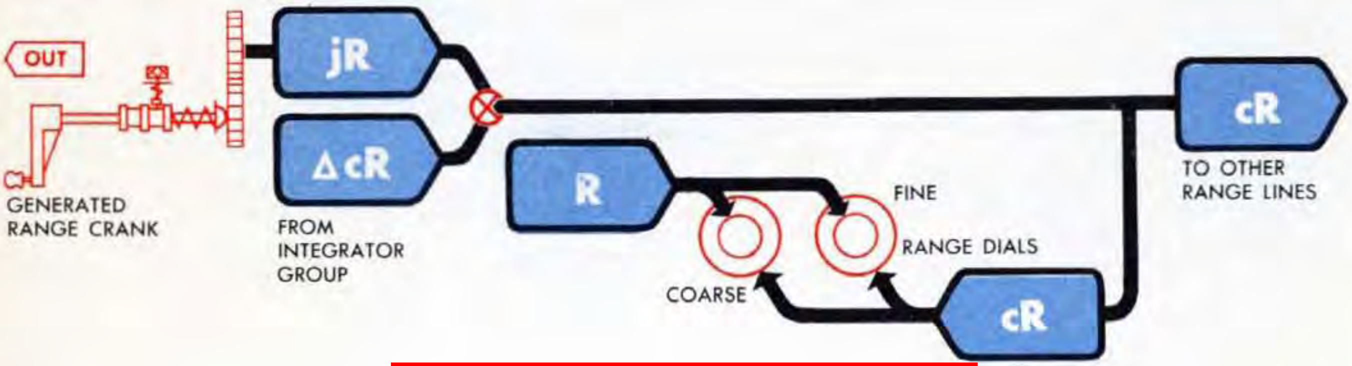
Making range and range rate corrections

Generated Range can be matched to Observed Range by turning the Generated Range Crank in either of its positions:

1 Turning the Generated Range Crank in its OUT position corrects the value of *cR* only.

2 Turning the Generated Range Crank in its IN position corrects both the value of *cR* and the *rate* at which *cR* is being generated.

As soon as tracking begins and the initial value of Observed Range has positioned the *inner* Range Dials, the Range Operator at the Computer must match the *outer* Generated Range Dials to the inner Observed Range Dials.



To match the dials, the Operator turns the Generated Range Crank in its OUT position, until the Y-shaped indexes on both sets of Range Dials are lined up. This initial setting of Generated Range is called *jR*. When the Generated Dials are matched to the Observed Dials, *jR* is equal to *R*. Matching the indexes puts an accurate value of Range onto all Range lines in the Computer, since *jR* is the only Range value going into the *cR* line at this moment.

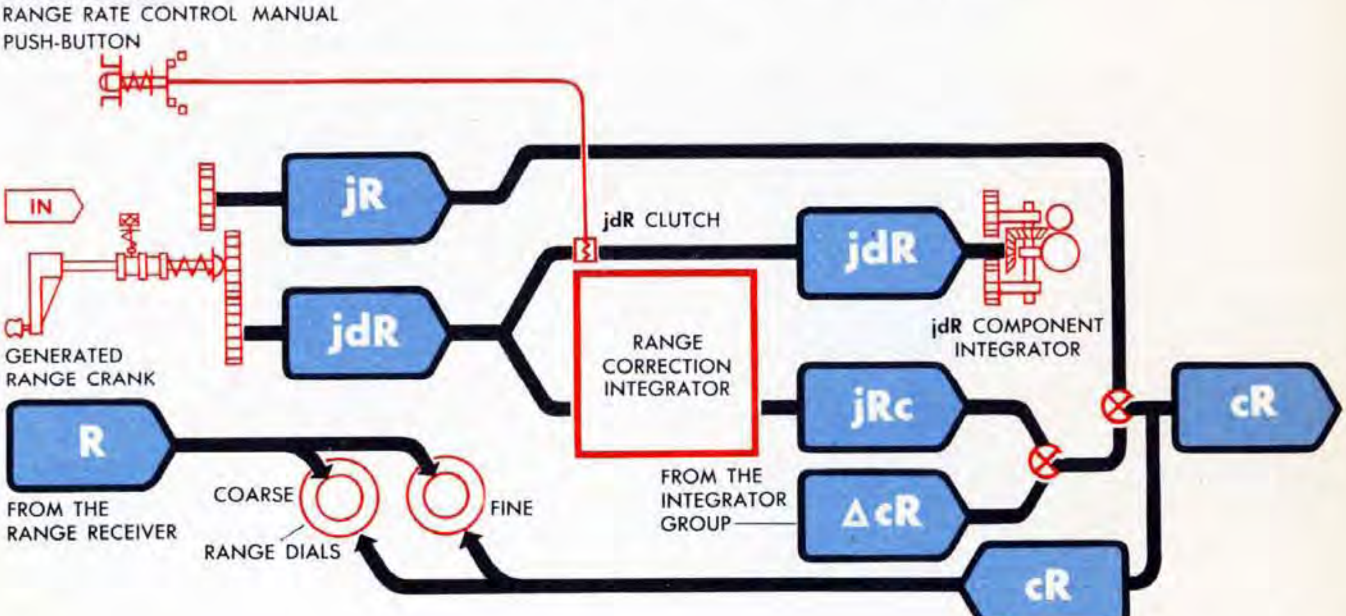
Now the Time Motor is turned on. Immediately the Range Integrator begins to compute continuous Changes of Generated Range, $\triangle cR$, which are added to the initial *jR* input, giving continuous values of Generated Range, *cR*. If *cR* changes at the same rate as *R*, both sets of Range Dials *turn together and the indexes remain matched*. But if *cR* does not change at the same rate as *R*, the Generated Dials will turn at different rates from the Observed Dials and their fixed indexes will not remain matched.

If the dials do not remain matched, two Range corrections are needed: a Linear Range Correction, *jRc*, to match Generated Range to Observed Range at the dials, and a Range Rate Correction, *jdR*, to make the Generated and Observed Range Dials turn at the same rate.

Turning the Generated Range Crank in its IN position puts a Linear Range Correction into the *cR* line to match the indexes on the Generated Range Dials to the indexes on the Observed Range Dials.

Range Rate Corrections as well as Linear Range Corrections may be introduced by turning the Generated Range Crank in its IN position, but only when the necessary electrical circuits are completed. The Range Rate Control Switch must be at MANUAL. Also, the Range Rate Control Manual Push-button must be depressed while the Generated Range Crank is turned. This energizes the *jdR* clutch, enabling Range Rate Corrections to enter the *jdR* Component Integrator. Through the Rate Control Computing Mechanism, *jdR* corrects the rate of change of Generated Range. This correction alters the rate of rotation of the Generated Range Dials.

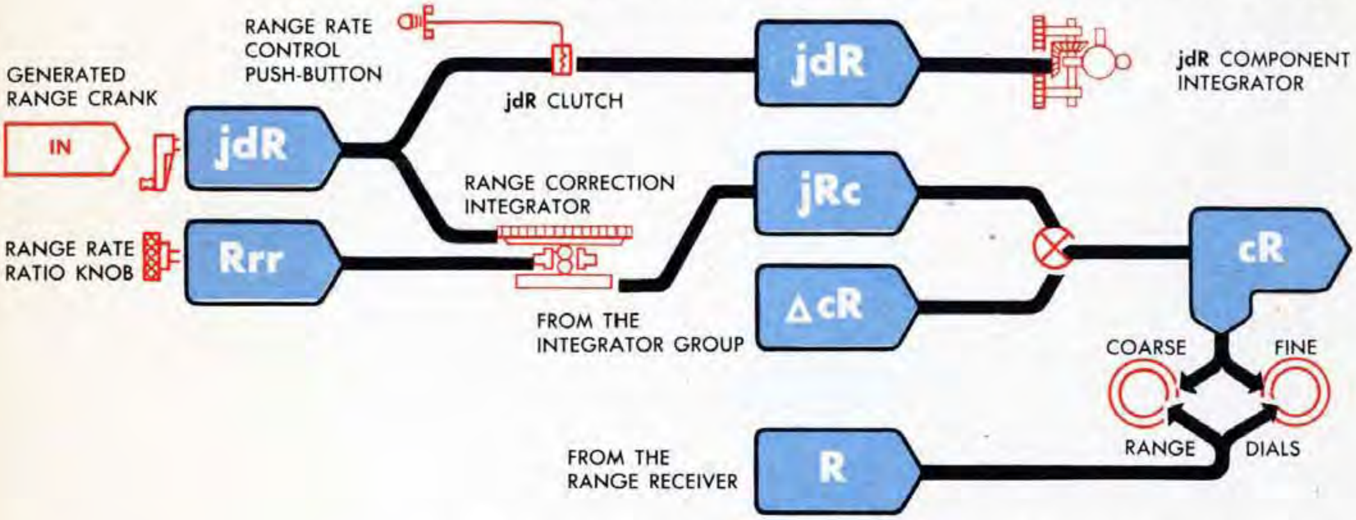
The ratio between the Linear Range Correction and the Range Rate Correction may be varied by changing the position of the Range Correction Integrator carriage. This is accomplished by turning the Range Rate Ratio Knob.



The RANGE CORRECTION INTEGRATOR

The Range Rate Correction, *jdR*, set in by turning the Generated Range Crank in the IN position does two jobs:

1. As a Rate Correction, *jdR* is an input to the *jdR* Component Integrator in the Rate Control Computing Mechanism.
2. *jdR* drives the disk of the Range Correction Integrator and produces the Linear Range Correction, *jRc*. *jRc* repositions the *cR* line to match Generated Range to Observed Range.



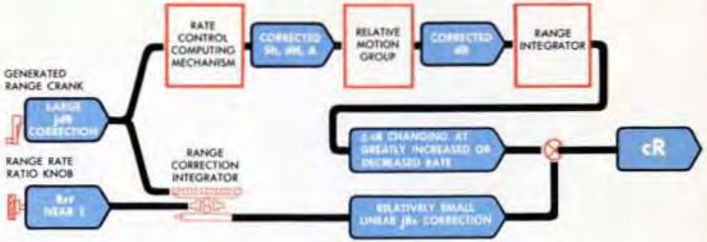
The ratio between the sizes of the Rate Correction, *jdR*, and the Linear Correction, *jRc*, is controlled by the position of the carriage of the Range Correction Integrator. This carriage is positioned by turning the Range Rate Ratio, *Rrr*, Knob. The size of *Rate* Correction, *jdR*, is determined by the amount of *jRc* needed to match the Range Dials. The *jdR* Crank is turned until the Range Dials match. The carriage setting made by the *Rrr* Knob is altered as tracking progresses because the ratio between the necessary *Linear* Range Correction and the necessary Range *Rate* Correction must be altered as the Range Rate error decreases.

Linear Correction, *jRc*, will always be relatively small when the Generated Range Dials are continually being matched to agree with the Observed Range values. The size of *Rate* Correction, *jdR*, however, will depend on the degree of inaccuracy of the Target Motion estimates. A large Rate Correction will usually be needed at the beginning of tracking before the estimates of *Sh*, *dH*, and *A* have received any corrections through Rate Control. As tracking progresses, and *Sh*, *dH*, and *A* become more nearly correct, a smaller Rate Correction will be needed.

Without the Range Correction Integrator it would take a long time to put in a large correction to Range Rate. Many small corrections to Linear Range, *cR*, would have to be made before the rate of change of *cR* would be correct.

The Range Correction Integrator makes it possible to put in a larger or smaller Range Rate Correction while putting in the amount of Linear Range Correction required to match *cR* to *R* at the dials.

How the integrator carriage is positioned

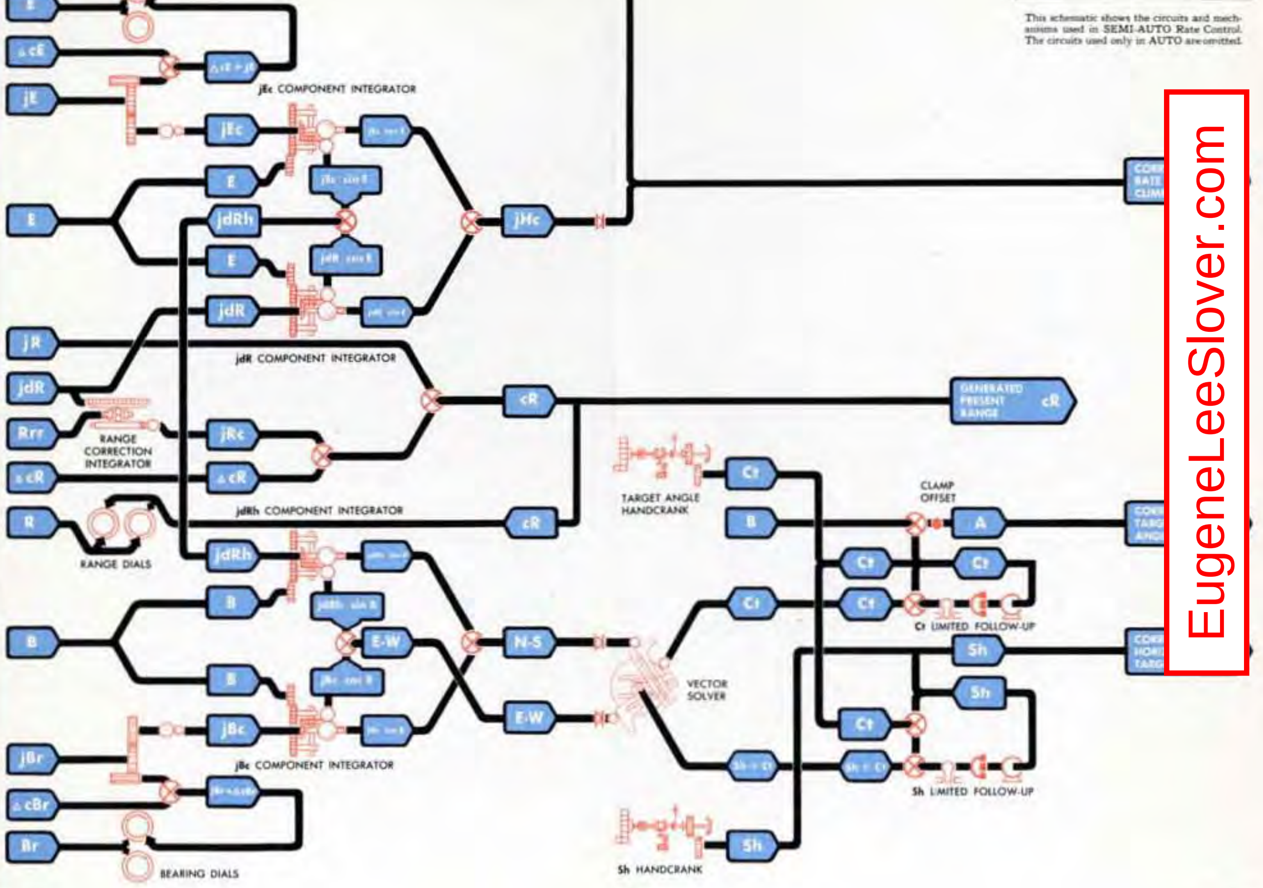


When the difference between *cR* and *R* is small, but there is a *big* difference between the rates at which *cR* and *R* are changing, the *Rrr* Knob is turned toward 1, positioning the Range Correction Integrator carriage near the center of the integrator disk. With the carriage near the center, a relatively *small* linear correction, *jRc*, comes from the integrator roller for many revolutions of the integrator disk by *jdR*. *cR* receives a small *jRc* linear correction, just enough to match the Range Dials. A large *jdR* correction feeds into the Rate Control Computing Mechanism, causing the *rate of change* of *cR* to be greatly increased or decreased.

If the rates of change of *cR* and *R* differ only slightly, but the difference between *cR* and *R* is relatively large, the *Rrr* Knob is turned toward 5. This moves the Range Correction Integrator carriage toward the outer edge of the integrator disk. With the carriage near the edge of the disk, a relatively large *jRc* correction comes from the output roller for a small *jdP* value driving the integrator disk. The Linear Range Correction, *jRc*, is relatively *large*, but only a small value of *jdR* is going into the Rate Control Computing Mechanism. The correction to the *rate of change* of *cR* will be relatively *small*.

COMPUTER MK. 1, MOD. 7
SEMI-AUTOMATIC RATE CONTROL
SCHEMATIC DIAGRAM

This schematic shows the circuits and mechanisms used in SEMI-AUTO Rate Control. The circuits used only in AUTO are omitted.



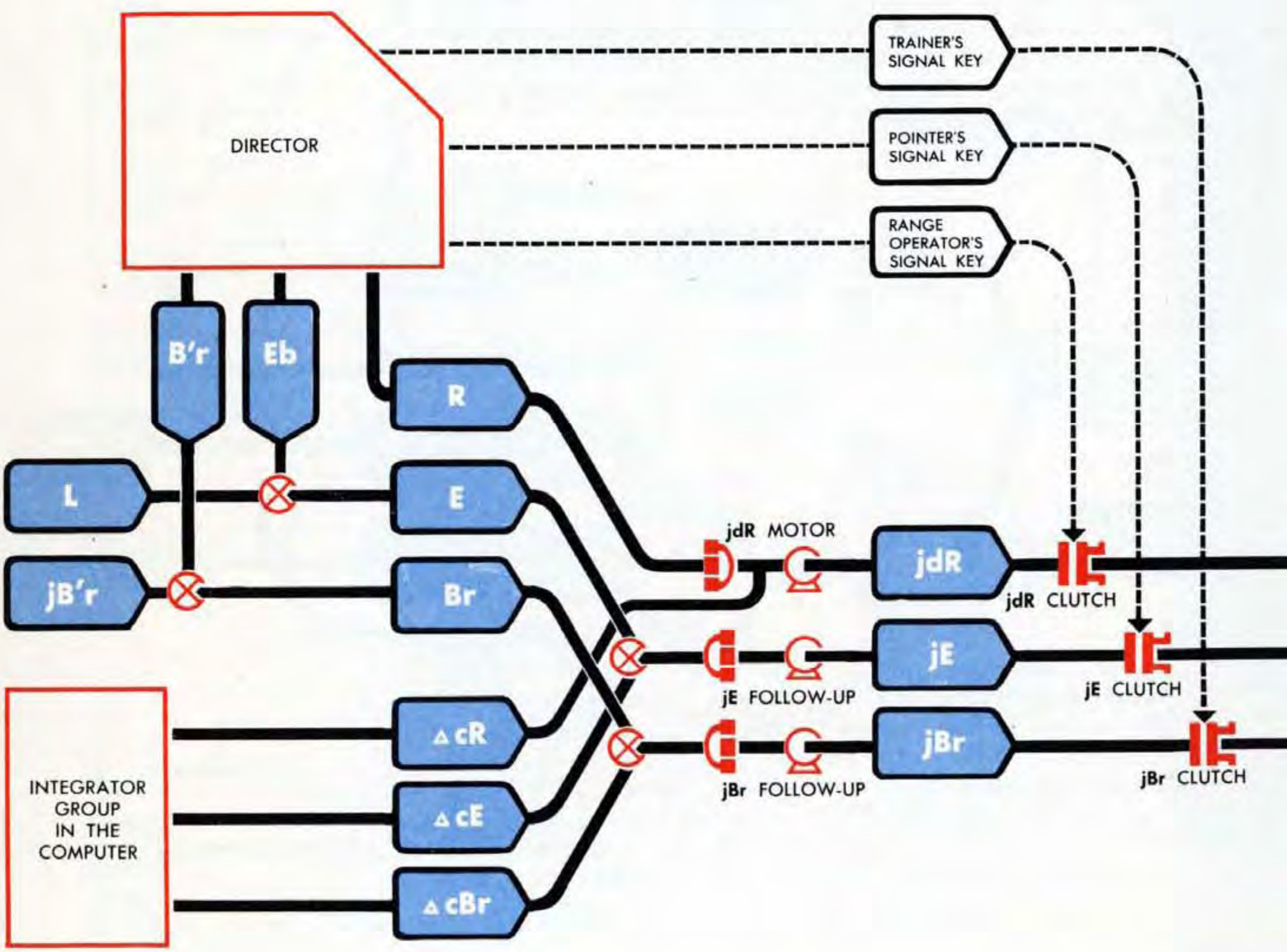
AUTOMATIC RATE CONTROL

The main difference between Automatic and Semi-automatic Rate Control lies in the method by which the Rate Corrections are put into the Rate Control Computing Mechanism.

In Semi-automatic Rate Control, the Rate Corrections, *jdR, jEc* and *jBc,* are put into the Rate Control Computing Mechanism by the Computer Crew.

In Automatic Rate Control, these Rate corrections are controlled by the Director Crew and are put into the Rate Control Computing Mechanism automatically whenever the Director Crew close their Rate Control signal keys while turning their handwheels to keep the sights on the Target.

This is a simplified block schematic of the
RATE CONTROL GROUP in AUTOMATIC RATE CONTROL

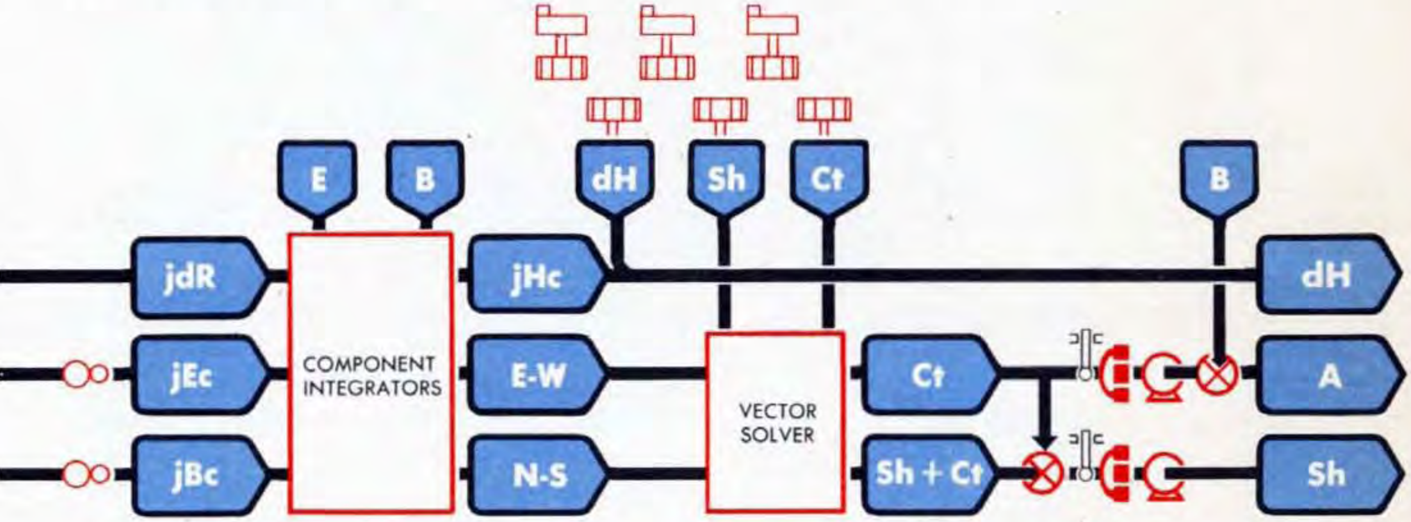


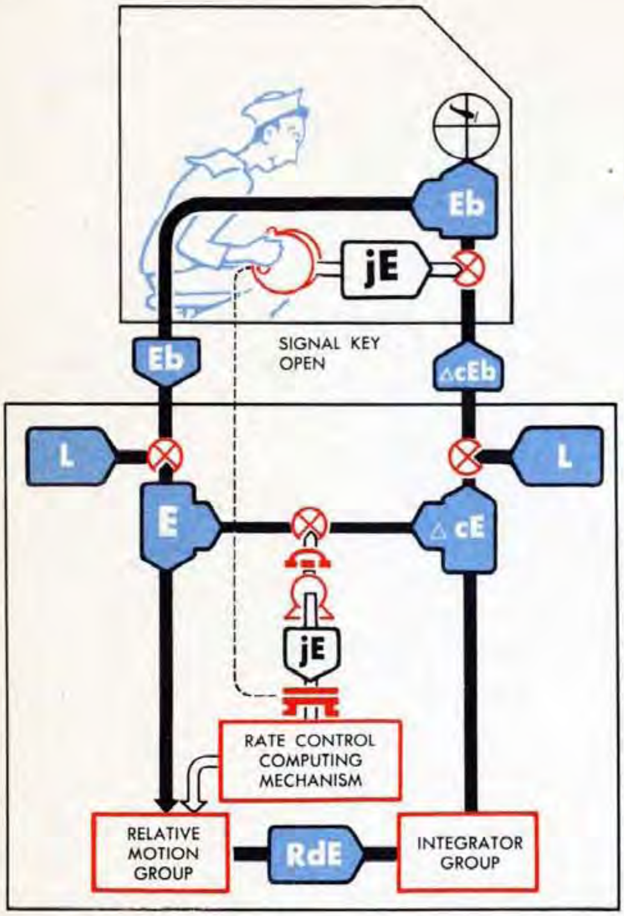
In Automatic, Semi-automatic, and Manual Rate Control, the Pointer, Trainer, and Range Operator turn their handwheels to put in corrections which make up the differences between the Generated Changes of Target Position and the Observed Changes of Target Position. They do this to keep their sights on the Target and to send down to the Computer the correct values of Observed Target Position at every instant.

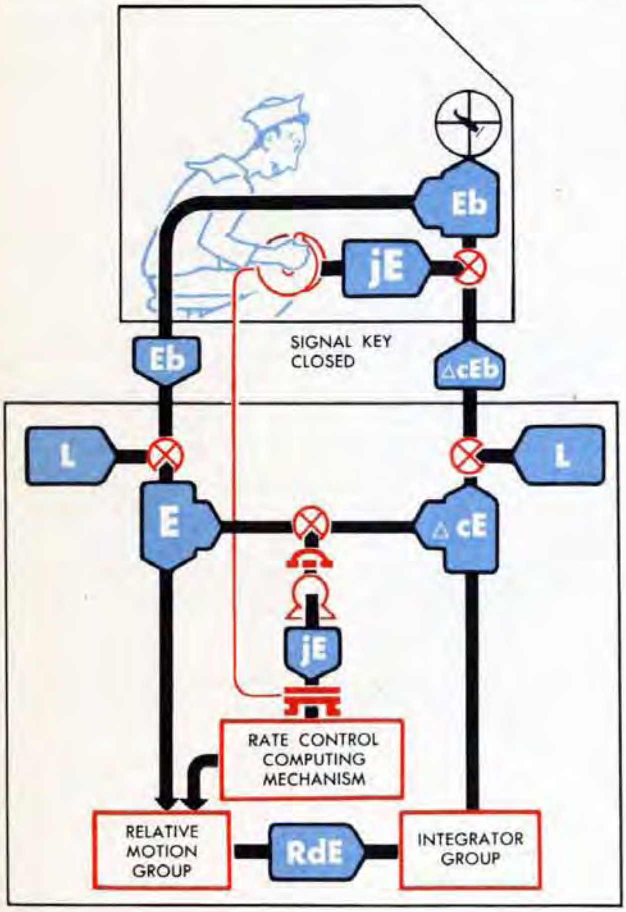
In Automatic Rate Control, the Director Operators have the additional responsibility of putting all or part of their handwheel corrections into the Rate Control Computing Mechanism in the Computer. They put these corrections in by closing their Rate Control signal keys as they turn their handwheels to keep the sights on the Target.

In the Computer, the Generated and Observed Target Position values are continuously being compared. The differences between the Observed and Generated Target Position values offset the contacts of the *jdR* Motor and the *jE* and *jBr* Follow-ups. When the Director Operators have their signal keys closed, clutches are engaged connecting the output lines from the motor and follow-ups to the Rate Control Computing Mechanism. The *jdR* Motor and the *jE* and *jBr* Follow-ups continuously drive the differences between the Observed and the Generated Target Position values into the Rate Control Computing Mechanism, as values of *jdR, jEc,* and *jBc.*

In FULL Automatic Operation, the Control Switch and Range Rate Control Switch are both turned to AUTO. The Control Switch energizes the *jE* Follow-up and the *jBr* Follow-up. The Range Rate Control Switch energizes the *jdR* Motor and Clutch when the Range Operator's Signal Key is closed. The different electrical circuits controlled by these switches are explained in detail on pages 258-261.







In Automatic Rate Control, the processes by which Generated Bearing and Generated Elevation are corrected are similar.

The pointer's job

Suppose that the Generated Changes of Elevation, $\triangle cEb$, are not keeping the Pointer's sight on the Target.

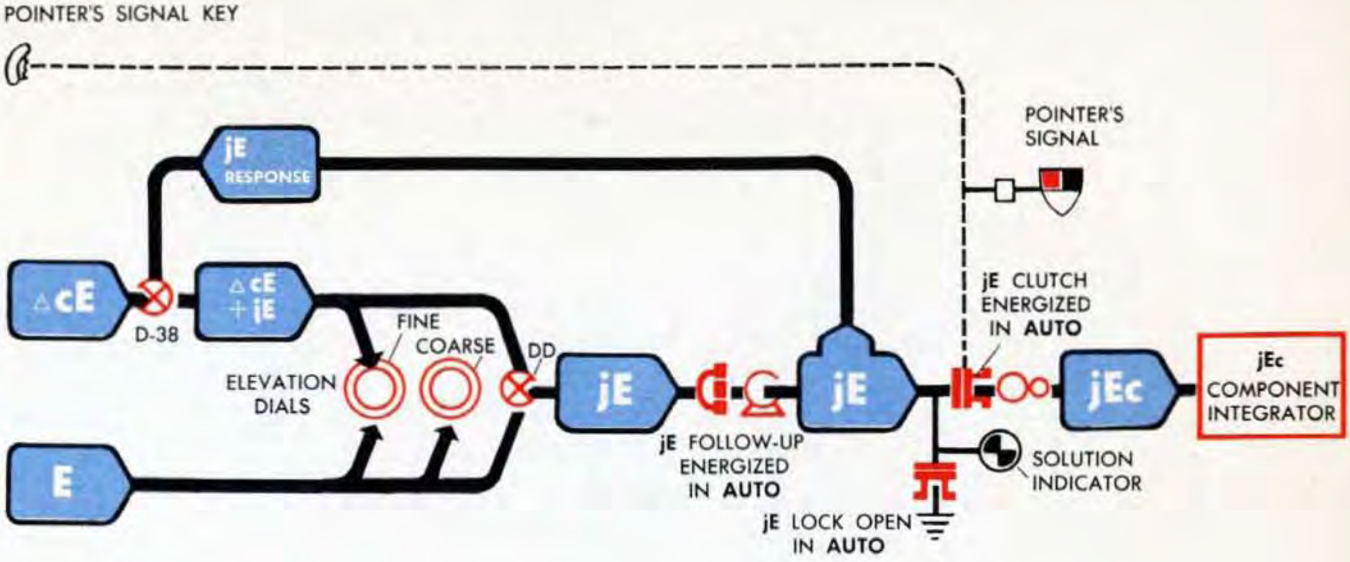
The Pointer's sight, driven by $\triangle cEb$ from the Integrator Group in the Computer, is above or below the Target and is steadily moving farther from the Target. The value of *Eb* going down to the Computer is *incorrect*, *E* is incorrect, and the Rate of Change of $\triangle cE$ is also incorrect.

The Pointer turns his handwheels an amount, *jE*, to put the crosshair of his sight onto the Target. The values of *Eb* and *E* in the Computer are now *correct*. When on the Target, the Pointer presses his signal key and continues to turn his handwheels to keep on Target.

The correction, *jE*, put in by the Pointer as he turns his handwheels is continuously added to $\triangle cEb$ to keep the value of *Eb* correct. In the Rate Control Group, the changes of *E* are continuously compared with $\triangle cE$. The difference between $\triangle cE$ and *E* is *jE*, the amount the Pointer puts in. *jE* offsets the contacts of the *jE* Follow-up. When the Pointer's Signal Key is closed as he turns his handwheels, the clutch on the *jE* line in the Computer is engaged and the follow-up drives *jE* into the Rate Control Computing Mechanism as Elevation Rate Correction, *jEc*.

The Rate Control Computing Mechanism computes corrections to Target Motion values, *Sh*, *dH*, and *A*. The corrected Target Motion values correct Elevation Rate, *RdE*, until the Integrator Group generates $\triangle cEb$ at a rate which keeps the Pointer's sight on the Target automatically without any handwheel correction.

When *RdE* is correct, $\triangle cEb$ changes at the same rate as *Eb*, and $\triangle cE$ changes together with *E*. No *jE* correction is needed.



Rate-controlling elevation in auto

Observed Changes of Target Elevation, *E,* and Generated Changes of Target Elevation, △*cE,* from the Integrator Group position the two sides of differential DD, where they are compared.

The difference between *E* and △*cE* is the differential output, *jE*. *jE* is the *Angular* Correction to Generated Elevation made by the Pointer. *jE* offsets the contacts of the *jE* Follow-up. If the Pointer in the Director has his signal key closed, the clutch on the *jE* line is engaged. The *jE* Follow-up drives *jE* through ratio gearing producing *jEc*. *jEc* is the *Linear* Elevation *Rate* Correction which goes into the *jEc* Component Integrator in the Rate Control Computing Mechanism.

From this point on, the part played by *jEc* in the computation of corrections to Target Motion values is EXACTLY THE SAME AS IN SEMI-AUTOMATIC RATE CONTROL.

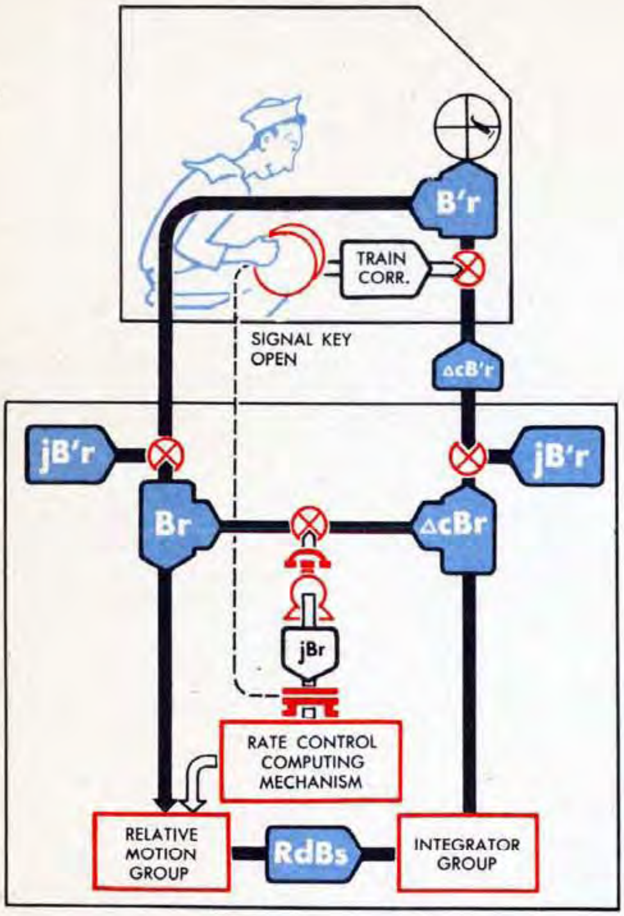
The Angular Elevation Correction, *jE,* is not only used to form Elevation Rate Correction, *jEc,* but is also driven back to differential D-38 where it is added to △*cE*. *jE* + △*cE* acts as response to the *jE* Follow-up and keeps the Generated Dial turning with the Observed Dial.

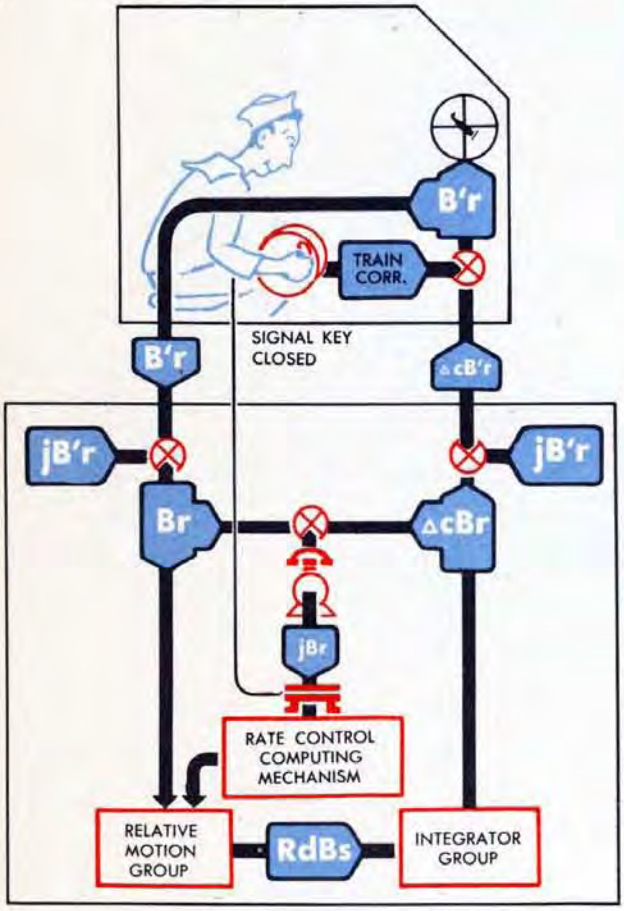
When the Pointer has his signal key closed, the signal flag near the Elevation Dials shows red, indicating that the clutch on the *jE* line is engaged.

Rotation of the Solution Indicator while the flag shows red indicates that Rate Corrections are being made. It shows that the Pointer is turning his handwheels and the *jE* line to the Rate Control Computing Mechanism is turning.

When the Solution Indicator stops turning, the Elevation part of the problem is solved. The Generated Changes of Director Elevation are being computed at a rate which keeps the sights on Target in elevation.

The trainer's job





Suppose that Generated Changes of Director Train, $\triangle cB'r$, are not keeping the Trainer's sight on the Target.

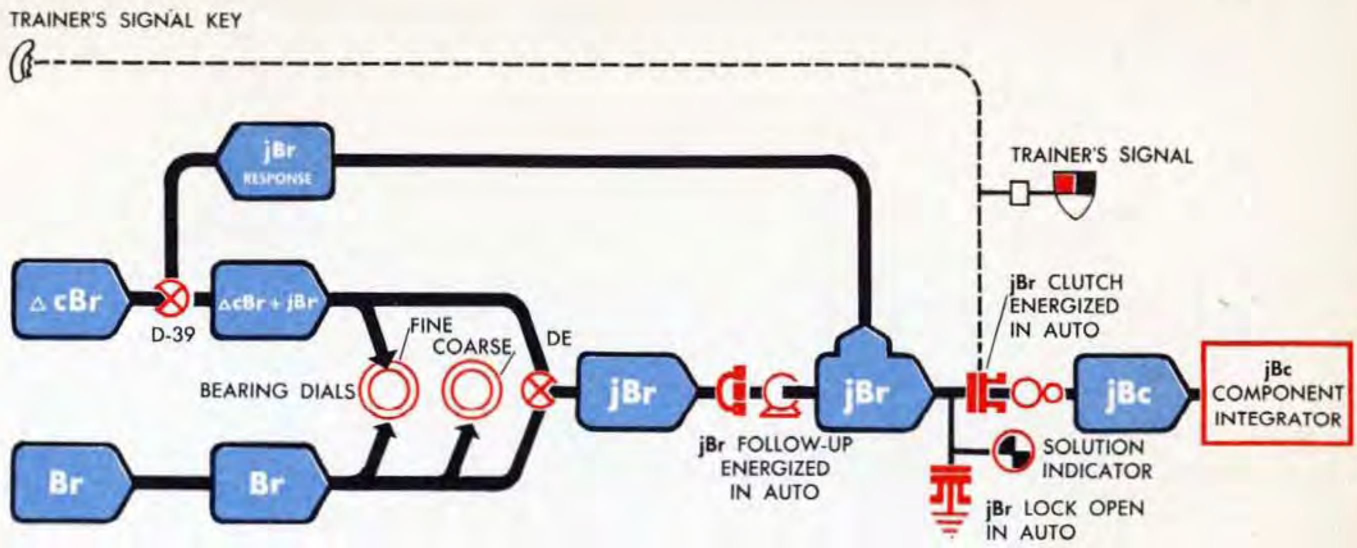
The Trainer's sight, driven by $\triangle cB'r$ from the Integrator Group in the Computer, is not centered on the Target and is steadily moving away from the Target. The value of $B'r$ going to the Computer is incorrect, and Br and Deflection Rate, $RdBs$, in the Computer are also incorrect.

The trainer turns his handwheels an amount to put the crosshair of his sight onto the Target. The values of $B'r$ and Br are now correct.

When the crosshair is on the Target, the Trainer presses his signal key, and continues to turn his handwheels to keep on the Target. By turning his handwheels he puts in a Train Correction which is added to $\triangle cB'r$ to *keep* the values of $B'r$ and Br correct. The Train Correction is referred to the horizontal plane by adding $jB'r$. It then exists in Br as a correction called jBr.

In the Rate Control Group, the changes of Br are continuously compared with $\triangle cBr$. The difference between $\triangle cBr$ and Br is the amount jBr, which offsets the contacts of the jBr Follow-up. When the Trainer's Signal Key is closed as he turns his handwheels, the clutch on the jBr line is engaged and the jBr Follow-up drives jBr into the Rate Control Computing Mechanism.

The Rate Control Computing Mechanism computes corrections to the inputs to the Relative Motion Group. Deflection Rate, $RdBs$, is corrected until the integrators generate $\triangle cB'r$ at a rate which keeps the Trainer's sight on the Target automatically without any Train Correction.



Rate-controlling bearing in auto

Observed Changes of Relative Target Bearing, *Br*, are compared with Generated Changes of Relative Target Bearing, △*cBr*, at differential DE in the Rate Control Group.

The difference between changes of *Br* and △*cBr* is the differential output, *jBr*. *jBr* is the *Angular* Correction to Generated Bearing made by the Trainer. *jBr* offsets the contacts of the *jBr* Follow-up. When the Trainer in the Director has his signal key closed, the clutch on the *jBr* line is engaged. The *jBr* Follow-up drives *jBr* through ratio gearing producing *jBc*. *jBc* is the *Linear* Deflection *Rate* Correction which goes into the *jBc* Component Integrator in the Rate Control Computing Mechanism.

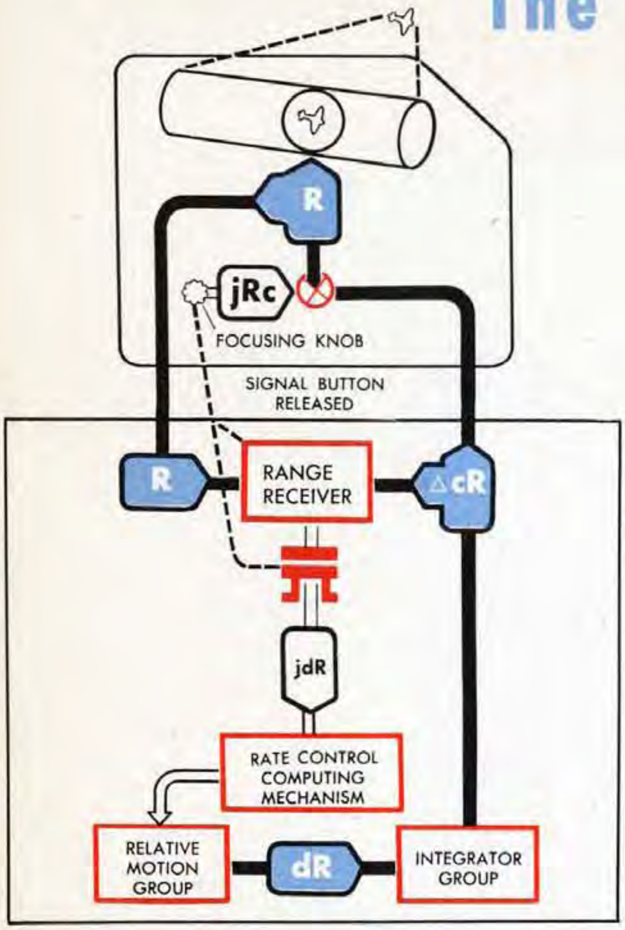
From this point on, the part played by *jBc* in the computation of corrections to Target Motion values is the same as in Semi-automatic Rate Control.

Besides producing Deflection Rate Correction, *jBc, jBr* is driven back to differential D-39, where it is added to △*cBr*. *jBr* + △*cBr* acts as response to the *jBr* Follow-up and also keeps the Generated Dial turning with the Observed Dial.

The Trainer's Signal Flag and the Solution Indicator at the Bearing Dials work in the same way as the flag and indicator at the Elevation Dials. When the signal flag shows red the Trainer has his signal key closed and the clutch on the *jBr* line is engaged. When the Solution Indicator is turning and the flag shows red, Deflection Rate Corrections are being made. The Trainer is turning his handwheels and the *jBr* line to the Rate Control Mechanism is turning.

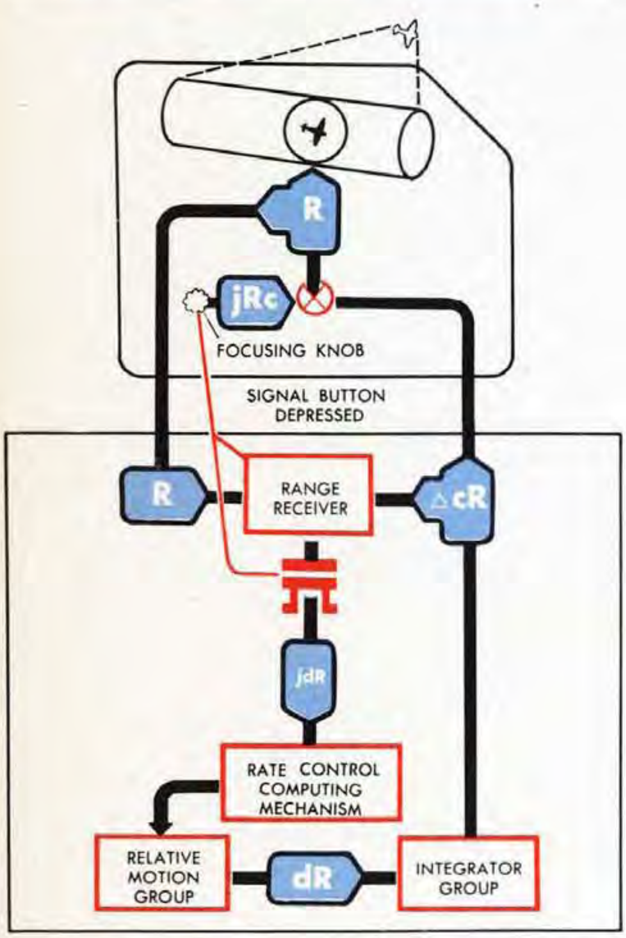
When the Solution Indicator stops turning, the Bearing part of the problem is solved, the Generated and Observed Relative Target Bearing Dials turn together, and Generated and Observed Bearing are changing at the same rate.

The range operator's job



Whenever Generated Changes of Range, △*cR*, do not keep the Range Finder in focus, the △*cR* values are incorrect. When the Range Finder is out of focus the value of *R* going down to the computer is also incorrect.

To correct the value of *R*, the Range Operator turns his knob until the diamond field seems to be the same distance away as the Target. Once in focus, the Operator keeps his signal button depressed, as he corrects to *remain* in focus. The amount he turns his knob, *jRc*, is continuously added to △*cR* to keep the value of *R* correct.



In the Rate Control Group, the value of *R* is continuously being compared with *cR*. The difference between *R* and *cR* is equal to the amount *jRc* which the Range Operator is adding. This difference offsets the contacts of the *jdR* Motor. When the Range Operator's Signal Button is depressed, the clutch on the *jdR* line is engaged and the *jdR* Motor drives *jdR* into the Rate Control Computing Mechanism as a rate correction.

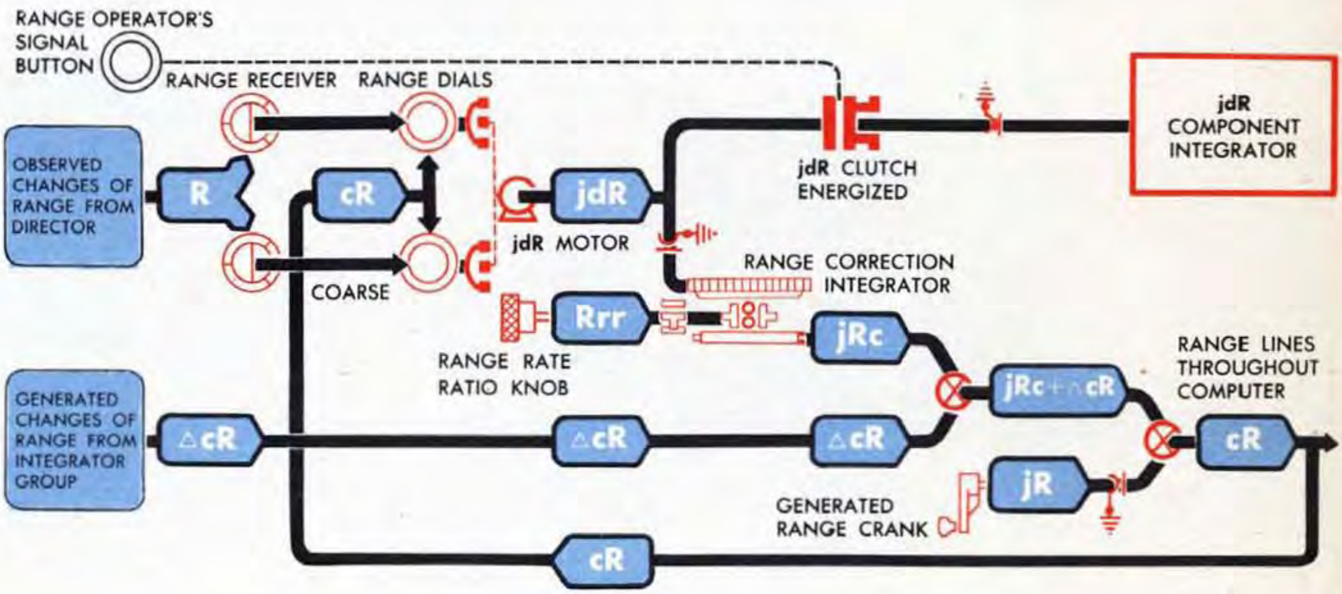
The Rate Control Computing Mechanism computes corrections to *Sh*, *dH*, and *A*, and sends corrected values of these quantities to the Relative Motion Group. These quantities are corrected until the value of Range Rate, *dR*, causes the Integrator Group to generate △*cR* at a rate which will keep the Range Finder in focus without help from the Range Operator. When *dR* is correct, *R* and *cR* change at the same rate and are equal. There is no difference between them when they are compared, and no *jdR* input is needed.

Rate-controlling range

In the Computer, Observed Range, *R*, is received electrically at the Range Receiver. At the Range Receiver contacts, *R* is compared with *cR*. When *R* and *cR* are not equal, the *jdR* Motor is energized whenever the Range Finder Signal Key is closed.

Even in FULL Automatic Rate Control, the amount of *jdR* feeding into the Rate Control Computing Mechanism is determined by the hand setting of the Range Rate Ratio Knob, which positions the carriage of the Range Correction Integrator. The disk of the Range Correction Integrator is turned by *jdR;* the integrator output is *jRc,* the linear correction to Generated Range, *cR*. The *jdR* Motor drives an amount, *jdR,* producing enough *linear* correction *jRc* to match *cR* with *R* at the Range Dials. When the Range Operator has his signal button depressed, the clutch on the *jdR* line is engaged. The *jdR* Motor drives *jdR* through the clutch and into the *jdR* Component Integrator in the Rate Control Computing Mechanism.

When *cR* and *R* are matched and are changing at the same rate, the Range Receiver contacts remain synchronized and the Range Dials turn together. *cR changes at a rate which keeps the Range Finder continuously focused correctly*. The Range part of the problem is solved.



The DOUBLE-SPEED RANGE RECEIVER

RANGE DIALS

OBSERVED RANGE DIALS

SEGMENTS AND DIALS DRIVEN BY **c**R

The Double-speed Range Receiver is located below the Range Dials. The coarse synchro motor is directly below the coarse Range Dials and the fine synchro motor directly below the fine Range Dials. Between each synchro motor and its dials is a contact assembly consisting of brushes, segments, and slip rings.

The synchro rotors are driven by Observed Range, *R*, which is transmitted electrically from the Director. The rotor of the coarse synchro is attached to the coarse Observed Range Dial. The rotor of the fine synchro is attached to the fine Observed Range Dial.

Here are the Observed Range Dials, removed from the Computer. Contact brush A and slip ring A are attached to the under side of the coarse dial. Trolley contact E and slip ring E are attached to the under side of the fine dial.

Here the Observed Dials have been removed to show the contact segments. Contact brush A on the coarse Observed Range Dial bears against segments B and C, and isolated contact D. Segments B and C, and isolated contact D, are attached to the coarse Generated Range Ring Dial, and are driven mechanically by Generated Range *cR*. Trolley contact E on the fine Observed Range Dial bears against segments F and G. Segments F and G are attached to the fine Generated Range Ring Dial and are also driven mechanically by Generated Range, *cR*.

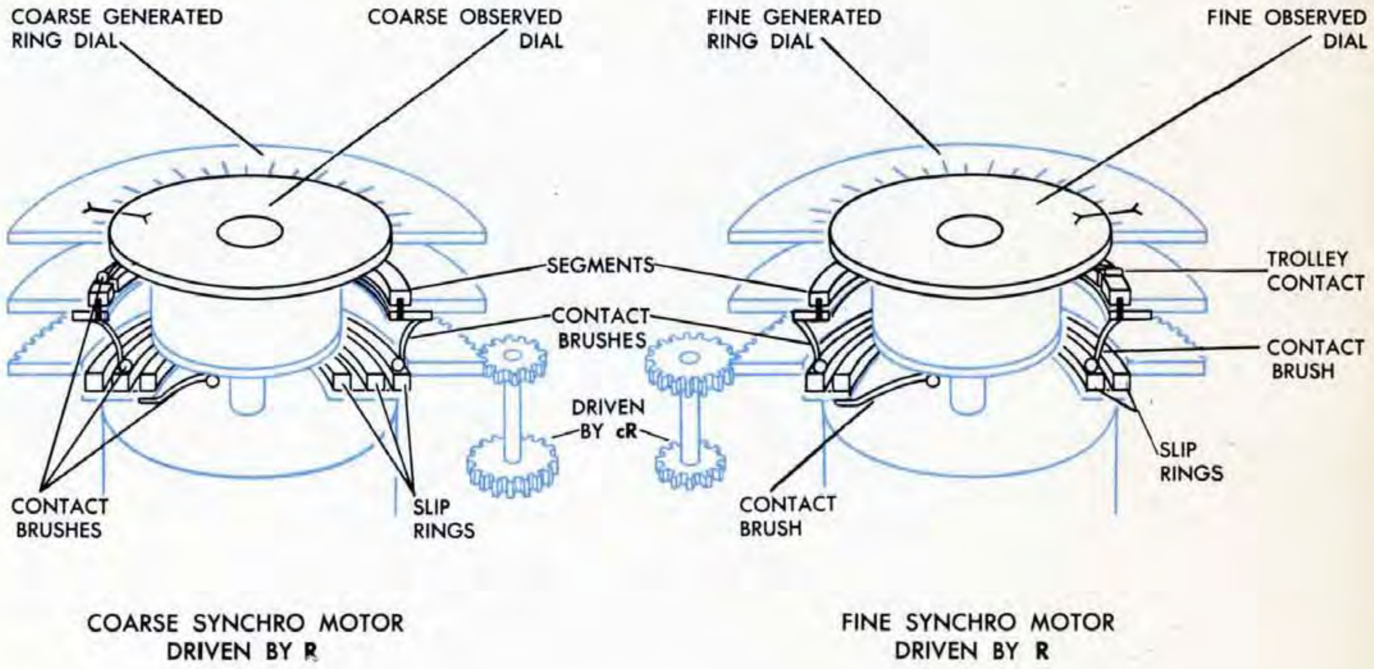
A contact brush is attached to the under side of each of the five segments. Each of these five contact brushes bears against one of the five slip rings shown here. Rings B, C, D, F and G are fastened to the unit mounting plate, and are connected by wires to the *jdR* Motor. Contact brushes X and Y are also fastened to the unit plate. Ring D of the coarse contacts is connected by a wire to brush Y. Brush Y bears against slip ring E on the fine Observed Range Dial, while brush X bears against slip ring A on the coarse Observed Range Dial.

While segments F and G and the fine Generated Range Dial revolve 36 times, segments B and C, isolated contact D, and the coarse Generated Range Dial, revolve only once. Trolley contact E and the fine Observed Range Dial revolve 36 times while brush A and the coarse Observed Range Dial revolve once.

The Range Receiver is like other double-speed receivers in that the rotors of its two synchro motors are driven by signals coming in electrically. It is unlike other double-speed receivers in that the follow-ups of most receivers drive an amount proportional to the signals on their rotors, *while the Range Receiver motor drives an amount proportional to the DIFFERENCE between R and cR.*

As in the case of all double-speed receivers, the coarse and fine Range Receiver synchro motors operate coarse and fine contacts which control the action of a servo motor. The servo motor controlled by the Range Receiver synchros is the *jdR* Motor. When a target is sighted and tracking first begins, the difference between Observed Range, *R,* and Generated Range, *cR,* may be large. When this is the case, the coarse contacts are in control of the *jdR* Motor. However, as soon as the coarse contacts are synchronized, the fine contacts are in control of the *jdR* Motor.

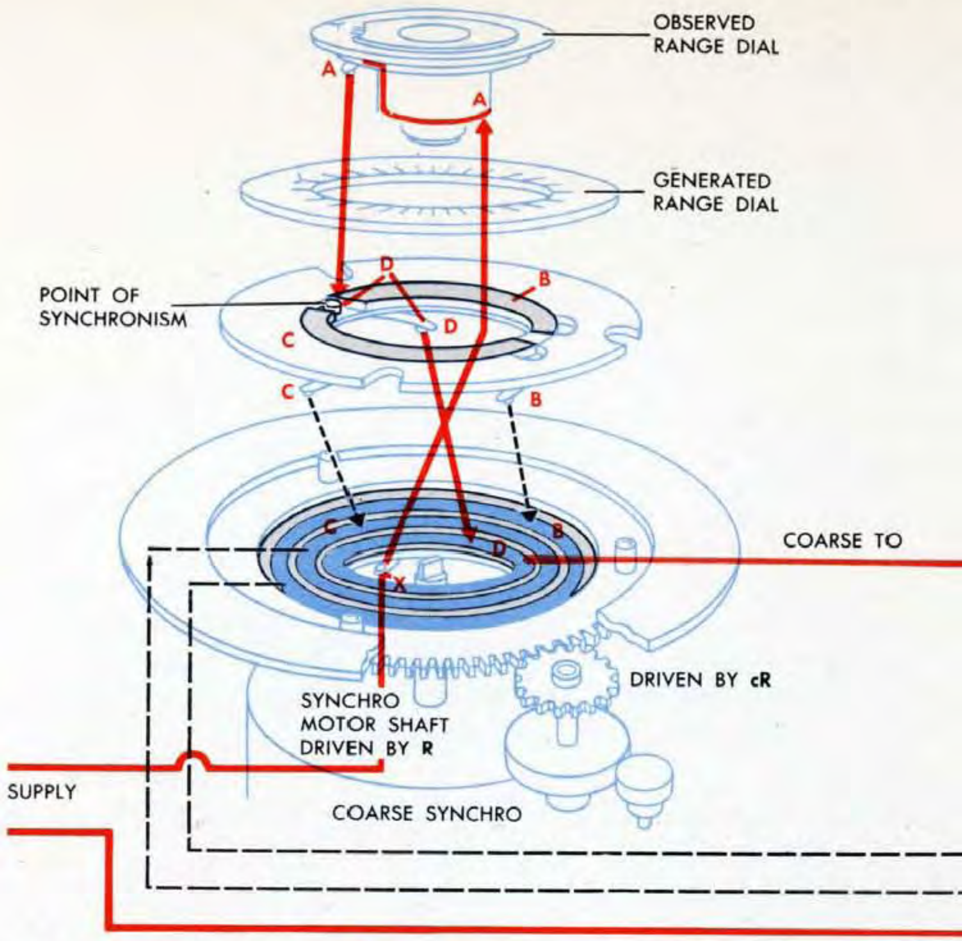
This sketch shows the position of the parts of the Double-speed Range Receiver:



The Observed Range Dials are attached to the synchro motors and are driven by *R*.

The segments are attached to the ring dials and are driven by *cR*.

The slip rings are attached to the unit mounting plate and are connected electrically to the *jdR* Motor.



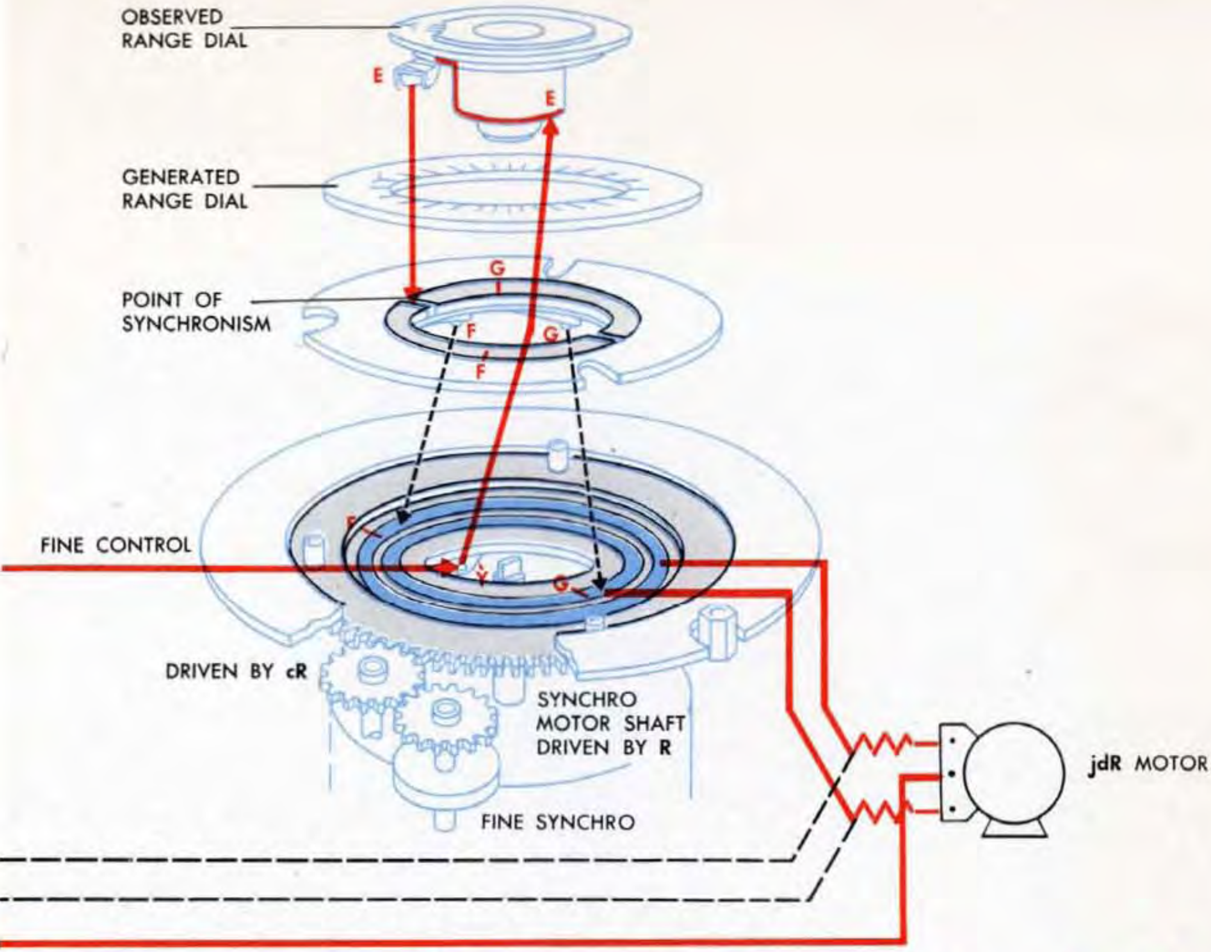
The Coarse Control Electrical Circuits

Slip ring A and contact brush A are fastened to the under side of the Observed Range Dial. Slip ring A is in contact with brush X which is connected to one side of the power supply. Contact brush A touches one of the three segments, B, C, or D. Segments B, C, and D are rotated mechanically by Generated Range, *cR*.

When contact brush A touches segment B, the electrical circuit to the *jdR* Motor is completed through segment B, contact brush B, and ring B, energizing the *jdR* Motor and driving it in one direction.

When contact brush A touches segment C, the electrical circuit to the *jdR* Motor is completed through segment C, contact brush C, and ring C, energizing the *jdR* Motor and driving it in the opposite direction.

When contact brush A touches the isolated contact D as shown in this diagram, the electrical circuit to contact brush Y on the *fine* contacts is completed through the isolated contact D, contact brush D, and ring D.



The Fine Control Electrical Circuits

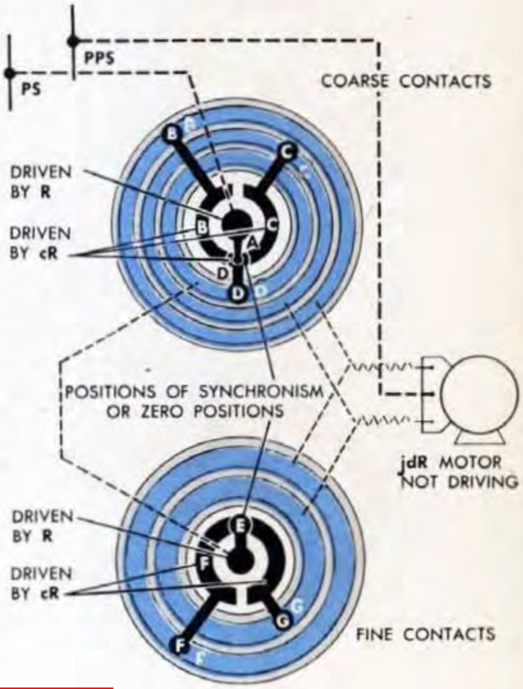
The fine contacts are in control of the *jdR* Motor when the electrical circuit from the coarse contacts is completed to trolley contact E. On the fine contacts, trolley contact E and slip ring E are fastened to the under side of the Observed Range Dial. Slip ring E is in contact with brush Y which is connected to the power supply through the coarse contacts. Trolley contact E touches one of the two segments, F or G. Segments F and G are rotated mechanically by Generated Range, *cR*.

When trolley contact E touches segment F, the electrical circuit to the *jdR* Motor is completed through segment F, contact brush F, and ring F, driving the motor in one direction.

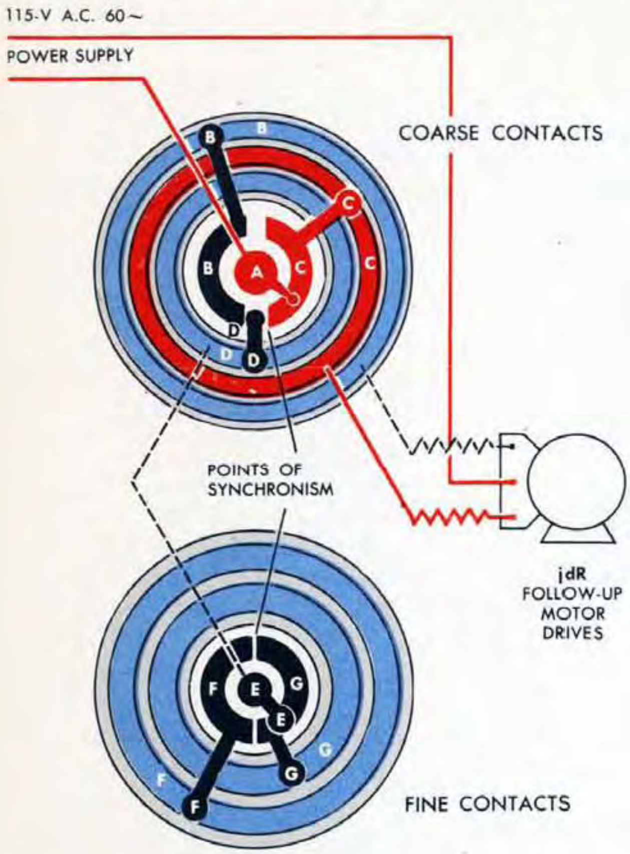
When trolley contact E touches segment G, the electrical circuit to the *jdR* Motor is completed through segment G, contact brush G, and ring G, and the motor drives in the opposite direction.

