HMS *Ocean* and the Vampire at Riverside Museum

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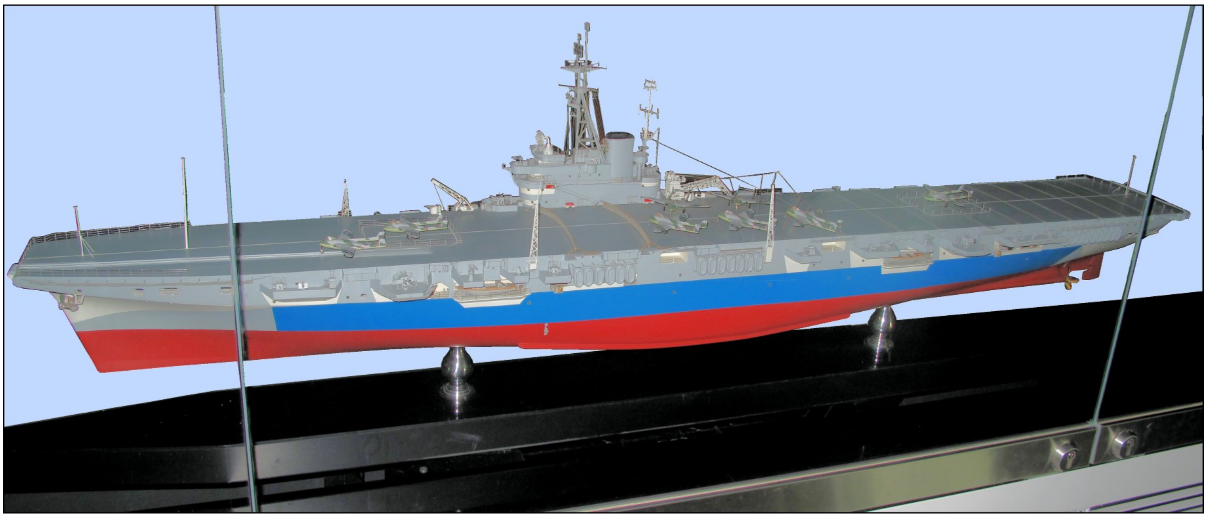
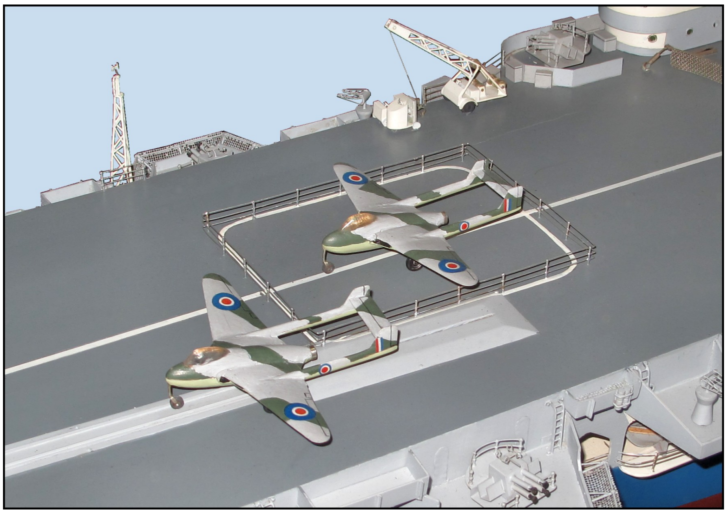
1.0 Introduction. The Glasgow Museums have an outstanding collection of almost 700 ship models many of which are on display at Glasgow's Riverside Museum of Transport and Travel. This Research Technical Note describes some of the features of just one of these ship models; the 1/96th scale model of the aircraft carrier HMS *Ocean* (I.D. No. T.1963.XX) currently on display on the ship conveyer. This model is interesting as it also displays models of de Havilland Vampires, one of Britain's early jet powered fighter aircraft. This note briefly introduces HMS *Ocean* and then explains some details of the Vampire jetfighter.



2.0 HMS *Ocean*, (Pennant No. R68). HMS *Ocean* was a Colossus Class Light Fleet Aircraft Carrier[(1)] of 13,190 tons displacement. She was built on Clydeside by Alexander Stephen & Sons of Linthouse and Commissioned in 1945, ref. 1. HMS *Ocean* had a flight deck length of 690 feet (210 m), a beam of 80 feet (24 m), two lifts, eight arrester wires and one catapult. She had a maximum speed of 25 knots and a range of 12,000 nautical miles at 14 knots, ref. 2. The Colossus Class design was based on a scaled down version of the HMS *Illustrious* Class but with a large aircraft compliment achieved by a lack of armour. They were designed for rapid construction, in merchant yards, to make up for the shortfall in carriers but designed to be much more capable than escort carriers. The hull was built to Lloyd's rules for merchant ships up to the main deck but with improved subdivision of compartments to reduce secondary damage by flooding, ref. 2.

HMS *Ocean* could carry 48 aircraft[(2)] and saw service in: the British withdrawal from Palestine in 1948, deployment in Korea in 1952 & 53, joined the Home Fleet's Training Squadron in 1954, had an active role in the Suez crisis of 1956 with the world's first ever large-scale helicopter borne assault into Port Said. She went into Extended Reserve in 1958 and was scrapped, at Faslane, in 1962, ref. 1.

