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The F-16 Head-Up Display System

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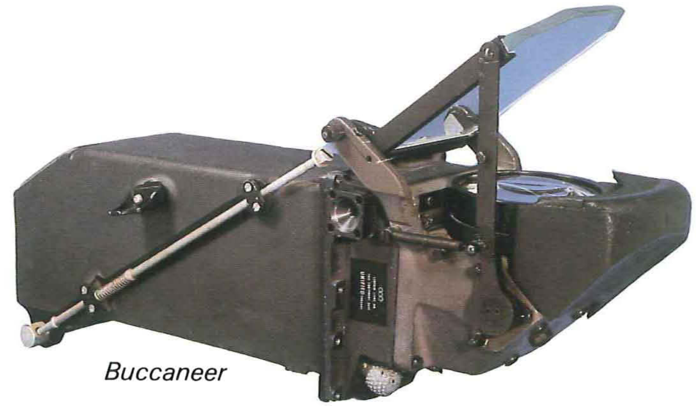
A MOST DISTINGUISHED ANCESTRY

The F-16 HUD is the latest of a long line of Marconi Avionic Head-Up Displays which originated in 1960 with the first production, CRT based, Strike Sight for the Buccaneer aircraft. This sight proved so valuable operationally that the concept of presenting vital aircraft flight parameters in a 'head up' form gained widespread acceptance. Since then more than 3,500 HUDs for over 30 different aircraft types have been produced by the Company, including the first operational all digital system for the USAF/USN Vought A-7D/E Corsair II.



Buccaneer

A-4M

A-7D/E

F-16

Marconi Avionics pioneered the development of the self contained HUD weapon aiming computing system (abbreviated to HUD/WAC) and several advanced concepts including the electronic tracer gunsight. Systems of this type have been produced for the USMC A-4M and the General Dynamics prototype YF-16. This unmatched background of operational experience contributed strongly to the design of the F-16 HUD, the most advanced in production today.

A Well-Bred Flight Instrument

THE PRIMARY FLIGHT INSTRUMENT

The Head Up Display dominates the F-16 instrument panel. Its relative size and primary position in the cockpit reflect its importance to the pilot as a primary aid in his demanding task of flight and weapon system management.

The HUD provides a link between him and his on-board sensors and computers which enables him to perceive and act on all the information required for an effective mission without looking down from the real world situation with which he is confronted. With the display focussed at infinity and centred in his forward field of view he can study the terrain over which he is flying and remain alert for any threat situation which may develop while continually being made aware of vital flight and mission parameters by his display.

By means of his mode selector panel and stick mounted controls he can select the operational mode most suited to his immediate situation. The HUD then presents the parameters required by that selection as electronically derived symbols designed to provide the maximum assistance to the pilot with the minimum amount of display clutter.

