PART 1

◀ SECTION 3 — AI23D ▶

CHAPTER 6 — COMPUTERS

Contents

General

1. The two computers (computer red and external computer) are part of the AI system and can be considered together. They are analogue computers and form part of the complete steering system shown in Fig 1. The inputs and outputs of the computers are shown in Fig 2.

2. The purposes of the computers are:

a. To provide steering information to enable the pilot to fly the correct course.

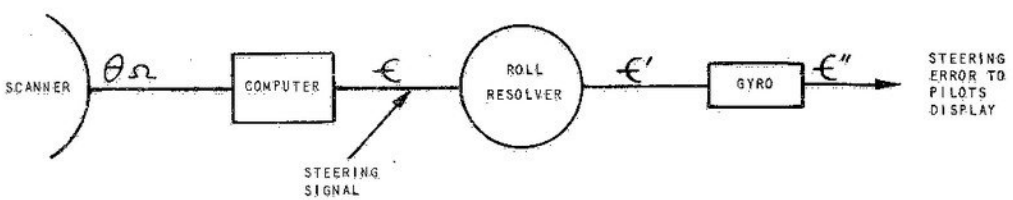
b. To provide information to the weapons to enable them to fire at the appropriate time to hit the target.

c. To provide weapon slaving.

d. To provide the Red Top weapon pack with K-factor, altitude gain and fuzing information.

Steering

3. From the scanner misalignment signals, the angle between the sightline and radar roll axis is determined in azimuth and elevation. The sightline rates are determined from rate gyros on the scanner and these are used to compute the appropriate steering signal (course equation) as shown in Tables 1 and 3. The purpose of the roll resolver is to resolve these steering signals in azimuth and elevation (space axes) to the aircraft axes of yaw and pitch. The steering signals are then backed-off by aircraft rates in the gyro to give steering error which is used to deflect the steering dot on the pilot's display.



1—3—6 Fig 1 Steering System

Events

4. The events computed serve two distinct purposes. Some of them automatically change the approach course being computed in the computer red, eg 'time-to-go' and Launch Warning. Others are used to initiate and control the missile firing sequence. The event equations are given in Table 2.

5. The range and range rate used in these equations are obtained from two sources, namely the ranging unit long for the 'time-to-go' event and the ranging unit short for the others. The ranging unit long operates from 80 NM inwards and the ranging unit short from 80,000 feet inwards.

6. Indication of events b and c below is given on the B-scope by two reductions in the diameter of the time circle; the first reduction to $\frac{2}{3}$ and the second reduction to $\frac{1}{3}$ its normal diameter. Breakaway is indicated on the display by a large cross appearing in place of the time circle and steering dot.

a. The 'time-to-go' signal changes the approach course and, for COMPUTER switch positions 1, 2, or 3, changes the scaling of the gyroscope from unity to 0·5.

b. At the first reduction in diameter of the time circle:

(1) *Red Top.* Launch Warning is issued, the approach course changes, roll axis lock occurs, and the missile head starts to scan.

(2) *Firestreak.* Launch Warning and Fire Signal are issued simultaneously (ie Range Outer), and the approach course changes.

c. At the second reduction in diameter of the time circle:

(1) *Red Top.* Fire Signal is issued 2 seconds after Launch Warning; this is the automatic firing point (ie the outer range bracket).

(2) *Firestreak.* This is the last chance to fire and occurs 2 seconds before Range Inner (ie breakaway).

d. Breakaway occurs at:

(1) *Red Top.* The inner range bracket or 'too few seconds' to collision of Red Top.

(2) *Firestreak.* Range Inner.

Weapon Information

7. Slaving and other information is supplied to the missiles as follows:

a. *Firestreak.* The slaving signals are the same as those used to position the steering dot so that the missile eye is aligned with it, but only up to 5° max (max steering dot deflection = 6°).

b. *Red Top.* The Red Top slaving signals are of the form $\epsilon = \theta + \frac{1}{16}\Omega$ and are given in aircraft axes. The term $\frac{1}{16}\Omega$ is introduced to overcome the lag in the missile head at high sightline rates. Additionally, the following information is given to Red Top by the radar:

(1) Closing speed for the determination of the K-factor to be used.

(2) Altitude gain control to allow for the different aerodynamic characteristics of the missile at different altitudes; this adjusts the sensitivity of the control system.

(3) The approach angle to the target, to inform the missile whether it is approaching from the front or rear; this information is required for fuzing purposes. The front is defined as a cone of semi-angle 70° from the front of the target.

