1 Flight Engineering

Self-Propelled

As the sun set over Milan on a warm day during the International Air Week in late September 1910, the poet Filippo Tommaso Marinetti, founder and leader of the Futurist Movement, took flight over the city. The biplane in which he was a passenger was piloted by the record-breaking Peruvian aviator Jean Bielovucic, whose friend and compatriot Chavez had died in an accident a few days earlier after successfully crossing the Alps.[1] During the brief sortie, in addition to experiencing 'increasing weightlessness [and] an infinite sense of voluptuousness', Marinetti felt his chest opening up 'like a great hole into which the entire horizon of the sky flowed deliciously, smooth, fresh, torrential'.[2] Later, he would claim that this flight propelled him towards the new conception of art and language, set out in the first lines of his 'Technical Manifesto of Literature' of 1912: 'Sitting on the fuel tank of an aircraft, my stomach warmed by the pilot's head, I sensed the ridiculous inanity of the old syntax inherited from Homer. A pressing need to liberate words, to drag them out of their prison in the Latin period . . . This is what the whirling propeller told me, when I flew two hundred metres above the mighty chimney pots of Milan!'[3] The aircraft's propeller had become a component with sufficient life of its own that

A Rockwell B-1B Lancer from the 28th Bomb Wing at Ellsworth Air Force Base, South Dakota, flies over the Pyramids in 1999.

it would ‘conquer the seemingly unconquerable hostility that separates out human flesh from the metal of motors’.

The machine on which Marinetti had taken his turn was common enough: a ‘Box-Kite’ biplane designed and constructed by the Voisin brothers, who in 1907 had established the world’s first aircraft factory at Billancourt, outside Paris, making any design that a customer wanted. (A Russian prince ordered a machine with a propeller shaped like a spiral staircase – a flight of steps; a Dutch client paid for a set of wings to be grafted onto a light carriage known as a ‘fly’ – the design failed to take off.) Earlier they had made a glider with biplane wings and an elevator in front, similar to the configuration of the Wright Flier. Dissatisfied with its handling, however, and in an effort to obtain a measure of automatic longitudinal stability, they fitted the aircraft with a fixed biplane horizontal ‘tail’, between the two surfaces of which the single rudder operated. The craft, which was, in effect, a giant box-kite with an elevator and a rudder,

Louis Paulhan at the controls of his Voisin biplane, during the famous Aviation Week at Rheims in August 1909. Note the small, bullet-shaped fuel tank, on which Marinetti would squat when flown by Bielovucic during the International Air Week in Milan just over a year later.

flew reasonably well. Its pilot sat on the lower wing with his feet protruding into a short cockpit equipped with elevators. On either side of him extended two sets of wings, upper and lower joined together by vertical struts and by four vertical panels, which, for lateral stability, combined to form symmetrical screens on each end of the wing with, at their centre, what has been described as a wide oblong ‘window frame’.

Whereas the Wrights deliberately produced a machine that was entirely dependent upon the pilot’s skill for its stability, the popular Voisin machine, then, was intended to be automatically stable, reducing the need for flying expertise and even allowing it to carry ‘paying’ cargo. Hence, above and behind the pilot, atop the small tin fuel tank, there was enough space for a single passenger, whose lower body, as indicated in Marinetti’s manifesto, would have been partially shielded from the airflow by the aviator’s head. Directly behind the passenger, but enclosed in the body in the

The Voisin-Delagrange Box-Kite, constructed and flown in 1907, and the first European aircraft to break the records established by the Wright brothers’ Flier in December 1903.

front of which sat the pilot, was a noisy fifty-horsepower Antoinette engine driving a propeller, whose blades whirled between the outriggers carrying the tail, pushing rather than pulling the craft along. Hence Marinetti, elevated above the pilot, had before him an unrestricted vision, and could feel 'the ferocious and flushing massage of the crazy wind' full on.

The propeller is a rotating wing, generating lift exactly as a fixed wing does, but with its blades directing air backwards so that lift becomes propulsive thrust. Since wing technology in 1910 was rudimentary, the propeller, carefully crafted out of laminated and lacquered wood, was the most valuable part of the aircraft and its blades needed constant care and attention. In fact, a rag drawn into a spinning propeller's axis was sometimes enough to destroy the carefully machined edges of the blades; objects weighing only a few ounces were injurious even though, in use, the blades were designed to bear immense air pressures. At the time of Marinetti's flight, experiments were under way with other materials (copper, lacquer-impregnated linen) and technologies (metal castings) in order to reduce propeller torsion and air friction. But these developments were too heavy – and the Voisin Box-Kite machine was already rather overweight – so, in order to balance the need for lightness and strength, wood, despite its fragility, remained the preferred material for some time to come. In its curious mixture of fragility and strength, the propeller implied other antitheses, too: of the natural and the artificial; of the visible and the invisible; of component and ornament. Such properties imply that the object was more than just a cipher of civilization's mobility, but the shift it presented from stasis into movement implies a larger aesthetic problem: the relationship between the concrete and the abstract, force and flight. A French engineer wrote: 'isn't [the propeller] soul-like in its infinite smallness with respect to the whole aircraft, in its imponderability when spinning at high speeds, in its invisibility as it traverses the ether's azure?'[4] As Jeffrey Schnapp has suggested:

> The wooden propeller's intermediate position between the weightlessness associated with the airplane's sail-like wings and the weight associated instead with the engine (in other words, between the aerial and metallic aspects of an aircraft's identity), corresponded to its location at a symbolic crossroads: right at the center of the cross formed by the airplane's wings and its perpendicular fuselage.[5]

Since now it transformed motive power into actual physical thrust, the propeller was assuming mythical proportions; as it now seemed that it alone, and not the wing, was responsible for the conquest of the air, it had come to symbolize that very visible dematerialization of matter in which the miracle of flight was thought to consist.

The propeller merged and confused sense impression. At the end of Proust's *La Prisonnière*, Marcel and Albertine hear the noise of an aircraft over Versailles: 'I had at last been able to attach the buzzing to its cause, to that little insect throbbing up there in the sky, perhaps six thousand feet above me; I could see it hum'; the propeller made noise visible.[6] This sense of the singular nature of the propeller emerged, too, in Léger's account of a visit made to the 1912 Paris Air Show in the company of Brancusi and Duchamp:

> The latter, whose character was dry and somehow unfathomable, was silently walking around the propellers that were on show. Suddenly he turned to Brancusi and said: 'Painting is finished! Who can do better than this propeller. Tell me, can you do that?' He had a great predilection for the precision of objects like those. We had too, but not in so categorical a way. Personally, I was drawn more towards the engines, to

the metal machinery, than to the wooden propellers . . . But I still remember how stunning they were. My God, they were marvellous.[7]

Notwithstanding Brancusi's awed comments, these propellers clearly revealed themselves in Léger's series known as *Contrastes de Formes*, lying behind its rotating formal combinations; then, in 1918, the propellers proper appeared in the two versions of *Les Hélices*, cramped canvases both with little space to breathe, never mind aspire to the sky. Finally, in a pair of watercolours, *La Cocarde* and *L'Avion Brisé*, in which Léger took a crashed aeroplane as the subject, the propellers are only one element among many; their characteristic curvature cannot overcome the angular disjointedness pressing into them, splintering them. Here, the

Fernand Léger, *La Cocarde* (c. 1916), one of a series of works in watercolour on paper featuring aircraft in various stages of destruction, recalled from the artist's time at the Front.

object has ceased to be an autonomous form, but simply represents a technological sublime; mechanical and the organic part of the great machine of modern civilization.

It took Léger's great friend, Robert Delaunay, to spot fully the technical and spatial possibilities of the spinning propeller, as well as of Voisin's Box-Kite, the machine that bore it so bravely. The aircraft appears first in *L'Equipe de Cardiff*, its wings reflecting sunlight breaking through a dark blue sky, broken by cloud; it is met by the hemispherical track of a Ferris wheel clearly intended to

Robert Delaunay, *L'Hommage à Blériot*, 1914, containing representations of a Voisin, an Antoinette, and several Blériots.

mark the radius of a prop; next *Soleil, Tour, Aeroplane*, in which the Voisin was partially merged into an apocalyptic array of propeller-like forms and circles of light. Finally, *L'Hommage à Blériot* features the Voisin once again, now deep red, flying in the sunset over Paris, its wings enclosed by a halo of purple and golden sunlight. This time, however, other machines are more or less prominent. A monoplane – what appears in profile to be an Antoinette – is ascending into the air to the left of the Voisin, while in the lower right eager mechanics are readying another monoplane for flight, in the direction of the disc at the dead centre of the picture. Dominating the lower half of the canvas is a beautifully shaped, giant red and mauve tractor propeller, prominent before the distinctive spindly undercarriage of what is recognizably the aircraft in which Blériot crossed the English Channel five years earlier, encircled by circles of blue, red, green and yellow.