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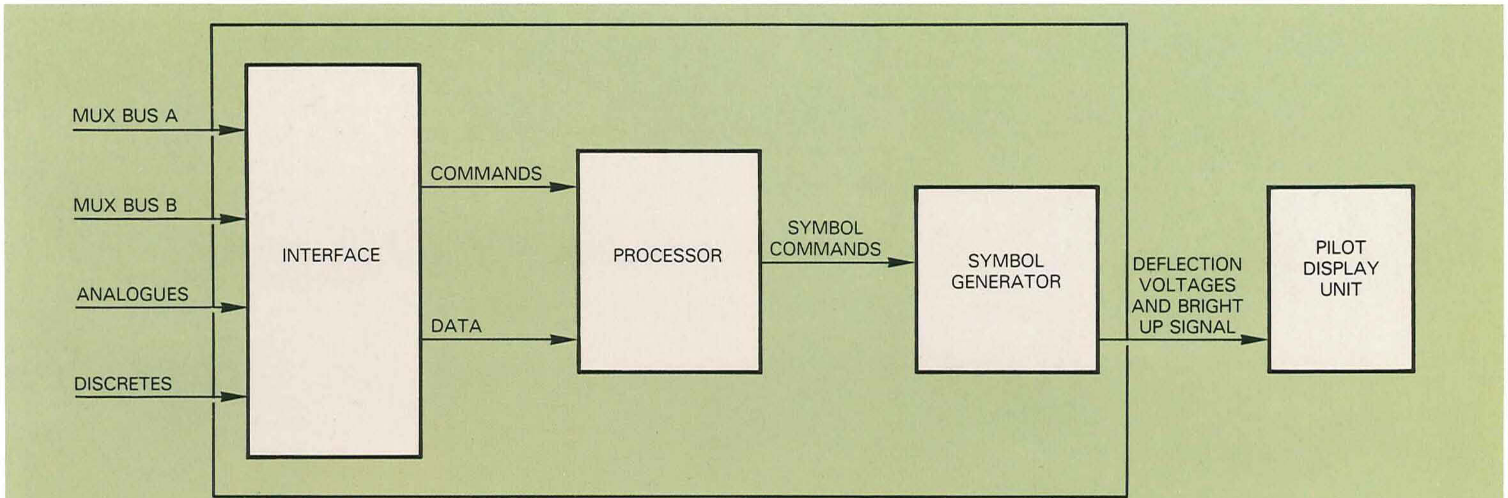
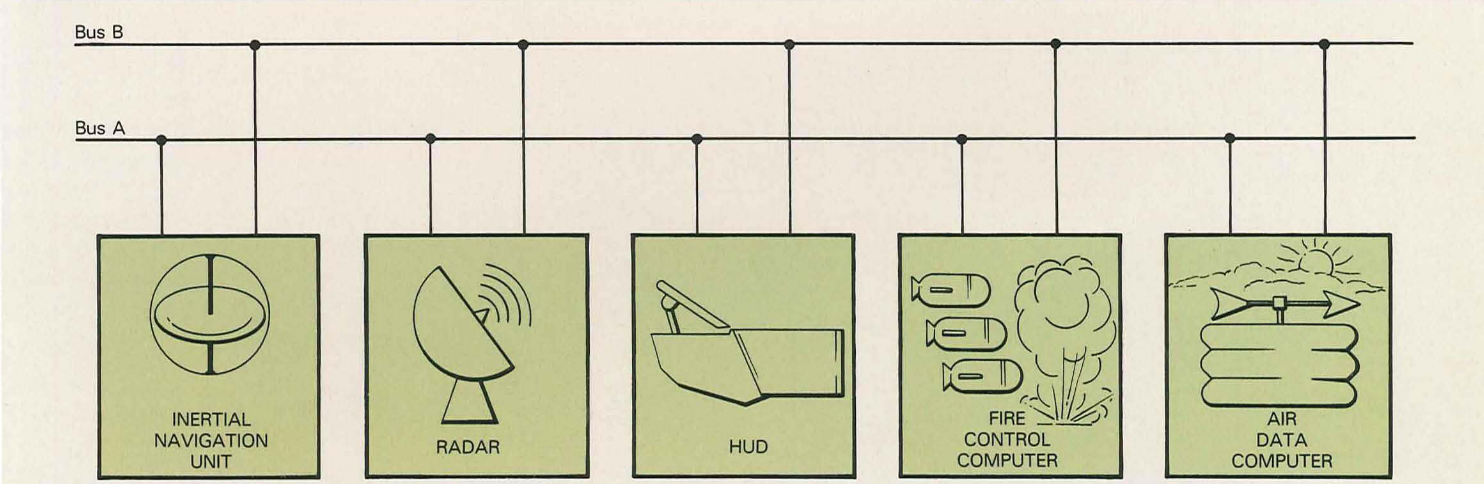
The display set is activated by input signals received from other systems and sensors of the airplane avionic network. These input signals are the information source relating to attack, navigation, weapon aiming and landing modes and also to essential airplane flight information including altitude, airspeed, pitch, roll and heading. The role of the display set is to process these signals and generate the symbols necessary to provide the pilot with a visual display of information appropriate to the mode of operation.

The inputs can be received in digital, analogue or discrete form but by far the greatest amount of data arrives as digital signals via one of the two aircraft digital multiplexed bus lines (MUXBUS). The MUXBUS provides a digital data highway on which information can be passed to or from the individual systems to which it is linked. Its use obviates the necessity for the vast number of dedicated data lines which it replaces.



HUD Set-Block Diagram



Major MUXBUS Connections

With Excellent Connections

Pilot's Display Unit

The Pilot's Display Unit (PDU) contains three functional groupings, the cathode ray tube (CRT) assembly, the optical module and the control panel all mounted on a rigid chassis. The chassis itself contains a number of electronic components, power supplies for the CRT and standby sight, video drive circuits, video protect circuits and autobrilliance controls.

The CRT provides the means whereby the electronic signals representing the display symbology are converted to a visual form for presentation to the pilot. The CRT assembly includes the CRT itself, the CRT deflection coils, a small matching circuit to compensate for minor variations in individual CRTs and a magnetic shield to eliminate electro-magnetic interference problems.

The optical module projects a collimated display of the imagery created on the CRT face directly into the pilot's forward field of view. It consists of two main components, the lens assembly and the combiner assembly. The lens system is a 5″ grouping which directs the image produced by the CRT onto a mirror which deflects it 90° through the final lens components onto the combiner glass. The combiner is a glass plate made extra strong to withstand aerodynamic loads in a canopy-off situation which superimposes the CRT imagery on the pilot's view of the real world. Also included in the optical module are facilities for the injection of a standby sight which is entirely independent of the main electronic circuitry.

The control panel is attached to the front of the optical module and provides off/on switching, brilliance control, day/night selection, standby sight controls, night filter control, camera control, wingspan control, speed selection control and declutter facilities. Mode selection is performed on the Stores Management Panel.