Notations, Suffixes and Abbreviations

8. a. *Notations.*

ϵ = Steering signal

E = Scanner elevation relative to the horizontal

θ = Scanner angle

Ω = Sightline rate

$\dot{h}$ = Rate of change of height

K = Constant (values given in Table 3)

R = Range

$\dot{R}$ = Range rate

V = Aircraft speed

P/P_o = Static pressure ratio

γ = Pitch angle from MRG

b. *Suffixes.*

$_{az}$ = Azimuth

$_{el}$ = Elevation

$_{l}$ = Long

$_{s}$ = Short

c. *Abbreviations.*

PNK: Proportional navigation using a K-factor. The number following the abbreviation denotes the value of K.

QLP: Quasi lead pursuit course. The number following the abbreviation denotes the prediction time in seconds.

PP: Pure pursuit course.

Table 1 — Course Equations

	Course	*Azimuth*	*Elevation*
1	Pure pursuit	$\epsilon_{az} = \theta_{az}$	$\epsilon_{el} = \theta_{el}$
2	Quasi Lead Pursuit		
	a. Switch position 2 and 3	$\epsilon_{az} = \theta_{az} + 12\Omega_{az}$	$\epsilon_{el} = \theta_{el} + 12\Omega_{el}$
	b. Switch position 4, 5 and 6 ...	Prop nav in azimuth	$\epsilon_{el} = \theta_{el} + 10\Omega_{el}$
3	Proportional Navigation		
	a. Switch position 4, 5 and 6, prior to Launch Warning.	$\epsilon_{az} = 10\Omega_{az}$	Quasi lead in elevation
	b. Switch position 4, 5 and 6, after Launch Warning.	$\epsilon_{az} = 1 \times \Omega_{az}$	$\epsilon_{el} = 1 \times \Omega_{el}$
4	Hold Down (Fly level)		$\epsilon_{el} = -0{\cdot}01h$
5	Constant Angle (E-servo)		$E = \theta_{el} + \gamma + 2°$
	a. If $E > 16°$		$\epsilon_{el} = \theta_{el} - 12°$
	b. If $E < -2°$ (fighter above target)		See Table 3
6	Look Angle Limit (Ramp function)		
	If $\theta_{az} > +25°$ or $< -25°$	$\epsilon_{az} = K\Omega_{az} - 2{\cdot}3 \begin{cases} +\theta_{az} & -25° \\ -\theta_{az} & +25° \end{cases}$	

Note: The following sign convention is used:

a. Scanner angles up and to the right are positive.

b. Sightline rates driving up and to the right, ie to increase scanner angle, are positive.

Table 2 — Events

These are the Dynamic Equations

1	Time-to-go	$R_t = 9000 - 29{\cdot}5\,\dot{R}_t$
2	Firestreak Range Brackets:	
	a. Range Outer (Launch Warning and Fire Signal simultaneously)	$R_s = 12{,}600 - 7800\,P/P_o - 8{\cdot}72\,\dot{R}_s$
	b. Last chance to fire	$R_s = 5000 - 1700\,P/P_o - 5{\cdot}85\,\dot{R}_s$
	c. Breakaway (Range Inner)	$R_s = 5000 - 1700\,P/P_o - 3{\cdot}85\,\dot{R}_s$
3	Red Top	
	a. Weapon Information:	
	(1) K-factor	$8{\cdot}2 - \dfrac{3{\cdot}8\,\dot{R}_s}{2500}$
	(2) Altitude gain control (AGC)	$14{\cdot}7\,P/P_o$
	(3) Angle forecast	$\cos^{-1}\dfrac{\dot{R}_s + V}{1200}$
	b. Range Brackets:	
	(1) Launch warning (2) Fire signal (outer range bracket) (3) Breakaway (inner range bracket) — Modes 2 and 3 (below 27,000 ft)	$R_s = 9500 - 5200\,P/P_o - 5{\cdot}75\,\dot{R}_s$ $R_s = 9500 - 5200\,P/P_o - 3{\cdot}75\,\dot{R}_s$ $R_s = 1600 - 5.7\,\dot{R}_s$
	(4) Launch warning (5) Fire signal (outer range bracket) (6) Breakaway (inner range bracket) — Modes 4, 5 and 6 (all altitudes) and modes 2 and 3 (above 27,000 ft)	$R_s = 10{,}000 - 13\,\dot{R}_s$ $R_s = 10{,}000 - 11\,\dot{R}_s$ $R_s = 5500 - 6\,\dot{R}_s$

Note 1: In the above equations, the sign of $\dot{R}$ must be borne in mind, ie if it is a closing rate $\dot{R}$ is considered to be negative.