In the sketch above, trolley contact E is at the point of synchronism, touching both segments F and G. The *jdR* Motor is energized to drive in both directions at once and therefore does not drive at all. As long as trolley contact E remains at the point of synchronism, Observed Range, *R*, and Generated Range, *cR*, are equal.

The electrical circuit to the *jdR* Motor is always completed through the Range Rate Control Switch and the Range Finder Signal Button.

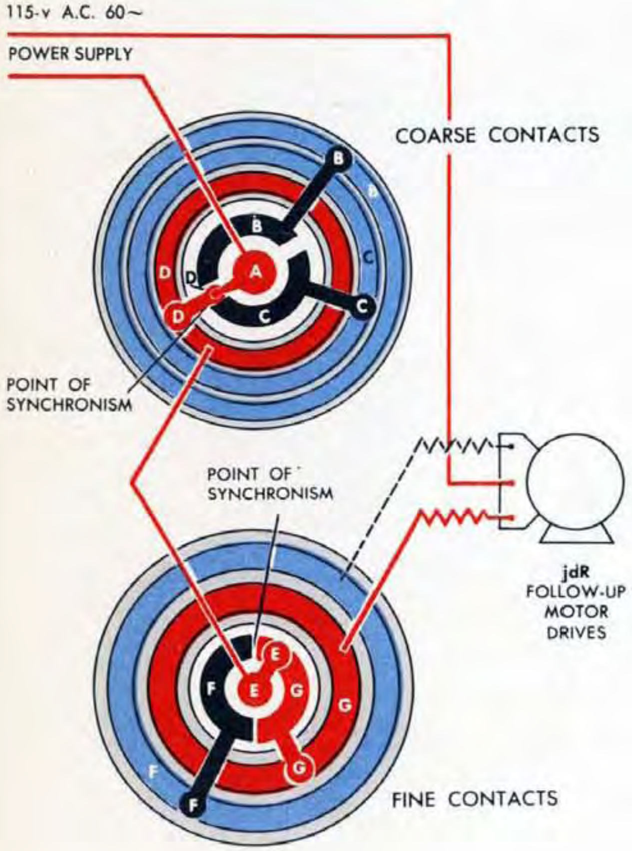


When the COARSE Contacts are in control



The coarse contacts of the Double-speed Range Receiver control the *jdR* Motor when the difference between *R* and *cR* is greater than 550 yards; otherwise the fine contacts are in control.

At the beginning of tracking, suppose that *R* is much greater than *cR*. Contact brush A on the coarse contacts would be off its point of synchronism on isolated contact D and on segment C, completing the circuit to the *jdR* Motor through segment C, contact brush C, and ring C. The *jdR* Motor is energized and drives the disk of the Range Correction Integrator, producing Linear Correction, *jRc*, and increasing the linear value of *cR*. *jdR* also feeds into the *jdR* Component Integrator, causing a range *rate* correction. Isolated contact D is driven counterclockwise toward its point of synchronism with contact brush A.



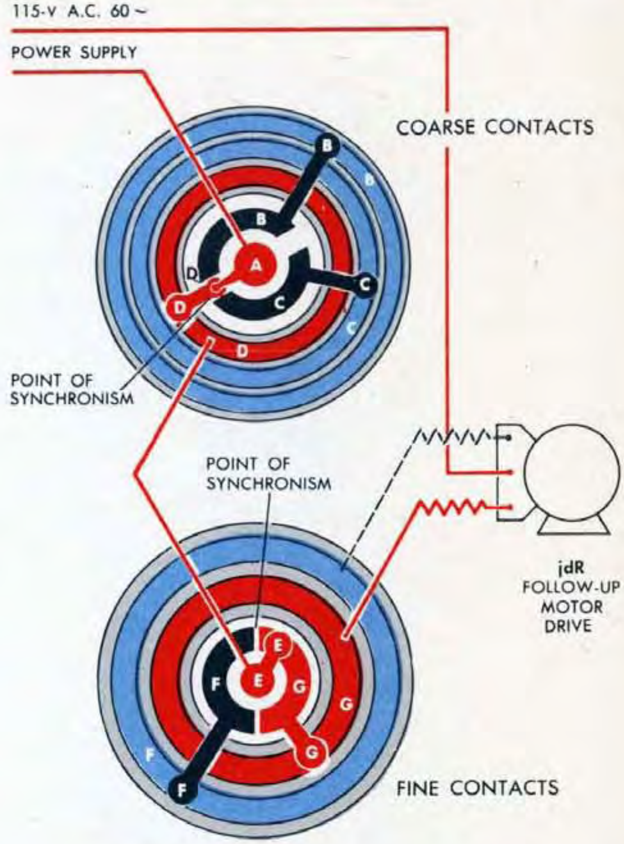
Now *R* is only slightly greater than *cR*. Isolated contact D has reached its point of synchronism, touching contact brush A.

Now the electrical circuit is completed through contact brush D and ring D of the coarse contacts to trolley contact E of the fine contacts, and the fine contacts are in control of the *jdR* Motor.

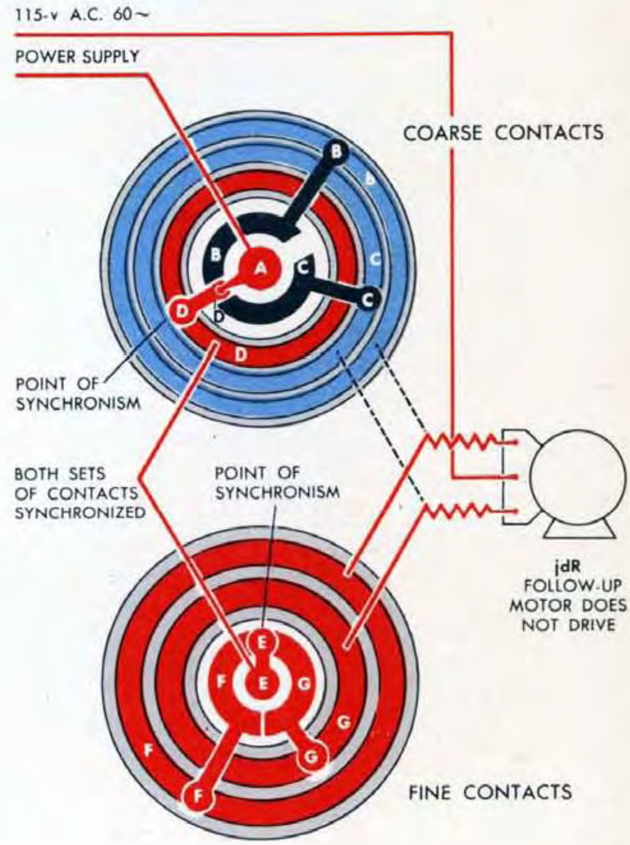
When the FINE Contacts are in control

Since *R* is still slightly greater than *cR*, the point of synchronism will be counterclockwise from trolley contact E. Now the electrical circuit to the *jdR* Motor is completed through segment G, contact brush G, and ring G. Therefore the *jdR* Motor continues to drive segments F and G clockwise to bring the point of synchronism under trolley contact E. This will make *cR* equal *R*.

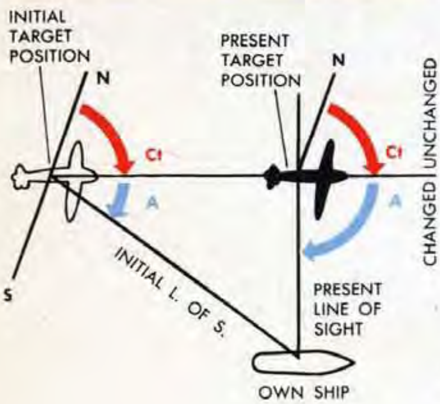
If *R* had been slightly smaller than *cR*, the point of synchronism would have been clockwise from trolley contact E. The electrical circuit to the *jdR* Motor would have been completed through segment *F*, contact brush F, and ring F, and the *jdR* Motor would have been driven in the *opposite* direction, *decreasing* the value of *cR*.



When *R* and *cR* are equal and are changing at the same rate, trolley contact E is at the point of synchronism, touching both segments F and G. The *jdR* Motor is energized to drive equally in both directions at once and therefore does not drive at all.



The TARGET COURSE INDICATOR



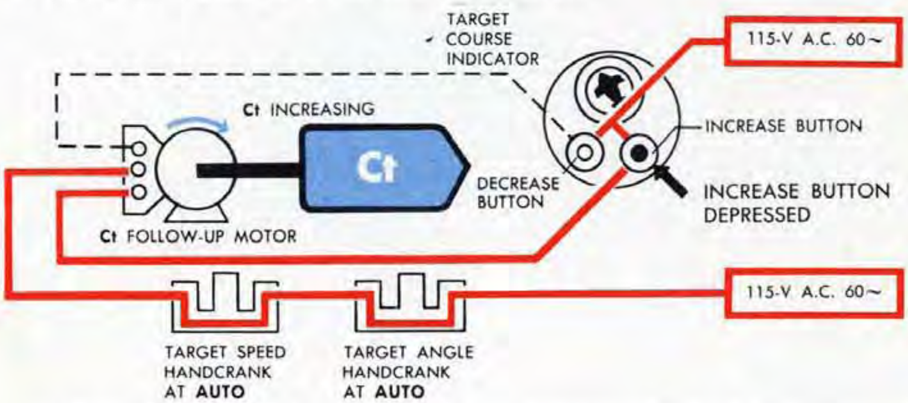
This is a Target Course Indicator. It is fastened to the side of the Star Shell Computer on top of the Computer Mark 1.

Target Angle, *A*, changes continuously as the relative position of Own Ship and Target changes, but Target Course, *Ct*, is measured from *North*, and therefore remains constant as long as the direction of motion of the Target does not change. For this reason and others, *Ct* is used to estimate the direction of motion of the Target.

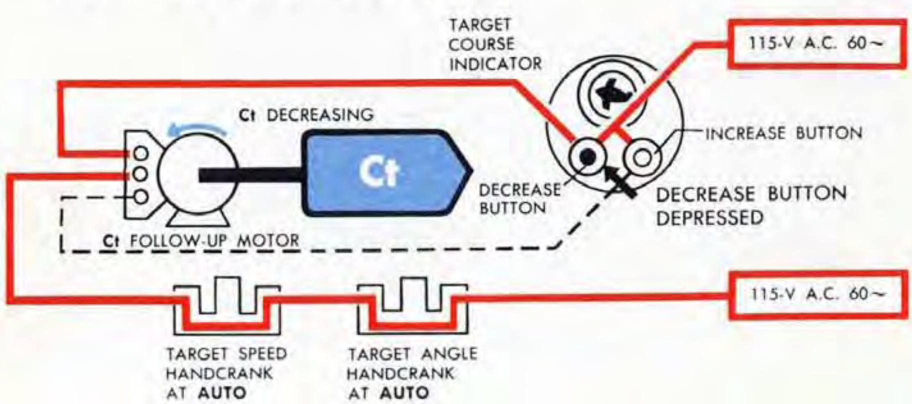
Corrections to Target Course, *Ct*, may be made faster by using the Target Course Indicator than by using the Target Angle Handcrank.

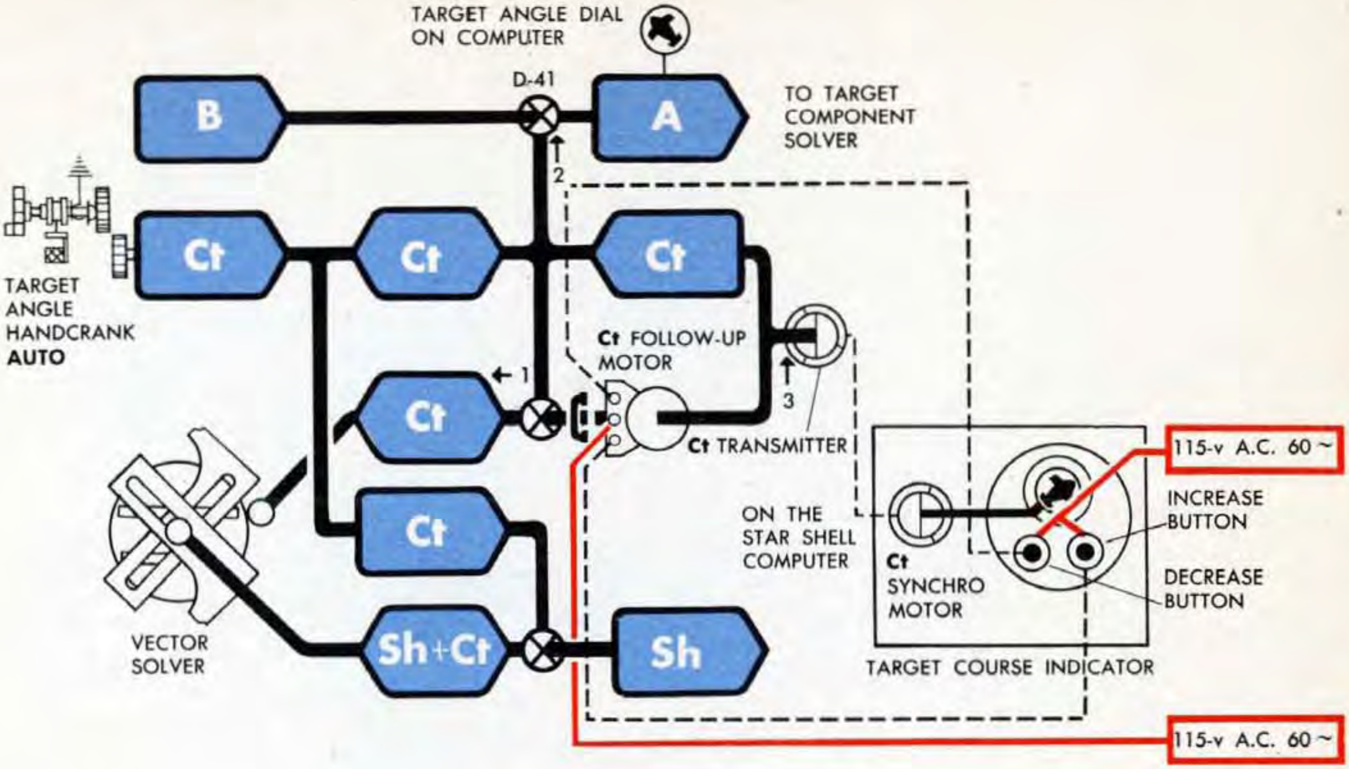
The Target Course Indicator contains a dial, a synchro motor, an INCREASE Button, and a DECREASE Button. Target Course, *Ct*, is read on the graduated index plate, opposite the bow of the Target on the dial.

The INCREASE and DECREASE Buttons on the Target Course Indicator are connected electrically through relays to the *Ct* Follow-up Motor in the Rate Control Group in the Computer. When the INCREASE Button is depressed and the Target Speed and Target Angle Handcranks are at AUTO, the *Ct* Follow-up Motor is energized and drives in the direction *to increase the value of Ct in the Computer.*



When the DECREASE Button is depressed, the *Ct* Follow-up Motor is energized to drive in the *opposite* direction, *decreasing the value of Ct in the Computer.*





A single-speed transmitter is connected to the *Ct* shaft line. Whenever the *Ct* Follow-up Motor drives, the increase or decrease in *Ct* repositions the rotor of the *Ct* Transmitter. This *Ct* Transmitter is connected electrically to the synchro motor in the Target Course Indicator.

As soon as the rotor of the *Ct* Transmitter is moved to a new position, the increase or decrease in the value of *Ct* is transmitted to the synchro motor in the Target Course Indicator. The rotor moves to a new position corresponding to the new position of the *Ct* Transmitter. Since the dial of the Target Course Indicator is attached to the synchro rotor, the dial is moved to the new position and the value of *Ct* in the Computer can always be read on the Target Course Indicator Dial.

The Computer Operators can correct Target Course, *Ct*, in the Computer by pressing the INCREASE or DECREASE Button on the Target Course Indicator. These buttons operate relays which control the direction of rotation of the *Ct* Follow-up Motor. As long as either button is depressed, the *Ct* Follow-up Motor will drive new values of *Ct* to three mechanisms:

1. To the Vector Solver, repositioning the vector gear.
2. To differential D-41 where *Ct* is subtracted from $B + 180°$, giving a corrected value of *A*.
3. To the *Ct* Transmitter, to be transmitted back to the Target Course Indicator.

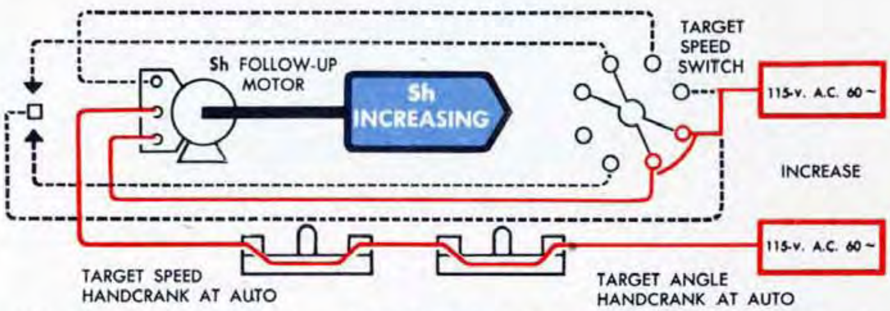
The TARGET SPEED SWITCH

This is the Target Speed Switch. It is located on the top of the Computer Mark 1 at the front left corner.

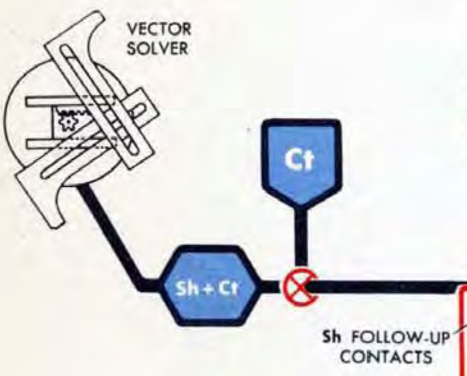
The Target Speed Switch has two uses:

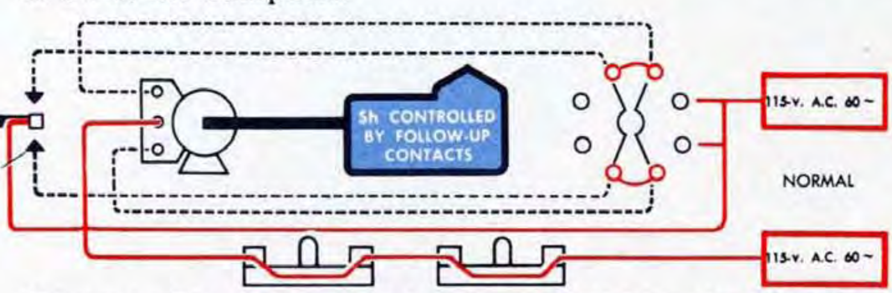
1. It can be used instead of the Target Speed Handcrank for putting initial or corrective values of *Sh* into the Computer quickly.
2. It can be used to run *Sh* to zero in preparing the Computer for a dive attack.

The Target Speed Switch energizes the *Sh* Follow-up Motor only when both the Target Speed and Target Angle Handcranks are at AUTO. The Switch has three positions: INCREASE, DIVE ATTACK, and NORMAL.

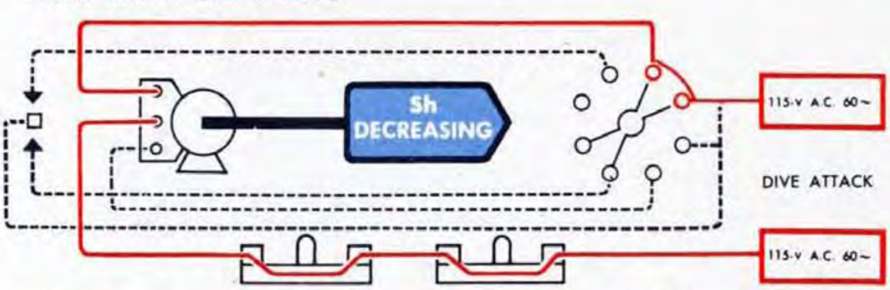


When the Target Speed Switch is held at INCREASE, the *Sh* Follow-up Motor drives in the direction to *increase* the value of *Sh* in the Computer.





When the Target Speed Switch is at NORMAL, the *Sh* Follow-up Motor is energized by the follow-up contacts on the *Sh* line from the Vector Solver.

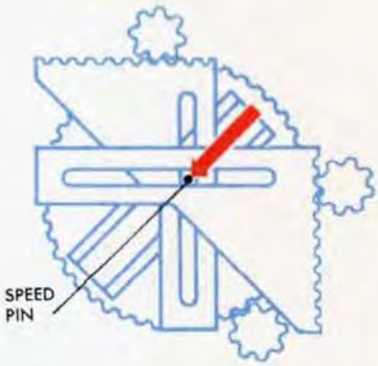


When the Target Speed Switch is at DIVE ATTACK, the *Sh* Follow-up Motor drives in the direction to *decrease* the value of *Sh* in the Computer.

A detent holds the switch at DIVE ATTACK, allowing the Operator to shift the Range Rate/Diving Speed Handcrank to HAND and crank in DIVING SPEED while *Sh* is running to zero.

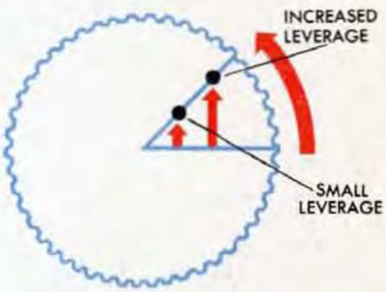
Making large changes in **target speed**

To put a large change of Target Speed into the Computer quickly, the Computer Operator holds the Target Speed Switch at INCREASE or DIVE ATTACK and watches the Target Speed Counter until the desired value appears. Holding the switch at DIVE ATTACK will rapidly *decrease* the Target Speed value, and holding the switch at INCREASE will rapidly *increase* the Target Speed value in the Computer.

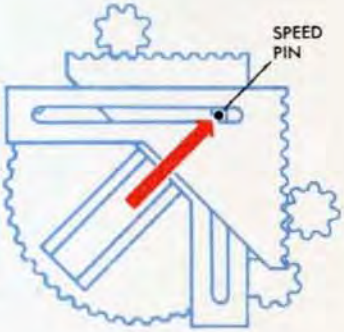


Making large changes in **target angle**

When a large change in Target Angle is reported, the Computer Operator shifts the lever of the Target Angle Handcrank to HAND and sets the new value of Target Angle onto the Target Dial. If a large change occurs in Target Angle but is not reported and set in by hand, the Vector Solver input racks will attempt to move the vector gear to its new position. Under these circumstances the racks may push the speed pin to the center of the vector gear instead of rotating the vector gear. With the speed pin at or near the center of the vector gear, the Vector Solver racks cannot turn the vector gear because the leverage is too small.

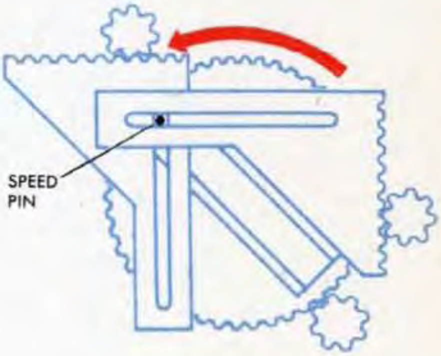


Assisting the vector solver when the speed pin runs to the center



When the speed pin in the Vector Solver runs to the center of the vector gear, the Computer Operator holds the Target Speed Switch at INCREASE. This increases the value of Target Speed in the Computer, running the speed pin away from the center of the vector gear, and holding it there, until the racks can turn the vector gear to its correct position.

If the position of the vector gear is 180° in error, it will be necessary to rotate the vector gear by turning the Target Angle Handcrank until the Vector Solver racks are again able to position the vector gear.



Dive attack

When preparing the Computer for Special Dive Attack Procedure, the Target Speed Switch is held at DIVE ATTACK until the value of *Sh* is zero.

THE CONTROL SWITCH

This is the Control Switch. It is located on the top of the Computer Mark 1 at the front righthand corner.

The Control Switch controls the electrical circuits to these mechanisms:

The *jE* Follow-up

The *jBr* Follow-up

The *jE* Clutch and Lock

The *jBr* Clutch and Lock

The two *B'r* Follow-up Motors

The Control Switch has three positions: AUTO, SEMI-AUTO and LOCAL.

Control Switch at AUTO

When the Control Switch is turned to AUTO and the Target Speed Handcrank is at AUTO, for Automatic Rate Control, these electrical connections are made:

1. The *jE* and *jBr* Follow-ups are connected to the power supply.
2. The *jE* Clutch can be energized by the Pointer's Signal Key.
3. The *jBr* Clutch can be energized by the Trainer's Signal Key.
4. The Director Train Receiver is connected to the power supply and the Director Train Receiver contacts control the two *B'r* Follow-up Motors.
5. The *jE* and *jBr* locks are de-energized and spring open, allowing the *jE* and *jBr* Follow-ups to drive their lines.

The Pointer's Signal Key

Whenever the Pointer's Signal Key is depressed, the Pointer's Signal at the Computer is energized and the signal changes from black to red. With the Control Switch at AUTO and the Target Speed Handcrank at AUTO, depressing the Pointer's Signal Key also energizes and engages the *jE* Clutch.

The Trainer's Signal Key

Whenever the Trainer's Signal Key is depressed, the Trainer's Signal at the Computer is energized and the signal changes from black to red. With the Control Switch at AUTO and the Target Speed Handcrank at AUTO, depressing the Trainer's Signal Key also energizes and engages the *jBr* Clutch.

Control Switch at SEMI-AUTO

When the Control Switch is turned from AUTO to SEMI-AUTO, for Semi-automatic and Manual Rate Control, these electrical changes are made:

1 The *jE* and *jBr* Follow-ups are disconnected from the power supply.

2 The *jE* Clutch can no longer be energized by the Pointer's Signal Key.

3 The *jBr* Clutch can no longer be energized by the Trainer's Signal Key.

4 The Director Train Receiver remains connected to the power supply and still controls the contacts of the two *B'r* Follow-up Motors.

5 The *jE* and *jBr* Locks are connected to the power supply.

When the *jE* and *jBr* Locks are energized, the jaws engage and lock the shaft lines from the *jE* and *jBr* Follow-up Motors.

Control Switch at LOCAL

When the Control Switch is turned from SEMI-AUTO to LOCAL, for Local Control, these electrical changes are made:

1 The Director Train Receiver is disconnected from the power supply.

2 The Local Control Contacts are connected to the power supply and control the two *B'r* Follow-up Motors.

The *jE* and *jBr* Locks remain energized and locked.

The RANGE RATE CONTROL SWITCH

This is the Range Rate Control Switch. It is located on top of the Computer Mark 1, to the left of the Range Dials.

The Range Rate Control Switch controls the electrical circuits to the *jdR* Motor and the *jdR* Clutch. The *jdR* Motor is the Range Receiver servo.

The switch has two positions: AUTO and MANUAL

AUTO is used for Automatic Range Rate Control.

MANUAL is used for Semi-automatic and Manual Rate Control and for Local Control.

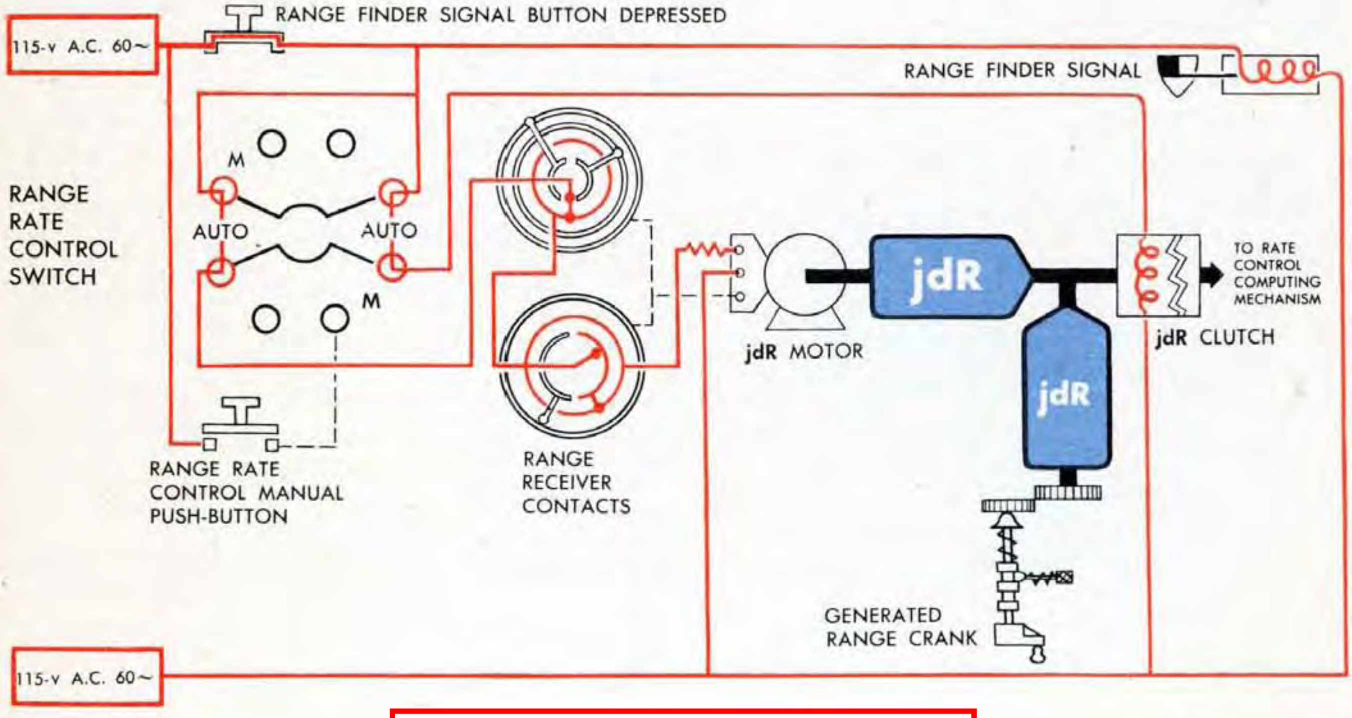
When the RANGE RATE CONTROL SWITCH is turned to AUTO

When the Range Rate Control Switch is turned to AUTO, two electrical circuits are completed whenever the Range Operator has his signal button depressed.

1 The Range Receiver contacts are connected to the power supply.

2 The *jdR* Clutch is connected to the power supply and is therefore engaged.

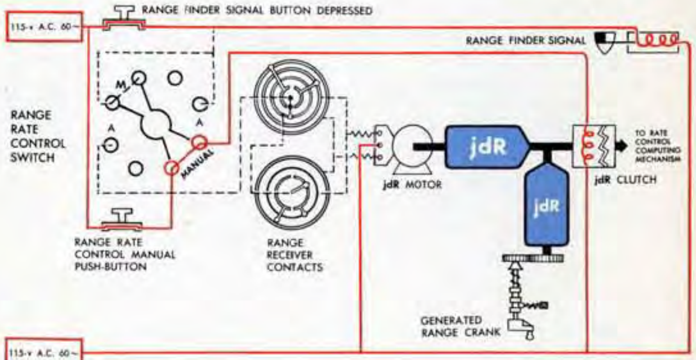
Whenever the Range Operator depresses his signal button, the Range Finder Signal near the Range Dials changes from black to white.

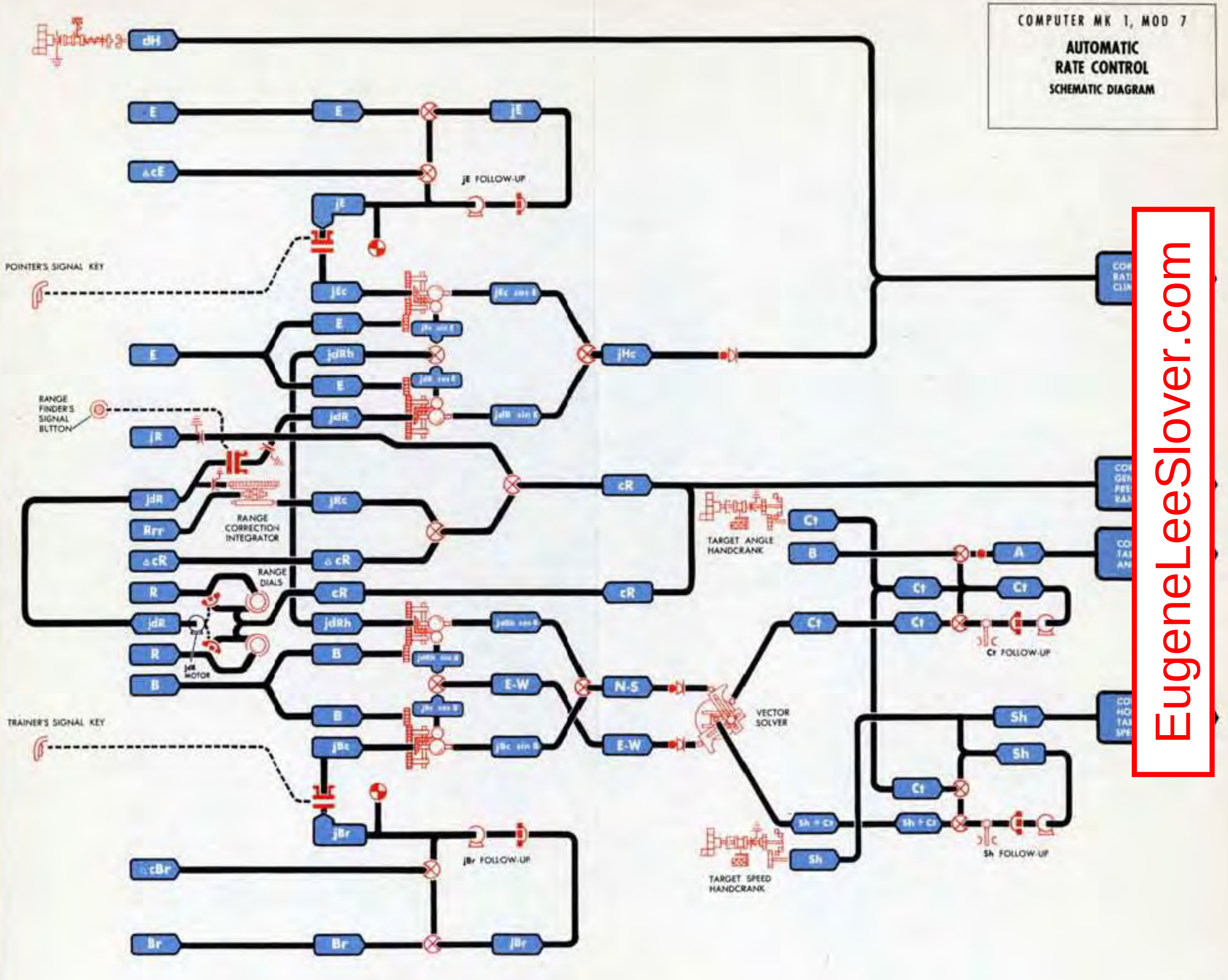


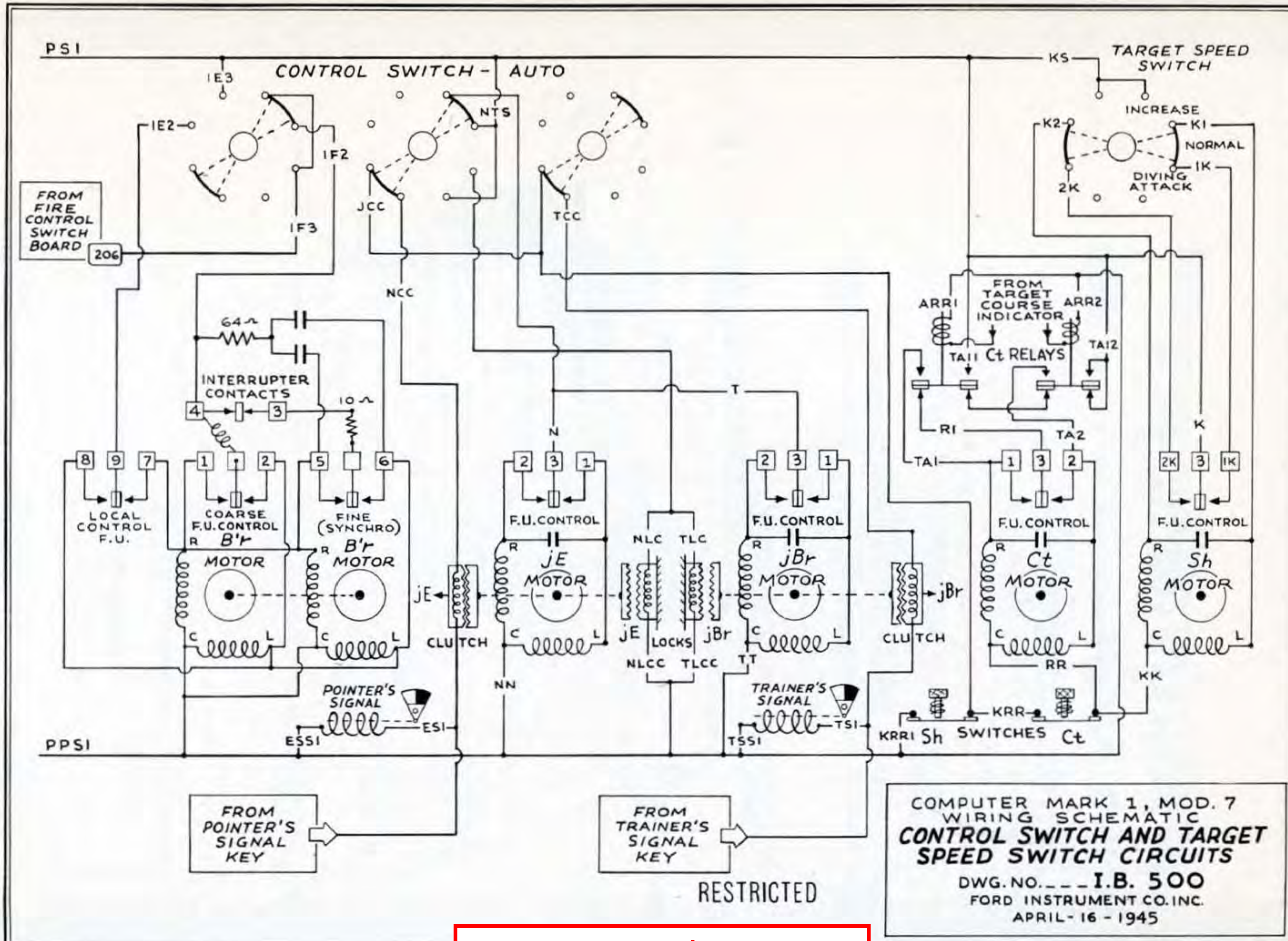
When the RANGE RATE CONTROL SWITCH is turned to MANUAL

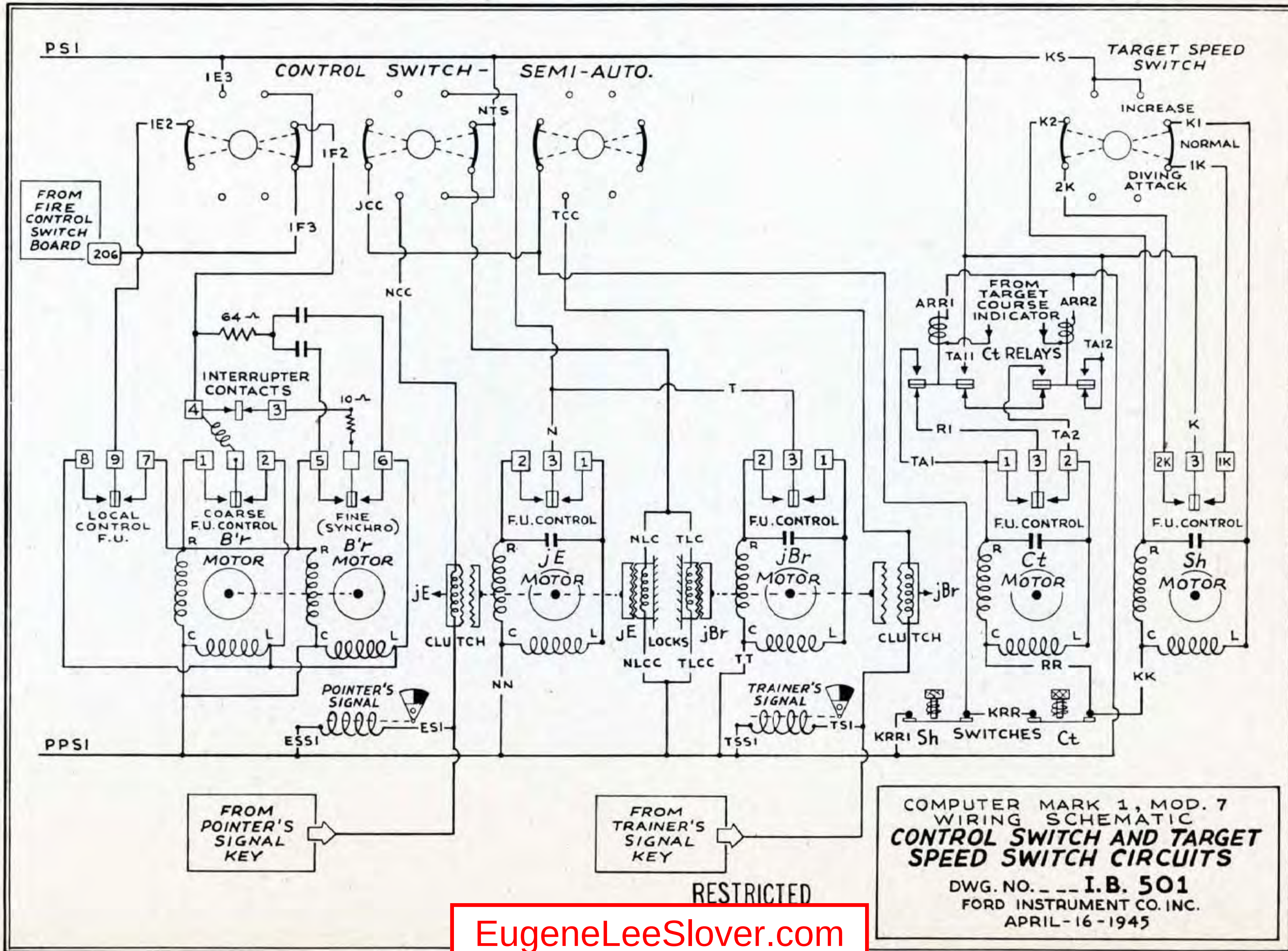
When the Range Rate Control Switch is turned to MANUAL and the Range Rate Control Manual Push-button is depressed, the circuit to the *jdR* Clutch is completed, engaging the clutch. When the clutch is engaged, *jdR* Rate Corrections can be put into the Computer by hand, by turning the Generated Range Crank in its IN position.

The circuit to the Range Finder Signal is completed whenever the Range Finder Signal Button is depressed.

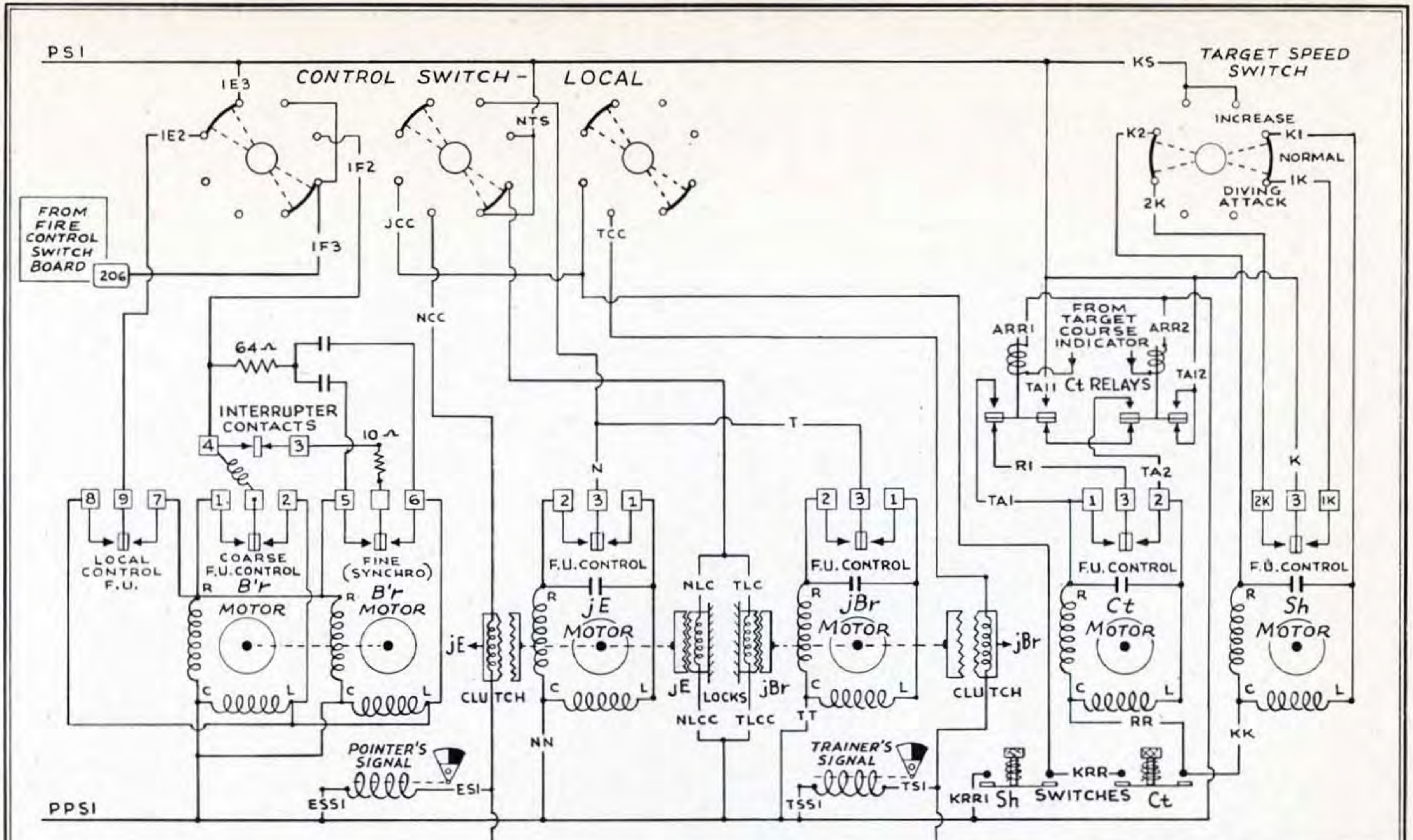





PSI
CONTROL SWITCH - AUTO
TARGET SPEED SWITCH
KS
INCREASE
NORMAL
DIVING ATTACK
K1
K2
1K
2K
1E3
1E2
1F2
1F3
NTS
JCC
TCC
NCC
FROM FIRE CONTROL SWITCH BOARD
206
64 ~
10 ~
INTERRUPTER CONTACTS
FROM TARGET COURSE INDICATOR
ARR1
ARR2
TA11
Ct RELAYS
TA12
R1
TA2
TA1
N
T
K
LOCAL CONTROL F.U.
COARSE F.U. CONTROL B'r
FINE (SYNCHRO) B'r
MOTOR
MOTOR
F.U. CONTROL
jE MOTOR
NLC
TLC
F.U. CONTROL
jBr MOTOR
F.U. CONTROL
Ct MOTOR
F.U. CONTROL
Sh MOTOR
jE
CLUTCH
jE
LOCKS
jBr
NLCC
TLCC
jBr
CLUTCH
NN
TT
RR
KK
POINTER'S SIGNAL
ESSI
ESI
TRAINER'S SIGNAL
TSSI
TSI
KRR1
Sh
KRR
SWITCHES
Ct
PPSI
FROM POINTER'S SIGNAL KEY
FROM TRAINER'S SIGNAL KEY
RESTRICTED
COMPUTER MARK 1, MOD. 7
WIRING SCHEMATIC
CONTROL SWITCH AND TARGET SPEED SWITCH CIRCUITS
DWG. NO.___ I.B. 500
FORD INSTRUMENT CO. INC.
APRIL - 16 - 1945


PSI
CONTROL SWITCH - SEMI-AUTO.
TARGET SPEED SWITCH
KS
INCREASE
NORMAL
DIVING ATTACK
K2
K1
2K
1K
1E3
1E2
1F2
1F3
NTS
JCC
TCC
NCC
FROM FIRE CONTROL SWITCH BOARD
206
64 Ω
INTERRUPTER CONTACTS
10 Ω
FROM TARGET COURSE INDICATOR
ARR1
ARR2
TA11
Ct RELAYS
TA12
R1
TA2
TA1
T
N
K
LOCAL CONTROL F.U.
COARSE F.U. CONTROL
FINE (SYNCHRO)
B'r MOTOR
B'r MOTOR
F.U. CONTROL
jE MOTOR
jBr MOTOR
Ct MOTOR
Sh MOTOR
CLUTCH
jE
jBr
NLC
TLC
LOCKS
NLCC
TLCC
TT
NN
RR
KK
POINTER'S SIGNAL
TRAINER'S SIGNAL
ESI
ESSI
TSI
TSSI
KRR1
Sh
SWITCHES
KRR
Ct
PPSI
FROM POINTER'S SIGNAL KEY
FROM TRAINER'S SIGNAL KEY
COMPUTER MARK 1, MOD. 7
WIRING SCHEMATIC
CONTROL SWITCH AND TARGET SPEED SWITCH CIRCUITS
DWG. NO. I.B. 501
FORD INSTRUMENT CO. INC.
APRIL-16-1945

RESTRICTED



COMPUTER MARK 1, MOD. 7
WIRING SCHEMATIC
CONTROL SWITCH AND TARGET SPEED SWITCH CIRCUITS
DWG. NO. --- I.B. 502
FORD INSTRUMENT CO. INC.
APRIL-16-1945

RESTRICTED

THE PREDICTION SECTION

If projectiles could travel in a straight line at the impossible speed of several thousand miles per second, a Prediction Section would not be needed. The guns could be aimed and fired directly at any moving target.

But projectiles neither travel in a straight line, nor at several thousand miles per second. Even at the short range of 3000 yards, the projectile of a 5-inch gun takes about 4½ seconds to reach the Target. During the 4½ seconds, an air target traveling at 300 knots could have moved more than 700 yards, well out of danger of the burst of the projectile.

The Prediction Section establishes a Line of Fire along which the guns must point in order for the projectiles to hit the moving Target, and a fuze setting time such that the projectiles will burst close to the Target.

The Line of Fire is established by two lead angles, one in Elevation and one in Deflection. The lead angles are the angles by which the gun must be aimed ahead of, or lead, the Target to allow for these factors:

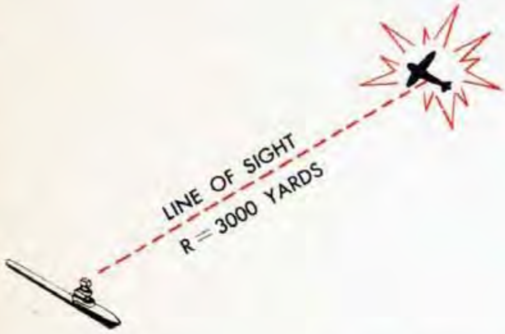
1. The movement of Target and Ship during flight of the projectile.
2. The curvature of the trajectory of the projectile due to Gravity and Drift.
3. The effect of Wind and Changes in Initial Velocity of the projectile.

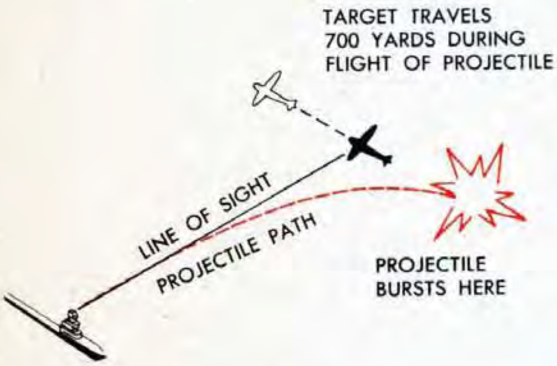
The lead angle in Elevation is called Sight Angle, *Vs*. Sight Angle, *Vs,* is the difference between the Elevation of the Line of Sight above the horizontal and the Elevation of the Line of Fire above the horizontal.

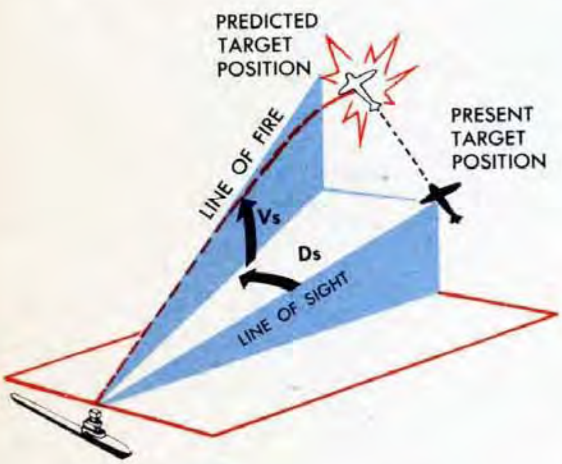
The lead angle in Deflection is called Sight Deflection, *Ds*. Sight Deflection, *Ds,* is the angle between the vertical plane through the Line of Sight and the vertical plane through the Line of Fire, measured in a slant plane.

For clarity, the slant plane in which *Ds* is measured is shown at the elevation of the Present Line of Sight. It is explained later that this slant plane is actually at a different elevation.

The computed fuze time is called Fuze Setting Order, *F*. Fuze Setting Order, *F,* is the computed time between the firing of the gun and the burst of the projectile.



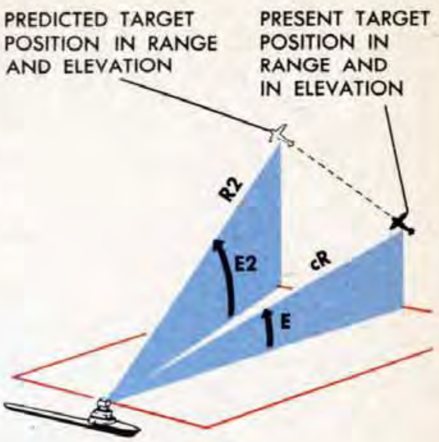




NOTE:

Several quantities in the Prediction Section contain a prime, ($'$), after the symbols, such as Rt'. A prime in the Prediction Section indicates that the computed quantity is not the true value defined by the symbols but is the symbol value plus an unwanted quantity introduced for design reasons. In each case, the unwanted quantity is removed mechanically in later computations. In all other sections of the Computer Mark 1, the presence of a prime in a symbol indicates that the quantity is measured in relation to the deck plane.

In order for the Prediction Section to compute *Vs* and *Ds*, the length of time required for the projectile to reach the Target must be computed. This quantity is called Time of Flight, *Tf*. Knowing the Time of Flight and the rates at which Range, Elevation and Bearing are changing, the changes in Range, Elevation and Bearing that take place during the Time of Flight can be computed. These changes are used to determine where the Target will be at the end of the Time of Flight. Target Position at the end of the Time of Flight is called Predicted Target Position.

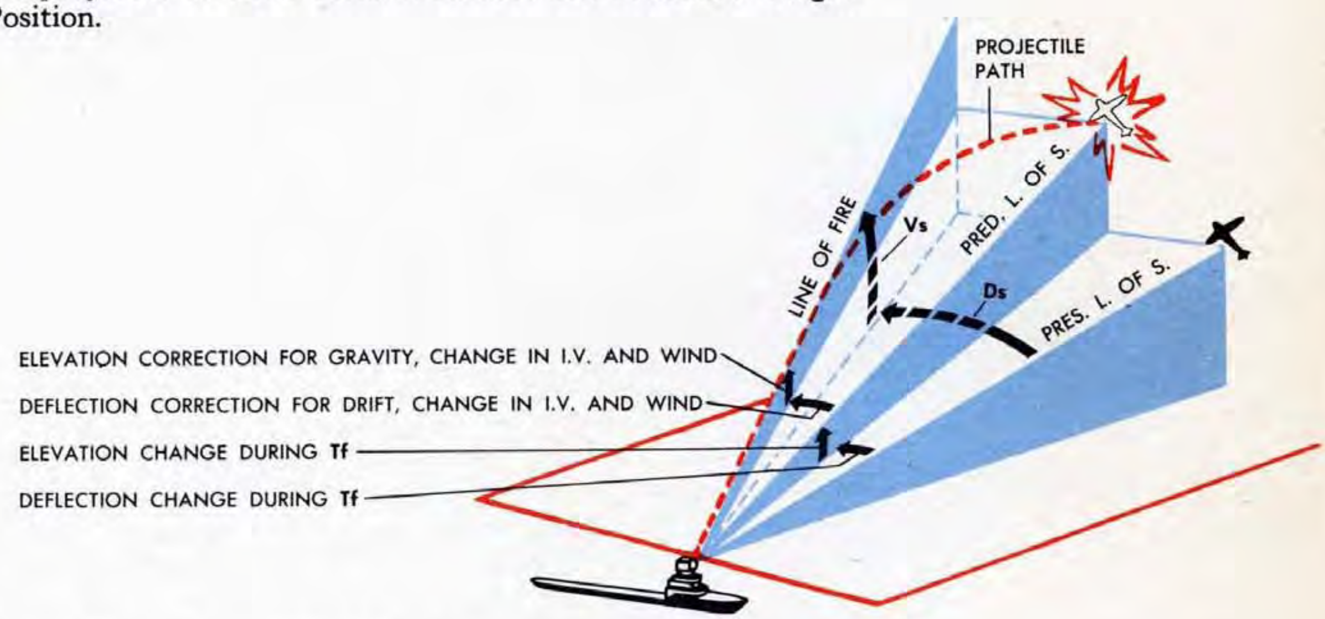


The Prediction Section performs three basic operations in computing lead angles *Vs* and *Ds* and Fuze Setting Order, *F*.

First it computes the Predicted Target Position and the Predicted Line of Sight to this predicted position. The Range to the Predicted Position is called Advance Range, *R2*. The Elevation of the Predicted Position is called Predicted Elevation, *E2*.

Second, it uses the Range and Elevation of the Predicted Target Position to compute the angles by which the Line of Fire must be offset from the Predicted Line of Sight to allow for the ballistic quantities: Gravity, Drift, Wind, and Changes in Initial Velocity of the projectiles.

Third, it uses the Range and Elevation of the Predicted Target Position to compute Fuze Setting Order, *F*, which will cause the projectile to burst when it reaches the Predicted Target Position.

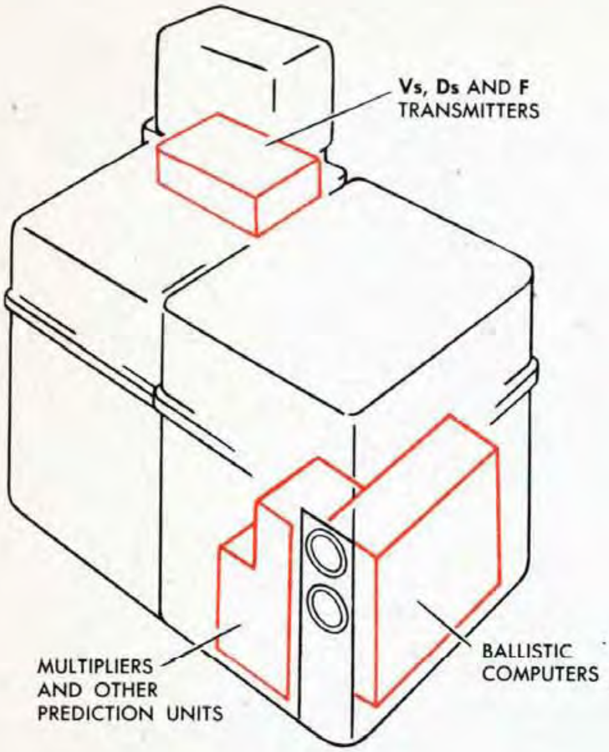


Sight Angle, *Vs*, and Sight Deflection, *Ds*, are the angles by which the Line of Fire must be offset from the Present Line of Sight to allow for all the Prediction factors.

With the guns aimed along the Line of Fire, the curved trajectory will carry the projectile *down* and *over* to the Predicted Target Position.

The Line of Fire established by *Vs* and *Ds* is established from a horizontal plane and is correct only when the deck is horizontal.

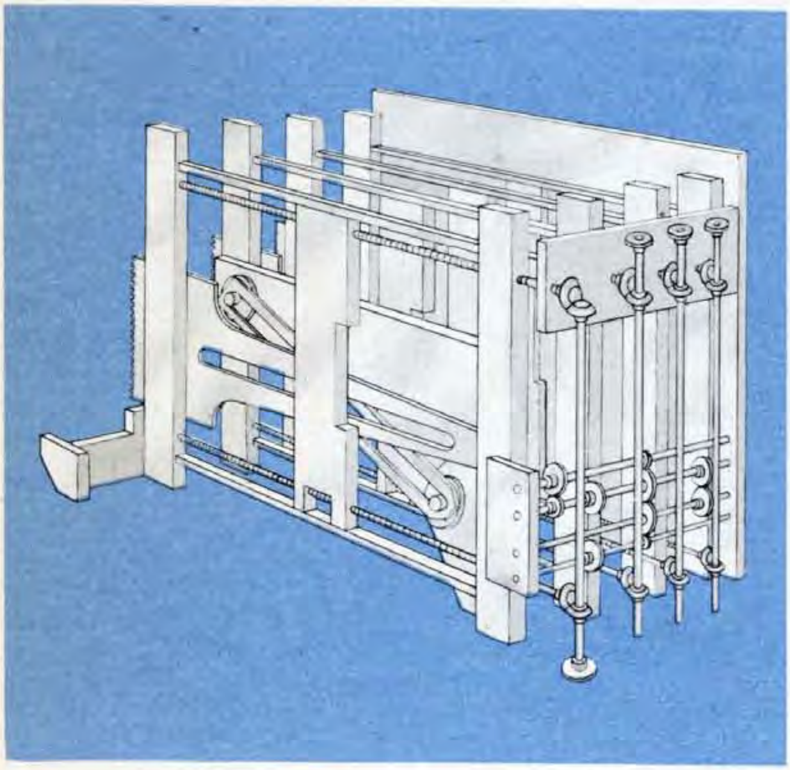
The MECHANISM in the PREDICTION SECTION



The mechanism in the Prediction Section includes: four Prediction Multipliers, four Ballistic Computers, the Range Rate Corrector, the Complementary Error Corrector, two Wind Component Solvers, five Follow-ups in addition to those in the Ballistic Computers, three Single-speed Spot Receivers, the Fuze, Sight Angle, and Sight Deflection Transmitters, and various differentials, handcranks, dials, and counters.

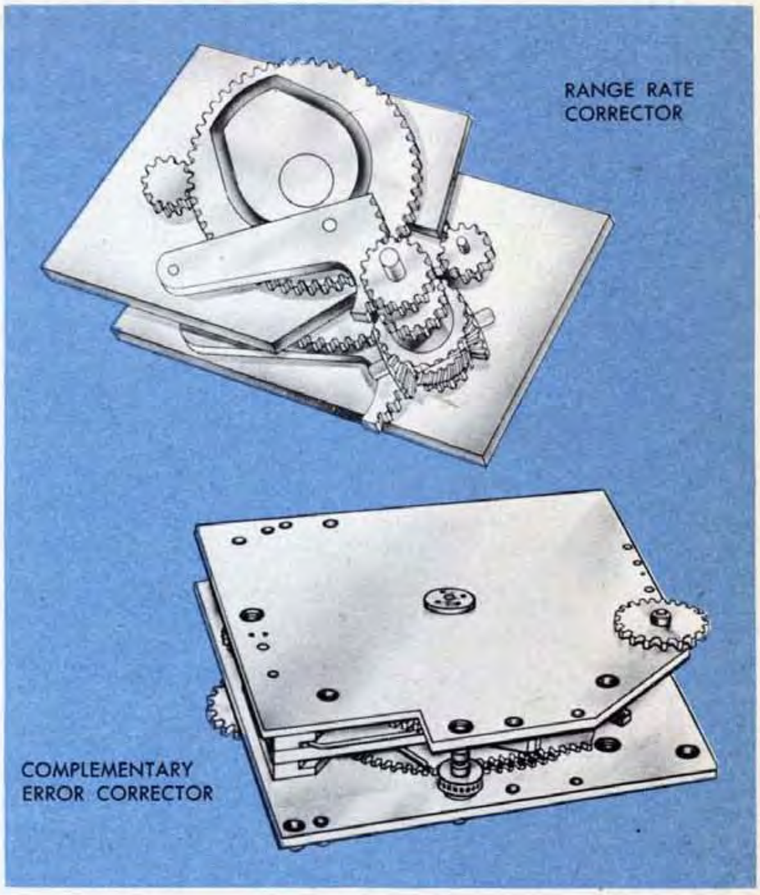
The Prediction Multipliers, Ballistic Computers, Range Rate Corrector, Complementary Error Corrector, and the Prediction Follow-ups are all located in the lower front section of the Computer Mark 1. The *Vs, Ds,* and *F* Transmitters are located in the upper rear section of the Computer.

The locations of the Wind Component Solvers and the Spot Receivers are described later in this chapter.

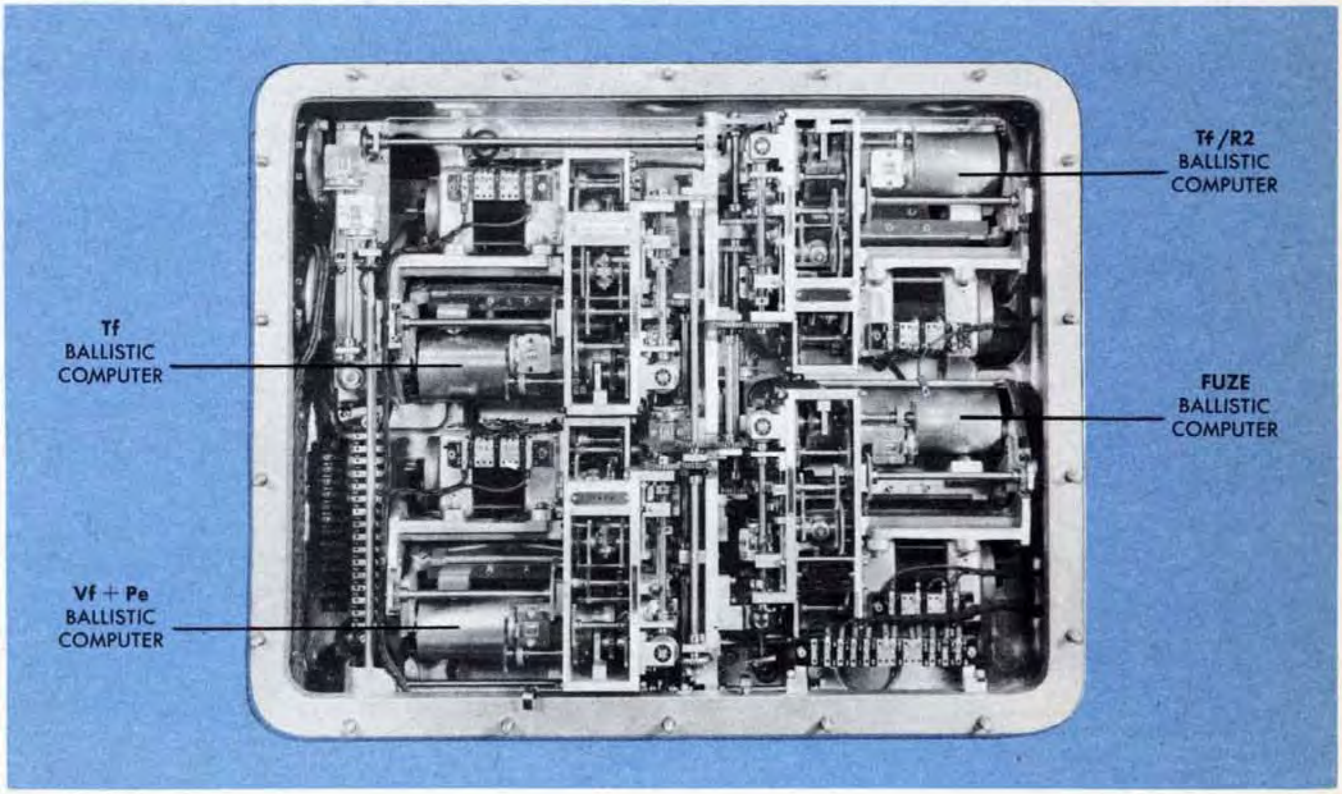


THE PREDICTION MULTIPLIERS are four screw-type multipliers assembled together in a bank. Three of these multipliers are used to compute the changes in Range, in Elevation, and in Deflection, during the Time of Flight. The fourth multiplier is used to compute the change in Range during the time between the setting of the fuze and the firing of the projectile.