Rate Sensor Unit

The Rate Sensor Unit (RSU) contains the rate gyros and associated electronics necessary to produce the outputs of pitch, yaw and roll rates together with normal acceleration which are required for accurate air to air weapon delivery. The unit contains its own power supply and self test facilities and is linked to the remainder of the system through a single connector.

Electronic Unit

The Electronic Unit (EU) is the brain of the HUD system. It is a small digital computer optimised for its specific function and, as such, possesses all the advantages inherent in digital systems. It employs a 16K, EPROM memory which enables programme alterations to be effected with no changes in system hardware. It provides extensive self-testing facilities and its own dedicated analogue to digital circuitry.

It accepts inputs of aircraft data either in analogue form or as digital numbers from the aircraft digital data distribution bus together with discrete inputs from dedicated circuits and converts these to a digital form acceptable to the processor section. The processor section performs the necessary arithmetic to convert these signals into demands on the symbol generator section. The symbol generation section in turn converts these demands into analogue output signals which serve to drive the deflection coils of the CRT.

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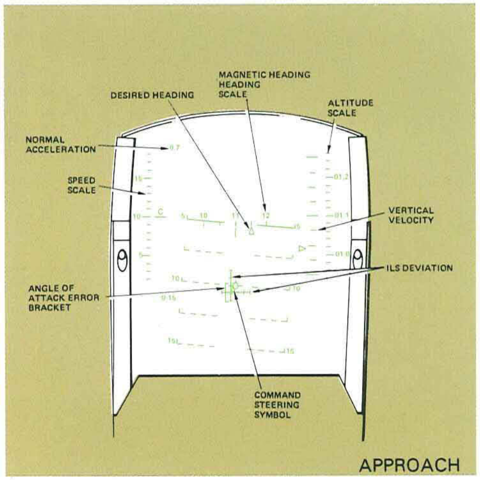
The basic flight reference symbology for the F-16 Head-Up Display system provides the pilot with a concise, comprehensive indication of the state of the aircraft. The accompanying illustrations of typical symbologies for navigation and approach modes indicate the format of the display for non weapon delivery modes.

For Efficient Flight Management



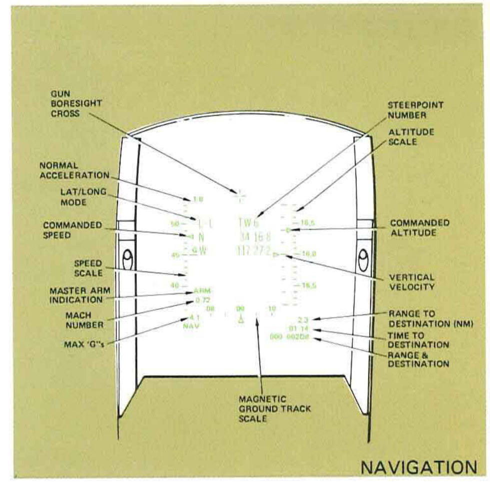
APPROACH

- **Speed scale**
  Moving tape scale on left-hand side of display.
  Numerals represent tens of knots
  Pilot selectable display of groundspeed (G), true airspeed (T) or calibrated airspeed (C).
- **Altitude scale**
  Moving tape scale on right-hand side of display.
  Numerals represent hundreds of feet
  Barometric altitude displayed (plus radio altitude for European F-16).
- **Heading scale**
  Horizontal tape.
- **Vertical velocity scale**
  Inertially derived vertical velocity displayed in the range ±2000 ft/min.
- **Velocity vector**
  Inertially derived
  Pilot selectable drift cut-out facility.
- **Climb/dive display**
  Inertially derived, referenced to velocity vector symbol.
  Bars present pilot with indication of aircraft climb and roll.
  Bars displayed at 2.5° intervals geared 1:1 with outside world for Climb <60° and 2:1 for Climb >60°
  Backup pitch display referenced to gun boresight cross.

Additional flight reference information is given in the form of numerical readouts as follows:

Displayed below airspeed scale

- ARM, ILS or SIM indicating master arm selected, ILS selected or simulated weapon delivery
- Mach number readout
- Maximum 'g's available
- Mode mnemonic



NAVIGATION

Displayed below altitude scale

- Range to go
- Time to go
- Compacted display of range to steerpoint and steerpoint number

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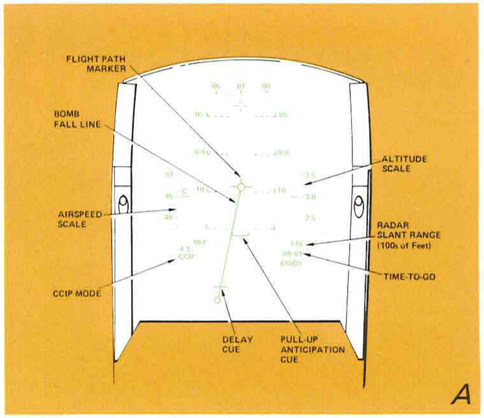
The F-16 HUD processor provides the pilot with air-to-ground aiming sights, steering commands and cues derived from algorithms mechanised in the Fire Control Computer. The flexible nature of the air-to-ground symbology mechanisation allows a large growth capability for any of the air-to-ground modes under the control of the FCC.

