

EVOLUTION OF COMBAT PERFORMANCE OF THE
HAWK LIGHT COMBAT AIRCRAFT

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SUMMARY

The paper reviews the progressive evolution of the BAe Hawk from its original concept as the advanced flying trainer aircraft for the RAF to the currently planned developments as a light attack aircraft. The developments are described in aerodynamics propulsion and systems to give improvement in performance and weapon delivery capability appropriate to effective light attack operational roles.

1. INTRODUCTION

The Hawk concept originated from the decision in the 1970's for the RAF to reorganise its flying training from the previous multi-aircraft system to a more integrated system in which advanced training could be accomplished on a single aircraft capable of taking the trainee pilot from the basic level to advanced flying training, weapon training and on to operational training.

In parallel with this RAF concept of integrated training the Hawk was also conceived in design as capable of development towards a light attack aircraft. These developments from the two-seat training version were through systems, performance and weapon capability developments, within controlled cost targets suited to potential market opportunities and local defence requirements.

2. DEVELOPMENT OVERVIEW

The original Hawk to meet RAF requirements, designated T Mk.1, was developed to a limited operational capability with Air-Air and Ground Attack weapons, as a secondary light attack aircraft, T Mk.1A.

The first export development was to meet a requirement for an advanced training and ground attack aircraft, accomplished by the development of additional weapon carriage and associated systems, designated the Mk.50 series.

This theme of development for the dual role of flying training and combat capability was taken further with additional weapon and system capability, performance improvements and uprated engine, embodied in the Mk.60 series.

Further development was seen on the basis of the developed airframe, for the roles of advanced systems and crew training and of a light attack aircraft. In the first of these developments, the Mk.100 series, enhanced ground attack capability is introduced through improved avionic systems giving self-contained navigation to targets, greater attack accuracy, versatile programmable displays and a database system to give future system development capability.

The development to a single-seat version of the aircraft had been seen as a logical step to a full operational light strike aircraft in which the development capability in aerodynamics, performance, systems and sensors would be justifiable.

This development, the Mk.200 series, is again on the basis of the original airframe, but changing the front of the fuselage to new equipment and cockpit modules. By this means equipment and weapon system configurations for a range of operational roles are available and include:

- * Night/All weather intercept from airborne alert
- * Close support
- * Interdiction
- * Reconnaissance
- * Maritime strike.

The enhancement of systems and performance, coupled with role capability and low visibility make the Series 200 an effective low cost light attack aircraft.

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3. CURRENT STATUS OF THE HAWK DEVELOPMENT PROGRAMME

The T Mk.1 is currently in service with the RAF and has achieved a total of 287,500 flying hours.

A number of the T Mk.1 aircraft have been converted to T Mk.1A standard and are operational.

The Mk.50 series is in service with 3 other air forces.

The Mk.60 series is in service with a further 4 air forces.

The Mk.100 series is in the development stage through avionic systems ground rigs and will reach a flight development stage in 1987.

The Mk.200 series has been designed initially as a demonstration and development aircraft and will fly in this role in May 1986 with further plans to fly specific equipment development versions in 1987.

4. EVOLUTION OF COMBAT DEVELOPMENT

The original concept of the Hawk, in its advanced training role, was to provide an aircraft able to represent many of the operational characteristics of the front line combat aircraft, within a limiting cost constraint both in design, development and production, as well as in operating costs.

Thus the aircraft was conceived as a small subsonic aircraft, built around an existing production engine of reasonable fuel economy, at the start of its development life. The aircraft was sized on requirements for landing speeds appropriate for flying training and internal fuel for adequate endurance for the required training syllabus. This led to a modest take-off thrust/weight ratio (0.5) moderate wing loading and capability for good payload/radius.