The title of the painting is misleading since Delaunay is obviously paying homage, not to the man, Louis Blériot, '*le grand constructeur*', but to his machine, the Blériot XI, the unique design of which – rear rudder, enclosed cockpit, horizontal stabilizer and

On 23 October 1911 in North Africa, Captain Carlos Piazza of the Italian Expeditionary Force stands in front a Blériot monoplane in which he is about to make the world's first military flight.

swivelling landing gear to permit cross-wind take-offs – had propelled its pilot so far; a machine which, in contrast to the Wright Flier, and the Voisin Box-Kite, was a monoplane, a design that air racing had proved to be faster than biplanes of similar weight and power. Its engine arrangement, too, pointed forwards; the tractor propeller pulling rather than pushing its single-minded inventor into history and, as an *homme d'affaires*, into the embrace of the military men. By the end of 1910 there were almost forty military pilots and thirty military aircraft in France; the majority of the machines were of Blériot's design. At dawn on 23 October 1911 Captain Carlos Piazza, Commander of the Italian Expeditionary Force sent to North Africa during the Italo-Turkish war, made the first operational flight in a military aircraft when, at the controls of a Blériot XI, he carried out a one-hour reconnaissance of Turkish positions between Tripoli and Azizia.[8] In February 1914, after several weeks of sustained work, Robert Delaunay completed his *Hommage*; within six months, Blériot's machines, sporting the *cocardes* of the French air force and the roundels of the British flying corps, were being employed as spotter planes over northern France, reporting troop movements, directing artillery fire and harassing the enemy. This, perhaps, is what he had in mind when he described the elements of the pictures as creating '*simultané forme*'; the circular form of the propellers contained the future.

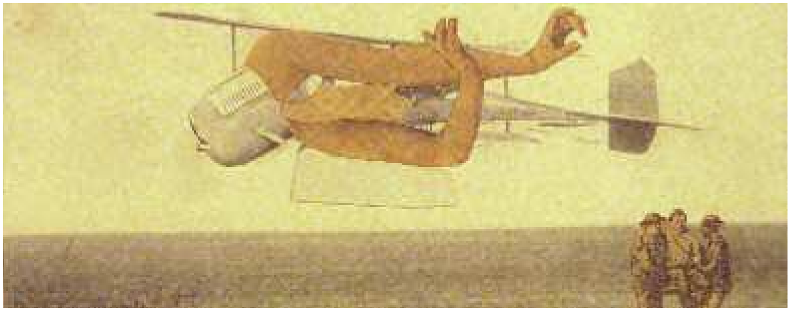
Within the year more specialized machines were taking on a number of combat roles: *ad hoc* bombers, dropping explosive projectiles on Zeppelin sheds, or makeshift fighters, circling the battlefield, with rifles and guns welded onto pylons for sporadic use by the vigilant observer behind the pilot. Already the French ace Roland Garros was flying a Morane-Saulnier aircraft equipped with a nose-mounted machine-gun and steel deflector plates on the propeller blades to prevent damage by the arc of fire. He was forced

Man and machine in harmony, as the eye and the gunsight converge. A 1917 advertisement for Fokker's fighters.

down behind enemy lines in 1915, and the Germans pounced on the new weapon technology. After inspecting the deflector, Anthony Fokker, a Dutch aircraft designer working on a new fighter for the German air force, proposed a key modification. A cam would be attached to the crankshaft of the engine in line with each propeller blade, and, when the blade reached a position in which it might be struck by bullets from the machine-gun, the relevant cam would actuate a pushrod that, by means of a series of linkages, prevented the gun from firing. Once the blade was clear, the linkages retracted, allowing the gun to fire. This synchronized machine-gun was fitted to the new Fokker E aircraft, which began arriving on the Western Front in late 1915, and gave the German pilots a devastating advantage since, for the first time in the air, the pilot was wedded to his machine; his gun coincided with his eye.

Commissioned by a British publisher, Le Corbusier's *Aircraft* (1935) was the culmination of the architect's obsessive aestheticization of the flying machine over the previous twenty years. Written, he claims, 'to inform the general public, questions of technique apart, as to what stimulus there may be in [the aeroplane] for contemporary society, divided at the moment between a desire to retrace its steps and to embark on the conquest of a new civilization', the book is by turns maddening, stimulating and, in certain respects, disturbing: 'What an unexpected gift to be able to come from above with a machine gun at the beak's tip spitting death fanwise on men crouched in holes'.[9]

Max Ernst, having served in the trenches as an infantryman, certainly knew the experience of being strafed from above, and *Murdering Aeroplane*, one of his early Dada collages, recalls the feeling of being under fire. Circling above the flat horizon, the pulverized landscape of northern France, an aircraft has assumed a monstrous form, half man, half machine. The nose, wing, fuselage



and *empannage* at the tail are constructed out of metal, as expected; but from the forward cowling there emerges a tangle of anatomically impossible arms, the left hand having perhaps just dropped its load over the trio on the blasted land, and the right, with its wrist cocked back, about to fire another dart at the poor bloody infantry. But then we notice that each of the three figures walking out of the frame has one arm either missing or maimed, and the ghastly possibility emerges: this is not a representation of ordinance at all, but rather of spoil, for instead of being dropped as bombs the limbs are now propelled away by the rapacious, silver-beaked machine.

