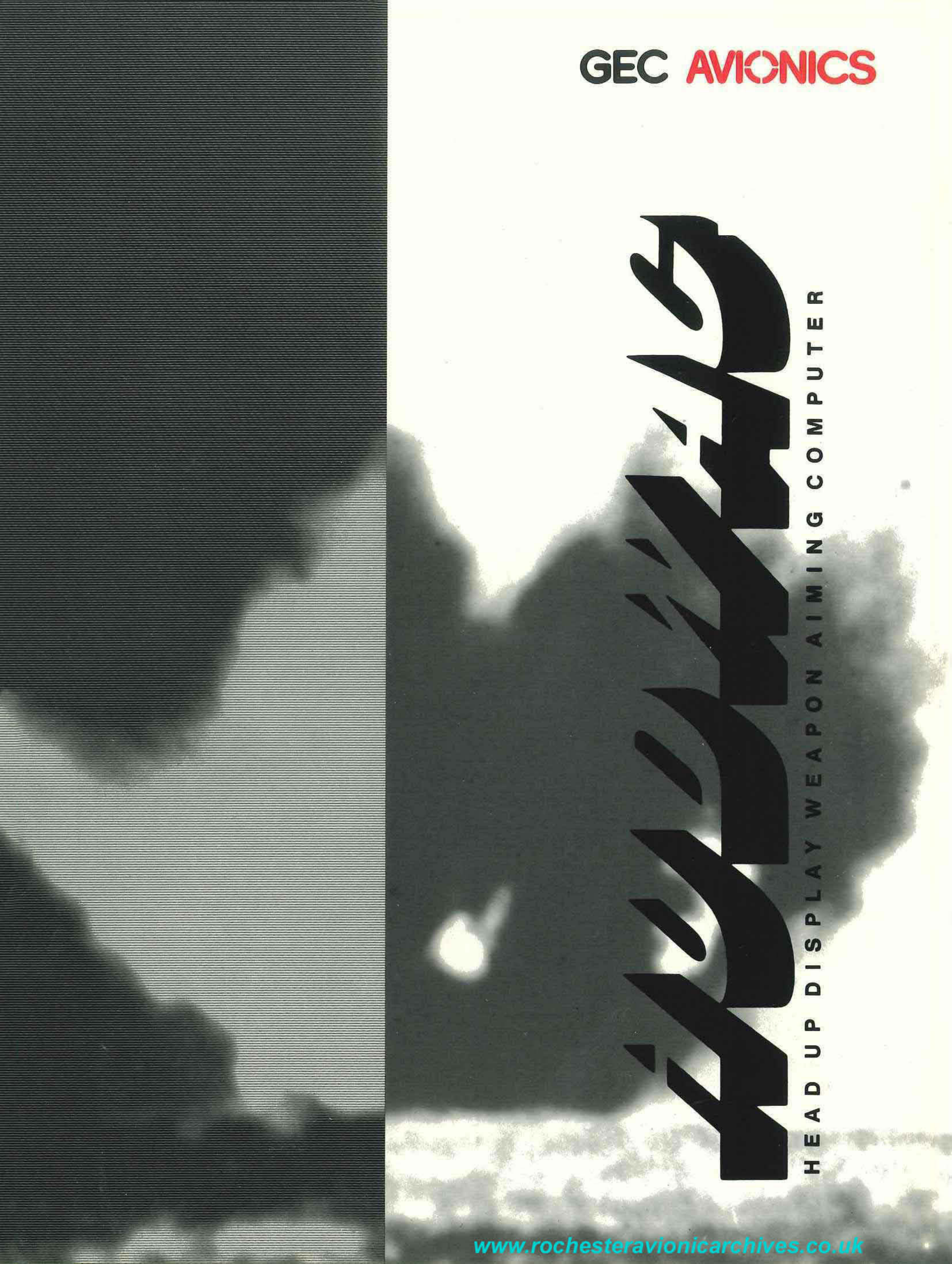
GEC AVIONICS



HEAD UP DISPLAY WEAPON AIMING COMPUTER

For Successful Tactical Operations

Tactical air forces form a major part of a country's military capability. In recent years, however, developments in anti-aircraft systems have rendered tactical aircraft increasingly vulnerable to surface fire. To be successful in a hostile tactical environment aircraft must operate at low altitudes where exposure to enemy radar is minimised and anti-aircraft weaponry rendered far less effective. To operate safely at these levels the pilot must maintain a constant look-out and cannot afford the distraction of having constantly to look down and scan his instrument panel.

The GEC Avionics Head Up Display Weapon Aiming Computer (HUDWAC)

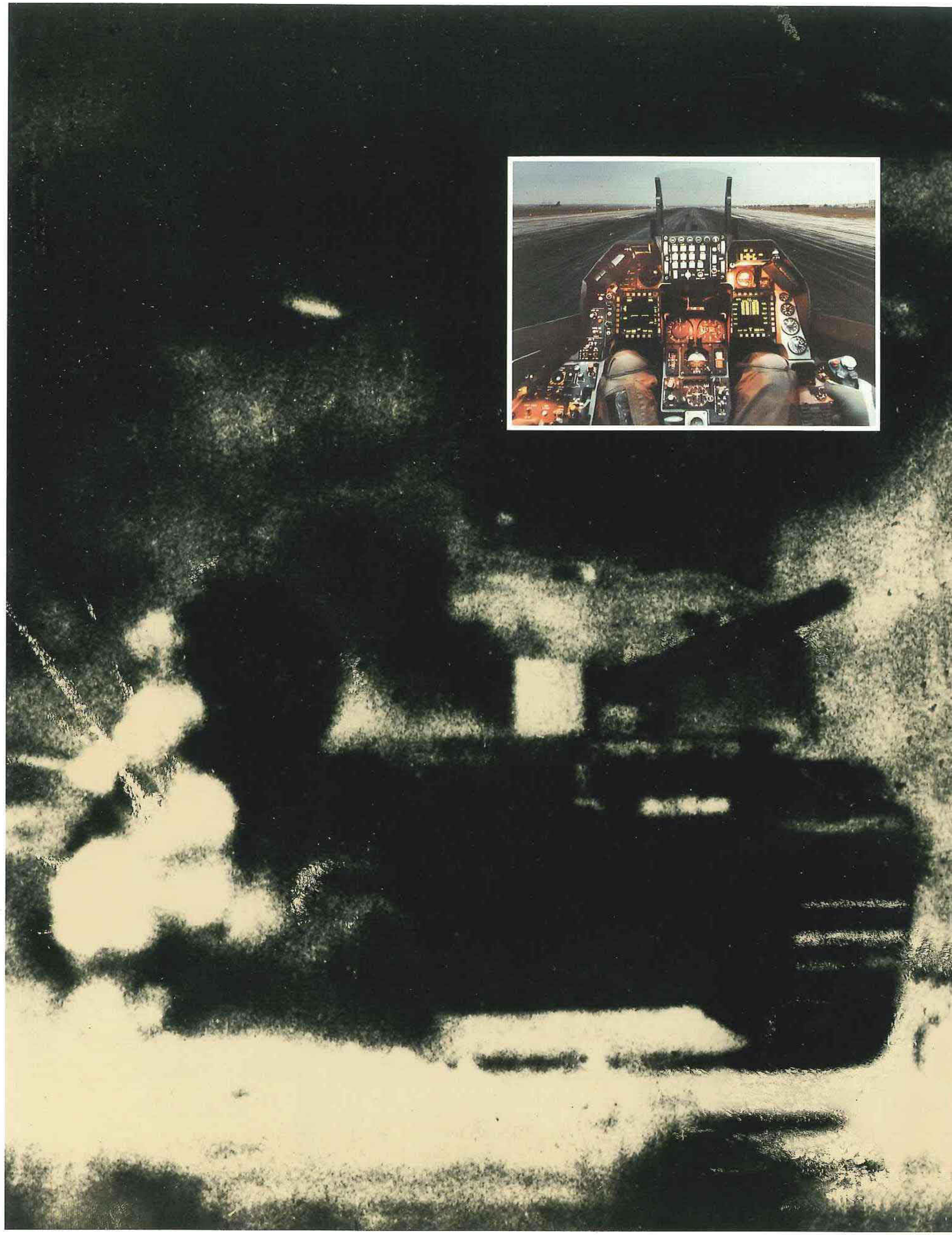
The HUDWAC provides a highly cost effective solution to the problem of successful low level operations. It presents flight parameters and continuously calculated weapon aiming solutions on a transparent screen immediately in front of the pilot. The symbols on this screen are focused at infinity and enable the pilot to concentrate his attention on the tactical situation while continually being made aware of vital flight and mission parameters by his display.

