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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.

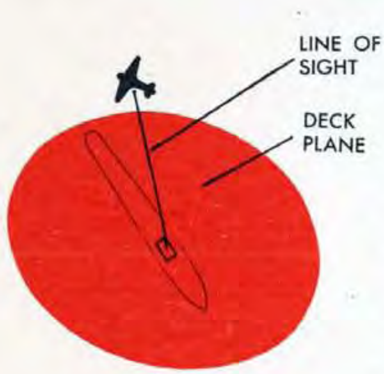
Br cannot be measured directly by the Gun Director Mark 37.

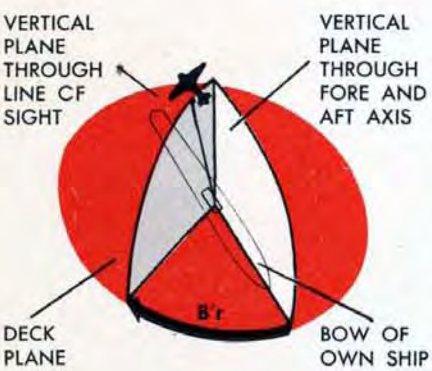
Since the Director is mounted on a roller path in the deck plane, the whole Director trains in the *deck* plane, and tilts with the deck as Own Ship rolls and pitches. When the sights are on the Target, the Director measures the Target's bearing relative to the fore and aft axis of Own Ship *in the deck 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.

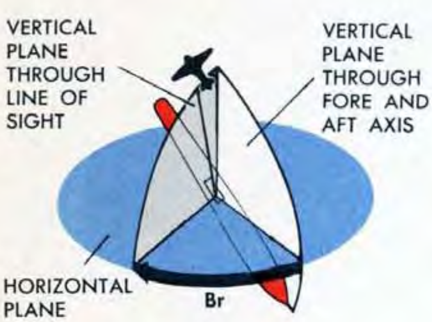
In order to convert $B'r$ to Br, the Computer Mark 1 must continuously compute the amount by which $B'r$ differs from Br. This computed difference between $B'r$ and Br is called Deck Tilt Correction, $jB'r$.

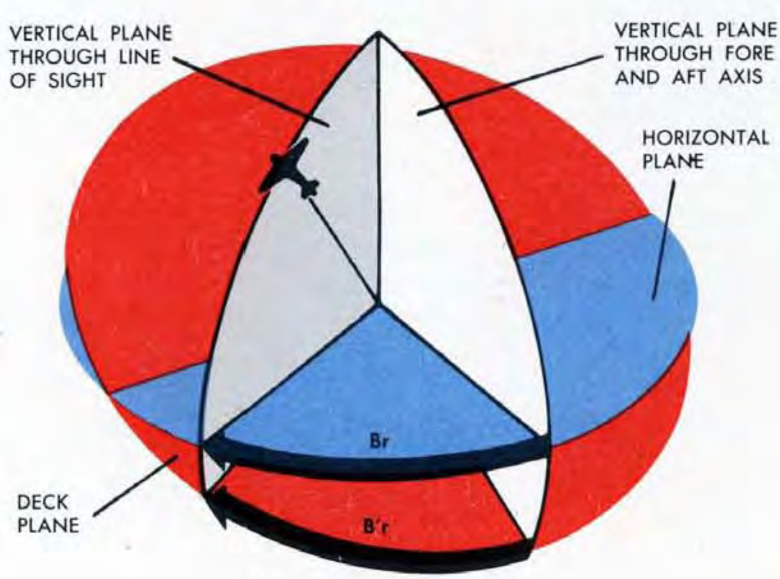
Br is obtained by continuously adding the computed Deck Tilt Correction, $jB'r$, to the measured value of Director Train, $B'r$.

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



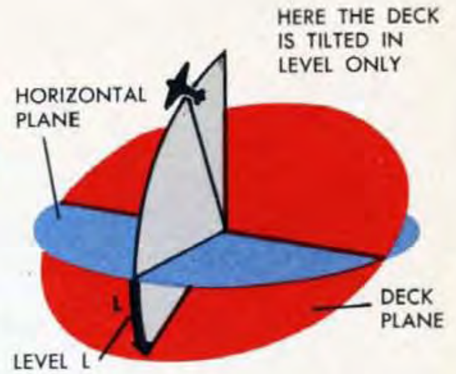






NOTE:
Strictly speaking, the term "deck plane" does not mean a plane through the deck, but a plane through the Director sights parallel to the Director roller path.

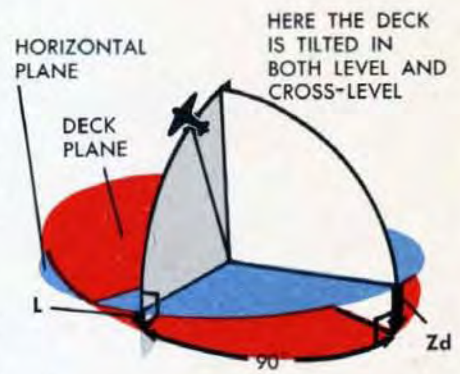
THE INPUTS
to the deck tilt group



The quantities used in computing Deck Tilt Correction, *jB′r,* are Director Train, *B′r,* Level, *L,* and Cross-level, *Zd.*

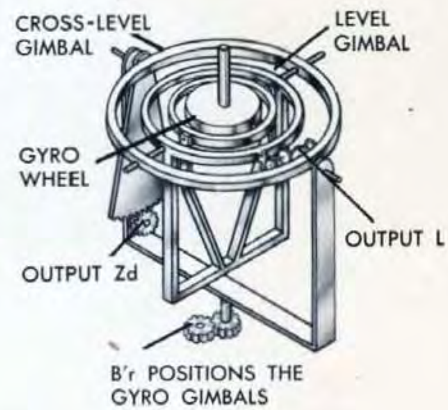
Level, *L,* and Cross-level, *Zd,* are measures of deck inclination.

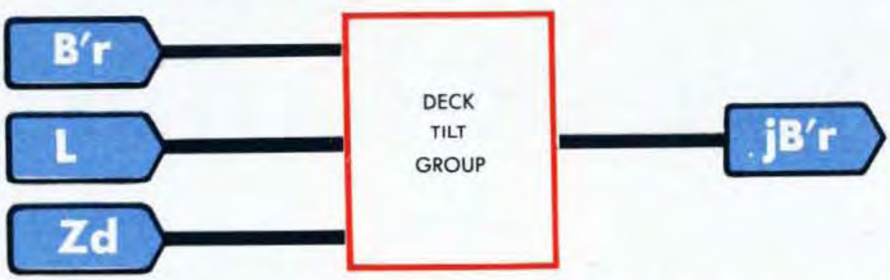
Level, *L,* is the angle between the horizontal plane and the tilted deck plane measured in the vertical plane through the Line of Sight. The correction for *L* is positive when the deck toward the Target tilts down.



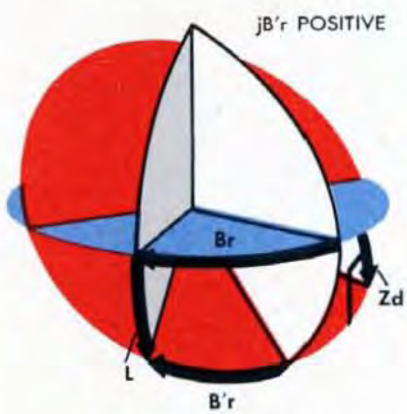
Cross-level, *Zd,* is the angle between the horizontal and the tilted deck measured in a plane at right angles to the deck plane, and at right angles to the vertical plane through the Line of Sight. The correction for *Zd* is positive if, when facing the Target, the deck to the left tilts down.

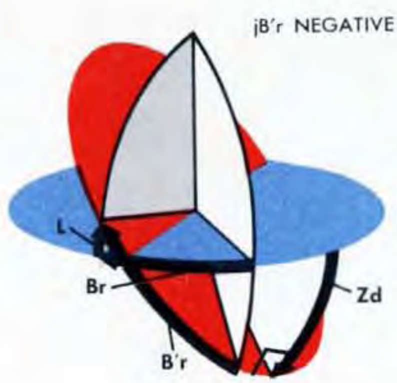
L and *Zd* are continuously measured by the Stable Element. The Stable Element contains a gyro which, within its limits of operation, always remains in the horizontal plane regardless of the inclination of the deck. The Computer transmits the value of Director Train, *B′r,* by a shaft line to the Stable 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.



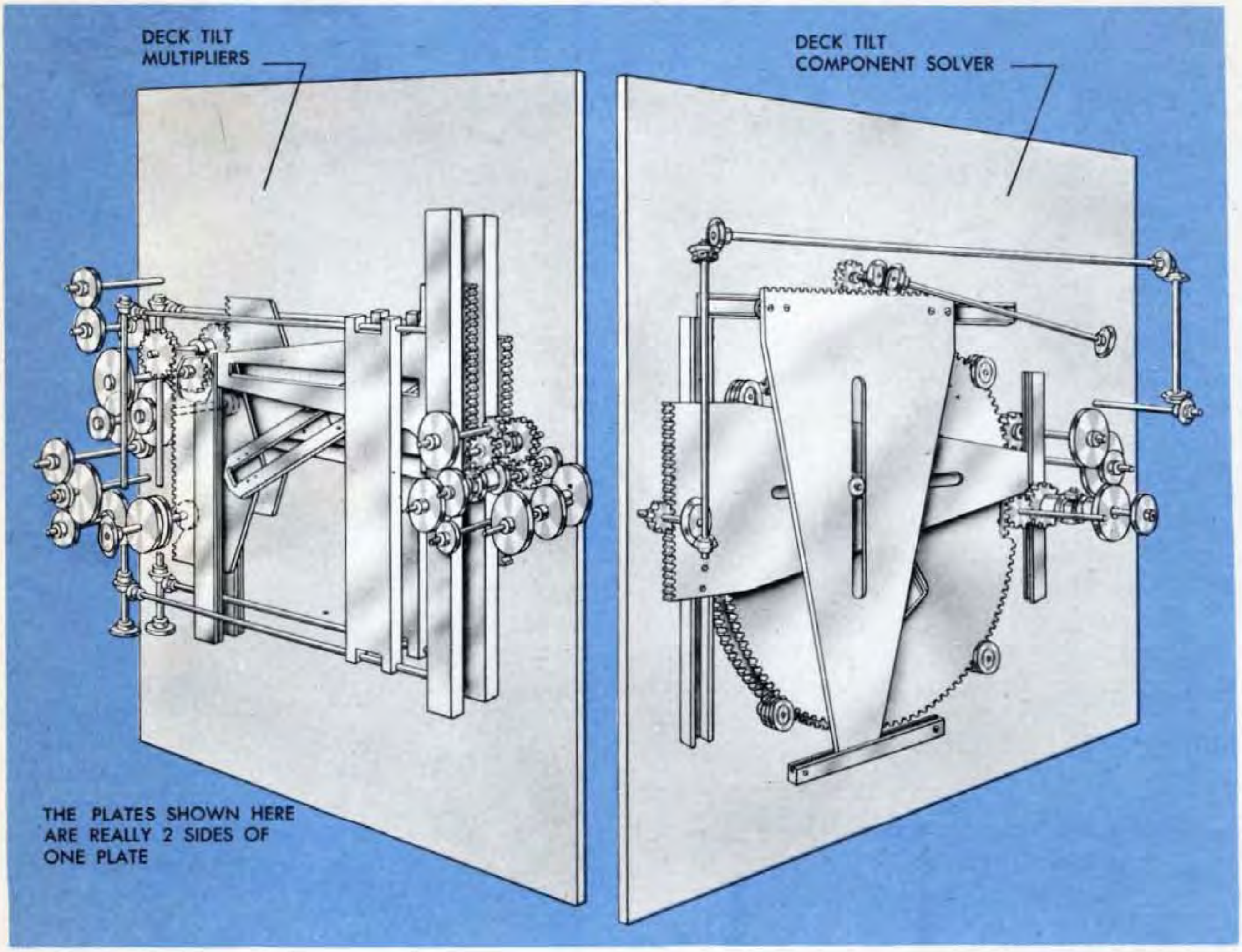


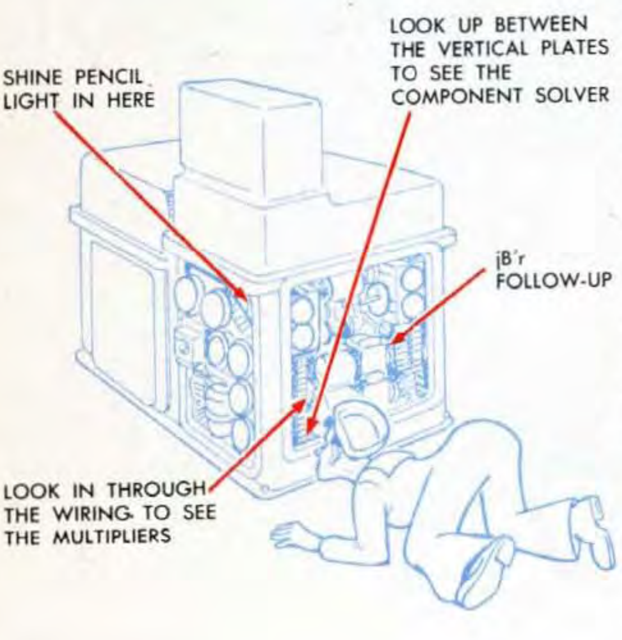
Deck Tilt Correction, *jB′r,* may be either positive or negative. When *Br* is larger than *B′r, jB′r* is positive. When *Br* is smaller than *B′r, jB′r* is negative.





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:

$$jB'r = K[Zd(L - L\cos 2B'r) + K_1 L \cdot L \sin 2B'r]$$

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

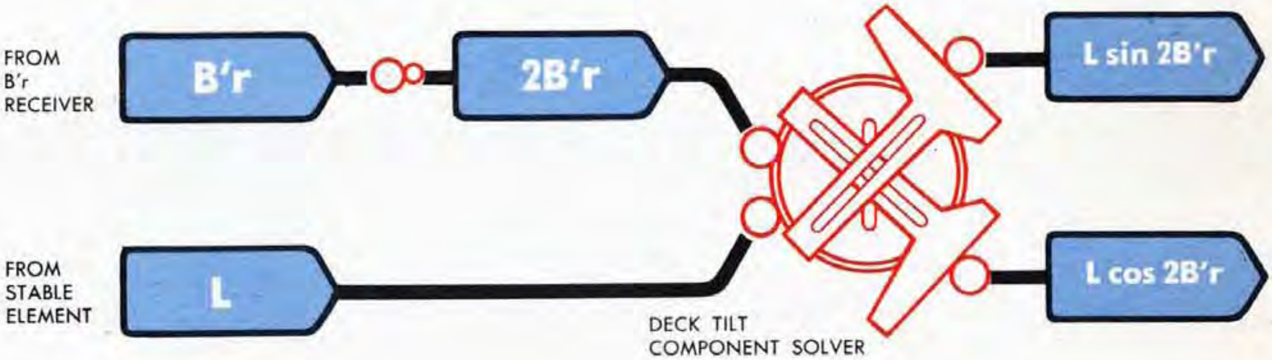
The first step in the solution of the *jB′r* equation is to compute the quantities *L* sin *2B′r* and *L* cos *2B′r*. These two quantities are computed in the Deck Tilt Component Solver.

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.



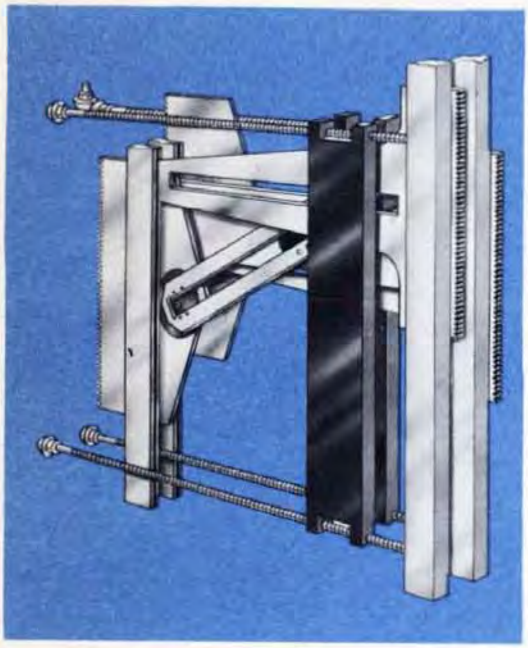
Director Train, *B′r*, from the *B′r* Receiver is multiplied by 2 in a gear ratio producing *2B′r*. The value of *2B′r* positions the vector gear. Level, *L*, from the Stable Element is the cam input.

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.

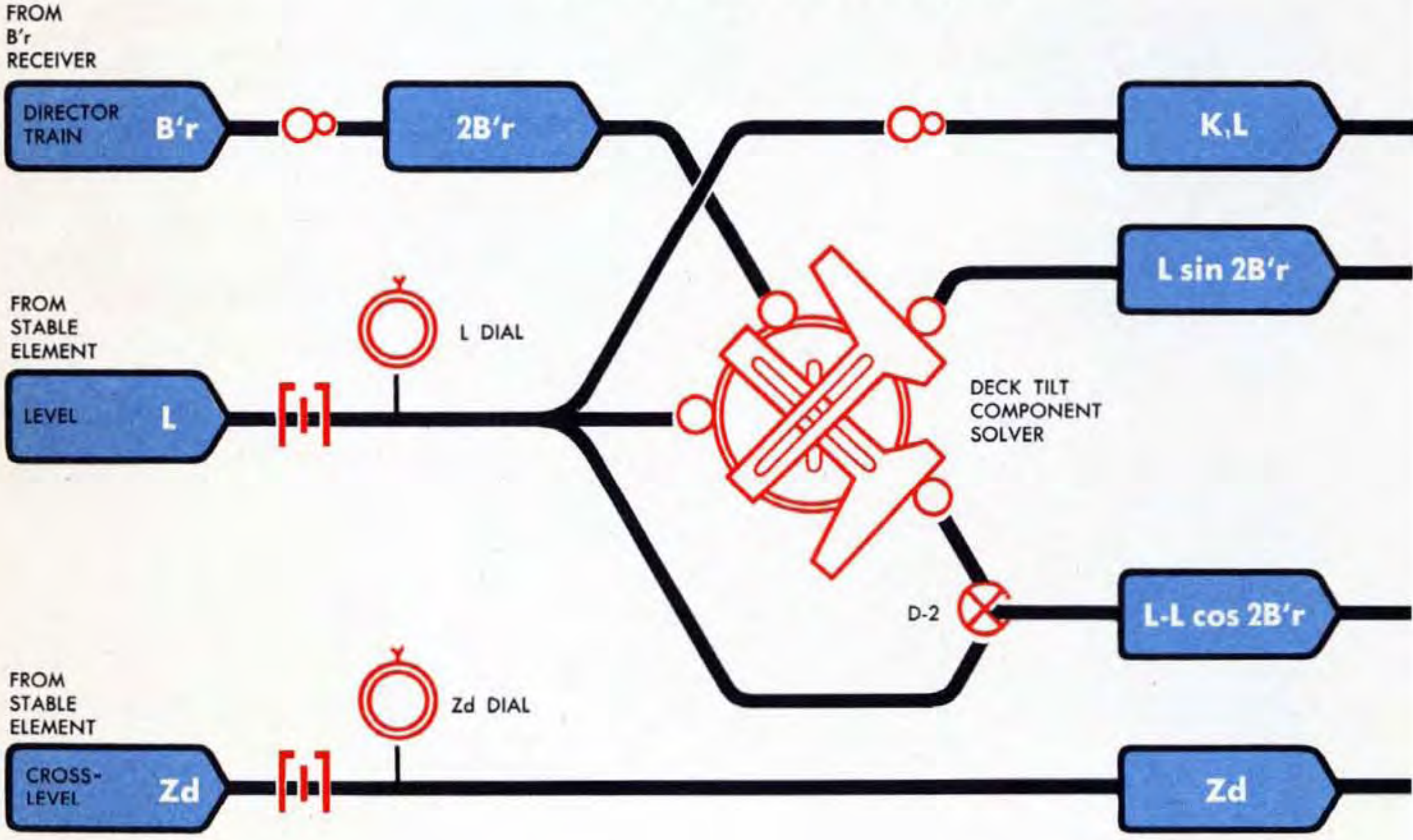
The $L \cos 2B'r$ output of the Deck Tilt Component Solver is subtracted from L at differential D-2. The result, $(L - L \cos 2B'r)$, positions the input rack of one of the multipliers. Zd positions the lead screw. The multiplier output is the first term of the Deck Tilt equation:

$$Zd\ (L - L \cos 2B'r).$$

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.



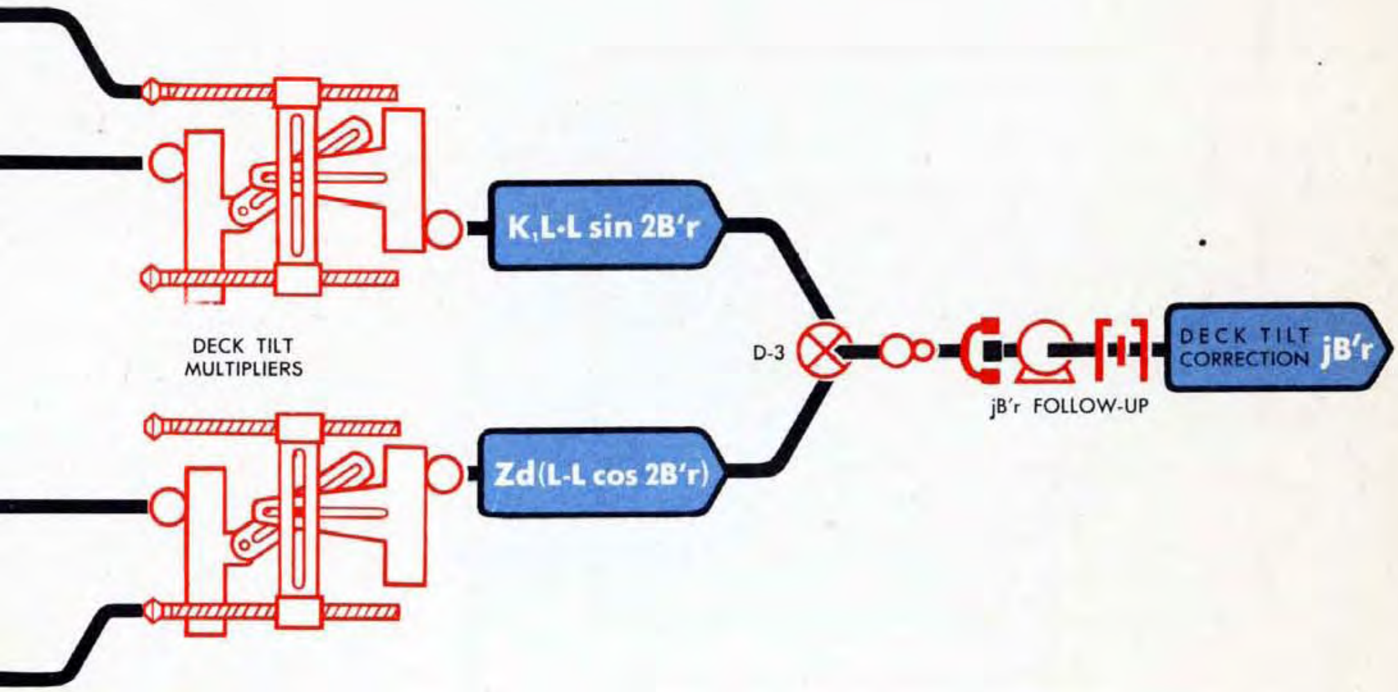
complete the equation

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.

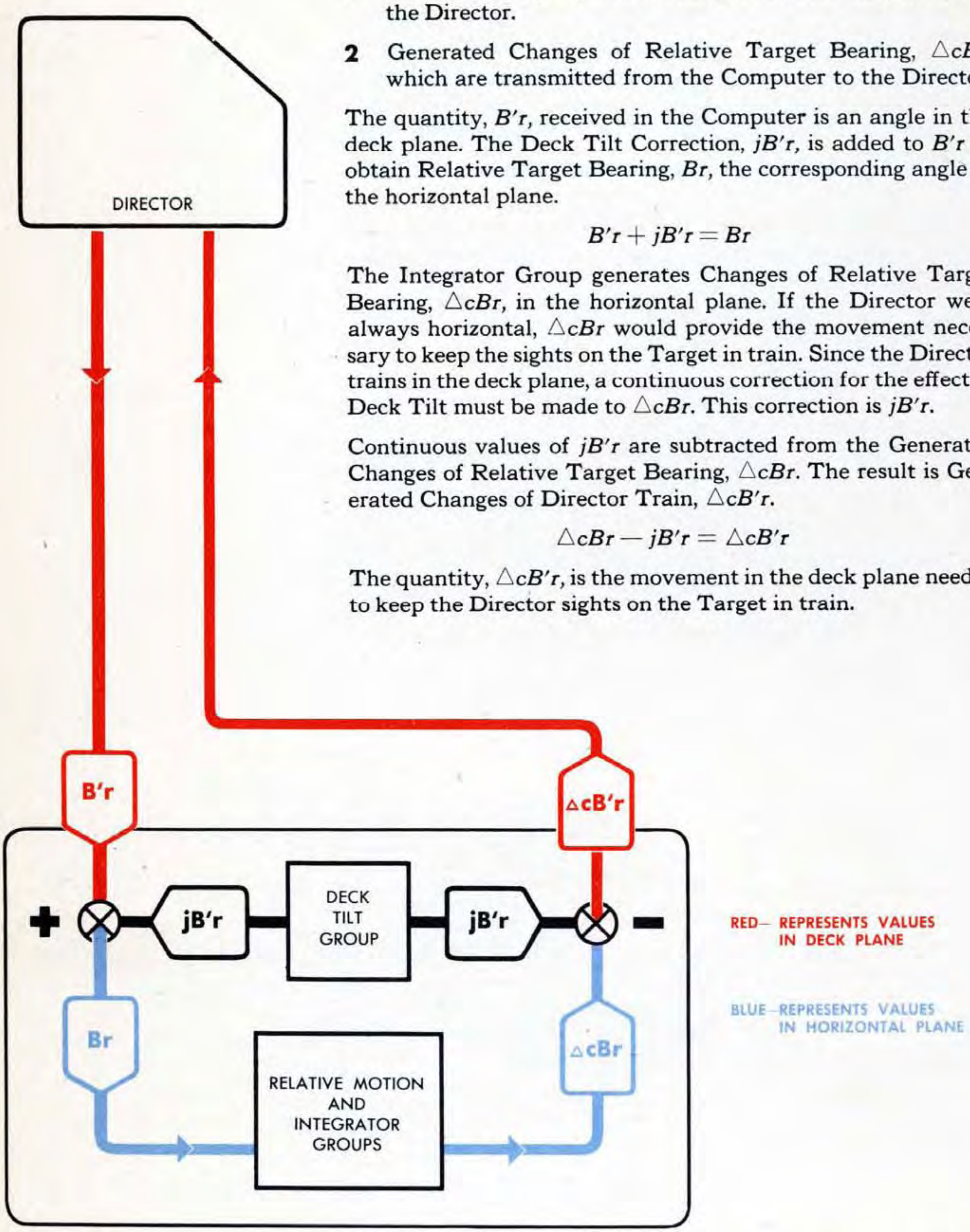
$$B'r + jB'r = Br$$

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.



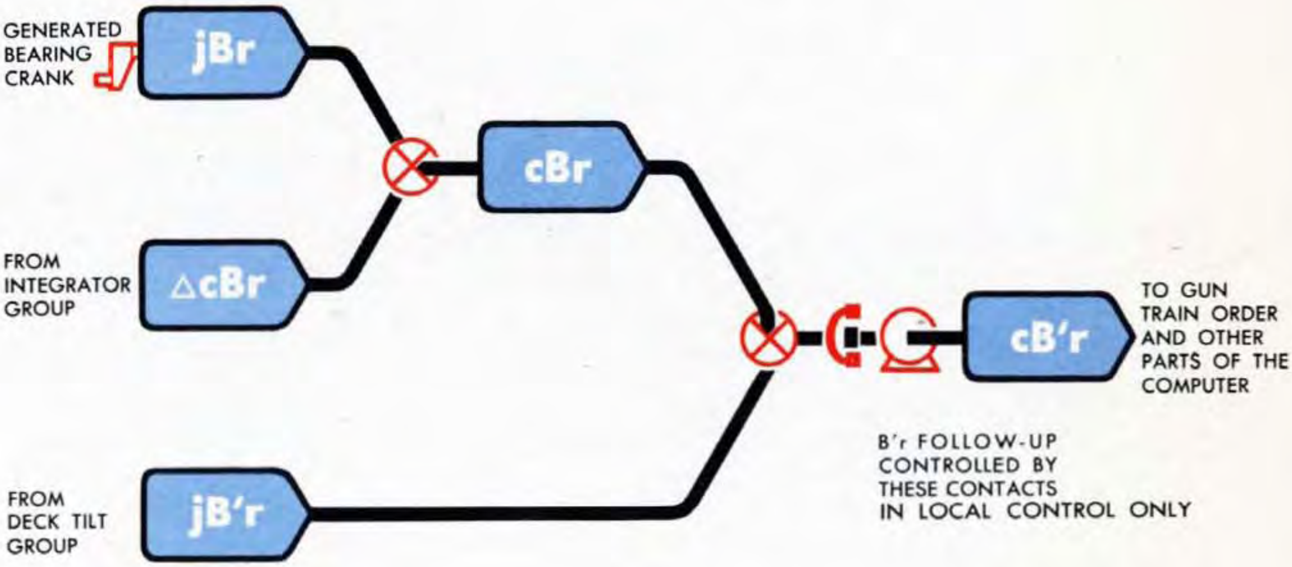
jB'r in Local Control

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*.

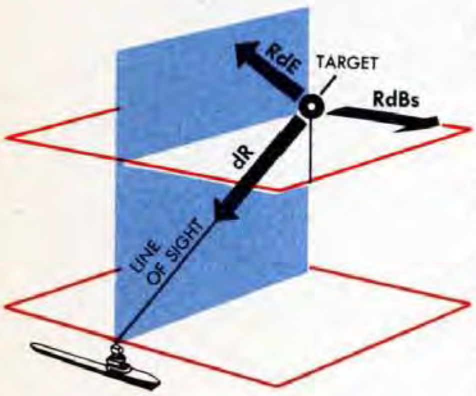
Generated Director Train, *cB'r*, consists of a manual setting of Relative Target Bearing, *jBr*, plus the Generated Changes of Bearing, △*cBr*, from the Integrator Group, plus the Deck Tilt Correction, *jB'r*.

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:

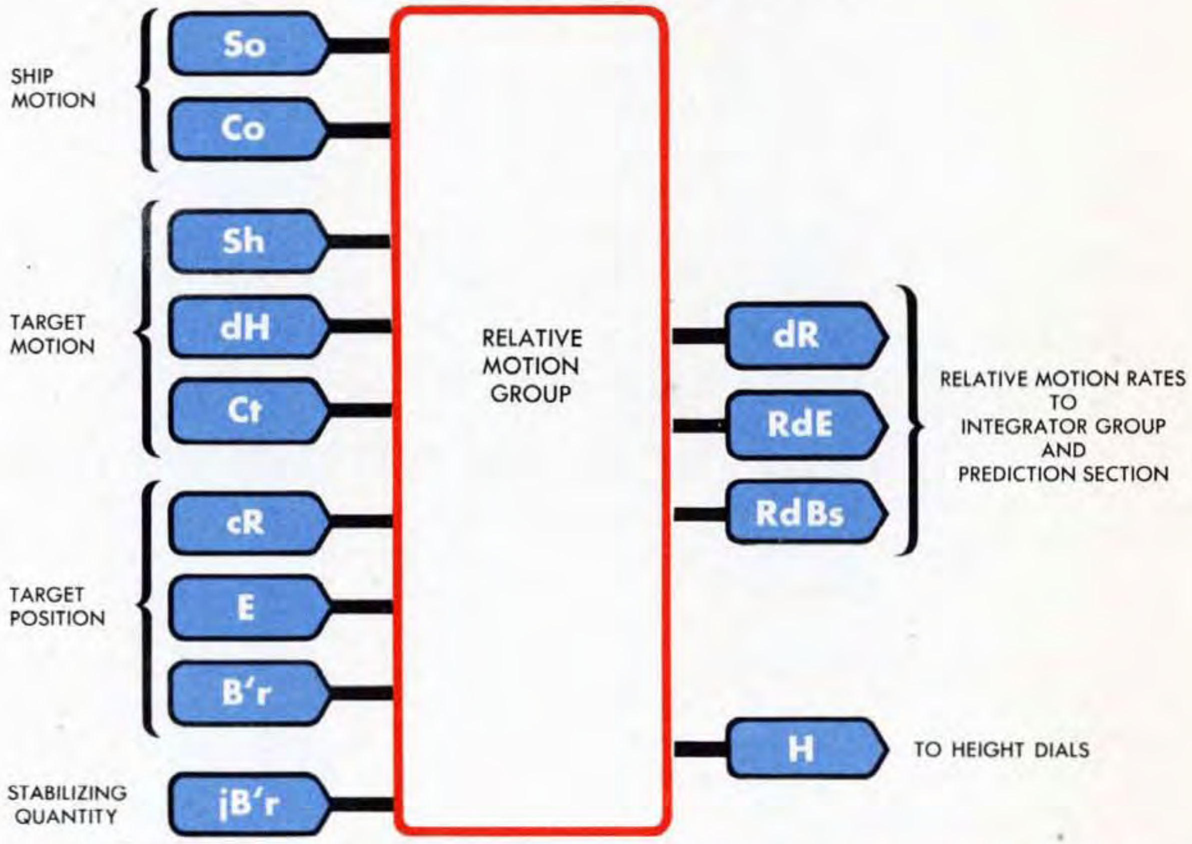
1 Ship Motion inputs
2 Target Motion inputs
3 Target Position inputs.

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.

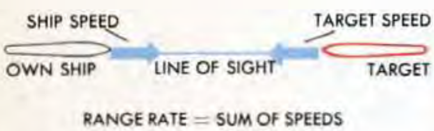
The fourth output, Target Height, *H,* goes only to the Height Dials.

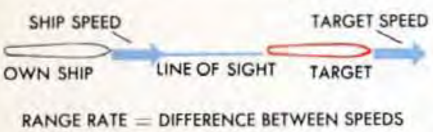
COMPONENTS

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.

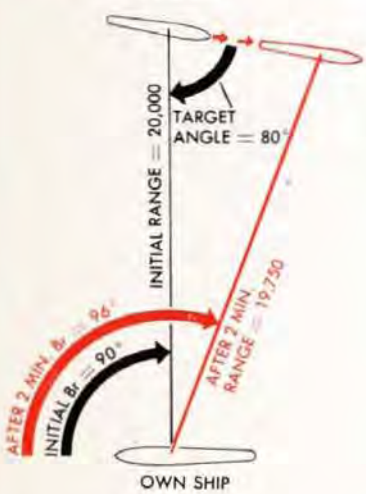
When they are moving in opposite directions, the sum of their speeds is the Range Rate. When they are moving in the same direction, the difference in their speeds is the Range Rate.

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°.

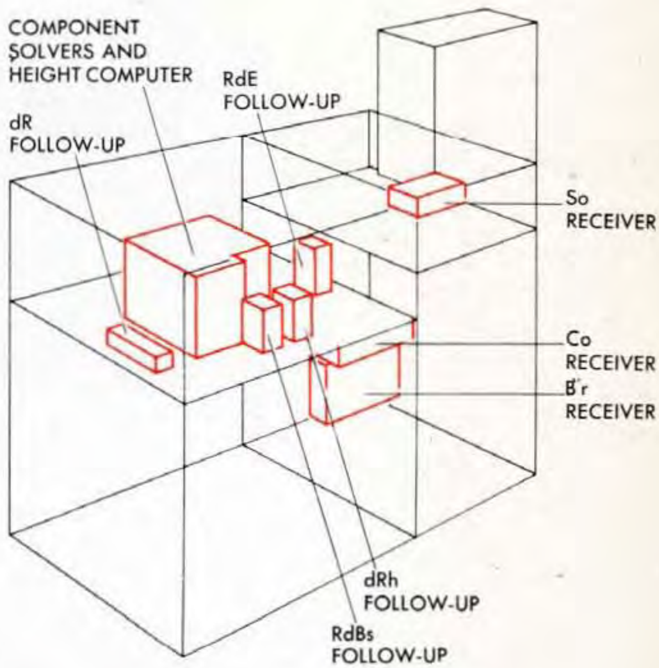
If, however, with the same initial relative positions, Target Angle, *A*, had been 80° and the Target had moved at 30 knots for two minutes, the results would have been quite different. Range would have decreased only 250 yards, to 19,750 yards, while Relative Bearing would have increased approximately 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*.

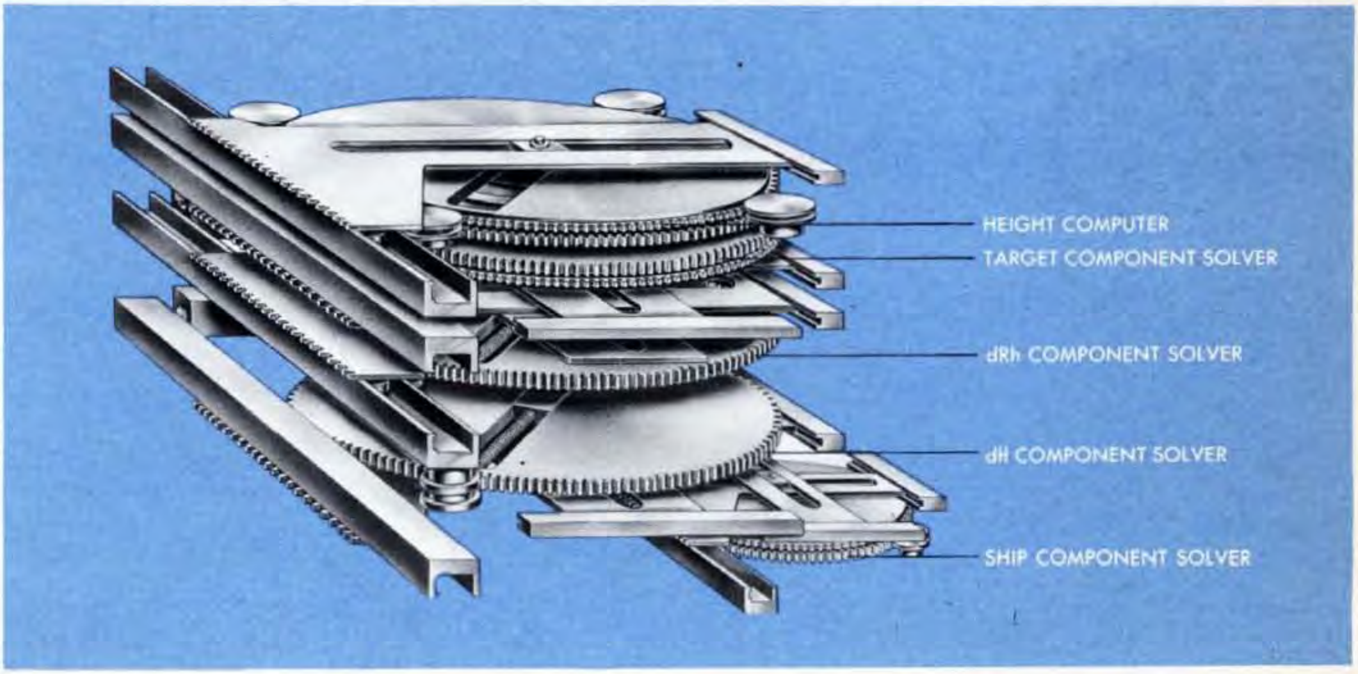
In the same way, the effect of Own Ship Speed on Range and Bearing depends on the value of Ship Speed, *So*, and Relative Target Bearing, *Br*.

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.

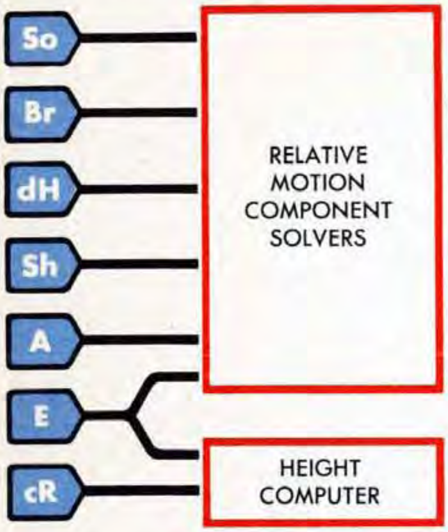


THE MECHANISM
in the relative motion group

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.

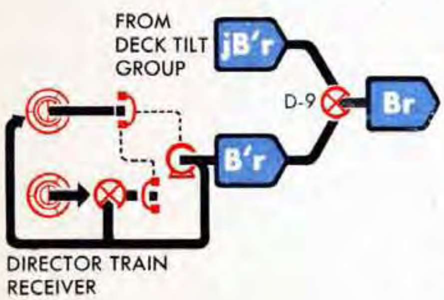


The inputs to the Component Solvers



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.

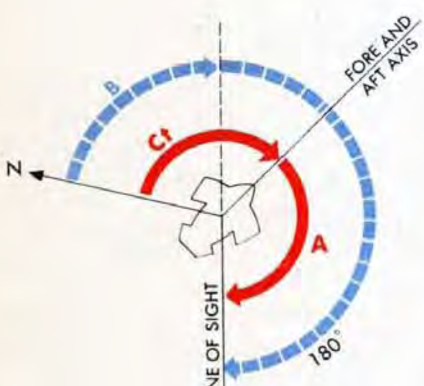
The quantities which must be computed for use by the component solvers are Relative Target Bearing, *Br*, Target Angle, *A*, and Target Elevation, *E*.



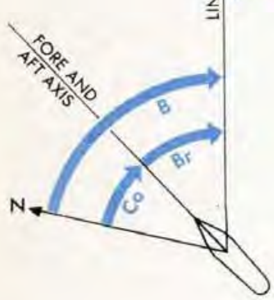
Relative Target Bearing, *Br*, is computed by adding Deck Tilt Correction, *jB'r*, to Director Train, *B'r*. Deck Tilt Correction, *jB'r*, is computed in the Deck Tilt Group. Director Train, *B'r*, is transmitted electrically from the Director to the *B'r* Receiver. Deck Tilt Correction, *jB'r*, is added 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 $B + 180° - Ct$. *B* is True Target Bearing and *Ct* is Target Course.



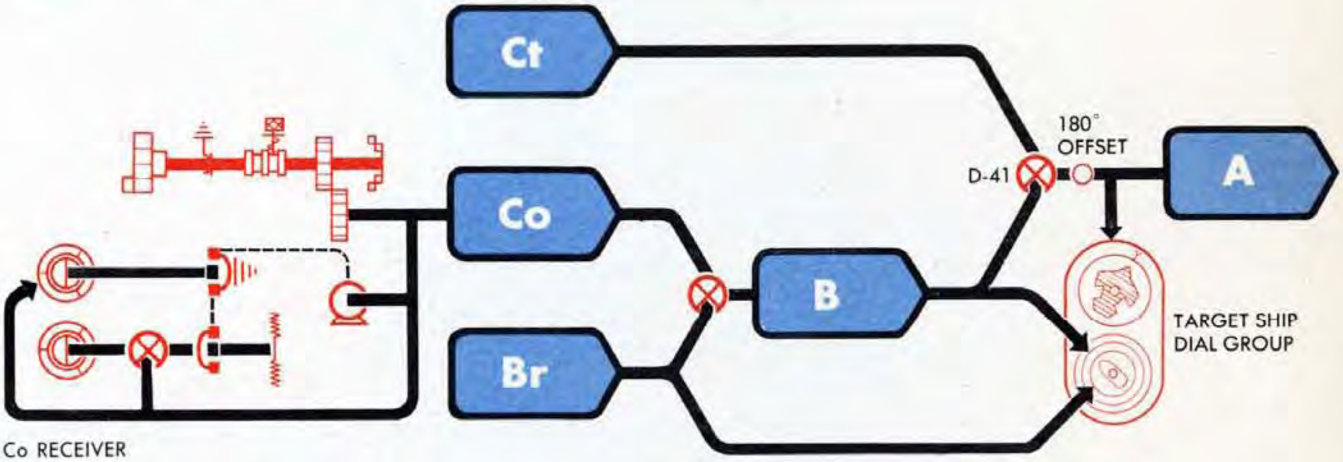
True Bearing, *B*, is the horizontal angle between a North-South vertical plane and the vertical plane through the Line of Sight, measured clockwise from North. The value of *B* is computed by adding Relative Target Bearing, *Br*, to Ship Course, *Co*.



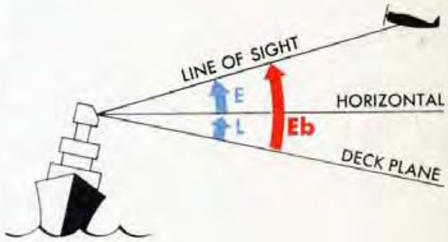
Ship Course, *Co*, is the horizontal angle between a North-South vertical plane and the vertical plane through the fore and aft axis of Own Ship, measured clockwise from North to the bow of Own Ship. The value of *Co* is either received electrically at the *Co* Receiver or is put in by hand at the Ship Course Handcrank.

Br is added to *Co* at differential D-26. The differential output is True Bearing, *B*.

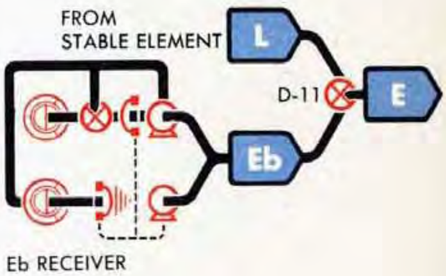
Target Course, *Ct*, is the horizontal angle between the North-South vertical plane and a vertical plane through the direction of motion of the Target, measured clockwise from North to the bow of the Target. *Ct* is estimated and set into the Computer through the Target Angle Handcrank. At differential 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*.



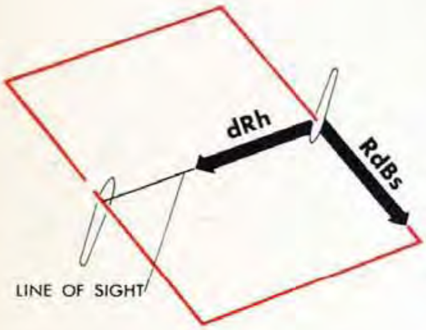
The speed inputs to the component solvers, *So*, *Sh*, and *dH*, need no initial computation inside the Computer.

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



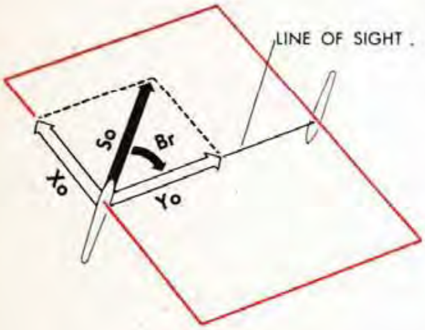
For the sake of clarity, this discussion of Relative Motion for a surface target assumes that the Line of Sight lies in a horizontal plane at the level of the Director. Actually the Line of Sight to a surface target is slightly depressed. If the Line of Sight is assumed to be horizontal, only two Relative 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.

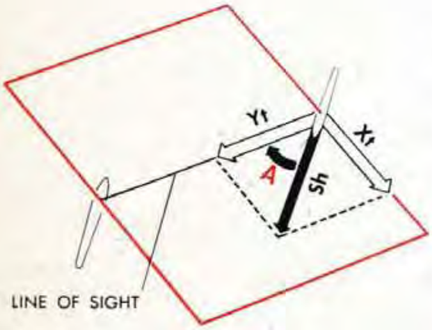
The outputs are:

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



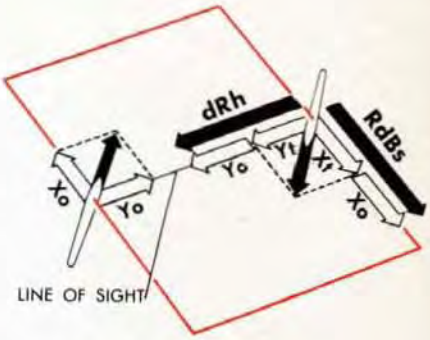
The Target Component Solver is also a cam-type component solver. The inputs are Horizontal Target Speed, *Sh,* and Target Angle, *A*. *Sh* positions the cam and *A* positions the vector gear.

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.

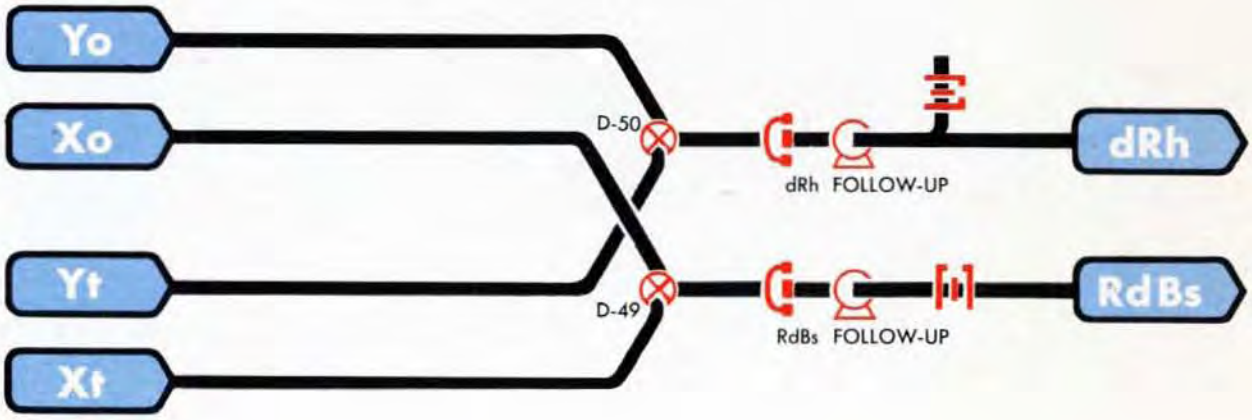
In the same way, the Deflection Components, *Xo* and *Xt*, are combined to obtain Deflection Rate, *RdBs*.

$$RdBs = Xo + Xt$$

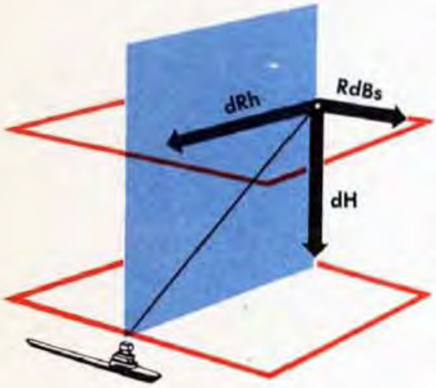
In the diagram, *Xo* and *Xt* are positive because the motion of both Own Ship and Target is causing the Line of Sight to deflect to the right. Deflection of the Line of Sight to the right is considered positive because it increases Bearing.

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.

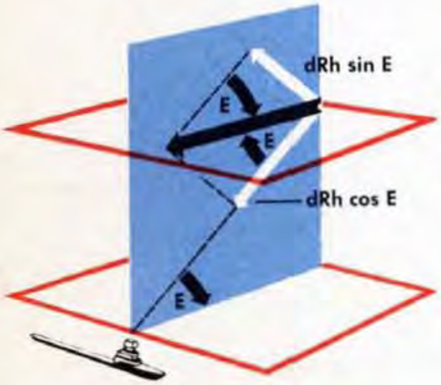
As in the case of the surface target, the Ship and Target Component Solvers are used to produce Horizontal Range Rate, *dRh,* and Deflection Rate, *RdBs.*

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

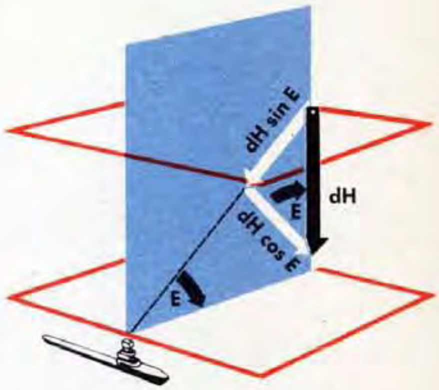
Rate of Climb, *dH,* is the vertical component of the Target's actual speed. *dH* is positive when the Target is climbing, and negative when the Target is diving.

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

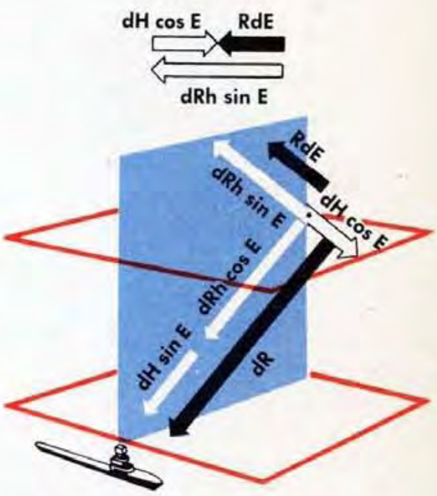
The *dH* Component Solver and the *dRh* Component Solver produce two pairs of components.

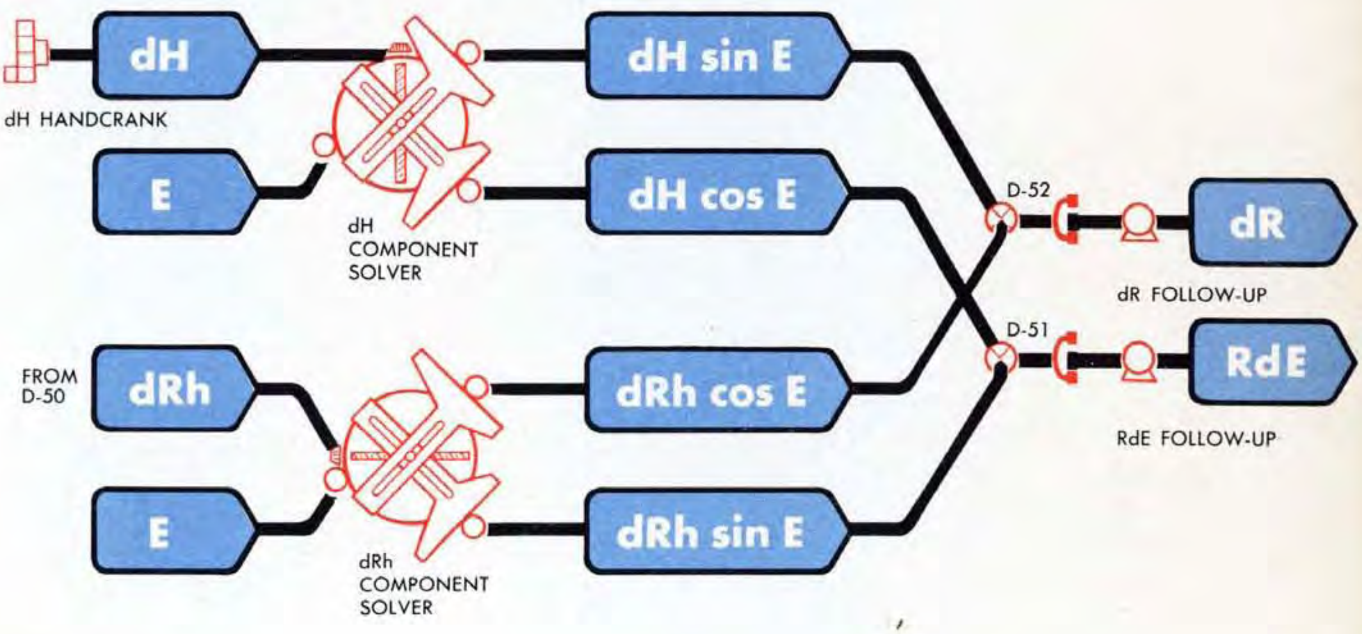
The Components along the Line of Sight are combined at differential D-52 to obtain Direct Range Rate, *dR*.

The Components perpendicular to the Line of Sight in the vertical plane are combined at differential D-51 to obtain Linear Elevation Rate, *RdE*.

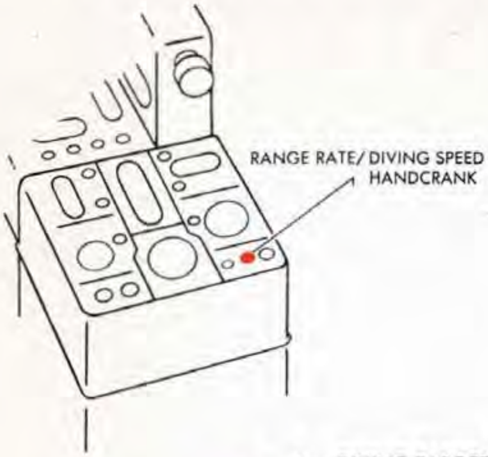
Direct Range Rate, *dR,* is positive when Range is increasing. Linear Elevation Rate, *RdE,* is positive when Elevation is increasing. In this diagram, *dR* is negative and *RdE* is positive.

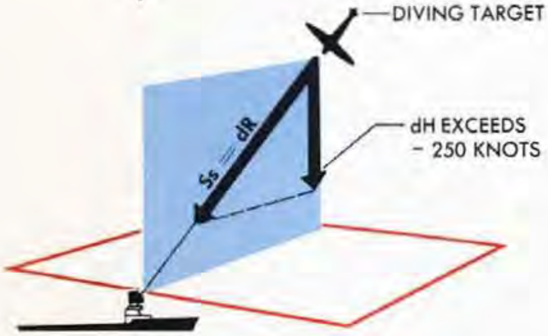
Both *dR* and *RdE* are amplified by velocity-lag follow-ups.

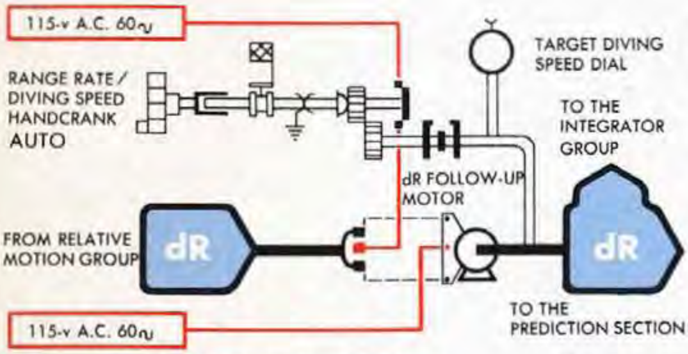




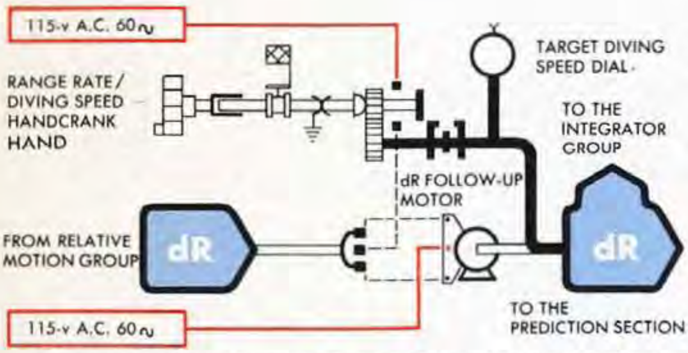
THE RANGE RATE DIVING SPEED HANDCRANK







dR MOTOR DRIVES dR SHAFT LINE



RANGE RATE/DIVING SPEED HANDCRANK DRIVES dR SHAFT LINE

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.

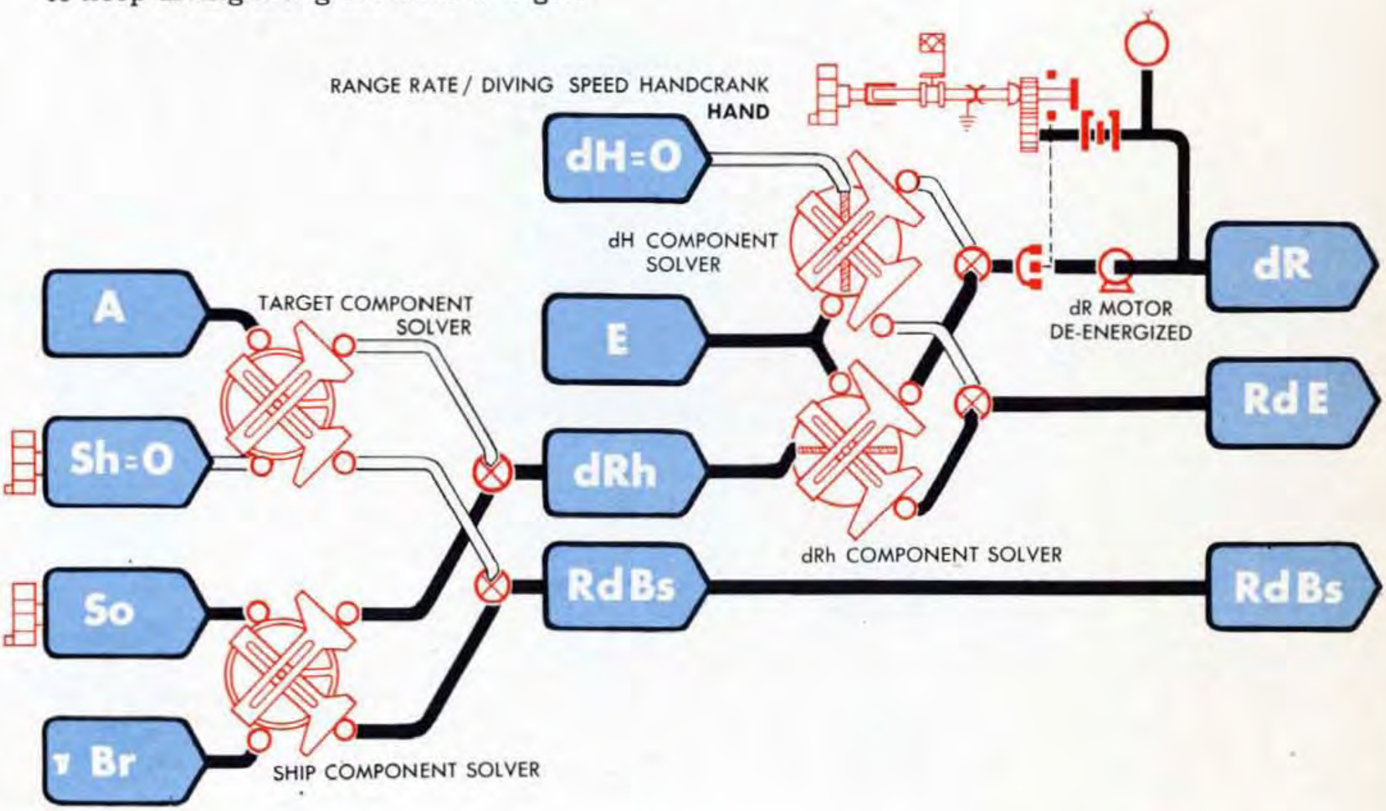
How the handcrank is used

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.

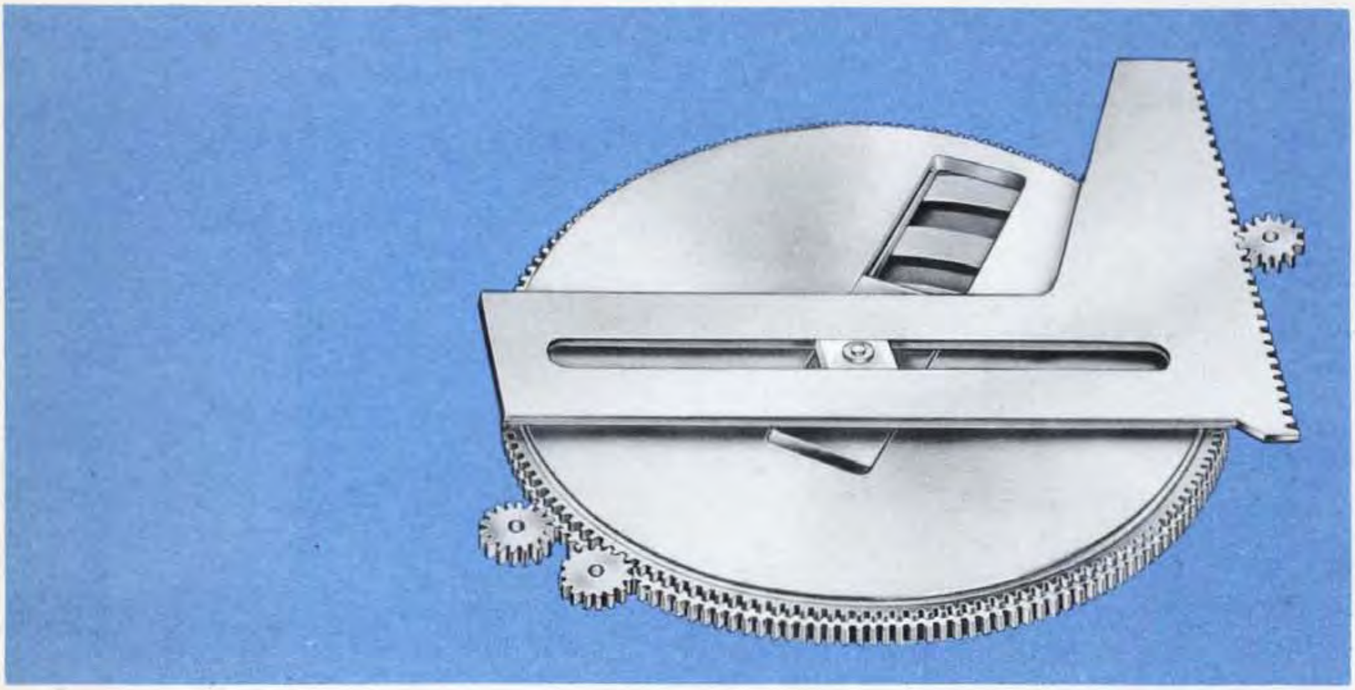
Why dH and Sh are turned to zero

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.

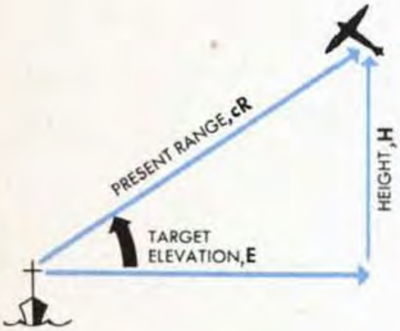
The Height Computer positions the Height Dials. Although Height is not actually used in computing Gun Orders, it is sometimes needed in finding *Present Range* or *Target Elevation.*

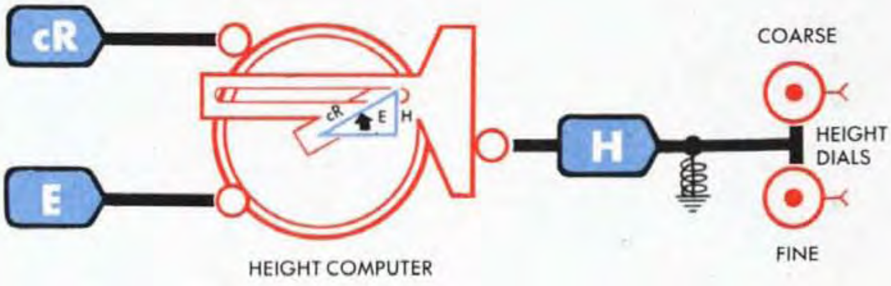
The Height Computer is a cam-type component solver with only one output rack. It is located on top of the Relative Motion Component Solvers.

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:

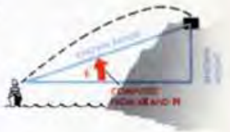
The Operator sets in the calculated value of Range and then reads the Height Dial.

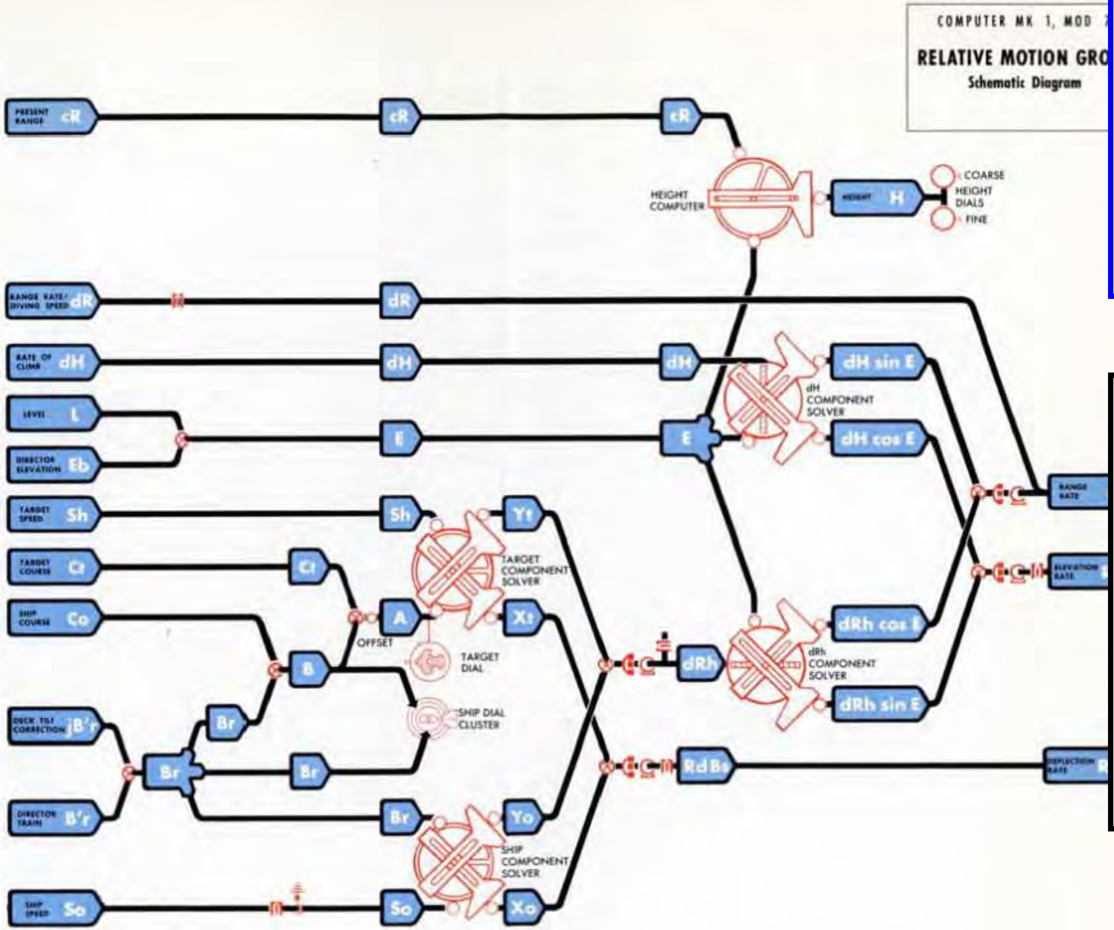
If the Height reading does not correspond to the known height, the angle of Target Elevation must be wrong.

Target Elevation is adjusted until the correct Height reading shows on the Height Dials at the Computer.

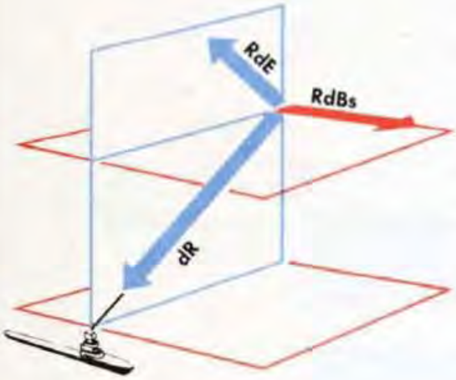
When both Range and Height readings are correct, the value of Target Elevation is also correct.

The Height Dials are also used for certain other purposes, as prescribed by *ship's doctrine*.





THE INTEGRATOR GROUP

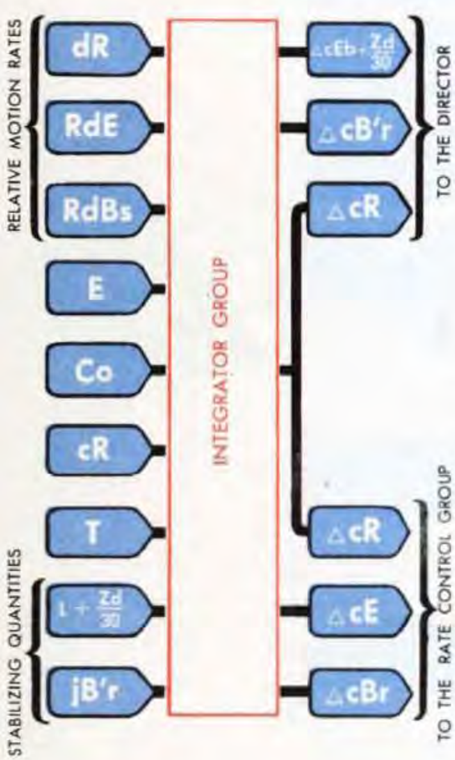


The Integrator Group computes *Linear* Changes of Generated Range, and *Angular* Changes of Generated Elevation and Relative Target Bearing, using the three Relative Motion Rates, *dR*, *RdE* and *RdBs*.

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

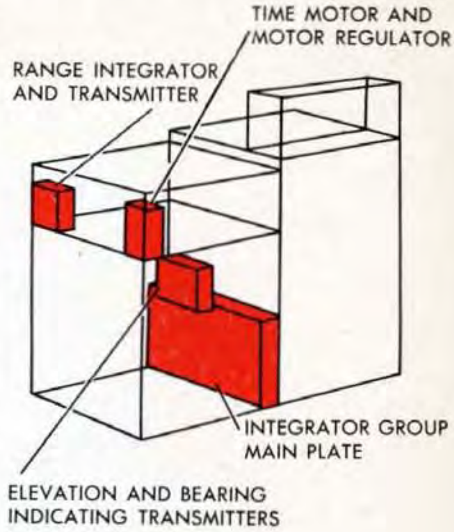
The mechanism in the Integrator Group includes five disk integrators, two cams, the Time Motor, the Time Motor Regulator, five single-speed transmitters, and various differentials.

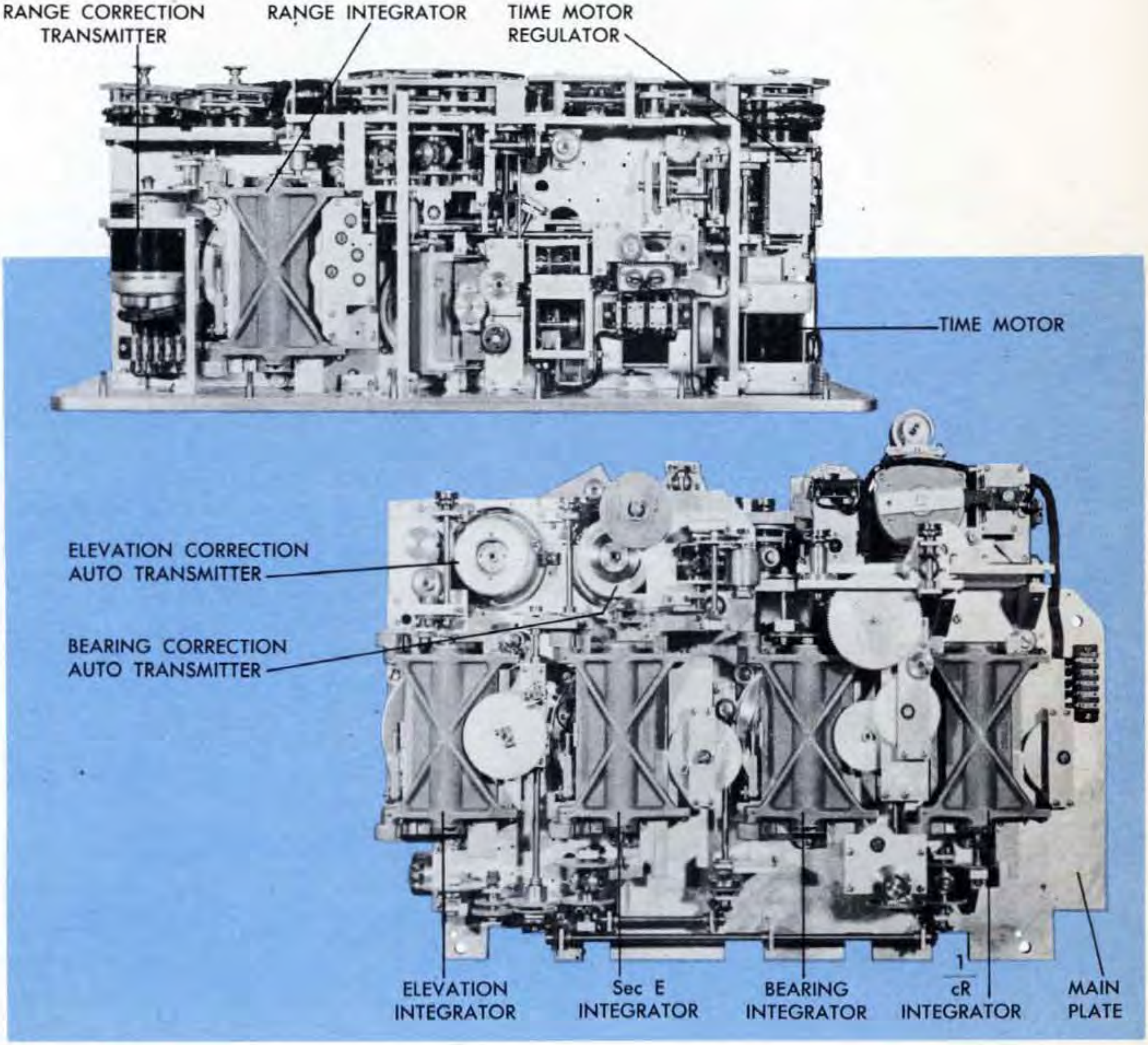
The Range Integrator, the Range Correction Transmitter, the Time Motor, and the Time Motor Regulator can be seen from the front of the Computer Mark 1.

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.

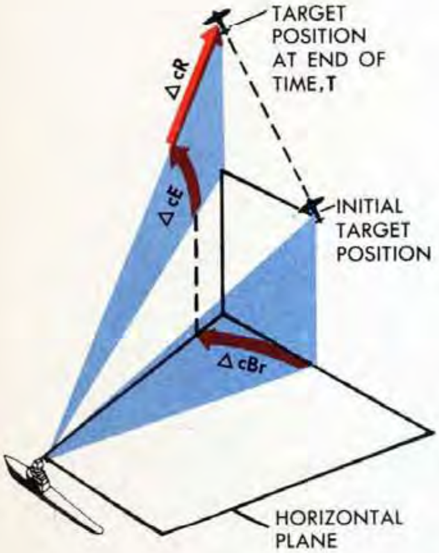




INCREMENTS

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.

