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USAF EVALUATION OF THE HARRIER GR Mk 1

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TECHNICAL REPORT No. 69-26

JUNE 1969

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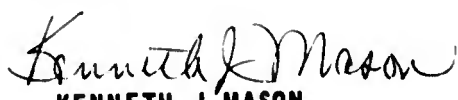
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FOREWORD

This report presents the results of a qualitative evaluation of the Harrier GR Mk 1 VSTOL aircraft built by Hawker Siddeley Aircraft Limited. The evaluation was conducted at the manufacturer's flight test facility at Dunsfold, Surrey, England, between 16 and 27 January 1969.

The evaluation was authorized by the British Ministry of Technology in response to a request from the United States Air Force. The aircraft, test facilities and ground and flight instruction were provided by Hawker Siddeley Aircraft Limited. The cooperation and assistance of the Ministry of Technology and H.S.A.L. are gratefully acknowledged. The author is particularly indebted to Mr. D.M.S. Simpson who conducted the Harrier checkout program.

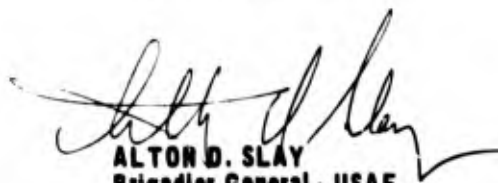
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ABSTRACT

A qualitative flight test evaluation was conducted on the Harrier GR Mk 1 VSTOL aircraft, S/N XV-743, at Dunsfold, England, from 16 January 1969 to 27 January 1969. The aircraft was an early production model aircraft and had not been fitted with the following standard equipment: navigation/attack system, head-up display, engine pressure and temperature limiters, Martin-Baker Mk 9 ejection seat and production wheel brakes. Each of the two evaluation pilots received a normal checkout program and an evaluation flight for a combined total of twenty-one flights and 8.5 flying hours. The aircraft was very easy to fly during vertical and partially jetborne flight, and appeared very capable of being an effective ground attack fighter. The Harrier incorporated many unique features designed to permit operations from unprepared sites with a minimum of support equipment. The aircraft crashed on the last scheduled evaluation flight. The aircraft was destroyed and Major Rosburg, the evaluation pilot, was fatally injured.

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List of Abbreviations and Symbols

<u>Item</u>	<u>Definition</u>	<u>Units</u>
AGL	above ground level	- - -
APU	Auxiliary Power Unit	- - -
ft	feet	- - -
g	acceleration due to gravity	ft per sec ²
HUD	Head-Up Display	- - -
INS	Inertial Navigation System	- - -
KIAS	Knots Indicated Airspeed	- - -
MDC	Micro Detonating Cord	- - -
Mk	Mark	- - -
rpm	revolutions per minute	- - -
VSTOL	Vertical Short Takeoff and Landing	- - -
VTO	Vertical Takeoff	- - -
%	percent	- - -
β	sideslip angle	deg
ϕ	bank angle	deg



INTRODUCTION

A qualitative evaluation of the Hawker Siddeley Harrier GR Mk 1 VSTOL aircraft was conducted by Major Charles R. Rosburg and Major Kenneth J Mason of the Air Force Flight Test Center during January 1969. The evaluation was made at the Hawker Siddeley flight test facility at Dunsfold, Surrey, England, and consisted of 21 flights and 8.5 hours flying time. Each pilot completed a normal transition program and one heavyweight evaluation flight with five external stores, two 100-gallon fuel tanks, two rocket pods and one centerline reconnaissance pod.

The Harrier GR Mk 1 (ground attack reconnaissance Mark 1) was a VSTOL jet fighter capable of operating from relatively unprepared runways or landing sites. It was powered by a single Pegasus 101 vectored thrust engine with a short lift uninstalled thrust rating of 19,000 pounds (15 seconds). Aircraft empty weight was 12,200 pounds and internal fuel capacity was 5,000 pounds. Seven external store stations were available, two under each wing and three on the fuselage. External store combinations could be carried up to a maximum of 5,000 pounds. The aircraft was controlled during jet-borne flight by reaction controls, interconnected with the aerodynamic flight control system and powered by bleed air from the high pressure compressor. The reaction control ducts were pressurized in jet-borne flight with no gas flowing until the flight controls were displaced from neutral. Flight control displacement decreased engine air flow and increased exhaust gas temperatures. Because of these higher temperatures, jet-borne flight was one of the limiting parameters on the Pegasus engine. A time-temperature relationship has been established for engine life under compressor bleed conditions and a digital counter was installed to record "bleed counts." The latest Pegasus 101 engines had an engine life of 200 hours and no Harrier engine had ever been replaced because of expired bleed life.

The aircraft evaluated was a production model Harrier, but it lacked several important features which will be standard equipment on the final production aircraft. Items missing were: Navigation/Attack system, Head-Up display, Martin-Baker Mk-9 ejection seat, engine jet pipe temperature and pressure ratio limiters and production wheel brakes. The Nav/attack system, HUD and ejection seat were evaluated separately, but the lack of this equipment in the test aircraft greatly limited the evaluation.

