AIRCRAFT DECK HANDLING
A
CONCISE HISTORY

BY

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ABSTRACT

The article traces the problems, and their solutions, encountered in establishing the practices of the safe and reliable operation of aircraft from ships, beginning with the first experiments in America and ending with the key inventions of the early 1950s, which still form essential components of the most modern conventional carriers.

Introduction

Before one can consider the mechanics of the deck handling of aircraft in early days, one has first to consider the type of decks involved, and that consideration has to be set against the speed of technological development in that era. Technical change has accelerated enormously in this century, and particularly in the second half. Prior to that, things proceeded at a much more leisurely pace. Depending upon the particular choice of datum, one can say that it took between 5 and 10 **thousand years** from the establishment of civilization to the achievement of controlled, powered flight by the WRIGHT brothers. Only 60 years after that, man was in space, but much of that progress was made in the last 20 of those 60 years.

Man was probably travelling over water in some primitive way at around the time that civilization began, but he was only travelling under mechanical power perhaps 50 years before the WRIGHTS flew. So when we come to examine the early juxtaposition of ships and aircraft, it is not only the aircraft which are new. The first shipborne experiments with aircraft, 'circus stunts' as even one of the proponents described them, began in 1910, less than a decade after the WRIGHTS, and with aircraft whose technology had barely improved. Aircraft were biplanes whose wing cellules were essentially wooden box-girders, braced with wooden struts and steel wire to similarly-constructed fuselages, which were vestigial and uncovered to save weight. Engine horsepower rarely exceeded 80H.P., and was often half of this. So the aircraft were light, flimsy and slow, with little margin of safety between maximum speed and stalling speed. It is not surprising that naval men, only just becoming familiar with leviathans of steel plate, driven by steam turbines and armed with massive guns, should have had substantial reservations about aircraft and their usefulness to the fleet at sea. And if they were no use there, what use were they at all?

Consequently, much of the period under consideration was characterized by aviation and naval pioneers working together against a background of incredulity and often antagonism from senior naval officers. The antagonism stemmed from the need to alter perfectly good warship decks and gun turrets to accommodate the noisy, oil-dripping little toys that a few crackpots and charlatans had invented in their wildest moments. Those alterations constituted the first decks ever produced to handle aircraft on warships. The first of all were built in America and, remarkably, incorporated technical aspects which were then overlooked for another 20 years.

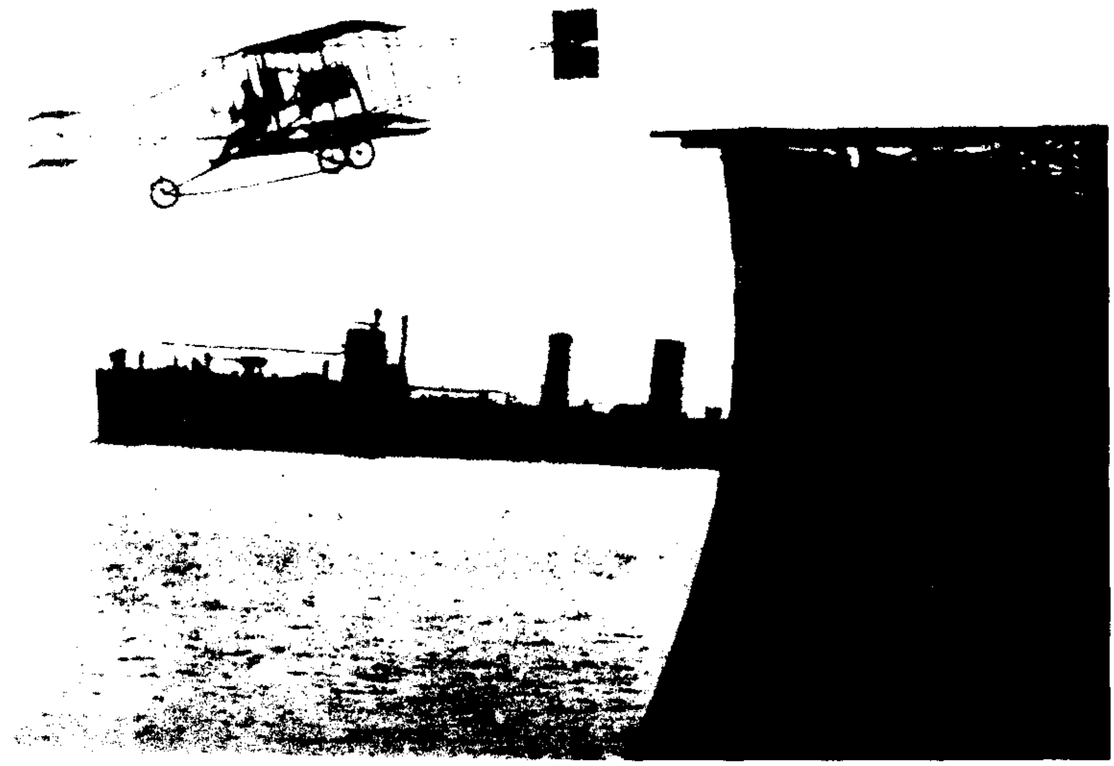

FIG. 1—14 NOVEMBER 1910 - EUGENE ELY'S CURTISS PUSHER TAKES OFF FROM USS 'BIRMINGHAM', THE FIRST SHIPBORNE TAKE OFF IN HISTORY

The pioneers

CAPTAIN W.I. CHAMBERS USN instigated these first trials. There was, of course, no existing large flat expanse of deck built into any warship and so one had to be purpose-built. The vessel was USS *Birmingham* and a timber platform 83 feet long was constructed over her forecastle. Hence we come to the first common thread of deck handling, which was to last for several years, the combination of lighter and crane. The trials aircraft could not land on the ship and so it was lightered out to it, and hoisted into position by crane and/or derrick. The aircraft was a Curtiss pusher biplane, flown by a civilian demonstration pilot, Eugene ELY. Whilst *Birmingham* sat at anchor in Hampton Roads, on 14 November 1910 ELY made the world's first takeoff from a ship (FIG.1).

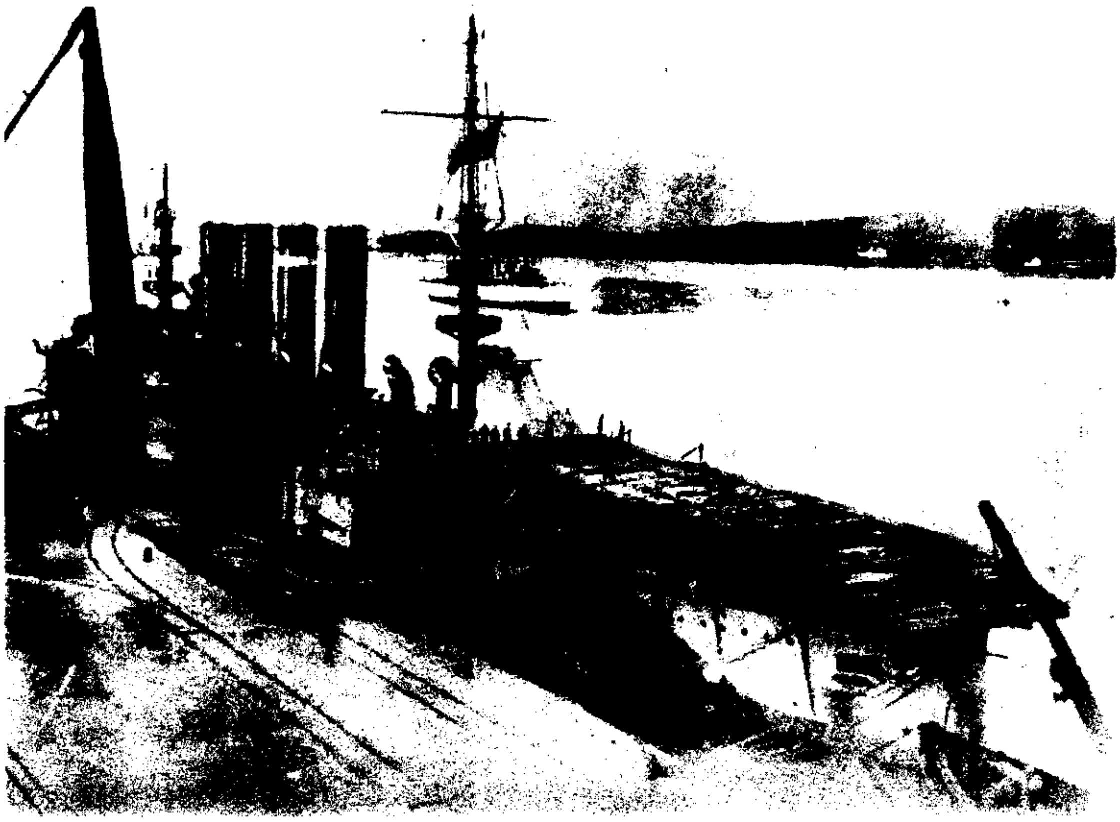

FIG. 2—THE LANDING DECK BUILT ON USS 'PENNSYLVANIA' FOR THE FIRST EVER SHIPBOARD LANDING IN JANUARY 1911

Landing required a larger platform, and one 119 feet in length was then built on the quarterdeck of the USS *Pennsylvania* (FIG.2). Remarkably, someone's foresight led to the installation of two landing aids which would eventually be commonplace. The platform was equipped with:

- 22 athwartships arrester ropes, weighted in this case with sandbags
- A crash barrier; a canvas sheet suspended from the rear of the bridge.

The landing trial took place in San Francisco Bay on 18 January 1911, the ship again being at anchor. ELY landed the Curtiss pusher quite comfortably, catching the 11th wire and pulling up after a 50 feet landing run (FIGS 3 & 4). The wires were cleared from the deck and a short while later he took off again.

FIG. 3—EUGENE ELY TOUCHES DOWN ON USS 'PENNSYLVANIA', 18 JANUARY 1911

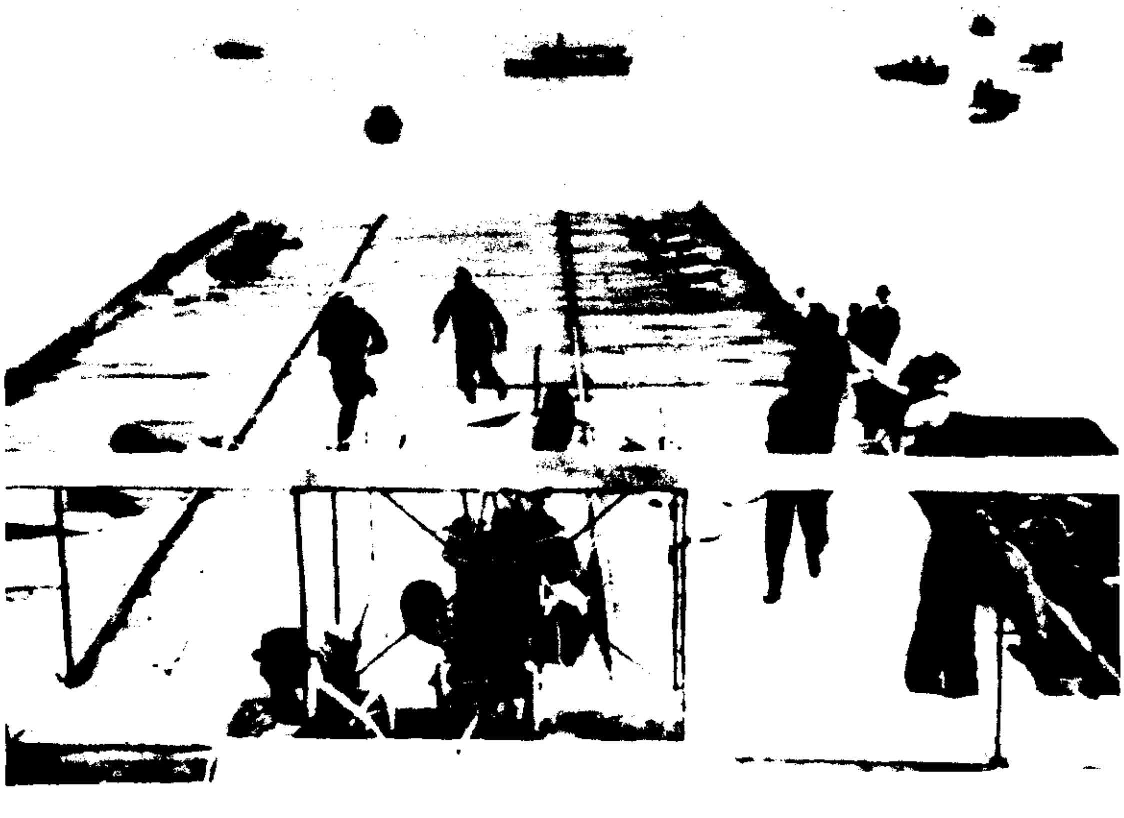

FIG. 4—THE END OF ELY'S LANDING RUN, SLOWED BY ATHWARTSHIPS ROPES WEIGHTED BY SANDBAGS

FIG. 5—CURTISS FLYING BOAT BEING HOISTED ABOARD USS 'NORTH CAROLINA', NOVEMBER 1915. A BOAT BOOM WAS INSERTED INTO A GUN BARREL TO IMPROVISE A HOIST

A few weeks later *Pennsylvania* took part in one last aviation experiment. With the landing platform now removed, she hoisted aboard Glenn CURTISS in the seaplane which he had landed alongside (FIG. 5). In the space of two months, the US Navy had successfully tested, albeit in embryonic form, nearly all of the significant techniques which would be used in shipborne aviation for the next thirty years. Having established such a leading position, not only in general aviation but also with the first trials of aeroplanes and ships, the Americans then seemed to lose interest, and the initiative was ceded to Europe.

Whilst Russia had created the first aviation parent ship in the world, a balloon ship called *Russ* in 1905, the next steps in developing the use of heavier-than-air machines with warships lay undoubtedly with the Royal Navy. Britain's lagging position in European aviation prompted the formation of an Aviation Sub-Committee of the Committee for Imperial Defence and its recommendations led, in April 1912, to the formation of a Royal Flying Corps (RFC), comprising a:

- Military Wing
- Naval Wing
- Central Flying School.

Prior to this official move, four naval officers had learned to fly at Eastchurch in 1911, and they continued to fly, turning Eastchurch into the first naval flying school. It was this cadre of naval pilots which pushed the boundaries forward.

Their prompting led to the duplication of the American trials. The battleship *Africa*, lying at Sheerness, was fitted with a track over its foredeck and on 10

January 1912, LIEUTENANT Charles SAMSON took off from that track. A similar deck was built on the battleship *Hibernia* and, during the Naval Review off Weymouth on 2 May 1912, SAMSON made the first takeoff from a ship underway. He had to land ashore because there was no provision for landing back on the ship.

Most of the RFC, including the Naval Wing, took part in the Military Manoeuvres of summer 1912, and the Navy decided to incorporate the Naval Wing into the Naval Manoeuvres of 1913. To provide a shipborne base, the cruiser *Hermes* was fitted with a tracked takeoff platform and a canvas hangar, and thus was commissioned the first parent ship for seaplanes. The seaplanes took off from the track on wheeled trolleys, landing on the sea near the ship, and being hoisted back on board. Most of the aviation vessels commissioned during World War 1 were seaplane carriers, some with a takeoff deck forward, and some without. The formula of seaplanes and cranes remained the pattern for some long time.

It became quickly apparent that seaplanes, with the drag and weight of water-soaked floats, offered inferior performance to landplanes. The variety of decks on seaplane carriers could and did launch landplanes, but only within range of friendly shores, and thus usually only as trials. The number of seaplane carriers was limited, and many of them were much slower than fleet vessels. The concept of the turret platform was developed, whereby a short deck, often less than twice the length of the aircraft it carried, was built over a capital ship's forward gun turret. Eventually a large part of the Home Fleet's capital ships carried a platform and a landplane, for fleet defence against air attack.