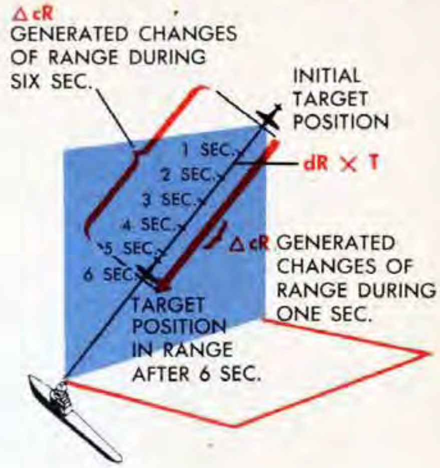
An integrator can be thought of as continuously multiplying a rate, which is constant during very short time intervals, by equally short intervals of time. The product for each time interval is added to the sum of the previous products to produce a total linear change of Target Position.

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



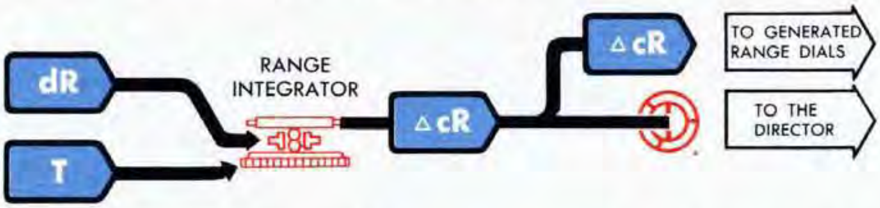
Direct Range Rate, *dR*, indicates the Rate at which Range is changing in yards per minute. To compute the linear Range change during a definite length of time, this equation is used:

LINEAR RATE × TIME = LINEAR DISTANCE

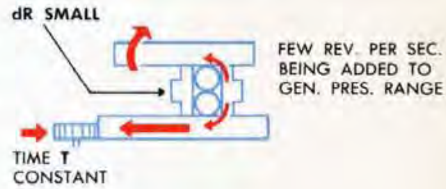
Range Rate, *dR*, × Time, *T*, = Changes of Range, $\triangle cR$, generated during Time, *T*.

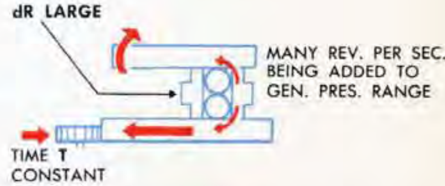
The range integrator

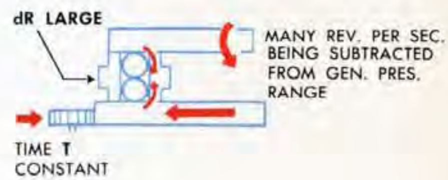
The Range Integrator continuously multiplies Range Rate, *dR*, by Time, *T*, to generate the Changes in Range during any time period. Direct Range Rate, *dR*, from the Relative Motion Group positions the carriage of the Range Integrator. Time, *T*, is supplied by the Time Motor. The Time Motor, controlled 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, $\triangle cR$.



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.





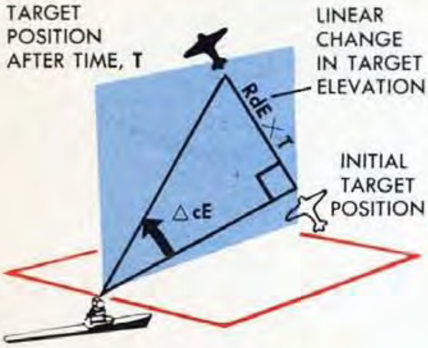


The value of $\triangle cR$ during a small time interval, such as 1/10 second, is the increment of Range Change during 1/10-second based on the value of *dR* during that 1/10-second interval. The value of $\triangle cR$ during a longer time period, such as 10 seconds, is the SUM of the increments generated 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, $\triangle cR$ represents accurate Generated Changes of Range during that time period.

In the Computer, $\triangle cR$ 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.

$\triangle cR$ 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



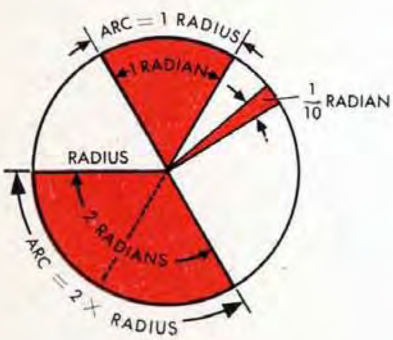
Generated Changes of Target Elevation, $\triangle cE$, are *angular* increments.

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.

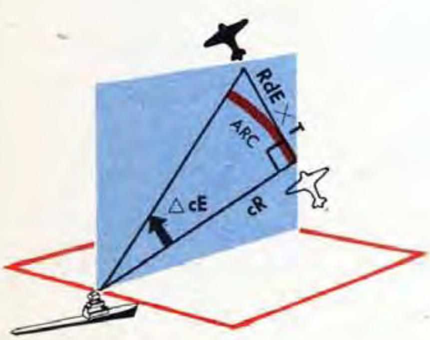


If the arc cut off is 1/10 the length of a radius, the angle equals 1/10 radian.

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:

$$\frac{\text{arc}}{\text{radius}} = \text{angle in radians}$$



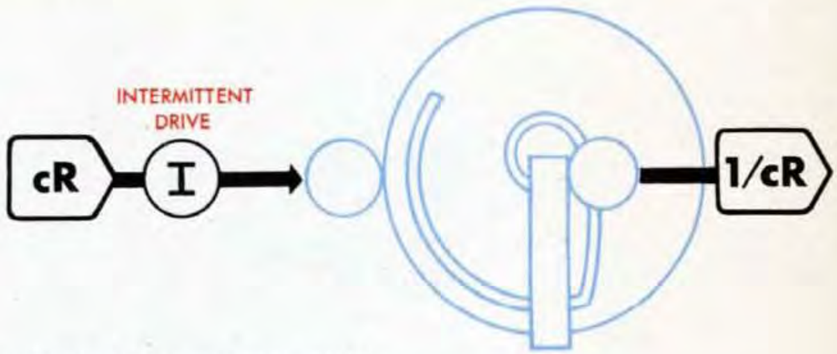
An arc of radius cR can be drawn in the vertical plane of sight from the initial Line of Sight to the Line of Sight at the end of Time, T.

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

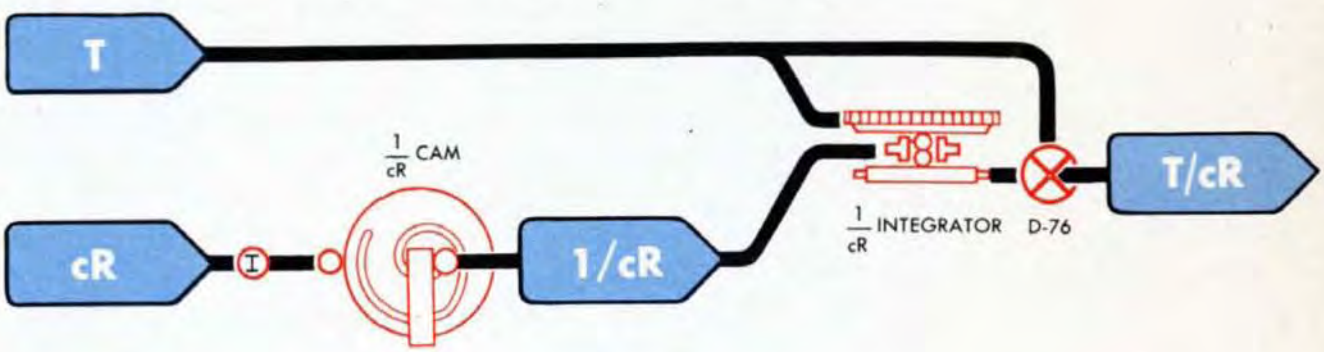
The first term in the $\triangle cE$ equation is obtained from a reciprocal cam. The $1/cR$ cam is grooved so that for every input of Generated Present Range, cR, the output is the reciprocal of cR, or $1/cR$. Multiplying by the reciprocal of cR instead of dividing by cR reduces the number of mechanisms 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, $\triangle cBr$.

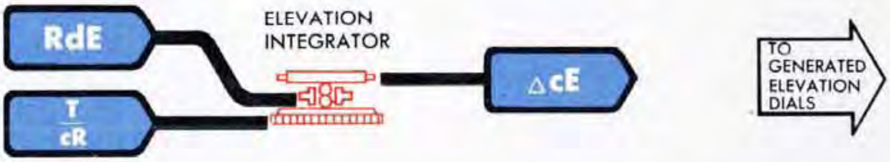


The ELEVATION integrator

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 $\triangle cEb + Zd/30$.

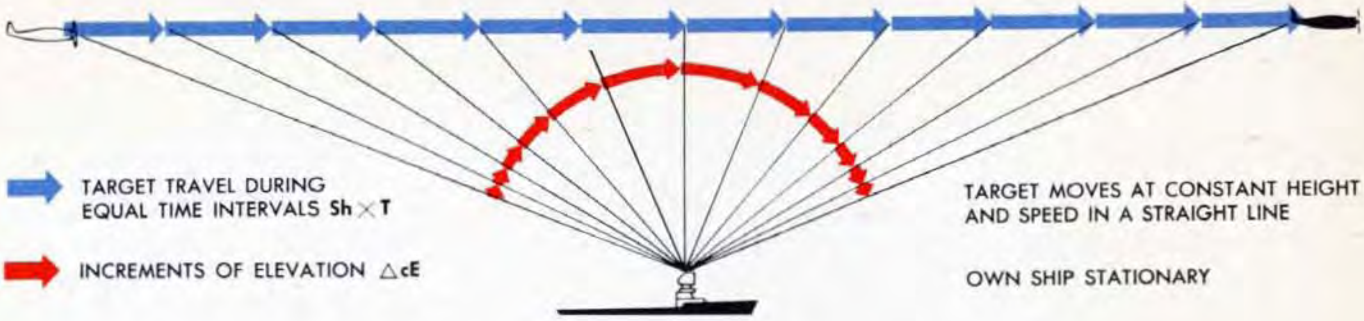
In some installations, $L + Zd/30$ is transmitted to the Director from the Stable Element, and $\triangle cE$ is transmitted from the Computer alone. The two quantities are added in the Director.

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.

Quick Reference Index

How increments of elevation vary

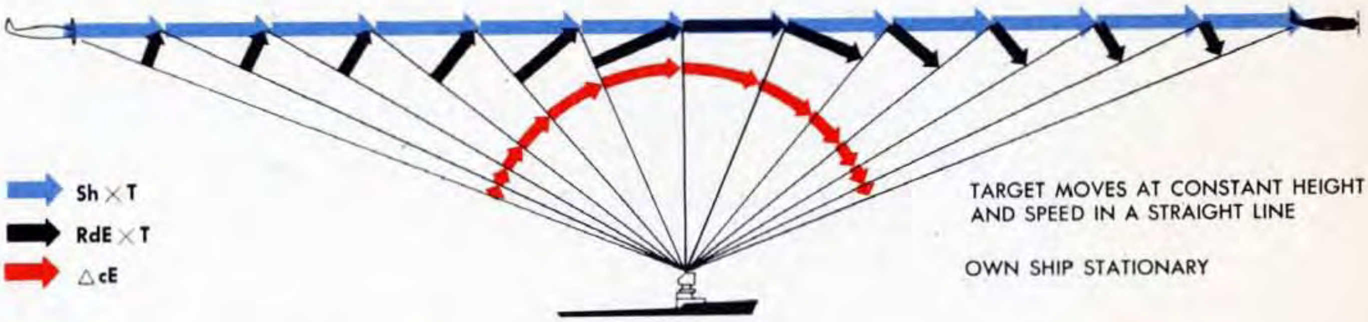


Suppose a Target is moving at a constant height and at a constant speed while Own Ship is stationary, as shown here.

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.

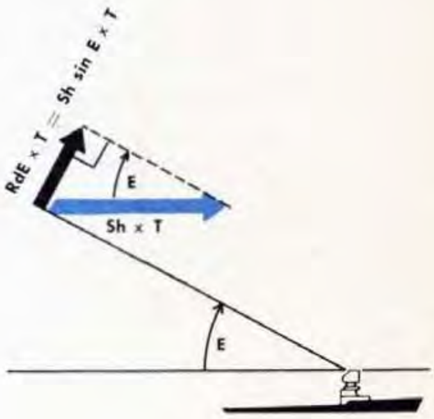
From the instant tracking begins until the Target is directly overhead, the Angular Increments of Elevation for equal Time intervals increase in size. As the Target moves away from Own Ship, the Angular Increments of Elevation begin to decrease for equal Time intervals.



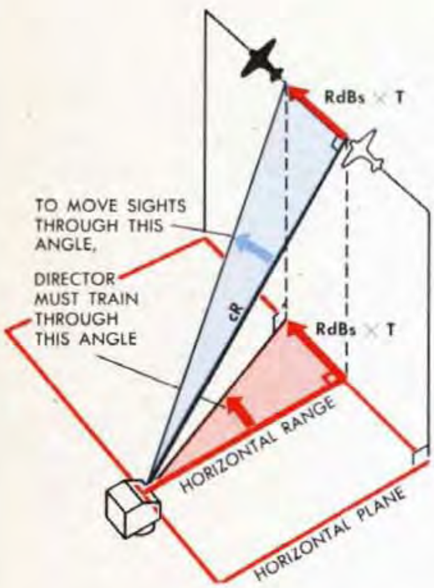
cR varies during the equal Time intervals because Range decreases as the Target approaches Own Ship and increases as soon as the Target has passed over Own Ship and is moving away. △*cE* varies inversely as *cR* or directly as *1/cR*.

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. △*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.

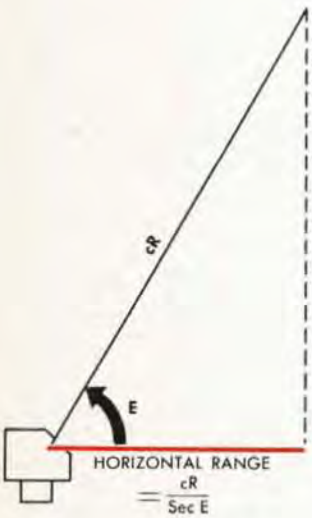
$$\triangle cB = \frac{RdBs \times T}{\text{Horizontal Range}}$$

To compute Horizontal Range:

$$\text{Sec } E = \frac{cR}{\text{Horizontal Range}}$$

Therefore:

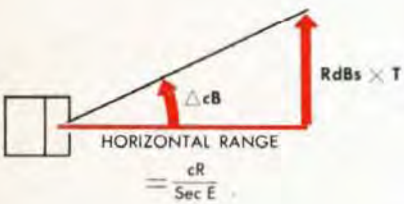
$$\text{Horizontal Range} = \frac{cR}{\text{Sec } E}$$



$\triangle cB$ 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.

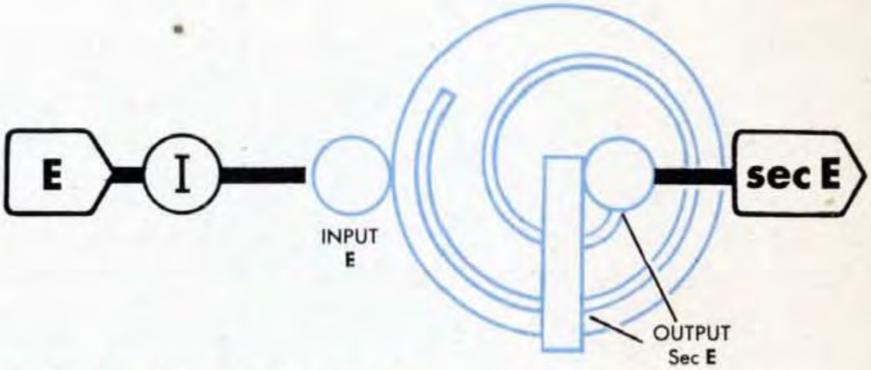
$$\frac{RdBs \times T}{cR/\text{Sec } E} = \triangle cB \text{ in radians}$$



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.

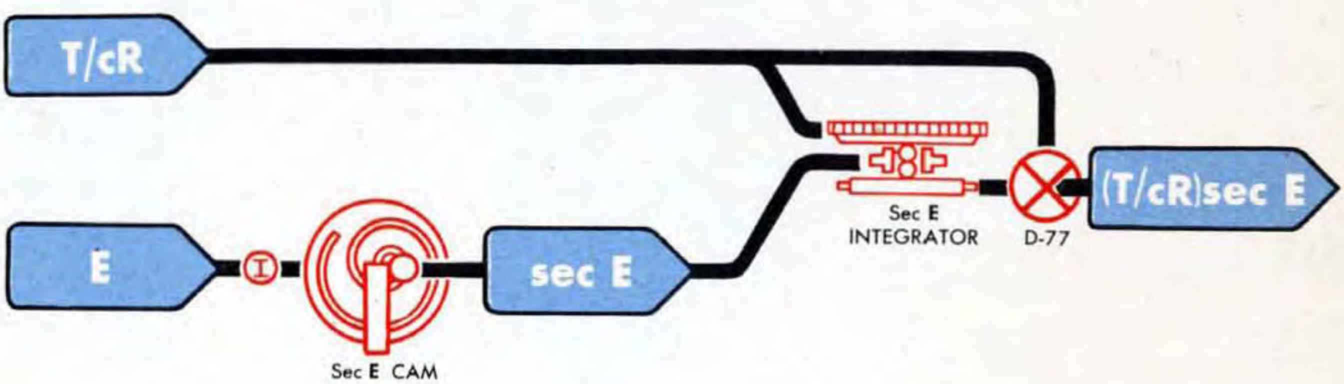
The sec E integrator

Sec E positions the carriage of the Sec E Integrator.

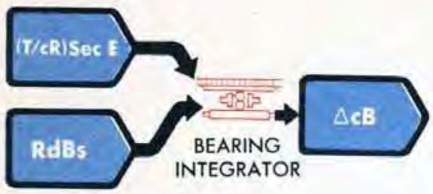
T/cR from the $1/cR$ Integrator drives the disk.

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

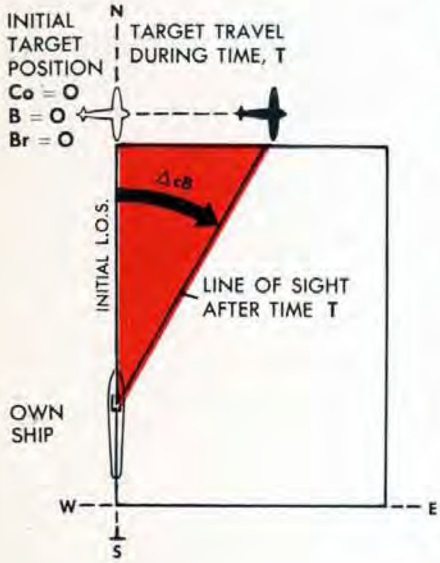
The computation of $\triangle cB$ is completed by multiplying (T/cR) Sec E by $RdBs$. This is done in the Bearing Integrator.



The BEARING integrator



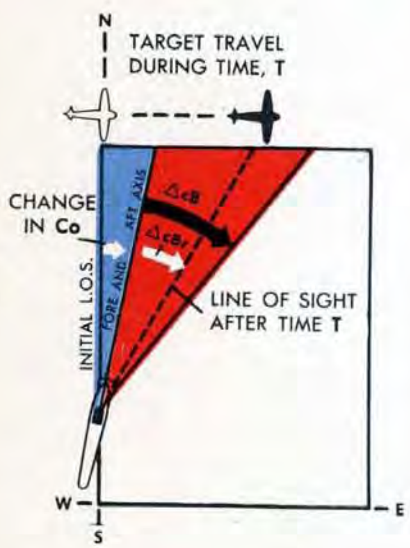
$(T/cR)\sec E$ from the Sec E Integrator rotates the disk of the Bearing Integrator. Deflection Rate, *RdBs,* positions the integrator carriage. The output from the roller is Generated Changes of True Bearing, $\triangle cB$.



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

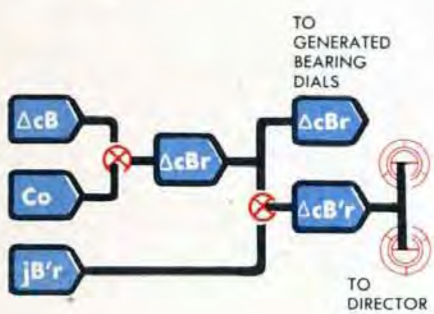
To understand why this is necessary, take a simple example in which Ship Course, *Co,* and True Target Bearing, *B,* are zero. Relative Target Bearing, *Br,* is also zero. The Target is tracked until it moves to the position shown. During this time, the Bearing Integrator computes a value of Generated 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, $\triangle cB$.

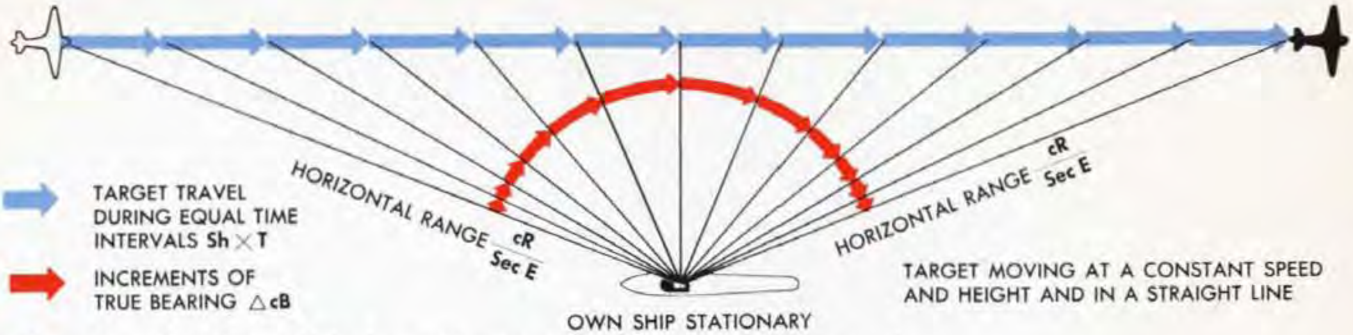
In the example shown, $\triangle cBr$ represents the total value of Relative Target Bearing, *Br*. $\triangle cBr$ positions the Generated Bearing Dial on top of the Computer.



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.

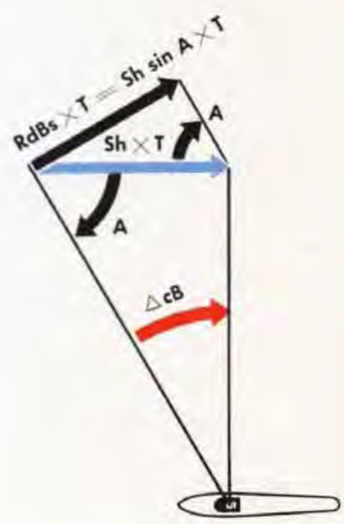
From the moment tracking begins until the Target is exactly abeam of Own Ship, the angular increments of Bearing, $\triangle cB$, increase in size, although the linear increments of Target Motion are equal. As the Target passes abeam of Own Ship and begins to move away, the angular increments begin to 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.



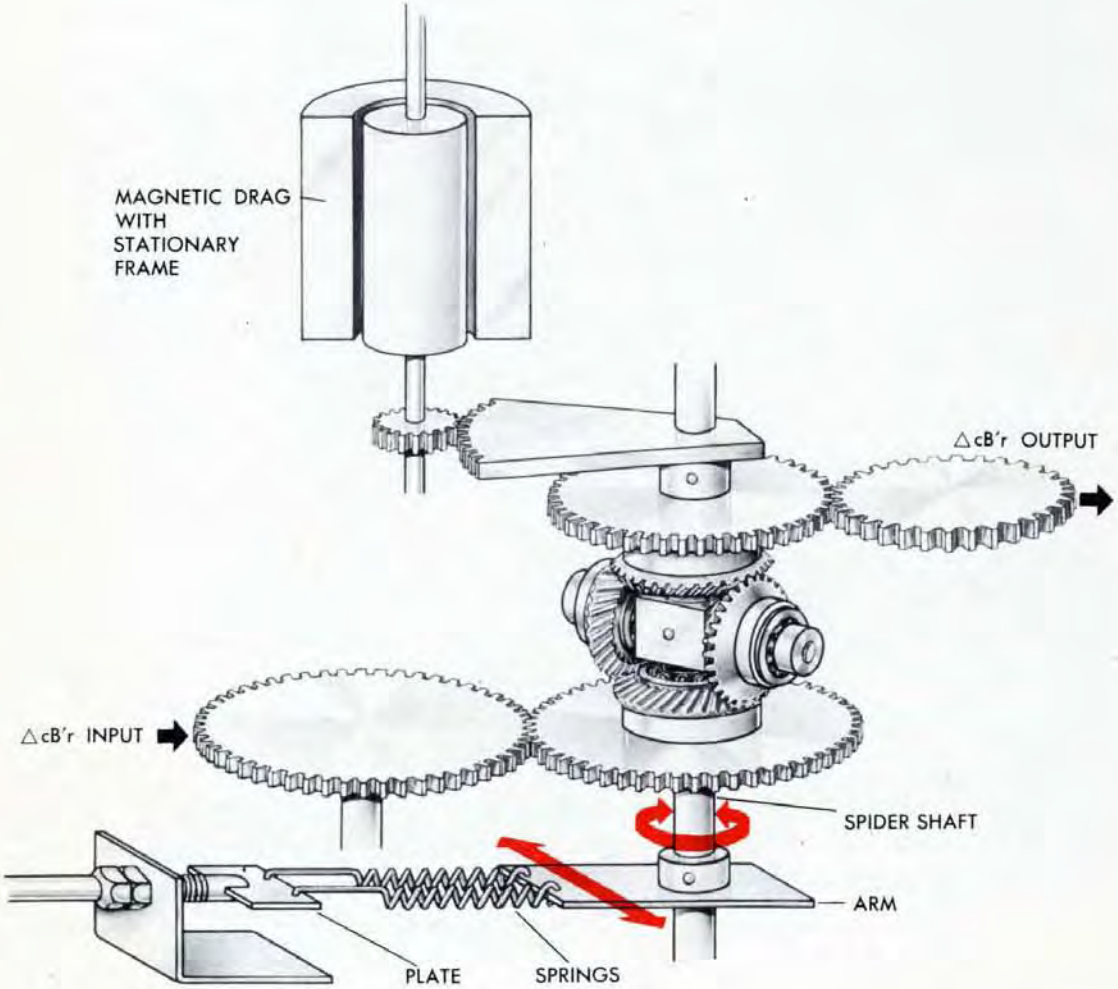
Then $\triangle cB = \dfrac{RdBs \times T \times \sec E}{cR}$

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.

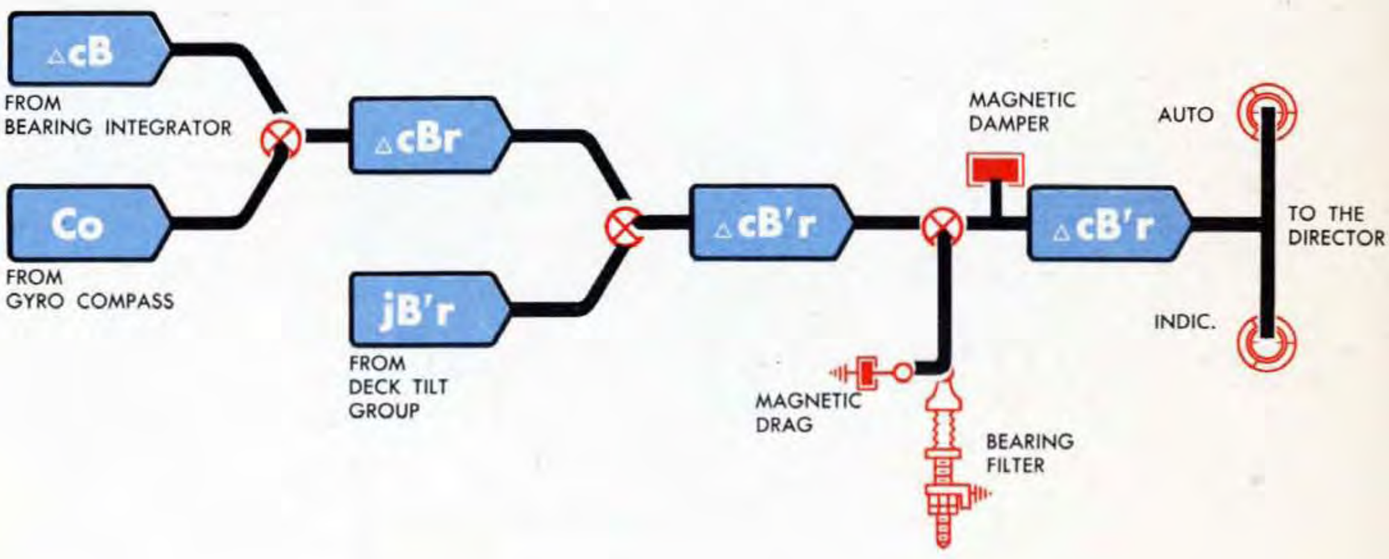


How the bearing filter works

△*cB′r* is both the input and the output of the differential. When the value of △*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 △*cB′r* input is rough or reverses direction suddenly, the normal inertia of the △*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 △*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 △*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

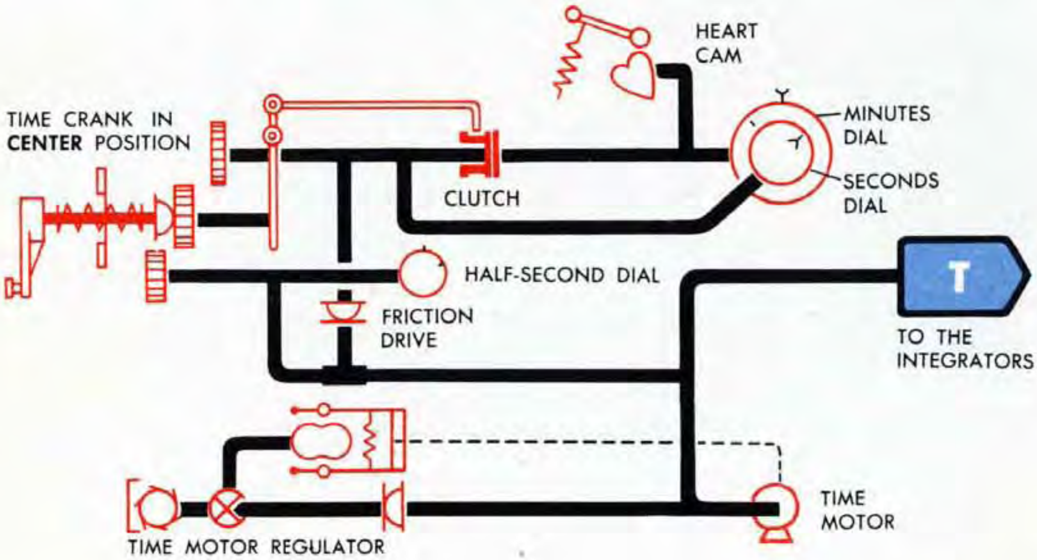
There are three Time Dials: a ring dial graduated in minutes, an inner dial graduated in seconds, and a small half-second dial with one graduation

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.



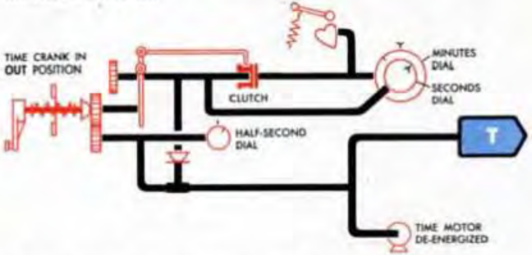
OPERATION DURING TESTS

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.

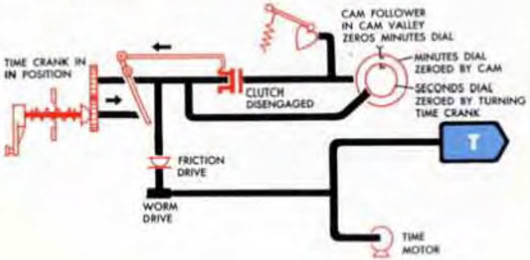
Zeroing the Time Dials

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.

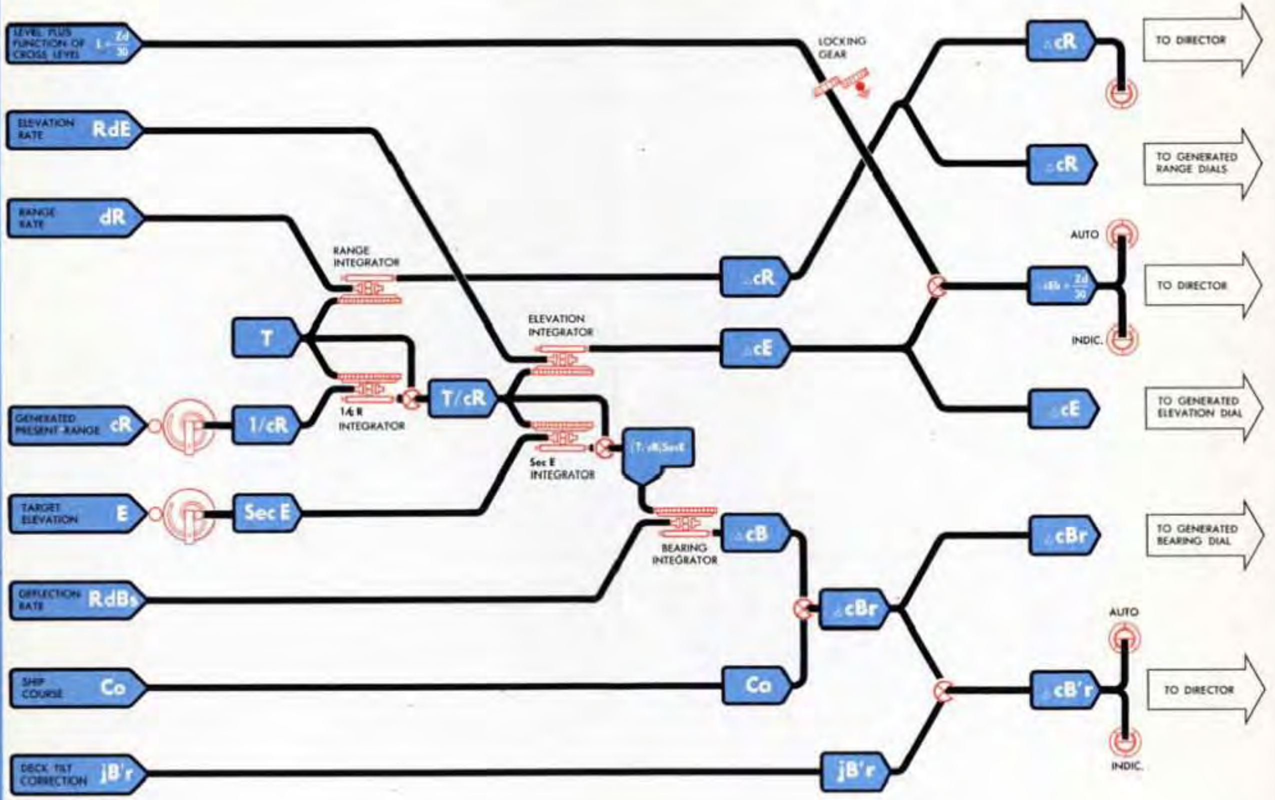
A friction drive on the line allows the Time Crank to be turned in the IN position to zero the Seconds Dial without disturbing the setting of the Half-second Dial.



COMPUTER MK 1, MOD 7

THE INTEGRATOR GROUP

SCHEMATIC DIAGRAM



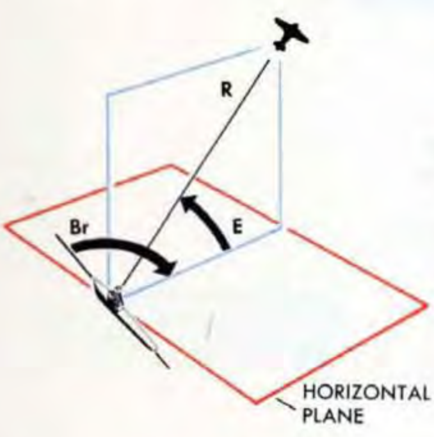
RATE CONTROL

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."*

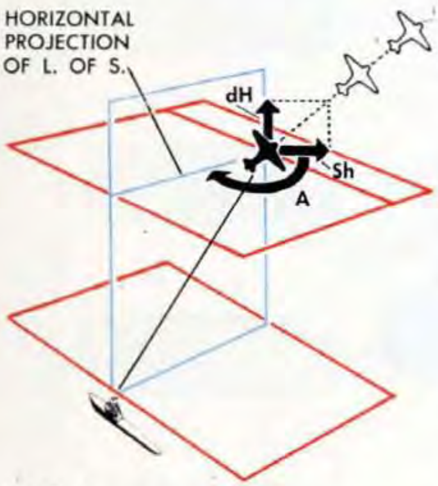
TARGET POSITION INPUTS TO THE RATE CONTROL MECHANISM



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.

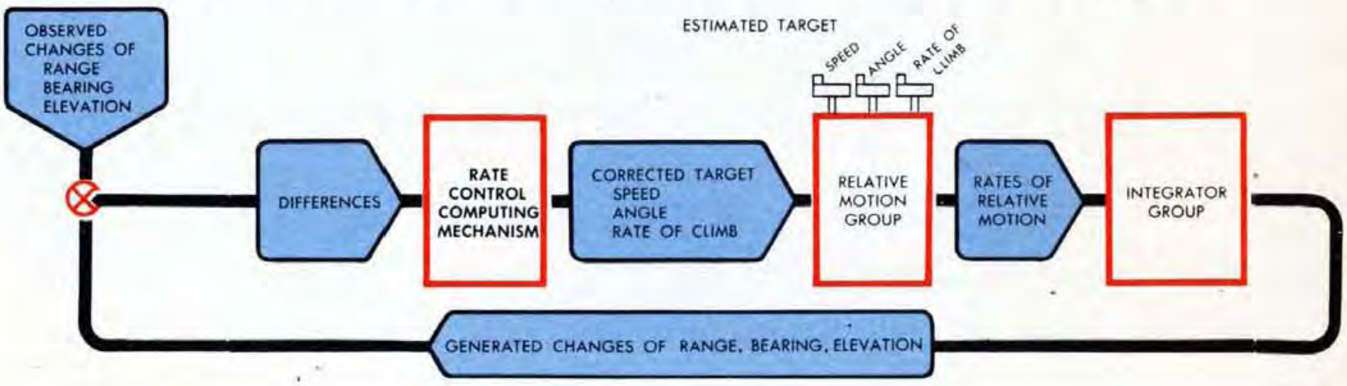
Correcting target motion estimates

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.

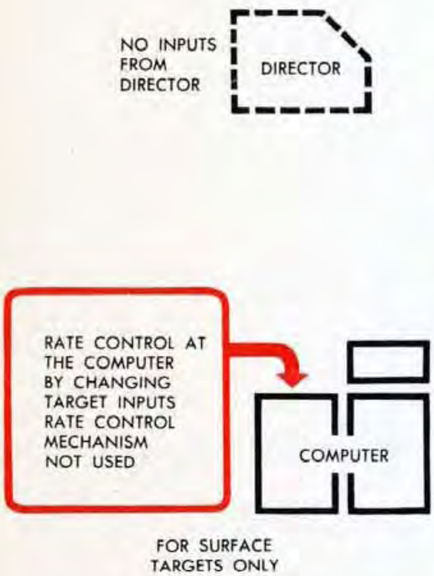
This simplified schematic summarizes Rate Control through the Rate Control Computing Mechanism



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.

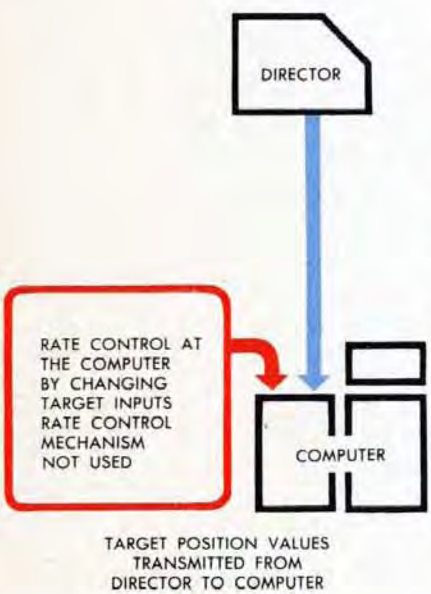
LOCAL CONTROL



Two methods DO NOT USE the rate control mechanism

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

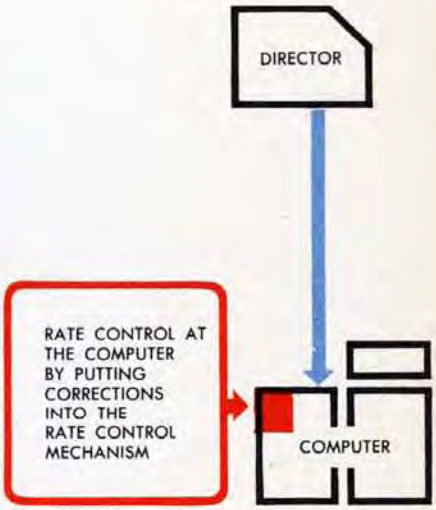


MANUAL RATE CONTROL also consists of direct estimated hand corrections of Target Motion values, but instead of being based on intermittent reports, these corrections are made with the aid of dial movements which represent continuous observation of the Target from the Director. The Computer Control Switch 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

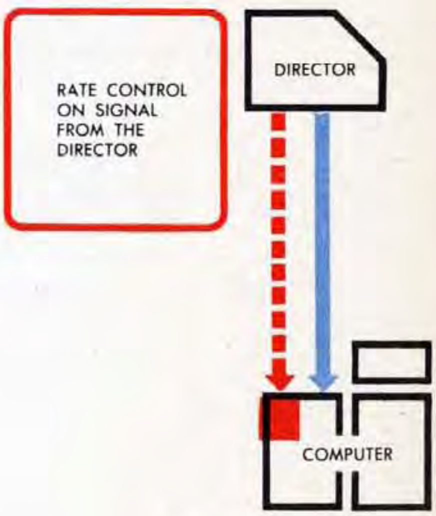
In SEMI-AUTOMATIC RATE CONTROL, the Rate Control Computing Mechanism does the work which in Manual Rate Control is done mentally by the operators. When the Generated Dials move out of synchronism with the Observed Dials, the Computer Operators put in Rate Corrections through the Generated Range, Generated 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.

SEMI-AUTO
RATE CONTROL



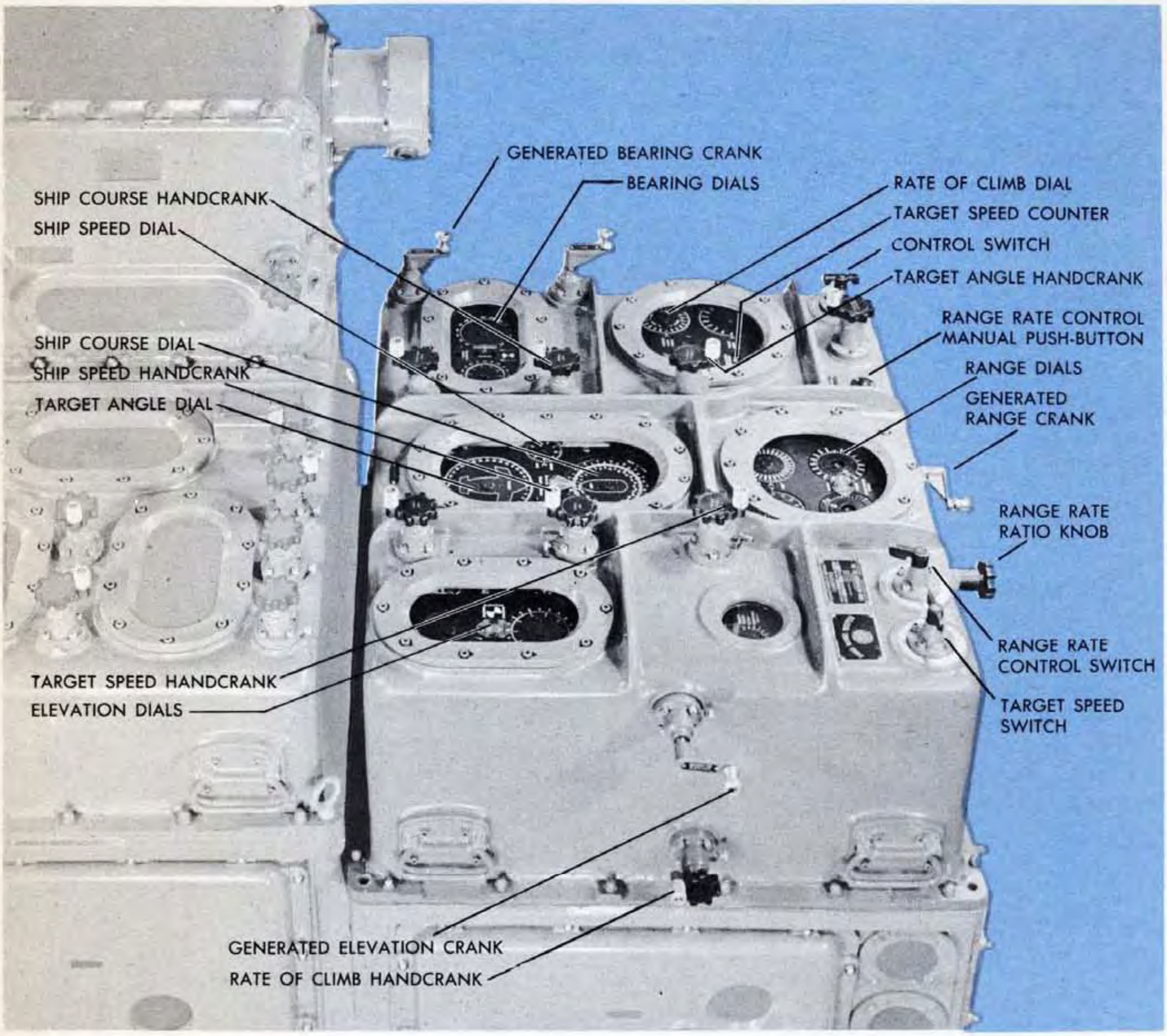
AUTO
RATE CONTROL

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.

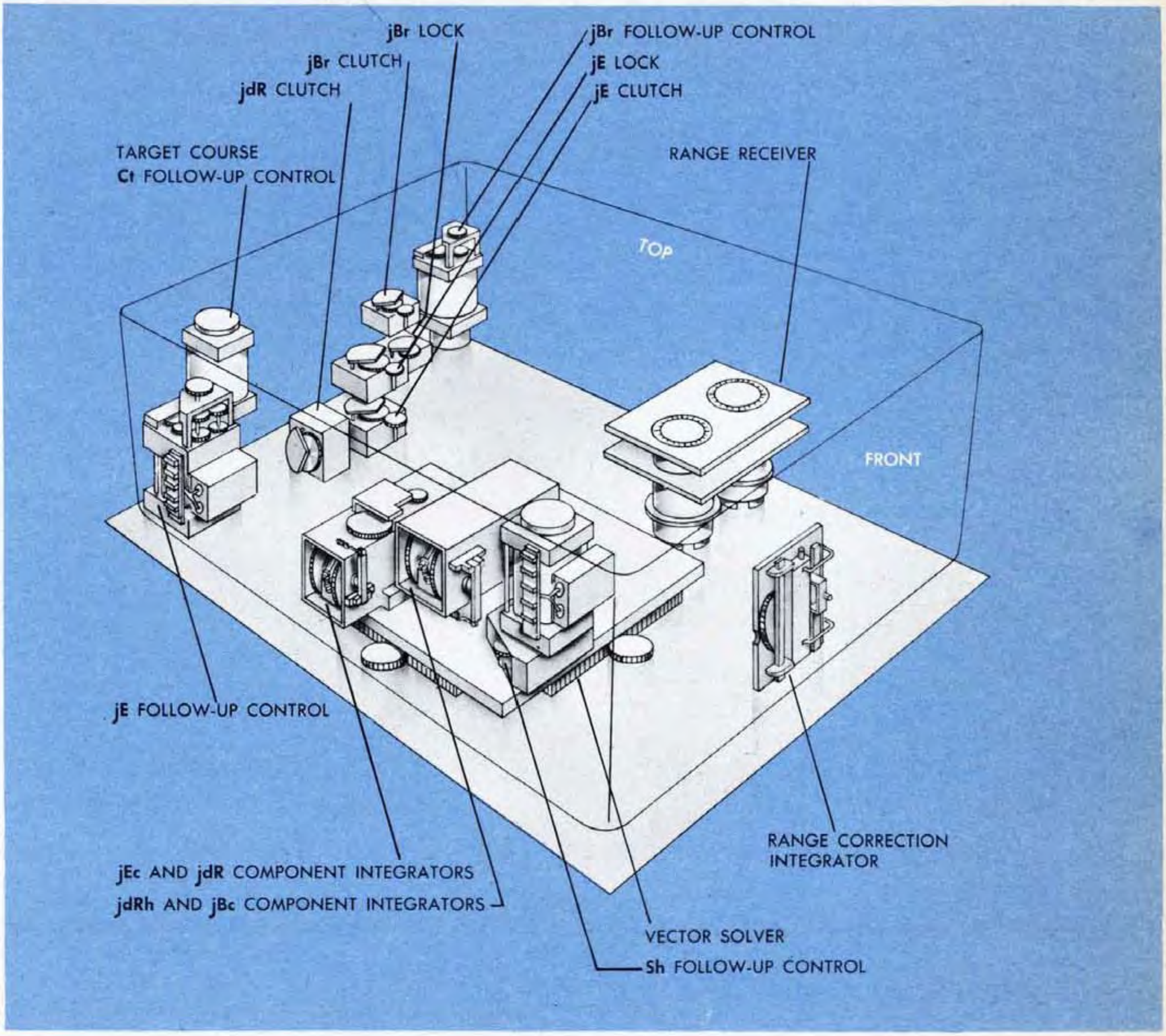
HANDCRANKS and DIALS used in RATE CONTROL



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.

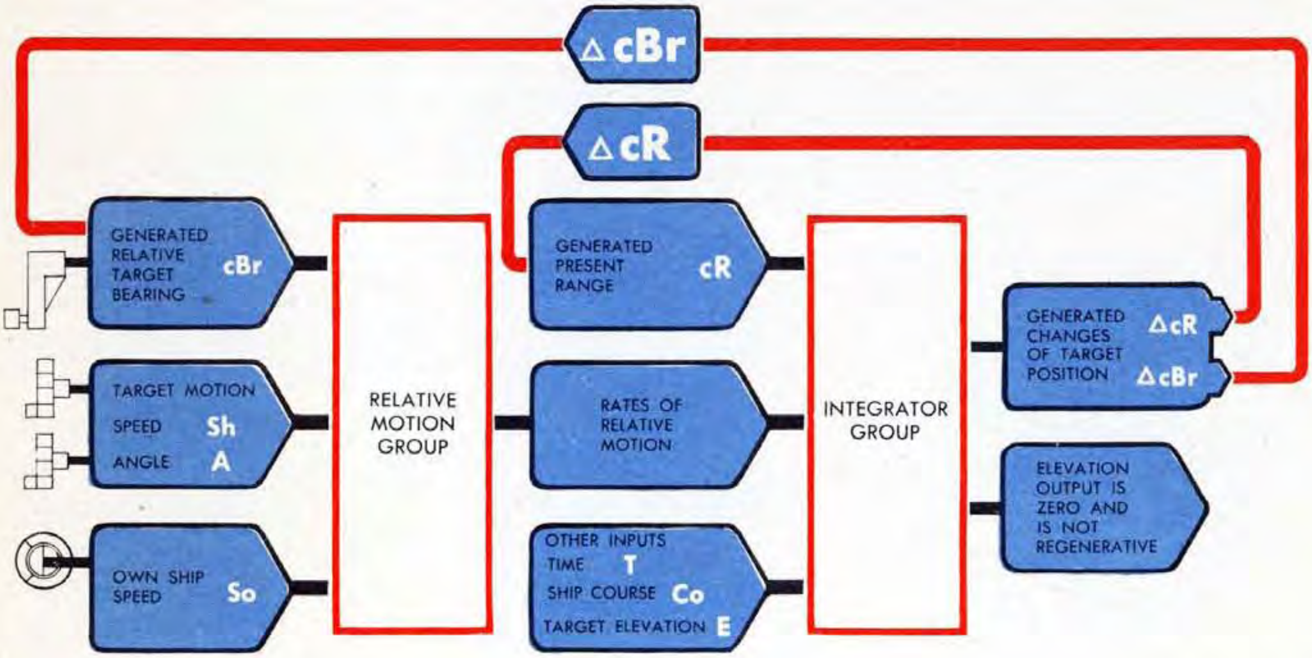
Used for surface targets only

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

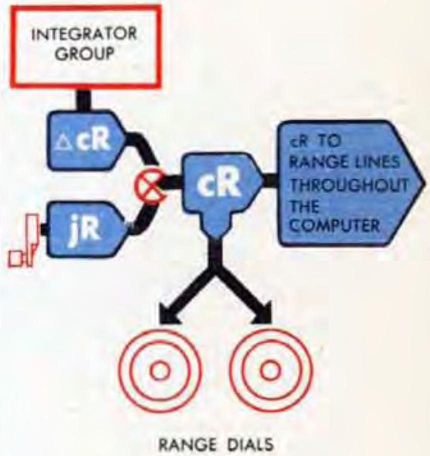
When a Target is sighted, Observed Range, *R*, is phoned down to the Plotting Room and is put into the Computer through the Generated Range Crank in its OUT position. The hand input of Range is called *jR*.

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*.



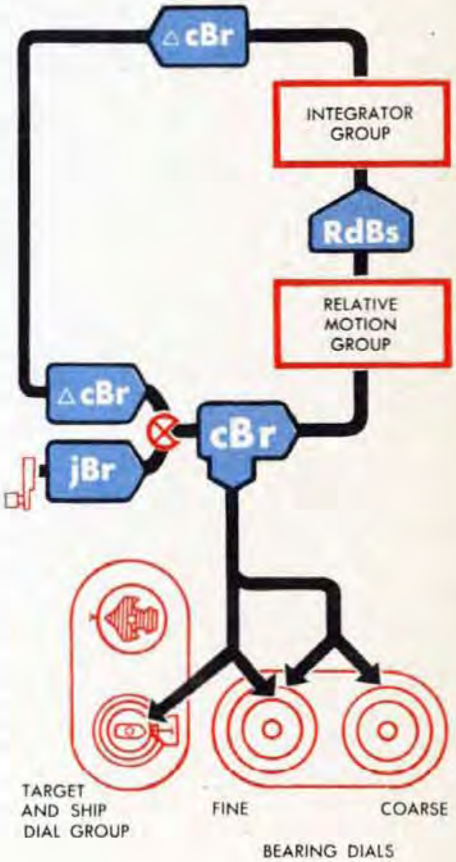
Bearing

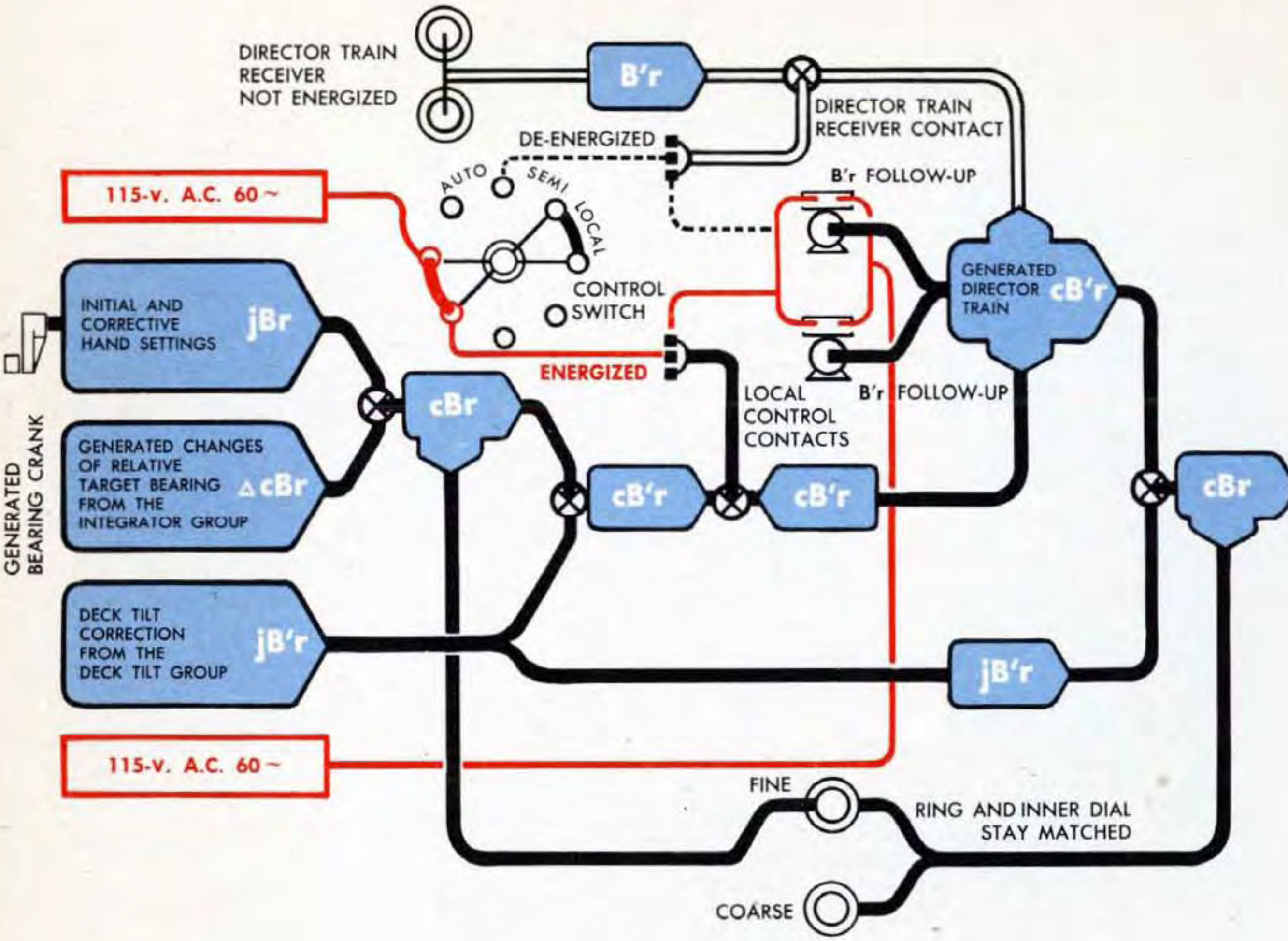
Relative Target Bearing, *Br*, is phoned down from the observation station on deck and put into the Computer through the Generated Bearing Crank. After the initial Observed Bearing input, corrections to Generated Bearing called *jBr* are put into the Computer through the same Generated Bearing Crank. 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.

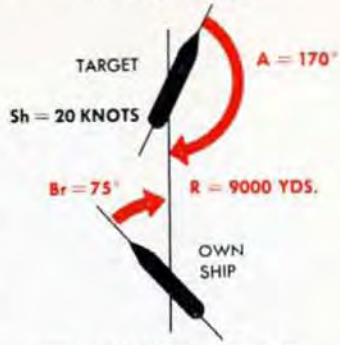
Target Angle, *A*, is estimated at 170 degrees.

Target Speed, *Sh*, is estimated at 20 knots.

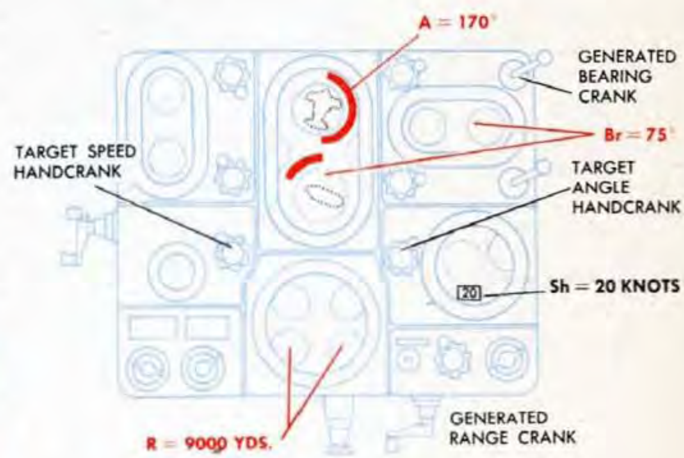
These values are set into the Computer by turning the Generated Range and Bearing Cranks, and the Target Speed and Target Angle Handcranks.

The Time Switch is turned ON and the Computer begins to generate Range and Bearing.

TARGET ESTIMATES



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.

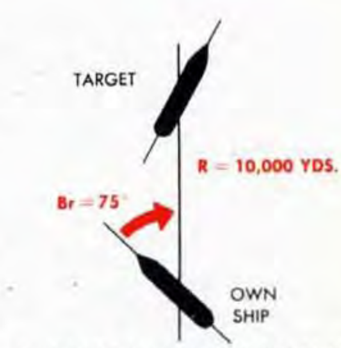
A quick reading of Range and Bearing generated by the Computer shows that:

Generated Present Range, *cR* = 9725 yards

Generated Relative Target Bearing, *cBr* = 75°40′.

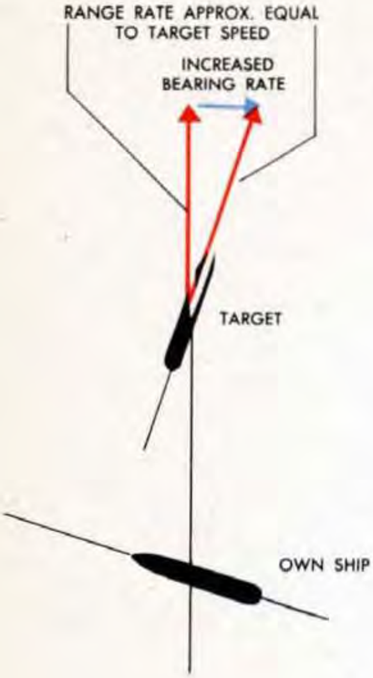
A comparison of the observed and generated values shows that during the elapsed time of one minute, *cR* increased 275 yards less than *R*, and *cBr* increased 40 minutes more than *Br*.

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.

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.

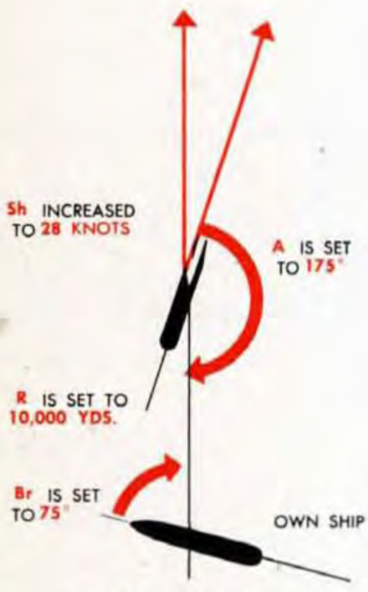
The Operators reset the Computer to the *observed* values:

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.



CORRECTED SETUP

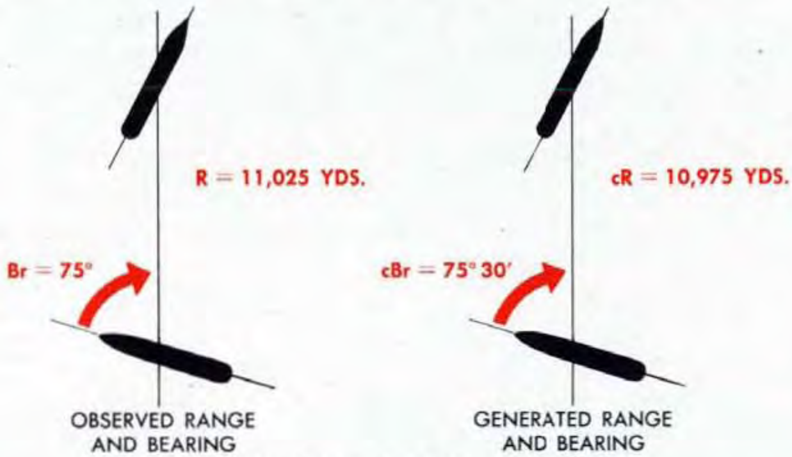
Completing the problem

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, $cBr = 75°30'$



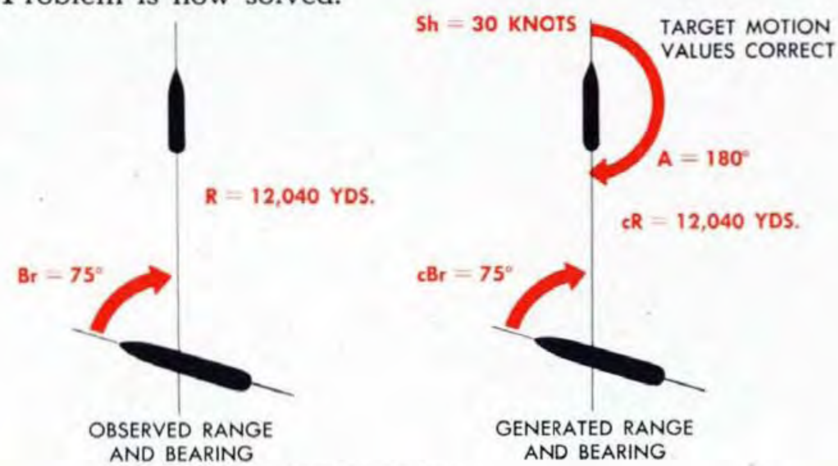
AFTER TWO MINUTES

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

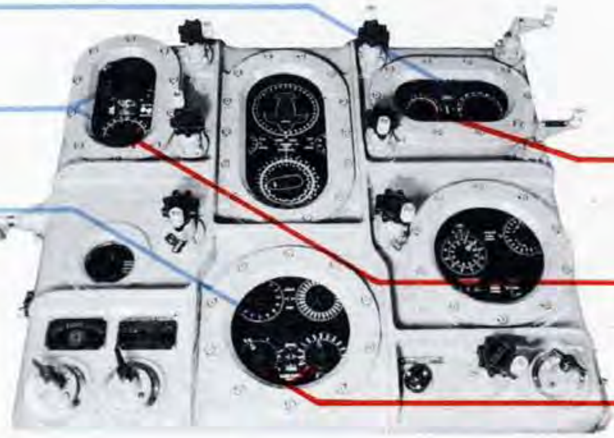
MANUAL CONTROL OF RATES

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

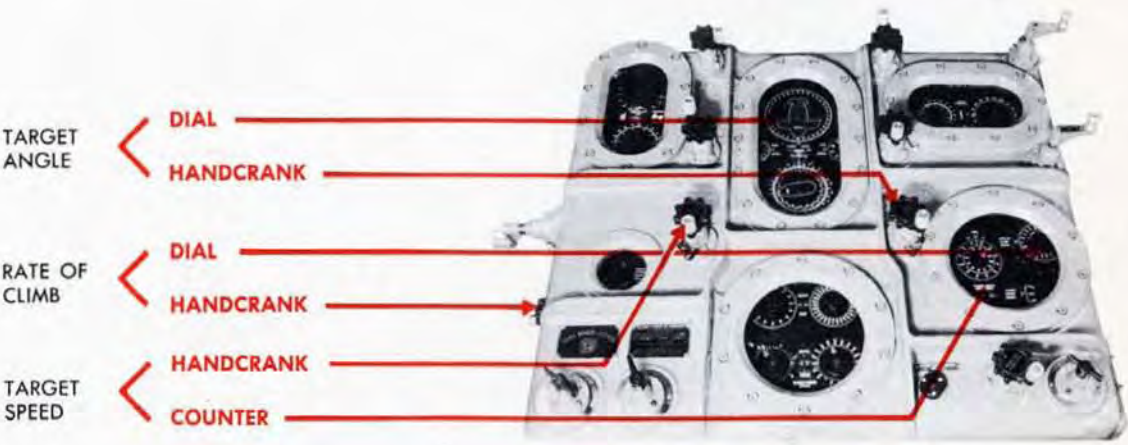
The Rate Control Computing Mechanism used in Automatic and Semi-automatic Rate Control is not designed to compute corrections to the Target Motion inputs when Target Speed is less than about 70 knots. For this reason, Local Control and Manual Rate Control are the only types of Rate Control which can 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.

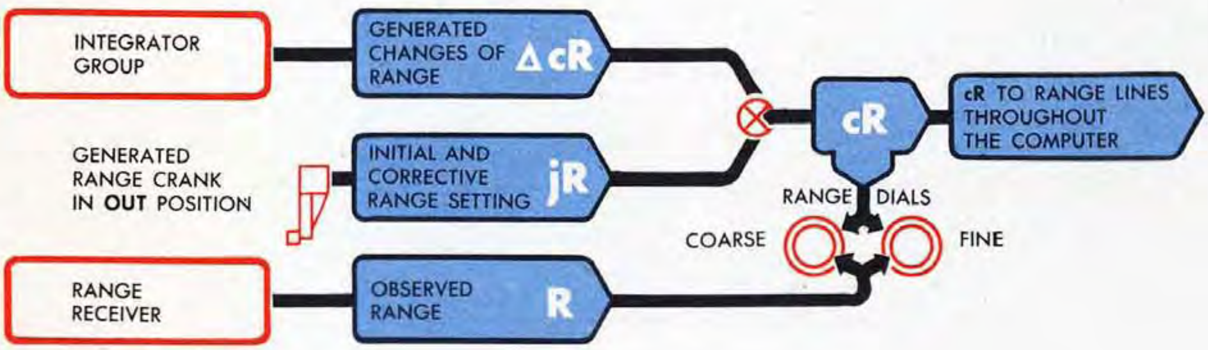
Information that will help the Operators determine which of the Target Motion quantities should be corrected is contained in the chapter on Operating Instructions, page 128.

How the dials receive observed and generated values

Range

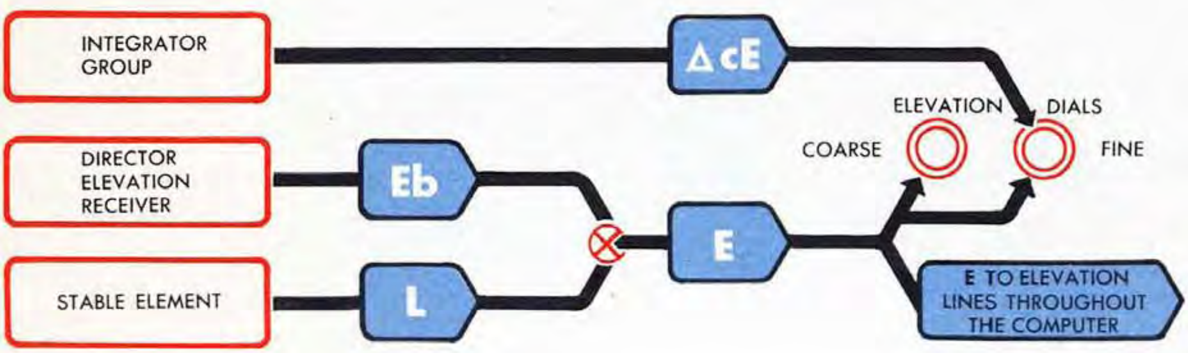
Observed Range is transmitted from the Director to the Range Receiver in the Computer. Observed Range positions the fine and coarse inner Range Dials. Generated Range, *cR*, positions all the other Range lines in the Computer, and the fine and and coarse outer Range Dials.

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.



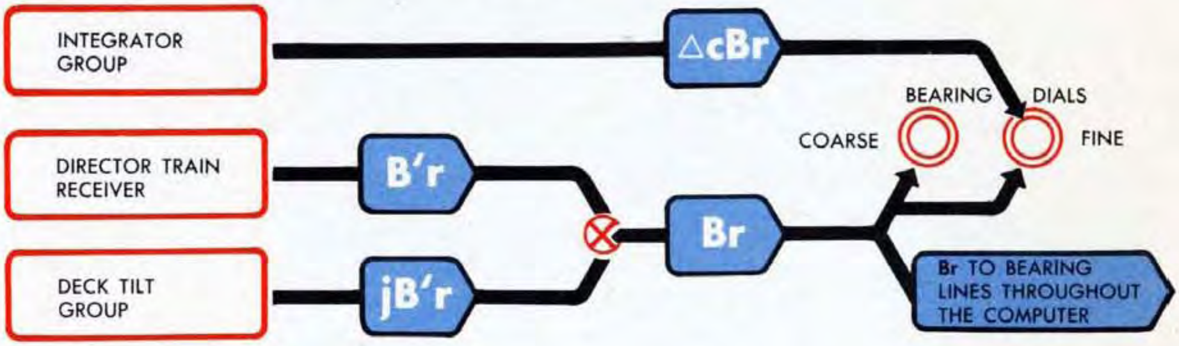
Elevation

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, $\triangle cE$, from the Integrator Group, turn the Generated Elevation Dial.

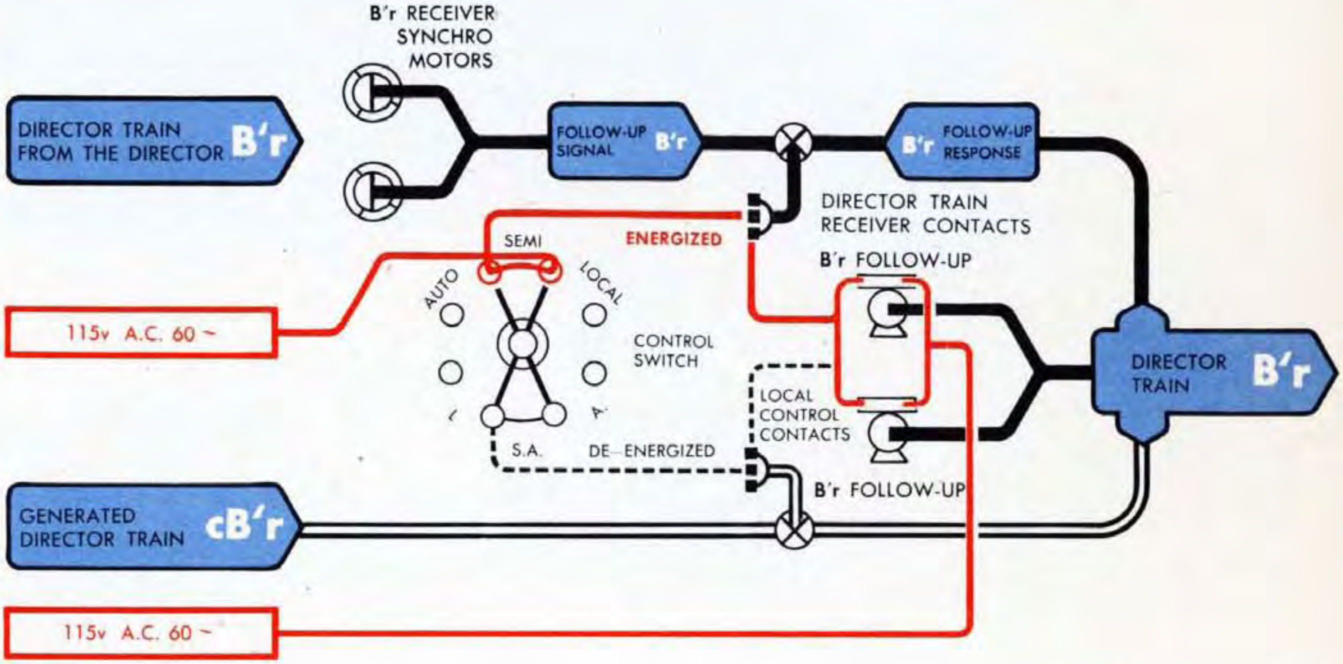


Bearing

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.



 Quick Reference Index

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.

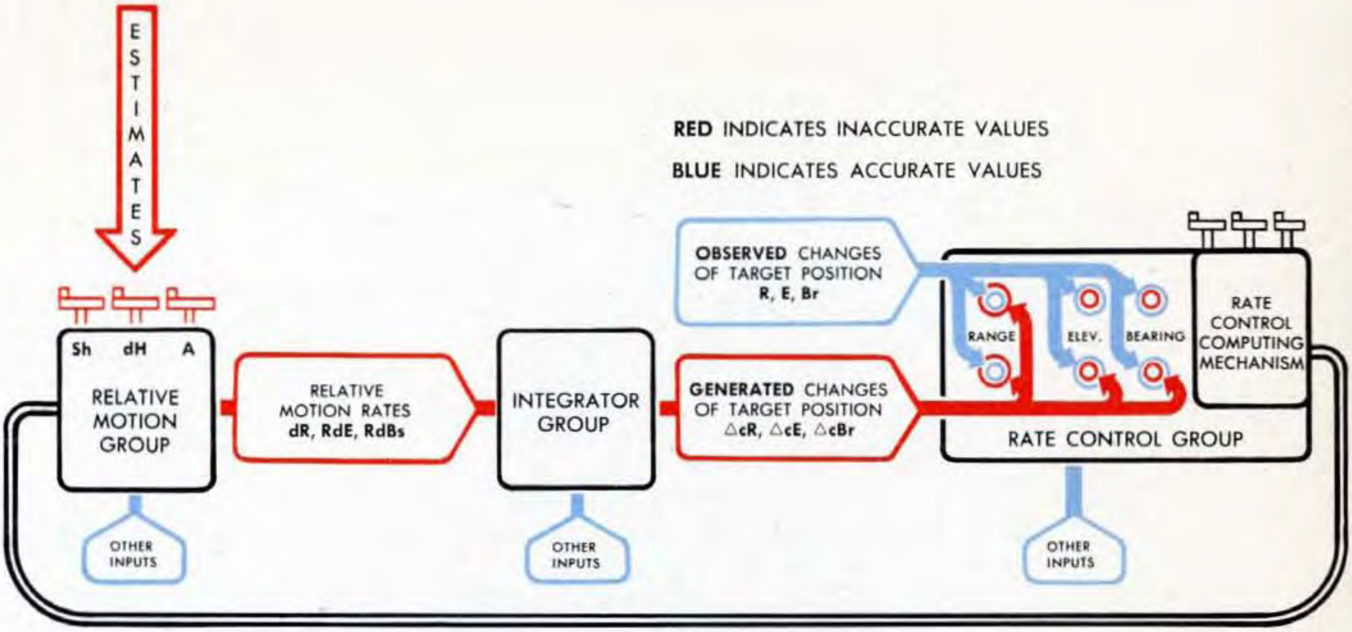
If the Generated Elevation Dial begins to turn faster or slower than the fine Observed Elevation Dial, the Elevation Operator uses the Generated Elevation Crank to put enough Elevation Rate Correction, *jEc*, into the Rate Control Computing Mechanism to make the Elevation Dials turn together.