No test instrumentation was installed; however, an onboard tape recorder was provided as a part of the standard production aircraft, and was used for recording performance parameters during the evaluation flights.

The aircraft was evaluated primarily as a close support fighter operating from unimproved sites close to a battle area. It was recognized that there were many other possible missions for which the Harrier might be suited, but it was felt that this was the type of mission which most completely exploited its unique capabilities. To minimize logistics problems, the aircraft could be armed at a primary base and then dispatched to a forward area where it could land and remain on alert status until needed. After a strike, it would return to the primary base for re-arming. Such an aircraft would necessarily have to be as self support-

ing as possible, and a great amount of effort has been spent designing the Harrier for such an operation. The requirements for this specific mission strongly influenced many of the conclusions reached by the evaluating pilots. For example: since the advantage to such an operation would be in the minimal total reaction time to reach the target, any system that would unnecessarily delay a strike should be improved or eliminated whenever possible.

TEST AND EVALUATION

OPERATIONAL ANALYSIS

ENTRANCE AND CREW STATION EVALUATION

Normal entry and exit were accomplished by means of a ladder placed against the aircraft. To reduce the ground support equipment necessary for field operations, a retractable step and built-in handholds and foot-steps were provided.

The Harrier cockpit was considered an excellent compromise between visibility requirements and the need to place a large number of instruments in a small area. Very important field of vision requirements in a vertical landing aircraft impose severe space limitations on cockpit design. The cockpit must be narrow to allow good downward vision on either side, and cockpit instruments must be kept below a certain level to allow a good downward view to the front. Because almost all of the available space had been used for instruments and controls, the cockpit appeared cluttered when viewed for the first time. It was soon realized that the cockpit was very functional. In most instances, the instruments and controls were well grouped and all switches and controls were easily reached. The Head-up display (HUD) contained all the primary flight instrumentation, but was not installed in the evaluation aircraft.

Visibility

Side and forward visibility were adequate, but visibility to the rear was restricted by the large intakes. Downward visibility to the front was barely adequate despite considerable design effort expended in keeping the windscreen area as low as possible and free of obstructions.

Instrumentation, Communication Equipment, and Controls

A tacan bearing and distance indicator was placed on a vertical panel just forward of the right console. In this position it was difficult to read accurately and was very difficult to adequately crosscheck during instrument flight. In addition, the compass card was not slaved to aircraft heading and did not provide relative bearing information. The length of the instrument behind the compass face and its proximity to the fuselage structure precluded the face being tilted toward the pilot. There appeared to be no better place available to relocate the instrument or to improve its readability; however, the compass card should be slaved to aircraft heading to improve its usefulness.

The standby (secondary) attitude indicator had no pitch graduation marks on its face and had a relatively large aircraft symbol which completely covered the horizon bar near the center. Small pitch changes on the instrument were difficult to see. The secondary attitude indicator should be replaced by a more functional one.

The UHF radio control box was located on the bottom of the center pedestal in front of the control stick because there appeared to be no better place to locate it. In this position, it was difficult to change channels during formation flight and it would be especially difficult during night or weather formation. A remote channel indicator on the instrument panel would eliminate the need to look down during channel changes, but it would not solve the problem completely.

No better position could be suggested for either the tacan indicator or the UHF control box, and their placement was considered optimum under the existing space limitations. Since enlarging the cockpit would result in unacceptable visibility restrictions, this dilemma illustrates the need for a great deal of emphasis in VSTOL cockpit design. This effort should include miniaturization and instrument combinations wherever practical.

A conventionally operating elevator and aileron trim button was installed on the control stick grip. A movement of approximately 3/4ths of an inch was required to activate the trim motors. The movement was considered excessive and uncomfortable and should be reduced.

The Harrier Head-Up Display was designed to include the primary flight and navigation instrumentation. The only deficiency noted in the bench demonstration provided was a digital altimeter with minimum increments of 50 feet. This graduation was considered too large to be used in flight near precision approach minimums.

A very compact and complete weapon control panel was mounted on the bottom left side of the instrument panel. The panel was approximately four inches high and six inches wide and provided control and jettison functions for a variety of stores on the seven external stations.

A parking brake was incorporated as a necessity for dispersed operations. It was mounted on the throttle quadrant in a position which precluded opening the throttle with the parking brake set. This was particularly important because the tires would slide at approximately 65% rpm with the brakes locked, and a takeoff attempted under these conditions would probably cause a tire blowout which then might prove disastrous.

The very reliable and simple exhaust nozzle control lever first applied in the P-1127 series aircraft has been retained in the Harrier with no major changes. Its ease of operation and effectiveness during VSTOL flight, and especially during transitions, was outstanding. This concept is still the standard against which all similar VSTOL controls should be judged.

To provide throttle control from idle (27% rpm) to maximum power (103.5% rpm) without excessive throttle travel, a non-linear throttle response gradient was built into the system. Although a large change in throttle sensitivity occurred at about the one-third throttle point,

the design allowed a very comfortable 0.1-g acceleration per inch of throttle travel in the hover power region and adequate control at lower power settings. This sensitivity change increased the workload during formation flight in that power regime, but the throttle was considered acceptable.