From this design concept other characteristics were achieved appropriate to the advanced training role:

- * Good field performance from low speed high lift capability and low wing loading
- * Good climb capability from thrust/weight and lift/drag ratios
- * Good operational radius of action with substantial payload
- * Agility over subsonic Mach number range from low wing loading and combat thrust to weight ratio
- * Capable of demonstrating supersonic operation in diving flight
- * Good flying qualities through simple flight control system
- * Good weapon/store carriage capability with minimal change in flying qualities.

These features, required for the training role, include many of the necessary characteristics of a combat capable aircraft and through the aerodynamic, performance and weapon system developments envisaged lead to a highly capable attack aircraft.

In essence the development philosophy is based on the good payload/radius capability which can be developed for combat applications:

- * Substantial weapon loads from hot or high operational bases delivered to distant targets
- * Combat air patrol with air strike capability at substantial distance out from base or longer patrol time closer in
- * Performance and flying qualities appropriate to target acquisition in air-air weapon attack, delivery of ground attack weapons and anti-shipping strike.

In pursuance of this development to the required combat capability the essential developments are in aerodynamics, performance and weapon systems, within the basic Hawk airframe and the affordable engine and equipment availability.

AERODYNAMIC DEVELOPMENTS (FIG. 1)

The flying qualities and performance characteristics referred to in paragraph 4 have been the subject of design studies and wind tunnel development tests at low speed, high speed and at high Reynolds number leading to flight trials.

Improvements of wing performance from the T Mk.1 wing configuration have been achieved without major structural changes.

At low speeds, through flap systems and wing flow control improvements the usable high lift has been increased by 15%.

At higher speeds the usable maximum lift has been increased by 28% at $M = 0.5$ and by 22% at $M = 0.8$. Initially improvements in the control of flow separation gave higher usable lift through better handling to higher angle of attack. Further improvements were obtained from application of leading-edge camber, modification of rear airfoil section to improve rear loading and use of rear camber by partial flap deflection.

Additionally, aerodynamic developments for weapon and external fuel tank carriage have been necessary to increase attack effectiveness through range/payload capability. In general these improvements have been realised through wind tunnel and flight development tests. The Hawk configuration, with a moderate sweep and aspect ratio wing, and wing section designed for high subsonic Mach number, is tolerant of store additions under the wing with minimal changes in longitudinal stability and centre of gravity. Thus a wide range of store types and configurations has been possible in the development of combat configurations.

6. ENGINE DEVELOPMENTS (FIG. 2)

In parallel with evolution of the aircraft from the training role, progressively towards the Light Attack role, the need to improve performance, compatible with operational roles and weapon delivery, has required progressive engine development.

Primary interest has been in improvements in operations with heavy loads in high ambient temperature at airfields above sea level and in maintaining combat performance particularly in low level attack.

The engine is a development of the non-reheated Adour engine designed for the Jaguar aircraft. It was selected for Hawk because of its new technology (at the time), its moderate operating temperatures and pressures, and rugged construction.

The first mark of Hawk Adour was designated the Mk. 151, and was MoD funded for the Hawk T Mk. 1 aircraft.

An uprated version designated Mk. 861/861A was developed with PV funding for Mk. 60 series export Hawks. Thrust improvement at SL, ISA, static conditions is 10%. Changes include a modified LP compressor, revised turbine nozzle and exhaust mixer areas, modified fuel system and new HP and LP turbine blades.

The Mk. 871 engine is the latest standard of Hawk engine. The uprating is achieved by increasing the max LP speed by 4% to 108% and raising the turbine entry temperature limit. The major changes (over Mk. 861A) are shown on Fig. 2. The Mk. 871 engine still features state of the art technology, leaving scope for still further growth with the use of advanced compressor and turbine technology in the future.

These engine developments have been achieved without significant changes to the basic engine dimensions and optimisation for other climates is also possible.