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.

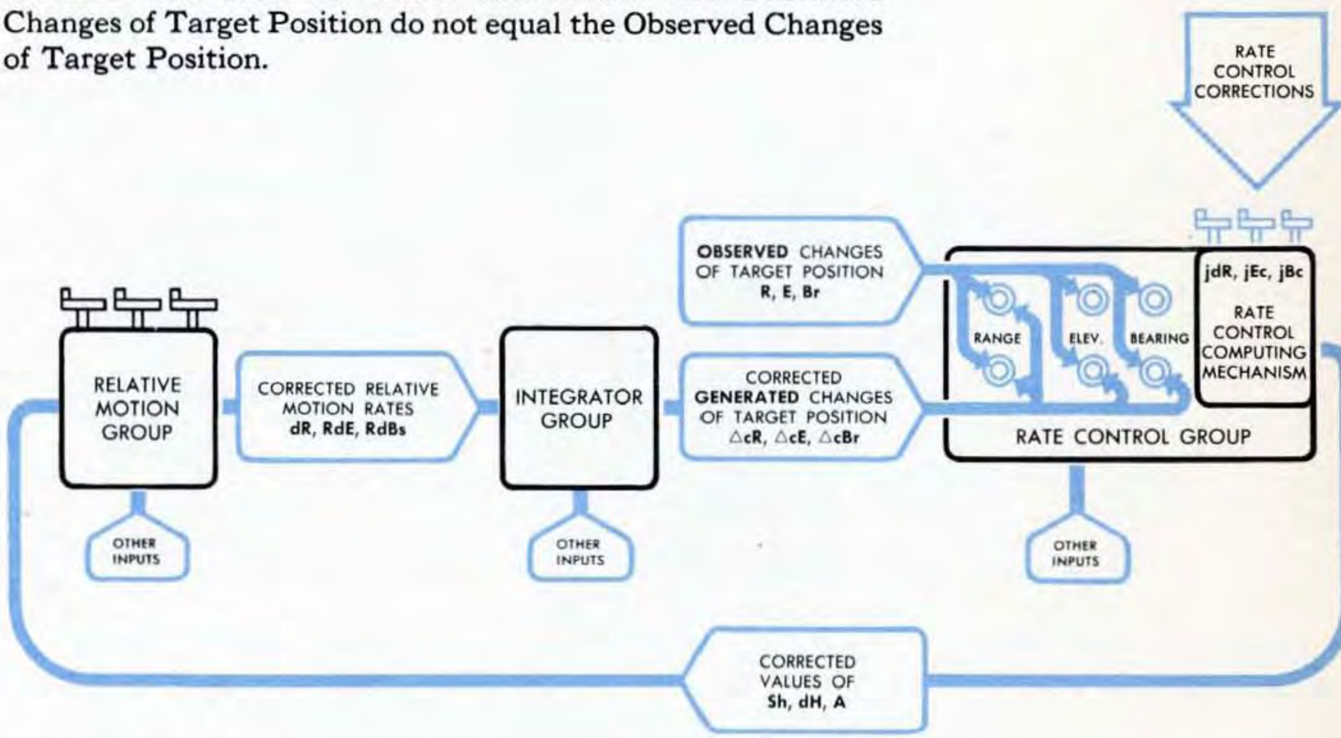
The Rate Control Computing Mechanism uses the three Rate Corrections, *jdR*, *jEc*, and *jBc* to compute a correction to *dH* and corrected values of *Sh* and *A*. These values are then transmitted mechanically to the Relative Motion Group.

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.

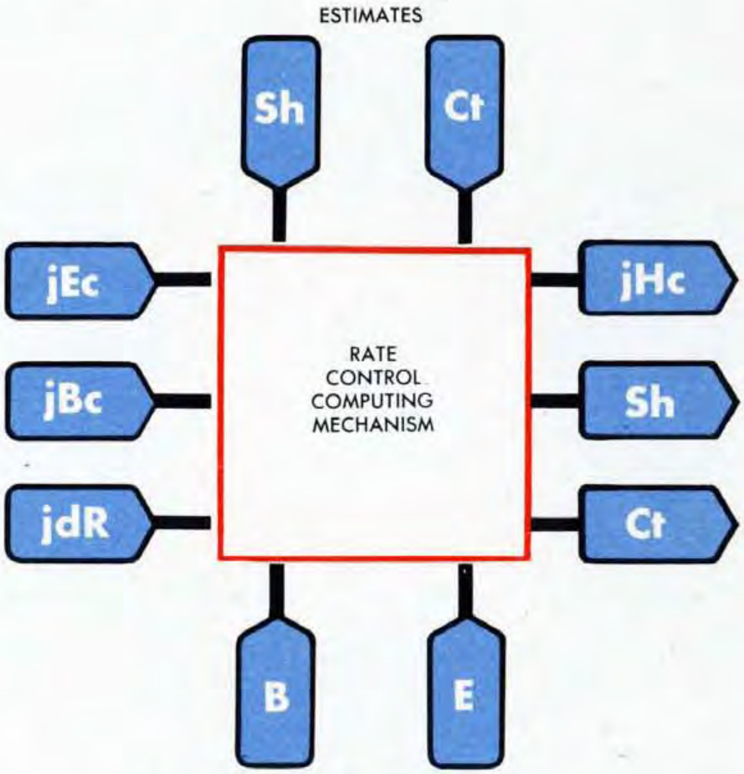
The RATE CONTROL COMPUTING MECHANISM

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:

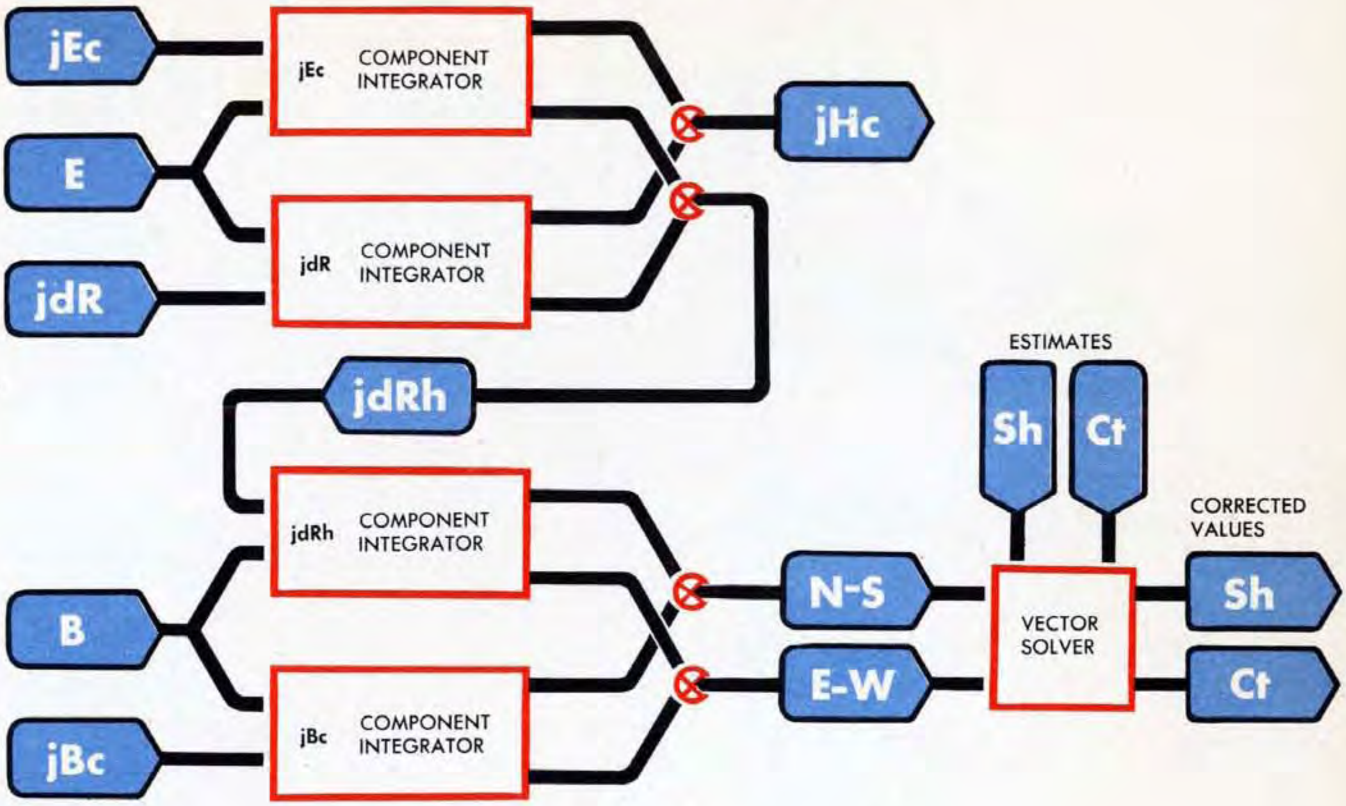
1 Linear Elevation Rate Correction, *jEc*
2 Linear Deflection Rate Correction, *jBc*
3 Direct Range Rate Correction, *jdR*
4 True Target Bearing, *B*
5 Observed Target Elevation, *E*
6 Horizontal Target Speed (estimated), *Sh*
7 Target Course (estimated), *Ct*



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

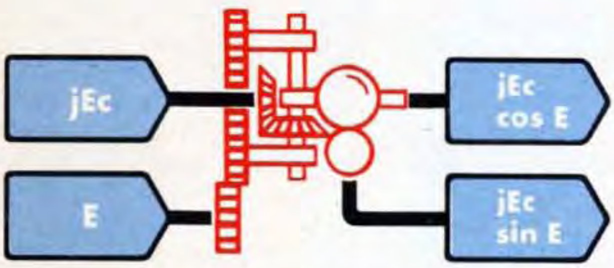
An East-West Correction to the Horizontal Target Speed Vector

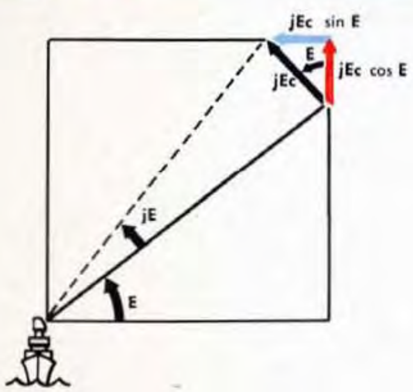
The Vector Solver is initially positioned by the estimated values of Horizontal Target Speed, *Sh*, and Target Course, *Ct*. The *N-S* and *E-W* Speed Corrections reposition the Vector Solver racks. Moving these racks corrects the previous Vector Solver values of *Sh* and *Ct*. The outputs of the Vector 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





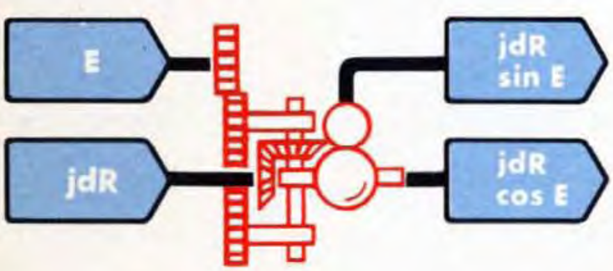
Elevation Rate Correction, *jEc,* is one input to the *jEc* Integrator. *jEc* turns the input roller. Target Elevation, *E,* is the other input. *E* positions the angular input gear.

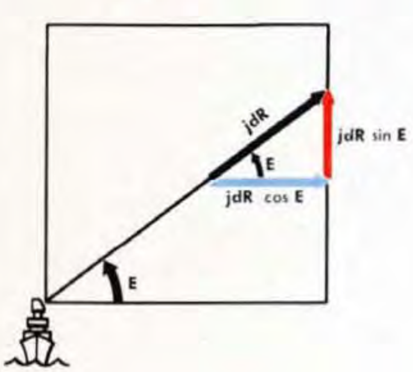
The *jEc* Component Integrator breaks *jEc* into vertical and horizontal components:

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.

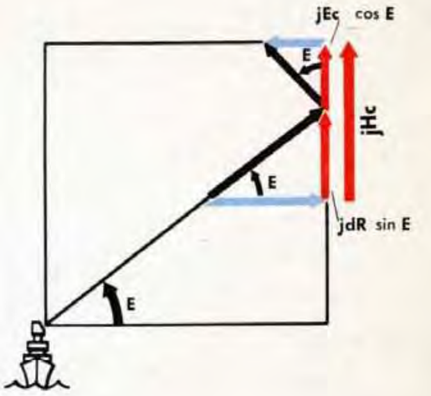
The *jdR* Component Integrator breaks *jdR* into vertical and horizontal components:

1 The vertical component is *jdR* sin *E*.

2 The horizontal component is *jdR* cos *E*.

The components of jEc and jdR are combined

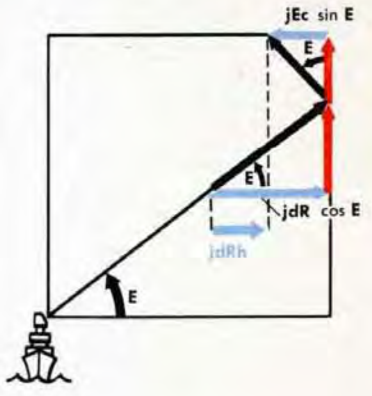
The *jEc* and *jdR* Component Integrators each produce one vertical and one horizontal component.



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.

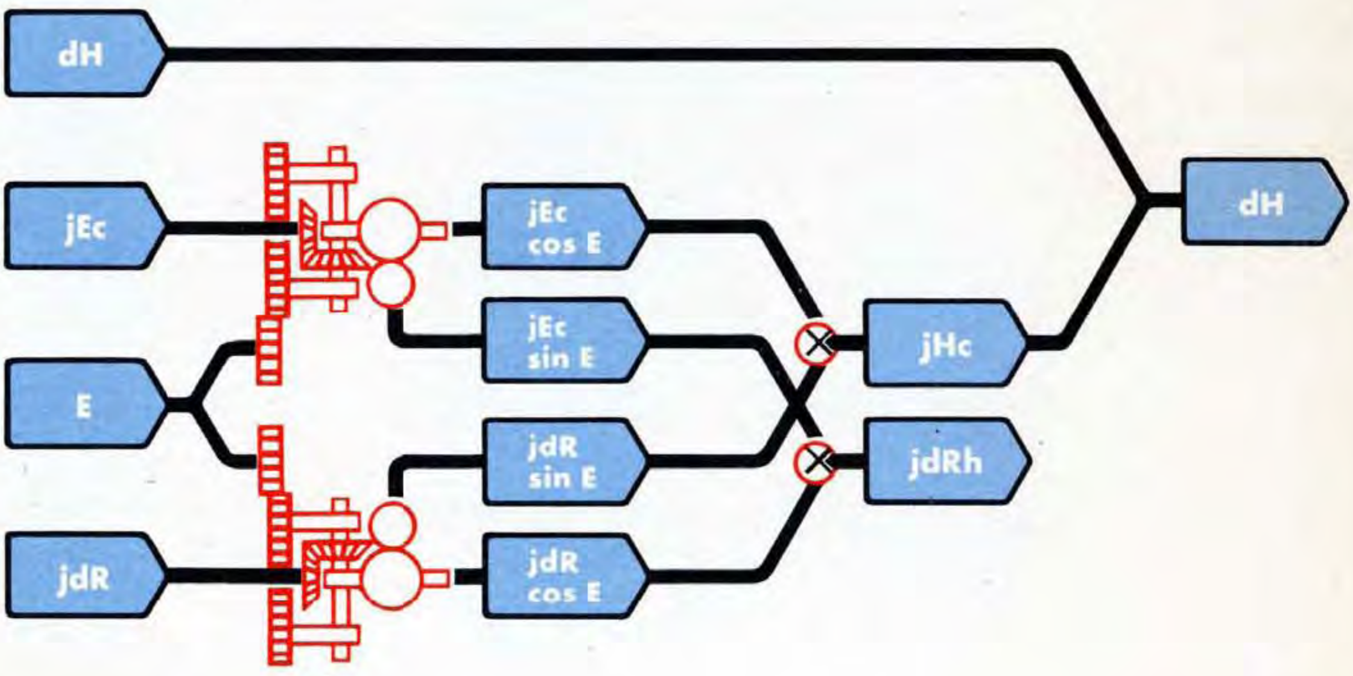


The two horizontal components, one from each component integrator, are combined, giving *jdRh*. In this example, one component is subtracted from the other because they are in opposite directions.

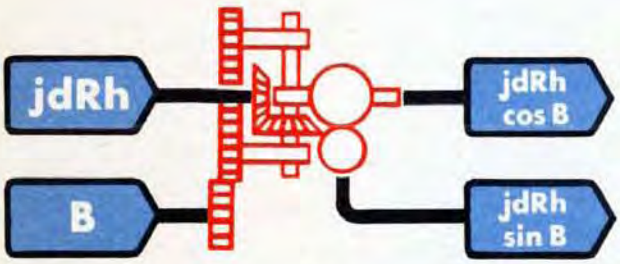
$$jdR \cos E - jEc \sin E = jdRh$$

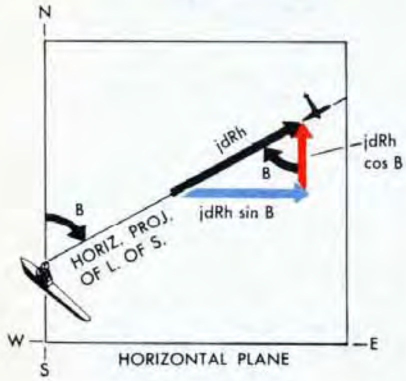
jdRh is a horizontal correction in the plane containing the Line of Sight. It is not a correction to a Target value, but is used as an input to the jdRh Component Integrator. jdRh is called the Horizontal Range Rate Correction.

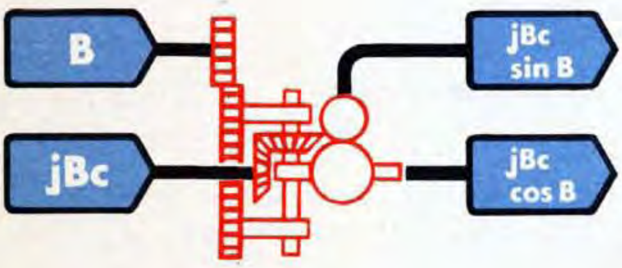
Remember that the job of the Rate Control Computing Mechanisms is to produce corrections to *Sh, dH,* and *Ct*. The first of these three corrections, *jHc*, is computed by the first pair of component integrators and is used to correct Rate of Climb, *dH*.

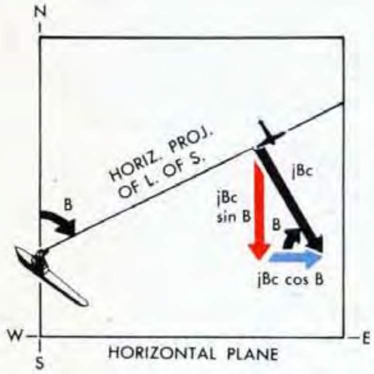


The BEARING COMPONENT INTEGRATORS









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.

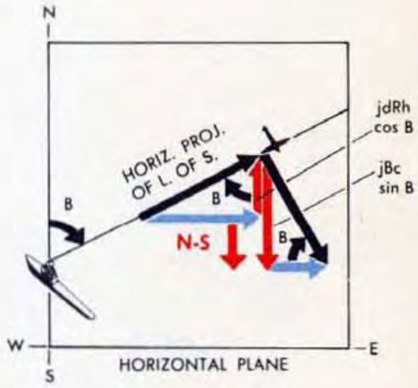
The outputs are two components at right angles to each other:

1 Along the *E-W* axis, *jBc* cos *B*.

2 Along the *N-S* axis, *jBc* sin *B*.

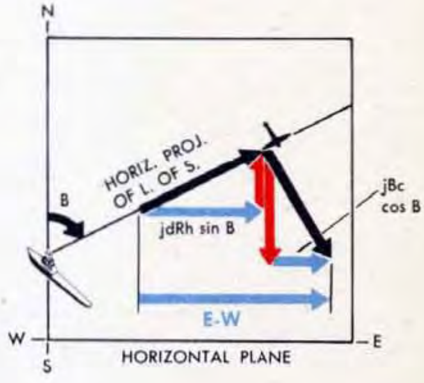
The components of jdRh and jBc are combined

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.

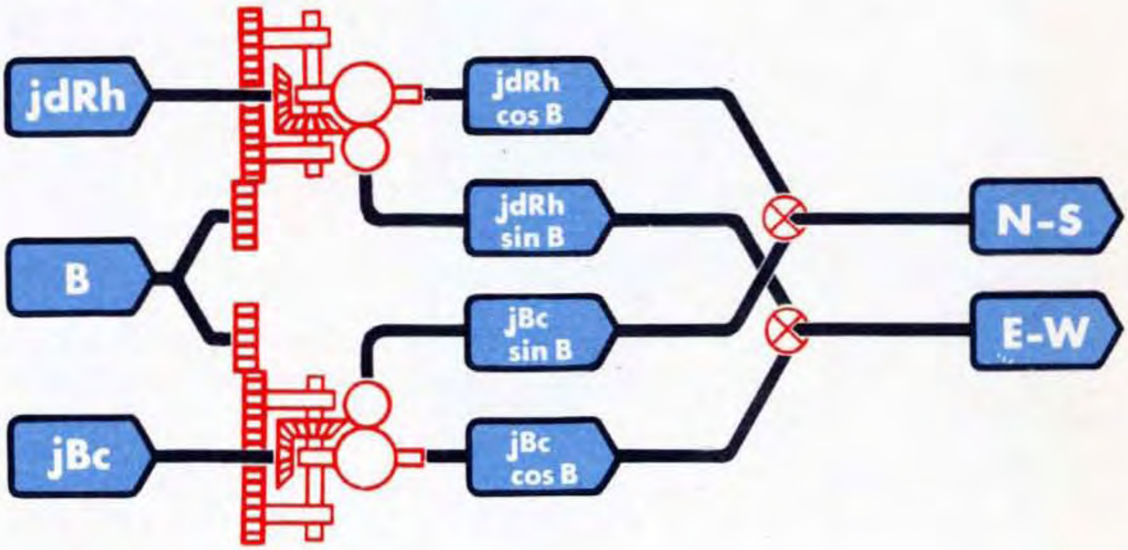
$$jBc \sin B - jdRh \cos B = \text{total } N\text{-}S \text{ correction.}$$



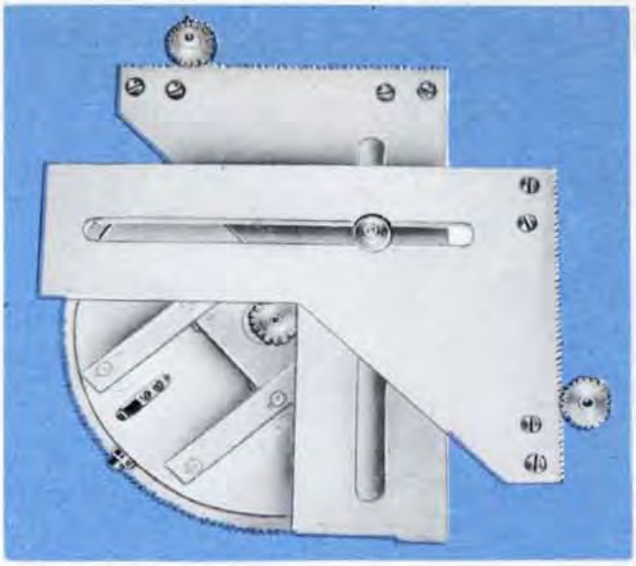
The two *E-W* components, one from each component integrator, are combined to obtain the total *E-W* correction. Since they are in the same direction in this example, the components are added.

$$jBc \cos B + jdRh \sin B = \text{total } E\text{-}W \text{ correction.}$$

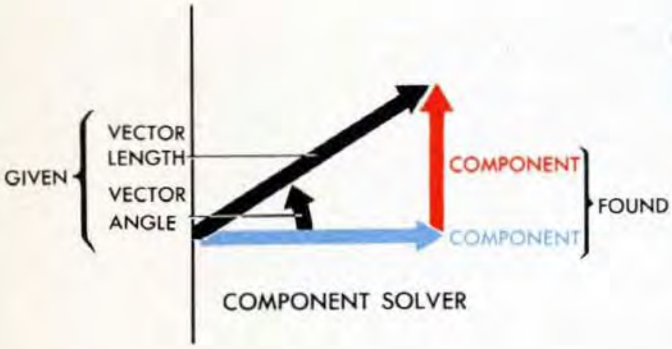
These *N-S* and *E-W* corrections are sent to the Vector Solver, where they correct the estimated values of Horizontal Target Speed, *Sh*, and Target Course, *Ct*.



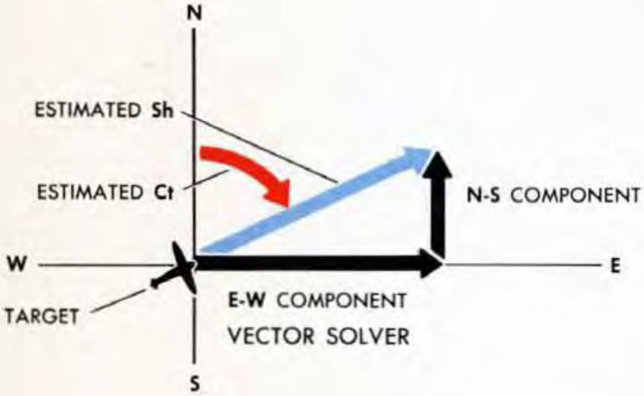
The VECTOR SOLVER



The Vector Solver is a component solver which can also work in reverse. For details, see OP 1140, page 106.

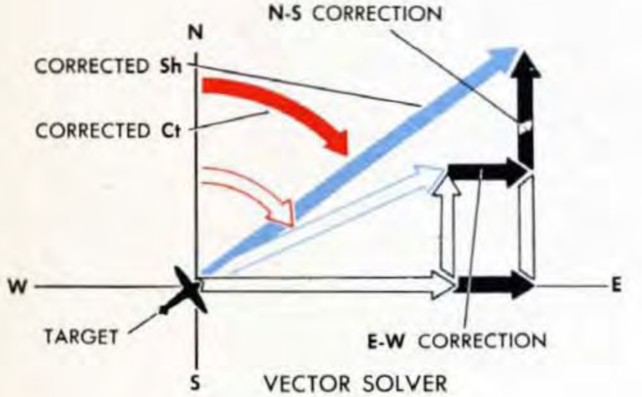


The estimated manual inputs of Horizontal Target Speed, *Sh*, and Target Course, *Ct*, set up a vector in the Vector Solver. This vector positions the Vector Solver racks at the values of the *N-S* and *E-W* components of this vector. During this operation, the Vector Solver acts as an ordinary component solver.

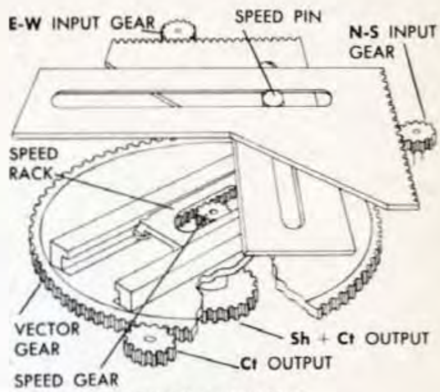


When the *N-S* and *E-W* Rate Corrections coming from the component integrators reposition these same racks, the racks change the length and direction of the vector and so correct the values of *Sh* and *Ct*.

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.



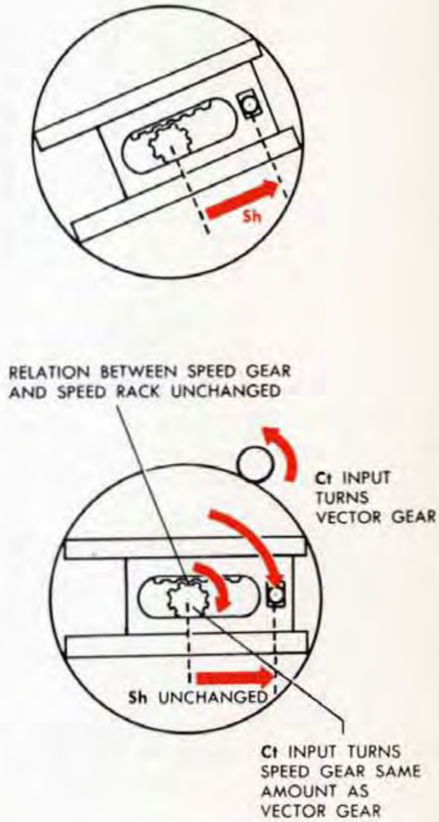
The vector solver outputs



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*.

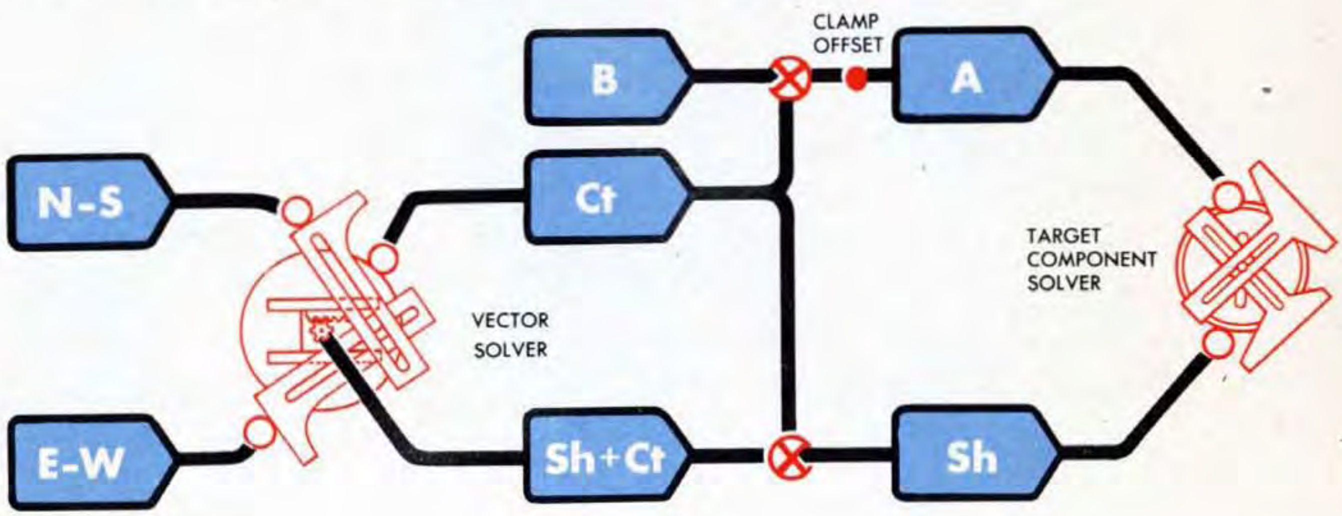


When there is a change in the *direction* of the vector only, both the vector gear AND THE SPEED OUTPUT GEAR must be turned together in order to keep the same vector length or speed. The speed gear is therefore turned for every input of *Ct* as well as for inputs of *Sh*, and the position of this speed 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°.

$$B + 180^\circ - Ct = A$$

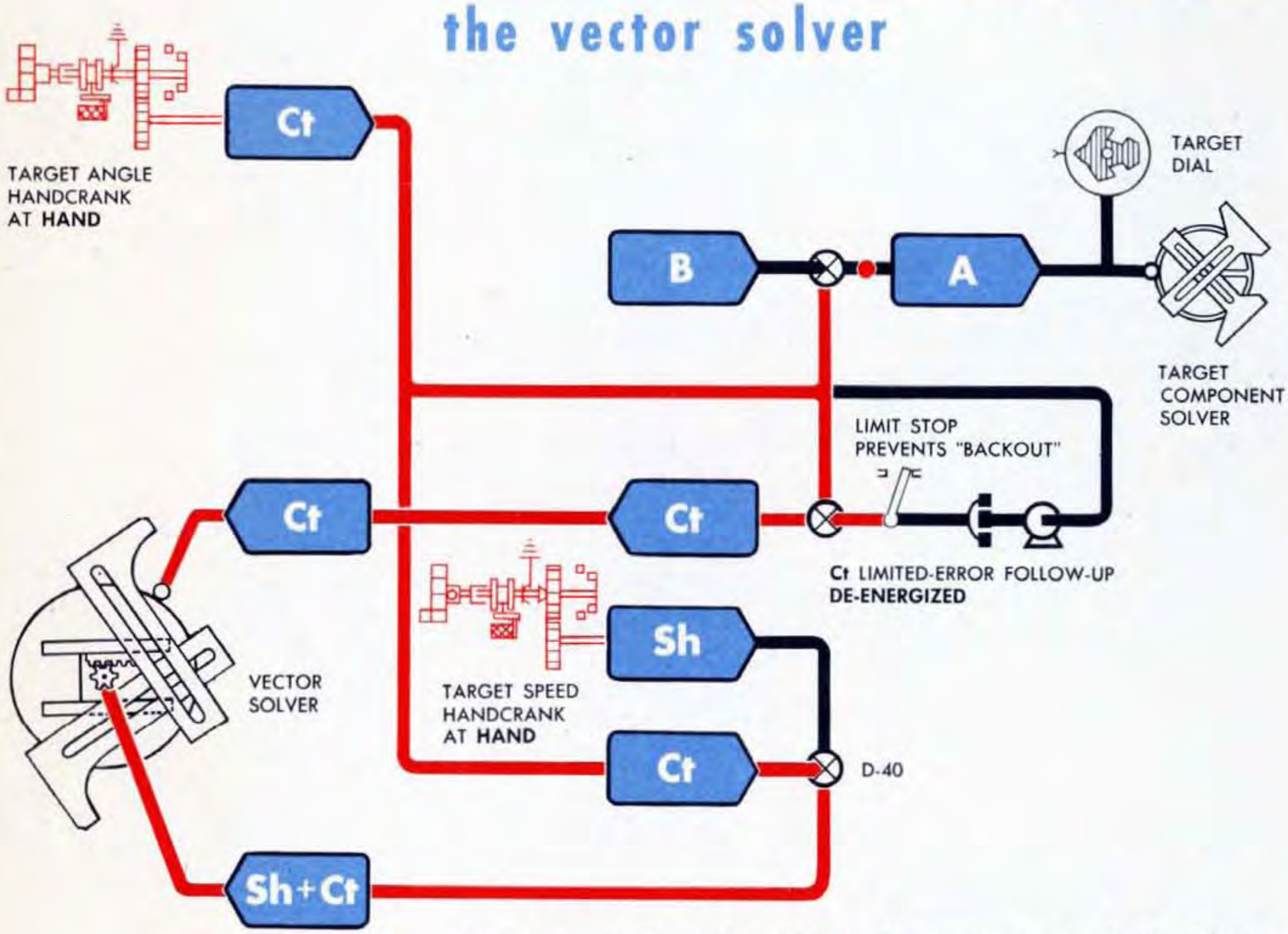
The corrected values of Target Angle, *A*, and Target Speed, *Sh*, go to the Target Component Solver in the Relative Motion Group. The Vector Solver is aided in positioning both the *Sh* and *Ct* lines by a special limited-error follow-up on each line.



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.

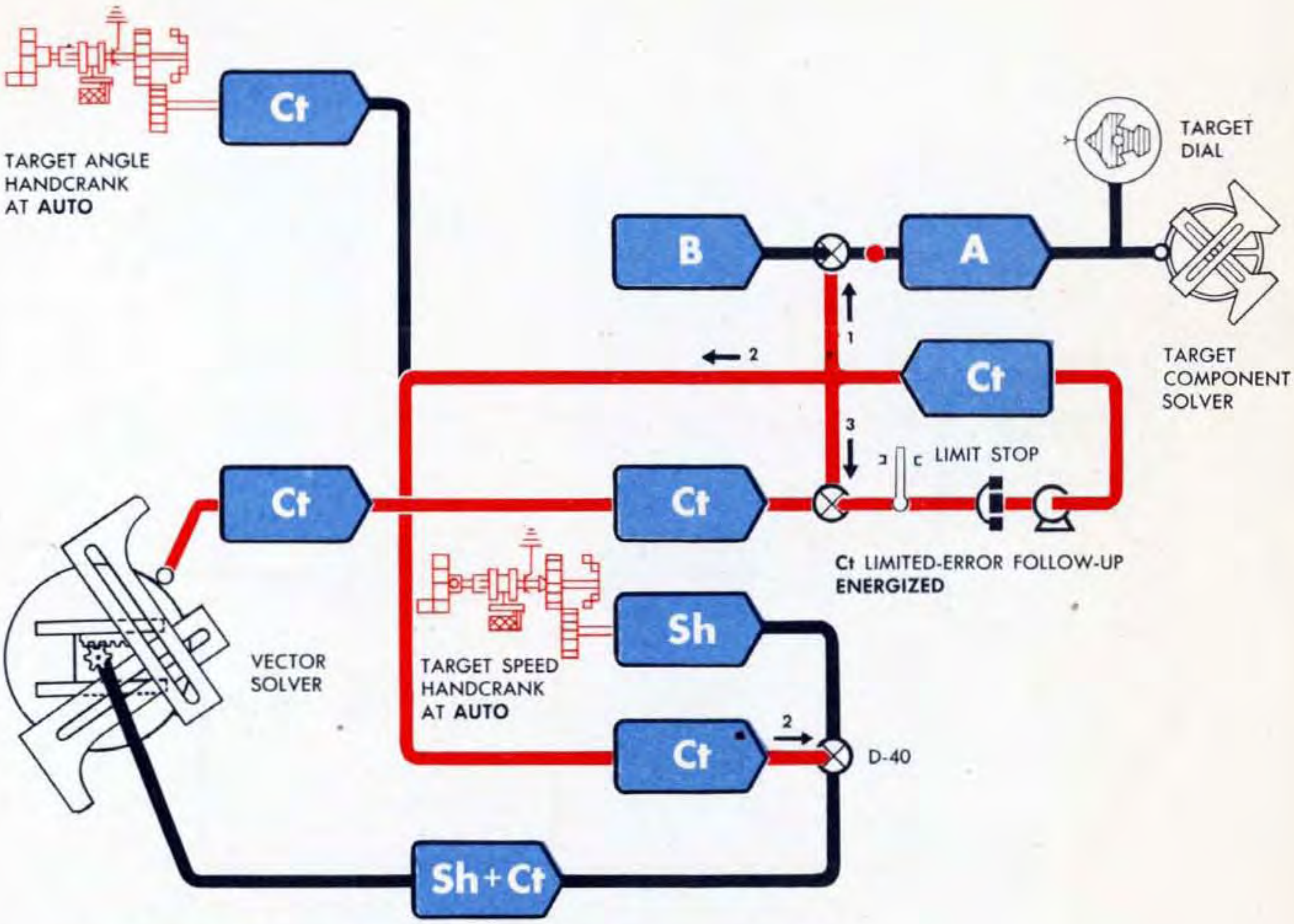
How manual Ct inputs position the vector solver



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*.

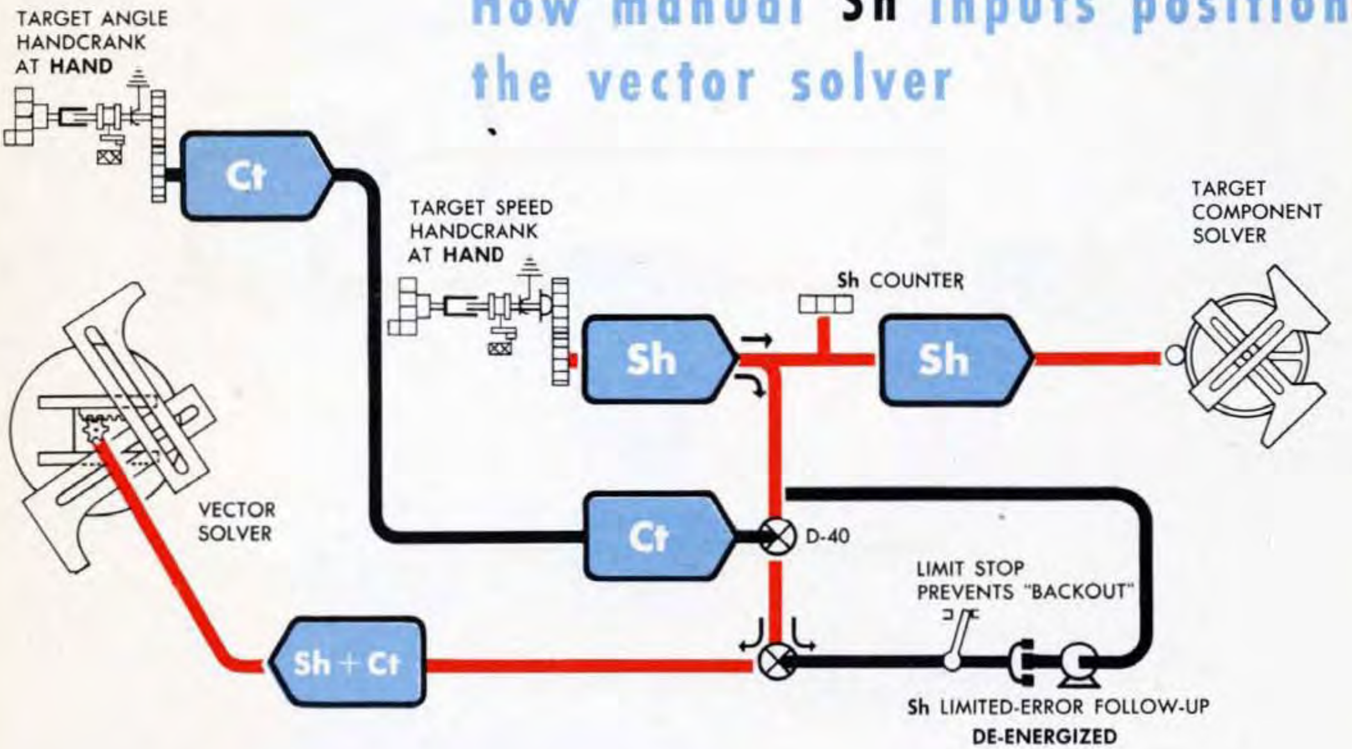
2. The differential at which *Ct* is subtracted from the *Sh* + *Ct* output of the Vector Solver to keep *Sh* at its proper value.

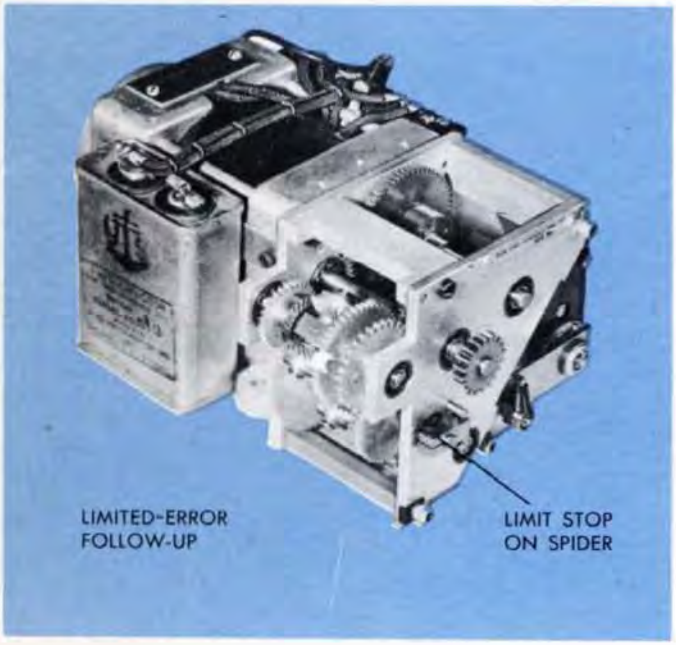
3. The differential of the *Ct* Follow-up, as the response to the signal from the Vector Solver.

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.

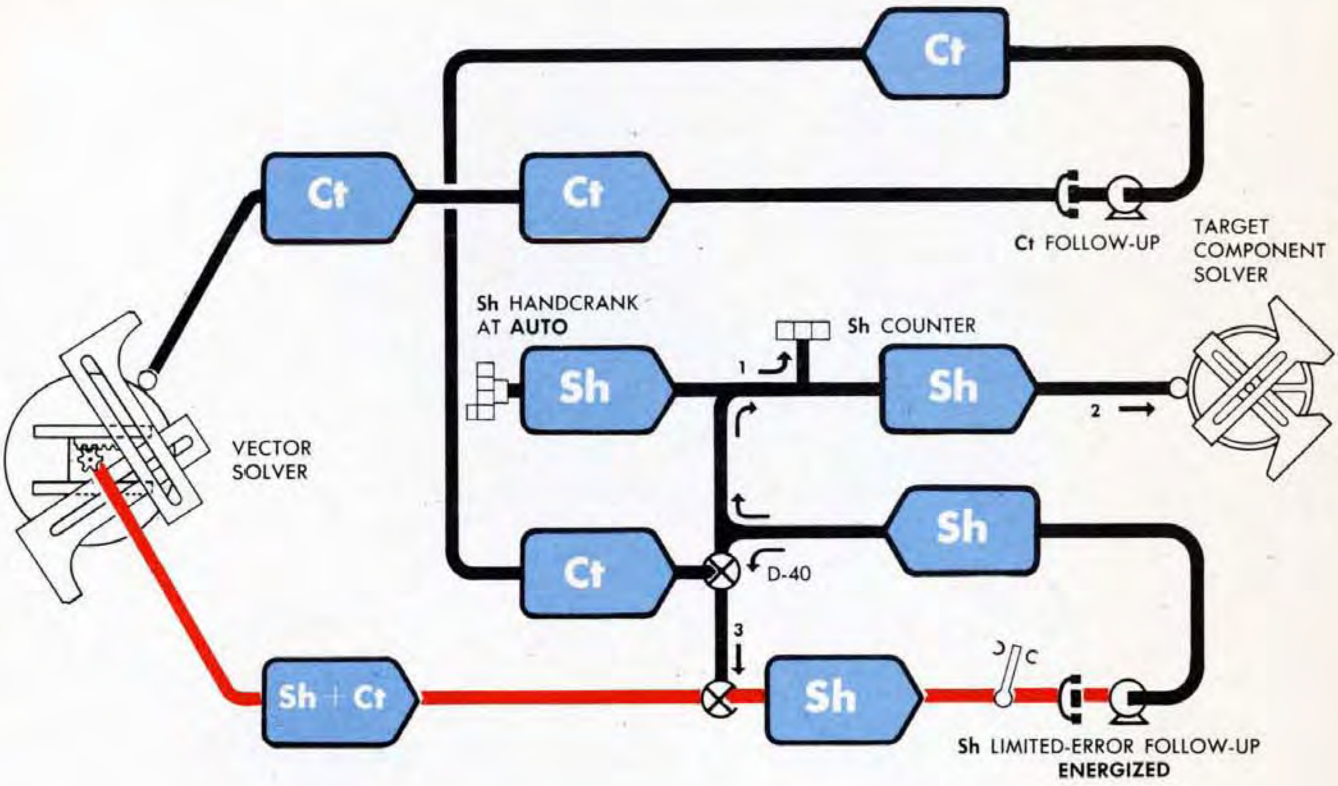
How manual Sh inputs position the vector solver





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.

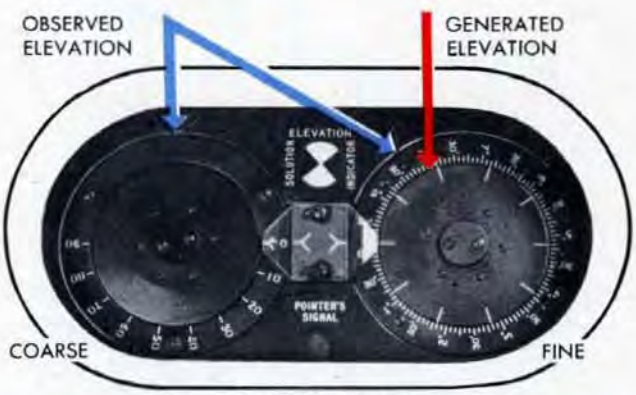
In Semi-automatic Operation, the Computer Operators turn the Generated Cranks to put Rate Corrections into the Rate Control Computing Mechanism to keep the Generated and Observed Dials turning together.

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.

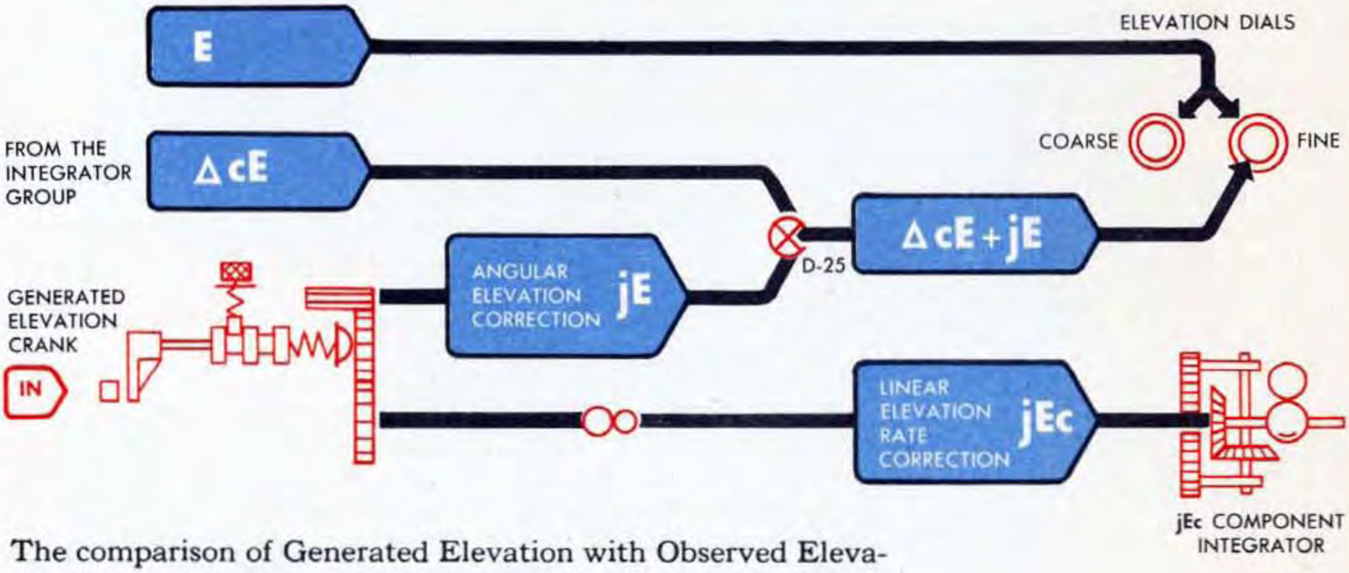
If the Generated Elevation Dial turns faster or slower than the fine Observed Elevation Dial, and the Pointer's Signal is red indicating that the Pointer's sight is on the Target, the Elevation Operator turns the *jE* Crank in its IN position until the graduations on the dials rotate together.

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.

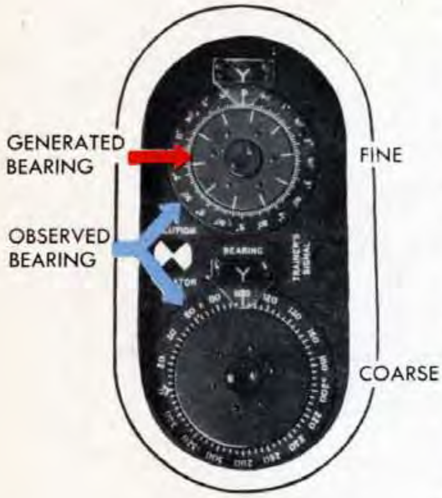
The job of the Rate Control Computing Mechanism is to correct *Sh, dH,* and *A.* Since *Sh* and *dH* are linear rates, *Angular* Elevation Correction, *jE,* must be converted into a *linear rate* correction before it can be used in correcting *Sh* and *dH.* The Linear Elevation Rate Correction, *jEc,* 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



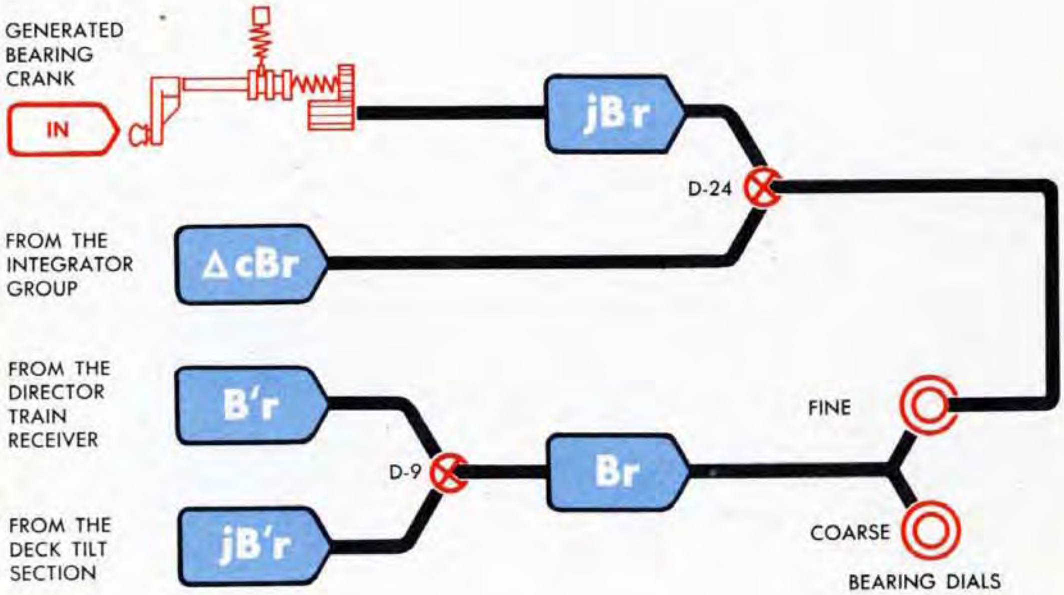
These are the Bearing Dials. They operate in the same way as the Elevation Dials.

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.

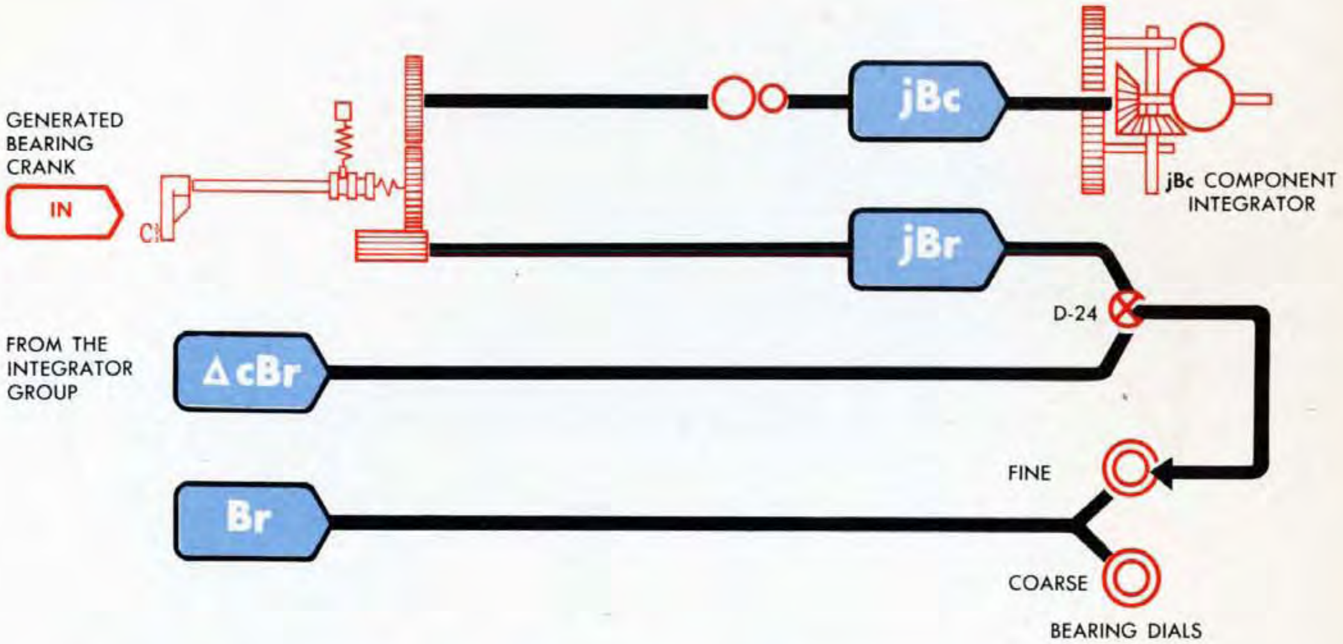
If the Generated Relative Target Bearing Dial turns faster or slower than the fine Observed Relative Target Bearing Dial, and if the Trainer's Signal is red indicating that the Trainer's sight is on the Target, the Bearing Operator corrects Generated Bearing by turning the *jBr* Crank in its IN position.

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 continuosly 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.*

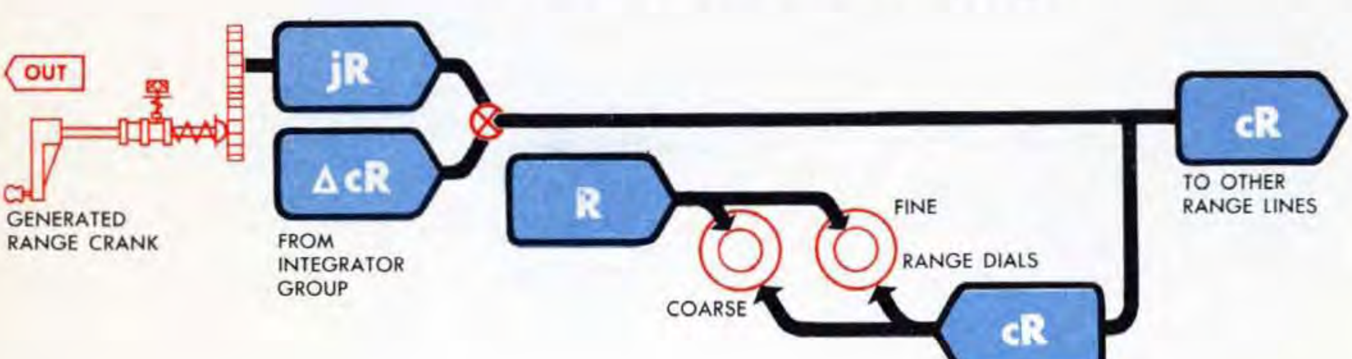
Making range and range rate corrections

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.

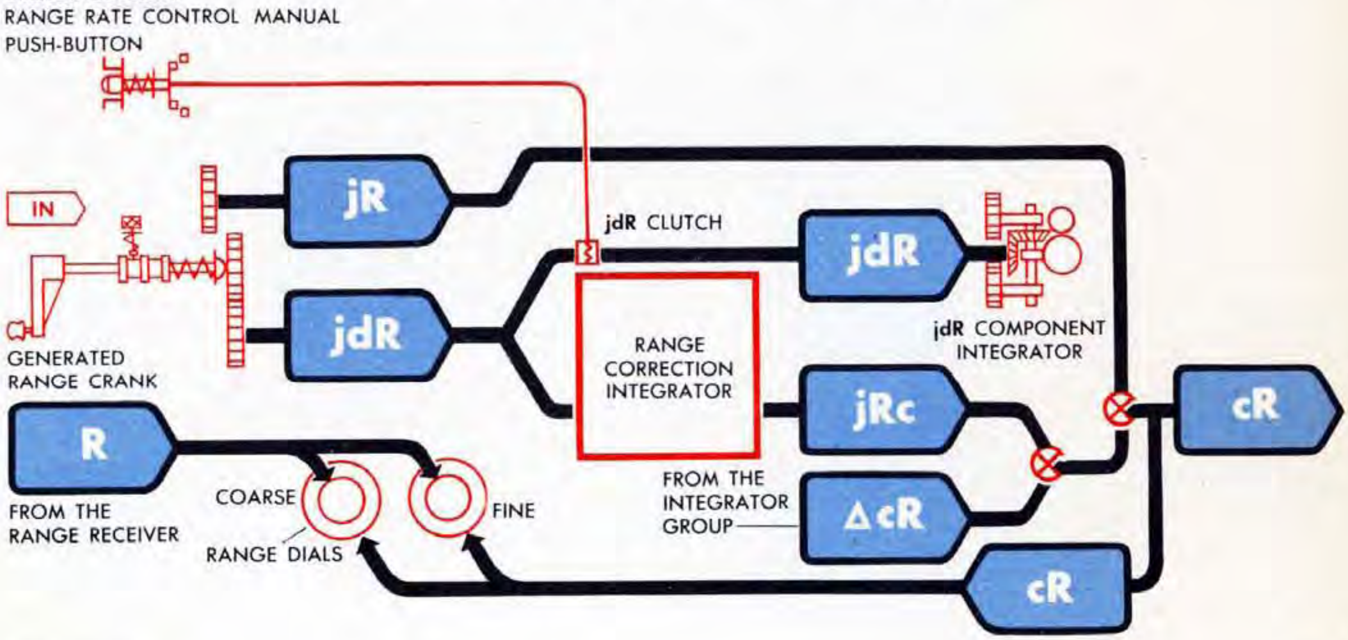
Now the Time Motor is turned on. Immediately the Range Integrator begins to compute continuous Changes of Generated Range, $\triangle cR$, which are added to the initial *jR* input, giving continuous values of Generated Range, *cR*. If *cR* changes at the same rate as *R*, both sets of Range Dials *turn 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.

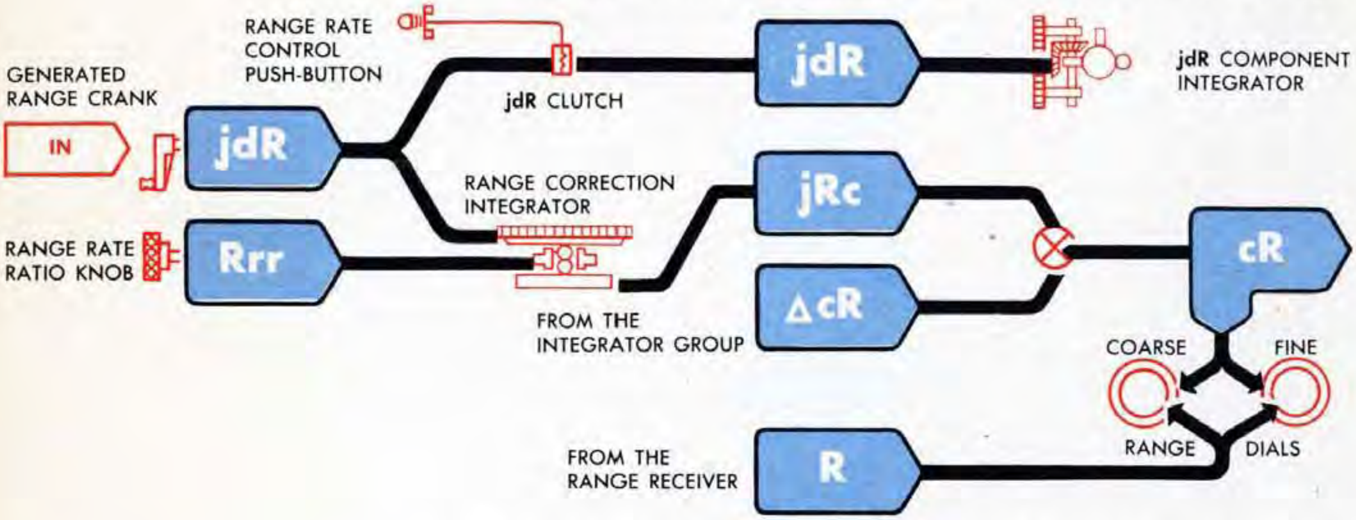
The ratio between the Linear Range Correction and the Range Rate Correction may be varied by changing the position of the Range Correction Integrator carriage. This is accomplished by turning the Range Rate Ratio Knob.



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.



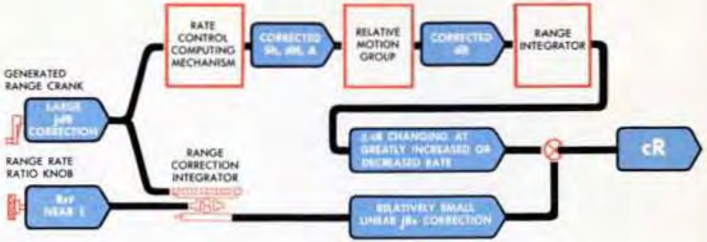
The ratio between the sizes of the Rate Correction, *jdR,* and the Linear Correction, *jRc,* is controlled by the position of the carriage of the Range Correction Integrator. This carriage is positioned by turning the Range Rate Ratio, *Rrr,* Knob. The size of *Rate* Correction, *jdR,* is determined 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

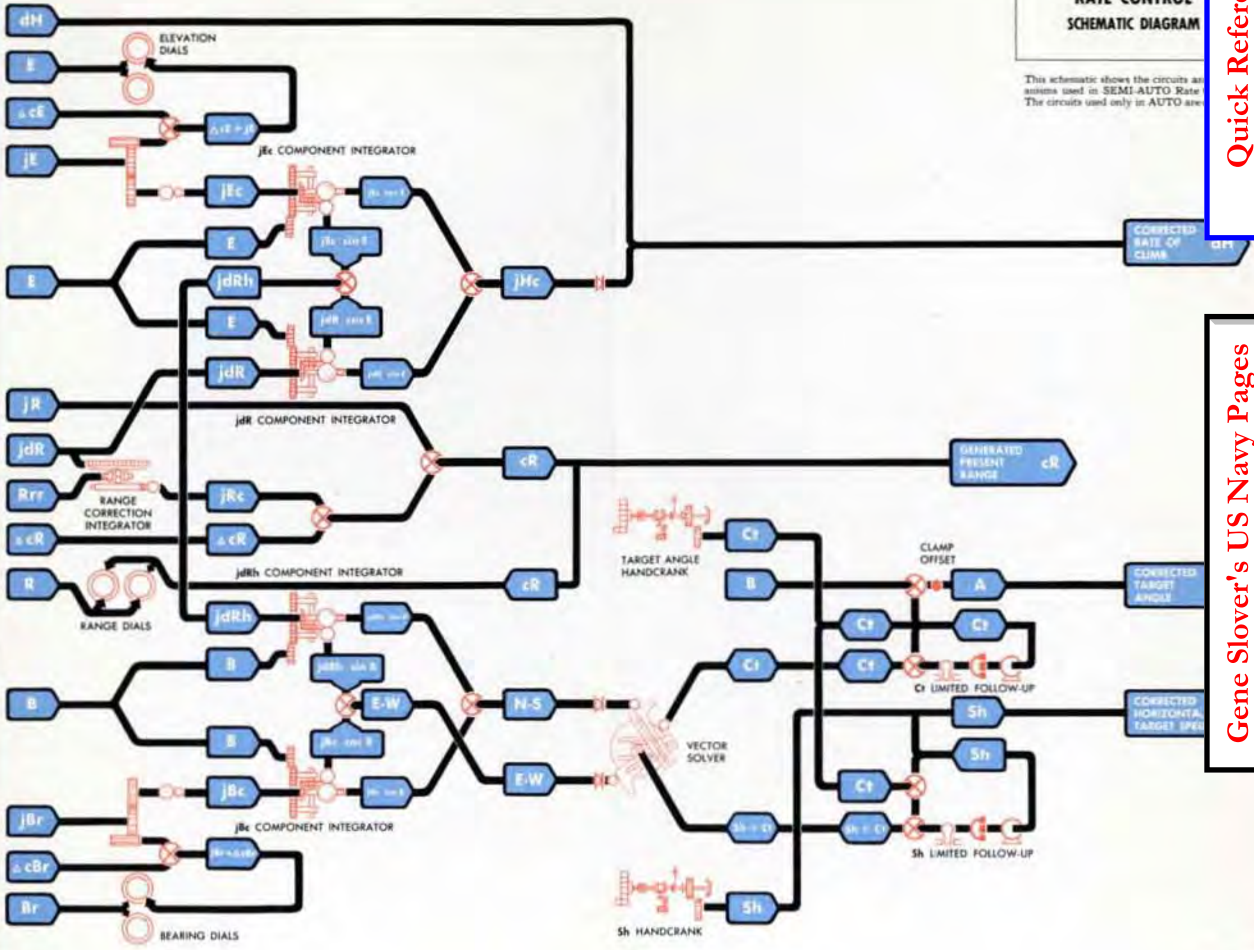


When the difference between *cR* and *R* is small, but there is a *big* difference between the rates at which *cR* and *R* are changing, the *Rrr* Knob is turned toward 1, positioning the Range Correction Integrator carriage near the center of the integrator disk. With the carriage near the center, a 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
SEMI-AUTOMATIC RATE CONTROL
SCHEMATIC DIAGRAM

This schematic shows the circuits an... mechanisms used in SEMI-AUTO Rate... The circuits used only in AUTO are...



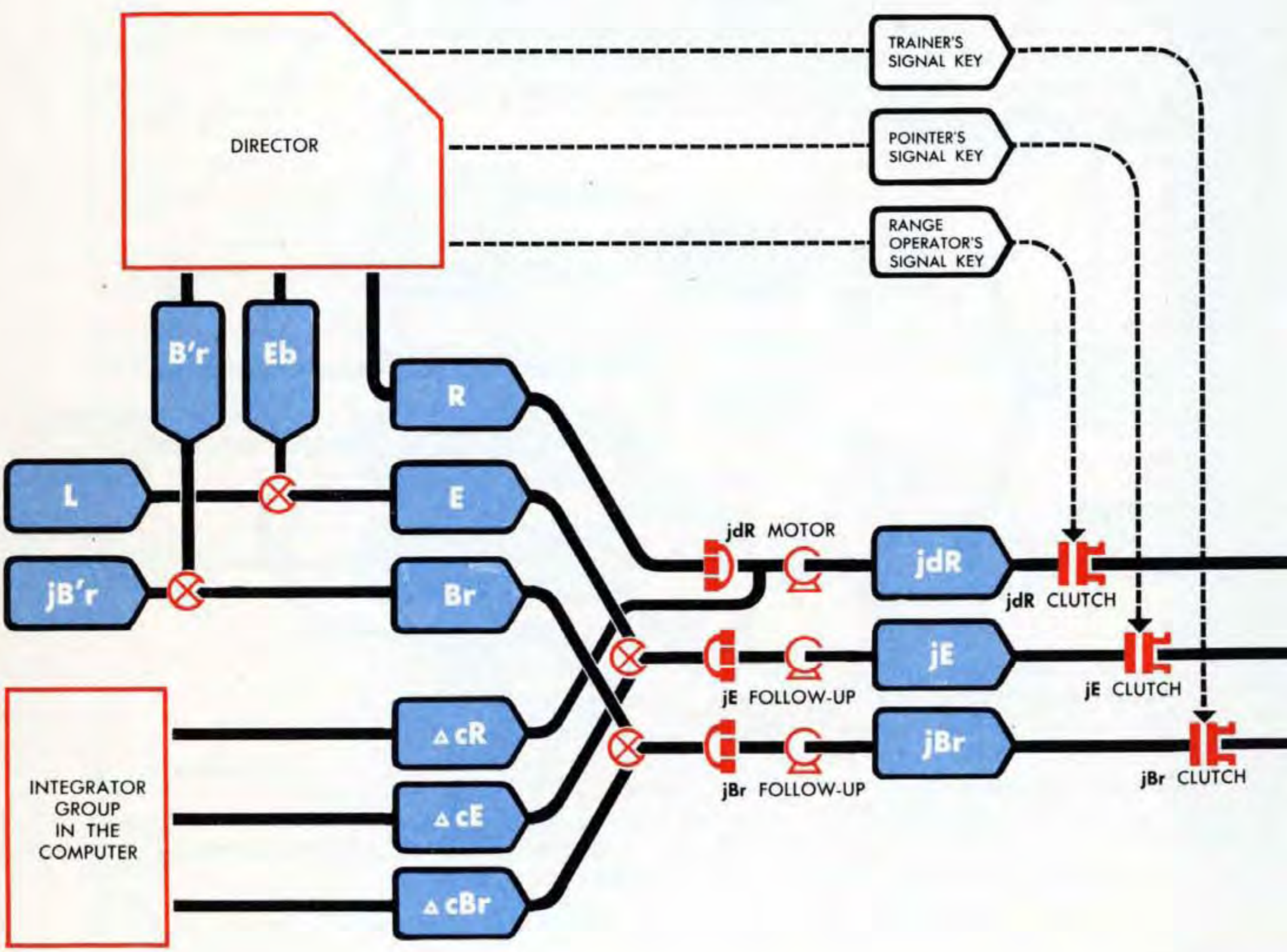
AUTOMATIC RATE CONTROL

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



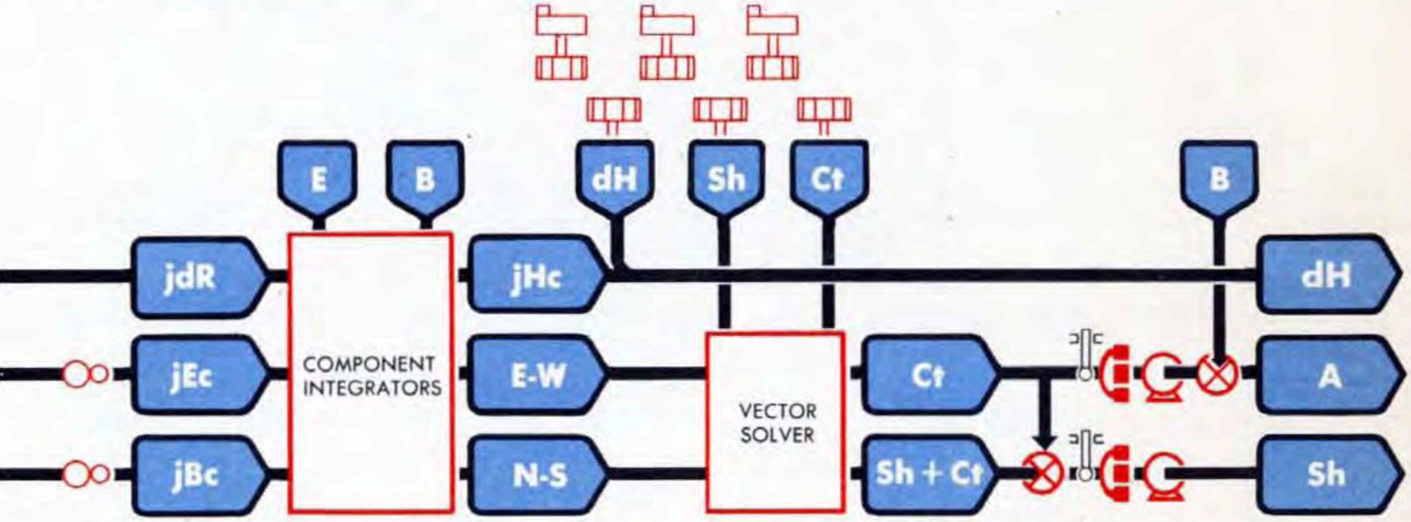
Gene Slover's US Navy Pages Quick Reference Index

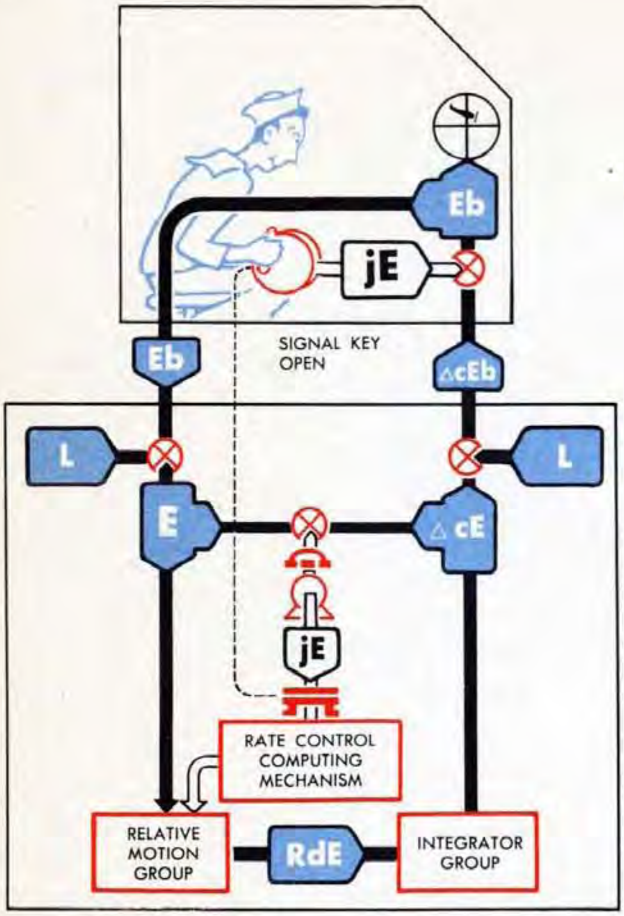
In Automatic, Semi-automatic, and Manual Rate Control, the Pointer, Trainer, and Range Operator turn their handwheels to put in corrections which make up the differences between the Generated Changes of Target Position and the Observed Changes of Target Position. They do this to keep their sights on the Target and to send down to the Computer the correct values of Observed Target Position at every instant.

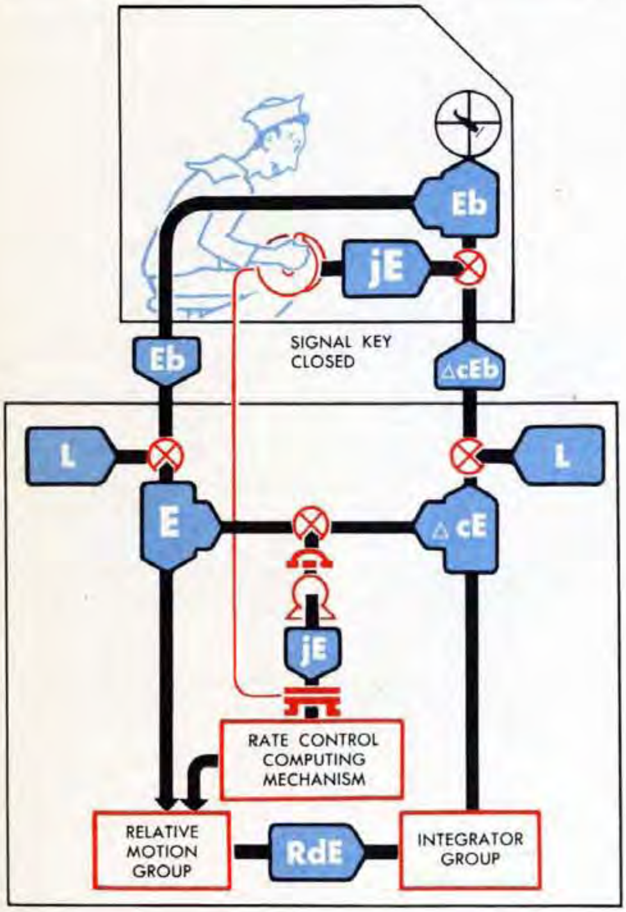
In Automatic Rate Control, the Director Operators have the additional responsibility of putting all or part of their handwheel corrections into the Rate Control Computing Mechanism in the Computer. They put these corrections in by closing their Rate Control signal keys as they turn their handwheels to 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, △*cEb*, are not keeping the Pointer's sight on the Target.