A central warning system was incorporated which was similar to the master caution panels found in most U.S. military aircraft. The system included two flashing attention lights mounted above the instrument panel and an accompanying audio signal in the pilot's headset. These additions greatly increased the effectiveness of the total system and should be considered for inclusion in all future aircraft.

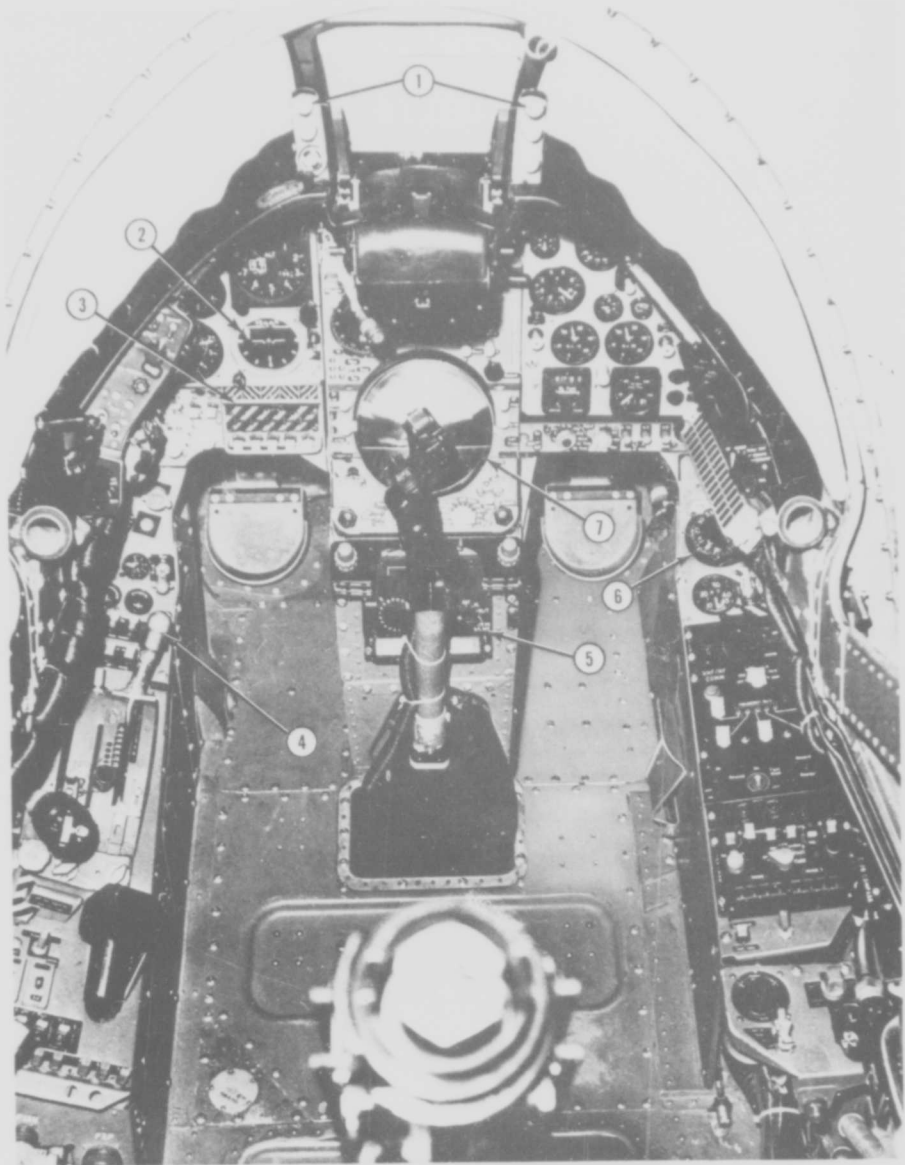
GROUND OPERATION

An auxiliary power unit was built into the Harrier to provide electrical power and starting capability without external equipment. The unit was reliable and provided smooth engine starts. An APU should be considered a necessity for any aircraft intended for dispersal to remote areas.

A non-linear nosewheel steering system was incorporated to provide a short turning radius with proper sensitivity at high speeds. The nosewheel could be turned 45 degrees to either side of center, allowing the aircraft to pivot about the outrigger wheel. The sensitivity with the rudders near center was 2 degrees per inch of rudder travel, while the overall sensitivity was approximately 20 degrees per inch. The resulting large change in sensitivity as rudder displacement increased was disconcerting at first, but presented no problems after a little experience was gained. The non-linear steering system was designed to give a maximum ground maneuver capability on unprepared sites. Although the extreme variation in sensitivity made ground handling less than optimum, the system was very functional. This is one of several examples of practical compromises used to give the Harrier special capabilities required for dispersal to unprepared sites.