Advanced Capability

The HUDWAC contains a small but efficient digital computer which, in addition to generating the required display, can perform a variety of navigation and weapon aiming functions. Depending on user requirements, it can provide continuously computed impact points for bombs, guns and rockets for air to ground operations plus the most effective weapon solutions available today for air to air and, depending on the aircraft's sensor fit, a full range of navigation information.

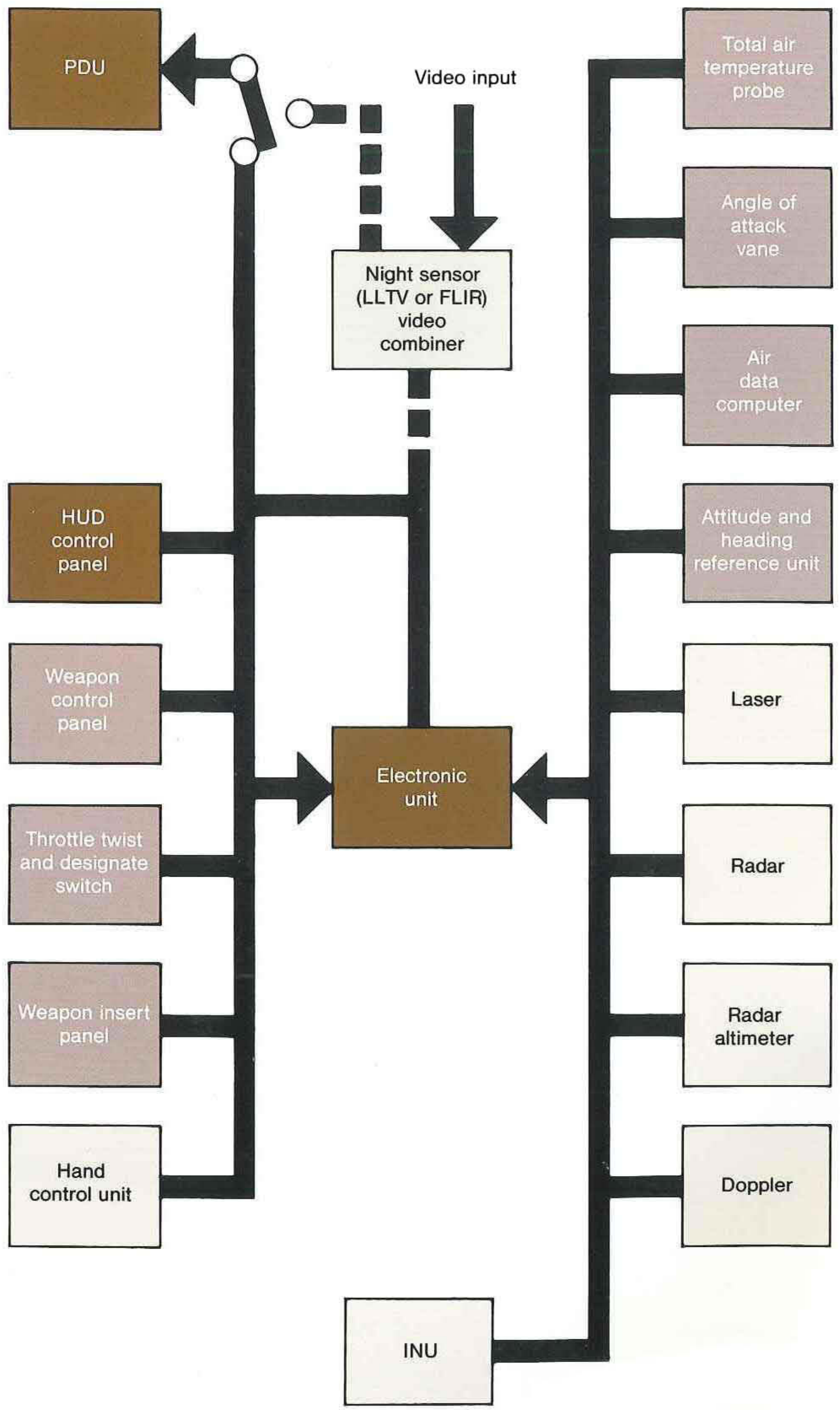
By providing continuous solutions for air to ground weapon release it not only improves accuracy in attacking targets of opportunity but also eliminates the requirement for preplanned (and predictable) 'canned' attacks on fixed ground installations. Elimination of 'canned' parameters greatly increases the attacking aircraft's survivability in the face of hostile ground fire.

In the air combat arena the ability to remain 'Head Up' and have flight information superimposed on the sector of sky containing the aggressor greatly increases successful manoeuvring potential, particularly in the close-in dogfight.