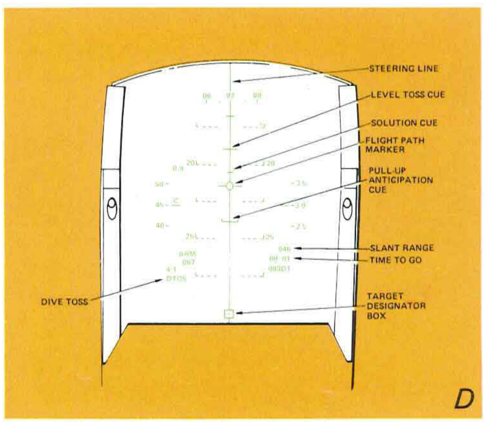
The accompanying illustrations provide a selection of air-to-ground modes which illustrate the F-16 HUD symbology.

Devastating Ground Attack



CCIP MODE *A*

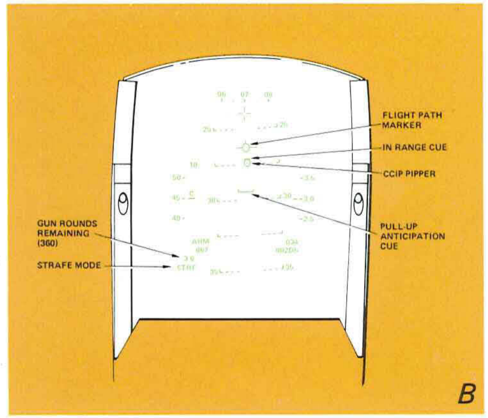
- **Aiming symbol**
  Computed weapon impact point. Pilot depresses weapon release push-button when aiming symbol overlays target.
- **Pull-up anticipation cue**
  Ground and fragmentation avoidance indicator. Impending breakaway indicated by proximity of PUAC and velocity vector.
- **Bomb fall line**
  Links velocity vector and aiming symbol.
- **Weapon release**
  Indicated by flashing velocity vector.



STRAFE MODE *B*

CCIP aiming symbology used, weapon release effected by trigger on side stick controller.

- **In-range cue**
  Appears when slant range to target is less than 4,000 ft.

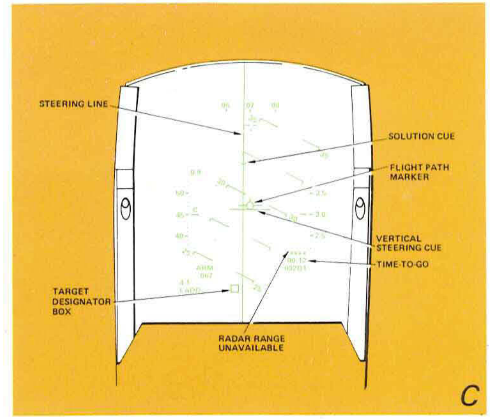


DIVE-TOSS MODE *D*

- **Target designator box**
  Enables pilot to designate target manually. Following designation, symbol is ground and velocity stabilised on target.
- **Steering line**
  Pilot steers to keep velocity vector centred on steering line.
- **Solution cues**
  This mode provides the pilot with cues prior to automatic weapon release.

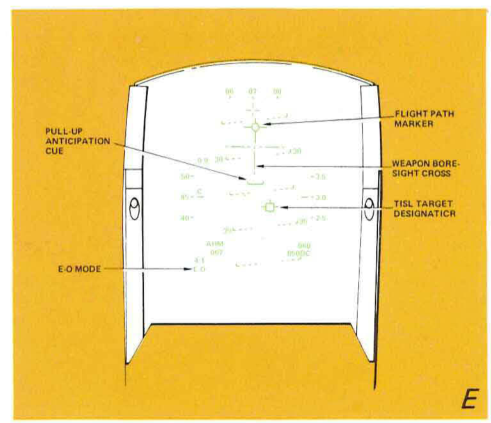
ELECTRO-OPTICAL (EO) MODE *E*

- **E-O reticle**
  Provides pilot with indication of E-O weapon sightline.
  Pilot steers E-O weapon over target and designates.
- **TISL target designator**
  Provides the pilot with an indication of the position of a target as designated by the Target Identification Set, Laser.



LOW ALTITUDE DROGUE DELIVERY (LADD) MODE *C*

- **Target designator**
  Provides target position information Positioned to selected steerpoint or markpoint co-ordinates.
- **Steering line**
  As for dive toss mode.
- **Vertical steering command bar**
  Used in conjunction with steering line to provide pilot with fly-to information for pull-up.
- **Solution cue**
  Provides pilot with cue for pull-up and release. Pilot selects pull-up range for safe escape given the weapon used. Cue provides time-to-go to pull-up initiation.



