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Nike Hercules Time-to-Intercept
Servo/Potentiometer System

This system; part of the total Nike Hercules Intercept Computer System; is utilized in three different modes during a mission. It is also used in three different ways during pre-missile launch and during missile flight.

The three different modes that the Time-to-Intercept System is used during a mission are:

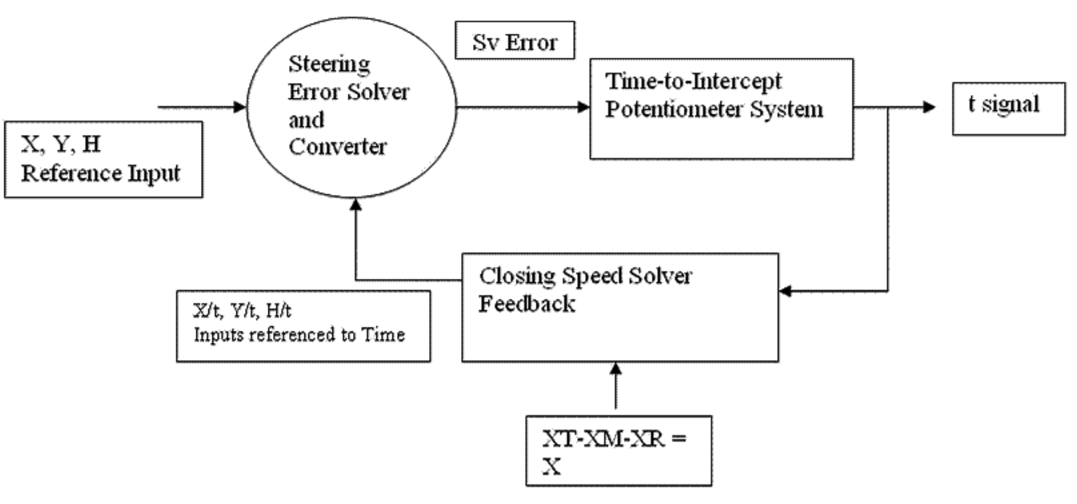
1) **Prior to launch, the Time-to-Intercept System displays estimated mission time. This estimate is necessary to evaluate a "Ready To Fire" indication. This time includes Launch, Missile Away, Boost, Roll Stabilize, and Flight Time.**
2) **During flight, and after "Dead Time" (about 7.5 seconds that includes Missile Away, Boost and Roll Stabilize), the Time-to-Intercept System continuously calculates and counts down 'course time' in a second by second mode. This can last up to 100 seconds and will continue until 24 seconds to intercept.**
3) **At 24 seconds to intercept, the Time-to-Intercept System will switch to 'Fine Time' which is 4 times more precise than 'Course Time". This mode gives much sharper steering to the missile that increases air drag and friction, but insures a clean kill.**

The three different ways that the Time-to-Intercept System is used during the Nike Mission is:

1) **The Time-to-Intercept System gives a visual indication of both the estimated mission time and the Time-to-Intercept on both the face of the Time-to-Intercept Box and the Vertical Plotting Board.**
2) **The Time-to-Intercept System supplies time based feedback or input to several computation amplifiers that indicates steering errors.**
3) **The Time-to-Intercept System includes several mechanical, cam driven, switches that perform critical mission tasks at the appropriate time in flight.**

Critical to understanding the operation of the Time-to-Intercept System, is to also understand that part of this system is the Steering Error Solver, the Steering Error Converter and the Closing Speed Solver. All three of these sub-systems use the output of the time potentiometers in their algebra to recognize and solve steering errors of the missile, basically by 'optimizing' the time of flight to the target.

A simple block diagram of the Time-to-Intercept System could look like below.



A helpful way to understand the purposes of the Time-to-Intercept System is to start considering what is called 'The One Dimensional Flight Problem'. This is a theoretical intercept in which a missile is flying at a known, optimal velocity, directly head on with a non-maneuvering target that is flying at a constant velocity. Kind of a variation of the popular algebra problem, 'there are two trains traveling towards each other….'.

