MARCONI-ELLIOTT
AVIONICS

Navigation and Attack System Options

jaguar
INTERNATIONAL

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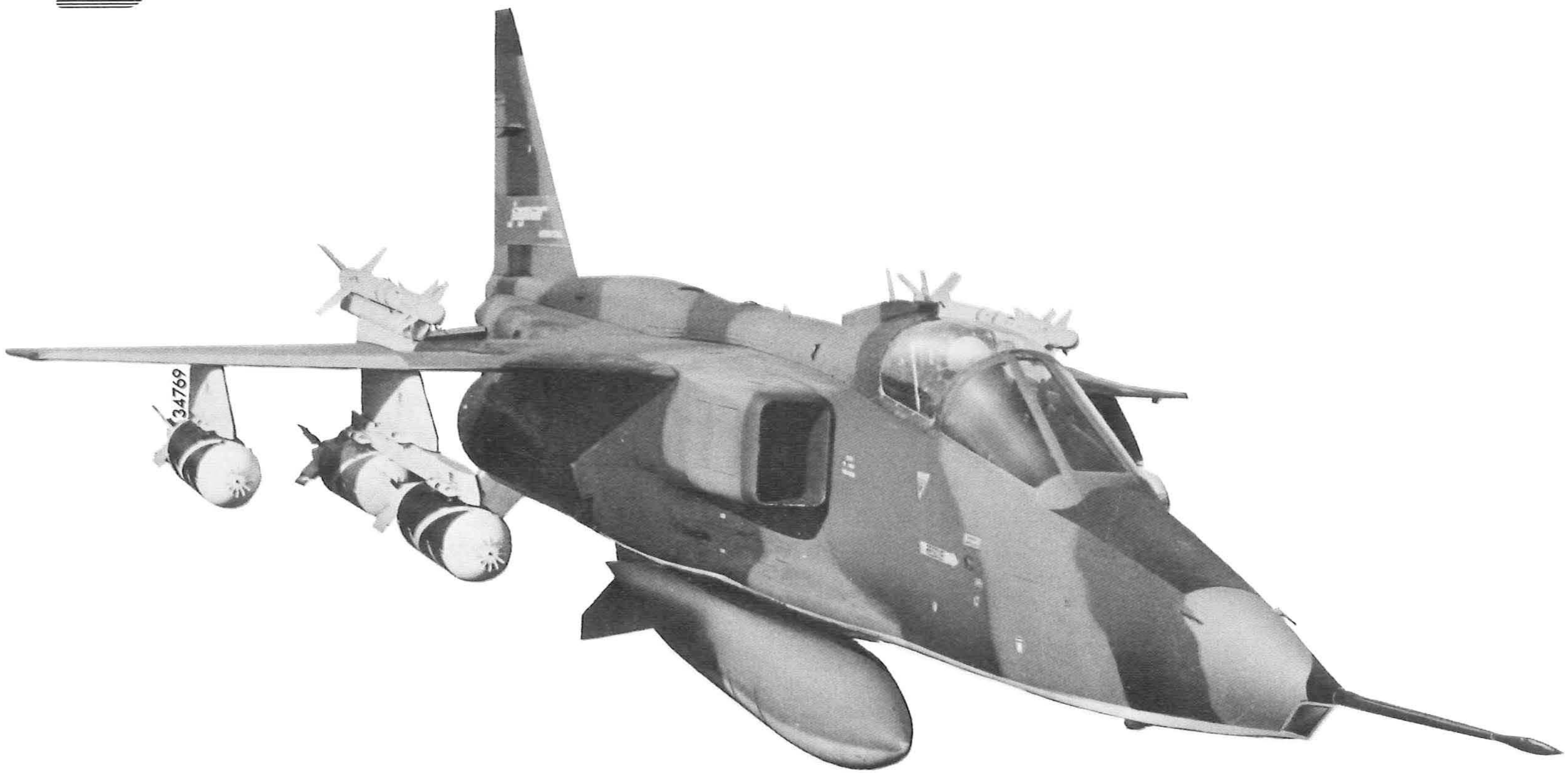
JAGUAR INTERNATIONAL



Manufactured jointly by BRITISH AIRCRAFT CORPORATION and AVIONS MARCEL DASSAULT BREUGET AVIATION

THE VERDICT OF THE USER

"The object is to put the bomb on the target
and JAGUAR does this better than anything else we have . . ."

Our Capabilities

MARCONI
ELLIOTT
AVIONICS

Avionic Systems

Instrumentation
Air Data Computers
Low Airspeed Sensors
Engine Instruments
Fuel Quantity Gauging
Fuel Mass Flowmeters
Gyros
Accelerometers

Flight Control
Stability Augmentation
Autopilots/Flight Directors/
Autothrottles
Automatic Landing
Fly-by-Wire Systems
Quadruplex Actuators

Airborne Computing
Task-Orientated Computers
Central Processors
FFT Frequency Analysers
MTI Cancellers

Navigation
Air Data Systems
VOR/ILS and DME
TACAN
Doppler Systems
Inertial Systems
Automatic Direction Finders
OMEGA
Radio Map
Naval Compass Stabiliser

Airborne Communication
HF & VHF Systems
Tactical Systems
Selective Calling (SELCAL)
Communication Control
Antenna Couplers
Data Link Systems

Maritime Aircraft Systems
Sonics Data Processing
Tactical Navigation

Displays
Electronic Head-Up Displays
Electronic Head-Down Displays
Multi-Mode & TV Tabular
Situation Displays
Projected Map Displays
Digital Scan Converters

Airborne Radar
Airborne Interception
Airborne Early Warning
Mapping
Terrain Following
Maritime Radar

Weapon Systems
Digital Head-Up Display Weapon
Aiming System
Digital Inertial Navigation &
Attack Systems
Stores Management
TV Weapon Control

Electro-Optical Systems
Low-light Television
Closed-Circuit Television
TV Missile Guidance, Gathering
& Tracking
Command & Video Data Links
Simulators & Trainers

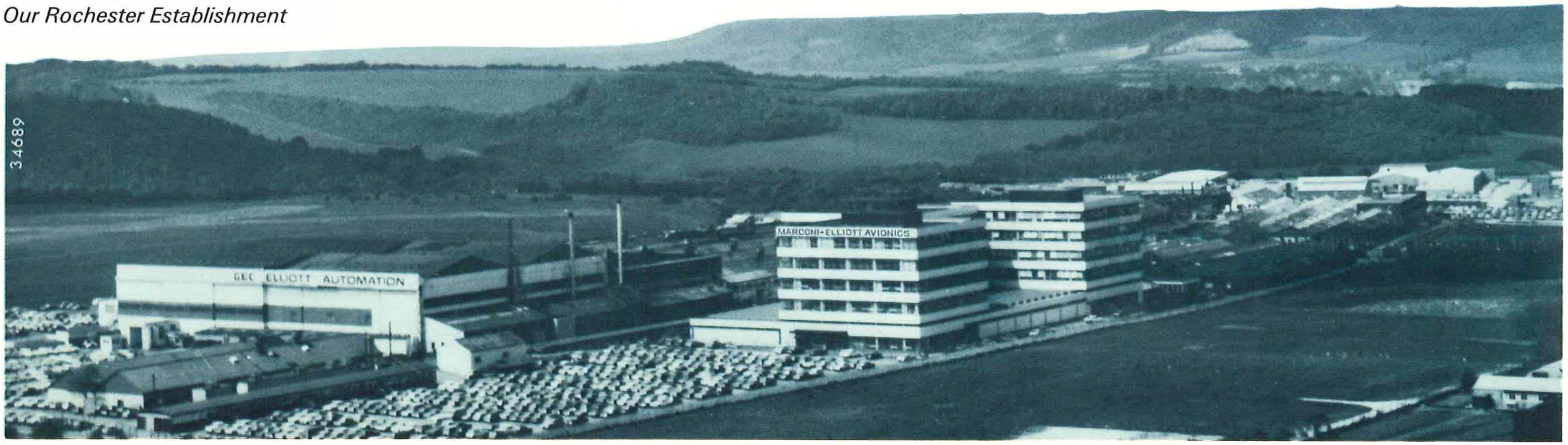
Powerplant Control
Digital Engine Control
Fuel Management
Range/Endurance Computing
Engine Intake Control
Nozzle Control

Automatic Testing
Computer-controlled Testing
Equipment

THE QUEEN'S AWARD TO INDUSTRY
1968 1969 1970 1971 1975

Establishments Basildon—Borehamwood—Rochester. A GEC-Marconi Electronics company.

Our Rochester Establishment



Contents

Synopsis

The increasing deployment of both simple and sophisticated anti-aircraft weapon aiming systems, in both mobile and fixed based Army Units, poses an increasing threat to the successful operation of strike and ground attack aircraft against defended targets. This problem has long been recognized with regard to the European air war scenario and extensive studies, carried out by a number of defence research organisations, have indicated the greatly reduced vulnerability of aircraft flying at high speed and low level in the presence of dense anti-aircraft defences.

From the air force commander and operational pilot's view points however, low level operations whilst conferring a much lower vulnerability to ground defence, pose increasingly difficult problems in relation to navigation and weapon aiming. All experience of air warfare shows that the lowest losses are sustained by the attacking force when the element of surprise is greatest. This maxim implies very strongly, that attacking aircraft must be able to hit their target accurately on their first pass, since the execution of second and third pass attacks against alerted defence units almost certainly proves expensive in aircraft losses. This has been evident in all air warfare conflicts since 1914.

In turn, the requirement for first pass low level attack imposes stringent demands on the accuracy of navigation and weapon aiming by the pilots of the attacking aircraft. When these accuracy requirements are superimposed upon the high pilot work load associated with the basic control of the aircraft in high speed low level flying, it becomes increasingly difficult to achieve the maximum accuracy and operational effectiveness without some form of assistance

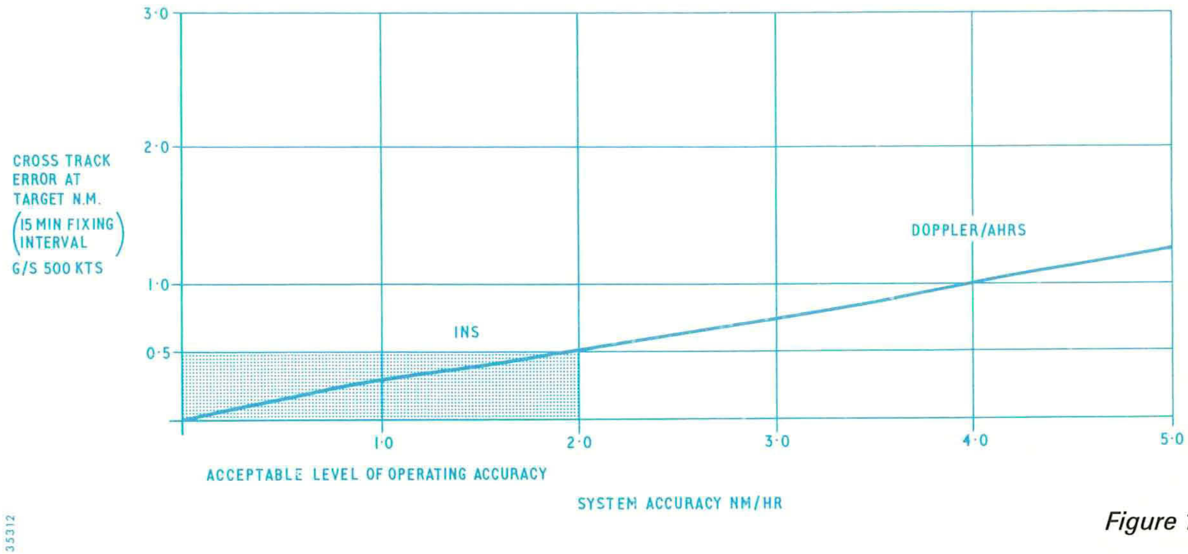


Figure 1

from an automated navigation and weapon aiming system.

The B.A.C. Jaguar aircraft, with the associated Marconi-Elliott Avionic Systems Navigation and Weapon Aiming Sub-System (NAV/WASS), was designed from the outset to provide a totally integrated aircraft and navigation attack system which was optimised around the accurate navigation and low level delivery of bombs against targets in such critical operational conditions.

The four major NAV/WASS displays (Head Up Display, Projected Map Display, Navigation Control Unit and Horizontal Situation Indicator) have been designed as an integrated part of the cockpit layout. They provide the pilot with the optimum conversion of display information to enable him to navigate to the target with minimum cross track error (better than ½ mile) and to identify and bomb the target, using an automatic release point, with the highest degree of accuracy on his first pass run.

Figure 1 indicates the achieved operational accuracy of various types of automatic navigation systems, together with the required cross track accuracy necessary to achieve the visual target recognition and identification in the altitude/speed band of low level operations. Only inertial navigation systems have the requisite navigation accuracy, without excessive in-flight fixing routines with their significant increased cockpit load, to achieve the necessary navigation accuracy to allow first pass attacks. Alternatively, it can be shown that when using aircraft with higher accuracy navigation systems the number of aircraft required to achieve target destruction on the first pass is substantially decreased.

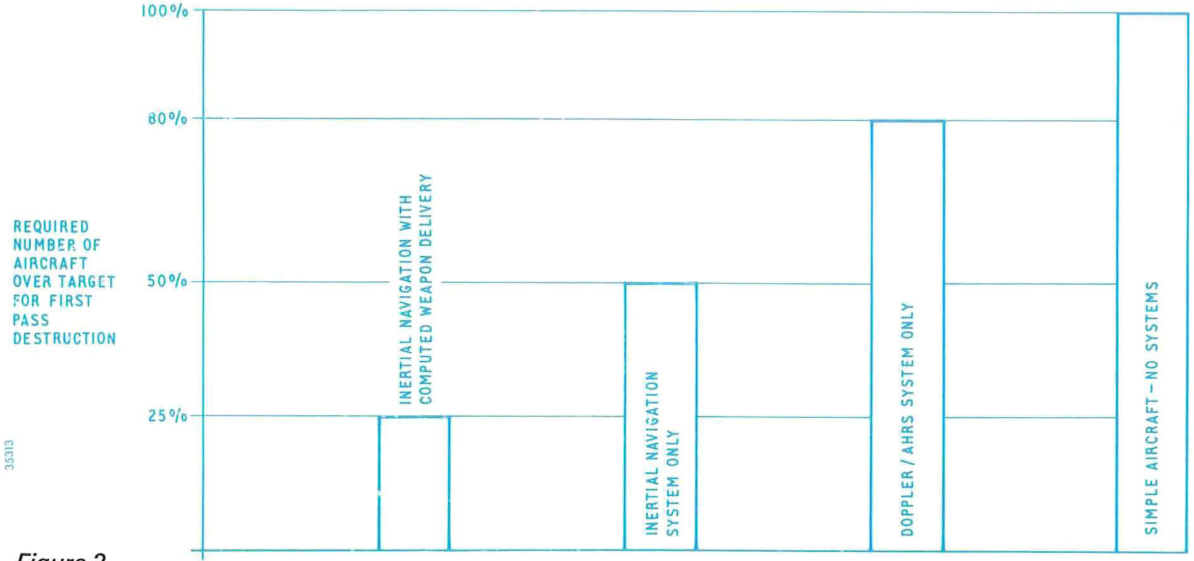


Figure 2

The required number of aircraft over the target is still further decreased when account is taken of the increased aiming precision of automatically aided weapon delivery, as opposed to the manual pilot judgment. When account is taken of the navigation accuracy of the Jaguar inertial navigation system and the increased accuracy of weapon aiming/delivery, particularly under pilot combat stress conditions, it can be readily shown that the number of Jaguar aircraft required for target destruction on the first strike is reduced by a factor of three or four in comparison with aircraft which are not equipped with an optimised low altitude weapon delivery/navigation system. (Fig. 2). The development of any system of this type against so demanding a requirement and its subsequent introduction into RAF squadron service has necessarily required an extensive programme of equipment development, test and operational trials.

It is worth commenting that the development of any other system and its associated integration into an aircraft will require a similarly extensive and equivalent development programme aimed at optimising the inter-relationship between the aircraft and the associated avionic system. At this time the Jaguar is the only NATO strike aircraft in squadron service in which there has been this intimate and far reaching relationship between the development of the aircraft and its associated navigation/attack system starting at the very beginning of the aircraft design. Indeed, only one other aircraft, namely the LTV A7 D & E, can boast of a similar integrated weapon aiming capability which was in fact introduced after the basic aircraft type had been established in production. No other contemporary or competitive aircraft either incorporates, or is able to incorporate, the unique features of the Jaguar integrated display system and its associated weapon delivery sensors without significant modification and development trials programme.

The first part of this brochure describes the operation of the existing Marconi-Elliott Avionic Systems navigation weapon aiming system, as supplied for the Jaguar aircraft and now in operational service in the R.A.F.

In its initial form the system was designed to be completely self contained permitting accurate low level attacks by guns, bombs and rockets up to 500 miles radius from base in visual daylight conditions and visibilities of the order of 1½ miles.

The original requirements for which the Jaguar system was developed, namely long and short range strike at high speed low level, remains unchanged. However, the rapid development of the ability for night movement and night action by World armies is placing an increasing premium on the ability of strike aircraft to operate as effectively under night and all weather conditions as they currently do under daylight conditions.

The object of the second part of this brochure is to describe the various options by which the existing Jaguar NAV/WASS system may be extended to allow the effective operation at low level and high speed under night conditions.

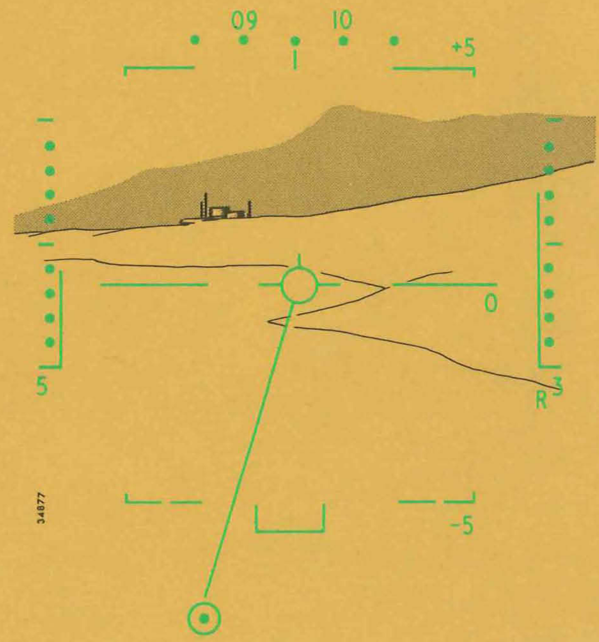
It is important to stress that the various additional or replacement sub-systems are not interdependent upon one another. That is to say, each sub-system may be changed or added as an individual option, depending on the customer air force, without requiring the incorporation of all of the other modifications. Inclusion of all of the other modifications outlined here would result in an aircraft with an operational capability very much in advance of aircraft currently planned for use in NATO airforces.