The wheel brakes on the evaluation aircraft were not production model brakes, and according to the manufacturer's test pilots, were less satisfactory than the same model brakes on other Harriers. It was virtually impossible to stop the aircraft with the brakes on the first two flights without experiencing a considerable amount of brake shudder. The brakes improved after some air was removed from the hydraulic system, but the problem was never totally corrected. An effective anti-skid system aided in maximum braking down to 15 knots; below 15 knots, no anti-skid protection was provided. Caution was necessary to prevent sliding the tires at low speeds.

Idle thrust was too high for taxiing and it was necessary to lower the nozzles 45 to 65 degrees to avoid excessive taxi speeds. The nozzles were always raised to the fully aft position as soon as the aircraft stopped to avoid overheating the tires.



- | | | | |
|---|-----------------------------|---|--------------------------------------|
| 1 | ATTENTION LIGHTS | 5 | UHF RADIO |
| 2 | STAND-BY ATTITUDE INDICATOR | 6 | TACAN BEARING AND DISTANCE INDICATOR |
| 3 | WEAPON CONTROL PANEL | 7 | MOVING MAP DISPLAY |
| 4 | NOZZLE CONTROL LEVER | | |

Figure 1 AIRCRAFT COCKPIT (EJECTION SEAT REMOVED)

TAKEOFFS

Vertical Takeoffs

Vertical takeoffs were accomplished by establishing 55% rpm, moving the nozzle control level to the hover stop, and advancing the throttle to full power. Engine acceleration was quite rapid and the aircraft usually became airborne as the engine reached maximum rpm. No heavy-weight vertical takeoffs were attempted and an ample thrust-to-weight margin was always available. Some "ground effect" instability about all axes was apparent up to 10 to 15 feet even with the auto-stabilization system on. Without the auto-stab system engaged, the instability was markedly more noticeable, but the aircraft was not difficult to control. As the unstable area was passed, the required control movements were considerably reduced and the aircraft became very easy to fly. For accelerating transitions, the nozzle control lever was moved forward of the hover stop to start the aircraft accelerating. Almost any rate of nozzle movement was satisfactory as long as it was not so rapid as to cause the aircraft to sink. Care was required to keep the aircraft in the proper attitude, especially directionally. As the nozzle control level approached the forward stop, a moderate nosedown trim change and airframe buffet occurred. The buffet was apparently caused by the proximity of the engine exhaust flow to the elevator, and was noticeable anytime the nozzles were fully aft. Early accelerating transitions were controlled primarily by holding the aircraft straight and maintaining a relatively level pitch attitude. As proficiency increased, the pitch attitude was changed to hold approximately 8 degrees angle of attack for a more efficient transition.

Rolling Vertical Takeoffs

Rolling vertical takeoffs were designed to minimize the possibility of foreign object damage during takeoffs from unprepared sites. The prescribed technique was to release brakes and slam the throttle forward from 55% rpm with the nozzles aft. As the engine reached maximum rpm, the nozzles were rotated to either 75 or 81 degrees depending on whether the takeoff was to be followed by an accelerating transition or a hover. The ground speed at lift-off was estimated to be between 20 and 30 knots, which should be sufficient to clear any debris resulting from the maneuver.

During short takeoffs, the brakes were released at 55% rpm and the throttle was advanced to full power with the nozzles aft. As the pre-computed takeoff speed was reached, the nozzle control was moved aft to a pre-set short takeoff stop. Takeoff was usually immediate and fairly abrupt, accompanied by the low altitude instability experienced during vertical takeoffs. As the aircraft became safely airborne, the nozzle control was advanced as during the vertical takeoffs and transition. The auto-stabilization system seemed of more value during the short takeoff than during the vertical takeoff. To be suddenly thrust into the air in neutrally stable, partially jet-borne flight, was a somewhat startling experience, and the auto-stab system increased the comfort of the maneuver considerably. Some short takeoffs were made without using the STO stop. As takeoff speed was reached the nozzle control was moved smoothly aft until the aircraft flew off the ground. This technique gave a much smoother takeoff than use of the STO stop, but may not produce maximum performance. The relative merit of each of the two techniques is being investigated by the manufacturer.

Conventional Takeoffs

To increase the Harrier's rough field landing and takeoff capabilities, relatively large, low pressure tires were used on the nose gear and main gear. The soft tires were restricted to 160 knots rolling speed and limited conventional takeoffs to gross weights of 16,200 pounds or less. Except for a very rapid acceleration (about 700 feet to 100 knots at maximum conventional gross weight), conventional takeoffs were quite ordinary and easily accomplished.

FLIGHT CHARACTERISTICS

The Harrier's handling characteristics in conventional flight were satisfactory. The flight controls were light and there was good harmony in control pressures.

There was ample stall warning in both unaccelerated and accelerated stalls. The warning consisted of buffet and a pronounced wing rock, especially during accelerated stalls. The angle of attack attained prior to wing rock varied with altitude and the rate at which g force was applied. At 30,000 feet a fairly abrupt turn produced wing rock at 9 degrees angle of attack. When the acceleration was increased more gradually the wing rock occurred at 14 degrees. At 10,000 feet, 16 degrees angle of attack was attained prior to wing rock.