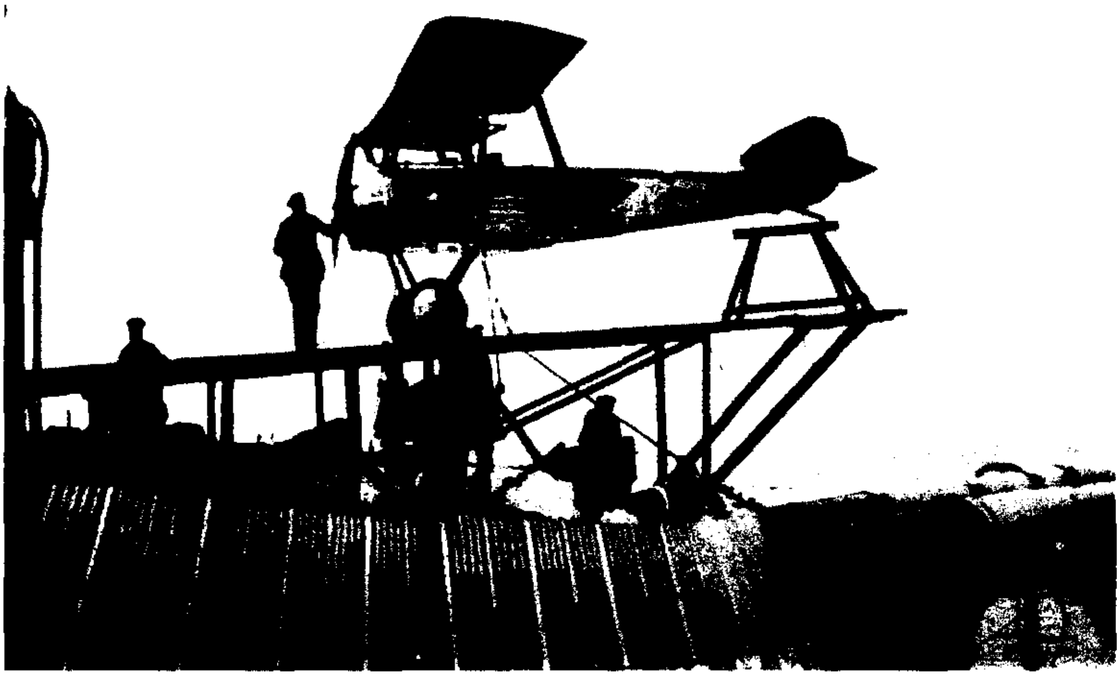

FIG. 6—SOPWITH PUP ON THE TURRET PLATFORM OF A WWI CAPITAL SHIP. THE TAIL GUIDE TRESTLE SUPPORTED THE AIRCRAFT IN FLYING POSITION

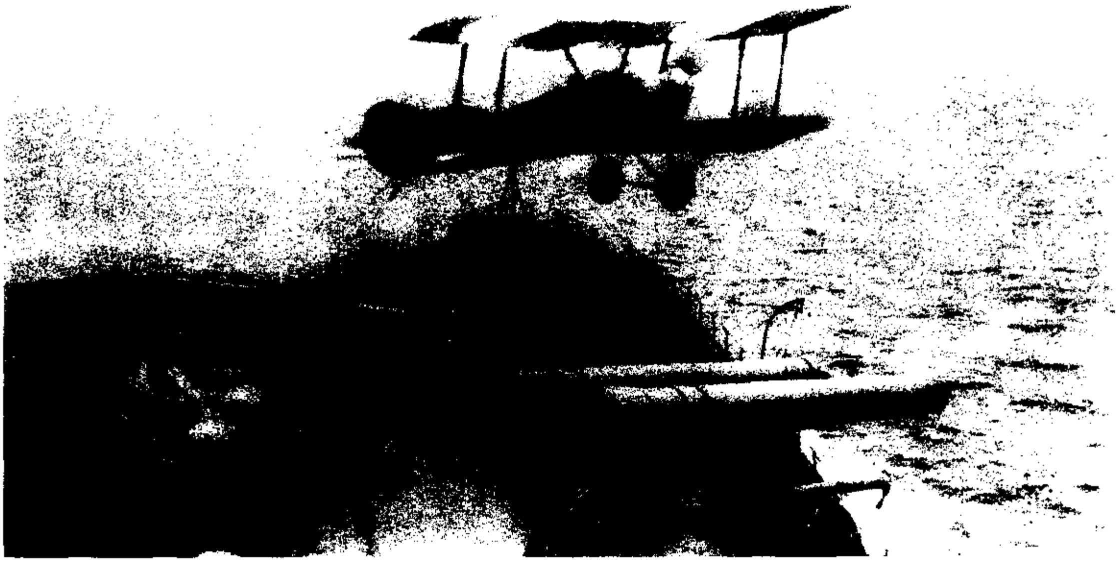

FIG. 7—SOPWITH CAMEL TAKING OFF IN LITTLE MORE THAN ITS OWN LENGTH FROM A CAPITAL SHIP'S TURRET PLATFORM

A ship underway into a normal headwind experiences maybe 40 knots of wind over the deck. Many aircraft of this era could fly quite well at 40 knots, hence their ability to take off in their own length. With no room, or indeed necessity, to gather speed to raise the tail on takeoff, the aircraft sat on its ramp in its flying position, its tail supported by a Tail Guide Trestle, and secured to the deck by a Quick Release Strop (FIG. 6). With engine at full power and the platform turned into wind, the pilot would signal to the launching officer to pull the Quick Release and takeoff was immediate (FIG. 7). Unless land was in range, the aircraft would have to ditch in the sea at the end of its sortie. This was not as dangerous as it may seem; the aircraft were fitted with flotation gear and few pilots were lost. It was expensive in aircraft. Recovery of a wheeled landplane at sea remained a problem.

'Furious' trials 1917–18

It was not a problem which had been ignored. As early as 1912, there had been proposals for a clear deck ship, from various sources, but progress had been slow. Jackie FISHER, when First Sea Lord, had developed a scheme to attack the Pomeranian coast, his Baltic campaign, and three large light cruisers, of suitable draft for working in the Baltic, had been planned. In early 1917, the third one, *Furious*, was nearing completion. The first two, *Glorious* and *Courageous*, were not popular with their crews and, with FISHER retired, the Baltic scheme had been abandoned. BEATTY required a fast seaplane carrier for fleet work, and orders were given for the conversion of *Furious*. Her forward 18" gun was not fitted, the upper deck being converted to a takeoff platform, and the motor spaces below into hangarage and other aircraft support stores (FIG. 8).

A small team of skilled pilots, with a batch of the very handy Sopwith PUP fighters, were posted to *Furious* to carry out the flight trials (FIG. 9). With her 228ft long forward deck, takeoff from *Furious* underway was no problem, but the longer deck offered the tantalising chance of landing back on board. There was the problem of the superstructure in the way, however. SQUADRON COMMANDER Edwin DUNNING made his approach from astern as *Furious* steamed at 22 Knots down Scapa Flow. There was about 46 Knots of wind over the deck, more than enough to maintain the PUP's controllability. He dodged around the superstructure, sideslipped the aircraft over the for-

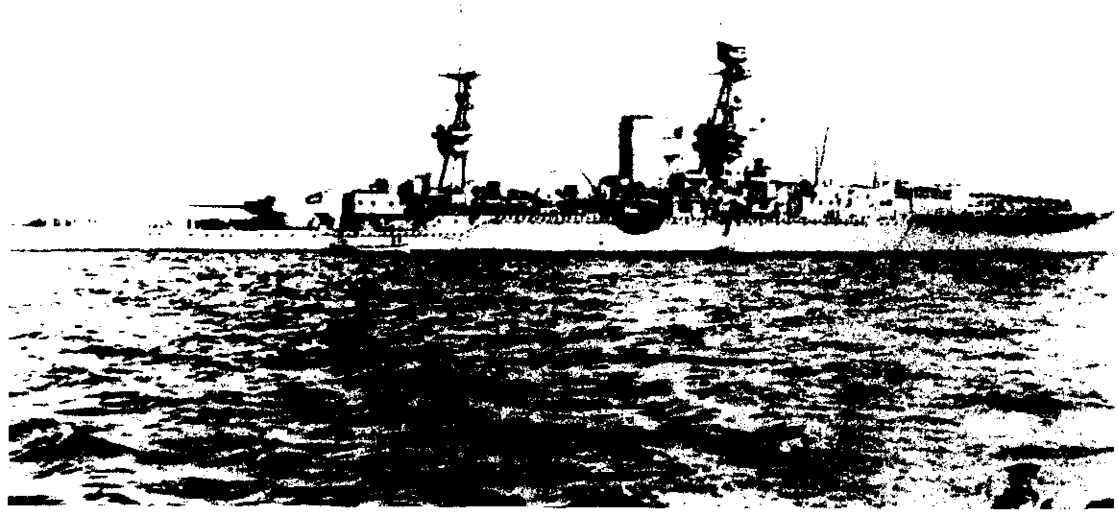

FIG. 8—'FURIOUS', IN THE SUMMER OF 1917. THE TAKE-OFF DECK HAS BEEN INSTALLED FORWARD, BUT THE 18" GUN IS RETAINED AFT

ward deck, and cut the throttle as the rest of his team rushed out to drag the PUP down on to the deck. With this first landing of a warplane upon a moving warship, on August 2nd 1917, the real aircraft carrier was conceived. Sadly, DUNNING was killed a few days later, trying the experiment for the third time. It was obvious that such a technique was right on the limits of even the best pilots. The answer was to create a separate aft-facing landing deck.