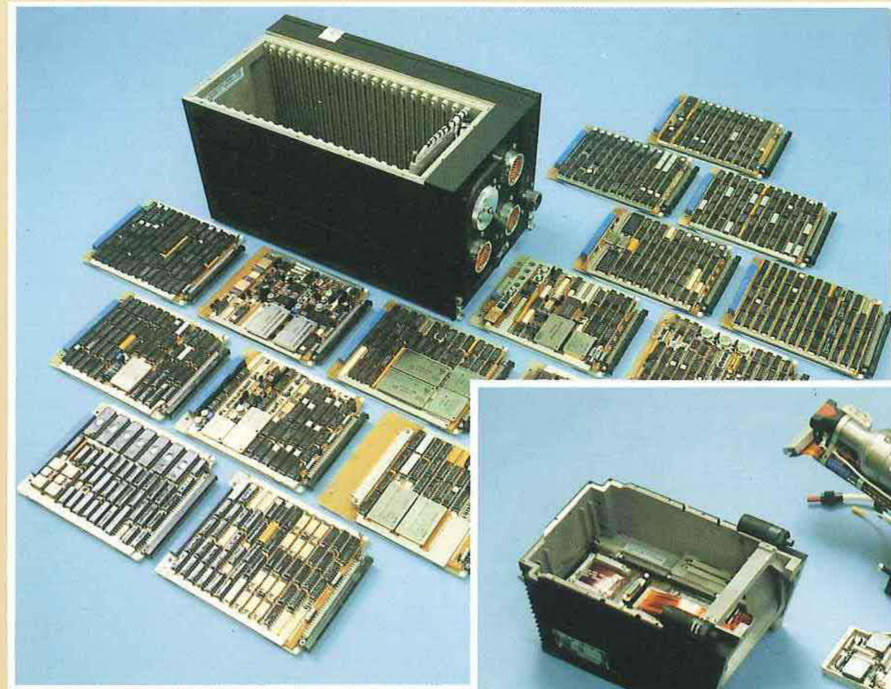
A Versatile System

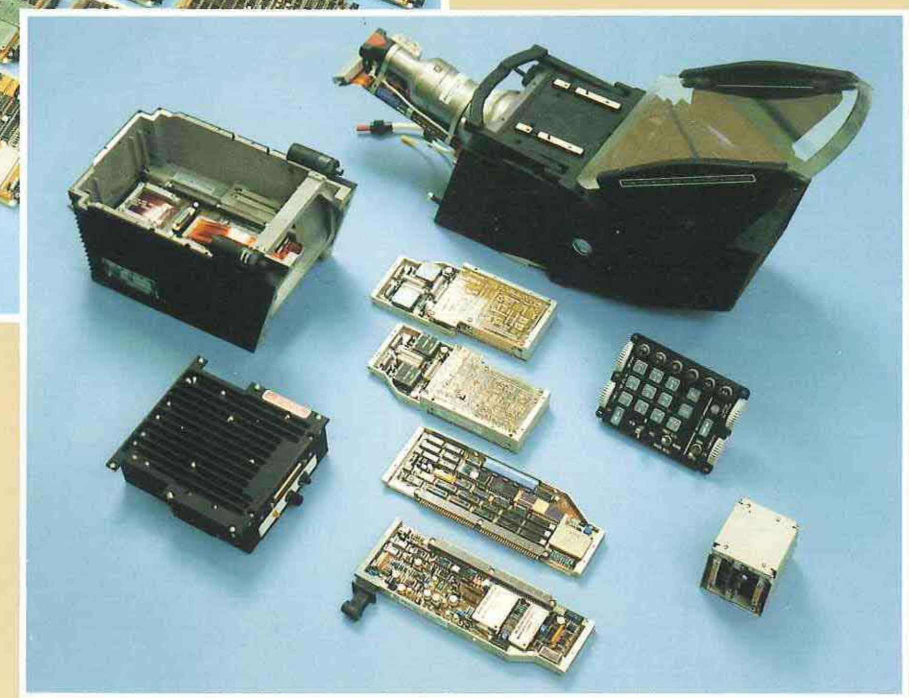
The HUDWAC is compatible with a wide range of sensor and other aircraft system inputs. It can accept signals in synchro, analog, discrete or digital form. This versatility is made possible by the modular construction of the Electronic Unit which enables interface modules to be engineered to the individual aircraft's requirements.



The Electronic Unit

The Electronic Unit (EU) consists of three functional sections: the interface section, processor section and the symbol generation section. Inputs from the various aircraft systems and sensors are received in the interface section where they are converted into digital numbers acceptable to the processor. The processor uses these inputs and its stored program to instruct the symbol generator. The symbol generator in turn converts these demands into analog output signals which drive the deflection coils and bright up circuitry of the cathode ray tube (CRT) in the Pilot's Display Unit. To enhance night operational capability the EU can also contain a field store where the symbols to be transmitted are stored until the vertical retrace period of the raster scan. Cursive symbology is then written over the raster video.





The Pilot's Display Unit

The Pilot's Display Unit (PDU) consists of a cathode ray tube on which the required symbology is drawn, an optical system which projects the symbology into the pilot's field of view and a control panel all mounted in a rigid chassis. Also contained within the chassis are the high voltage power supplies, video drive circuitry, video protect circuitry and automatic brilliance control.

Deflection voltages from the EU symbol generator are amplified by the video drive circuitry and position the CRT beam. At the same time bright up signals from the same source are fed to the CRT grid and enable the symbols to be seen. The optical unit then relays these symbols to the combiner glass where they are reflected to the pilot by a partially reflecting surface.

The Pilots Control Panel (PCP) is normally mounted on the optical module immediately in front of the pilot. The configuration of the PCP can be tailored to suit customer requirements.

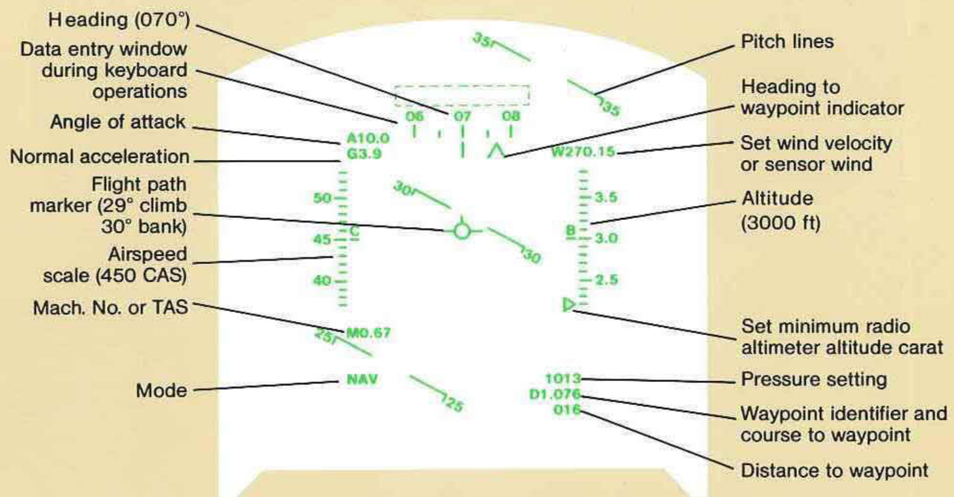
Symbology

The HUDWAC provides the pilot with displays for instrument flying, navigation and both air to air and air to ground weapon delivery. The symbology depicted is similar to that used on the extremely successful and versatile fighter the F-16 Fighting Falcon. This symbology has evolved over 3 generations of HUDs in service and is the result of exhaustive research.

The use of erasable programmable read only memory (EPROM) storage allows the symbology to be easily changed or supplemented when operational needs or extended capabilities dictate.

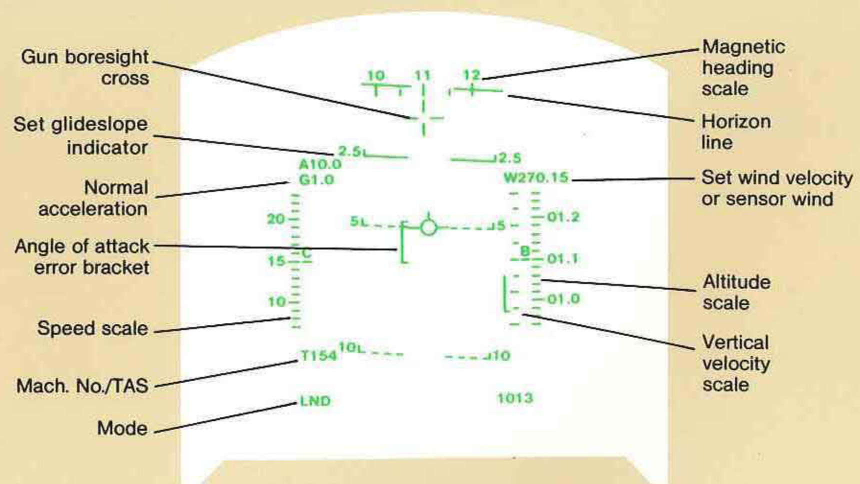
Navigation Mode

- 10 selectable waypoints
- Moving tape speedscale (CAS) numerals represent tens of knots
- Digital readout of Mach or TAS
- Heading scale
- 1.1 geared pitch ladder, pitch bars displayed every 5° climb/dive
- Flight path marker
- Course and distance to selected waypoint
- Moving tape altitude scale. Radar or barometric height, pilot selectable, numerals in hundreds of feet
- Pilot selectable minimum altitude warning



Landing Sub-mode

- Automatic entry on gear down selection
- Expanded altitude tape scale
- Vertical speed indicator
- Pilot selectable desired glideslope indicator
- Digital angle of attack readout
- Angle of attack error bracket

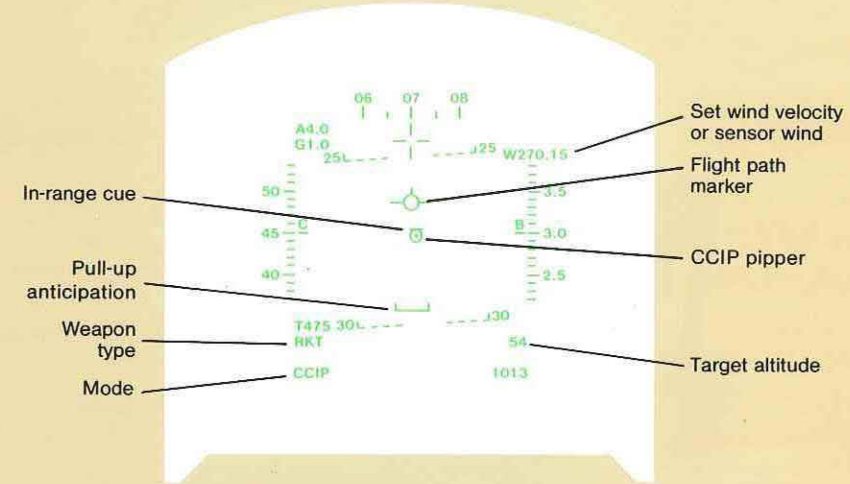


Comprehensive Ground Attack Modes

All the ground attack modes free the pilot from constraints of dive angle, speed or height control. The Continuously Computed Impact Point (CCIP) marker position is updated 50 times a second, negating the requirement for target tracking.