During cruise flight where the auto-stab was disengaged, (automatically above 250 KIAS) the Harrier exhibited nearly neutral spiral stability, positive static longitudinal stability and an almost deadbeat short period. The Dutch roll mode was characterized by a high ϕ to β ratio with a pronounced oscillation in bank. Stability and control during cruising flight were satisfactory.

A few tracking passes were made to investigate handling qualities during weapons delivery. The aircraft was stable and very responsive, and tracking was relative easy. No aircraft handling or response deficiencies were found which would limit the Harrier's capabilities as a weapons delivery vehicle.

Except for the normal decrease in performance, it was difficult to detect any differences in handling qualities between a clean aircraft and one with five external stores. It should be possible to increase the external load without any appreciable decrease in handling qualities.

LANDINGS

Vertical Landings

Decelerating transitions to vertical and short landings were made using various nozzle and throttle techniques. The method used for most vertical landings was to establish a conventional final approach in the landing configuration and simply move the nozzle control to the hover stop. Power was advanced to maintain the established flight path to a level off point at about 50 feet. As the aircraft approached the desired landing spot and slowed to 50 knots or less, the thrust vector was controlled by aircraft attitude, as in a helicopter, to bring it to a hover.

From the stabilized hover, a rate of descent was established by a momentary power reduction. An attempt was made to maintain a comfortable

rate of descent all the way to touchdown. The same ground effect instabilities occurred during landing as occurred on takeoff. Since the reaction controls used engine compressor air for a power source, one result of the ground effect was a slight increase in rate of descent as flight control usage increased. The normal tendency was to increase power to counter this effect. A better procedure was to allow the aircraft to continue the descent without a power change, as the increase in descent rate was usually well within structural limits. Smooth landings were seldom attempted because of engine temperature increases due to reingestion and because the ground effect region was not comfortable.

Short Landings

The technique for transition to partially jet-borne flight required for short landings was somewhat different than that used for vertical landings. A fixed throttle technique was used exclusively as it was judged more practical for operational use than a pre-computed fixed-nozzle landing. On a normal final approach, the nozzles were positioned in the region of 50 to 60 degrees down. As airspeed decreased, the desired power was set and the nozzles were moved to the vicinity of the hover stop. As airspeed continued to decrease, the nozzle control lever was used to establish and maintain 8 degrees on the angle of attack indicator. The nozzle control was moved in the same sense as a throttle-forward to decrease angle of attack and aft to increase angle of attack. The proper angle of attack was held throughout the final approach. As the aircraft approached the runway, a slight landing flare was made and the aircraft was either lowered to the runway with the throttle, or the nozzle angle was increased to reduce airspeed and aerodynamic lift. The most useful procedure was to place the nozzle lever to the braking stop while about five feet above the ground. With the nozzles 17 degrees forward of vertical, (braking stop) the aircraft decelerated rapidly and an immediate firm landing was made. This procedure was used for maximum performance short landings because it afforded the maximum use of powered nozzle braking. Engine power remained at the same high setting used for final approach and initial deceleration was quite effective. At some undetermined speed around 60 knots, the wheel brakes were more effective than the reverse thrust of the engine. In this region, the throttle was retarded to idle to increase the weight on the tires and the aircraft was stopped with the brakes. Although the initial deceleration after touchdown was quite rapid, the effectiveness of wheel brakes during the remainder of the landing roll seemed less than that of other fighter aircraft. The effect of crosswinds during short landings was magnified because of the slow speed of the aircraft. The technique used to compensate for crosswinds during final approach and landing was to keep the aircraft aligned with the externally mounted yaw vane and allow it to touch down in a crab. Upon touchdown the aircraft aligned itself with the direction of travel without any assistance from the pilot. This fortunate ability of the Harrier should be studied for incorporation in future STOL designs because of the large crab angles required for short landings. (Or similarly, high bank angles required if the slipping technique is used in a crosswind.) The Harrier's self-alignment on touchdown was probably due in large part to initially touching down on the centerline mounted main gear, which was aft of the longitudinal center of gravity.

The fixed throttle short landing technique automatically resulted in the proper final approach speed for a particular gross weight and

power combination. The higher the power setting, the slower the resulting approach speed. The limiting safe power setting would be that which barely allowed enough power margin to cushion the landing. The maximum allowable power setting varied with glide path angle, and at the time of the evaluation had not been established. Fixed power short landings were advantageous for training situations, since a low power setting which used no engine bleed life required the same technique, and afforded the same training benefit, as landings with higher power settings.

Rolling Vertical Landings

Rolling vertical landings were made as a part of the normal transition program. The reason for rolling vertical landings was to eliminate ingestion of debris thrown up by the vertical exhaust gas. Two techniques were used to attain a moderate speed across the ground from a stable hover condition. The first was to simply lower the nose, helicopter fashion, and allow the aircraft to accelerate forward. The throttle was used to establish a descent and the aircraft was rotated to a level pitch attitude prior to touchdown. The second, and more comfortable technique, was to move the nozzle control forward to 2 to 3 degrees from the hover stop, maintain a level attitude, and land the aircraft with the throttle. Both procedures were easy and satisfactory.