Furious went back into the dockyards and emerged almost a year later, with her after 18" gun replaced by a landing-on deck. Whilst the landing trials were completely unsuccessful, due to the massive turbulence of smoke and disturbed air from the superstructure, several more of the deck equipments

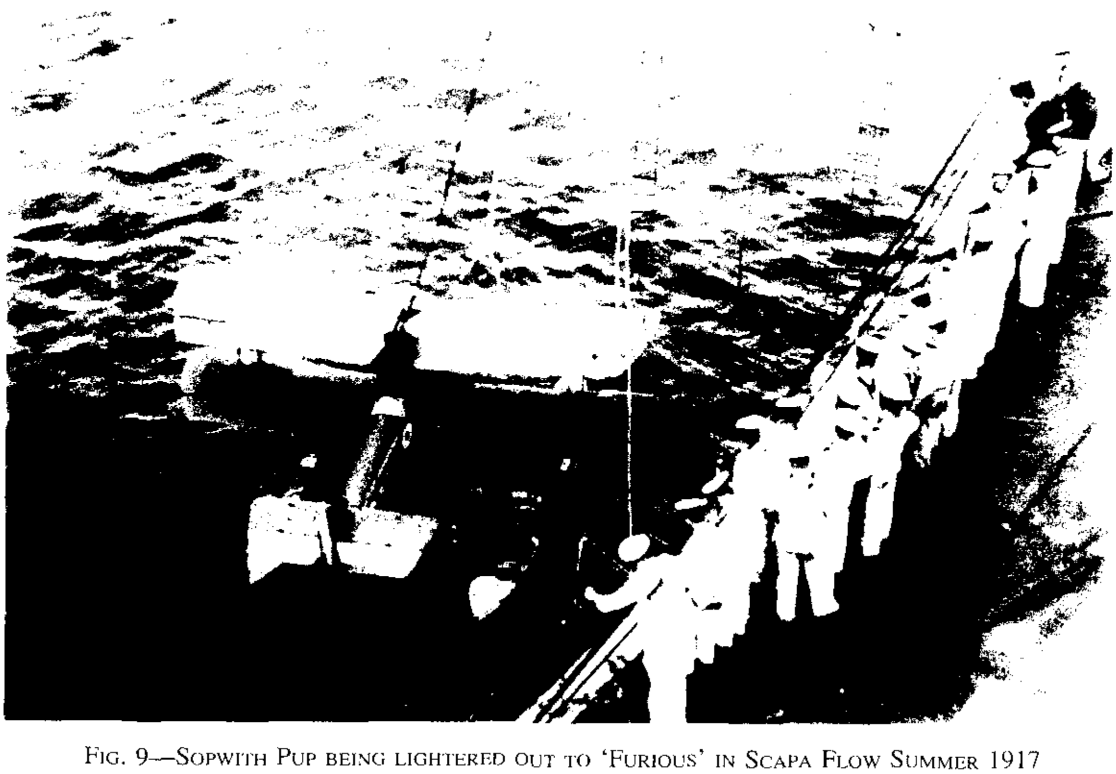

FIG. 9—SOPWITH PUP BEING LIGHTERED OUT TO 'FURIOUS' IN SCAPA FLOW SUMMER 1917

Fig. 10—Summer 1918. A Sopwith Pup caught up in the turbulence over 'Furious's' after deck. The early installation of axial hold-down wires can clearly be seen

were installed in *Furious* at that date (Fig. 10). There were athwartship wires, although these were soon removed, plus fore and aft wires. The latter served not so much as arrester gear, but hold-down gear, aimed at keeping the aircraft straight during its landing run, and then keeping it safely on deck. Possibly because of the landing problems, a crash barrier was rigged just aft of the bridge, comprising a number of vertical cables stretched over a steel frame (Fig. 11).

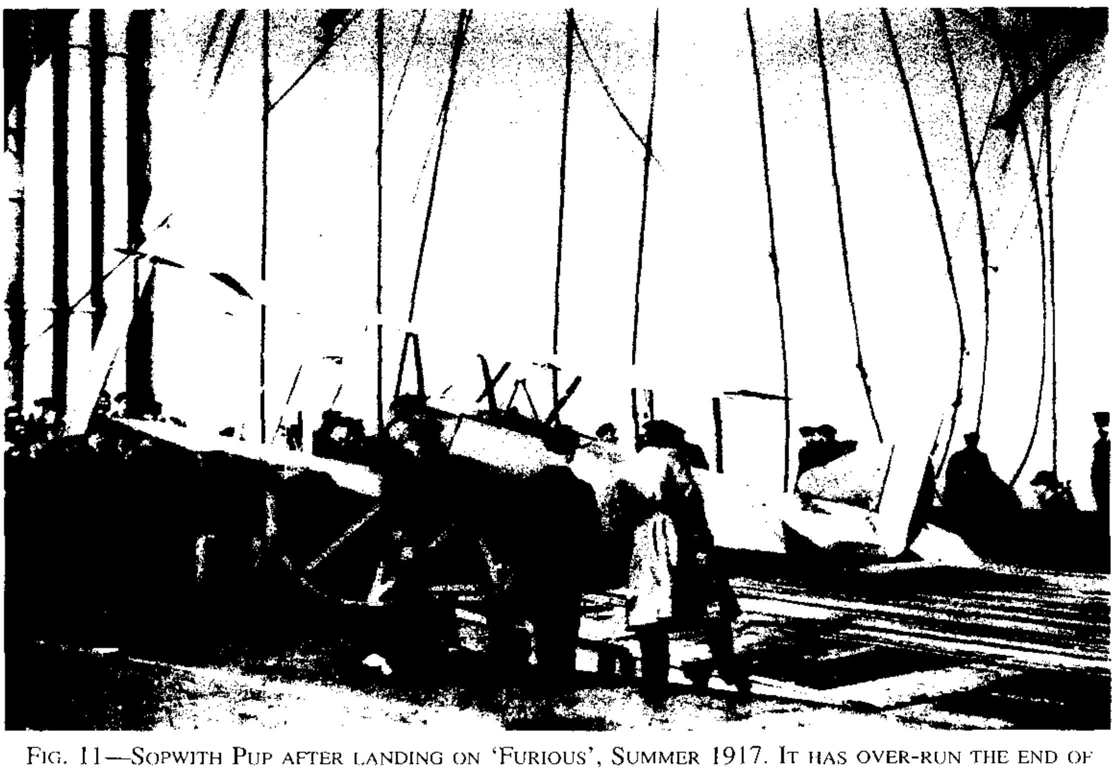

Fig. 11—Sopwith Pup after landing on 'Furious', Summer 1917. It has over-run the end of the wooden decelerating ramp and gone into the rope safety barrier