CCIP Rockets Mode (Guns similar)

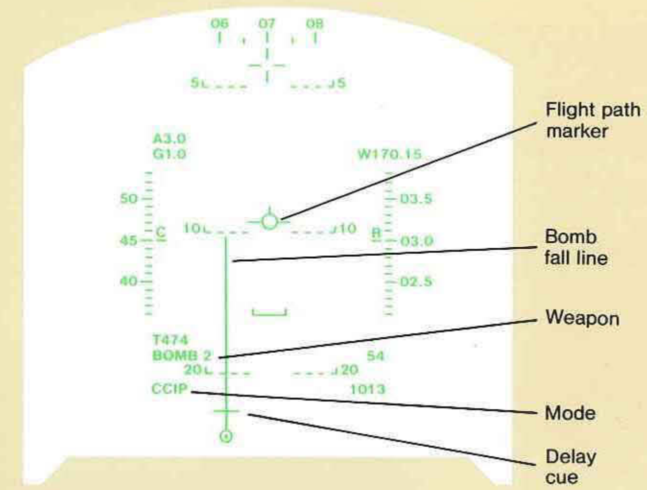
- Aiming symbol
- In range cue appearing at range desired by customer (typically 1.5 seconds time of flight for guns, 2.5 seconds for rockets)
- Pull up anticipation cue for ground and fragmentation avoidance
- Breakaway cross flashed at minimum firing range (not shown)



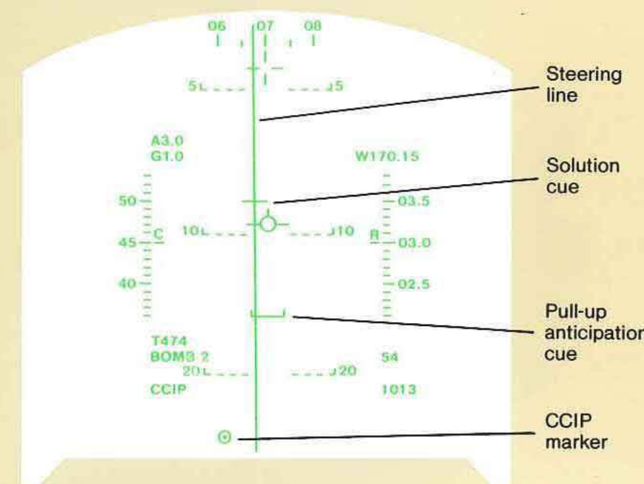
CCIP Bombs Mode

- Bomb fall line to aid alignment of CCIP marker with target
- CCIP provides centre stick aiming for stick bomb release
- Steering line and solution cue to enable targets below the aircraft nose at weapon release to be accurately attacked
- Pull up anticipation cue
- Breakaway cross for ground and fragmentation avoidance
- Flashing flight path marker as weapon release indication

Pre Designate



Post Designate



An Adaptable System

With over twenty five years of experience in fitting HUDs and HUDWACs to a wide variety of aircraft the Company is the world leader in HUD technology. Over 6500 HUD systems have been produced and are employed in over twenty-five different aircraft types. Of these systems more than 1700 are HUDWACs and have been fitted to the A-4, Mirage, F-16, Draken, MiG 21, F-4 and F-5 among others.

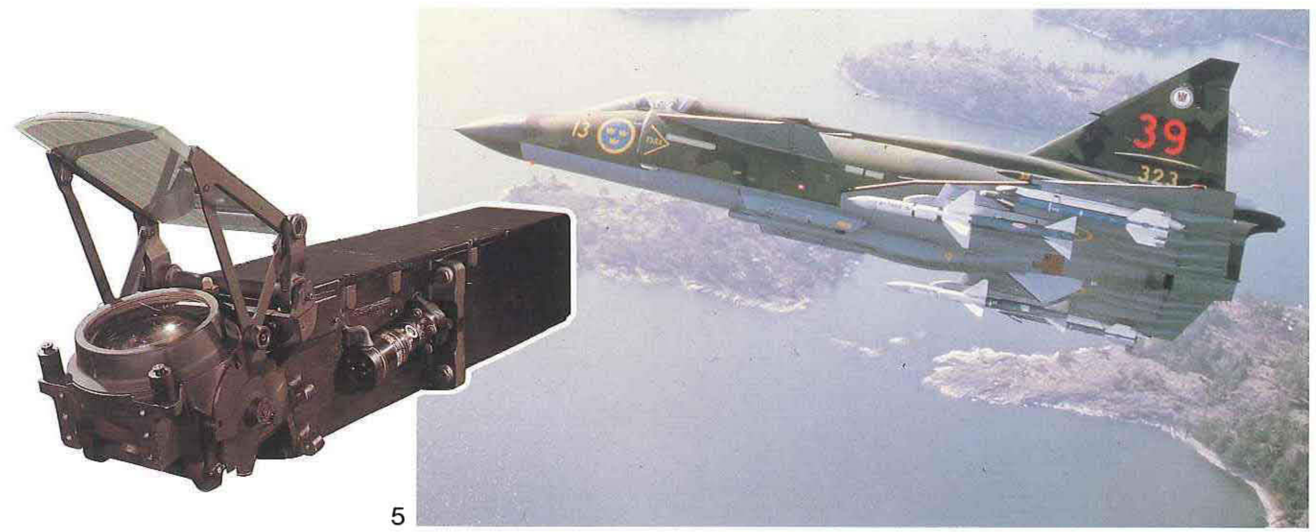
1 A-7
2 F-5
3 Draken
4 A-4M
5 Viggen
6 Mirage 5

1

2

3

4



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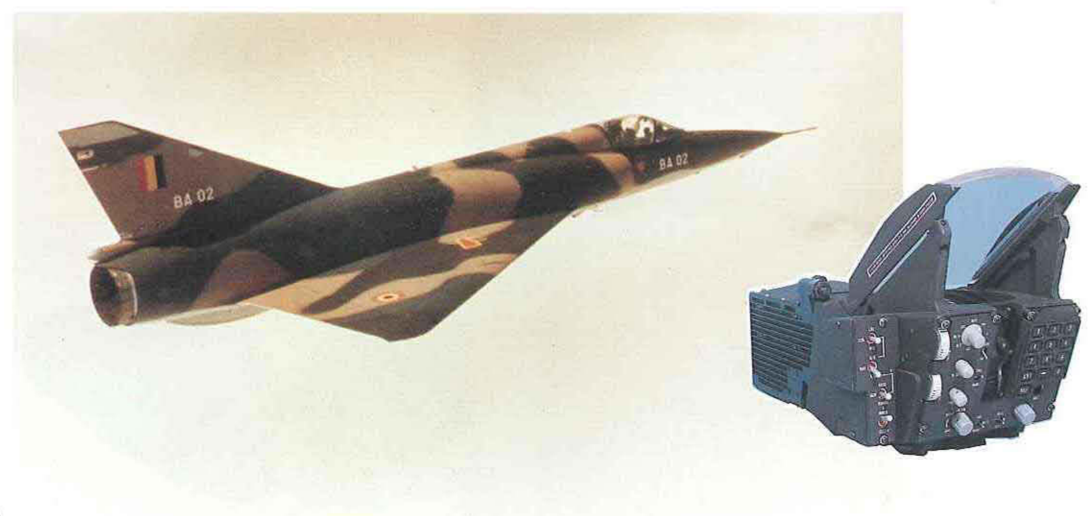


