History

Chapter 1 - The origins of the P.1127

1. Genesis

The roots of the Harrier lie in the mid-1950's, a time when the possibility of vertical take-off, fixed-wing aircraft had begun to be investigated in several countries. Airframe and engine designers were stimulated by the growing military awareness of the vulnerability of large air bases to tactical nuclear weapons, while the opportunity to operate civil airliners from the centre of cities provided a further impetus. Most importantly, the rapid progress in engine and airframe technology finally made such aircraft appear truly practicable.

There had already been proposals, mainly German and American, for rocket, jet and propeller driven aircraft that took off vertically, being launched from a gantry or rail, or from sitting vertically on a tail-mounted undercarriage. However, although such aircraft had flown, in the shape of the Bachem Ba349 Natter of 1944, the Convair XFY-1, Lockheed XFV-1 and Ryan X-13 of a decade later and the attempts at launching F-100 Super Sabres with rocket boosters (ZELL), none had proven practical to operate in day to day service. What was clearly needed was a propulsion system that would not over-compromise the operational aspects of a VTOL aircraft, while issues of aircraft control peculiar to flying below the stall also needed to be addressed.

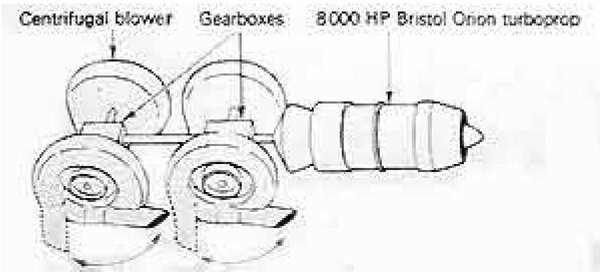
Britain, and especially Rolls-Royce, played an important part in such developments. The Derby based firm test flew the twin-Nene powered Thrust Measuring Rig, or 'Flying Bedstead', in 1953, providing them with ground-breaking experience in low-speed and hovering flight. However, the main line of development at Rolls-Royce was not towards single (or twin) engines used for both vertical and forward flight, but rather in the development of specialised lift engines, a concept conceived by the company's Chief Scientist, Dr A.A. Griffith. The rationale behind this scheme was that by using a bank of small lift engines for take-off and landing, each with a high thrust to weight ratio, the airframe and forward propulsion system could be optimised for the cruise condition. This optimisation would hopefully result in vastly improved efficiency, offsetting the parasitic weight of the lift engines. These proposals found their earliest, and most ambitious, expression in Griffith's scheme for a supersonic, vertical take-off airliner to fly from London to Australia, power for take-off and landing being provided by several dozen RB108 lift engines.

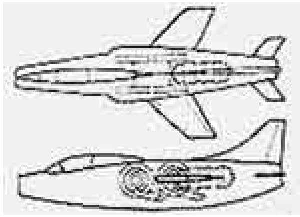
The lift engine concept was warmly received by the British Government, leading to the issue of an official specification for an experimental aircraft to underpin the theory. Two companies that tendered to this specification, ER 143T, were Avro and Shorts. The Avro proposal was to modify one of their 707 delta test aircraft with six RB108s in the centre fuselage, able to tilt to provide some forward thrust in lieu of a separate propulsion engine. However, it was Shorts' proposal, the delta wing, fixed undercarriage SC1, with four RB108s for vertical flight and a single RB108 propulsion engine that was successful, the first of two prototypes (XG600) flying conventionally in 1957, tethered hovering tests commencing during the following year.

Although the lift engine concept that underpinned the SC1 was simple in theory, its practical application proved more difficult. In order to be safe to fly the SC1 had to be equipped with a full authority auto-stabiliser, utilising an analogue computer. The failure of a single lift engine would lead to an instant asymmetric lift force, which could only be safely countered by the triplex auto-stabiliser system. While this level of redundancy was designed to ensure that no single failure would cause an accident, in 1963 the second prototype (XG905) crashed when all three auto-stabiliser gyros failed, killing the pilot.