Typical changes in engine characteristics in the development from T Mk.1 to 200 Series are:

* Static thrust increase I.S.A., S.L.	13%
* Thrust increase at 0.8 M, I.S.A., S.L.	41%
* Static thrust increase I.S.A. +35°C, S.L.	26%
* Thrust increase 0.8 M, I.S.A. +35°C, S.L.	38%
* SFC change at Maximum Rating, I.S.A., S.L.	-2%

7. SYSTEM DEVELOPMENTS

The systems fitted to the Hawk T Mk.1 were kept as simple as possible, but with sufficient capability to achieve the desired training task. Thus the basic navigation is achieved using a twin gyro platform and conventional radio and radio navigation equipment. In the advanced flying training role no weapons system is fitted, in the weapons training role a gyro gunsight is fitted, together with a simple stores management system to control the centreline gun, and the training stores carried at the inboard wing pylons. This capability is extended for the T Mk.1A to allow the use of operational weapons.

For the Mk.50 and 60 Series a more comprehensive weapon control system is fitted, allowing the carriage of up to nine weapons. A wide range of weapons has been cleared on the aircraft, including air-air missiles. In all cases the export Hawk aircraft are very comprehensively furnished with radio and radio navigation equipment to meet individual customer requirements.

An up-dated, programmable, version of the weapon management system will shortly be introduced, allowing even greater flexibility for future operational stores. The system is currently being installed in the BAe demonstrator G-HAWK and will fly this year.

BAe recognised that there would be a need for training on more advanced avionic systems, and that, for operational use, it would not be possible to rely on beacon based navigation aids. Thus an Enhanced Ground Attack (EGA) system has been designed and is now running on a ground proving rig which includes a full Hawk cockpit and visual displays. This facility enables the system to be flown and demonstrated, and will be used during the future expansion and development of the system.

The system employs an Inertial Navigation platform, a Head-Up Display, Head Down multi-colour display and Hands-on-Throttle and Stick (HOTAS) controls. Coupled with the new Weapon Control System, and a

comprehensive standard of radio and conventional standby displays the cockpit of the EGA Hawk should satisfy even the most demanding of pilots!

The EGA system can be fitted to a two seat Hawk, designated the Mk. 100 Series, for both training and operational use. The use of a MIL-STD 1553 B Data Bus simplifies the addition of such equipment such as Forward Looking Infra-Red (FLIR) sensors, and Laser ranging.

The EGA system also forms the heart of the operational single seat Hawk, the Mk. 200 Series. This aircraft has been designed to allow the greatest possible degree of flexibility to meet individual customer requirements. The aircraft is fitted with an inboard gun installation that can accept up to two 25 mm Aden guns, although the 30 mm Aden could be fitted if required. The use of a "gun pack" approach enables the gun bay to be used for other purposes if needed, for instance it would be simple to fit a specialised reconnaissance pack in lieu of guns.

The lines of the aircraft have been chosen with the possible fit of a modern multi-mode radar in mind. The hinged nose can accept a radar dish of up to 24" diameter. The use of a separate hinged nose makes it a simple task to cater for other equipment, such as FLIR and Laser, should the aircraft be intended primarily for day/night ground attack use. With a radar fitted the aircraft would be more suitable for an anti-shipping or air defence role.

Also under development are the electronic counter measures so essential today. The aircraft can be fitted with a radar warning system, and with chaff and flare dispensers. Active jamming pods can be carried on the wing pylons.

The system has been designed with considerable spare capacity to allow for future growth and gives the Hawk a remarkably comprehensive capability now and in the future.

8. PERFORMANCE (FIGS. 3 - 6)

The performance improvements in terms of mission effectiveness come from the increased capability for take-off with larger payloads, particularly in the "hot and high" conditions. In addition the improvement through development in attack speeds and agility enhances the combat capability to give overall effectiveness in the light attack role.

The developments to improve maximum lift, lift/drag ratio and combat thrust have been taken to a standard to enhance combat capability through higher agility at maximum usable performance conditions.

The sustained turn is improved to a higher level and also extended over a wider speed range to give better minimum turn radius and higher turn rates at operational attack speeds.

The instantaneous turn rate is achieved at low negative specific excess power and low turn radius, inside 0.3 n.m., and thus gives minimal speed loss in turning manoeuvres, typically less than 20% speed loss in 180° turns.