Conventional Landings

Conventional landings were not appreciably different than other fighter aircraft except for the use of powered nozzle braking during part of the landing roll, and the aircraft's ability to land in a crab. (See discussion on short landings.) The outrigger landing gear has been redesigned and strengthened over that used in the P-1127/Kestrel series aircraft, and there was no leaning over to one side as in the previous models. This eliminated the associated directional control problems during takeoffs and landings as experienced with the earlier aircraft.

PERFORMANCE

Some performance data was gathered on one of the evaluation flights using the cockpit instrumentation and the onboard tape recorder. The takeoff configuration for the flight was 2 rocket pods outboard with ballast simulating 19 rockets in each pod, 2 full one-hundred Imperial gallon drop tanks inboard, and a ballasted reconnaissance pod on the centerline. None of the instruments were calibrated and the data was not reduced to standard day conditions. The main intent of the performance check was to compare a few of the manufacturer's performance figures with evaluation flight test data. The uncorrected test data equaled or exceeded the manufacturer's performance figures in almost every instance. Figure 2 compares the test data with the manufacturer's performance charts.

A cruise fuel flow check was made at 30,000 feet pressure altitude and 0.87 Mach number with the five-external store configuration. The nautical miles per pound of fuel computed from the test point was 0.1405. This figure was 12 percent greater than that computed from the manufacturer's test data (0.12493). The difference was probably due to uncalibrated instruments in the evaluation aircraft.

Some random performance figures were taken during landing practice with the configuration listed in the preceding paragraph. Three short

takeoffs, closed patterns and short landings required an average of 260 pounds of fuel. A vertical takeoff and accelerating transition to 220 knots used 80 pounds of fuel and 25 seconds with the five store configuration and 1,700 pounds of fuel remaining.

Takeoff and landing distances were not measured, but merit some comment with respect to short unprepared site operations. At similar gross weights, short landing always required considerably more distance than short takeoffs (approximately 700 feet for takeoff, and 2,000 feet for landing with 2,500 pounds of internal fuel and 2,500 pounds of external stores). Landing distance will remain longer than takeoff distance until some method of deceleration is devised to match the 1-g (approximate) acceleration available for takeoff. Therefore, operating sites must be limited to those long enough to permit a safe short landing or the aircraft must be flown in at vertical landing weight. (Approximately full internal fuel and no stores.) A possible solution might be to land the aircraft with the desired armament load but at a fuel state that would permit a vertical landing. It could then be refueled and made ready for a mission.

HARRIER GR MK 1 S/N XV-743
 2 100-IMPERIAL GALLON DROP TANKS
 2 MATRA ROCKET PODS (BALLASTED)
 1 RECONNAISSANCE POD (BALLASTED)
 INITIAL GROSS WEIGHT 19,700 lb
 TIME AND FUEL FROM BRAKE RELEASE
 ○ UNCORRECTED TEST DATA