Despite this tragic accident, the SC1 contributed a vast amount of knowledge to Shorts, Rolls-Royce and the government establishments involved, pioneering the investigation of such matters as hot gas ingestion, ground erosion and short take-off techniques. This experience, allied with the investment of money and effort involved, meant that Rolls-Royce became firmly wedded to the lift jet scheme as the most effective solution for vertical take-off jet aircraft, including fighters. The prospect of selling several engines, albeit relatively simple ones, for each aircraft produced offered a tempting vision for the company. However, by the time that the SC1 began flying, a competing proposition had appeared whose origins lay across the English Channel.

French interest in VTOL was stimulated at the same time, and for the same reasons, as British interest. The first concrete results were to come in 1956, when the engine company SNECMA began tests of the Atar powered C.400, a tail-sitting test vehicle reminiscent of Ryan's earlier tests with Rolls-Royce Avon powered rigs that had preceded the X-13. The French experiments culminated in the tests of the C.450 Coleoptere in 1959, like the X-13 a tail-sitting aircraft, albeit one with a radically different annular wing.





Wibault's proposed powerplant (left) for his Gyroptere (right), with four vectoring blower nozzles.

Despite this officially sanctioned effort one French aircraft designer, Michel Wibault, came to regard aircraft that could take-off vertically from a more conventional attitude as a better solution for a VTOL combat aircraft - the Americans having already discovered the severe piloting difficulties of taking-off and landing lying on one's back. Wibault began to sketch the design of a single-seat, single-engine fighter to be used mainly for tactical nuclear strike missions. In order to achieve vertical lift he envisaged the use of four centrifugal blowers disposed around the aircraft's centre of gravity. These would deliver compressed air via rotating nozzles on the blower casings, power being delivered via gearboxes from a Bristol Orion engine, at 8,000 shp the most powerful turboshaft engine available. Residual thrust from the Orion would exhaust at the rear of the aircraft, a cascade of vanes allowing this thrust to be vectored in addition to the main component from the blowers.

Wibault called his design the Ground Attack Gyroptere. Although by no means the first proposal for an aircraft featuring what became known as vectored thrust, the Gyroptere saw the first application of the four nozzle, single engine layout that was to become the hallmark of the Harrier. During 1955/56 Wibault approached both the French and US governments in the hope of gaining support for his project, only to be rebuffed. Despite this, NATO's American funded Mutual Weapons Development Programme, based in Paris, showed some interest in his scheme. The head of aeronautical development at MWDP, Colonel Johnny Driscoll, soon passed on Wibault's March 1956 brochure to Bristol Aero-Engines in England. At the time Bristol were developing the Orpheus engine as part of the MWDP sponsored Fiat G.91 light fighter programme, thereby ensuring that the two organisations already had a good understanding of each other. Bristol's Technical Director, Stanley Hooker, instructed that in the light of this previous contact a serious study of the Wibault proposal should be undertaken.

The main burden of this task fell on the shoulders of Gordon Lewis of the company's Project Office. He soon saw that the poor efficiency of the centrifugal compressors could be overcome by replacing them with an axial-flow fan using the first two low pressure stages from the Olympus 21 engine, driven by an

Orion via 1.5:1 ratio gearbox .The airflow from the fan would exhaust via two lateral, vectoring nozzles, with both the core and the fan having separate air-intakes. This engine design, numbered BE.48, was completed by early August 1956 and Wibault sketched a revised Gyroptere around it. However, the BE.48 was quickly replaced by the BE.52 proposal at Bristol. In this, Lewis replaced the Orion with an Orpheus, which was not only lighter, but also allowed the fan, now using three Olympus stages, to be directly driven by a low-pressure turbine added to the Orpheus. This eliminated the gearbox, saving further weight. The BE.52 was the subject of a joint Lewis/Wibault patent taken out in January 1957, which included provision for a pair of rear vectoring nozzles in place of the previous cascade assembly.