Also the 1 g acceleration is maintained at 5-7 kts/sec. up to the attack speeds and hence small speed losses in manoeuvre are quickly recovered.

Mission performance has been greatly extended by providing capability for take off with substantial payload, comprising combinations of air-air and air-surface attack weapons and fuel. In this way operation at substantial radius of action or for long times on station for air surveillance or reconnaissance missions can be achieved from relatively short airfields.

Typical gains in performance are:

- * Take off distance at 3600 Kg. payload reduced 49%.
- * From 4000 ft. runway take-off mass increased 20%.
- * From 2500 ft. runway take-off mass increased 25%.
- * Maximum level speed increased from .81 to .85 M at S.L.
- * Sustained turn 15 deg./sec. from 0.3 to 0.75 M and minimum turn radius .22 n.m. at S.L.
- * Instantaneous turn 22°/sec., .28 n.m. radius at S.L.

Also typical mission performance achievable is:

- | | |
|-----------------------------|--|
| * Airspace denial (Hi-Hi) | 4 hours on station at 50 n.m. (Missiles,gun) |
| * Close Air Support (Lo-Lo) | 130 n.m. (5000 lb. bombs, guns) |
| * Interdiction (Hi-Lo-Hi) | 530 n.m. (5000 lb. bombs, guns) |
| * Reconnaissance (Lo-Lo) | 380 n.m. (Pod, missiles) |
| * Anti Shipping (Hi-Hi) | Strike at 800 n.m. radius (Sea Eagle) |
| * Ferry | 2000 n.m. |

9. CONCLUDING REMARKS

Hawk evolution, through the concept of an advanced flying training aircraft with potential for light attack operational capability, has been carried through at an affordable level.

The objective in this design evolution has been to make available a series of aircraft with considerable commonality and resultant benefit to costs of ownership of a mix of aircraft in the series.

At the present time the development has been taken as far as:

Maximum operating weight increased 50%

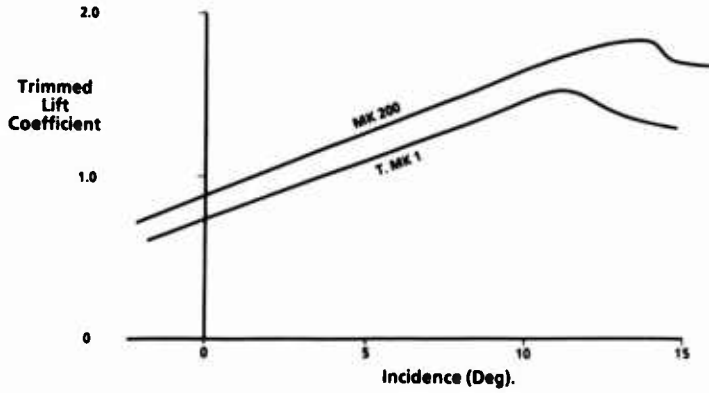
Maximum disposable load increased 125%

Maximum range increased 65%.

The planned evolution has been indicated in this paper and extends into the next decade, developing systems and performance towards improving operational capability to meet role requirements for specific customer scenarios.

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High Lift Development Low Speed