Abbreviations

AA	Air to Air
ADAM	Clearance Altitude Director and Monitor System
ADC	Air Data Computer
AHRS	Attitude & Heading Reference System
ARU	Acceleration and Rate Unit
ASV	Air to Surface Vessel
ATC	Advanced Technology Computer
ATR	Aircraft Technical Racking
BITE	Built in Test
CCD	Charge Coupled Device
CCIP	Continuously Computed Impact Point
CCRP	Continuously Computed Release Point
CCU	Camera Control Unit
DCU	Display and Control Unit
DR	Dead Reckoning
EU	Electronic Unit
FLIR	Forward Looking Infra Red
GP	General Purpose
GW	Guided Weapon
HC	Hand Controller
HF	High Frequency
HSI	Horizontal Situation Indicator
HT	High Tension
HUD	Head-Up Display
IAS	Indicated Air Speed
IFF	Identification Friend or Foe
IFU	Interface Unit
ILS	Instrument Landing System
IN	Inertial Navigation
IP	Initial Point
JB	Junction Box
K	1,000
LED	Light Emitting Diode
LLTV	Low Light Television
LRMTS	Laser Ranging Marked Target System
LRU	Line Replaceable Unit
LSI	Large Scale Integration (Circuits)
MEASL	Marconi-Elliott Avionic Systems Limited
MRCA	Multi Role Combat Aircraft
MSI	Medium Scale Integration (Circuits)
NAV/WASS	Navigation and Weapon Aiming Sub-system
NCU	Navigation Control Unit
NE	Northings and Eastings (Offset)
PDU	Pilot's Display Unit
PEU	Platform Electronics Unit
PLAND	Planned Attack Mode
PLF	Precise Local Fix
PMD	Projected Map Display
PSM	Power Supply Module
PSU	Power Supply Unit
RA	Radio Altimeter
SAM	Surface to Air Missile
SIT	Silicon Intensifier Target
TAS	True Air Speed
TR	Transmitter Receiver
Tgt Opp	Target of Opportunity
UHF	Ultra High Frequency
USMC	United States Marine Corps
VCU	Video Combiner Unit
VSI	Vertical Speed Indicator
VSU	Video Signals Unit
WAMS	Weapon Aiming Mode Selector
WPT	Waypoint (Turning Point)

PART 1

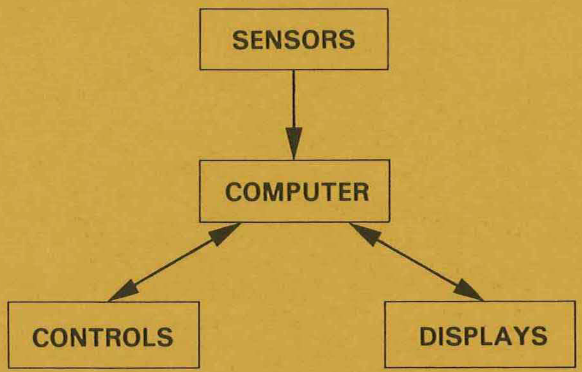
A System Description



Navigation Attack System

The Marconi-Elliott Avionics NAV/WASS has been designed to meet the aircraft mission requirements in the most effective and reliable way possible. Careful selection of equipment requiring minimum development, together with planned system integration have produced in the Jaguar aircraft, Europe's most comprehensive navigation and weapon system.

Description of System
The Navigation and weapon aiming sub-system comprises four principle groups of equipment. The sensors, which measure what the aircraft is doing and feed these measurements into the computer; the computer sub-system which processes this measured information into a form which can be used by the pilot; the cockpit controls which control the system's mode of operation and lastly, the cockpit displays which show to the pilot the computer's outputs of converted measurement information and also information, such as target or waypoint position, which is being input into the computer.



Inertial Velocity System

E3R Inertial Platform
The basic sensor is the E3R Inertial Platform, a fully manoeuvrable four gimbal, pure inertial platform which uses three single degree of freedom gyroscopes and three accelerometers. Information on aircraft acceleration heading and velocity is passed via the Platform Electronic Unit and Interface Unit to the digital Computer.

Platform Electronics Unit
The Platform Electronics Unit is a hybrid computer which processes the signals from the E3R and provides outputs of velocity and attitude. In addition, it monitors the correct operation of the E3R and its power supplies as well as controlling the automatic erection sequence and selection of reversionary modes.

Power Supply Unit
Accepting raw aircraft power, the Power Supply Unit generates all the stabilised supplies and precision frequencies required by the inertial system.

Central Computing System

920M Computer
The central computer for the NAV/WASS is the 920M, an 8192 word store machine which has 18 bits in a word and a store cycle time of 2µ sec. Inputs are received from some 14 different sources via the interface unit. Elliott programming experience has made possible the packaging of the program so that this small unit can perform all the functions normally associated with machines of much larger capacity and size.

Interface Unit
Enables the digital computer to receive and transmit information from and to other units in the aircraft in compatible signal form. It also supplies the power for the computer and Navigation Control Unit.

ASSOCIATED SENSORS
The other sensor data used by the 920M computer is as follows:

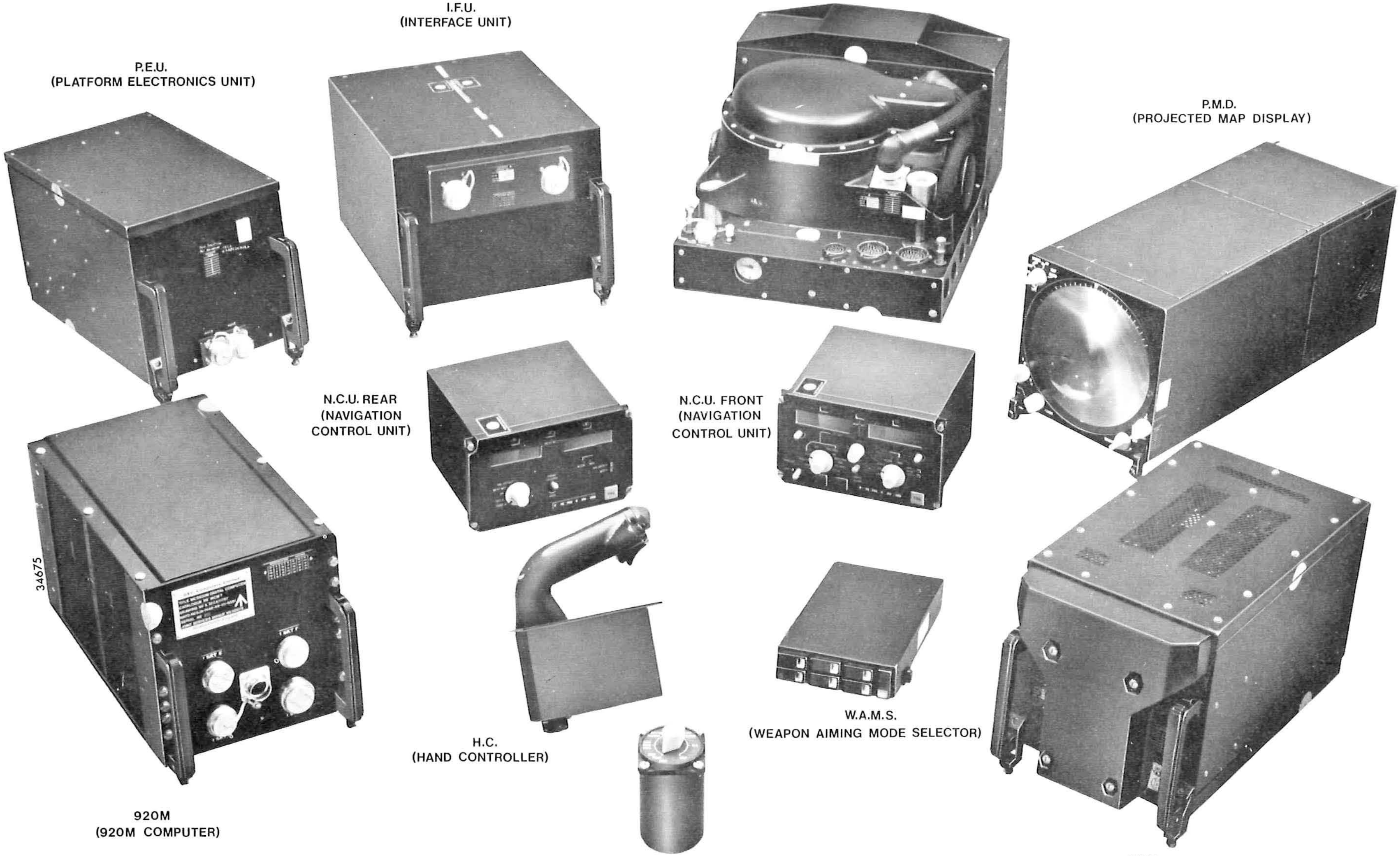
Marconi-Elliott
Air Data Computer
Provides T.A.S., I.A.S., barometric height for weapon aiming and navigation

Radio Altimeter
Provides radio height for weapon aiming

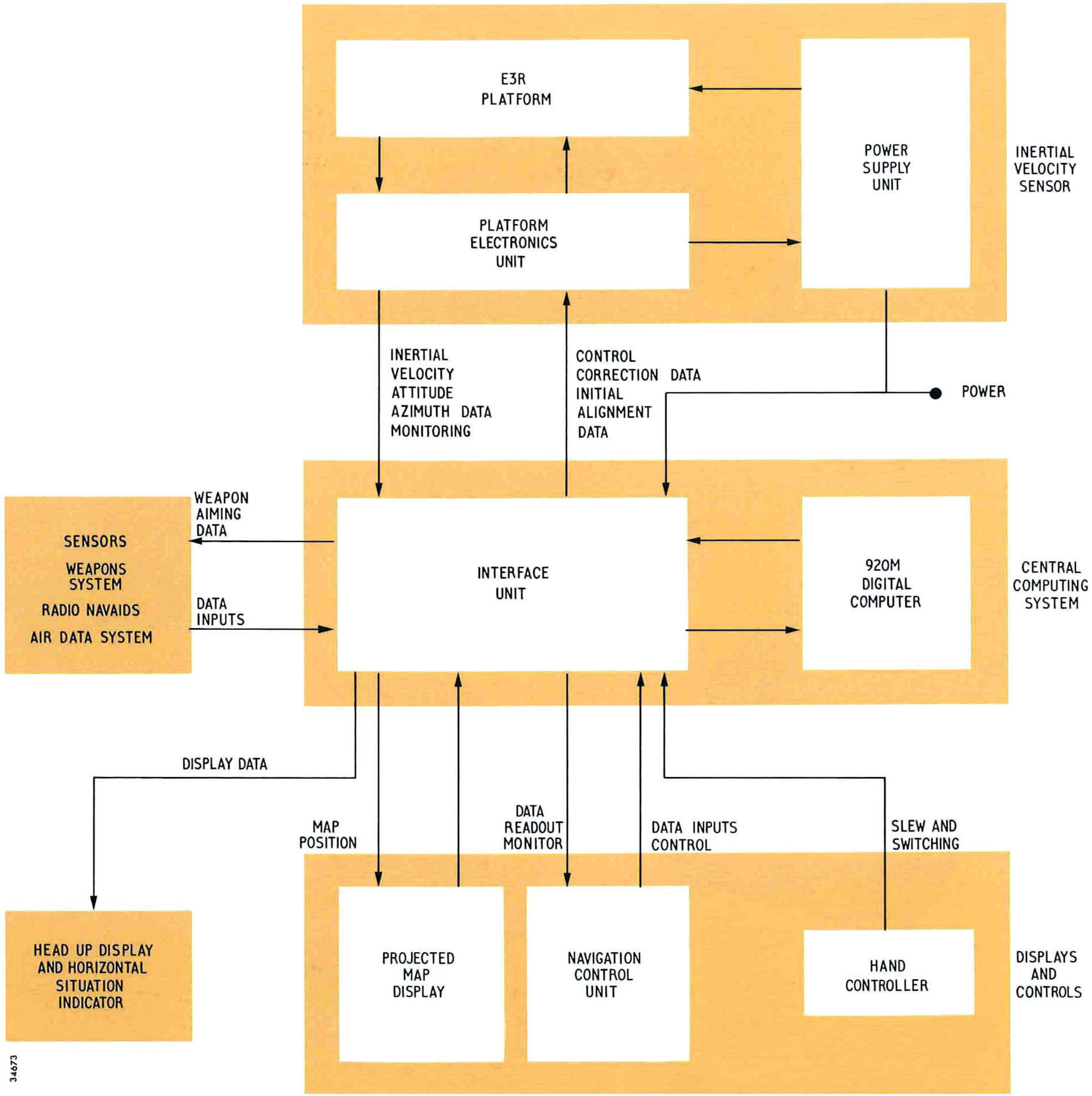
Ferranti Laser Ranger
Provides laser target range and laser marked target direction for weapon aiming and target identification

TACAN
Provides TACAN range and bearing for offset TACAN

I.L.S.
Provides I.L.S. direction for flight director on approach

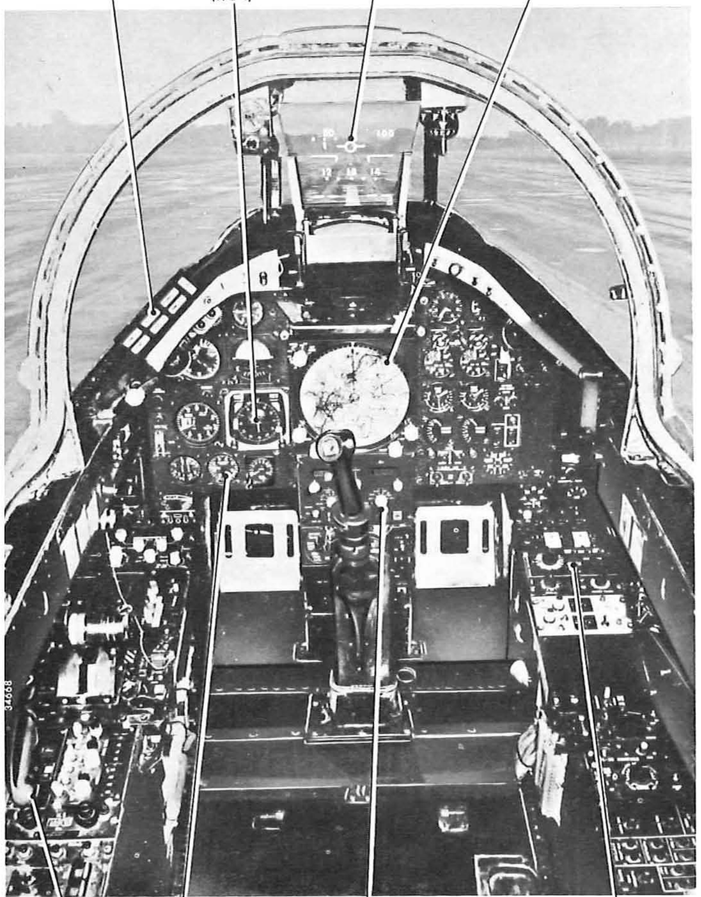

E3R
(E3R PLATFORM)
I.F.U.
(INTERFACE UNIT)
P.E.U.
(PLATFORM ELECTRONICS UNIT)
P.M.D.
(PROJECTED MAP DISPLAY)
N.C.U. REAR
(NAVIGATION
CONTROL UNIT)
N.C.U. FRONT
(NAVIGATION
CONTROL UNIT)
34675
W.A.M.S.
(WEAPON AIMING MODE SELECTOR)
H.C.
(HAND CONTROLLER)
920M
(920M COMPUTER)
H.S.I. MODE SWITCH
(HORIZONTAL SITUATION INDICATOR MODE SWITCH)
P.S.U.
(POWER SUPPLY UNIT)

Navigation and Weapon Aiming Sub-System Block diagram



Displays and Controls

Pilots Aspect



The Jaguar aircraft cockpit layout has been designed from the start to give the optimum presentation to the pilot of the very large amount of useful information produced by the system which is helpful to him in flying the mission. The use of the computer generated outputs not only produces a wide range of information which is complementary and gives the pilot a very good overall picture, but it also allows the relevant group of information which is required for the particular part of the mission to be selected and the non-relevant information to be deleted.

Head-Up Display

The Smiths Head-Up Display presents to the pilot the information he requires for the flight mode in progress, superimposed on his normal view of the terrain ahead. Parameters not required for the particular flight mode are occulted from the display. The display is a combination of alpha-numeric and symbolic information which is formed electronically on the face of a bright cathode ray tube and viewed, by means of a combining glass, via a collimating lens. The symbols are focussed at infinity enabling the pilot to scan the outside world and the display at the same time without re-focussing his eyes.

Projected Map Display

The pilot has a continuous reference to the aircraft present position and "track made good" superimposed on the projected image of air topographical maps. A white triangle at the circumference of the display shows demanded track to the next waypoint. When the track made good line lies opposite the demanded track index the aircraft is being steered correctly towards the waypoint/target. He may also 'look ahead' by selecting for display a waypoint (turning point) or target. Frame changing is automatic and aircraft position is continuously updated by a closed loop drive system. Two scales are available on selection. Meridian convergence and curvature of parallels are compensated for in the digital computer. An area approximately 1200 x 1500n.m. is contained in a single cassette of 35mm coloured film.

Navigation Control Unit

Enables the pilot to control the navigation system through switch on, alignment, waypoint setting and selection, fixing and reversionary operation. The unit provides readouts of navigation data and system malfunction indications. Twelve waypoints may be inserted as well as information on wind, off-sets and other data.

Twenty quantities may be displayed, including latitude, longitude, heading, groundspeed and magnetic variation or other information as required. An NCU with limited functions is provided for the rear cockpit of the two seat aircraft.

Horizontal Situation Indicator

The Smith's Horizontal Situation Indicator displays computer, compass, Tacan, range, ILS and UHF information. Warning flags indicate malfunctions or when a particular facility is not switched on.

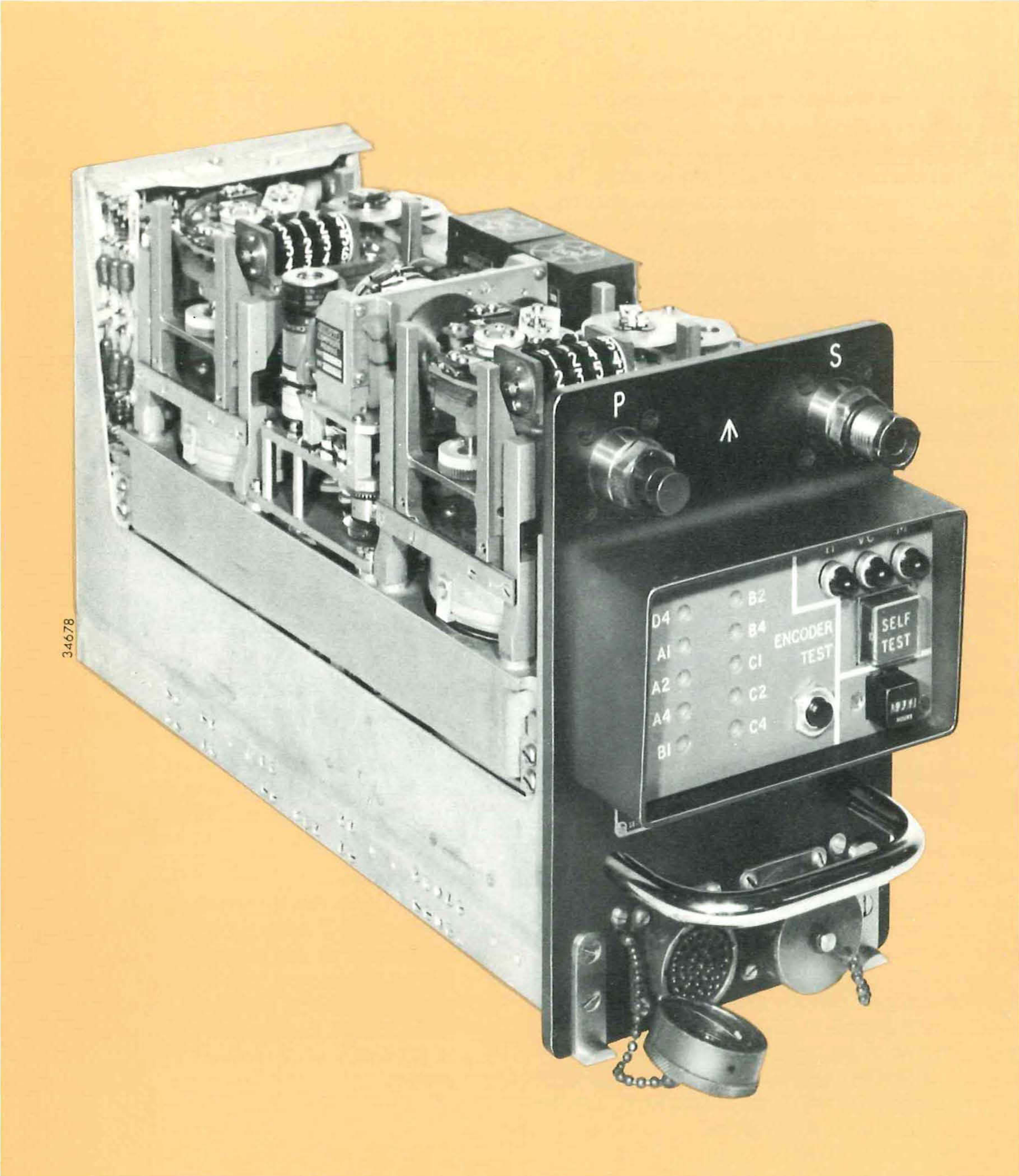
Weapon Aiming Mode Selector

The Weapon Aiming Mode Selector (WAMS) enables the pilot to put the system into a weapon aiming mode, to select the type of bombing attack he wishes to make and to select the ranging method that is to be used. The unit also initiates a height fixing procedure.