Most photographs of HMS *Ocean* show the flight deck with piston engined aircraft. The connection between HMS *Ocean* and the de Havilland Vampire goes back to December 1945, when a modified Vampire flown by Captain Eric 'Winkle' Brown RN landed on the deck of HMS *Ocean* off the Isle of Wight – the first ever carrier landing of a purely jet-powered aircraft[(3)], ref. 1 to 6. The aircraft used in these early landing and take-off flights was a Vampire F.10 (LZ551/G) modified with 40% extra flaps, long travel oleo undercarriage legs, and an arrester hook[(4)]. This aircraft is preserved at the Fleet Air Arm Museum, Yeovilton, ref. 4.



3. 0 The Vampire Jet Fighter and its Engine. I do not intend to go into a detailed history of the Vampire, that has been done by others in particular David Watkins in reference 12. The Vampire jetfighter was the second British jet powered aircraft to enter service with the Royal Air Force (the first being the two engined Gloster Meteor[5]). It was designed by the de Havilland Aircraft Company Ltd., which was formed in 1920 by Sir Geoffrey de Havilland (1882 – 1965), one of Britain's aviation pioneers, see **Appendix 1** for a very brief history of the de Havilland Aircraft Company. Only six Vampires were delivered to the RAF before the end of World War 2 and initial production of the early aircraft was carried out by English Electric Ltd. at Samlesbury as de Havilland's were fully committed to the production of the Mosquito, ref. 13.

The Vampire first flew on the 20th September 1943 the test pilot being Geoffrey de Havilland jr, the son of the Company's founder[6]. The design originated from early 1942 when the opportunity arose to design a jet fighter aircraft to Specification E.6/41, ref. 3. The Air Ministry decided to award the design of the aircraft and engine to the de Havilland/Halford partnership. The de Havilland design team was headed by Sir Geoffrey de Havilland and included R.E. Bishop as chief designer, R.M. Clarkson as chief aerodynamicist, and C.C. Walker as chief engineer de Havilland (engines), ref. 12.

The resulting aircraft, designated the DH 100 Vampire, was initially named the 'Spider Crab', ref. 3. The layout was dictated by the single engine jet power plant and featured a small pod-like fuselage of oval cross-section with tail surfaces on slender twin tail booms, rather reminiscent of the American P-38 Lightning, ref. 13. Equipped with four 20mm Hispano cannon the Vampire was designed to be a fighter aircraft. A diagram of the cannon arrangement is shown in reference 12. The pilot's cockpit was positioned forward of the wings and gave a good view for take-off and landing and attack. The view to the rear was not so good as it was obstructed by the armour plate of the pilot's seat. The windscreen was bullet-proof and the rearward sliding hood was a two-piece Perspex canopy[7]. An expanding rubber seal provided the means of sealing the canopy. The cockpit was pressurised from a Marshall cabin supercharger[8].

Since there was no propeller the opportunity was taken to use a tricycle undercarriage. This again improved the forward view which became important when the aircraft was developed into the Sea Vampire for deployment on carriers. The other advantage of the tricycle undercarriage was the reduction in ground effects from the impingement of the jet exhaust, even so the Vampire could not remain on idle for long otherwise the exhaust would melt the tarmac, ref. 3.

The aircraft design was of mixed wood and metal construction. A cutaway section of the Vampire is shown in reference 14. This form of composite construction reduced weight and improved performance, but also conserved cockpit warmth, ref. 12. The rear fuselage, wings, booms and tail were all-metal aluminium stressed skin and flush riveted. The nose section (from bulkhead No. 1 to bulkhead No. 4) was of wooden construction (moulded plywood[9]) similar to that used in the construction of the de Havilland Mosquito.

The twin boom arrangement: simplified engine changes, minimised air intake ducts and tailpipe length thus avoiding undue friction losses. The disadvantages: increased weight, decreased tail stiffness and increased wetted areas were minimised by careful design, ref. 12. The wings were straight but highly tapered with a thickness/cord ratio of 14%, ref. 13. The wing aileron was outboard, with the flaps split by the tail boom inboard on each wing. There was an air brake just outboard of the flap. The engine air intakes were at each wing root, with fuselage plates forward of the intakes to prevent ingestion of stagnant "boundary layer" airflow, ref. 15. Between the boom after ends was a single tailplane and elevator, and at each boom end was a tailfin and rudder[10]. Flight controls were not powered and operated through cable connections, ref. 15. Ailerons, elevator and rudders were fitted with trimming tabs. Details of the cockpit layout controls are shown in references 12 and 16.

A key player in the Vampire development was the close association between de Havilland and engine designer Major Frank B. Halford (1894 – 1955). He was one of Britain's great aircraft engine designers, ref. 10 & 11. The engine for the Vampire was designed by Frank Halford and his design team, which included John Brodie and Dr E. S. Moult. They had been working on the design and development of a jet engine since 1941. The principal events in the development of this engine, originally designated the 'H.1' and later the 'Goblin' are listed in Appendix VI of reference 11. Astonishingly, the first motoring tests were carried out on 13th April 1942, just 248 days from the first drawing was issued. Significantly, in January 1945, the engine successfully completed a full service type test. The first ever for a jet propulsion engine. In February of that year the de Havilland Engine Company received Turbine Engine Technical Certificate No. 1. The aircraft was designed around a single jet engine based upon the Frank Whittle centrifugal compressor type of engine[5][11][12][24], ref. 17. However, the engine that Halford designed was radically different from the Whittle design in two ways (a section of the engine is shown in references 7 and 18):

1. It used a single-entry centrifugal compressor (Whittle used a double-entry).
2. Had straight through combustion chambers discharging the hot gases direct to the turbine (Whittle used reversed flow chambers to discharge the hot gases to the turbine in the middle of the engine so as to produce a very compact engine [13]).