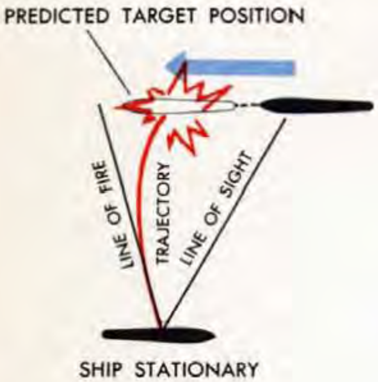
THE RANGE RATE CORRECTOR and **THE COMPLEMENTARY ERROR CORRECTOR** are double-cam computing units which compute a Range Rate Correction and an Elevation Correction respectively.



THE BALLISTIC COMPUTERS are four assemblies, each containing a barrel-type cam, a follow-up, and various shafts and gears. One ballistic computer computes each of the following quantities: Time of Flight, Tf, Time of Flight divided by Advance Range, $Tf/R2$, Superelevation plus Elevation Parallax, $Vf + Pe$, and Fuze Setting Order, F.

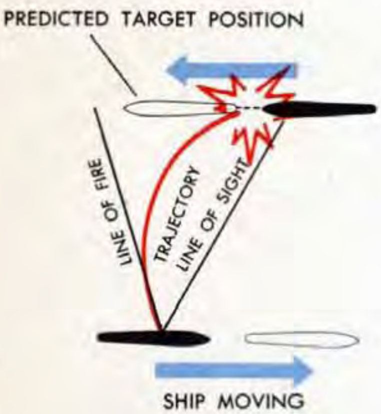


Why relative motion rates are used in prediction



While the projectile is in the air, both Target and Own Ship are moving. The motion of the Target during the Time of Flight affects the gun aim because it determines where the Target will be when the projectile arrives. The motion of Own Ship during the Time of Flight also has an effect on the gun aim, although the projectile leaves Own Ship at the beginning of the Time of Flight.

The motion of Own Ship affects the gun aim because it affects the trajectory of the projectile. *A projectile fired from a moving ship, besides moving in the direction in which the gun is pointed, also moves in the same direction and at the same speed as the ship is moving at the moment when the projectile leaves the gun.*

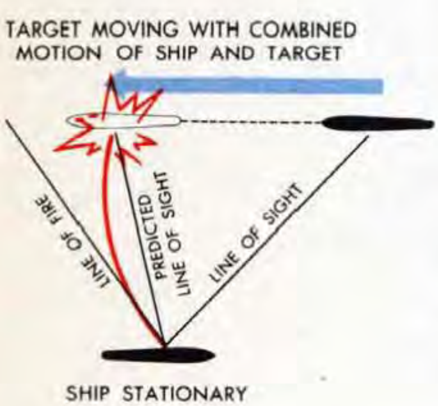


To demonstrate this fact, assume that Own Ship is stationary. A projectile is fired at a Predicted Target Position, directly abeam, and makes a hit.

Now assume that Own Ship is moving. A projectile is fired from exactly the same place, in exactly the same direction, at the same Predicted Target Position, but this time the projectile will burst behind the Predicted Target Position, because the projectile is moving in the direction and with the speed of Own Ship, in addition to the motion imparted by the firing of the gun.

If instead of Own Ship moving, Own Ship were stationary and the Target were moving with the combined velocity of the previous Ship and Target Motion, the effect on the Prediction calculations would be almost the same.

For example, here is a case in which Own Ship and Target are both moving. The Line of Fire is computed to allow for motion of the Target during the Time of Flight and the extra curvature of the trajectory due to Ship Motion.



Here Own Ship is stationary and the Target is moving with the combined velocity of Ship and Target in the previous case. The Line of Fire is almost the same as in the previous case, since the extra motion of the Target is offset by the straighter trajectory of the projectile.

Since the effect of Own Ship Motion is approximately the same as that of additional Target Motion, the Relative Motion Rates, *dR*, *RdE*, and *RdBs*, are used instead of Target Motion Rates in computing the Predicted Position of the Target. Thus the Prediction Section allows for the effect of Own Ship Motion on the trajectory by treating Own Ship Motion as if it were additional Target Motion.

Predicted target position

To obtain the change in Target Position relative to Own Ship during the Time of Flight, the three Relative Motion Rates must be multiplied by Time of Flight, *Tf*. The three products represent the approximate *linear* movement of the Target while the projectile is in flight:

1. The linear Range Rate multiplied by Time of Flight is the approximate change in Range during the Time of Flight.

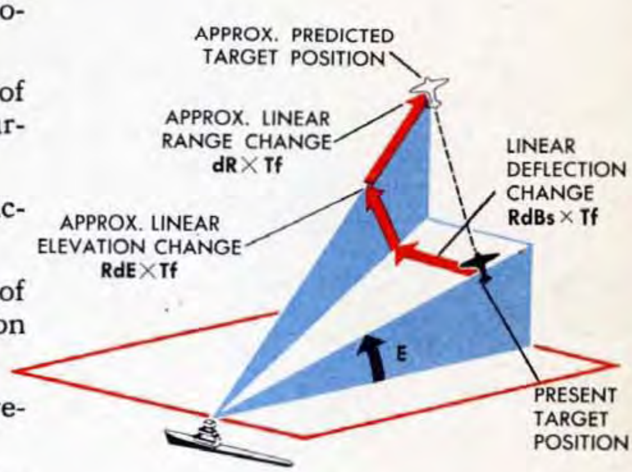
   $dR \times Tf$ = Approximate Linear Range Prediction

2. The linear Elevation Rate multiplied by Time of Flight is the approximate change in Elevation during the Time of Flight.

   $RdE \times Tf$ = Approximate Linear Elevation Prediction

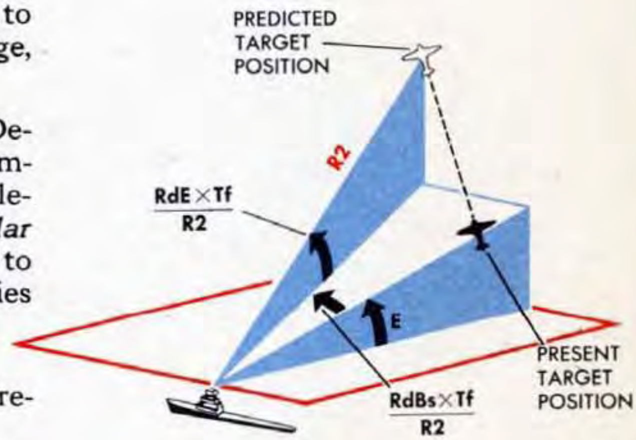
3. The linear Deflection Rate multiplied by Time of Flight is the approximate change in Deflection during the Time of Flight.

   $RdBs \times Tf$ = Approximate Linear Deflection Prediction



$dR \times Tf$, if added to Generated Present Range, *cR*, will produce an approximate value of the Range to the Predicted Target Position, called Advance Range, *R2*.

Before the Target movement in Elevation and Deflection during the Time of Flight can be used in computing the lead angles, the *linear* predictions in Elevation and Deflection must be converted into *angular* predictions. The linear quantities are converted to angular quantities by dividing the linear quantities by Advance Range, *R2*.

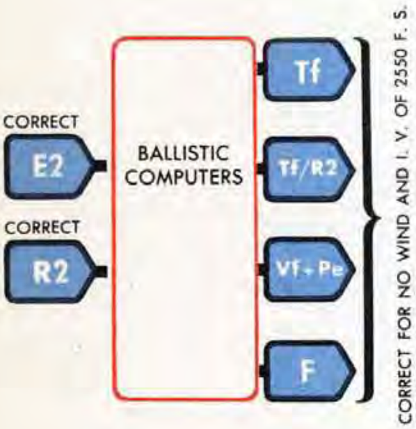


$\frac{RdE \times Tf}{R2}$ is an approximate *Angular* Elevation Prediction. The quantity $\frac{RdE \times Tf}{R2}$ is added to Target Elevation, *E*, to produce an approximate value of the Elevation of the Predicted Target Position, called Predicted Target Elevation, *E2*.

The Angular Deflection Prediction is computed by the same method. $\frac{RdBs \times Tf}{R2}$ is an approximate Angular Deflection Prediction. The quantity $\frac{RdBs \times Tf}{R2}$ is used in computing Sight Deflection, *Ds*.

PREDICTED TARGET POSITION

Approximate values of Predicted Target Position in Range, Elevation, and Deflection are computed by multiplying the three Relative Motion Rates by *Tf* or *Tf/R2*. Since the change of position in two of the three directions is affected by motion in the other directions, corrections must be made to the approximate values of Predicted Target Position to make them accurate. The Range Prediction must be corrected for the effect of the Elevation and Deflection Predictions, and the Elevation Prediction must be corrected for the effect of the Deflection Prediction. When these corrections have been made, accurate values of *R2* and *E2* are obtained.

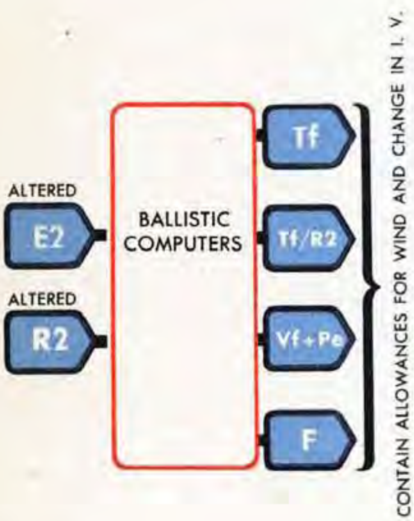


The accurate values of *R2* and *E2* are used as inputs to the ballistic computers which compute the ballistic quantities: Time of Flight, *Tf*, Time of Flight divided by Advance Range, *Tf/R2*, Superelevation plus Elevation Parallax, *Vf + Pe*, and Fuze Setting Order, *F*. The barrel cams in the ballistic computers are cut in such a way that the output values of *Tf*, *Tf/R2*, *Vf + Pe*, and *F* correspond to the particular combination of values of *R2* and *E2* going into the ballistic computers, that is, *the ballistic values are related to the Predicted Target Position.*

The ballistic values on the cams do not make allowances for Wind or for changes in the Initial Velocity of the projectile, although both these factors change the trajectory of the projectile.

To correct the outputs from the ballistic computers for Wind and Initial Velocity, alterations are made to the cam inputs, *R2* and *E2*.

The Computer Mark 1 computes an imaginary Predicted Target Position such that the trajectory computed using the *R2* and *E2* of this *imaginary* Predicted Target Position will place the shells at the *actual* Predicted Target Position.



Using the *R2* and *E2* of this imaginary Predicted Target Position as inputs to the ballistic computers, ballistic predictions are computed which are combined with the values of the Imaginary Target Position to establish a Line of Fire *which allows for motion of Ship and Target during the Time of Flight and also for Wind and changes in Initial Velocity.*

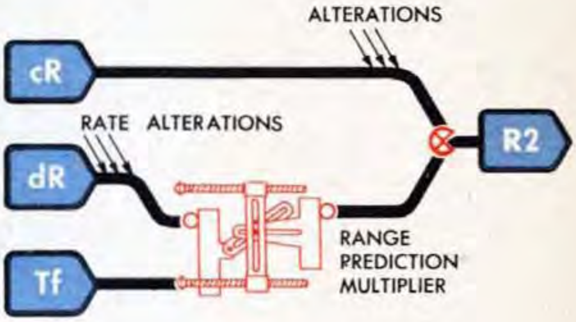
The Prediction Multipliers

Both in correcting the approximate values of Predicted Target Position to make them accurate and in altering the accurate Predicted Target Position values to allow for Wind and changes in Initial Velocity, the values needed depend on the length of the Time of Flight.

Since both the rates and the correction and alteration quantities must be multiplied by the same *Tf* or *Tf/R2*, they are combined and fed into the same set of multipliers. This avoids using separate multipliers for the modifying quantities alone. In this way each rate and the quantities used in correcting and altering it are multiplied by *Tf* or *Tf/R2* in one multiplier.

Range prediction

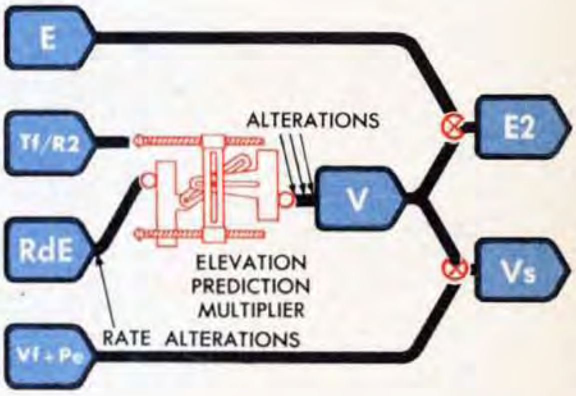
Direct Range Rate, *dR*, altered by three additional quantities, is one input to the Range Prediction Multiplier. Time of Flight, *Tf*, is the other input. Generated Present Range, *cR*, is altered by three linear quantities. The altered *cR* is added to the output of the Range Prediction Multiplier in a differential. The output of the differential is Advance Range, *R2*, containing allowances for Wind and changes in Initial Velocity.



Elevation prediction

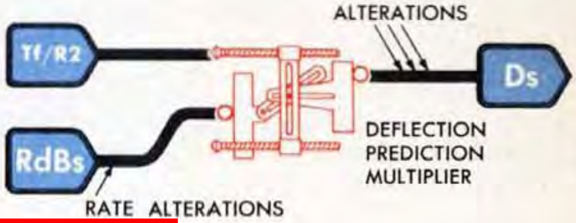
Elevation Rate, *RdE*, altered by one additional quantity is one input to the Elevation Prediction Multiplier. *Tf/R2* is the other input. The multiplier output is altered by three linear quantities to obtain Elevation Prediction, *V*.

Elevation Prediction, *V*, plus Present Target Elevation, *E*, is Predicted Target Elevation, *E2*. *V* plus one quantity to allow for Superelevation and Vertical Parallax is Sight Angle, *Vs*. Both *E2* and *Vs* contain allowances for Wind and changes in Initial Velocity.



Deflection prediction

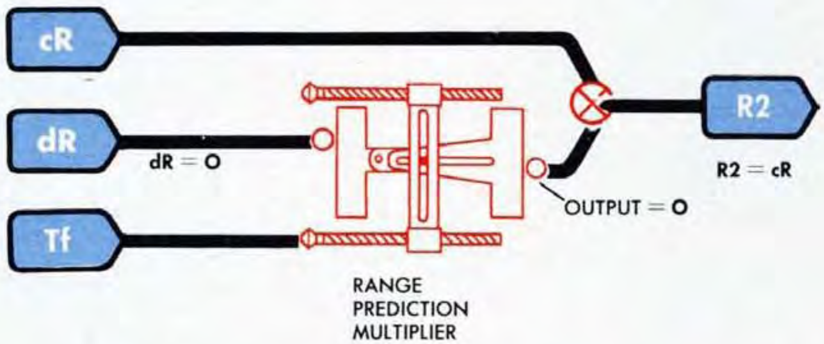
Deflection Rate, *RdBs*, altered by one additional quantity, is one input to the Deflection Prediction Multiplier. *Tf/R2* is the other input. The multiplier output is altered by three additional quantities to obtain an accurate value of Sight Deflection Angle, *Ds*, which contains allowances for Wind and changes in Initial Velocity.



Regeneration

In describing the computation of the predicted values of Range, Elevation, and Bearing, it has been assumed so far that the value of Time of Flight, *Tf*, is known. Actually the value of *Tf*, like that of several other quantities in the Prediction Section, depends on the values of *R2* and *E2*. All of these quantities, including *Tf*, are computed at the same time as *R2* and *E2*, by a method called *Regeneration*.

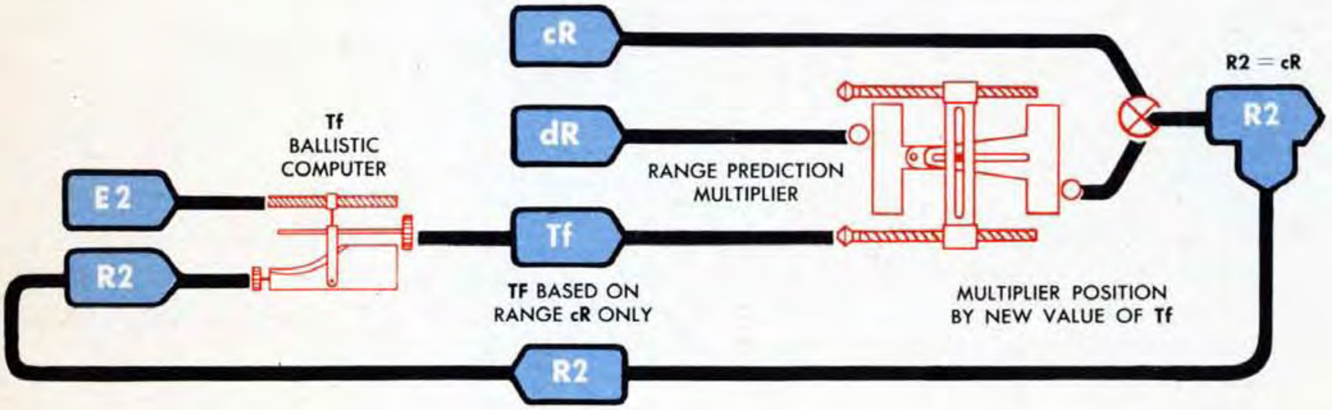
Regeneration is the use of an output from a network as an input to the same network. A study of the regeneration of *R2* in a simplified Range Prediction network will show how this is done.



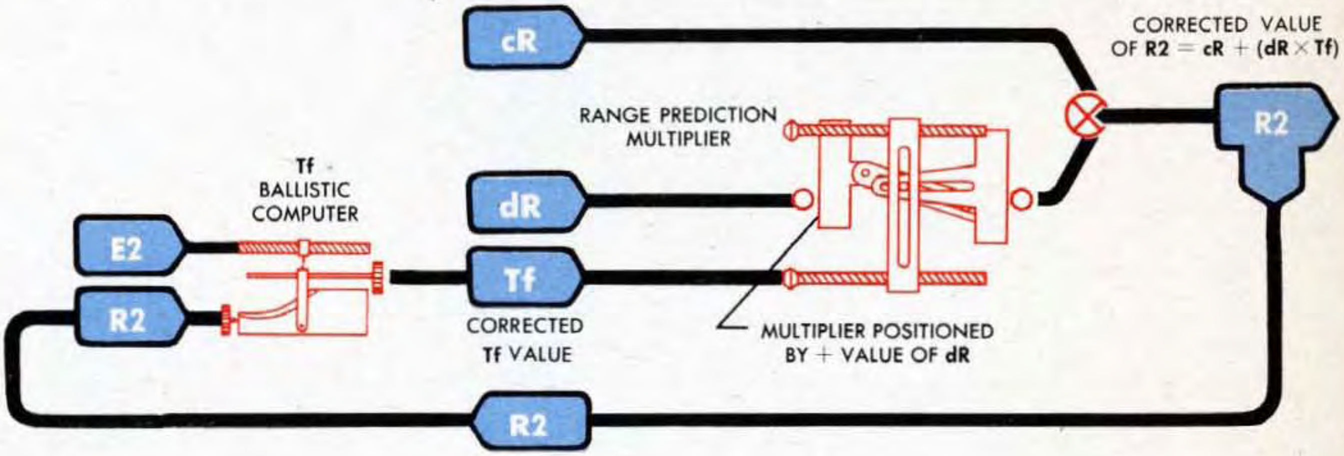
If the Direct Range Rate, *dR*, is zero, the output from the multiplier is also zero, and the value of the *R2* output from the network will be equal to *cR*.

This *R2* value is now fed back to become an input to the *Tf* Ballistic Computer. This *R2*, together with a value of *E2*, produces a value of *Tf* corresponding to this Range.

The new value of *Tf* positions the lead screw input of the Range Prediction Multiplier.



If Direct Range Rate, *dR*, now changes from zero to a positive value, this value of *dR* will be multiplied by the *Tf* value in the multiplier. The multiplier output will change the *R2* value, causing a small change in *Tf*. This change in *Tf* will cause a small additional change in *R2*. Both *R2* and *Tf* continue to change in value until the *Tf* value change is too small to affect the *R2* value. The *Tf* value then becomes the true value for the *R2* on the output line.



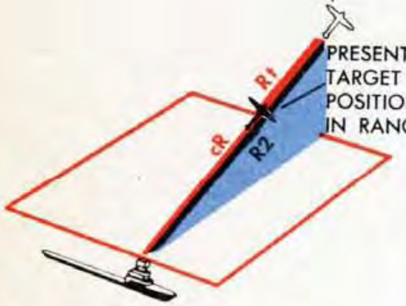
The whole regeneration process takes place almost instantly.

The following description covers the calculation of *R2* and *E2* for 2550 f.s. Initial Velocity and zero Wind. The way in which the Computer Mark 1 allows for changes in *I.V.* and effects of Wind by altering *R2* and *E2* will be described at the end of this chapter.

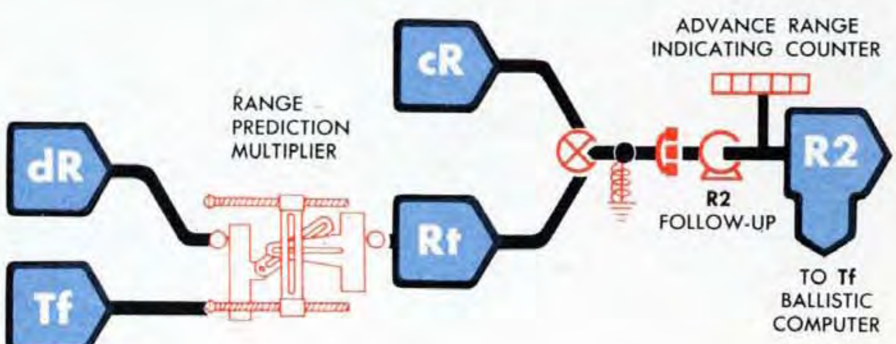
COMPUTING ADVANCE RANGE, R2

Three computing mechanisms are used in the *R2* network. They are: the Range Prediction Multiplier, the *Tf* Ballistic Computer, and the Range Rate Corrector.

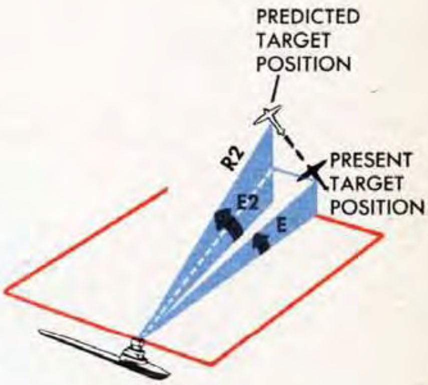
The range prediction multiplier



Direct Range Rate, *dR*, plus an additional rate to allow for the effect of the Elevation and Deflection Predictions on Range, is one input to the Range Prediction Multiplier. Time of Flight, *Tf*, from the *Tf* Ballistic Computer is the other input. The multiplier output is *Rt*. *Rt* is the Range change to compensate for the relative movement of Target and Own Ship during Time of Flight. *Rt* is added to Generated Present Range, *cR*, to obtain Advance Range, *R2*. This value of *R2* is the accurate Advance Range for 2550 *I.V.* and zero Wind. *R2* is amplified by a velocity-lag follow-up. A branch of the *R2* line feeds back to become an input to the *Tf* Ballistic Computer.

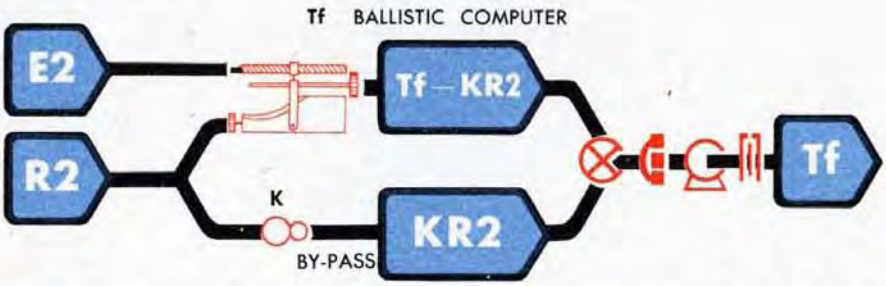


The Tf ballistic computer



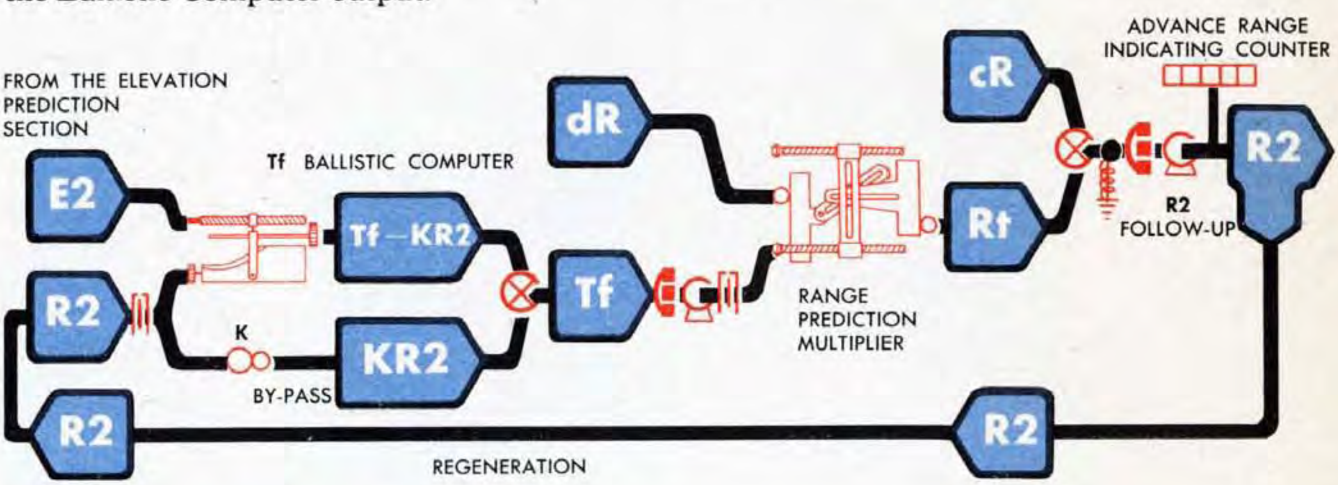
The two inputs to the Tf Ballistic Computer are Advance Range, $R2$, and Predicted Target Elevation, $E2$.

$R2$ turns the ballistic cam. $E2$ moves the cam follower along the cam. The cam output is not the true value of Tf but is the difference between the true value and a straight-line approximation of Tf. The straight-line approximation is called $KR2$. The output of the cam is therefore $Tf - KR2$.



A branch of the $R2$ line by-passes the Tf cam in the Tf Ballistic Computer. A gear ratio is used on this branch line to multiply $R2$ by a constant to obtain the quantity $KR2$, which is the straight-line approximation of Time of Flight. $KR2$ is added to the cam output, $Tf - KR2$, in a differential. The differential output is Tf.

The Tf Ballistic Computer contains a velocity-lag follow-up to increase the torque on the Tf line. The follow-up output is Tf, the Ballistic Computer output.

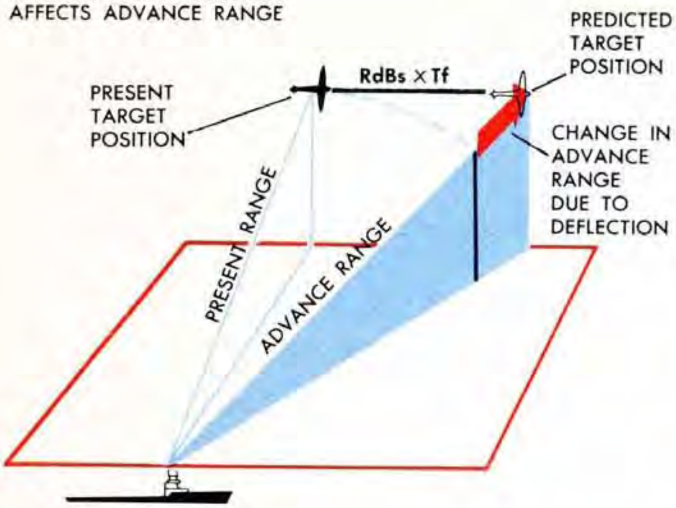


The range rate corrector

The quantity added to Range Rate, dR, to allow for the effect of Elevation and Deflection during the Time of Flight is computed in the Range Rate Corrector. This unit and the quantity it computes are described on the following page.

How Target Deflection and Elevation affect Advance Range

HOW TARGET DEFLECTION AFFECTS ADVANCE RANGE

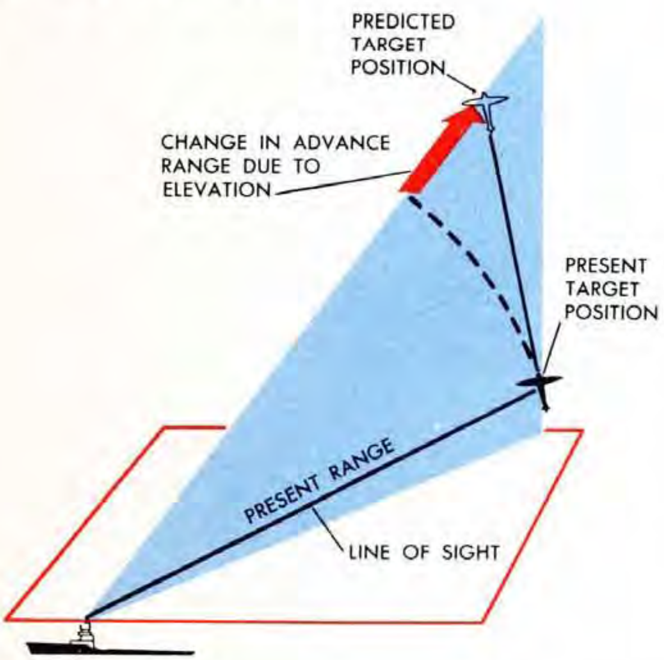


During the time of flight of a projectile, the linear Deflection and Elevation of the Target cause linear changes in Advance Range. This can be shown by studying the movement of a Target during the Time of Flight, beginning at an instant when Direct Range Rate, *dR*, is zero. Remember that the Computer Mark 1 assumes the Target is traveling a straight course.

How target deflection affects range

Direct Range Rate, *dR*, is zero when Target Angle, *A*, is exactly 90 degrees. If *A* is 90° and the Target travels horizontally at right angles to the Line of Sight, Range to a Target traveling a straight course increases during the Time of Flight by an amount represented by the red arrow.

HOW TARGET ELEVATION AFFECTS ADVANCE RANGE



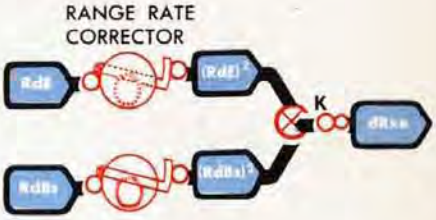
How target elevation affects range

Suppose that at the beginning of the Time of Flight the Target is climbing at right angles to the Line of Sight in the vertical plane through the Line of Sight. Range Rate, *dR*, is zero. As the Target flies to its Predicted Position during the Time of Flight, Range increases by an amount represented by the red arrow.

The total linear correction to Range caused by Target Elevation and Deflection during the Time of Flight is the sum of changes represented by the two red arrows.

Computing the Correction

To find the linear correction to Range for Deflection and Elevation during the Time of Flight, an alteration to the Range *Rate* is computed so that, when multiplied by *Tf*, it will produce the desired *linear* correction to Range. This alteration is called Range Rate Correction, *dRxe*. The equation for solving *dRxe* is: $dRxe = [(RdE)^2 + (RdBs)^2] \times K$. This equation is solved in the Range Rate Corrector.

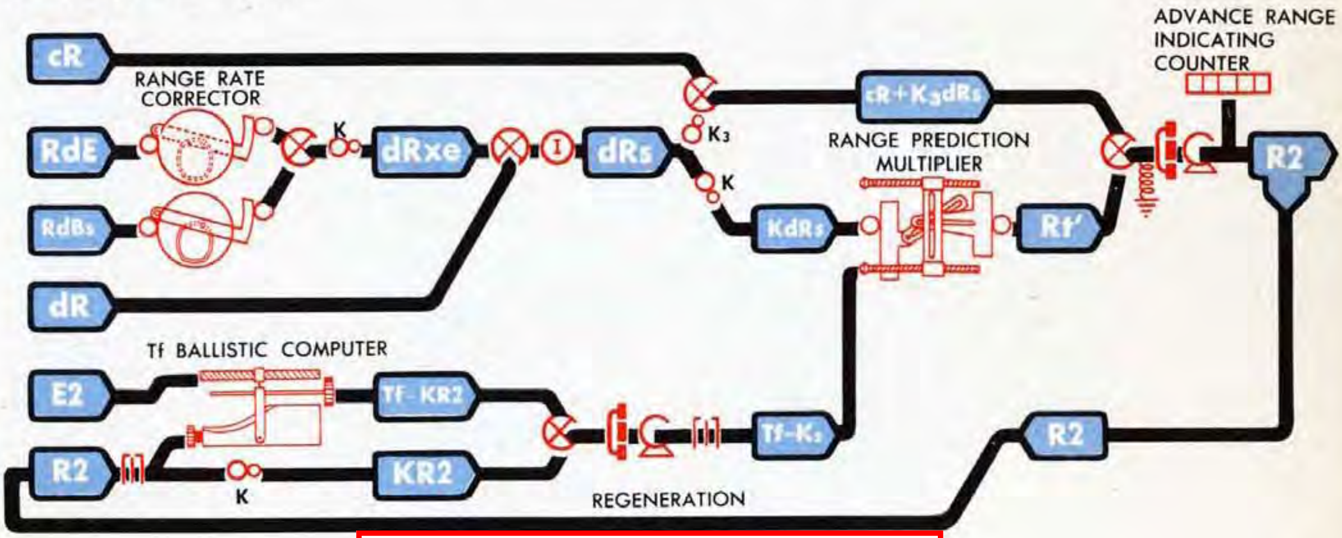


The Range Rate Corrector contains a differential and two "square" computing cams, each with a sector follower. Elevation Rate, *RdE*, is the input to one cam. Deflection Rate, *RdBs*, is the input to the other cam. The cam outputs are $(RdE)^2$ and $(RdBs)^2$. These two quantities are added in the differential. *K* is introduced by a gear ratio. The output of the gear ratio is *dRxe*, the output of the Range Rate Corrector.

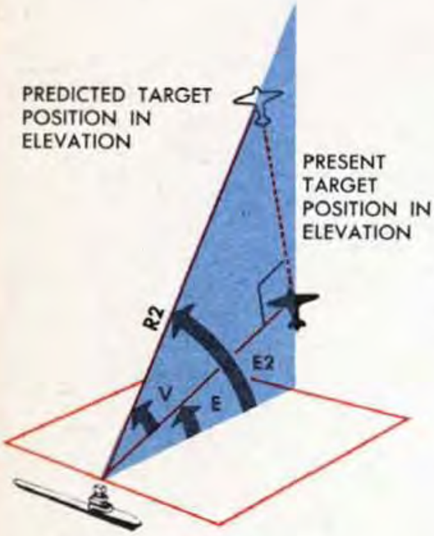
The alteration *dRxe* must be multiplied by *Tf* to produce the Total Linear Correction to Range. In the Computer Mark 1, it does not exist as a separate quantity but is part of the output from the Range Prediction Multiplier. The alteration *dRxe* combines with the Direct Range Rate, *dR*. *dR* plus *dRxe* is called Prediction Range Rate, *dRs*. *dRs* positions the rack of the Range Prediction Multiplier and is multiplied by Time of Flight, *Tf*. The multiplier output is *Rt'*, which consists of the Linear Range Change during Time of Flight, plus the Linear Correction to Range caused by the Deflection and Elevation of the Target during the Time of Flight.

The *dRs* input to the Range Prediction Multiplier is multiplied by a constant *K*. The Time of Flight input to the multiplier is *Tf* minus a constant K_2, or $Tf - K_2$. These constants are needed in computing the Range correction for Wind, and will be explained in detail later.

The constant, K_2, introduced in the multiplier input, $Tf - K_2$, produces an error in the multiplier output. To remove this error, a branch of the *dRs* line is multiplied by another constant, K_3, through ratio gearing to obtain a correction quantity, K_3dRs. K_3dRs is added to Generated Range, *cR*. When $cR + K_3dRs$ is added to the multiplier output, K_3dRs corrects the error in the multiplier output.



COMPUTING PREDICTED TARGET ELEVATION, E2



Predicted Target Elevation, *E2*, is the sum of Target Elevation, *E*, and Elevation Prediction, *V*.

$$E2 = E + V$$

Without corrections for Wind or changes in Initial Velocity, Elevation Prediction, *V*, is *Vt*, the Angular Change in Elevation during the Time of Flight, minus *Vx*, an Angular Correction for Complementary Error.

$$V = Vt - Vx$$

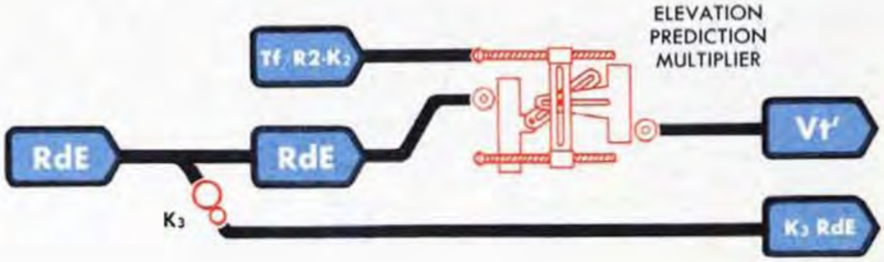
Vt is computed in the Elevation Prediction Multiplier network. *Vx* is computed in the Complementary Error Corrector.

The Elevation Prediction Multiplier has two inputs: the Linear Elevation Rate, *RdE*, and Time of Flight divided by Advance Range, *Tf/R2*. *RdE* positions the input rack; *Tf/R2* positions the lead screw. *RdE* multiplied by *Tf* would produce the *linear* change in Elevation during Time of Flight. Since an *angular* change in Elevation during Time of Flight is needed to aim the guns, *RdE* is multiplied by *Tf* and divided by *R2*. The multiplier output is *Vt*.

$$\frac{RdE \times Tf}{R2} = Vt$$

Vt is the Elevation Prediction which compensates for the relative motion of Target and Own Ship during the Time of Flight.

Actually the input to the lead screw of the Elevation Prediction Multiplier is $Tf/R2 - K_2$. The constant, K_2, is needed in connection with a Wind rate allowance which will be explained in detail later. Because of this constant in the input, the multiplier output is not *Vt*, but *Vt'*, and contains an error. To correct this error, a branch of the *RdE* line is multiplied by another constant, K_3, in a gear ratio. K_3RdE by-passes the multiplier and is added to the multiplier output, *Vt'*, after the Complementary Error Correction, *Vx*, has been subtracted from *Vt'*.



Complementary Error is the change in Elevation caused by the Deflection Prediction.

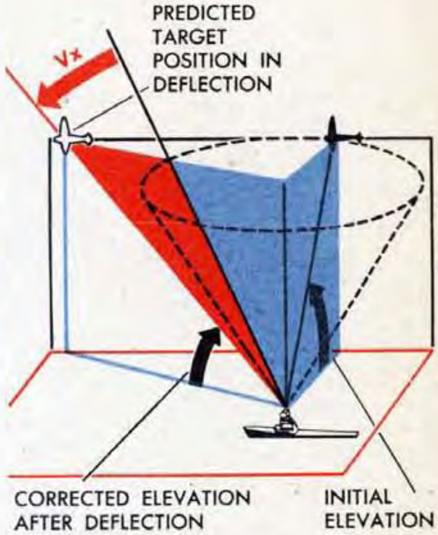
The effect on Elevation of a train correction for Target Deflection can be seen by studying a simple problem. Assume that the target is flying on a straight course at right angles to the Line of Sight, at a constant height, and at a constant speed. The Range and the height of the Target at the Present Target Position establish the Initial Elevation.

The diagram shows that if a train correction only were made to compensate for Target Deflection, the Predicted Line of Sight would not run to the Target but would pass above it. The Deflection of the Target has made necessary a smaller angle of Elevation. This change in Elevation is the Complementary Error.

To allow for the Complementary Error, Predicted Elevation must be reduced by a computed quantity called Complementary Error Correction, Vx. Vx is subtracted from Vt to obtain an accurate value of Elevation Prediction, V.

The value of Vx is computed in the Complementary Error Corrector. It is the product of $(Ds)^2$ and a function of $E2$.

$$Vx = (Ds)^2 \times f(E2)$$

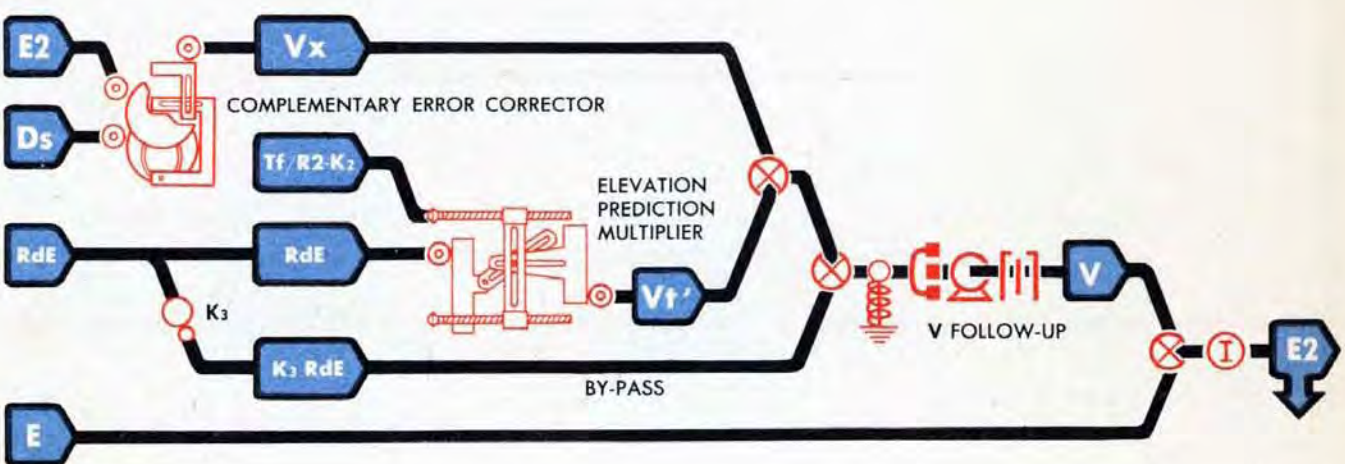


The Complementary Error Corrector is a two-cam computing multiplier. The two inputs are Sight Deflection, Ds, and Predicted Elevation, $E2$. Ds is squared by one cam and a function of $E2$ is computed by the other cam. $(Ds)^2$ is then multiplied by $f(E2)$. The multiplier output is the Complementary Error Correction, Vx. Vx is subtracted from the Elevation Prediction Multiplier output, Vt', at a differential. The differential output is added to the multiplier by-pass, K_3RdE, to obtain V. V is the corrected angular Elevation Prediction to compensate for Target Motion during Time of Flight.

$$V = Vt' - Vx + K_3RdE = Vt - Vx$$

V is amplified by a velocity-lag follow-up and is added to Target Elevation, E, to obtain Predicted Target Elevation, $E2$.

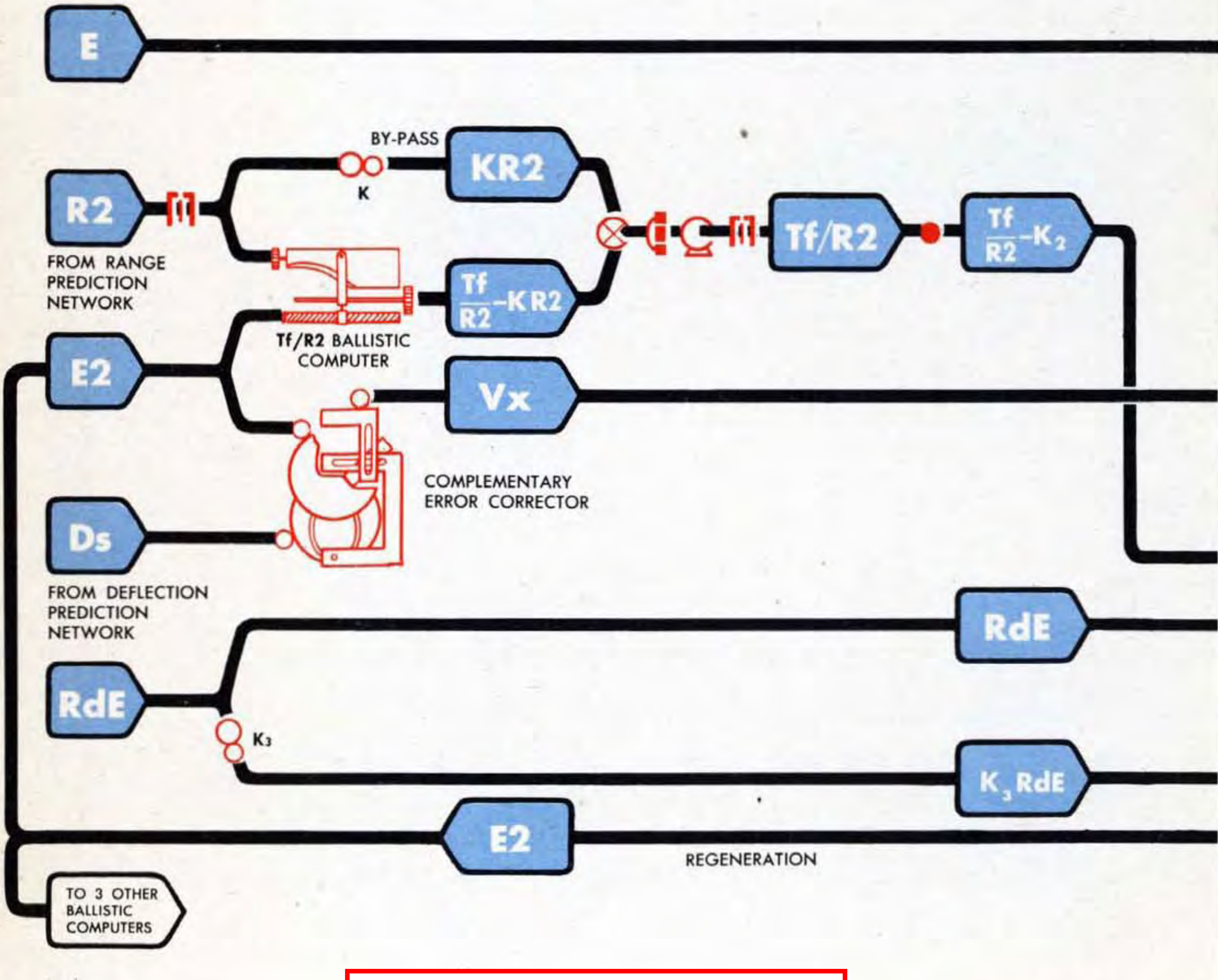
$$E2 = V + E$$



The Elevation Prediction Network

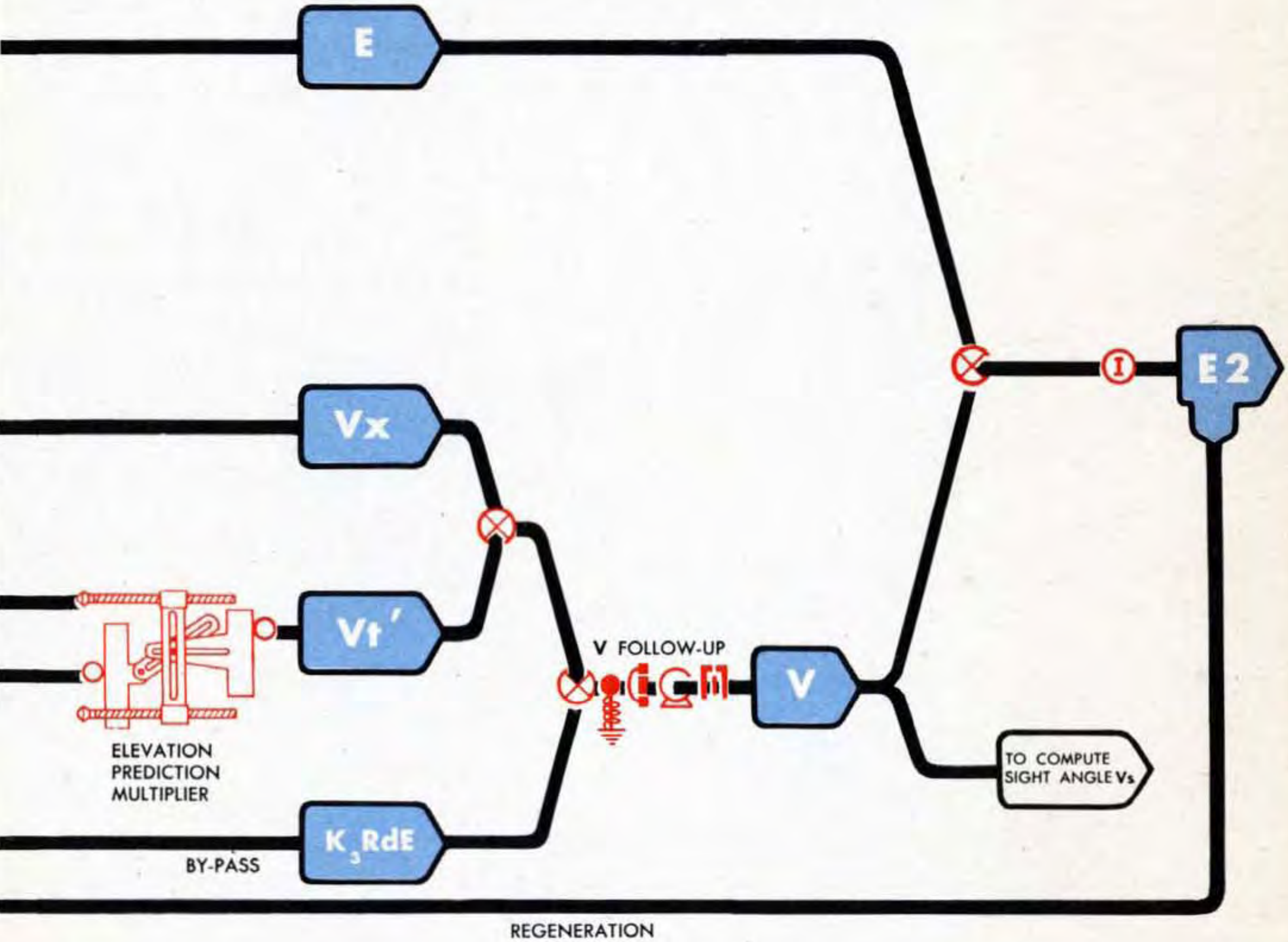
Predicted Elevation, *E2*, regenerates in the same way as Advance Range, *R2*. *E2* becomes an input to the *Tf/R2* Ballistic Computer. The other input to this Computer is *R2*.

R2 rotates the cam of the *Tf/R2* Ballistic Computer while *E2* moves the cam follower along the cam. The cam output is *Tf/R2 − KR2*, which is the difference between *Tf/R2* and a straight-line approximation of *Tf/R2*.

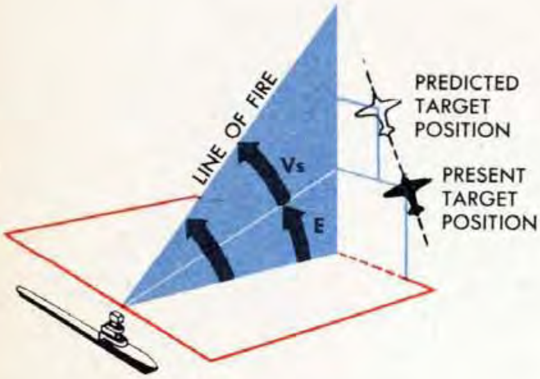


A branch of the $R2$ shaft line by-passes the $Tf/R2$ cam. Ratio gearing on this shaft line multiplies $R2$ by K to produce $KR2$, which is a straight-line approximation of $Tf/R2$. $KR2$ is added to the cam output $Tf/R2 - KR2$ to obtain $Tf/R2$. $Tf/R2$ is amplified by a velocity-lag follow-up and is the output of the ballistic computer. $Tf/R2$ is then used in the Elevation Prediction Multiplier.

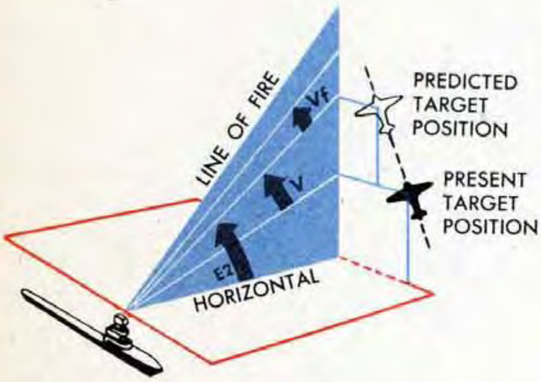
$E2$ also regenerates to become an input to the Time of Flight, $Vf + Pe$, and Mechanical Fuze Ballistic Computers. $E2$ is also a regenerative input to the Complementary Error Corrector and to the Elevation Wind Component Solver which is described later in this chapter.



COMPUTING SIGHT ANGLE, Vs



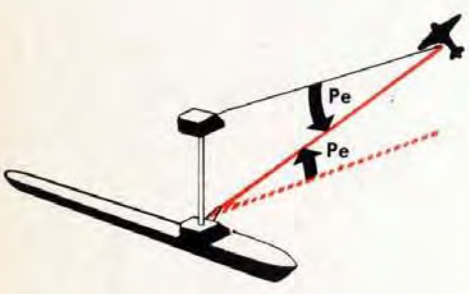
Sight Angle, *Vs,* is the angular difference between the elevation of the Line of Fire above the horizontal and the elevation of the Line of Sight above the horizontal, both of these elevation angles being measured in vertical planes.



Without allowance for Wind or changes in Initial Velocity, *Vs* is made up of three Elevation quantities: *V, Vf,* and *Pe.*

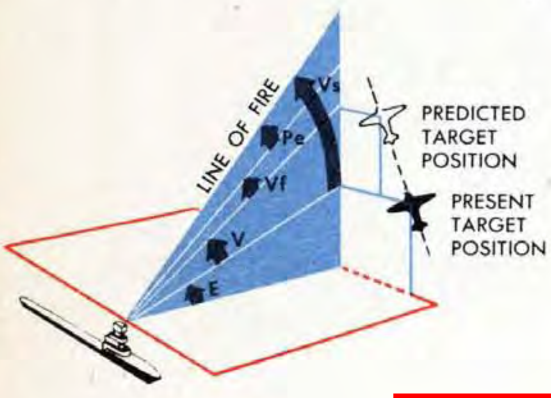
1 Elevation Prediction, *V,* is the angular Elevation change during Time of Flight. *V* is the vertical angle between the slant plane of the Present Line of Sight and the slant plane of the Predicted Line of Sight.

2 Superelevation, *Vf,* is the angle the gun must be elevated above Predicted Target Elevation, *E2,* to compensate for curvature of the trajectory in the vertical plane.



3 Elevation Parallax Correction, *Pe,* is the angle needed to compensate Gun Elevation for the vertical difference between the height of the Director and the height of the gun.

When no wind is blowing and when the Initial Shell Velocity is 2550 f.s., $Vs = V + Vf + Pe$.

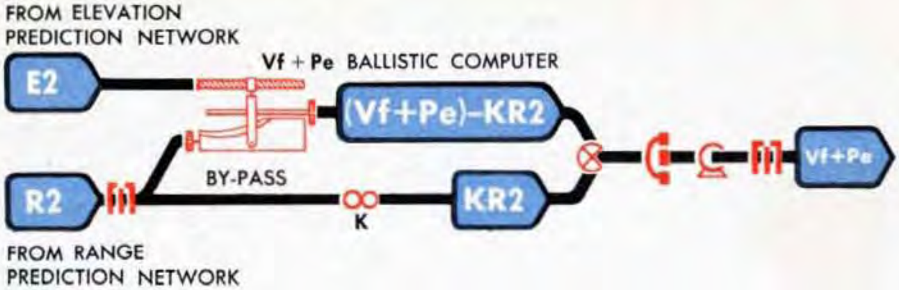


The computation of *V* has been described in the Elevation Prediction network. $V = Vt - Vx$. *Vf* and *Pe* are both computed in one ballistic computer.

A detailed description of the Elevation Parallax Correction, *Pe,* is given in the chapter on Parallax, page 350.

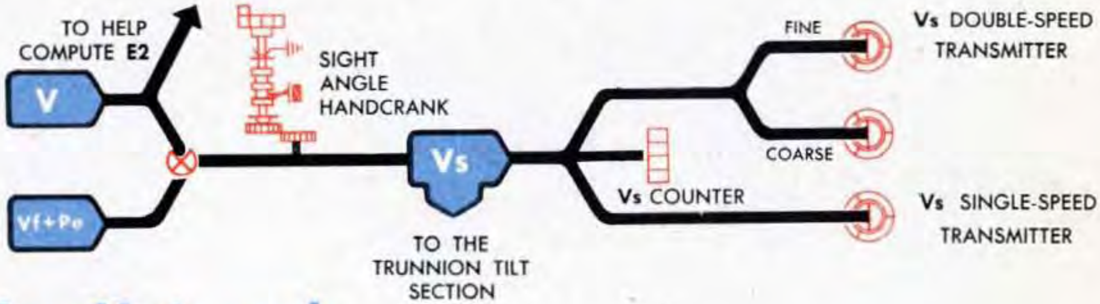
The Vf+Pe Ballistic Computer

Superelevation, *Vf*, and Elevation Parallax Correction, *Pe*, are both computed in one ballistic computer. This is possible because both Superelevation and Elevation Parallax are functions of Advance Range, *R2*, and Predicted Target Elevation, *E2*.



R2 rotates the ballistic cam in the *Vf* + *Pe* Ballistic Computer. *E2* moves the cam follower along the cam. The cam computes the difference between the true value of *Vf* + *Pe* and a straight-line approximation of *Vf* + *Pe*. The straight-line approximation is called *KR2*. The cam output is (*Vf* + *Pe*) – *KR2*. A branch of the *R2* line by-passes the cam. Ratio gearing on this line multiplies *R2* by a constant, producing the straight-line approximation, *KR2*. *KR2* is added to the cam output (*Vf* + *Pe*) – *KR2*, to obtain *Vf* + *Pe*. A velocity-lag follow-up amplifies the torque on the line. The follow-up output is the ballistic computer output, *Vf* + *Pe*.

Vf + *Pe* is an angular Elevation Correction and is added to *V* in a differential to obtain Sight Angle, *Vs*.



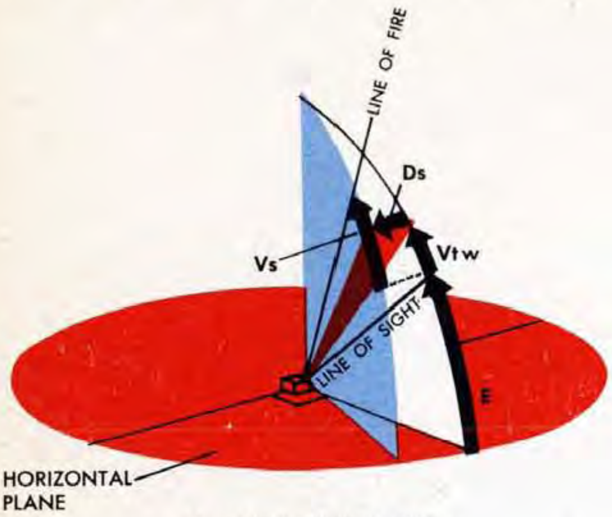
How Vs is used

Sight Angle, *Vs*, goes to the Trunnion Tilt Section of the Computer Mark 1 where it is used in computing the Gun Orders.

Vs also positions the two Sight Angle Transmitters. One of these is a double-speed transmitter. The other is a single-speed transmitter. Both transmitters send *Vs* to the gun mounts to offset the gun sights.

If some of the Computer's transmission circuits are not energized but the circuits for the Sight Angle Transmitters are energized, these transmitters may be set by hand according to any information available. This is done by turning the Sight Angle Handcrank in the IN position and watching the Sight Angle Counter. The handcrank and counter are on the rear top of the Computer.

COMPUTING SIGHT DEFLECTION, Ds



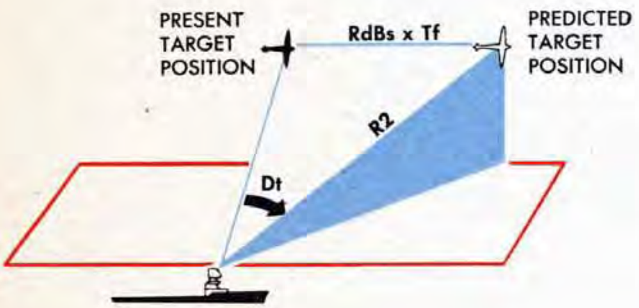
Ds WHEN WIND IS ZERO AND I.V. IS 2550 F. S.

Sight Deflection, *Ds,* is the angle between the vertical plane through the Line of Sight and the vertical plane through the gun axis. *Ds* is measured in a slant plane at right angles to the vertical plane through the Line of Sight, at angle *Vtw* above the Line of Sight.

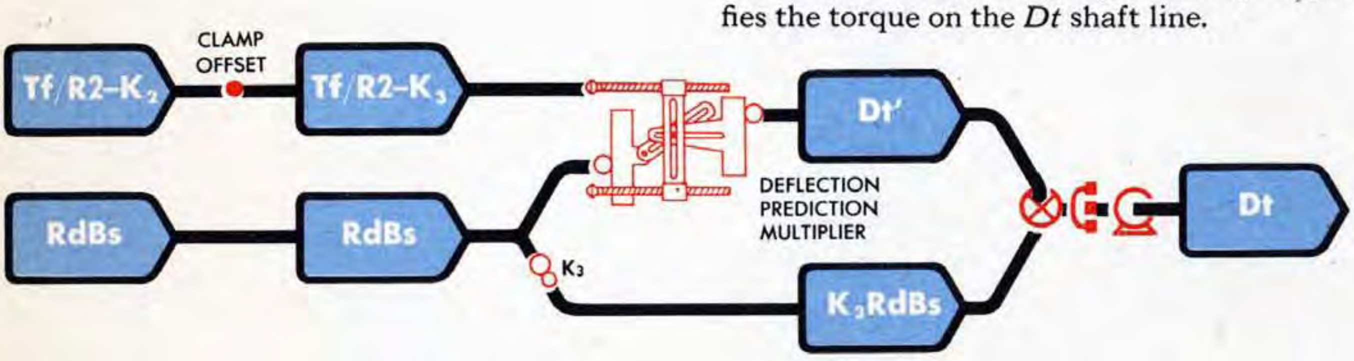
Without Wind or Initial Velocity corrections, *Ds* is made up of two Deflection quantities, *Dt* and *Dfs. Dt* is the Deflection Prediction for relative movement of Target and Own Ship during the Time of Flight. *Dfs* is the Drift Correction.

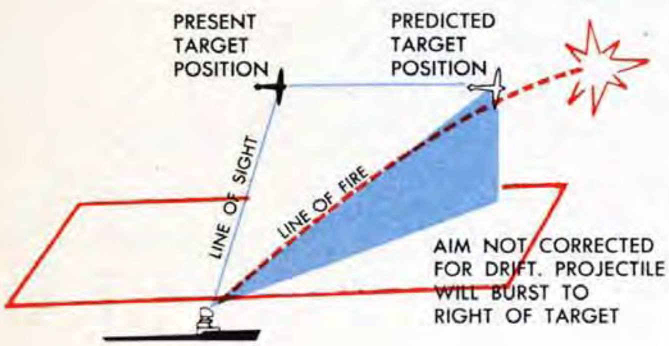
$$Ds = Dt - Dfs$$

Dt is computed by the Deflection Prediction Multiplier network.



The Deflection Prediction Multiplier multiplies Linear Deflection Rate, *RdBs,* by $Tf/R2 - K_3$, to obtain Dt'. $Tf/R2 - K_3$ is obtained by adding an offset constant K to $Tf/R2 - K_2$, the quantity used in the Elevation Prediction Multiplier. The quantity K_3 offsets the lead screw input to the Deflection Prediction Multiplier and causes an error in the multiplier output. To correct this error, a branch of the *RdBs* line is multiplied by a constant K_3 through a gear ratio, to produce a correction quantity K_3RdBs. K_3RdBs by-passes the multiplier and is added to Dt' in a differential to obtain *Dt*. A velocity-lag follow-up amplifies the torque on the *Dt* shaft line.



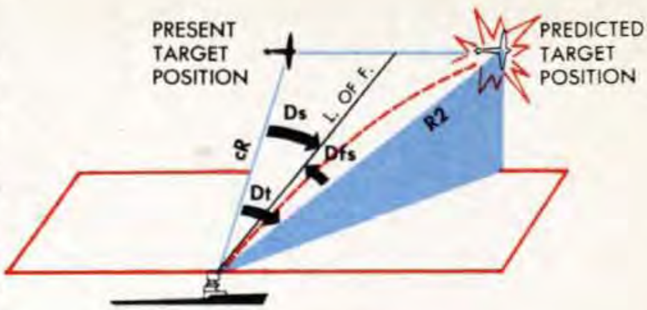


Drift

In order to prevent projectiles from turning end over end in flight, guns are rifled to rotate or spin the projectiles. The rifling in the gun barrels causes the projectiles to spin clockwise. This spin causes the projectile path to curve to the right. Guns must therefore be trained to the left of the Predicted Target Position to compensate for the curve.

Drift Correction, Dfs

It has been found that the average correction needed to compensate for drift is approximately proportional to the Elevation Correction, $Vf + Pe$, when $I.V.$ is 2550 f.s. $Vf + Pe$ from the $Vf + Pe$ Ballistic Computer is converted to Drift Correction, Dfs, by a gear ratio on a branch of the $Vf + Pe$ shaft line.

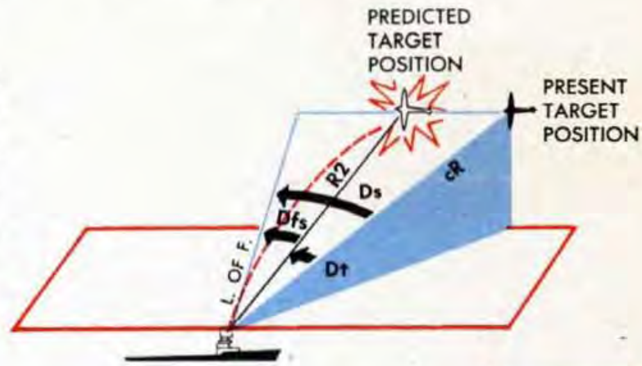


Dfs is subtracted from Dt at a differential to obtain Sight Deflection, Ds.

$$Ds = Dt - Dfs$$

When Dt is positive, which it is when the Target is deflecting to the right of the Line of Sight, Dfs, will make Ds less positive than Dt.

When Dt is negative, which it is when the Target is deflecting to the left of the Line of Sight, Dfs will make Ds more negative than Dt.

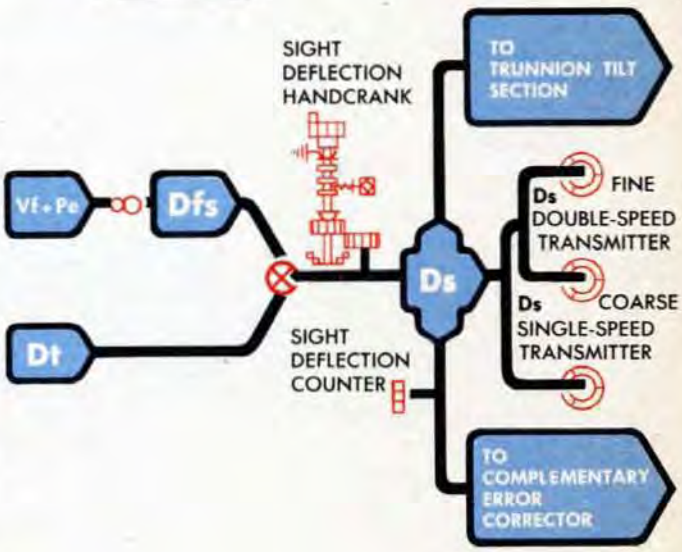


Where Ds is used

Ds goes to the Trunnion Tilt Section, where it is used in computing the Gun Orders.