With this much-refined engine Bristol felt able to begin soliciting financial support from MWDP, in order to move beyond the design stage. Colonel Driscoll's successor, Colonel Willis 'Bill' Chapman, was firmly behind the proposal, and in mid-1958 agreement was reached for MWDP to fund 75% of the redesignated BE.53, with Bristol funding the other 25%. In the meantime, Bristol had sent brochures out to industry to see just what kind of aircraft could be designed around their radical new engine.

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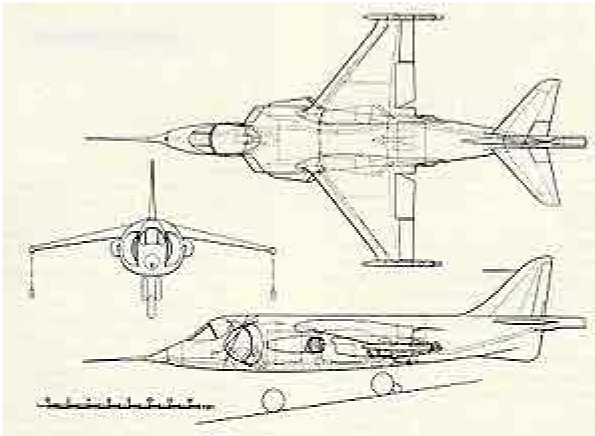
2. Design

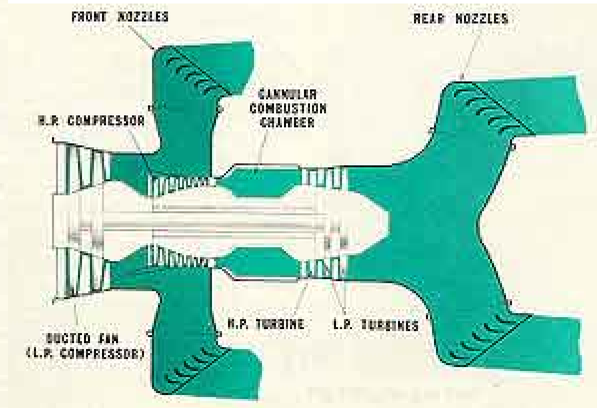
The first company that Bristol approached was Shorts in Northern Ireland. Not only were Shorts the most experienced in terms of VTOL aircraft design, they were also partly owned by Bristol's parent company, making such a move natural. However, Shorts were firmly committed to the SC1 and with it the concept of using lift engines to achieve vertical flight. Although they did scheme a design around the BE.53, Shorts' motive for this appear to have been to allow them to establish contact with MWDP. Once this contact was achieved, the Belfast-based firm concentrated on promoting the SC1. Although this first attempt at getting an airframe design for the BE.53 ended so discouragingly, prospects were soon to brighten for the Bristol team.

The source of these renewed prospects came from Hawker Aircraft Limited at Kingston upon Thames in Surrey. Hawker had an unmatched record of success, having had its aircraft in front line service with the RAF or Royal Navy since 1925 - and if the aircraft of its forebear, Sopwith Aviation, are included, this record stretched back to before the First World War. In the mid-1950s the company was enjoying worldwide success with the Hunter, while its Sea Hawk design was being built by Armstrong Whitworth, a sister company in the Hawker Siddeley group. However, 1957 was to be a watershed year for Hawker. Back in 1954 work had begun on a design to meet OR 329, a specification calling for an all-weather, missile equipped Mach 2+ interceptor for the RAF. Although their submission, the P.1103, was unsuccessful in meeting the RAF's requirement, Hawker saw the need for something to succeed the Hunter. To this end, they re-designed the P.1103 as a single-seat, general-purpose fighter-bomber, numbering it P.1121. Although not officially sanctioned by the RAF, Hawker went ahead with design and prototype construction of the P.1121 as a private venture, confident that customer interest would soon be stimulated. Then, in April 1957, the British Minister of Defence, Duncan Sandys, pulled the rug out from under the entire aircraft industry when he announced that most future fighter and bomber development was to be cancelled in favour of guided missiles. As fighters were Hawker's forte the future suddenly began to look much bleaker for the company.