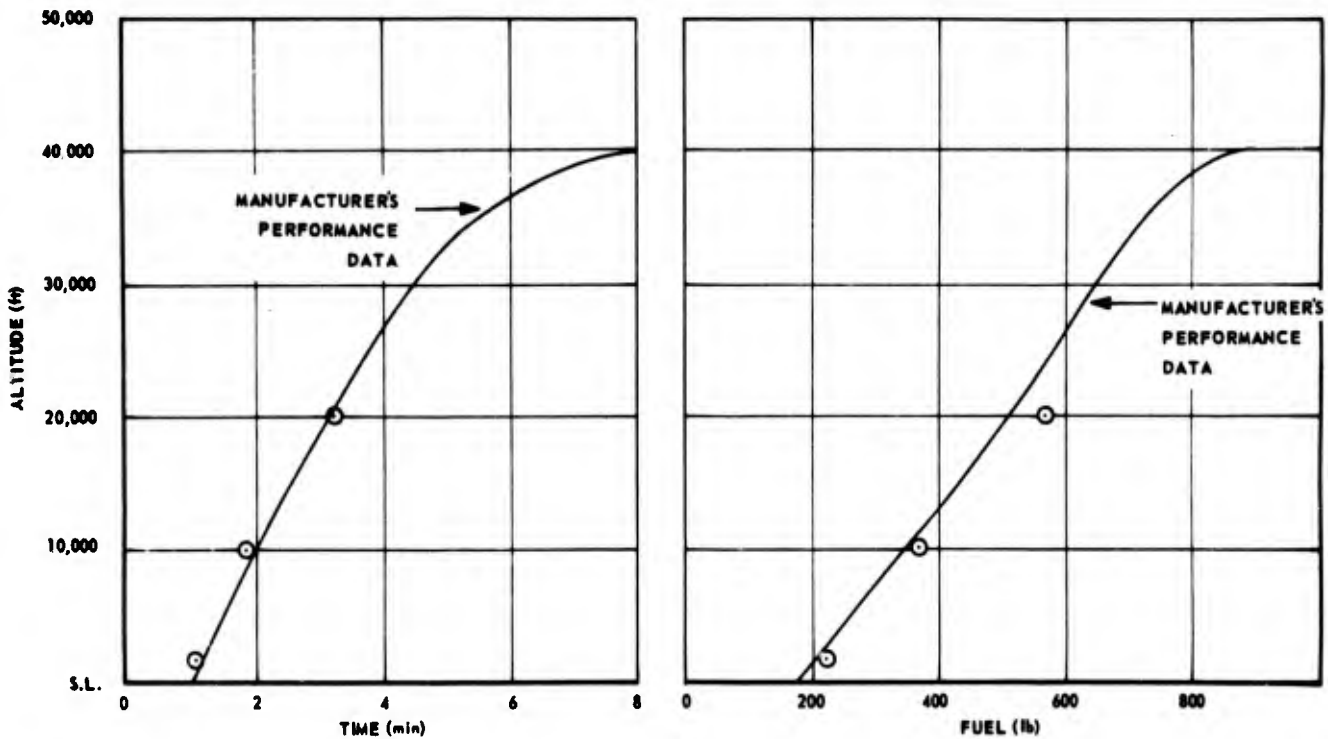


Figure 2 CLIMB PERFORMANCE

SYSTEMS EVALUATION

The evaluation pilots were given a bench demonstration of the Harrier's Navigation/Attack system, but did not fly the system in an aircraft. It was still in the development and test stages and some design details had not been finalized. Further evaluation is recommended when the system becomes operational.

In general, the Nav/Attack system had some outstanding features which could make it very valuable for overall employment of the aircraft. It was felt, however, that it would not be particularly useful for the specific mission described in the introduction to this report. In addition, the attack modes were too inflexible and should be improved.

The Harrier's Nav/Attack system consisted of an inertial navigation system with a slaved moving map display and an inertially directed attack feature. Seventy millimeter transparent photographs were used to project a map on the Navigation and Display Computer on the center pedestal. The projection was slaved to the present position counters, so that the INS present position was in the center of the display. Although the moving map display was designed for VFR use only, and still had some deficiencies in clarity and resolution, it was judged a considerable advance over inertial systems without map displays, and should be considered for all inertial navigation systems in tactical fighters.

The INS also furnished present position latitude and longitude signals to a reconnaissance pod where it was copied on each photograph for later correlation and identification.

The attack feature of the Nav/Attack system had two main release modes; manual for guns, rockets and bombs and automatic for retarded and free fall bombs. Planned attack and unplanned attack options were available in the automatic mode. Manual release was restricted to a single slant range for each type of weapon. Planned attack was limited to a maximum dive angle of 25 degrees, and the unplanned attack appeared excessively complicated. (In an unplanned attack, the pilot would be required to start the attack at an estimated 12 seconds from the target, change phases, update range information with the left hand, and fly the aircraft to keep the azimuth bar aligned with the target.) The inflexibility of the system is indicated by the fact that only the complicated unplanned attack was suitable for bomb deliveries beyond 6,000 feet slant range or at dive angles greater than 25 degrees. A means of changing the manual mode fixed slant range in flight would greatly increase system usefulness. Some type of automatic ranging would provide even greater flexibility. Either or both of these improvements should be incorporated.

A Martin-Baker Mk 9 ejection seat was designed for the Harrier. It was not installed in the evaluation aircraft, but was seen in the emergency equipment shop at Dunsfold. A torso harness was used which increased the complexity of the strap-in procedure over that of the older Mk 6 seat used in the evaluation aircraft. The strap-in procedure was too complicated and time consuming for a quick reaction aircraft, and the harness system should be redesigned.

The Mk 9 seat had a relatively long burning rocket designed to allow escape from a descending aircraft at low altitude. Although the

seat will probably have increased capabilities over its predecessors, it was still far from the optimum escape system for VSTOL aircraft. An ejection system capable of providing safe escape probabilities comparable with those found in conventional fighter aircraft would probably have to be a vertical seeking seat that could turn and thrust the seat upward from an unlevel attitude. Development of such a seat should be one of the prime objectives of efforts relating to VSTOL flight.

An explosive wire (micro detonating cord) was installed around the edge of the plexiglass canopy to cut the canopy loose for ground egress. This was considered an effective, lightweight method of canopy removal for an aircraft with no jettison capability. Detonation of the MDC will eventually be included in the ejection system. Until then, the pilot must eject through the canopy. The MDC should be added to the ejection sequence as soon as possible.

SUMMARY STATEMENT

There were no aircraft handling problems or systems deficiencies which would preclude use of the Harrier as an effective close support fighter. Therefore, the remaining factor in determining the aircraft's possible usefulness is performance. The performance spot checks made during this evaluation closely matched the manufacturer's performance data, and it was felt that the manufacturer's data was accurate. On the basis of the manufacturer's published performance data, the Harrier had adequate performance to be a useful close support fighter with dispersal capability. Planned engine thrust increases should make the aircraft a very useful and effective VSTOL fighter. Pegasus 10 and 11 engines are expected to be available in 1970 and 1971, respectively. The Pegasus 10 has been tested to the design sea level uninstalled thrust of 20,000 pounds. Pegasus II thrust is advertised to be 21,500 pounds at sea level and 15 degrees centigrade, decreasing to 21,000 pounds at 30 degrees centigrade. Both engines are the same size as the currently installed Pegasus 101. Specific fuel flow is expected to be at least as good as that of the Pegasus 101. Figure 3 shows a mission profile computed from the manufacturer's performance data. Since fuel specifics are expected to be similar for the Pegasus 101, 10 and 11, the only change in the profile due to the different engines would be in takeoff roll. Only 80 percent of the thrust increase of the later engines has been used in the takeoff computations to compensate for duct losses and possible weight increase due to engine installation.