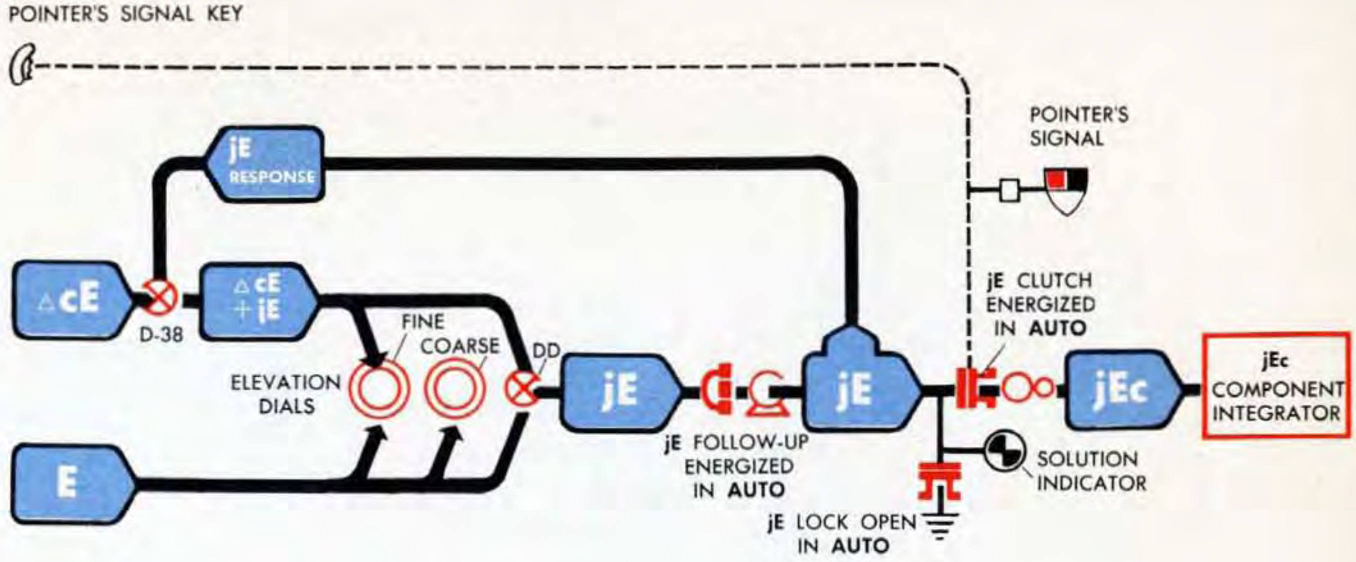
The Pointer's sight, driven by △*cEb* from the Integrator Group in the Computer, is above or below the Target and is steadily moving farther from the Target. The value of *Eb* going down to the Computer is *incorrect, E* is incorrect, and the Rate of Change of △*cE* is also incorrect.

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 △*cEb* to keep the value of *Eb* correct. In the Rate Control Group, the changes of *E* are continuously compared with △*cE*. The difference between △*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 △*cEb* at a rate which keeps the Pointer's sight on the Target automatically without any handwheel correction.

When *RdE* is correct, △*cEb* changes at the same rate as *Eb,* and △*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.

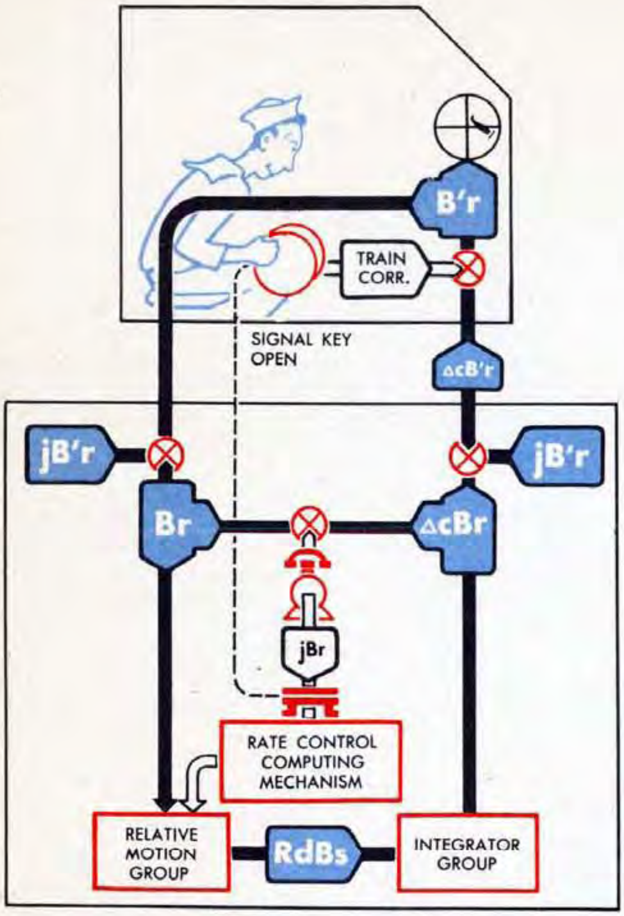
From this point on, the part played by *jEc* in the computation of corrections to Target Motion values is EXACTLY THE SAME AS IN SEMI-AUTOMATIC RATE CONTROL.

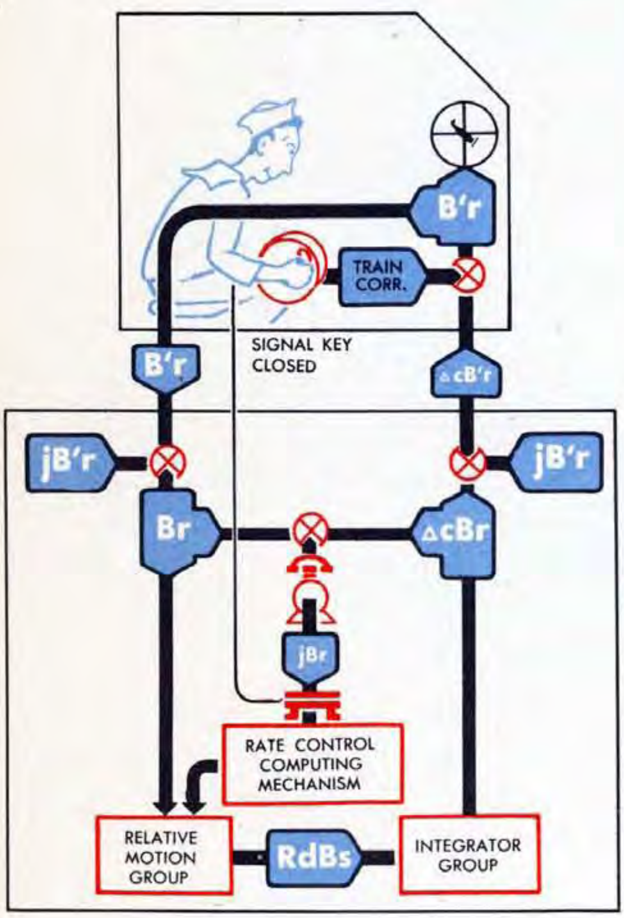
The Angular Elevation Correction, *jE*, is not only used to form Elevation Rate Correction, *jEc*, but is also driven back to differential D-38 where it is added to △*cE*. *jE* + △*cE* acts as response to the *jE* Follow-up and keeps the Generated Dial turning with the Observed Dial.

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, $\Delta cB'r$, are not keeping the Trainer's sight on the Target.

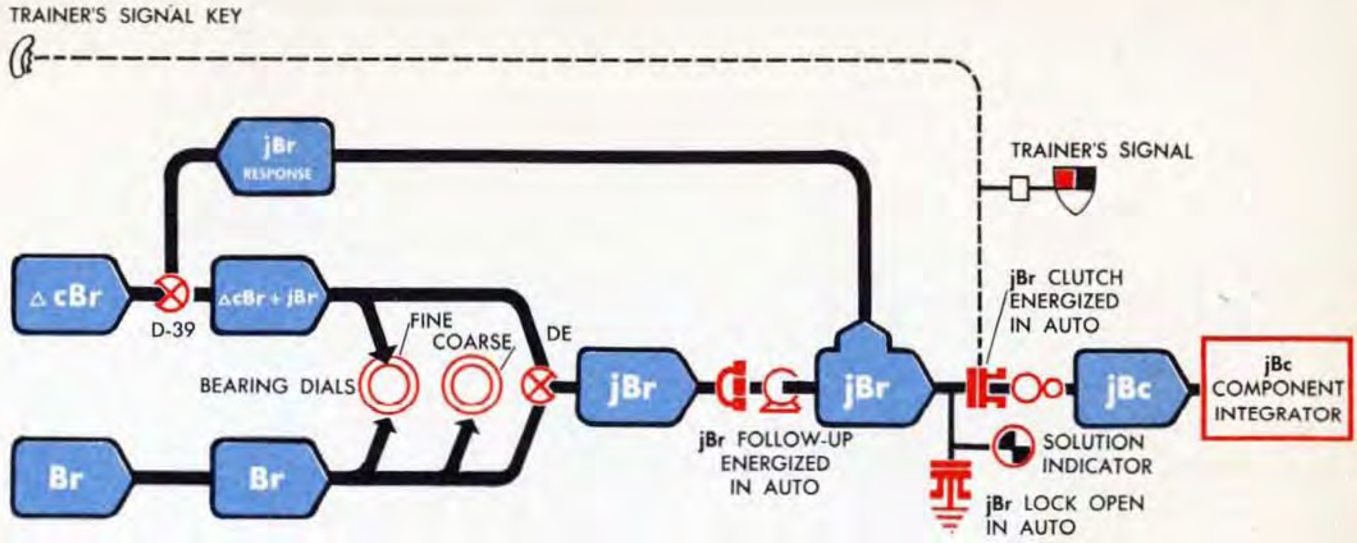
The Trainer's sight, driven by $\Delta cB'r$ from the Integrator Group in the Computer, is not centered on the Target and is steadily moving away from the Target. The value of $B'r$ going to the Computer is incorrect, and Br and Deflection Rate, $RdBs$, in the Computer are also incorrect.

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 $\Delta cB'r$ 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 ΔcBr. The difference between ΔcBr 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 $\Delta cB'r$ 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.

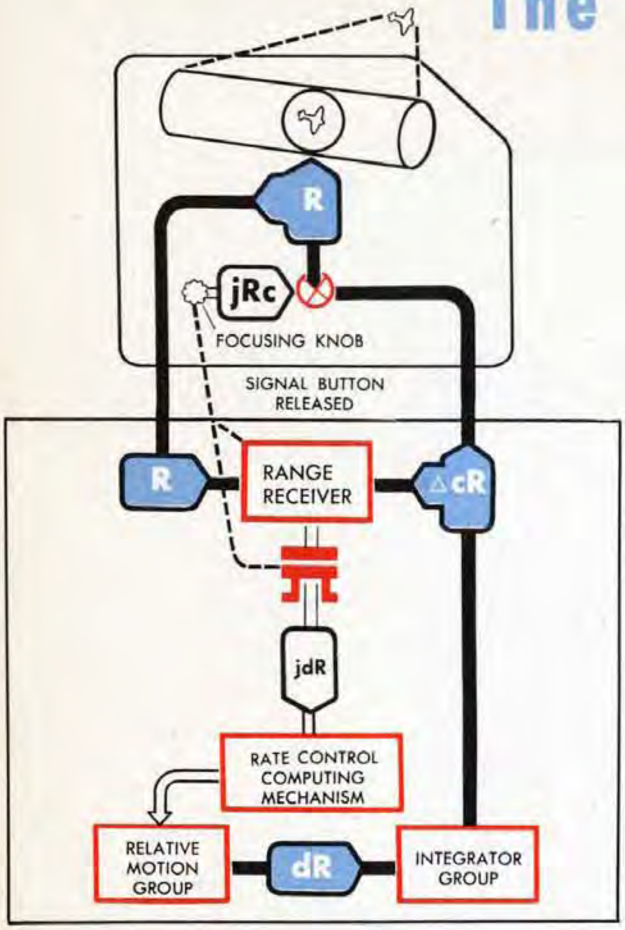
From this point on, the part played by *jBc* in the computation of corrections to Target Motion values is the same as in Semi-automatic Rate Control.

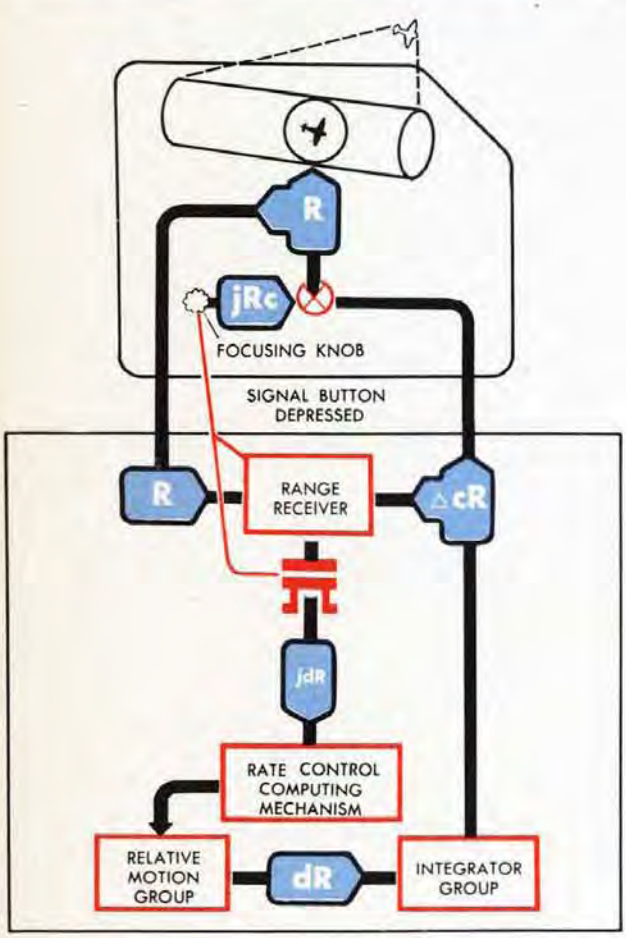
Besides producing Deflection Rate Correction, *jBc, jBr* is driven back to differential D-39, where it is added to △*cBr. jBr* + △*cBr* acts as response to the *jBr* Follow-up and also keeps the Generated Dial turning with the Observed Dial.

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, $\triangle cR$, do not keep the Range Finder in focus, the $\triangle cR$ 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 $\triangle cR$ 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.

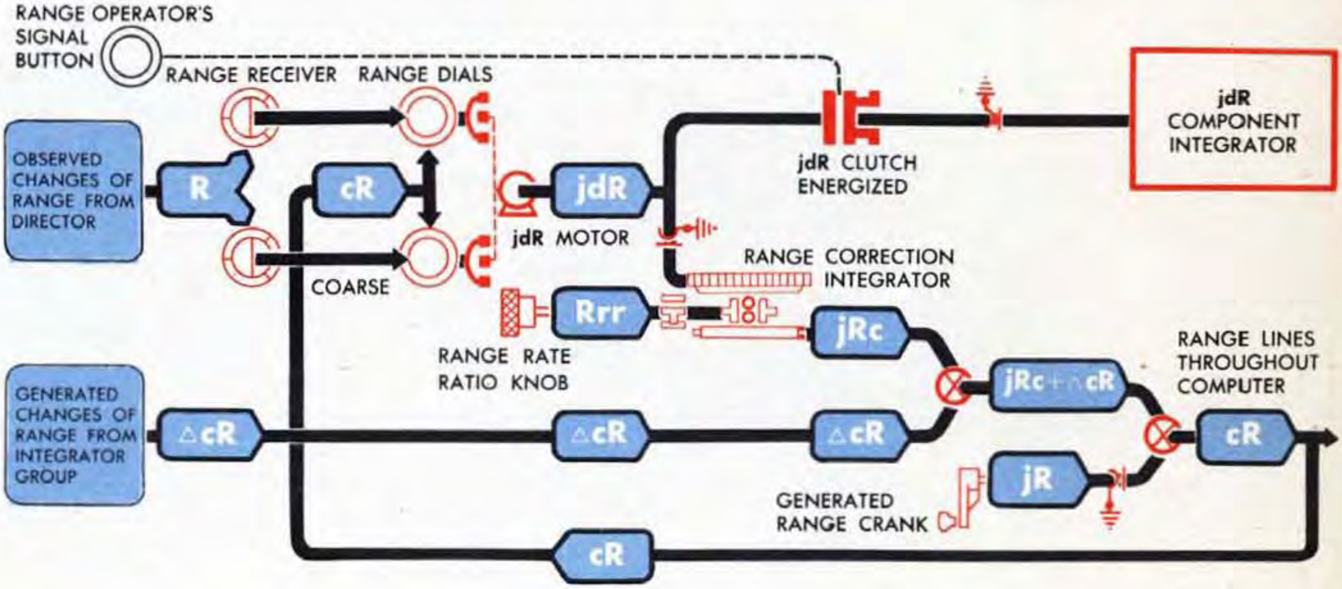
The Rate Control Computing Mechanism computes corrections to *Sh*, *dH*, and *A*, and sends corrected values of these quantities to the Relative Motion Group. These quantities are corrected until the value of Range Rate, *dR*, causes the Integrator Group to generate $\triangle cR$ at a rate which will 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 cR

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*.

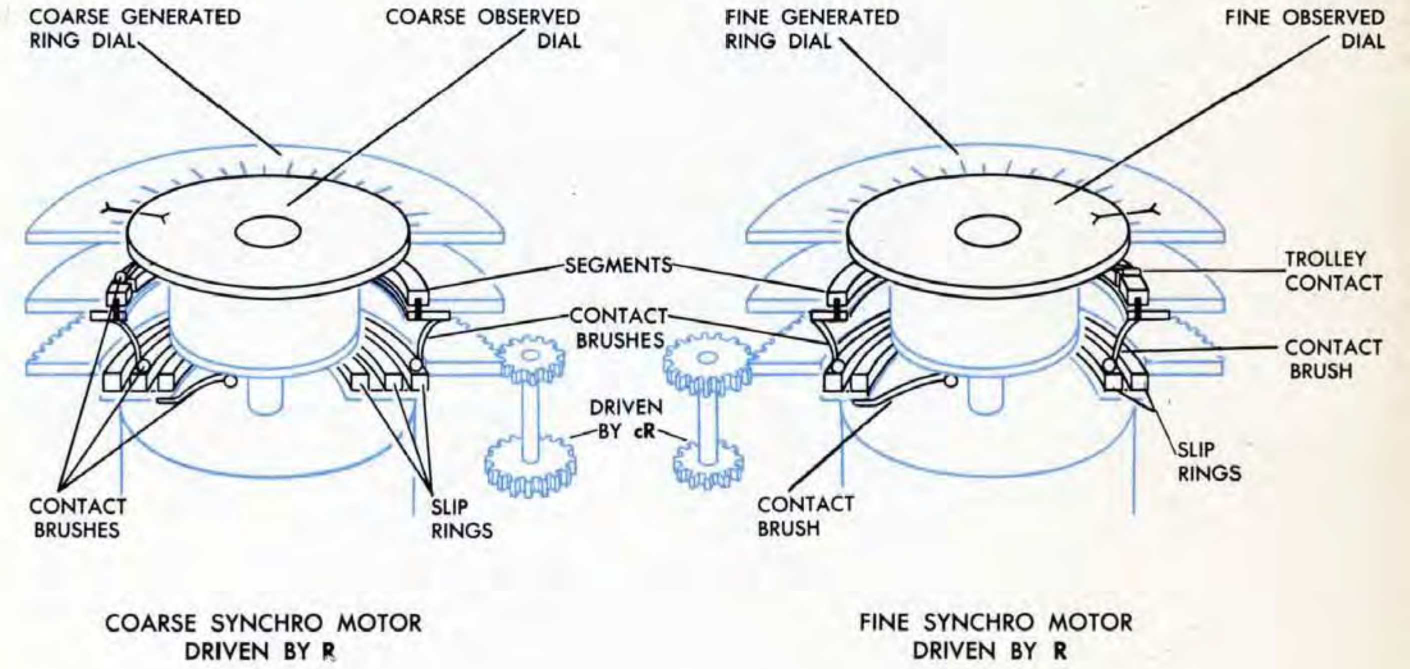
A contact brush is attached to the under side of each of the five segments. Each of these five contact brushes bears against one of the five slip rings shown here. Rings B, C, D, F and G are fastened to the unit mounting plate, and are connected by wires to the *jdR* Motor. Contact brushes X and Y are 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.

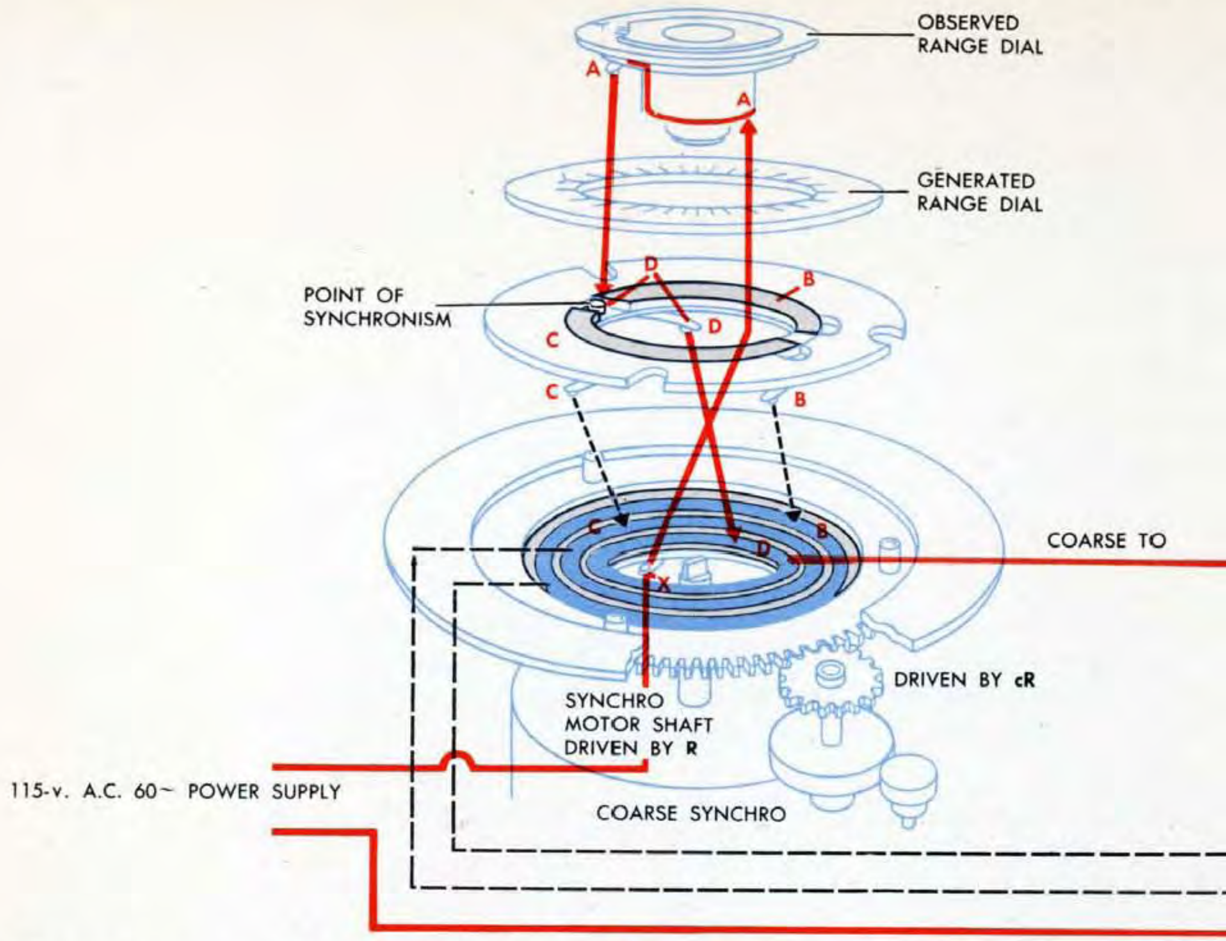
This sketch shows the position of the parts of the Double-speed Range Receiver:



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.



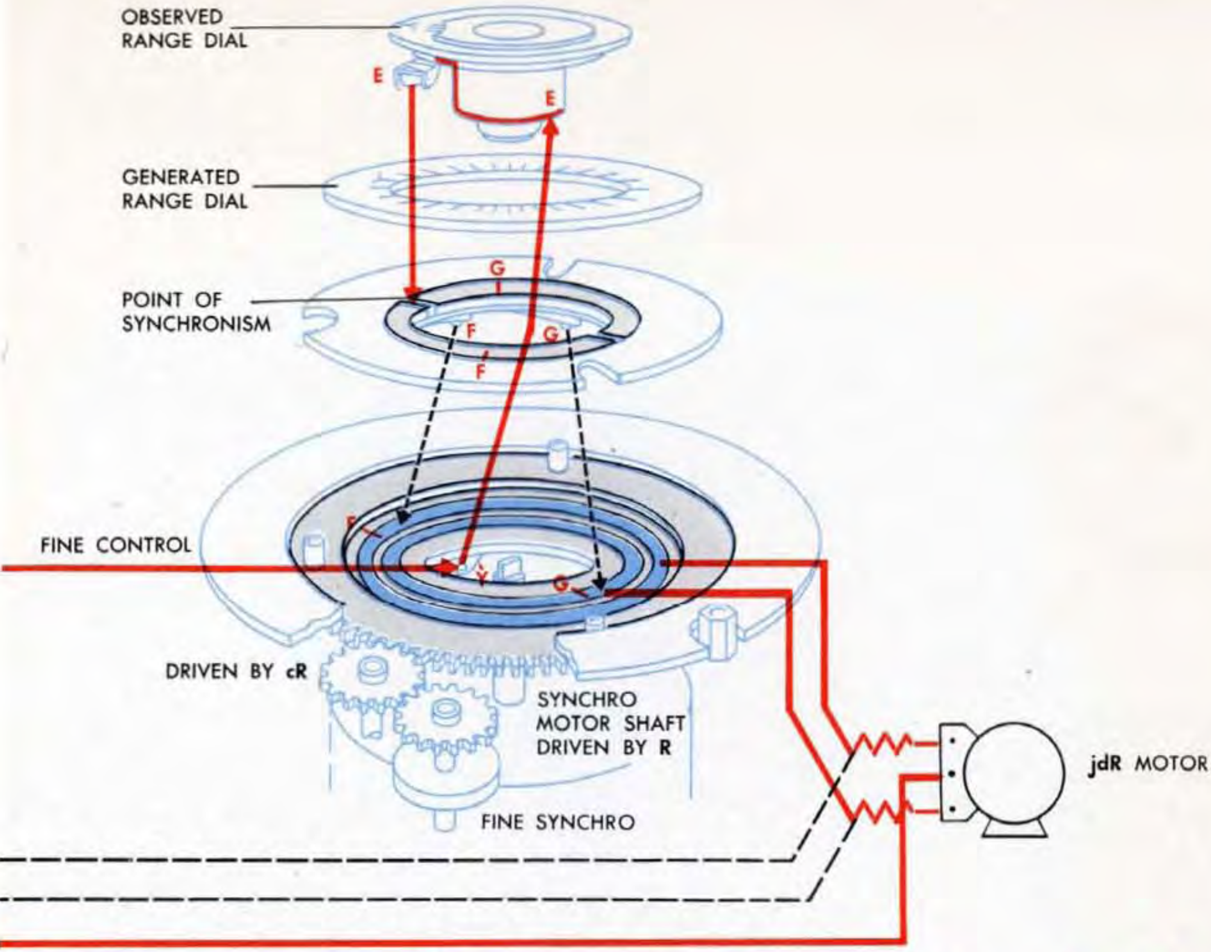
The Coarse Control Electrical Circuits

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

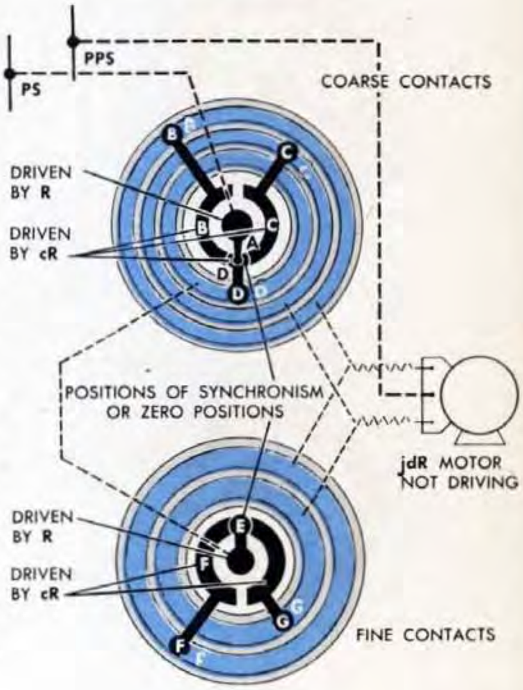
The fine contacts are in control of the *jdR* Motor when the electrical circuit from the coarse contacts is completed to trolley contact E. On the fine contacts, trolley contact E and slip ring E are fastened to the under side of the Observed Range Dial. Slip ring E is in contact with brush Y which is 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.

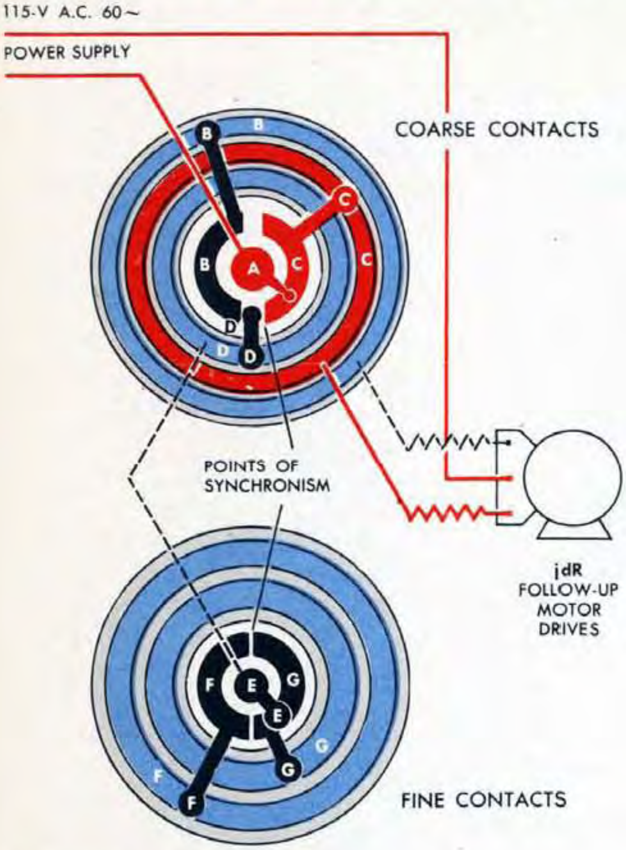
When trolley contact E touches segment G, the electrical circuit to the *jdR* Motor is completed through segment G, contact brush G, and ring G, and the motor drives in the opposite direction.

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.

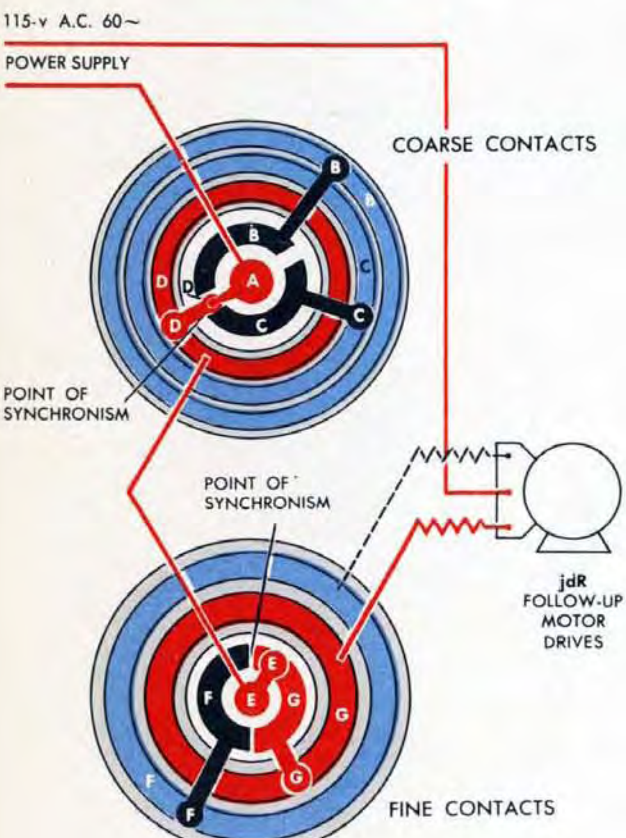


When the COARSE Contacts are in control



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.



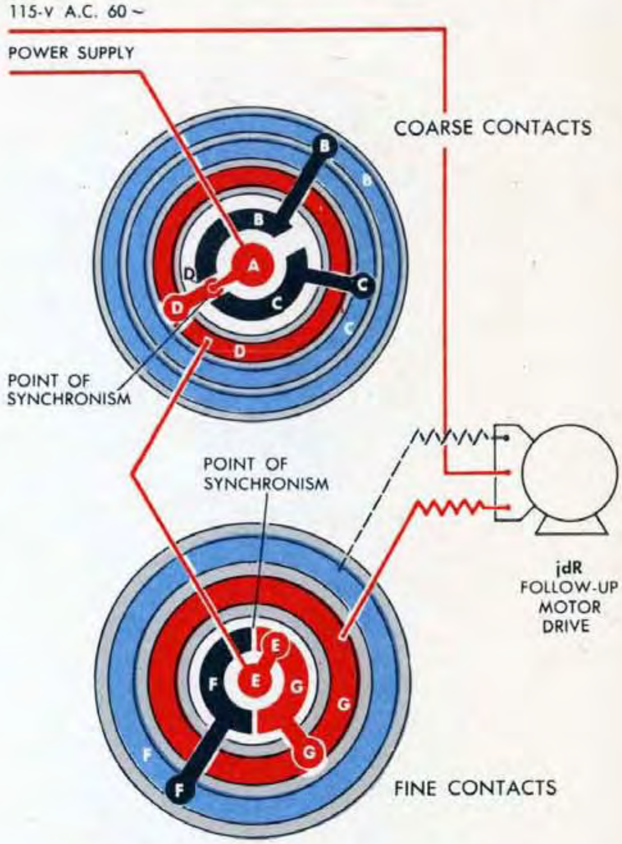
Now *R* is only slightly greater than *cR*. Isolated contact D has reached its point of synchronism, touching contact brush A.

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.

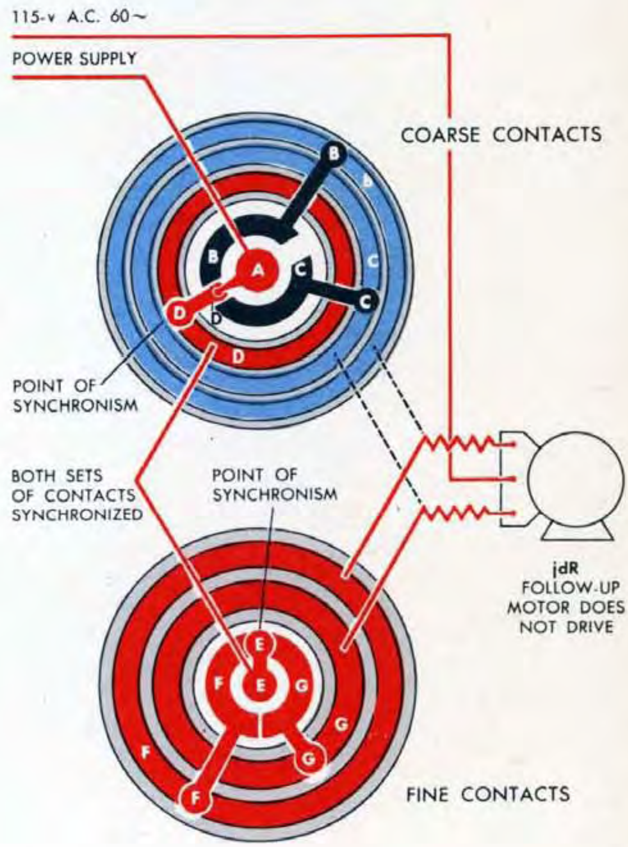
When the FINE Contacts are in control

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*.



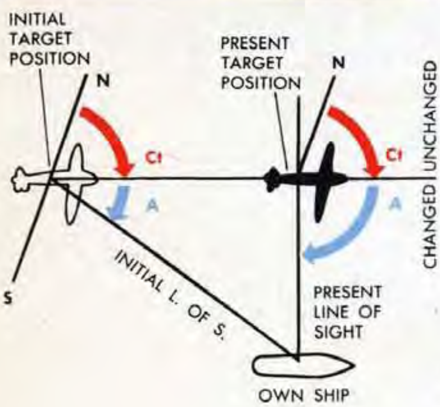
When *R* and *cR* are equal and are changing at the same rate, trolley contact E is at the point of synchronism, touching both segments F and G. The *jdR* Motor is energized to drive equally in both directions at once and therefore does not drive at all.



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.

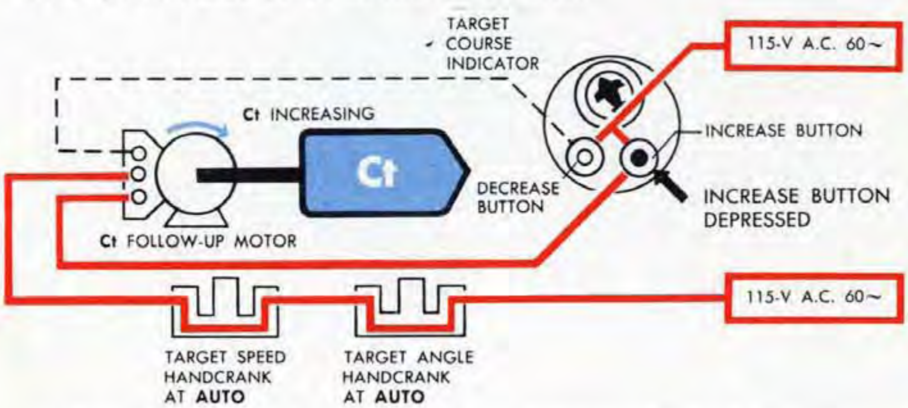
Target Angle, *A*, changes continuously as the relative position of Own Ship and Target changes, but Target Course, *Ct*, is measured from *North*, and therefore remains constant as long as the direction of motion of the Target does not change. For this reason and others, *Ct* is used to estimate the direction of motion of the Target.



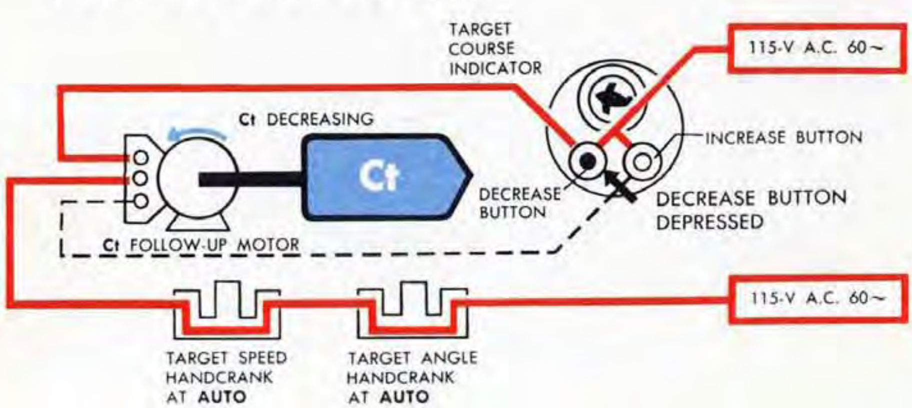
Corrections to Target Course, *Ct*, may be made faster by using the Target Course Indicator than by using the Target Angle Handcrank.

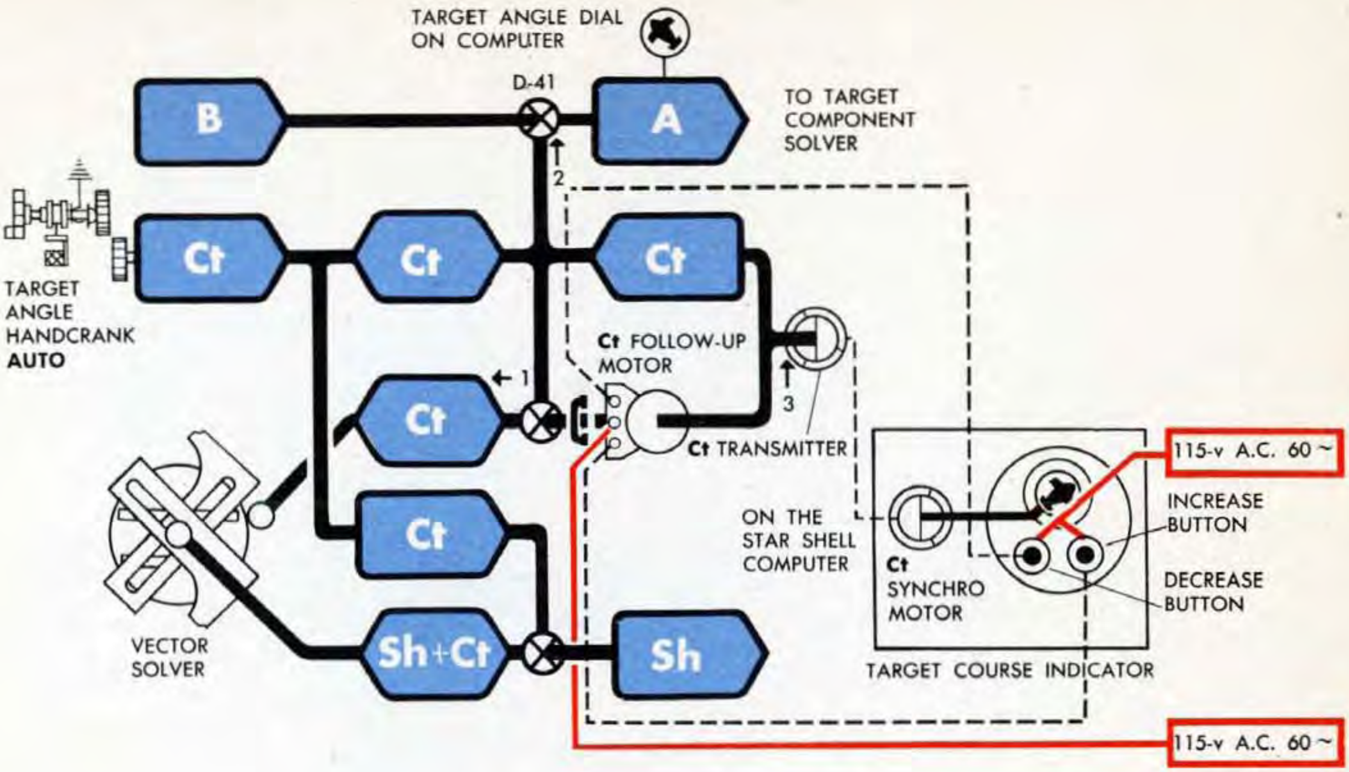
The Target Course Indicator contains a dial, a synchro motor, an INCREASE Button, and a DECREASE Button. Target Course, *Ct*, is read on the graduated index plate, opposite the bow of the Target on the dial.

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.

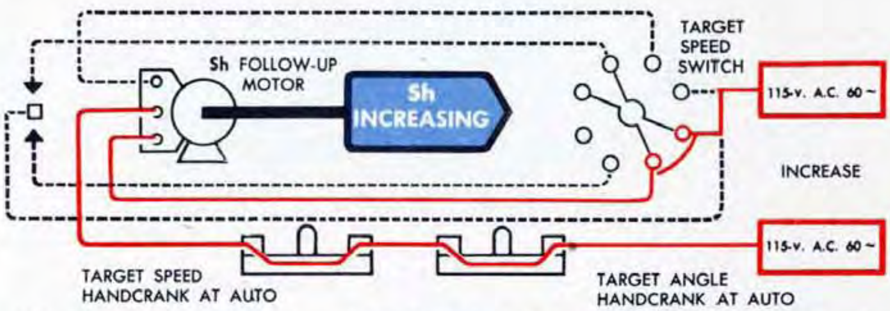
The TARGET SPEED SWITCH

This is the Target Speed Switch. It is located on the top of the Computer Mark 1 at the front left corner.

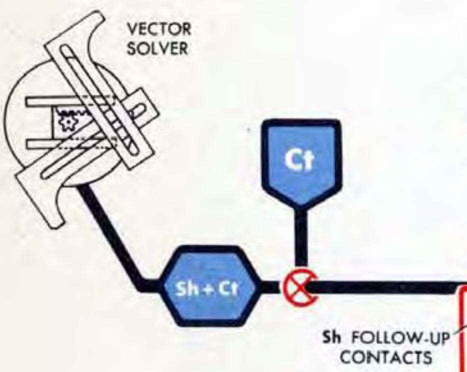
The Target Speed Switch has two uses:

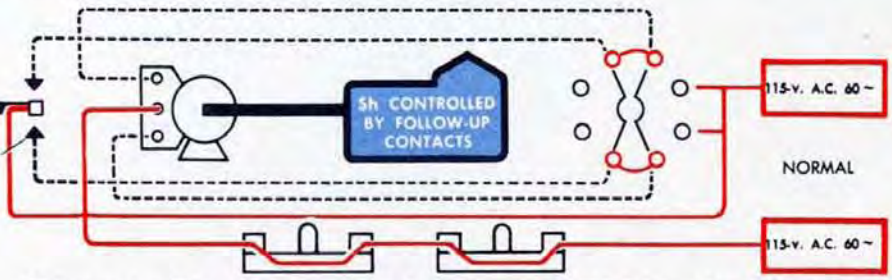
1. It can be used instead of the Target Speed Handcrank for putting initial or corrective values of *Sh* into the Computer quickly.
2. It can be used to run *Sh* to zero in preparing the Computer for a dive attack.

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.

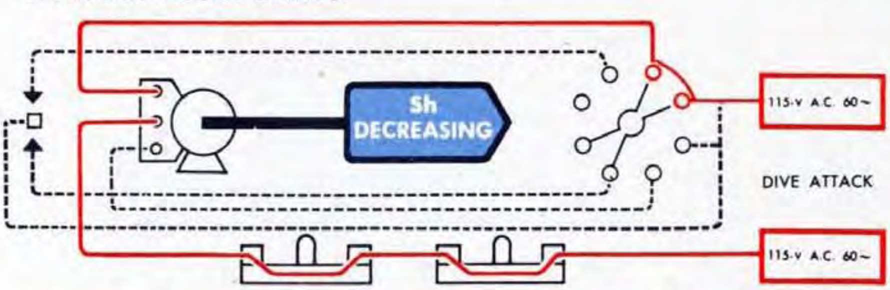


When the Target Speed Switch is held at INCREASE, the *Sh* Follow-up Motor drives in the direction to *increase* the value of *Sh* in the Computer.





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.

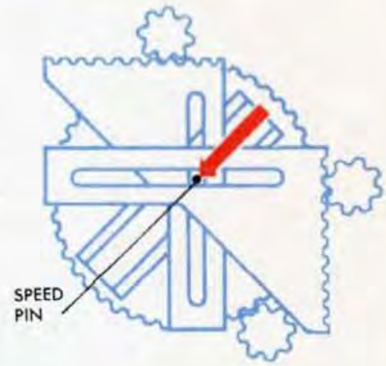


When the Target Speed Switch is at DIVE ATTACK, the *Sh* Follow-up Motor drives in the direction to *decrease* the value of *Sh* in the Computer.

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.

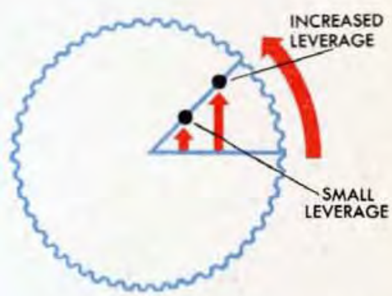
Making large changes in **target speed**

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.



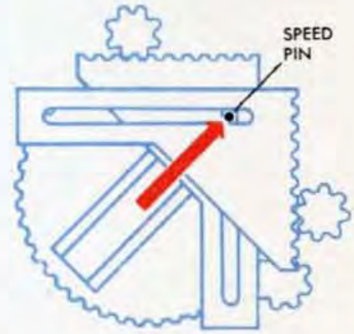
Making large changes in **target angle**

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.

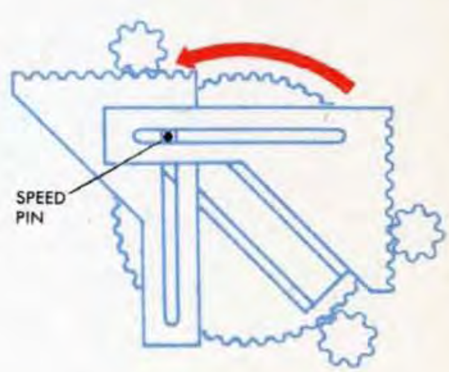


Assisting the vector solver when the speed pin runs to the center

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.

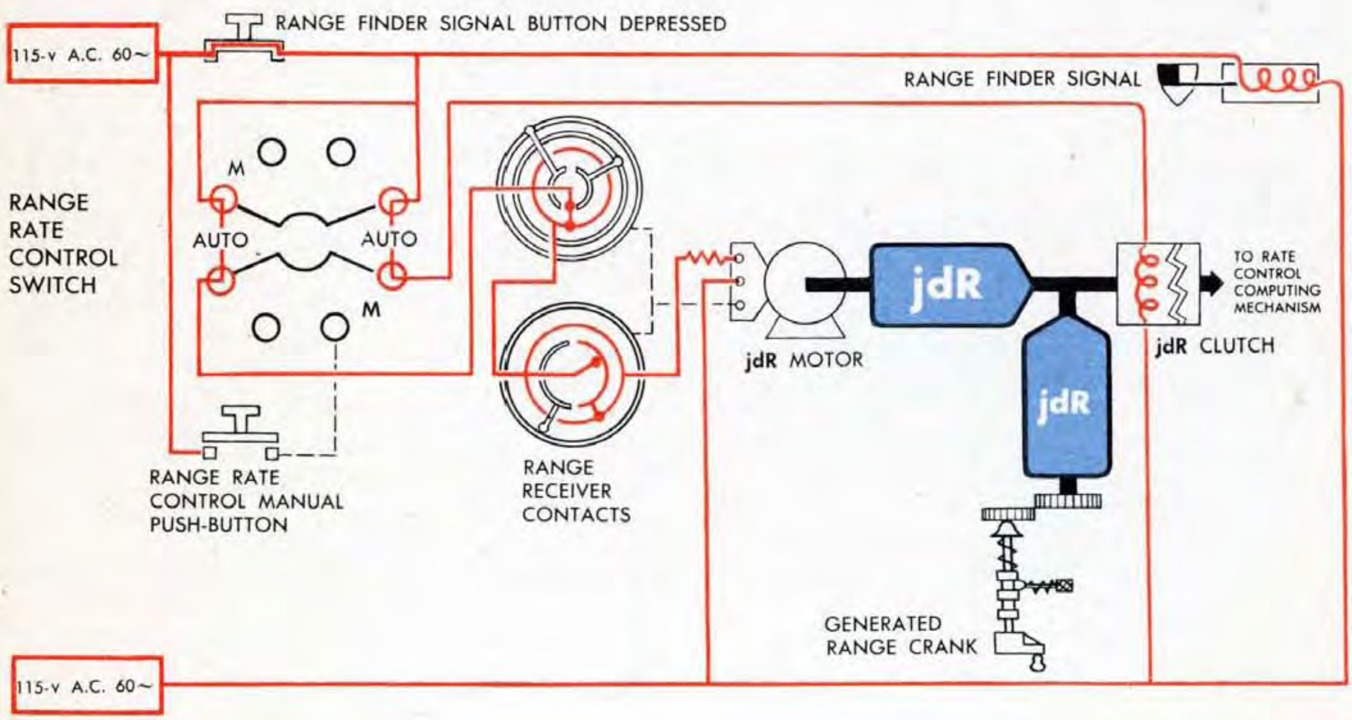
MANUAL is used for Semi-automatic and Manual Rate Control and for Local Control.

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.

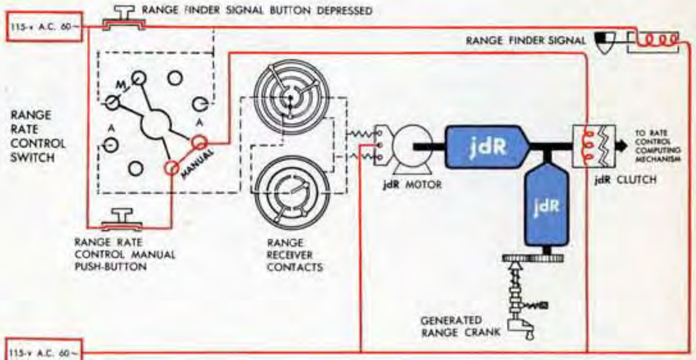
Whenever the Range Operator depresses his signal button, the Range Finder Signal near the Range Dials changes from black to white.

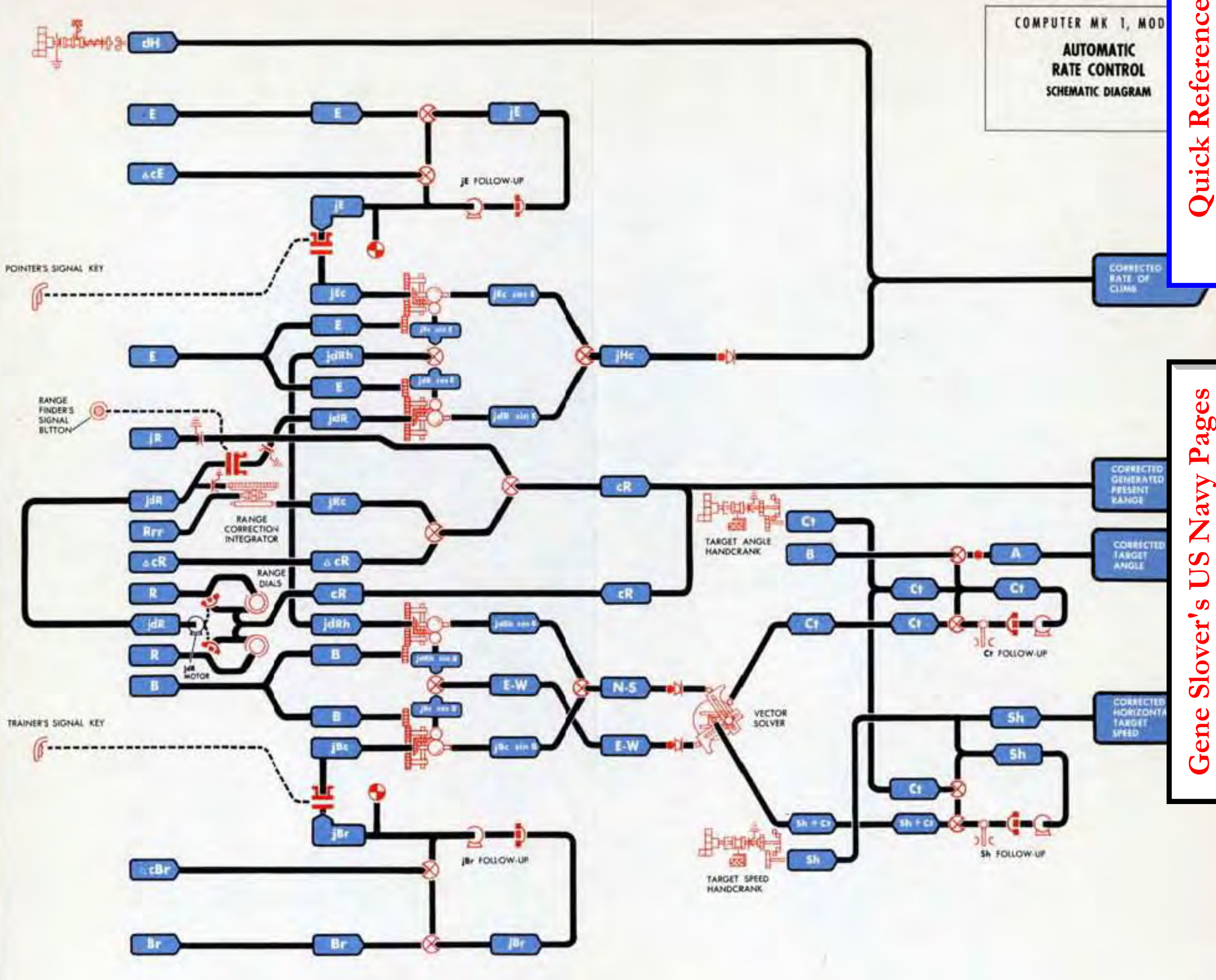


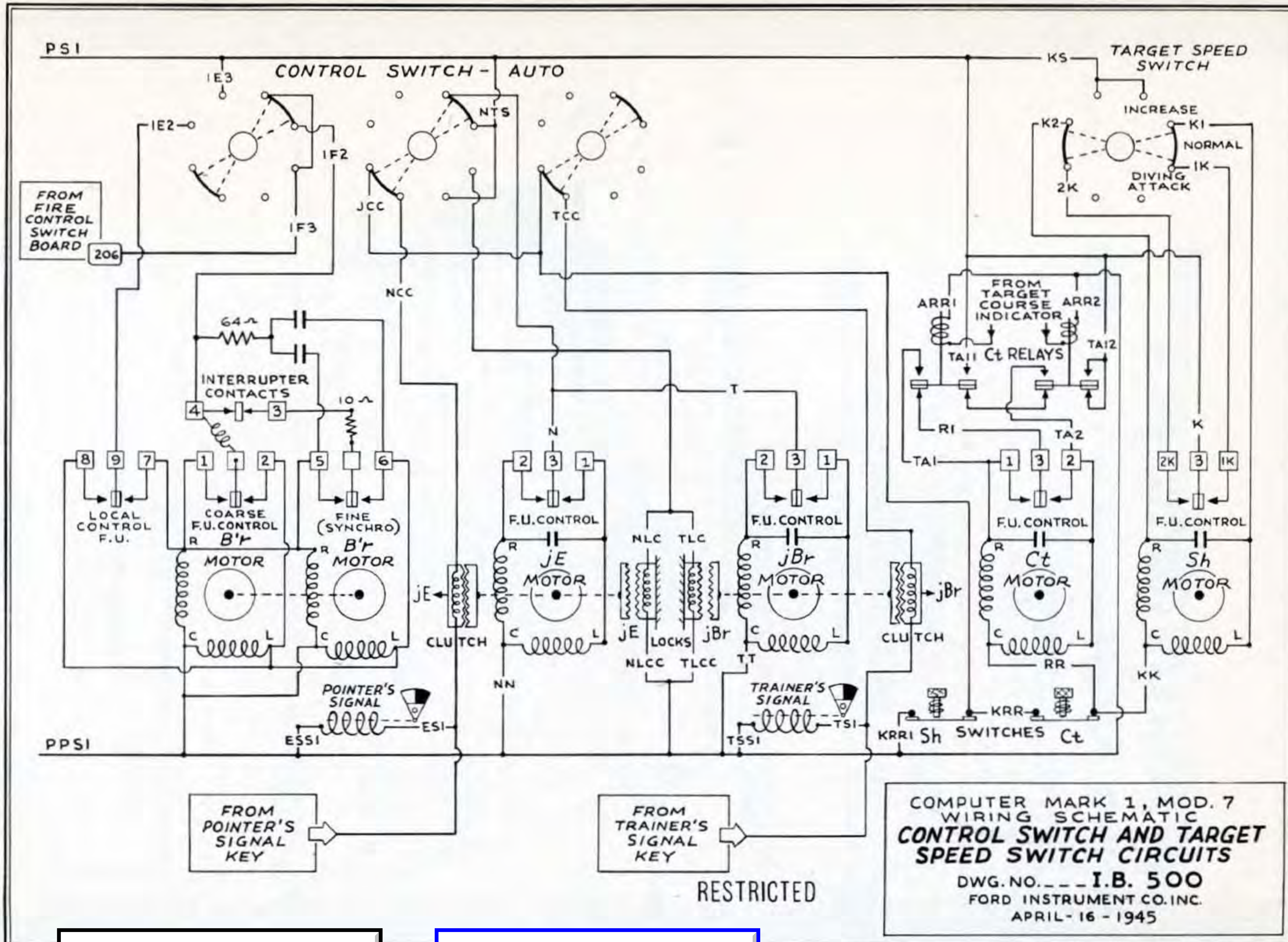
When the RANGE RATE CONTROL SWITCH is turned to MANUAL

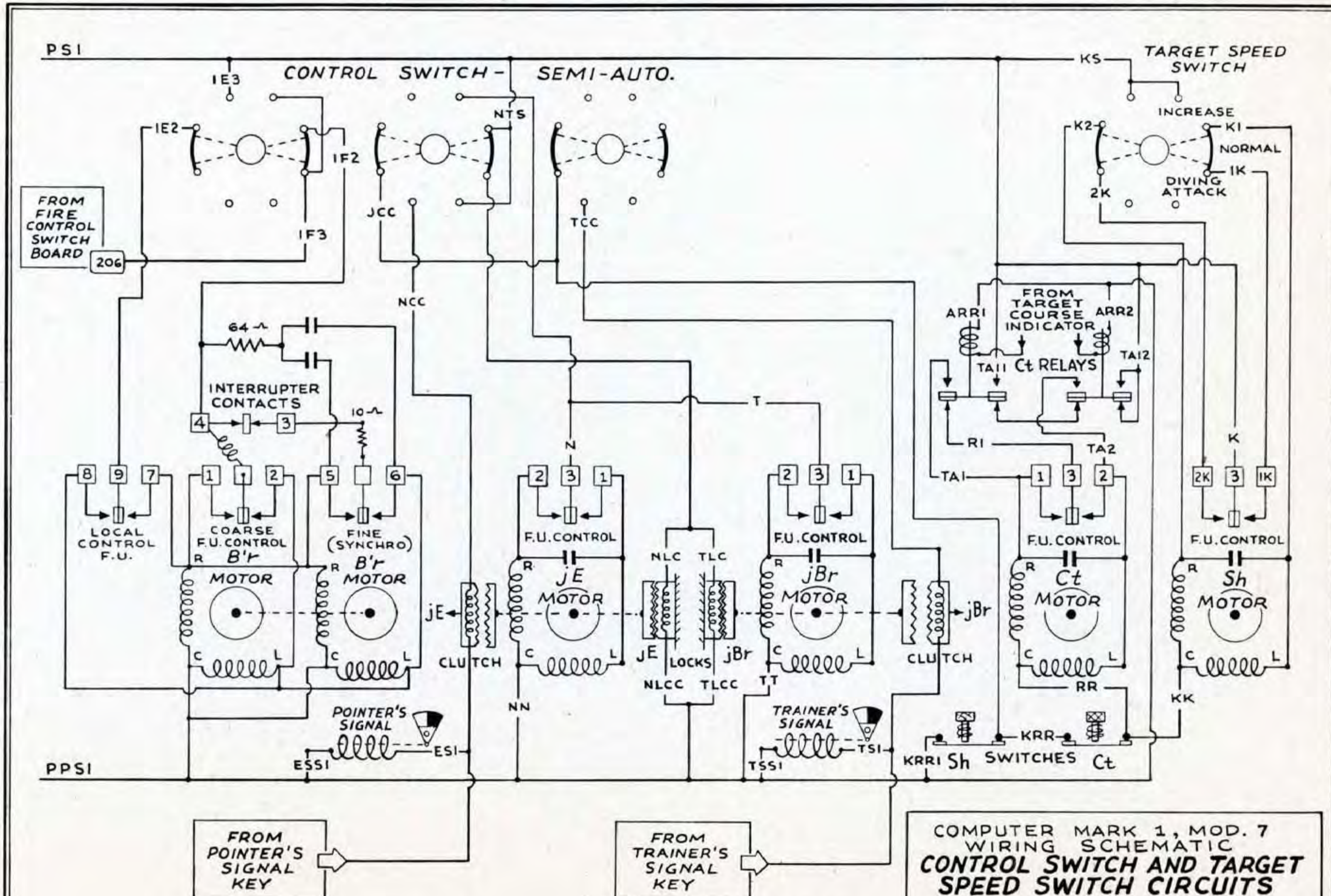
When the Range Rate Control Switch is turned to MANUAL and the Range Rate Control Manual Push-button is depressed, the circuit to the *jdR* Clutch is completed, engaging the clutch. When the clutch is engaged, *jdR* Rate Corrections can be put into the Computer by hand, by turning the Generated Range Crank in its IN position.

The circuit to the Range Finder Signal is completed whenever the Range Finder Signal Button is depressed.

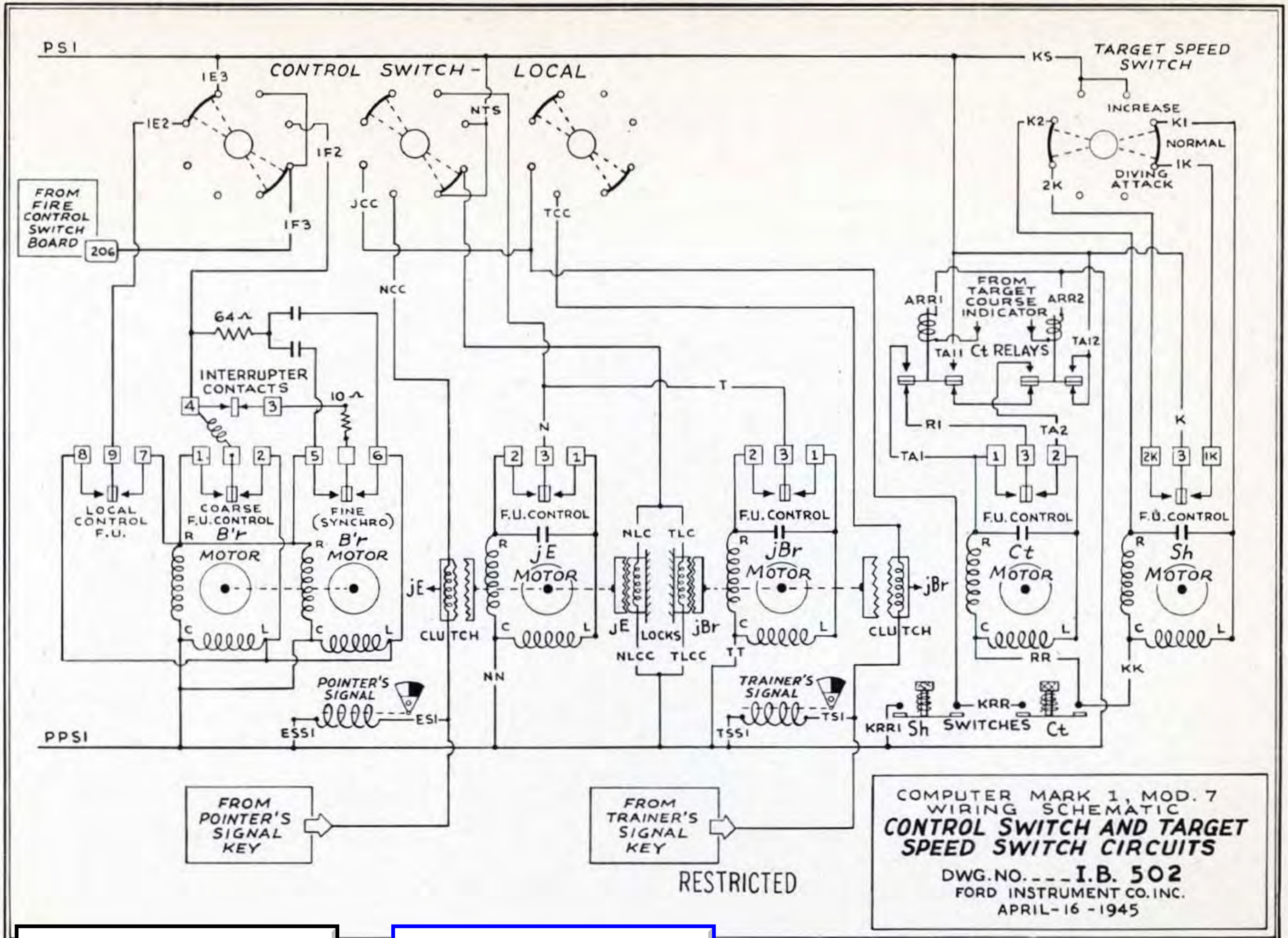





PSI
CONTROL SWITCH - AUTO
TARGET SPEED SWITCH
KS
IE3
IE2
IF2
IF3
NTS
JCC
TCC
NCC
INCREASE
NORMAL
DIVING ATTACK
K2
KI
IK
2K
FROM FIRE CONTROL SWITCH BOARD
206
64 Ω
10 Ω
INTERRUPTER CONTACTS
FROM TARGET COURSE INDICATOR
ARRI
ARR2
TAI1
TAI2
Ct RELAYS
RI
TA2
TAI
T
N
K
LOCAL CONTROL F.U.
COARSE F.U.CONTROL
B'r MOTOR
FINE (SYNCHRO)
B'r MOTOR
F.U.CONTROL
jE MOTOR
jBr MOTOR
Ct MOTOR
Sh MOTOR
jE
jBr
CLUTCH
NLC
TLC
LOCKS
NLCC
TLCC
TT
NN
RR
KK
POINTER'S SIGNAL
ESI
ESSI
TRAINER'S SIGNAL
TSI
TSSI
KRR
KRRI
Sh
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

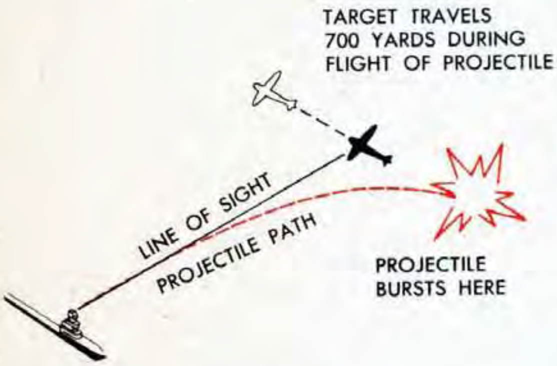

PSI
CONTROL SWITCH - SEMI-AUTO.
TARGET SPEED SWITCH
INCREASE
NORMAL
DIVING ATTACK
FROM FIRE CONTROL SWITCH BOARD
206
INTERRUPTER CONTACTS
FROM TARGET COURSE INDICATOR
Ct RELAYS
LOCAL CONTROL F.U.
COARSE F.U. CONTROL
B'r MOTOR
FINE (SYNCHRO)
B'r MOTOR
F.U. CONTROL
jE MOTOR
jBr MOTOR
Ct MOTOR
Sh MOTOR
CLUTCH
LOCKS
POINTER'S SIGNAL
TRAINER'S SIGNAL
Sh SWITCHES 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

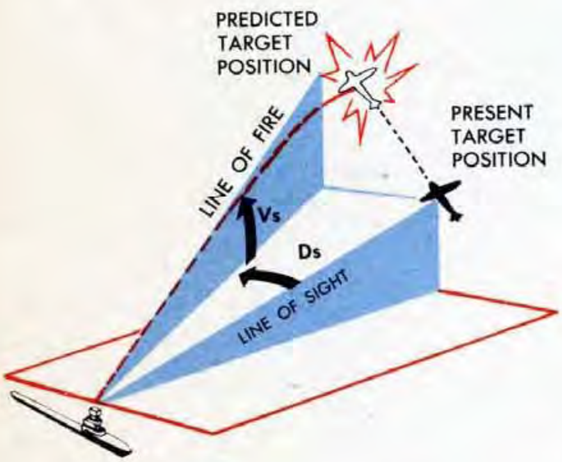
RESTRICTED



PSI
CONTROL SWITCH - LOCAL
IE3
IE2
IF2
IF3
NTS
JCC
TCC
NCC
FROM FIRE CONTROL SWITCH BOARD
206
TARGET SPEED SWITCH
KS
INCREASE
K2
K1
NORMAL
1K
2K
DIVING ATTACK
FROM TARGET COURSE INDICATOR
ARR1
ARR2
TA11
Ct RELAYS
TA12
R1
TA2
TA1
K
64 ~
INTERRUPTER CONTACTS
10 ~
T
N
LOCAL CONTROL F.U.
COARSE F.U. CONTROL B'r
FINE (SYNCHRO) B'r
MOTOR
F.U. CONTROL
jE
MOTOR
NLC
TLC
LOCKS
NLCC
TLCC
jBr
F.U. CONTROL
jBr
MOTOR
F.U. CONTROL
Ct
MOTOR
F.U. CONTROL
Sh
MOTOR
CLUTCH
CLUTCH
NN
TT
RR
KK
POINTER'S SIGNAL
ESI
ESSI
TRAINER'S SIGNAL
TSI
TSSI
KRR
KRR1
Sh
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. 502
FORD INSTRUMENT CO. INC.
APRIL - 16 - 1945

THE PREDICTION SECTION





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.

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.

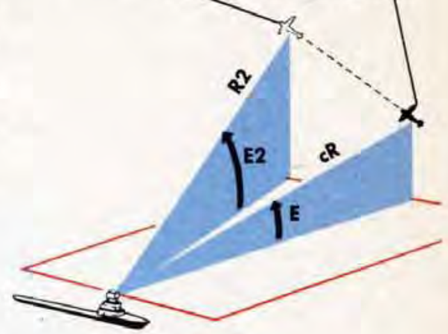
The lead angle in Elevation is called Sight Angle, *Vs*. Sight Angle, *Vs*, is the difference between the Elevation of the Line of Sight above the horizontal and the Elevation of the Line of Fire above the horizontal.

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.

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.

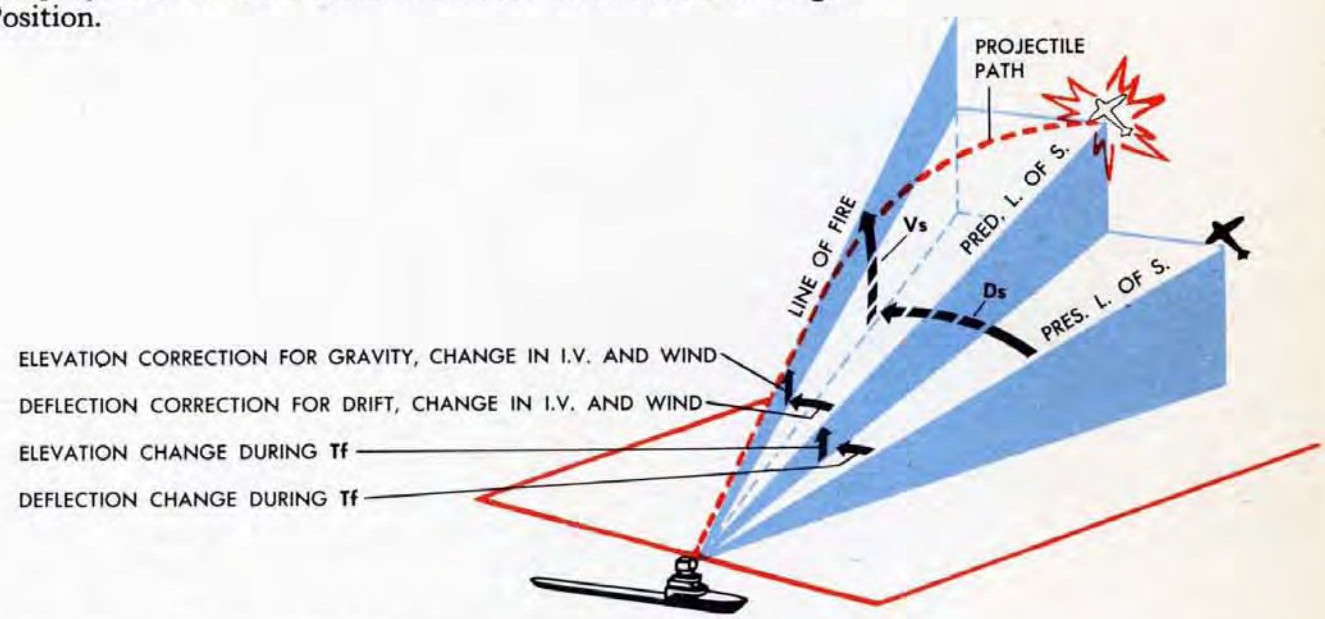


The Prediction Section performs three basic operations in computing lead angles *Vs* and *Ds* and Fuze Setting Order, *F*.

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.

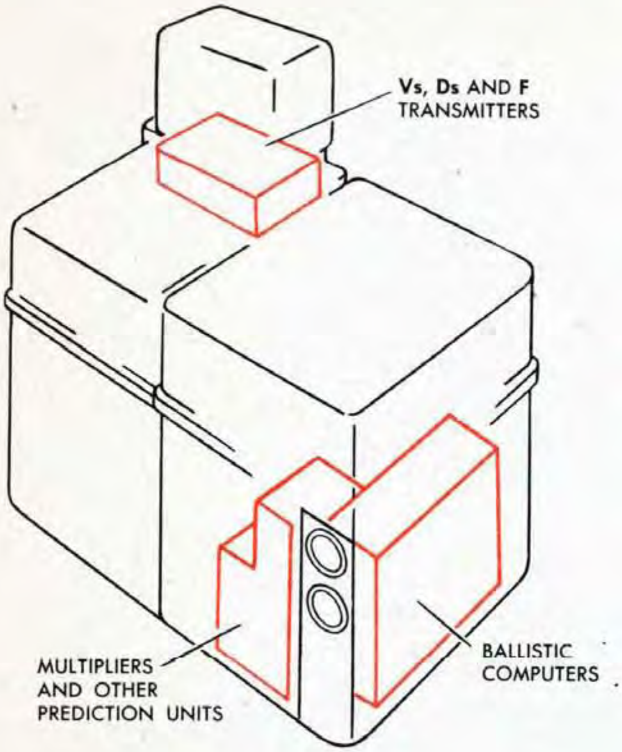


Sight Angle, *Vs*, and Sight Deflection, *Ds*, are the angles by which the Line of Fire must be offset from the Present Line of Sight to allow for all the Prediction factors.

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.