The Goblin arrangement was longer as a result of the straight through combustion design and the use of a single-entry compressor meant that the overall diameter was greater than an equivalent Whittle design. The use of the single-entry compressor was considered justified for several reasons, ref. 18, including:

- Uninterrupted direct air flow to the eye of the impeller.
- The full Ram effect of the forward speed of the aircraft could be utilised.
- There was no rearward-facing impeller eye and hence no need for air passages to a rear-facing intake.
- Only two bearings for the rotating assembly were required compared to three for a double-sided impeller.
- The axial load on the turbine blades could almost be balanced by the forward-acting thrust on the single-entry impeller.

The engine was a close fit in the Vampire fuselage, ref. 19. This fulfilled a de Havilland policy of building engines to suit the aircraft, ref. 18. The Goblin engine eventually developed into the de Havilland Ghost engine that powered the world's first production commercial jet airliner the de Havilland Comet.

One essential requirement for the success and reliability of the jet engine was advanced material technology. The stresses generated in certain components due to the loading and the effect of very high temperatures, 2000° C near the burner to a 'cooled' 790°C at the turbine blades, ref. 18, required the use of advanced materials to resist creep rupture, corrosion and scaling. **Appendix 2** lists some of the materials used for the critical components, in particular note the use of Nimonic 80 for the turbine blades a material with a very high nickel content to resist creep rupture(14).

3.1 The Role of the Vampire. The intended role of the Vampire was that of a single-seat fighter but was commissioned into the RAF just too late to see combat in the Second World War. Nevertheless it was built in large numbers(32) and served in many air forces throughout the world in several variants including: fighters, fighter-bombers, two-seat night fighters, two-seat trainers and a carrier-based Sea Vampire, which became the Royal Navy's first jet aircraft, ref. 3 & 15.

The problem common to all early jets was the low power available(15). The jet engine's acceleration was sluggish and the fuel capacity of the Vampire was too limited, ref. 5. This meant that the Sea Vampires were unsuitable as front-line carrier fighters but the flying trials on HMS *Ocean* had impressed the Navy and 18 aircraft, Sea Vampires F.20, were obtained to gain experience in carrier jet operations. The Sea Vampire was powered with the more powerful Goblin II engine (3000 lbf max. thrust at 10,200 rpm at sea level, ref. 7), had a strengthened wing and enlarged dive brakes and flaps to reduce landing speed. The small size of the Vampire allowed it to be parked below deck, in a hanger, without the need for folding wings(16). Apart from it being the first pure-jet aircraft to land and take off from an aircraft carrier at sea. Several aviation firsts and records were made including:

- The first RAF fighter with a top speed of over 500 mph, ref. 3.
- A modified aircraft with a de Havilland Ghost engine set a world altitude record of 59,446 ft, in March 1948(17), ref. 3.
- The first jet aircraft to fly across the Atlantic, in July 1948(18), ref. 13.
- The first catapult launch of a jet aircraft in the UK on 15th July 1948(19). This was also the first catapult take-off by a British tricycle undercarriage aircraft, ref. 12.
- The first testing of the production deck landing mirror system, ref. 12

Bizarrely, Sea Vampires were used in flexible deck landing trials, from 1947 to 1955, to develop undercarriage-less fighters. Removal of the undercarriage would save weight. The saving could be utilised as extra fuel or greater payload. Eric Brown was involved in these trials, ref. 5. Photographs of the landing trials on HMS *Warrior* (the same class of aircraft carrier as HMS *Ocean*) are shown in references 5 and 12. The trials demonstrated that this technique was practicable but did not become standard practice.

The Vampire served with many air forces worldwide including commonwealth and non-commonwealth countries. The last Vampires in service were with the Swiss Air Force and were not retired until 1990, ref. 3 & 15.

3.2 Handling Characteristics. The handling of the Vampire is well described in reference 13, 'Jet Jockeys' by Peter Caygill, and further details are in reference 12 by David Watkins. There is also a personal account of a first flight given by Wing Commander Maurice A. Smith in reference 16, and an eyewitness account of deck landing of Vampires at night by Charles Gardner in reference 20. These night landings by Lt. Clark and Lt. Perrett on 19th June 1950 were the first night landings by jet aircraft on a carrier, although successful experimental flights had been made by the United States Navy.

The most worrying features, or should I say lack of features, on the Vampire was no ejector seat[20] and no re-light in the event of an engine flame-out[21]. Pilots were killed attempting to bale out of the Vampire and in the event of a flame-out it was considered best to glide the aircraft to land rather than bale out, this actually happened on two occasions to Pilot Officer John Jennings, ref. 13.

The Vampire gave warning of a stall with slight buffeting and recovered quickly and comfortably. However, there were fatalities, the Vampire was unforgiving, in a high-speed stall it had a tendency to flick over with dire consequences. Eric Brown in a test dive experienced violent porpoising at a speed of Mach 0.72 where he was flung up and down in the cockpit, cracking his head against the canopy, ref. 5.

In general, pilots were in favour of the Vampire and once they had experience of flying a jet aircraft few would want to go back to the noise and vibration of an airscrew propelled piston engine aircraft[22]. The Vampire was good at aerobatics and handled superbly but was short on power, this had implications when it came to be used for carrier deployment as discussed below. In gunnery practice; the four cannon packed closely together under the fuselage, gave a very concentrated fire, ref. 12.