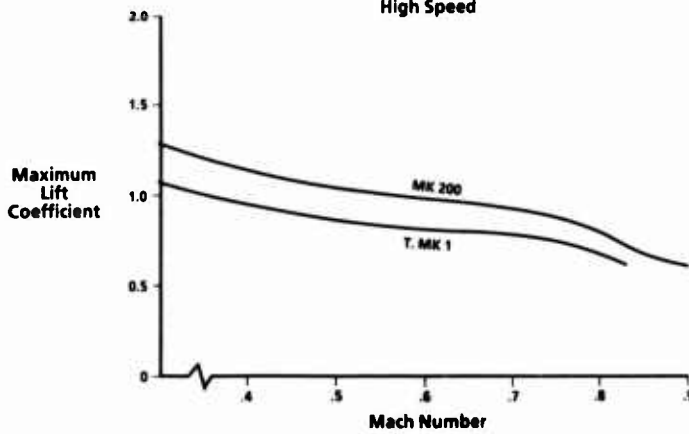


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FIGURE 1A

**BRITISH
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High Lift Development High Speed

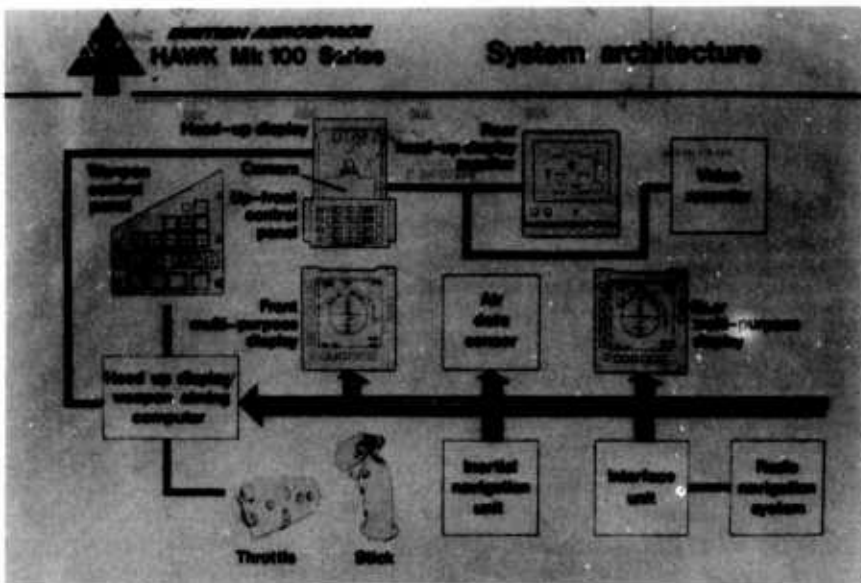


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FIGURE 1B