Using this problem, we can put in the numbers, such as a velocity of the missile, Vm = 500 yds/sec, target velocity, Vt = 200 yds/sec and a total flight distance of 80,000 yds. Using the equation of:

$t = \frac{Distance}{closing\ velocity}$ or $114.3 = \frac{80,000}{700}$ **the estimated time-to-intercept is 114.3 seconds.**

But what if the time to intercept is NOT 114.3 seconds, for various reasons? Or what if the velocity of the missile (Vm) is different? Let's change the 'actual' time to 105 seconds.

$t = \frac{Distance}{closing\ velocity}$ or $105 = \frac{73,500}{700}$ **You can see that the distance has changed to**

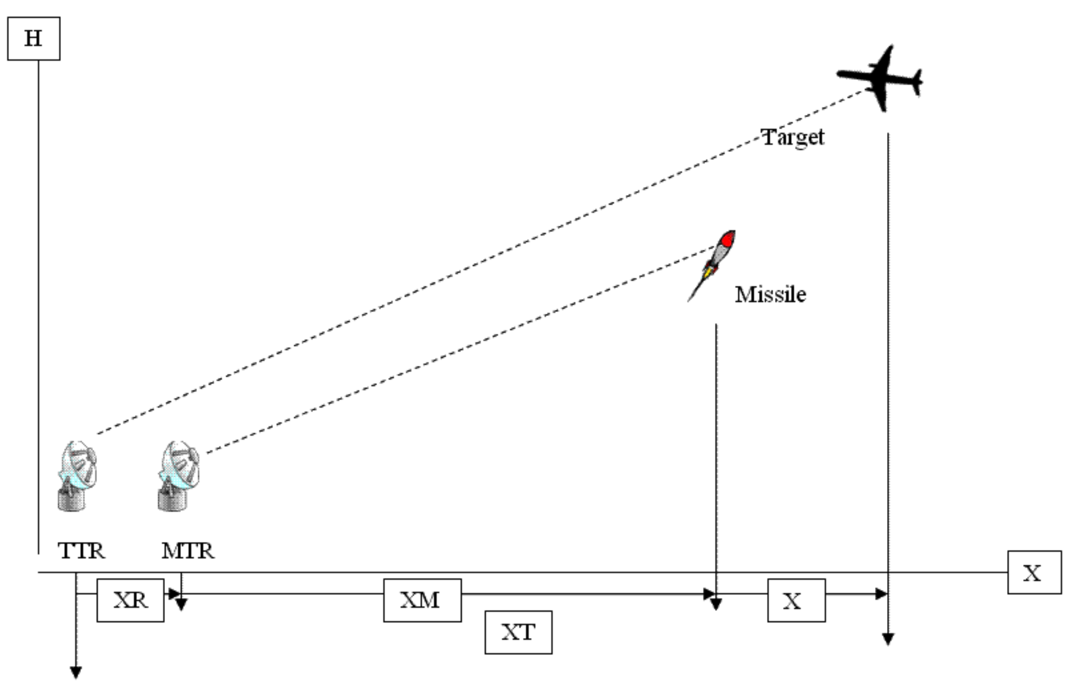
73,500 yards. This is a miss of 4,500 yards. And there would be a similar problem if the velocity was different.

Let's keep considering how the Time-to-Intercept computer helps solve these issues. We know that changes in calculated time will cause an incorrect intercept point, and that velocity is a large contributor to the calculated time to intercept. Therefore, let's consider the Closing Speed Solver.

Closing Speed Solver

Going back to our 'One Dimensional Intercept', remember that, in an optimum flight, the missile would be flying directly at the target. In that case, velocity and time would also be optimum.

We also know that we have the actual position information, in earth coordinates, of the missile (Xm, Ym, Hm) from the MTR, as well as the same for the target (Xt, Yt, Ht) from the TTR. And from this information, we also know the flight distance remaining and velocities. All of this information, as well as the Time-to-Intercept current time solution, and the radar parallax solution, are supplied as inputs to the Closing Speed Solver. To visualize this information, refer to this figure.



TARGET/MISSILE EARTH COORDINATE IN X

Although, due to drawing complexity, the above figure only displays the X axis, if you visualize turning the drawing in a circle, you can see that we also have the coordinate data on all three axis. Further, as this data updates at a rate of 500 times per second, we also have dynamic velocity data on all axis.