6

7 F-4
8 A-6
9 Buccaneer
10 F-16
11 MiG 21

7

8

9

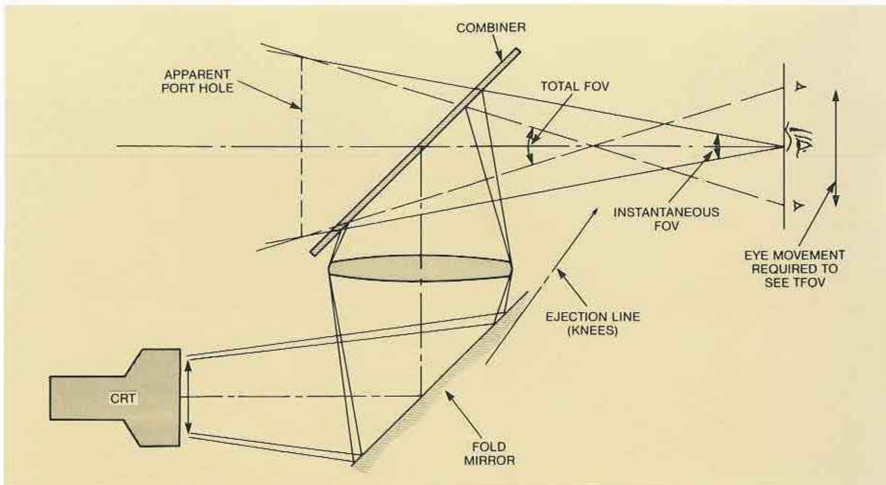
10

11

Conventional (Refractive) HUD

Principle

Light from a cathode ray tube (CRT) is bent so that light rays all pass through another point to produce an image. With a conventional HUD this is achieved by lenses which bend light by refraction, the changing of velocity of the rays as they pass from one refractive index to another, from glass to air.



Refractive Head Up Display – Principles of Operation

The CRT generates image symbology, which is collimated (focussed at infinity) by the lens system and reflected to the pilot's eye by a semi-silvered glass mirror. The pilot's forward view of the outside world is combined through this transparent semi-mirror (combiner) with the collimated imagery, providing flight, navigation and weaponry cues.

Field of View

The angular coverage of the imagery seen by the pilot is the field of view. Total Field of View (TFOV) is the total angular coverage of the CRT imagery which can be seen by the pilot as he moves his head around (referred to as a port hole). The Instantaneous Field of View (IFOV) is the angular coverage of the imagery which can be seen by a pilot at any specific instant. The IFOV is a function of the diameter of the collimating lens and the distance between the pilot's eyes and the combiner.

The cockpit size and shape of an aircraft constrains the space available for a HUD. The rear of the HUD must clear the ejection line, the top must clear the cockpit canopy, the glareshield dictates the bottom of the HUD, and the instrument panel cut-out limits it laterally. The only way to increase FOV then is to increase the collimating lens diameter. The latest night vision HUD as fitted to the F-16C/D has a 6.7 inch lens – offering the maximum FOV (20° by 15°) practical using refractive optics.

Symbology

Flight instrumentation information with the full range of weapon aiming capabilities is displayed on the HUD by cursive, or stroke written, symbology. A development of this standard cursive HUD is the raster night vision HUD, which can display imagery from an electro-optical sensor in raster format, with conventional symbology overlaid.

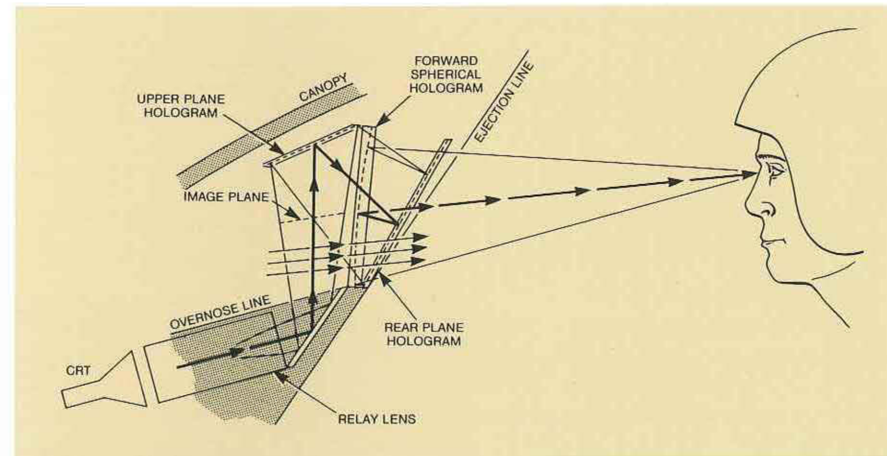
Raster HUD

By using a Forward Looking Infra-Red (FLIR) sensor, an electro-optical image of the scene in front of the aircraft can be overlaid on the real scene with a raster HUD. The FLIR picture is scaled (one to one) with the outside world, permitting the pilot to fly at low level by night in fair weather, providing a realistic night capability to relative simple day ground attack fighters.

Holographic (Diffractive) HUD

Principle

New techniques using the diffraction of light by holograms, which replace sets of lenses, have led to wider FOV displays of very high brightness with savings in weight and space. Holograms, or diffraction gratings, are made by exposing a photosensitive material surface (dichromated gelatine) to two coherent beams of laser light, forming a series of interference fringes throughout the depth of the gelatine film. During the developing process, these fringes (small line-like features) are converted to planes of high and low refractive index parallel to the film surface, producing a diffractive grating. Hence, the light is bent by diffraction, not refraction. A holographic combiner uses a layer of gel sandwiched between two pieces of glass, and the optical system uses a combination of three holographic combiners. An unusual characteristic of this type of HUD is that the TFOV and IFOV are almost identical.



Holographic Head Up Display – Principle of Operation

Operation

The holographic combiner acts as a very selective mirror or spectral filter. It is a very efficient reflector of light of a specific frequency and all other light is transmitted very efficiently, ie. the lens is transparent to all visible wavelengths other than a narrow spectrum of light – the narrow bandwidth green phosphor on the CRT. This light is reflected very efficiently (about 90%), while still allowing all other light to pass straight through. Because of the narrow bandwidth in which holograms operate, white light is effectively transmitted at about 90%.

Field of View

By using this diffraction pattern the display lens is built into the combiner, so that the lens can be made as large as the combining glass. With this larger lens, which is also now closer to the pilot's eyes, twice the IFOV than that of a conventional HUD can be achieved. Our holographic HUD for the F-16/A-10 LANTIRN programme has a FOV of 30° azimuth and 18° elevation.

Advantages

The wide angle HUD allows target acquisition and attack within a wide azimuth coverage permitting use of FLIR or laser marked target seeker over a significantly greater FOV. In addition, diffractive optics allow up to twice the brightness of both symbol and raster (FLIR) displays than is available with conventional optics. And finally, a wider angle HUD is of considerable benefit in air combat.