Hand Controller

The Hand Controller is used to position symbols on the Head-Up Display, change the symbology during weapon aiming phases, manually position the film on the moving map display during random position updates or in setting up waypoints. It is also used to alter the values of data set up in the digital indicators prior to insertion of the data into the system.

Air Data Computer



The Marconi-Elliott 'Jaguar' Modular Air Data Computer is one of a family, large numbers of which have been produced for the Lockheed C-5A Galaxy, Hawker Siddeley Nimrod and BAC 1-11 aircraft.

The Air Data Computer provides the following information:

Pilot's Display
Pressure Altitude* for the servo/barometric altimeter
Mach number for the combined speed indicator
Signals for the Head-Up Display
  Pressure Altitude*
  Indicated airspeed
  Mach number

Height Reporting
  Gillham coded digital signal of altitude for automatic altitude reporting

Navigation and Weapon Aiming Sub-System
  Altitude*
  Indicated Airspeed
  True Airspeed

*The computer has potential for the inclusion of static source error correction.

System Description
The Air Data Computer is contained in a short ½ ATR Arinc case and consists basically of four modular sub units: —
  Pressure Altitude Transducer Module
  Indicated Airspeed Transducer Module
  Computing and Output Module
  Power Supply Module

The altitude and airspeed transducer modules are virtually identical. Each contains a pair of free deflection aneroid capsules which deflect in response to altitude and airspeed respectively and, via cam-corrected servo follow-up mechanisms, produce shaft outputs which are linear with altitude and indicated airspeed.

These transuducers have outstanding accuracy and stability with very low hysteresis and their balanced twin configuration makes them particularly insensitive to environmental effects.

The transmission of altitude and airspeed to the computing and output module is by means of simple transfer gears. Mach number is computed by proven classical cam/differential gear methods and the required Indicated Airspeed Output is derived directly from the output from the Airspeed Transducer.

For applications where variations in airframe or store configurations require different corrections, the mechanism can be arranged to accommodate several characteristics, the required one being selected by external connection changes or switching.

Self Test
Self test facilities are incorporated which cause the computer servos to run to pre-determined settings. Lamps in the front panel extinguish when the servos are correctly stationed at these points. The encoder output is checked by depressing a button on the front panel which causes a series of lamps to display the numerical value of the encoder output.

Maintenance Advantages
Absence of the need for preventative maintenance, the simplicity of testing and of repair by module exchange, all result in reduced maintenance in terms of skill, time and spares holding, and contribute to a reduction in the overall cost of ownership.

ACCURACY

The specified operating temperature is from +70°C to −30°C
Accuracy over normal temperature range +10°C to +50°C.

Pressure Altitude:
± 25 ft at sea level or 0.25% of altitude

Computed Airspeed:
± 2 knots from 110 knots to 150 knots
± 3 knots above 150 knots

Mach Number:
± 0.01M up to M = 1, thereafter 1%

True Airspeed:
1% or ± 5 knots

Unit Sizes and Weights

The following table gives the physical characteristics of the system

UNIT	MAX POWER CONSUMPTION	WIDTH	DEPTH	HEIGHT	A.T.R.	WEIGHT
E3R PLATFORM	POWERED BY PSU	34.2cm (13.5in	39.3cm 15.5in	25.4cm 10in)		24.4Kg (54lb)
PLATFORM ELECTRONICS UNIT	POWERED BY PSU	19.4cm (7.6in	32cm 12.6in	19.4cm 7.6in)	3/4 SHORT	10.4Kg (23lb)
POWER SUPPLY UNIT	300W 28VDC 1080W 200V 400 HZ	19.4cm (7.6in	32cm 12.6in	19.4cm 7.6in)	3/4 SHORT	16.3Kg (36lb)
920M DIGITAL COMPUTER	POWERED BY IFU	19.4cm (7.6in	32cm 12.6in	19.4cm 7.6in)	3/4 SHORT	14.5Kg (32lb)
INTERFACE UNIT	330W 28VDC 240W 200V 400 HZ	26.3cm (10.4in	32cm 12.6in	19.4cm 7.6in)	1 SHORT	14.5Kg (32lb)
PROJECTED MAP DISPLAY	300W FROM 1 PHASE OF 200V 400HZ	19cm (7.5in	45.7cm 18in	19cm 7.5in)		15.8Kg (35lb)
NAVIGATION CONTROL UNIT	POWERED BY IFU 35W 28VDC	18.7cm (7.4in	18.4cm 7.2in	11.4cm 4.5in)		3.4Kg (7.5lb)
HAND CONTROLLER	2W 28VDC 4W FROM 1 PHASE OF 200V 400HZ	8.2cm (3.2in	14.6cm 5.7in	20.3cm 8in)		0.9Kg (2.0lb)
WEAPON AIMING MODE SELECTOR	22W 28VDC	14cm (5.5in	25.4cm 10in	3.5cm 1.4in)		1.1Kg (2.5lb)
AIR DATA COMPUTER	50W FROM 1 PHASE OF 115V 400Hz	13cm (5.1in	32.5cm 12.8in	19.4cm 7.6in)	1/2 SHORT	8.2Kg (18lb)

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Navigation

The Navigation and Weapon Aiming System in an advanced aircraft such as Jaguar must be capable of taking on those functions normally carried out by possibly a three or four man aircrew on earlier aircraft. The pilot of Jaguar gets more assistance from the system and has more tactical freedom in the execution of an accurate attack than the pilot of any other European aircraft. He can choose any direction, height or speed at which to make his attack and is completely independent of other aids.

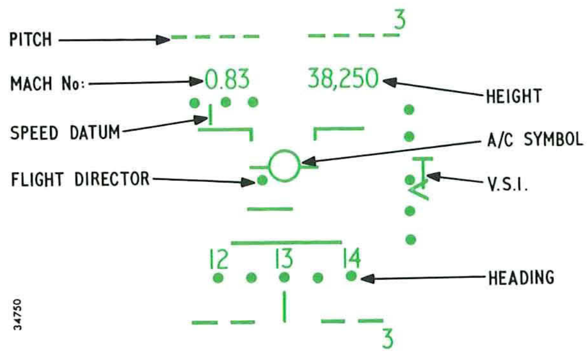
Pre-Flight Actions
After switching on the systems, the pilot's first action on entering the cockpit is to start the E3R Inertial Platform on its alignment cycle by switching the NCU mode switch to align and inserting into the digital computer the present position of the aircraft, the height and magnetic variation.

Whilst the E3R is gyrocompassing, details of the sortie are inserted into the computer by means of the Navigation Control Unit and the Hand Controller. Such details include the position of waypoints (turning points), targets and destination and also of diversion airfields.

Positions can be defined in latitude and longitude or in bearing and range from a Tacan beacon or a waypoint,or in feet in Northings and Eastings (NE) from a position defined by latitude and longitude. When the Navigation Control Unit 'NAV' light comes on, indicating that the platform is aligned, the pilot selects the mode switch from ALIGN to NAV and selects his first destination from the turning points which he has inserted into the computer. He then confirms that the Projected Map Display and the Head-Up Display show the correct information for the completed pre-flight checks and the aircraft is ready for take-off.

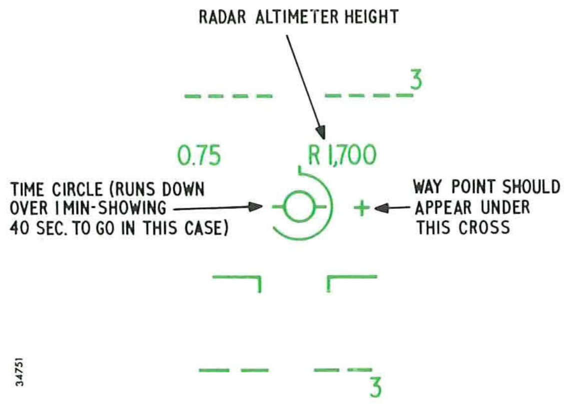
A rapid align facility is available which permits the platform to be aligned in three or four minutes rather than the ten or twelve minutes that the normal align method takes. The navigation accuracies obtained after "rapid align" are, in practice, very close to those obtained after a normal alignment.

In Flight
Pilot read out in flight is provided by the Head-Up Display, on which is superimposed a flight director giving steering commands to keep the aircraft on its planned track at any height which the pilot selects.



Navigation Mode

When the aircraft gets to within two minutes of a waypoint, or target, a "time to go" circle appears which starts to unwind at one minute to go. The Head-Up Display changes from navigation mode to either close navigation, in the case of a waypoint, or the first selected attack mode in the case of a target. The flight director on the Head-Up Display is replaced by a ground stabilised marker which physically points out to the pilot the computed ground position of the waypoint or target. This facility overcomes the often difficult problem of early recognition of waypoint or more important, the target, when the aircraft is at low level.



Close Navigation Mode

Where the ground and computed positions differ, the system can be updated by the pilot by use of a fixing facility which puts the actual position of the aircraft, as confirmed by a visual sighting, into the computer. The pilot will also, of course, refer to the Projected Map Display which shows him his present position and direction to the waypoint.

Approaching each waypoint the next destination is selected on the Navigation Control Unit and the "Change Destination" button pressed when the waypoint is overflown.

The projected map display allows the pilot to up-date the navigation system position accuracy at any time during the flight when he overflies an identifiable geographical feature depicted on the map. By selecting "Random" on the Fix switch of the navigation control unit the position of the map is frozen whilst the navigation system continues to compute the on-going position of the aeroplane. The pilot can then use the hand controller to reposition the map so that the geographical feature which he has just overflown is centred in the middle of the map and the amount of the input correction of position in terms of radial/distance error is displayed upon the navigation control unit read-out.

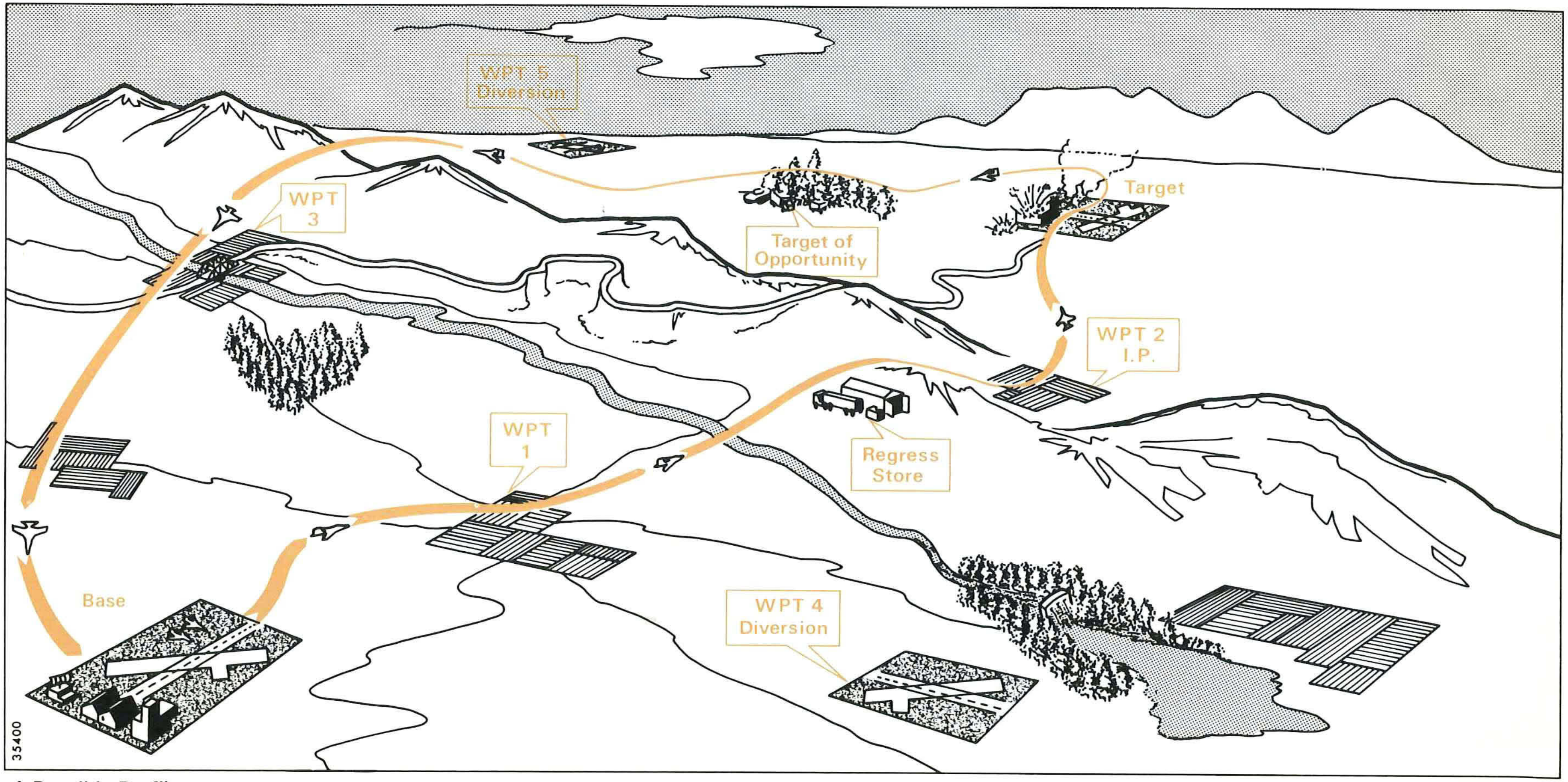
If the pilot chooses to insert this fixed correction he will press the "Insert" button on the Navigation Control Unit and the map will then move to the current position of the aircraft, as calculated by the inertial navigation system, but now corrected by the radial fix error input.

The use of the map for the fixing routines means that it is not necessary to identify any particular planned fix positions before the commencement of the sortie thus enabling the pilot to avoid overflight of locations which may have hitherto unknown defences.

In addition to the random fixing facilities, a planned fix facility against the preflight identified fix points is also provided, which is executed by similar switching routines.

Selections available on the Projected Map Display permit the pilot to look ahead to any waypoint or target at will and also allow the map to be either North or Track orientated. Should he overfly a position to which he wishes to return later, or which he wishes to report on landing, the simple action of pushing the "Insert" button on the Navigation Control Unit at the moment the position is overflown, stores the latitude and longitude in the computer from where it can be recalled and displayed on the Navigation Control Unit at any time. This facility is called the "Regress Store".

On his return to base, the pilot can complete a flight-directed ILS approach and landing.



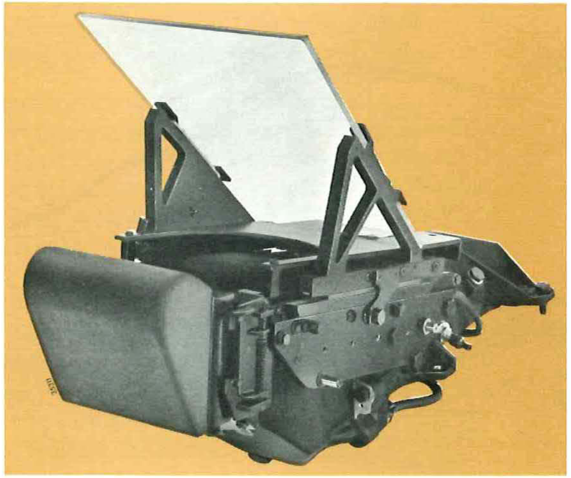
A Possible Profile

Information Displayed During Sortie

The following information is displayed on the NAV/WASS displays:

Head-Up Display (Smiths Industries Ltd)

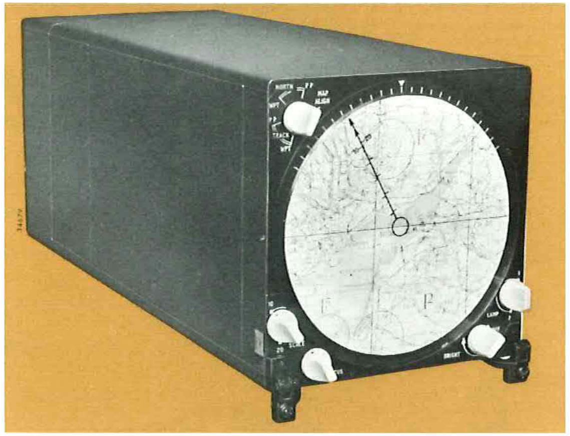
- Artificial Horizon
- Aircraft symbol showing flight path angle and bank angle
- Pitch angle
- Zenith and Nadir stars representing climb and dive angles when related to the aircraft symbol
- Flight director showing computed command track in azimuth to a destination
- Aircraft True or Magnetic heading
- Steering error
- Airspeed or Mach number
- Speed error from a pre-selected speed
- Baro-inertial or Radio height
- Vertical speed
- Angle of attack
- Time-to-go
- Fixing cross to indicate waypoint position on the ground
- Aiming information for air to ground and air to air including stadiametric ranging display
- Position of target indicated by target bar
- Safe pass distance during bombing modes



Pilot's Display Unit

Projected Map Display

- Aircraft present position
- Aircraft track
- Track to selected waypoint
- Track error
- Look ahead to selected waypoint
- Two map scales
- 10 and 20 n.m. distance markers
- North or Track orientation
- Spare lamp and brightness control



Navigation Control Unit

- Computed wind speed and direction
- Aircraft true heading
- Aircraft ground speed
- Aircraft present latitude and longitude
- Latitude and longitude of any waypoint (up to a total of 8) plus base and Regress Store*
- Offset position defined as a bearing and range from a waypoint*
- Offset position defined as a bearing and range from a Tacan beacon*
- Offset position defined in feet north and east (NE) of a waypoint *
- Runway heading for ILS approach*
- Aircraft magnetic heading
- Height above sea level of any waypoint or base*
- Wind speed and direction*
- Warning light if a system unit fails

*As set by the pilot

Horizontal Situation Indicator (Smiths Industries Ltd)

- Aircraft heading, True or Magnetic
- Range to Waypoint or Tacan beacon
- Aircraft track
- Command heading to next destination
- Deviation from command track
- Deviation from ILS glide slope
- Validity of ILS localiser and glide slope information
- TO/FROM flags give directional sense of steering instructions

Weapon Aiming

The NAV/WASS makes the necessary calculations for the accurate weapon aiming of bombs, guns or rockets. It also provides sighting symbols on the Head-Up Display appropriate to the weapons being aimed. Information from all the aircraft sensors is translated into weapon aiming symbols on the Head-Up Display, by the digital computer. The ballistic parameters of the wide variety of weapons carried by the Jaguar are stored in the computer. The ballistics of any additional new types of weapons can be stored very quickly in the system by means of the Program Loading Unit.

Bombing Modes
A bombing attack is initiated by the pilot selecting the type of attack he wishes to make, on the Weapon Aiming Mode Selector.