Ds also positions the two Sight Deflection Transmitters, one of which is a double-speed transmitter and the other a single-speed transmitter. Both transmitters send Ds to the guns to offset the gun sights in Deflection.

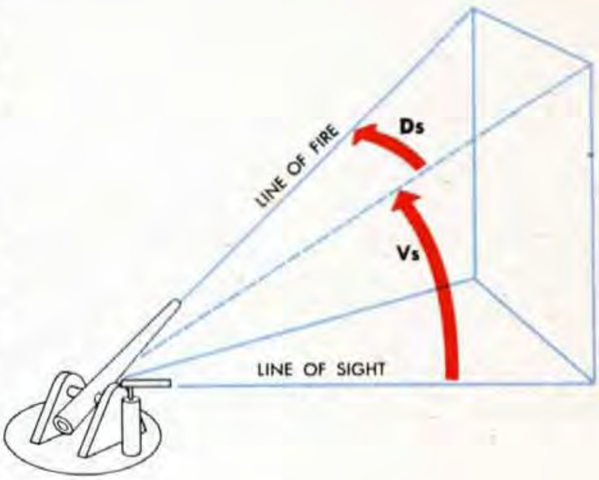
Ds goes also to the Complementary Error Corrector in the Elevation Prediction Section.



Using Vs and Ds at the Guns

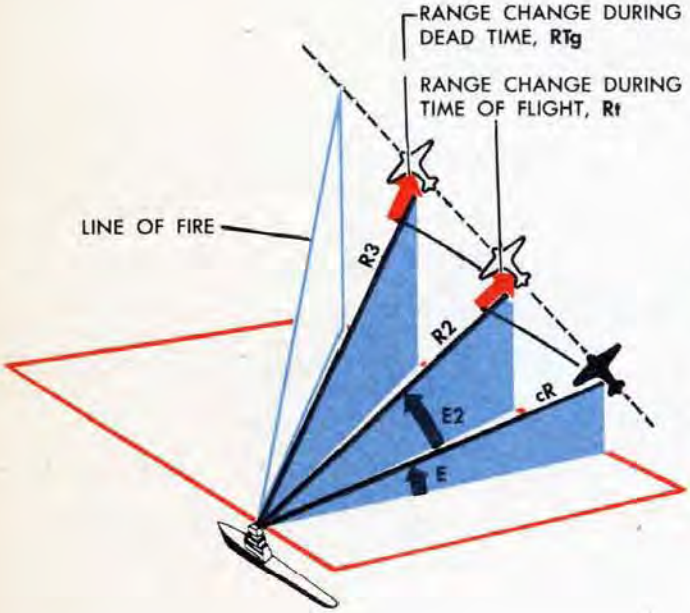
When Gun Elevation Order, $E'g$, and Gun Train Order, $B'gr$, are used to position the guns, the gun sights are offset from the guns by Sight Angle, Vs, and Sight Deflection, Ds. Thus, the observer at the gun may view the Target through the gun sight.

Vs and Ds may also be used in firing against surface targets when Gun Orders $B'gr$ and $E'g$ are not available. With the gun sights offset by Vs and Ds, moving the gun to bring the sights onto the Target will elevate and train the gun to the correct Line of Fire.



If some of the Computer's transmission circuits are not energized, but the circuits for the Sight Deflection Transmitters are energized, these transmitters may be set by hand according to any information available. This is done by turning the Sight Deflection Handcrank in the IN position and watching the Sight Deflection Counter. The handcrank and counter are on the rear top of the Computer.

COMPUTING FUZE SETTING ORDER, F



The fuze of a projectile must be set so that the projectile will burst at the end of a given time interval after it is fired. The projectile must be timed to burst at the Predicted Target Position.

Fuze Setting Order, *F*, is the computed fuze time, in seconds, at which the fuze must be set.

If a projectile fuze could be set in the gun at the instant the projectile is fired, the Fuze Setting Order would equal Time of Flight, *Tf*. But since fuzes must be set several seconds before firing, in a separate Fuze Setter, the fuze time will be different from Time of Flight.

The changes in Target Position taking place during the time between setting the fuze and firing the fuzed projectile must be considered. The time between the setting of the fuze and the firing of the projectile is called *Dead Time*. Dead Time usually varies from 2½ to 5 seconds, depending on the skill of the gun crew and other factors, and is determined by ship's doctrine. The value needed for setting the fuze is the value that Time of Flight will have at the end of Dead Time. The value of Time of Flight at the end of Dead Time depends on the values Advance Range and Predicted Target Elevation will have at the end of Dead Time.

It has been found that the change in *E2* during Dead Time is usually small. The Computer Mark 1 therefore computes no new value of Predicted Target Elevation. The principal change in Target Position during Dead Time occurs in Advance Range, *R2*. A new quantity, Fuze Range, *R3*, must be computed. Fuze Range, *R3*, is the approximate value that Advance Range, *R2*, will have at the end of Dead Time. *R3* is calculated by computing the linear Range Change during Dead Time, *RTg*, and adding *RTg* to the present value of Advance Range, *R2*.

$$R3 = R2 + RTg$$

RTg is computed in the Dead Time Prediction Multiplier.

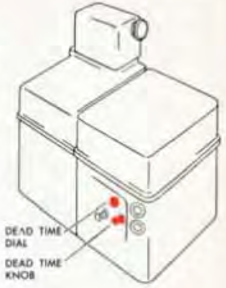
R3 and *E2* are used in the Fuze Ballistic Computer to obtain Fuze Setting Order, *F*.

The dead time prediction multiplier

The inputs to the Dead Time Prediction Multiplier are Direct Range Rate, dR, and Dead Time, Tg. The output is Range Change during Dead Time, RTg.

$$RTg = dR \times Tg$$

The value of Dead Time is determined by each ship for its particular gun crews. It is set into the Computer manually by turning the Dead Time Knob on the left side of the lower front section of the Computer Mark 1. RTg is added to $R2$ at a differential. The differential output is Fuze Range, $R3$.

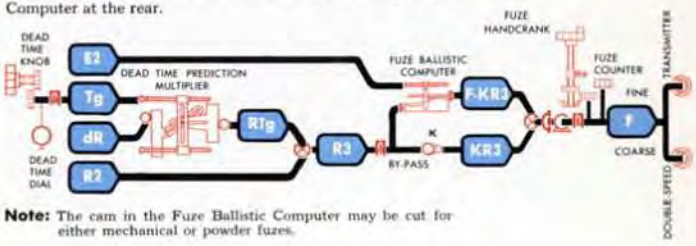


The fuze ballistic computer

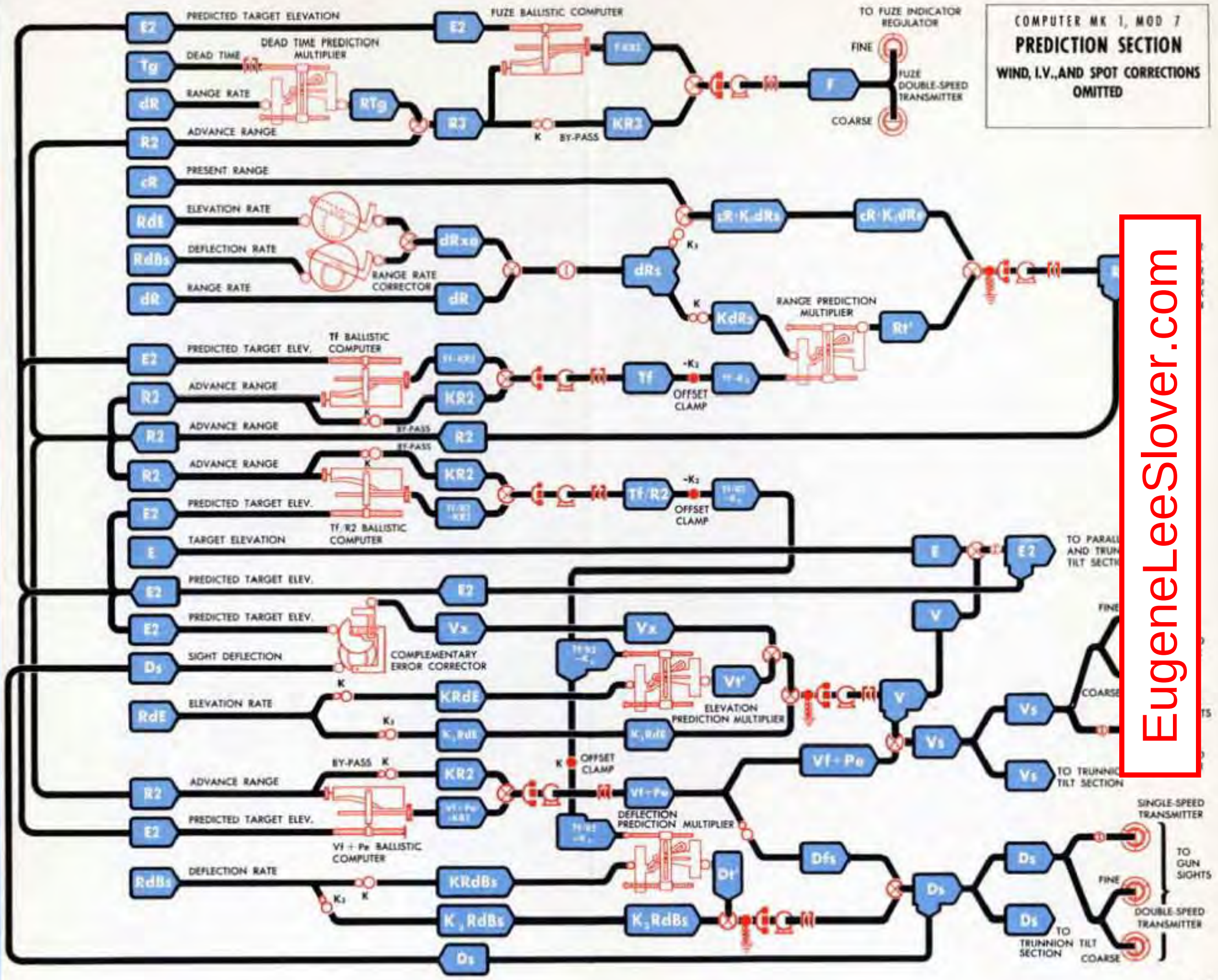
Fuze Range, $R3$, positions the cam in the Fuze Ballistic Computer. Predicted Elevation, $E2$, positions the cam follower. The cam computes the difference between Fuze Setting Order, F, and a straight-line approximation of F, called $KR3$. The cam output is $F - KR3$.

A branch of the $R3$ line by-passes the cam. A gear ratio on this line produces $KR3$. $KR3$ is added to the cam output, $F - KR3$, at a differential to obtain Fuze Setting Order, F. F is amplified by a velocity-lag follow-up which positions the Fuze Setting Order Transmitter. The Fuze Setting Order Transmitter is a double-speed transmitter.

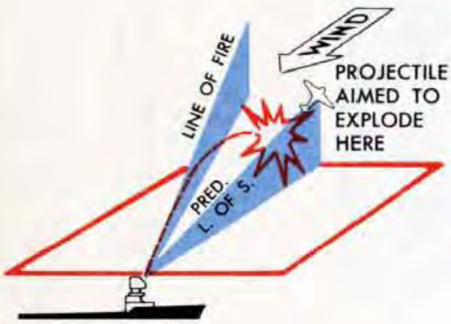
If for any reason some of the Computer's transmission circuits are not energized, but the circuit for the Fuze Setting Order Transmitter *is* energized, the transmitter may be set by hand according to any information available. This is done by turning the Fuze Handcrank in the IN position and watching the Fuze Counter. The handcrank and counter are on top of the Computer at the rear.



Note: The cam in the Fuze Ballistic Computer may be cut for either mechanical or powder fuzes.

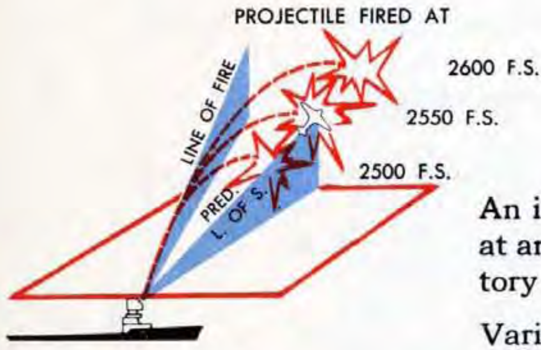


How Vs, Ds, and F are corrected to allow for WIND and change in INITIAL VELOCITY



Up to this point the three prediction quantities, *Vs, Ds,* and *F*, have been computed for a problem where no Wind is blowing and where all projectiles are being fired at an Initial Velocity of 2550 f.s. These conditions seldom exist in actual operation. Allowances for the effect of Wind and changes in Initial Velocity are therefore included in the predictions.

Wind may change the normal trajectory of a projectile in several ways. Its effect depends on the strength of the Wind and the direction from which it is blowing.



An increase or decrease in the Initial Velocity of a projectile, at any given gun elevation, will lengthen or shorten the trajectory of a projectile.

Variations in trajectory which may be caused by Wind and changes in Initial Velocity are not included on the cams of the four ballistic computers in the Prediction Section. The ballistic data cut onto these cams is based on the trajectory a projectile will follow when there is no Wind and Initial Velocity is 2550 f.s. The cam outputs must be corrected for the effects of Wind and changes in Initial Velocity.

The cam outputs are corrected by altering the values of the two cam inputs, *R2* and *E2*. The alterations of *R2* and *E2* are based on *I.V.* inputs and on three computed Wind Rates. The amounts that *R2* and *E2* are altered are computed through mechanism equations. Mechanism equations are shortcut approximations of the true equations. Constants are used in mechanism equations in such a way that these equations can be solved through use of gear ratios, clamps, and mechanisms that are already in the computer for other purposes.

The alterations of *R2* and *E2* change the ballistic cam outputs. These changes help to correct *Vs, Ds,* and *F* for the effects of Wind and any deviation in *I.V.* from 2550 f.s. Further corrections for these effects are necessary and will be described in turn.

How wind may affect trajectory

Wind is always considered to be blowing in the *horizontal* plane. Depending on the direction from which the Wind is blowing and the Target Elevation, a projectile that would normally hit a Target may be affected in several ways.

If the Target is at a low Elevation and the Wind is blowing along the plane of the Line of Fire against the projectile, the projectile will burst short of the Target. To compensate for this, the computations must be based on a longer Range.

Under the same conditions, if the Wind is blowing with the projectile, the projectile bursts beyond the Target. To compensate for this, the computations must be based on a shorter Range.

If the Wind is blowing from the right at 90° to the Line of Fire, the projectile will burst to the left of the Target. To compensate for this the gun must be trained to the right.

If the Wind is blowing from the left at 90° to the Line of Fire, the projectile will burst to the right of the Target. The gun must be trained to the left.

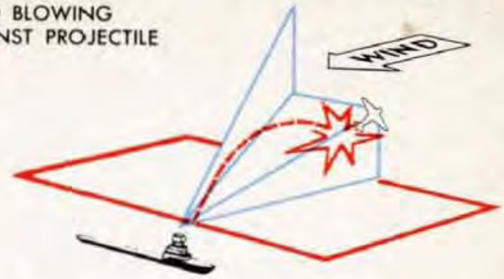
If the Target is at a high elevation and the Wind is blowing against the projectile along the plane through the Line of Fire, the Wind effect will tend to elevate the trajectory. To correct for this, the Elevation of the gun must be reduced.

Under the same conditions, if the Wind is blowing with the projectile, the Wind effect will tend to depress the trajectory. To correct for this, the Elevation of the gun must be increased.

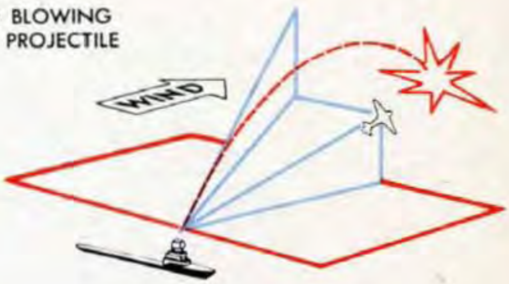
The examples given here are special cases. Normally the Wind does not blow exactly along or at right angles to the plane of the Line of Fire, but has COMPONENTS in, or at right angles to, the plane through the Line of Fire.

The Wind effect on the Range, Elevation, and Deflection Predictions is found by computing the components of Wind in three directions: along the Line of Fire for Range, at right angles to the Line of Fire in the vertical plane for Elevation, and at right angles to the Line of Fire in the horizontal plane for Deflection.

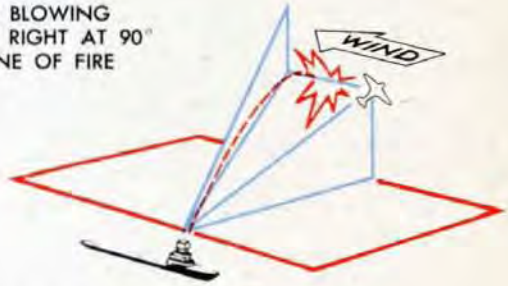
WIND BLOWING AGAINST PROJECTILE



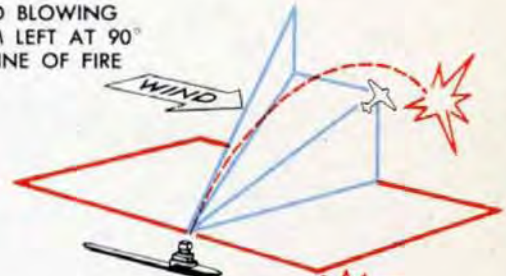
WIND BLOWING WITH PROJECTILE



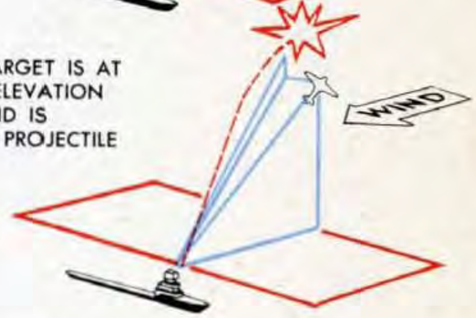
WIND BLOWING FROM RIGHT AT 90° TO LINE OF FIRE



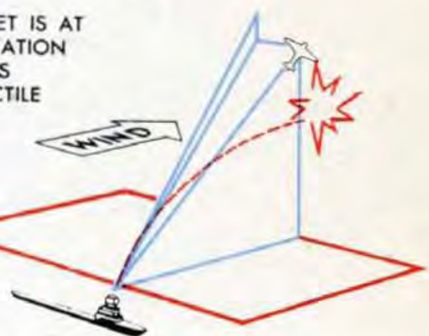
WIND BLOWING FROM LEFT AT 90° TO LINE OF FIRE



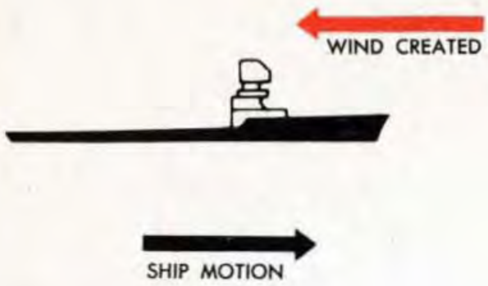
WHEN TARGET IS AT A HIGH ELEVATION AND WIND IS AGAINST PROJECTILE



WHEN TARGET IS AT A HIGH ELEVATION AND WIND IS WITH PROJECTILE

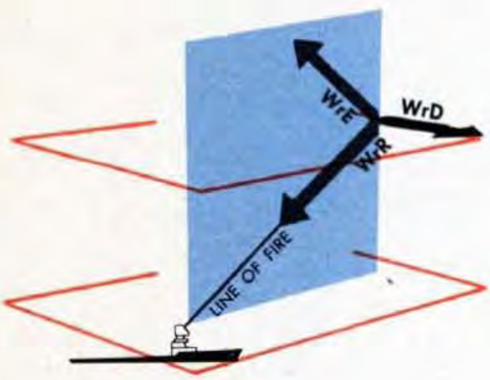


COMPUTING WIND RATES



Even when there is no wind the motion of Own Ship creates wind which can be felt on the moving ship. This wind caused by Own Ship Motion has the same speed as Own Ship Speed and a direction opposite to Own Ship Course.

A projectile fired from a ship in motion retains the ship's motion during its flight, and, in effect, a wind due to this motion will blow against the projectile.



When the True Wind is blowing, the trajectory of a projectile will be affected by both the True Wind and the Wind caused by Own Ship Motion. True Wind and Wind caused by Own Ship Motion must be combined to obtain the APPARENT WIND, the wind acting on the projectile. This is done by finding two components of True Wind and two components of Wind caused by Own Ship Motion. The components in the same directions are combined to obtain two components of Apparent Wind.

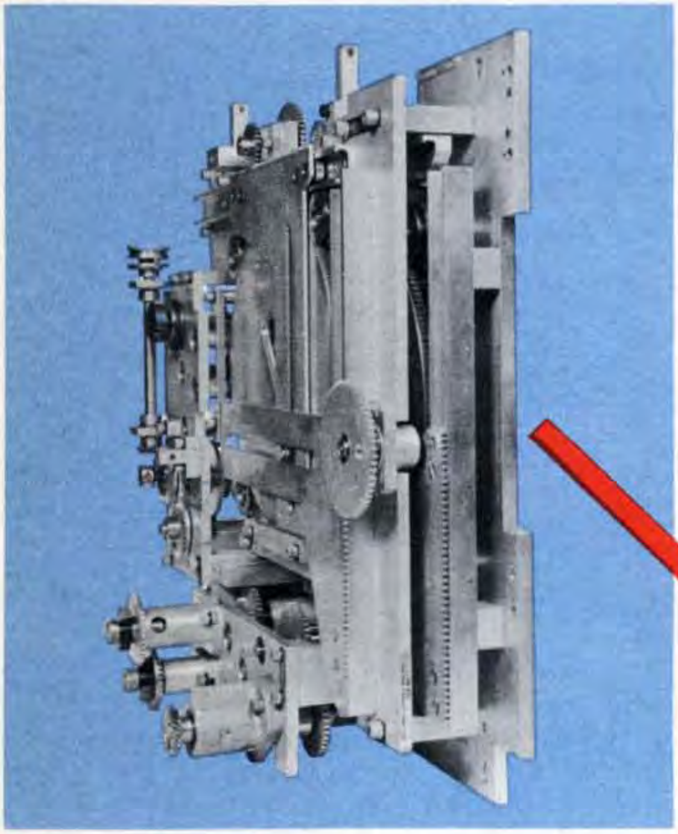
One component of Apparent Wind, at right angles to the plane of fire, is the Wind Rate affecting Deflection Prediction, *WrD*. The other component of Apparent Wind, in the plane of fire, is used in computing the other two Wind Rates:

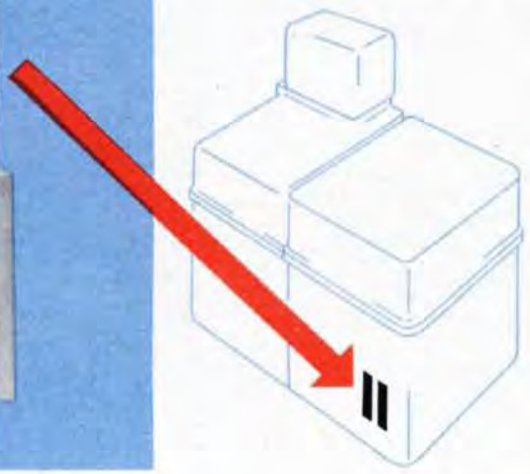
The Wind Rate affecting Range Prediction, *WrR*.

The Wind Rate affecting Elevation Prediction, *WrE*.

Two Wind Component Solvers and the Own Ship Component Solver are used in computing the Wind Rates.

The two Wind Component Solvers are in the lower front section of the Computer Mark 1.





The horizontal wind component solver

The Horizontal Wind Component Solver is a cam-type component solver. Its two inputs are:

True Wind Speed, Sw, which positions the cam.

Predicted Wind Angle, Bwg, which positions the vector gear.

True Wind Speed, Sw, is put into the Computer Mark 1 manually by turning the Wind Speed Handcrank to set the Wind Speed Dial.

Predicted Wind Angle, Bwg, is the angle between the direction from which the wind is blowing and the vertical plane approximately through the Line of Fire, measured in the horizontal plane clockwise from the direction from which the wind is blowing.

Bwg is computed as follows: First, Wind Direction, Bw, is subtracted from True Target Bearing, B, to obtain Wind Angle, Bws. Wind Direction, Bw, is the horizontal angle between the North-South vertical plane and the direction from which the wind is blowing. Bw is put into the Computer manually at the Wind Direction Handcrank. Bws is the horizontal angle between the direction from which the wind is blowing and the vertical plane through the Line of Sight. $B - Bw = Bws$.

Sight Deflection, Ds, is then multiplied by a constant, K, and is added to Wind Angle, Bws, to obtain Bwg.

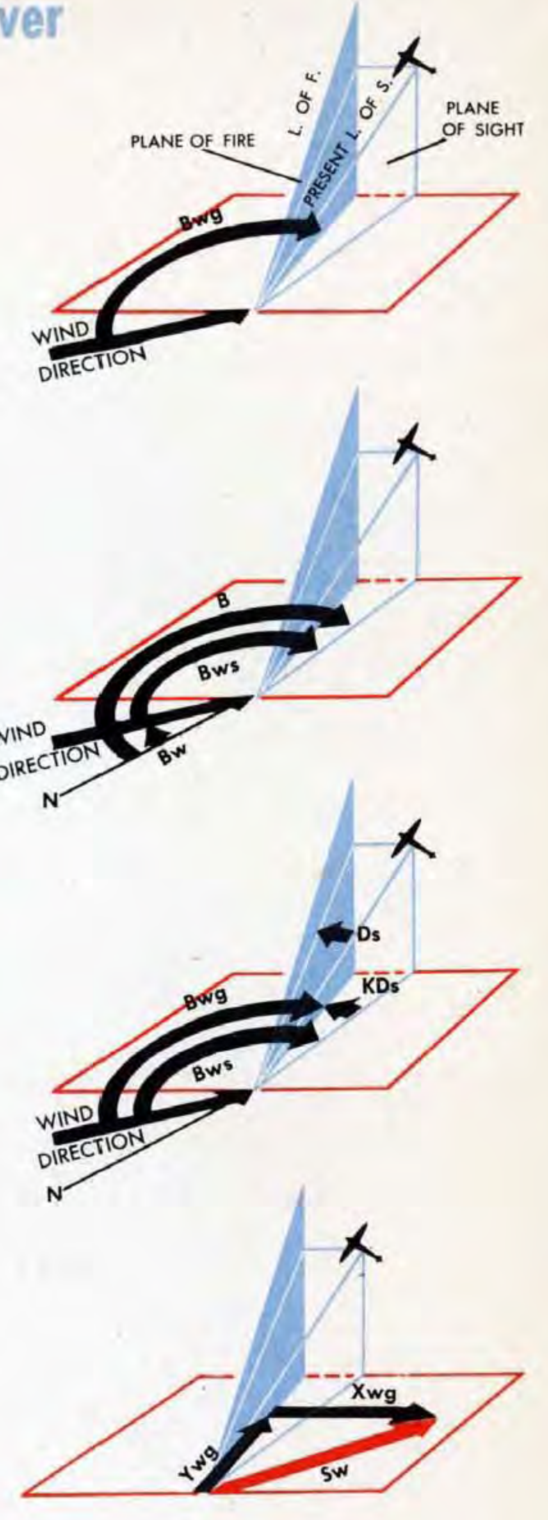
$$Bws + KDs = Bwg$$

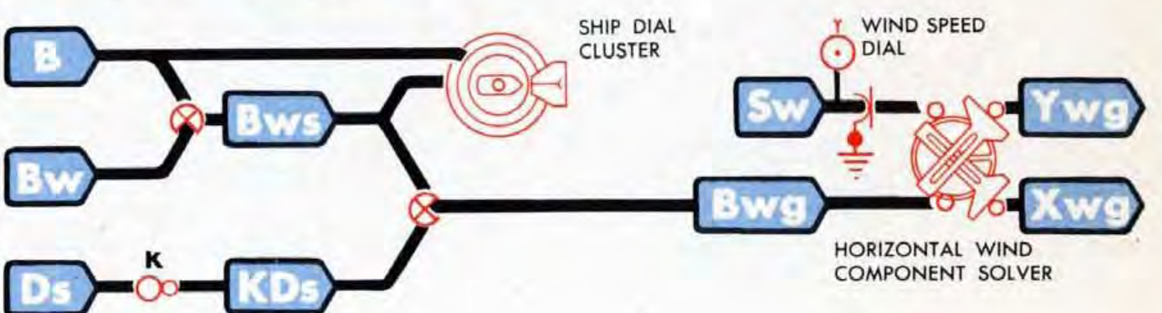
If KDs is a minus value, the equation for Bwg is: $Bwg = Bws + (-KDs)$.

Sight Deflection, Ds, is the Deflection angle between the vertical plane through the Line of Sight and the vertical plane through the axis of the gun. Ds is measured in a slant plane perpendicular to the vertical plane through the Line of Sight. Multiplying Ds by the constant K approximately refers Ds from its slant plane to the horizontal plane.

The outputs of the Horizontal Wind Component Solver are two components of True Wind Velocity:

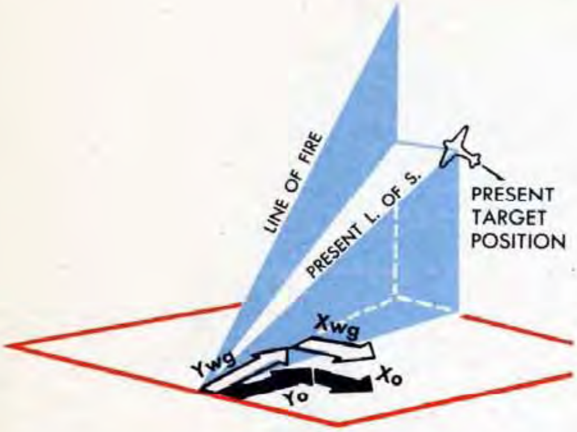
1. Ywg, the horizontal range component of True Wind Velocity in the vertical plane approximately through the Line of Fire.
2. Xwg, the horizontal deflection component of True Wind Velocity perpendicular to the vertical plane approximately through the Line of Fire.



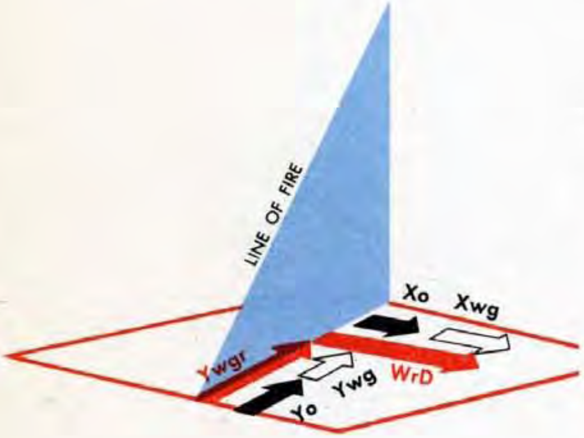


How components of apparent wind are computed

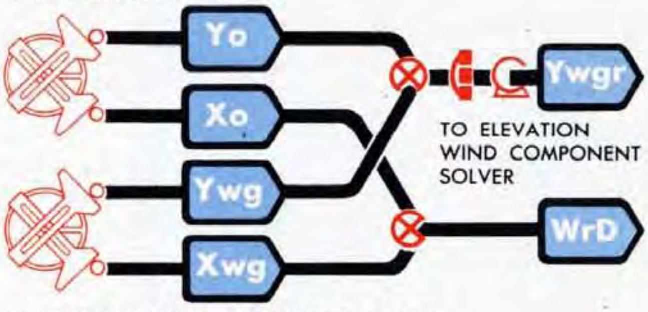
Wind caused by Own Ship Motion is equal to Own Ship Speed; therefore the two components of Own Ship Velocity, *Xo* and *Yo*, reversed in sign, are used as the two components of Wind caused by Own Ship Motion.



Xo and *Yo* lie in and at right angles to the vertical plane containing the LINE OF SIGHT, while *Xwg* and *Ywg*, the components of True Wind Velocity, lie in and at right angles to the vertical plane containing the LINE OF FIRE. To avoid use of additional mechanisms in computing Wind effects, *Xo* and *Yo* are used as approximations of components of Own Ship Motion relative to the plane of the Line of Fire. Since the angle between the planes of sight and fire is usually small, the error involved may be disregarded.



Xo is combined with *Xwg* to obtain *WrD*, the horizontal component of Apparent Wind Velocity at right angles to the vertical plane containing the Line of Fire. *Yo* is combined with *Ywg* to obtain *Ywgr*, the horizontal component of Apparent Wind Velocity in the plane of the Line of Fire.



WrD is the component of Apparent Wind Velocity affecting Deflection Prediction. It is called the Deflection Wind Rate and is one of the three Wind Rates needed in Prediction.

Ywgr is the horizontal component of Apparent Wind Velocity in the vertical plane of fire. *Ywgr* is not a final Wind Rate, but is used to compute the components of Apparent Wind Velocity affecting Range and Elevation Predictions, which are the two other Wind Rates.

NOTE:
Ballistic Wind values are substituted for True Wind values when prescribed by *ship's doctrine*. In this case the Computer corrects for Apparent Ballistic Wind.

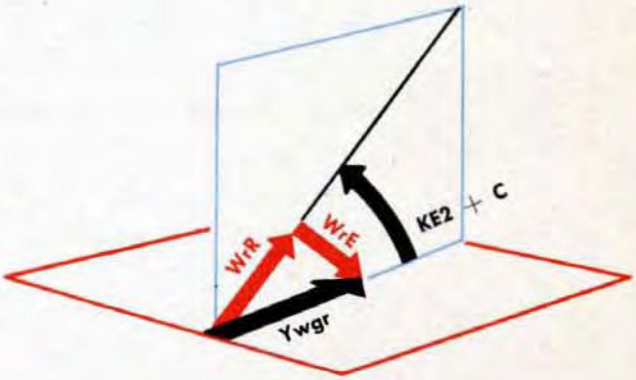
The elevation wind component solver

The Elevation Wind Component Solver is a screw-type component solver.

The two inputs are *Ywgr,* which positions the screw, and *KE2 + C,* which positions the vector gear.

KE2 + C is an empirical quantity which gives the best average results for all problems.

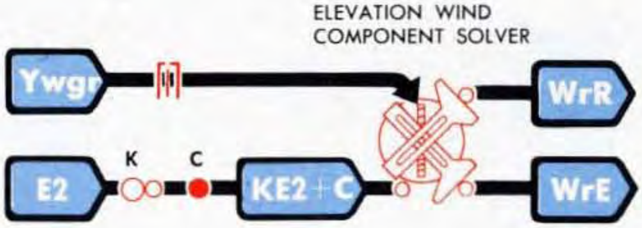
KE2 + C is computed as follows: Predicted Target Elevation, *E2*, is multiplied in a gear ratio by a constant, *K*, to obtain *KE2*. Constant *C* is offset at a clamp on the *E2* shaft line to obtain *KE2 + C*.



The Elevation Wind Component Solver computes two components of *Ywgr:*

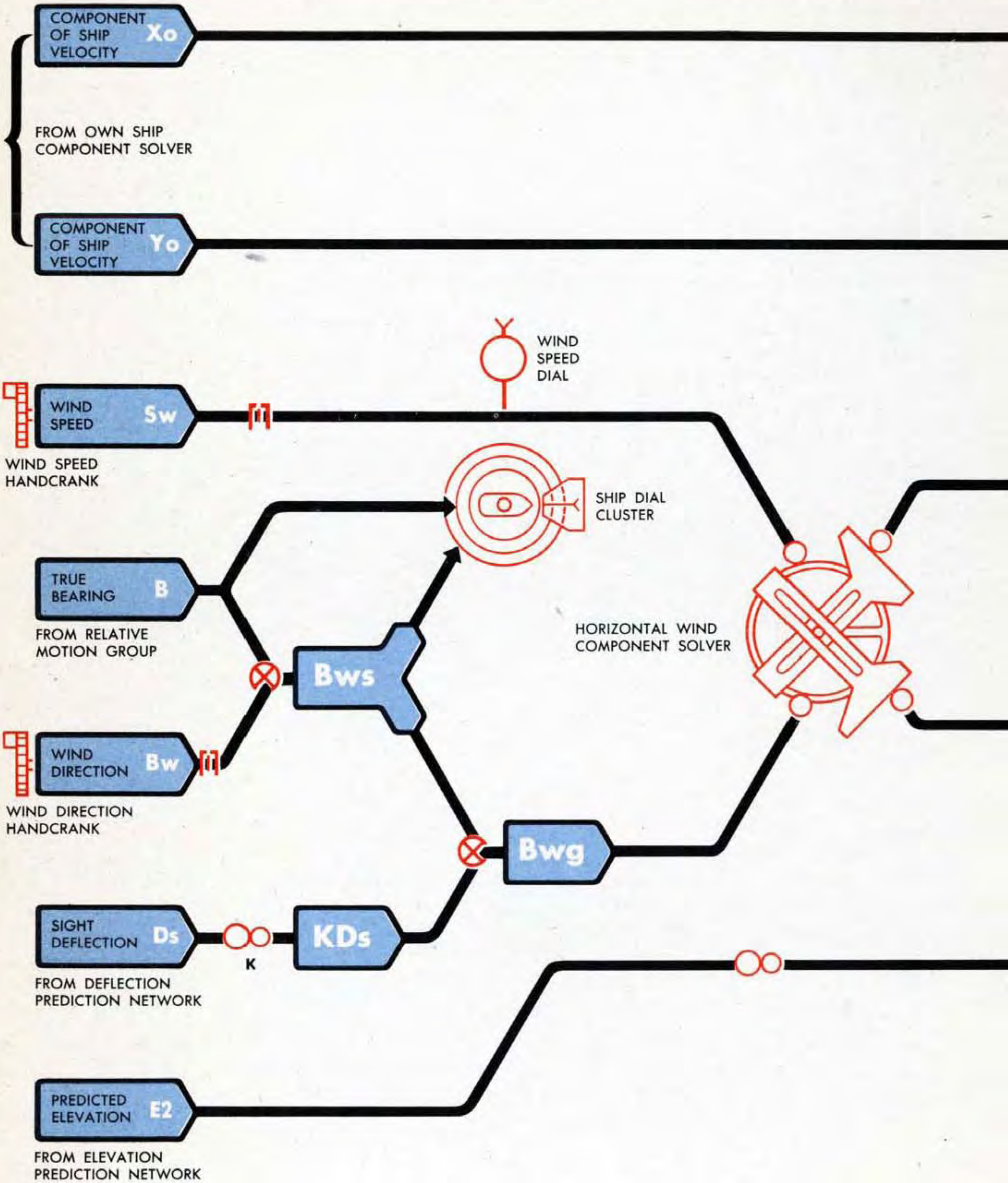
1 The component of Apparent Wind Velocity affecting Range Prediction is the Range Wind Rate, *WrR*.

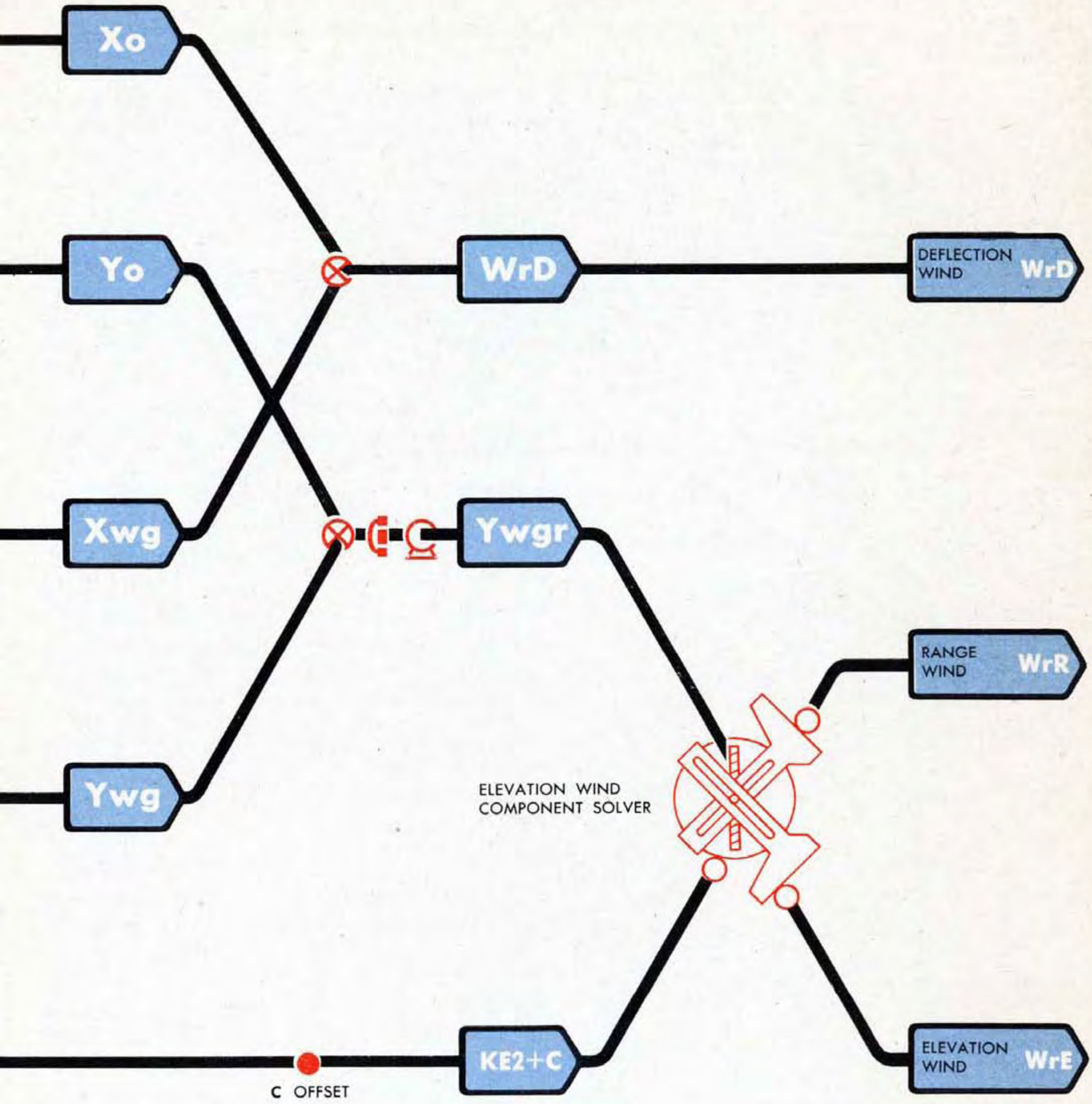
2 The component of Apparent Wind Velocity affecting Elevation Prediction, is the Elevation Wind Rate, *WrE*.



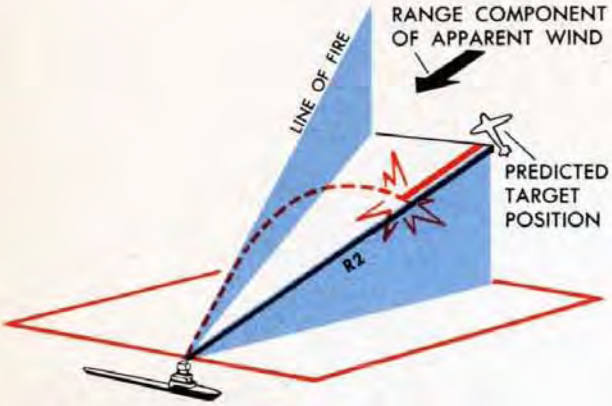
The three Wind Rates, *WrR, WrE,* and *WrD* are used to adjust the Range, Elevation, and Deflection Predictions for the effect of Wind.

SCHEMATIC of the WIND RATES



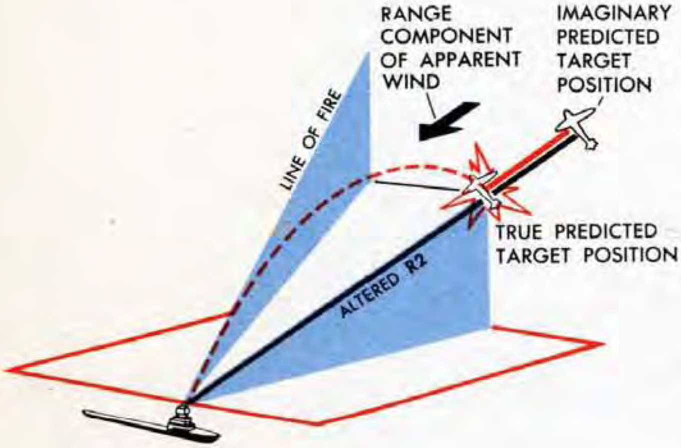

Xo
Yo
Xwg
Ywg
WrD
DEFLECTION WIND WrD
Ywgr
RANGE WIND WrR
ELEVATION WIND COMPONENT SOLVER
C OFFSET
KE2+C
ELEVATION WIND WrE

Changing R2 to allow for WIND



The amount by which $R2$ must be altered to allow for the effect of wind depends on:

1. The value of the Range Wind Rate, WrR, and
2. The length of time the wind blows on the projectile, that is, Time of Flight, Tf.



The effect of Range Wind on a projectile can be seen by studying a problem in which a wind is blowing against a projectile along the Line of Fire. Assume that this wind, by blowing against the projectile during its Time of Flight, will cause the projectile to burst short of the Target.

If Advance Range, $R2$, is now increased to an imaginary Predicted Target Position, a projectile fired using this imaginary $R2$ will travel to the Target's true Predicted Position.

The change of Range to allow for Wind is made by increasing or decreasing Advance Range, $R2$, depending on the direction of the Wind component.

In the Computer Mark 1, Advance Range, $R2$, is altered by increasing or decreasing the linear output of the Range Prediction Multiplier by a computed amount. The amount that the multiplier output must be increased or decreased is Rw, Linear Range Prediction to compensate for Wind effect. Range Wind Rate, WrR, is needed in the mechanism equation used to obtain Rw. This equation is:

$$Rw = K_1 WrR \, (Tf - K_2)$$

WrR from the Elevation Wind Component Solver is multiplied by K_1 by means of a gear ratio. The remainder of this equation is solved in the Range Prediction Multiplier. Rw does not exist as a separate quantity but is included in the multiplier output.

The range prediction multiplier does two jobs at once

The Range Prediction Multiplier multiplies Prediction Range Rate, *dRs,* by Time of Flight, *Tf,* to produce the Range Prediction, *Rt.*

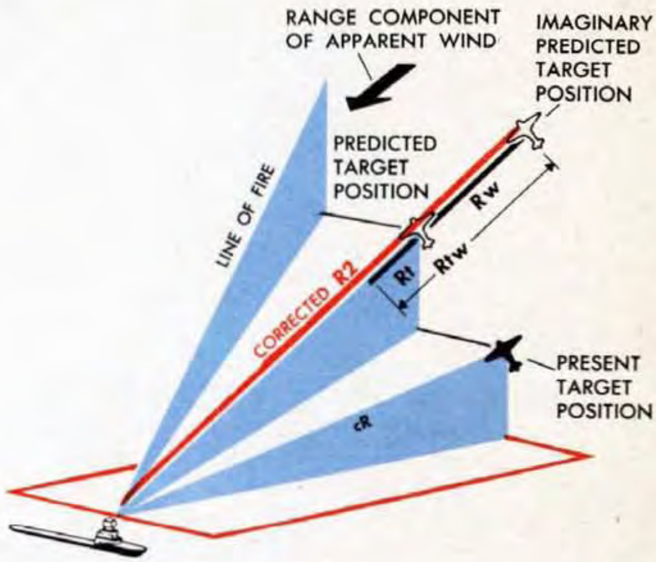
$$Rt = dRs \times Tf$$

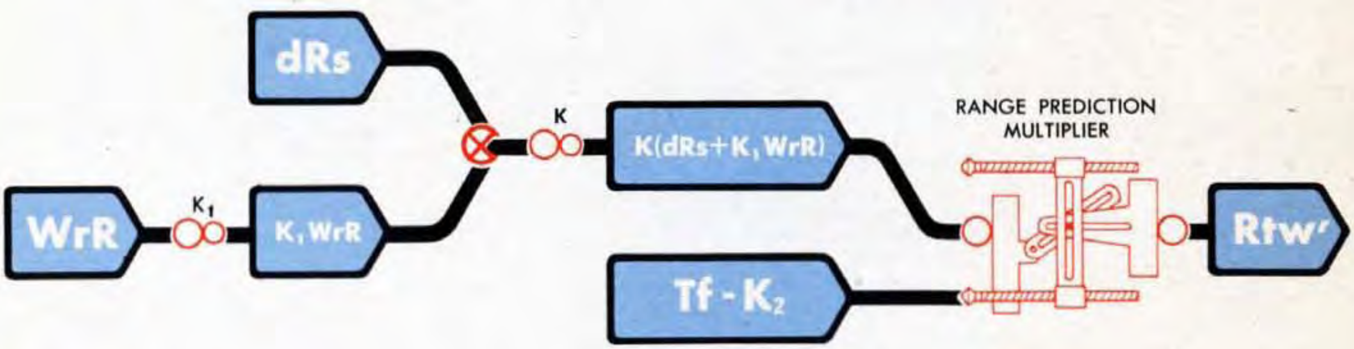
The same multiplier also multiplies K_1WrR by $Tf - K_2$. These two computations are made in the same multiplier to save mechanisms. K_1WrR is added to dRs to obtain $dRs + K_1WrR$. The quantity $dRs + K_1WrR$ is then multiplied by the constant K in a gear ratio to obtain the quantity:

$$K\ (dRs + K_1WrR)$$

In the Range Prediction Multiplier, $K\ (dRs + K_1WrR)$ is multiplied by $Tf - K_2$ to obtain Rtw'.

$$K\ (dRs + K_1WrR) \times (Tf - K_2) = Rtw'$$





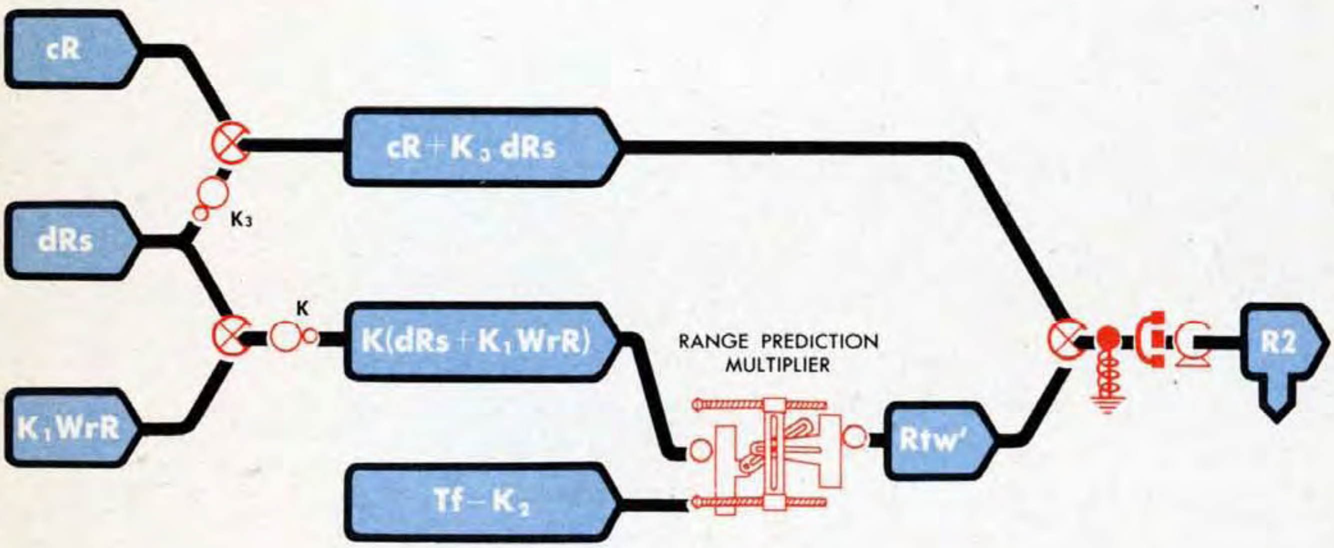
K is a constant used to change knots to yards per second. K_2 is required for computing Rw. Because only one multiplier is used instead of two, dRs is also multiplied by K_2. This means that the output of the multiplier will be Rtw' ($= Rt' + Rw$) instead of Rtw. (See NOTE on page 266.) The necessary correction is applied by a branch of the dRs line which bypasses the multiplier.

The range prediction multiplier by-pass

The constant K_2, which is introduced into the equation for *Rtw′*, is needed to produce *Rw*, but is not needed to produce a correct value of *Rt*. Since *dRs*, as well as *WrR*, is multiplied by this constant, K_2, the Range Prediction Multiplier output, *Rtw′*, contains an error, $(-K \cdot K_2 \cdot dRs)$. This error in *Rtw′* is cancelled by the K_3dRs by-pass. K_3dRs is first added to *cR*. Then the sum of *cR* and K_3dRs is added to *Rtw′* to obtain *R2*.

$$Rtw' + cR + K_3dRs = R2,$$

where $K_3 = K \times K_2$.



WHEN THE VALUE OF *R2* HAS BEEN ALTERED TO COMPENSATE FOR WIND, *R2* NO LONGER REPRESENTS THE DISTANCE FROM OWN SHIP TO THE TRUE PREDICTED TARGET POSITION. IT IS THE ADVANCE RANGE TO AN *IMAGINARY* PREDICTED TARGET POSITION.

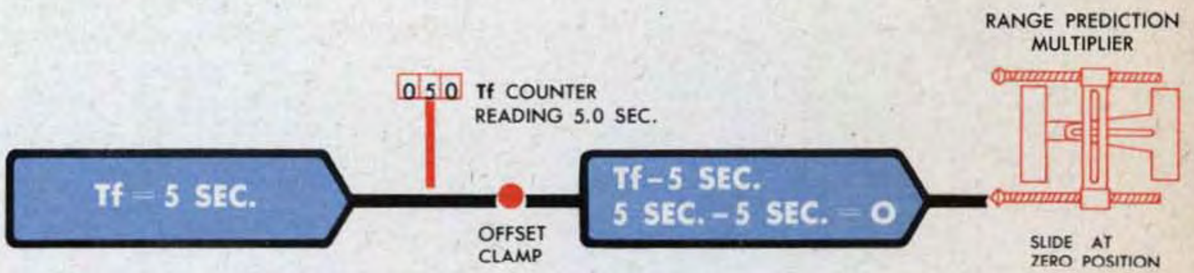
How the multiplier input is changed from Tf to Tf−K_2

K_2 is an offset.

The value of this constant, K_2, is 5 seconds.

In order to produce a value of $Tf - 5$ for every input of Tf, the multiplier slide is set so that it is at its zero position when the Tf Counter reads 5 seconds.

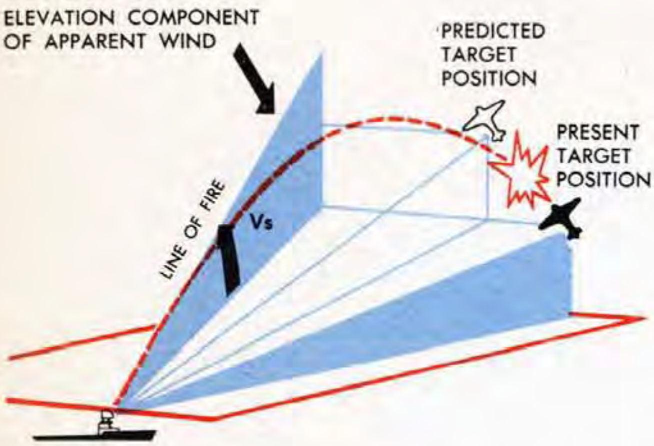
The position of the slide always represents five seconds less than the value of Tf, and causes the second input to be multiplied by $Tf - K_2$.

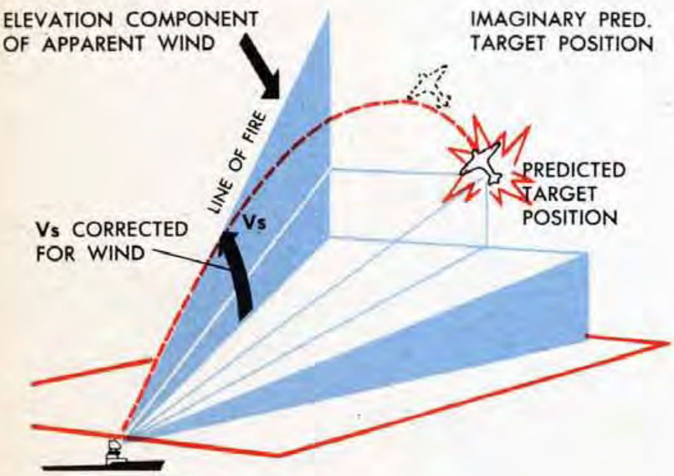


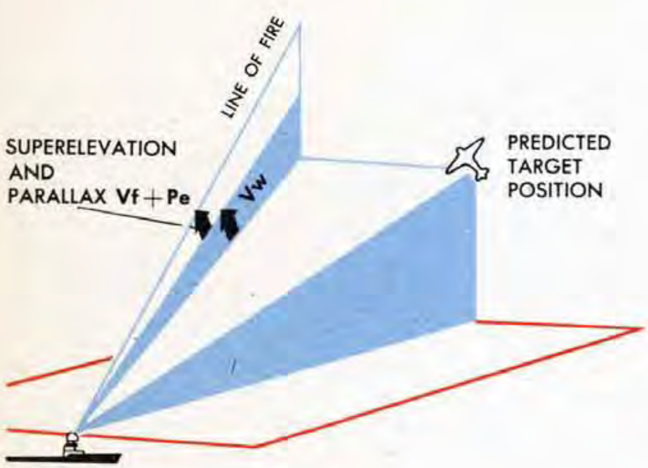
Correcting F to allow for wind

Since the altered value of *R2* is used in the Fuze network, the value of Fuze Setting Order, *F*, contains an allowance for Wind.

Correcting Vs to allow for WIND







The effect of the Elevation Wind on a projectile can be seen by studying a problem where the wind is blowing at right angles to the Line of Fire, in the vertical plane through the Line of Fire. Assume that this wind would depress a projectile below its normal trajectory and cause it to burst below the Target.

If an imaginary Predicted Target Position is assumed above the True Predicted Target Position, and *Vs* is increased accordingly, a projectile fired using this *Vs* would be carried downward by the wind and would burst at the True Predicted Position.

The Elevation Correction for Wind is made therefore by decreasing or increasing Sight Angle, *Vs*.

In the Computer Mark 1, Sight Angle, *Vs*, is corrected for Wind by decreasing or increasing the output of the Elevation Prediction Multiplier by a computed amount. The angular amount that the multiplier output must be altered is *Vw*, Elevation Prediction to compensate for Wind. The Elevation Wind Rate, *WrE*, is used in the mechanism equation for *Vw*. The equation is:

$$Vw = K_1 WrE \times (Tf/R2 - K_2)$$

WrE is multiplied by K_1 by means of a gear ratio to produce $K_1 WrE$. The quantity K_2 is introduced by an offset in the *Tf/R2* line.

The value of *Tf/R2* is affected by the constants used in the RANGE Prediction for Wind because the altered *R2* is used in computing *Tf/R2*. The constants, K_1 and K_2, in the *Vw* equation are such that they supplement the Range constants, thereby completing the solution for *Vw*.

The quantity $K_1 WrE$ is multiplied by $Tf/R2 - K_2$ in the Elevation Prediction Multiplier. *Vw* does not exist as a separate quantity, but is part of the output of the Elevation Prediction Multiplier.

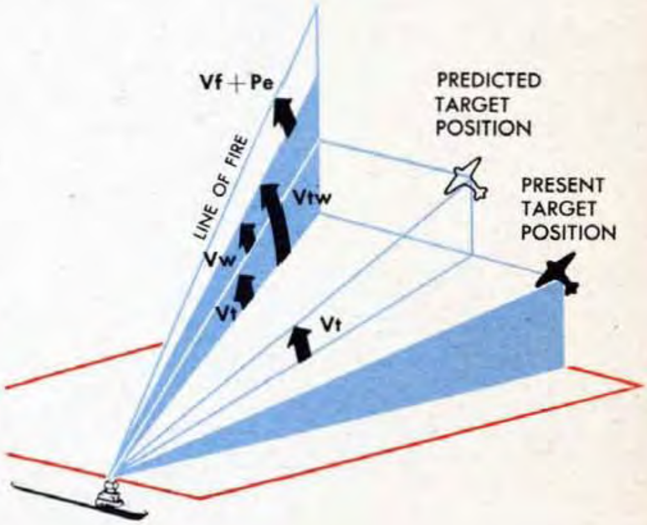
Vw alters *E2* and *E2* alters *R2*. These two quantities in turn alter all the Prediction quantities.

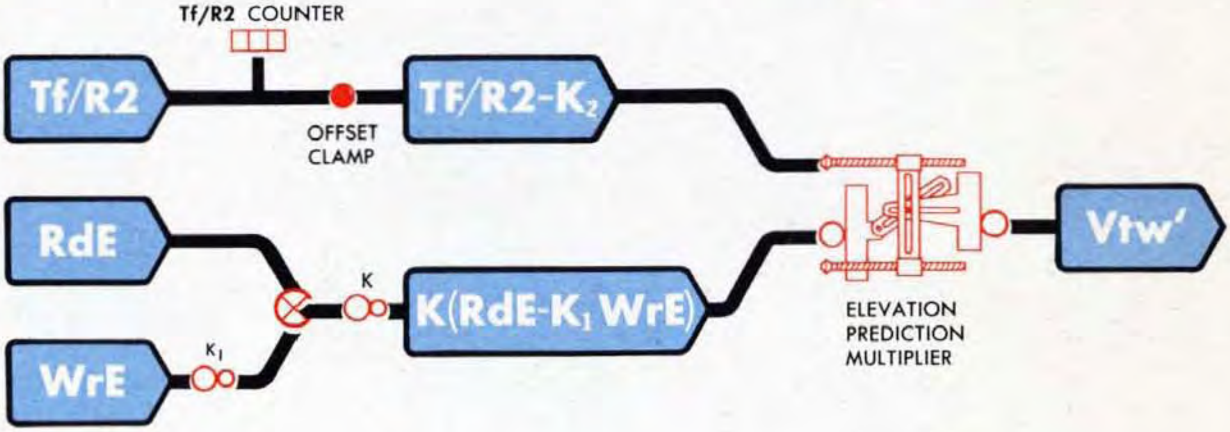
The elevation prediction multiplier

Linear Elevation Rate, RdE, is multiplied by $Tf/R2$ in the Elevation Prediction Multiplier to compute Vt, the Elevation Prediction to compensate for Relative Motion during the Time of Flight. Instead of using two multipliers, one to multiply RdE by $Tf/R2$ and another to multiply $K\,WrE$ by $Tf/R2 - K_2$, both of these computations are made in the Elevation Prediction Multiplier. K_1WrE is subtracted from RdE to obtain $RdE - K_1WrE$. $RdE - K_1WrE$ is then multiplied by a constant K, and $K(RdE - K_1WrE)$ is multiplied by $Tf/R2 - K_2$.

$$K(RdE - K\ WrE) \times (Tf/R2 - K_2) = Vtw'$$

The multiplier output, Vtw', is the sum of Vt' and Vw. Vt' is an incorrect value of Vt for reasons explained in the note on page 266. The necessary correction is applied by means of the RdE by-pass.





The elevation prediction multiplier by-pass

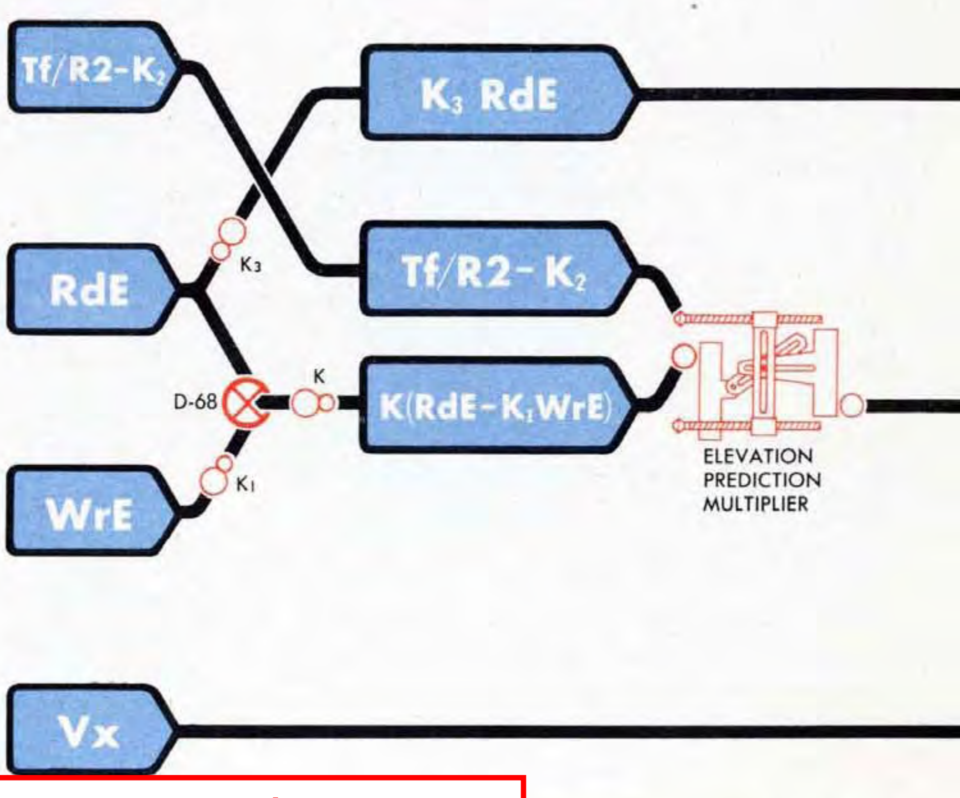
The constant K_2 which is introduced into the equation for solving Vtw is needed in producing an accurate value of Vw but is not needed to produce a correct Vt value. Since not only the Wind Rate, WrE, but also Linear Elevation Rate, RdE, is multiplied by this constant, the Elevation Prediction Multiplier output, Vtw', contains an error which is a function of RdE. This error in Vtw' is corrected by the K_3RdE by-pass.