In order to solve for Closing speed, the desired quantity X is always measured from the missile to the target, as displayed on the figure above. The simplified equation to solve would be (for X only):

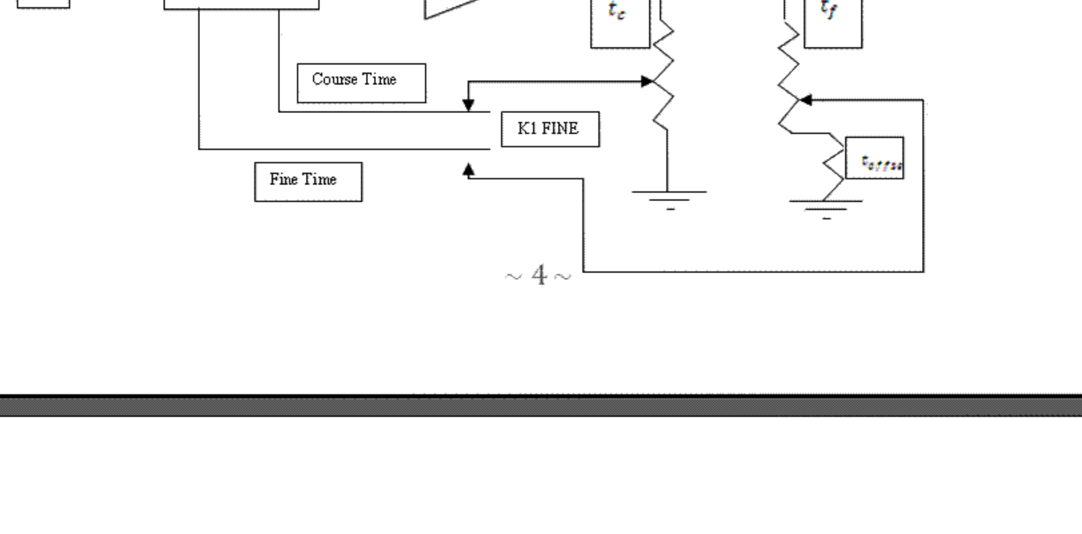
$X = X_T - X_R - X_M$

Here is where the Time-to-Intercept system enters the process. In order to take this real time coordinate data and obtain the ideal closing velocity, the known earth coordinates is divided by the remaining time-to-intercept, as tapped from the time potentiometers. The result of the Closing Speed Solver would be computed as:

$$\frac{X}{t} = \frac{X_T - X_{R-X_M}}{t}$$

And, of course, the inputs of all axis must be solved and factored, as well.

To help understand how the changing earth coordinates of the target and missile are divided by time, following is a schematic figure of the X axis amplifier circuitry.



You will note that there is a resistor, t_{offset} tapped to the fine time resistor. This is placed at the .25 second node and holds the amplifier gain constant from .25 seconds to zero. This prevents the x/t amplifier from overloading as time approaches zero.

Summary

What I hope that I described above is this:

From the coordinates and coordinate changes supplied from the radars, we know the actual closing velocity. Likewise, from the same information, as well as the real earth coordinates, we can calculate (using the time information), what the ideal closing velocity should be. If these outputs do not sum to zero, then there must be a steering error. (It better be, as it is the only factor that we can change)

The output from the Closing Speed Solver is the input to the Steering Error Solver. This sub-system, if the inputs are not zero (On Trajectory), will start the process of sending steering commands to the missile. Course changes will continue until the output of the Closing Speed Solver is zero (On Trajectory).

Mechanical Switches

At the beginning of this document, it was mentioned that there where mechanical components as part of the Time-to-intercept System. One of these was the visual display of mission time. The other was time sensitive switches, cammed to the time potentiometer arm. These switches/relays are:

1) **K79 MISSILE AWAY + 4. This relay is timed to allow for launch, booster seperation and roll stabilization. Steering commands are sent and time starts driving down.**
2) **t = 24 SECONDS. S3 closes. When S3 closes, time feedback changes from course time to fine time. This is discussed above in more detail.**
3) **t = 10 SECONDS. S4 and K2 closes. 1 second order shaping is changed to 2 second order shaping. This is part of the fin order solver circuit.**
4) **t = .25 SECONDS. S7 closes. This closes K35, Burst Enabled.**
5) **t = 0 SECONDS. S8 closes and energizes the ERROR AT BURST relays and the indicated miss distance is indicated on the event recorder. If indicated, the LIMITED TARGET DAMAGE indicator is energized on the BCO Console.**