However, despite Sandys' cancellation of the last 100 Hunters for the RAF, large export orders from India and Switzerland meant that the company had some breathing space. The P.1121 project went on, with the company arguing that it was the ideal aircraft to cover the transition period before the full introduction of the missile arsenal of the future. Nevertheless, with the clear pronouncement that fighters were out of favour with the RAF, Hawker realised that they might need an alternative product within a few years if they were not to go out of business when the Hunter ceased production.



General arrangement of the Hawker P.1127 design, mid-1959.



Airflow in the Pegasus 2, showing the common inlet for both compressors.

It was against this background that the company received copies of Bristol's brochure for the BE.53, one from their agent in France (Gerry Morel) at the Paris airshow of 1957, the other as a result of a letter from Sir Sydney Camm, Chief Designer of Hawker, to Stanley Hooker enquiring as to what Bristol were doing about VTOL engines. In early June 1957 Ralph Hooper, a designer in the company's Project Office, received one of the BE.53 brochures. He was initially unimpressed by it. However, he quickly drew up a scheme for an aircraft around the engine proposal. The BE.53 outlined in the brochure was equipped with vectoring nozzles for the fan airflow only, all attempts at vectoring the core flow having been put aside. This severely hampered the kind of aircraft Hooper could design. His initial scheme recognised these limits by being a three seat observation/liaison aircraft with no warload, being forced to sit at a nose high angle on a tail wheel undercarriage in order to have any hope of vertical flight. This scheme was initially called the 'High Speed Helicopter' and given the company designation P.1127. In an attempt to reduce the estimated weight, Hooper quickly refined the design to incorporate two seats and a pair of lateral intakes in place of the original ventral one, as well as incorporating reaction controls at the aircraft's extremities that would use air piped from the engine for low speed control. However, the limits imposed by only vectoring 50% of the engine's thrust were still evident.

It was at this point that what Ralph Hooper calls "the blinding flash of the obvious" occurred. He realised that if the hot air from the engine core could be bifurcated, as on the Sea Hawk, an extra pair of nozzles could be added and 100% of the thrust would be available for vertical flight. This proposal was tentatively accepted by Bristol and Hooper drew up a new P.1127 design on the basis of this. This revised P.1127 was designed as a ground attack aircraft, capable of VTOL at a weight of 8,500 lb., while it could carry a 2,000 lb. warload from a 200 yard short take-off. Hawker prepared a brochure for this aircraft in August 1957, a copy being shown to Colonel Chapman from MWDP at the Farnborough airshow the following month. He approved of the general concept, but thought that greater warload-radius performance would be required. To this end Hawker and Bristol proposed water injection for the engine, allowing a near doubling of internal fuel from the 2,000 lb of extra thrust, a new P.1127 brochure with this feature added being produced in October. This brochure also proposed that the engine be re-designed to feature contra-rotating spools for the fan and core in order to eliminate gyroscopic effects in hovering flight. Bristol were resistant to this idea as it would mean that the fan could no longer use Olympus blades, but Hawker wanted to eliminate the need for auto-stabilisation and saw such a change as vital.

While such differences of opinion between engine and airframe designers existed, by late 1957 both companies were working closely together, with the P.1127 and BE.53 projects feeding ideas into each other. For both companies, however, V/STOL was by no means the most important prospect for the future. The only significant combat aircraft that Sandys had permitted the RAF to develop was a replacement for the Canberra to meet General Operational Requirement 339. It was in order to win this competition that Hawker stopped all work on the P.1127 in late 1957, to concentrate resources on their GOR 339 proposal, the P.1129. However, English Electric and Vickers were favourites for the contract right from the start, and despite further submissions based on a P.1129 incorporating features from the Avro 739, and on developed versions of the P.1121, Hawker was still faced with a dead end when Hunter production ended. With this in mind, P.1127 design was renewed in January 1958, with greater resources in design and other departments dedicated to it. Further contact with MWDP led to a variant being drawn up with the emphasis being put on VTO, the original 'bent-pipe' nozzles being replaced with shorter, lighter nozzles featuring cascades. The most important change to the P.1127 was, however, to come from Bristol, who informed Hawker in March 1958 of their decision to re-design the engine. This was now to feature a new fan whose two-stages were to supercharge the core, allowing the separate inlets to the Orpheus to be eliminated, and removing the main obstacle to counter rotation of the engine spools.