The multiplier output, Vtw', is first combined with Complementary Error Correction, Vx, at differential D-70. Vtw' minus Vx is then corrected by adding K_3RdE at differential D-71. The output of differential D-71 is angular Elevation Prediction, V.

$$V = Vtw' - Vx + K_3RdE,$$

or

$$V = Vtw - Vx$$



Sight Angle, *Vs*, is corrected for the effect of the Elevation Wind Rate because Elevation Prediction, *V*, containing the Wind Correction, is used in computing *Vs*.

$$Vs = V + Vf + Pe$$

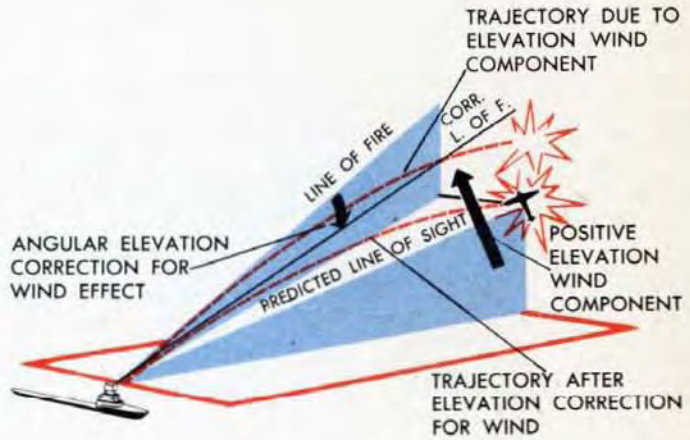
Predicted Target Elevation, *E2*, which is used as an input to the four ballistic computers, is also altered for the effect of the Elevation Wind Rate because the altered Elevation Prediction, *V*, is used in computing *E2*:

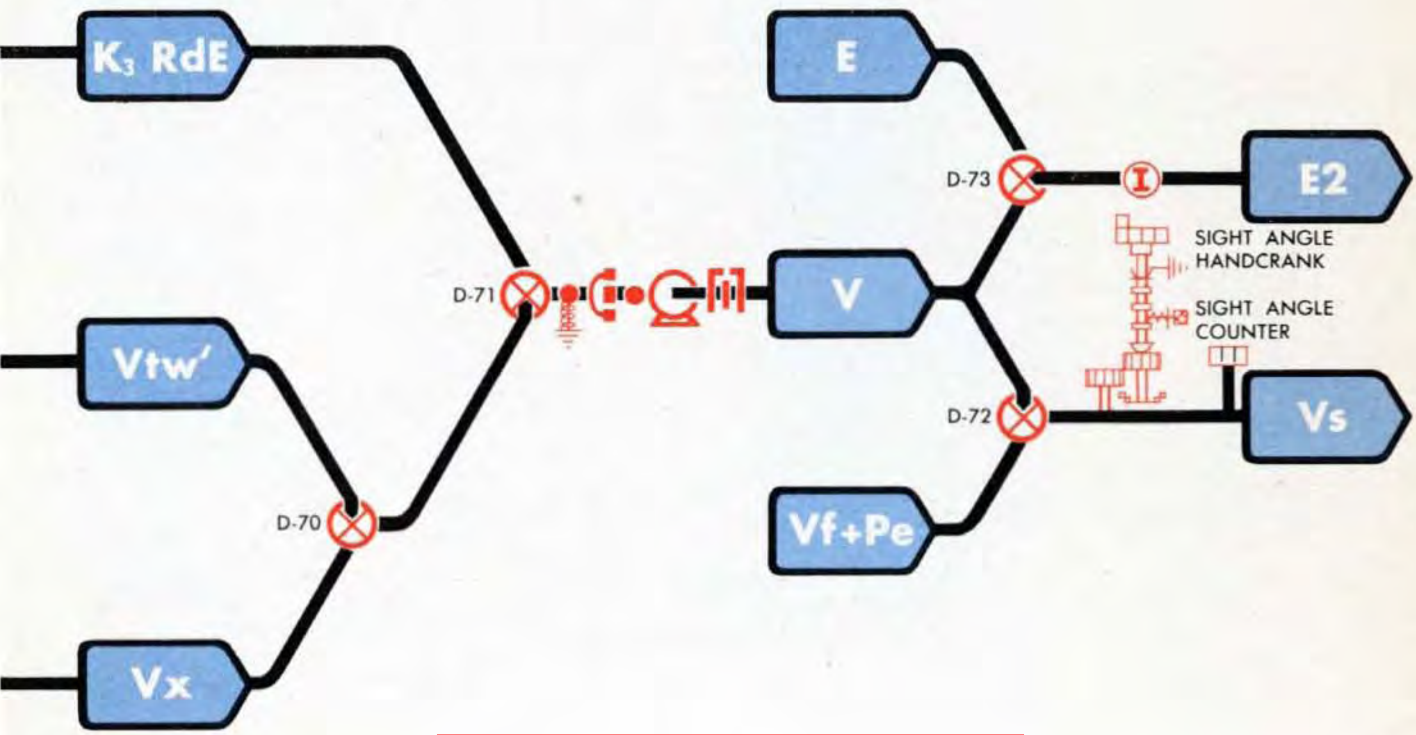
$$E2 = E + V$$

Why WrE is SUBTRACTED from RdE

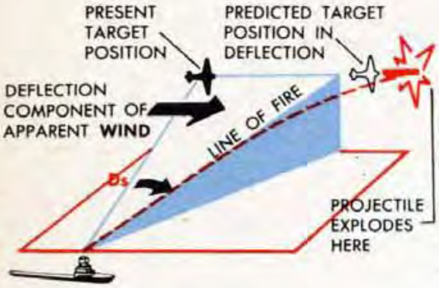
The Elevation Wind Rate is positive when the Wind is upward, since it tends to increase the Elevation of the projectile. The angular correction for a positive Elevation Wind Rate must reduce the Elevation. For this reason a positive Elevation Wind Rate, *WrE*, must be subtracted from the Elevation Rate, *RdE*, to reduce *Vs* and lower the Line of Fire.

When the Elevation Wind Rate is downward, it is a negative rate. This rate is still subtracted from *RdE*. Subtracting a negative value increases *Vs* and raises the Line of Fire.



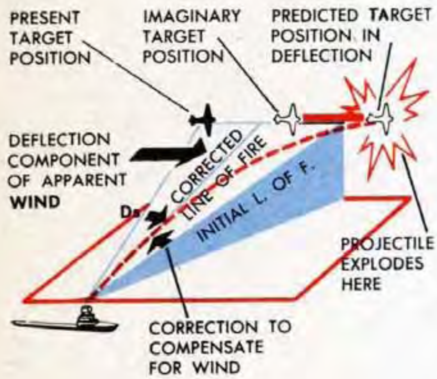


Correcting Ds to allow for WIND



The effect of the Deflection Wind Rate on a projectile can be seen by studying a problem where the Apparent Wind is coming from the left at right angles to the Line of Fire. This Wind would blow the projectile to the right, and would cause it to burst to the right of the Target.

If the Target's Predicted Position is assumed to be to the left of its True Predicted Position, and if Sight Deflection, *Ds*, is altered so that it is correct for this imaginary Predicted Target Position, a projectile fired using this value of *Ds* will burst at the True Predicted Target Position.



In the Computer Mark 1, the value of *Ds* is corrected for the effect of Wind by decreasing or increasing the output of the Deflection Prediction Multiplier by a computed amount. The angular amount by which the multiplier output must be altered is *Dw*, the Deflection Prediction to compensate for Wind. Deflection Wind Rate, *WrD*, is used in the mechanism equation for computing *Dw*. The equation used is:

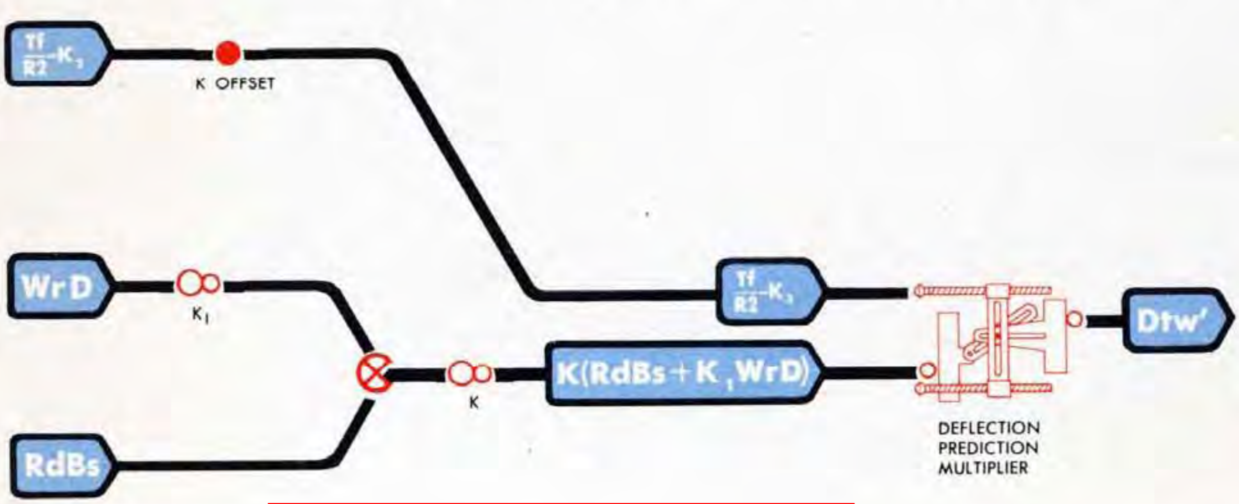
$$Dw = K_1 WrD \times (Tf/R2 - K_3)$$

WrD is multiplied by K_1 in a gear ratio to produce $K_1 WrD$.

The quantity $Tf/R2 - K_2$, used in computing the Elevation Prediction for Wind, is offset by an additional constant to obtain $Tf/R2 - K_3$. Then $K_1 WrD$ is multiplied by $Tf/R2 - K_3$ in the Deflection Prediction Multiplier.

Like *Rw* and *Vw*, *Dw* does not exist as a separate quantity. *Dw* is part of the output of the Deflection Prediction Multiplier.

The constants K_1 and K_3 in the *Dw* equation supplement the changes already made to $Tf/R2$ by the Range and Elevation Wind Predictions and complete the solution for *Dw*.



The deflection prediction multiplier

The output of the Deflection Prediction Multiplier is *Dtw'*, the sum of *Dt'* and *Dw*. *Dt'* is the sum of *Dt* and an unwanted quantity. (See NOTE on page 266.) *Dw* is the Deflection Prediction for Wind.

K_1WrD is added to $RdBs$ to obtain $RdBs + K_1WrD$. $RdBs + K_1WrD$ is first multiplied by a constant, K, and is then multiplied by $Tf/R2 - K_3$ to produce *Dtw'*.

$$K(RdBs + K_1WrD) \times (Tf/R2 - K_3) = Dtw'$$

The unwanted quantity in *Dtw'* is $(-K_3RdBs)$. It is removed by a multiplier by-pass.

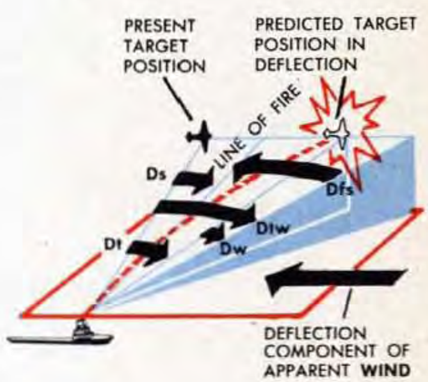
The multiplier by-pass

A branch of the *RdBs* line is multiplied by K_3 at a gear ratio to produce K_3RdBs, the quantity used as the multiplier by-pass. K_3RdBs is added to the multiplier output *Dtw'*, to obtain *Dtw*, the Deflection Prediction to compensate for Relative Motion and Wind.

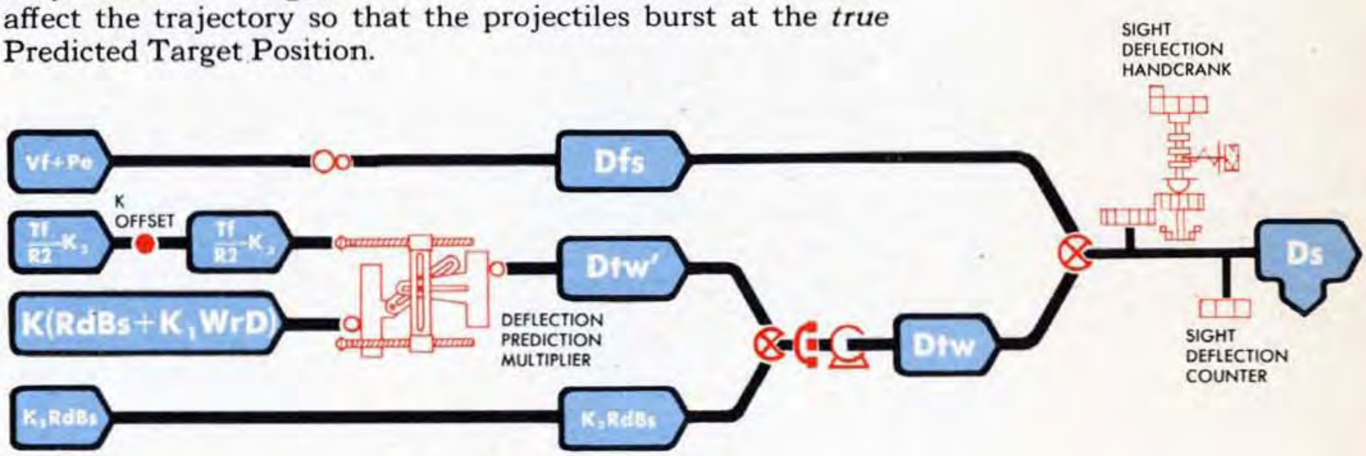
$$Dtw' + K_3RdBs = Dtw$$

Dtw is amplified by a velocity-lag follow-up. Drift Correction, *Dfs*, is subtracted from *Dtw* at a differential. The differential output is Sight Deflection, *Ds*.

$$Dtw - Dfs = Ds$$



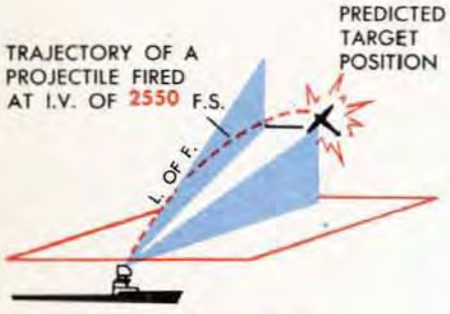
Since a prediction for the effect of Wind is contained in the value of *Dtw*, *Ds* also contains this Wind prediction. Projectiles fired using this adjusted value of *Ds* will be fired at an *imaginary* Predicted Target Position, but the Wind and Drift will affect the trajectory so that the projectiles burst at the *true* Predicted Target Position.



Using the adjusted values of *Vs*, *Ds*, and *F*, accurate values of Gun Train Order, Gun Elevation Order, and Fuze Setting Order can be computed, which will take into account not only Relative Motion, Drift, and Gravity, but also the effect of Wind on the projectile during the Time of Flight.

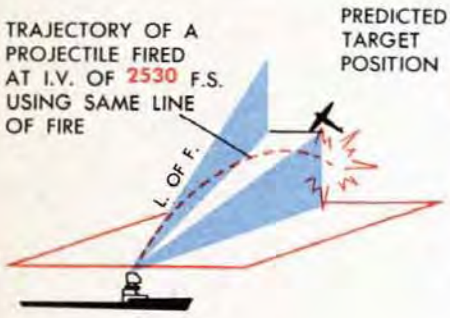
The only remaining corrections to *Vs*, *Ds*, and *F*, necessary to insure accurate predictions, are the corrections to allow for changes in the Initial Velocity of the projectiles.

INITIAL VELOCITY



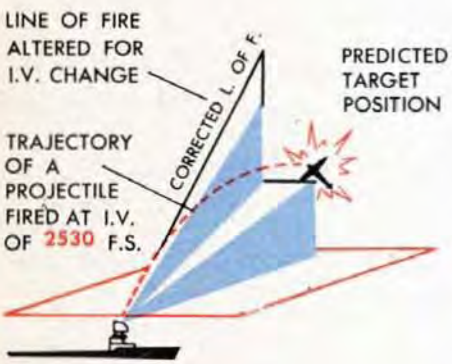
If all projectiles could be fired at an Initial Velocity of 2550 f.s., the computations for *Vs, Ds,* and *F* already described would be accurate.

All projectiles cannot be fired at an Initial Velocity of 2550 f.s. because wear on the gun rifling and changes in temperature and humidity of the powder charges all act to alter the Initial Velocity. An altered Initial Velocity will change the trajectory of a projectile. To offset this change in the trajectory, *Vs, Ds,* and *F* must be corrected. These corrections are called *I.V.* corrections.



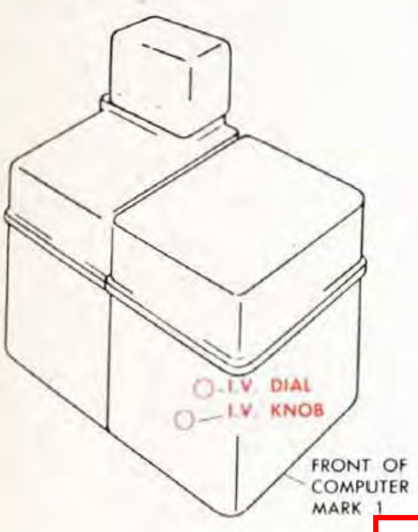
How a change in initial velocity alters a trajectory

A projectile fired at an *I.V.* below 2550 f.s. will travel more slowly and will drop sooner than a projectile fired at or above 2550 f.s. velocity. Without *I.V.* corrections, the projectile fired at a low *I.V.* would burst short of and below the Predicted Target Position. The *I.V.* corrections to *Vs, Ds,* and *F* to compensate for this changed trajectory are, therefore, based on an increased Advance Range, *R2,* an increased Advance Elevation, *E2,* and an increased Superelevation, *Vf.*



Determining the value of initial velocity

Each Computer computes for several guns. The average Initial Velocity of all the guns is determined according to ship's doctrine. This average Initial Projectile Velocity is the value of Initial Velocity, *I.V.*, used at the Computer.



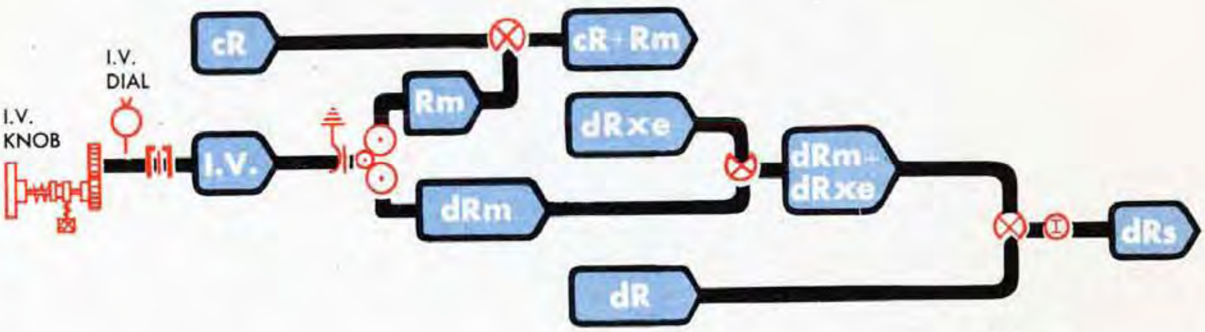
Putting I.V. into the computer

The ordered average Initial Velocity is set into the Computer by turning the *I.V.* Knob. The value of *I.V.* is read on the *I.V.* Dial. When *I.V.* is 2550 f.s., the *I.V.* Dial reads 2550, and the *I.V.* alteration in the Computer is zero. When *I.V.* is more or less than 2550 f.s., the value of the *I.V.* alteration in the Computer is equal to the difference between 2550 f.s. and the *I.V.* Dial reading.

Altering R2 for a change in initial velocity

Two alterations are made in Advance Range, *R2*, for each change in Initial Velocity, *I.V*.

The first alteration, called *Rm*, is obtained by means of a gear ratio on the *I.V*. shaft line. Thus, it will be proportional to the change in Initial Velocity. *Rm* is added to Generated Range, *cR*, at a differential.

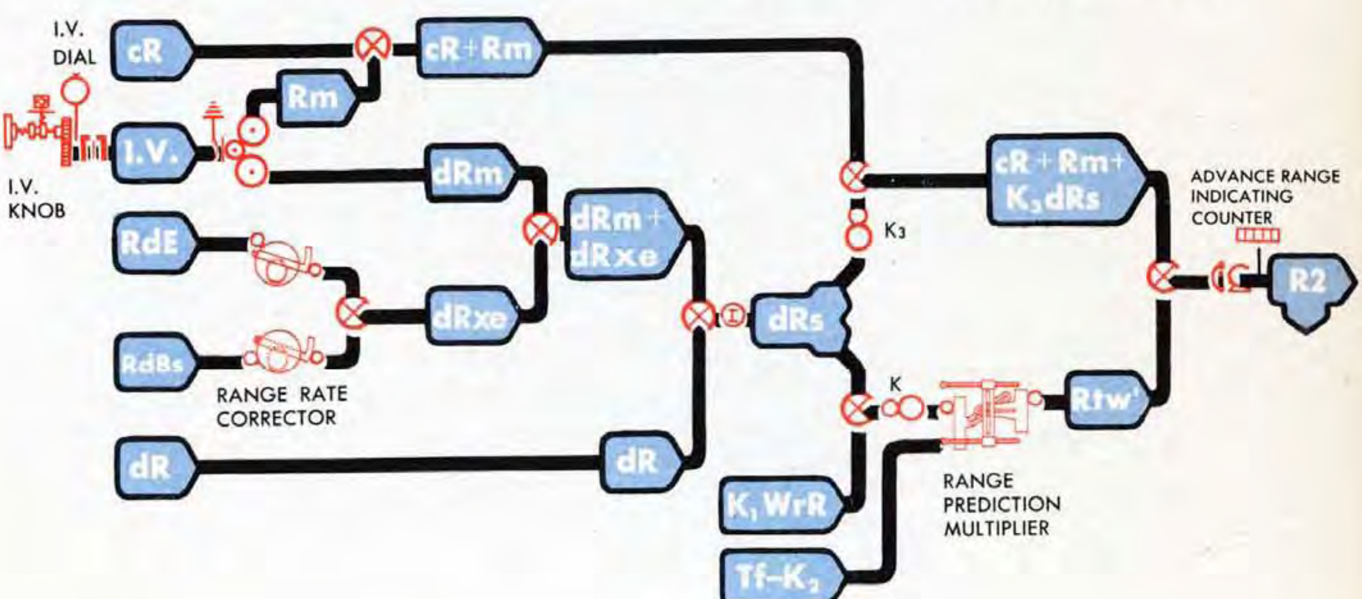


The second *I.V*. alteration is proportional both to the change in *I.V*. and to the value of Time of Flight, *Tf*. This alteration is obtained by multiplying *I.V*. by a constant to produce *dRm*.

In order to multiply *dRm* by *Tf* in the Range Prediction Multiplier, *dRm* is used to alter Prediction Range Rate, *dRs*. The alteration quantity, *dRm*, is added to Range Rate Correction, *dRxe;* then the sum of *dRxe* and *dRm* repositions the *dRs* shaft line. The *I.V*. alteration, ($dRm \times Tf$), does not exist as a separate quantity, but is contained in *Rtw′*, the output of the Range Prediction Multiplier. $dRm \times Tf$ is the *I.V*. alteration of Range Prediction.

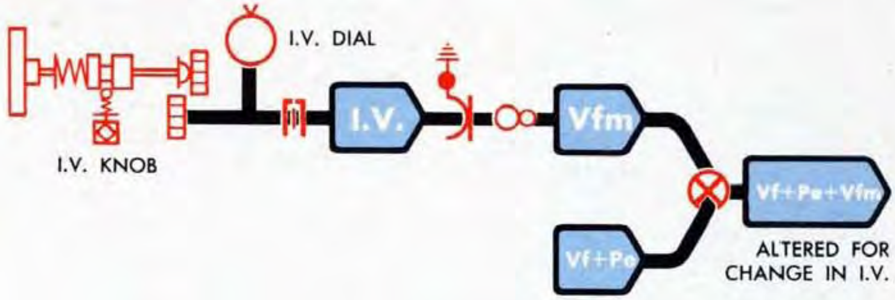
Since Advance Range, *R2*, is the sum of the two quantities *Rtw′* and ($cR + Rm + K_3dRs$), each of which contains an *I.V*. alteration, both *Rm* and ($dRm \times Tf$) are contained in *R2*.

NOTE:
Although the 5″/38 cal. projectiles have a standard or nominal Initial Velocity of 2600 f.s., the ballistic cams and *I.V*. gearing of the Computer were designed for projectiles with an intermediate Initial Velocity of 2550 f.s. One of the reasons why 2550 f.s. was chosen instead of 2600 f.s. was that, from a base of 2550 f.s., *I.V*. corrections can be made in either direction, thus reducing the size of the maximum correction and increasing the accuracy of the average correction.



Correcting Vf for a change in I.V.

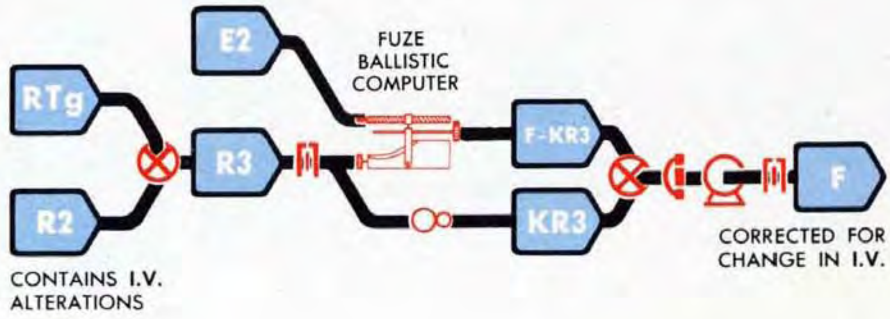
Since a decrease in Initial Velocity causes the projectiles to drop and explode below the Target, the value of Superelevation, *Vf*, must be increased. One part of the *I.V.* correction to *Vf* is called *Vfm*. *Vfm* is computed by multiplying the value on the *I.V.* shaft line by a constant at a gear ratio. *Vfm* is added to the output of the $Vf + Pe$ Ballistic Computer, forming the quantity $Vf + Pe + Vfm$, which represents Superelevation containing an *I.V.* alteration, plus Elevation Parallax. The *I.V.* alterations of *R2* and *E2* also play a part in correcting *Vf*, because *R2* and *E2* are the inputs to the $Vf + Pe$ Ballistic Computer.



How Fuze Setting Order, F, is corrected for a change in I.V.

The value of *R2* used in the Fuze Setting Order network contains an *I.V.* alteration. *R2* is added to the output of the Dead Time Prediction Multiplier to produce *R3;* therefore the *I.V.* alteration in *R2* is also contained in *R3*. *R3* turns the cam in the Fuze Ballistic Computer.

Since *R3* contains this *I.V.* alteration, the value of Fuze Setting Order, *F*, coming from the Fuze Ballistic Computer will be corrected for the deviation in *I.V.* from 2550. This *F* will set the fuze for a burst at the Predicted Target Position in spite of the lower Initial Velocity of the projectile.



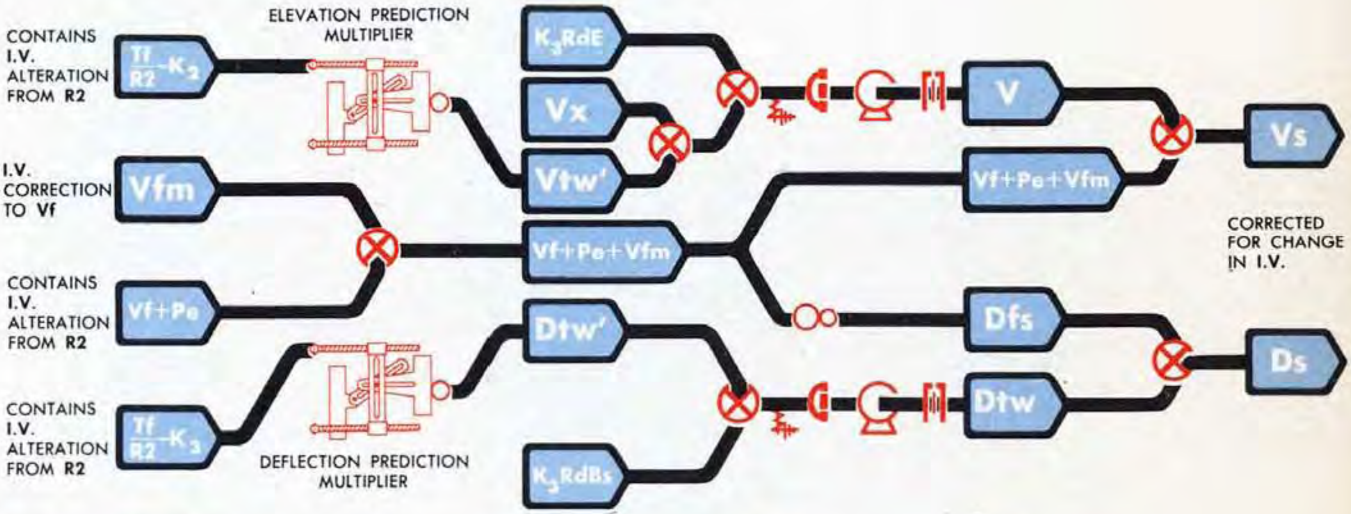
How I.V. alterations to R2 and Vf correct Vs

The value of *R2* containing an *I.V.* alteration positions the cam in the *Tf/R2* Ballistic Computer. The value of *Tf/R2* coming from this computer therefore also contains an *I.V.* alteration. The altered *Tf/R2* causes *I.V.* alterations to be contained in the Elevation Prediction quantities computed using this value of *Tf/R2*. These quantities are *Vtw'*, *V*, and *Vs*.

In addition to the *I.V.* corrections introduced by means of the altered *Tf/R2* line, *Vs* contains *I.V.* corrections introduced through the *Vf* + *Pe* + *Vfm* line.

Vf + *Pe* + *Vfm* contains two *I.V.* corrections. One is introduced by use of the altered value of *R2* as an input to the *Vf* + *Pe* Ballistic Computer. The other, *Vfm*, supplements the correction introduced by the altered *R2*.

Since the quantity *Vf* + *Pe* + *Vfm* is added to *V* to form *Vs*, all the *I.V.* corrections are introduced into *Vs*. The value of *Vs* includes all the elevation corrections to compensate for the drop of the projectile due to a change in Initial Velocity.

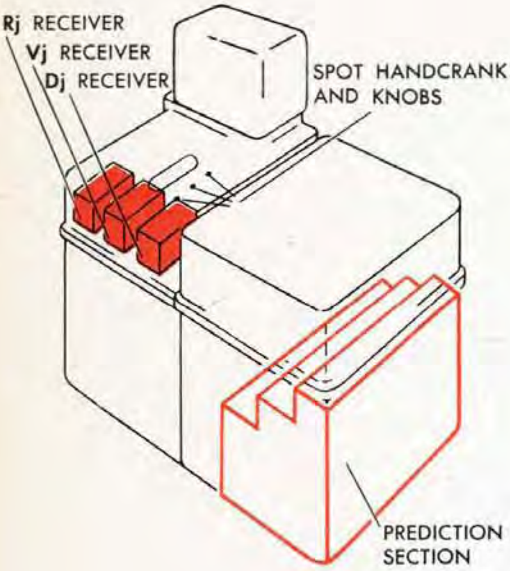


How I.V. alterations to R2 and Vf correct Ds

The *I.V.* alterations in *R2* introduce an *I.V.* alteration into *Tf/R2*. *Tf/R2* is part of the input to the lead screw of the Deflection Prediction Multiplier; therefore the output of this multiplier, *Dtw'*, also contains an *I.V.* correction.

The value of Drift Correction, *Dfs*, is obtained by a gear ratio from the *Vf* + *Pe* + *Vfm* line, which contains *I.V.* corrections. Therefore these corrections are also contained in *Dfs*.

Sight Deflection, *Ds*, consists of the two quantities, *Dtw* and *Dfs*. Each of these contains *I.V.* corrections; therefore *Ds* itself contains *I.V.* corrections. In this way *Ds* is altered to allow for the changes in Deflection required by the changed Initial Velocity.



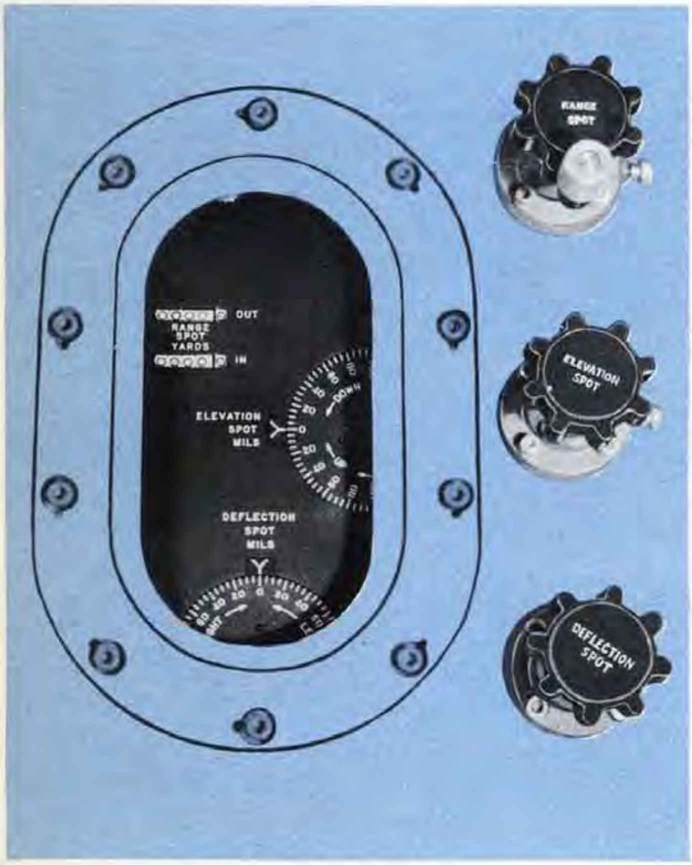
SPOTS

Spots are quantities which may be used to alter the values of the outputs of the Prediction Section. The use of Spots varies with each type of operation and is established by *ship's doctrine*.

There are three Spots used in the Prediction Section:

1. Range Spot, *Rj*, which is a linear alteration of Advance Range, *R2*.
2. Elevation Spot, *Vj*, which is an angular alteration of Sight Angle, *Vs*.
3. Deflection Spot, *Dj*, which is an angular alteration of Sight Deflection, *Ds*.

Each of these Spots may be put into the Prediction Section either by synchro transmission from the Director or by hand at the Computer.



SPOT COUNTERS, DIALS, HANDCRANK AND KNOBS

The spot mechanisms

Each Spot may be transmitted automatically from the Director to a single-speed receiver in the Computer. The Range Spot may be received at the *Rj* Receiver, the Elevation Spot at the *Vj* Receiver, and the Deflection Spot at the *Dj* Receiver. All three Spot Receivers are single-speed receivers.

The *Rj* Handcrank and the *Vj* and *Dj* Knobs each have two positions, IN and OUT. When the handcrank and knobs are in their OUT positions, they are disconnected from the *Rj*, *Vj*, and *Dj* lines. The electrical circuits to the *Rj*, *Vj*, and *Dj* Receivers are completed and the lines are positioned by the Spot receivers.

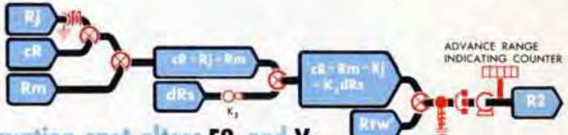
When the handcrank and knobs are in their IN positions, the circuits to the Spot receivers are broken, and the lines are positioned by the handcrank and knobs.

The total value of the Range Spots shows on the Range Spot Counter. The total values of the Elevation and Deflection Spots show on the Elevation and Deflection Spot Dials.

The Spot handcrank, knobs, dials, and receivers are in the rear top section of the Computer Mark 1. Shaft lines from the handcranks and receivers carry the Spot values to the Prediction Section at the front of the Computer.

How the range spot alters R2

Range Spot, Rj, is added to Generated Present Range, cR, at a differential. The output of this differential is used in computing Advance Range, $R2$; therefore $R2$ may be increased or decreased by use of the Range Spot, Rj.



How the elevation spot alters E2 and Vs

Elevation Spot, Vj, is added to K_3RdE and becomes part of the by-pass of the Elevation Prediction Multiplier. The by-pass quantity is used in computing V; therefore, V is offset by the amount of the Elevation Spot, Vj. Since the value of V containing the Spot is used in computing Vs and $E2$, the values of these quantities are also offset by Vj.

Any change in $E2$ caused by Elevation Spot, Vj, affects the outputs of the four ballistic computers. The effect of this change will be small, however, since the maximum Elevation Spot that can be introduced through the Vj line is 180 mils, and Elevation changes have less effect on the outputs of the ballistic units than changes in Advance Range.

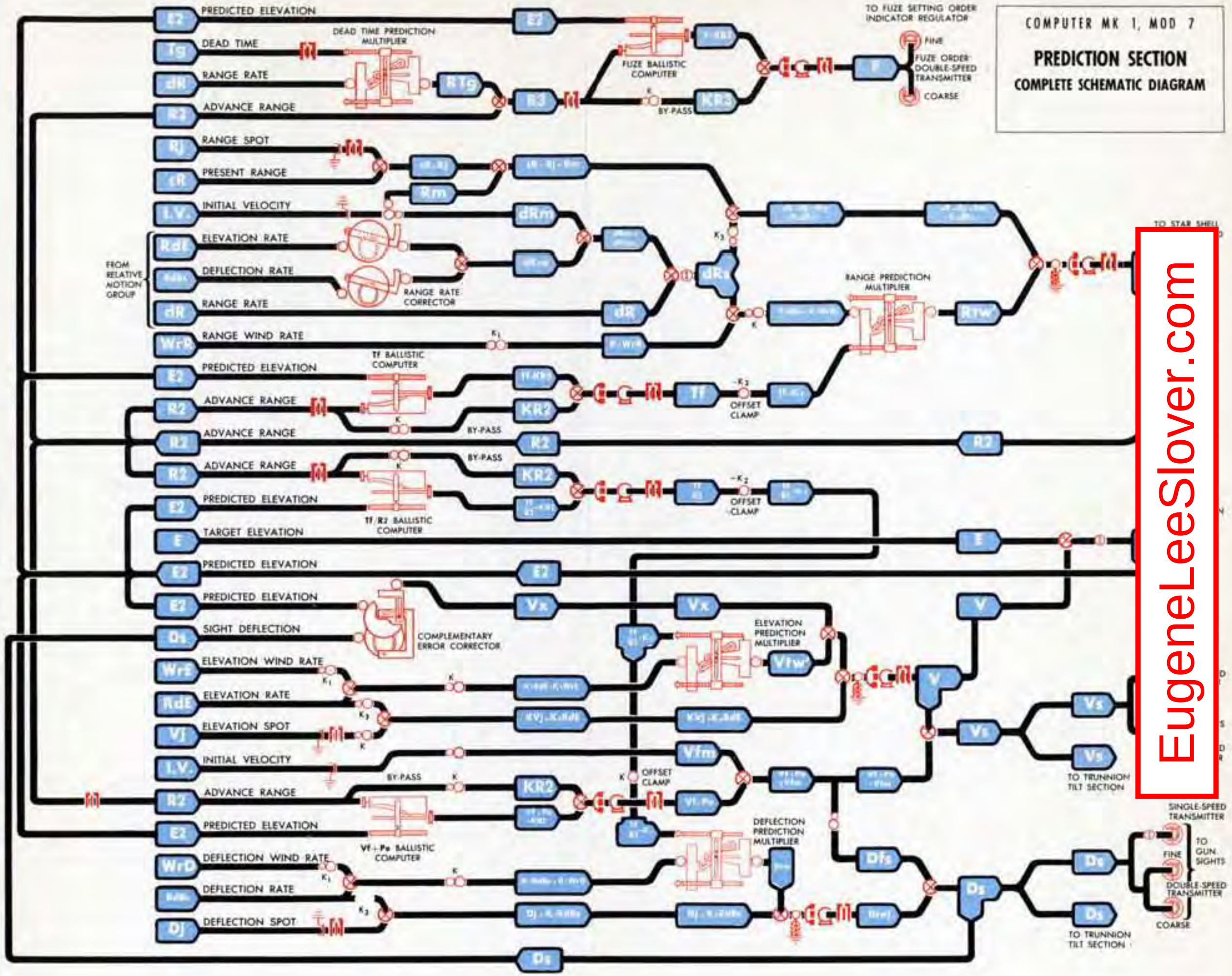
How the deflection spot alters Ds

Deflection Spot, Dj, is added to K_3RdBs and becomes part of the by-pass of the Deflection Prediction Multiplier. $Dj + K_3RdBs$ is added to the multiplier output, Dtw', to form $Dtwj$. Drift Correction, Dfs, is added to $Dtwj$ to form Ds. Ds is therefore offset by the amount of the Deflection Spot, Dj.

COMPUTER MK 1, MOD 7

PREDICTION SECTION

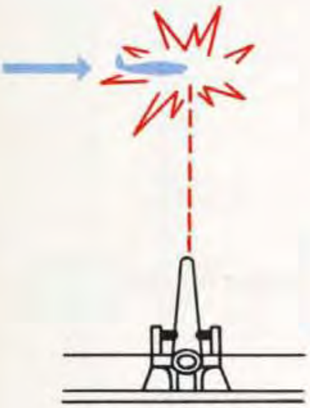
COMPLETE SCHEMATIC DIAGRAM



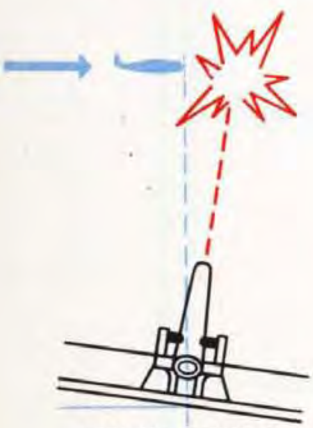
TRUNNION TILT

The guns are mounted between trunnions which tilt as the deck rolls and pitches. Trunnion Tilt Corrections are corrections to keep the guns pointing along the Line of Fire despite the tilting of the trunnions.

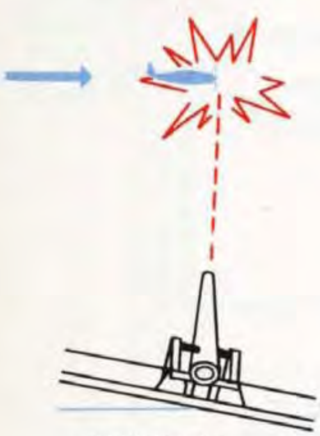
Since the trunnions are mounted parallel to the deck, the guns must train in the deck plane and elevate in a plane at right angles to the deck. The error in the gun aim caused by tilting of the trunnions must be corrected by continuously altering the Gun Elevation and Train Orders.



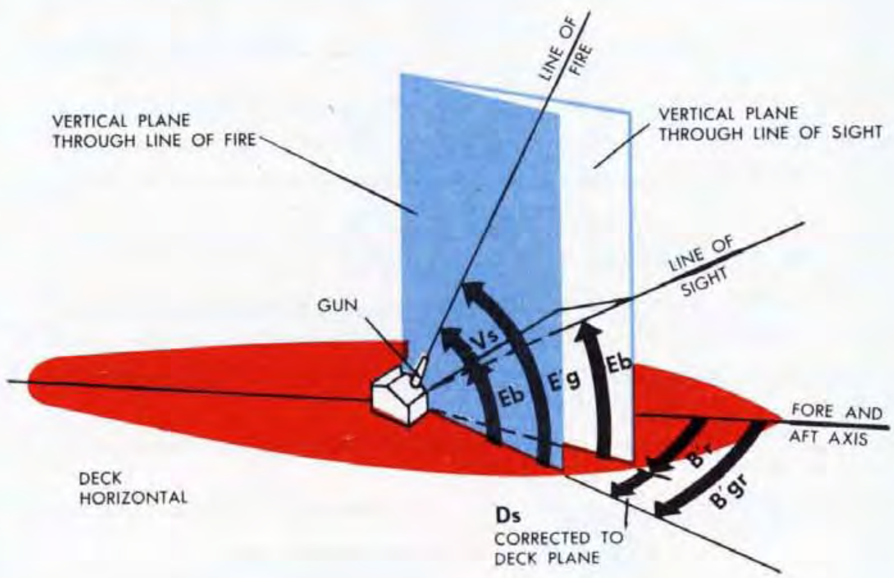
GUN AIM ESTABLISHED ON HORIZONTAL DECK



GUN AIM IS FALSE ON TILTED DECK WITHOUT TRUNNION TILT CORRECTIONS



TRUNNION TILT CORRECTIONS CORRECT GUN AIM FOR TILTED DECK

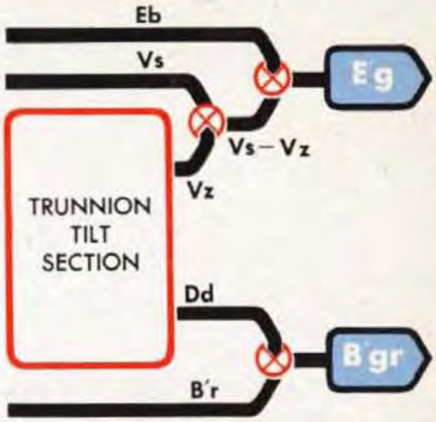


On a horizontal deck the Gun Elevation Order, *E′g*, consists of Director Elevation, *Eb*, plus Sight Angle, *Vs*.

On a horizontal deck the Gun Train Order, *B′gr*, consists of Director Train, *B′r*, plus Sight Deflection, *Ds*, converted to the deck plane. (*Ds* is measured in a slant plane. It must be converted to the deck plane before being used in the Gun Train Order.)

The Line of Fire established in this way from the horizontal deck is the line along which the gun must point to hit the Target. If the deck tilts, *the gun must be kept pointed along this Line of Fire, even though the Line will have a different elevation above the deck and a different train angle from the fore and aft axis of Own Ship.*

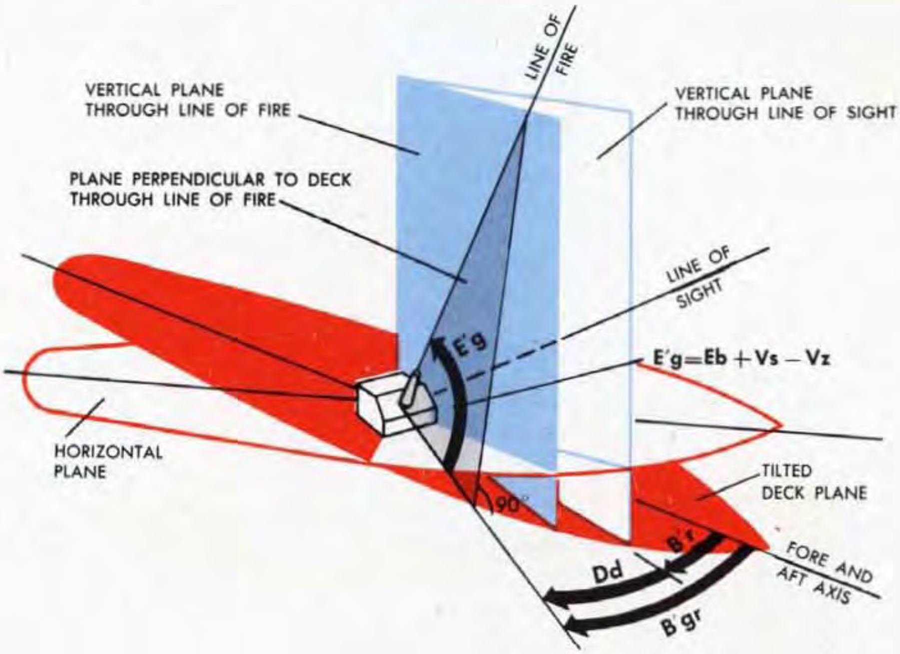
The Trunnion Tilt Section of the Computer Mark 1 computes two quantities. The first is Trunnion Tilt Elevation Correction, *Vz,* the second is Deck Deflection, *Dd,* which includes Trunnion Tilt Train Corrections.



Trunnion Tilt Elevation Correction, *Vz,* is continuously subtracted from $Eb + Vs$ to obtain Gun Elevation Order, *E'g,* measured from a tilting deck.

$$E'g = Eb + Vs - Vz$$

Deck Deflection, *Dd,* is the sum of Partial Deck Deflection, *jDd,* and Trunnion Tilt Train Correction, *Dz.*



The partial correction, *jDd,* represents *Ds* converted to the deck plane. *Dz* is approximately the Trunnion Tilt Train Correction to compensate for Cross-level, *Zd.*

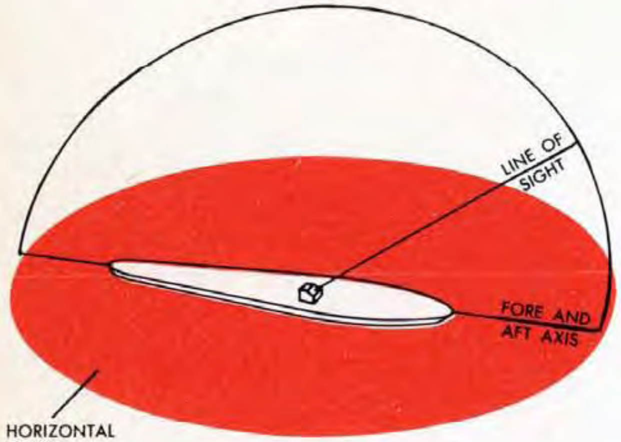
$$Dd = jDd + Dz$$

Deck Deflection, *Dd,* is continuously added to Director Train *B'r,* to obtain Gun Train Order, *B'gr,* measured in a tilting deck plane.

$$B'gr = B'r + Dd$$

The corrected Gun Train Order, *B'gr,* locates the base of a plane *at right angles to the deck* in which the gun can be elevated to lie on the Line of Fire. In this plane at right angles to the deck, the corrected Gun Elevation Order, *E'g,* continuously establishes the elevation of the Line of Fire above the tilting deck.

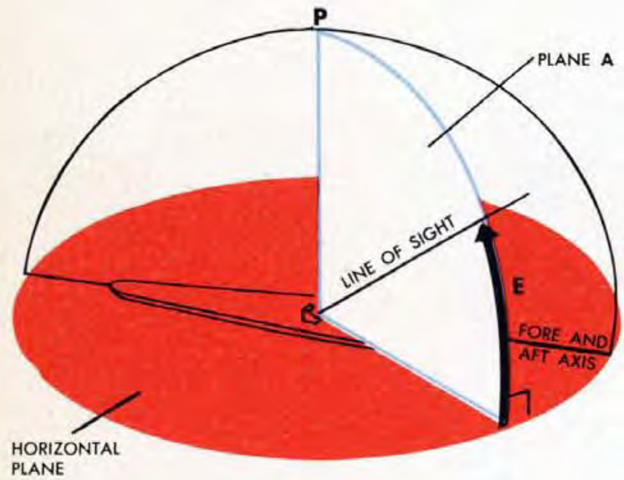
SETTING UP THE LINE OF FIRE FROM THE HORIZONTAL



To illustrate the Trunnion Tilt Corrections in detail a series of spherical diagrams will be used. The Director of Own Ship is considered to be at the center of the sphere or ball.

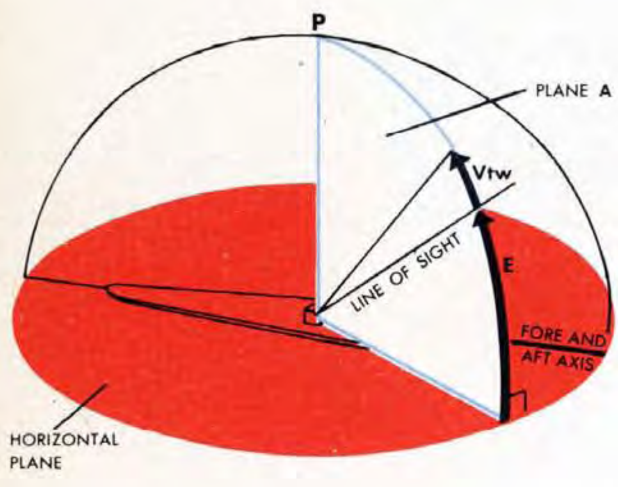
In these spherical diagrams any angle that has its vertex at the center of the sphere can be measured by the arc it cuts off on the surface of the sphere. (The vertex of an angle is the point where the two sides of the angle intersect.)

These diagrams show, first, how the Line of Fire is established on a horizontal deck and, second, how the Trunnion Tilt Corrections keep the gun pointing along the Line of Fire as the deck tilts.



A horizontal plane passes through the center of the sphere at the level of the Director of Own Ship. The Line of Sight runs from the center of the sphere to the Target

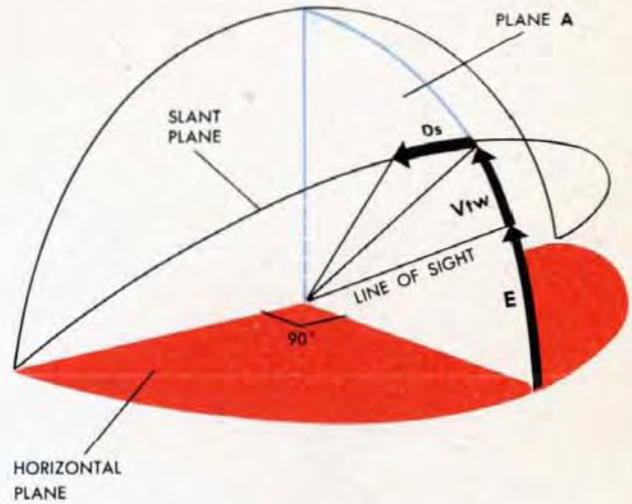
A line at right angles to the horizontal plane runs from the center of the sphere to point P at the top of the sphere. A vertical plane passes through this line and through the Line of Sight. This plane is called plane A, or the vertical plane through the Line of Sight.



Target Elevation, *E*, is the elevation of the Line of Sight above the horizontal in this vertical plane.

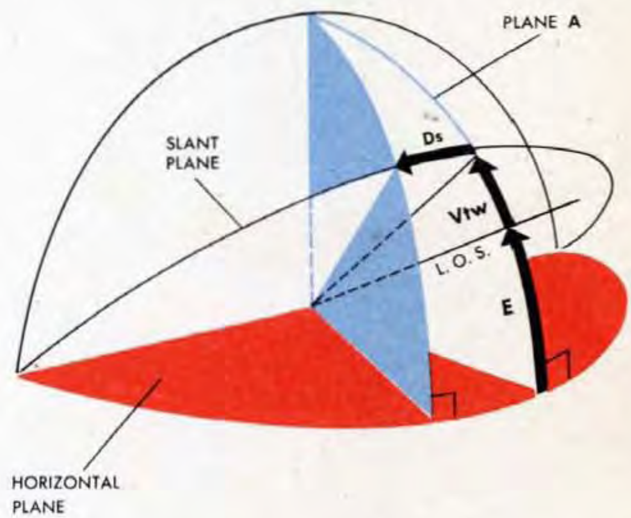
Angle *Vtw*, the Partial Elevation Prediction, is now added to *E* in the vertical plane through the Line of Sight. Both *E* and *Vtw* are measured by the arcs they cut off on the surface of the sphere.

A slant plane is now added at right angles to plane A and at angle $E + Vtw$ to the horizontal plane.



Sight Deflection, *Ds,* is measured in this slant plane. One side of *Ds* lies in the vertical plane containing the Line of Sight.

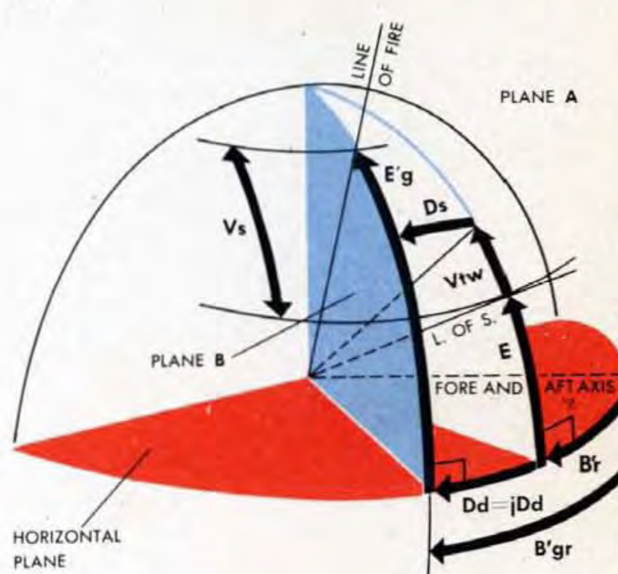
Another vertical plane, plane B, passes through the other side of angle *Ds.* This new vertical plane is the plane containing the Line of Fire.



The Line of Fire is now obtained by transferring angle *E* from plane A to plane B and adding *Vs* to angle *E* in this plane. Only the part of the slant plane actually contained in angle *Ds* is shown here.

Measuring the Line of Fire from the horizontal deck, the Gun Elevation Order, *E′g,* consists of *E* plus *Vs,* since *E* equals *Eb* when the deck is horizontal.

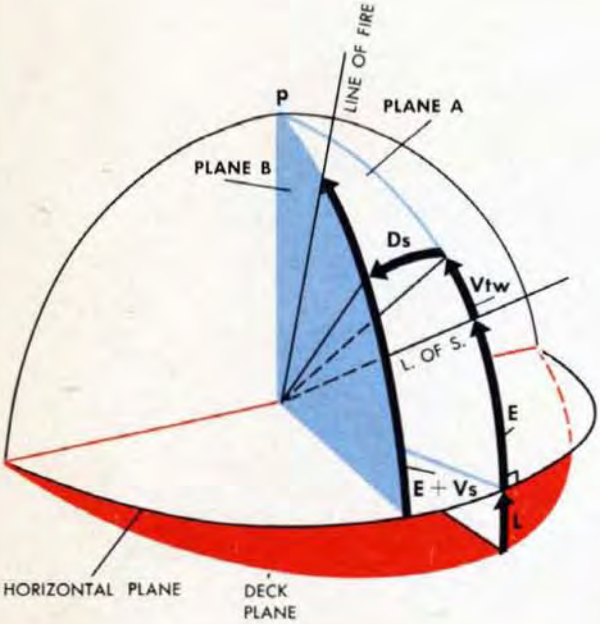
Gun Train Order, *B′gr,* is *B′r* plus *Dd.* Since the deck is horizontal, *Dd* consists only of *Ds* corrected to the deck plane. *Dz* is zero, since there is no Cross-level. *Dd,* therefore, equals *jDd.*



The Line of Fire shown in this picture must be maintained whether or not the deck is horizontal. The Trunnion Tilt Corrections alter the gun angles to keep the gun on the Line of Fire regardless of how the deck tilts.

THE LINE OF FIRE FROM A TILTED DECK

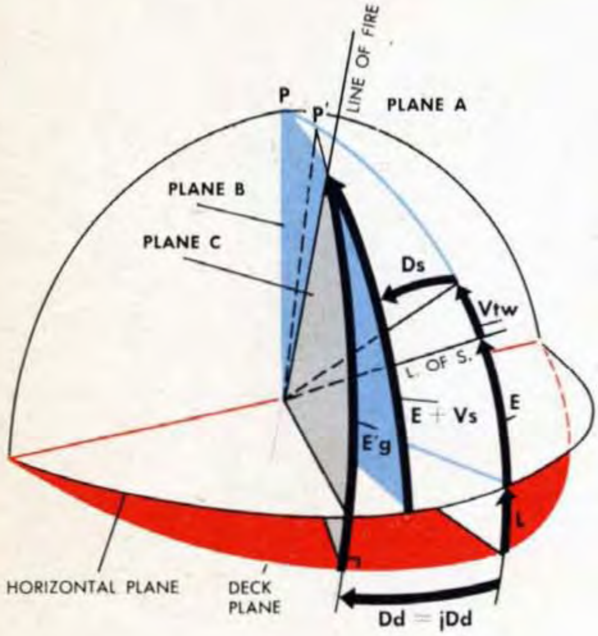
With level only



Now the deck is tilted down in Level.

Level, *L,* is the angle between the deck plane and the horizontal plane, measured in a vertical plane through the Line of Sight.

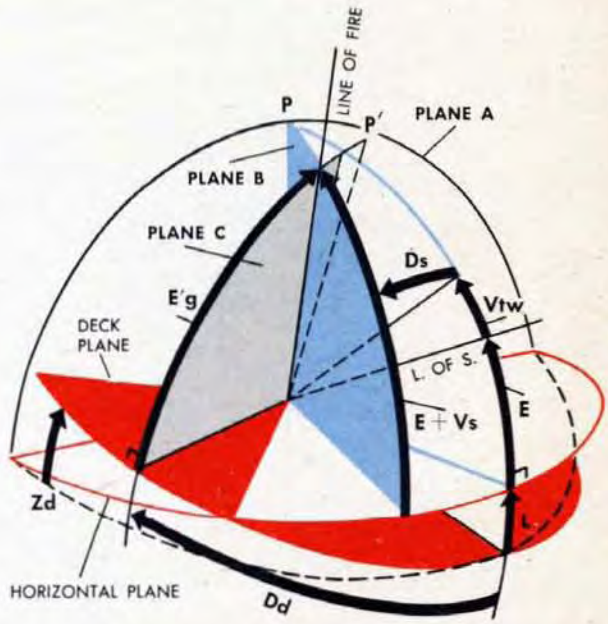
The Line of Fire as shown here has been established from the horizontal plane. Since the gun can only be elevated in a plane at right angles to the deck, a new plane must be found which passes through the Line of Fire, *and is at right angles to the deck.*



Plane C is this new plane. Since the deck is tilted, the line at right angles to the deck now passes through point P′. Plane C passes through this line, and through the Line of Fire. The train angle between plane A containing the Line of Sight and plane C containing the Line of Fire is Deck Deflection, *Dd*. *Dd* still consists of *jDd* only. *Dz* is zero since Cross-level, *Zd,* is zero.

The elevation of the Line of Fire above the deck in plane C is Gun Elevation Order, $E'g$, which now consists of $Eb + Vs$. The value of Vz is zero.

With level and cross-level



Cross-level, *Zd*, is the angle of roll of the deck about a line which is the intersection of the deck plane with the vertical plane through the Line of Sight.

When the deck is tilted in both Level and Cross-level, the line perpendicular to the deck passes through point P″.

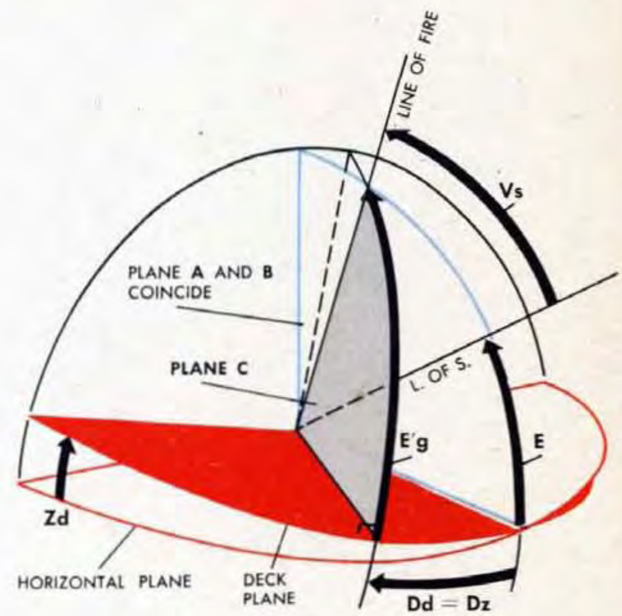
Plane C containing the Line of Fire now makes a different angle with plane A. *Dd* has changed by an amount, *Dz*, the Trunnion Tilt Train Correction to compensate for Cross-level.

It is difficult to show *jDd* and *Dz* separately in a diagram when both are present. A simple way to illustrate *Dz* is to show a case in which *jDd* is zero and where *Dd* consists only of *Dz*.

jDd is zero when *Ds* is at its zero position, that is, when the *Ds* Counter reads 500 mils. Then the Line of Fire lies in the vertical plane through the Line of Sight.

Here is such a case. Both *Ds* and *L* are zero. The deck is tilted in Cross-level only. Plane C, at right angles to the deck and passing through the Line of Fire, is at train angle *Dz* to plane A.

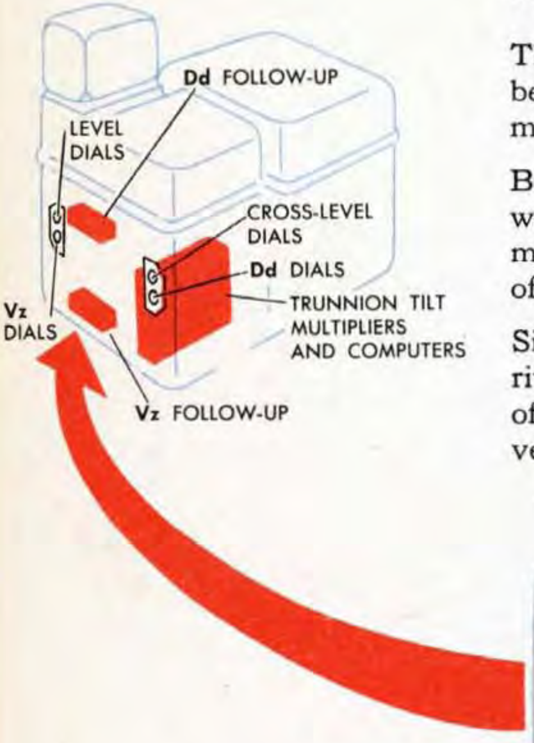
Here *Dd* = *Dz*.



The mechanisms and the equations

The Trunnion Tilt Section contains four computing mechanisms: a rack-type multiplier, a double-cam computing multiplier, and two special computers. This section also contains the *Vz* and *Dd* Follow-ups and Dials, the *L* and *Zd* Dials, various differentials, and a spring relief drive.

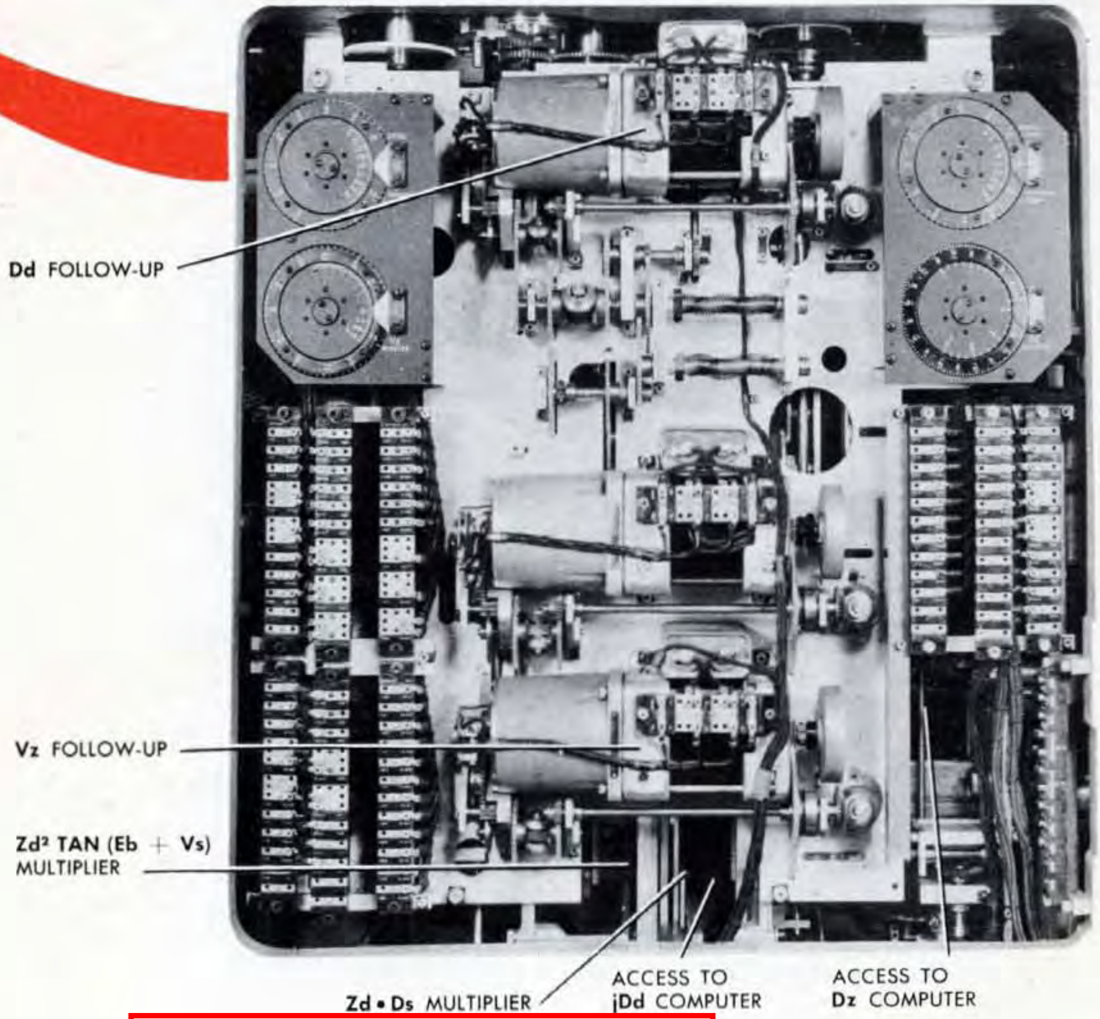
These mechanisms are all located at the back of the Computer Mark 1 and are used to solve the equations for *Vz* and *Dd*.



The true equations for both *Vz* and *Dd* are complex and cannot be solved mechanically without using many cumbersome mechanisms.

Because of this, the true equations have been modified in many ways. The modified equations can be solved with only a few mechanisms, and provide a solution within the required limits of accuracy.

Since the equations are modifications there is no point in deriving them here. They are just equations which give values of *Vz* and *Dd* close enough to the true values to keep the errors very small under most operating conditions.



COMPUTING Vz

Vz is the Trunnion Tilt Elevation Correction.