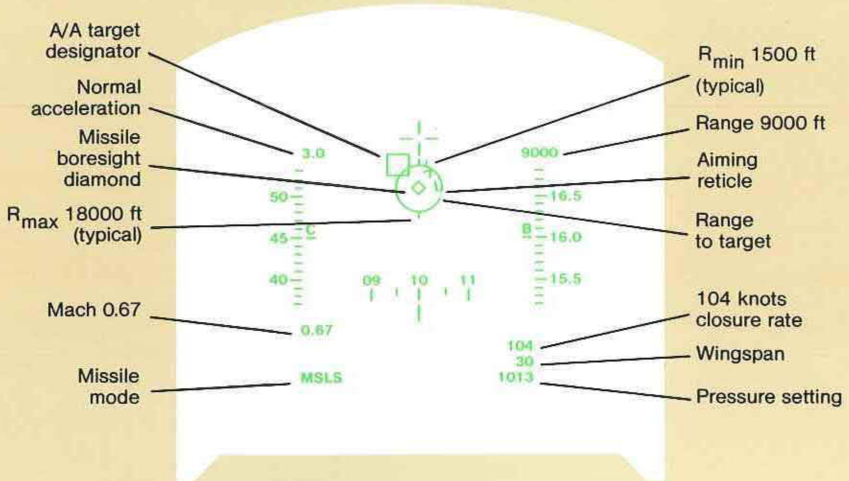
The latest missiles have a large aim-off capability against a manoeuvring target. To take full advantage of this, the HUD needs to display the missile seeker head circle scaled one to one, together with a target indicator driven by the radar. Only a HUD with a large field of view, particularly in the aircraft's vertical axis, can give this display capability.

Decisive Air to Air Modes

Air to air symbology is divided into four basic weapon delivery modes enabling both gun and missile firing.

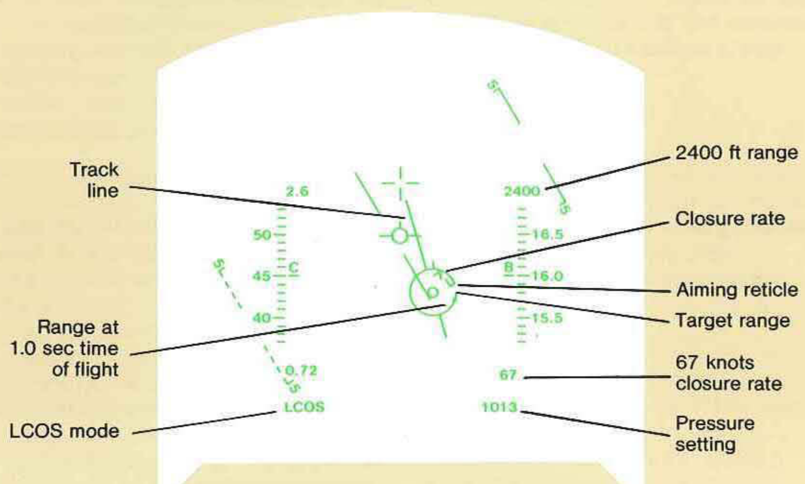
Air to Air Missiles Mode

- Target box indicates position of target locked on to by aircraft radar
- Missile boresight diamond indicates missile seeker line of sight
- Aiming reticle size is a function of missile selected and whether or not it is uncaged
- Range and closure rate to target indicated on aiming circle and as digital readout
- Missile range boundaries displayed
- Missile launch opportunity cues provided by flashing aiming reticle when missile launch parameters satisified



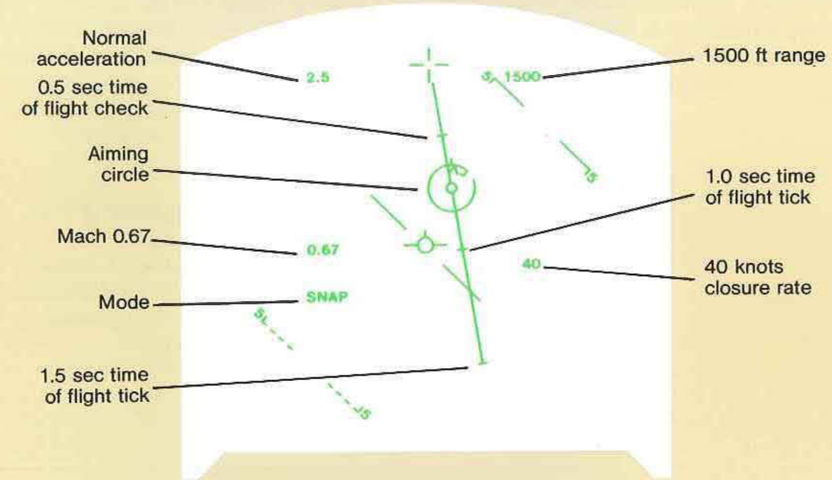
LCOS Mode

- Provides a gunnery solution for smooth tracking of the target
- Aiming reticle surrounding the aiming pipper is a fixed size for radar ranging or computed from pilot selected wingspan for stadiametric ranging
- Range is indicated on aiming reticle and as a digital readout
- Range at 1 second time of flight provided as a tick moving round the aiming circle circumference
- Closure rate is indicated on aiming reticle and as a digital readout
- Provision of line joining gun boresight cross to aiming reticle to aid establishment of correct aiming plane



Snapshoot Mode

- 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 on to the CCIL at the time of flight derived from target range
- Bullet time of flight ticks displayed on the CCIL for 0.5, 1 and 1.5 seconds

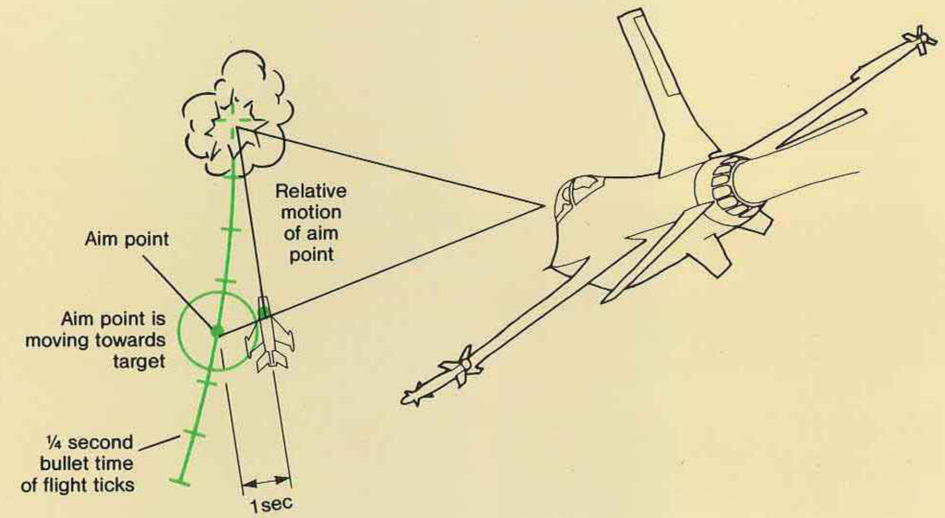


- Snapshoot Solution

  The gun cross symbol represents the gun boresight and the start of the bullet line

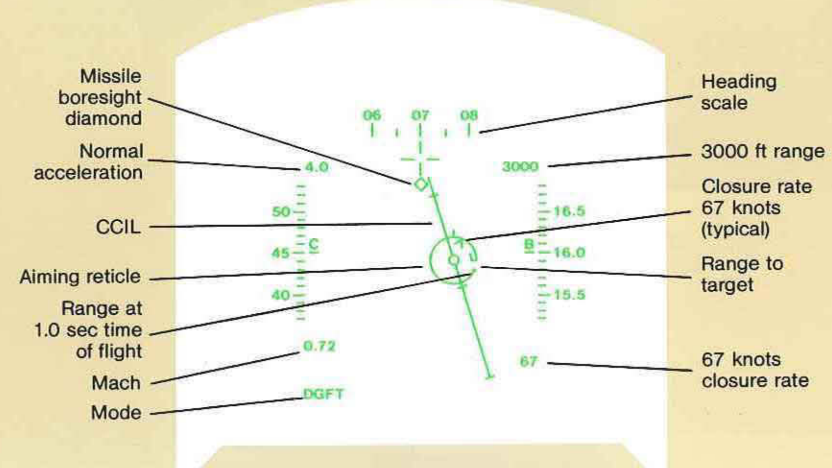
  Pilot manoeuvres to ensure target will fly through aim point

  Pilot estimates bullet time of flight



Dogfight Mode

- This mode can be entered instantaneously on depression of a control column or throttle switch
- It represents an amalgamation of missile, LCOS and snapshoot modes with the following provisos
- Range indication is as for LCOS mode
- Missile boresight diamond only is portrayed
- LCOS track line not displayed
- Aiming reticle centred on LCOS solution



24 Hour Operation

When used in conjunction with a night vision sensor such as Low Light Television or Forward Looking Infra-Red a night vision version of the HUDWAC makes twenty-four hours a day tactical operations possible.