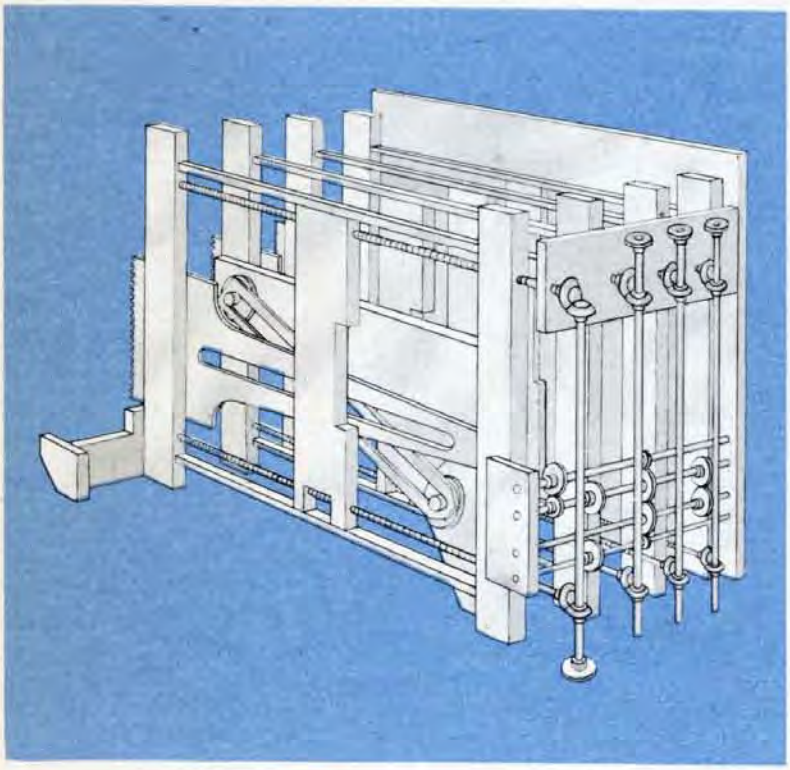
The MECHANISM in the PREDICTION SECTION



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.

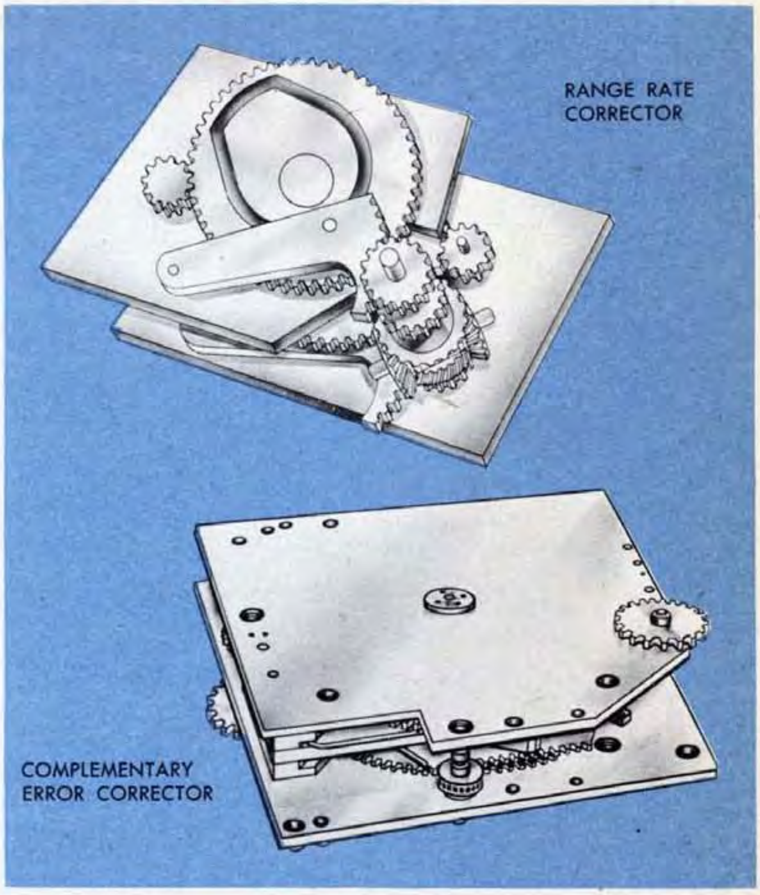
The Prediction Multipliers, Ballistic Computers, Range Rate Corrector, Complementary Error Corrector, and the Prediction Follow-ups are all located in the lower front section of the Computer Mark 1. The *Vs*, *Ds*, and *F* Transmitters are located in the upper rear section of the Computer.

The locations of the Wind Component Solvers and the Spot Receivers are described later in this chapter.

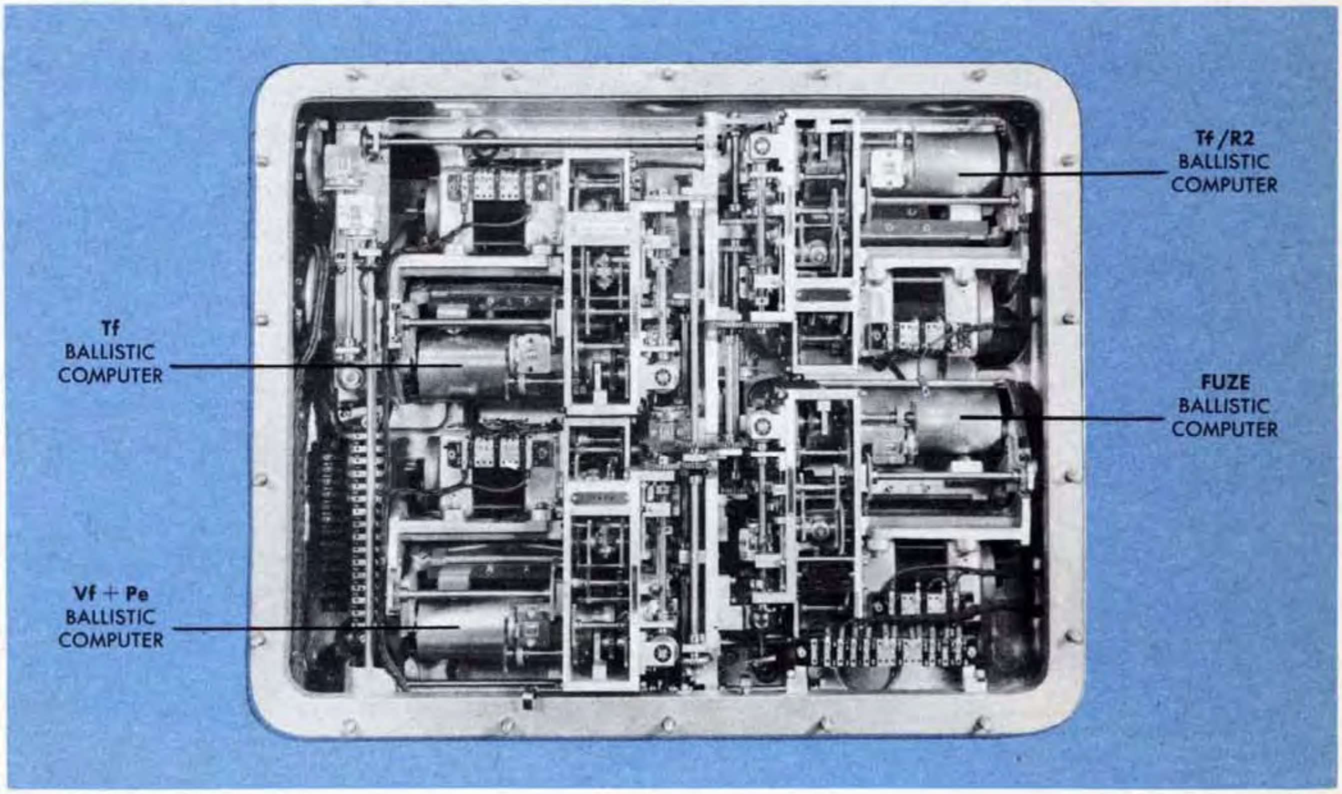


THE PREDICTION MULTIPLIERS are four screw-type multipliers assembled together in a bank. Three of these multipliers are used to compute the changes in Range, in Elevation, and in Deflection, during the Time of Flight. The fourth multiplier is used to compute the change in Range during the time between the setting of the fuze and the firing of the projectile.

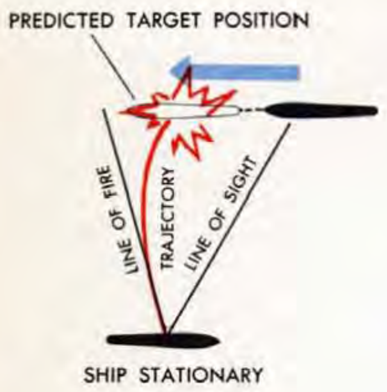
THE RANGE RATE CORRECTOR and **THE COMPLEMENTARY ERROR CORRECTOR** are double-cam computing units which compute a Range Rate Correction and an Elevation Correction respectively.

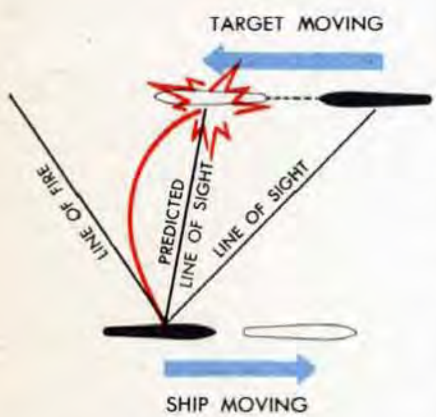


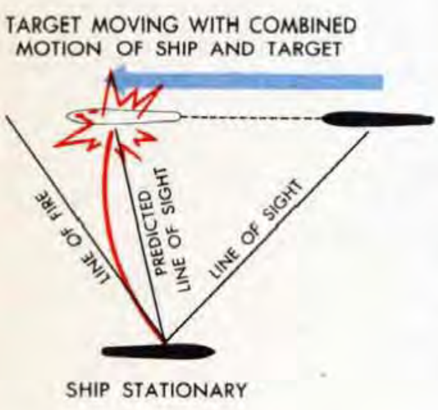
THE BALLISTIC COMPUTERS are four assemblies, each containing a barrel-type cam, a follow-up, and various shafts and gears. One ballistic computer computes each of the following quantities: Time of Flight, Tf, Time of Flight divided by Advance Range, $Tf/R2$, Superelevation plus Elevation Parallax, $Vf + Pe$, 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.

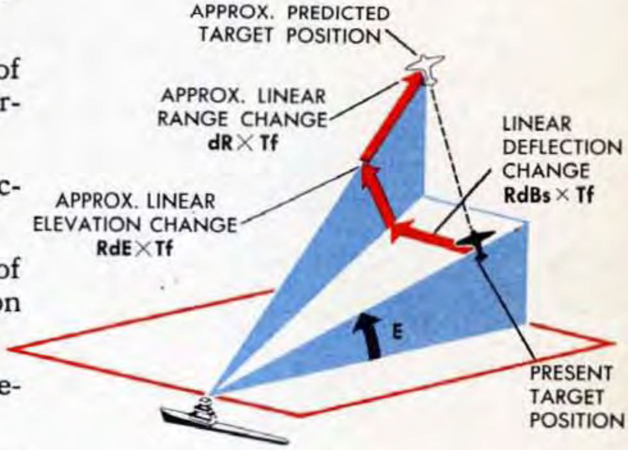
   $dR \times Tf$ = Approximate Linear Range Prediction

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

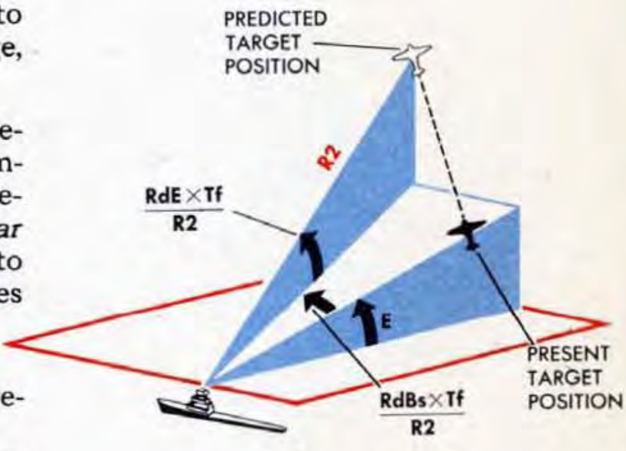
3. The linear Deflection Rate multiplied by Time of Flight is the approximate change in Deflection during the Time of Flight.

   $RdBs \times Tf$ = 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*.

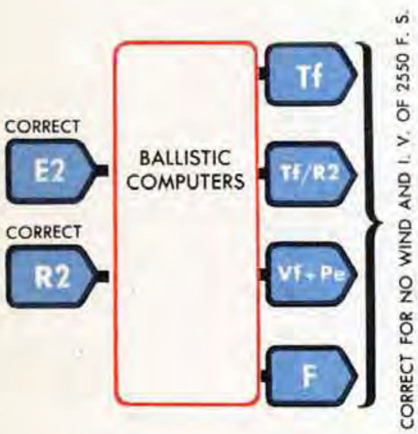
Before the Target movement in Elevation and Deflection during the Time of Flight can be used in computing the lead angles, the *linear* predictions in Elevation and Deflection must be converted into *angular* predictions. The linear quantities are converted to angular quantities by dividing the linear 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



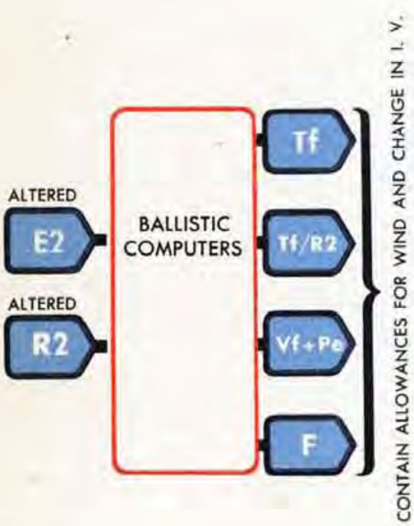
Approximate values of Predicted Target Position in Range, Elevation, and Deflection are computed by multiplying the three Relative Motion Rates by *Tf* or *Tf/R2*. Since the change of position in two of the three directions is affected by motion in the other directions, corrections must be made to the 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.*

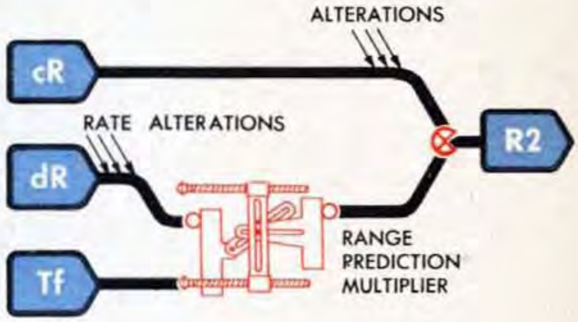
The Prediction Multipliers

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

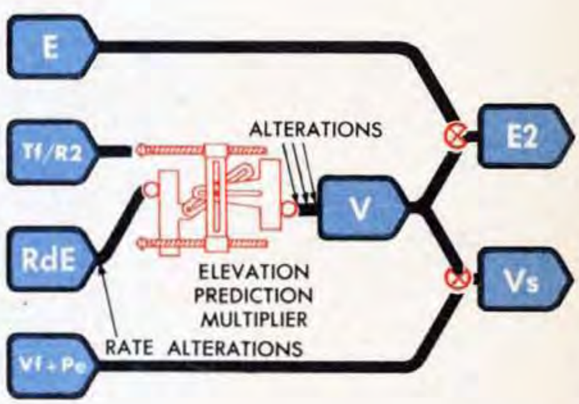
Direct Range Rate, *dR*, altered by three additional quantities, is one input to the Range Prediction Multiplier. Time of Flight, *Tf*, is the other input. Generated Present Range, *cR*, is altered by three linear quantities. The altered *cR* is added to the output of the Range Prediction Multiplier in a differential. The output of the differential is Advance Range, *R2*, containing allowances for Wind and changes in Initial Velocity.



Elevation prediction

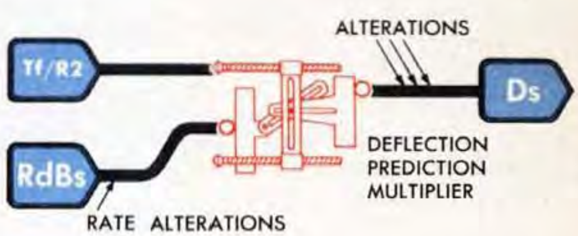
Elevation Rate, *RdE*, altered by one additional quantity is one input to the Elevation Prediction Multiplier. *Tf/R2* is the other input. The multiplier output is altered by three linear quantities to obtain Elevation Prediction, *V*.

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

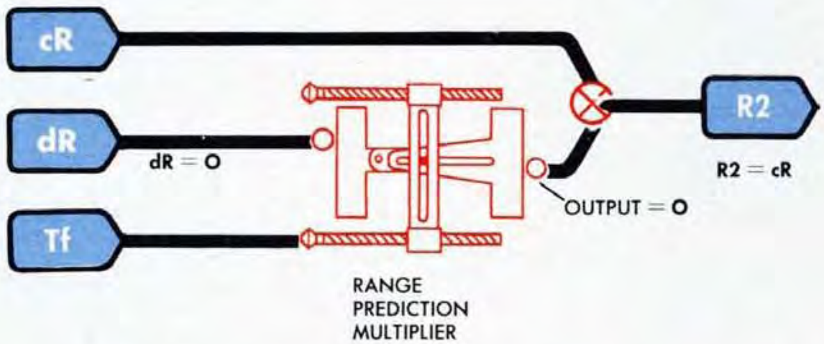
Deflection Rate, *RdBs*, altered by one additional quantity, is one input to the Deflection Prediction Multiplier. *Tf/R2* is the other input. The multiplier output is altered by three additional quantities to obtain an accurate value of Sight Deflection Angle, *Ds*, which contains allowances for Wind 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*.

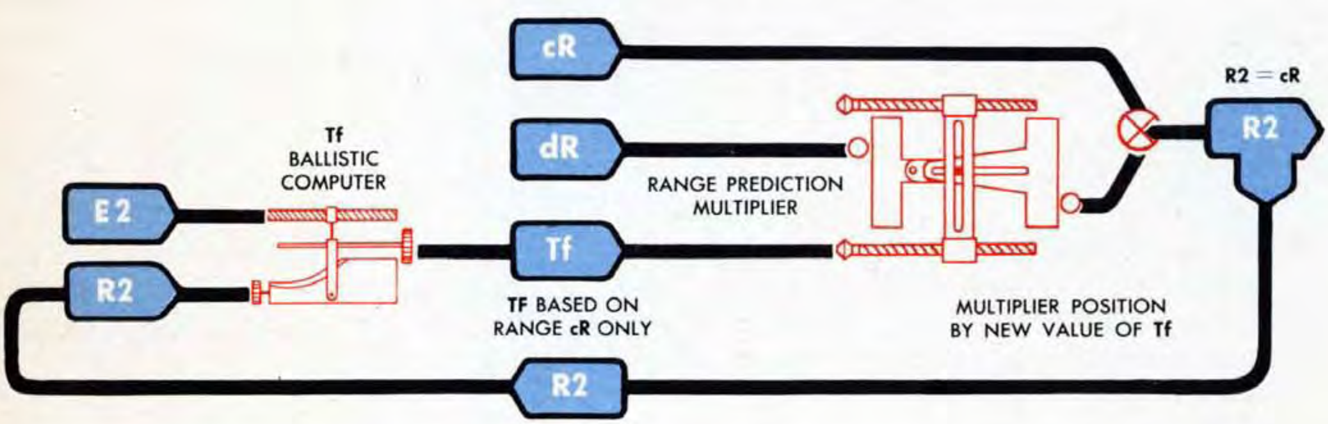
Regeneration is the use of an output from a network as an input to the same network. A study of the regeneration of *R2* in a simplified Range Prediction network will show how this is done.



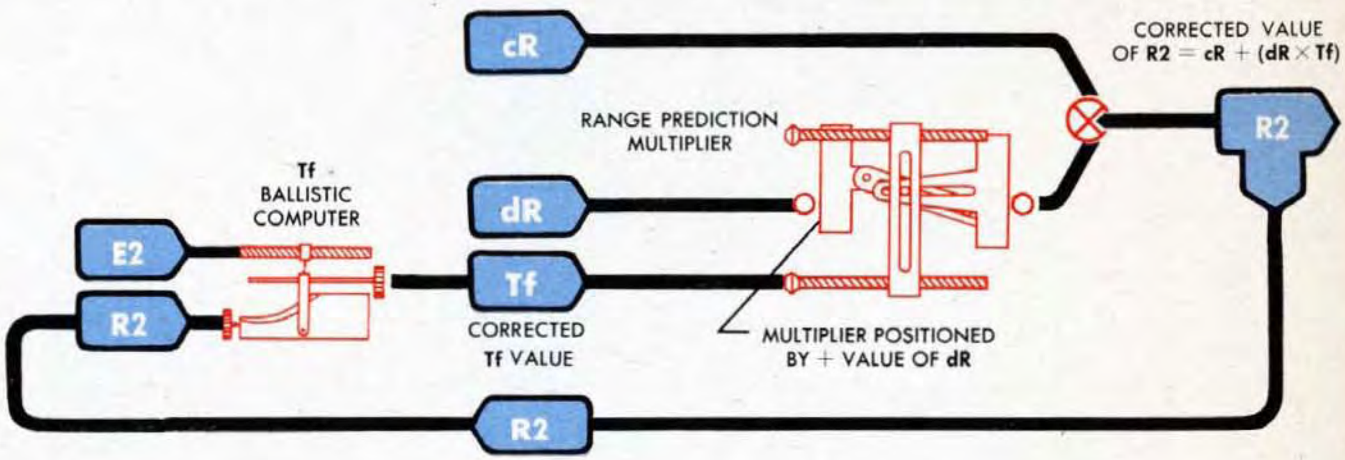
If the Direct Range Rate, *dR*, is zero, the output from the multiplier is also zero, and the value of the *R2* output from the network will be equal to *cR*.

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.

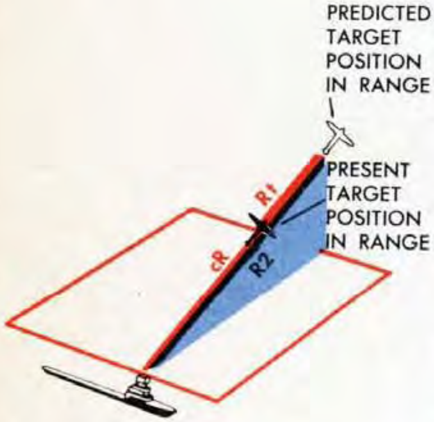
Quick Reference Index

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.

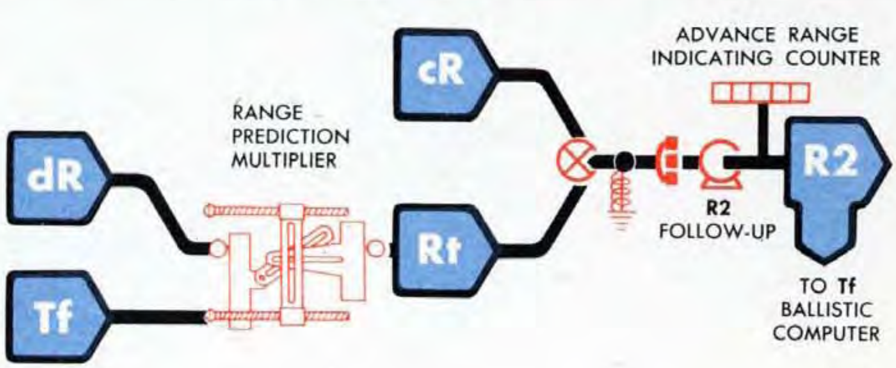
COMPUTING ADVANCE RANGE, R2

Three computing mechanisms are used in the *R2* network. They are: the Range Prediction Multiplier, the *Tf* Ballistic Computer, and the Range Rate Corrector.

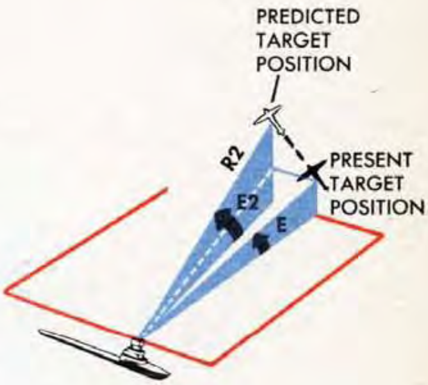
The range prediction multiplier



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.

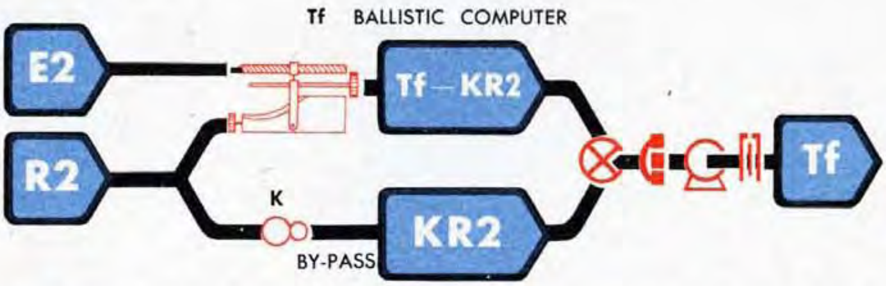


The Tf ballistic computer



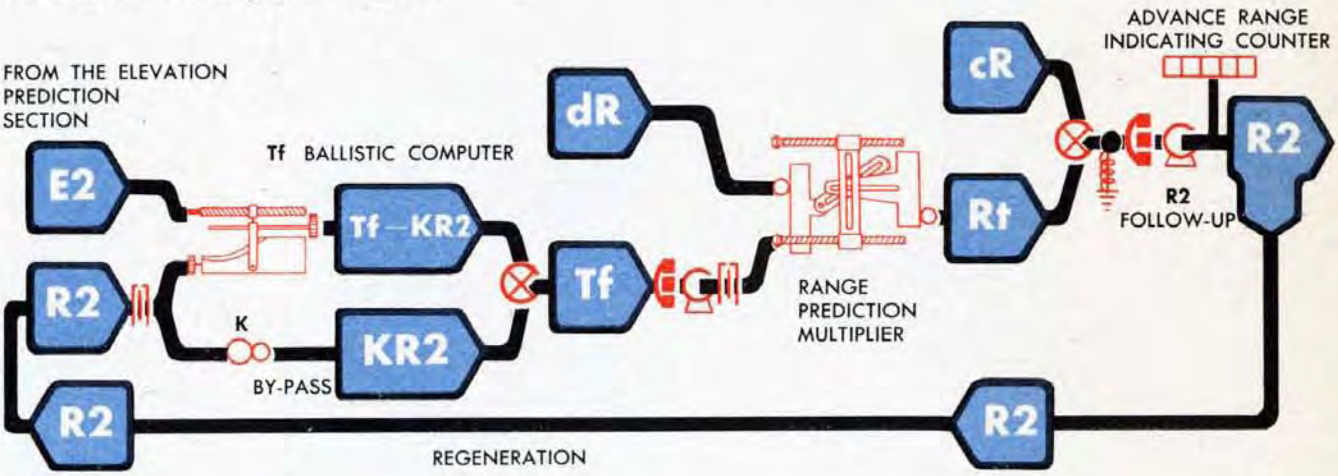
The two inputs to the *Tf* Ballistic Computer are Advance Range, *R2*, and Predicted Target Elevation, *E2*.

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.

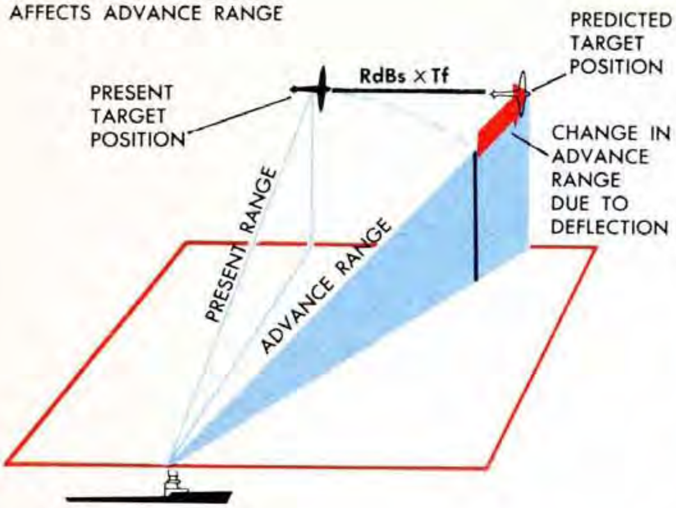


The range rate corrector

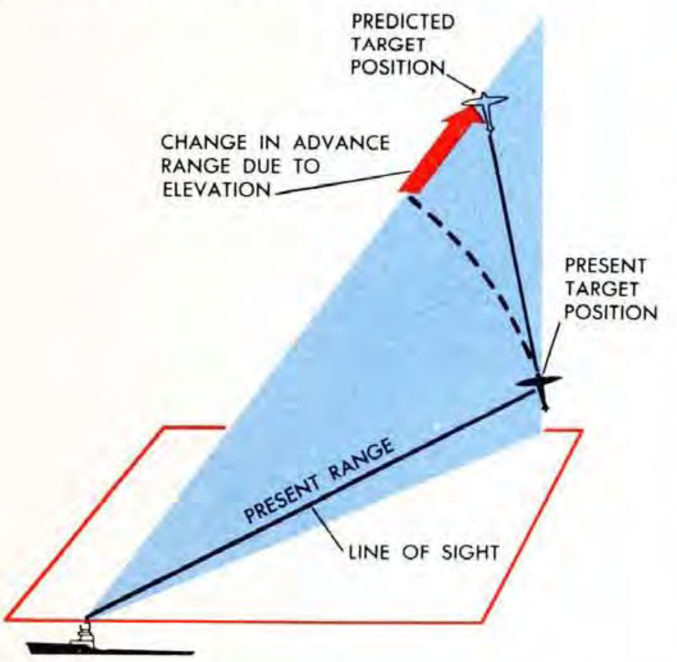
The quantity added to Range Rate, *dR*, to allow for the effect of Elevation and Deflection during the Time of Flight is computed in the Range Rate Corrector. This unit and the quantity it computes are described on the following page.

How Target Deflection and Elevation affect Advance Range

HOW TARGET DEFLECTION AFFECTS ADVANCE RANGE



HOW TARGET ELEVATION 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.

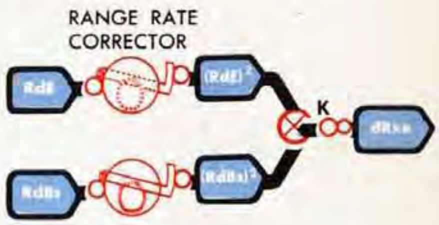
How target elevation affects range

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.

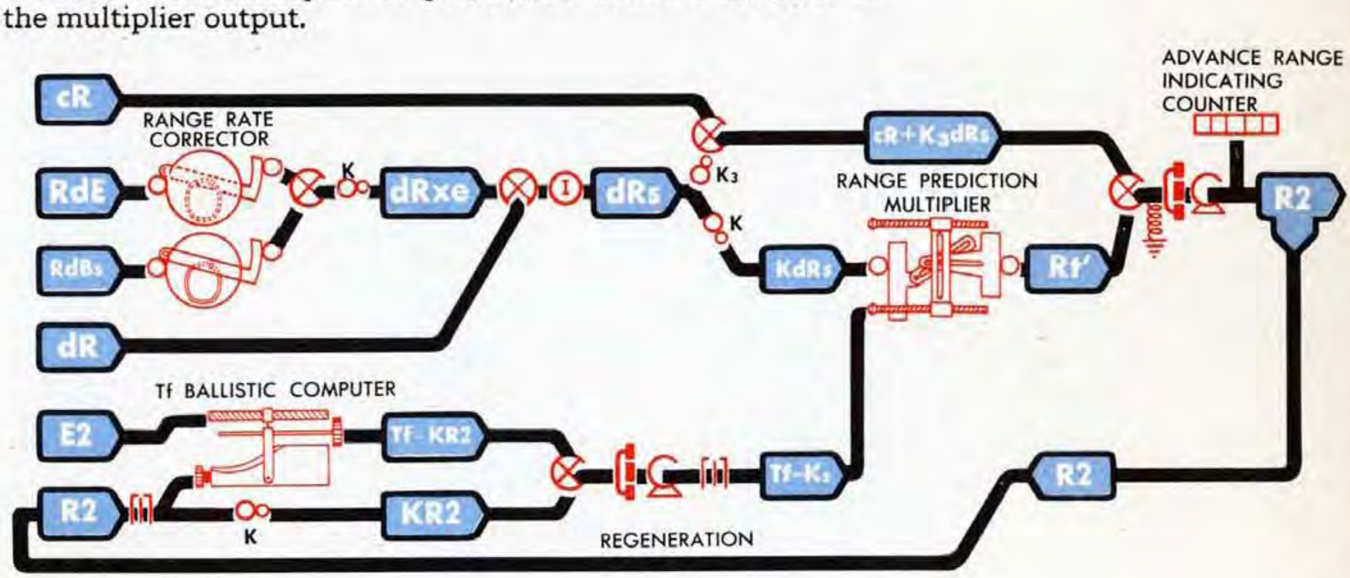


The Range Rate Corrector contains a differential and two "square" computing cams, each with a sector follower. Elevation Rate, *RdE*, is the input to one cam. Deflection Rate, *RdBs*, is the input to the other cam. The cam outputs are $(RdE)^2$ and $(RdBs)^2$. These two quantities are added in the differential. *K* is introduced by a gear ratio. The output of the gear ratio is *dRxe*, the output of the Range Rate Corrector.

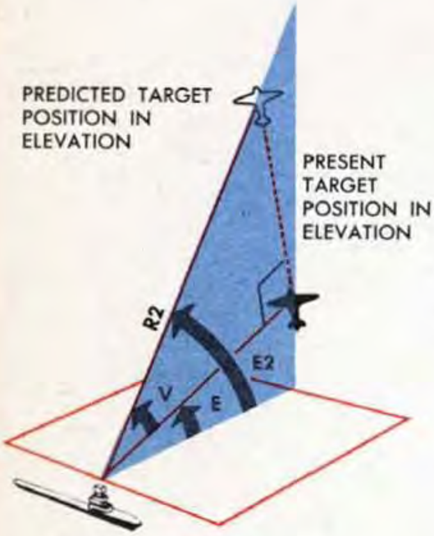
The alteration *dRxe* must be multiplied by *Tf* to produce the Total Linear Correction to Range. In the Computer Mark 1, it does not exist as a separate quantity but is part of the output from the Range Prediction Multiplier. The alteration *dRxe* combines with the Direct Range Rate, *dR*. *dR* plus *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.

$$V = Vt - Vx$$

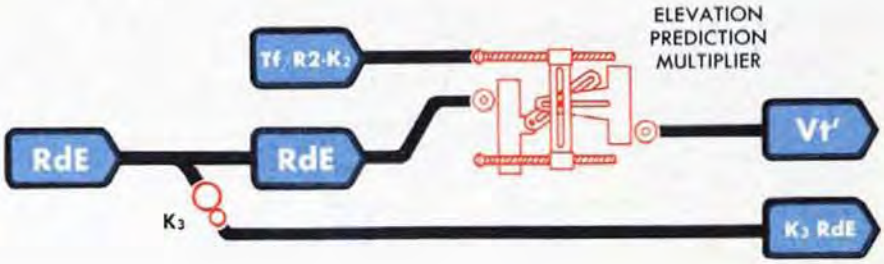
Vt is computed in the Elevation Prediction Multiplier network. *Vx* is computed in the Complementary Error Corrector.

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*.

$$\frac{RdE \times Tf}{R2} = Vt$$

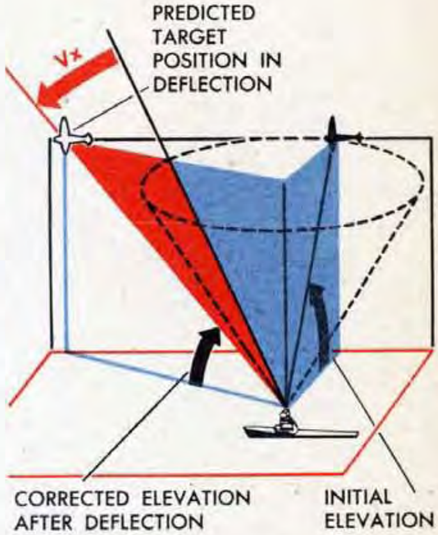
Vt is the Elevation Prediction which compensates for the relative motion of Target and Own Ship during the Time of Flight.

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 $E2$.

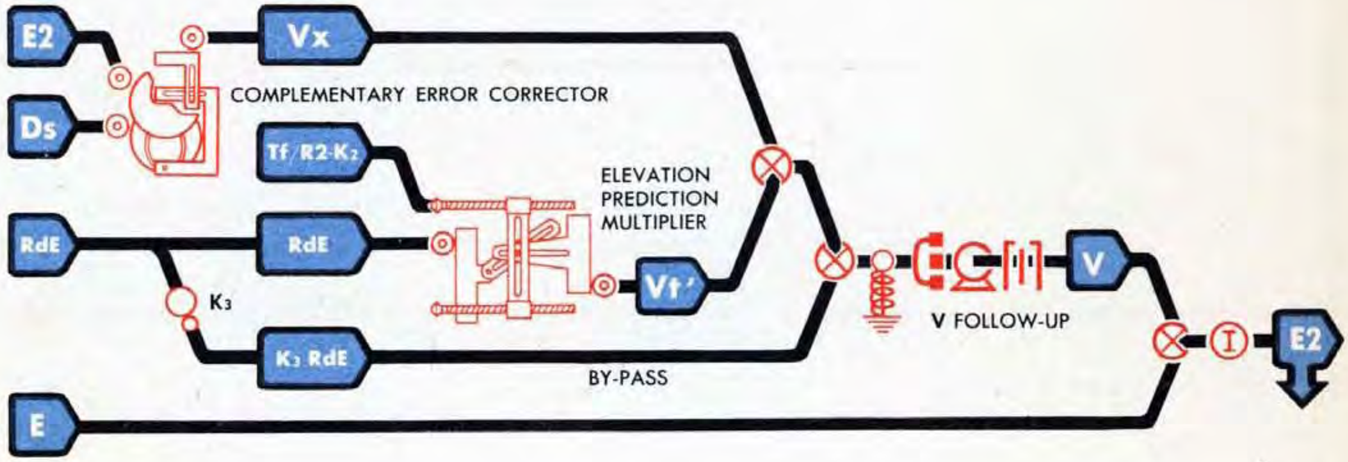
$$Vx = (Ds)^2 \times f(E2)$$

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, $E2$.

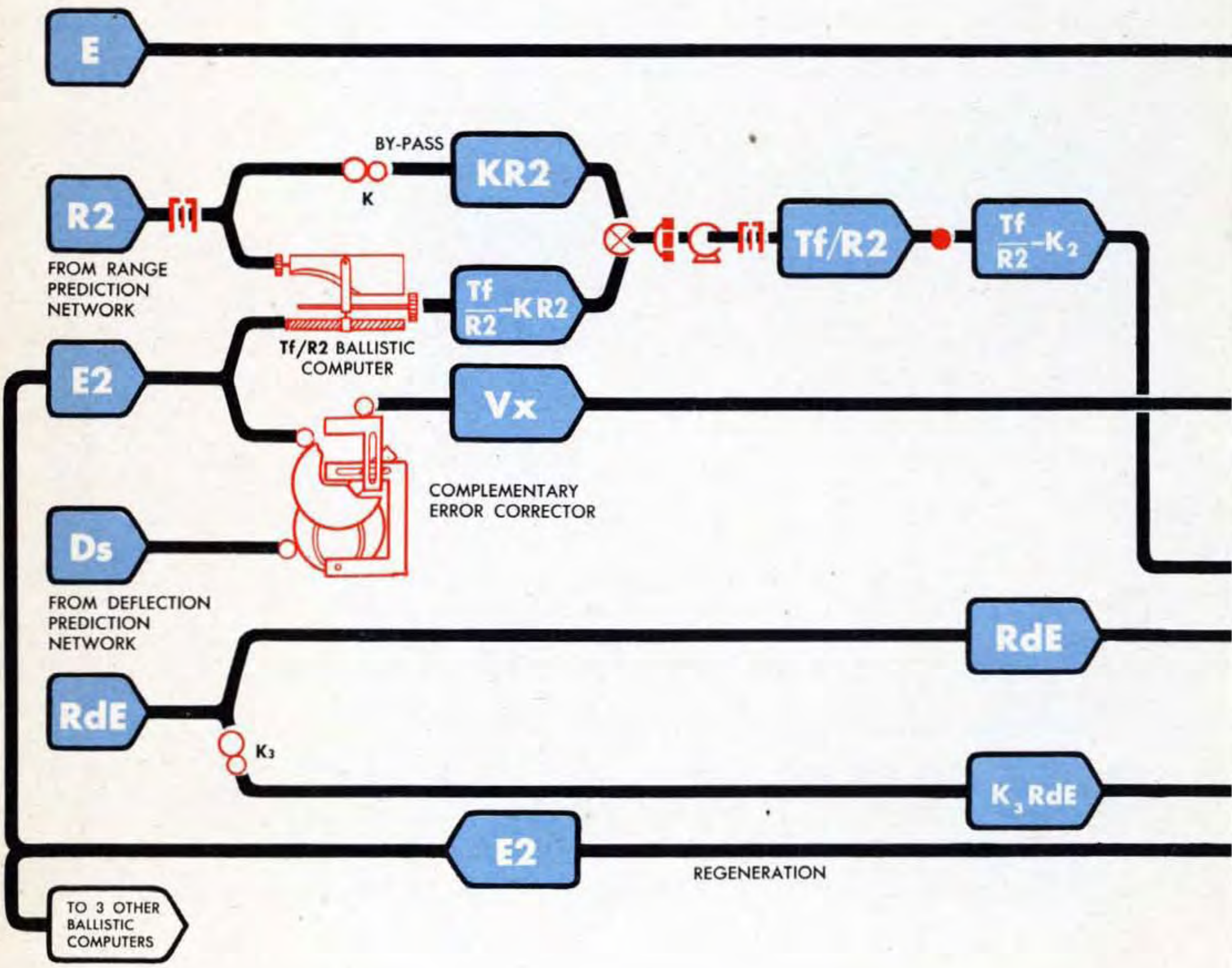
$$E2 = V + E$$



The Elevation Prediction Network

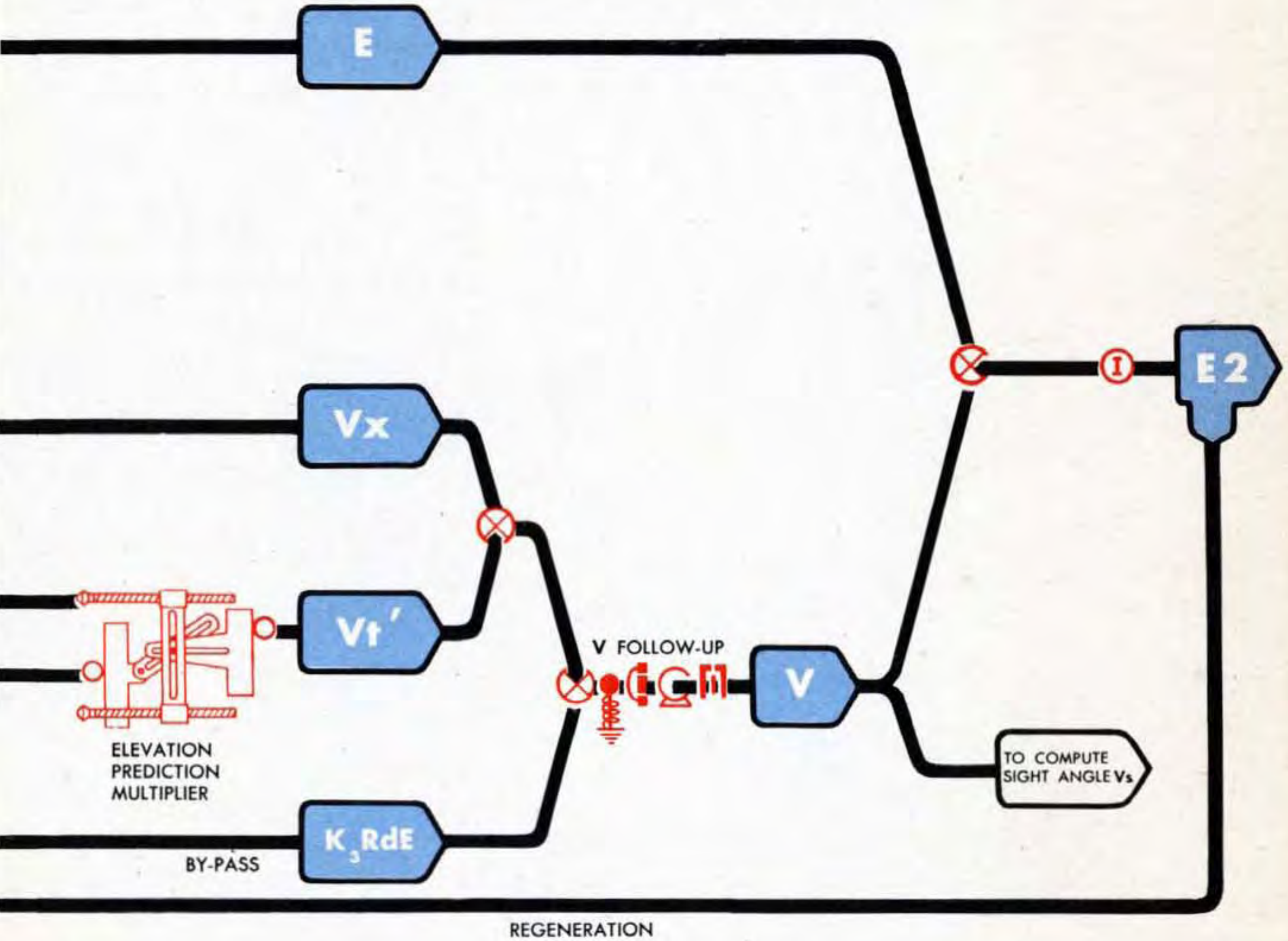
Predicted Elevation, *E2*, regenerates in the same way as Advance Range, *R2*. *E2* becomes an input to the *Tf/R2* Ballistic Computer. The other input to this Computer is *R2*.

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*.

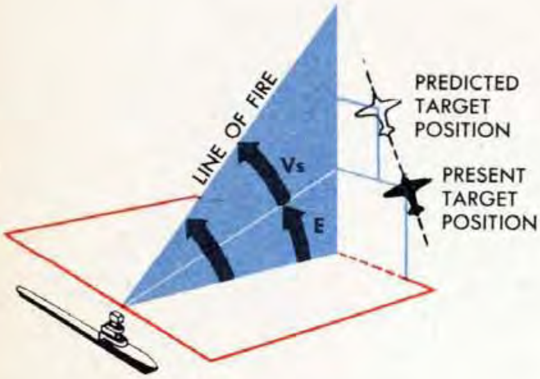


A branch of the $R2$ shaft line by-passes the $Tf/R2$ cam. Ratio gearing on this shaft line multiplies $R2$ by K to produce $KR2$, which is a straight-line approximation of $Tf/R2$. $KR2$ is added to the cam output $Tf/R2 - KR2$ to obtain $Tf/R2$. $Tf/R2$ is amplified by a velocity-lag follow-up and is the output of the ballistic computer. $Tf/R2$ is then used in the Elevation Prediction Multiplier.

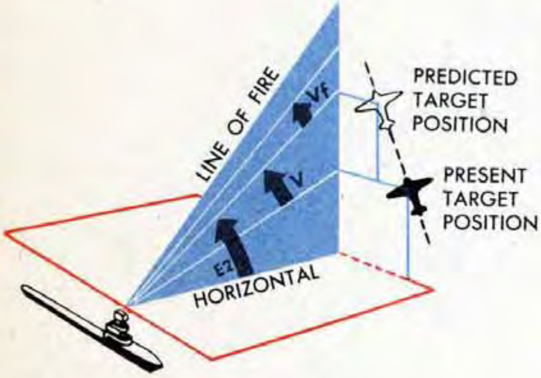
$E2$ also regenerates to become an input to the Time of Flight, $Vf + Pe$, and Mechanical Fuze Ballistic Computers. $E2$ is also a regenerative input to the Complementary Error Corrector and to the Elevation Wind Component Solver which is described later in this chapter.



COMPUTING SIGHT ANGLE, Vs



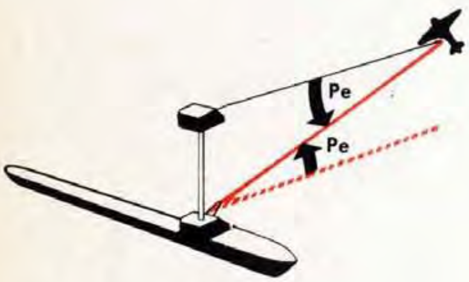
Sight Angle, *Vs,* is the angular difference between the elevation of the Line of Fire above the horizontal and the elevation of the Line of Sight above the horizontal, both of these elevation angles being measured in vertical planes.



Without allowance for Wind or changes in Initial Velocity, *Vs* is made up of three Elevation quantities: *V, Vf,* and *Pe.*

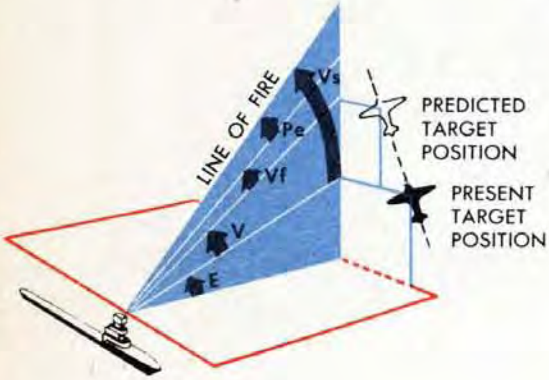
1. Elevation Prediction, *V,* is the angular Elevation change during Time of Flight. *V* is the vertical angle between the slant plane of the Present Line of Sight and the slant plane of the Predicted Line of Sight.

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., $Vs = V + Vf + Pe$.

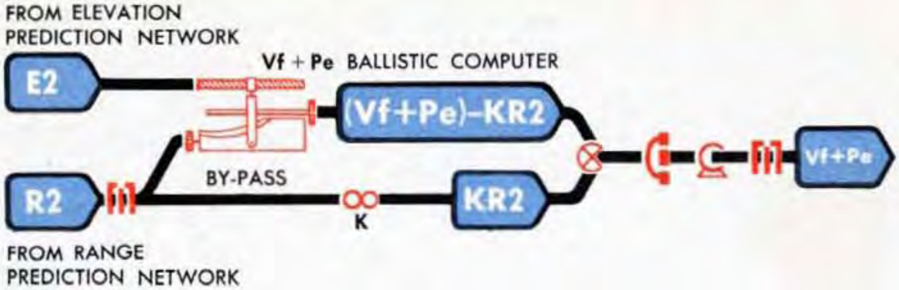


The computation of *V* has been described in the Elevation Prediction network. $V = Vt - Vx$. *Vf* and *Pe* are both computed in one ballistic computer.

A detailed description of the Elevation Parallax Correction, *Pe,* is given in the chapter on Parallax, page 350.

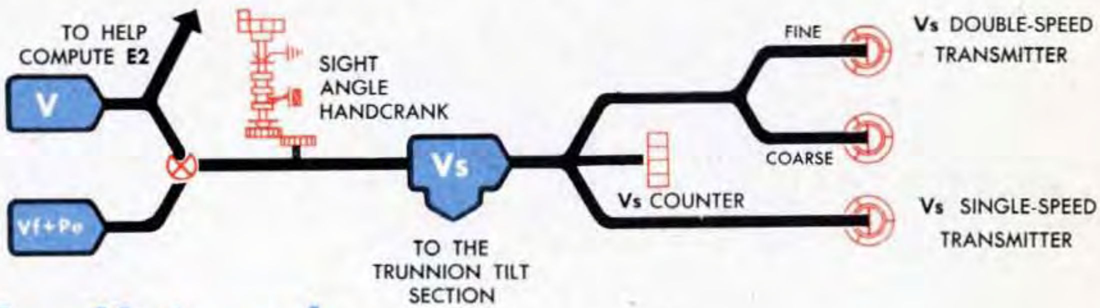
The Vf+Pe Ballistic Computer

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

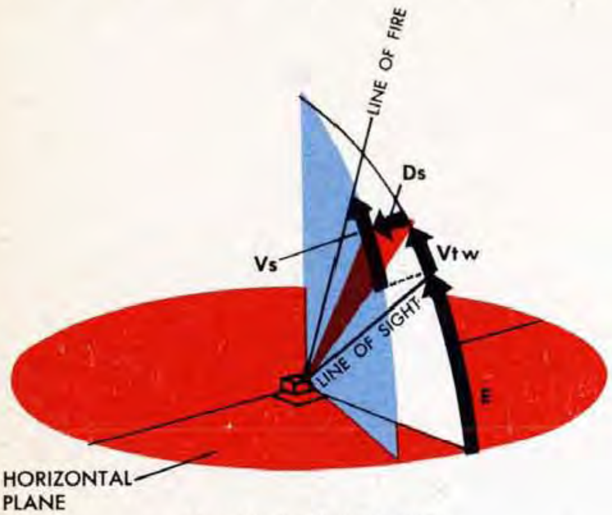
Sight Angle, *Vs*, goes to the Trunnion Tilt Section of the Computer Mark 1 where it is used in computing the Gun Orders.

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.

Quick Reference Index

COMPUTING SIGHT DEFLECTION, Ds



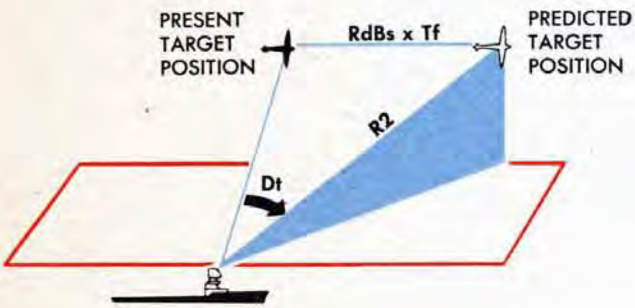
Ds WHEN WIND IS ZERO AND I.V. IS 2550 F. S.

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.

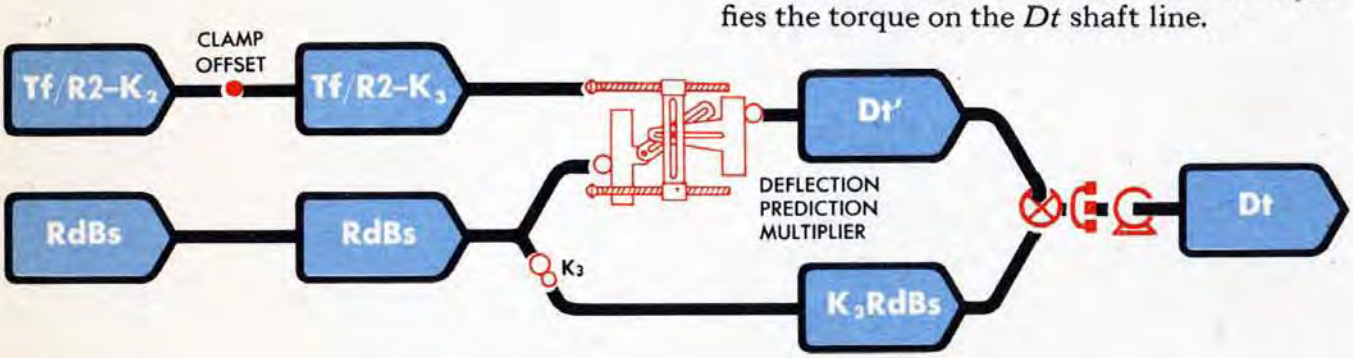
Without Wind or Initial Velocity corrections, *Ds* is made up of two Deflection quantities, *Dt* and *Dfs*. *Dt* is the Deflection Prediction for relative movement of Target and Own Ship during the Time of Flight. *Dfs* is the Drift Correction.

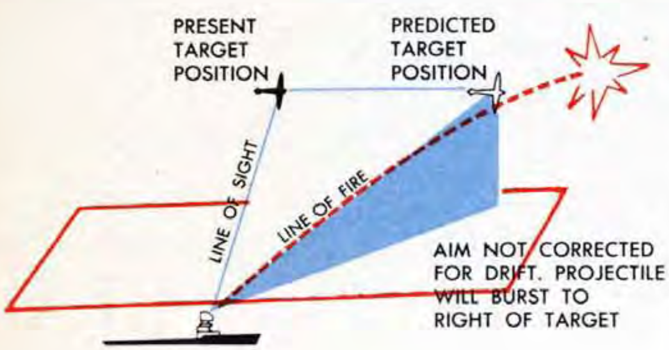
$$Ds = Dt - Dfs$$

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.

Quick Reference Index

Drift Correction, Dfs

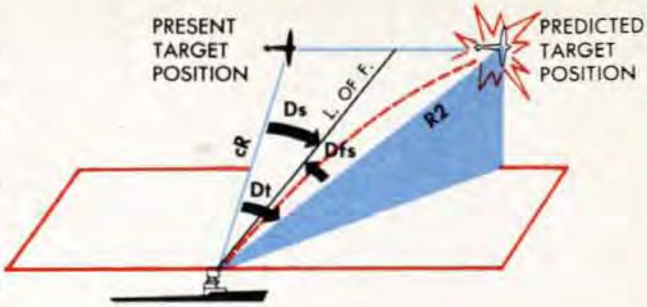
It has been found that the average correction needed to compensate for drift is approximately proportional to the Elevation Correction, $Vf + Pe$, when $I.V.$ is 2550 f.s. $Vf + Pe$ from the $Vf + Pe$ Ballistic Computer is converted to Drift Correction, *Dfs*, by a gear ratio on a branch of the $Vf + Pe$ shaft line.

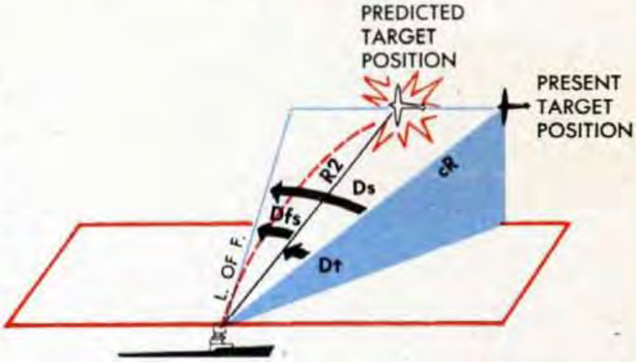
Dfs is subtracted from *Dt* at a differential to obtain Sight Deflection, *Ds*.

$$Ds = Dt - Dfs$$

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*.



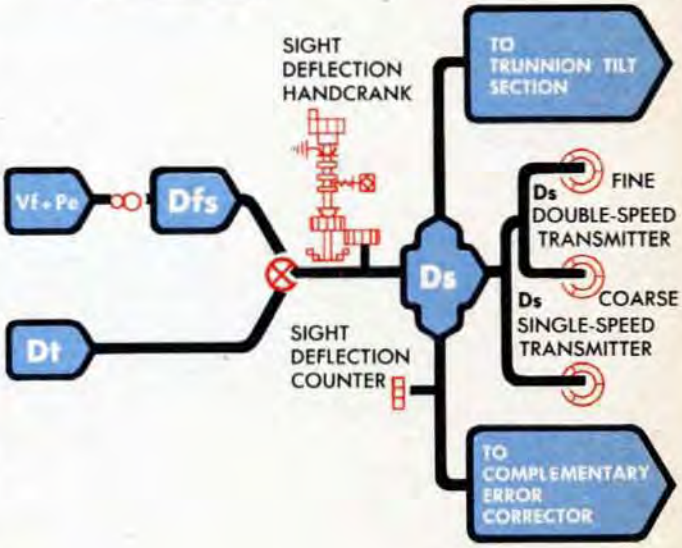


Where Ds is used

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.

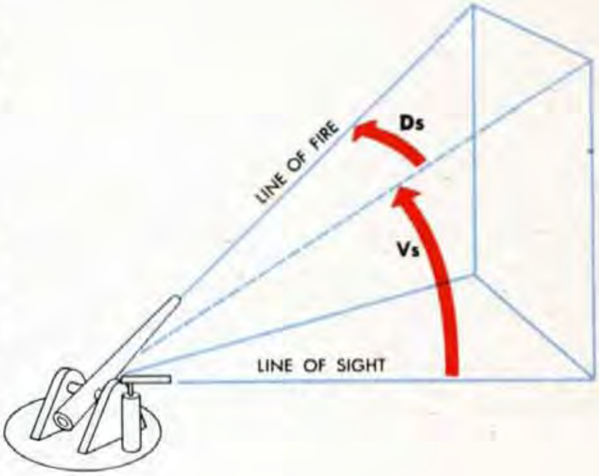
Ds goes also to the Complementary Error Corrector in the Elevation Prediction Section.



Using Vs and Ds at the Guns

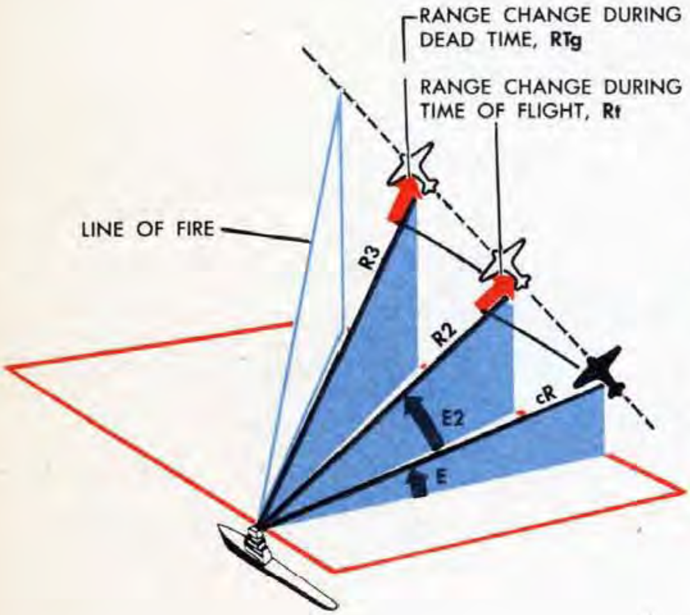
When Gun Elevation Order, *E′g*, and Gun Train Order, *B′gr*, are used to position the guns, the gun sights are offset from the guns by Sight Angle, *Vs*, and Sight Deflection, *Ds*. Thus, the observer at the gun may view the Target through the gun sight.

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.

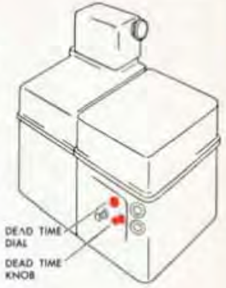
R3 and *E2* are used in the Fuze Ballistic Computer to obtain Fuze Setting Order, *F*.

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*.

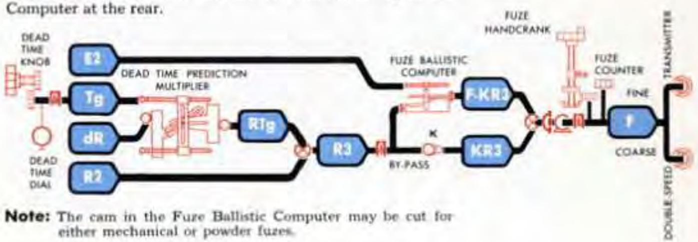


The fuze ballistic computer

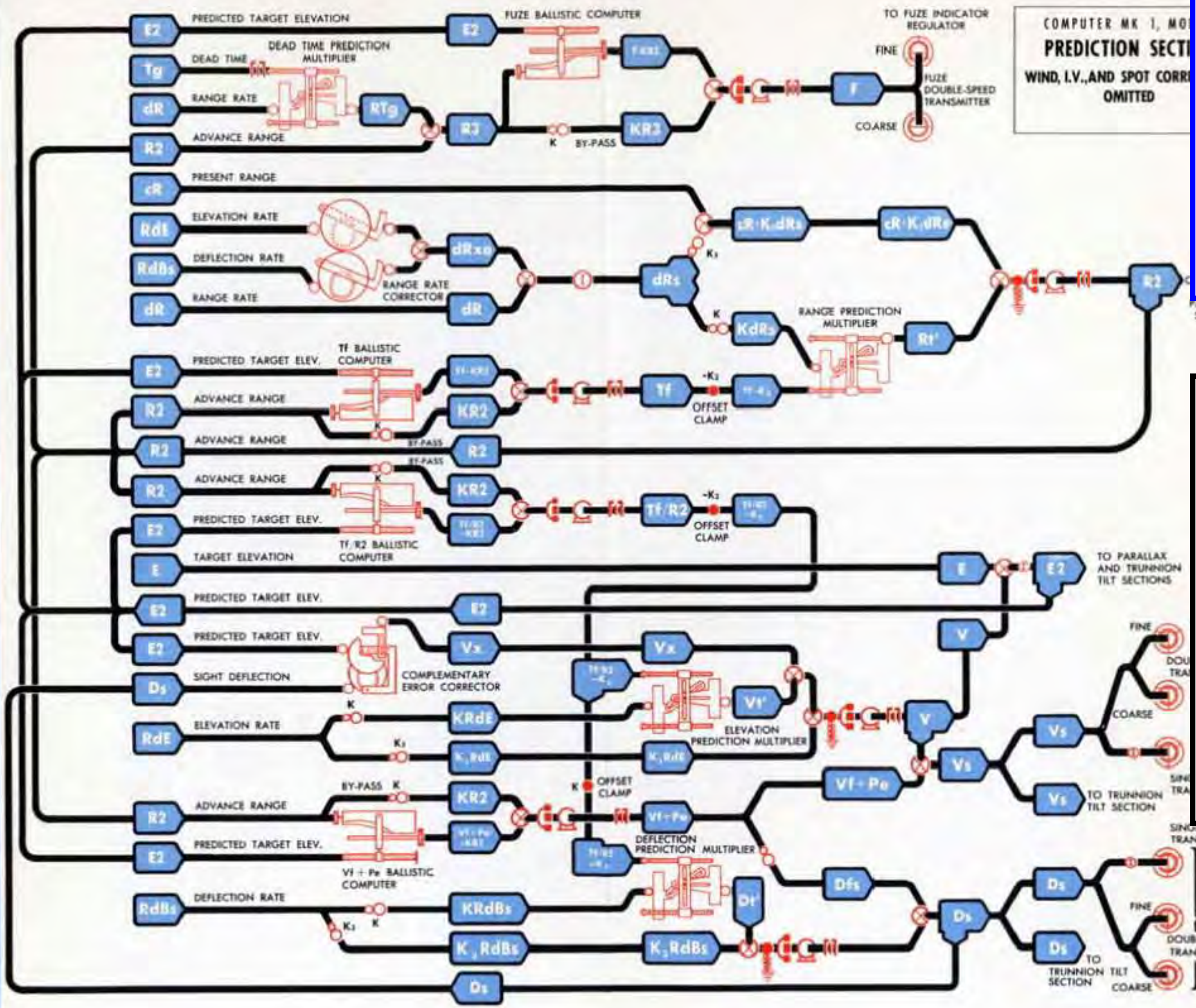
Fuze Range, *R3*, positions the cam in the Fuze Ballistic Computer. Predicted Elevation, *E2*, positions the cam follower. The cam computes the difference between Fuze Setting Order, *F*, and a straight-line approximation of *F*, called *KR3*. The cam output is *F – KR3*.

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.

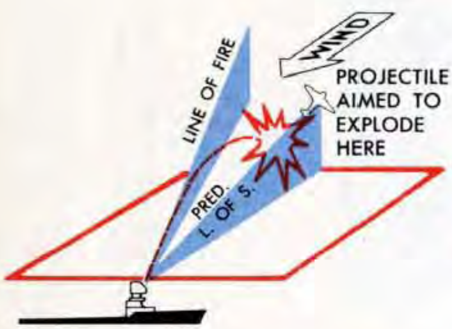
If for any reason some of the Computer's transmission circuits are not energized, but the circuit for the Fuze Setting Order Transmitter *is* energized, the transmitter may be set by hand according to any information available. This is done by turning the Fuze Handcrank in the IN position and watching 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.

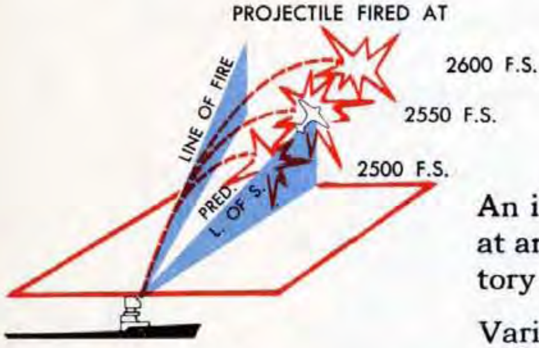


How Vs, Ds, and F are corrected to allow for WIND and change in INITIAL VELOCITY



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.

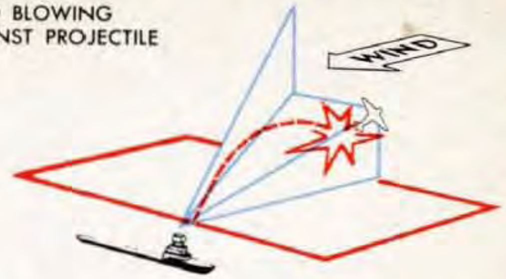
If the Target is at a high elevation and the Wind is blowing against the projectile along the plane through the Line of Fire, the Wind effect will tend to elevate the trajectory. To correct for this, the Elevation of the gun must be reduced.

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.

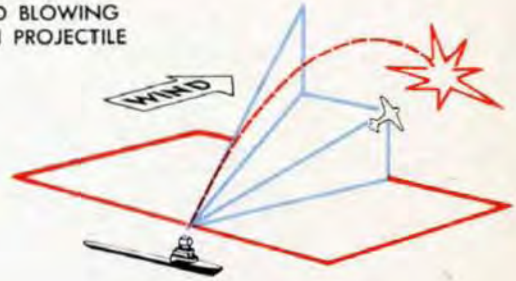
The examples given here are special cases. Normally the Wind does not blow exactly along or at right angles to the plane of the Line of Fire, but has COMPONENTS in, or at right angles to, the plane through the Line of Fire.

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.

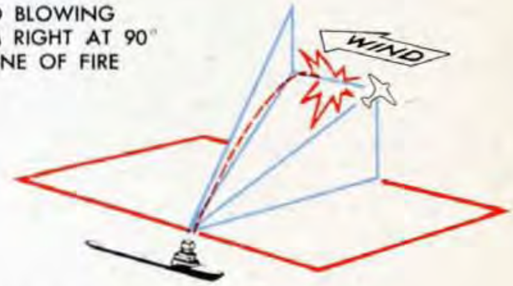
WIND BLOWING AGAINST PROJECTILE



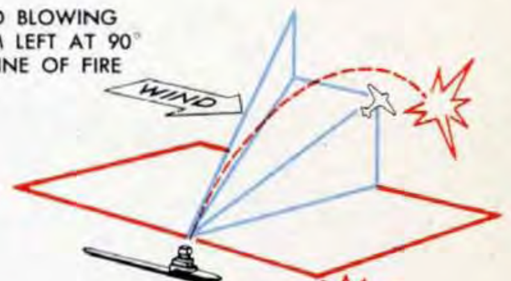
WIND BLOWING WITH PROJECTILE



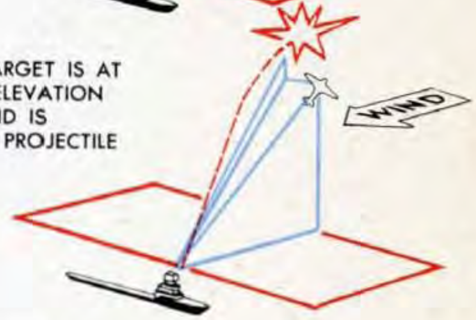
WIND BLOWING FROM RIGHT AT 90° TO LINE OF FIRE



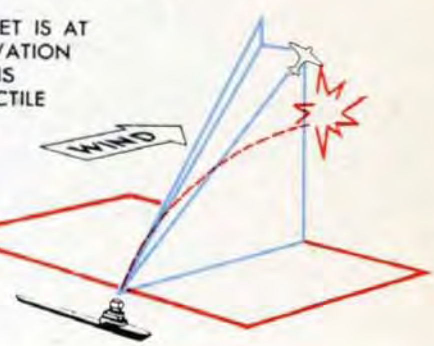
WIND BLOWING FROM LEFT AT 90° TO LINE OF FIRE



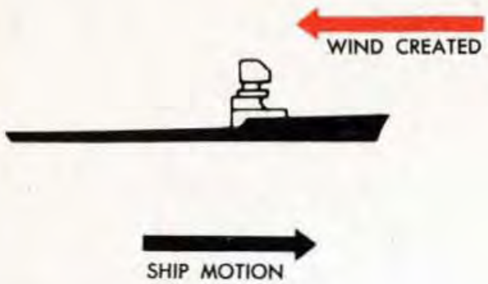
WHEN TARGET IS AT A HIGH ELEVATION AND WIND IS AGAINST PROJECTILE



WHEN TARGET IS AT A HIGH ELEVATION AND WIND IS WITH PROJECTILE

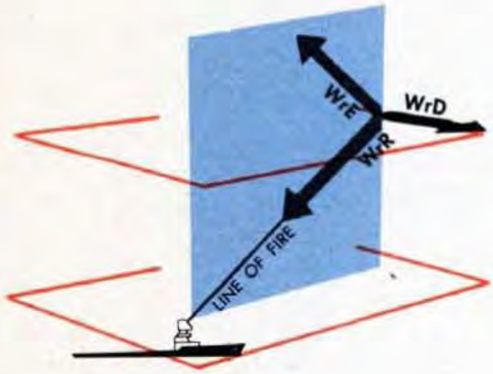


COMPUTING WIND RATES



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.

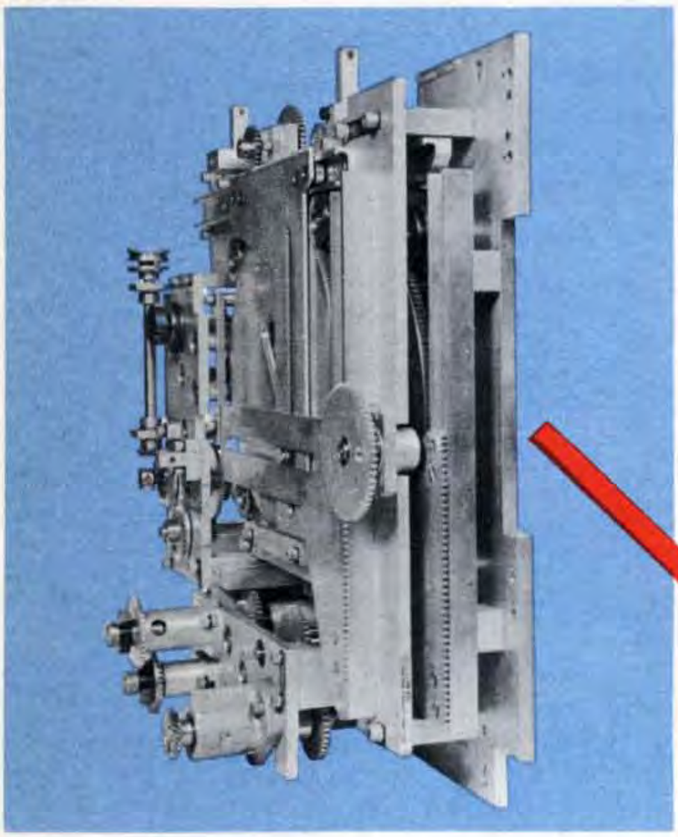
One component of Apparent Wind, at right angles to the plane of fire, is the Wind Rate affecting Deflection Prediction, *WrD*. The other component of Apparent Wind, in the plane of fire, is used in computing the other two Wind Rates:

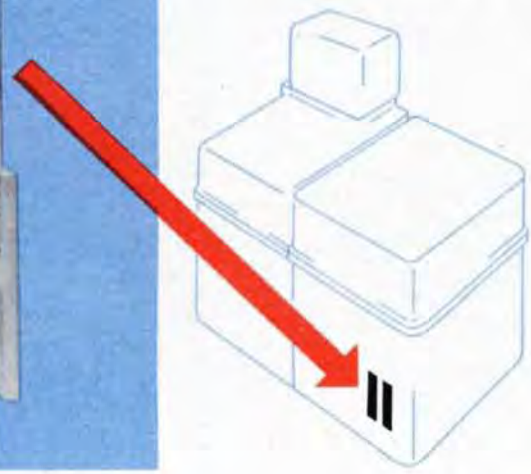
The Wind Rate affecting Range Prediction, *WrR*.

The Wind Rate affecting Elevation Prediction, *WrE*.

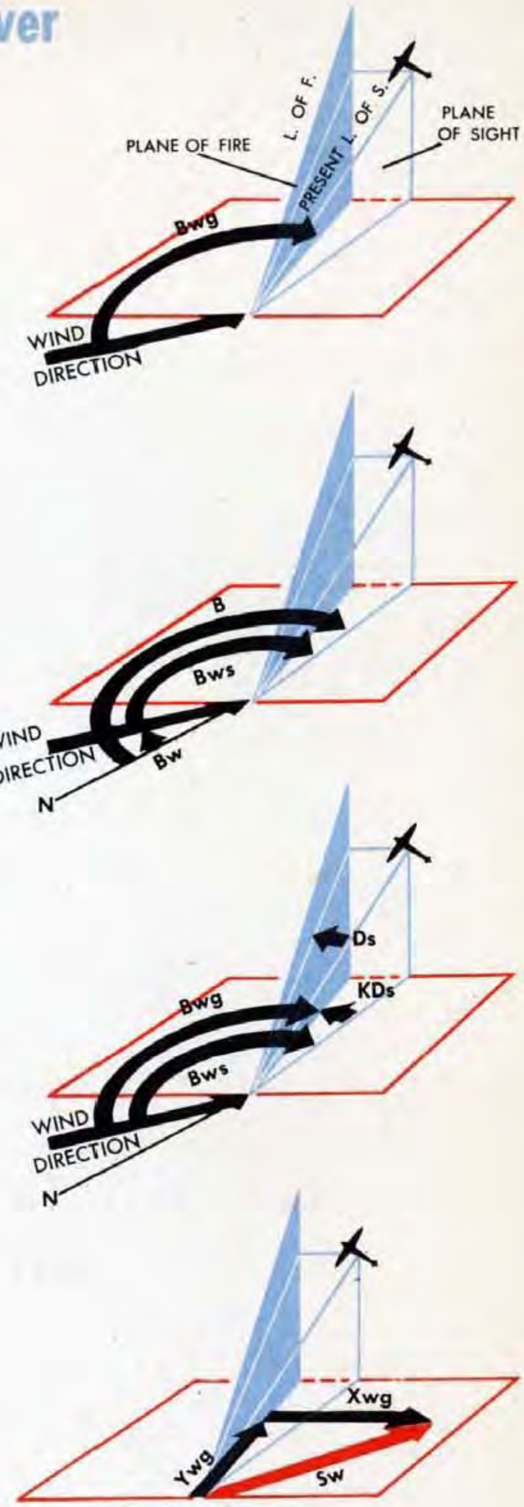
Two Wind Component Solvers and the Own Ship Component Solver are used in computing the Wind Rates.

