PART 1

◀ SECTION 3 — AI23D ▶

CHAPTER 7 — APPLICATION

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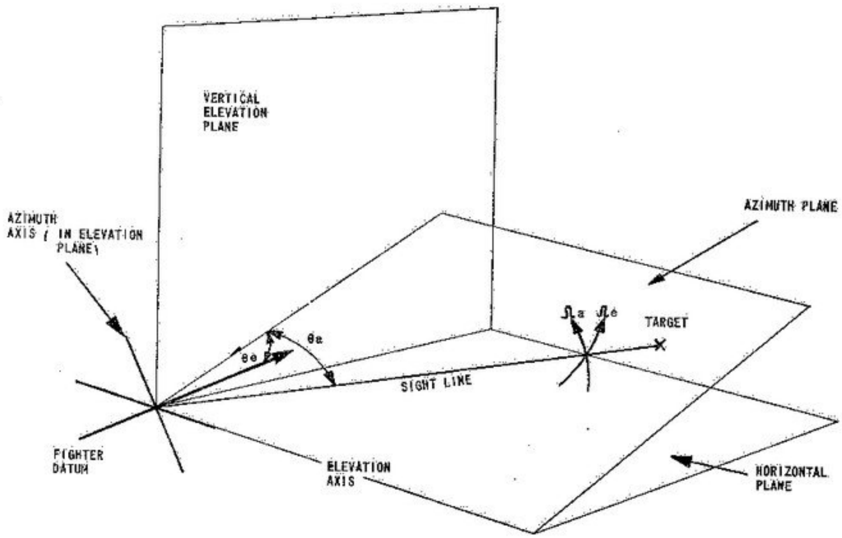
General

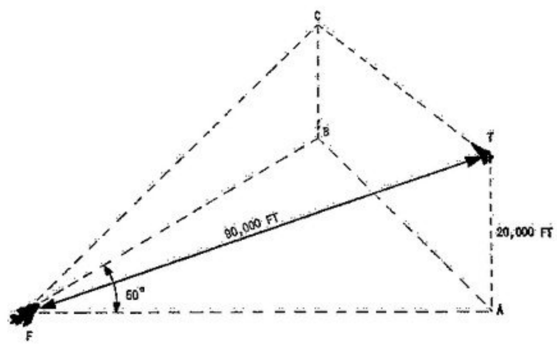
1. Part 1, Section 1, Chapter 1 describes what the radar is required to do, and the previous chapters of this section indicate how the radar does it in mechanical terms. This chapter discusses the link between them and highlights some of the important features.

Azimuth Sighting Error

2. It has been shown how the radar is roll stabilised during search, acquisition and tracking up to the Launch Warning for Red Top, or throughout for Firestreak. This is achieved by maintaining the elevation axis of the scanner horizontal. Since the elevation axis can be considered as the inner gimbal, it is not true to say that the azimuth scan is on a horizontal plane. From Fig 1 it can be seen that azimuth scan is along a plane which is inclined to the horizontal plane whenever there is a finite look angle. Examination of Fig 4 in Chapter 1 of this section also helps to clarify this point.