4.0 Carrier Layout. HMS *Ocean* was a type of carrier known as a CATOBAR carrier, i.e. a *Catapult-Assisted Take-Off But Arrested-Recovery* carrier. The main superstructure is a flat-top flight deck with lifts leading to hangers in the space below the flight deck[23]. When raised the lift platforms form part of the flight deck and can withstand the impact of landing aircraft. On the starboard side there is an island superstructure comprising: a funnel for the boiler uptakes, the bridge, flying control, signalling and radio station. At the stern there is a roundown that approaching aircraft must clear, hitting the roundown would not be survivable. Near the aft end of the flight deck there are a number of tensioned arresting wires spread across the deck, for aircraft recovery, with the arresting gear operating units below the deck. This hydraulic arresting gear tensions the wires and is essential to absorb the momentum of the landing aircraft, so that it will come to rest (in about 100 to 150 feet) within the limited length of the available flight deck. It is operated like the reverse of the catapult, a diagram of an arresting gear is shown in reference 21.

At the forward end are catapults for launching aircraft at a speed at which flight can be sustained. The advantage of the catapult launch is that a high wind speed is not required to get the aircraft launched, although it is normal practice for the carrier to steam at full power in case an emergency landing or rescue is required. HMS *Ocean* had a single catapult, on the forward port side, of the pneumatic-hydraulic type, a diagram of this type is shown in reference 21. This type of catapult was sufficient for launching of a Sea Vampire. Larger, faster, more powerful jet aircraft were being designed and it was necessary to develop a steam catapult for use on future carriers. The evolution of the slotted cylinder steam catapult is discussed by C. C. Mitchell in reference 22.

When aircraft are parked forward, the available flight deck is reduced in length and barriers for emergency are placed across the deck, two such barriers can be seen on the model. The barriers are tensioned by means of two retractable stanchions. In the event of an aircraft failing to pick-up an arresting wire (or an arresting hook failure) the barriers are the last line of defence to hold the aircraft[26][27]. The introduction of the angled flight deck avoided the need for these barriers.

Two aviation fuels were normally carried, AVGAS – a high octane gasoline (petrol) for piston type engines and is highly volatile, and AVCAT – a jet fuel more similar to diesel fuel developed for use on carrier borne turbo-prop and jet type engines and is less volatile than some of the kerosene fuels. Note that aviation kerosene AVTUR fuel was not used on aircraft carriers but may be used on land based aircraft, ref. 21.

The aviation fuel is contained in tanks well below deck. AVGAS is always carried in special protected stowage tanks. AVCAT is carried in double-bottom tanks but with protected stowage for fuel delivery to the aircraft. An diagram of a protected stowage tank is shown in reference 21. The main fuel tank sits on the double-bottom and is surrounded by a saddle tank that is at all times open to the sea. Fuel is pumped, to the aircraft, from the main tank via a draw-off tank. As fuel is withdrawn from the draw-off tank, seawater follows up in the saddle tank and into the main tank. The tank is considered to be empty when the main tank is full of seawater, but there will be fuel in the draw-off tank. This system eliminates the highly dangerous vapour concentrations in a partly filled tank. The main aim is to deliver water free and filtered fuel to the aircraft and this is done by a system of float valves and filters. The fuel is delivered to fuelling stations by mains arranged around the hanger(s) and flight deck. Fuel is supplied to the aircraft through a collapsible hose fitted with a pressure nozzle. The system is designed so that all unused fuel is drained back to the protected stowage. A separate de-fuelling system is fitted to de-fuel aircraft and to clear the hoses after fuel delivery.

4.1 Carrier Operations. The main concern of carrier operations[28] was, of course, landing and take-off on a limited runway length (around 200 yards for HMS *Ocean*), and in rough weather the deck would be pitching and rolling. Aircraft are launched forward into the wind and recovered astern. The landing was eventually proved to be simple and straightforward provided the right technique was used. The unobstructed view from the Vampire cockpit and tricycle undercarriage made deck landings uneventful, ref. 12. There was, however, always the possibility of mechanical failure due to: arrester hook attachment failure, or the back end pulling off or an arresting wire parting. There were also the effects of funnel gasses and roundown turbulence to contend with, ref. 5.

The carrier would steam into the wind to provide a wind speed over the deck of about 25 to 30 knots (HMS *Ocean* had a maximum speed of 25 knots). The aim being to reduce the difference in relative speed of the aircraft and the carrier. The stalling speed of a Vampire with Goblin II engine with undercarriage and flaps down was about 85 mph (74 knots), ref. 13. If there is no wind the carrier must steam at high power to produce the conditions required, ref. 21.

The aircraft is arrested by a tail hook on the aircraft engaging one of the arresting wires spread across the flight deck near the after end. During landing these arresting wires are raised clear of the deck so there is a good chance of the tail hook engaging a wire. Ideally the pilot should line up the aircraft in the middle of the wires (there is a white line down the flight deck) but the arrangement would have been tested to allow for off-set landings, ref. 5. The deceleration would be around 3g, much higher than this and there would be a risk of the tail hook being pulled out from the aircraft structure.

An important member of the team is the ‘batsman’ (Deck Landing Control Officer) who guides the pilot in their approach by means of signals with two paddles, or bats, to give attitude and height information, ref. 5. At night the ‘bats’ were illuminated, ref. 20. There would also be batsman’s spotters who would check that: the hook is down, the flaps are down, arresting wires are up, and that the green affirmative light is on[29]. The Vampire would approach the centre line of the deck and as it arrived about 15 or 20 feet over the roundown, in a nose up attitude, the batsman would wave ‘cut’ and the pilot would shut the throttle. The Vampire would sink the last few feet still nose up with the hook down to pick up an arresting wire, ref. 20. With the aircraft safely landed the tension in the wires is released and hook disengaged. The aircraft would taxi forward to the parking area. The arresting units are reset to tension the wires for the next aircraft, ref. 21.