Ralph Hooper incorporated this revised engine, the BE.53/2, into a re-designed P.1127 by the end of March. He was forced to work over a weekend to meet a deadline for a meeting with MWDP the following week, and has commented that things became exciting when he realised that the design now "fitted together much better". The improved efficiency of the engine allowed the fuel load to be reduced, whilst inverting the engine allowed the accessories to be placed ahead of the wing box, reducing frontal area and weight. A further refinement was the addition of the familiar bicycle undercarriage with wing-tip outriggers, the cropped delta wings being given increased anhedral at the same time. The design was now essentially that of the P.1127 that was to fly in October 1960, although much work remained before that stage was reached.

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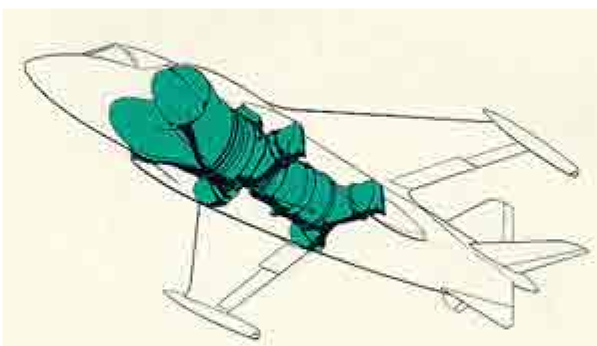
3. Construction

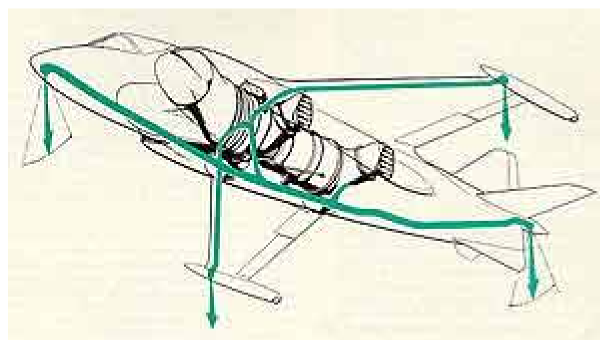
The new version of the P.1127 presented to MWDP in March 1958 met with strong approval from them. They had already intimated that the BE.53 was about to receive funding from NATO, and with such encouraging developments the level of resources and personnel devoted by Hawker to the aircraft increased significantly. Much Drawing Office effort was vainly devoted to coming up with a different undercarriage proposal as Sir Sydney Camm professed to be offended by the existing bicycle scheme. In May construction began of wind tunnel and ground effect models although as Hawker had no wind tunnel of their own, and British government facilities were not made available, some of these had to be tested in the wind tunnel at Kingston Technical College. However, this was only a temporary expedient as in June 1958 the Royal Aircraft Establishment offered its wind tunnels for testing. This was the first positive sign of official British support for the project, prompted by the first musings by the Operational Requirements Branch of the RAF on the development of a possible V/STOL replacement for the Hunter FGA.9 in the ground attack role, although this was unknown to Hawker. With the engine now firmly financed, and with design and construction of the P.1121 winding down in the face of official indifference, Hawker began detail design of the P.1127's wing in August 1958.