1—3—7 Fig 1 Radar Reference Axes



1—3—7 Fig 2 Example of Elevation Distortion

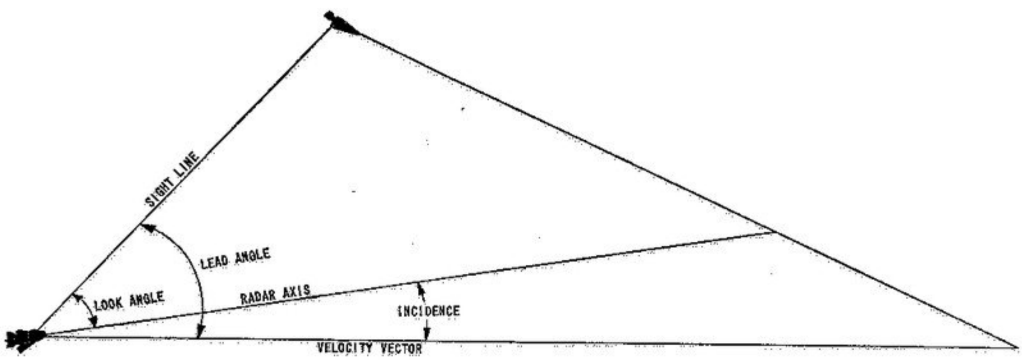
3. The azimuth plane is a plane drawn through the sightline and perpendicular to the elevation plane. With small look angles this is not particularly significant, but at large look angles the inclination of this plane can introduce quite significant differences.

4. Consider, for example, a target 50° off the fighter's nose, at a slant range of 90,000 feet and 20,000 feet above the fighter whose radar axis is horizontal (see Fig 2). The angle of inclination of the sightline from the horizontal (angle AFT in the diagram) is 13°. However, the elevation look angle (angle BFC) is 24·5° and the azimuth look angle (angle CFT) is 47°. The inclination of the azimuth plane is also the reason for the cut-offs in the scan pattern (refer to Fig 4 in Chapter 1 of this section).

5. Additionally the gyros which measure sightline spin are mounted on the scanner and since the scanner is locked to the sightline, the sightline spin measured is not in either the horizontal or vertical plane but is in the azimuth plane and a plane through the sightline perpendicular to the azimuth plane.

Computed Look-Angle Errors

6. The various types of possible approach courses are described in Part 1, Section 1, Chapter 1. These define the *lead* angles required for each type of course as functions of range, range rate and sightline spin. The radar computes the required *look* angle for each course since all measurements are made relative to the airframe. Fig 3 shows that the *lead* angle, which is the angle between the sightline and the direction of motion, differs from look angle, which is the angle between the sightline and the airframe. The difference is due to the incidence of the aircraft. Therefore, the radar uses body axis tracking as opposed to velocity vector tracking. In real terms this means that the aircraft lags behind the required course by the incidence term.



1—3—7 Fig 3 Look and Lead Angles

Elevation Programming

7. The actual approach laws used in the red computer are given in Table 1 of Chapter 6 of this Section. As far as the azimuth laws are concerned, these conform with the set of laws derived in Section 1, Chapter 1. The laws are switched at a point given by the equation

$$R = 29{\cdot}5\dot{R} - 9000 \text{ feet},$$

which is commonly referred to as the 'time-to-go' point ($\frac{R}{\dot{R}} \doteqdot$ time-to-go). This point is also used to switch in the elevation programme if the fighter is below the target. Prior to 'time-to-go', the steering dot is programmed to hold the fighter at a lower altitude than the target, thus conserving manoeuvrability. When the total elevation angle exceeds 16°, the aircraft is directed to fly and maintain a constant 12° look angle.

8. When attacking high speed targets with Red Top, a proportional navigation course with $K = 10$ is flown. This course is limited to a maximum look angle of 25° to avoid exceeding the missile limit of 30° when installed on the aircraft.

9. It has already been explained that at Launch Warning the radar roll axis is locked when carrying Red Top. This is to avoid the various resolutions through roll angle and thereby improve the accuracy of the slaving signals. For this reason also, the laws in both azimuth and elevation (which are now synonymous with aircraft pitch and yaw) are made the same and therefore independent of roll angle.

Interpretation of the Steering Dot

10. Prior to Launch Warning with Red Top, and to firing with Firestreak, courses in azimuth and elevation are computed. Error signals between the required look angle and the actual look angle are now resolved into airframe axes, then smoothed and limited by the gyroscope unit. The displayed signals are now in pitch and yaw terms, ie a steering dot deflection in the aircraft's pitch plane calls for fore and aft stick movement; sideways deflection calls for lateral stick movement.