Take-off was a different matter. The carrier would steam into the wind at high power in order to increase the wind speed over the deck to a safe minimum. The limited power of the Vampire meant that normal (free) take-off, without the use of a catapult, on a flight deck of about 200 yards was always a concern[15]. Eric Brown seems to have had no difficulty taking-off normally from HMS *Ocean*, ref. 5. Presumably the modified Vampire would have been lightly loaded as regards fuel and armament and in any case the first catapult launch of a jet aircraft in the UK was still some years away[30]. Reference 12 explains how on, HMS *Illustrious*, the Sea Vampire had to be pushed to the very end of the flight deck (i.e. to near the roundown), with full throttle applied the aircraft trundled slowly along the deck. They always got airborne but were inclined to fall off the front end of the carrier a bit!

The first catapult launch of a jet aircraft in the UK, took place on 15th July 1948. This was by a Sea Vampire F.21. This was also the first catapult take-off by a British tricycle undercarriage aircraft. The peak acceleration was 4.9g, representing an end speed of 89.4 knots, a record for a piloted aircraft in Great Britain at that time, ref. 12. During the deck landings by night, ref. 20, the Vampires were catapulted of HMS *Theseus* a similar Colossus type carrier as HMS *Ocean*.

5.0 After the Vampire - the Venom and Sea Vixen. The de Havilland DH 112 Venom was developed from the Vampire. These two aircraft have many similarities, both aircraft have twin boom tails, and are often confused. The Venom was a slightly larger aircraft with thiner wings, more powerful engine and wing tip fuel pods. It was designed as a single-seat fighter-bomber and two-seat night fighter, ref. 23. The naval variant, the Sea Venom, had folding wings and arrestor hook, ref. 40. The Venom was withdrawn from RAF service in 1962, although the Swiss Air Force did not retire their Venoms until 1983, ref. 23.

The next, and final development of the de Havilland twin boom aircraft was the DH 110 Sea Vixen. It was a twin engine, two-seat, all weather jet fighter for the Fleet Air Arm. Powered by Rolls-Royce Avon 208 turbojet engines the Sea Vixen was capable of Mach 0.91 (690 mph) at sea level[(31)], and was the first British aircraft to be armed solely with missiles, rockets and bombs. It served as a carrier-based fleet defence fighter into the 1970's, ref. 24.

6.0 Preserved Aircraft. There are a number of preserved *Vampires* and there is a preservation group at web site: http://www.vampirepreservation.org.uk/.

7.0 Captain Eric 'Winkle' Brown RN. Before summarising this note a few words about Eric Brown are appropriate. Born in Leith in 1919 he died in 2016 at the age of 97. His autobiography 'Wings on My Sleeve', ref. 5, has some incredible stories on the early jet aircraft, German as well as British, and deck landings on aircraft carriers. He is in the *Guinness Book of Records* for having flown more aircraft types (487) than any other pilot. He also has made more aircraft carrier take-off and landings (2, 407 and 2,271) than any other pilot, ref. 25, – a truly astonishing record that is unlikely ever to be repeated.

8.0 In Summary. The de Havilland Vampire and its jet engine belong to an age when Britain was at the cutting edge of aircraft design and engineering. The pressure of a World War helped to make this possible. There was also a generation of engineers who had the experience and drive to overcome the difficulties of new technology and make the required leap forward that was necessary to meet the challenges of the jet age. It was a time when it was still possible for one Company to carry out the design, development and construction of a new aircraft and its engine virtually from scratch. Today the market place is totally different, Britain does not build complete aeroplanes and we now have only one main aircraft engine builder - Rolls-Royce.

As I write this note the modules for two new aircraft carriers for the Royal Navy have been built on the Clyde and the complete carriers assembled at Rosyth Dockyard on the River Forth; one has been delivered and the other is fitting out. There have been arguments about the cost and the capability of the aircraft for these carriers. It remains to be seen how effective these carriers will become.

9.0 Notes.

(1) Originally there were sixteen Light Fleet Carriers ordered, but only eight were built to the Colossus Class design: HMS *Colossus*, HMS *Glory*, HMS *Venerable*, HMS *Ocean*, HMS *Theseus*, HMS *Triumph*, HMS *Vengeance*, and HMS *Warrior*. Two ships, HMS *Perseus* and HMS *Pioneer*, entered service as aircraft maintenance carriers without catapults and arresting gear. The final six were modified to handle larger and faster aircraft, re-designated as the Majestic Class. Three of these Majestic Class were heavily upgraded with three British developments allowing the operation of large, fast, jet powered aircraft: the angled flight deck, the steam catapult, and the mirror landing aid, ref. 2.

(2) As explained in reference 2. The original Light Fleet Carrier design was for 41 aircraft. The actual number of aircraft carried depended on a redesign of the available parking area and the mix of types of aircraft carried. The final number of aircraft carried could be up to 52.