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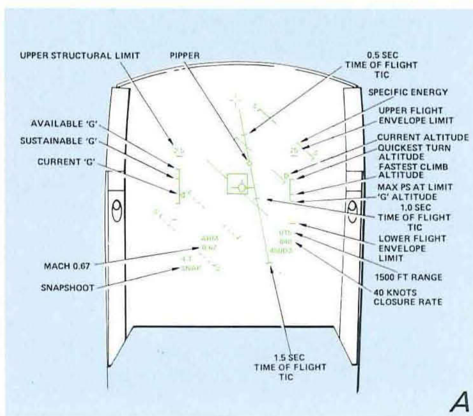
Air-to-air symbology is divided into four basic weapon delivery modes enabling both gun and missile firing. In all air-to-air modes, Energy/Management (EM) scales may be selected in place of the airspeed and altitude scales, these are represented for Snapshoot mode in the accompanying figures.

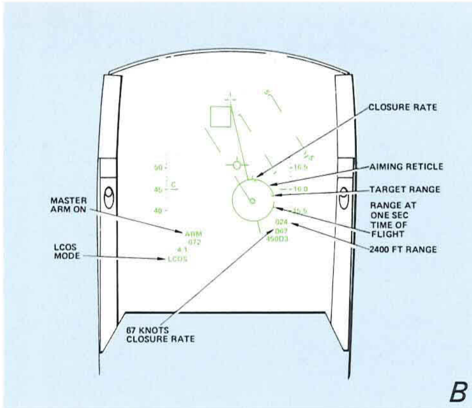


And Supremacy In Air Combat

SNAPSHOOT MODE *A*

Provides the pilot with a gunnery solution optimised for transient firing opportunities using a continuously computed impact line (CCIL) derived from the lead angles computed for fixed bullet times of flight. The aiming pipper is interpolated onto the line at the time-of-flight derived from target range.

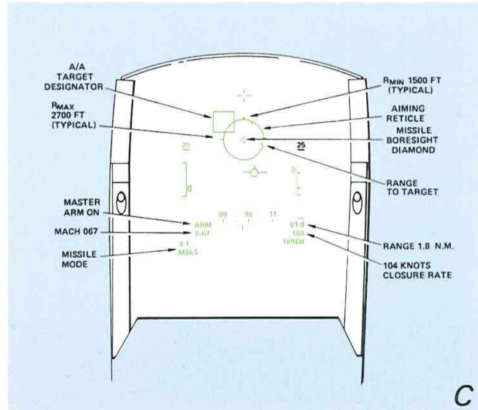
- **E/M symbology**
  Provides cues for pilot to maximise air-to-air combat performance.
  Left-hand scale displays acceleration cues.
  Right-hand scale displays altitude cues.
- **Structural limit**
  Represents limit normal acceleration for currently configured aircraft structure.
- **Max available 'g's**
  Indicates maximum normal acceleration that can be achieved on a non-sustained basis.
- **Max sustainable 'g's**
  Represents maximum normal acceleration that can be sustained.
- **Normal acceleration**
  Current 'g's reference.
- **Specific energy**
  Numeric readout in thousands of feet of normalised energy height (sum of potential and kinetic energies).
- **Energy rate**
  Normalised rate of change of specific energy.
  Pointer is horizontal for constant specific energy.
- **Upper and Lower Flight envelope limits**
  Flight envelope boundaries at aircraft specific energy form scale boundaries for altitude cues.
- **Altitude for quickest turn**
  Altitude for smallest radius level turn at current specific energy level.
- **Altitude for fastest climb**
  Indication of altitude where the maximum energy rate can be effected at unit load factor.
- **Max Ps at Limit 'g'**
  Representation of altitude where the maximum energy rate can be effected at limit load factor.
- **Current altitude**
  Current altitude reference.



LCOS MODE *B*

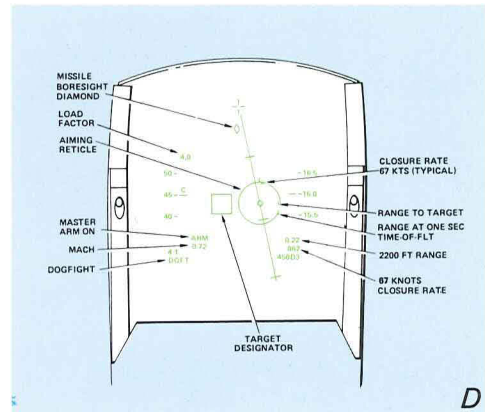
Provides a gunnery solution for smooth tracking of the target. The lead angle calculated on the basis of the range (radar or stadiametric) to the target is used to position the aiming pipper which forms the basis for associated symbology.