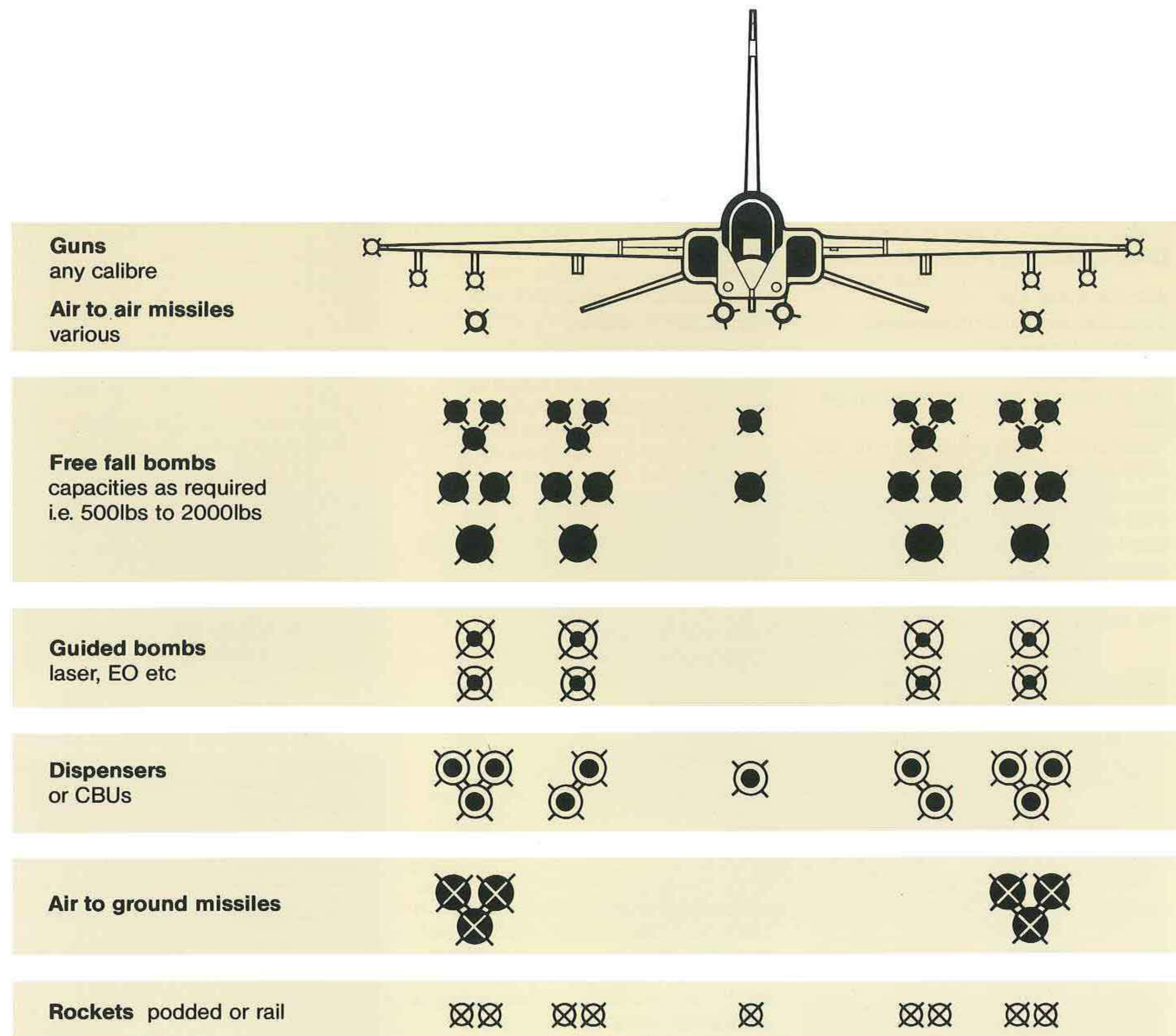
This is achieved by operating the HUDWAC in a raster scan mode compatible with the sensor output. The pilot then sees on his combiner glass a composite of his symbology and the sensor picture superimposed in one to one correspondence with the real world. This enables him to fly at low level at night using essentially the same visual cues that he would during the day. Enemy formations advancing under cover of darkness can be attacked with the same precision and effectiveness as during full daylight. At the same time visual identification of unlit air to air threats becomes possible and 'visual' night attacks using guns and missiles become a reality.

LLTV pod

FLIR pod

Exceptional Weapons Versatility

The exceptional versatility of the HUDWAC is graphically illustrated below. The modes of operation and weapon aiming capability of the system allow for a complete range of armament configurations. Any armament currently available can be catered for, whilst new weapons can be accommodated easily.



Training ordnance and dispensers as required

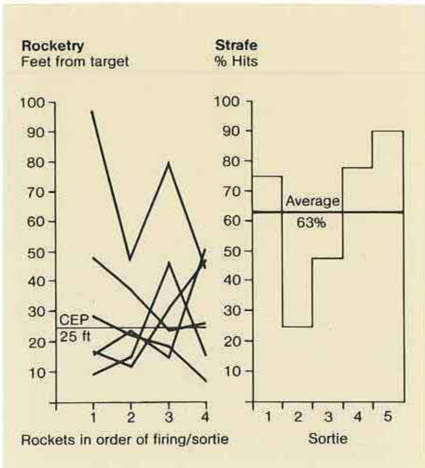
Flight Trials Results

Actual flight trials results illustrate the flexibility of the HUDWAC in the air to air scenario and clearly demonstrate the system capability both against a manoeuvring target and with a moving pipper.

Rocketry

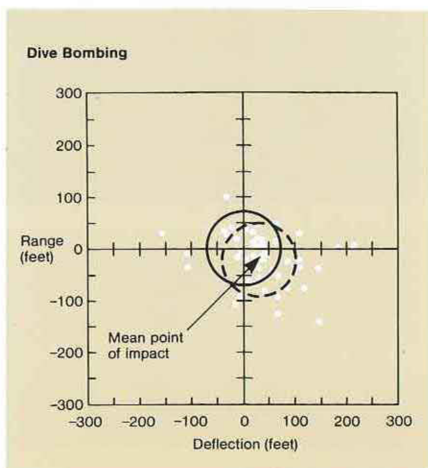
MiG 21 MF firing SNEB rockets, nominal release conditions: 500 knots, 15° dive, slant range 1000 metres.

Superimposition of results from 6 consecutive rocket firing sorties.



Dive Bombing Trial

Aircraft A-4M 426
Type delivery CCIP cumulative
Weapon type Mk76
No. weapons 44
Mean point of impact deflection 34 feet
Mean point of impact range –19 feet
Nominal release conditions
True airspeed 450 knots approx.
Dive angle 30° to 45°
Slant range 5000 feet to 6400 feet
Altitude 3000 feet to 5000 feet
10.44 Milliradians CEP about the target



Strafe

Trials results MiG 21 MF over 5 consecutive sorties against a 15 x 15 feet target, nominal parameters: 450 knots, 15° dive, 1 second burst, 900 metre slant range.

Air to Air Guns

The graph shows the single shot probability of a kill with increasing air range. It shows clearly that the HUDWAC is 4 TIMES MORE EFFECTIVE THAN A/GGS in angle off situations at air ranges greater than 1500 feet. In other words 4 times fewer bullets are required per kill.

Air to Air Firing Trial

Dassault Mirage 50. Radar ranging. Firing ranges between 350 to 800 metres.