(3) Not unexpectedly there is a bit of controversy over this claim. It appears that earlier that year (November 1945) an American composite (mixed propulsion) jet and piston engined aircraft a Ryan FR-1 Fireball had made an unintentional carrier landing under jet power after its piston engine failed, ref. 1 & 3. The date of the first landing of the Vampire on HMS *Ocean* also seems to be confusing. Some references, e.g. refs. 1, 37, and 38 quote the first jet landing as being on the 4th December 1945. Eric Brown on page 143 of reference 5 states the 3rd December but a photograph of a landing is dated the 4th December so it is not surprising that there is some confusion. As well as the Vampire, HMS *Ocean* was also used to test new piston engine aircraft: the Hawker Sea Fury and the de Havilland Sea Hornet, ref. 2

(4) Sea Vampires for Naval service have a tail above the jet exhaust to house the arrester hook (which falls through the jet exhaust stream, ref. 14), photographs are shown in references 4 & 12. The arrester hook fell by gravity but during the flexible deck trials an electric motor system and an alternative hydraulic system were fitted, ref. 12. The tail and arrester hook are not shown on the models so the models are Vampires rather than Sea Vampires.

(5) The early British jet engines had low power output hence the need for two engines on Britain's first jet powered service aircraft the Gloster Meteor. The engine developed by Frank Halford was more powerful than the Whittle engines used on the Meteor and hence a single-engined jet fighter became viable.

(6) Geoffrey de Havilland jr was tragically killed on 27 September 1946 when test flying a DH 108 "Swallow" experimental aircraft that employed the main fuselage section and engine of the de Havilland Vampire mated to a longer fuselage with a single tailfin and swept wings, ref. 26 & 27.

(7) There were canopy failures, some with fatal consequences. A one-piece 'teardrop' canopy was developed and retrofitted to many earlier aircraft, ref. 12. The bullet-proof windscreen was also useful protection from bird strikes which are more likely to occur with jet aircraft than propeller aircraft, ref. 5.

(8) Early aircraft were not fitted with a pressure cabin. When a cabin pressurisation system was fitted there were height limitations due to canopy seal collapsing problems and canopy contraction caused by low temperature at high altitudes, ref. 12.

(9) The wooden construction method is briefly detailed by Watkins in reference 12. The plywood, used for the fuselage, had an inner and outer skin of birch with a filling of balsa or quipo (also known as bongo) wood. The stressed structural members were of spruce. Balsa or quipo wood was also applied in the form of battens to the outside of the inner plywood skin in positions not occupied by the spruce stress members. The timber was glued into position. The outer surface of the fuselage was covered with Madapollam fabric (a soft cotton with a Linen weave) as part of the plywood protective treatment and gave some weathering resistance and excellent key for dope applications.

(10) The details of the tail structure of the Vampire did radically alter, depending on the variant, for structural and aerodynamic reasons. These details are discussed in references 12 and 15. For example, with drop tanks, it was necessary to alter the tailplane chord, and fit 'acorns' to the fin and tail junction. Further testing showed that the tailplane could be lowered, to simplify production, without affecting compressibility characteristics and still be clear of the jet efflux. The tailfin shape was also modified from the trapezoidal to a curved shape. The night fighter variant had the tailplane extended outboard of the booms. Finally on the T.11 and T.22 trainer variants the 'acorns' were removed, the tailplane extensions outboard of the booms were retained and a dorsal fairing extended forward along the tail booms was fitted.

(11)By as strange twist of fate, the first Whittle/Power Jets W.2.engines for the Meteor were not available and so a prototype Meteor first flew with Halford's H1 (Goblin) engines on 5th March 1943, ref. 28. Other aircraft to fly with the early H1/Goblin engines were the American aircraft: Lockheed XP.80 (P-80 Shooting Star) Fighter in January 1944, ref. 11, and the Curtiss XF15C mixed propulsion (propeller and jet engine) Navy Fighter in 1945, ref. 39.

(12) Australian Vampires were powered with Roll-Royce Nene jet engines, ref. 3 and 12, this engine had a double entry impeller (like Whittle's engine)and straight through combustion chambers discharging the hot gases direct to the turbine (like Halford's Goblin engine). Additional scoop air intakes 'elephant ears' were required to be fitted. Photographs of Nene engined Vampires are shown in reference 12.

(13)The idea of a reverse flow combustion system, resulting in a compact engine, was put to use later in some designs of gas turbine engine starters to start up the main jet engine, see Fig. 11-9 of ref. 30.

(14) Materials for use in jet engines have continued to advance, these include improved nickel superalloys, single crystal blades, ceramic coatings and titanium alloys for use in large fan blades. Non-metallic materials have also been developed such as ceramic turbine blades, and carbon fibre composites.

(15)The fundamental problem is that aircraft must have a certain air speed, over the wings, to provide lift for take-off so that flight can be sustained. Steaming the carrier at high power into the wind provides some of the air speed necessary for a safe take-off. The remaining air speed must come from the speed of the aircraft during launch. With an airscrew driven aircraft you get an immediate increase in lift from the slipstream from the propeller even if the aircraft is not moving, but with a jet aircraft you have none of this and have to rely on the increase in the aircraft speed during the take-off. With the early jet engines the acceleration was very sluggish and could not be relied on in an emergency requiring a sudden increase in speed. This fact, and the limited fuel capacity were the two main reasons for the Vampire not going into front line service with the Royal Navy, ref. 5.

(16) The Vampire was small enough the go down the lift, to the hanger below, by turning athwartships. A photograph of a Vampire on the lift is shown in reference 20. If a Vampire like aircraft with folding wings is seen; it is a Sea Venom, ref. 40.

(17) Aircrews would be expected to fly at high altitude (the ceiling for the Sea Vampire was 43,500 feet, Appendix 1 of ref. 12). Oxygen to enable flying at these high altitudes was carried in small bottles pressurised to 3000 lb/square inch. Aircraft carriers had oxygen producing plant consisting of: an air purification unit, air separation unit, and a compressor unit capable of compressing oxygen to about 3,500 lb/square inch, ref. 21.