Gyroscope Errors

11. The gyroscope that is used to smooth and limit ◀the error signals has a sensitivity of 1 second. It▶ therefore backs off any demand by the rate of turn of the fighter. Since both the input and the output of the gyroscope unit have limiters set at 6° it is impossible for demands greater than this to be fed to the display. Thus if the true demand calls for a turn of 10°/second the signal displayed will be 6° and this can be zeroed with a rate of turn of 6°/second. In such circumstances the actual demand will build up. Demanded rates of more than 6°/second are unlikely to be called for except at low speed/low altitude.

PART 1

SECTION 4 — LIGHT FIGHTER SIGHT

CHAPTER 1 — LIGHT FIGHTER SIGHT

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Introduction

1. The light fighter sight (LFS) is a gyro compensated sighting system which presents an aiming mark to the pilot by means of a reflected image.

2. In the GUNS mode, the LFS acts as a gyro prediction sight, where deflection of the sightline is proportional to the rate of turn of the sightline and the sensitivity of the gyro. The sightline is also compensated for gravity drop and for velocity jump.

3. In the guided weapon mode, the gyro is virtually caged and acts as a fixed reflector sight. The sightline in this case is parallel to the missile line, no deflection being applied when sighting.

4. The AI can be used in conjunction with the LFS to provide radar ranging for guns and missile firing.

Components

5. The LFS system consists of a control unit Type L Mk 7, and a sighting head Type 2 Mk 5. ▸◂

6. *Control Unit.* The control unit is in the forward equipment bay; it carries out the following functions:

a. Controls the gyro sensitivity as appropriate for the weapon to be fired.

b. Deflects the gyro as required to position the aiming mark.

c. Provides restraint to the gyro to prevent it toppling.

7. *Sighting Head.* The sighting head is located at eye level directly forward of the pilot (pupil only in the T5). The head contains the gyro controlled sighting system, a reflector, display components and controls, including a brightness control on the underside of the sighting head. The reflector can be folded flat when not in use. The display and controls are as follows and are shown in Fig 1:

a. *Aiming Mark Display.* The aiming mark consists of a 'pipper' inside broken concentric circles of 8·25, 17·5 and 35 mils. Two short lines, projecting radially from both sides of the outer circle, subtend 70 mils at their extremities, and indicate the plane of the aircraft wings. Range is visually assessed by relating the span of the target to the aiming mark. On a target with a wingspan of 23 feet, the circles represent ranges of 920 yards, 460 yards, and 230 yards. In the GW mode, the aiming mark is aligned with the missile boresight. In a GUNS attack, the aiming mark is depressed to give a pegged range of 375 yards. This depression allows for the difference between the gun line and the missile line, and gives fixed gravity drop and velocity jump angle inputs.

b. *Event Markers Display.* Two event markers are displayed on the reflector, below the aiming mark, at the appropriate times. The left hand (A) marker indicates that one or both missiles have acquired the target and appears in response to a signal from the missile pack. The right hand marker (a circular spot of light) appears during radar ranging in response to the 'in range' signal from the AI.

c. *Airspeed Setting Control.* This control is not used, being provided to adjust the sightline in elevation to compensate for the variation in velocity jump angle of rockets which occurs when incidence changes with speed and/or altitude. The control rotates against a HIGH and LOW scale, both graduated from 250 to 500 knots. With speed set against the HIGH scale, the sight is accurate for that speed at 40,000 feet: a speed setting on the LOW scale is accurate at sea level.

d. *Brightness Control.* This controls the brightness of the aiming mark.

e. *Gunsight Caging.* In an LFS GUNS attack, the aiming mark is caged to the existing depression angle whenever the GS CAGE button on the control column is depressed.