The *Vz* equation has two terms: one is $K \cdot Zd^2 \tan(Eb + Vs)$. The other term is $K_1\, Zd \cdot Ds$. Each of these terms is computed in a multiplier; then the two terms are added together in a differential.

The whole equation is:

$$Vz = K \cdot Zd^2 \tan(Eb + Vs) + K_1\, Zd \cdot Ds.$$

The *K* terms are constants introduced by gearing.

The Zd² tan (Eb + Vs) Multiplier

$Zd^2 \tan(Eb + Vs)$ is computed in a double-cam computing multiplier. The cams in this multiplier are a square cam and a tangent cam.

Cross-level, *Zd*, from the Stable Element goes to the square cam in this multiplier, which puts values of Zd^2 into the multiplier mechanism. (Zd^2 is also driven out to be used in computing *jDd*.)

Director Elevation, *Eb*, is added to Sight Angle, *Vs*, in differential D-13. Their sum, $Eb + Vs$, positions the tangent cam, putting $\tan(Eb + Vs)$ into the multiplier mechanism.

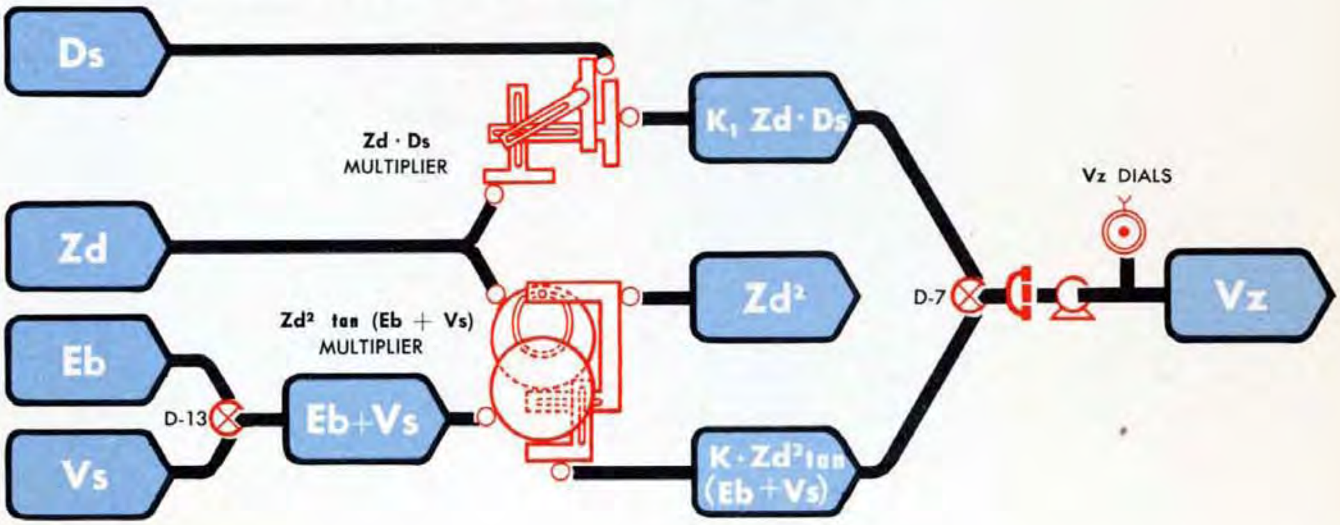
The multiplier output is $K \cdot Zd^2 \tan(Eb + Vs)$, the first term of the *Vz* equation.

The Zd · Ds Multiplier

$K_1\, Zd \cdot Ds$ is computed in a rack-type multiplier.

Cross-level, *Zd*, goes to the input rack. Sight Deflection, *Ds*, positions the input pivot arm. The output is $K_1\, Zd \cdot Ds$, the second term of the *Vz* equation.

The outputs of these two multipliers are added in differential D-7. The differential output is *Vz*, the Trunnion Tilt Elevation Correction. *Vz* is amplified by a compensated follow-up. Its value can be read on dials at the back of the Computer.



COMPUTING Dd

Deck Deflection, *Dd,* consists of Sight Deflection, *Ds,* corrected to the deck plane, and the train corrections for Trunnion Tilt.

The equation for *Dd* consists of the two terms, *jDd* and *Dz.*

$$Dd = Dz + jDd$$

Dz is approximately the Trunnion Tilt Train Correction for Cross-level.

jDd is approximately Sight Deflection, *Ds,* corrected to the deck plane.

The values of *jDd* and *Dz* are each computed in a special computer.

The Dz Computer

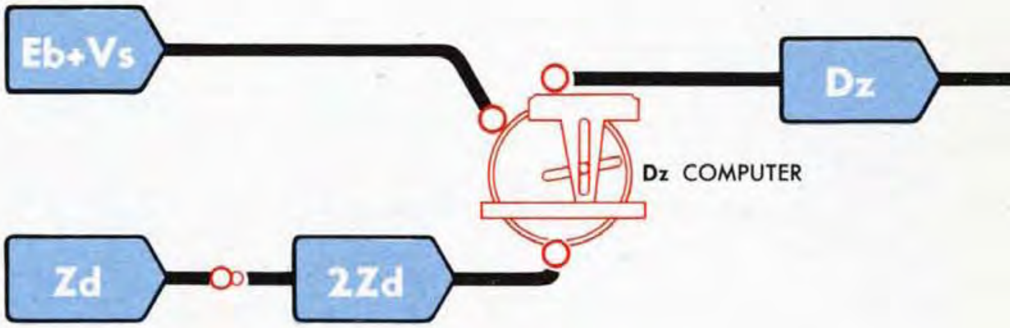
The *Dz* Computer is a component solver with only one rack.

This Computer solves the equation $f(Eb + Vs)\sin 2Zd$, which gives a close approximation of the true value of *Dz.*

$Eb + Vs$, which was one of the inputs to the $Zd^2 \tan(Eb + Vs)$ Multiplier, also positions the computing cam in the *Dz* Computer, putting in $f(Eb + Vs)$.

Cross-level, *Zd,* becomes *2Zd* through gearing, and the value of *2Zd* positions the vector gear.

The output is $f(Eb + Vs)\sin 2Zd$, which is called *Dz.*



The jDd Computer

The quantity $\sin^{-1}[Ds \cdot \sec(E2 + L - K \cdot Zd^2)]$ is used to give a good approximation of the real value of *jDd*.

Sin^{-1} means "the angle whose sine is;" therefore angle *jDd* is the angle whose sine is $Ds \cdot \sec(E2 + L - K \cdot Zd^2)$.

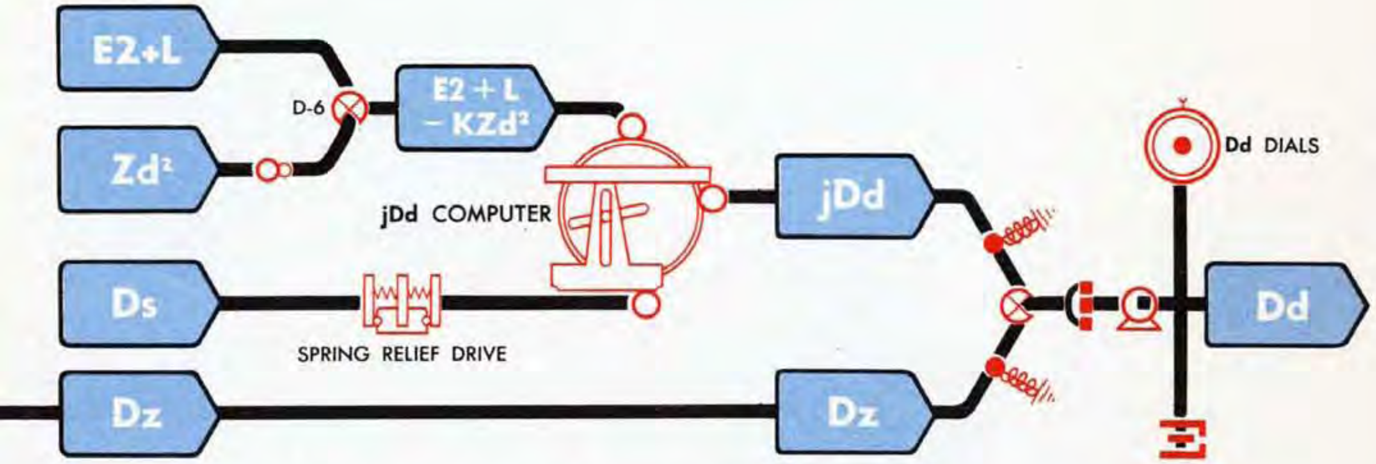
Since the secant is the reciprocal of the cosine, the equation for *jDd* can also be written in this form:

$$jDd = \sin^{-1}\left(\frac{Ds}{\cos(E2 + L - K \cdot Zd^2)}\right)$$

This equation is solved in the *jDd* Computer, which is similar to a component solver with only one rack.

A component solver used in the ordinary way has outputs equal to the cam input multiplied by the sine and cosine of the vector gear input angle.

In the *jDd* equation the value needed is THE ANGLE WHOSE SINE IS $Ds/\cos(E2 + L - K \cdot Zd^2)$. The output, therefore, comes from the vector gear instead of from the rack. The inputs position the cam and the rack.



The value of Zd^2 obtained from the square cam of the $Zd^2 \tan(Eb + Vs)$ Multiplier is multiplied by *K* in a gear ratio and subtracted from $(E2 + L)$ in differential D-6, giving $(E2 + L - K \cdot Zd^2)$. This value positions the cosine cam of the *jDd* Computer, which gives $\cos(E2 + L - K \cdot Zd^2)$.

Sight Deflection, *Ds*, from the Prediction Section positions the rack of this Computer.

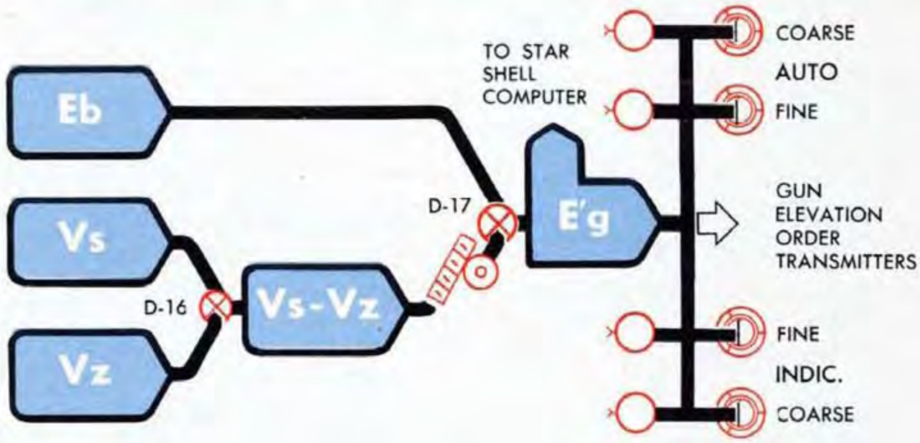
The output from the vector gear is $\sin^{-1}\dfrac{Ds}{\cos(E2 + L - K \cdot Zd^2)}$ or $\sin^{-1}[Ds \cdot \sec(E2 + L - K \cdot Zd^2)]$ which is *jDd*.

The value of *Dz* from the *Dz* Computer is added to *jDd* in differential D-8. The output of this differential is Deck Deflection, *Dd*. *Dd* is amplified by a compensated follow-up, and can be read on dials at the rear of the Computer.

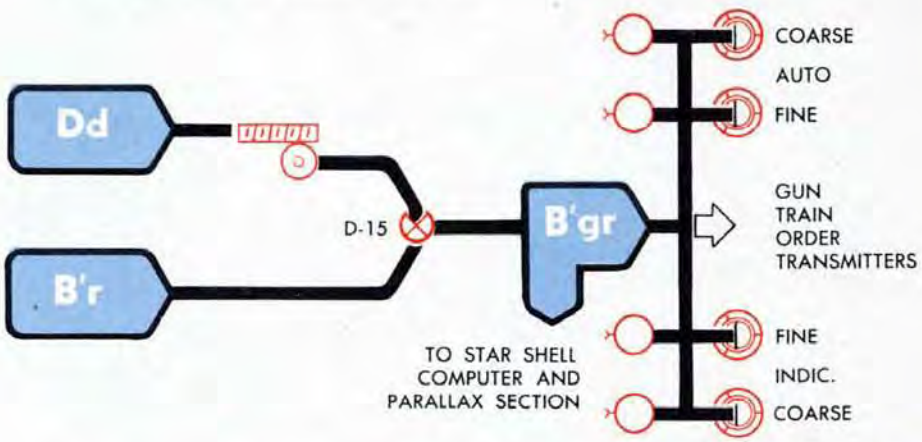
The gun orders

The Gun Elevation Order, *E′g*, is computed by subtracting Trunnion Tilt Elevation Correction, *Vz*, from Sight Angle, *Vs*, in differential D-16, and then adding the output $Vs - Vz$ to Director Elevation, *Eb*, in differential D-17. The output from D-17 is $Eb + Vs - Vz$, which is Gun Elevation Order, *E′g*.

E′g positions two double-speed transmitters. The *E′g* Transmitters are used to operate indicators at the guns and the automatic gun control equipment. The value of *E′g* may be read on the transmitter dials.



The Gun Train Order, *B′gr*, is computed by adding Deck Deflection, *Dd*, to Director Train, *B′r*, at differential D-15. The output from the differential is *B′gr*. *B′gr* positions two double-speed transmitters, which operate indicators at the guns and the automatic gun control equipment. The value of *B′gr* may be read on the transmitter dials.

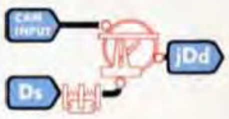


To prevent *B′r* and *Eb* from backing into the *Dd* and $Vs - Vz$ lines, respectively, irreversible worms are provided on these lines as mechanical safeguards. This insures that correct values of the Gun Orders will reach the transmitters.

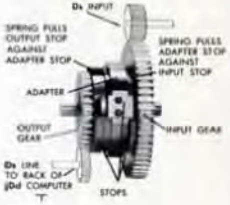
In addition to being used at the guns, *B′gr* may be used in the Parallax Section of the Computer Mark 1, and both *E′g* and *B′gr* are used in the Star Shell Computer Mark 1.

The spring relief drive

A spring relief drive is placed on the *Ds* input line going to the rack of the *jDd* Computer.



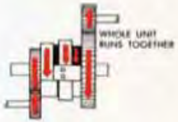
The spring relief drive is needed because the limits of travel of the *jDd* Computer rack become less than the limits of *Ds* when the cam follower pin is near the center. This occurs at high values of $E2 + L - K{\cdot}Zd'$.



When the cam follower pin is at the outer edge of the cam, rack travel is limited only by the *Ds* limit stop. However, when the follower pin is near the center of the cam, rack travel is reduced, being controlled by the angular limits of the vector gear.

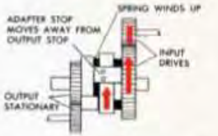
The relief drive mechanism uses two gears and an adapter, each having a stop piece attached. The gear stops are held by two strong clock springs against the sides of the stop on the adapter.

The whole relief drive turns together when the *Ds* line to the rack is free to move.

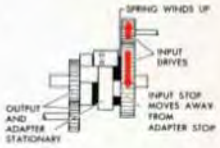


When travel of the *Ds* rack is limited by the vector gear, the output gear of the relief drive cannot turn. A further change in *Ds* will turn the input gear to the relief drive. Depending on the direction of rotation, one spring or the other will wind, thereby absorbing the additional change of *Ds*.

If the *Ds* line continues to drive after the rack has reached one limit of travel, the input gear stop will rotate the adapter. Since the output gear is held, rotation of the adapter will be absorbed by the output gear spring. If the *Ds* line turns in the other direction beyond the limit of rack travel, the input gear spring will absorb the excess input.



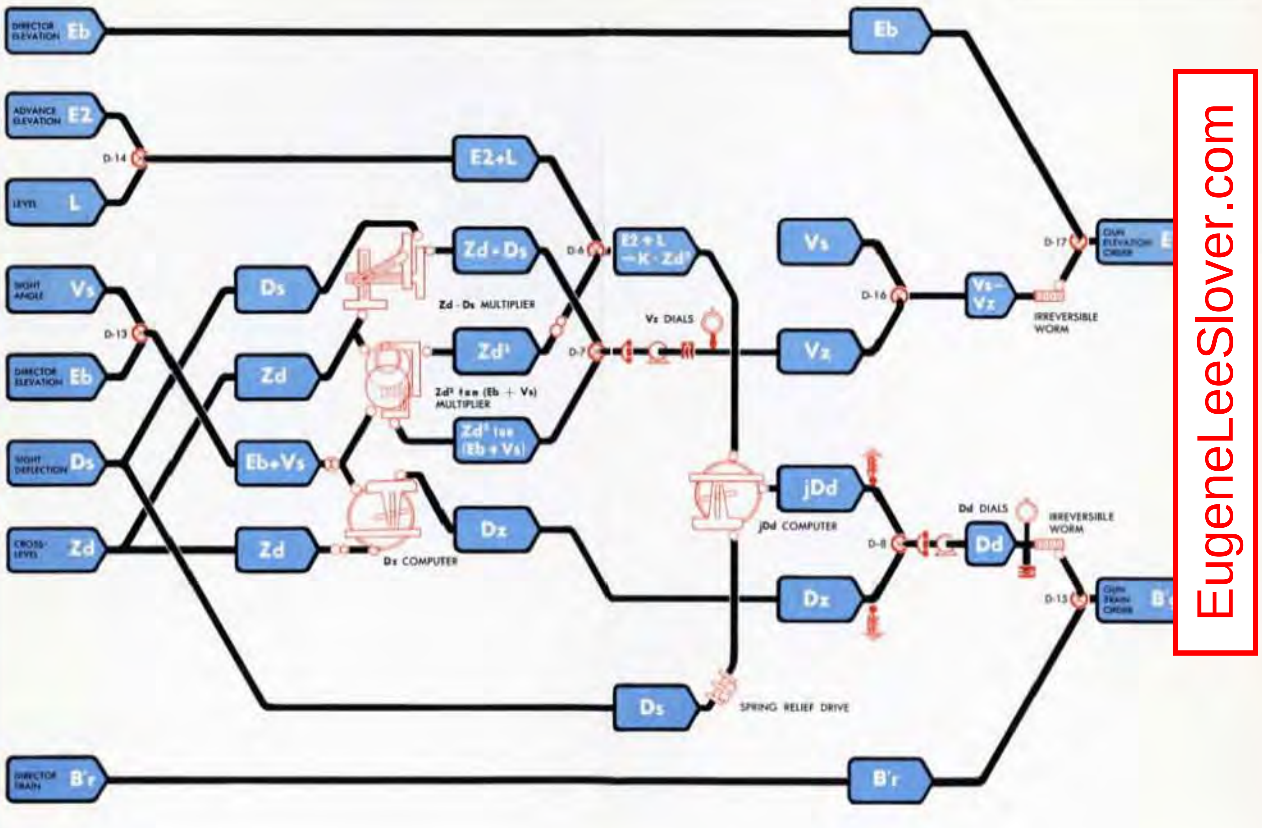
When the cam input changes so as allow sufficient travel of the rack, the springs restore the output gear to its original position relative to the input gear. Then the spring relief drive again acts as a solid connection.



NOTE:
The chapter on *Limits of Accurate Computation* describes the effect on the Gun Orders of the failure of *Ds* to drive into the *jDd* Computer at high values of $E2 + L - K{\cdot}Zd'$.

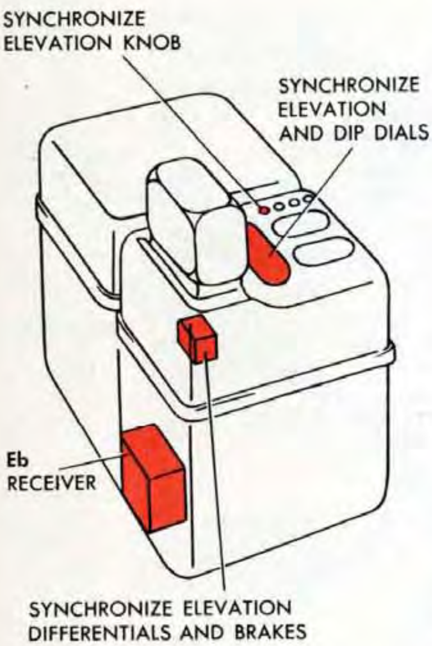
COMPUTER MK 1, MOD 7

TRUNNION TILT SECTION
SCHEMATIC DIAGRAM



The SYNCHRONIZE ELEVATION GROUP

The Synchronize Elevation Group consists of the *Eb* Receiver, the *E* Differential, and the Synchronize Elevation Mechanism.



The units of the Synchronize Elevation Group are located in the rear of the Computer. The *Eb* Receiver, the *E* Differential, and all the elements of the Synchronize Elevation Mechanism except the dials and knob are located in the lower rear. The Synchronize Elevation Dials, the Dip Dials, and the Synch *E* Knob are on the top rear.

The *E* Differential is used in Continuous Aim to provide a continuous correct value of Target Elevation, *E*.

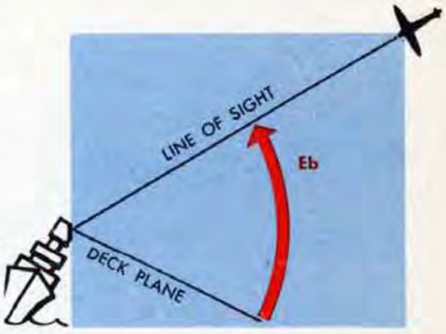
The Synchronize Elevation Mechanism is used to provide for methods of fire which can be used against surface targets but which are not usually practical against air targets. This mechanism can be thought of as a device which takes advantage of the additional fire control methods offered by surface targets.

These other methods are described in this chapter in sufficient detail to show the functions of the Synchronize Elevation Mechanism.

In showing how the Synchronize Elevation Group is used, the *E* Differential is introduced first, and then elements of the Synchronize Elevation Mechanism are added to it as the need for each is briefly explained.

The E Differential

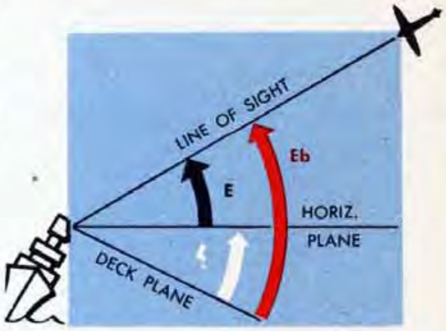
For Continuous Aim the Computer must make continuous accurate computations of gun and fuze orders. To compute these it needs continuous correct values of Director Elevation, *Eb*, for use in the Trunnion Tilt Section and Gun Elevation Order, and continuous correct values of Target Elevation, *E*, for use in the Relative Motion Group and Prediction Section.



Since the Director sights are stabilized to keep them on the Target during the roll and pitch of the Ship, the Director continuously measures Director Elevation, *Eb*.

Director Elevation, *Eb*, is the angle between the deck plane and the Line of Sight, measured in the vertical plane through the Line of Sight. *Eb* is transmitted electrically to the *Eb* Receiver in the Synchronize Elevation Group in the Computer.

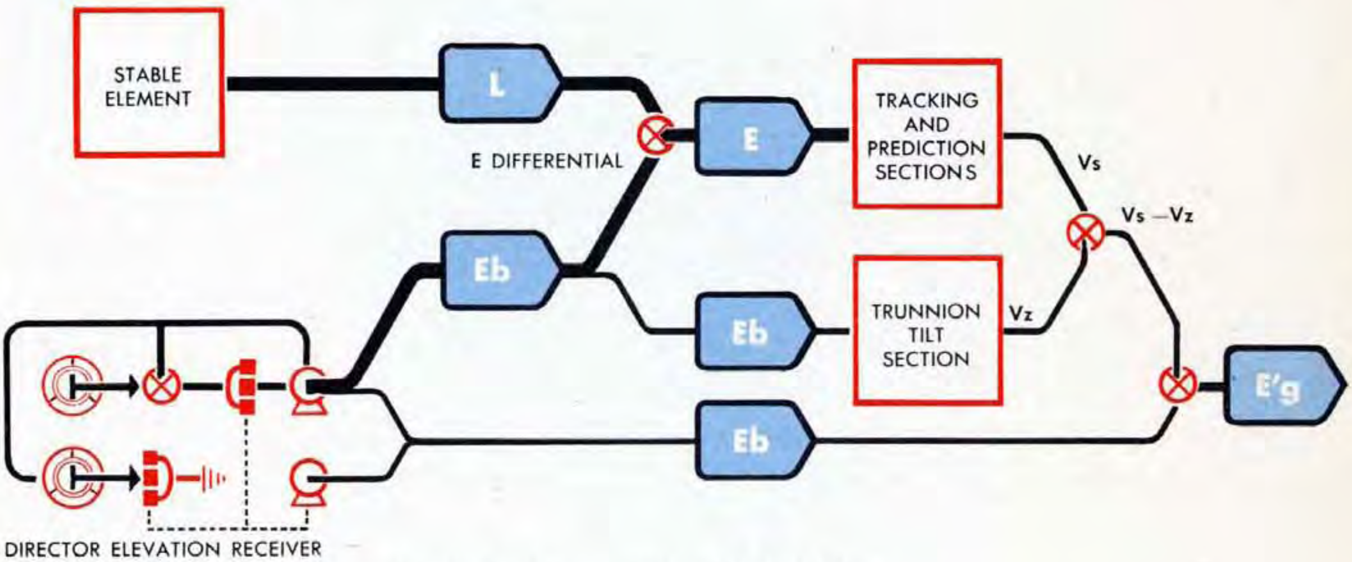
Target Elevation, *E*, is the angle between the horizontal and the Line of Sight, measured in a vertical plane through the Line of Sight.



Director Elevation, *Eb*, consists of Target Elevation, *E*, plus Level, *L*. Level, *L*, is the angle between the horizontal plane and the deck plane, measured in the vertical plane through the Line of Sight.

The value of Target Elevation, *E*, is computed at the *E* Differential where the value of *L* from the Stable Element is continuously subtracted from *Eb*.

This is the only function of the *E* Differential in Continuous Aim: to provide a continuously correct value of Target Elevation, *E*, by subtracting *L* from *Eb*.



If the Computer had been designed to compute only for Continuous Aim using Director inputs, the Synchronize Elevation Mechanism would not have been needed. Continuous E *from the* E *Differential could simply have been transmitted throughout the Computer by shaft lines.*

A general description of the FUNCTION of the SYNCHRONIZE ELEVATION MECHANISM

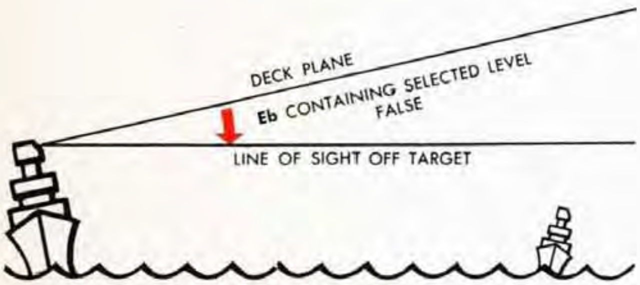
The three jobs of the Synchronize Elevation Mechanism are summarized here and the mechanism is built up schematically. A detailed description of the function and arrangement of the mechanism follows this summary.

The three jobs of the Synchronize Elevation Mechanism are:

1 Adapting the Computer for Selected Level Fire, with Level selected at the Director. This is done by "interrupting" the *E* line in the Computer.

2 Adapting the Computer for use without an input of Director Elevation, *Eb,* from the Director.

3 Restoring the Computer for Continuous Aim, using an input of Director Elevation, *Eb,* from the Director. This is called "synchronizing Elevation."



Selected Level Fire, with Level selected at the Director

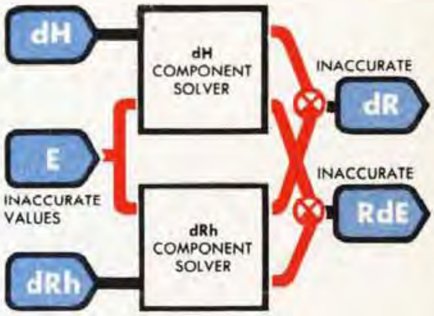
Selected Fire is used against surface targets when Continuous Aim is impractical. There are several factors which can make Continuous Aim impractical: The values of Level and Cross-level may become larger than the limits of operation of the stabilizing equipment, or various casualties may occur. Also there are a number of situations in which Selected Fire is required by *ship's doctrine.*

One type of Selected Fire is Selected Level Fire, with Level selected at the Director. In this type of fire the Director sights are not continuously leveled to remain on the Target, but incline with the deck. Since the crosshairs of the sights are swept up and down across the Target by Own Ship Motion the value of *Eb* at the Director is inaccurate except at the moment when the Pointer's crosshair is actually on the target.

The selected value of *L* may be varied at will, even within one roll, to permit a higher rate of fire.

1. Adapting the Computer for Selected Level Fire, with Level selected at the Director

When the inaccurate values of *Eb* from the Director are received in the Computer, they combine with values of *L* at the *E* Differential and produce inaccurate values of *E*.

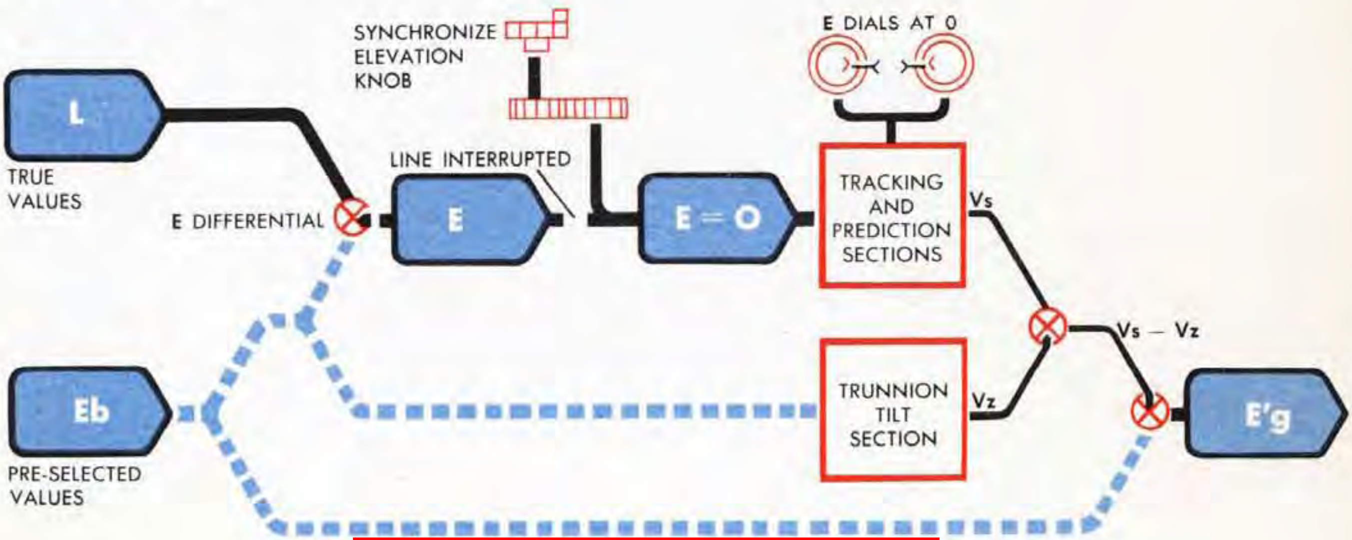


The inaccurate values of *E* must not be allowed to enter the Tracking or Prediction Sections of the Computer. In the Relative Motion Group of the Tracking Section they would cause false values of *dR* and *RdE* to be computed, resulting in false values of Generated Range, *cR*, and other generated quantities. In the Prediction Section the inaccurate values of *E* would produce false Prediction outputs.

There are therefore two problems in adapting the Computer for Selected Level Fire, with Level selected at the Director: The first problem is to keep the inaccurate values of *E* out of the Tracking and Prediction Sections. The second is to provide a substitute value of *E* in place of the continuous correct *E* needed by these sections.

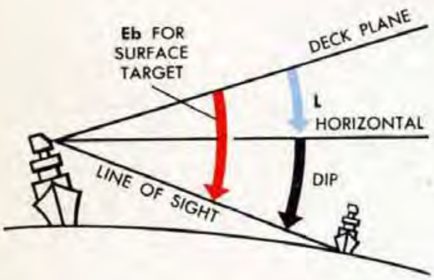
The inaccurate *E* is kept out of the Tracking and Prediction Sections by "interrupting" the *E* line. This is done by means of a differential, which is described later. The effect of using this differential is the same as if a shaft were removed on the *E* line.

The substitute value of *E* is provided by means of a handcrank called the Synchronize Elevation Knob, which is used to position the *E* line to the Tracking and Prediction Sections. The value of *E* at which the line is positioned is zero, since Selected Level Fire is only used against surface targets, for which the actual *E* is always close to zero. As long as the actual value of *E* is within about 3 degrees of zero, a zero *E* is sufficiently accurate for use in the Computer.



2. Adapting the Computer for use without an input of Eb from the Director

It is possible to fire without the aid of the Director Elevation input, *Eb*, by positioning the Computer *E* and *Eb* shafting at the Computer itself.



There are two main reasons why this arrangement is desirable:

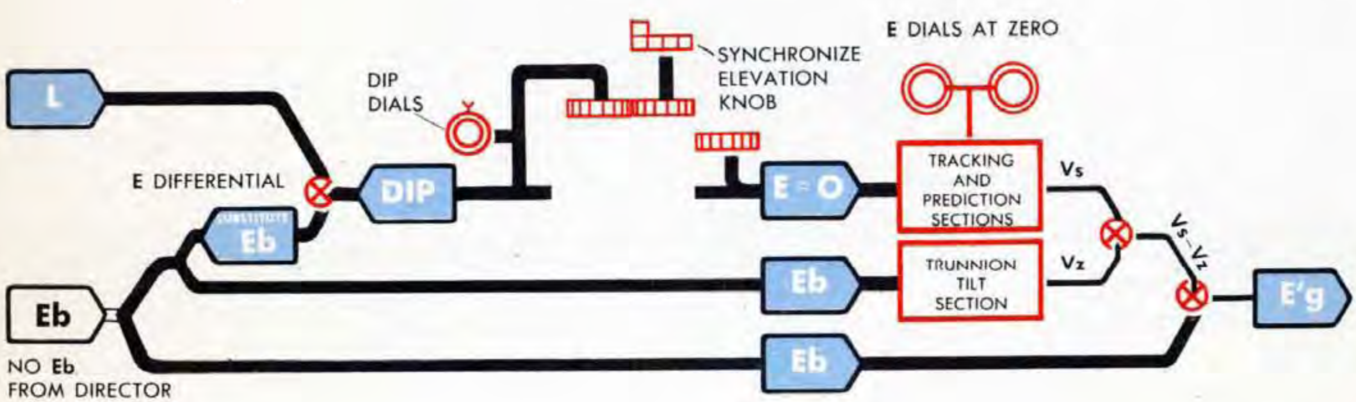
1 To allow for CASUALTIES. The Director may suffer casualties which will cut off the three main Director inputs to the Computer, namely *R*, *B′r* and *Eb*. In order to use the Computer, substitutes must be provided. Values of Range, *R*, and Relative Bearing, *B r*, may be obtained from some other source and set into the Computer directly. The substitute value of *Eb*, however, must be computed.

2 To provide greater FLEXIBILITY. There are several types of firing, including shore bombardment and blind firing, in which it is often preferable to compute a substitute value of *Eb* at the Computer rather than to measure *Eb* from the Director. Sometimes *Eb* cannot be measured from the Director and therefore *must* be computed. The Director may continue to supply *R* and *B′r*, or the values of these quantities may come from some other source as specified by *ship's doctrine*.

The substitute value of *Eb* used in the Trunnion Tilt Section and in Gun Elevation Order is computed with the aid of the Dip Dials in the Synchronize Elevation Mechanism. The Dip Dials compute a negative value of Target Elevation, *E*. This negative value of *E* is called Dip.

The Dip Dials are graduated in such a way that when they are matched and set at the value of Range, the *E* line going to the *E* Differential is positioned at the correct Dip angle.

Dip is set into the Computer by using the Synchronize Elevation Knob. At the *E* Differential the value of Dip is combined with *L* from the Stable Element to form a substitute value of *Eb* for use in the Trunnion Tilt Section and the Gun Elevation Order.



3. Restoring the Computer for Continuous Aim

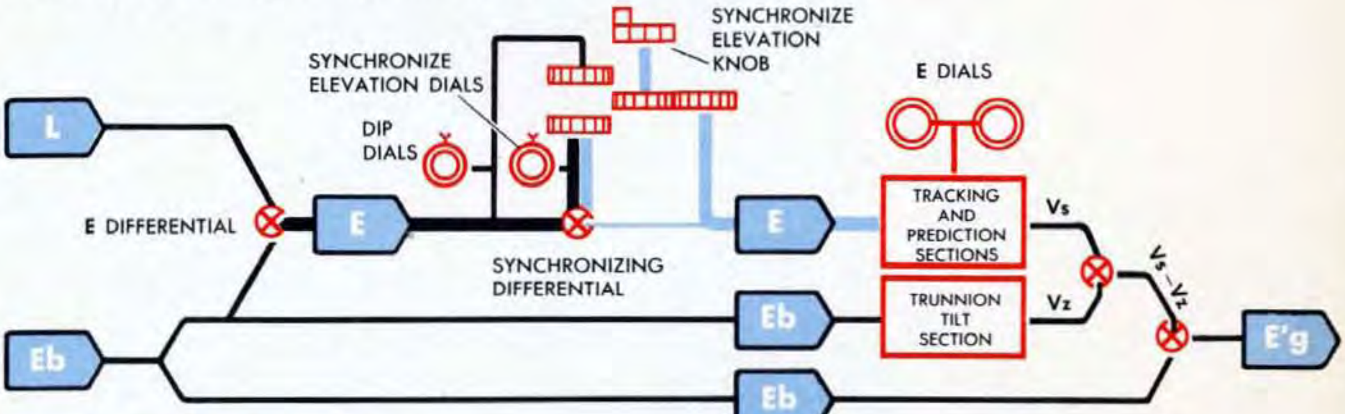
The synchronizing differential

The *E* line must be interrupted in order to prevent inaccurate values of *E* from entering the Tracking and Prediction Sections. It must also be put together again in order that the Computer may compute for Continuous Aim. To allow the line to be interrupted and restored easily, the *E* line is interrupted by means of a differential rather than by removal of a shaft. The differential used is differential D-12 and is called the "synchronizing differential."

The spider of the synchronizing differential is connected to the *E* line going to the Tracking and Prediction Sections. A branch of this line can be connected to the Synchronize Elevation Knob.

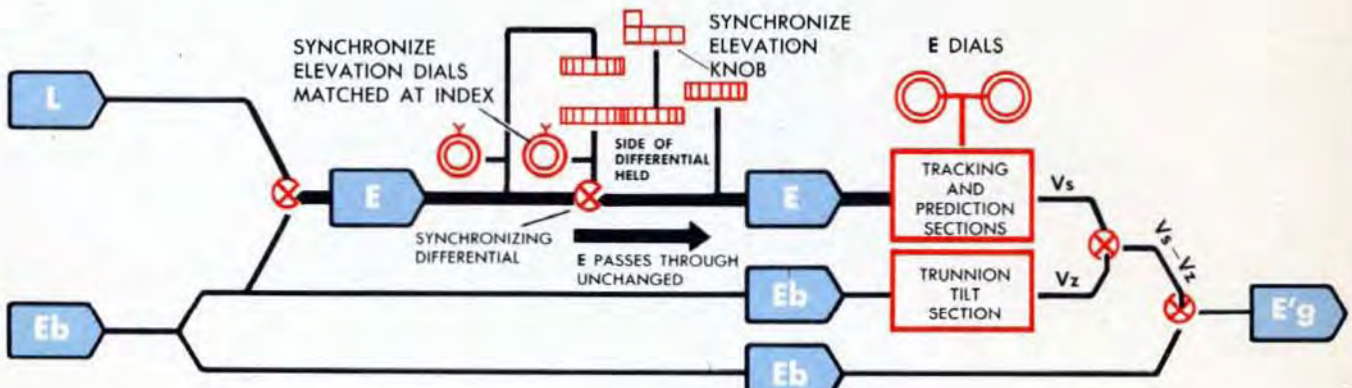
Interrupting the E LINE

When the *E* line going to the Tracking and Prediction Sections is connected to the Synchronize Elevation Knob, the *E* line is interrupted. Values of *E* from the *E* Differential come in on one side of D-12 and back out on the other side, rotating a set of dials called the Synchronize Elevation Dials. The required value of *E* is set into the Tracking and Prediction Sections by the Synchronize Elevation Knob.



Restoring the E LINE

When the side of D-12 connected to the Synchronize Elevation Dials is held by the Synchronize Elevation Knob, rotation of the other side of D-12 rotates the spider. The differential acts as a direct gear drive. To equalize the values of *E* coming in and going out of D-12, the Synchronize Elevation Dials are matched and held at their fixed index. The *E* lines then turn as a single line and are said to be synchronized.

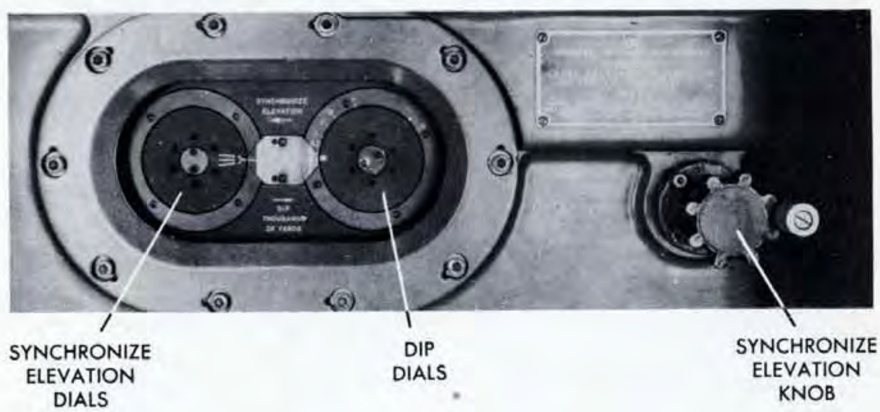


The SYNCHRONIZE ELEVATION MECHANISM

The Synchronize Elevation Mechanism includes the Synchronize Elevation Knob, the Synchronize Elevation Dials, the Dip Dials, the synchronizing differential D-12, two brakes on differential D-12, and a push-button switch.

The Synchronize Elevation Dials

The Synchronize Elevation Dials consist of an inner and an outer dial with planetary gearing between them. These dials have index marks but no numbers. These marks must be matched at the fixed index for normal operation.

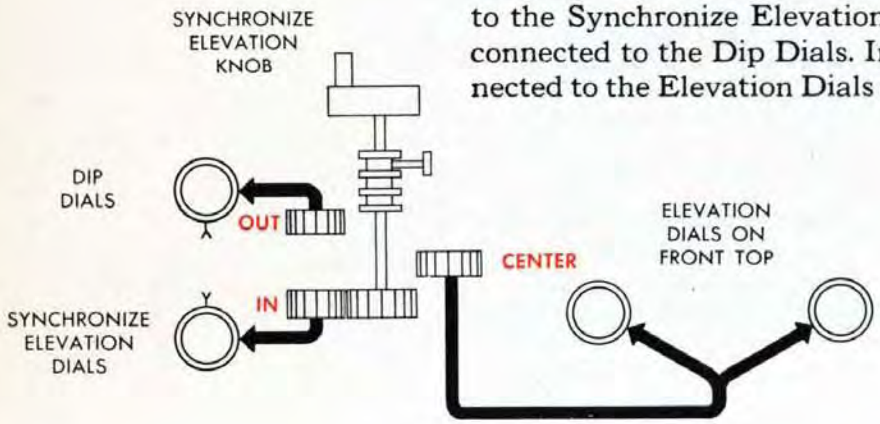


The Dip Dials

The Dip Dials consist of an inner and an outer dial connected by planetary gearing. The inner dial has one broad white mark on it. The outer dial has uneven calibrations in thousands of yards of Range, from 0.5 to infinity.

The Synchronize Elevation Knob

The Synchronize Elevation Knob has three positions: IN, CENTER, and OUT. In its IN position, the knob is connected to the Synchronize Elevation Dials. In its OUT position, it is connected to the Dip Dials. In its CENTER position, it is connected to the Elevation Dials on the front top of the Computer.



The Differentials and Brakes

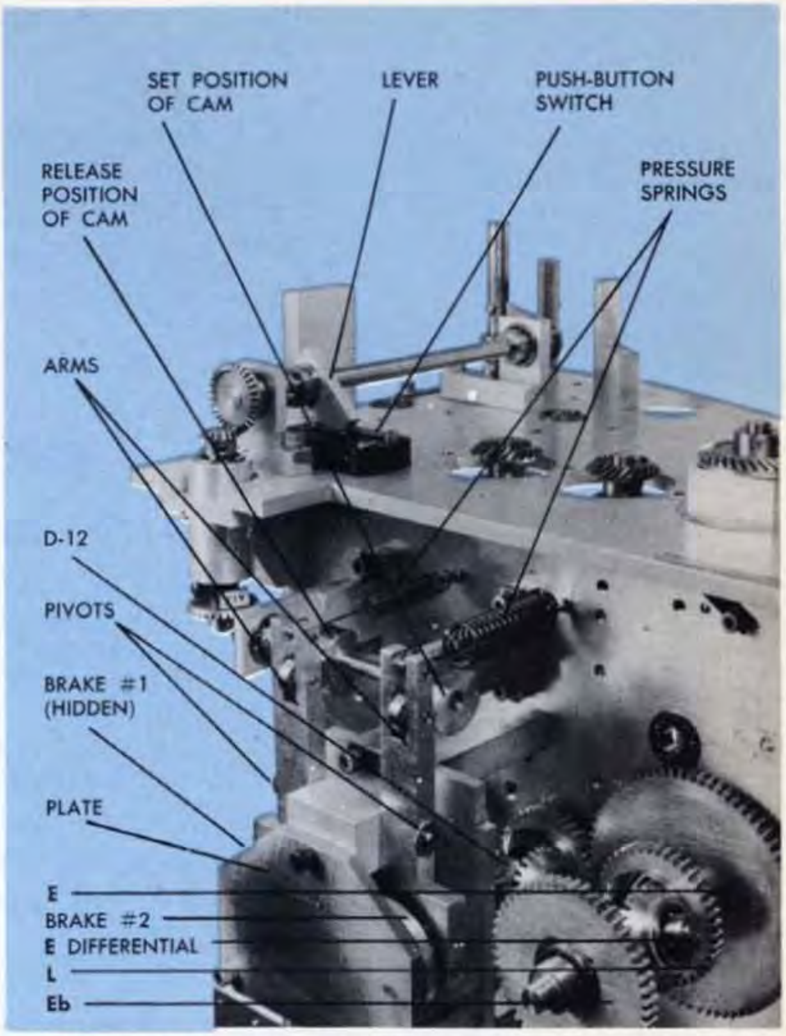
This drawing shows the relative positions of the *E* Differential and differential D-12, and the arrangement of the two brakes.

The output gear on the spider of the *E* Differential meshes with one input gear of D-12. The other input gear of D-12 meshes with a gear on the shaft carrying brake #1. Brake #2 is on the spider of D-12.

The brakes are cork-faced disks, spline-coupled to the shaft.

When a brake is released, the cork-faced disk turns freely with its shaft. When a brake is set, the cork face is pressed against a stationary plate. The friction between the cork face and the plate puts a drag on the shaft. However, it is still possible to turn the shaft by means of the Synchronize Elevation Knob.

The brakes are positioned by arms which are operated through cams at the tops of the arms. Either brake is set by the spring on its arm, unless released by its cam. These cams are arranged in such a way that when one brake is set, the other is released.



POSITION OF BRAKES WHEN THE SYNCHRONIZE ELEVATION KNOB IS **OUT**

The position of the Synchronize Elevation Knob controls the brakes by moving a lever which turns the shaft holding the cams. The cams pivot the arms. When one of the arms pushes a brake against the plate, the other arm pivots in the opposite direction, moving the other brake away from the plate. The released brake turns with its shaft.

The Push-button Switch

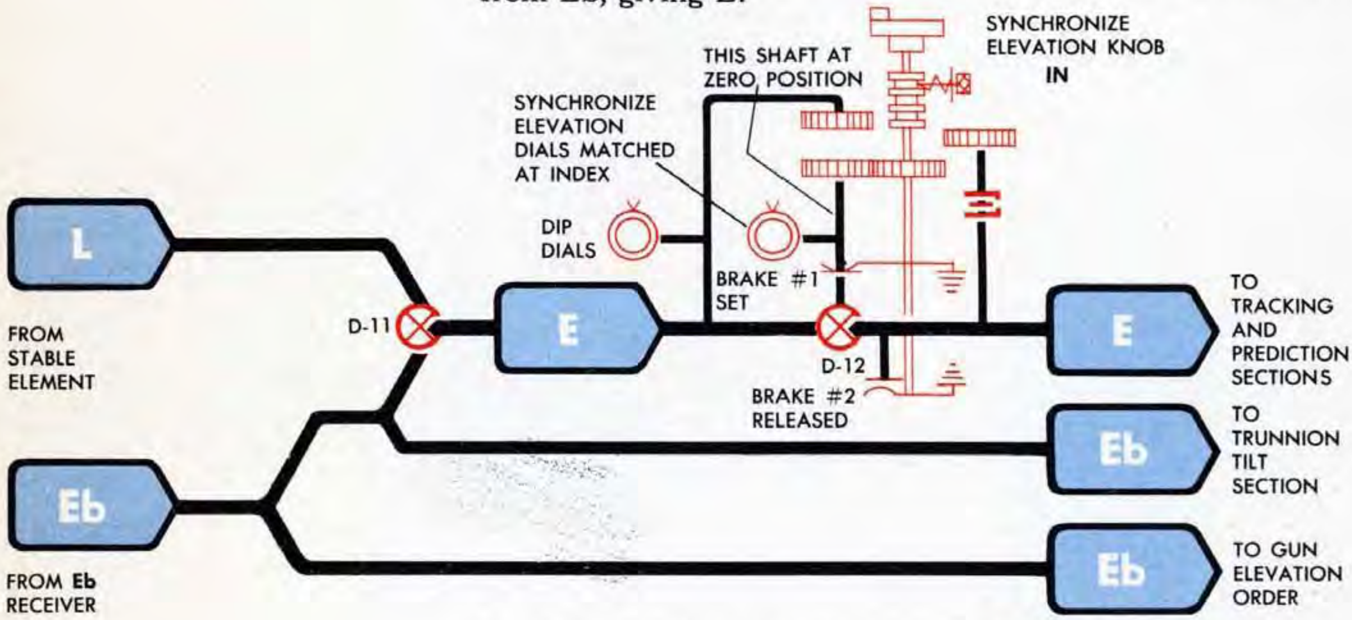
The push-button switch is controlled by a lever moved by the Synchronize Elevation Knob. Pulling the knob to its OUT position moves the lever and presses the push-button. This cuts out the Director Elevation Receiver, by de-energizing the *Eb* Follow-up Servos.

The Elevation Lines in Continuous Aim

In Continuous Aim with the Director operating, continuous *Eb* is needed in the Trunnion Tilt Section and for making up Gun Elevation Order. Continuous *E* is needed in the Tracking and Prediction Sections.

Eb from the Director is continuously received at the *Eb* Receiver. Two servo motors in this receiver position the *Eb* line. One part of the *Eb* line goes directly to form the Gun Elevation Order, *E′g*. Another part of the *Eb* line branches into a line going to the Trunnion Tilt Section and a line going to the *E* Differential.

At the *E* Differential, *L* from the Stable Element is subtracted from *Eb*, giving *E*.



The Synchronize Elevation Mechanism on the *E* line is positioned to allow *E* to pass through differential D-12 unchanged. The Synchronize Elevation Knob is in its IN position. Putting the knob IN sets brake #1 on the side gear of D-12 and releases brake #2 on the spider of D-12.

The Synchronize Elevation Knob has been turned in its IN position until the Synchronize Elevation Dials match at their fixed index. Turning the knob in its IN position turns the side gear of D-12 against the friction of brake #2. This motion backs out on the spider of D-12 and synchronizes the *E* line by making the value of *E* going to the Tracking and Prediction Sections equal to the value of E coming from the E Differential, D-11.

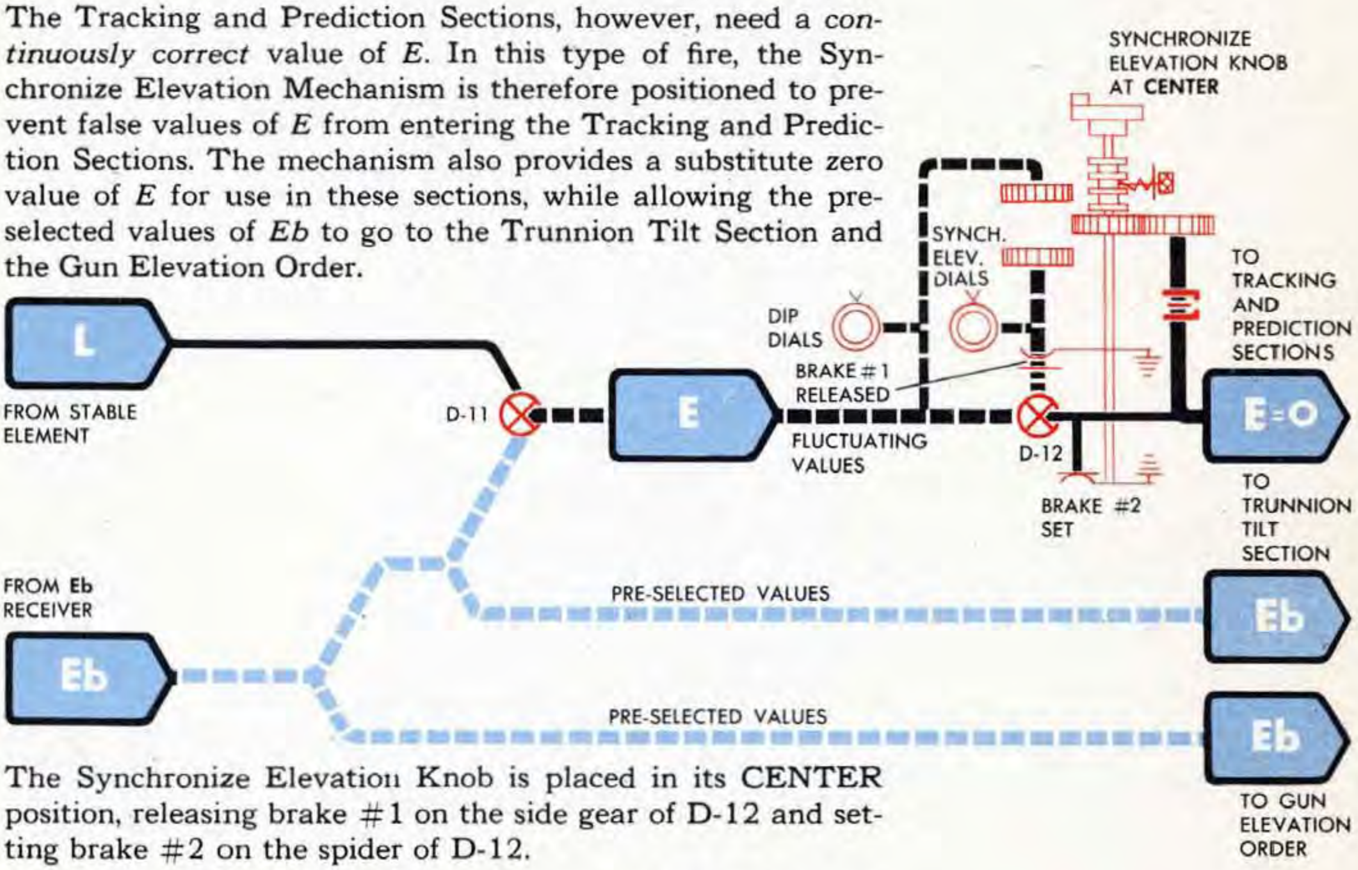
For Continuous Aim with the Synchronize Elevation Knob in its IN *position, the whole Synchronize Elevation Group may be thought of as a single differential, D-11, where* L *is continuously subtracted from* Eb *to form* E.

The Elevation Lines in Selected Level Fire, with Level selected at the Director

In Selected Level Fire, with Level selected at the Director, the Director sights are not "leveled," but are positioned at some pre-selected angle to the deck. The crosshairs therefore sweep across the target as the deck rolls or pitches, and the value of *Eb* is false except at the moment that the Pointer's crosshair is on the Target.

At the moment that the crosshair *is* on the Target, the selected Level equals the actual Level and the value of *Eb* is correct. In order for the guns to be correctly pointed at this moment, the pre-selected value of *Eb* is transmitted to the Computer for use in the Trunnion Tilt Section and the Gun Elevation Order.

The Tracking and Prediction Sections, however, need a *continuously correct* value of *E*. In this type of fire, the Synchronize Elevation Mechanism is therefore positioned to prevent false values of *E* from entering the Tracking and Prediction Sections. The mechanism also provides a substitute zero value of *E* for use in these sections, while allowing the pre-selected values of *Eb* to go to the Trunnion Tilt Section and the Gun Elevation Order.



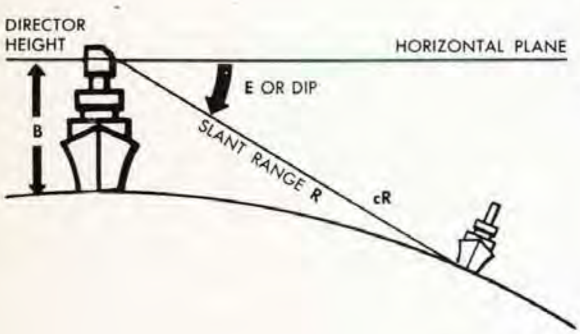
The Synchronize Elevation Knob is placed in its CENTER position, releasing brake #1 on the side gear of D-12 and setting brake #2 on the spider of D-12.

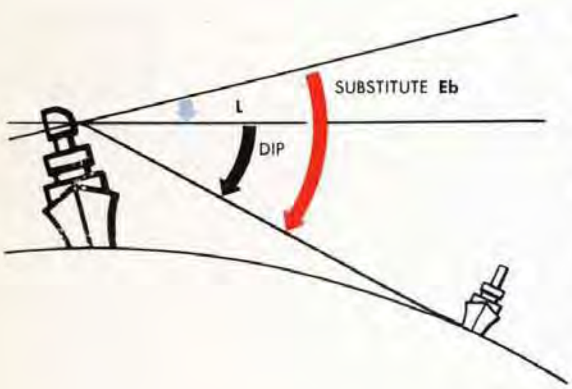
The pre-selected values of *Eb*, received at the *Eb* Receiver, position the *Eb* lines to the Trunnion Tilt Section, the Gun Elevation Order, and the *E* Differential.

At the *E* Differential, true values of *L* are subtracted from pre-selected values of *Eb*, giving inaccurate values of *E*. These values of *E* position one side gear of D-12, but since brake #2 is set, they merely back out through the other side gear of D-12 and turn the Synchronize Elevation Dials.

With the Synchronize Elevation Knob, the *E* line to the Tracking and Prediction Sections is turned until the Target Elevation Dials on the front of the Computer read zero.

The Elevation Lines in Firing without a Director





The Computer Mark 1 may be used without a Director for controlling fire against a surface target.

Since the computation of Gun Elevation Order is based on the angle *Eb*, a substitute value of *Eb* must be provided when the Director is not used. This substitute value of *Eb* must closely approximate the value ordinarily supplied by the Director

The substitute value of *Eb* is composed of Level, *L*, from the Stable Element, plus Dip, the negative value of *E* based on the Director position.

In the Computer Mark 1, Dip is computed by this equation:

$$\text{Dip} = \sin^{-1} \frac{2AB + B^2 + R^2}{2(A+B)R}$$

where R = Slant Range to the Target, in yards
A = means radius of the earth, in yards
B = Director Height above the waterline, in yards

Because this equation contains only one variable, *R*, no computing mechanism is necessary except the Dip Dial, which is calibrated in suitable graduations.

Although the equation is set up for slant range, general practice is to use *R2* because of the convenient location of the *R2* Counter to the Dip Dial and Knob. This is permissible because of the very negligible error in the computation of Dip for a surface problem where *R2* is substituted for *cR*.

The graduations on the Dip Dial are spaced so that, when the value of Range is at the fixed index, the *E* line is positioned at the corresponding value of Dip. This angle of Dip is a substitute for the angle through which the Director Line of Sight would have to be depressed from the horizontal in order to meet the waterline of the Target.

Dip is set into the *E* line with the Synchronize Elevation Knob in its OUT position. The Dip value is combined with the selected value of Level from the Stable Element, in differential D-11. This differential positions the *Eb* shafting to a value conforming to the value it would have if the Director were in control.

The *E* line on the other side of differential D-12 is held fixed at zero in order to furnish zero Elevation to the Tracking and Prediction Sections as in Selected Level Fire.

Setting up for Dip

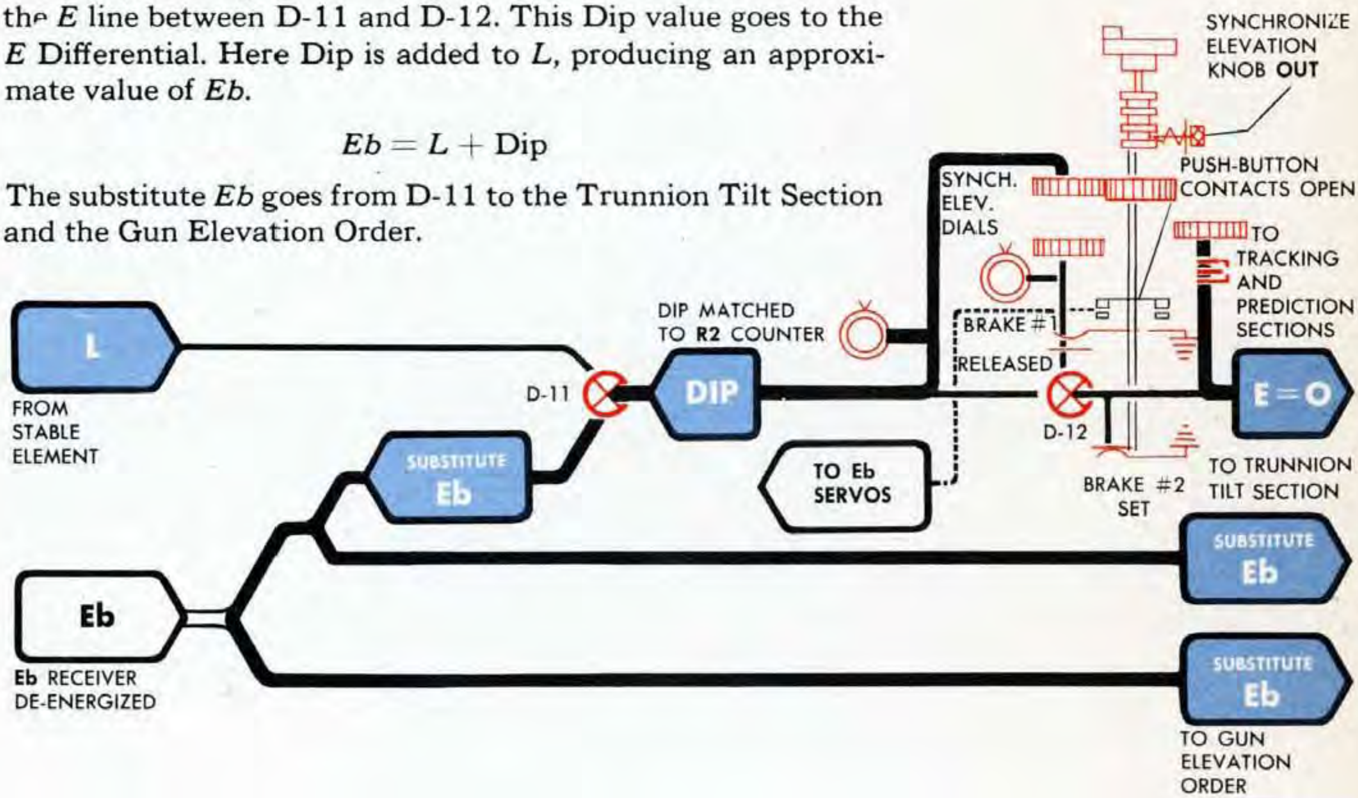
In adapting the *E* lines in the Computer for operation without a Director, the Synchronize Elevation Knob is first put in its CENTER position. This releases brake #1 and sets brake #2, "interrupting" the *E* lines. The knob is then turned until the *E* line going to the Tracking and Prediction Sections is positioned at zero. The zero is read on the *E* Dials on the front of the Computer.

The knob is next pulled to its OUT position. This does not change the position of the brakes; therefore the *E* line to the Tracking and Prediction Sections remains at zero. Pulling the knob OUT moves a lever which depresses a push-button, de-energizing the *Eb* Receiver. In its OUT position the Synchronize Elevation Knob is connected to the Dip Dials and the *E* line between D-11 and D-12. The knob is turned in this position until the Dip Dial reading is matched to the value on the *R2* Counter.

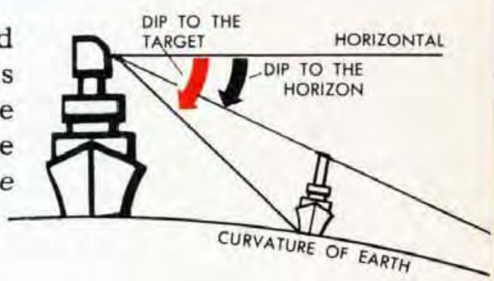
Matching the Dip Dial reading to *R2* puts a value of Dip into the *E* line between D-11 and D-12. This Dip value goes to the *E* Differential. Here Dip is added to *L*, producing an approximate value of *Eb*.

$$Eb = L + \text{Dip}$$

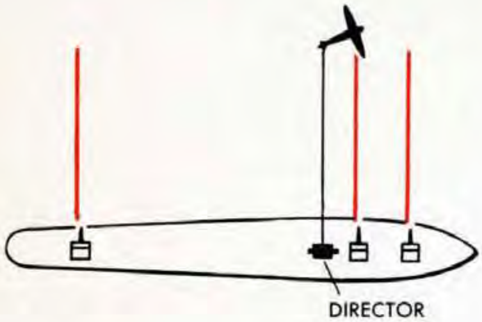
The substitute *Eb* goes from D-11 to the Trunnion Tilt Section and the Gun Elevation Order.

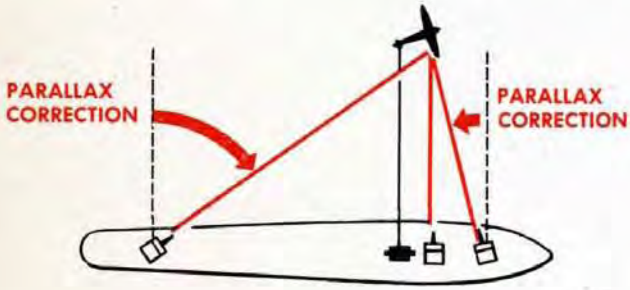


Dip to the Target is the angle between the horizontal and a Line of Sight *to the waterline of a surface target*. This should not be confused with Dip to the horizon, which is the angle between the horizontal and a Line of Sight to the horizon. Whenever Dip is mentioned in this book *Dip to the Target* is meant unless otherwise specified.



PARALLAX





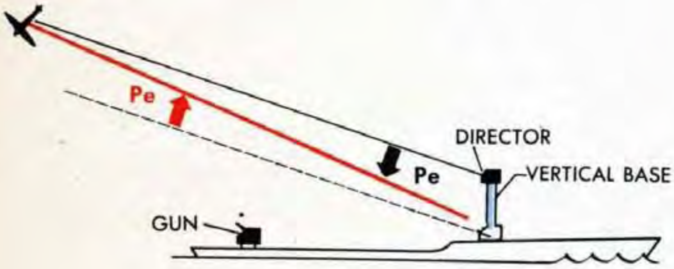
The Gun Elevation and Gun Train Orders computed by the Computer Mark 1 are based on observations made from a Director. These orders are correct for guns located at that Director.

But if these same Gun Orders are used to position guns located at a distance along the deck from the Director, the projectiles from these guns will travel *parallel* to the projectiles from the guns near the Director and will not hit the Target.