(18)This was part of the annual RAF goodwill mission to the USA, but became a race with the Americans. Obiham wing (54, 72 and 247 Squadrons) were the first to fly the route via Stornoway, Keflavik (Iceland), Bluie West One (Greenland) and Goose Bay (Canada). Fuel margins were critical.

Mosquitoes provided back up for navigation and meteorological information. The USAF attempt was in the opposite direction in Lockheed F-80's. The Vampire F.3's won by just a single leg, ref. 13.

(19) Once catapult trials on the Sea Vampire were completed (July 1948) it became routine for catapulting to be used when conditions for free take-off were not possible. A photograph of a Sea Vampire taking-off from the catapult of HMS *Theseus* (a similar aircraft carrier to HMS *Ocean*) is shown in reference 20.

(20) Apart from the first few, all the DH 115 Vampire T11 two-seat advanced trainers were fitted with Martin Baker Type 3B ejector seats, ref. 12 & 13. Similarly the original batch of Sea Vampire T22 trainers lacked ejector seats, but these were later retrofitted, ref. 12. [During 2013 a visitor to Riverside Museum, who worked for Martin-Baker the aircraft ejection seat Company, told me that they keep two Meteor jet aircraft still flying as part of their testing of the ejector seats].

(21) Development on re-lighting was carried out as early as March 1945 and was successful with the engine running at 6,000 rpm (Appendix VI ref. 11). However, re-light was not fitted on the production aircraft.

(22) To outside personal the early jet aircraft were extremely noisy. To the pilot in a well-sealed cockpit it was much quieter, free of vibration and less tiring compared to an airscrew propelled piston engine aircraft. For modern jet aircraft noise reduction is a big issue along with other environmental considerations such as exhaust pollutants. These issues are discussed briefly in references 30 and 31.

(23) On some carriers the flight deck is armoured. On HMS *Ocean* the armour was minimum but did include 10mm splinter protection, ref. 33. During World War 2 both the Americans and Japanese found to their cost that unarmoured carriers were vulnerable from aerial bombs and kamikaze attacks. Some British carriers had armoured decks, which also enclosed the hanger sides and ends, though this did reduce the hanger height and restrict the types of aircraft that could be carried. The use of armoured carriers gave some protection from aerial bombs while the armoured hangar sides and ends helped to minimise damage and casualties from explosions or fires within or outside the hangar, ref. 34.

(24) It was recognised that an axial flow compressor and a single annular combustion chamber would give a true 'straight through' design that would be more efficient, have a smaller frontal area and other advantages over a centrifugal compressor, ref. 29. However, there was little practical experience at the time (1941) of axial flow compressors and practically nothing was known about single large annular type combustion chambers, but there was a fair amount known about small individual combustion chambers, ref. 29. The time scale, dictated by the urgency of the war, to develop a reliable axial flow design was considered to be too great. A centrifugal compressor was simpler and cheaper to produce, was more rugged, and there was extensive experience of small centrifugal compressors developed as aero-engine superchargers. For example, centrifugal compressors were used to supercharge piston engines like the Napier Sabre (another Halford design), Bristol Pegasus, and Rolls-Royce Merlin engines. As a result the early British jet engines used centrifugal compressors; modern turbojet engines now use axial flow compressors, but see note (25) below.

(25) The Germans used a Junkers Jumo 004B jet engine to power the production Messerschmitt Me.262 during the Second World War. This used an axial flow compressor, but this engine had a very short operational life (35 hours limit for the turbine wheel, ref. 32) and there were many fatal accidents, ref.17. In contrast, the Goblin engine had to endure a 100 hours service type test as requirement of the Turbine Engine Technical Certificate No. 1 it acquired in February 1945, ref. 11. Flying early jet aircraft, regardless of make or engine, was risky and there were fatal accidents involving British and American pilots.

(26) Captain Eric Brown, in reference 5, describes several accidents with the emergency barriers. These accidents (and also landing trials on flexible decks) were one of the reasons for the adoption of the angled flight deck; a British invention in August 1951 by Captain Dennis Cambell, a former naval test pilot, ref. 5. Having an angled deck (to port side) allowed an aircraft that missed the arresting wires to accelerate away (a bolter) and make another landing attempt without crashing into barriers or parked aircraft on the forward deck. It also allowed aircraft to be catapulted off the forward deck whilst aircraft were landing astern on the angled deck. The whole arrangement increased the efficiency of operations as well as improved safety.

(27)The barriers were normally of steel-cable construction and were designed to halt a Firefly or Sea Fury (both are airscrew aircraft), but for Sea Vampire landings one of the barriers was replaced by two stout nylon ropes joined by vertical webbing. This was to avoid cutting right through the cockpit of an airscrew-less aircraft, ref. 20.

(28) Captain Eric Brown in reference 5 pages 207 to 209 describes what was involved in carrier operations, during exercises, from take-off to interception to landing.

(29) Charles Gardner, ref. 20, was told that the lights used at the time of the night landings on HMS *Theseus* were genuine traffic lights (i.e. red-amber-green) originally from a Sauchiehall Street (a well known Glasgow street) crossing!

(30) Reference 35 mentions "The subsequent take off was completed using rockets". This is the only reference I have been able to find on the use of rocket assistance in connection with the jet operations on HMS *Ocean* and they are not mentioned in references 5 or 6, nor do any of the photographs of the

take-off appear to show rockets. de Havilland certainly did produce assisted take-off rockets, the Sprite and Super Sprite, the former was designed for use on the Comet 1 jet airliner and flew in that aircraft in 1951, ref. 37. During the Korean War, in 1952, Hawker Sea Furies (an airscrew aircraft) from HMS *Ocean* did utilise rocket assistance take-off, ref. 38.