Note 2: The range bracket equations above are represented in graph form in Part 1, Sect 8, Chap 1 and 2.

Table 3 — AI23D Approach Courses (GW)

Target Speed Switch (COMPUTER mode switch)	*Fighter Above or Below Target*	*Azimuth or Elevation*	*Initial Approach*	*Steering Signals*		*Gyro Sensitivity*
				After Time-to-go	*After Launch Warning*	
Switch position 4, 5 and 6 1·35M 1·6M 1·9M RED TOP	—	Azimuth	PNK = 10	PNK = 10	PNK = 1	1 sec
	Below	Elevation	$h \rightarrow 12$	QLP + 10	PNK = 1	
	Above	Elevation	QLP + 10	QLP + 10	PNK = 1	
Switch position 3 1·1M RED TOP	—	Azimuth	QLP + 12	QLP + 12	QLP + 12	0·5 sec
	Below	Elevation	$h \rightarrow 12$	QLP + 12	QLP + 12	
	Above	Elevation	QLP + 12	QLP + 12	QLP + 12	
Switch position 2 0·9M RED TOP	—	Azimuth	PP	QLP + 12	QLP + 12	0·5 sec
	Below	Elevation	$h \rightarrow 12$	QLP + 12	QLP + 12	
	Above	Elevation	PP	QLP + 12	QLP + 12	
Switch position 1 0·7M FIRESTREAK	—	Azimuth	PP	PP	PP	0·5 sec
	Below	Elevation	$h \rightarrow 12$	PP	PP	
	Above	Elevation	PP	PP	PP	

Note 1: In all Red Top cases there is an Azimuth Look Angle limit of 25°.

Note 2: If Launch Warning is reached prior to 'time-to-go', the computer is switched to the *After Launch Warning* course.

Note 3: In Proportional Navigation when $K = 10$, azimuth sightline rate is limited to 0·75°/sec.

Note 4: If, before time-to-go, the scanner elevation to the horizontal reaches 16°, the computer demands a constant angle $\theta E = 12°$. These cases are shown by the symbol $h \rightarrow 12$.

Note 5: During kinematic ranging Red Top fast, the constant angle phase is inhibited.

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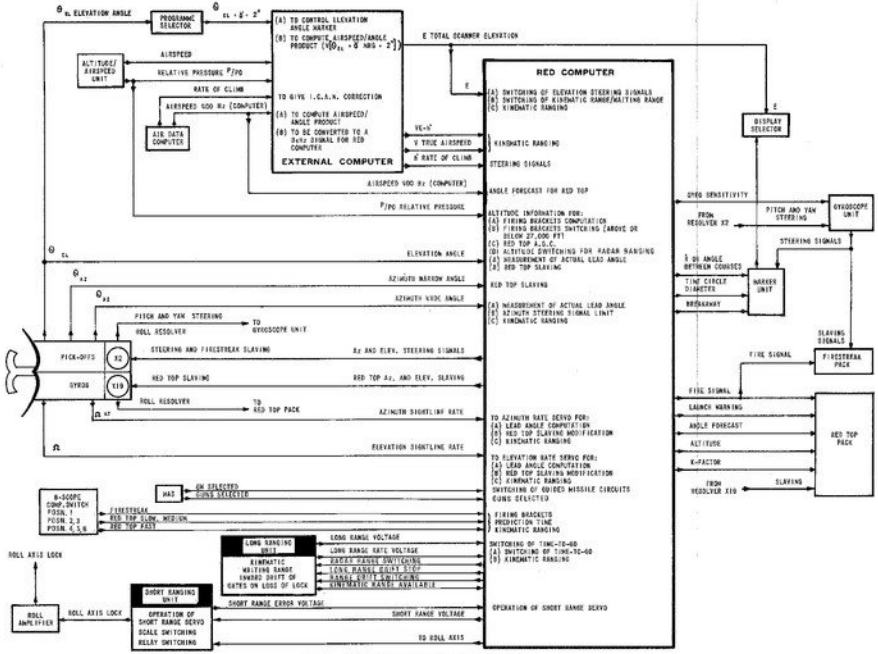

1 – 3 – 6 Fig 2 Computers – Inputs and Outputs

{New Facility Updating}

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