System Switching

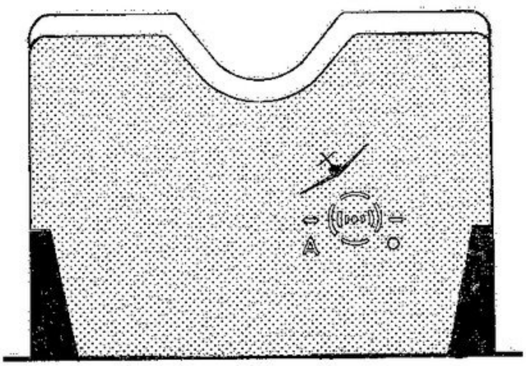
8. The LFS runs up and the display illuminates whenever the MAS is selected away from the OFF position. With CRT selected on the LFS/CRT switch, the LFS runs up into a 'standby' condition; on selection of LFS on the LFS/CRT switch, manual missile firing circuits are made, radar ranging becomes operative, and the acquisition (A) light circuit is activated. ▶◀

Note: To return the AI to the normal search mode after operating the LFS, it is only necessary to select the LFS/CRT switch back to CRT.

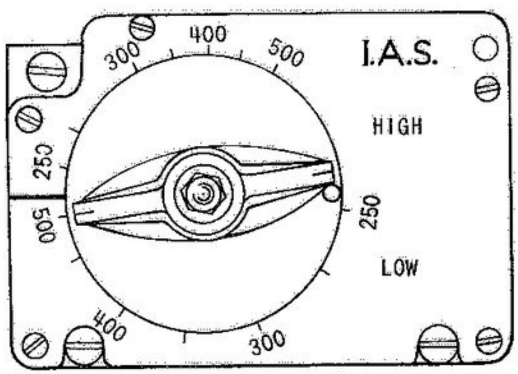
Radar Ranging

9. a. *Missiles.* This facility becomes effective on selection of LFS on the LFS/CRT switch and GW on the MAS. The AI scanner is programmed to the missile boresight and a preset range gate sweeps between 5000 and 10,000 feet at altitudes above 15,000 feet and between 3000 and 6000 feet at altitudes below 15,000 feet. The LFS 'in range' marker lamp illuminates whenever a target is seen within the gate. The AI does not lock on and the lamp remains illuminated for as long as a target remains within the sweep.

b. *Guns.* This facility becomes effective on selection of LFS on the LFS/CRT switch and GUNS on the MAS. The AI scanner is programmed to the guns boresight position 1·9° below the missile boresight. A preset range gate is generated between 1350 feet and 500 feet in range. The LFS 'in range' marker lamp illuminates whenever a target is seen within this gate.



DISPLAY



AIRSPEED SETTING CONTROL AND SCALES

1—4—1 Fig 1 LFS Sighting Head Display and Controls

LFS Limitations

10. The limitations in the use of the system are as follows:

a. The gyro is fully run up within one minute of switching on.

b. In a GUNS attack, the maximum deflection of the sightline is 12° from its central position. If 12° is exceeded, the anti-topple circuit is energised and the gyro returns to its central position.

Principles of Operation

11. The LFS operates as a lead computing gyro sight in accordance with the principles of operation described fully in AP 112E-0310-1A, Section 1. The sight head is depicted in Fig 2 and the gyro in Fig 3. The following explanation of LFS operation may be better understood by reference to AP 112E-0309-1. Note that the temperature and azimuth coils in Fig 3 are not used in this application.

12. In the GW mode the sensitivity coil voltage is adjusted to provide a sensitivity of 0·25 secs, and no voltage is applied to the elevation coils. In effect the LFS provides a pure pursuit aiming index.

13. In the GUNS mode the voltage applied to the sensitivity coil is adjusted to give a sensitivity which is determined to approximate to fixed firing parameters corresponding with a range of 375 yards.