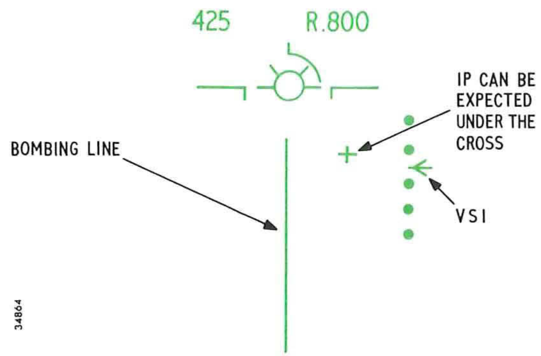
There are four main types of bombing mode, two against planned targets and two against unplanned targets. These modes are as follows:

Planned Targets
Planned Mode (PLAND)
Precise Local Fix Mode (PLF)
Both these modes use the Continuously Computed Release Point (CCRP) mechanisation with automatic weapon release.

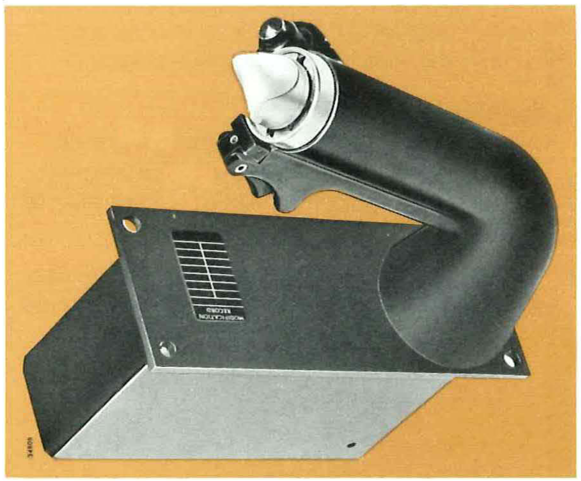
Unplanned Targets
Target of Opportunity Mode (TGT OPP)
Continuously Computed Impact Point (CCIP)
The TGT OPP mode is also mechanised as a CCRP attack whilst the CCIP mode is used for all other unplanned targets. At the pilot's discretion the CCIP mode may also be selected for a weapon drop against planned targets and targets of opportunity, after the target has been identified visually at the start of the weapon release run.

In the CCIP mode the computer continuously generates the progressive impact point of the weapons on the ground together with the bomb fall line and the pilot makes a manual release when the CCIP point crosses the target.

The planned attack mode is used against a target whose position and height are known and are stored in the computer. The Navigation accuracy of the system is such that aircraft position can be updated at a predetermined initial point (I.P.) as much as 150n.m. from the target and an accurate track will be flown to the target regardless of any en-route evasive manoeuvres which may be necessary.



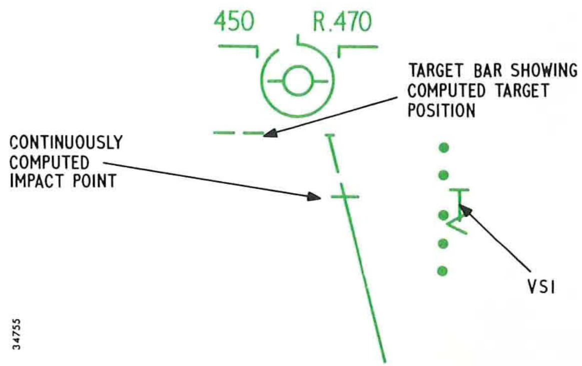
PLF Track Symbology



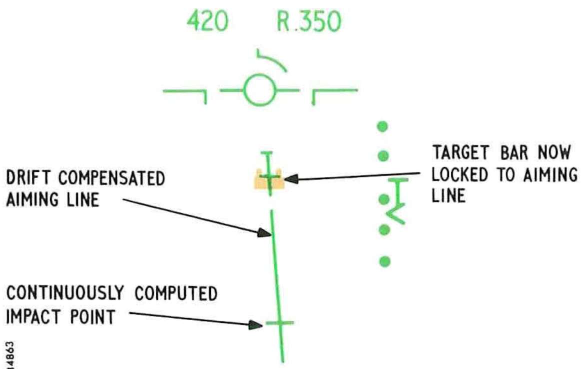
Hand Controller

A Precise Local Fix procedure can also be used against a target whose position is defined in N & E offsets from a waypoint. When the aircraft approaches the waypoint chosen as the IP, the Head-Up Display automatically changes from Navigation to "PLF" and the flight director is replaced by a ground-stabilised marker which points out the IP to the pilot. The pilot then updates the system by placing the marker on the I.P. using the Hand Controller and, by pressing the Hand Controller trigger, phase changes to an attack mode. Steering information to the target is then displayed.

In planned attacks during the acquisition phase, a stabilised target bar is positioned by the computer on the head up display overlaying the computed target position, together with a time to go circle and drift compensated bomb fall line. On sighting the target the pilot flies the aircraft in azimuth to keep the bomb fall line tracking over the target. By operating the hand controller he places the target bar over the target. This provides the computer with accurate information on the position of the target. As the target is approached, the pilot changes to the strike phase. The computer continuously works out the changing sight line and ground stabilises the target bar on the target, thus reducing the corrections required to be made by the pilot.



Acquisition Symbology



Tracking Strike Symbology

In the continuously computed release point mode (CCRP) the target bar and target track down the bomb fall line until they reach the continuously computed impact marker when automatic release occurs.The system then provides navigation steering to the next waypoint or target, or to return to base.

Target of opportunity attacks permit the pilot to complete fully computed attacks against unplanned targets without having to do the setting up procedures necessary for a planned attack. By selecting 'TGT OPP' on the Weapon Aiming Mode Selector, the Head-Up Display immediately changes to an attack mode and the pilot can carry out an attack against any target with the full accuracy of the system.

In addition to the automatic CCRP release mode described above it is also possible to make a manual release using a continuously computed impact point (CCIP) generated by the computer. The CCIP marker in fact appears in both the automatic and manual release modes but is only used independently for a manual release when the prime CCIP mode selection is made on the weapon aiming mode selector. In this mode the pilot tracks the target with the bomb fall line and depresses the manual release switch as the CCIP marker crosses the target.

The laser ranging/marked target seeker provides the primary target ranging information for computed release point for both the CCRP and CCIP modes. Two modes of laser information are provided. The laser ranging mode in which the laser boresight is slaved to the target bar or CCIP point and the combined laser ranging/marked target seeking mode which provides a blind attack capability against a target which has been laser marked by ground forces or other aircraft.

In the Laser Ranging and Marked Target Seeking attack, the computer directs the target bar until marked target returns are detected. The seeker then locks on and drives the target bar to be over the target prior to automatic ranging. It is not necessary for the pilot to see the target.

Additional back up ranging modes use triangulation methods with a combination of radio or barometric altimeter mixed with inertial vertical velocity. Initiation of the back up modes is by means of the weapon aiming mode selector.

Other Weapon Modes
In addition to the free fall and retarded bomb attacks, the system also computes and displays CCIP aiming marks for guns and rockets in air to ground attacks.

In the Air to Air Mode the system also computes digitally the precise "lead angle" for the air to air reticle displayed on the Head-Up Display.

Weapon Aiming Mode Selector Unit

Reversionary Modes

A failure within the Navigation and Weapon Aiming sub-system could invalidate navigation instructions and displayed information. As it is not always possible for the pilot to analyse a failure correctly and take the proper remedial action, a comprehensive automatic failure detection system is written into the computer program. Checks are made to ensure that units are operating within known parameters and basic data sources are compared with others providing the same information. In addition, power supplies are monitored so that specific units can be shut down to prevent damage to equipment.

Lamps on the Navigation Control Unit illuminate to indicate a failure and also the unit that has failed. In addition a larger "FAIL" lamp simultaneously lights to attract the pilot's attention to the fact that a failure has occurred.

The computer program is written so that various failures or combination of failures cause automatic reversion to other modes of navigation. An automatic reversion cannot be over-ridden by the pilot.

The system is designed to maintain a high degree of operational capability in the event of either a computer or inertial velocity sensor failure. In the event of computer failure the inertial velocity sensor is stabilised as a second order Schuler tuned attitude reference by the Platform Electronic Unit thereby continuing to provide a very accurate attitude reference for flight control and weapon aiming.

Additional "raw" information such as Tacan may be fed directly to various displays, e.g. HSI thus bypassing the failed computer. In the event of the failure of the inertial velocity sensor, a secondary navigation mode using a secondary heading and air data information is executed by the computer, thereby giving an accurate output of DR information to the pilot for the rest of the flight to the target and on the return. The built in test and reversionary mode of the system has been designed to give the pilot as clearly as possible an indication of system status and sensor operation and to provide the pilot with sufficient redundancy of system operation so that even in the event of a major sub-system failure the sortie may be continued, albeit at a lower level of system performance.

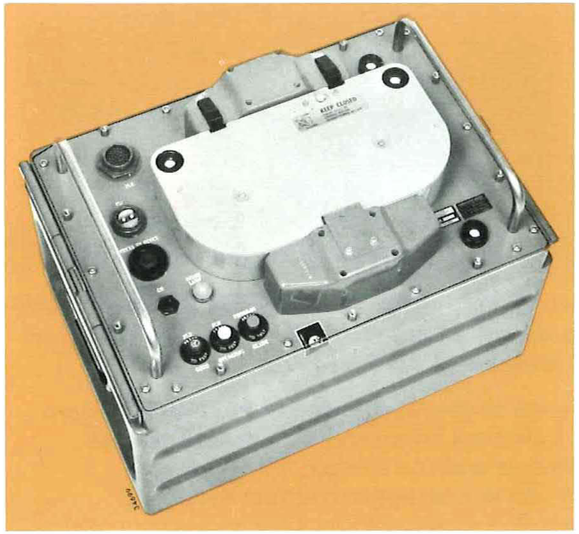
Maintenance

The 920M Computer is an exceptionally valuable tool when used in the servicing role. Besides providing a continuous built in test facility (BITE) in flight, the computer also provides a complete avionic system performance and unit serviceability checkout on the ground.

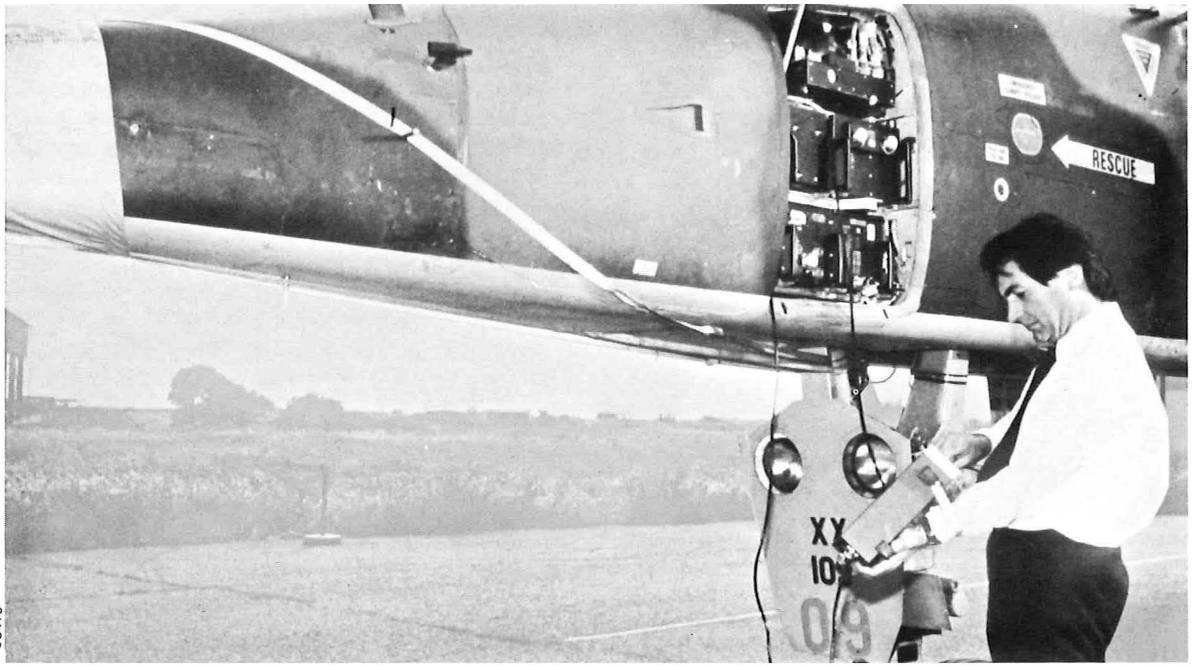
Because the routine removal and replacement of units increase failure rates by the breaking and remaking of electrical connections, the sytem has been designed so that first line testing is done by the 920M Computer with the units in situ in the aircraft.

When required, the first line test program is loaded into the computer by the portable Program Loading Unit. This takes only a few minutes and can be done at any place with a 28V supply. Besides checking the NAV/WASS, the program also checks systems which interface with the NAV/WASS. Visual indication is given, of any servicing checks failed, together with an indication of which unit should be replaced, on the Navigation Control Unit indicators. The first line test facility, combined with the ability of NAV/WASS to monitor itself for faults in flight, reduces the time required for fault finding and rectification. The manual selections during first line test are simple and few. However, should the operator make an error, this is automatically detected; the Navigation Control Unit indicators flash and the test sequence stops until the correct selection is made. In addition to reducing servicing times, and therefore aircraft turn around times, the simplicity of the whole testing procedure enables personnel with lower technical skills to be employed in first line servicing of this comprehensive system than is possible with less sophisticated systems.

Portable Program Loading Unit



Aircraft Access Bay



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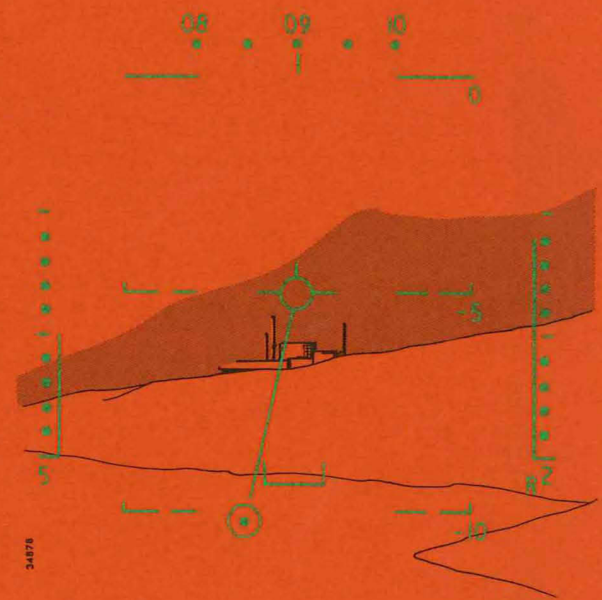
PART 2

Options Available



Introduction

Extension to Night and All Weather Operation
The primary function of the proposed modifications is to extend the highly effective daytime capability of the Jaguar to night and all weather operations. In the course of these modifications the re-allocation of weapon aiming in the Head-Up Display Weapon Aiming System gives a useful increase in the amount of central computer program storage for other tasks, including sensor management. A further increase in program storage is readily available by the substitution of the latest variant of the 920 computer range, the 920ATC, which extends the main storage to 32,000 words.

The integration of these equipments, with the major change of the substitution of a map and ranging radar for the existing laser ranger and marked target seeker (LRMTS) equipment, is discussed in this second half of the brochure.

The prime means of extending the daylight capability to night and all weather operation is the installation of additional sensors to the aircraft which can augment the pilot's capabilities in order to provide waypoint and target detection and identification in as extreme a range of meteorological conditions as possible.

Modification 1. Radar Installation
Modification 1 requires the most significant change to the existing aircraft, since it consists of the removal of the existing Ferranti LRMTS laser system from its present position in the nose of the aircraft and its replacement by a multi-moded radar system.

The original purpose of the laser ranger and marked target seeker was two-fold, namely:

1 to provide target ranging inputs to the weapon aiming sub-system.

2 to provide target identification to the pilot of targets which have been independently "laser marked" by ground forces or other aircraft.

Because of the present high effectiveness of the weapon aiming system against targets in level terrain conditions the additional accuracy conferred by a laser ranging input is unlikely to produce a significant higher target accuracy. However, in undulating terrain, a laser ranging input is likely to produce significant improvements. In these latter conditions however, it is probable that on 30-40% of the occasions the target aspect will be sufficient to provide an adequate range return from the radar range mode of the proposed multi-range radar.

The trade-off position is therefore as follows:

Pluses

1 Deriving from the installation of the radar, accurate target ranging during level terrain attacks and for 30-40% of undulating terrain attacks.

2 Ground mapping target capability giving radar prominent target/waypoint detection in all weathers.

3 Air to air ranging mode giving accurate missile launch envelope calculation and display for AA/GW and tracer line gun mode.

4 Terrain clearance aiding in all weather conditions.

Minuses

1 Deletion of LRMTS Sensor reduces day time weapon delivery accuracy on 70% of attacks over undulating terrain (i.e. on approximately 40% of occasions).

2 No inherent detection capability against targets laser marked by ground forces.

Modification 2. Alternate Laser Installations
Alternative laser installations which would either permit the installation of the existing Ferranti LRMTS or a simpler ranging only system are described in Modification 2.

These installations permit the retention of the high accuracy daylight weapon delivery mode for both day and night operations at the expense of a slight additional penalty in cost and weight.

Modification 3. Improved Head-Up Display System
Modification 3 is the installation of the Elliott 664 Head-Up Display weapon aiming system, as chosen for the F16, which gives three major advances over the present earlier generation Head-Up Display system installation in the aircraft.

1 It provides a full raster mode on the Head-Up Display, which allows the display of night sensor information, or scan converted radar information on the Head-Up Display, together with super-imposition of the Head-Up Display symbology. Systems of this type have completed flight trials and pre-production models are currently being delivered to U.S. Navy aircraft.

2 The 8192 word GP Digital Computer incorporated in the HUD system allows all of the weapon aiming calculations to be carried out in the Head-Up Display thereby freeing some 2,000 words in the central 920M Computer for the additional tasks, such as sensor management and integration required in an expanded system.

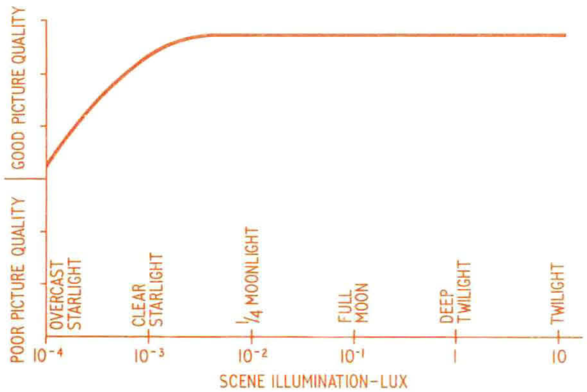
3 The additional capability of the general purpose Digital Computer in the Head-Up Display allows the generation in the display of the considerably greater number of symbols required for the expanded role capability of the new system.

Modification 4. Night Vision Sensor

Modification 4 is the installation of a night imaging sensor for the visual detection and identification of targets in low light conditions. M.E.A.S.L. proposal for this sensor uses an existing airborne LLTV camera, together with improved signal processing circuitry. The combination of the signal processing circuitry with the LLTV camera allows operations down to light levels to the order of 10^{-4} LUX with a high percentage of operational success and at an acceptable initial cost.

The performance of Low Light TV sensors under various levels of illumination is shown in Figure 1. From this it will be seen that even though a more expensive and more complex forward looking infra-red sensor allows operation in all levels of night illumination, a signifcant increase in the period of operation can be obtained by using a lower cost and simpler low light television camera. This very significant increase in operational capability enhances the effectiveness of the Jaguar aircraft to a point which is unequalled by any other aircraft.

Figure 1



Alternatively, a forward looking infra-red system could be installed, in a removeable pod mounted on a weapon station, with associated benefits of a wider operational envelope and the associated disadvantages of increased cost and weight. In both instances the output from the system is displayed upon the advanced Head-Up Display installation in Modification 3, which then performs the primary attack computation in the aircraft in both day and night conditions.