The first day of 1959 saw the announcement that English Electric and Vickers had been jointly awarded the contract for GOR 339, the aircraft being developed to specification OR 343 as the ill-fated TSR 2. This was the final nail in the coffin of the P.1121 as a possible production aircraft, the only hope for this design now resting in a research contract in support of TSR 2 development. Even this hope was to be unfulfilled and the incomplete prototype was removed from the Experimental Department later in 1959. The company's hopes now rested on the P.1127, which was always designed as a prototype combat aircraft, with provision to carry operational equipment and weapons. With the TSR 2 firmly 'in the bag' the RAF now felt able to make public its desire to replace the Hunter with a V/STOL strike fighter. In the same month that that they were told about the TSR 2 contract, Hawker learned that the Ministry of Supply was considering an order for two prototype P.1127s. Early in March the first draft of General Operational Requirement 345 reached Hawker, outlining a need for an aircraft clearly in the P.1127 mould to enter service in 1965. With British government interest in the P.1127 now clearly evident Hawker felt able to begin construction of two prototypes in advance of official funding. The first drawings were issued to the Experimental Department during March 1959, while the last major design change was made in the following month when the reaction control system was changed from using low to high pressure bleed air, the pipes required by the original scheme having proven unfeasibly bulky. This prompted a further modification to the engine, the BE.53/2 with its Orpheus 3 core being superseded by the BS53/3 that used an Orpheus 6 to cater for the demand for high pressure bleed air.

Government interest was further illustrated in May 1959 when they sent Hawker a firm specification, ER 204D, for the prototype P.1127s. Although all this interest was welcome to Hawker, it did mean that the P.1127 was now facing in two directions - towards domestic needs and European ones. While the RAF had been drawing up its plans, NATO had been firming up its needs for a V/STOL light fighter to replace the Fiat G.91. By 1959 these needs were becoming more than the basic P.1127 could meet, calling for the carriage of complex navigation and attack avionics and a possible supersonic ability. Despite this, as the P.1127 was clearly the most advanced aircraft in development MWDP continued to support it via the BE.53, although with less likelihood of ordering it into production for NATO forces.



P.1127 powerplant installation.



Initial P.1127 reaction control system for jet-borne flight.

With the first flight now scheduled for July 1960, Hawker authorised overtime for all departments working on the P.1127 in July 1959, the same month that the first BE.53/2 went on test at Bristol. This engine was soon to be renamed Pegasus 1, the BE.53/3 becoming the Pegasus 2. In October the newly formed Ministry of Aviation awarded a £75,000 holding contract for design work on the aircraft, while thoughts at Hawker now centred on preparing the flight test programme for their conceptually novel aircraft. To this end the head of Hawker's Project Office, Bob Marsh, accompanied Ralph Hooper to visit Bell Aircraft and the NASA facility at Langley Field in America. The reason for their visit was to examine the Bell X-14, a small, vectored thrust research aircraft powered by two Armstrong Siddeley Viper engines. In using vectored thrust and in having a jet reaction control system, the X-14 approximated to the P.1127, although it had significant gyroscopic engine forces that the P.1127 design had eliminated. At NASA the two Hawker engineers met John Stack, a P.1127 supporter since a visit to Kingston in August 1958. This enthusiasm was shown by Stack's initiation of free-flight model tests of the P.1127 that would be able to demonstrate transitions from vertical to conventional flight. This help was extended in September when Stack authorised the construction of a 10% peroxide powered transonic model of the P.1127. The free-flight model was first tested by NASA in January 1960 and quickly laid to rest British fears that transitions would be uncontrollable, these results greatly encouraging Hawker. Two Hawker test pilots, Bill Bedford and Hugh Merewether, undertook a further visit to NASA Ames in March 1960 in order to fly the X-14 and other research aircraft, although Merewether had an accident on 1 April that resulted in some damage to the X-14, although he was unhurt. Back in Britain both pilots flew the SC1 to gain further V/STOL experience.

By this time construction of the first two P.1127s was well advanced. Full contract cover and finance was received from the MoA on 22 June 1960, with the first aircraft, XP831, being taken from Kingston to Hawker's Dunsfold airfield on 15 July. Here final installation tests were carried out, with the first flight cleared Pegasus 2 arriving from Bristol during September. With the administrative hurdles of fitting an engine designed for MWDP to an aircraft designed to meet MoA requirements already overcome, all was now set for the aircraft's first flight.

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