- **Aiming reticle**
  Circle surrounding aiming pipper.
  Size fixed for radar ranging or computed from pilot selected wing-span for stadiametric ranging.
  Reticle joined to gun boresight cross by the bullet line.
- **Range indicator**
  Presents pilot with easily readable range indication.
- **Range at one second time of flight indicator**
  Time of flight tic moves around circumference of circle.
- **Closure rate indicator**
  Indication of rate of change of target range.
  Symbol is arrow head pointer which moves around reticle circumference.
- **Air-to-air target designator**
  Indicates target location.
  Symbol displayed only when radar ranging available.
  Symbol dashed when radar in COAST mode.
  Symbol replaced by target locater line when outside HUD field-of-view.



AIR-TO-AIR MISSILES (AAM) MODE *C*

- **Missile boresight diamond**
  Provides indication of the missile seeker line-of-sight.
  Seeker is slewable by HUD using commands signals from Fire Control Computer.
- **Aiming reticle**
  Provides basis for missile launch cue symbology.
  Range displays.
  Reticle size is a function of missile selected and whether that missile is uncaged.
- **Launch zone cues**
  Provide the pilot with missile launch opportunity cues.
  The boundaries of the dynamic missile launch zone (R_{MIN} and R_{MAX}) are displayed when the radar is locked and tracking the target.
  When target range lies within the launch zone boundaries, the reticle and associated cues flash to indicate a launch opportunity.



DOGFIGHT MODE *D*

This mode represents an amalgamation of Snapshoot and LCOS modes with the following provisos.

- Range indication as for LCOS mode.
- Seeker showing function available and missile boresight diamond is displayed.
- LCOS track-line not displayed.
- Aiming reticle centred on LCOS solution.

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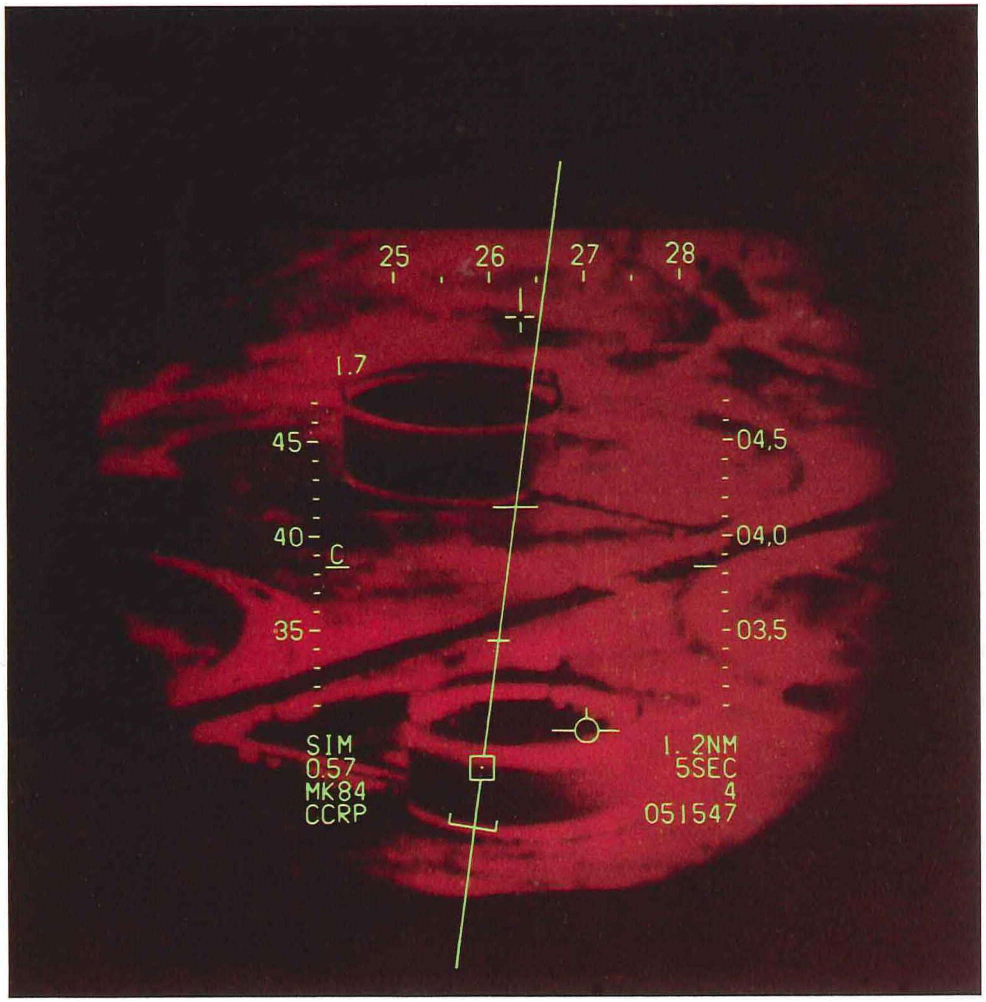