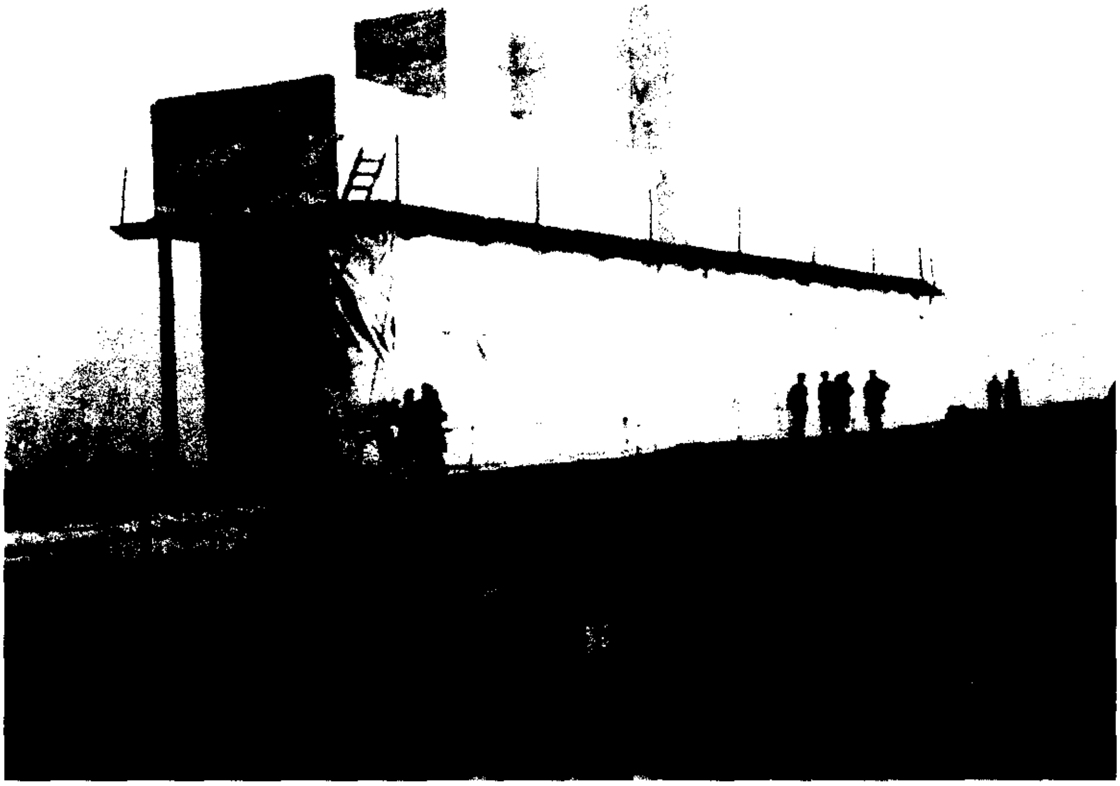

FIG. 12—THE WOOD AND CANVAS ISLAND BUILT ON 'ARGUS' FOR LANDING TRIALS, 1919/20

FIG. 13—LANDING TRIALS ABOARD 'ARGUS' WITH HER EXPERIMENTAL AND TEMPORARY CANVAS ISLAND. THE TRAP FLAP ENTRANCE INTO THE LONGITUDINAL WIRES WOULD BE DEPRESSED BY THE AIRCRAFT'S WHEELS

'Argus'—The first successful carrier

Even as *Furious* was proving that the traditional central superstructure was not acceptable in an aircraft carrier, the theoretical and model work had been going on, building upon ideas suggested as long ago as 1912, variously by FLIGHT COMMANDER Hugh WILLIAMSON and the Beardmore Company. That thought had been incorporated into Britain's and indeed the world's second aircraft carrier, *Argus*. She emerged as the first flush deck carrier in the late summer of 1918 and flying trials soon confirmed her as the world's first successful aircraft carrier, able to launch and recover her aircraft safely and consistently.

The lack of a bridge in *Argus* created some problems for her navigators. The flying trials in *Furious* had shown the impracticability of a traditional central superstructure but one of the proposed solutions to the problem had already been put forward, that of an offset island. A wood and canvas island was constructed on *Argus* (FIG. 12), and flying trials showed that this caused little problem to safe landings (FIG. 13). The location of the island to the starboard side is generally attributed to the effect of rotary-engined aeroplanes. Because the rotary engine, fitted to early shipborne aircraft such as the Sopwith PUP and 1½ STRUTTER, produced a gyroscopic effect when the aircraft turned, pilots would overshoot to the left, going with the gyroscopic precession rather than against it. Hence the island was placed to starboard, leaving a clear exit to port.

By the Armistice, the Royal Navy had two carriers, the rest of the world none. Britain's carrier fleet grew slowly over the next decade, and other countries joined the carrier world, notably Japan and the USA. Britain developed the offset island layout, in ships such as *Eagle* (FIG. 14) and *Hermes*, whilst the others favoured the flush-decker for some time.

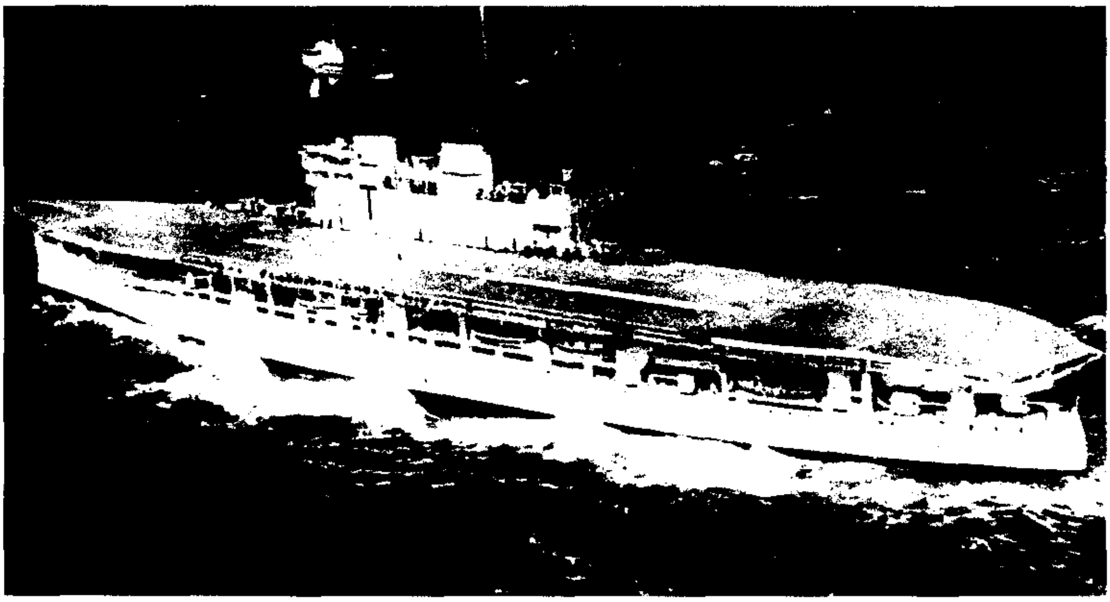

FIG. 14—'EAGLE', THE WORLD'S FIRST CARRIER WITH AN OFFSET ISLAND, COMMISSIONED IN 1924

Despite much practical experimentation in 1918/19 the use of longitudinal wires was soon eschewed. Pilots disliked them because of the uncertainty that their aircraft had been hooked, ship's officer disliked them because the installation tended to obstruct the lifts. Landing speeds were still so low that they were unnecessary, and the application of longitudinal hold-down wires soon faded. Their abandonment was balanced by the adoption of palisades at the edges of the deck, to prevent aircraft slipping over the side after an off-centre landing, introduced on *Furious* in 1926 (FIG. 15). It can be said that these were only made necessary because other, more constructive technologies had been abandoned and not replaced by better ones.

FIG. 15—'FURIOUS', AFTER HER MAJOR REBUILD, NOW A FLUSH-DECK CARRIER OF THE 1930S. THE PALISADES, INSTALLED IN 1926, WERE TO PREVENT AIRCRAFT GOING OVER THE SIDE AFTER A BAD LANDING

Inter-war period

In the inter-war years economy, where Britain had unilaterally created the 'Ten Year Rule', which stated that there would be no major conflict for ten years after the Armistice, and which was updated annually, naval aviation generally endured a raw deal. True, new carriers continued to join the fleet, but the aircraft were either modifications of landplanes or monstrosities specified by aviation-ignorant 'fishheads'. Bit by bit, Britain lost her lead in naval aviation.

So the naval airmen of 1925–35 flew a small number of often badly-specified but fundamentally safe aircraft. Take off from a carrier was generally little different than it would be from an airfield. The length of run was obviously a little shorter and an engine failure meant a ducking. The three carriers converted from the COURAGEOUS class cruisers had a secondary takeoff position, below the forward end of the main flight deck. At the forward end of the hangar was a very short deck from where operated the 'Slip Flight', usually of Fairey FLYCATCHER fighters, using techniques directly derived from the turret platform practice of tail trestle and quick release (FIG. 16).