Angular corrections to the guns are required when the point of fire is separated from the point of observation. These corrections are called Parallax Corrections. These Parallax Corrections cause the Lines of Fire from the various guns to converge at the Target. Directors, as well as guns, may receive Parallax Corrections, for reasons which will be explained in this chapter.

The Computer Mark 1 computes three Parallax Corrections: one is used by the guns only; the other two may be used by both guns and Directors.

Pe: Elevation parallax correction for vertical base



If the guns down on the deck were aimed at the same Elevation angle as the Director, their projectiles would burst below the Target. Elevation Parallax Correction, *Pe,* is a positive Elevation Correction to compensate for this difference in *height* between the Director and the guns.

Nearly all Directors are assumed to be 30 feet above the guns. *Pe* is used by the guns only.

Pe is computed in the *Vf* + *Pe* Ballistic Computer and is included in Gun Elevation Order, *E′g,* coming from the Computer Mark 1.

NOTE:
The diagrams in this chapter exaggerate the parallax angles because the ranges shown are necessarily short. Actually all Parallax Corrections are relatively small angles which change the Elevation and Train of the guns only slightly. Also these diagrams show the guns pointed directly at the Target. All predictions have been omitted.

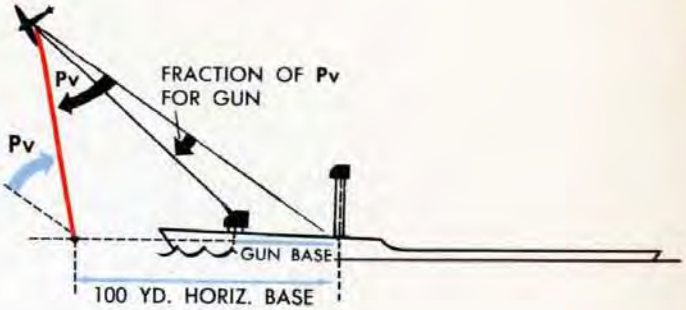
Pv: Elevation parallax correction for horizontal base

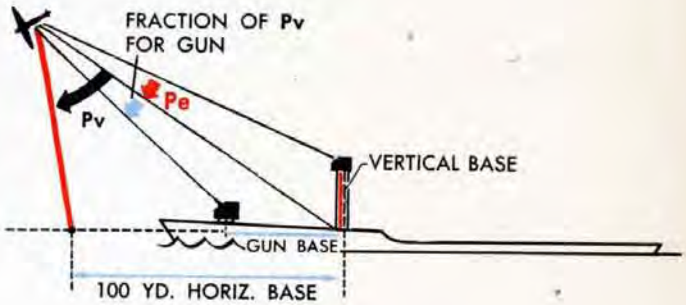
Unlike Elevation Parallax Correction, *Pe,* which is for a *vertical* base, Elevation Parallax Correction, *Pv*, is for a *horizontal* base.

The guns are located along the deck at varying distances from the Director.

A gun at a great distance from the Director will need a correction to Elevation in order to hit the Target. This correction is called Elevation Parallax, *Pv*. The amount of correction needed by the gun will depend on the gun's distance from the Director. The Computer Mark 1 computes one *Pv* unit parallax correction for a 100-yard horizontal base forward of the Director. The gun uses a fraction of this computed correction corresponding to its distance from the Director.

Here are *Pe* and *Pv*, the two Elevation Parallax Corrections.





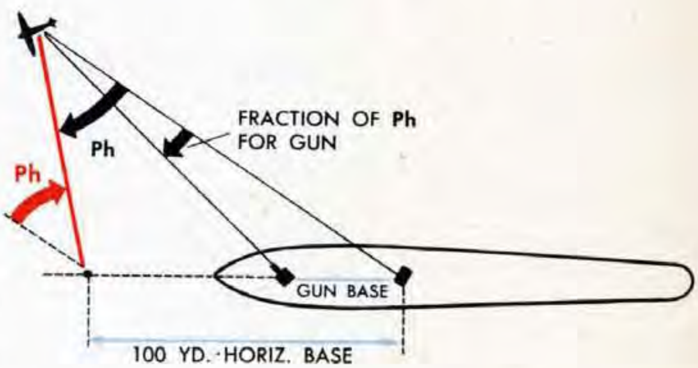
Ph: Train parallax correction for horizontal base

Because of the different locations of the guns along the deck from the Director, each gun needs a *train* parallax correction.

This train correction is called Train Parallax Correction, *Ph*.

As in the case of *Pv,* the Computer Mark 1 computes a unit Train Parallax Correction, *Ph,* for a 100-yard horizontal base forward of the Director. Then each gun uses a fraction of this unit parallax correction corresponding to its distance from the Director.

Pv *and* Ph *are not included in the Computer Gun Orders, but are transmitted separately to the mounts. Change gears are used at each gun mount to obtain the proper fraction of each unit correction. These fractions are then added to the Gun Orders.* Pv *is added to Gun Elevation Order,* E'g. Ph *is added to Gun Train Order.* B'gr.



NOTE:
Elevation Parallax Correction, *Pv,* is used by only a few gun installations.

Train Parallax Correction, Ph, is used by most gun installations.

On ships having two or more Directors, *Ph* is usually sent to the Directors.

In a few installations, *Pv* is also sent to the Directors.

How the PARALLAX corrections are used

To make the Gun Director Mark 37 System flexible, the Computer Mark 1 solves the fire control problem on the assumption that all directors and guns are located at one point on the deck. This point is called the *Reference Point*.

When there is only one Director on a ship, the Director is considered to be the Reference Point. The aim of each mount is corrected to allow for the distance of the mount from the Reference Point.

When there is more than one Director, the Reference Point may be a Director or a designated point.

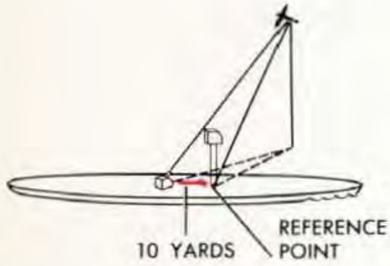
Correcting GUNS for parallax

The guns can be corrected by one or both of the unit Parallax Corrections calculated for a 100-yard horizontal base:

Elevation Parallax Correction, *Pv*
Train Parallax Correction, *Ph*

Each gun uses the fraction of each correction it needs, depending on its distance from the Reference Point.

How fractions of Ph and Pv are used



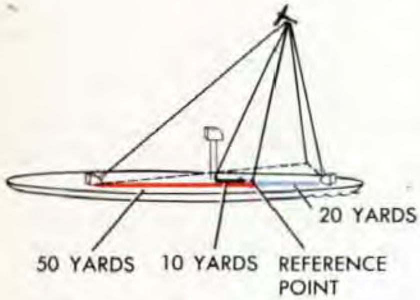
On the ship shown in the first illustration, the Director is the Reference Point, and therefore needs no correction.

The gun on the afterdeck is 10 yards from the Reference Point. Since 10 yards is 1/10 of 100 yards, this gun will use 1/10 of the *Ph* and *Pv* values from the Computer.

On the ship shown in the second illustration, the Reference Point is a designated point forward of the center of the ship.

The gun on the afterdeck is 50 yards from the Reference Point. Since 50 yards is 1/2 of 100 yards, this gun will use 1/2 of *Ph* and *Pv*.

The Director is 10 yards abaft the Reference Point. It uses 1/10 of the *Ph* correction.



The gun on the forward deck is 20 yards from the Reference Point. It uses 1/5 of the *Ph* and *Pv* corrections.

The guns forward of the Reference Point or Director use the Parallax Corrections in the direction in which they are computed. The guns aft of the Reference Point or Director reverse the direction of the corrections.

This example merely illustrates how *Ph* and *Pv* can be used to correct the gun orders. Guns near the Reference Point usually receive no *Ph* or *Pv* corrections.

Correcting DIRECTORS for parallax

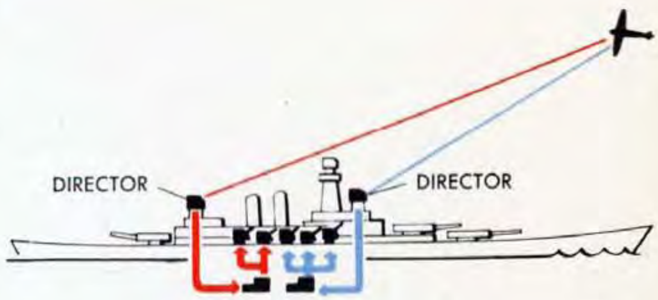
Why the directors are corrected

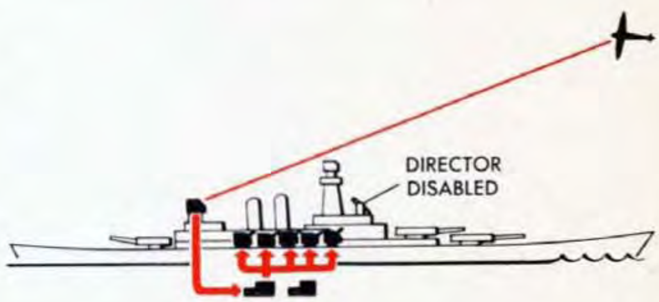
Each Director sends observations of Range, Director Elevation, and Director Train to a Computer Mark 1. Each Computer Mark 1 then computes Gun Orders for the guns connected to it. If one Director is disabled, the guns using Gun Orders based on its observations can be quickly connected to a Computer working with another Director.

Since the Directors are located at different points along the deck, each Director observes a slightly different angle of Director Train, *B′r*, for the same Target.

It is desirable to have these transmitted values of *B′r* uniform, so that any Director can supply *B′r* to any Computer.

To make the values of *B′r* uniform, all Directors must be corrected to one Director or to a Reference Point. This is done by using Train Parallax Correction, *Ph*, at the Directors.



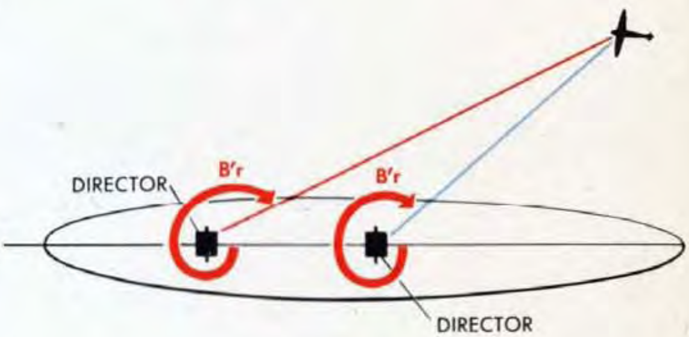


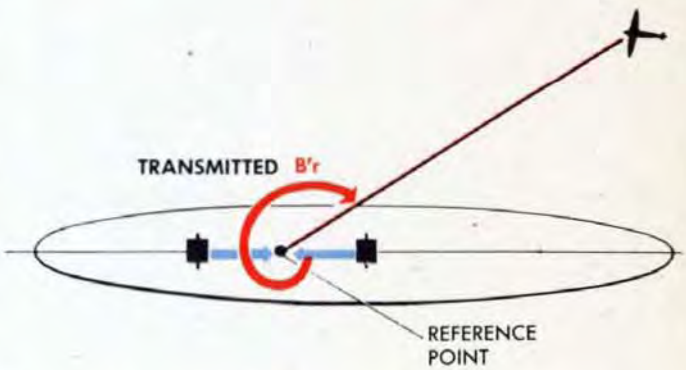
How the directors are corrected

Each Director takes the fraction of the *Ph* correction corresponding to its distance from the Reference Point, and adds this fraction to its observed value of *B′r*.

After the Directors have used the *Ph* correction, the values of *B′r* coming from all Directors will be identical for any one Target.

In the Gun Director Mark 37 System, Observed Range is not corrected to a Reference Point. Director Elevation is corrected to a Reference Point in only a few installations where Directors are widely separated.





B′r FROM EACH DIRECTOR IS CORRECTED TO THE REFERENCE POINT

A summary of the PARALLAX CORRECTIONS

Two factors make Parallax Corrections necessary:

1 The height of the Director above the guns (vertical base)

2 The horizontal distance between the Reference Point and the guns (horizontal base)

These two factors require three Parallax Corrections. Of the three Parallax Corrections, one compensates for the vertical base and two compensate for the horizontal base.

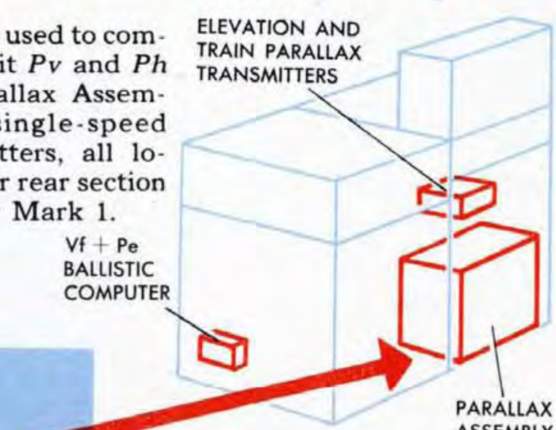
1 Elevation Parallax Correction, *Pe*, corrects for a ten-yard vertical base.

2 Elevation Parallax, *Pv*, and

3 Train Parallax, *Ph*, correct for a 100-yard horizontal base.

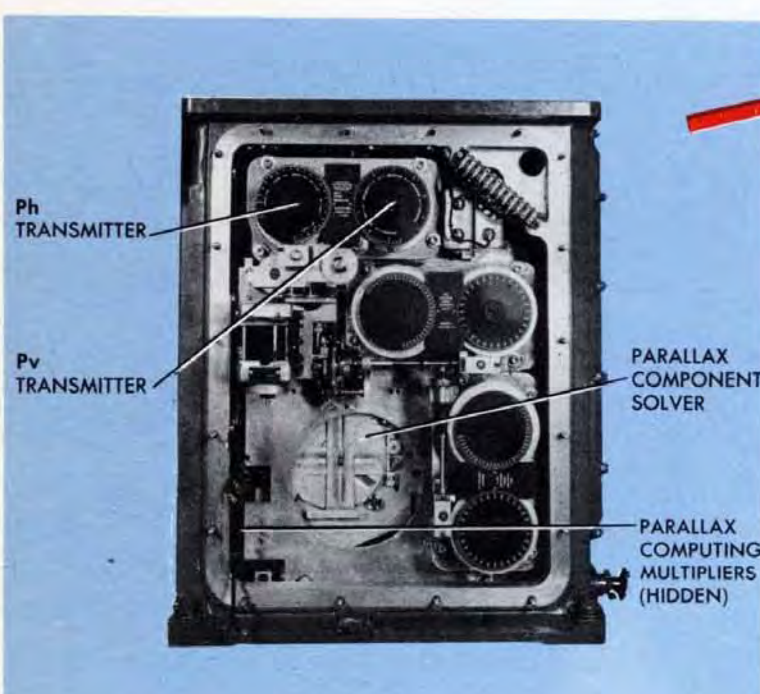
The mechanisms for computing Parallax

The mechanisms used to compute and transmit *Pv* and *Ph* include the Parallax Assembly and two single-speed synchro transmitters, all located in the lower rear section of the Computer Mark 1.



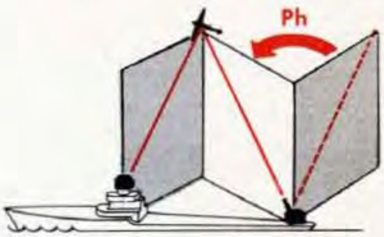
The Parallax Assembly contains the Parallax Component Solver and two computing multipliers.

Elevation Parallax Correction, *Pe*, is computed in the *Vf* + *Pe* Ballistic Computer and is transmitted to the guns as part of Gun Elevation Order, *E′g*.



Train parallax correction Ph

With the guns trained at the same angle as the Director sights, the additional angle of Gun Train needed to put the guns on the Target is *Ph.*



Train Parallax, *Ph,* is computed from three quantities:

1. Gun Train Order, *B′gr* (or Director Train, *B′r*)
2. Advance Range, *R2*
3. Predicted Elevation plus Level, *E2 + L*

How B′gr affects Ph

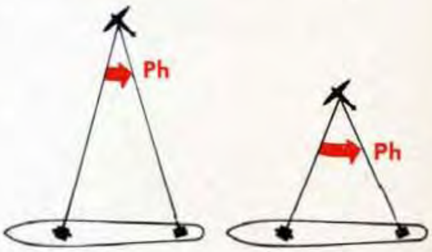
If a Target is directly aft of Own Ship, the angle of Gun Train, *B′gr,* is 180° and the *Ph* correction is zero.

As the Target moves farther abeam of Own Ship, *B′gr* decreases and *Ph* begins to increase.

Ph varies in proportion to the sine of *B′gr.*

How R2 and E2+L affect Ph

Ph varies as the reciprocal of Range in the deck plane. For long ranges, *Ph* is a small angle. For shorter ranges, *Ph* is a larger angle.

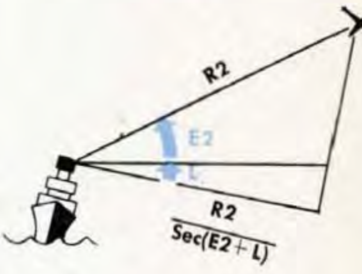


Advance Range, *R2,* is projected onto the deck plane because the gun is trained in that plane.

Finding the value of Range in the deck plane:

$$\sec\,(E2 + L) = \frac{R2}{\text{Range in the deck plane}}$$

$$\text{Range in the deck plane} = \frac{R2}{\sec\,(E2 + L)}$$



Ph, therefore, varies as the reciprocal of $\frac{R2}{\sec\,(E2 + L)}$

Since *Ph* varies as the sine of *B′gr* and as the reciprocal of $\frac{R2}{\sec\,(E2 + L)}$, the equation for *Ph* is

$$\sin B'gr \times \frac{\sec\,(E2 + L)}{R2} \times K \cdot 100 = Ph$$

The figure 100 represents the 100-yard horizontal base.

Since it makes no difference which value in the equation is divided by *R2,* the equation is arranged this way for mechanical convenience:

$$\sec\,(E2 + L) \times \frac{\sin B'gr}{R2} \times K \cdot 100 = Ph$$

NOTE:
This equation for *Ph* is derived fully in the supplement at the end of this chapter.

Two mechanisms solve

The equation for *Ph* is solved by a component solver and a computing multiplier. The equation is:

$$\sec (E2 + L) \times \frac{\sin B'gr}{R2} \times K \cdot 100 = Ph$$

The term $\frac{\sin B'gr}{R2}$ is computed in the Parallax Component Solver.

A computing multiplier, called the Train Parallax Computer, multiplies $\frac{\sin B'gr}{R2}$ by $\sec (E2 + L)$. Constants, *K* and 100, are introduced by gearing to produce the quantity *Ph*.

The parallax component solver

The Parallax Component Solver contains a reciprocal cam.

The input to the cam is Advance Range, *R2*. For every input of *R2* to the cam, the follower pin is pushed to a position representing $1/R2$.

The input to the vector gear is Gun Train Order, *B'gr*.

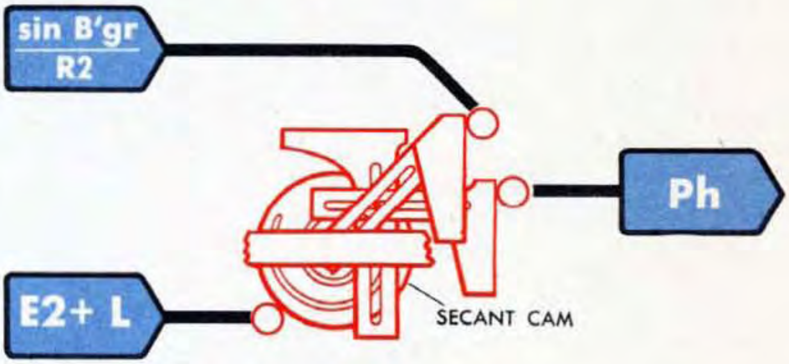
The two outputs of the Parallax Component Solver are:

$\frac{\sin B'gr}{R2}$, which is one of the terms in the equation for Train Parallax, *Ph*.

$\frac{\cos B'gr}{R2}$, which will be used later as a term in the equation for Elevation Parallax, *Pv*.

the equation for Ph

The train parallax computer



The Train Parallax Computer is a single-cam multiplier with a secant cam.

The input to the secant cam is $E2 + L$. For every input of $E2 + L$, the input slide moves to a position representing sec $(E2 + L)$.

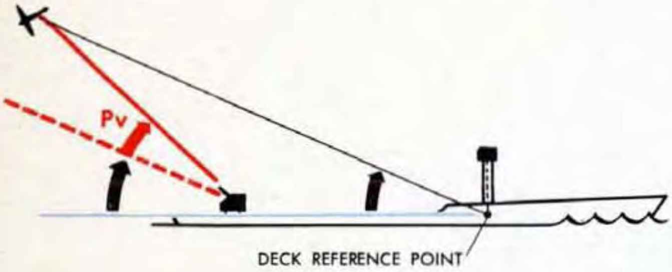
The input to the pivot arm rack is $\frac{\sin B'gr}{R2}$ from the Parallax Component Solver.

The Train Parallax Computer multiplies these two terms together.

Constants K and 100 are taken care of by the choice of gearing to produce the value of Train Parallax Correction, Ph:

$$\sec (E2 + L) \times \frac{\sin B'gr}{R2} \times K \cdot 100 = Ph$$

ELEVATION PARALLAX CORRECTION Pv



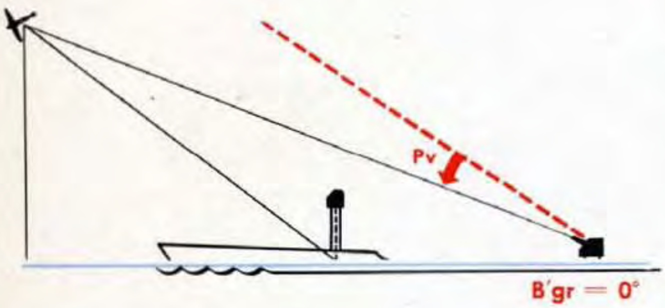
With the guns pointed at the same angle as a line of sight from the Deck Reference Point, the additional angle of Gun Elevation needed to put the guns on the Target is Elevation Parallax Correction, *Pv*.

Elevation Parallax Correction, *Pv*, is computed from three quantities:

1 Gun Train Order, *B′gr*

2 Advance Range, *R2*

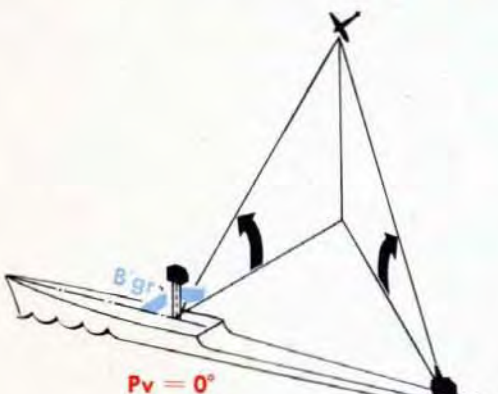
3 Predicted Elevation plus Level, *E2 + L*



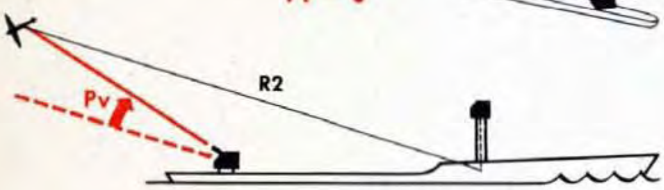
How B′gr affects Pv

Pv varies as the cosine of Gun Train Order, *B′gr*.

When the Target is directly ahead of Own Ship, *B′gr* is *zero*, and *Pv* is large. Cos $0^\circ = 1.0$.

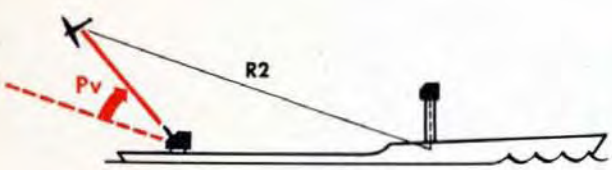


If the Target is directly abeam of Own Ship, *B′gr* is 90° and *Pv* is zero. Cos $90^\circ = 0$.



How R2 affects Pv

Pv varies inversely as Advance Range, *R2*.



When *R2* is long, *Pv* is a small angle.

When *R2* is short, *Pv* is a larger angle.

How E2 + L affects Pv

When $E2 + L$ is large, Pv is a relatively *large* angle.

When $E2 + L$ is small, Pv is a *small* angle.

Pv varies as sin $(E2 + L)$.

Since Pv varies as cos $B'gr$, *inversely* as $R2$, and as sin $(E2 + L)$, the equation for Pv is:

$$\sin(E2 + L) \times \frac{\cos B'gr}{R2} \times K \cdot 100 = Pv$$

The term $\frac{\cos B'gr}{R2}$ is one of the outputs of the Parallax Component Solver. This term is multiplied by sin $(E2 + L)$ in a computing multiplier called the Elevation Parallax Computer.

The Elevation Parallax Computer

The Elevation Parallax Computer is a single-cam type multiplier containing a sine cam.

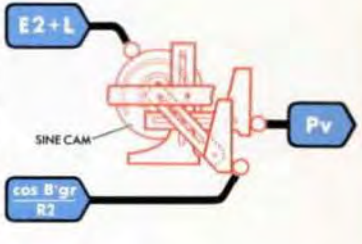
The value of $E2 + L$ positions the sine cam, giving a value of sin $(E2 + L)$ for every input value of $E2 + L$.

The value of $\frac{\cos B'gr}{R2}$ from the Parallax Component Solver is the input to the pivot arm rack.

The Elevation Parallax Computer multiplies one input by the other.

The constants, K and 100, are introduced through gearing to produce the Elevation Parallax Correction, Pv.

$$\sin(E2 + L) \times \frac{\cos B'gr}{R2} \times K \cdot 100 = Pv$$

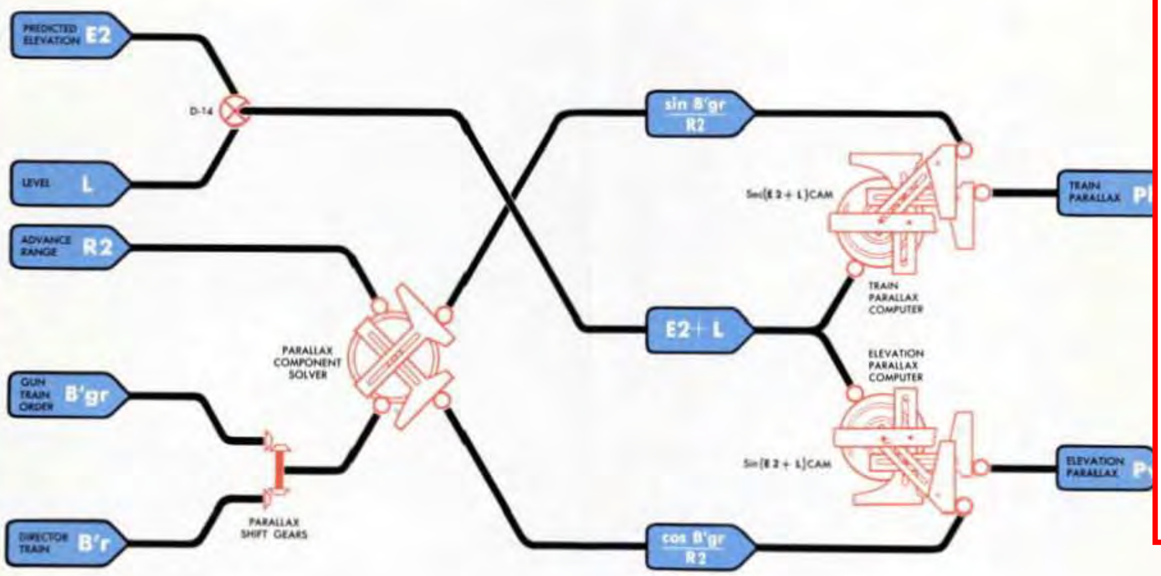


NOTE:
The equation for Pv is derived fully in the supplement at the end of this chapter.

COMPUTER MK. 1, MOD. 7

PARALLAX SECTION

SCHEMATIC DIAGRAM



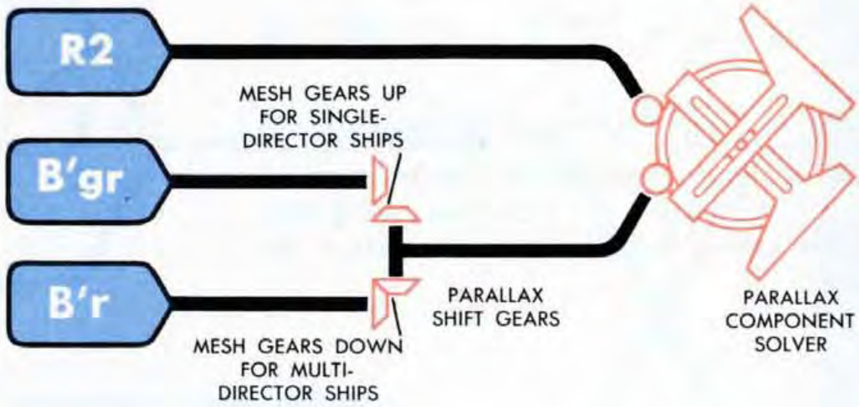
THE PARALLAX SHIFT GEARS

The Parallax shift gears are located on the input line to the vector gear of the Parallax Component Solver. They allow either Gun Train Order, *B′gr*, or Director Train, *B′r*, to be used as the input quantity.

B′gr is used on Single-Director Ships, such as DD's, AO's, and AV's.

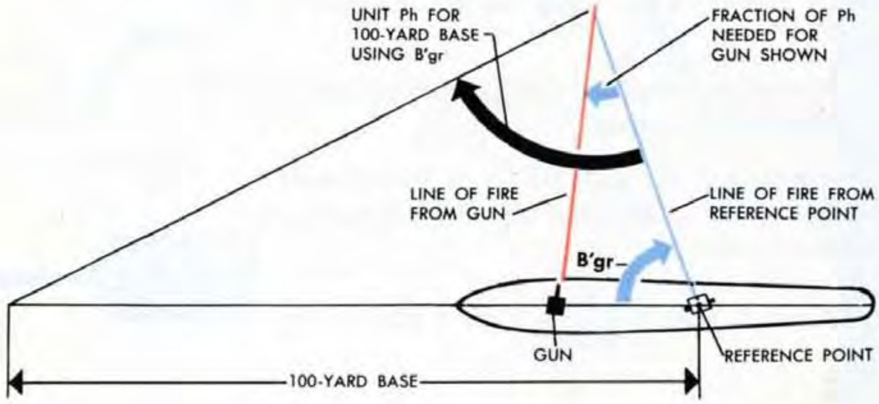
B′r is used on Multi-Director ships, such as BB's, CA's, CB's, and CL's.

Exception: *B′gr* is used on CV's.



Single - Director Ships

On ships with one Director, the Reference Point is always at the Director. Parallax Corrections are needed only to make the Line of Fire from the guns converge with the Line of Fire from the Reference Point. Therefore Gun Train Order, *B′gr*, is the only train angle involved and is used in the Parallax Component Solver.

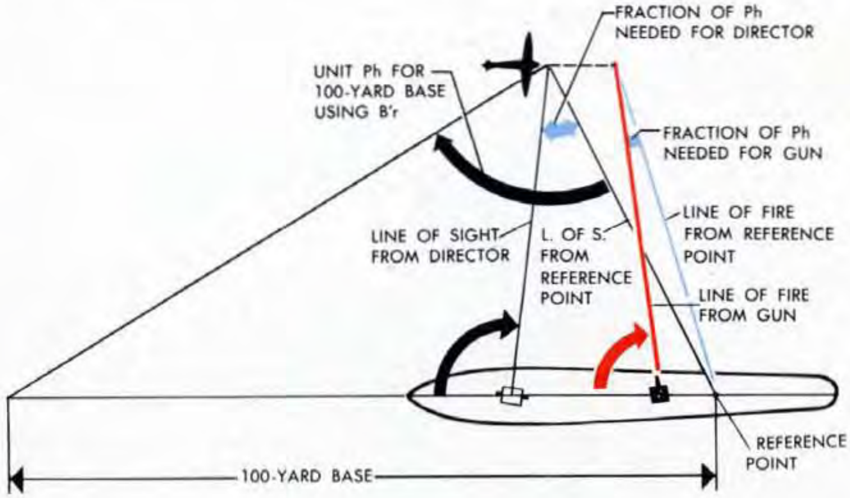


Multi - Director Ships

On Multi-Director ships, two complete sets of Parallax Corrections would be required to make accurate corrections to both the guns and the Directors.

A set of corrections based on *B′gr* would be needed to make the Line of Fire from each gun converge with the Line of Fire from the Reference Point. A set of corrections based on *B′r* would be needed to make the Line of Sight from each Director converge with the Line of Sight from the Reference Point.

Since the error involved is small, the Computer Mark 1 computes only one set of corrections for a 100-yard base, and uses it for both the Directors and the guns.

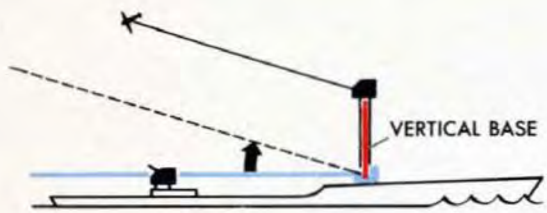


On Multi-Director ships, the guns are usually placed between the Directors; therefore the instrument farthest from the Reference Point is usually a Director rather than a gun.

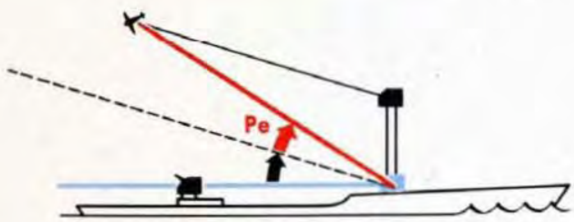
Since the largest fraction of each Parallax Correction will be used by the instrument farthest from the Reference Point, Parallax Corrections based on Director Train, *B′r*, are computed on Multi-Director ships and used for both Directors and guns.

The guns, being located nearer the Reference Point than the Directors, use smaller fractions of these Parallax Corrections. The errors in the smaller corrections are correspondingly smaller; therefore the Parallax Corrections based on *B′r* are sufficiently accurate for use at the guns.

ELEVATION PARALLAX CORRECTION, Pe

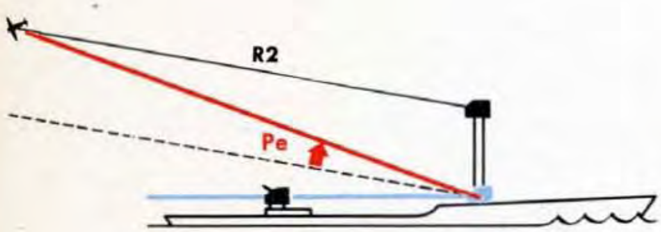


Elevation Parallax Correction, *Pe,* is the additional amount of Gun Elevation needed to compensate for the difference in height of the guns and the Director.



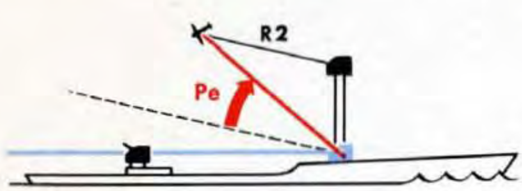
Pe is usually computed for a 30-foot vertical base.

The resulting correction is considered sufficiently accurate to compensate for the height of any Director above any gun and is *included in Gun Elevation Order, E′g, going to all the guns.*

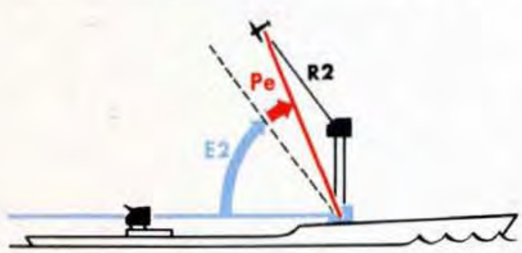


How R2 and E2 affect Pe

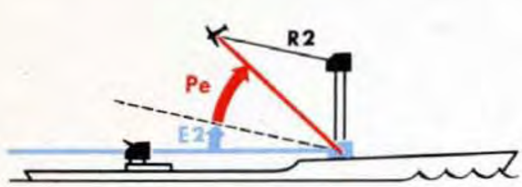
Pe is a function of Advance Range, *R2, and* Predicted Elevation, *E2.*



When *R2* is long, *Pe* is a small angle, and when *R2* is short, *Pe* is a *larger* angle.



Also, when *E2* is a large angle, *Pe* is a *small* angle. When *E2* is a small angle, *Pe* is a *larger* angle.

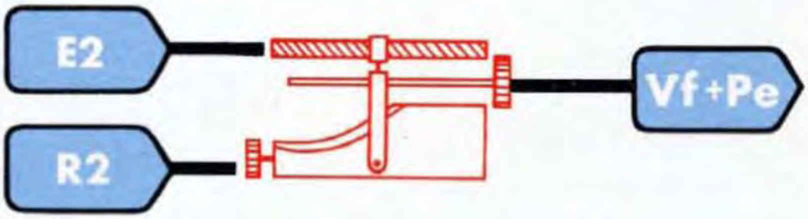


Notice that *Pe* is a function of *R2* and *E2* only. The values of Gun Train Order, *B′gr,* and Level, *L,* have no effect on the value of this correction.

The Vf+Pe ballistic computer

Pe is computed in the *Vf* + *Pe* Ballistic Computer in the Prediction Section.

E2 and *R2* are the inputs to the *Vf* + *Pe* Ballistic Computer.



R2 positions the ballistic cam. *E2* positions the lead screw that moves the cam follower along the cam.

Superelevation Correction, *Vf*, is the additional amount of Gun Elevation needed to compensate for the curve of the trajectory of the projectile.

Since *Vf* is also a function of *R2* and *E2*, one ballistic cam is cut to give the output of *Vf* + *Pe*. The value of *Pe* is therefore never on a shaft by itself, but is always included as part of the output of the *Vf* + *Pe* Ballistic Computer.

WHERE THE PARALLAX CORRECTIONS GO

Elevation Parallax Correction, *Pe*, becomes part of Gun Elevation Order, *E'g*, and is sent to all the guns.

Train Parallax Correction, *Ph*, positions a single-speed transmitter which sends *Ph* by synchro transmission to the guns and the Directors.

Elevation Parallax Correction, *Pv*, positions another single-speed transmitter which sends *Pv* to some guns, or to some Directors, or to some guns and some Directors, depending on the type of installation.

The **REFERENCE POINT** or **LINE** may be:

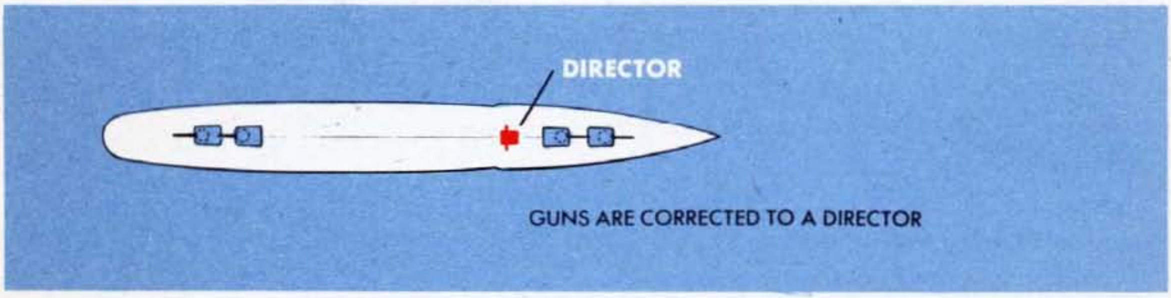
1 A Director

2 An imaginary point or line between two Directors

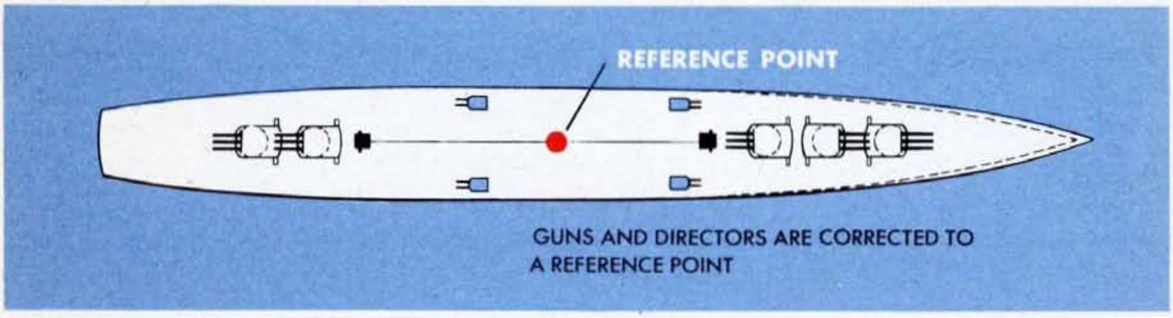
3 An imaginary line running through the Director

Here are some DIRECTOR and GUN

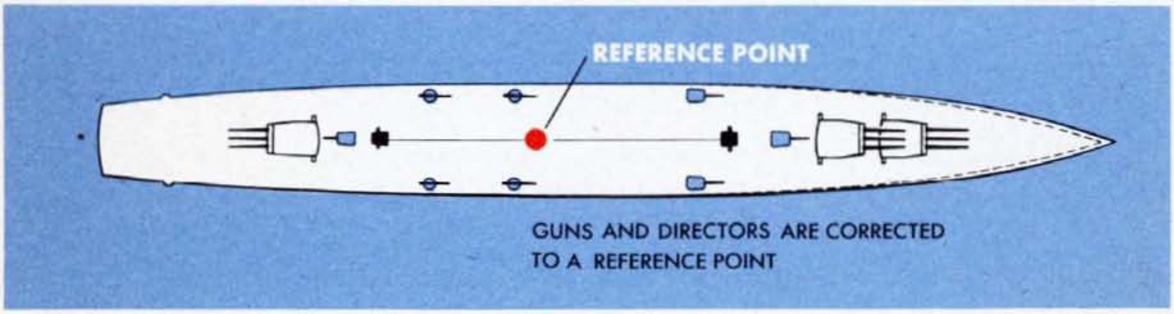
DESTROYER



LIGHT CRUISER



HEAVY CRUISER

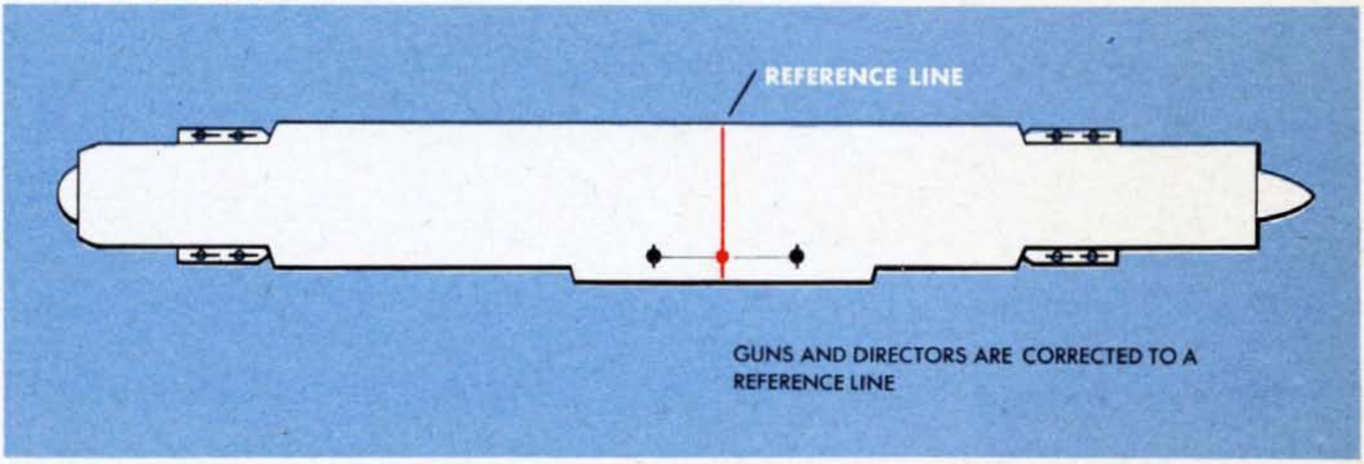


On a destroyer, the Director is the Reference Point.

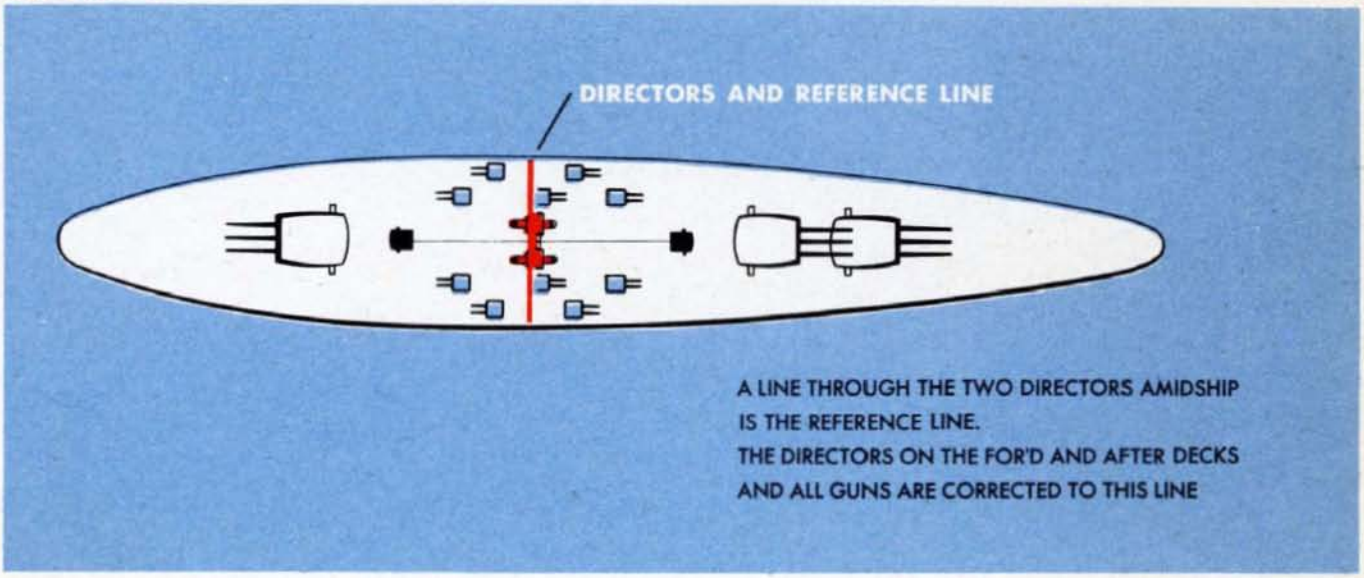
On other types of ships where guns and Directors are placed to starboard or port of an imaginary fore-aft line, corrections are made to a Reference *Line*. A Reference Line is a line running at right angles to the fore-aft axis and passing through a Reference Point or through one or two Directors.

arrangements for different types of ships

AIRCRAFT CARRIER



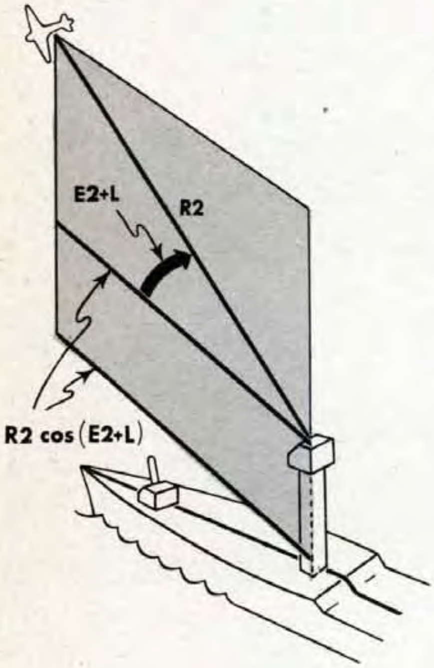
BATTLESHIP



Derivation of the parallax equations

This supplement is intended for those who wish to go further into the mathematical derivation of the equations for Train Parallax, *Ph,* and Elevation Parallax, *Pv.*

The equation for train parallax correction Ph



In the *Ph* derivation, Advance Range, *R2,* is projected onto the deck plane.

The first sketch shows that:

$$\text{Projected Advance Range} = R2 \cos (E2 + L)$$

The second sketch, where *bh* is the horizontal base between director and gun, shows that:

$$\sin B'gr = \frac{a}{bh}$$

$$a = bh \cdot \sin B'gr$$

Also, $\tan Ph = \dfrac{a}{R2 \cos (E2 + L) - n}$

Substituting for *a*

$$\tan Ph = \frac{bh \cdot \sin B'gr}{R2 \cos (E2 + L) - n}$$

Since n is small compared to $R2 \cos (E2 + L)$, it may be neglected.

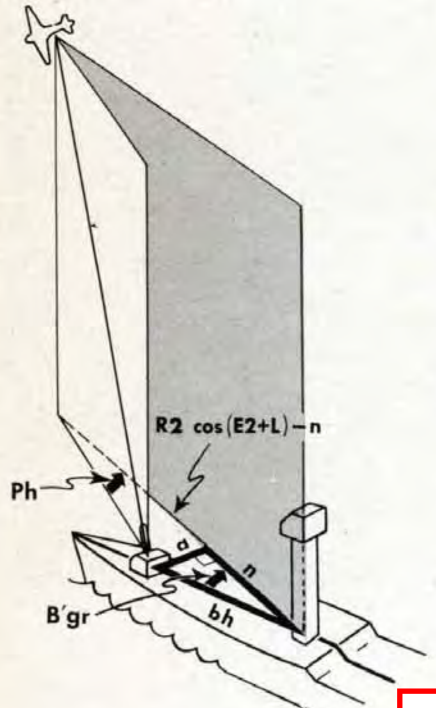
Also, for small angles, $K \tan Ph = Ph$

Then $Ph = \dfrac{K \cdot bh \cdot \sin B'gr}{R2 \cos (E2 + L)}$

Since *Ph* is defined for a 100-yard base, and

$$\frac{1}{\cos (E2 + L)} = \sec (E2 + L),$$

$$Ph = \frac{K \cdot 100 \cdot \sin B'gr \cdot \sec (E2 + L)}{R2}$$



The equation for elevation parallax correction Pv

In the vertical plane through the director,

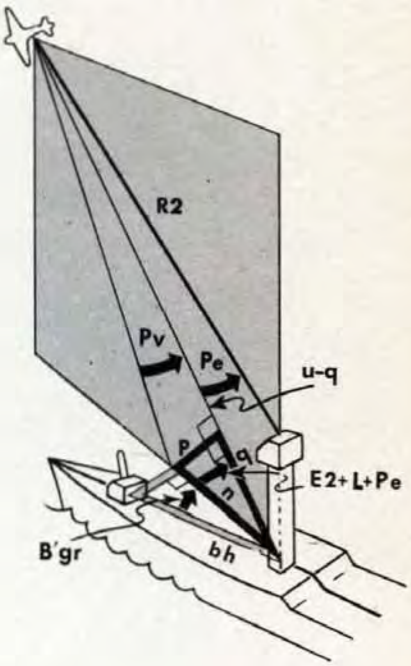
$$\tan Pv = \frac{p}{u - q} \qquad (1)$$

Also, $\frac{p}{n} = \sin (E2 + L + Pe)$

or, $p = n \sin (E2 + L + Pe)$

Substituting this value for p in equation (1)

$$\tan Pv = \frac{n \sin (E2 + L + Pe)}{u - q} \qquad (2)$$



In the deck plane,

$$\frac{n}{bh} = \cos B'gr \qquad n = bh \cdot \cos B'gr$$

Substituting this value for n in equation (2)

$$\tan Pv = \frac{bh \cdot \cos B'gr \cdot \sin (E2 + L + Pe)}{u - q}$$

Since Pe is small compared to $(E2 + L)$, it may be disregarded in the equation.

The term $u - q$ is assumed equal to $R2$, since the resultant small error may be neglected.

Also, for small angles, $K \cdot \tan Pv = Pv$.

Then, by elimination and substitution,

$$Pv = \frac{K \cdot bh \cdot \cos B'gr \cdot \sin (E2 + L)}{R2}$$

Since Pv is defined for a 100-yard base,

$$Pv = \frac{K \cdot 100 \cdot \cos B'gr \cdot \sin (E2 + L)}{R2}$$

Summary of the approximations and assumptions

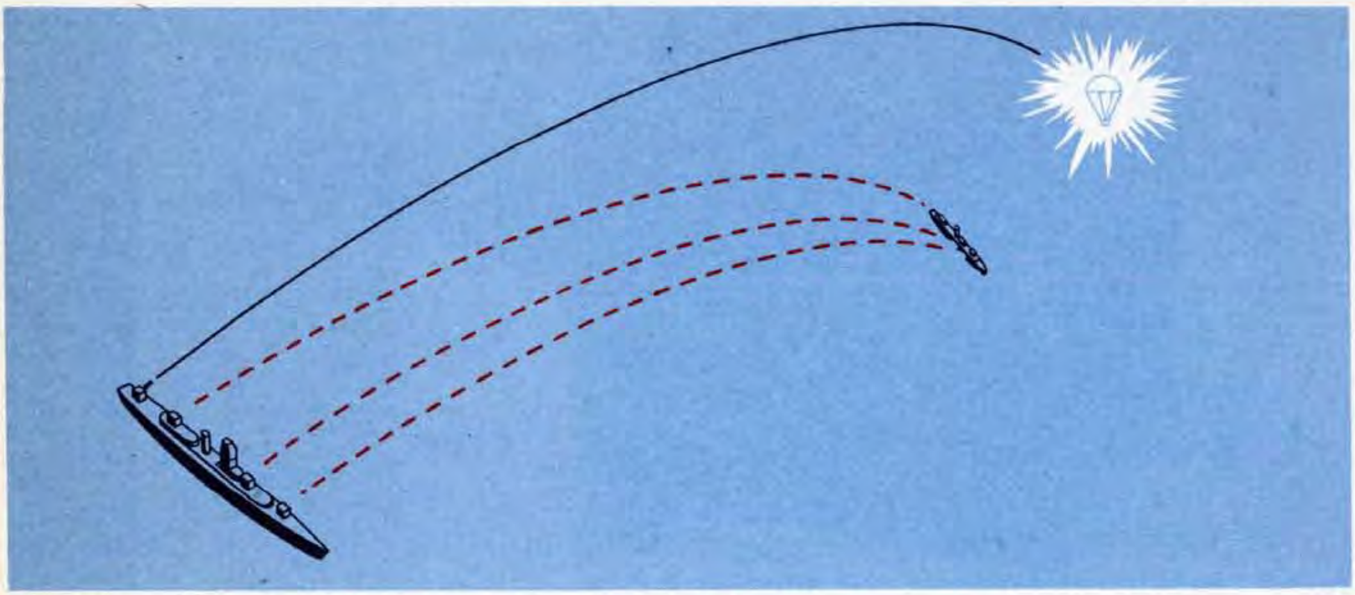
1 Unlike Elevation and Bearing, Range is not corrected to compensate for the separation of the guns and Directors.

2 Director Elevation, *Eb*, does not receive *Pv* except on certain types of aircraft carriers where the distance between the Directors is long.

3 All Directors are assumed to be 30 feet higher than the guns.

4 All guns are assumed to be on the center line, the fore and aft axis of the ship. There is no correction for Parallax due to displacement of the guns from this center line.

The STAR SHELL COMPUTER MARK 1



The Star Shell Computer Mark 1 is an instrument which computes and transmits gun and fuze setting orders for a gun firing star shells.

A star shell is a projectile containing, instead of the usual explosive charge, a flare attached to a parachute. When the shell bursts, the flare is set on fire and burns for approximately one minute as it floats down. The flare itself is called a "star."

Star shells are fired at night, usually to illuminate surface targets.

The Star Shell Computer is designed to control only one kind of star shell fire: FIRE TO ILLUMINATE A SPECIFIC TARGET WHICH HAS ALREADY BEEN DETECTED AND FOR WHICH GUN ORDERS ARE BEING COMPUTED BY THE COMPUTER MARK 1. While the Computer Mark 1 computes gun orders to HIT a given target, the Star Shell Computer takes those gun orders and uses them to calculate another set of gun orders to ILLUMINATE THAT SAME TARGET.

Star shells are also used to SEARCH an area for a possible target. For this purpose a *Star Shell Computer is not needed.* The guns firing star shells can be pointed and the fuzes timed according to ship's doctrine.

Often star shell fire from more than one gun is desirable for a search.

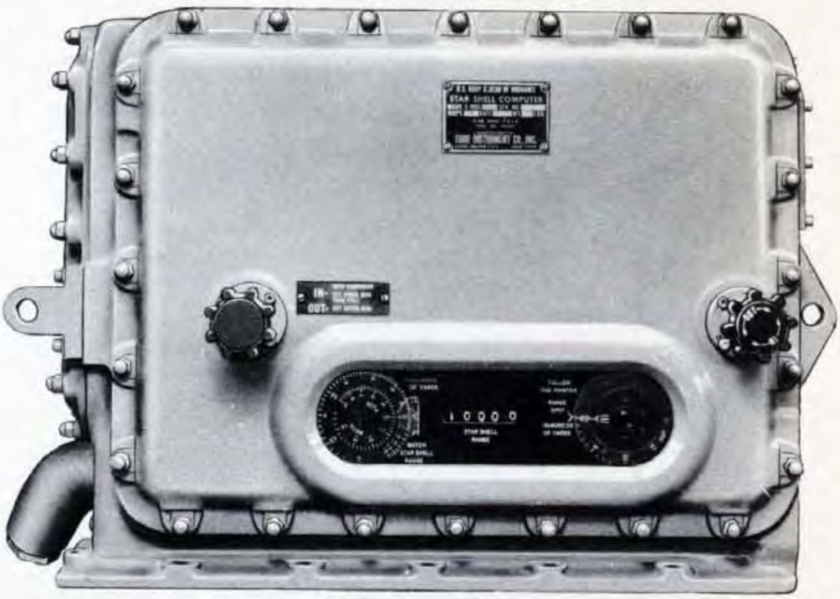
The star must form high enough above the water to allow time for the flare to burn out as it floats down. The Star Shell Computer is designed to compute a Fuze time and a Gun Elevation Order which will place the star 1000 yards beyond and 1500 feet above the moving Target, and a Gun Train Order which will place the star directly behind the Target after the star is half burned.

NOTE:
The Star Shell Gun Order Transmitters are 6DG's. The number and type of synchro-receiver installations which these transmitters can safely and accurately control at one time are limited. If it is desired to control more than one mount, the particular installation should first be investigated to determine the maximum practical load.

The Star Shell Computer computes three quantities:

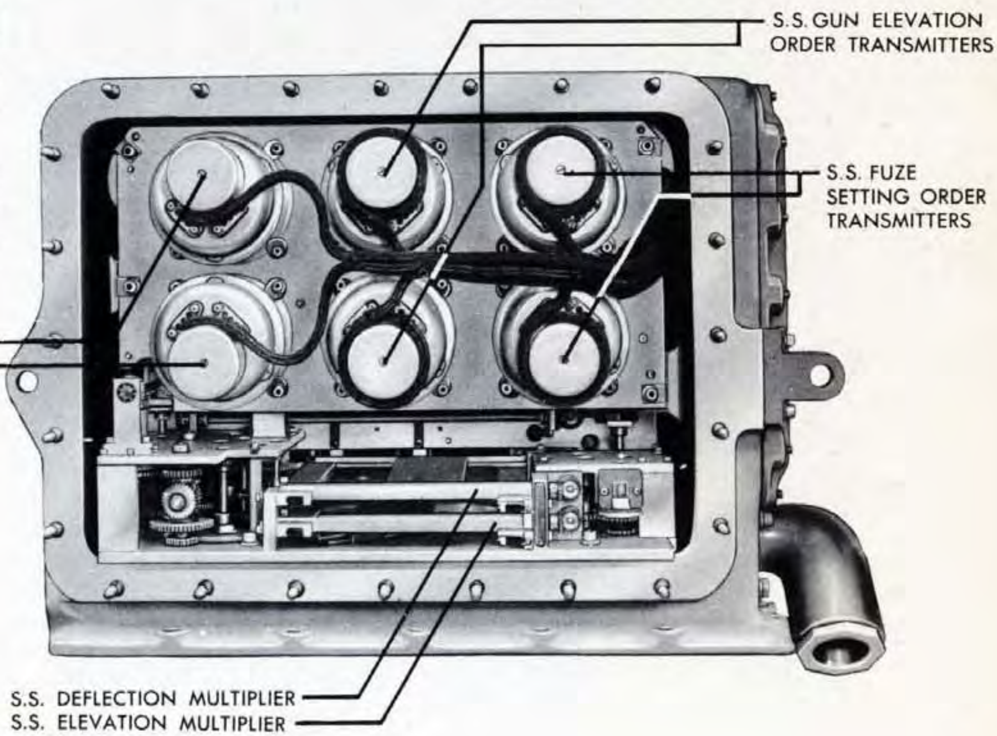
Star Shell Fuze Setting Order, Fn
Star Shell Gun Train Order, $B'grjn$
Star Shell Gun Elevation Order, $E'gjn$

The mechanism used to compute these quantities and transmit them to the gun firing the star shells includes two sets of special dials, two multipliers, three double-speed synchro transmitters, and a single-speed receiver. This mechanism is enclosed in a case on top of the Computer Mark 1.



Two sets of dials, the Star Shell Range Counter, and two operating knobs are on the front of the Star Shell Computer.

From the back, with the rear cover removed, the two multipliers and the three double-speed transmitters can be seen.



Star Shell RANGE

Here are the controls on the Star Shell Computer Mark 1.

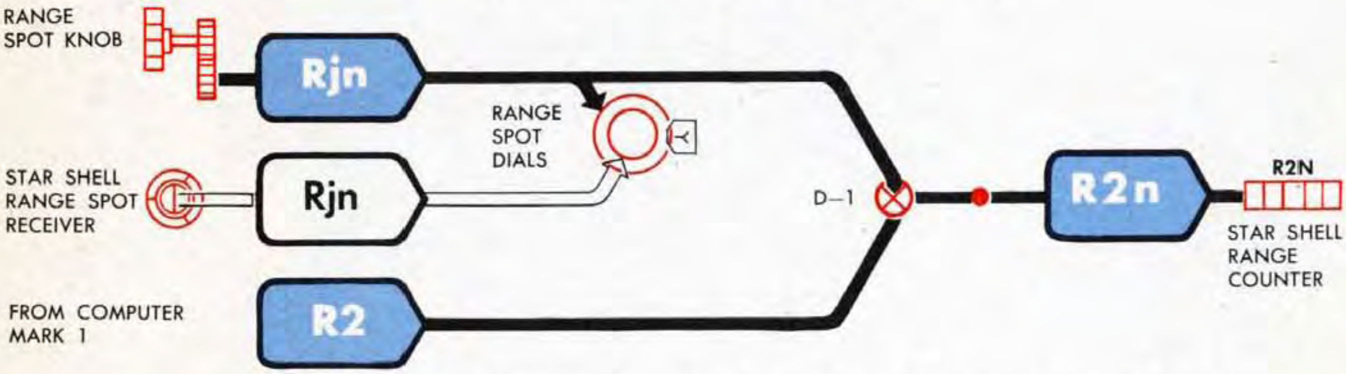
Star Shell Range, *R2n*, is the range to the point at which the star shell bursts, usually about 1000 yards beyond the Target. *R2n* consists of Advance Range, *R2*, plus Star Shell Range Spot, *Rjn*, plus 1000 yards.

$$R2n = R2 + Rjn + 1000$$

Advance Range, *R2*, is received by shaft from the Computer Mark 1.

Star Shell Range Spot, *Rjn*, is a hand input based on information received by synchro transmission. The value of *Rjn* is sent by synchro transmission from the Star Shell Spot Transmitter to a synchro motor and dial in the Star Shell Computer. The value of *Rjn* is put into the Star Shell Computer mechanisms by hand by turning the Range Spot Knob until the index on the Range Spot Ring Dial is matched with the pointer on the inner Receiver Dial.

Rjn is added to *R2* at differential D-1.

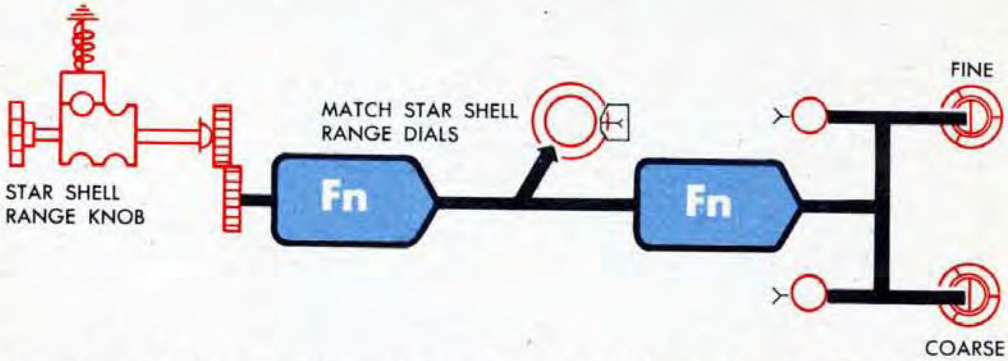


The additional 1000 yards is introduced at an offset clamp on the line to the *R2n* Counter. This clamp is adjusted to make the *R2n* Counter read 1000 yards more than the *R2* Counters in the Computer Mark 1 when *Rjn* is zero.

Star Shell FUZE SETTING ORDER

Star Shell Fuze Setting Order is a function of Star Shell Range *R2n*. When Range increases, Fuze Time increases, not only to make up for the longer Range, but also to take account of the declining velocity and the higher trajectory of the projectile.

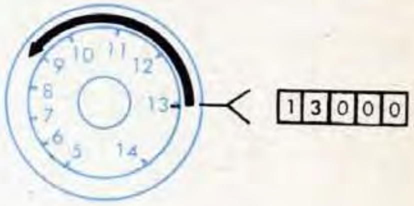
The Fuze line is connected to the *inner dial* of the Match Star Shell Range Dials. Matching this inner dial reading with the Star Shell Range Counter reading puts the correct value of *Fn* into the Star Shell Computer. The inner dial is positioned by the Star Shell Range Knob in its IN position.



The Fuze Dial is graduated to compute a function of *R2n*. The graduations are unequally spaced so that THE DIAL ITSELF TAKES THE PLACE OF A COMPUTING CAM.

Here the dial has been turned from 5000 yards to 9000 yards to match the Range Counter.

Here it has been turned from 9000 yards to 13,000 yards to match the Range Counter.



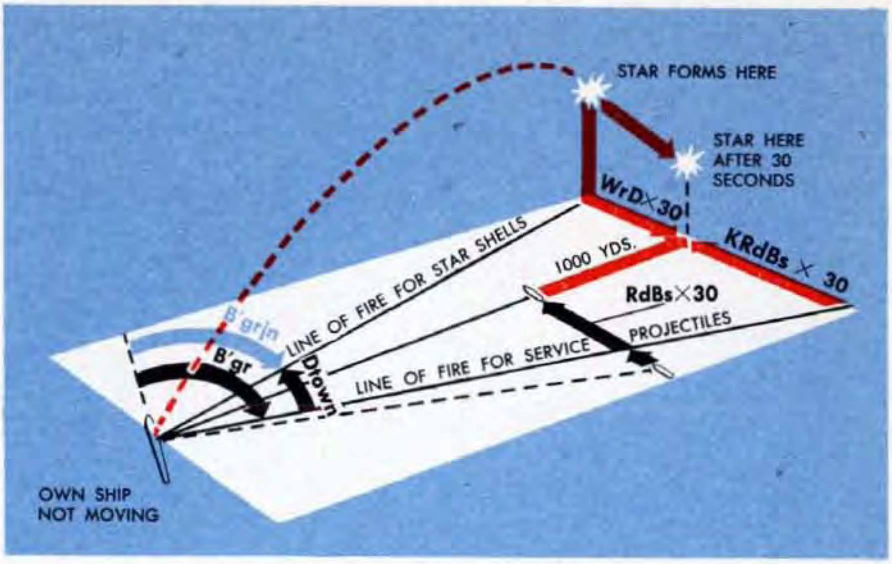
ALTHOUGH THE CHANGE WAS 4000 YARDS IN EACH CASE, THE AMOUNT OF ROTATION WAS GREATER FOR THE SECOND 4000 YARDS THAN IT WAS FOR THE FIRST 4000 YARDS.

When the *inner dial* is turned to match the Range Counter, the amount of rotation of the line is a *function* of the yards of Star Shell Range, *R2n*, and represents Star Shell Fuze Setting Order, *Fn*.