Modification 5. Improved Central Computer

Modification 5 is the substitution of the 920 ATC for the 920M central computer. The new 920 ATC is entirely software compatible with the existing Jaguar operation and its programs. However, because of its later technology, it offers a considerable expansion in speed and storage capability. This allows the simultaneous storage and operation of a number of additional functions which, with the smaller 920M computer, may currently require between flight reprogramming. The 920 ATC, which is in early production for the Nimrod Mk. II and is under development for the MRCA Air Defence Variant, offers 32,000 words 800 Nano second store with full range of operational capabilities which are currently planned for later types of attack aircraft such as the MIRAGE F1E and F16 Fighter.

Modification 6. Helmet Mounted Display

Modification 6 is the addition of the Elliott Helmet Mounted Sight system as an adjunct to the Central Computer/Head-Up Display system. The Jaguar Helmet Mounted Sight includes cueing to the radar and missile heads to enable lock on to be achieved against targets which are displaced from the aircraft boresight, therefore saving valuable seconds in air combat. In the ground attack role it provides, in conjunction with the Head-Up Display, director steering information against an off flight-line target which is observed by the pilot during a flyby.

Modifications 7 and 8. Cockpit Display Improvements

These two modifications relate to improved ergonomic design of the present Jaguar cockpit. The first of these is the provision of a target and target marking circuitry on the present Projected Map Display. In the event that the radar display for the aircraft is presented head-up on the raster Head-Up Display it will be possible to retain the Projected Map Display, with considerable advantages in both daylight and night operations.

The proposed modification of this display will enable the map to be annotated with points of direct interest to the pilot such as targets and defences, and forms a very useful extension to the present facility. The second part of this installation relates to the improved data entry panel, a keyboard control which, it is felt, will be a necessary adjunct to the greatly increased store capacity of the 920 ATC Computer.

Modification 9. Terrain Clearance Monitor

Associated with the ability to operate under night conditions is the necessity to maintain the overall safety of terrain and obstacle clearance which is achieved by the pilots during daylight conditions. The proposed improvements to the Jaguar include an additional simple Terrain Clearance Monitor which can be optimised around the particular nature of terrain profiles in the area of operations. It is considered that the use of this Terrain Monitor which is implemented in flight director form in the Head-Up Display, in conjunction with the head-up presentation of low light sensor information, should enable night time flight operations to be conducted at altitudes of 400 feet or so and speeds of 400 knots over areas of known terrain.

Modification 1
Radar

Antenna	Type	Inverted Cassegrain 14"5 (368 mm) Dia.
	Scanned Sector	140 °
Radar	Type	Monopulse
	Frequency	(X-) Band
	Pulse width	2 pulse width and 3 PRF, (selection being automatic according to the mode of operation) are used in order to obtain the best performance with respect to the prevailing meteorological conditions.
Modes of Operation	INTERCEPTION ROLE	Provides blind attack capability for firing of missiles etc. Search, lock-on and boresighted with target tracking and air to air ranging. ± 70° Sector 'B' scan in azimuth, one or two bar in elevation depending on system logic.
	STRIKE ROLE	Air to ground radar ranging and ground mapping capabilities, provide for blind penetration attack in bad weather conditions or at night.
	A.S.V. ROLE	Air to sea ranging enables attacks to be made on sea surface targets.

Table 1

The Radar currently considered most cost effective for installation in the Jaguar is the Thomson/CSF AGAVE, which is now being developed and for which production orders have been placed. Tables 1 and 2 show the relevant characteristics of this system.

The AGAVE Radar Unit is installed in the nose of the aircraft and the Laser "chisel" nose becomes pointed as shown in Figure 1. The Laser system may be re-situated as described in Modification 2. Besides minor re-arrangement of equipment in the main equipment bay, cockpit changes are necessary if a Radar Display Unit is to be fitted. This can only be achieved by the removal of the existing Projected Map Display (PMD). However, the PMD can be retained if the Advanced Technology HUD is fitted on which Radar and Low Light Television pictures can be displayed.

The Radar system will be controlled by the Hand Controller, which will become a combined unit integrating the Radar requirements into the existing NAV/WASS Hand Controller. A separate panel adjacent to the Hand Controller will contain some Radar switch functions and the IFF Control Unit must be repositioned.

Radar System Performance

The Table 2 below gives examples of the radar system performance anticipated.

Target	Target Detection Ranges Expected				Ground Attack Role n.m.
	AI Role n.m.	Target	ASV Role n.m.		
Fighter	10	Patrol Boat	20		Resultant Weapon aiming accuracies similar to those obtained with Laser Ranging
Light Bomber	15	Destroyer	70		
Heavy Bomber	30				

Table 2

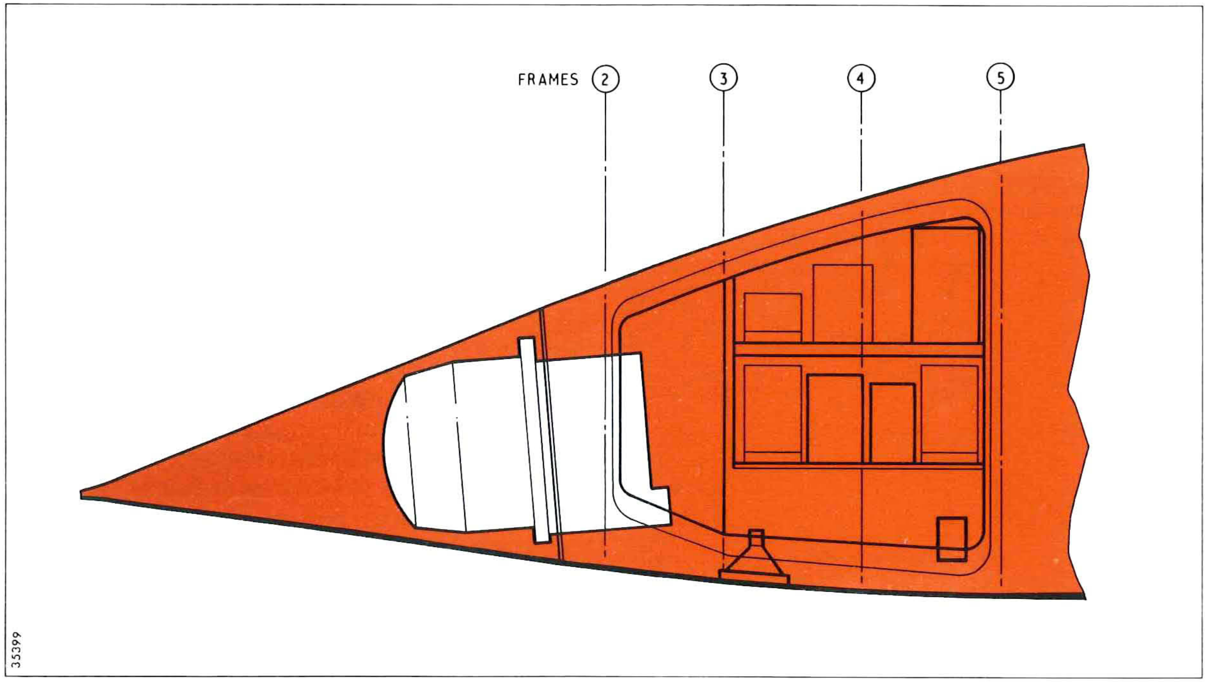


Figure 1 Agave Radar Installation in Nose

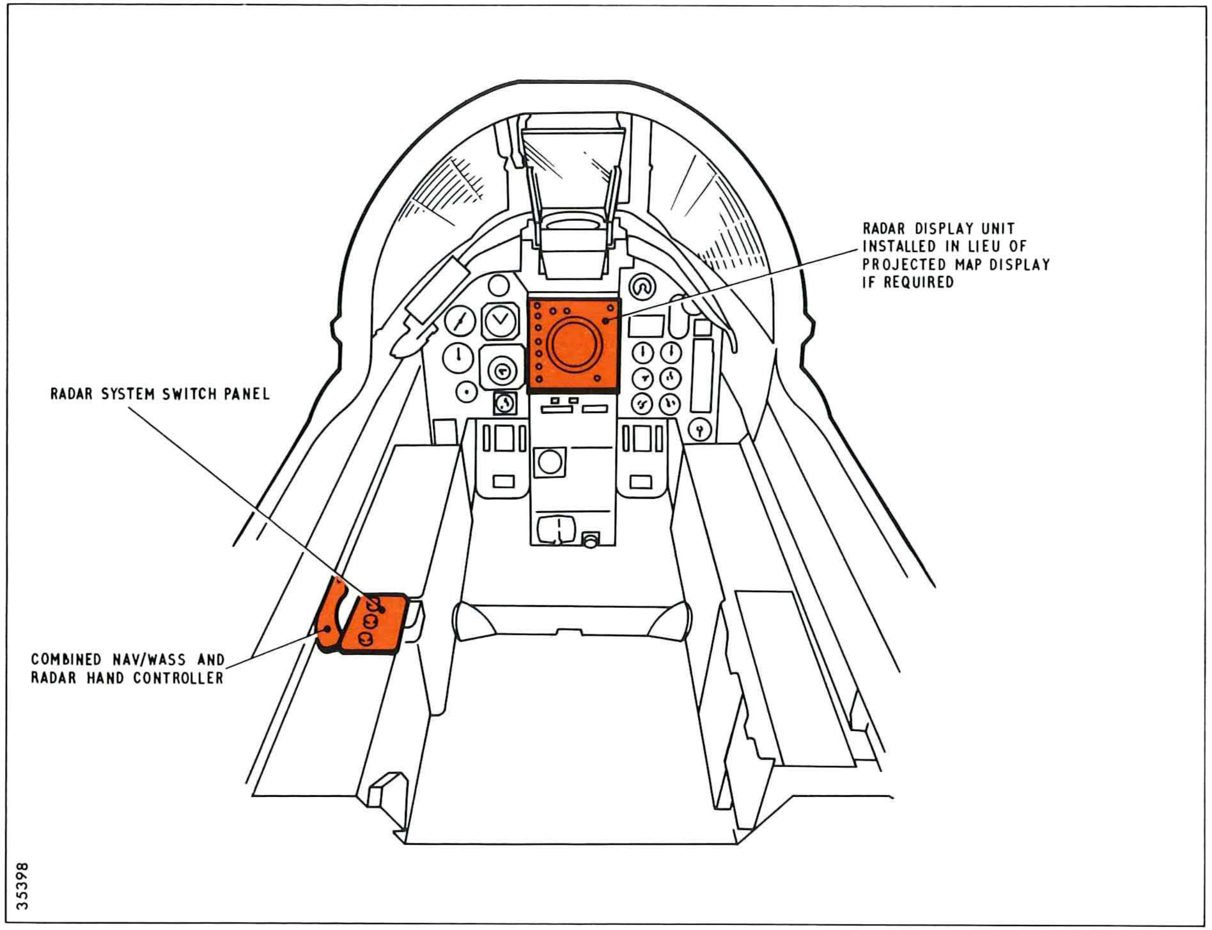


Figure 2 Cockpit Changes

Figure 2 illustrates these changes. Other system changes provide for the Radar System power and cooling requirements and revised pitot probe mounted from the front of the radome.

Modification 2 Alternative Laser Installation

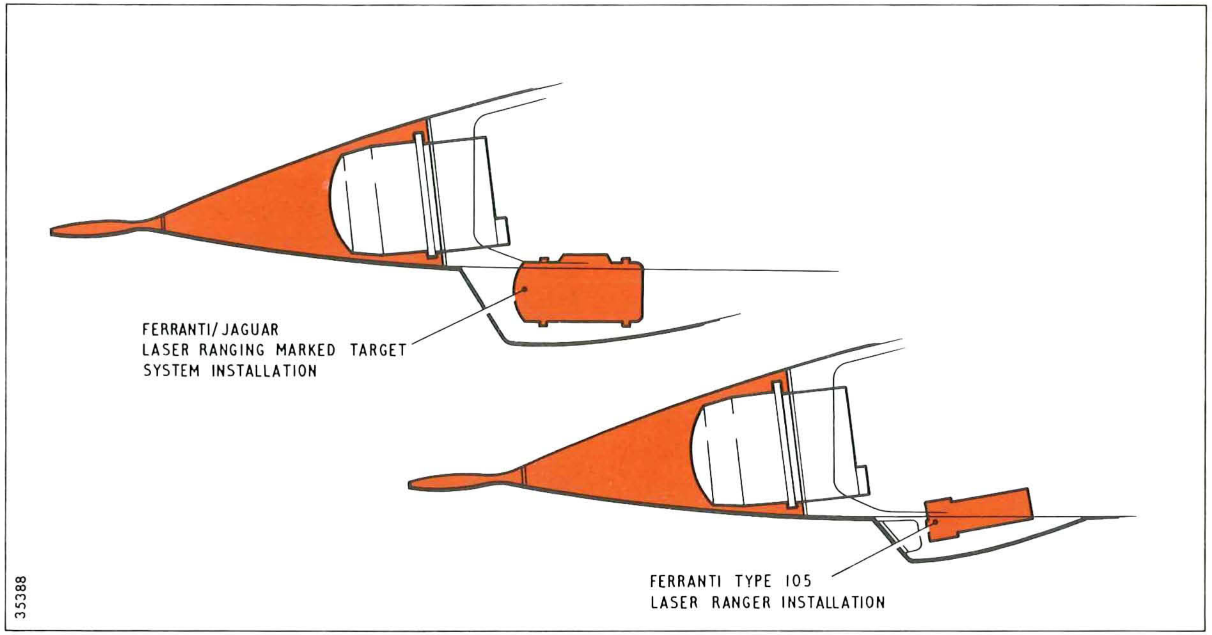


Figure 1 Laser Ranger in Nose

The Modification for the introduction of radar requires the laser system to be re-positioned in a fairing immediately under the radar nose if the laser system is to be retained for use in undulating terrain or with weapons such as the 'smart' bombs which can be aimed with greater accuracy.

Two alternate solutions are possible:

1 The full LRMTS with ranging and marked target location facilities. This retains the high visual ranging accuracy of laser ranging, together with the capability of "locking on" to and identifying ground targets which are laser illuminated by ground forces or by other aircraft.

2 The simpler Ferranti Type 105 laser ranger which gives a range only output to the system.

The full Laser Ranging Marked Target Seeker requires a larger fairing than is necessary for the Laser Ranger without the Marked Target Seeker as is shown in the diagram.

Modification 3
Advanced Technology Head-Up Display System

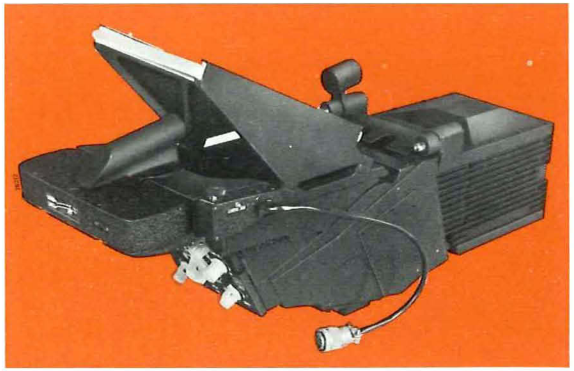
The '600' series of Head-Up Display Systems is a development version of the combat proven A-7 System and its A4M derivative and comprises the following units:

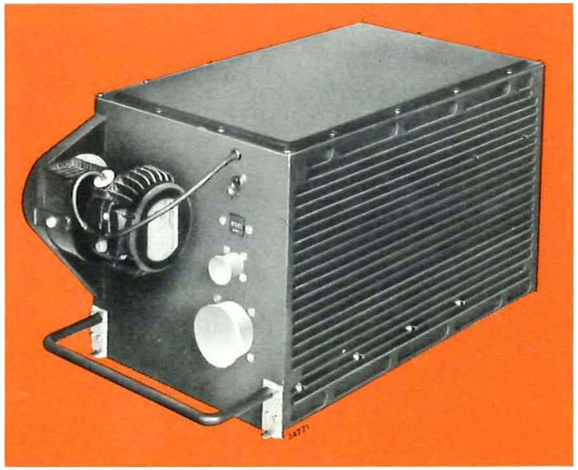
Pilot Display Unit (PDU)
Electronic Unit (EU)
Acceleration and Rate Unit (ARU)
Video Signals Unit (VSU)
Video Combiner Unit (VCU)

A helmet mounted sight unit is also available for use in target designation and seeker slewing/lock on modes.

Pilot Display Unit
The PDU is constructed in accordance with MIL-E-5400 and consists of two major assemblies; a dip brazed chassis containing the plug-in electronic modules and a light alloy casting containing the optical elements. Mounted on the optical module are the gun camera and control panel. An integral high voltage power supply module and cathode ray tube module provide both the normal stroke written symbology and TV raster scene.

The PDU is a well proven high accuracy optical system, with integral depressible standby sight and a night filter. The 5-inch diameter exit lens provides the largest possible instantaneous field of view necessary for displaying advanced air-to-air guns and missile launch mode symbology. This is of particular importance for high resolution in the raster mode where LLTV or radar is presented on the PDU and also to prevent cluttering of the various display symbologies. The PDU is designed to be installed in the Jaguar cockpit with a minimum of structural modifications to the existing PDU mounting.



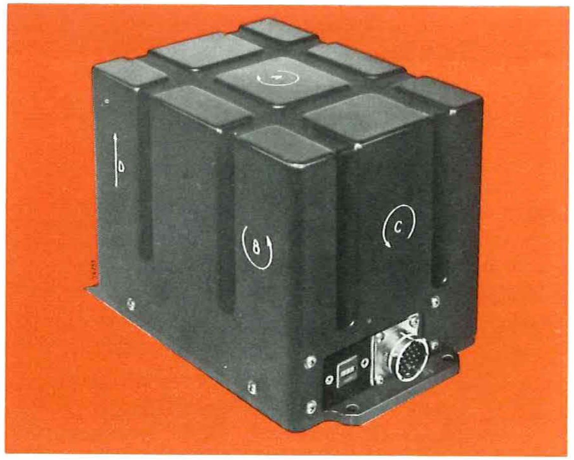


Electronic Unit
The EU consists of three main sections:

An interface that receives analog, serial digital data and discrete signals from the aircraft sensors.
A high-speed parallel operation digital processor that performs the calculations for symbology generation and weapon aiming.
A waveform generator that generates the analog deflection voltage for the lines, circles and alpha-numerics defined by the processor.

The digital processor has a 16-bit arithmetic facility with an 8K word program, which can be extended to 16K if so required. With the exception of circles and characters, all symbol shapes, orientations and positions are calculated by the processor, which defines the parameters of the constituent parts of the symbol in terms of binary digital words. This method gives maximum flexibility in symbol generation by making it part of the computer program, and calculates the symbol parameters in their roll resolved positions.

The high speed of the digital processor (1 microsecond add time, 12 microsecond multiply and divide) is particularly important for calculating and drawing the symbology necessary for advanced air to air guns snapshoot and missile launch weapon aiming.

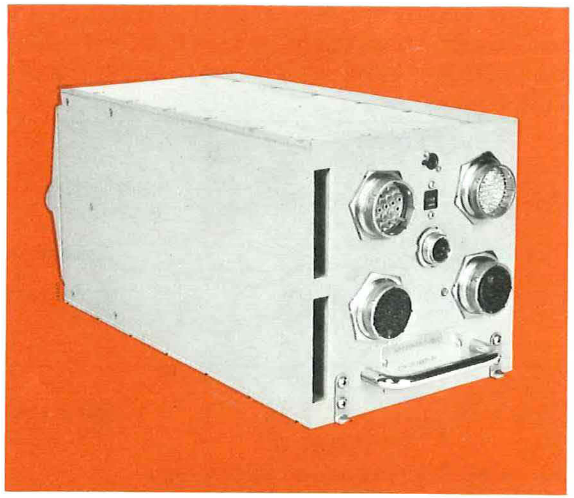


Acceleration and Rate Unit

The purpose of the ARU is to measure normal acceleration rates and angular velocity components in the roll, pitch and yaw axes. Outputs of these quantities are fed to the EU where they are used in the calculation of air to air guns snapshoot and missile launch weapon aiming.