Landing speeds were slow and most pilots could land with a reasonable level of safety. The pilot was in control of his own destiny on landing, even if the frequency of recovering a formation to the deck was pre-ordained by either the ship's captain or the squadron CO. Aircraft would queue up in the circuit around the ship, landing on when instructed, followed by a quick taxi forward to the lift to be struck below, to provide a clear deck and a lift at flight deck level for the next aircraft in line.

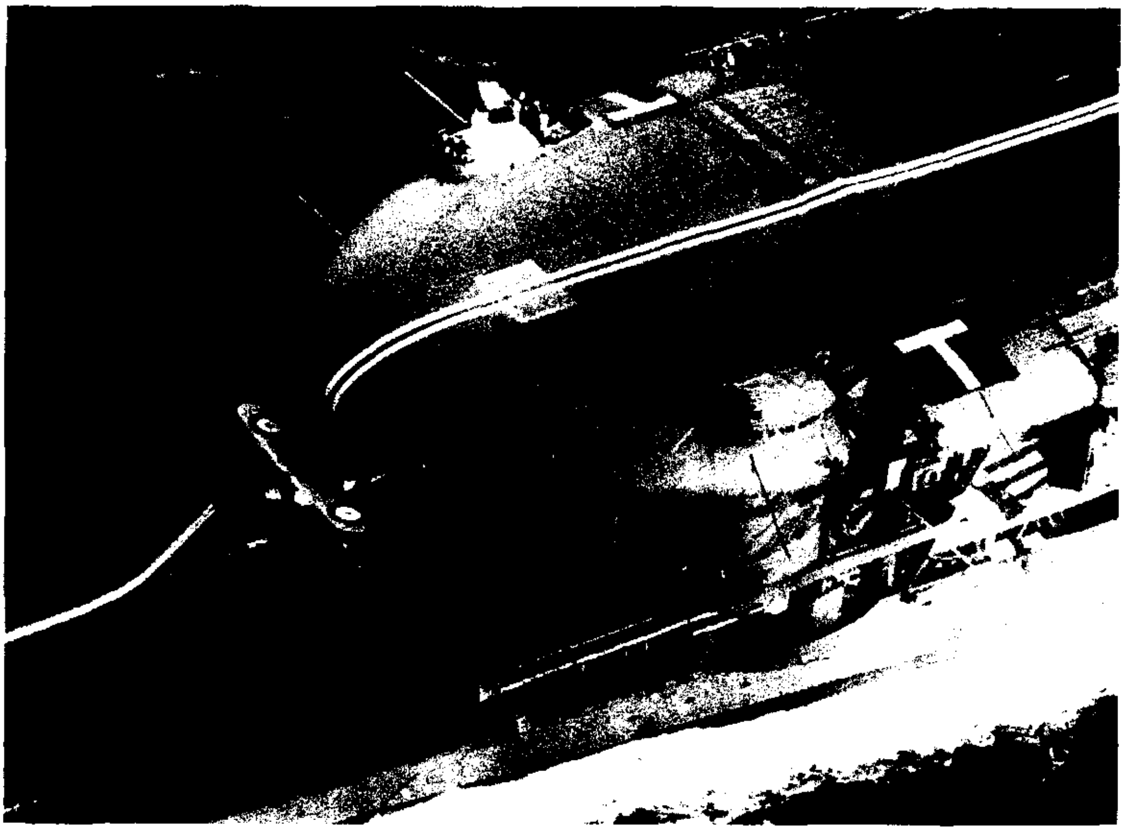

Fig. 16—Fairey Flycatcher behind the windbreak of the Slip Flight hangar, c 1930

New ideas and on towards war

Around 1930, a new light shone in the US Navy and carriers began to change from wallflowers to being belles of the ball. Carrier aircraft were specified as such from the beginning and their increased performance highlighted the paucity of deck aids to improve safety. The batsman was introduced to guide pilots to an accurate landing, and the lack of deceleration once the wheels touched deck finally received official attention. Thus it was that the US Navy re-introduced athwartship arrester wires to their carriers, some twenty years after they had attended the first ever deck landing.

Britain began to reconsider the installation of arrester wires around the same time, ostensibly because of the likely increases in aircraft performance but mainly because of the notional increase in aircraft capacity that they could bring to the carriers. The US Navy had developed the idea of the deck park, but this was impractical without arrester wires and, indeed, without the use of a safety barrier.

Arrester wires were re-evaluated by the Royal Navy, with trials aboard *Courageous* in January 1931 of a single wire. Later in the year a further set of trials employed three wires set further aft. A permanent installation was incorporated into *Courageous'* refit at the end of 1932; *Glorious* was equipped in 1933 but *Eagle* had to wait until 1937. The typical fit for a British Fleet Carrier of World War 2 was eight wires and pilots usually aimed to pick up the third.

FIG. 17—A SEAFIRE CRASHES INTO THE FORWARD DECK PARK OF A CARRIER IN THE PACIFIC, AFTER MISSING ALL THE ARRESTER WIRES AND VAULTING THE SAFETY BARRIER

Even with an arrested landing, aircraft could not be safely held in a forward deck park (FIG. 17) without an additional level of safety, the barrier. It seems that the barrier presented more development problems than arrester gear (FIG. 18). *Ark Royal* appears to have been the first British carrier to be fitted with a barrier, and that only just before the outbreak of the Second World War.

FIG. 18—A SEAFIRE WRECKED BY TAKING THE SAFETY BARRIER WHICH PROTECTED THE FORWARDED DECK PARK ON STRAIGHT DECK CARRIERS OF WW2

FIG. 19—THE EARLY CATAPULT INSTALLATION ON 'NORTH CAROLINA', 1916

One major operational problem in wartime was the need for the carrier to turn away from the fleet's course into wind, to launch and recover. Launching in particular could create a major separation between the carrier and the rest of the fleet. The catapult offered the chance of launching safely whilst well off the wind. Catapults had been fitted to capital ships for some years (FIG. 19), but a proper review took place again around 1930. The key was the development of an hydraulic catapult which could be fitted flush with the flight deck. Catapult launching was also seen as a complement to the use of arrester gear and barriers, in increasing aircraft capacity and also their operational value. From the mid-1930s onwards, accelerators were installed in the fleet carriers. The early British system required a four-wheeled trolley to launch the aircraft almost in flying position (FIG. 20) but, by the mid-war period, the American method of tail-down launching had been adopted, simplifying the whole operation.