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.

$$Bws + KDs = Bwg$$

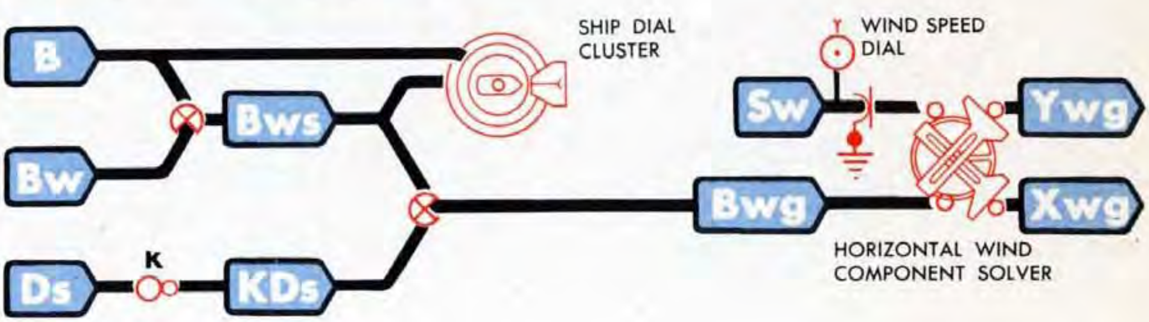
If KDs is a minus value, the equation for Bwg is: $Bwg = Bws + (-KDs)$.

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:

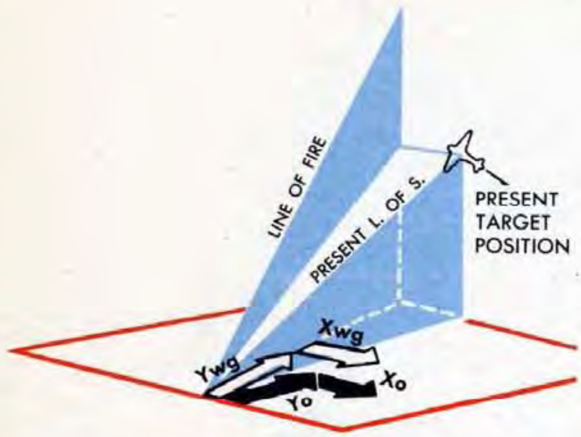
1 Ywg, the horizontal range component of True Wind Velocity in the vertical plane approximately through the Line of Fire.

2 Xwg, the horizontal deflection component of True Wind Velocity perpendicular to the vertical plane approximately through the Line of Fire.

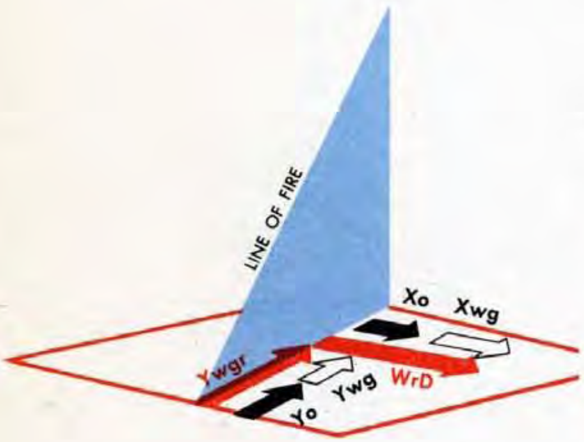


How components of apparent wind are computed

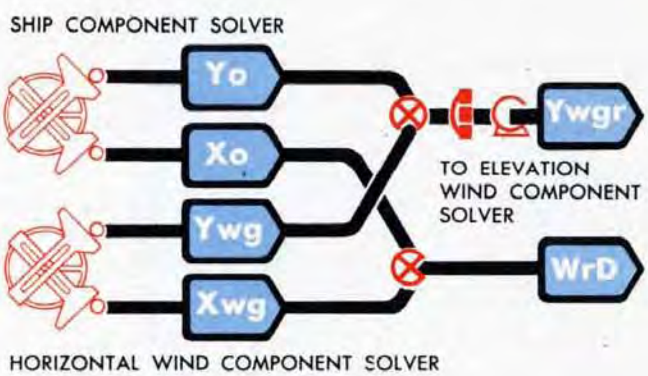
Wind caused by Own Ship Motion is equal to Own Ship Speed; therefore the two components of Own Ship Velocity, *Xo* and *Yo*, reversed in sign, are used as the two components of Wind caused by Own Ship Motion.



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.

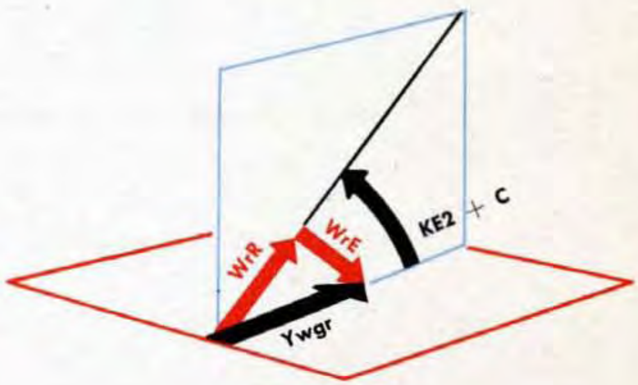
The elevation wind component solver

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.

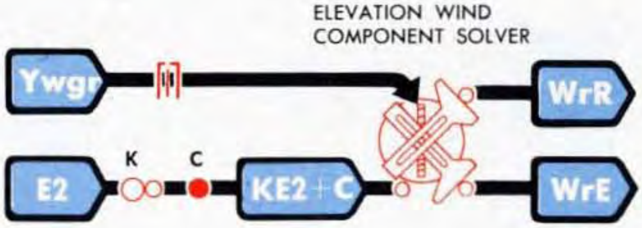
KE2 + C is an empirical quantity which gives the best average results for all problems.

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*.



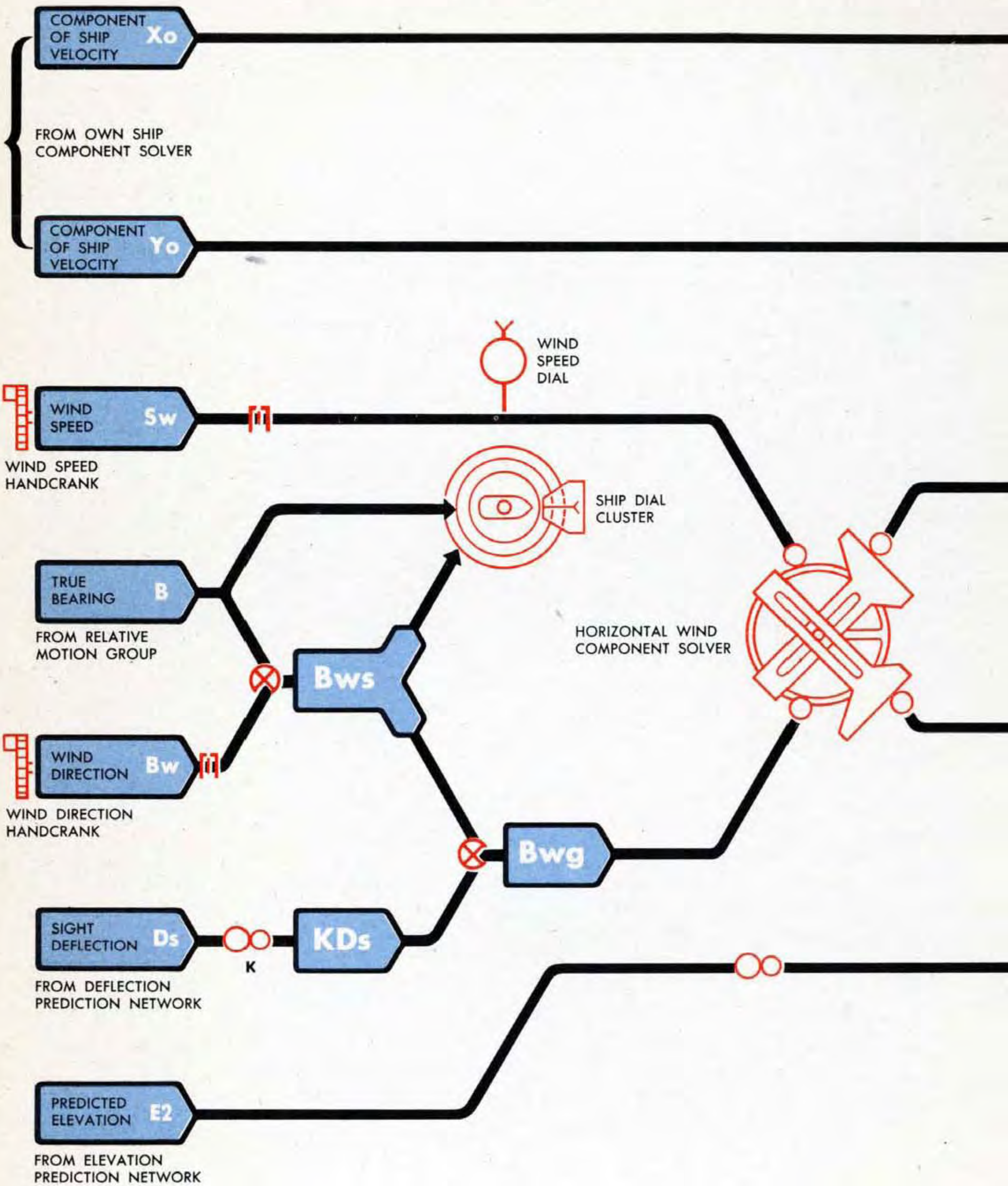
The Elevation Wind Component Solver computes two components of *Ywgr:*

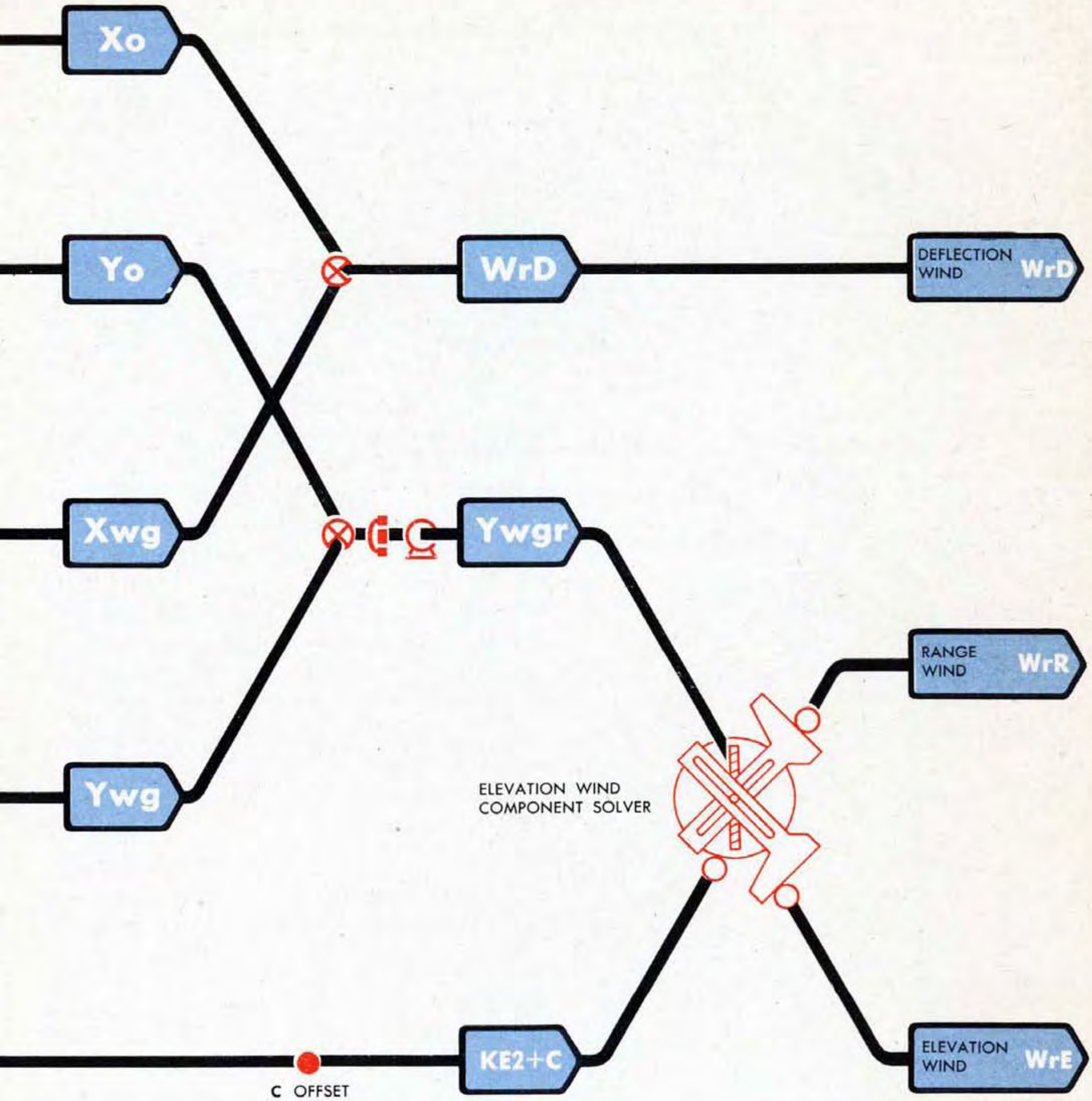
1. The component of Apparent Wind Velocity affecting Range Prediction is the Range Wind Rate, *WrR*.
2. The component of Apparent Wind Velocity affecting Elevation Prediction, is the Elevation Wind Rate, *WrE*.



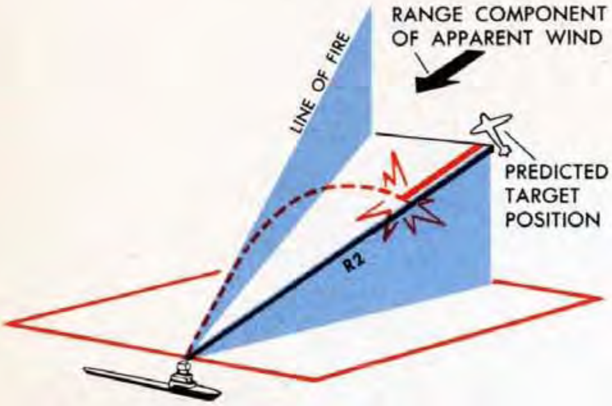
The three Wind Rates, *WrR*, *WrE*, and *WrD* are used to adjust the Range, Elevation, and Deflection Predictions for the effect of Wind.

SCHEMATIC of the WIND RATES



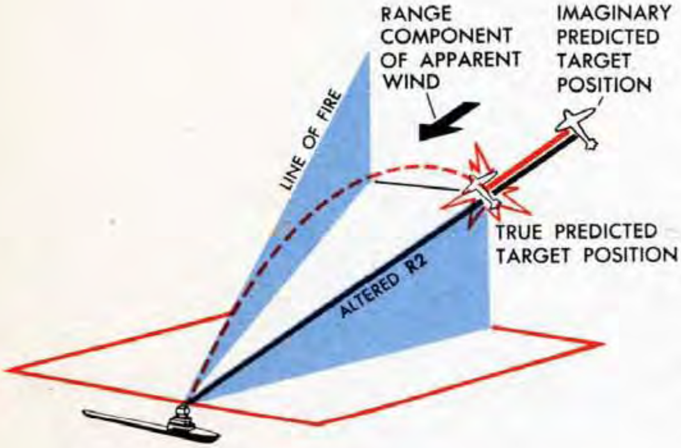

Xo
Yo
Xwg
Ywg
WrD
Ywgr
KE2+C
C OFFSET
ELEVATION WIND
COMPONENT SOLVER
DEFLECTION WIND WrD
RANGE WIND WrR
ELEVATION WIND WrE

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*.

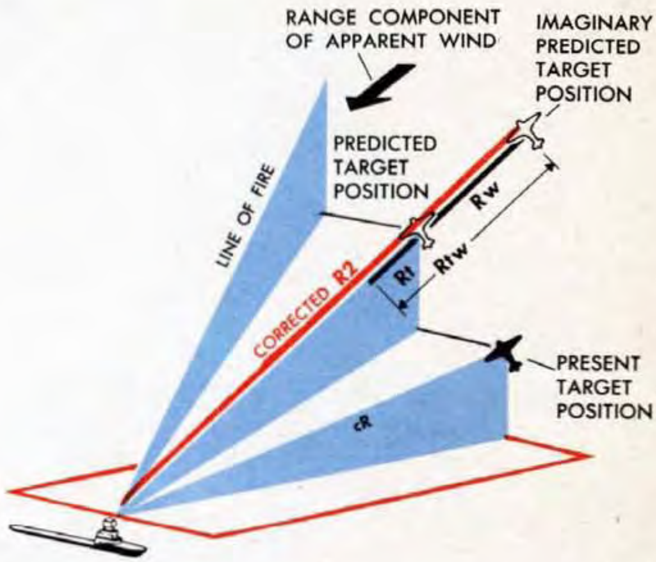
$$Rt = dRs \times Tf$$

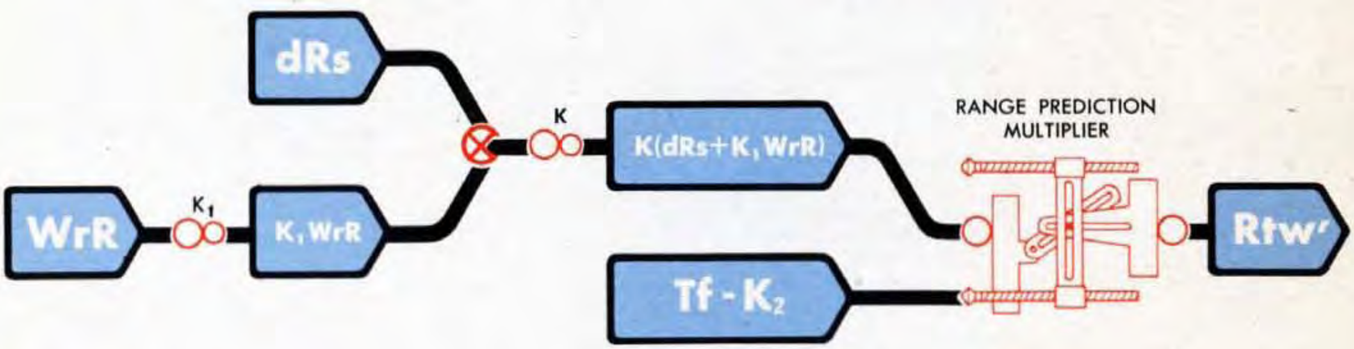
The same multiplier also multiplies K_1WrR by $Tf - K_2$. These two computations are made in the same multiplier to save mechanisms. K_1WrR is added to dRs to obtain $dRs + K_1WrR$. The quantity $dRs + K_1WrR$ is then multiplied by the constant K in a gear ratio to obtain the quantity:

$$K\,(dRs + K_1WrR)$$

In the Range Prediction Multiplier, $K\,(dRs + K_1WrR)$ is multiplied by $Tf - K_2$ to obtain Rtw'.

$$K\,(dRs + K_1WrR) \times (Tf - K_2) = Rtw'$$





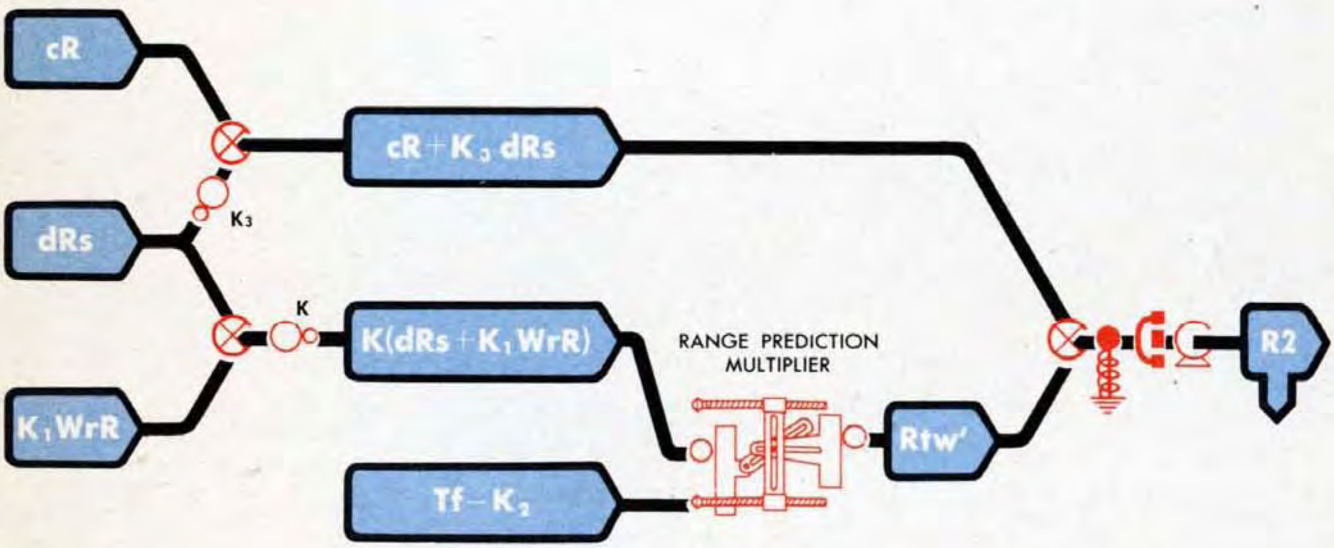
K is a constant used to change knots to yards per second. K_2 is required for computing Rw. Because only one multiplier is used instead of two, dRs is also multiplied by K_2. This means that the output of the multiplier will be Rtw' ($= Rt' + Rw$) instead of Rtw. (See NOTE on page 266.) The necessary 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.

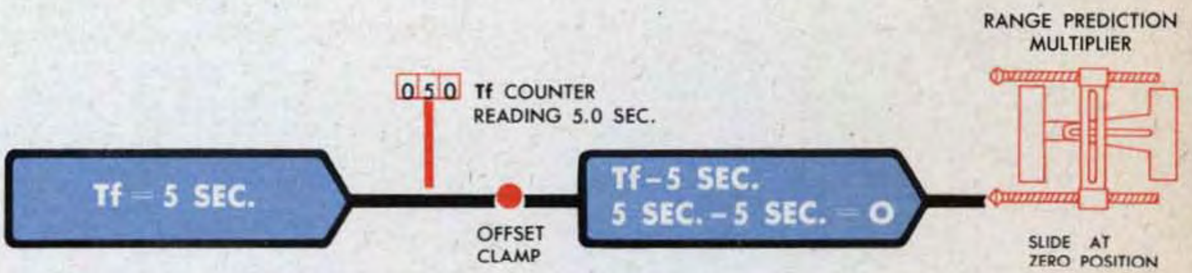
How the multiplier input is changed from Tf to Tf−K_2

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.

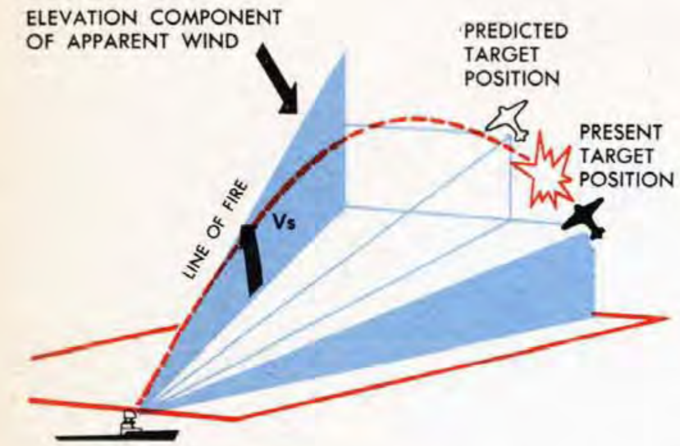
The position of the slide always represents five seconds less than the value of Tf, and causes the second input to be multiplied by $Tf - K_2$.

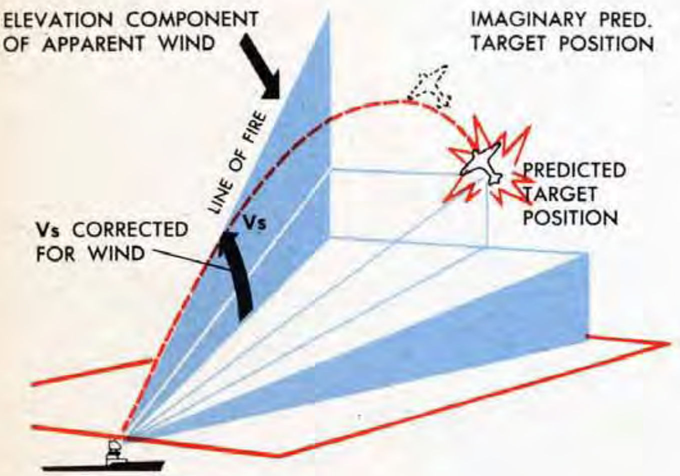


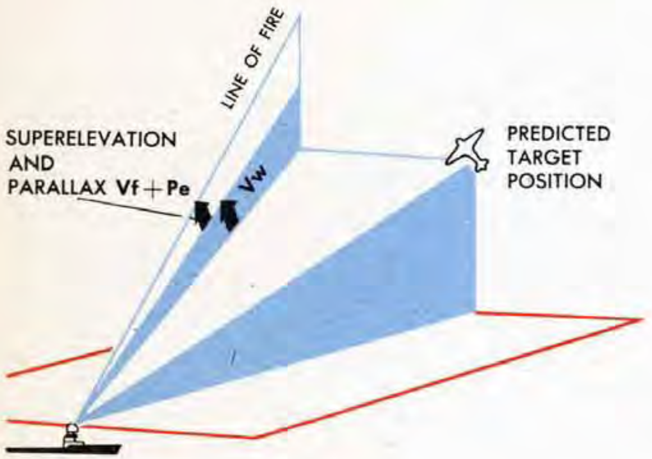
Correcting F to allow for wind

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_1WrE. 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_1WrE 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.

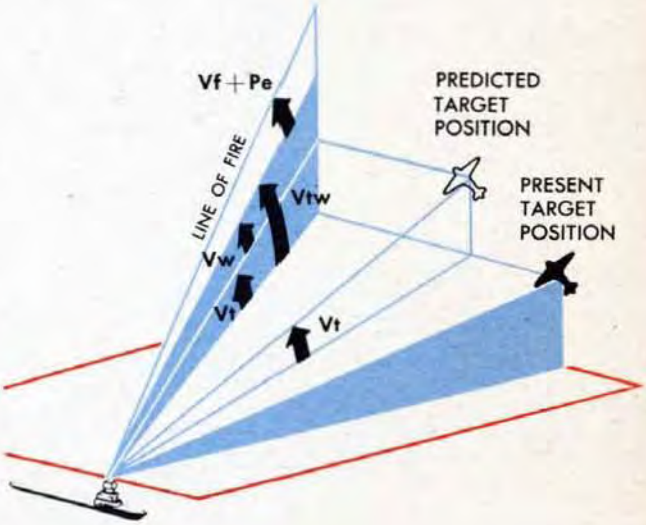
Vw alters *E2* and *E2* alters *R2*. These two quantities in turn alter all the Prediction quantities.

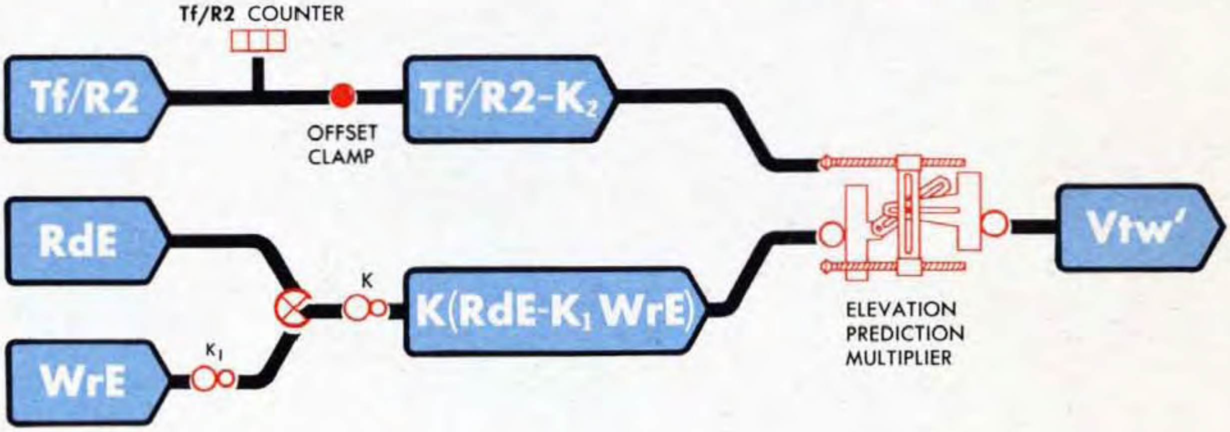
The elevation prediction multiplier

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

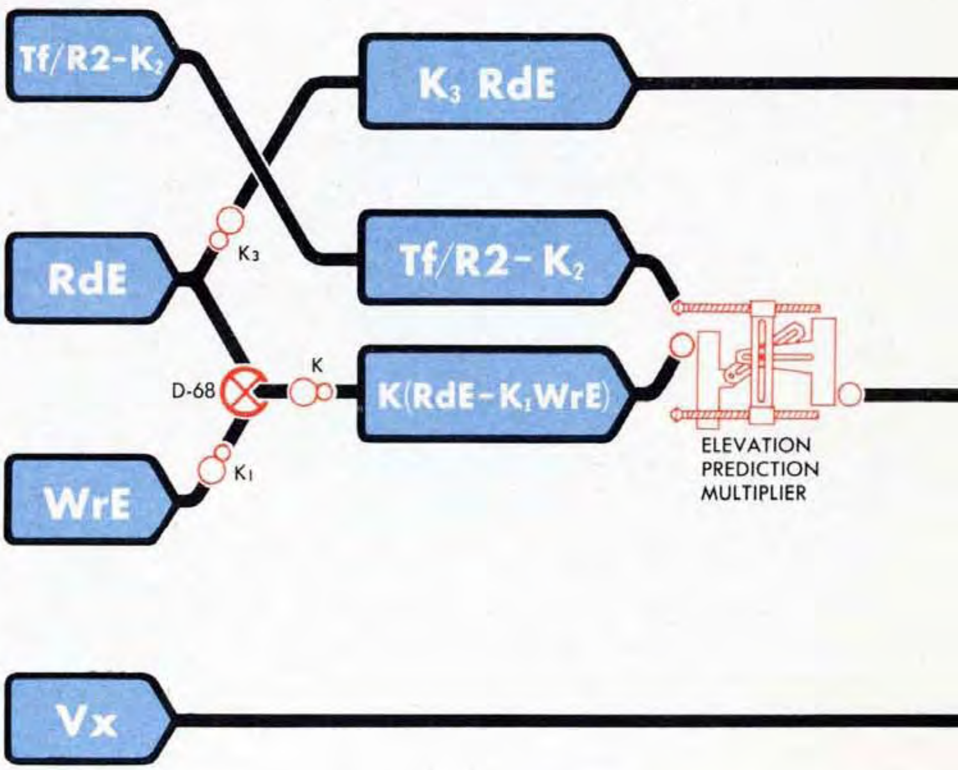
The constant K_2 which is introduced into the equation for solving Vtw is needed in producing an accurate value of Vw but is not needed to produce a correct Vt value. Since not only the Wind Rate, WrE, but also Linear Elevation Rate, RdE, is multiplied by this constant, the Elevation Prediction Multiplier 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.

$$Vs = V + Vf + Pe$$

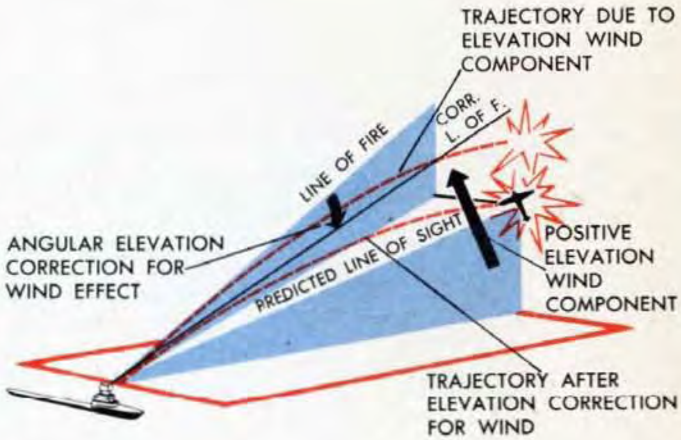
Predicted Target Elevation, $E2$, which is used as an input to the four ballistic computers, is also altered for the effect of the Elevation Wind Rate because the altered Elevation Prediction, V, is used in computing $E2$:

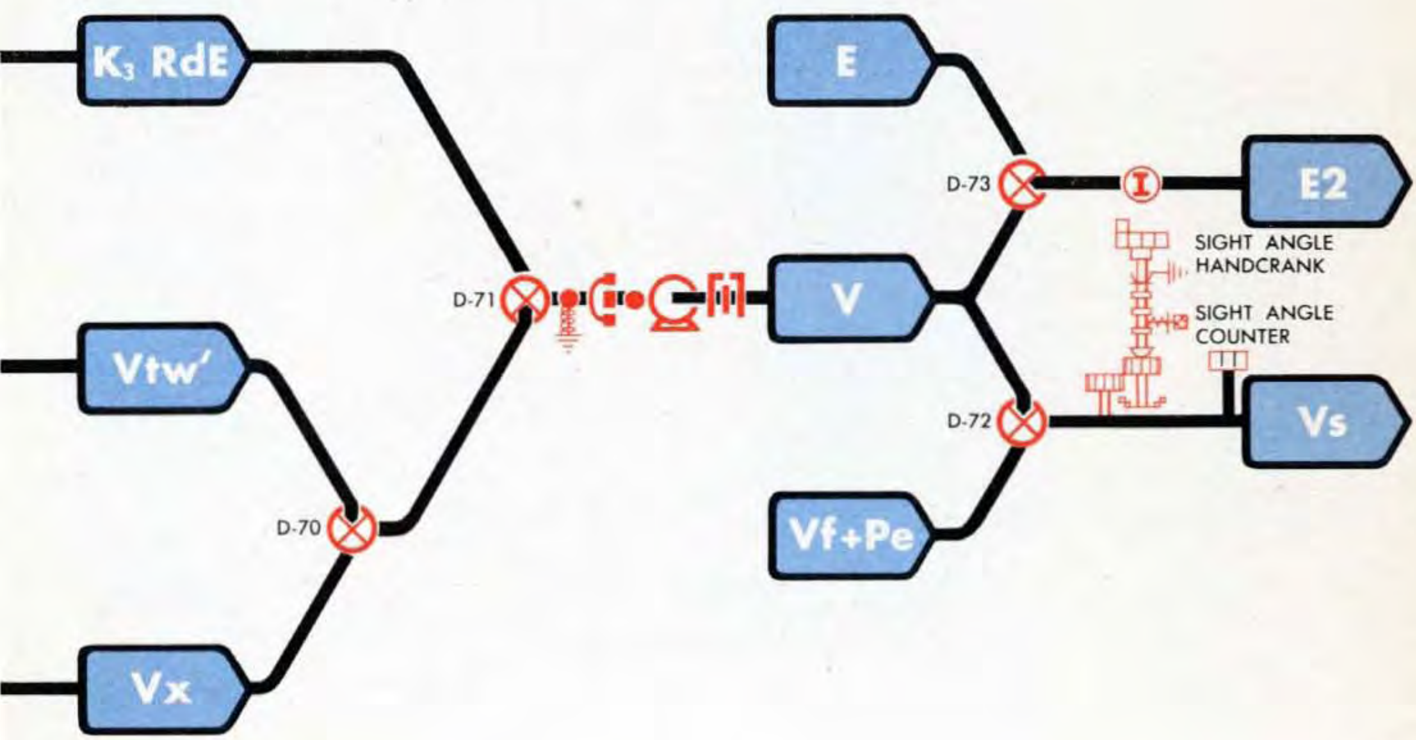
$$E2 = E + V$$

Why WrE is SUBTRACTED from RdE

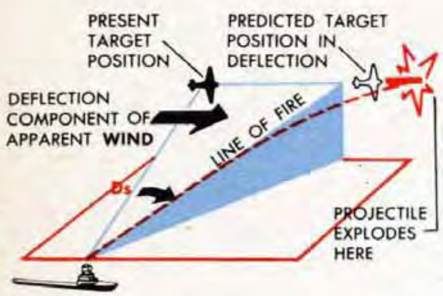
The Elevation Wind Rate is positive when the Wind is upward, since it tends to increase the Elevation of the projectile. The angular correction for a positive Elevation Wind Rate must reduce the Elevation. For this reason a positive Elevation Wind Rate, WrE, must be subtracted from the Elevation Rate, 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.

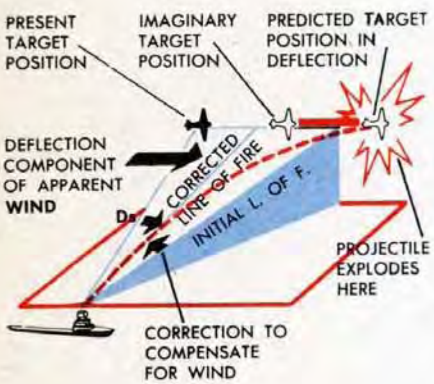




Correcting Ds to allow for WIND



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:

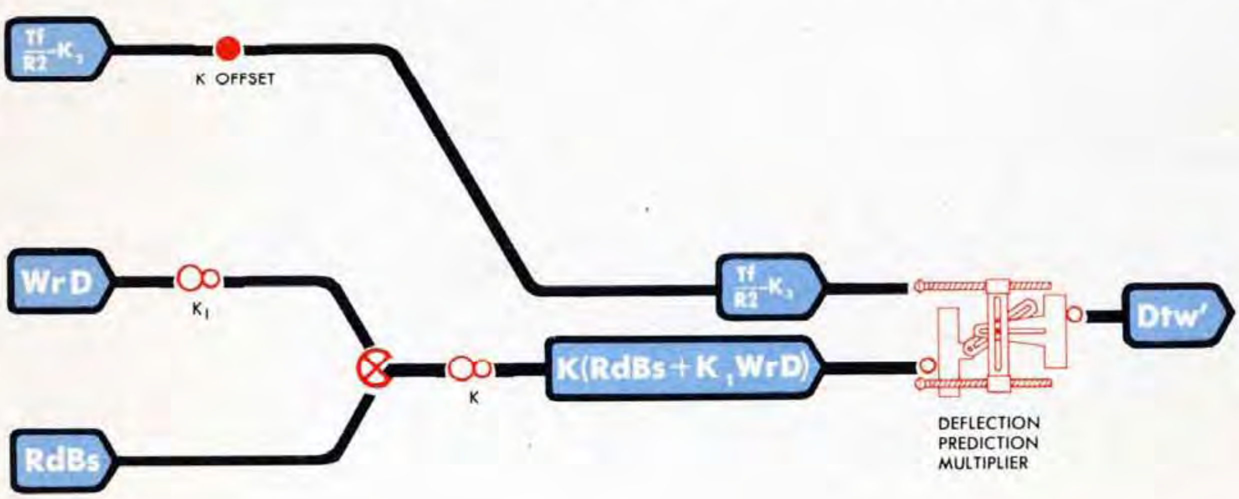
$$Dw = K_1 WrD \times (Tf/R2 - K_3)$$

WrD is multiplied by K_1 in a gear ratio to produce K_1WrD.

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_1WrD 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

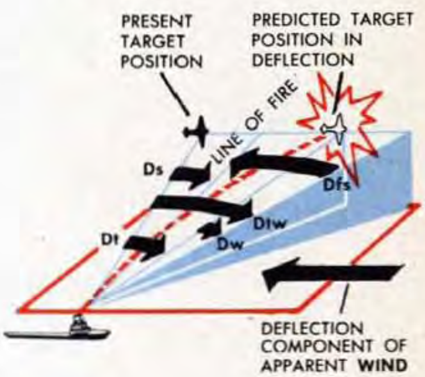
The output of the Deflection Prediction Multiplier is *Dtw′*, the sum of *Dt′* and *Dw*. *Dt′* is the sum of *Dt* and an unwanted quantity. (See NOTE on page 266.) *Dw* is the Deflection Prediction for Wind.

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



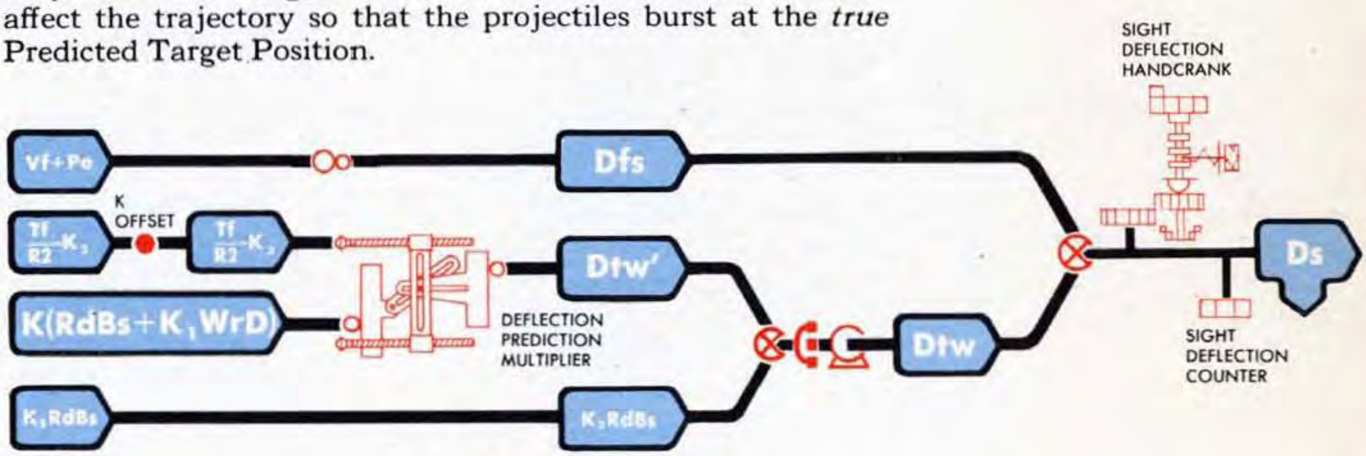
A branch of the *RdBs* line is multiplied by K_4 at a gear ratio to produce K_4RdBs, the quantity used as the multiplier by-pass. K_4RdBs is added to the multiplier output Dtw', to obtain *Dtw*, the Deflection Prediction to compensate for Relative Motion and Wind.

$$Dtw' + K_4RdBs = Dtw$$

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*.

$$Dtw - Dfs = Ds$$

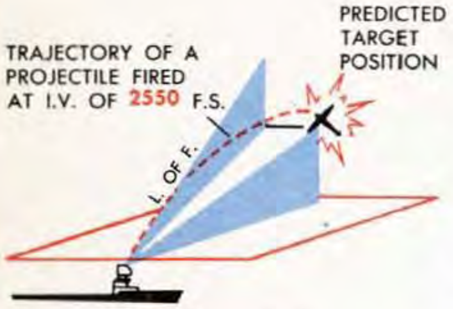
Since a prediction for the effect of Wind is contained in the value of *Dtw*, *Ds* also contains this Wind prediction. Projectiles fired using this adjusted value of *Ds* will be fired at an *imaginary* Predicted Target Position, but the Wind and Drift will affect the trajectory so that the projectiles 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.

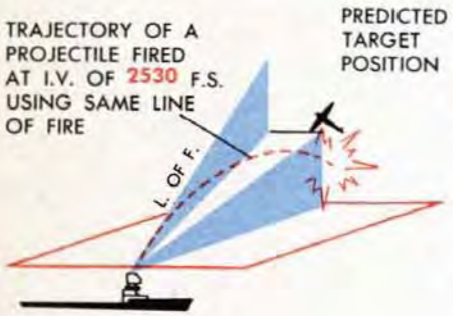
The only remaining corrections to *Vs*, *Ds*, and *F*, necessary to insure accurate predictions, are the corrections to allow for changes in the Initial Velocity of the projectiles.

INITIAL VELOCITY



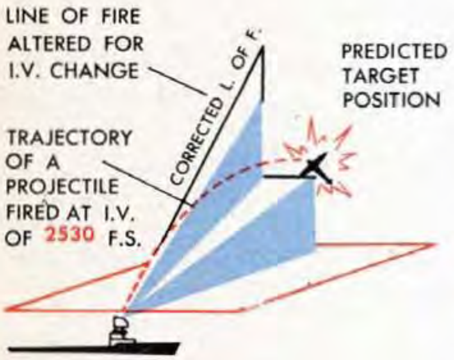
If all projectiles could be fired at an Initial Velocity of 2550 f.s., the computations for *Vs, Ds,* and *F* already described would be accurate.

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.



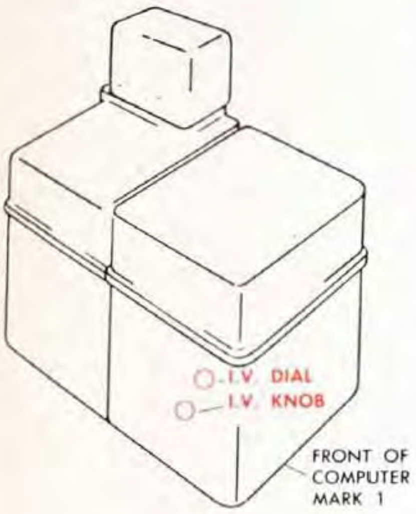
How a change in initial velocity alters a trajectory

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.



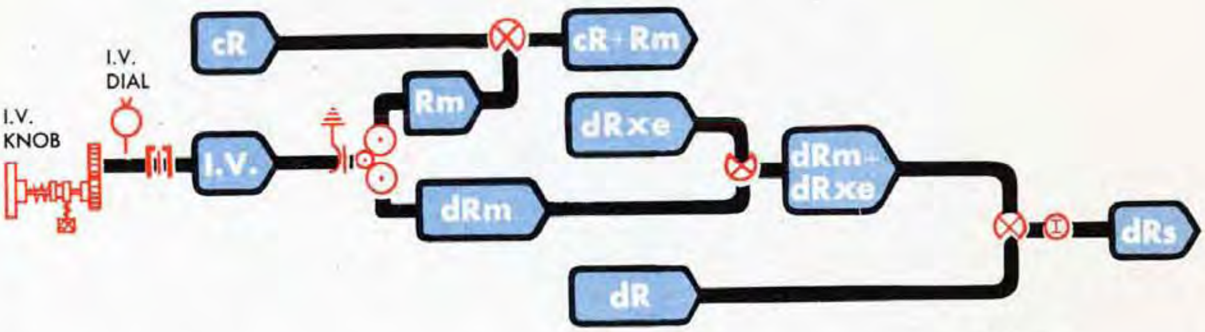
Putting I.V. into the computer

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.

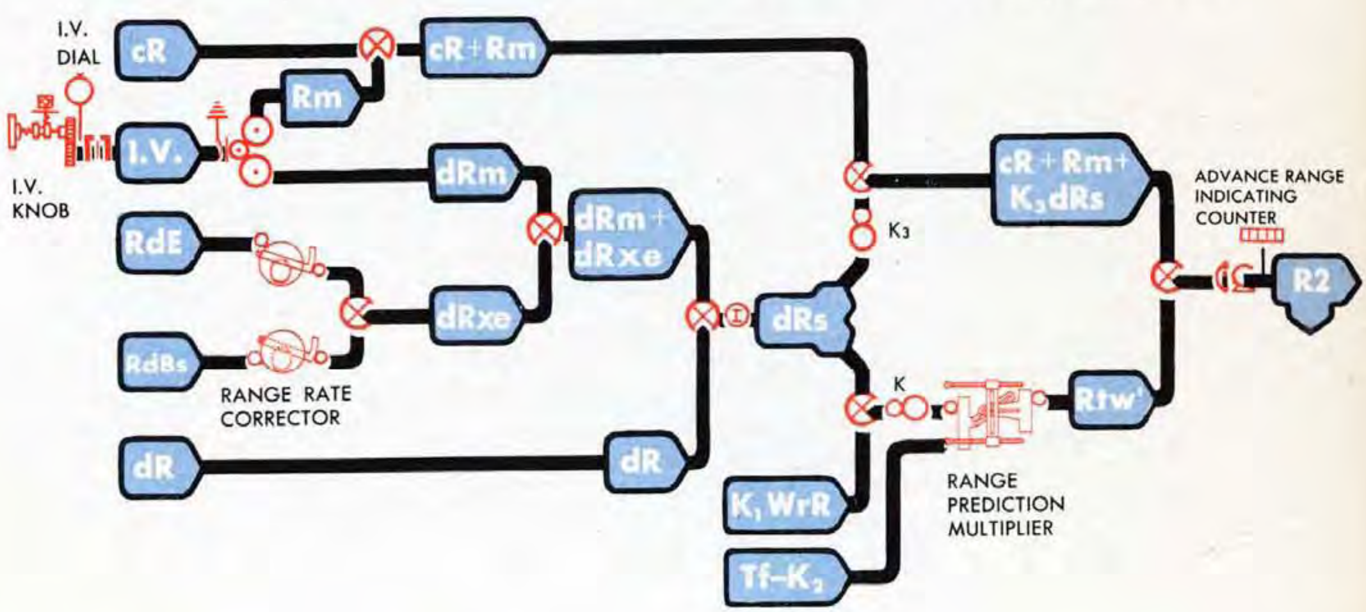


The second *I.V.* alteration is proportional both to the change in *I.V.* and to the value of Time of Flight, *Tf*. This alteration is obtained by multiplying *I.V.* by a constant to produce *dRm*.

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.

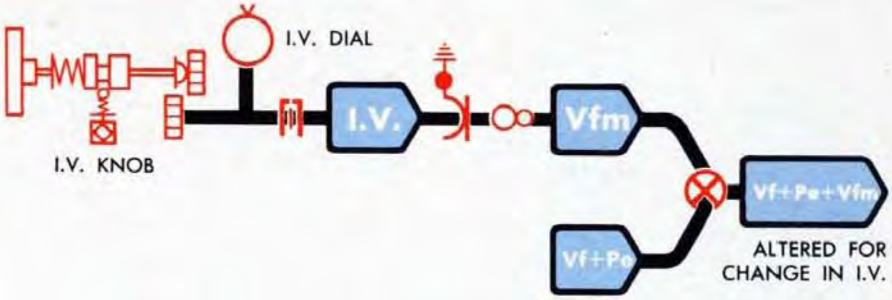
Since Advance Range, *R2*, is the sum of the two quantities *Rtw'* and ($cR + Rm + K_3dRs$), each of which contains an *I.V.* alteration, both *Rm* and ($dRm \times Tf$) are contained in *R2*.

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.

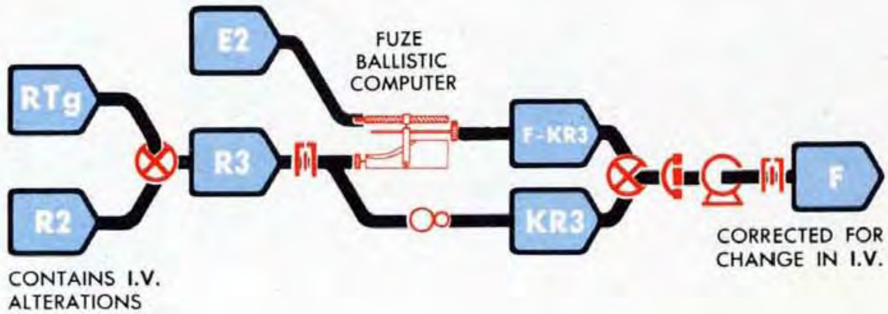
Since a decrease in Initial Velocity causes the projectiles to drop and explode below the Target, the value of Superelevation, *Vf*, must be increased. One part of the *I.V.* correction to *Vf* is called *Vfm*. *Vfm* is computed by multiplying the value on the *I.V.* shaft line by a constant at a gear 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.



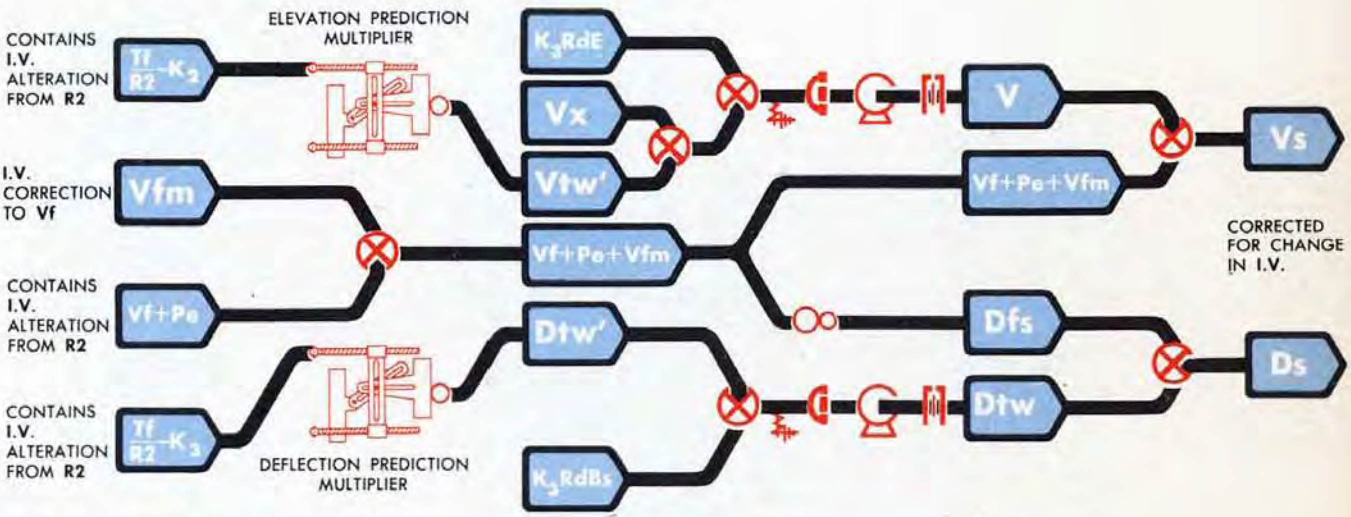
How I.V. alterations to R2 and Vf correct Vs

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.



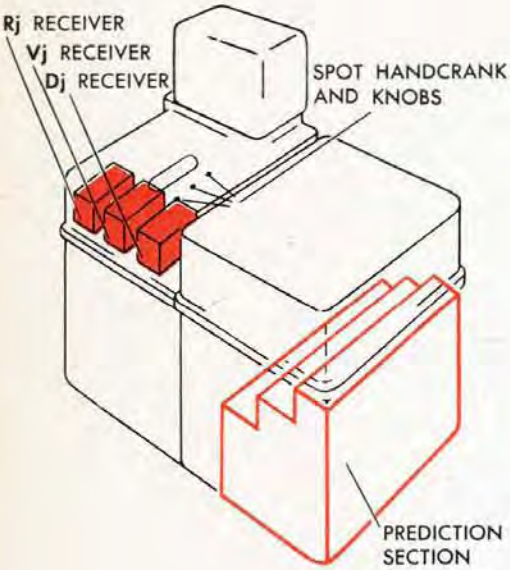
How I.V. alterations to R2 and Vf correct Ds

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



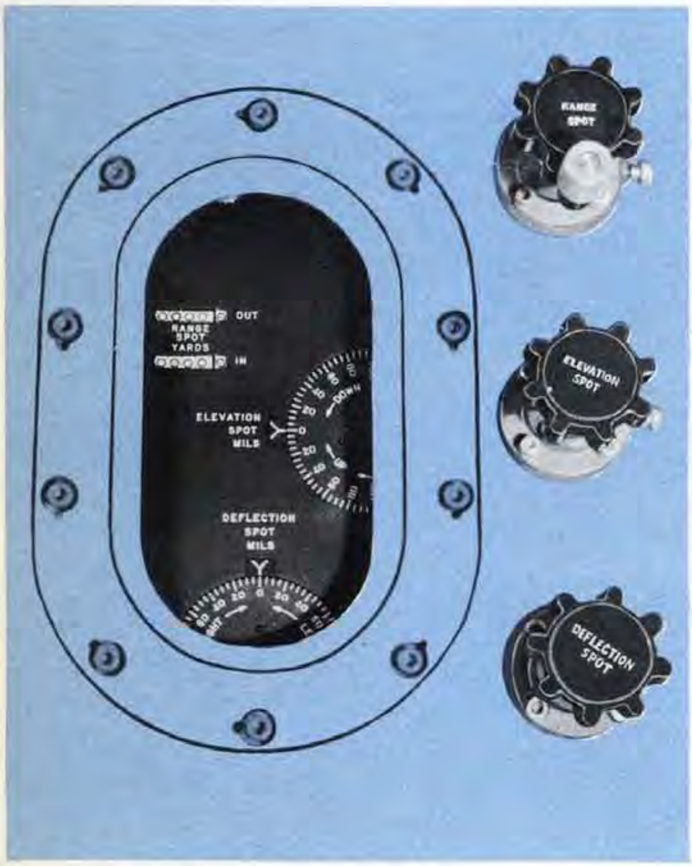
Spots are quantities which may be used to alter the values of the outputs of the Prediction Section. The use of Spots varies with each type of operation and is established by *ship's doctrine*.

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.

The spot mechanisms



SPOT COUNTERS, DIALS, HANDCRANK AND KNOBS

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.

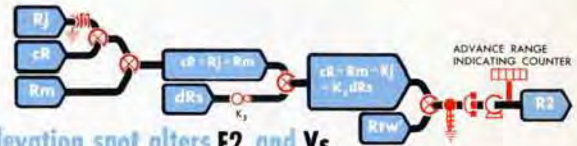
When the handcrank and knobs are in their IN positions, the circuits to the Spot receivers are broken, and the lines are positioned by the handcrank and knobs.

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.

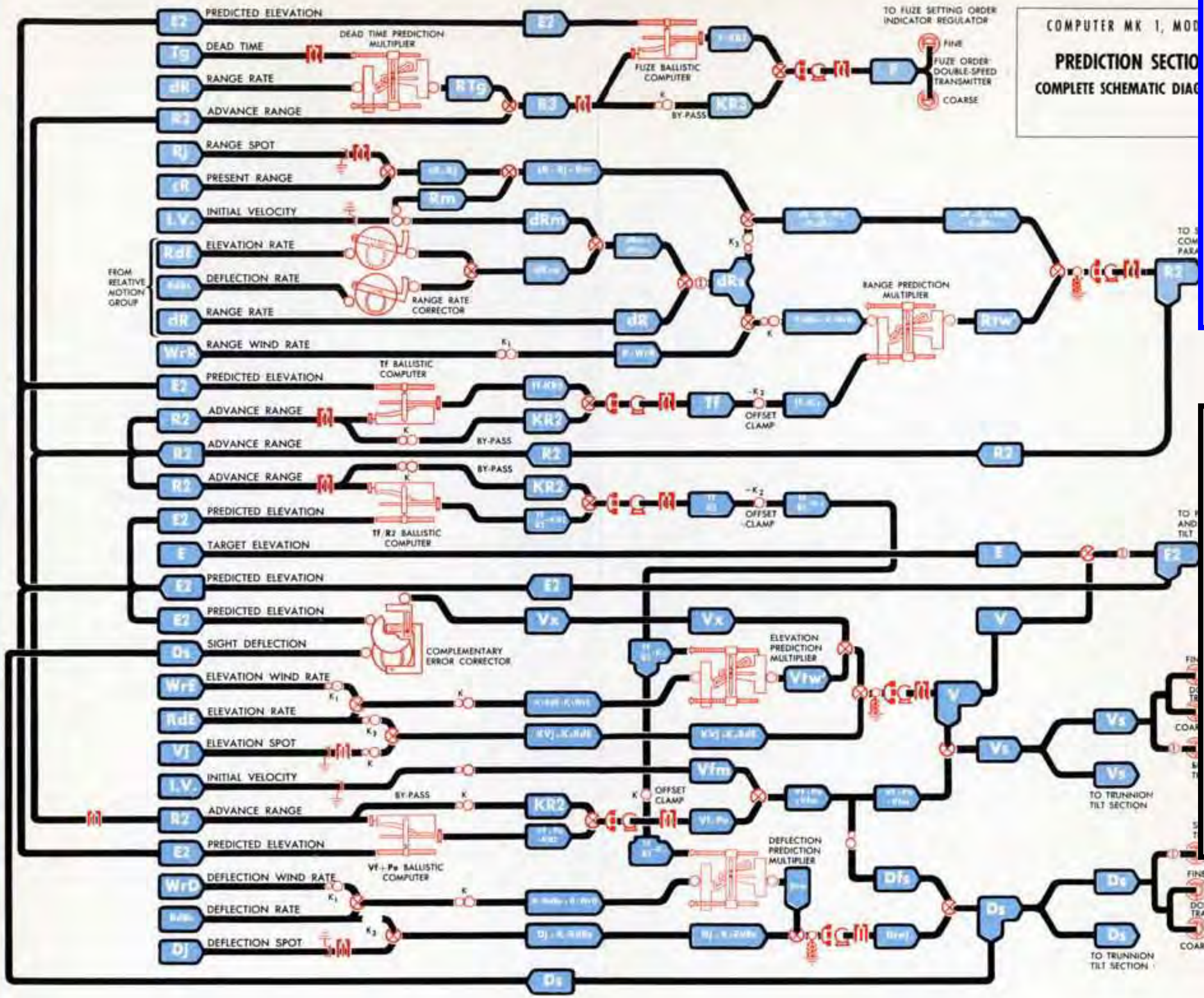
How the deflection spot alters Ds

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.

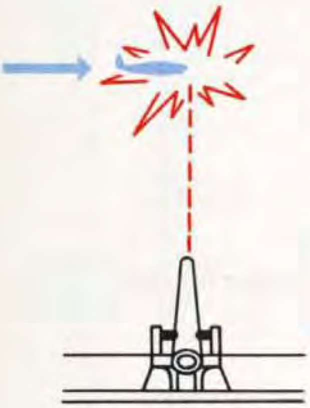
COMPUTER MK 1, MOD

PREDICTION SECTION

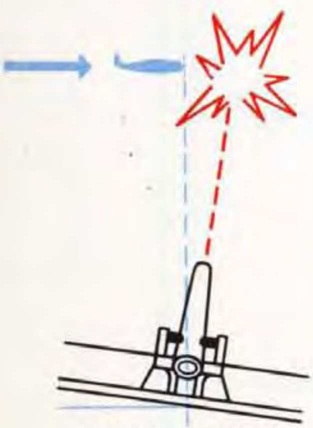
COMPLETE SCHEMATIC DIAG



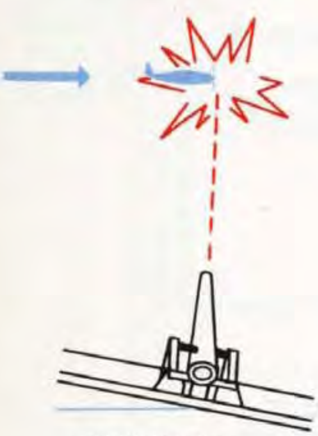
TRUNNION TILT



GUN AIM ESTABLISHED ON HORIZONTAL DECK



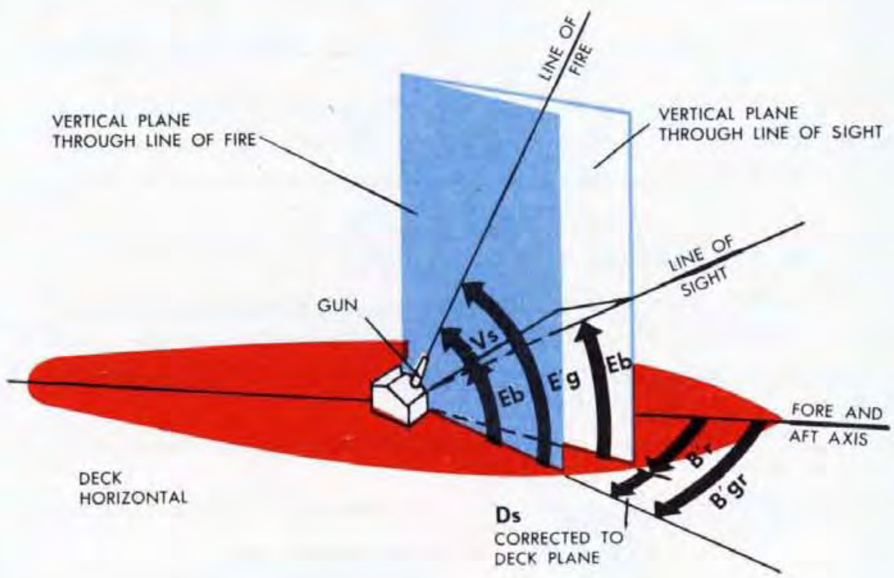
GUN AIM IS FALSE ON TILTED DECK WITHOUT TRUNNION TILT CORRECTIONS



TRUNNION TILT CORRECTIONS CORRECT GUN AIM FOR TILTED DECK

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.

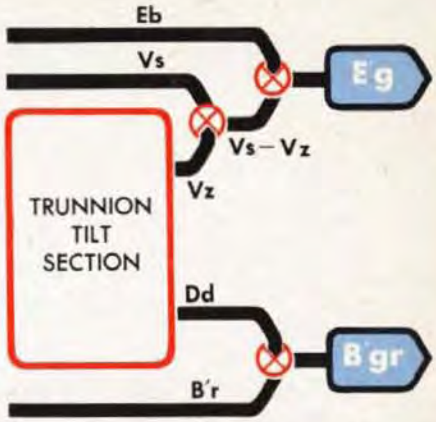


On a horizontal deck the Gun Elevation Order, *E′g*, consists of Director Elevation, *Eb*, plus Sight Angle, *Vs*.

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.*

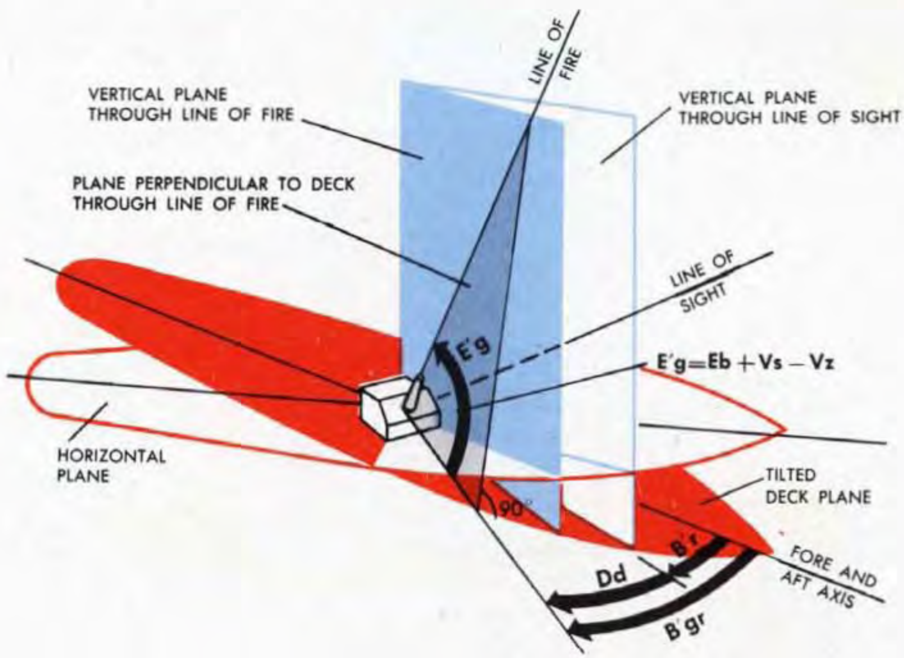
The Trunnion Tilt Section of the Computer Mark 1 computes two quantities. The first is Trunnion Tilt Elevation Correction, *Vz*, the second is Deck Deflection, *Dd*, which includes Trunnion Tilt Train Corrections.



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*.

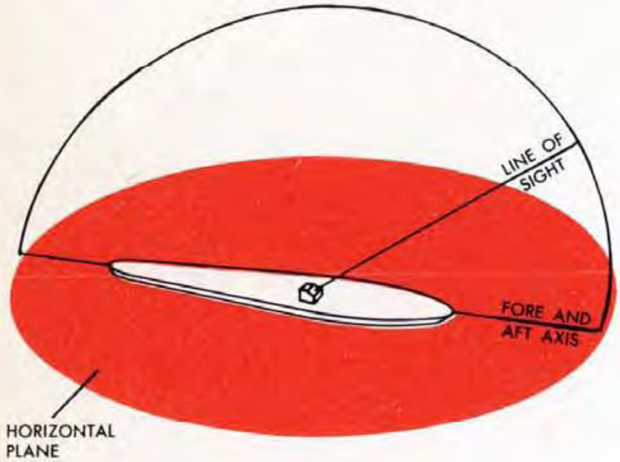
$$Dd = jDd + Dz$$

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.

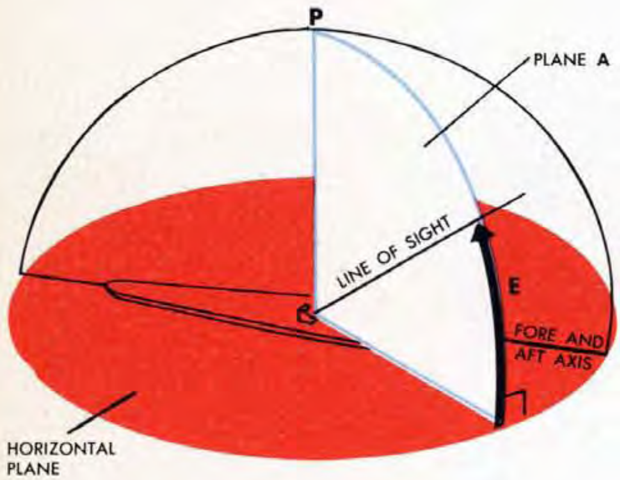
SETTING UP THE LINE OF FIRE FROM THE HORIZONTAL



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.)

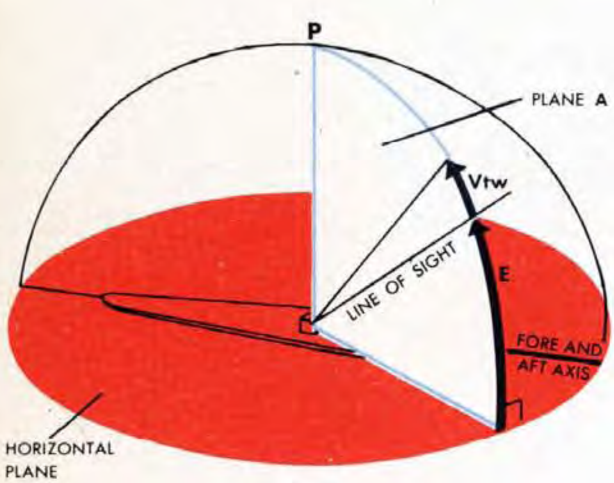
These diagrams show, first, how the Line of Fire is established on a horizontal deck and, second, how the Trunnion Tilt Corrections keep the gun pointing along the Line of Fire as the deck tilts.



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.

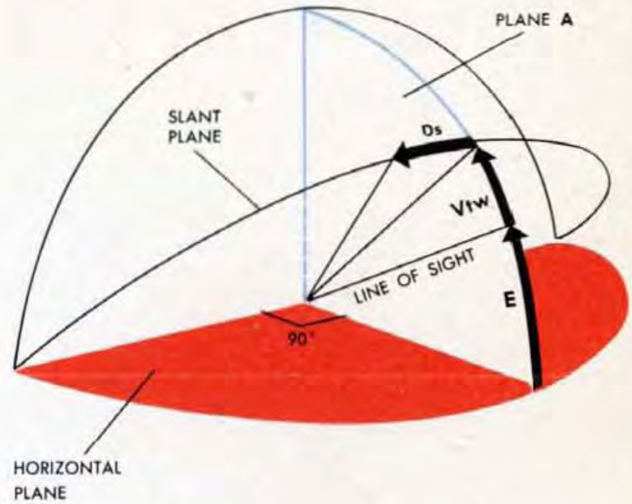
Target Elevation, *E*, is the elevation of the Line of Sight above the horizontal in this vertical plane.



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.

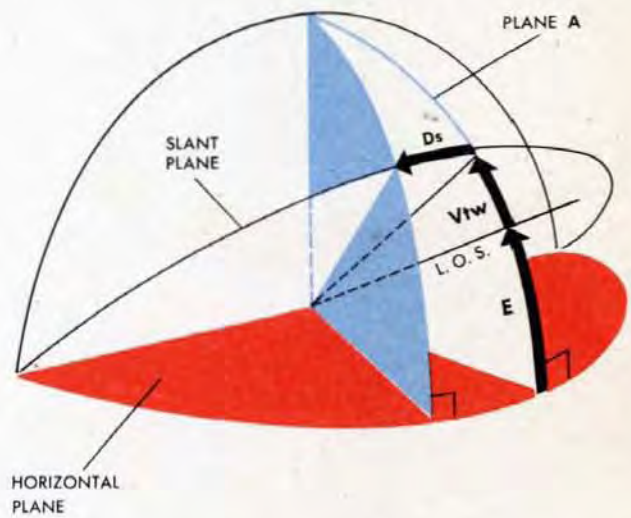
A slant plane is now added at right angles to plane A and at angle $E + Vtw$ to the horizontal plane.

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.

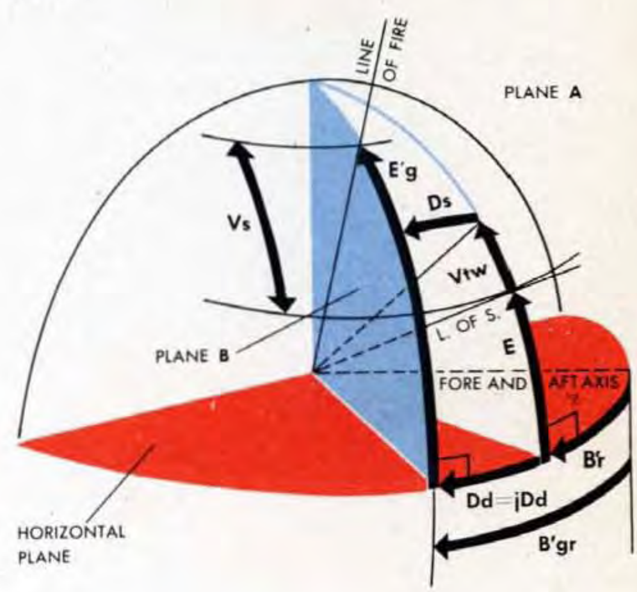
The Line of Fire is now obtained by transferring angle *E* from plane A to plane B and adding *Vs* to angle *E* in this plane. Only the part of the slant plane actually contained in angle *Ds* is shown here.



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.

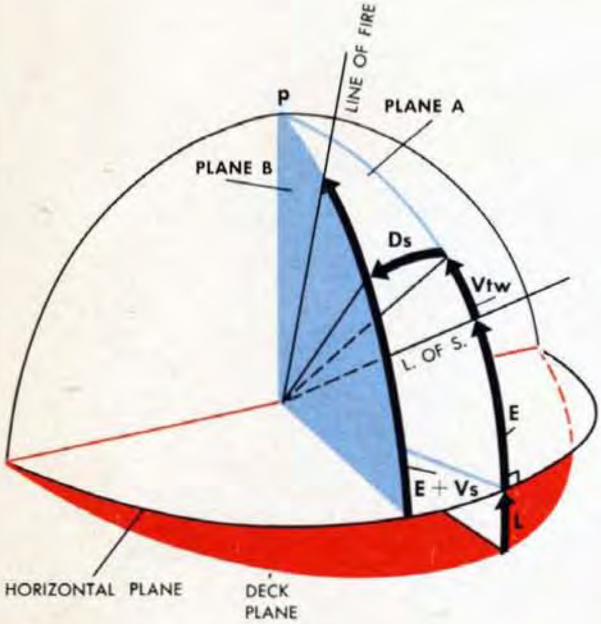
Gun Train Order, *B'gr*, is *B'r* plus *Dd*. Since the deck is horizontal, *Dd* consists only of *Ds* corrected to the deck plane. *Dz* is zero, since there is no Cross-level. *Dd*, therefore, equals *jDd*.

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

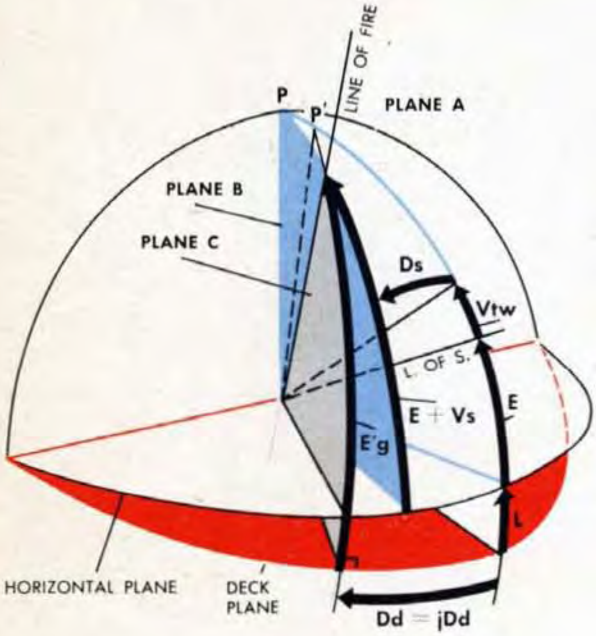
With level only



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″.

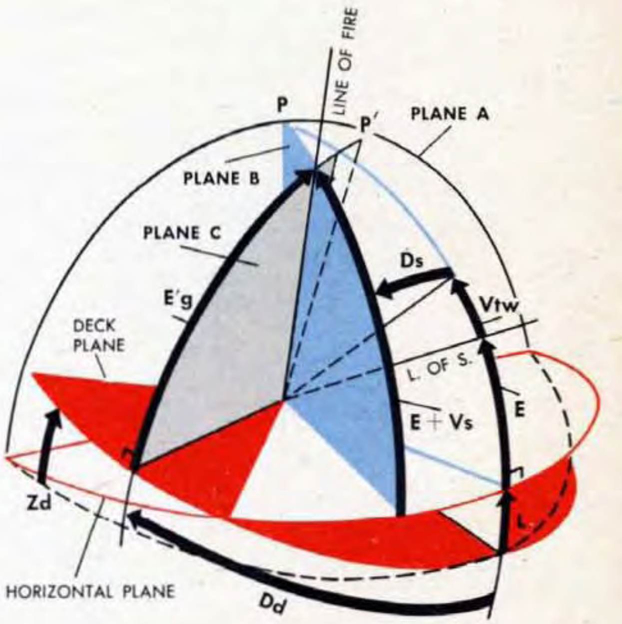
Plane C containing the Line of Fire now makes a different angle with plane A. *Dd* has changed by an amount, *Dz,* the Trunnion Tilt Train Correction to compensate for Cross-level.