Video Signals Unit

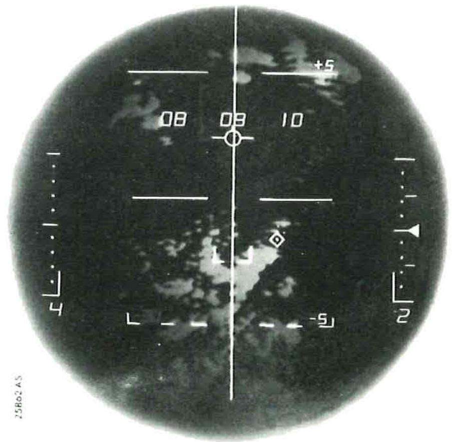
The VSU is necessary for operating the Head-Up Display system in a raster mode and provides deflection current signals to the PDU. It contains the X and Y deflection amplifiers, a low voltage power supply module, horizontal raster generator, relay switching and control circuits.



Video Combiner Unit

The VCU converts the stroke written symbology, generated by the EU, into raster signals and mixes them with the raster video signals from the radar or LLTV sensors. The incoming signals are combined into one video signal for display on the PDU as a raster scene. Two single ended 1-inch vidicon storage tubes are employed for the scan conversion process and are used in an interleaved manner for each converter channel in order to provide a continuous output signal at a 875 line 60Hz refresh frequency.

This unit, which is in production for the US Navy A-7 TRAM program, has been designed to overcome the problems of smear which results from the use of double ended scan converter tubes in a fast moving symbology scene.

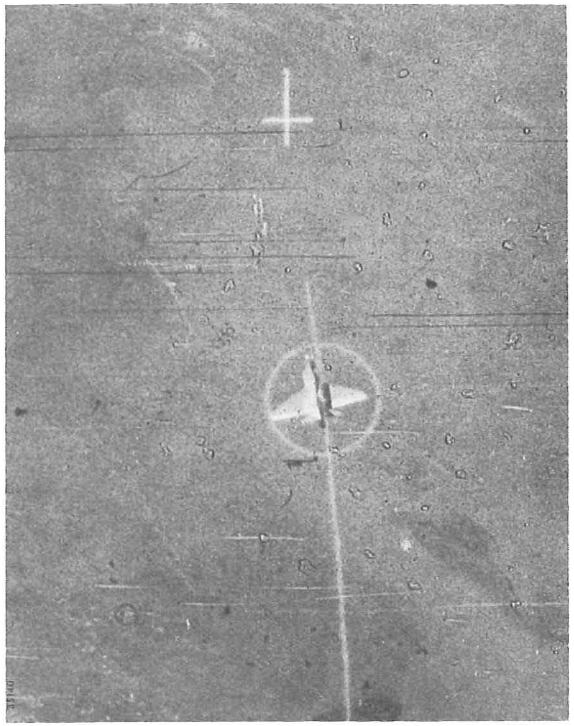


Modification 3
Advanced Technology Head-Up Display System
Continued

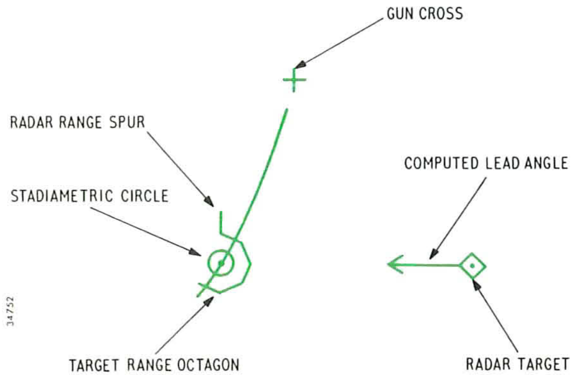
Hud System Weapon Aiming Capability
The 600 Series head-up display system which is in production for the U.S. Marine Corps A4M and which has also been selected for the General Dynamics F16 programme has been designed to include a very high degree of self contained weapon aiming capability within the head-up display computer unit itself and, in the above-mentioned programmes and others, it performs primary weapon aiming computation for both air to air and air to ground modes. In the proposed Jaguar system update it is intended that the weapon delivery modes will be shared between the head-up display and the 920ATC computer with the head-up display performing all of the air to air calculations and a back up CCIP mode and the 920ATC performing all of the primary air to ground modes and sensor management.

The head-up display weapon aiming modes include: –

Air to Air Guns Snapshoot Mode
This mode provides a very accurate calculated display of the bullet lines both through the air and the target range point. The use of the digital computer allows not only extreme accuracy but also very greatly improved dynamic performance of the sighting calculations and associated head-up display. These two factors have resulted in very substantial gains in air to air gunnery performance and the snapshoot bullet line display enables the pilot to take full advantage of the short term ''crossing target'' firing opportunities that occur in modern combat without the need for an extended tracking period. This mode can be operated with or without radar inputs, using a simple range only radar and stadiametric twist grip control respectively.
If Lock On radar is available then the HUD computer can be supplied with target position information from which to derive target crossing speed. An arrow symbol, its length proportional to the crossing speed and bullet time-of-flight is then positioned on the radar target symbol to show target relative movement and computed lead angle. The pilot opens fire on coincidence of the arrow head and the stadiametric range point on the bullet line.
These gun sight modes have been fully proven in development trials in U.S. Navy and U.S.A.F. programmes and represent the most effective air to air gun sight solution currently available for any type of aircraft.

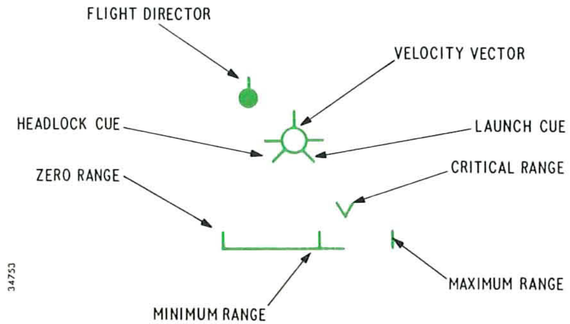


Typical Gun Snapshoot Display on Raster HUD



Air to Air Guns Snapshoot Symbology

Air to Air Missile Launch Mode
The air to air missile launch mode is an extension of the development work which has been carried out for the development of the tracer line bullet mode previously described. In the launch missile mode the head-up display computer calculates the missile launch envelope which exists for the instantaneous value of launch aircraft flight conditions and target manoeuvre. A flight Director symbol indicates the ''fly to'' command to bring the Jaguar to the optimum position in the computed launch envelope as well as indicating minimum and maximum launch range brackets, head lock required and similar symbols.
The launch range scale shows computed maximum and minimum ranges and critical range points, which are read against the target actual range shown by a horizontal moving symbol. Critical range is the ideal range to launch the missile with respect to the missile launch envelope having regard to the present and potential future target manoeuvre.



Air to Air Missile Launch Symbology

Air to Ground Mode

In the event of failure of the 920ATC computer the back up continuously computed impact point (CCIP) mode is used for all air to ground bombs (low or high drag), guns or rockets.

It effectively produces the identical computations which are carried out by the main 920ATC, within the head-up display computer. When the 920ATC Computer is functioning in the primary mode the control of the symbol display and computation of the CCIP and CCRP points, together with the ground stabilised target marker symbols, is carried out by the 920ATC computer in the manner described on pages 17 and 18 of this document.

Physical Characteristics

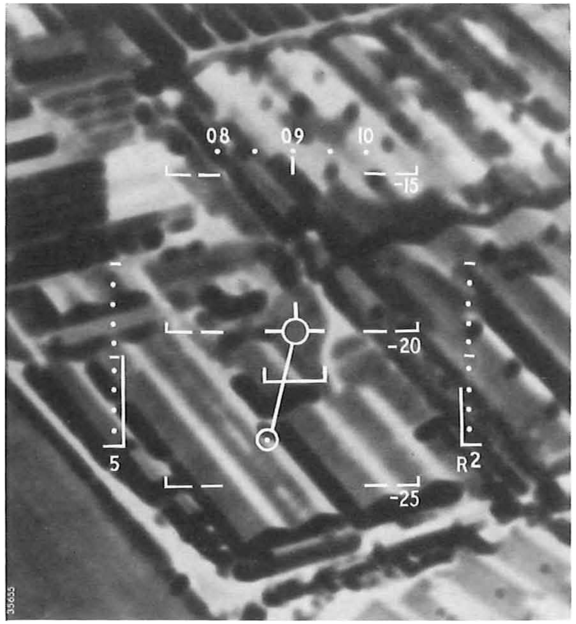
Total System Power Consumption; 353VA 3 phase
28V d.c. 102 watts

Dimensions	Width	Depth	Height	Weight
PDU	6.5″ 16.5 cm	22″ 55.9 cm	7″ 17.8 cm	35 lb (15.87Kg)
E.U.	¾ ATR short			25 lbs (11.34Kg)
ARU	6″ 15.2 cm	8″ 20.3 cm	6″ 15.2 cm	12 lbs (5.44Kg)
VCU	¾ ATR short			28 lbs (12.7Kg)
VSU	6″ 15.2 cm	9.8″ 24.9 cm	5.4″ 13.7 cm	14 lbs (6.36Kg)

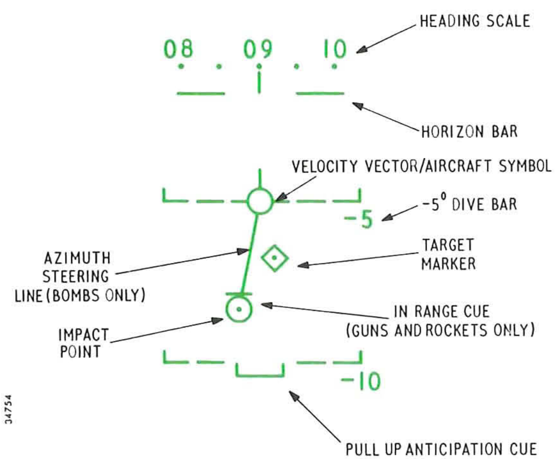
An alternate display symbology for this type of ground attack profile as used in the A4M aircraft is shown on this page.

With air to ground guns or rockets the azimuth steering line is deleted and an in-range cue appears on the impact point when the range is correct for these type weapons.

The pull-up anticipation cue is positioned with reference to the impact point and moves up as height is reduced to indicate proximity to the lowest safe height so as to be clear of bomb blast and the terrain. Should the pull-up anticipation cue become co-incident with the impact point then a breakaway cross will flash to command a pull-up.

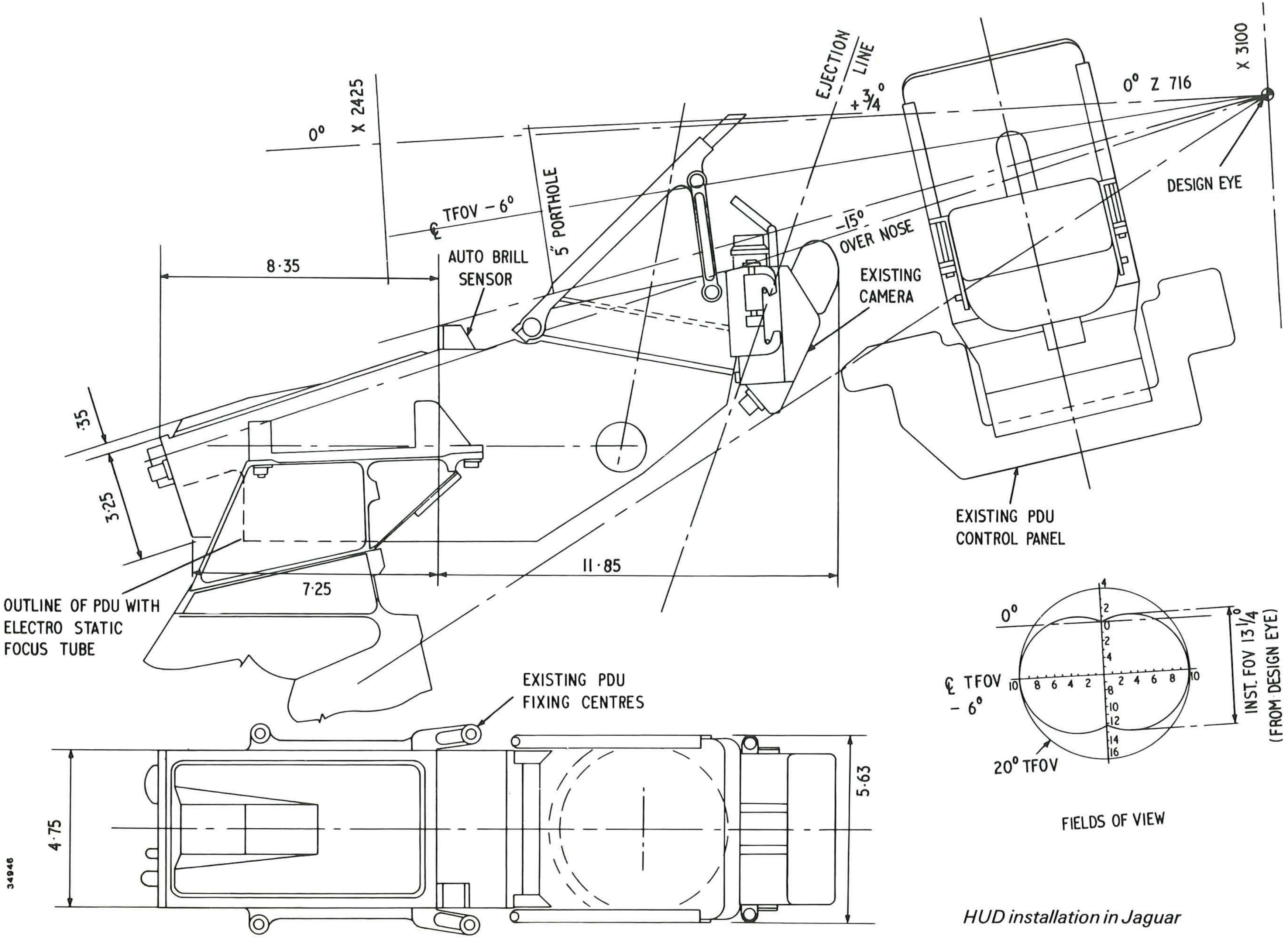


A Typical LLTV Presentation



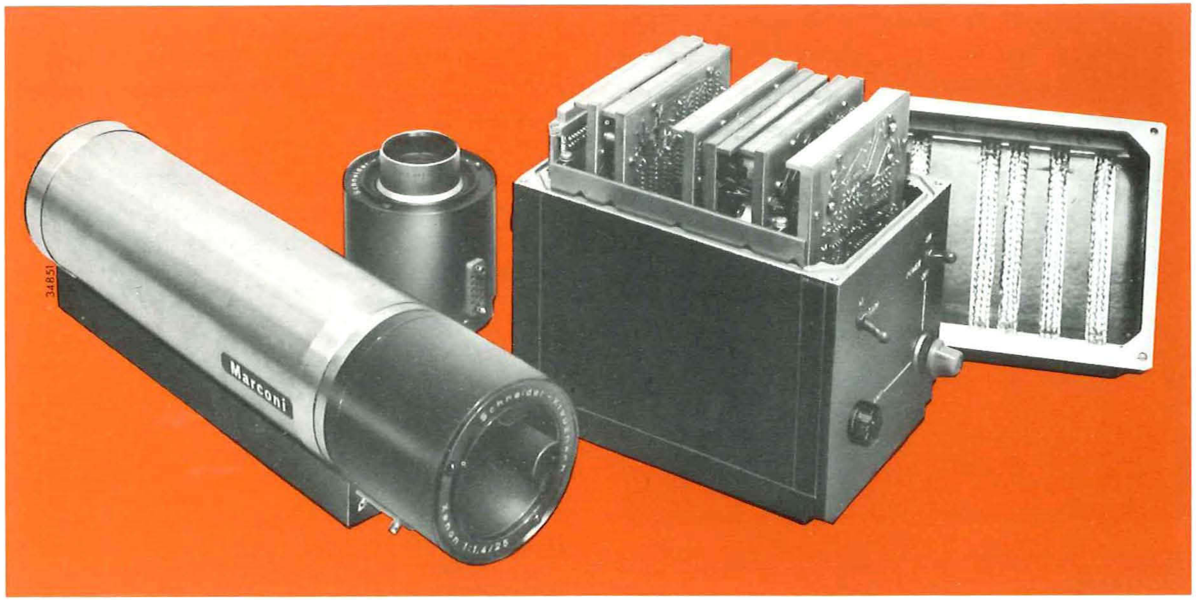
Air to Ground Symbology

Modification 3 Advanced Technology Head-Up Display Systems
continued



HUD installation in Jaguar

Modification 4
Night Vision Sensor



The Low Light Television (LLTV) sensor will be used to provide assistance with aircraft navigation and acquisition of targets under conditions of low light and at night. The installation will be based on the LLTV camera channel V324 which has been developed primarily for military applications and which is currently in production. The small size of the equipment, its auto-controlled operation as well as its ability to maintain a constant amplitude video signal output under conditions of a wide range of scene illumination levels, make this equipment particularly suitable for military aircraft installation.

The camera channel consists of two LRUs; the camera head which will be hard mounted in the forward section of the aircraft, and the Camera Control Unit (CCU) which can be located in any convenient area on the aircraft.

The camera head comprises the LLTV camera itself and the lens. In order to achieve the image resolution and sensitivity which are required in this application, the camera will be fitted with an Intensifier coupled to a Silicon Intensifier Target (SIT) Vidicon Sensor with 25mm photocathode.

This sensor combination will achieve resolution of approximately 500 lines per picture height at 10^{-4} lux on the photocathode. The camera is of cylindrical construction, with its electrical components packaged on three curved modules grouped around the sensor tube. The camera is connected to the CCU by a multicore cable with multipin connectors at each end.

In order to make it possible for the LLTV image to be used as a navigation and target acquisition aid, the camera is fitted with a lens giving approximately 20 degrees diagonal field of view. This allows the TV image to be displayed on the raster HUD on the aircraft, giving 1 : 1 superimposition with the real world.

To minimise the effects on the TV picture of aircraft induced motion and vibration which may result from low level high speed flight, the camera will be equipped with an Image Motion Compensation system. This system will provide motion compensation of up to ± 5% of picture width or height by electrical means without mechanical movement.

The CCU is housed in a light alloy case and can be fitted into a space equivalent to standard ½ ATR or ¾ ATR aircraft racking unit. All components housed in the CCU are contained on six printed boards which plug into a base or 'mother' board. In addition a test position is provided into which any one of the six boards can be plugged for service or adjustment.

The following modules form the CCU:

- Synchronising pulse generator
- Video processing amplifier
- Low voltage power supplies (double printed board)
- H.T. Generator
- Control Module.

The unit is fitted with three external connectors, namely, the camera cable connector, coaxial video signal output and 28v supply unit.

Possible positions on the aircraft for the location of the camera head are shown in figure 1 overleaf

Provisional Specification

Electrical

Input Power
28v dc to BS 2G 100 standard
Power consumption 40VA approximately

Scanning Standards
625 line 50Hz field 2 : 1 interlace

Modification 4
Night Vision Sensor
continued

Video Bandwidth
Flat to 6 MHz ± 1 db

Resolution
With ISIT sensor on high contrast test chart, at moderate light levels, approximately 500 TV elements per picture height.

Sensitivity
300 nA signal current gives 1V composite signal output.

Signal to Noise Ratio
Assuming 14pF head amplifier and target capacitance, not less than 38dB at 0.3uA Signal current. The corresponding video signal to noise ratio, including the effect of thermal and tube generated noise components will not be less than 28dB.

Scan Non-Linearity (excluding Sensor)
Not greater than ± 2%.