GROWTH CAPABILITY

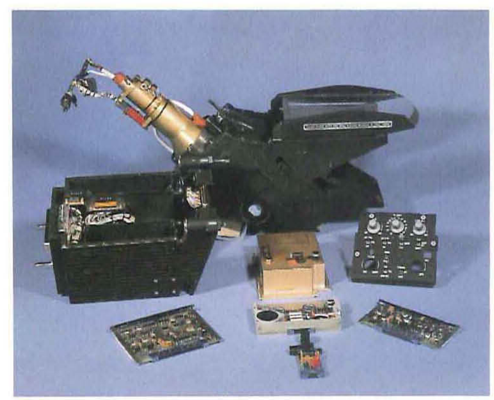
The F-16 is designed with an eye to the future and as such has provision for extended capabilities as new requirements arise. It can, for example, be modified to provide a dual mode day/night display in which the normal day stroke-written symbology is compatible with a raster scan providing an overlay of radar, low-light TV or forward looking infra-red imagery. The modification required for such an expanded capability can be achieved entirely by internal electrical changes in the EU and PDU and requires no extra LRUs or changes in the basic system architecture.

Other advanced features are continuously under development to ensure that the F-16 HUD retains its leading position as the pilot's most important aid in this important 'fighter pilot's aircraft'.

RELIABILITY

The F-16 HUD is designed for reliability through careful attention to detail in the entire process from engineering design through parts procurement, production and inspection to final delivery. This insistence on quality at every stage of the manufacturing process enabled the F-16 HUD to easily meet the requirements of the Reliability Improvement Warranty/Mean Time Between Failure Guarantee Programme. Predicted MTBF for the mature system is now 870 hours.

In service operational availability is further enhanced by the extensive built-in-test equipment (BITE) which enables front line flight crews to check out equipment, isolate and replace faulty LRUs and recheck equipment as part of a normal pre-flight inspection.



From An Adaptable And Reliable HUD

OPTIMUM MAINTAINABILITY

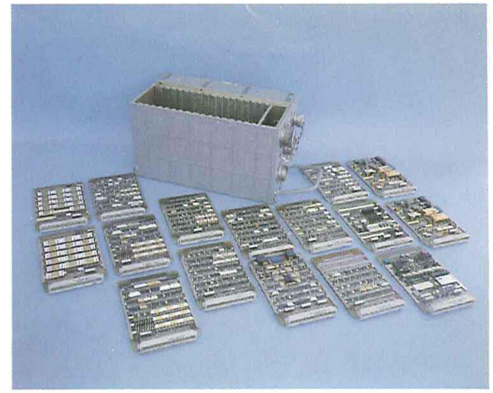
The F-16 HUD design incorporates the specific maintainability feature developed through the unparalleled experience of Marconi Avionics in the development of flight-worthy head-up displays. It is designed for simplified maintenance and low overall logistic support costs by providing a high level of diagnostic capability and complete interchangeability of LRUs without the need for calibration or major adjustment.

The low failure rate of individual electronic components and the integrated modular design of each LRU makes the F-16 HUD set far more suitable to 'on condition' maintenance procedures than it would be to any form of cyclic 'preventative maintenance' schedule. The basic maintenance design philosophy implemented by MAv is, therefore, one of as-required maintenance applied at the various task levels as follows:

Organisational Level
'On aircraft' maintenance by operation of the built-in-test (BIT) facilities to isolate a defective LRU, to replace it and subsequently recheck it. At this level no special Aerospace Ground Equipment (AGE) or specialized skills are required.