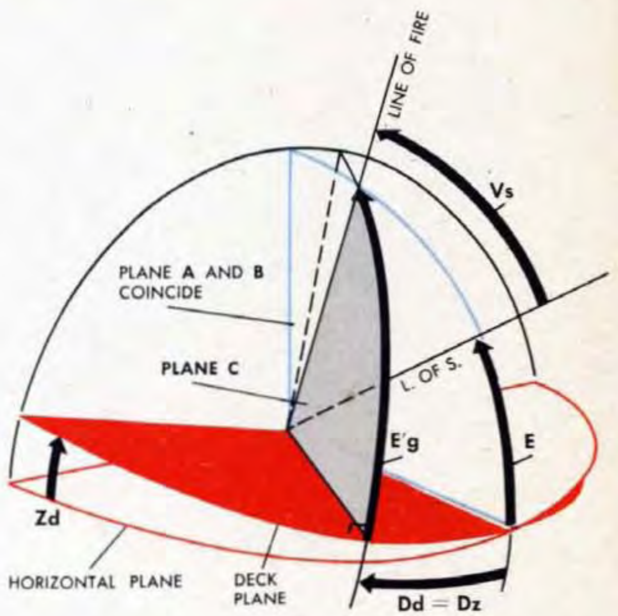
It is difficult to show *jDd* and *Dz* separately in a diagram when both are present. A simple way to illustrate *Dz* is to show a case in which *jDd* is zero and where *Dd* consists only of *Dz.*

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.*

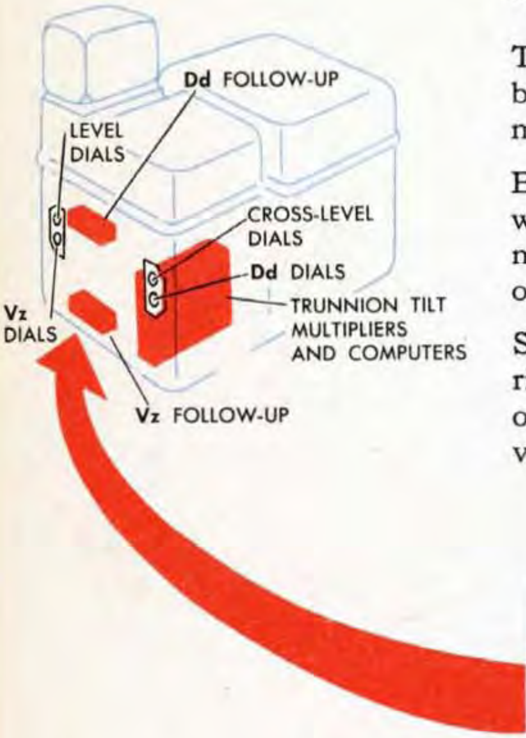




The mechanisms and the equations

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.

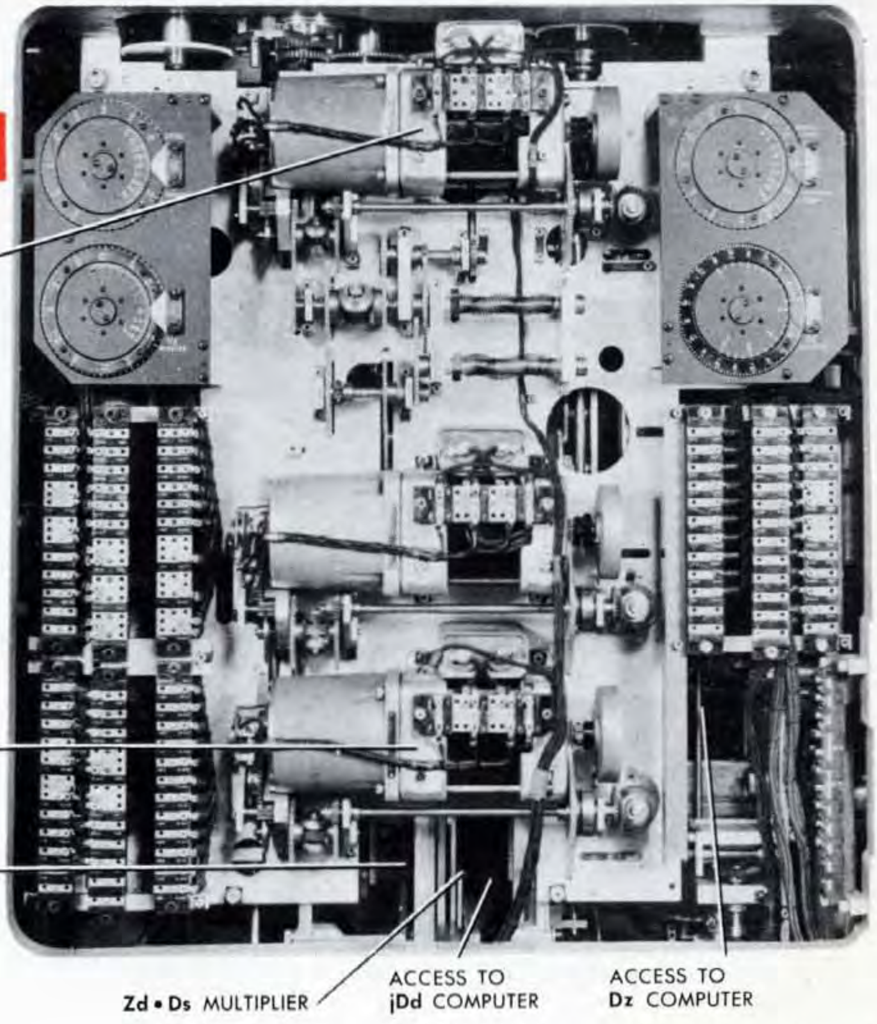
These mechanisms are all located at the back of the Computer Mark 1 and are used to solve the equations for *Vz* and *Dd*.



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.

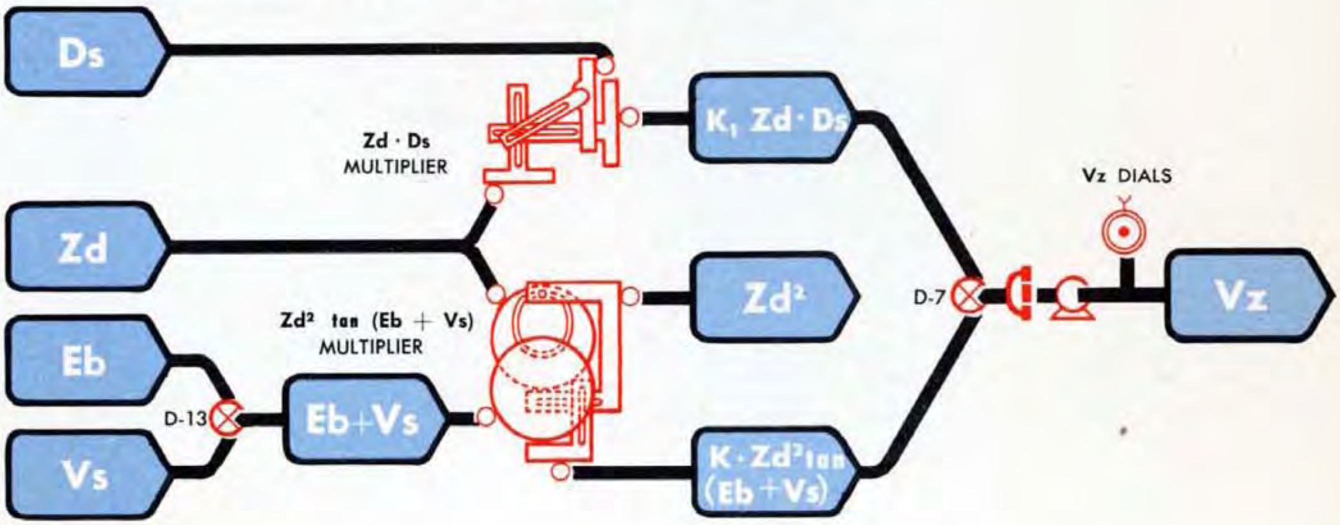
The multiplier output is $K \cdot Zd^2 \tan(Eb + Vs)$, the first term of the *Vz* equation.

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

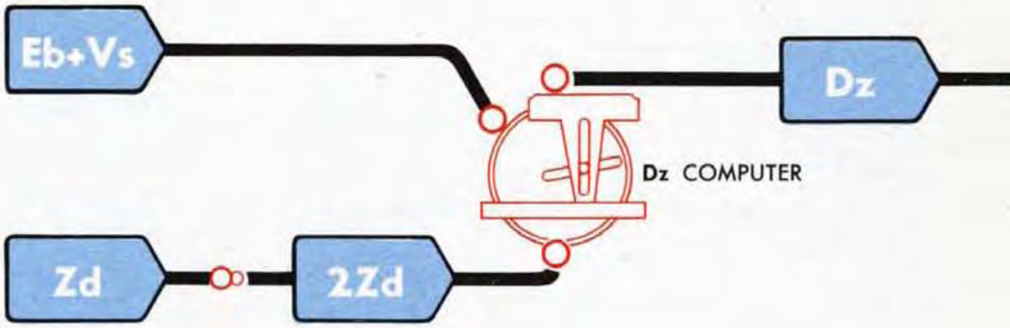
The *Dz* Computer is a component solver with only one rack.

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 $Ds \cdot \sec(E2 + L - K \cdot Zd^2)$.

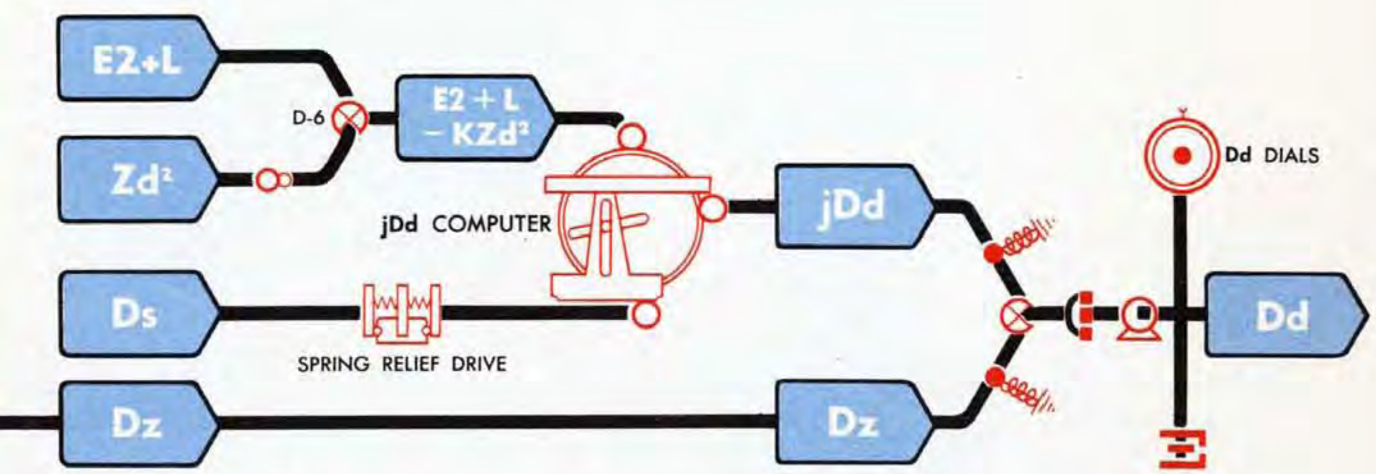
Since the secant is the reciprocal of the cosine, the equation for *jDd* can also be written in this form:

$$jDd = \sin^{-1}\left(\frac{Ds}{\cos(E2 + L - K \cdot Zd^2)}\right)$$

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.

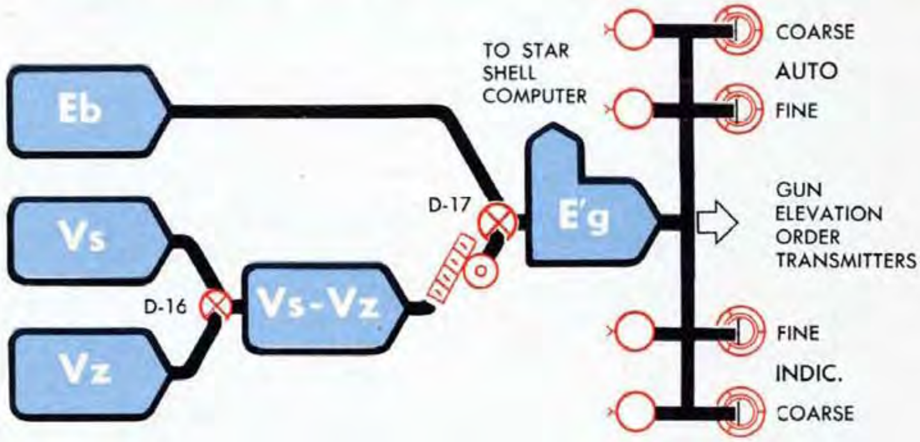
The output from the vector gear is $\sin^{-1}\dfrac{Ds}{\cos(E2 + L - K \cdot Zd^2)}$ or $\sin^{-1}[Ds \cdot \sec(E2 + L - K \cdot Zd^2)]$ which is *jDd*.

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.

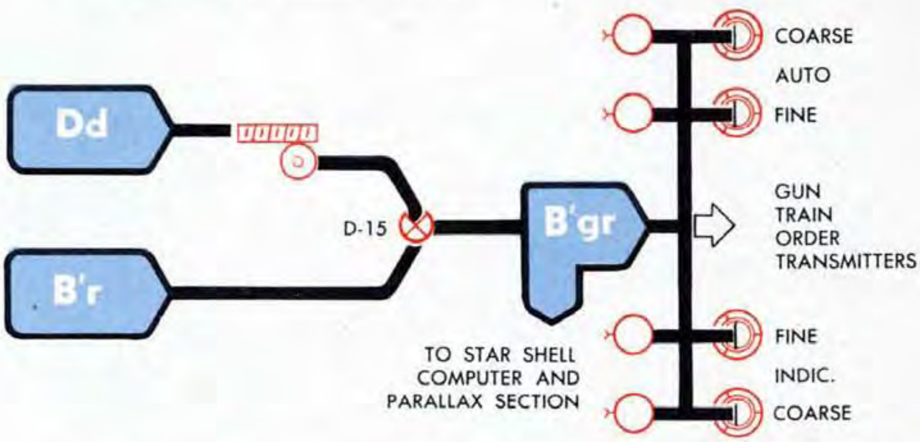
The gun orders

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.

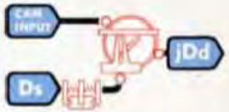


To prevent $B'r$ and Eb from backing into the Dd and $Vs - Vz$ lines, respectively, irreversible worms are provided on these lines as mechanical safeguards. This insures that correct values of the Gun Orders will reach the transmitters.

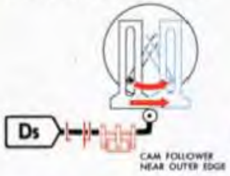
In addition to being used at the guns, $B'gr$ may be used in the Parallax Section of the Computer Mark 1, and both $E'g$ and $B'gr$ are used in the Star Shell Computer Mark 1.

The spring relief drive

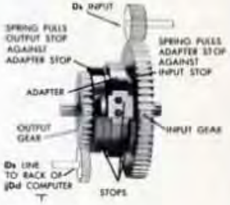
A spring relief drive is placed on the *Ds* input line going to the rack of the *jDd* Computer.



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 $E2 + L - K \cdot Zd'$.

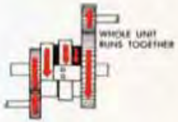


When the cam follower pin is at the outer edge of the cam, rack travel is limited only by the *Ds* limit stop. However, when the follower pin is near the center of the cam, rack travel is reduced, being controlled by the angular limits of the vector gear.

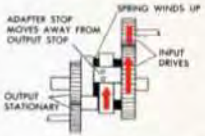


The relief drive mechanism uses two gears and an adapter, each having a stop piece attached. The gear stops are held by two strong clock springs against the sides of the stop on the adapter.

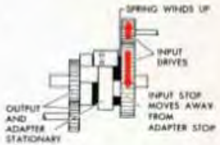
The whole relief drive turns together when the *Ds* line to the rack is free to move.



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.



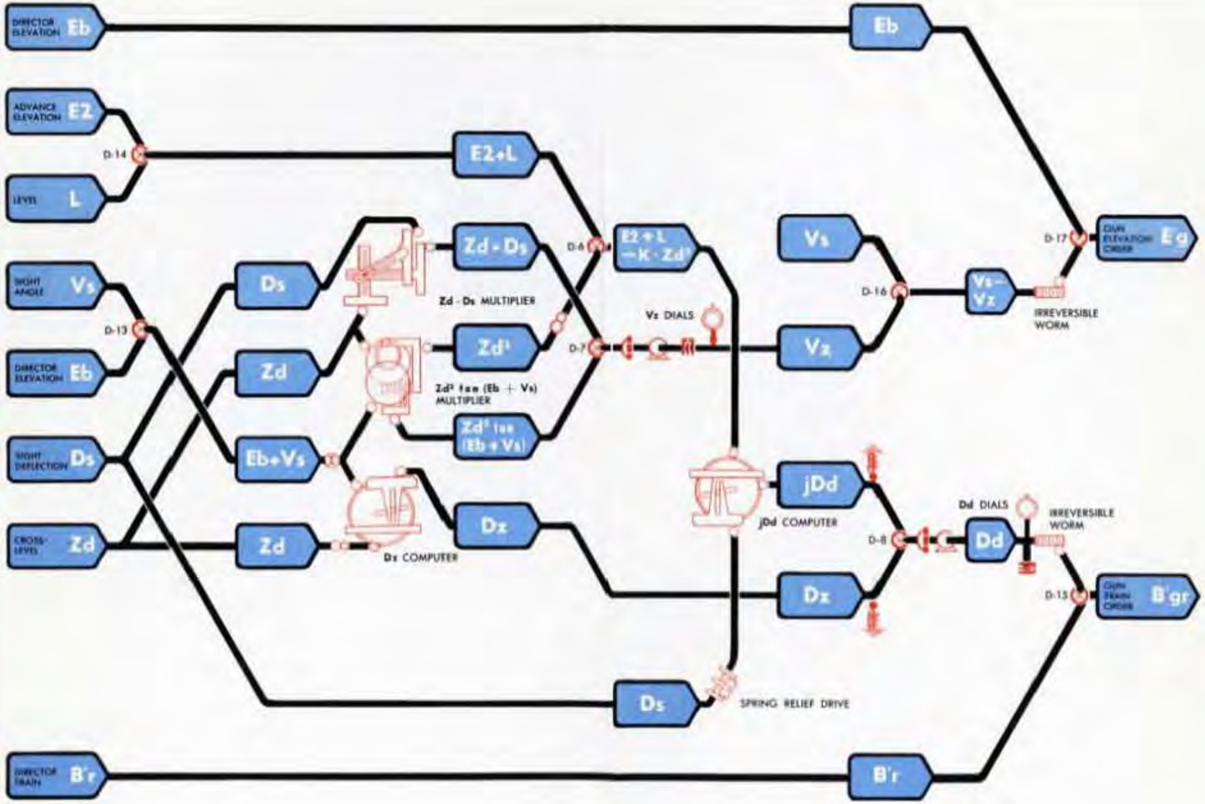
When the cam input changes so as allow sufficient travel of the rack, the springs restore the output gear to its original position relative to the input gear. Then the spring relief drive again acts as a solid connection.

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

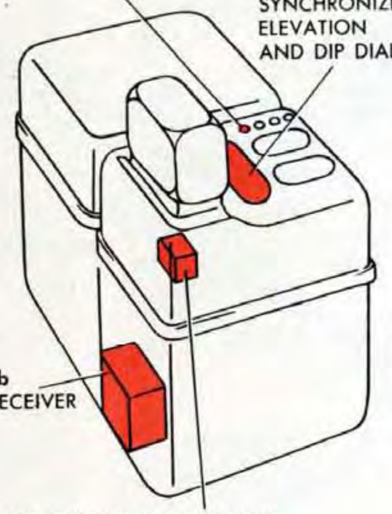
TRUNNION TILT SECT

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*.

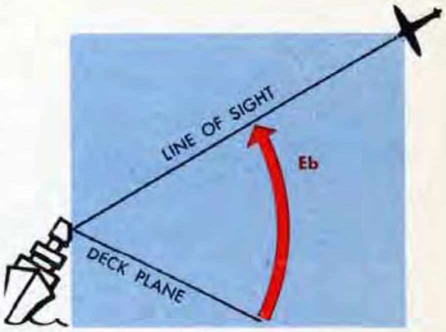
The Synchronize Elevation Mechanism is used to provide for methods of fire which can be used against surface targets but which are not usually practical against air targets. This mechanism can be thought of as a device which takes advantage of the additional fire control methods offered by surface targets.

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

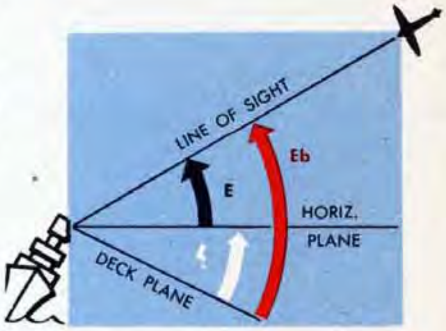
For Continuous Aim the Computer must make continuous accurate computations of gun and fuze orders. To compute these it needs continuous correct values of Director Elevation, *Eb*, for use in the Trunnion Tilt Section and Gun Elevation Order, and continuous correct values of Target Elevation, *E*, for 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.

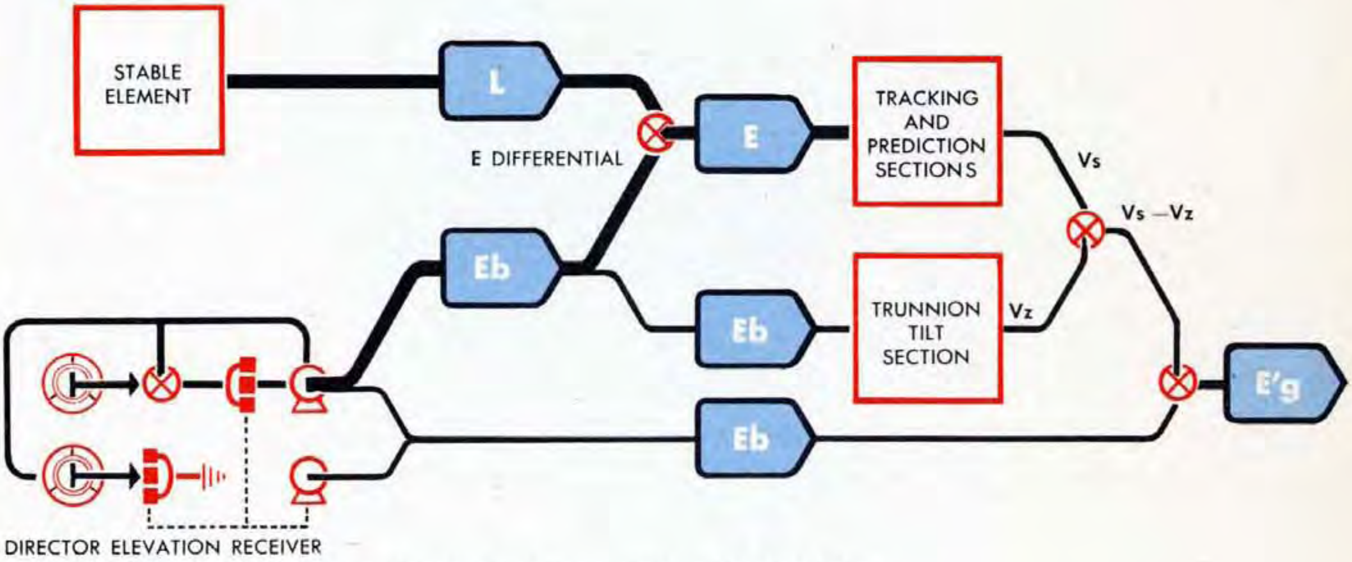
Target Elevation, *E*, is the angle between the horizontal and the Line of Sight, measured in a vertical plane through the Line of Sight.



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

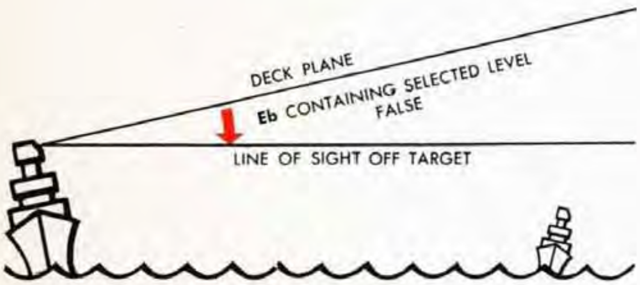
The three jobs of the Synchronize Elevation Mechanism are summarized here and the mechanism is built up schematically. A detailed description of the function and arrangement of the mechanism follows this summary.

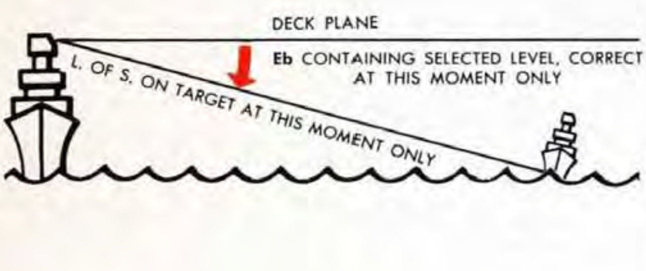
The three jobs of the Synchronize Elevation Mechanism are:

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."





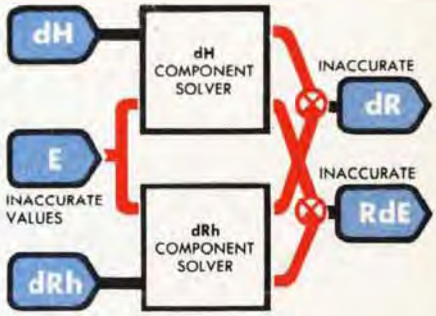
Selected Level Fire, with Level selected at the Director

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



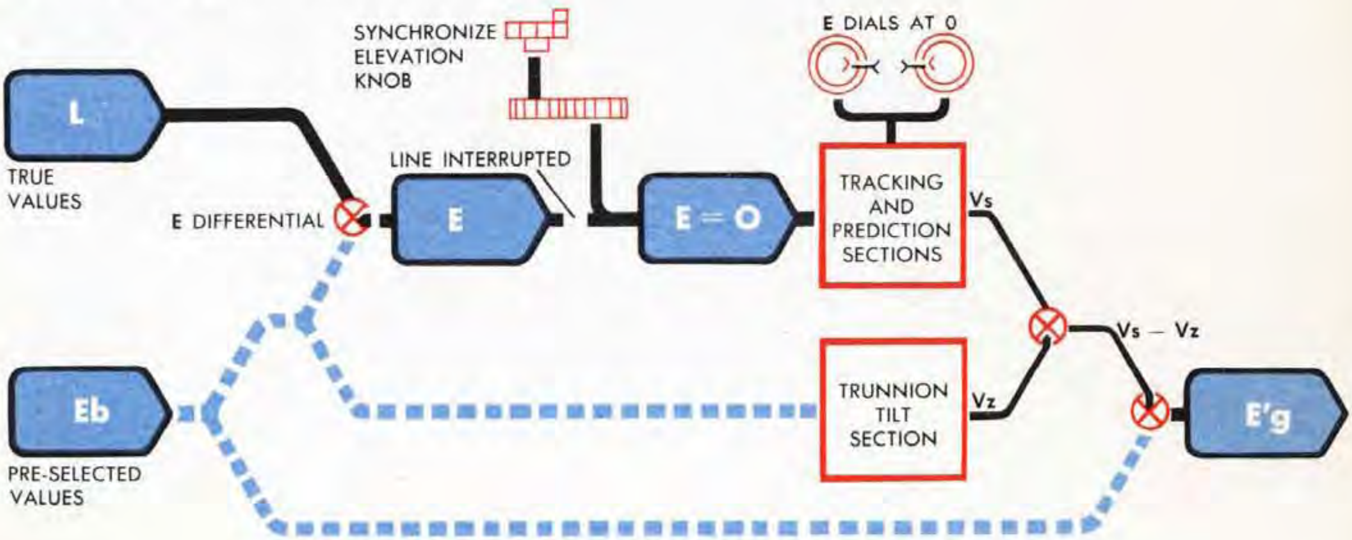
When the inaccurate values of *Eb* from the Director are received in the Computer, they combine with values of *L* at the *E* Differential and produce inaccurate values of *E*.

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.

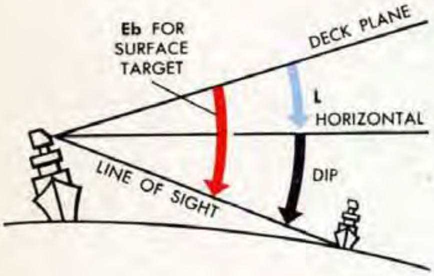
The inaccurate *E* is kept out of the Tracking and Prediction Sections by "interrupting" the *E* line. This is done by means of a differential, which is described later. The effect of using this differential is the same as if a shaft were removed on the *E* line.

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:

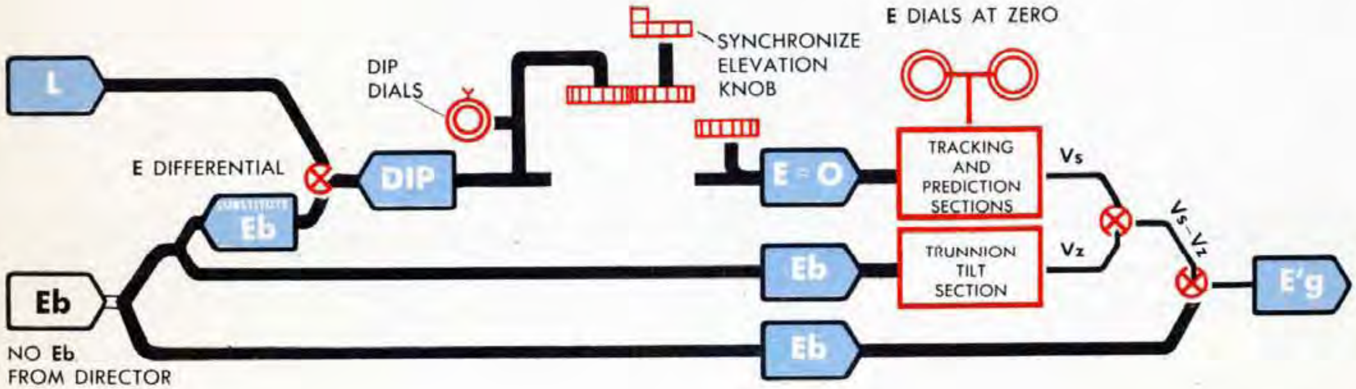
1 To allow for CASUALTIES. The Director may suffer casualties which will cut off the three main Director inputs to the Computer, namely *R*, *B′r* and *Eb*. In order to use the Computer, substitutes must be provided. Values of Range, *R*, and Relative Bearing, *B r*, may be obtained from some other source 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

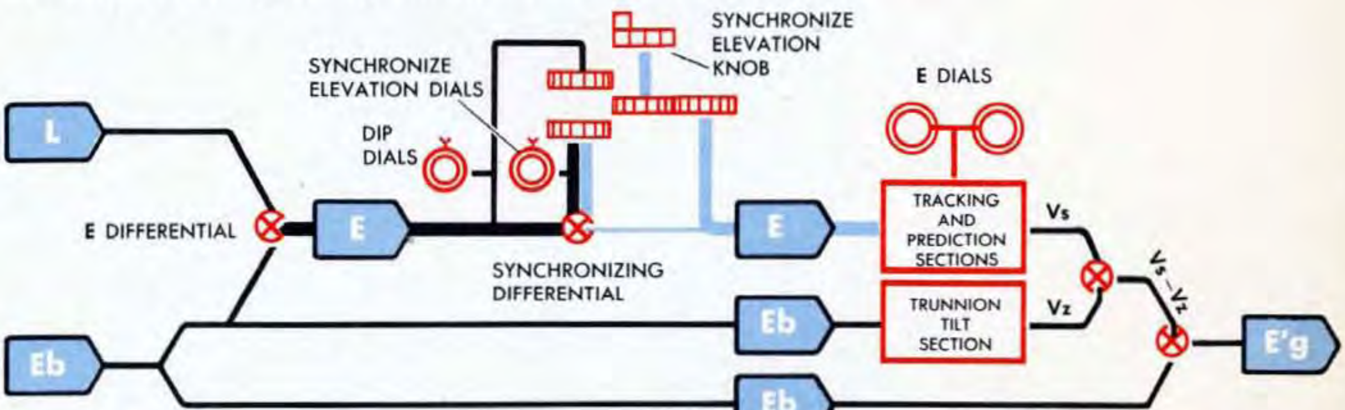
The synchronizing differential

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.

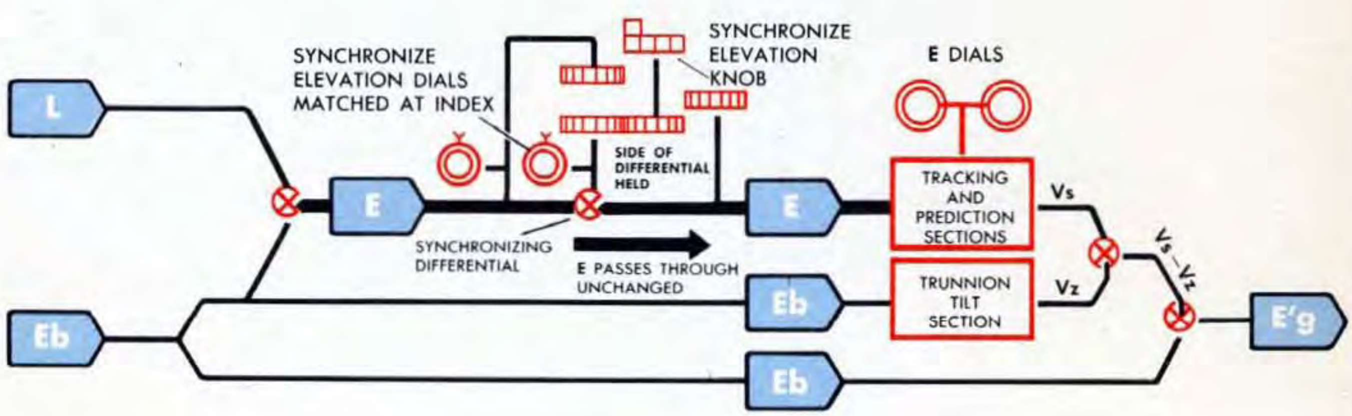
Interrupting the E LINE

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

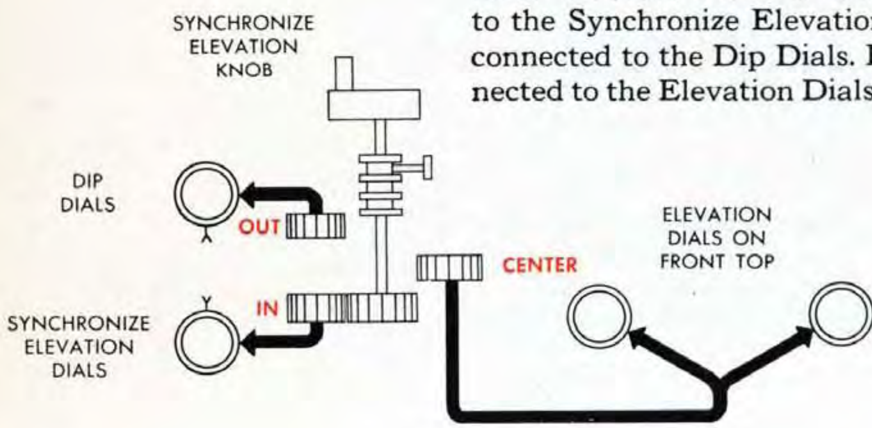
The Synchronize Elevation Dials consist of an inner and an outer dial with planetary gearing between them. These dials have index marks but no numbers. These marks must be matched at the fixed index for normal operation.

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

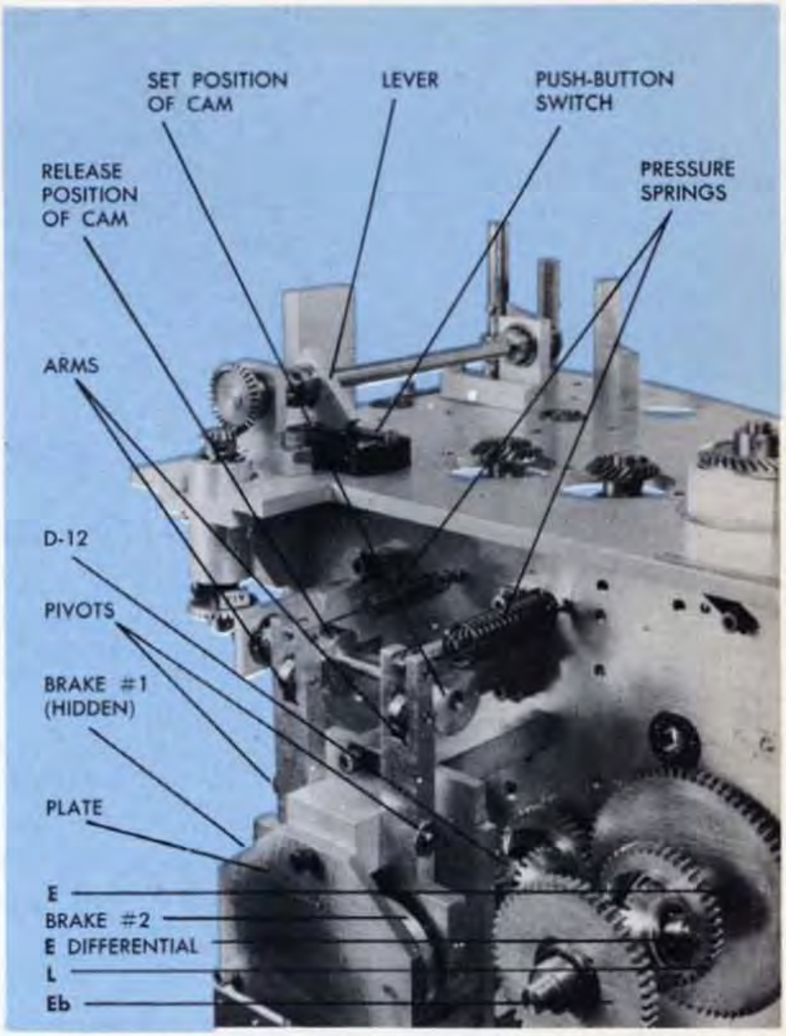
This drawing shows the relative positions of the *E* Differential and differential D-12, and the arrangement of the two brakes.

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

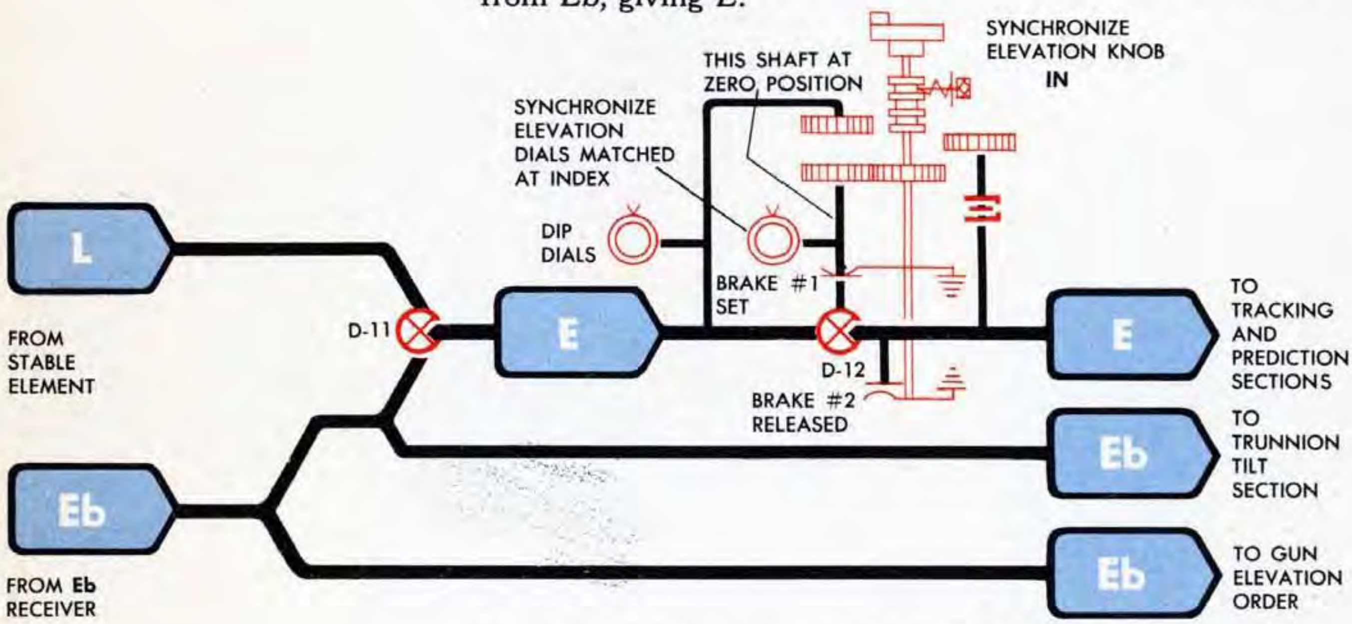
The push-button switch is controlled by a lever moved by the Synchronize Elevation Knob. Pulling the knob to its OUT position moves the lever and presses the push-button. This cuts out the Director Elevation Receiver, by de-energizing the *Eb* Follow-up Servos.

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.

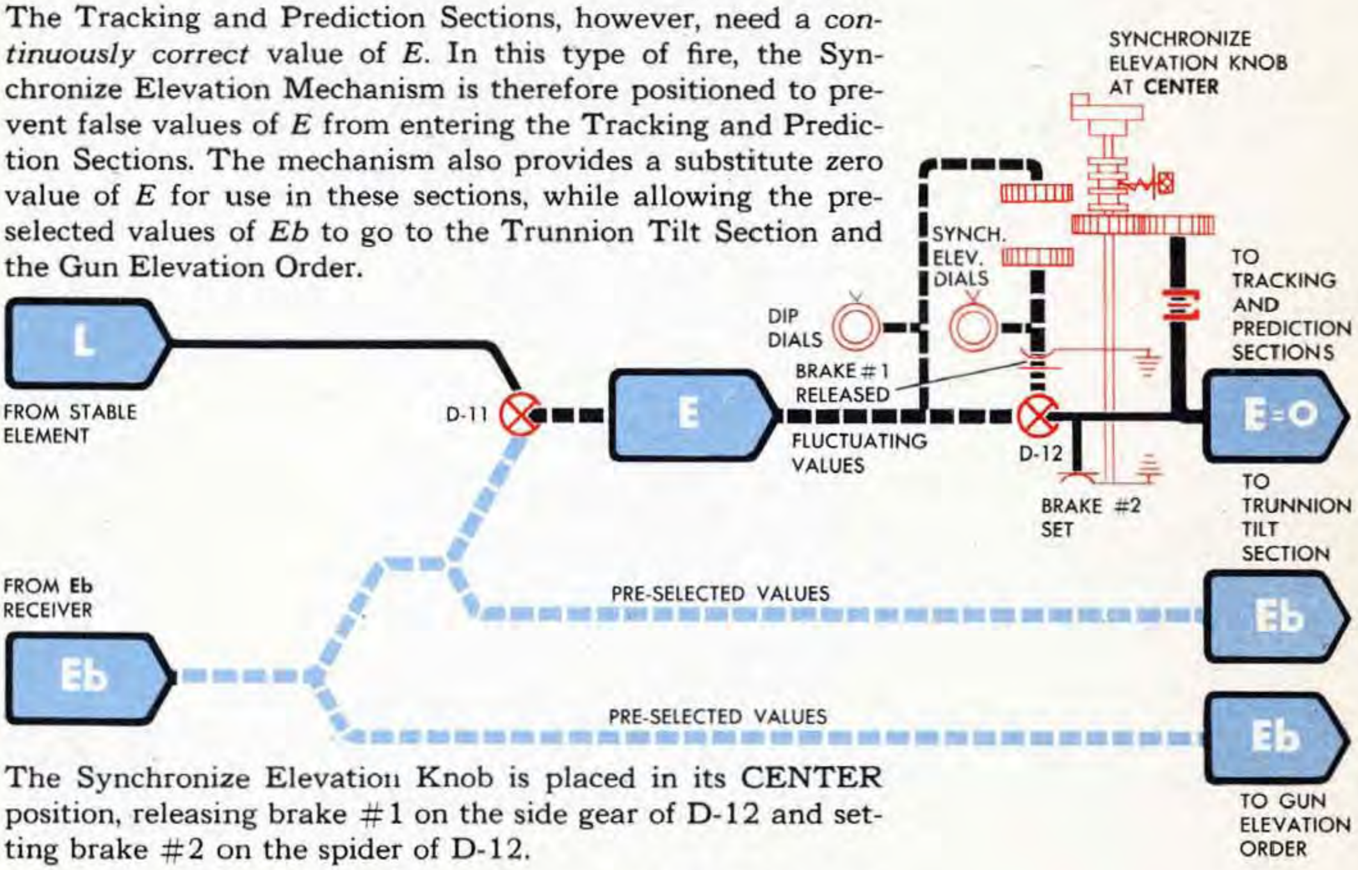
For Continuous Aim with the Synchronize Elevation Knob in its IN *position, the whole Synchronize Elevation Group may be thought of as a single differential, D-11, where* L *is continuously subtracted from* Eb *to form* E.

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.



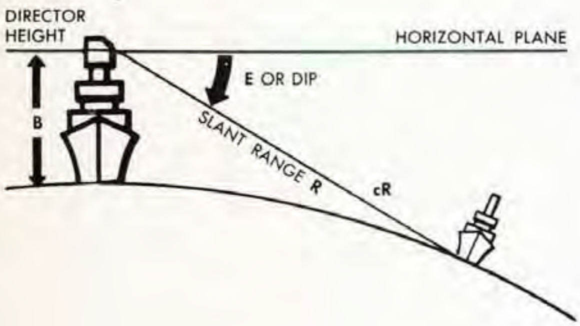
The Synchronize Elevation Knob is placed in its CENTER position, releasing brake #1 on the side gear of D-12 and setting brake #2 on the spider of D-12.

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.

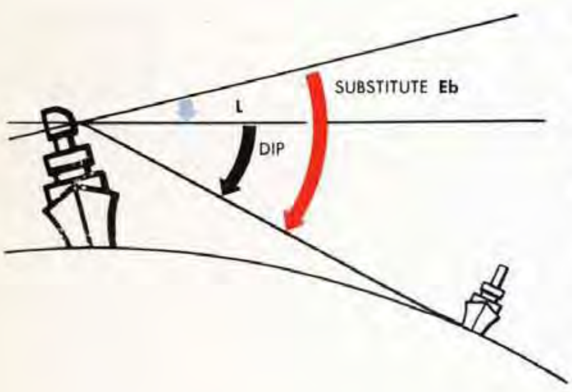
In the Computer Mark 1, Dip is computed by this equation:

$$\text{Dip} = \sin^{-1} \frac{2AB + B^2 + R^2}{2(A+B)R}$$

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

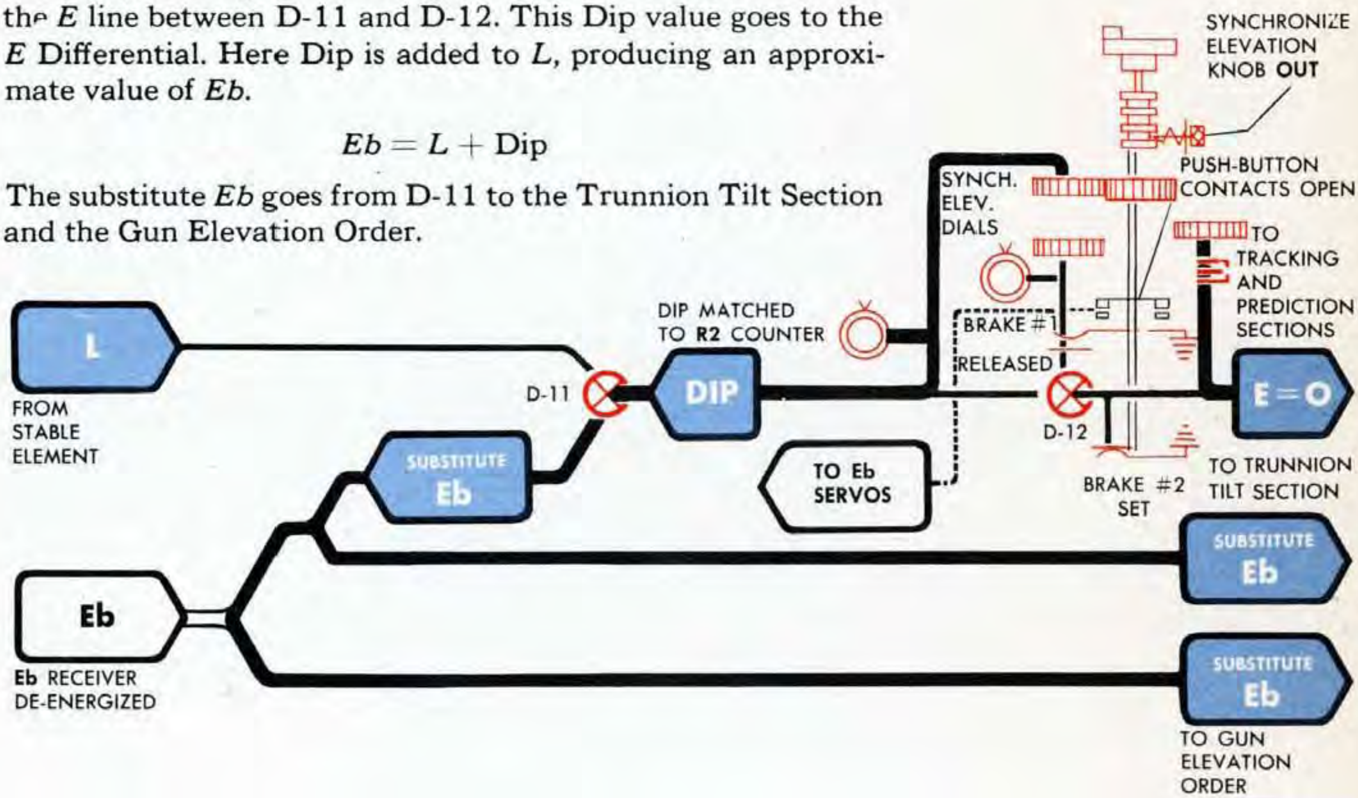
In adapting the *E* lines in the Computer for operation without a Director, the Synchronize Elevation Knob is first put in its CENTER position. This releases brake #1 and sets brake #2, "interrupting" the *E* lines. The knob is then turned until the *E* line going to the Tracking and Prediction Sections 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.

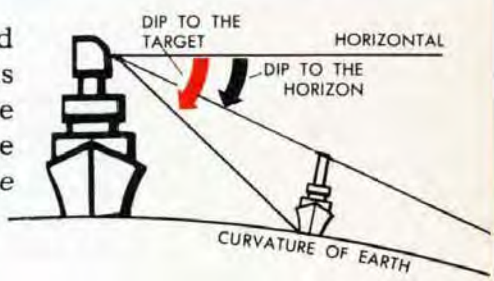
Matching the Dip Dial reading to *R2* puts a value of Dip into the *E* line between D-11 and D-12. This Dip value goes to the *E* Differential. Here Dip is added to *L*, producing an approximate value of *Eb*.

$$Eb = L + \text{Dip}$$

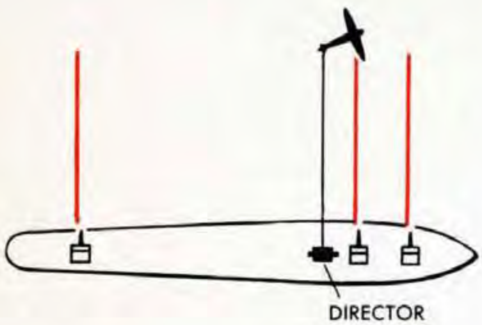
The substitute *Eb* goes from D-11 to the Trunnion Tilt Section and the Gun Elevation Order.

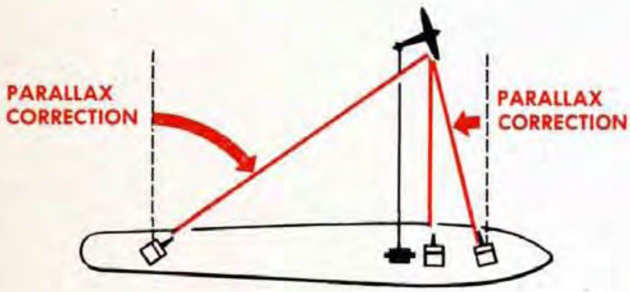


Dip to the Target is the angle between the horizontal and a Line of Sight *to the waterline of a surface target*. This should not be confused with Dip to the horizon, which is the angle between the horizontal and a Line of Sight to the horizon. Whenever Dip is mentioned in this book *Dip to the Target* is meant unless otherwise specified.



PARALLAX





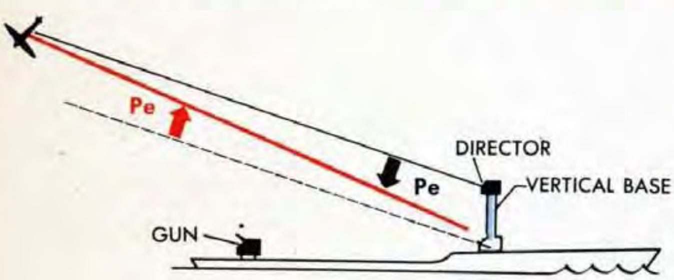
The Gun Elevation and Gun Train Orders computed by the Computer Mark 1 are based on observations made from a Director. These orders are correct for guns located at that Director.

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.

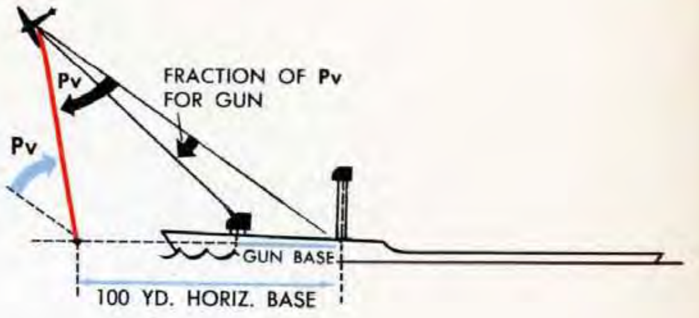
Pv: Elevation parallax correction for horizontal base

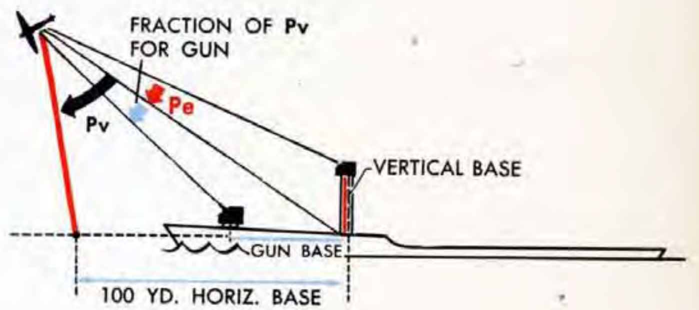
Unlike Elevation Parallax Correction, *Pe*, which is for a *vertical* base, Elevation Parallax Correction, *Pv*, is for a *horizontal* base.

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.





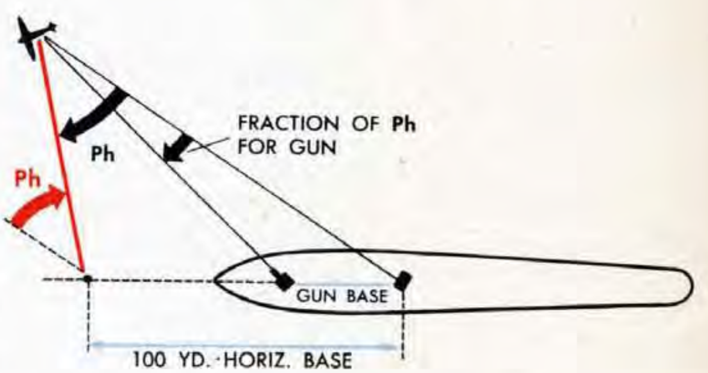
Ph: Train parallax correction for horizontal base

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.

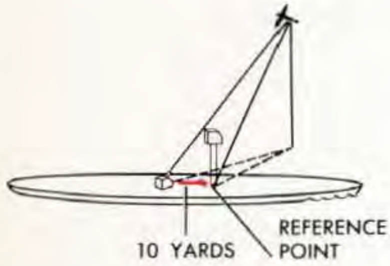
Correcting GUNS for parallax

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



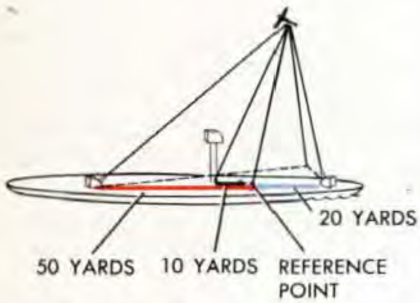
On the ship shown in the first illustration, the Director is the Reference Point, and therefore needs no correction.

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

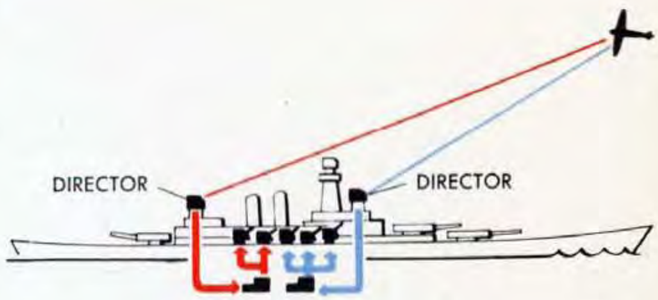
Why the directors are corrected

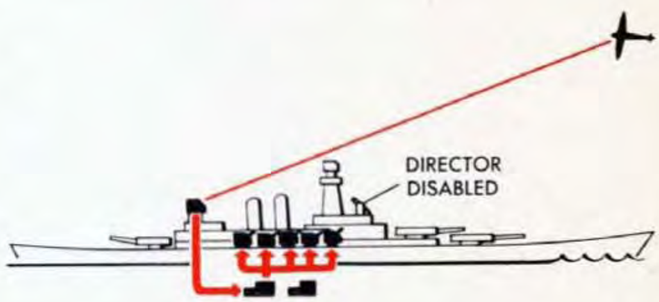
Each Director sends observations of Range, Director Elevation, and Director Train to a Computer Mark 1. Each Computer Mark 1 then computes Gun Orders for the guns connected to it. If one Director is disabled, the guns using Gun Orders based on its observations can be quickly connected to a Computer working 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.



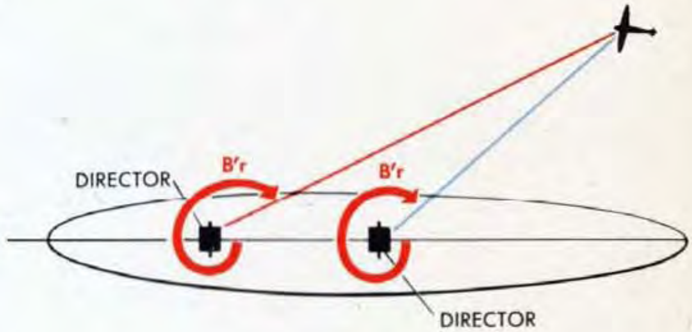


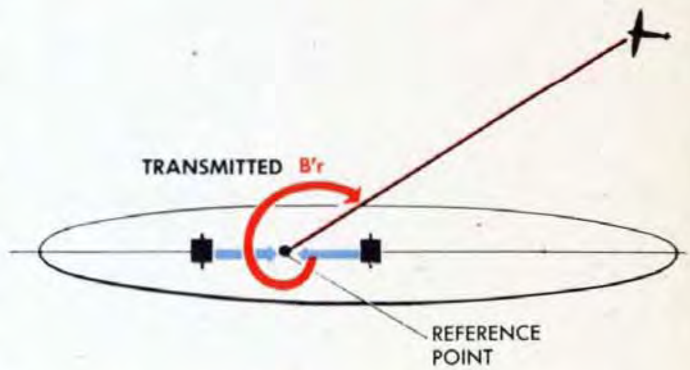
How the directors are corrected

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:

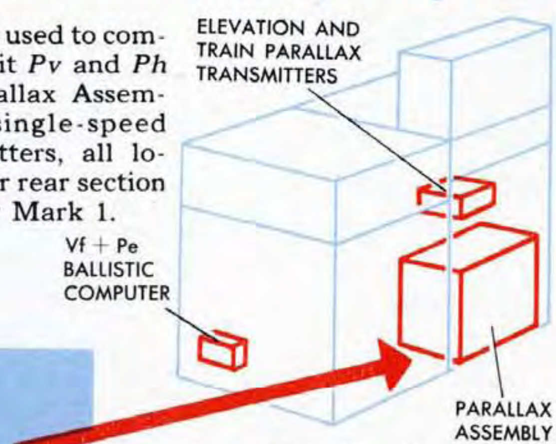
1. The height of the Director above the guns (vertical base)
2. The horizontal distance between the Reference Point and the guns (horizontal base)

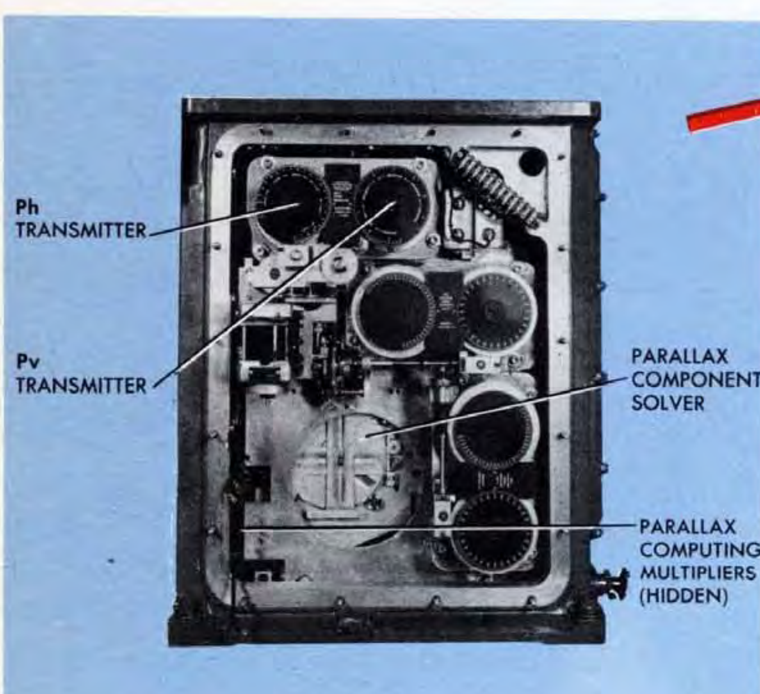
These two factors require three Parallax Corrections. Of the three Parallax Corrections, one compensates for the vertical base and two compensate for the horizontal base.

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.



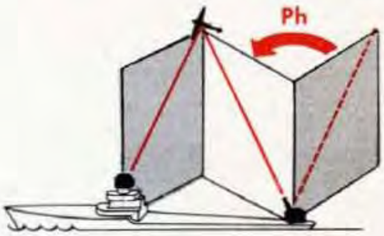


The Parallax Assembly contains the Parallax Component Solver and two computing multipliers.

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

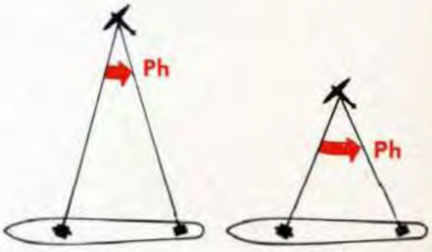
If a Target is directly aft of Own Ship, the angle of Gun Train, *B′gr,* is 180° and the *Ph* correction is zero.

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.



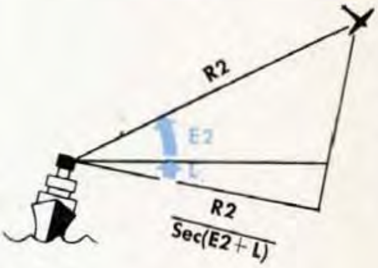
Advance Range, *R2,* is projected onto the deck plane because the gun is trained in that plane.

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*.

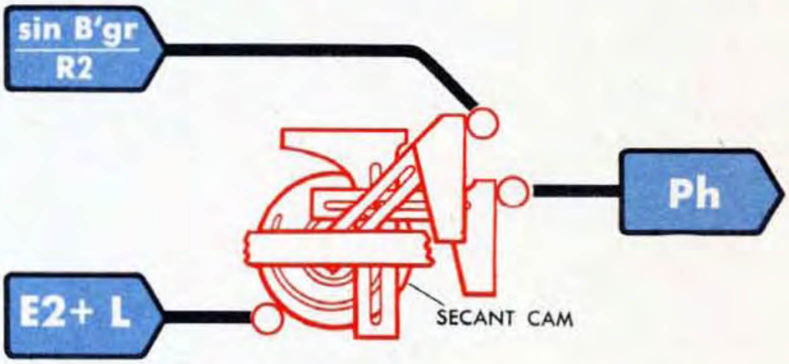
The two outputs of the Parallax Component Solver are:

$\frac{\sin B'gr,}{R2}$ 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 $(E2 + L)$.

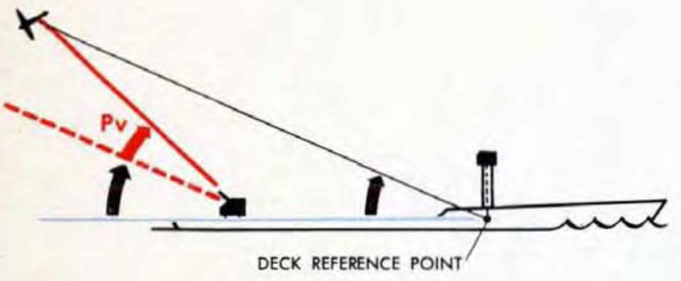
The input to the pivot arm rack is $\frac{\sin B'gr}{R2}$ from the Parallax Component Solver.

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*:

$$\sec (E2 + L) \times \frac{\sin B'gr}{R2} \times K \cdot 100 = Ph$$

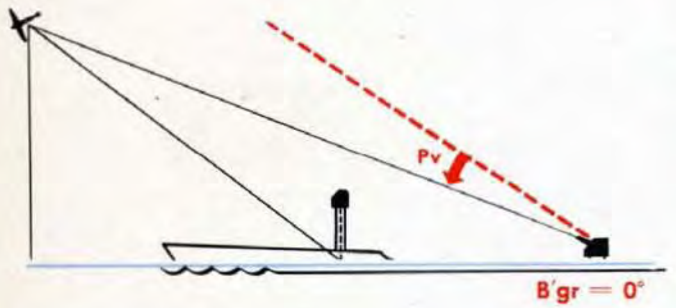
ELEVATION PARALLAX CORRECTION Pv



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*

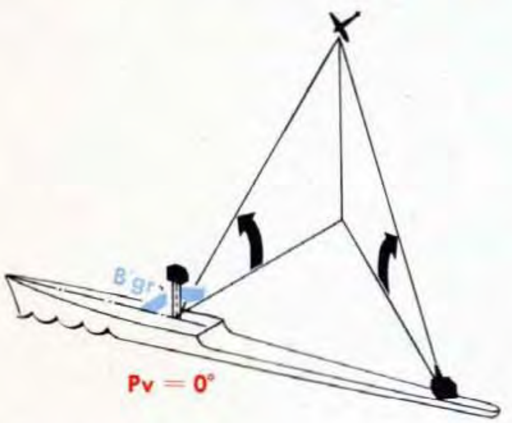


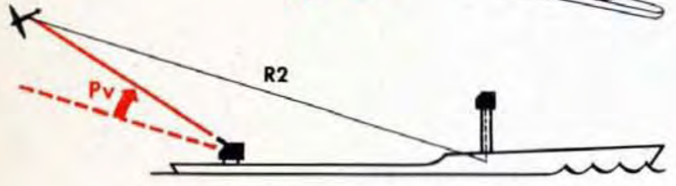
How B′gr affects Pv

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 $90^\circ = 0$.



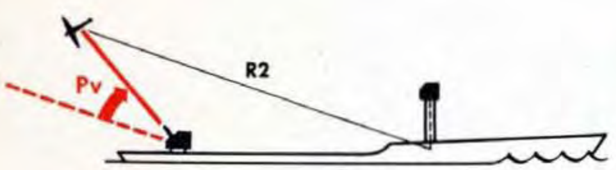


How R2 affects Pv

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

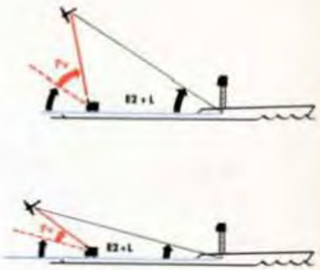
When $E2 + L$ is large, Pv is a relatively *large* angle.

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.

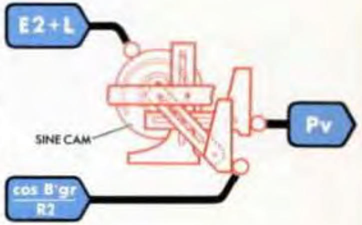
The value of $E2 + L$ positions the sine cam, giving a value of sin $(E2 + L)$ for every input value of $E2 + L$.

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.

$$\sin(E2 + L) \times \frac{\cos B'gr}{R2} \times K \cdot 100 = Pv$$

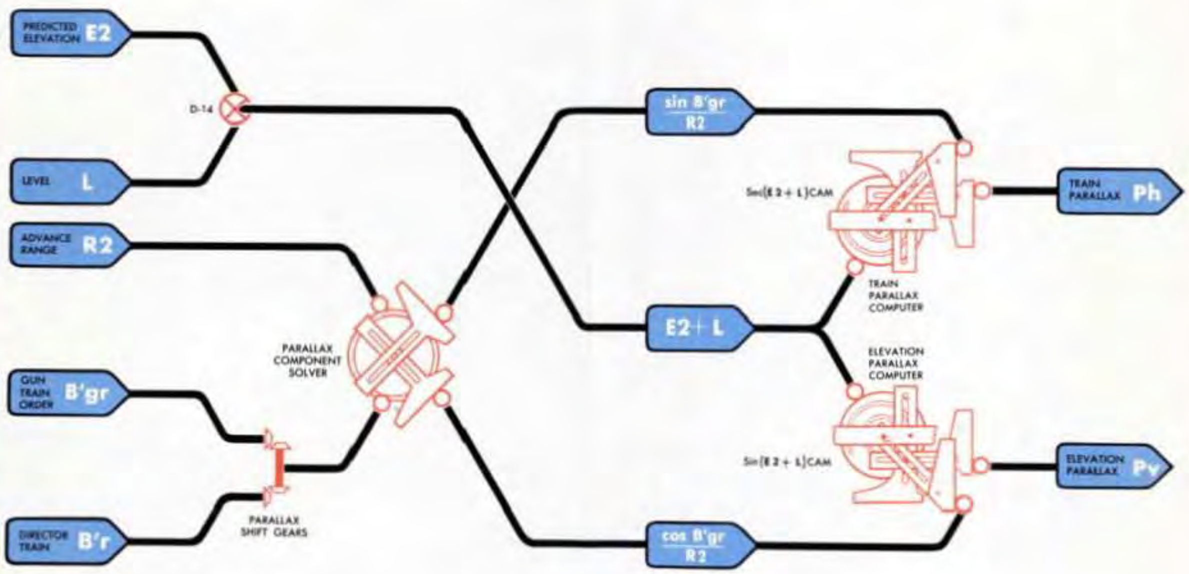


NOTE:
The equation for Pv is derived fully in the supplement at the end of this chapter.

COMPUTER MK. 1, MOD

PARALLAX SECTIO

SCHEMATIC DIAGRAM



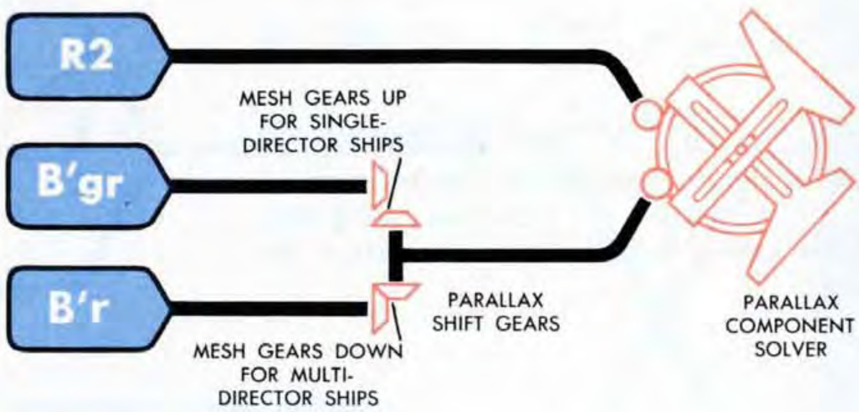
THE PARALLAX SHIFT GEARS

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.

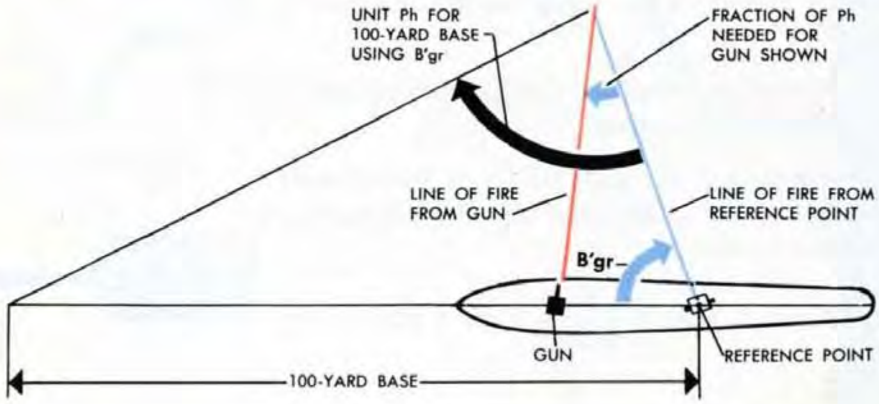
B′r is used on Multi-Director ships, such as BB's, CA's, CB's, and CL's.

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.

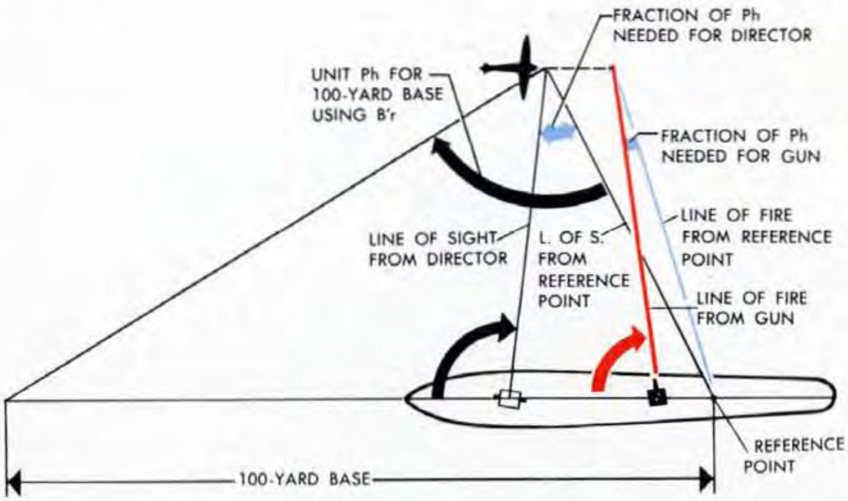


Multi - Director Ships

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.

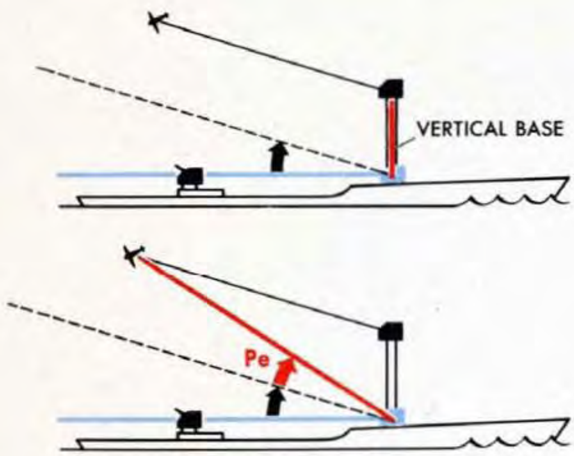


On Multi-Director ships, the guns are usually placed between the Directors; therefore the instrument farthest from the Reference Point is usually a Director rather than a gun.

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.

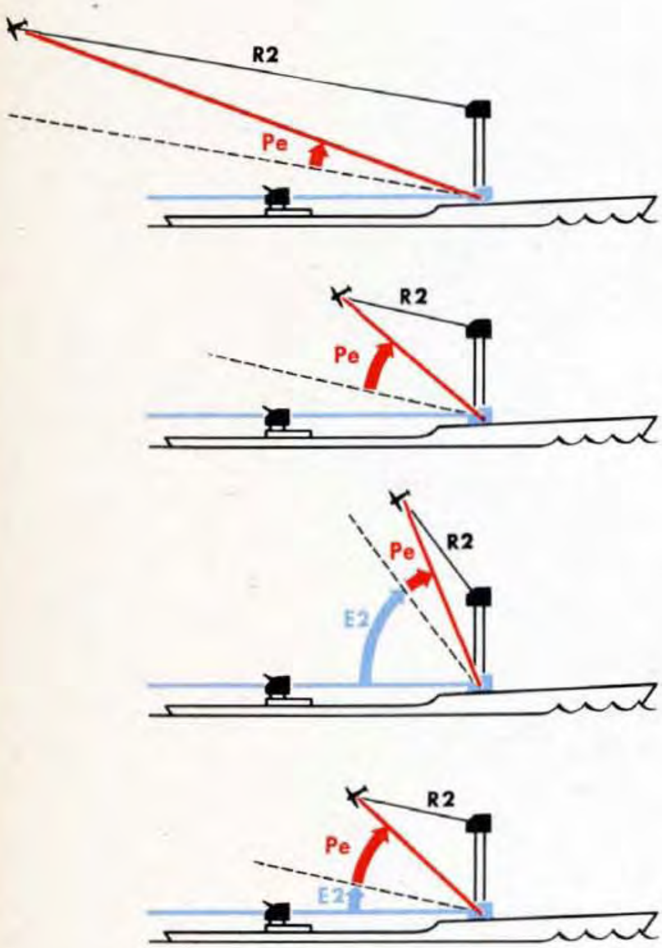
ELEVATION PARALLAX CORRECTION, Pe



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.