Gamma Correction
Preset over the range 0.6 to 0.7 or linear

Black Level Control
Automatic to picture black reference

Video Output
Nominal 1V peak to peak composite video and sync. into 75 ohms output.

Automatic Safety Circuits
Automatic shut down sequence to guard against tube damage as a result of video circuit malfunction or scan failure.

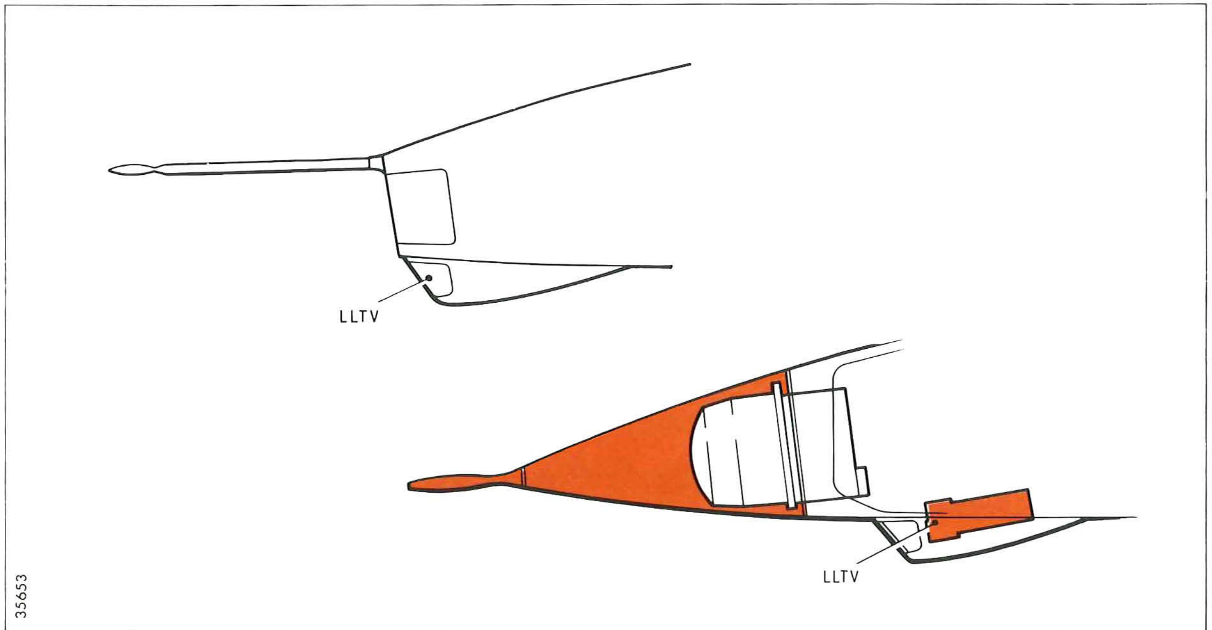


Figure 1

Environment
The equipment has been designed to meet the following environmental conditions.

Temperature

Storage	−40°C to +85°C
Operational	−20°C to +70°C

This does not include the sensor tube whose manufacturer recommended temperature limits should be observed.

Vibration
20-200Hz ± 0.001 in.
5-200Hz ± 0.040 in.

Shock
4000 bumps at 40g

Temperature cycling
−25°C to +55°C at 2°C per minute with one hour at each temperature limit.

Damp Heat
+40°C 93 ± 3% R.H.

Mechanical

Dimensions
Camera excluding lens
3.25in. diameter
16.00 in. long.

CCU
7.05in. high
4.96 in. wide
10.59in. deep (incl. connectors)

Lens
2.72in. diameter
3.75in. long

Weight

Camera	10 lbs
CCU	9 lbs
Lens	1 lb

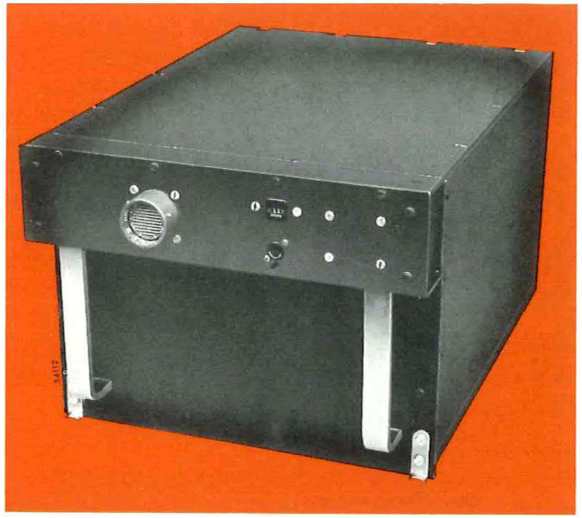
Modification 5
Improved Central Computer

The 920 Advanced Technology Computer (ATC) is an advanced concept in airborne computers. Whilst representing a significant improvement in terms of capacity, speed and flexibility over the 920M now used in the Jaguar Nav/attack system, being directly software compatible, it can use all existing 920M programs. The 920 ATC has been selected for the Sonics AQS 901 system and the Nimrod Central Tactical System which are currently under development.

Whilst retaining functional compatibility with earlier computers in the 920 series the 920 ATC introduces new features such as multi-accumulator operation, dual port access to the bulk memory and an extended hardware floating point operation. Its design makes maximum use of currently available LSI and MSI circuits. It is housed in a 1 ATR Short case which contains the central processor unit, power supply, 16 or 32K of 18 bit memory and 18 bit parallel input/output.

The 920 ATC is supported by an extensive library of input routines and Fortran and Coral compilers. The latter is the highly efficient Coral 66 level D. Application programs from other 900 series computers are available and are directly transferable to the 920 ATC.

The storage capacity and speed of the 920M Computer is adequate for the Jaguar system in its current form. At present there are three operational flight programs and one diagnostic test program. The addition of any new facilities to the system would require the compilation and issue of ''special to sortie'' progams which would increase the complexity and expense of operational system management.



It is, therefore, proposed that the 920M Computer is replaced by the 920 ATC for the Jaguar aircraft when equipped with any of the additional sensors and devices which are described in this part of the brochure.

The 920 ATC can readily integrate and manage the new systems as well as those already in the aircraft and would have the following advantages.

Integration of new sensors into existing computations and display system.

Reduction of the number of flight programs required.

Automatic Mode Control of new sensors.

Extended range of weapon ballistics including air to air and air to ground missile release envelope equations.

Improved built-in-test facilities.

Automatic mode control of new sensors.

Improved program maintainability, derived from the space capacity which would allow modifications to be embodied without the deletion of existing facilities or recompilation.

Overall programming, re-programming and amendment time and effort are considerably reduced using the Coral high level language facility and its compiler.

Quick reaction alert flight plans can be pre-programmed and called up when required.

When the 920 ATC is included in the system in conjunction with the Elliott type 664 advanced technology HUD, which has its own integral weapon aiming computer, the computing strength of the system is significantly increased giving a very high degree of system integrity and eliminating abortive missions. Duplication of the aiming calculations for some weapon modes would provide a reversionary capability equal in performance to the prime mode.

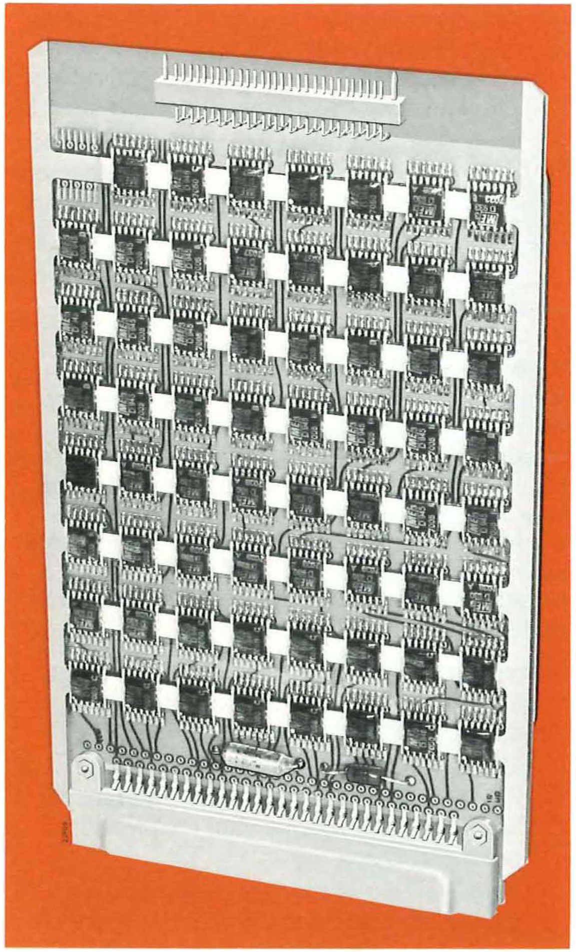
It would be necessary to provide additional interfaces for the new sensors in the existing Interface Unit from:

Those made redundant by the installation of the Type 664 HUD, the digital interface of which is much simpler than the present analogue type.

Replacement of the high power synchro output of range to the Horizontal Situation Indicator by the display of range and time to go on the NCU and/or HUD.

Reduction in size of the power supply module (PSM) because the 920 ATC has its own internal PSM whereas the 920M is supplied from the IFU.

Modification 5 Improved Central Computer
continued



A Typical Card

Functional Characteristics

Word Length
18 bits

Number Notation
Fixed point binary with negative numbers in two's complement form or in floating point with 18 bit exponent or 18 bit mantissa

Instructions
Single address instructions with address modification facility

Accumulator Stack
A stack of 64 store locations is allocated to provide multi-accumulator operation

Memory Type
Random access ferrite core memory modules integrated to provide both data and program store

Memory Capacity
16 or 32K words of internal memory with capability to directly address up to 256K word in total

Speed

Memory Access	0.35uS
Memory Cycle	1.0uS
Add/Subtract	2.4uS
Multiply	11.8uS

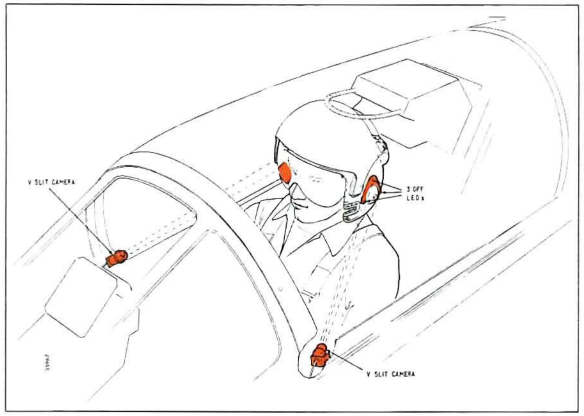
Interrupts
Four program priority levels 2 and 3 capable of handling demand from multiple sources

Input/Output
18 bit parallel peripheral i/face

Physical Characteristics

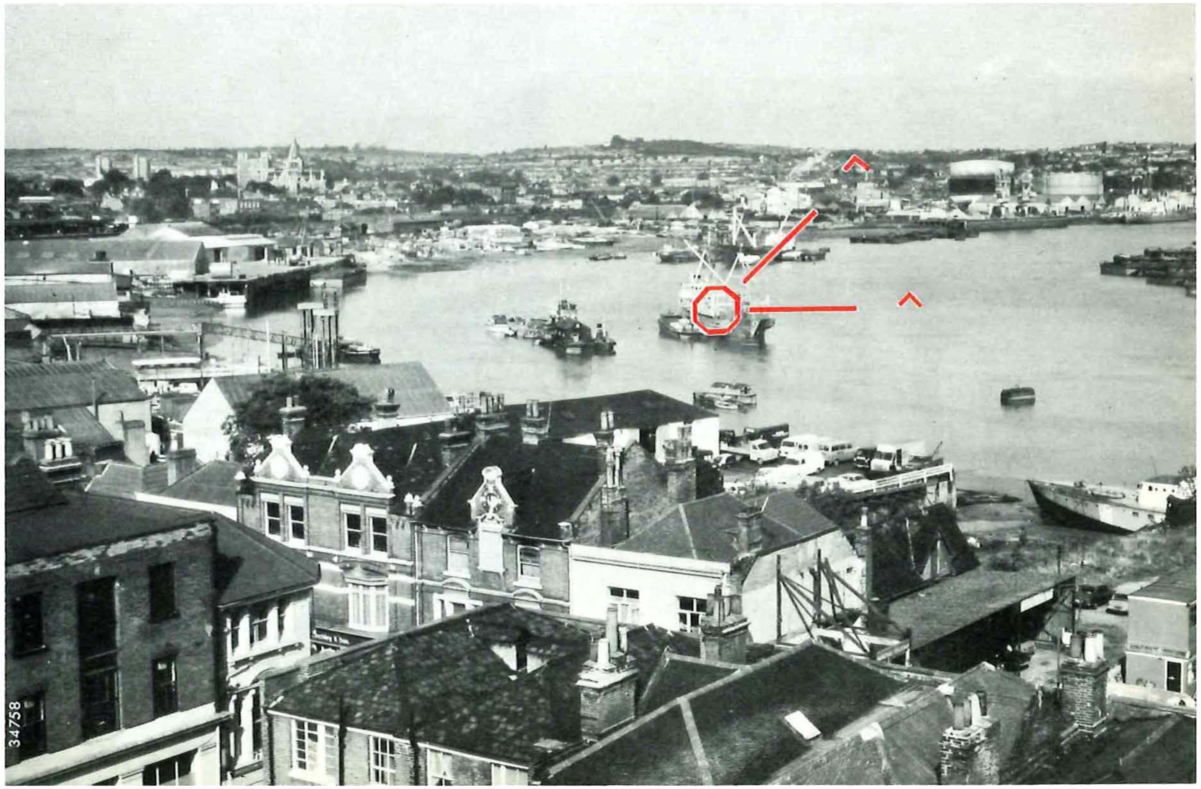
Power:	230VA of 3 phase 200V 400Hz
Environment:	Designed for the airborne environment and meets the following specifications: MIL E 5400, BS 3G 100, BS 2G 100, DEF 133
Size:	1 ATR Short (including 32K memory, Input/Output and Power Supply). 7.625 ins H x 10.125 ins W x 12.625 ins L. 19.37 cm H x 25.72 cm W x 32.07 cm L.
Weight (32K version):	35 lbs max. (15.8Kg)

Modification 6
Helmet Sight Unit



An extension to the Jaguar NAV/WASS System can be achieved by fitting a Helmet Sight Unit. This unit, which utilises either the 600 Series HUD computer or the 920 Series central computer to carry out the sight line angle computations, enables two important additional facilities to be incorporated. First, because the Helmet Sight viewing coverage is 360 degrees in azimuth, it enables target designation and navigation updates to be achieved when the particular ground feature is outside the field of view of the HUD i.e. in a fly by. Secondly, it can be used to slew radar and missile or TV seeker leads onto a target for "lock on" without having to manoeuvre the Jaguar into a bore sight or tracking situation against the target.

The Helmet Sight Unit consists of a miniature collimated optical system giving a display angle of 7 degrees. Helmet position sensing is achieved by the use of two miniature CCD devices which are fitted one to each side of the aircraft cockpit, and which detect positional changes of a LED array on the side of the helmet. The outputs from the two CCD devices are fed to the computer for processing



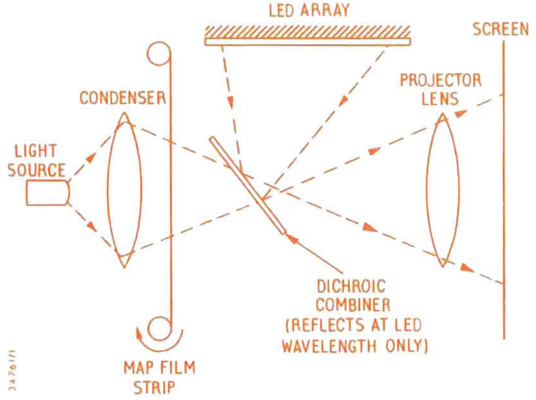
Modification 7
Projected Map Display Development

The projected map display (PMD) fulfils an essential role in navigation under high workload conditions. However, it cannot at present, be marked with flight plan details or with last minute information as can the hand held map. In some operations this can be a restriction. Development of the projected map display is, therefore, continuing with the following objectives:

To permit annotation of the map with flight plan data and other desired information.

To permit entry of data into the system during flight.

These objectives apply to conventional projected map displays and also to systems which present horizontal situation information on a multi-mode cathode ray tube.



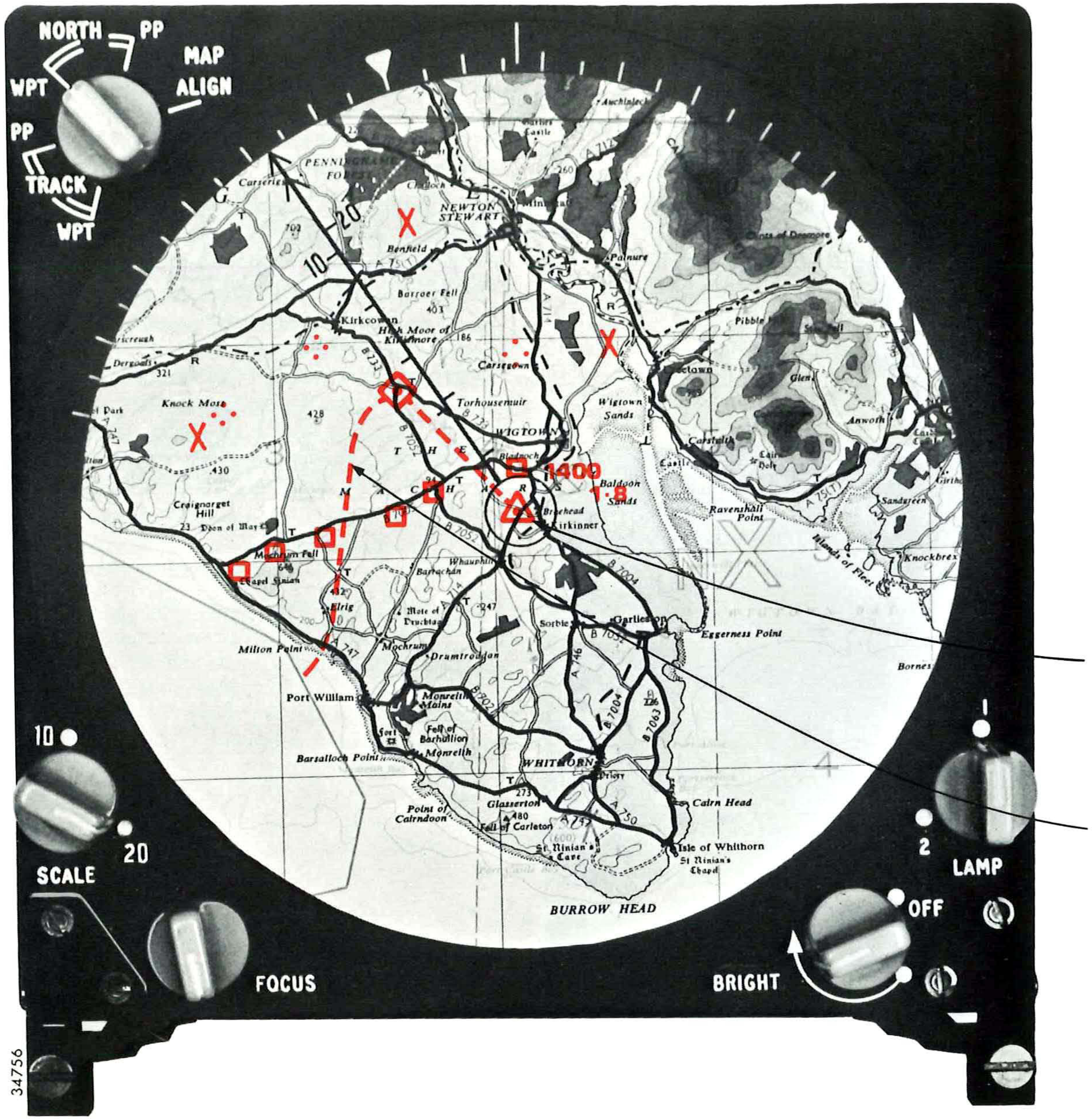
Light Emitting Diodes (LED) can be used to put symbols, lines or alphanumerics onto the projected image of a map. The LED is a small, rugged, light source which can be constructed by monolithic diffusion techniques in either fixed symbology or matrix addressable forms.