14. In any GUNS attack the sightline must be corrected for the following variables:

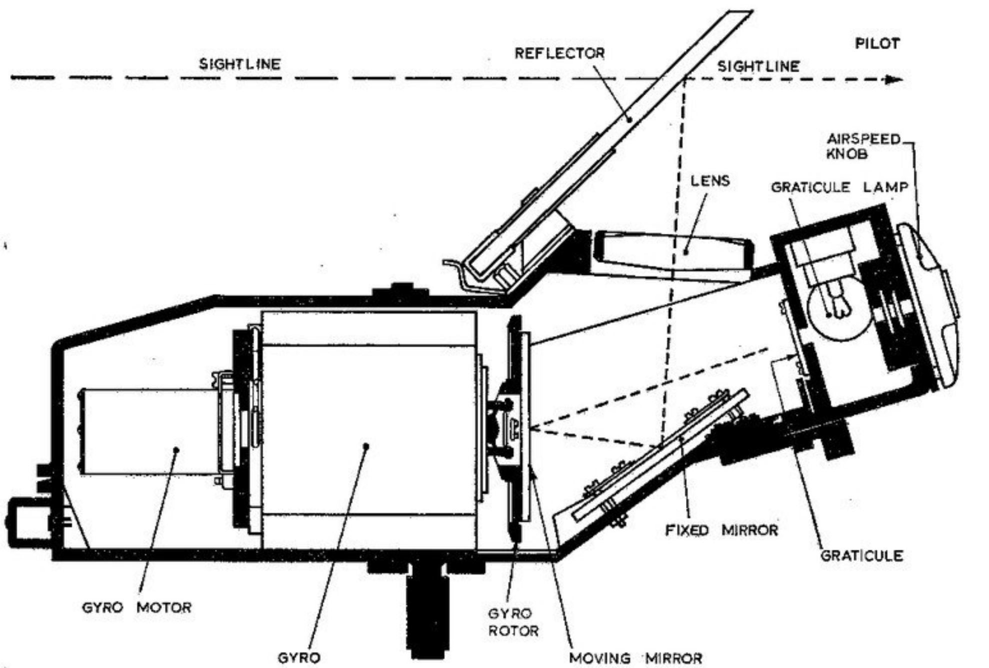
a. Target motion.

b. Gravity drop.

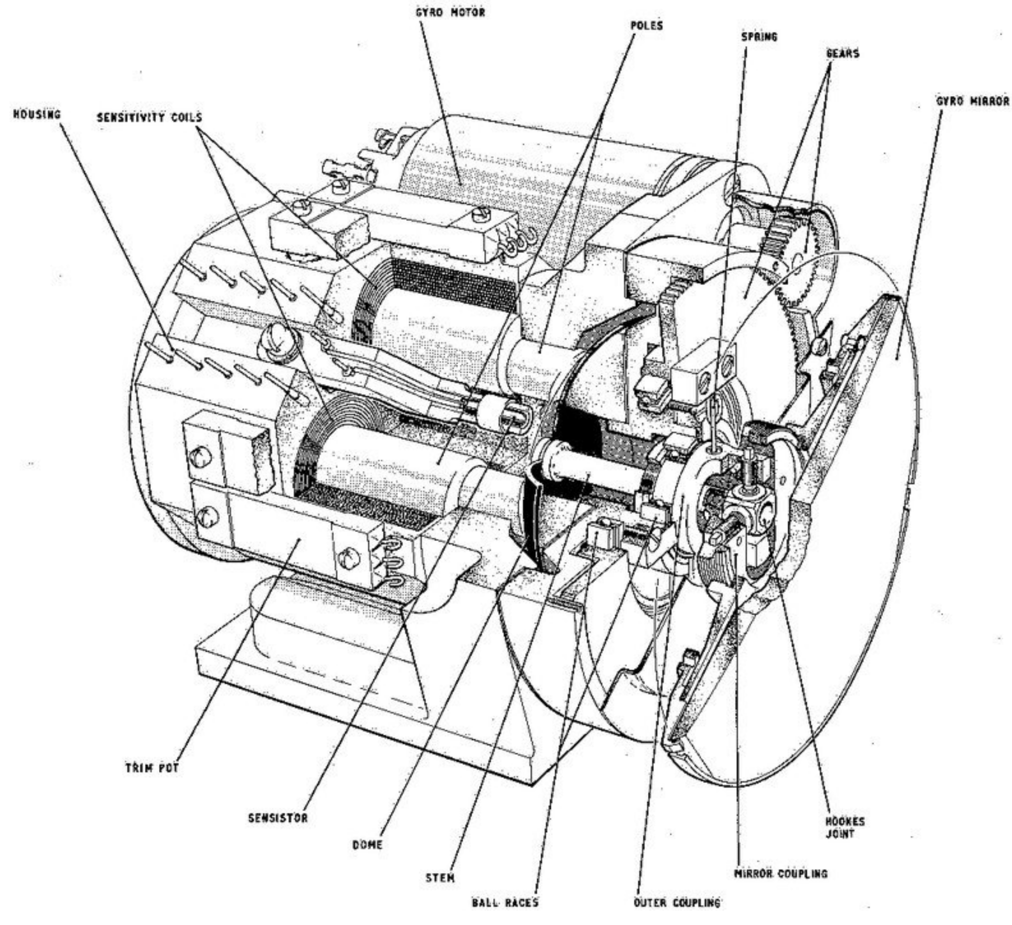
c. Velocity jump.