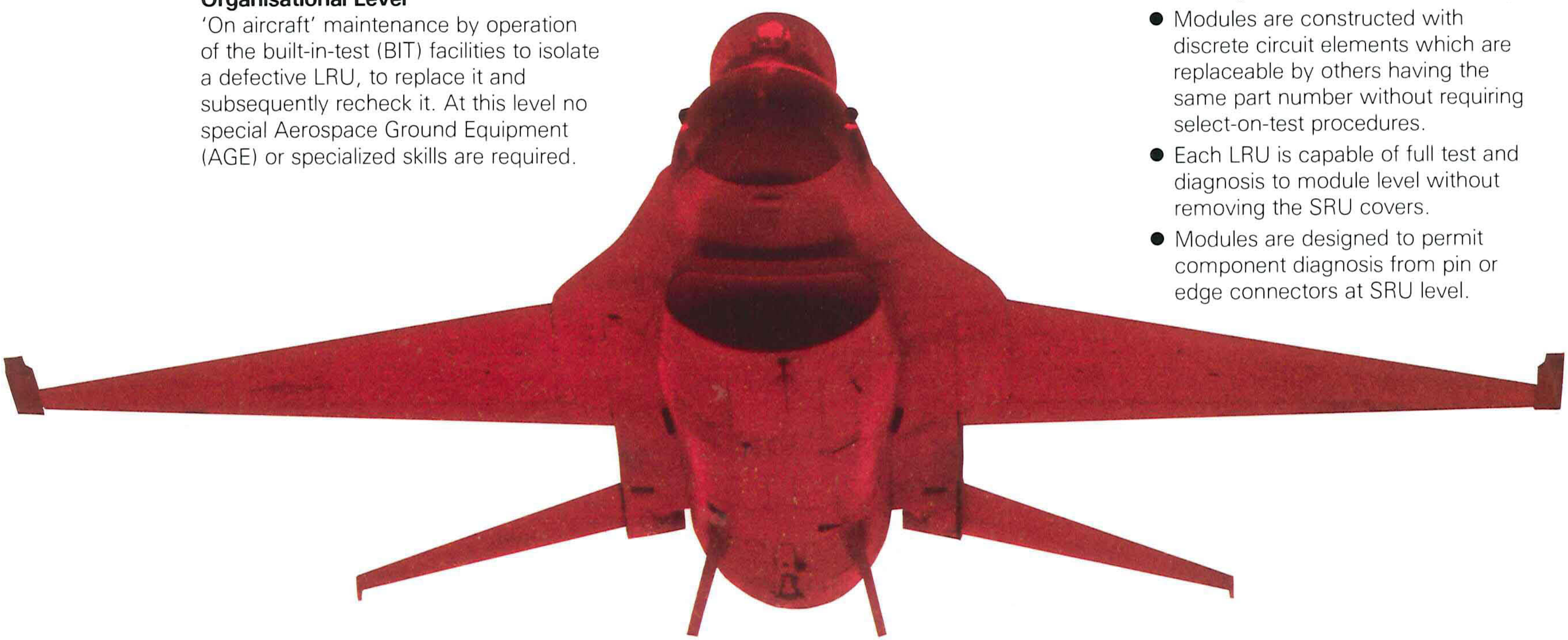
Intermediate Level
'Off aircraft' maintenance employs special test equipment to check-out faulty LRUs down to the shop replaceable unit (SRU) level. The SRUs are complete sub-assemblies with covers intact and can be removed and replaced with normal shop equipment. The complete LRU is then rechecked for serviceability and, if found satisfactory, returned to service. Using automatic test equipment the mean time for intermediate level corrective maintenance is 1.0 hours.

Depot Level
'Off aircraft' maintenance is conducted at a depot level maintenance unit (e.g. Base Repair Shop) where full diagnostic investigation of defective SRUs down to the functional block or active element level is possible. This is achieved using the full range of automatic manual and laboratory test equipment and enables the replacement of failed components and restoration to service of a completely serviceable SRU.



To ensure that the F-16 HUD is fully compatible with such a maintenance procedure careful attention to design detail is made in order that:

- No pre or post installation checks apart from normal functional checks are required.
- Each LRU is of modular construction designed for replacement at any geographic location without subsequent calibration or matching.
- Modules are constructed with discrete circuit elements which are replaceable by others having the same part number without requiring select-on-test procedures.
- Each LRU is capable of full test and diagnosis to module level without removing the SRU covers.
- Modules are designed to permit component diagnosis from pin or edge connectors at SRU level.



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A feature of the production arrangements for the F-16 HUD system is the degree of international co-operation involved. Not only have full production facilities been established at both Rochester, England and Atlanta, Georgia but, in addition, a major share of HUD production for NATO versions of the F-16 is carried out at continental European factories. The overall production programme is under the control of the central Programme Management Team at Rochester who work in close liaison with General Dynamics personnel to ensure a timely flow of production units built to the latest standards and incorporating the latest modifications.

In production—UNITED STATES

Through International Co-Operation

In continental Europe final LRU fabrication, assembly and testing is done in two of the participating countries, Holland and Norway. NV Optische Industrie, Oldelft Company of Delft, Holland is responsible for component and material purchase, sub-assembly manufacture, complete unit assembly and test of Pilot's Display Units, while Kongsberg Vapenfabrik of Norway is responsible for similar production and test of Electronics Units as well as for procurement and test of Rate Sensor Units. Both companies establish their own planning and process controls based on Rochester supplied drawings and specifications. All special test equipment is provided by Marconi Avionics, largely from production at its Atlanta facility.

In addition to overall control and monitoring of the four production lines, the Programme Management Team organises and supervises Intermediate Level Repair centres at General Dynamics and Fokker factories with Depot Level repairs being carried out at the Rochester based Aviation Service and Repair Division of Marconi Avionics.

In production—UNITED KINGDOM

In production—NORWAY

In production—THE NETHERLANDS

Marconi Avionics Limited
Airport Works, Rochester, Kent. ME1 2XX

A GEC-Marconi Electronics Company

Telephone: Medway (0634) 44400
Telegrams: Elliotauto Rochester
Telex: 96304

AIRBORNE DISPLAY DIVISION

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