(31) The Sea Vixen was capable of super sonic flight. However, during a demonstration to break the sound barrier at Farnborough on 6th September 1952 the first prototype aircraft disintegrated, both crew members and a large number of spectators were killed. Modification were made to the second prototype and there were major changes to the safety regulations at UK air shows as a result of this tragedy, ref. 24.

(32) The numbers of Vampires built depend on which reference you are looking at and what variants are included. Reference 3 quotes 3,268 while reference 15 quotes over 4,580 of all types.

10.0 References.

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Appendix 1
The de Havilland Aircraft Company Ltd. – a very brief history.

I do not intend go into the detailed history of the de Havilland Aircraft Company. Information can be obtained from references 8, 9, and 11. The de Havilland Aircraft Co. Ltd. was formed in 1920 by Sir Geoffrey de Havilland (1882 – 1965), one of Britain's aviation pioneers. The company set up their works at Stag Lane, Edgware, Middlesex to design and build a series of light aircraft. They also instigated, in 1923, the de Havilland School of Flying at the Stag Lane Aerodrome, adjacent to the Company works.

In the period between the first and second world wars de Havilland produced many designs of light aircraft for the private flyer and the small commercial market. They became one of the largest civil aircraft manufacturers with worldwide markets and companies set up in several countries. During this period their most famous aircraft was the *DH60 Moth* biplane. In 1934, following developments on variable-pitch metal propellers, they entered the propeller market with the creation of the de Havilland Propeller Company. The Second World War brought increased military work, their most significant aircraft being the famous *Mosquito* twin engined monoplane. Towards the end of the war saw the development of the *Vampire* jetfighter.

The de Havilland Aircraft Company were forward looking and it was certain that they would become involved with a new means of powering an aircraft. A key player in this development was the close association between de Havilland and engine designer Major Frank B. Halford, one of Britain's great aircraft engine designers, his is career is explained in references 10 and 11.

After the war there was continued developments in both civil and military aircraft, including the *Comet* and *Trident* jet airliners, the *Venom* jetfighter-bomber and *Sea Vixen* jetfighter. In 1960 the de Havilland Group of Companies was bought by Hawker Siddeley Aviation which subsequently became part of British Aerospace.

Appendix 2
Some of the Advance Construction Materials used in the Goblin II jet engine, ref. 18.

- **R.R.59** is an Aluminium alloy containing nickel, copper and other elements. Known as a Hiduminium alloy these alloys were developed, by Rolls-Royce, prior to the second world war. Manufactured by High Duty Alloys Ltd. of Slough, this alloy is heat treated to develop its properties and maintain its strength at high temperatures. It was used in the manufacture of the Compressor Impeller.
- **Nimonic 80** is an age hardening nickel alloy containing 18-21%Cr, and other elements, developed by Henry Wiggin & Co. of Hereford in 1941 as a high temperature, low creep superalloy. It was used in the manufacture of the Turbine rotating Blades.
- **Nimonic 75** is a nickel alloy containing 18-21%Cr, and other elements. It was used in the manufacture of the Nozzle Blades.
- **Hecla 153** is an Chrome-Molybdenum Alloy Steel manufactured by Dunford Hadfields Ltd. It was used in the manufacture of the Turbine Disc.
- **Jessops H.3.A** is a Chrome Alloy Steel manufactured by Jessop-Saville Ltd. of Sheffield. It was used in the manufacture of the Turbine Disc.
- **Jessops G.18B** is an Austenitic Alloy Steel containing 13%Cr, 13%Ni, 10%Co, and other elements. Manufactured by Jessop-Saville Ltd. of Sheffield. It was used in the manufacture of the Nozzle Blades.
- **H.R. Crown Max.** is an Austenitic Stainless Steel containing 23%Cr, 12%Ni, and other elements. Manufactured by Firth-Vickers Special Steels Ltd. It was used in the manufacture of the Nozzle Rings.
- **Inconel** is an Austenitic Nickel-Chromium superalloy that is oxidation and corrosion resistant material for service in extreme environments. It was used in the manufacture of the Combustion Chamber Flame Tubes.
- **D.T.D. 176A** is a niobium stabilised Austenitic Stainless Steel containing 18%Cr, 9%Ni, and other elements. It was used in the manufacture of the Nozzle assembly Bolts.
- **S.80** is a 16% Chrome, 2.5% Nickel Alloy Martensitic Stainless Steel. It was used in the manufacture of the Nozzle assembly Nuts
- **D.T.D. 272** is an Aluminium-Silicon Alloy. It was used in the manufacture of the Combustion Chamber front outer Casing.
- **F.D.P.** is an Austenitic Stainless Steel sheet containing 18%Cr, 11%Ni, and other elements. It was used in the manufacture of the Centre Casing and Jet Pipe assembly.
- **D.T.D. 281** is a Magnesium alloy containing 9%Al, and other elements. It was used in the manufacture of the Diffuser and Front Casing.

Note: Austenite is named after Sir William Chandler Roberts-Austin (1843-1902) a British metallurgist. Austenitic Stainless Steel is a chrome-nickel alloy steel. It has a face centred microstructure, is non-magnetic and is not hardenable by heat treatment. Martensite is named after Adolf Martens (1850-1914) a German metallurgist. Martensitic Stainless Steel is a chrome alloy steel. It has a body centred microstructure, is magnetic and can be hardened by heat treatment.