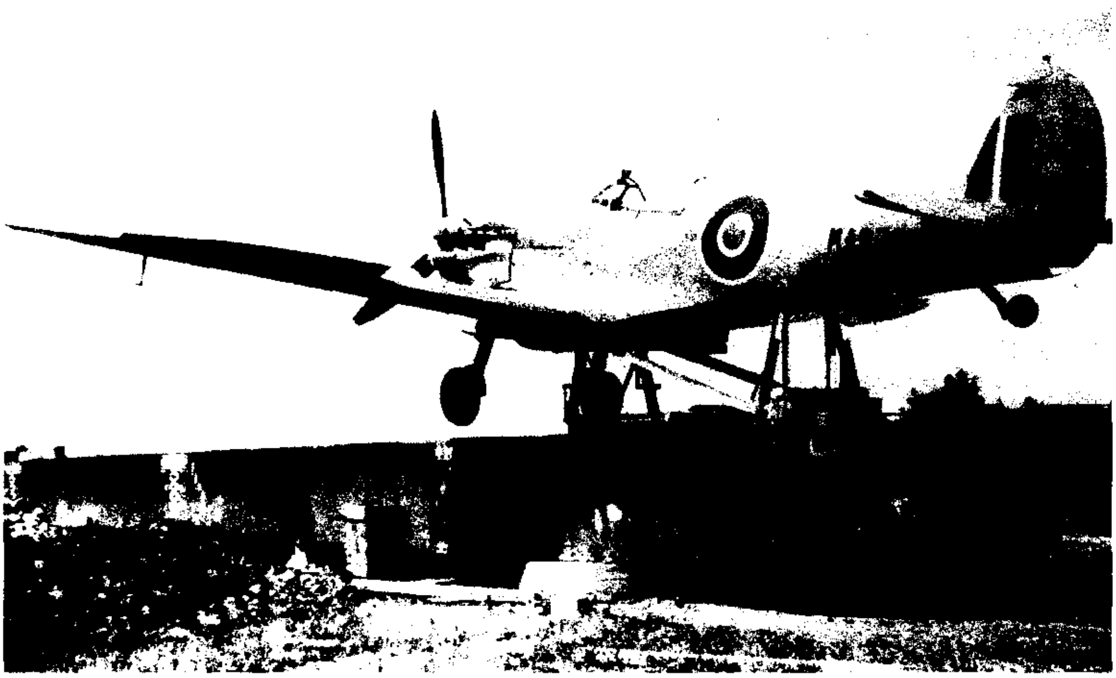

FIG. 20—SEAFIRE ON AN AIR STATION BASED BRITISH PATTERN CATAPULT, WHICH INCORPORATED A LAUNCHING TROLLEY

That then, is the encapsulation of the first thirty years of pioneering in shipborne aviation. Some of the ideas with which the major carrier navies went fighting in the Second World War stemmed directly from the first hesitant trials of ships and aircraft a generation earlier. Nothing else of significance was added under the stress of wartime. The essentials were:

- A clear deck with either an offset island to starboard, or no island at all
- Batsman to guide pilots to the deck
- Arrester wires to slow them quickly
- A wire rope crash barrier if all else failed.

The jet era

The advent of jets brought a new set of problems. Early jet engines produced relatively poor acceleration, requiring long takeoff runs. They were also very fuel hungry and naval jets had very little endurance or warload. The lack of a propeller and flatter angle of approach with a nosewheel aircraft produced an improved view from the cockpit, but the higher approach speed meant that the batsman had to react much faster. One line of thinking harked back to the days of trolleys and seaplanes: launch the jet from a trolley, which stayed on the flight deck. The saved weight of undercarriage could be carried as fuel load. The age-old question of safe recovery loomed again.

Trials at Farnborough led to the construction of a rubber deck on HMS *Warrior* (FIG. 21). This was actually an air cushion, formed by the inflation of lengths of second-hand large diameter fire hose. Both the landborne and shipborne trials proved the concept was reasonably safe, if Heath Robinson, and that indomitable inventor would have been impressed with the variety of deck-handling gear which would have resulted from having to remove a squadron of aircraft one by one from their helpless belly flop position, while their colleagues waited in the circuit for their turn to land on. It was obvious that some form of deck park off the main landing axis would have to be created, and thus was born the idea of the angled deck. In 1951 CAPTAIN (later REAR ADMIRAL) Dennis CAMPBELL and Lewis BODDINGTON were scheming

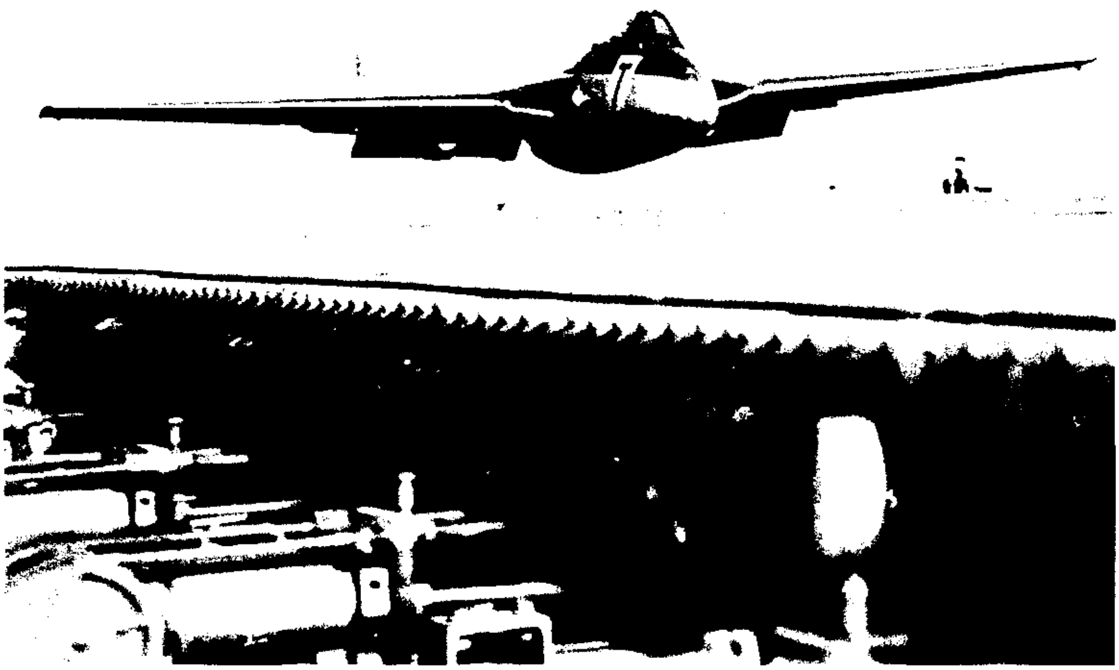

FIG. 21—SEA VAMPIRE LANDING ON THE INFLATED RUBBER DECK OF 'WARRIOR'

how to form the safe park and came to a solution which involved offsetting the landing line from the main deck axis (FIG. 22). It was but a short step to proposing an angled landing strip that permitted a safe overshoot from an

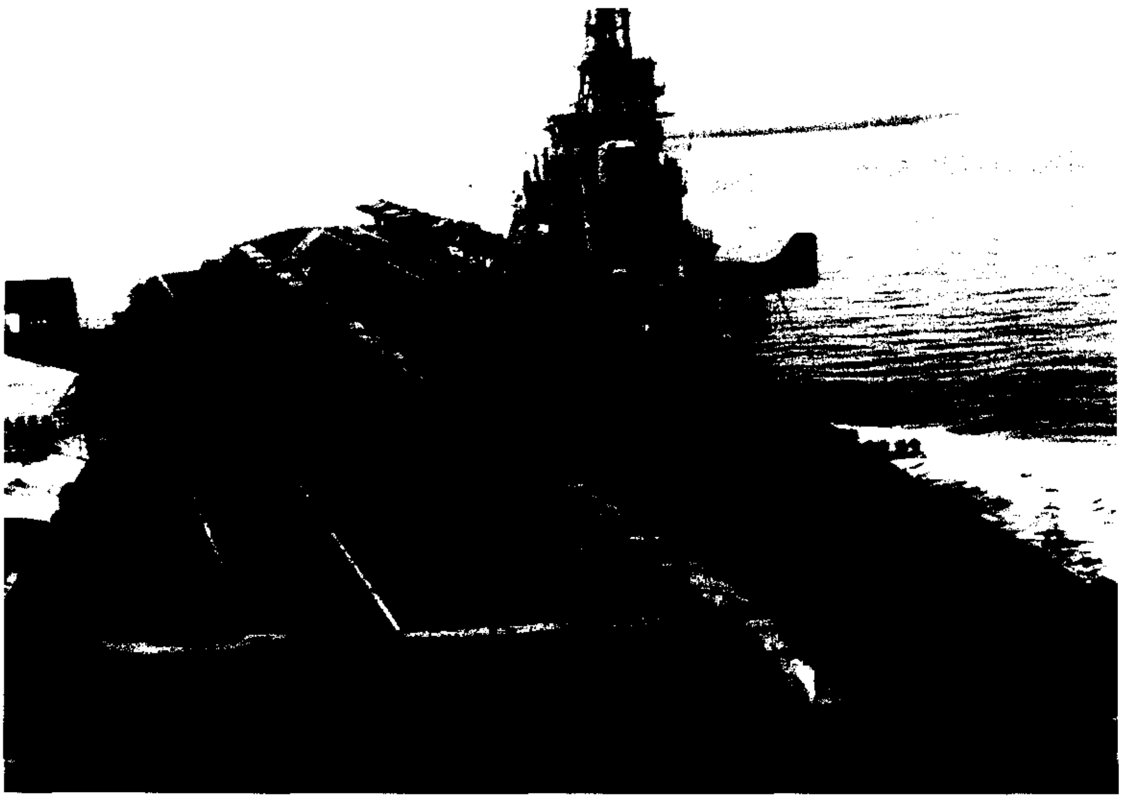

FIG. 22—THE ANGLED FLIGHT DECK OF 'CENTAUR', WITH THE LANDING SIGHT TO PORT AND THE AIRCRAFT PARK FORWARD TO STARBOARD

aborted landing, something which the conventional barrier did not allow and that additional safety benefits would flow from such an arrangement.