The computed value of *Fn* positions the Fuze Setting Order Transmitter.

The proper Star Shell Fuze Dial must be installed for the type of star shell being used. The mechanical fuze star shell requires the fuze dial marked "Mech. Fuze." The powder fuze star shell requires the fuze dial marked "Pwdr. Fuze."

Star Shell GUN TRAIN ORDER



The star from a star shell should form *1000 yards beyond* the Target, and should be in a *direct line* with the Ship and Target after it has burned *30 seconds,* which is half the life of the star.

The Gun Train Order, *B'gr,* computed by the Computer Mark 1, is such that service projectiles will *hit the Target.*

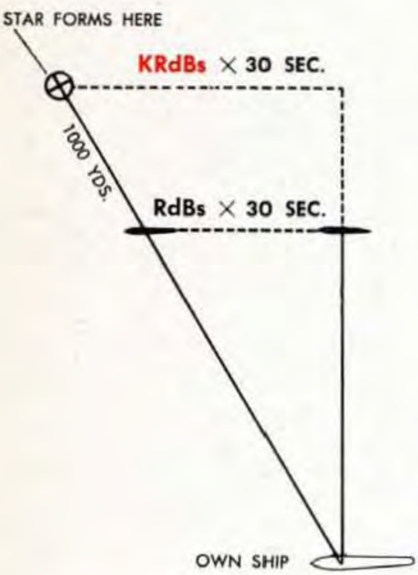
The Computed Star Shell Gun Train Order, *B'grn,* consists of *B'gr* plus a train correction to take account of both deflection of Ship and Target during the 30 seconds, and deflection of the star due to wind during the 30 seconds.

This train correction is called *Dtown.* $B'grn = B'gr + Dtown$

Dtown is an angular correction computed by the equation:

$$\frac{\text{linear rate} \times \text{time}}{\textit{range}} = \text{angular change}$$

The RATE in this equation is $KRdBs + WrD$, the sum of Ship, Target, and Wind motion horizontally across the Line of Sight.



As the diagram at the left indicates, star shell deflection due to *RdBs* is always greater than *RdBs* from the Computer Mark 1. The gearing carrying *RdBs* to the Star Shell Computer puts in a constant *K* which approximates this difference and produces *KRdBs.* Wind deflection, *WrD,* is added to obtain $KRdBs + WrD$, the total deflection rate.

The TIME in the equation is a constant, *K.* Its value is 30 seconds because Own Ship, Target, and the star should line up after the star has been burning 30 seconds.

The RANGE in the equation is Star Shell Range, *R2n.*

The equation for *Dtown* is therefore:

$$\frac{(KRdBs + WrD) \times K}{R2n} = Dtown$$

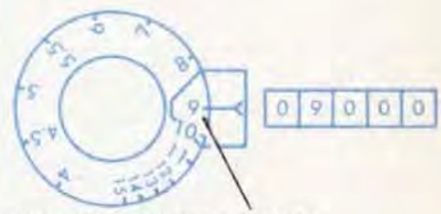
The equation for *Dtown* is solved by a dial and a screw-type multiplier.

The mechanism first computes the term $\frac{K}{R2n}$. This value is called *jDwn.*

The equation for *Dtown* can now be written:

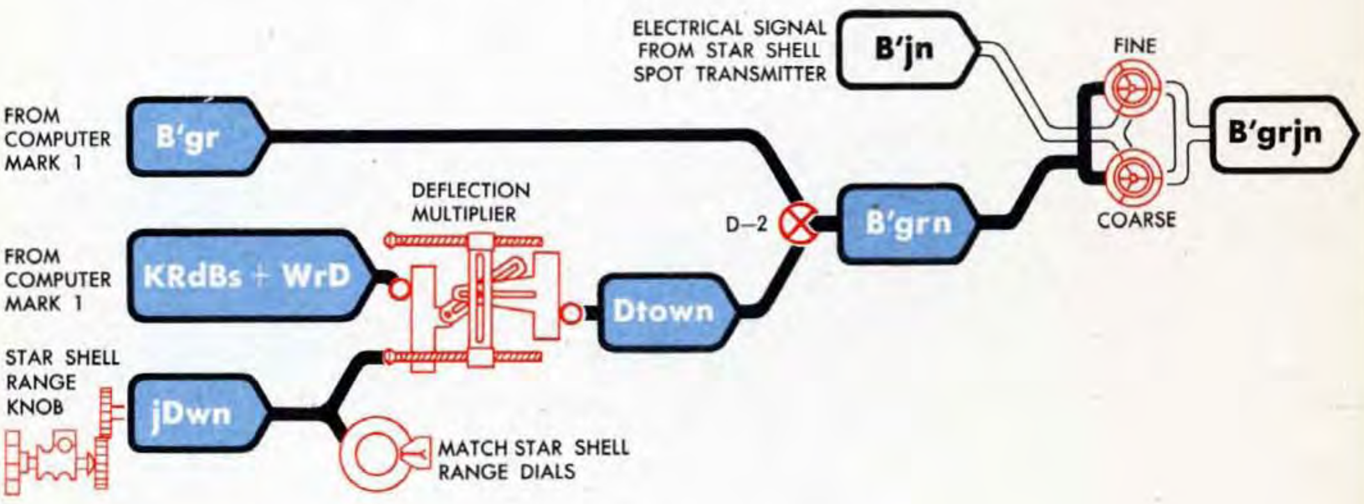
$$Dtown = jDwn \times (KRdBs + WrD)$$

jDwn is computed from *R2n* by the unequally spaced graduations on the ring dial of the Match Star Shell Range Dials. The ring dial acts as a computing cam just as the inner dial did in the Fuze Setting Order computation. The ring dial reading is matched to the Star Shell Range Counter reading by turning the Range Knob in its OUT position. This sets *jDwn* into the Deflection Multiplier.



RING DIAL MATCHED TO COUNTER PUTS jDwn INTO MECHANISM

The Deflection Multiplier is a screw-type multiplier which multiplies *jDwn* by *KRdBs* + *WrD*. *KRdBs* + *WrD* positions the rack; *jDwn* positions the lead screw. The output is *Dtown.*

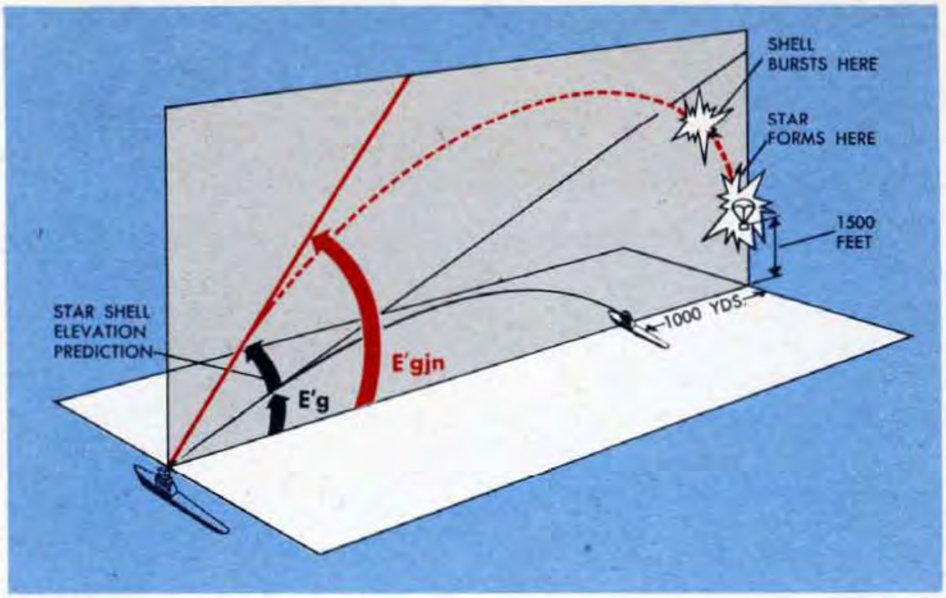


Computed Star Shell Gun Train Order, *B'grn,* is obtained by adding *Dtown* to Gun Train Order, *B'gr,* at differential D-2. In other words, the computation from Computer Mark 1 needed to hit the Target, and the correction needed to put the star, at half its life, in line with the Target, are combined to give Computed Star Shell Gun Train Order, *B'grn.*

B'grn drives a coarse and fine synchro differential generator in the Gun Train Order Transmitter. It is here that a further correction, Star Shell Deflection Spot, *B'jn,* is added electrically whenever needed. *B'jn* comes in electrically from the Star Shell Spot Transmitter in the Director.

The final output to the star shell gun is called Star Shell Gun Train Order, *B'grjn.*

Star Shell GUN ELEVATION ORDER



The Star Shell Elevation prediction must do more than simply correct Gun Elevation Order, *E′g*, from the Computer Mark 1, for the additional 1500 feet height of the star and the 1000 yards' additional range. It must include a correction for the fall of the star during the time interval between the burst of the shell and opening of the parachute, so that the star will *form* at an altitude of 1500 feet.

If the Star Shell Gun Elevation should be a *little* too low at the longer ranges, the star will explode just high enough to light up the surface for a few seconds before sputtering into the water.

NOTE:
The Star Shell Fuze Setting Order must also be highly accurate, for the same reason. The Star Shell Gun Train Order, however, can put the star several hundred feet to one side of the ideal location without seriously interfering with illumination.

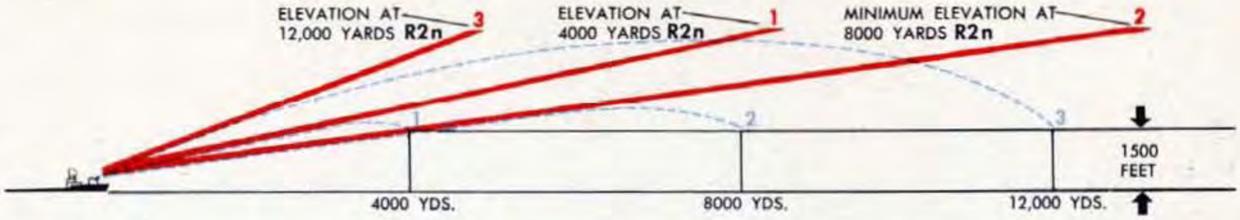
The equation for Star Shell Gun Elevation Order, *E′gjn*, has four terms.

The first term is $E'g + K$. The Star Shell Gun Elevation Order must put the star *beyond* and *above* the Target. This means that Star Shell Gun Elevation Order will always be larger than Gun Elevation Order, *E′g*, from the Computer Mark 1. *K* represents the minimum amount by which the Star Shell Gun Elevation Order always exceeds *E′g*.

$K_3 \cdot jDwn$ can be roughly pictured as a *negative* correction to Elevation, needed to keep the stars at the same height as range increases.

$K_1 \cdot Fn$ can be thought of as a *positive* correction to Elevation as range increases. It represents Superelevation. This term is further modified by Range Spot, *Rjn*.

E′jn is the Star Shell Elevation Spot, which is added electrically at the Star Shell Gun Elevation Order Transmitter.



Why there are both a positive and a negative elevation correction

As Star Shell Range, *R2n*, increases from a minimum of 4000 yards up to about 8000 yards, the gun must be *depressed* to keep the star at 1500 feet altitude. Beyond that range the elevation must be *increased* to hold the 1500 feet altitude as the range increases, because of the increasingly curved trajectory of the shell.

To approximate this variation, two elevation corrections are computed. If 4000 yards is taken as a base, then, as Star Shell Range increases from 4000 yards, one of these corrections is a *negative* correction to that base and the other is a *positive* correction.

The negative correction predominates during the short ranges where the shells travel almost in a straight line. The positive correction predominates at the longer ranges.

$K_3 \cdot jDwn$ The negative correction decreases as Range increases. It happens to vary in about the same way as *jDwn;* therefore *jDwn* from the ring dial of the Match Star Shell Range Dials is multiplied through gearing by a constant, K_3, to bring it into scale with the other Elevation values. The product, $K_3 \cdot jDwn$, is used as the negative Elevation correction. This explains why Star Shell Deflection, *jDwn,* is an input to the Star Shell Gun Elevation Order network.

$K_1 \cdot Fn$ The *positive* Elevation correction is Superelevation, the *increase* in the Elevation Angle needed to compensate for the increased drop in the shell as Range increases.

Superelevation is about the same function of Star Shell Range as Star Shell Fuze Setting Order, *Fn*. The *Fn* Dial of the Star Shell Range Dials can therefore be used to compute this correction. The value on the Fuze line is multiplied by a constant, K_1, producing $K_1 \cdot Fn$. $K_1 \cdot Fn$ is used as the input to the lead screw of the Star Shell Elevation Multiplier, which produces the positive Elevation Correction, $K_1 \cdot Fn(K_2 + Rjn)$.

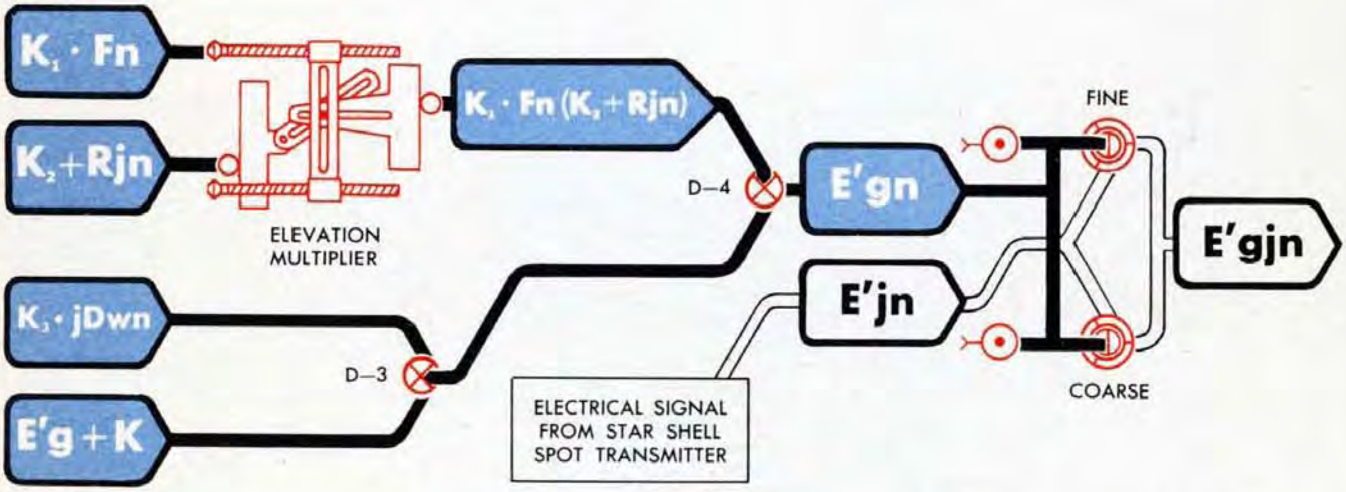
Summary of the Gun Elevation Computation

The equation for Star Shell Gun Elevation Order is:

$E'gjn = (E'g + K) + K_3 \cdot jDwn + K_1 Fn (K_2 + Rjn) + E'jn.$

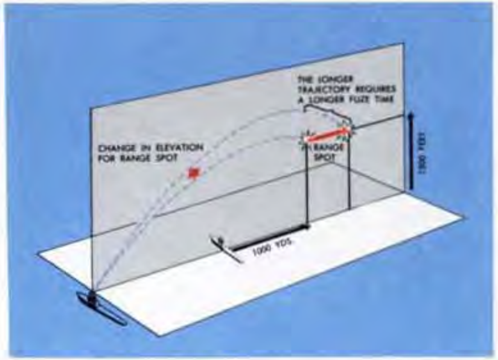
This equation is solved mechanically in four steps:

1. The Star Shell Elevation Multiplier multiplies $K_1 \cdot Fn$ by $K_2 + Rjn$.
2. $E'g + K$ from the Computer Mark 1 is added to $K_3 \cdot jDwn$ at differential D-3.
3. The output from D-3 is added to the multiplier output to obtain Computed Star Shell Elevation Order, $E'gn$. $E'gn$ drives coarse and fine synchro differential generators in the Star Shell Gun Elevation Order Transmitter.
4. In the Star Shell Gun Elevation Order Transmitter, Star Shell Elevation Spot, $E'jn$, is added electrically to Computed Star Shell Gun Elevation Order, $E'gn$, to obtain Star Shell Gun Elevation Order, $E'gjn$, the electrical output to the gun.



Star Shell Deflection and Elevation Spots

Star Shell Deflection and Elevation Spots are added directly into the Star Shell Gun Train and Elevation Orders by means of differential generators. These generators add an electrical input to a mechanical input and transmit their sum electrically. Star Shell Deflection and Elevation Spots are sent down electrically from the Director to these differential transmitters and are there added to the Computed Star Shell Gun Train and Elevation Orders. A detailed description of differential generators can be found in OP 1140, in the chapter on Synchros.



Star Shell Range Spots

Range Spots present a different problem. If, for example, it is desired to put a star 1500 yards beyond the Target instead of 1000 yards at the same altitude, all the Star Shell Orders have to be modified.

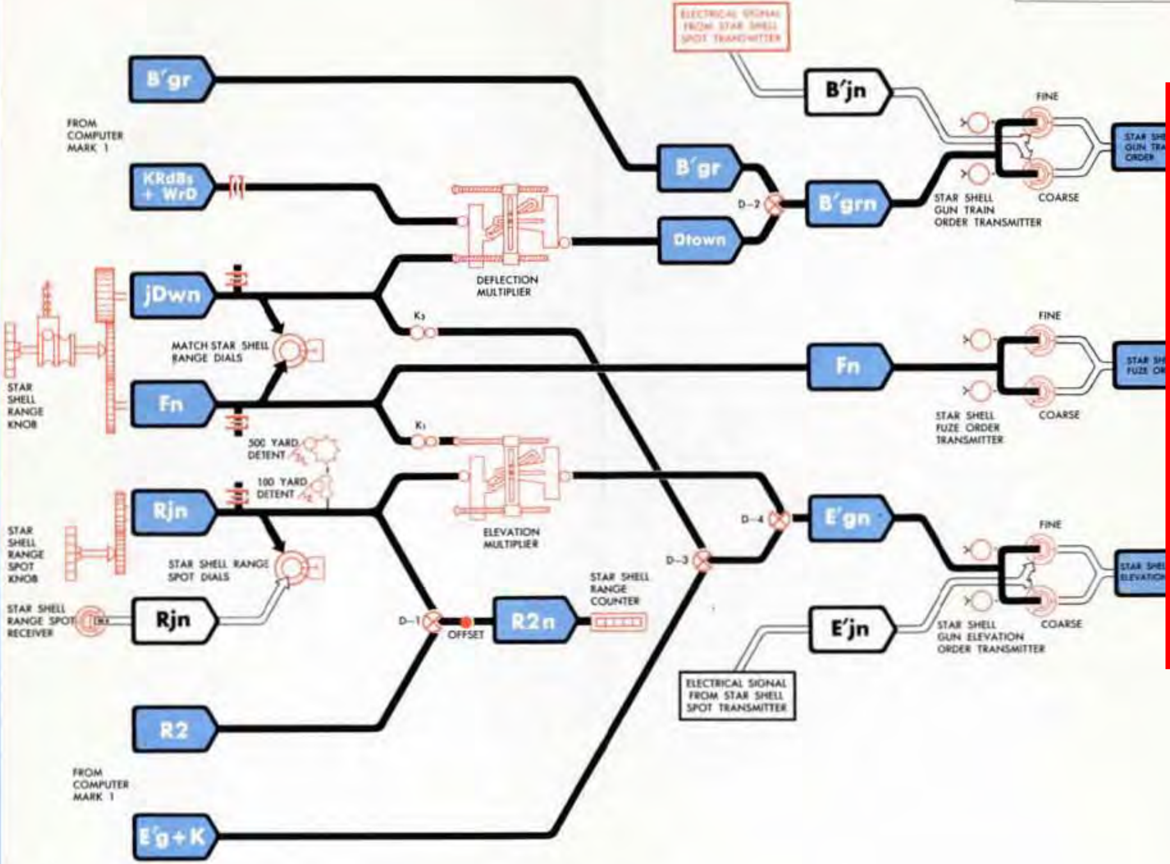
Fuze Time, *Fn*, must be longer, since the shell must travel farther. This change in Fuze Time is computed by matching the Fuze Dial to the new *R2n* value on the Star Shell Range Counter, which includes the spot. $R2n = R2 + 1000 + Rjn$.

A sufficiently accurate change in Star Shell Gun Train Order, *B'grjn*, results when the *jDwn* ring dial is matched with the new value on the Star Shell Range Counter. The change in Gun Train Order, which is not very important, has been omitted from the diagram above.

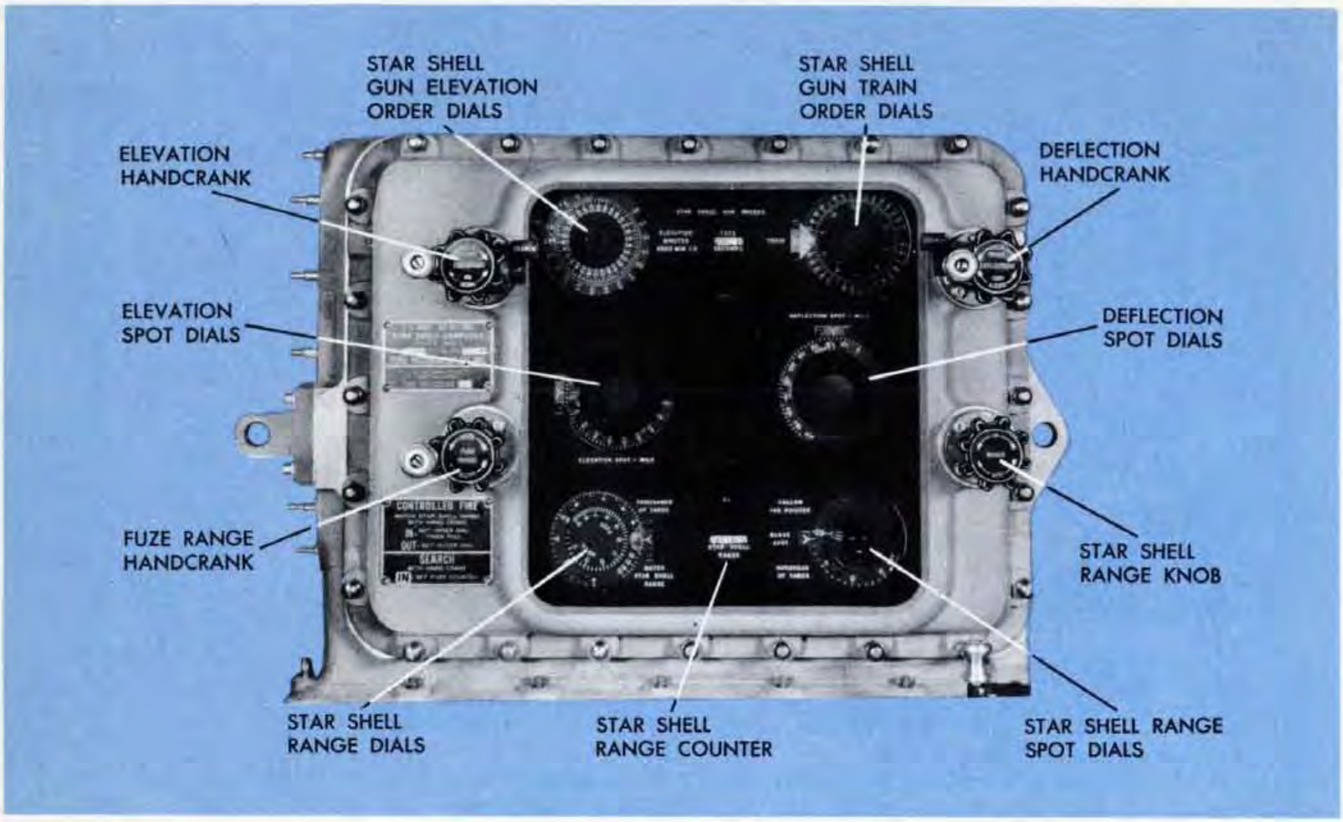
Star Shell Gun Elevation Order, *E'gjn*, must also be increased if a star is to burst an additional 500 yards beyond the Target and still form at 1500 feet altitude. Matching the *Fn* and *jDwn* Dials to the spotted value of Advance Range changes both the negative correction, $K_2 \cdot jDwn$, and the positive correction, $K_1 \cdot Fn$ in the Elevation computation. A third modification of the Elevation Order is needed to keep the star at 1500 feet. To approximate this modification, *Rjn* goes to the input rack of the Elevation Multiplier where K_2 is added as an offset. The multiplier output is $K_1 \cdot Fn\ (K_2 + Rjn)$.

STAR SHELL COMPUTER MARK 1 MOD 0

SCHEMATIC DIAGRAM



The STAR SHELL COMPUTER MARK 1 MOD 1



In order to implement the Star Shell Spot Transmitter Mark 1 and to provide for independent control of the Gun Order Transmitters, the Star Shell Computer Mark 1 Mod O was modified and was designated as Mod 1.

The computing mechanism in the Mod 1 is exactly like that in the Mod O, and, in general, operation of the Mod 1 is similar to that of the Mod O.

In the Mod 1, Elevation and Deflection Handcranks were added, each having two positions, SPOT and SEARCH. Elevation and Deflection Spot Dials were also added, and the window was enlarged to make the Star Shell Gun Elevation and Train Order Dials visible from the front.

With the handcranks in the SPOT position, Elevation and Deflection Spots may be introduced independently of the Star Shell Spot Transmitter Mark 1.

Elevation Spots are introduced through differential D-5 and Deflection Spots through differential D-6. The Elevation and Deflection Spot Dials indicate the respective quantities in mils. (The coarse Spot Dials remain within the graduation as long as the spots are within 200 mils.) Range Spots are introduced and indicated in this Mod as in Mod O. The Star Shell Spot Transmitter Mark 1 is still used for introducing normal Star Shell Spot Corrections.

For special types of control, other quantities may be set in by means of these spot handcranks.

In the SEARCH position, the handcranks control the Star Shell Gun Order Transmitters and Dials directly. Gun Train and Elevation Orders may be set at any desired values, independent of the rest of the mechanism.

The handcranks may be used in SEARCH position for controlling Search Fire. In this case the Gun Train Order is set in as desired, but the Elevation Order must be obtained from a previously prepared table. Such a table may be prepared by setting *E'g* on zero and reading *E'gin* for values of *R2n* set into the Star Shell Computer. Star Shell Fuze Order is set in with the Fuze Range Handcrank in its IN position. Since the gun orders are not stabilized in this type of control, Selected Level Fire is necessary.

The Star Shell Transmitters were designed to control only a single gun. When it is desired to control a complete battery, the problem should be set up on a Computer Mark 1.

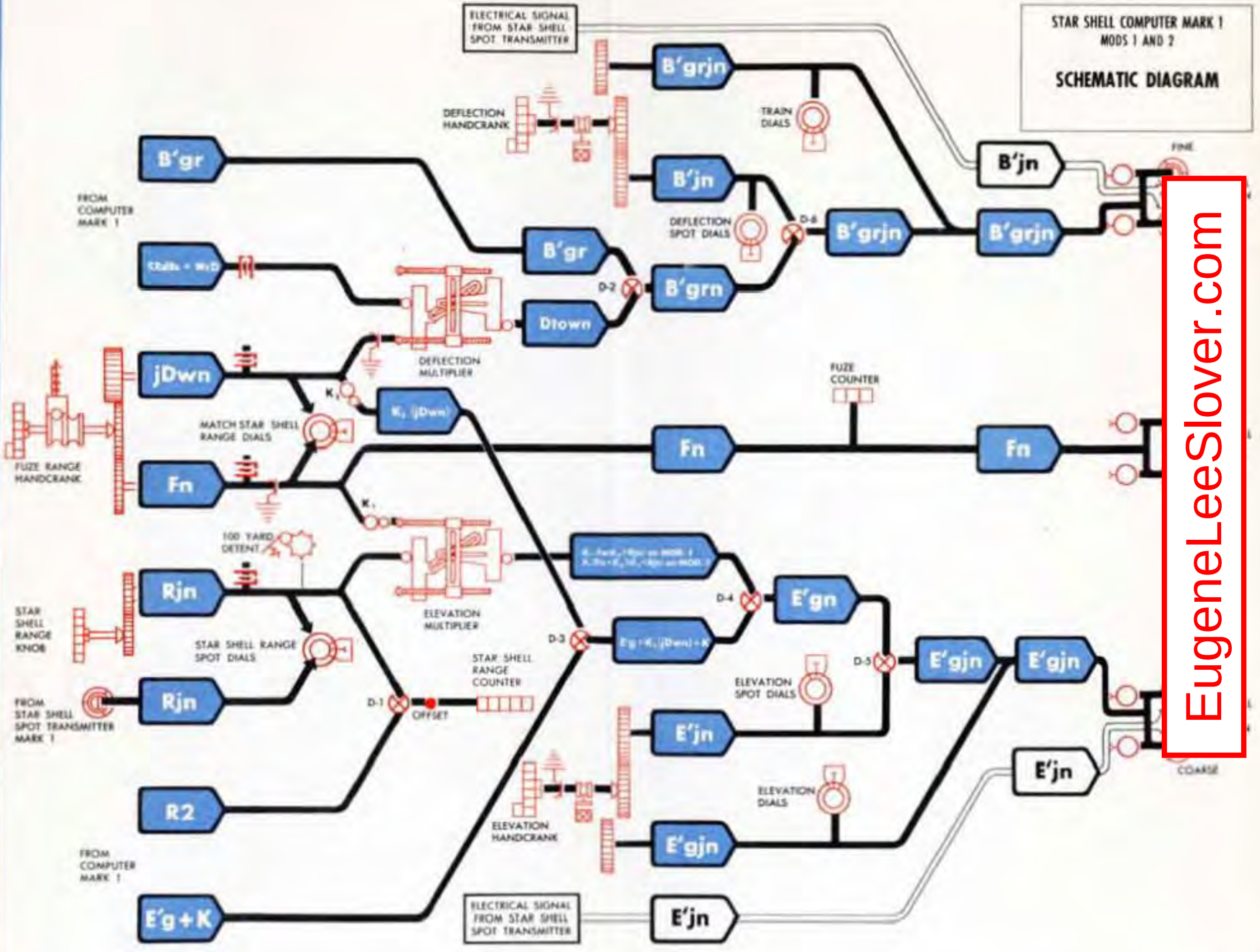
Controlling the fire of smoke projectiles

The design of the Mod 1 and the changes made in the Mod O by ORDALT 2117 permit the Star Shell Computer to be used for controlling the fire of smoke projectiles.

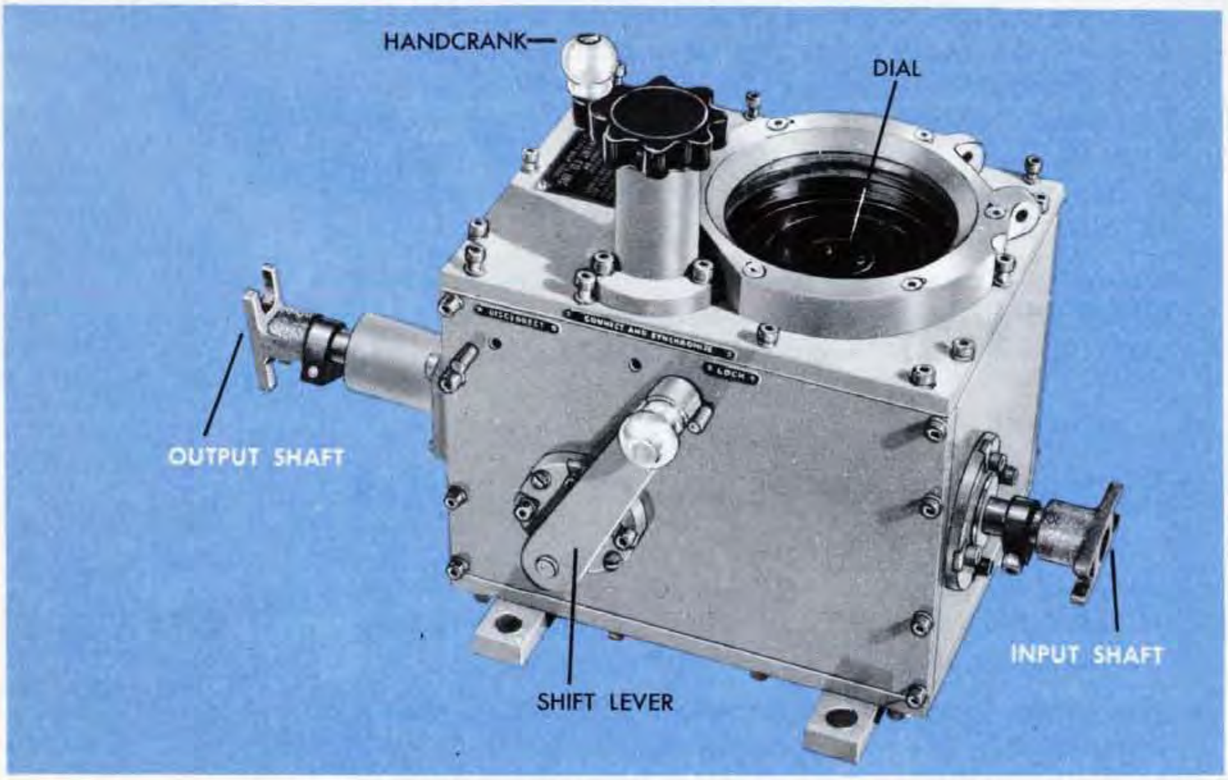
The Range Spot limit has been increased to IN 2857 in Mod 1 and is indicated by the red dot on the dial. To set up for control of smoke projectiles, Range Spot is set at IN 2857. This setting positions the Elevation Multiplier at zero, eliminating the effect of *Fn* on *E'gjn*. This places the burst about 2000 yards in front of the Target. Elevation Spots tabulated against *R2n* are used to introduce continuous corrections to place the burst from 25 to 50 feet above the water, instead of 1500 feet above the Target as computed by the Star Shell Computer. The Deflection Correction is the same as that for star shells, putting the smoke in line between Own Ship and Target 30 seconds after the burst.

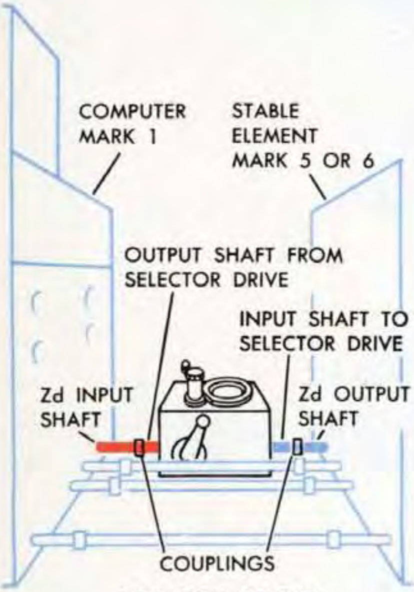
The STAR SHELL COMPUTER MARK 1 MOD 2

The Star Shell Computer Mark 1 Mod 2 is almost identical with the Mod 1, but is designed for the 5"/54 cal. guns and requires slightly different ballistic values. The *Fn* and *jDwn* Range Dials are calibrated slightly differently. There is also a difference in the output of the Elevation Multiplier in the Mod 2: An offset constant K_2 is added to *Fn* to make the multiplier output $K_1 (Fn + K_2)(K_3 + Rjn)$. In the Mod 2, the Elevation Multiplier is at the zero position with the Range Spot set at IN 2700 yards.



The SELECTOR DRIVE MARK 1





LOCATION OF THE SELECTOR DRIVE

The Selector Drive is a mechanism used to disconnect, and to connect and synchronize, the Cross-level shaft line between the Stable Element Mark 5 or 6 and the Computer Mark 1. It also provides a means of putting a selected value of Cross-level, *Zd,* into the Computer. Usually this selected value is 2000 minutes.

The Selector Drive is located between the Computer Mark 1 and the Stable Element Mark 5 or 6, replacing the Cross-level shaft which normally connects these two instruments. Two shafts, an input shaft and an output shaft, project from opposite sides of the Selector Drive. The Selector Drive *input* shaft is coupled to the *Zd output* shaft from the Stable Element. The Selector Drive *output* shaft is coupled to the *Zd input* shaft to the Computer. The *Zd* line to the Computer may be disconnected inside the Selector Drive, and a selected value of *Zd* may be put into the Computer through the Selector Drive output shaft by turning the Selector Drive Handcrank.

The Selector Drive mechanism is contained in a metal box. On the front is a shift lever with three positions: DISCONNECT, CONNECT AND SYNCHRONIZE, and LOCK. On top of the box are a dial assembly and the handcrank. The handcrank and dials are used for synchronizing the *input* and *output* shafts.

Why a selector drive is needed

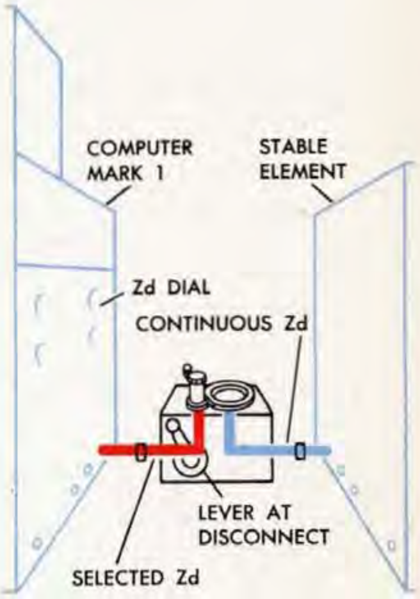
When the Director is searching for a target, the Stable Element must be operating in order to stabilize the Director sights and Range Finder. The Computer must be energized in order to supply *B'r* to the Stable Element. Since no other Computer outputs are required in this type of operation, needless wear on the Computer parts can be eliminated by setting the inputs of both *L* and *Zd* from the Stable Element at fixed values.

The type of Stable Element used on most ships permits the setting of *either* the Level *or* the Cross-level input to the Computer at a fixed value, but not both simultaneously. Installation of a Selector Drive Mark 1 on these ships makes it possible to set *both* the Level and the Cross-level inputs at fixed values at the same time. Level can be set at the Stable Element and Cross-level at the Selector Drive.

(Since the type of Stable Element used on destroyers of the DD409-420 class permits the setting of both the Level and Cross-level inputs to the Computer at fixed values, no Selector Drives are furnished for the Computers on these ships.)

Selected cross-level

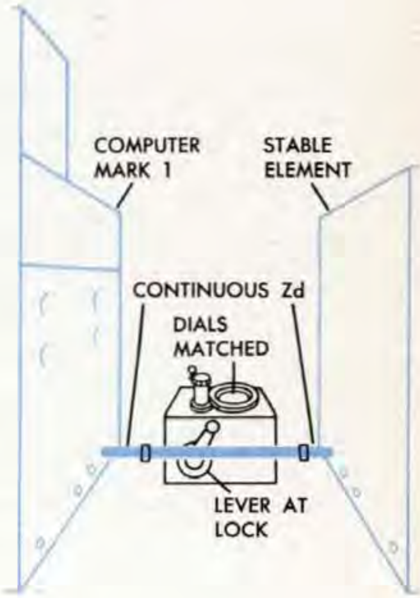
To set a selected value of Cross-level into the Computer when Level is being selected at the Stable Element, the Selector Drive shift lever is put in the DISCONNECT position. In DISCONNECT, *Zd* from the Stable Element does not drive the Computer but merely rotates the dials of the Selector Drive. A selected value of *Zd* is put into the Computer by turning the Selector Drive Handcrank until the required value is read on the *Zd* Dial on the rear of the Computer. This required value is usually zero, which is read as 2 000 minutes on the Computer *Zd* Dial.



Continuous cross-level

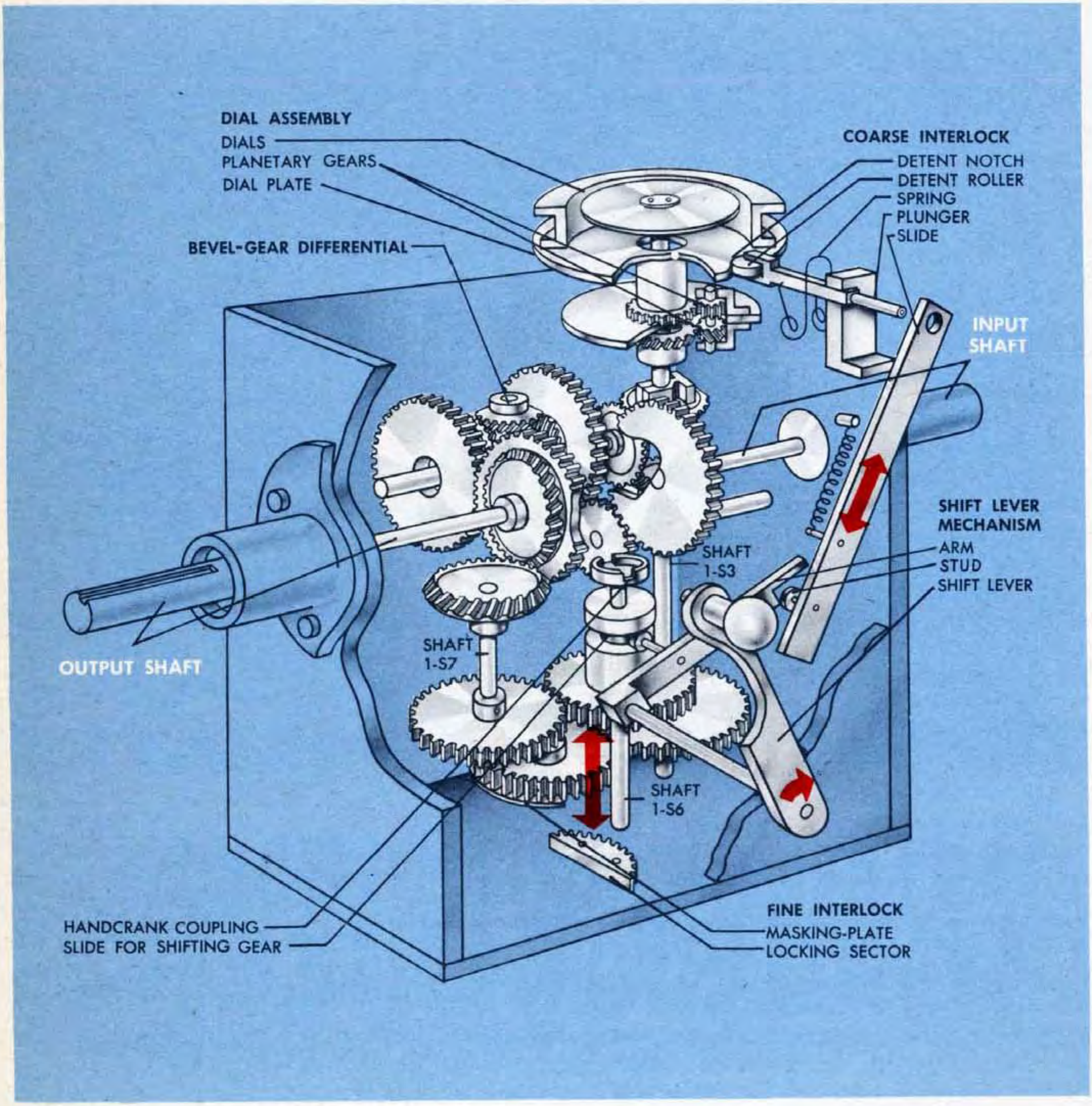
For Continuous Aim, continuous values of *Zd* are needed in the Computer. These continuous values are transmitted through the Selector Drive, which functions in Continuous Aim as a shaft between the Stable Element and the Computer.

To set the Selector Drive for transmitting continuous values of *Zd*, the shift lever is moved to the CONNECT AND SYNCHRONIZE position. The handcrank is turned until the indexes on both of the Selector Drive Dials are matched at the fixed index. This synchronizes the input and output shafts. The shift lever is then moved to the LOCK position. In the LOCK position the input and output shafts are *held in synchronism* and function as a direct drive between the Stable Element and the Computer.

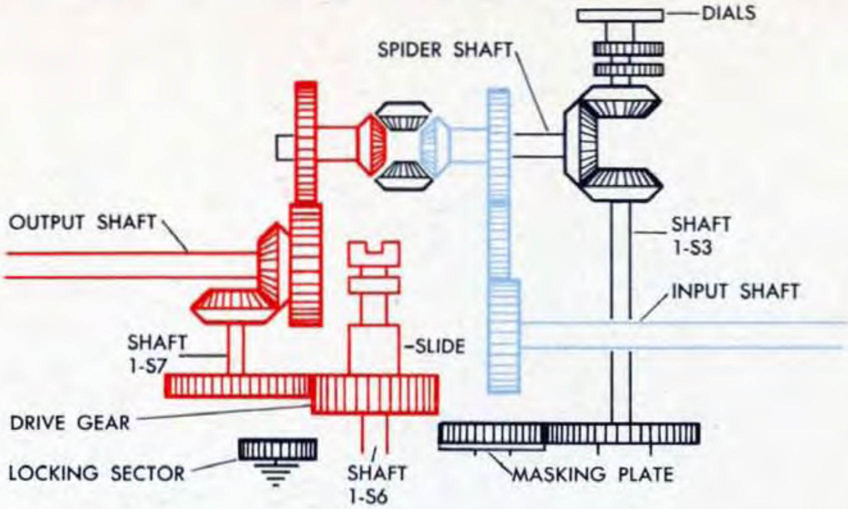


The SELECTOR DRIVE MECHANISM

The Selector Drive Mechanism consists of the input and output shafts, a bevel-gear differential, the handcrank assembly, the shift lever mechanism, the dial assembly, and a coarse and fine interlock.



The shaft lines



The input shaft from the Stable Element positions one side of the differential.

The output shaft is geared directly to the other side of the differential and to shaft 1-S7.

The spider of the differential is connected to the dials and to shaft 1-S3.

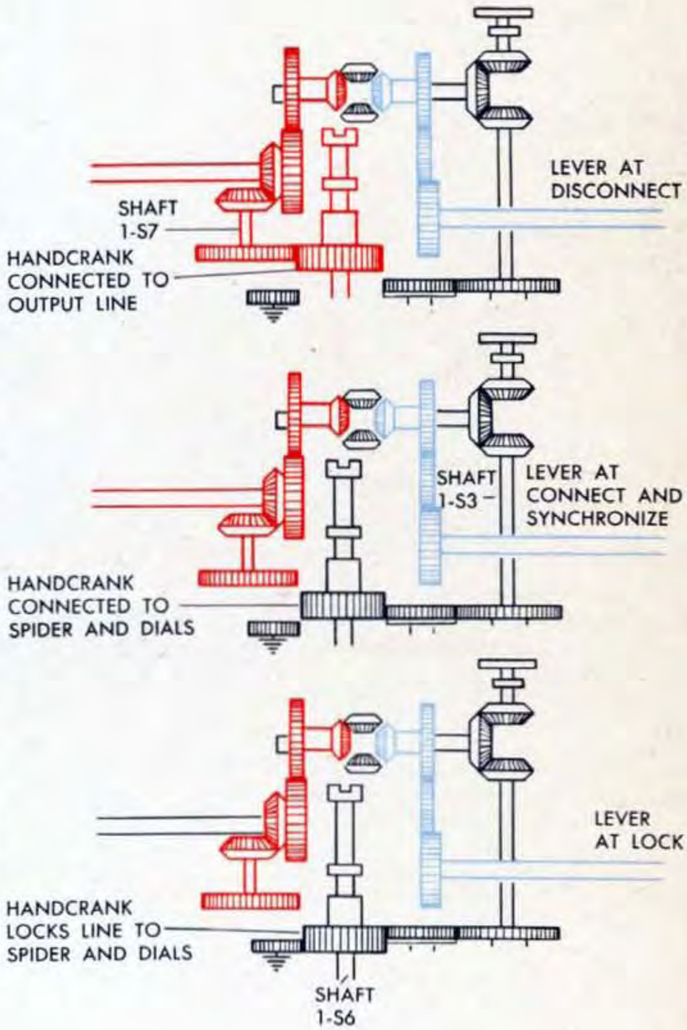
On shaft 1-S6 there is a slide carrying the drive gear. The slide permits the gear to be moved up and down along shaft 1-S6 by the shift lever.

The drive gear on shaft 1-S6 can be moved to any one of three positions by positioning the shift lever.

When the shift lever is in DISCONNECT position, the drive gear is in its highest position, meshing with the lower gear on shaft 1-S7. This connects the handcrank to the output shaft.

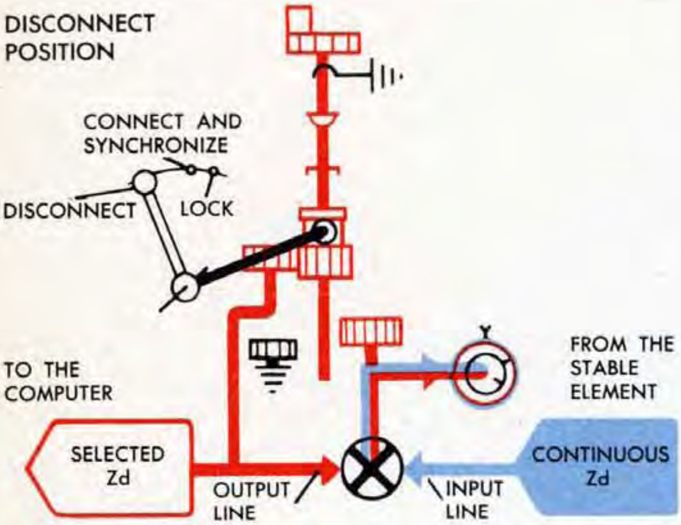
When the shift lever is in CONNECT AND SYNCHRONIZE position, the drive gear meshes with the masking-plate gear, which meshes with a gear on shaft 1-S3. Through these gears the handcrank is connected to the differential spider and the dials.

When the shift lever is in LOCK position, the drive gear is in its lowest position. It is still connected to the shaft line to the spider and dials, but now it also meshes with the fixed locking sector on the base plate of the Selector Drive. Since this locking sector is fixed, the drive gear in LOCK position locks shaft 1-S3, the differential spider, and the dials.



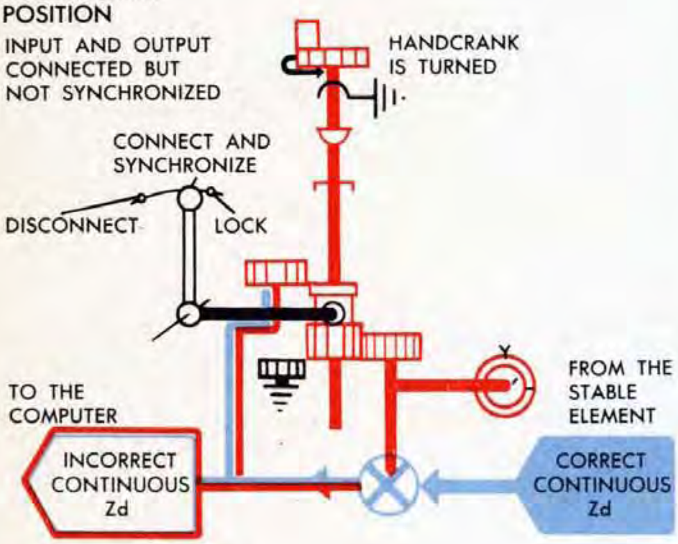
How the SELECTOR DRIVE works

DISCONNECT POSITION



CONNECT AND SYNCHRONIZE POSITION

INPUT AND OUTPUT CONNECTED BUT NOT SYNCHRONIZED



The Selector Drive receives continuous input values of *Zd* from the Stable Element.

In the DISCONNECT position of the shift lever, the handcrank is connected to the output shaft line. The *Zd* values from the Stable Element position the input line and, following the line of least resistance, back out through the spider of the differential, turning the Selector Drive Dials. A selected value of *Zd* is set into the Computer by turning the handcrank to position the output shaft. The selected value also backs out through the spider and dials. The selected value of *Zd* is read on the *Zd* Dial at the rear of the Computer.

In the CONNECT AND SYNCHRONIZE position, the handcrank is connected to the spider of the differential and to the dials. The continuous *Zd* values from the Stable Element position the input line and the input side of the differential. The handcrank holding friction prevents these input values from backing out through the spider; therefore, they drive out through the output side of the differential and turn the output shaft. The input and output lines are now connected but the value of *Zd* in the Computer may not be the same as the value of *Zd* in the Stable Element.

To SYNCHRONIZE the input and output shaft lines

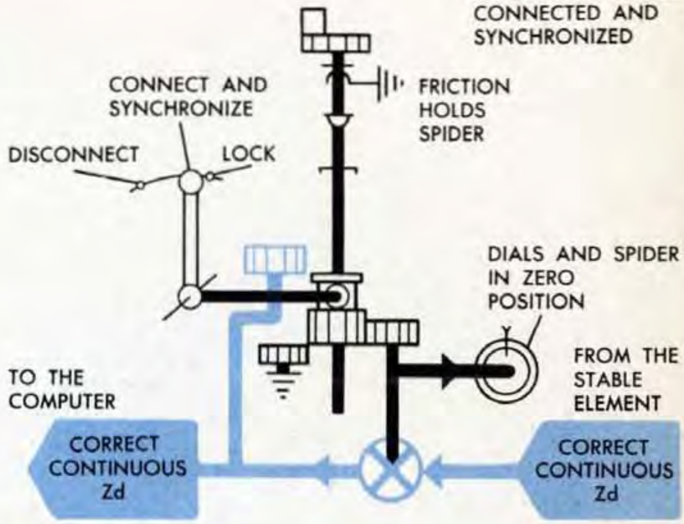
With the lever still at CONNECT AND SYNCHRONIZE position, the handcrank is turned, turning the differential spider until the spider is at its zero position. This handcrank input combines with the input from the Stable Element, and both drive out through the output side of the differential. As the handcrank is turned, the value of *Zd* on the output side of the differential approaches the value on the input shaft. When the differential spider reaches its zero position, the value on the output side of the differential equals the value driving through from the input side, and the input and output shafts are synchronized. The value of *Zd* in the Computer is equal to the value of *Zd* in the Stable Element.

Synchronism is complete when the spider has been turned to its zero position. The spider is in its zero position when the indexes on both dials are matched at the fixed index. The spider and dials are held stationary in this synchronized position by the holding friction on the handcrank. Continuous *correct* values of *Zd* now drive through the differential to the output shaft line. When the spider and dials are in their zero positions, the interlock mechanism is also in position to allow the shift lever to be moved to LOCK position.

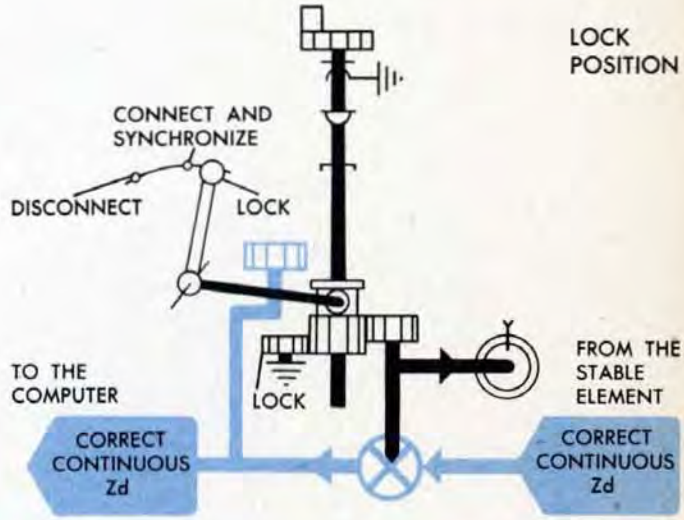
In LOCK position of the shift lever, the sector locks the shaft line to the spider and dials. The sides of the differential are held in synchronism, and correct continuous values of *Zd* from the Stable Element drive through the Selector Drive to the Computer. The mechanism now functions as a shaft carrying the varying *Zd* value from the Stable Element to the Computer. Turning the handcrank in the LOCK position will merely cause the friction drive to slip and will not throw the Computer and Stable Element out of synchronism.

CONNECT AND SYNCHRONIZE POSITION

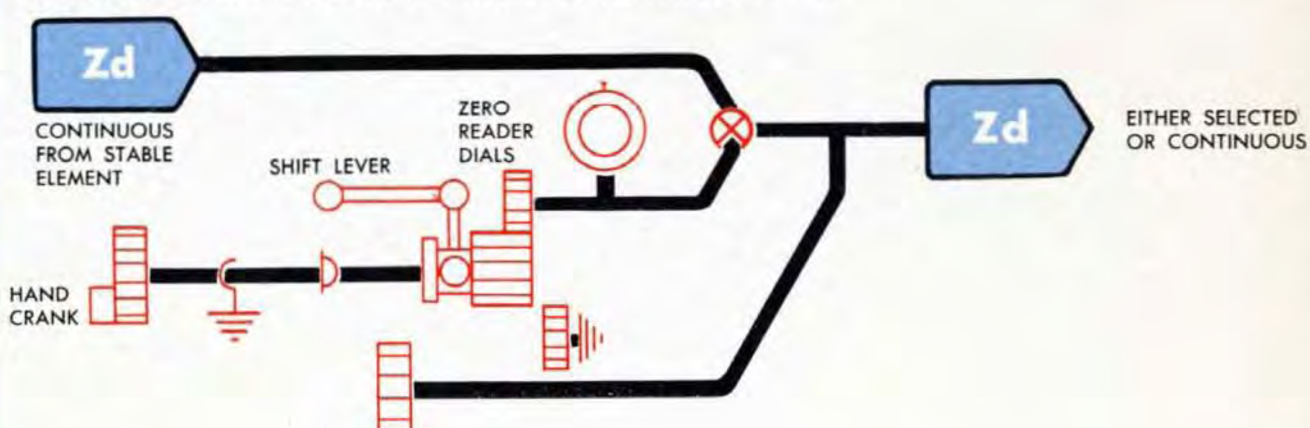
INPUT AND OUTPUT CONNECTED AND SYNCHRONIZED



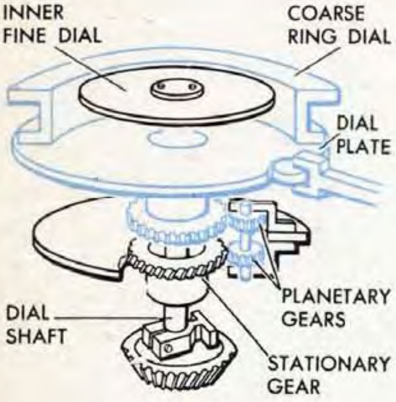
LOCK POSITION



THE SELECTOR DRIVE IS SHOWN THIS WAY IN THE MAJOR SCHEMATICS



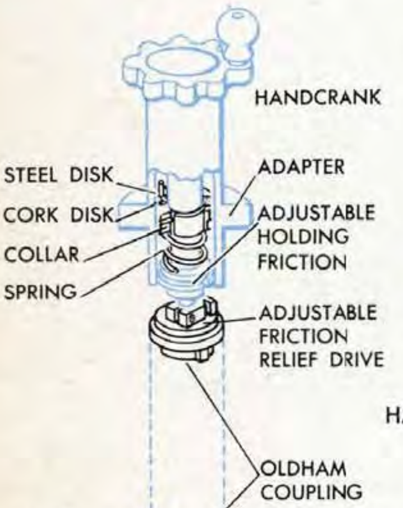
The dial assembly



PLANETARY DIALS

The inner fine dial and the disk carrying the planetary gears turn with the dial shaft. The planetary gears drive the coarse ring dial which is mounted on the dial plate. The planetary gearing is designed so that the ring dial makes one revolution for 18 revolutions of the inner dial.

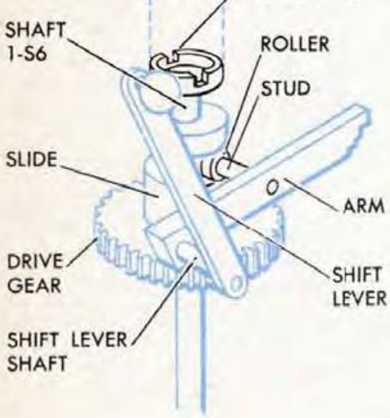
The handcrank assembly



HANDCRANK

The handcrank is a one-position handle. It has an adjustable holding friction inside the adapter and an adjustable friction relief drive. The handcrank is connected to shaft 1-S6 by an Oldham coupling. This coupling permits the top cover and handcrank to be removed without disturbing the shaft lines inside the Selector Drive.

The shift lever mechanism



SHIFT LEVER

The function of the shift lever mechanism is to move the drive gear from one position to another.

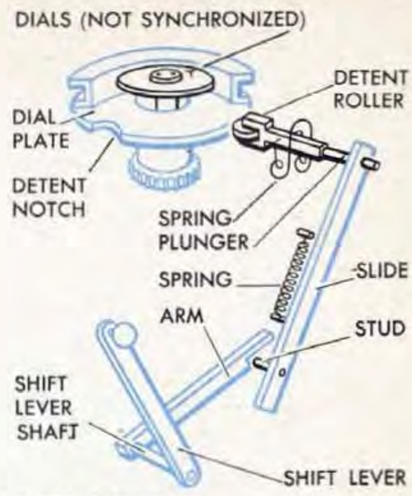
The grooved slide carrying the drive gear is keyed to shaft 1-S6. The slide and gear rotate with the shaft and may also move up and down on the shaft. An arm is pinned to the shift lever shaft. This arm has a stud on which is mounted a roller. This roller fits into a groove on the slide. As the shift lever is moved the arm and roller are rotated through an arc, raising or lowering the drive gear on the shaft. Moving the shift lever to any one of its three positions therefore also moves the drive gear to a corresponding position.

The coarse interlock

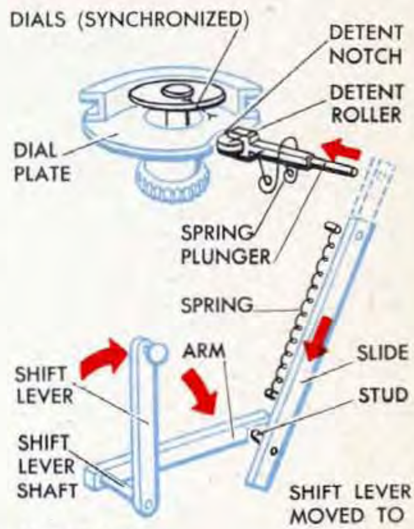
A coarse and fine interlock prevent the shift lever from being moved to the LOCK position when the input and output shafts are not synchronized. The coarse interlock is a linkage between the shift lever and the dials. It consists of an arm, a slide, and a plunger holding a detent roller. The arm is connected to the shift lever, at right angles to the lever.

When the shift lever is moved toward LOCK position, the end of the arm pushes against a stud on the end of the slide. The shift lever can move to the LOCK position only when the slide is free to move to its lower position. As long as the detent roller is out of the notch in the dial plate, the slide is held in its upper position by the plunger, which passes through a hole in the top of the slide. When the dials are not synchronized, therefore, the slide is held in its upper position, and the stud on the slide prevents the shift lever from moving to the LOCK position.

When the dials *are* synchronized at the fixed index, the notch in the dial plate lies opposite the detent roller. A spring pushes the detent roller into the notch. When the detent roller enters the notch the plunger is drawn out of the hole in the slide. The slide is free to move. As the shift lever is moved to LOCK position, the arm on the shift lever pushes against the stud and moves the slide to its lower position.



COARSE INTERLOCK IN CONNECT POSITION

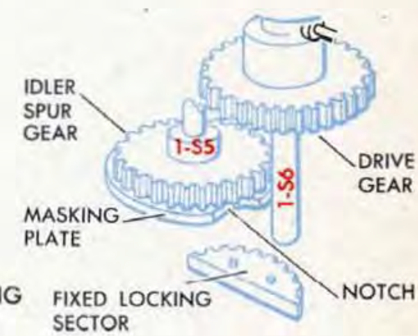


COARSE INTERLOCK IN LOCK POSITION

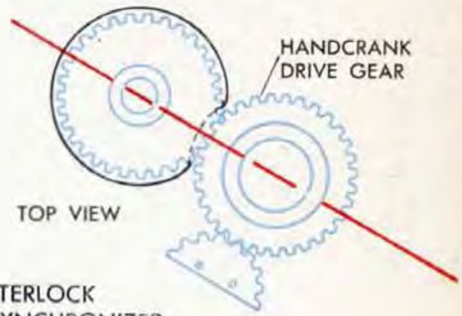
The fine interlock

The fine interlock consists of a masking plate on the bottom of the idler spur gear on shaft 1-S5. When the shift lever is in CONNECT AND SYNCHRONIZE position, the drive gear turns the shaft line to the spider and dials through this masked idler spur gear. The masking plate does not interfere with this operation.

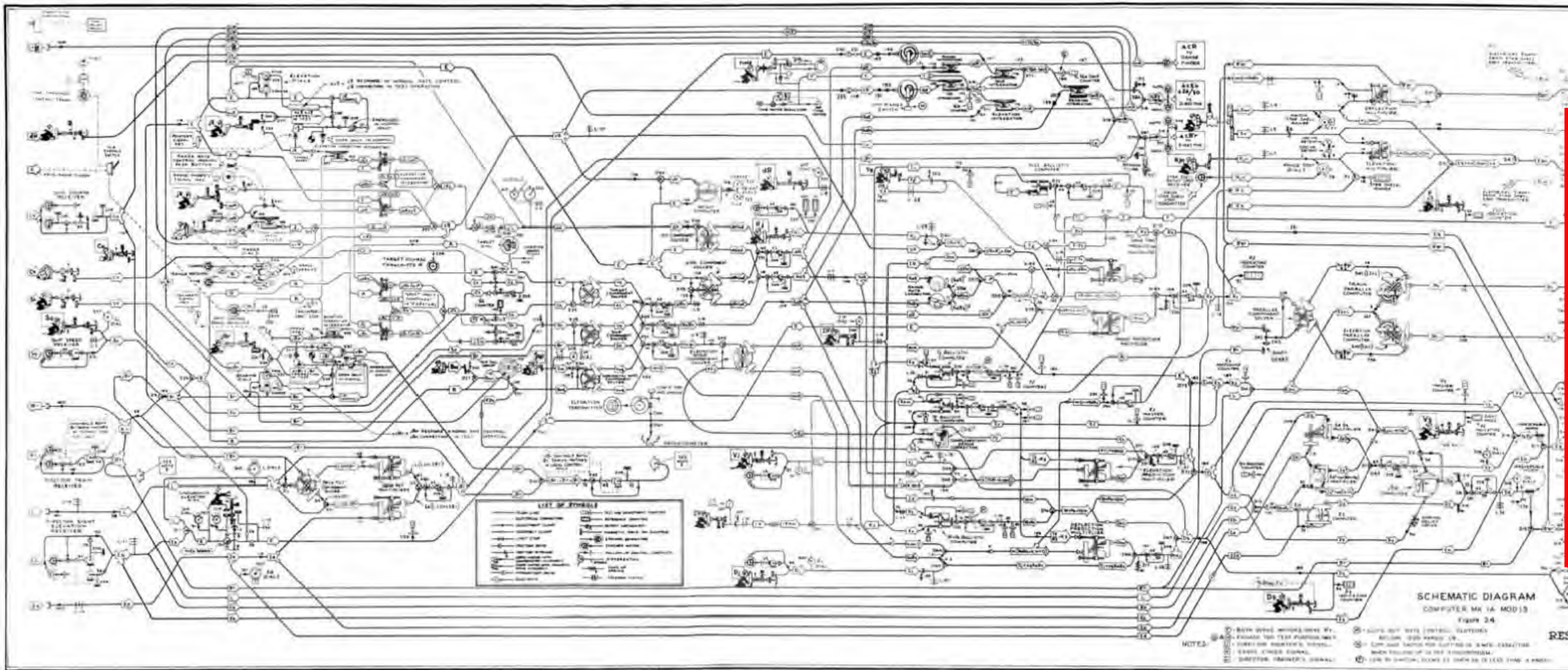
In LOCK position the drive gear must be lowered by the shift lever until it engages the fixed locking sector. The drive gear cannot be moved into mesh with the fixed locking sector until the notch in the masking plate lines up with the edge of the drive gear. When the dials are exactly matched at the index, the notch and drive gear are aligned. Thus, when the dials are synchronized, the notch allows the drive gear to drop into mesh with the locking sector.



LOCKING DETAIL



FINE INTERLOCK DIALS SYNCHRONIZED



SCHEMATIC DIAGRAM
COMPUTER MK 1A MOD 13
Figure 24

RESTRICTED