HARRIER GR MK 1
PEGASUS 101, 10 OR 11 WITH WATER INJECTION
4 MATRA 116 ROCKET PODS
2 30mm ADEN CANNONS
FULL INTERNAL FUEL (5,000 POUNDS)
INITIAL GROSS WEIGHT (19,500 POUNDS)

TAKEOFF ROLL:	
PEGASUS 101	740 ft
PEGASUS 10	550 ft
PEGASUS 11	350 ft

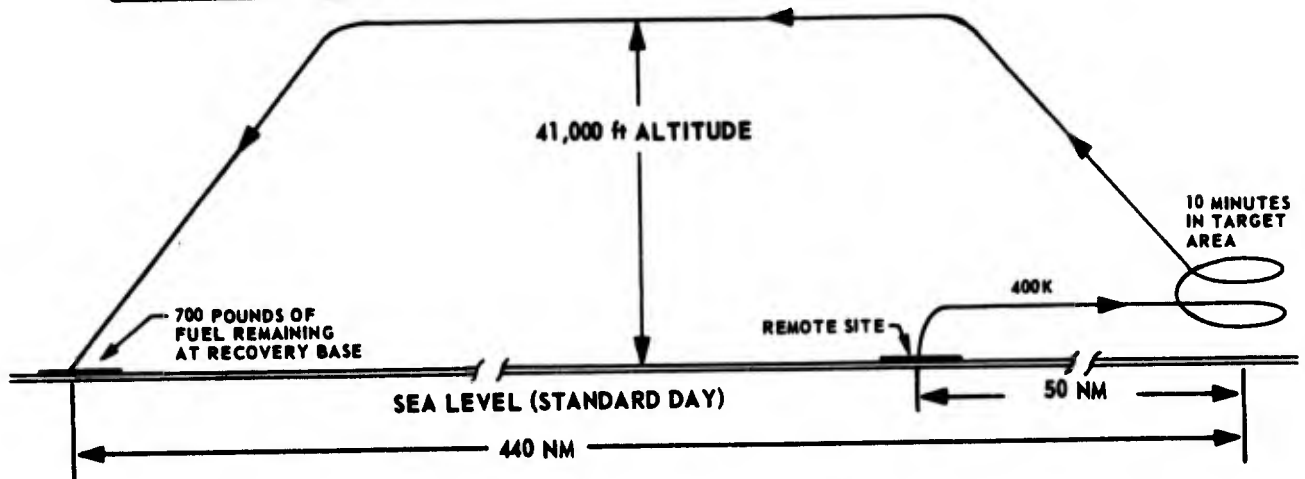


Figure 3 LO LO HIGH MISSION PROFILE

APPENDIX I

AIRCRAFT ACCIDENT

The first fatal accident in the history of the P-1127/Kestrel/Harrier series aircraft occurred on the final scheduled flight of this evaluation. The aircraft was destroyed and the evaluation pilot, Major Rosburg, was fatally injured on ejection. The cause of the accident was not available at the time this report was written, and no conclusions or recommendations could be made regarding aircraft safety or safety precautions relating to the accident. The pilot ejected at about 70 feet AGL in a 90-degree bank during an accelerating transition from a vertical takeoff. The ejection seat and parachute apparently worked properly, but there was not sufficient altitude available for a horizontal ejection to be successful. This accident was a classic instance which demonstrated the desirability of a vertical seeking seat. It could have saved the pilot's life. It is possible that other features available, such as a ballistically ejected parachute, or a canopy spread by an explosive charge or static line, also could have saved the pilot. Some combination of these features should be applied to all VSTOL ejection systems to provide the best possible chance of successful escape. The overall VSTOL accident record seems to justify any effort necessary to provide a safe escape capability under the adverse conditions often encountered in VSTOL flight.

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13. ABSTRACT A qualitative flight test evaluation was conducted on the Harrier GR Mk 1 VSTOL aircraft, S/N XV-743, at Dunsfold, England, from 16 January 1969 to 27 January 1969. The aircraft was an early production model aircraft and had not been fitted with the following standard equipment: navigation/attack system, head-up display, engine pressure and temperature limiters, Martin-Baker Mk 9 ejection seat and production wheel brakes. Each of the two evaluation pilots received a normal checkout program and an evaluation flight for a combined total of twenty-one flights and 8.5 flying hours. The aircraft was very easy to fly during vertical and partially jetborne flight, and appeared very capable of being an effective ground attack fighter. The Harrier incorporated many unique features designed to permit operations from unprepared sites with a minimum of support equipment.		

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