The first flying trials of the angled deck were made with off-centre lines painted on the axial deck of HMS *Triumph*, but the first metal deck built at an angle was American, on the USS *Antietam*.

The solution to launching jets heavy with fuel awaited the development of the steam catapult, developed by COMMANDER C.C. MITCHELL. His idea was patented in 1938 and refined after examining examples of the German V-1 launching ramps. The hydraulic catapult involved arrays of cables and pulleys and the maximum limits were a load of around 30,000 lbs and 75 knot launch speed. The steam catapult, powered from the ship's boilers, used a slotted cylinder with the aircraft hitched directly to the moving piston. The prototype steam catapult was installed in HMS *Perseus* in 1951 and trials were very successful. Later models could cope with higher aircraft weights and launch speeds, and the steam catapult became a standard fitting on all conventional carriers (FIGS 23 & 24).

FIG. 23—SEA VIXEN ON THE STEAM CATAPULT, WITH LAUNCHING STROP ATTACHED FORWARD AND THE HOLDBACK AT THE TAIL

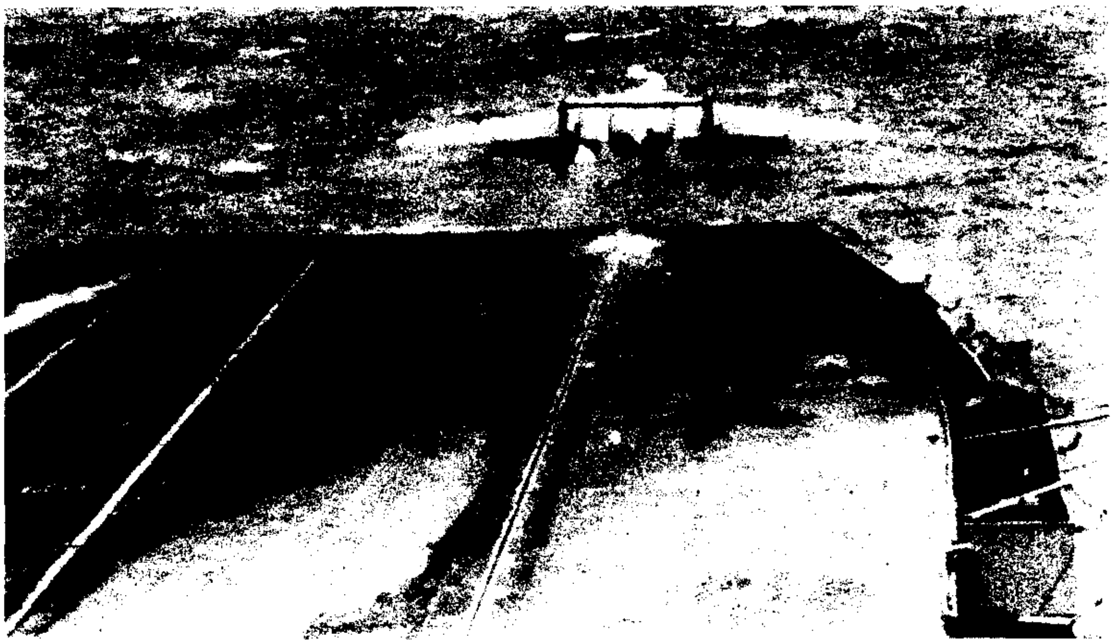

FIG. 24—SEA VIXEN JUST AIRBORNE FROM THE STEAM CATAPULT. THE LAUNCHING STROP IS JUST FALLING AWAY

The problem of the batsman (FIG. 25) remained to be resolved and a typist's powder compact came to the rescue. The lady's name has gone unrecorded, but CAPTAIN CAMPBELL and COMMANDER (later REAR ADMIRAL) Nicholas GOODHART borrowed it in their office one lunchtime to test an idea. The desktop tests showed that it was possible for a pilot to control his own approach if he followed an optically preset glidepath. Thus was born the Mirror Landing Sight, from which was developed the Deck Landing Projection Sight (FIG. 26), and the batsman found himself out of a job.

FIG. 25—THE BATSMAN BRINGS A FAIREY SWORDFISH INTO LAND DURING WORLD WAR 2

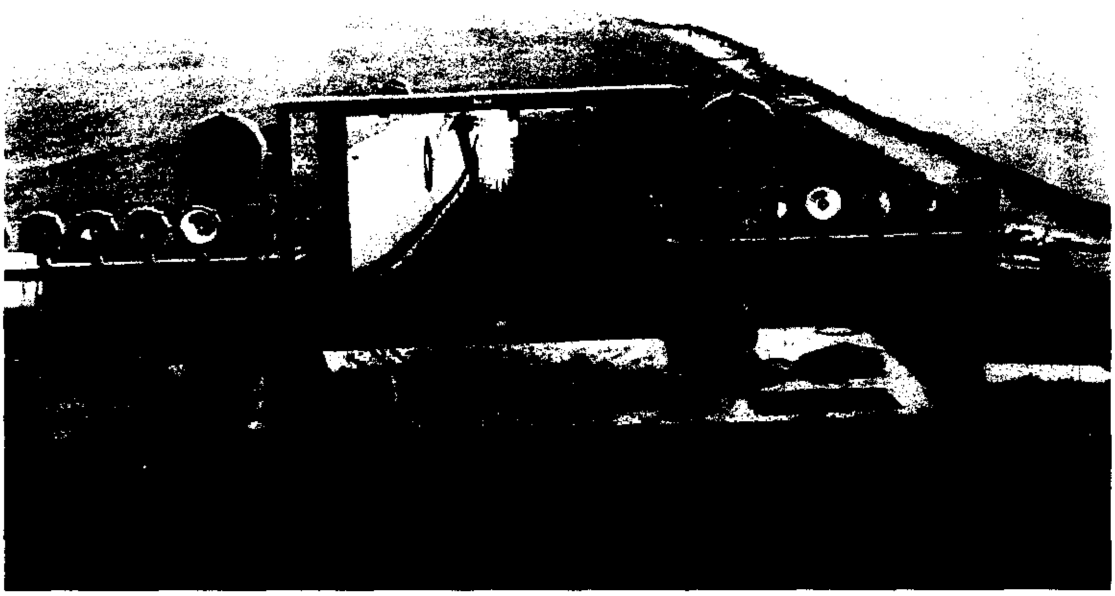

FIG. 26—MIRROR LANDING, SIGHT INSTALLED AT A NAVAL AIR STATION FOR DECK LANDING PRACTICE, 1950s

A new role was now found for a variation on the barrier theme. The traditional barrier had been superseded, but new barriers, for the safe retardation of aircraft whose undercarriage or hook would not go down, were introduced. Their material was now nylon and many aircrew have recovered safely into such barriers over the last 40 years (FIG. 27).

FIG. 27—SEA VIXEN TAKES THE MODERN SAFETY BARRIER AFTER A HOOK FAILURE

Conclusion

The safe assimilation of aircraft into the world of warship navies has been a halting process. The first trials showed astonishing prescience but many concepts were not adopted as standard practice for far too long The carrier navies of World War 2 finally combined the best practices and turned carrier aviation into a potent force. The development of the jet aircraft brought new challenges to flight deck equipment, but these were solved by the key inventions of the steam catapult, angled deck and mirror landing sight, permitting the safe operation of successive generations of heavier and faster conventional naval aircraft.

General references

LAYMAN R.D. 'Before the Aircraft Carrier.' *Conway Maritime Press*, London, 1989'

FRIEDMAN, N. 'British Carrier Aviation.' *Naval Institute Press*, Annapolis (USA), 1988

CRONIN R.C. 'Royal Navy Shipboard Aircraft Developments, 1911–1931.' Air Britain (Historians) Ltd. Tonbridge, 1990

THETFORD, O. 'British Naval Aircraft since 1912.' *Putnam and Company Ltd.*, London, 1982