Practical extensions of present day techniques permit some 40,000 diodes to be put in a square matrix of approximately 2 inch side with 100 diodes to the inch resolution. The cost of the matrix is relatively low on a production basis and the array is likely to have a useful life of the order of 40,000 hours when operated at brightnesses in the region of 2-3,000 ft. Lamberts.

The matrix is positioned on the inside wall of the P.M.D. and a Dichroic Combiner is placed between the light source and the lens in such a position that it reflects any images, constructed by the LED display, onto the PMD screen face.

Symbols are called up on the matrix by the computer so that, with either scale selected, they appear in the correct position on the projected map regardless of whether the map is moving or stationary. Such symbols can show defences by position and type, required tracks between any two places (such as I.P. and target), and flight plan or weapon availability data.

The installation of radar and night sensors does not mean that the PMD must be replaced by the radar or night sensor screen. The PMD, with its valuable overwrite facility, can be retained if the Marconi-Elliott Type 664 HUD, which has provision for displaying radar and LLTV/FLIR displays, is fitted.



Symbology and positioning of flight plan information will be standard. For example typical displays could be:

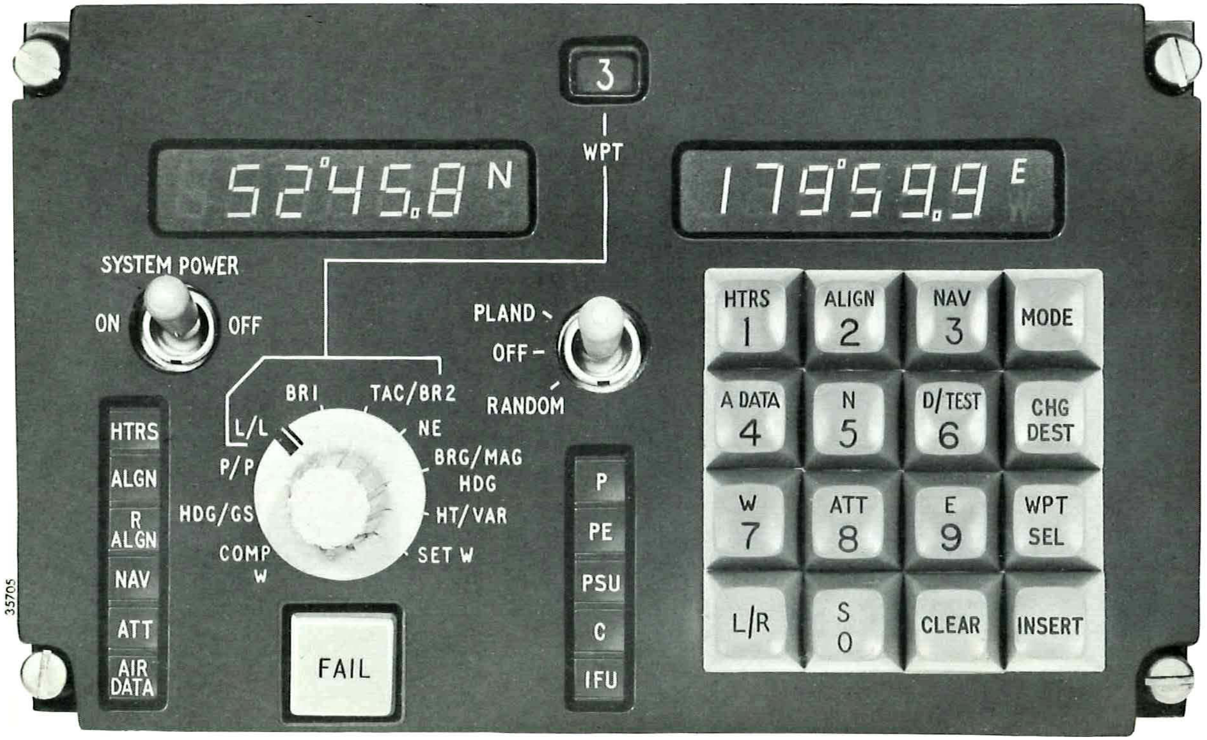
1400	–	Planned time to be at destination, waypoint or I.P.
□	–	Friendly position
⁛	–	Gun position
△	–	I.P.
– – –	–	Track, in this case from I.P. to target and planned escape route.
V	–	Regress Waypoint
X	–	SAM site
1·8	–	Minutes from I.P. to target (Alongside Map Centre)
◇	–	Target
Λ	–	Target of Opportunity (Automatically recorded at time of attack)

Modification 8
Keyboard Navigation Control Unit

For the operator who prefers to insert data by means of a keyboard, an NCU with 16 keys can be provided. The keyboard NCU permits data to be inserted more rapidly than is possible with the hand controller, although the hand controller must still be retained for use with the Projected Map Display and Head-Up Display.

With the 920 ATC Computer in the system, the amount of additional data capable of being processed could make a keyboard desirable. An example of such a keyboard NCU is shown.

Function selection would be by switch as with the present NCU. Mode selection would be achieved by pressing the "Mode" key and then a numeral key, the number of which represents the required mode in order of normal selection, for example 1=Heaters, 2=Align. A "Clear" button is provided to eradicate incorrectly selected data or mode.



Modification 9
Terrain Clearance Altitude Director and Monitor System

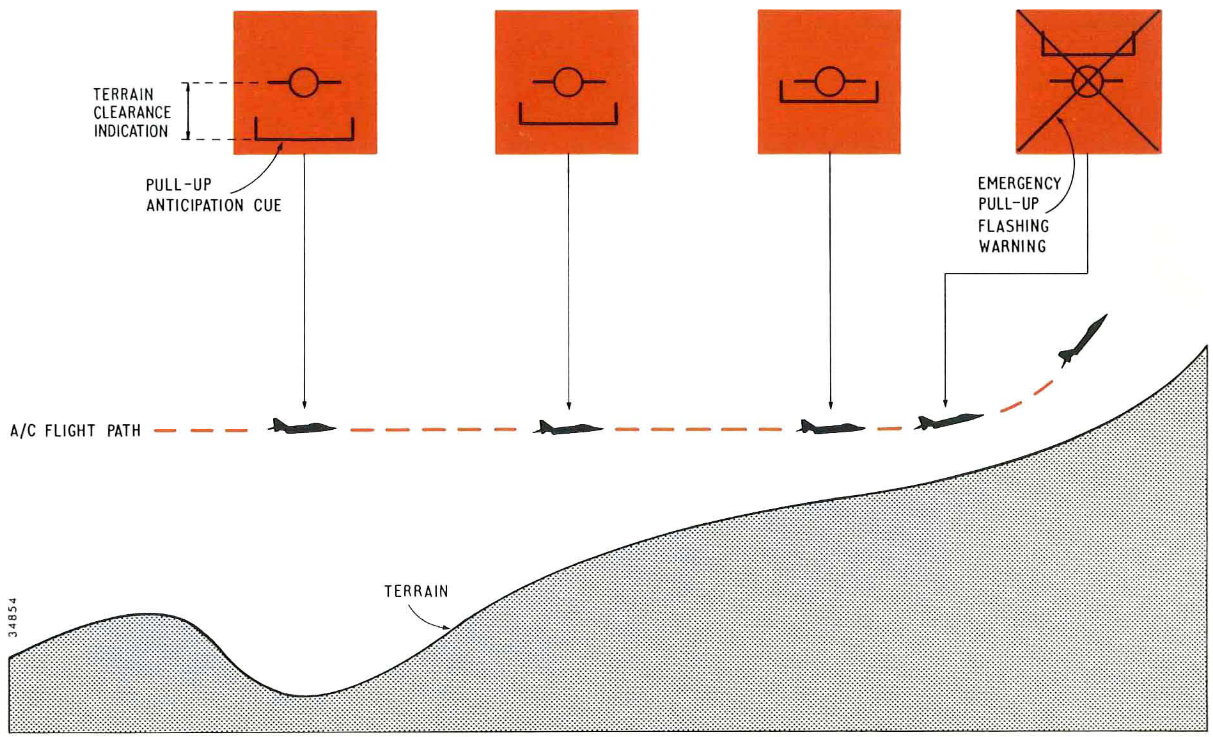
Improvements in ground based anti-aircraft defences make it necessary for aircraft employed on air to ground operations to fly as near to the terrain as is consistent with aircraft mission effectiveness requirements and safety.

The Clearance Altitude Director and Monitor System (ADAM), whilst not achieving the full capability of an auto Terrain Following System does allow the aircraft to be operated at night and in all weather conditions closer to the ground with a higher degree of safety than would otherwise be the case and by relieving the pilot of at least part of the workload associated with manual low altitude flying, helps to improve his over all operational performance.

The system provides the pilot, via his Head-Up Display, with a Flight Director giving pitch guidance to enable the aircraft to follow terrain undulations within a pre-set clearance height band, and with a Clearance Altitude Monitor, which provides both pull-up anticipation and pull-up warning information.

The system has been designed to take the utmost advantage of equipments installed in existing aircraft so that retrofit to include an ADAM facility would be relatively simple.

Flight Director
Basic System
Complementary filtered height information derived from the radar altimeter and Air Data Computer is used to provide control to a pilot selected clearance height, the control laws for which include terms to compensate for differences in terrain ruggedness which occur between different areas of an operating region. This technique overcomes several of the performance limitations which would otherwise result from the system's inability to sense terrain ahead and allows a smooth flight over cliffs and ridges whilst preventing excessive ballooning over peaks. In essence, the Flight Director in its basic form provides guidance to control the aircraft to follow the terrain undulations within an altitude band which is optimised for each region. The effective use of regional compensation in the manner proposed is possible because the accuracy of the existing navigation system enables the aircraft's position with respect to terrain defined regions to be known to a high accuracy.



Modification 9
Terrain Clearance Altitude Director and Monitor System
continued

Altitude Monitor
Basic System

This monitor assists the pilot to achieve a high level of safety when the aircraft is operated at low altitudes, both with and without the Flight Director engaged. It presents graded pull-up anticipation information on the HUD when the aircraft enters a height band which the system assesses as a potentially hazardous operating zone and which finally culminates in a flashing pull-up warning signal when a minimum safety ground clearance zone is penetrated.

Basic System Configuration

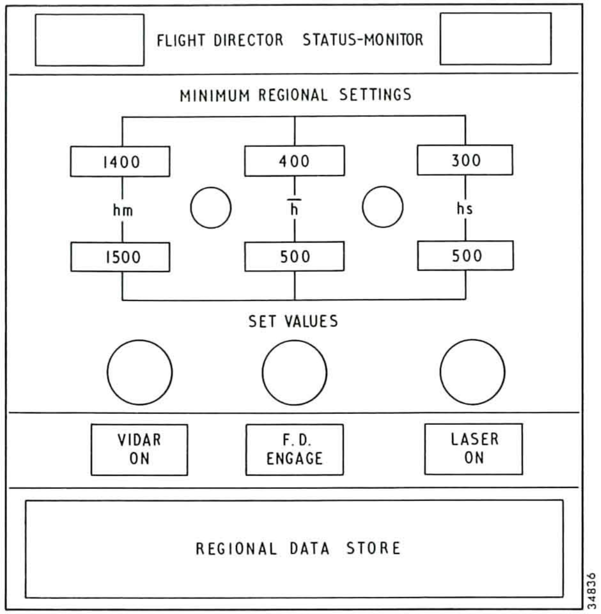
The data processing required by both the Flight Director and Altitude Monitor will be performed in the Nav Attack Computer and all the additional equipment required to implement the basic system will be housed in a single Display and Control Unit (DCU).

Regional terrain data is loaded into the system by insertion into the DCU of a pre-programmed Regional Data Store Module, the data applicable to the current part of the region being displayed on the DCU and is automatically fed into the system. Controls are provided to allow the pilot to select higher set values than the minimum extracted from the data store, but selection of lower values is inhibited. A flashing light, with a cancelling facility, gives warning of a change in set values. This light may be duplicated at a position close to the pilot's normal field of view.

System Extensions

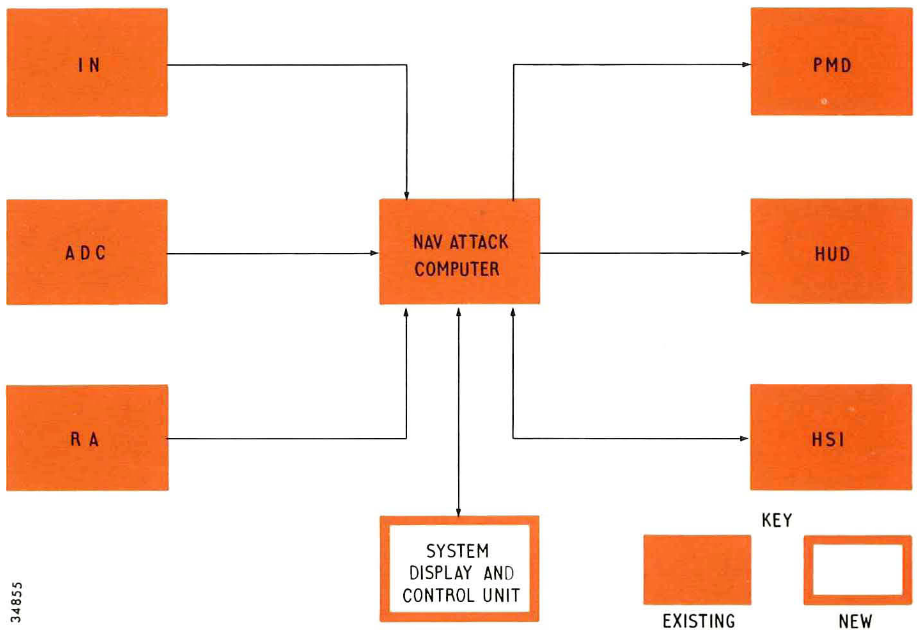
The performance of the basic system can be enhanced by the use of automatically derived information of the range and inclination of the sky line ahead obtained directly from the aircraft's television or forward looking infra-red sensors, or by using terrain ahead information derived by the laser ranger. This improves the terrain following capability of the system as well as its safety monitoring.

Display and Control Unit ▶

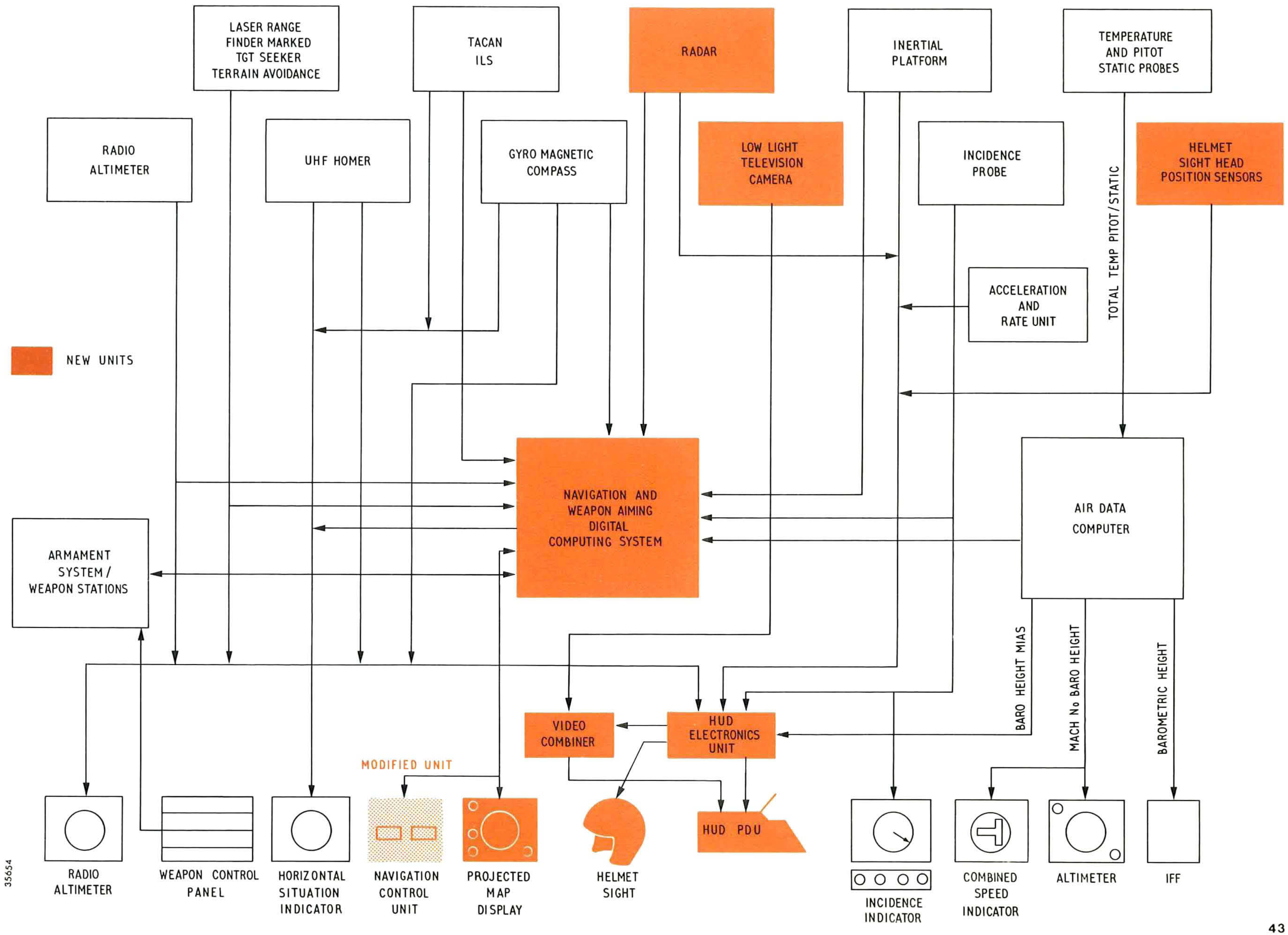


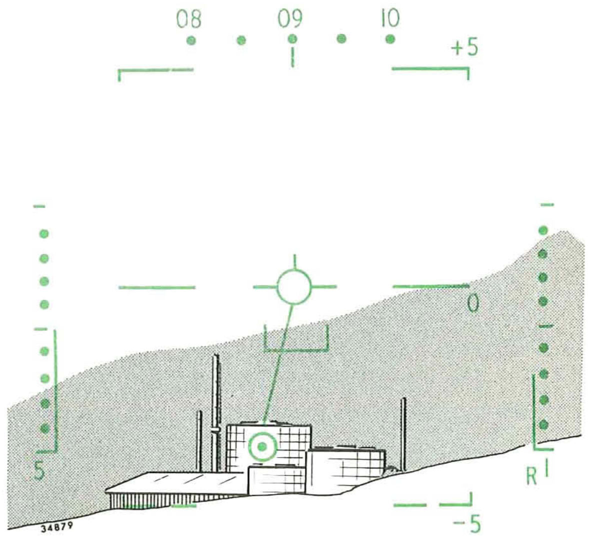
A Regional Situation Display can be provided on the Projected Map Display which presents a plan view of the region being overflown, together with minimum setting contours. The relative position of an aircraft present position and course symbol to the contours provides an anticipation of change of minimum setting, whilst contour shading gives an indication of the sense of the next change.

An independent emergency pull-up warning can be provided either in the Head-Up Display or in a separate location on a glare shield. This gives significant protection against collision with the ground even if the primary ADAM system has failed.



Advanced Avionics Block Diagram of System with all Options Incorporated

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