Air to Air Missiles

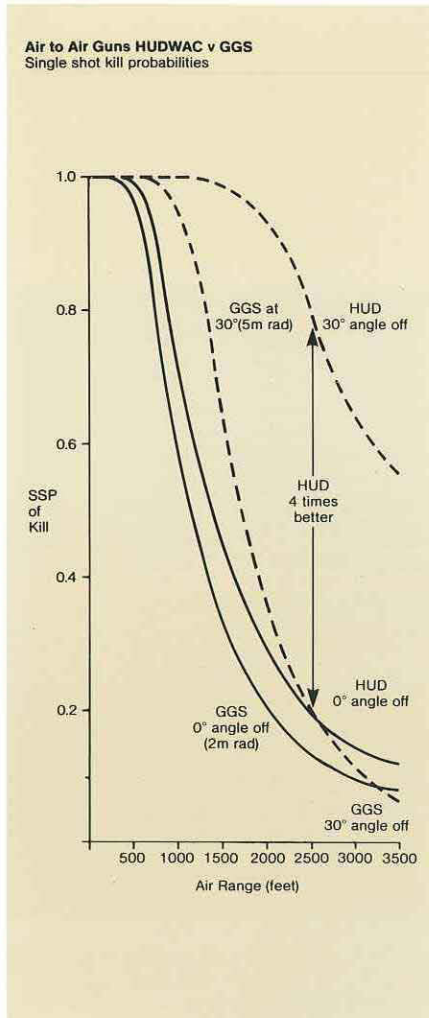
An air to air missile must be launched inside its air range and load factor envelopes. Failure to launch inside parameters is wasteful of missiles and an analysis of SE Asian combat statistics shows that 50% of missile launches occurred out of the launch envelope. The HUDWAC is programmed to provide a flashing Head Up launch cue to indicate to a pilot that he is inside the missile envelope, together with steering information to the best chance of success launch zone.

Air to Ground

The accuracy of a fixed depression gunsight is typically 27 milliradians CEP in the bombs mode, whereas a HUDWAC demonstrates an accuracy of 7-10 milliradians. This means that the number of bombs required to be dropped for a 95% confidence level against a 10 metre diameter target will be NEARLY 4 TIMES FEWER WITH THE HUDWAC, representing a substantial weapons saving and decrease in the total number of aircraft required for the attack.

Accuracy

The accuracy of a HUDWAC system is best illustrated by a performance comparison with a gyro gunsight (GGS) for air to air weaponry and a fixed depressible sight for air to ground weapon delivery.



Air to Air Guns

Target manoeuvre	Stabilised flight	Butterfly	Pipper moving at 10 mils/sec relative to target
% Bullets inside 4m radius	15	15	10
Bullets inside 9m radius	41	42	31
% Frequency of at least 3 bullets inside 4m radius	34	35	24
% Frequency of at least 3 bullets inside 9m radius	53	63	54

Cost of Ownership

Reliability and Maintainability are a major feature of the HUDWAC System. All systems are subject to RST and 'Burn In' before delivery, giving a high confidence level of reliability and high MTBFs.

During the design and manufacture CADMAT (Computer Aided Design Manufacture and Test) principles are employed.

CADMAT is the basis of good design, ease of maintenance, 'Testability' and fast turn around times.

Automatic Test Equipment

The depot ATE for the HUDWAC system is provided by our sister division ATED to the USAF MATE procurement standard. This standard will provide throughout the USAF:

Equipment Commonality
Transportable Test Software
Lower Operating/Logistic Costs
Standard Operator Skill Levels

The ATE includes system design features from current commercial technology:

The processor has MIL-STD 1750 instruction set architecture and the Jovial MIL-STD 1589 System Software is comprised of the modules –

Operating System (MOS)
Test Executive (MTE)
ATLAS Compiler (MAC)
On-Line Editor (MOLE)

Source level Test Programs are written in the ATLAS 716 language and instrument independent CIIL coding controls instruments on the IEEE 488 Bus.

The ATE interface is defined by the ICA standard.

The HUDWAC MATE is directly derived from that illustrated which was designed and developed to meet the US Military requirements for the SCADC contract.

The contract number is F33657-85-C-0025.

Maintainability

Testability at the design stage is a major contributary factor in ensuring ease of maintenance for the HUDWAC system. Comprehensive built-in test equipment (BITE) enables front line flight crews to check out the complete system, isolate and replace faulty line replaceable units (LRUs) and recheck the system as part of a normal pre-flight inspection without the use of any specialised ground equipment. Indeed, the low failure rate of individual electronic components and the modular design of the system make any form of scheduled maintenance unnecessary. The basic philosophy is therefore one of unscheduled removals as and when a failure occurs. The faulty LRU is replaced and despatched to an intermediate level work shop for test and repair.

HUDWAC LRUs are designed to permit automatic dynamic functional testing on the ATE via the external connector. Diagnosis is to a sub assembly/module level, the faulty item is replaced and the LRU returned serviceable, typical turn around time is one hour.

The faulty module is returned to depot where the modules are tested on ATE with diagnosis to component level. Test Programs are prepared using ATPG (Automatic Test Programme Generation), an integral part of the CADMAT philosophy.

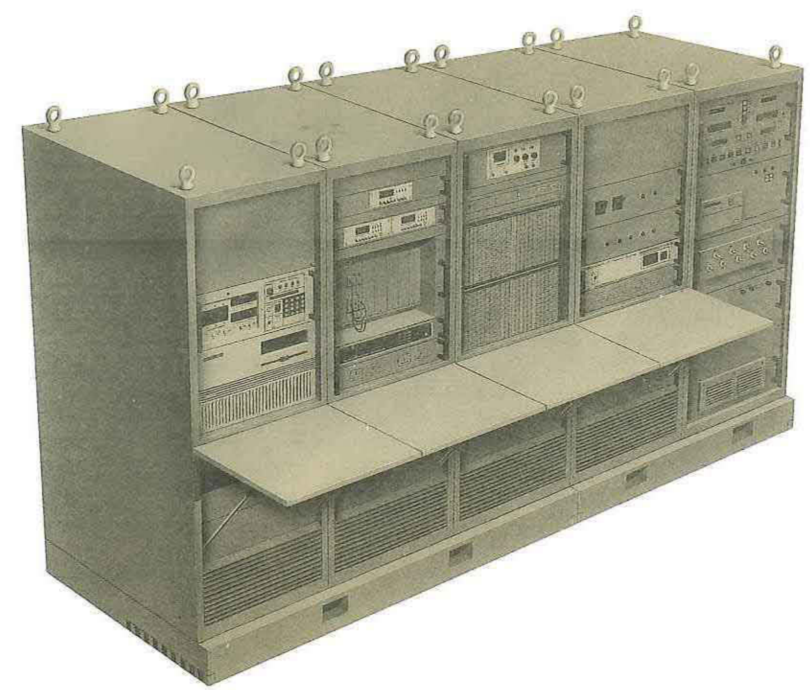
This maintenance philosophy removes the requirement for specialised skills on the flight line, ensures the most effective use of test equipment and considerably reduces the long term cost of equipment ownership by reducing logistic support costs.

Reliability

High reliability is a feature of all our HUDWAC systems. This is achieved by careful control of the entire process from engineering design, through parts procurement, production and inspection to final delivery. A comprehensive quality control procedure ensures that each production system meets the high standard of reliability that is a hallmark of our HUD design.

This insistence on quality at every stage of the manufacturing process is exemplified by our HUD system for the General Dynamics F-16 which has consistently and easily exceeded the requirements of its Reliability Improvement Warranty.

Reliability is further ensured by application of RST procedures with temperature cycling and vibration over the 'burn in' period.



GEC AVIONICS

GEC Avionics Limited

Airborne Display Division

Airport Works Rochester Kent England
Telephone: Medway (0634) 44400
Facsimile: (0634) 816036
Telex: 96304

Designed by ASRD Graphics Printed in England PL7781