FIGURE 2



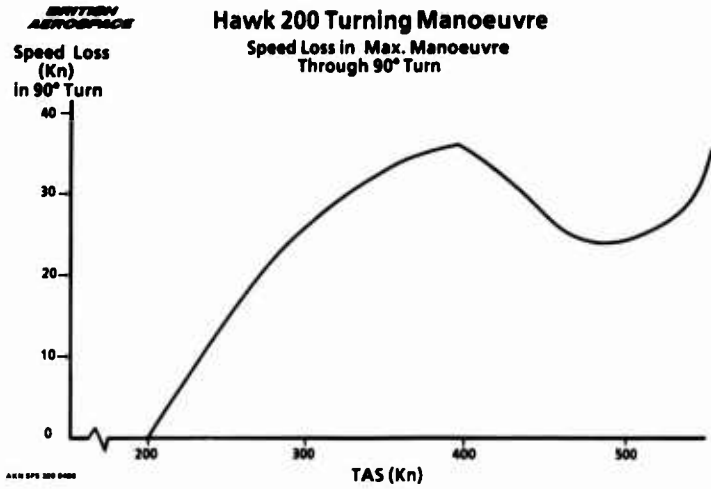


FIGURE 4A

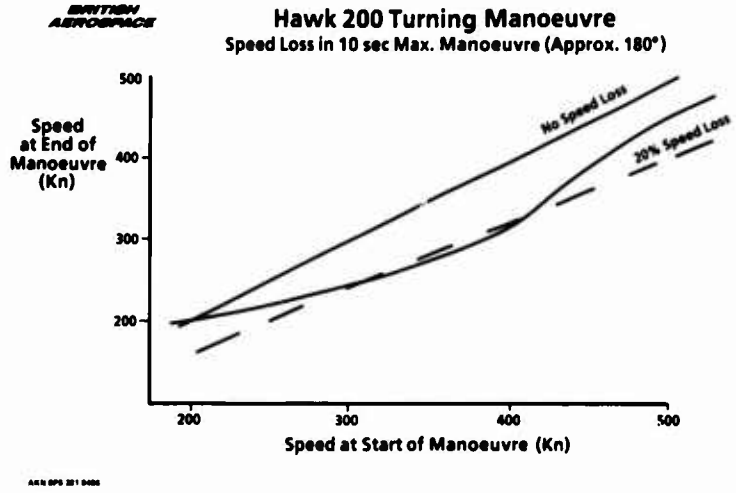


FIGURE 4B

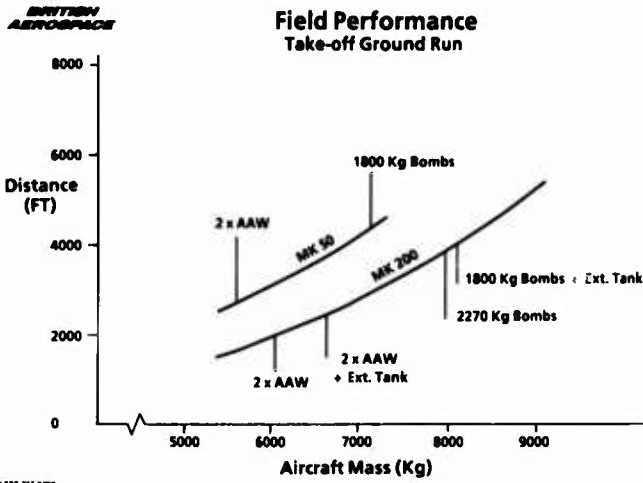


FIGURE 5

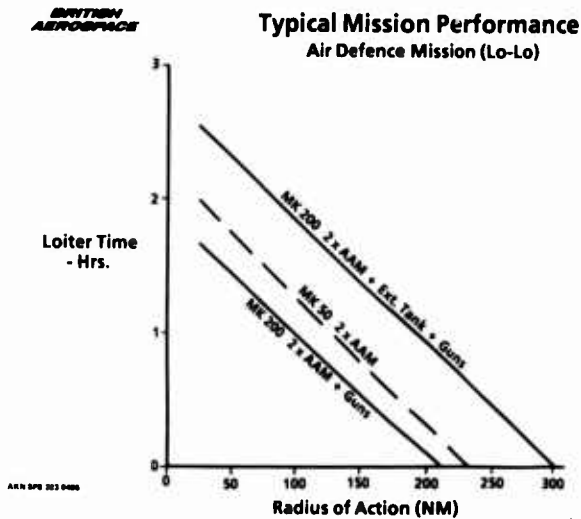


FIGURE 6A

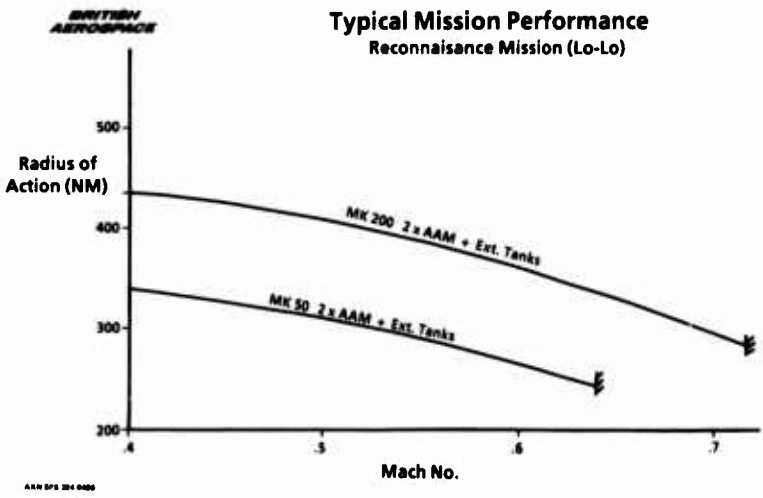


FIGURE 08