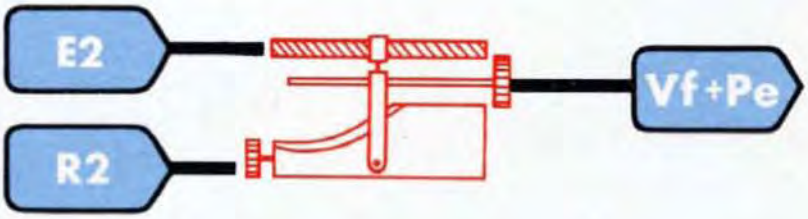
Also, when *E2* is a large angle, *Pe* is a *small* angle. When *E2* is a small angle, *Pe* is a *larger* angle.

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:

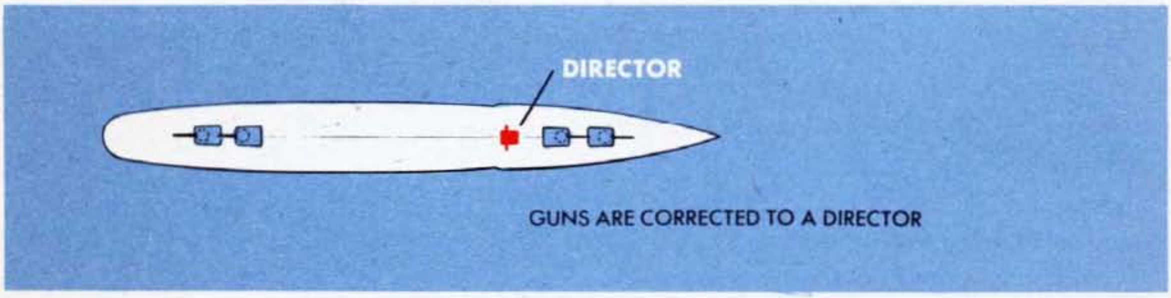
1 A Director

2 An imaginary point or line between two Directors

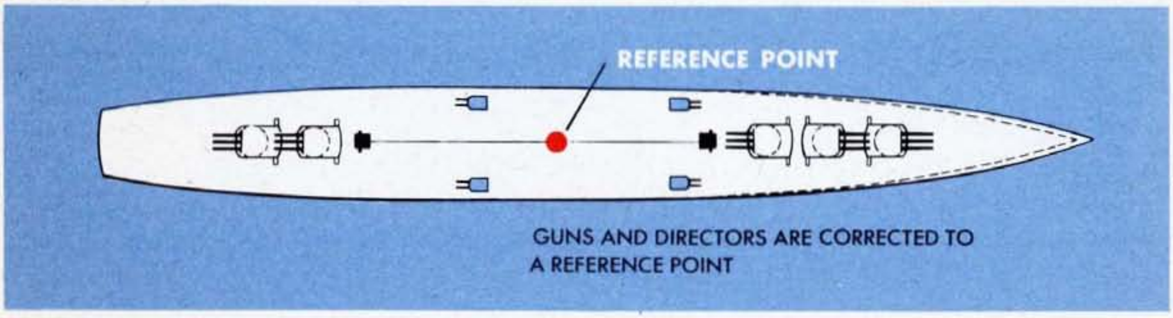
3 An imaginary line running through the Director

Here are some DIRECTOR and GUN

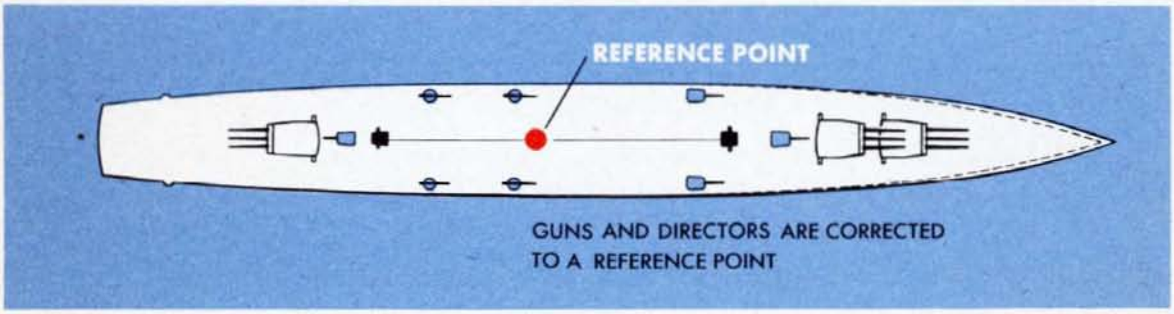
DESTROYER



LIGHT CRUISER



HEAVY CRUISER

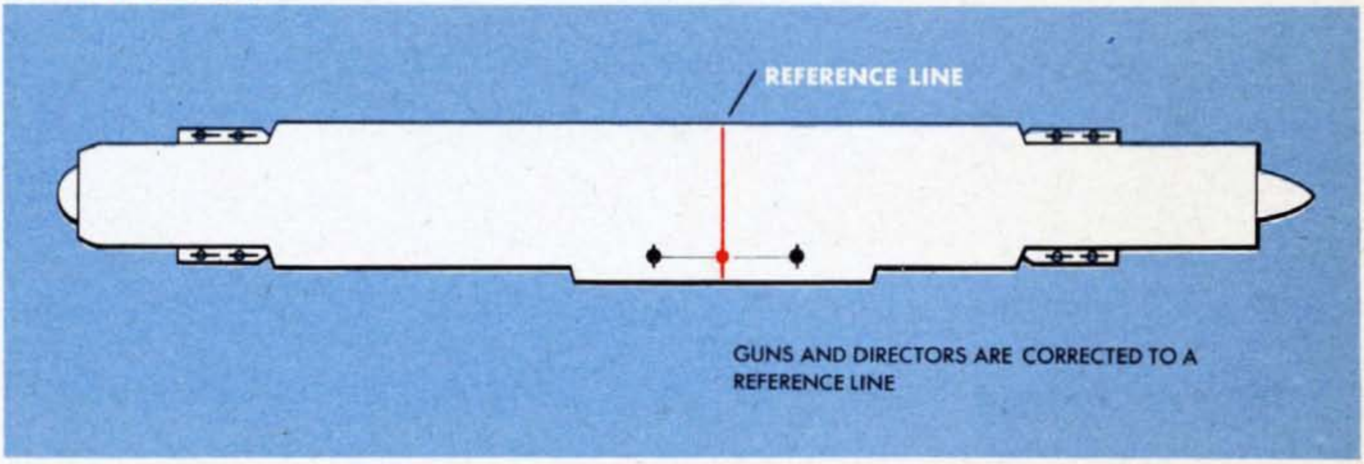


On a destroyer, the Director is the Reference Point.

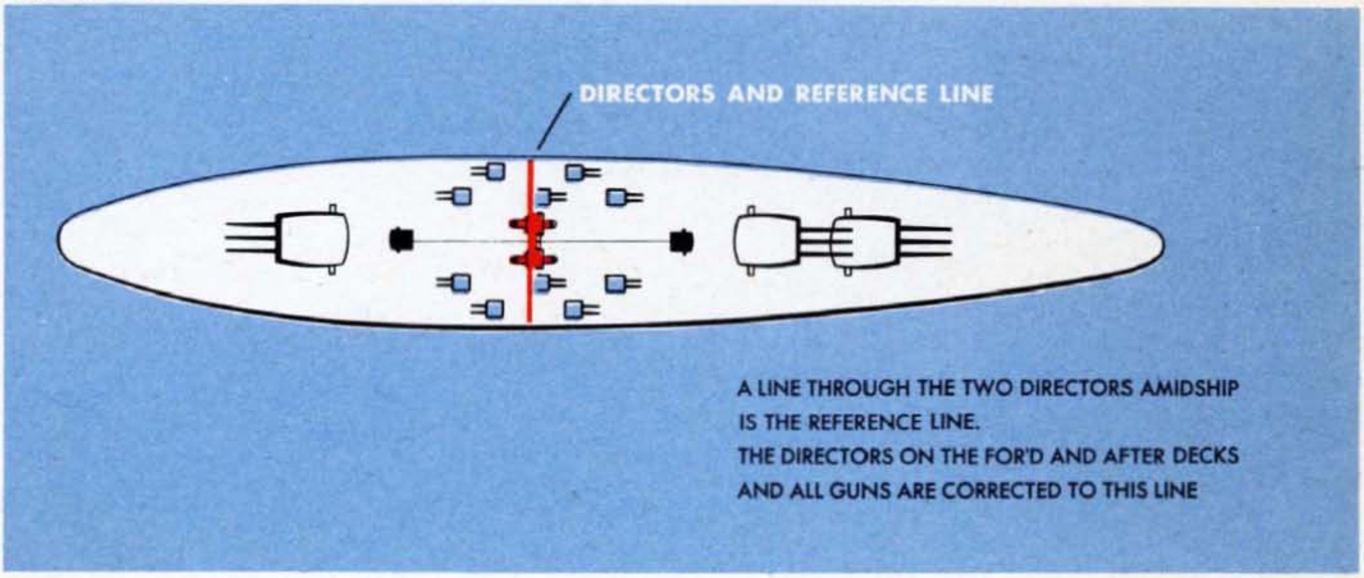
On other types of ships where guns and Directors are placed to starboard or port of an imaginary fore-aft line, corrections are made to a Reference *Line*. A Reference Line is a line running at right angles to the fore-aft axis and passing through a Reference Point or through one or two Directors.

arrangements for different types of ships

AIRCRAFT CARRIER



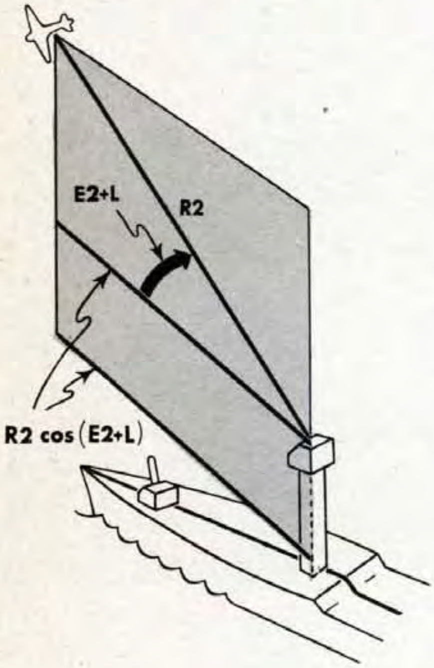
BATTLESHIP



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:

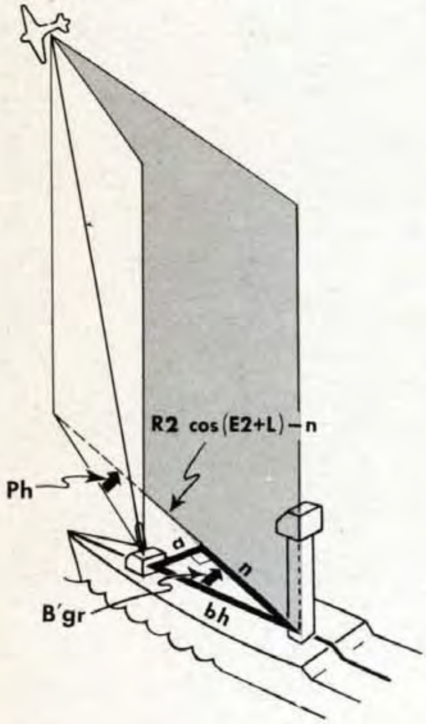
$$\sin B'gr = \frac{a}{bh}$$

$$a = bh \cdot \sin B'gr$$

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,

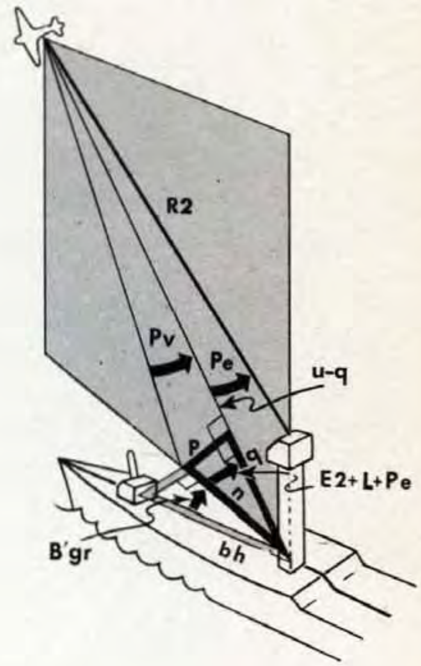
$$\tan Pv = \frac{p}{u-q} \qquad (1)$$

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,

$$Pv = \frac{K \cdot bh \cdot \cos B'gr \cdot \sin(E2 + L)}{R2}$$

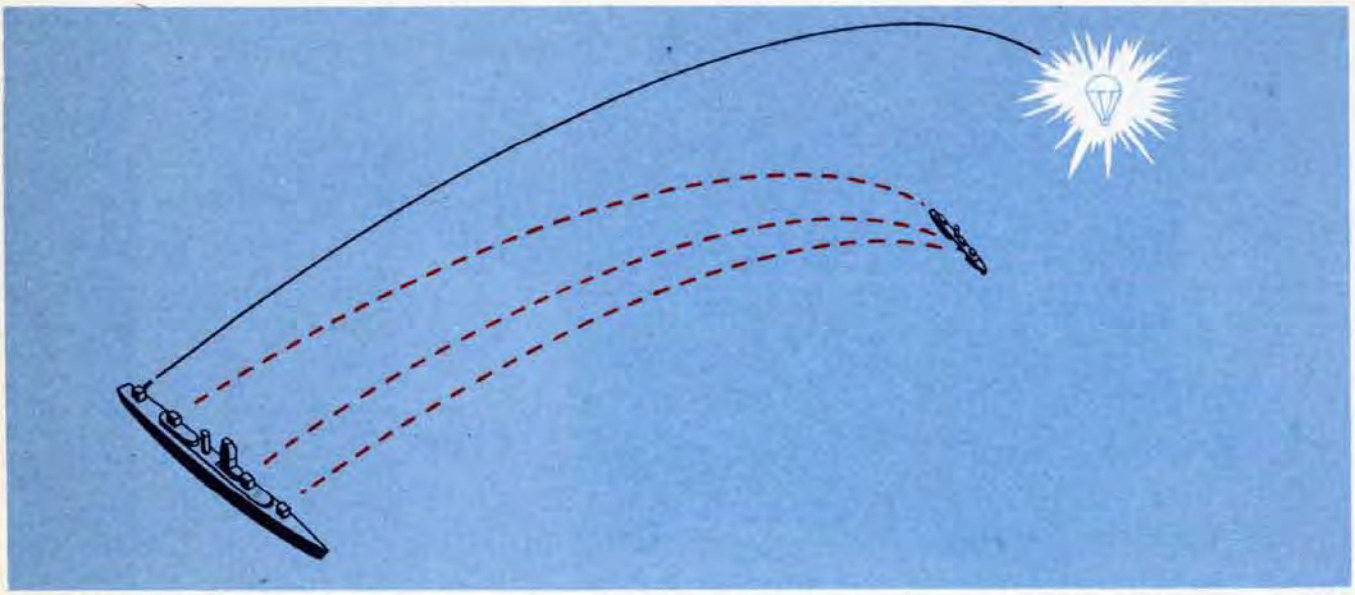
Since Pv is defined for a 100-yard base,

$$Pv = \frac{K \cdot 100 \cdot \cos B'gr \cdot \sin(E2 + L)}{R2}$$

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.

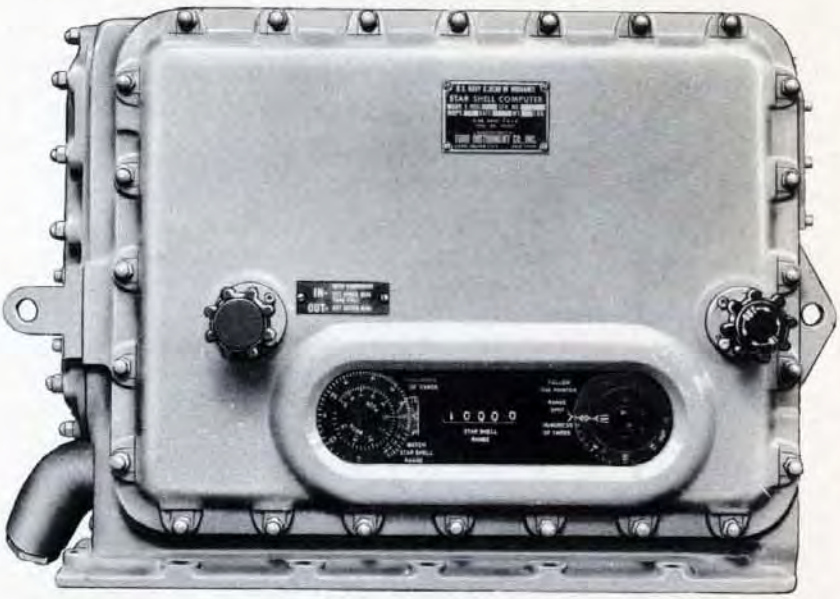
The star must form high enough above the water to allow time for the flare to burn out as it floats down. The Star Shell Computer is designed to compute a Fuze time and a Gun Elevation Order which will place the star 1000 yards beyond and 1500 feet above the moving Target, and a Gun Train Order which 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:

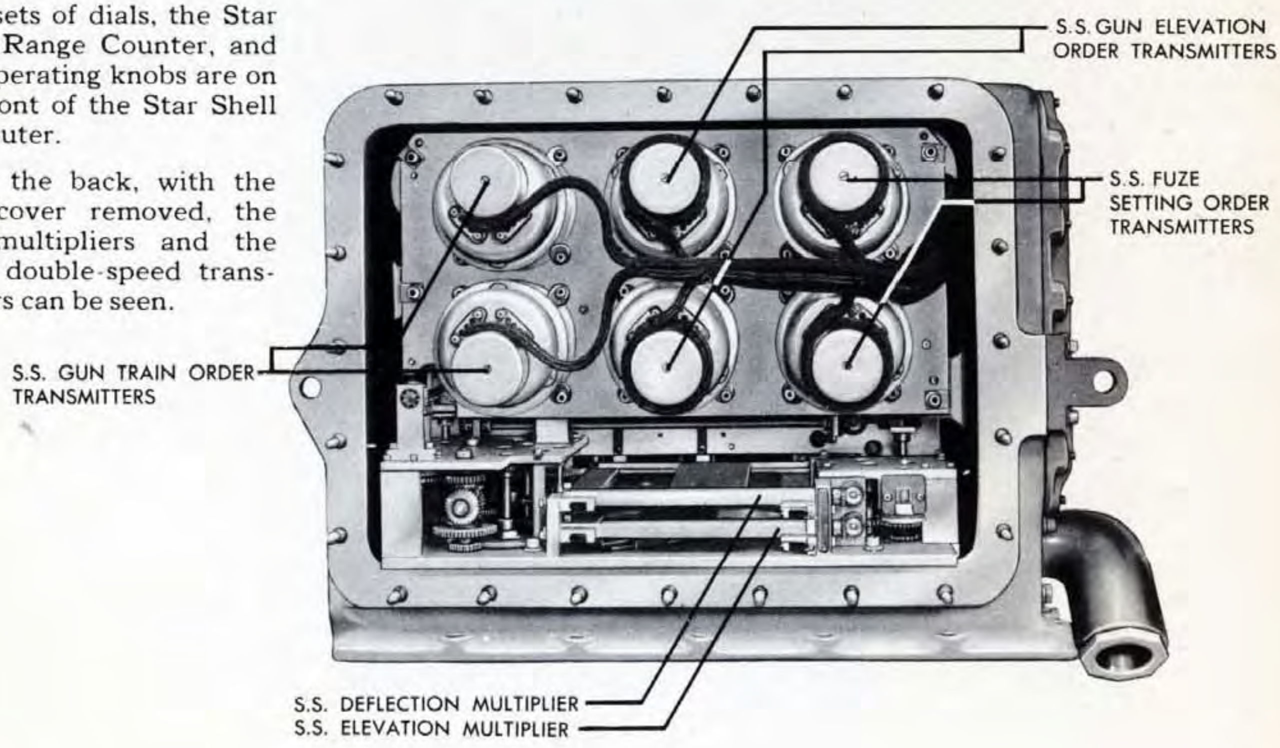
Star Shell Fuze Setting Order, *Fn*
Star Shell Gun Train Order, *B′grjn*
Star Shell Gun Elevation Order, *E′gjn*

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.

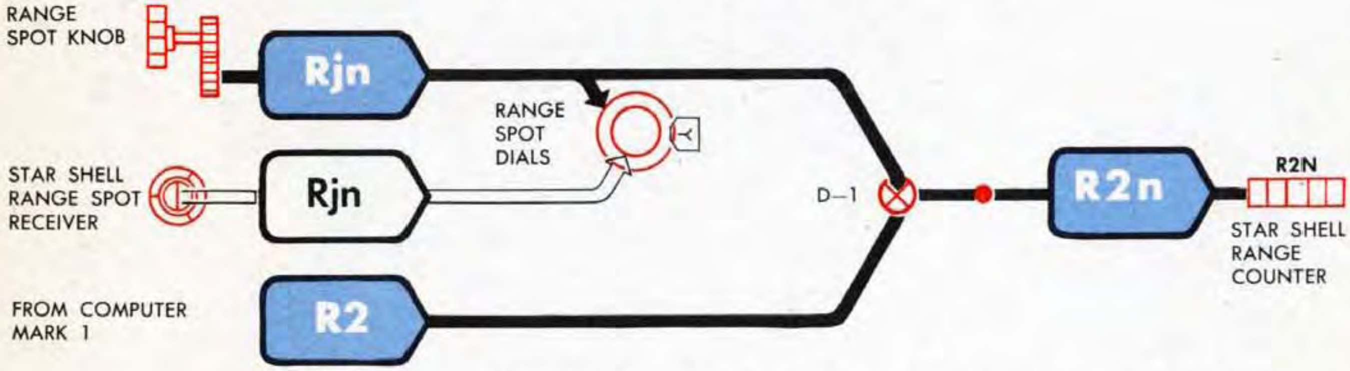
Star Shell Range, *R2n,* is the range to the point at which the star shell bursts, usually about 1000 yards beyond the Target. *R2n* consists of Advance Range, *R2,* plus Star Shell Range Spot, *Rjn,* plus 1000 yards.

$$R2n = R2 + Rjn + 1000$$

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.

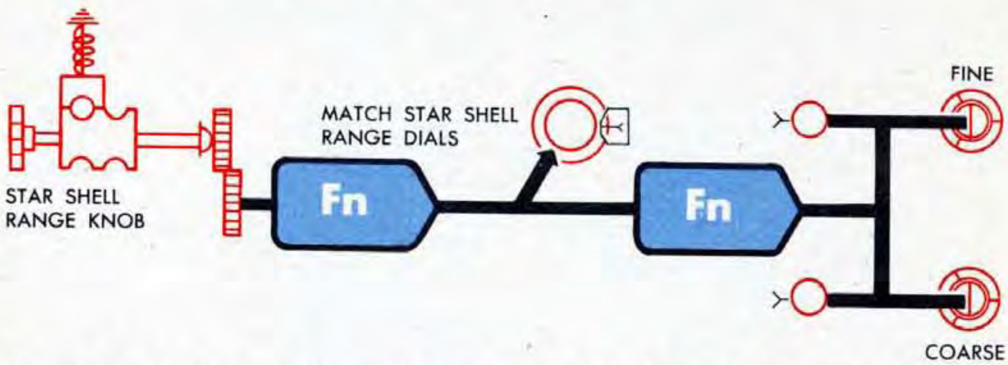


The additional 1000 yards is introduced at an offset clamp on the line to the *R2n* Counter. This clamp is adjusted to make the *R2n* Counter read 1000 yards more than the *R2* Counters in the Computer Mark 1 when *Rjn* is zero.

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.

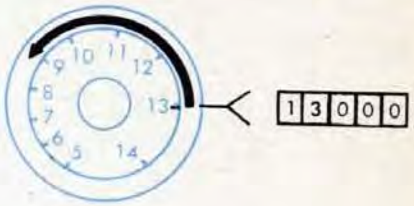
The Fuze line is connected to the *inner dial* of the Match Star Shell Range Dials. Matching this inner dial reading with the Star Shell Range Counter reading puts the correct value of *Fn* into the Star Shell Computer. The inner dial is positioned by the Star Shell Range Knob in its IN position.



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.



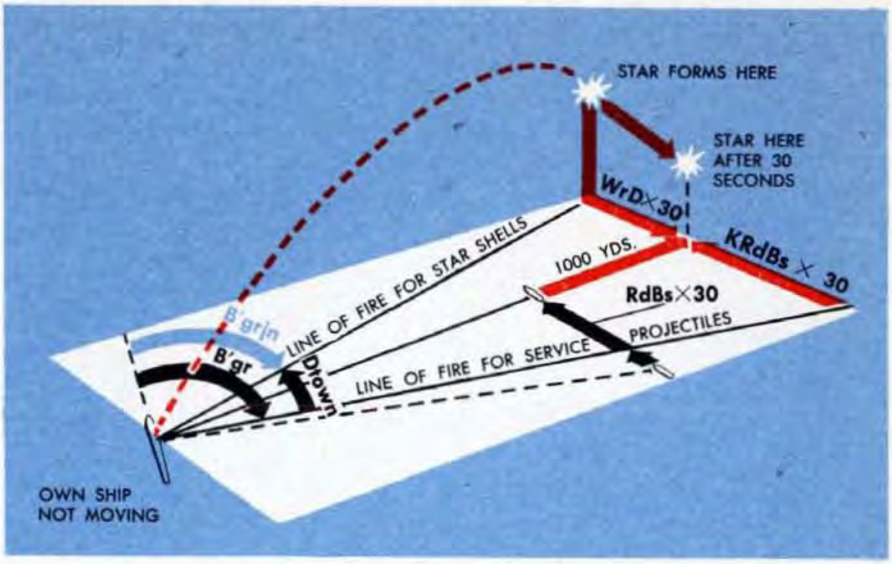
ALTHOUGH THE CHANGE WAS 4000 YARDS IN EACH CASE, THE AMOUNT OF ROTATION WAS GREATER FOR THE SECOND 4000 YARDS THAN IT WAS FOR THE FIRST 4000 YARDS.

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*.

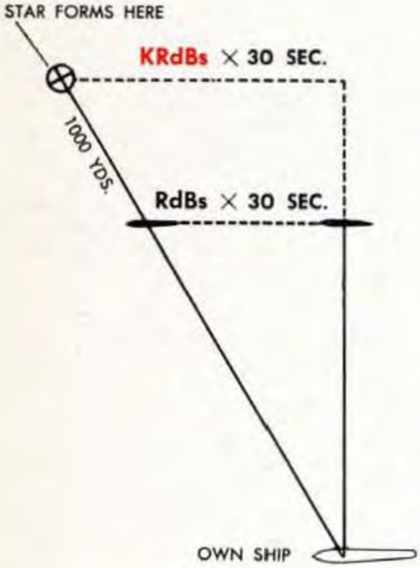
The Computed Star Shell Gun Train Order, *B′grn*, consists of *B′gr* plus a train correction to take account of both deflection of Ship and Target during the 30 seconds, and deflection of the star due to wind during the 30 seconds.

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:

$$\frac{(KRdBs + WrD) \times K}{R2n} = Dtown$$

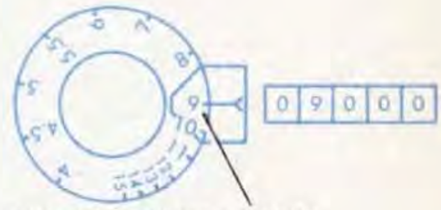
The equation for *Dtown* is solved by a dial and a screw-type multiplier.

The mechanism first computes the term $\frac{K}{R2n}$. This value is called *jDwn*.

The equation for *Dtown* can now be written:

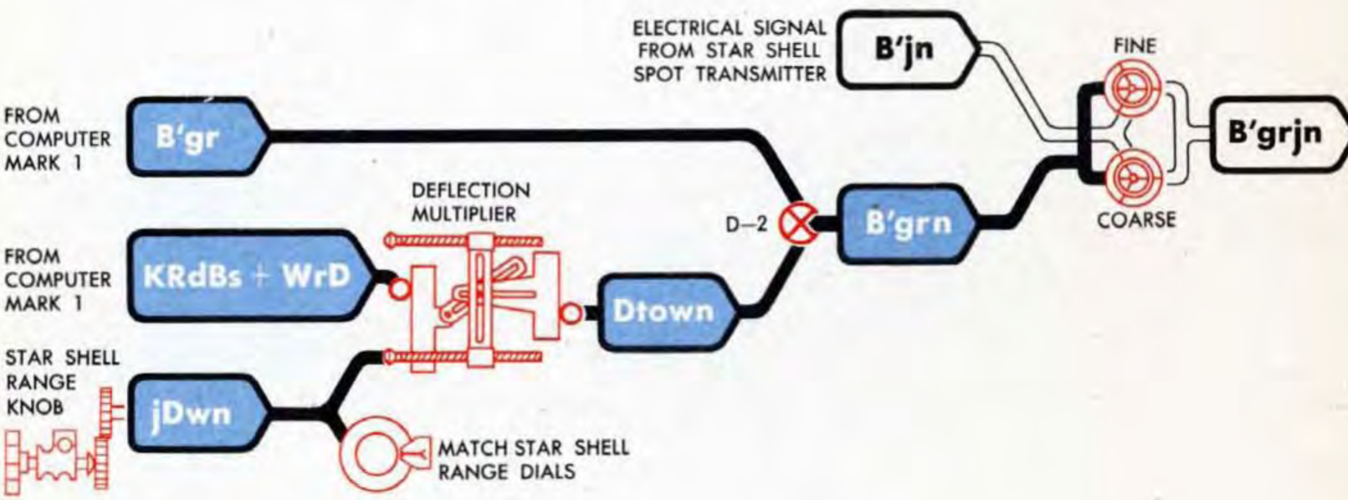
$$Dtown = jDwn \times (KRdBs + WrD)$$

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*.

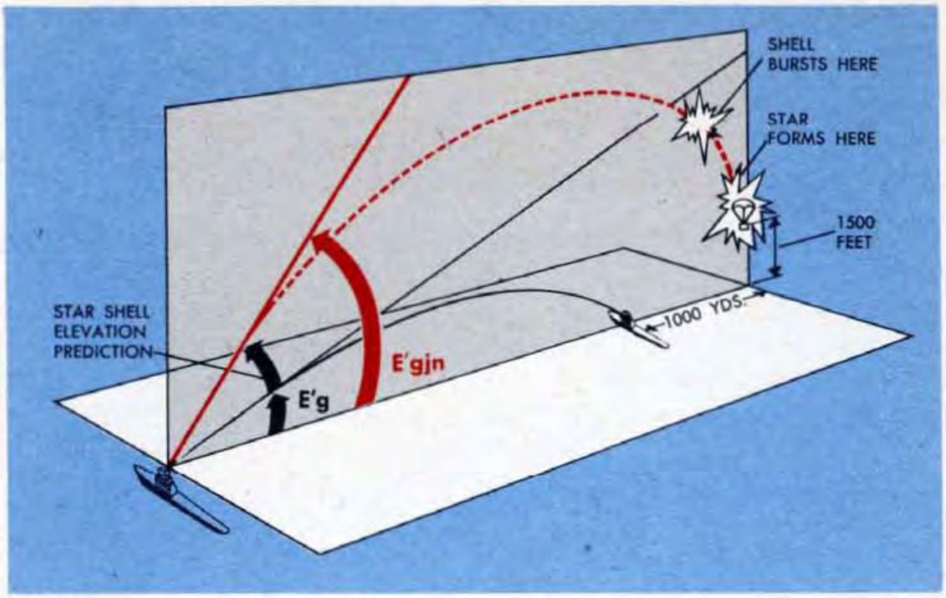


Computed Star Shell Gun Train Order, *B'grn*, is obtained by adding *Dtown* to Gun Train Order, *B'gr*, at differential D-2. In other words, the computation from Computer Mark 1 needed to hit the Target, and the correction needed to put the star, at half its life, in line with the Target, are combined 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.

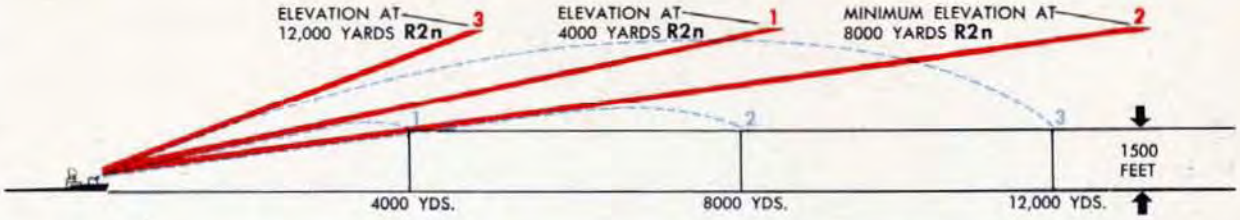
The equation for Star Shell Gun Elevation Order, *E′gjn*, has four terms.

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.



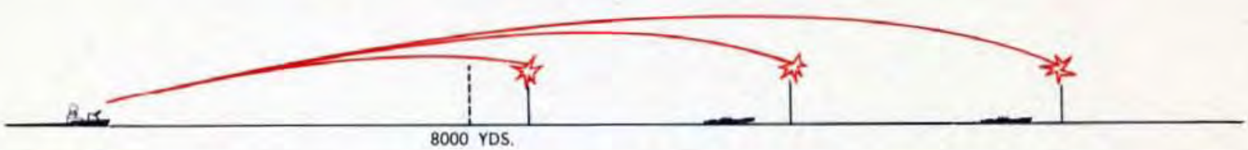
Why there are both a positive and a negative elevation correction

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 • 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 • 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:

$E'gjn = (E'g + K) + K_3 \cdot jDwn + K_1 Fn\,(K_2 + Rjn) + E'jn.$

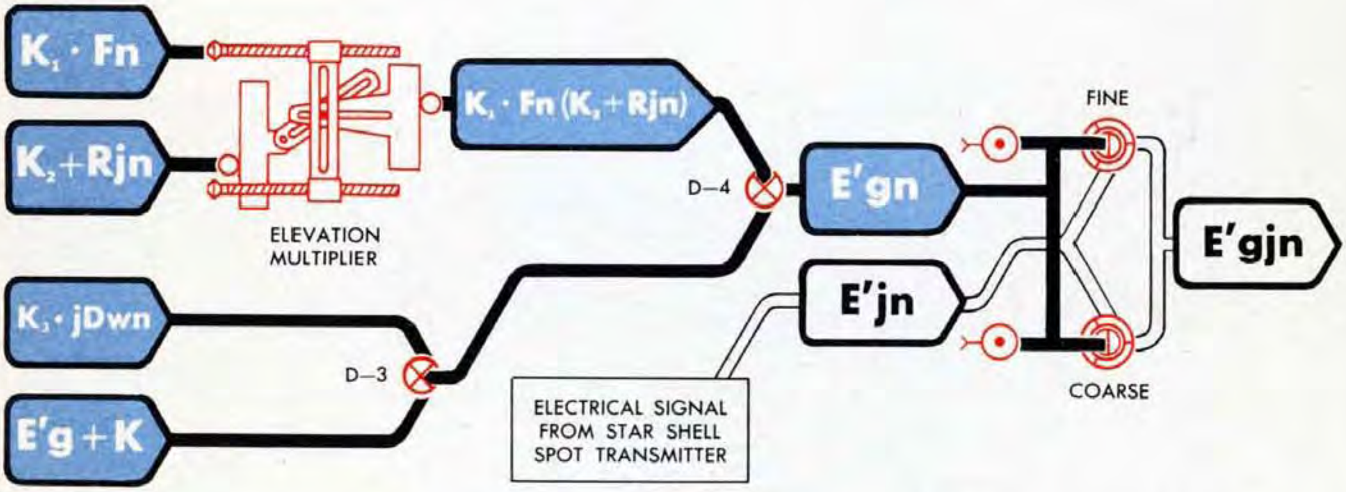
This equation is solved mechanically in four steps:

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.

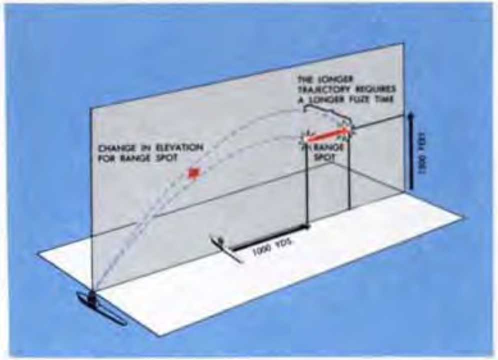
3 The output from D-3 is added to the multiplier output to obtain Computed Star Shell Elevation Order, $E'gn$. $E'gn$ drives coarse and fine synchro differential generators in the Star Shell Gun Elevation Order Transmitter.

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.



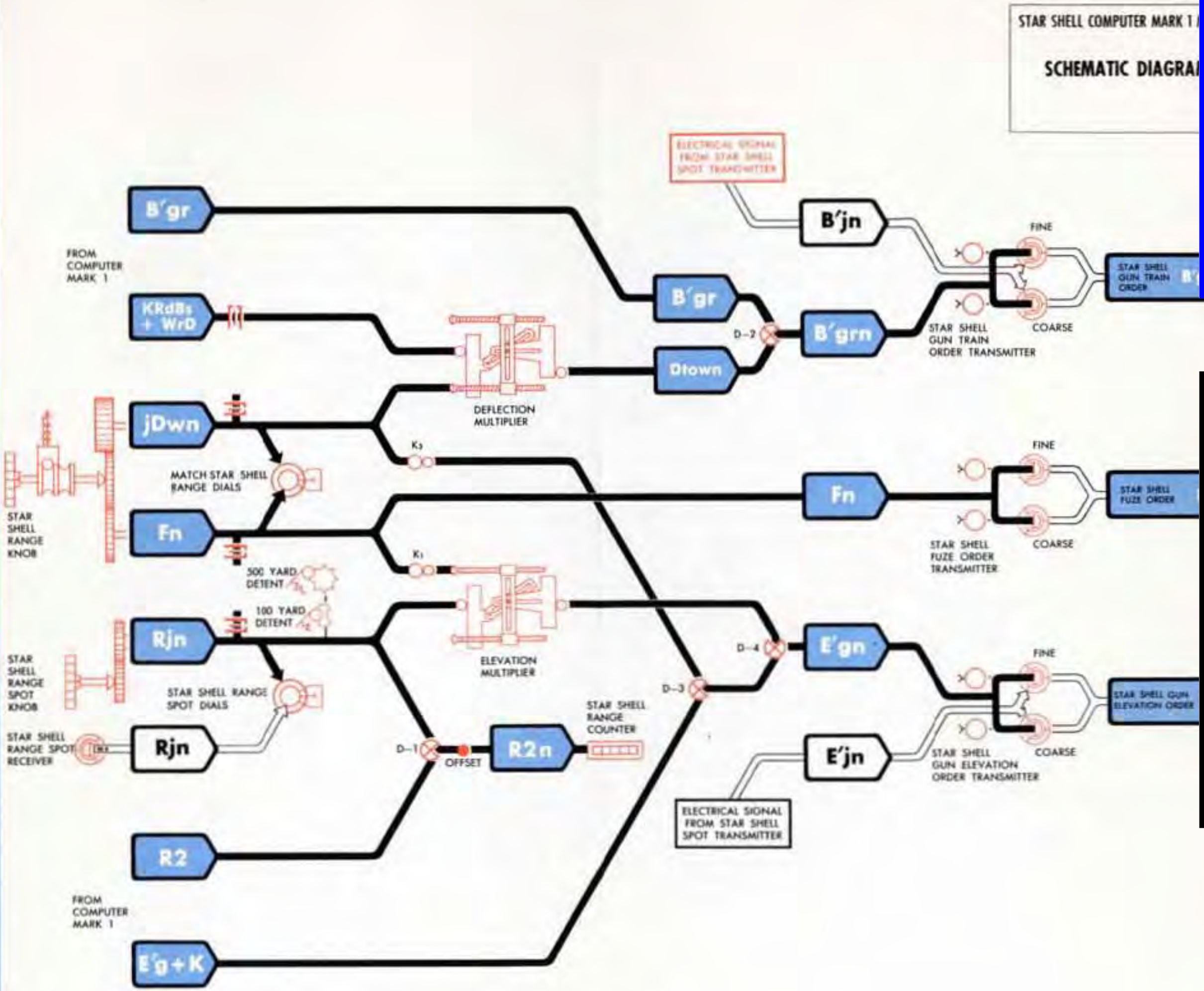
Star Shell Range Spots

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.

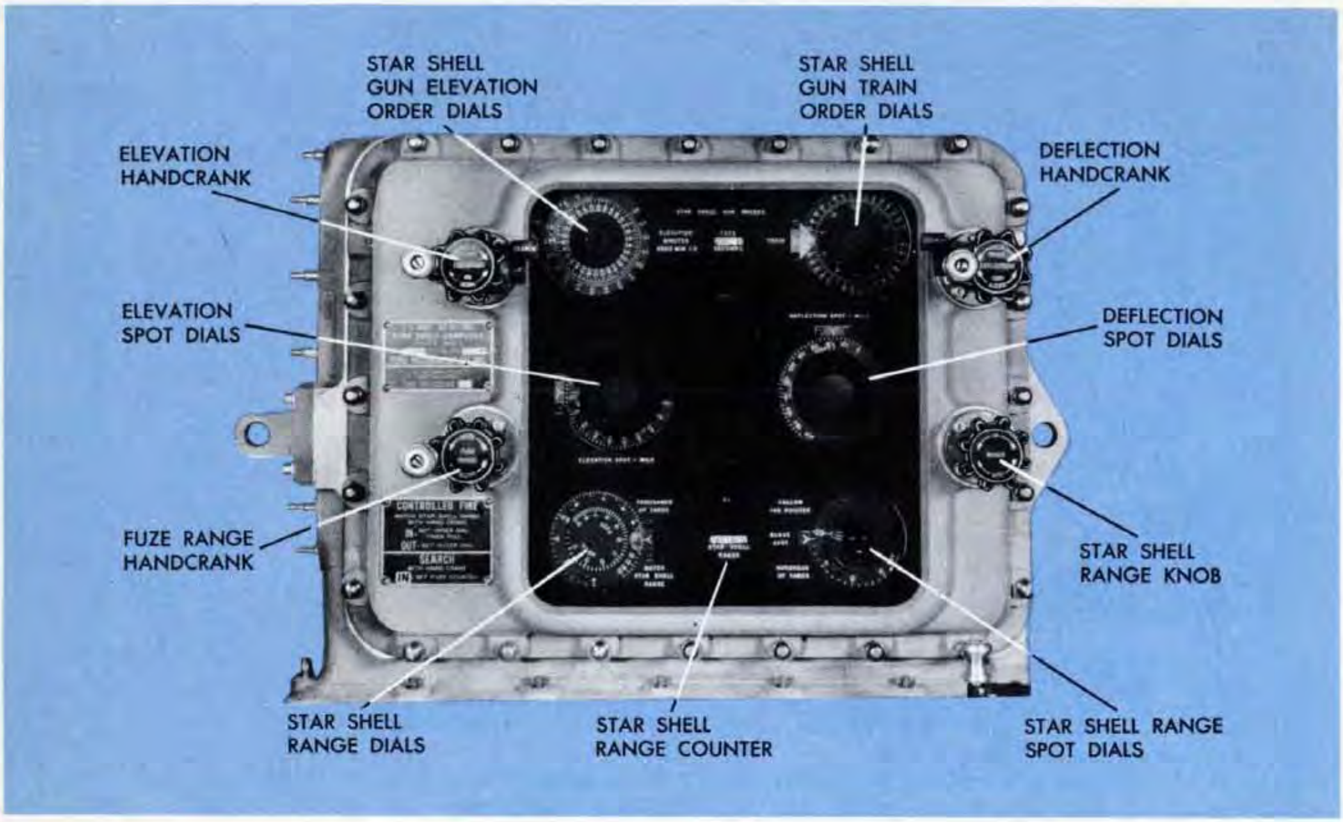
Fuze Time, *Fn*, must be longer, since the shell must travel farther. This change in Fuze Time is computed by matching the Fuze Dial to the new *R2n* value on the Star Shell Range Counter, which includes the spot. $R2n = R2 + 1000 + Rjn$.

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, $K_3 \cdot jDwn$, 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 $K_1 \cdot Fn\ (K_2 + Rjn)$.



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'gjn* 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.

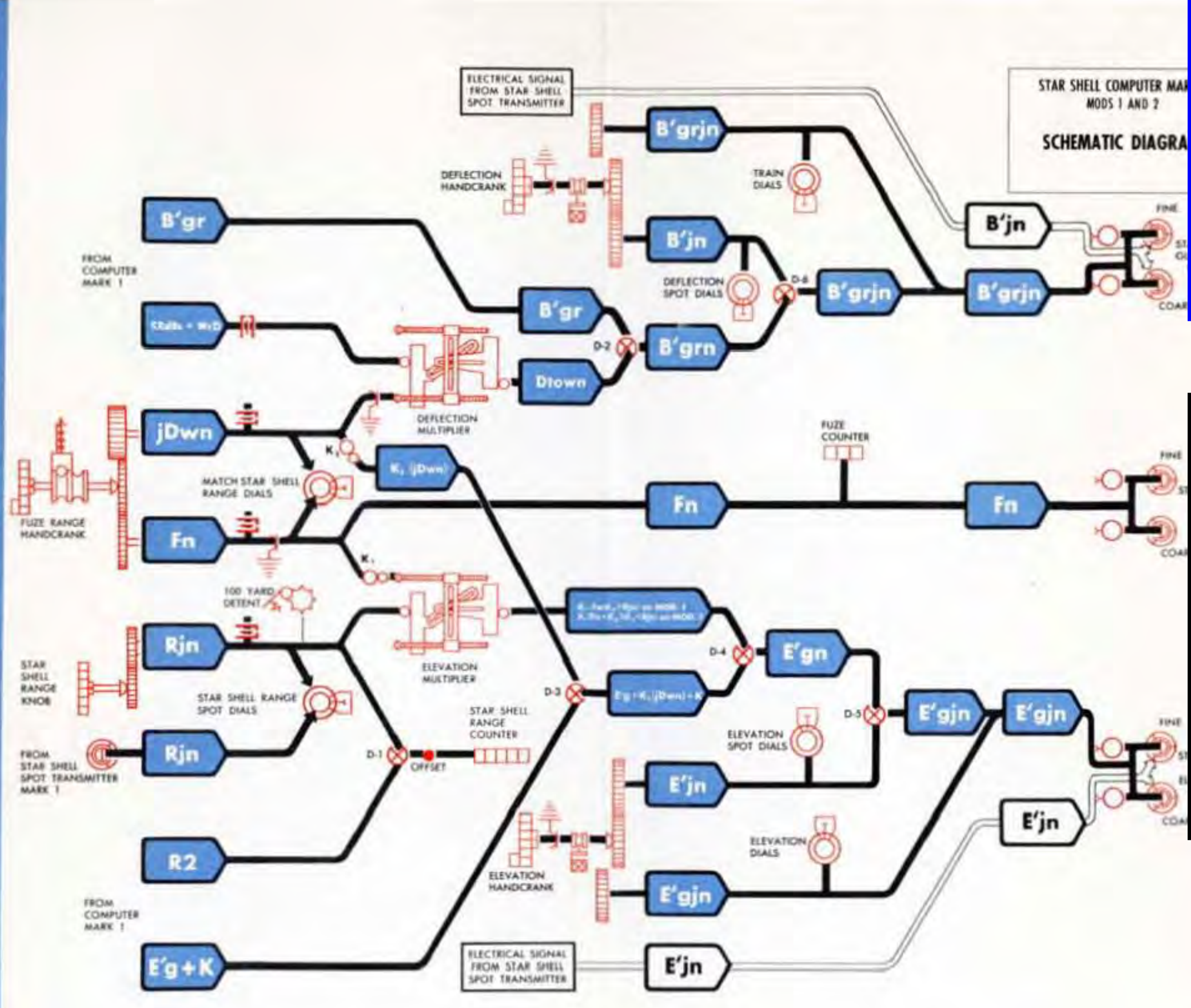
Controlling the fire of smoke projectiles

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.

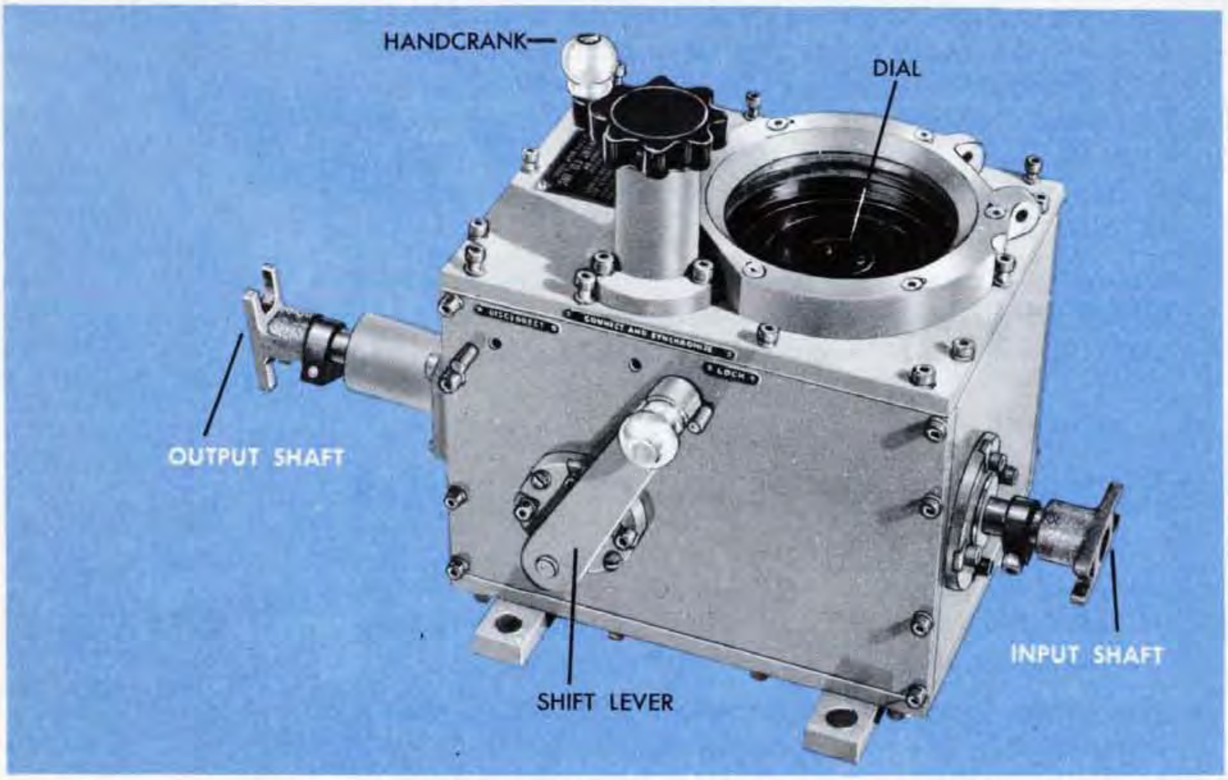
The Range Spot limit has been increased to IN 2857 in Mod 1 and is indicated by the red dot on the dial. To set up for control of smoke projectiles, Range Spot is set at IN 2857. This setting positions the Elevation Multiplier at zero, eliminating the effect of *Fn* on *E'gjn*. This places the burst 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.

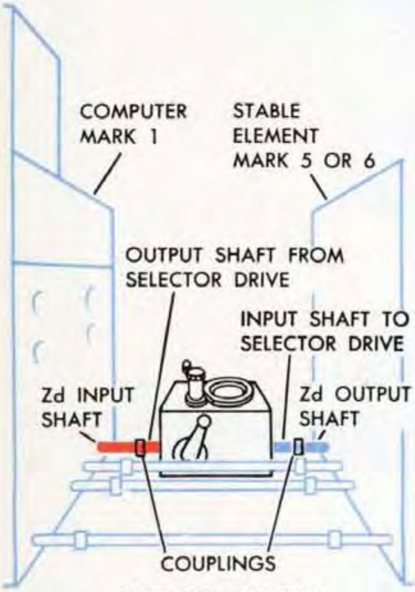
The STAR SHELL COMPUTER MARK 1 MOD 2

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.

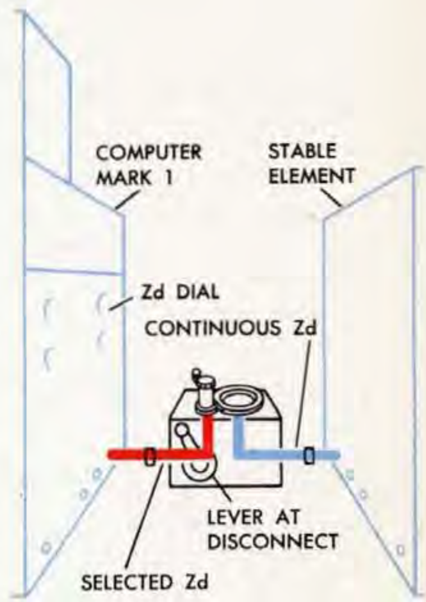
The Selector Drive mechanism is contained in a metal box. On the front is a shift lever with three positions: DISCONNECT, CONNECT AND SYNCHRONIZE, and LOCK. On top of the box are a dial assembly and the handcrank. The handcrank and dials are used for synchronizing the *input* and *output* shafts.

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.

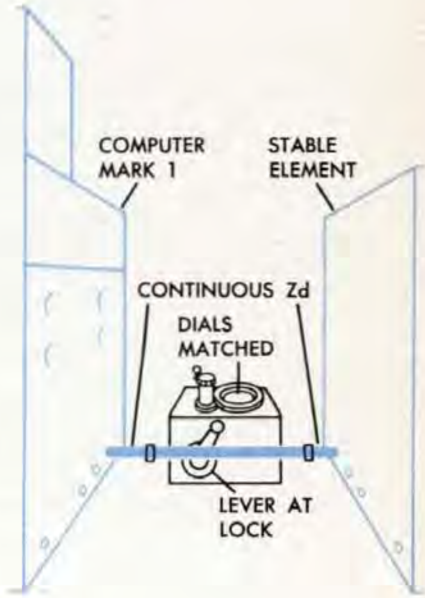
The type of Stable Element used on most ships permits the setting of *either* the Level *or* the Cross-level input to the Computer at a fixed value, but not both simultaneously. Installation of a Selector Drive Mark 1 on these ships makes it possible to set *both* the Level and the Cross-level inputs 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.



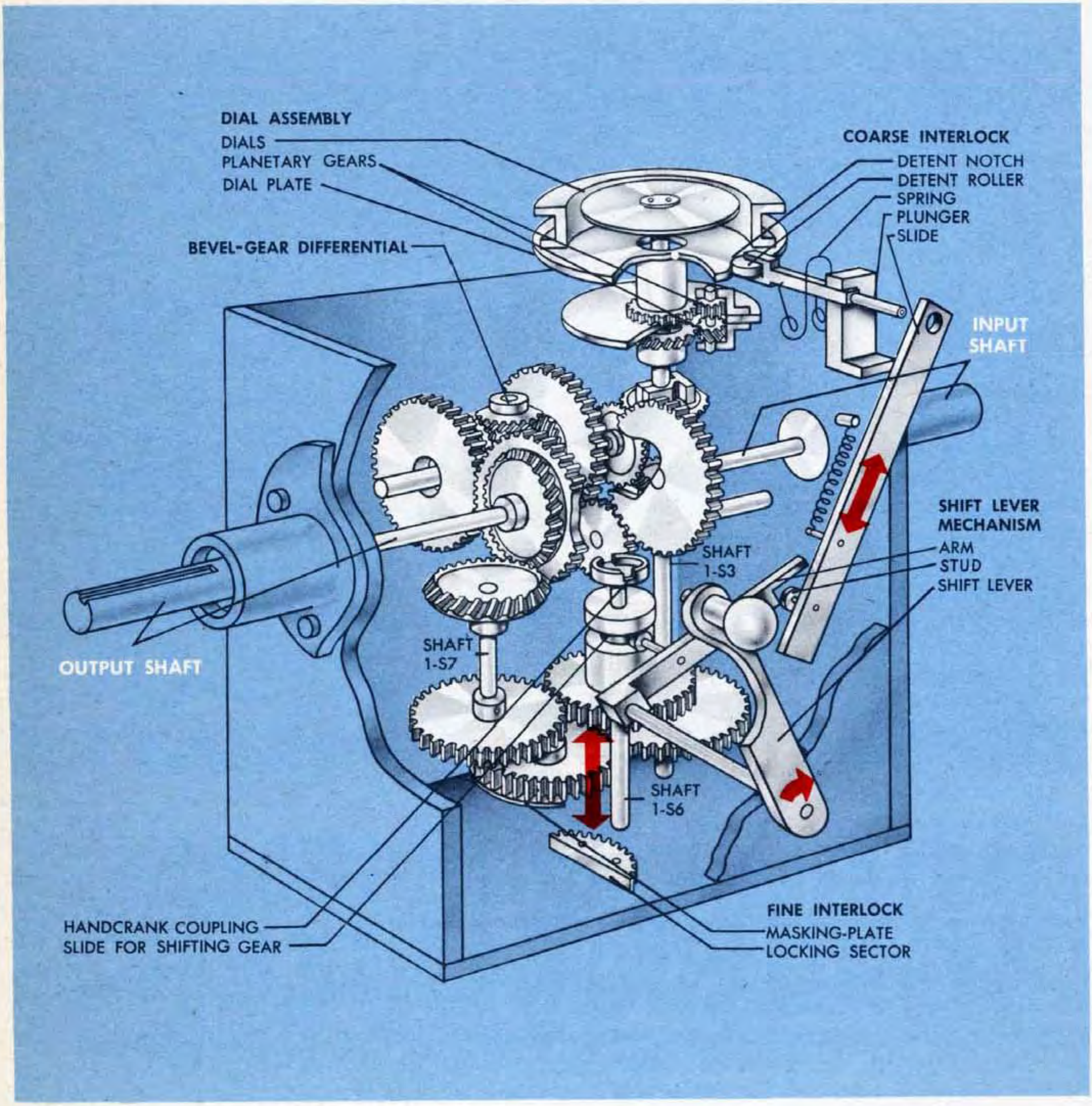
Continuous cross-level

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.

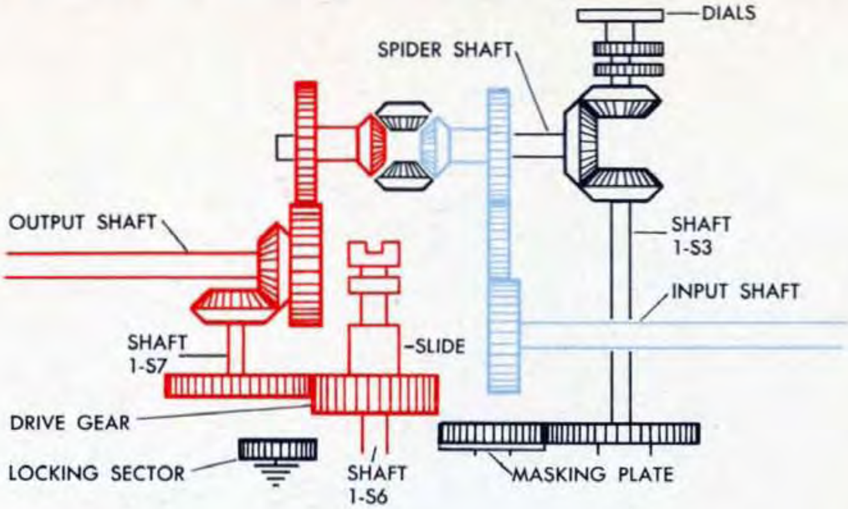
To set the Selector Drive for transmitting continuous values of *Zd*, the shift lever is moved to the CONNECT AND SYNCHRONIZE position. The handcrank is turned until the indexes on both of the Selector Drive Dials are matched at the fixed index. This synchronizes the input and output shafts. The shift 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.

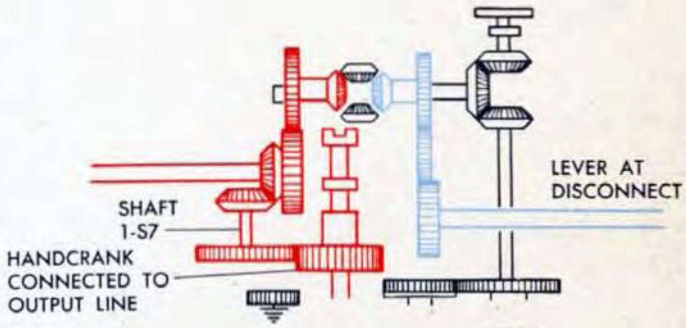
On shaft 1-S6 there is a slide carrying the drive gear. The slide permits the gear to be moved up and down along shaft 1-S6 by the shift lever.

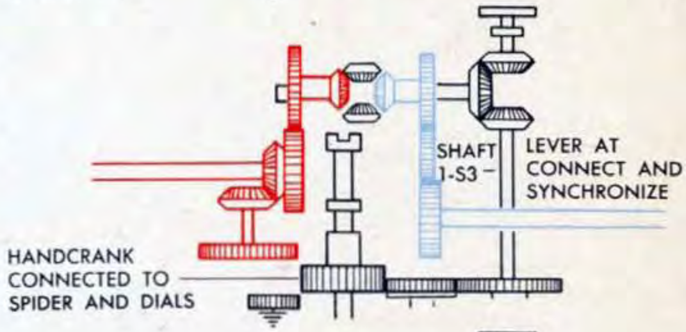
The drive gear on shaft 1-S6 can be moved to any one of three positions by positioning the shift lever.

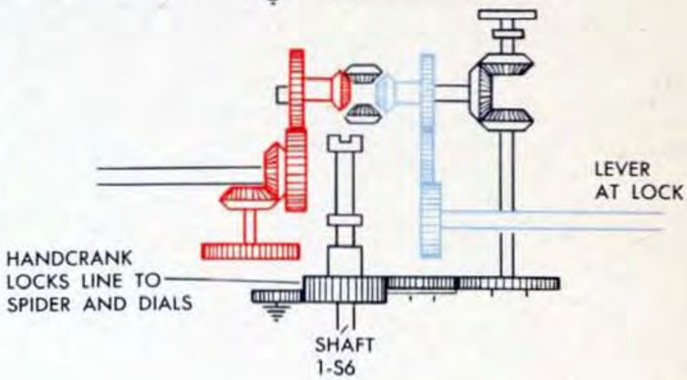
When the shift lever is in DISCONNECT position, the drive gear is in its highest position, meshing with the lower gear on shaft 1-S7. This connects the handcrank to the output shaft.

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.

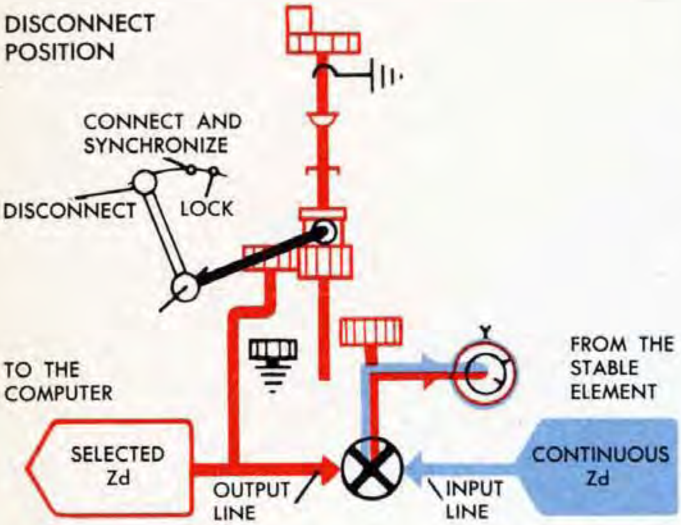
When the shift lever is in LOCK position, the drive gear is in its lowest position. It is still connected to the shaft line to the spider and dials, but now it also meshes with the fixed locking sector on the base plate of the Selector Drive. Since this locking sector is fixed, the drive gear in LOCK position locks shaft 1-S3, the differential spider, and the dials.

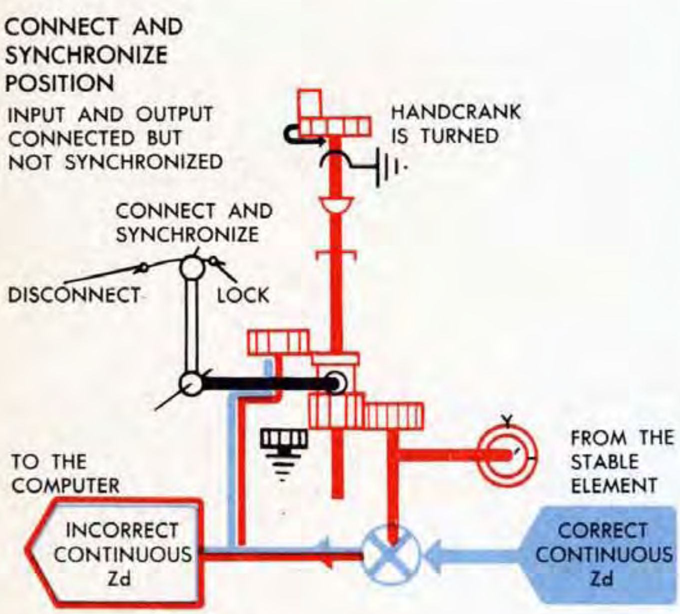






How the SELECTOR DRIVE works





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

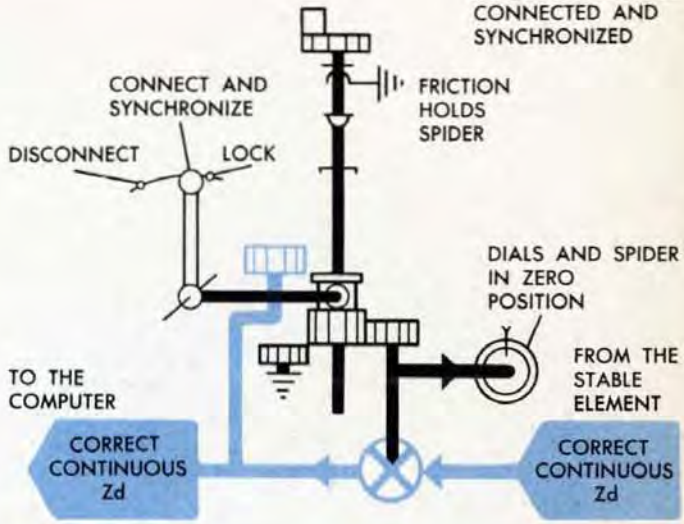
With the lever still at CONNECT AND SYNCHRONIZE position, the handcrank is turned, turning the differential spider until the spider is at its zero position. This handcrank input combines with the input from the Stable Element, and both drive out through the output side of the differential. As the handcrank 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.

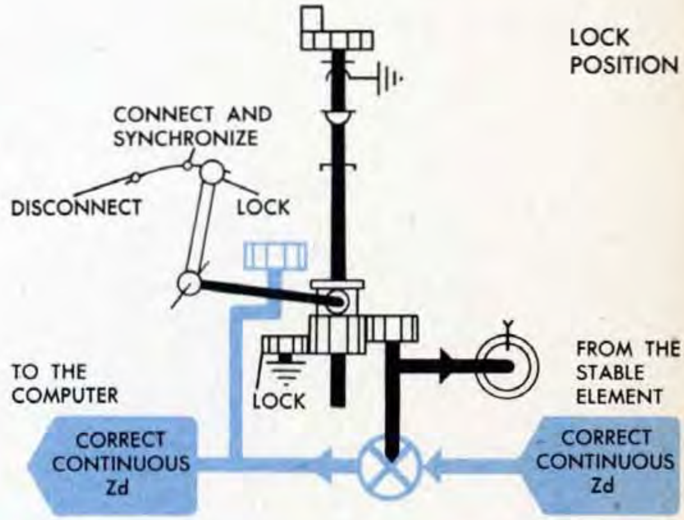
In LOCK position of the shift lever, the sector locks the shaft line to the spider and dials. The sides of the differential are held in synchronism, and correct continuous values of *Zd* from the Stable Element drive through the Selector Drive to the Computer. The mechanism now functions as a shaft carrying 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

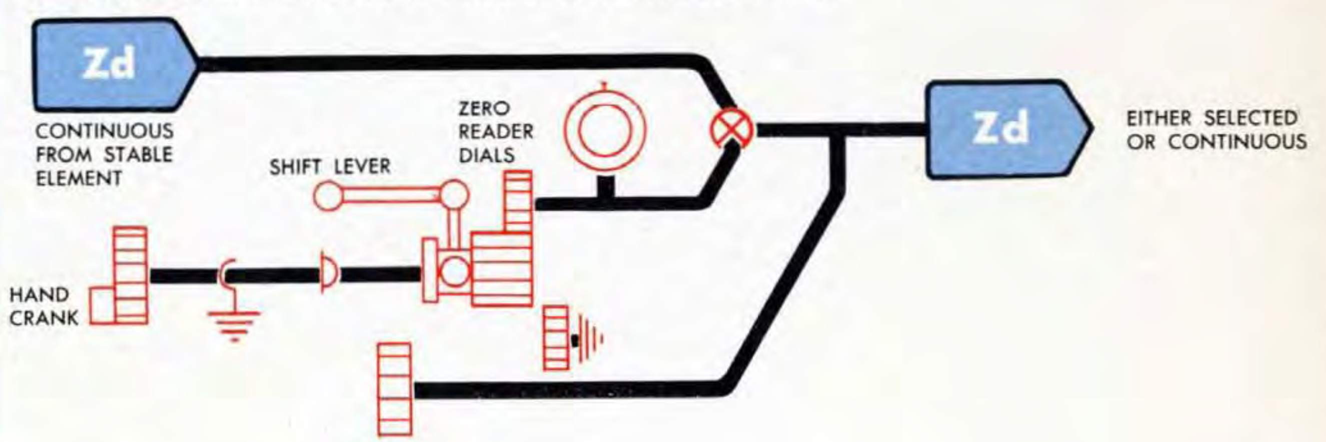
INPUT AND OUTPUT CONNECTED AND SYNCHRONIZED



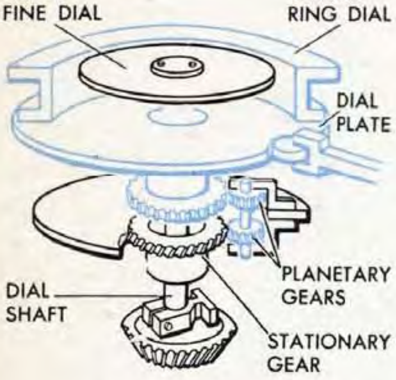
LOCK POSITION



THE SELECTOR DRIVE IS SHOWN THIS WAY IN THE MAJOR SCHEMATICS



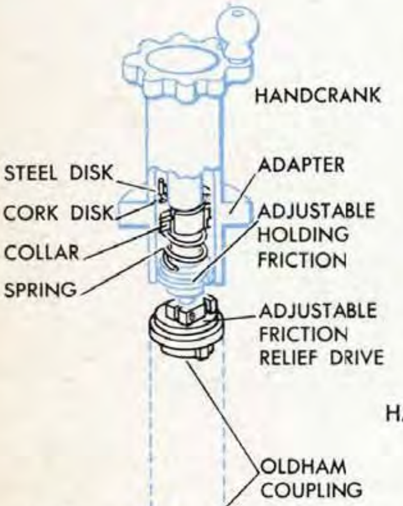
The dial assembly



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.

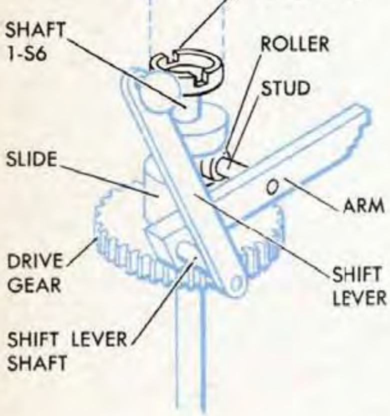
The handcrank assembly



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.

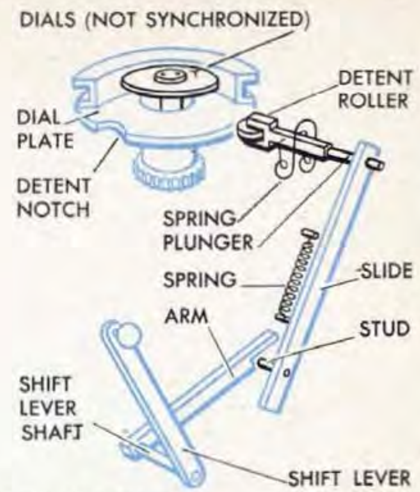
The grooved slide carrying the drive gear is keyed to shaft 1-S6. The slide and gear rotate with the shaft and may also move up and down on the shaft. An arm is pinned to the shift lever shaft. This arm has a stud on which is mounted a roller. This roller fits into a groove on the slide. As the shift 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

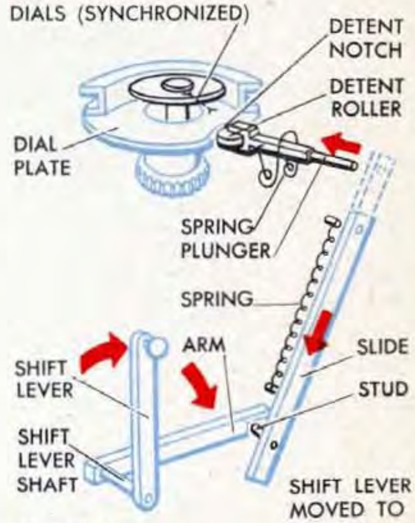
A coarse and fine interlock prevent the shift lever from being moved to the LOCK position when the input and output shafts are not synchronized. The coarse interlock is a linkage between the shift lever and the dials. It consists of an arm, a slide, and a plunger holding a detent roller. The arm is connected 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

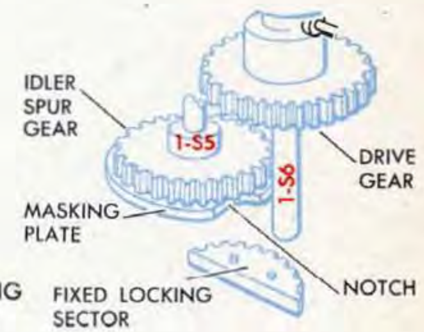


COARSE INTERLOCK IN LOCK POSITION

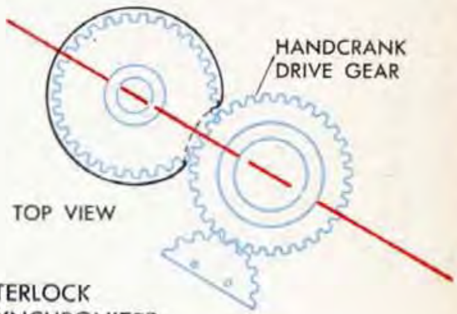
The fine interlock

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.

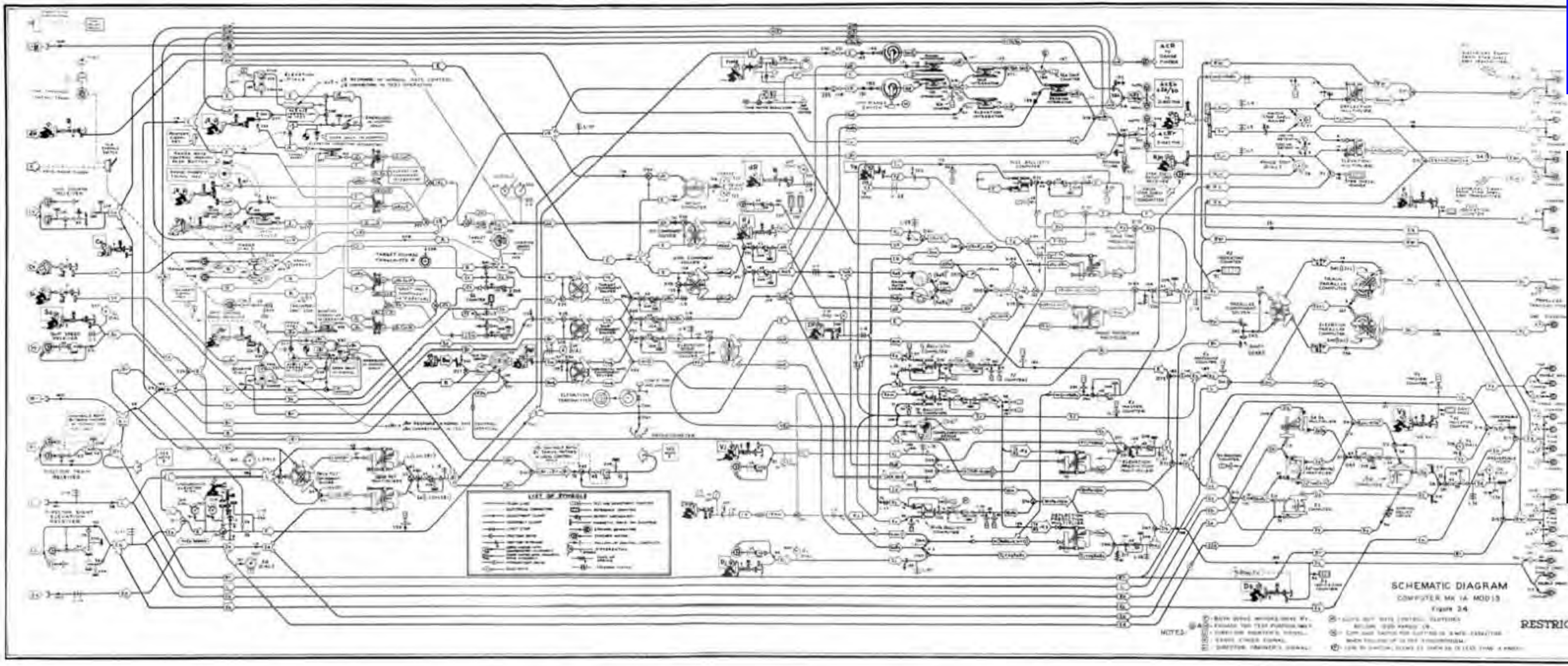
In LOCK position the drive gear must be lowered by the shift lever until it engages the fixed locking sector. The drive gear cannot be moved into mesh with the fixed locking sector until the notch in the masking plate lines up with the edge of the drive gear. When the dials are exactly matched at the 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 15
Figure 24

RESTRICTED