15. *Target Motion.* Lead for target motion is required to aim the guns ahead of the target at a position in space corresponding to the predicted target position at bullet impact. The angular correction for this factor is normally the largest sightline correction and is determined by the following formula:

$$\frac{\text{Target crossing speed} \times \text{Bullet time of flight}}{\text{Range}}$$



1—4—1 Fig 2 LFS Sighting Head



1–4–1 Fig 3 LFS Gyro – Typical

Target crossing speed is sensed by the rate of turn required to track the target, which is in effect the rate of precession of the gyro. A fixed voltage is applied to the sensitivity coils to equate to a range of 375 yards. The following parameters are fixed (known values in brackets):

a. Range (375 yards).

b. Closing speed.

c. Firing airspeed (IAS) (350 knots).

d. Firing altitude (5,000 feet).

Note: The sensitivity coil voltage may be adjusted at first line servicing.

16. *Gravity Drop*. In a GUNS attack the vertical drop of the bullets due to the effect of gravity is expressed as $32{\cdot}2 \times$ bullet time of flight. In the LFS a fixed voltage is applied to the elevation coils to provide the required vertical shift of the sightline to compensate for this factor. However, the elevation coils are positioned in a plane perpendicular to the plane of the aircraft wings, which results in an error when firing with bank applied.

17. *Velocity Jump*. Any angular difference between the muzzle velocity vector and the velocity vector of the aircraft will result in the bullets following the resultant of the two vectors. At low angles of attack this factor is not normally large; however, at high aircraft angles of attack this factor is significant and must be allowed for in the sighting solution. The plane of correction is perpendicular to the plane of the aircraft wings and is therefore in the same plane as the corrections provided by the elevation coils. The fixed voltage applied to the elevation coils may therefore provide a fixed correction for velocity jump; however, it is not possible to compensate for variations in g loading by this method. It should be noted that the deflection provided by the elevation coils is proportional to the restraining effect provided by the sensitivity coil, thus any applied correction for velocity jump will be valid only at fixed values of the following parameters (known values in brackets):

a. Angle of attack.

b. Firing airspeed (TAS) (375 knots).

c. Range (375 yards).

18. *Parallax*. A further fixed sightline correction is required to compensate for the vertical displacement of the sight head from the gun barrels. The numerical value of this correction is small and is applied by the elevation coils.

Bulb Changing

19. Access to the LFS bulb is by raising the hinged upper cover of the sight head to which the bulb is attached. The cover is raised by applying upward pressure at the projecting screw which is positioned above the HIGH – 300 knots mark.

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