Of course, it may be that Ernst's intention in this rough and ready collage was to imply the technological metamorphosis that took place between 1914 and 1918: the sense that aircraft, once the preserve of eccentric amateurs, were in the hands of a war machine becoming increasingly inhumane. Le Corbusier's account is explicit about the role played by the Great War in the development of aircraft:

> The war was a tremendous lever for aviation. In a feverishly accelerated rhythm, at the command of the State, the order of Authority, all doors were opened to discovery. Success was achieved, the aim reached,

Max Ernst, *Murdering Aeroplane* (1920).

astounding progress made. All this was to kill and destroy . . . If the war had not happened, aviation would still be pottering in poor little workshops of mechanics, in the fields of Lucerne . . . War was the hellish laboratory in which aviation became adult and was shaped to flawless perfection.[10]

The suggestion emerges that as aircraft develop they create a special breed of humanity, 'aces', characterized by their 'reckless courage, foolhardiness, contempt for death'; a breed whose great exploits – flying across the water, over the desert, against the odds – exist in inverse proportion to the fragile contingencies of their machines.

Charles Lindbergh is offered as an example of such an 'ace', a military man, who on Friday 20 May 1927, at 7.52 a.m., took off in a silver-winged monoplane and flew from the United States to France, the 92nd person to fly the Atlantic but the first to fly it alone. His aircraft was a Ryan NYP, based on its M-1, but customized with a massive 237 hp Wright J-5C Whirlwind engine. The wings were specially extended for greater range, but to fly 7,500

Charles Lindbergh's *Spirit of St Louis* takes off from Roosevelt Field, New York, on 20 May 1927, with Paris still 33 hours away.

km (4,650 miles), with a safety margin, demanded 2,700 lb of fuel and meant placing a huge tank in front of the cockpit, blocking all forward vision except by periscope and side windows. For the duration of the 33-hour flight, Lindbergh was effectively flying blind; his machine led the way. Le Corbusier recalled: 'Over night at Paris, the wires announced that Lindbergh was flying over French soil, that at a given hour, in the darkness he would be at Le Bourget. Paris hastens by all roads towards this wonder man. What an ovation. What joy.'[11] Harry Crosby, an American writer then living in Paris, witnessed the landing and described it in his diary:

> Then sharp swift in the gold glare of the searchlights a small white hawk of a plane swoops hawk-like down and across the field – C'est lui Lindberg, LINDBERG! [*sic*] and there is pandemonium wild animals let loose and stampede towards the plane and C and I hanging on to each other running and the crowd behind stampeding like buffalo and a pushing and a shoving and where is he where is Lindberg where is he and the extraordinary impression I had of hands thousands of hands weaving like maggots over the silver wings of the Spirit of Saint-Louis and it seems as if all hands in the world are touching or trying to touch the new Christ and that the new Cross is the Plane and knives slash at the fuselage hands multiply hands everywhere scratching tearing it.[12]

It seemed that the little Ryan machine, rather than its pilot, was exciting the mass frenzy; a will to consume the machine. Newspaper accounts bore witness to Lindbergh's reaction to the welling crowds: he screamed at the *gendarmerie*, 'For God's sake, save my machine.'[13] Later, his pilot's log barely stated the facts: 'Roosevelt Field, Long Island, New York, to Le Bourget Aerodrome, Paris, France. 33 hrs. 30 min. (Fuselage fabric badly torn by souvenir hunters.)'[14] In his later accounts of the flight, Lindbergh was modest about his own achievement and stressed it was the aircraft that had borne him across the water, and in particular its engineering. In Paris, a few days after he landed, he told newspapermen, 'You fellows have not said enough about that wonderful motor'; and so when Lindbergh returned to Washington and Calvin Coolidge pinned the Distinguished Flying Cross on him, he ensured that proper due was also given to the Ryan. 'For we are proud', said the President, 'that in every particular this silent partner represented American genius and industry. I am told that more than 100 separate companies furnished materials, parts or service in its construction.'[15] Hence, the flight was not the heroic lone success of a single daring individual, but the climax of the co-operative effort of an elaborately connected set of technologies.

A couple of years after the flight, Brecht wrote his cantata *Der Flug des Lindberghs*. His Lindbergh, however, is no hero; at his arrival, he asks to be carried to a dark shed, so that 'no-one sees / my natural weakness'. His flight was sustained for the good of those who built *The Spirit of St Louis*:

> Seven men built my machine in San Diego
> Often twenty-four hours without a break
> Using a few metres of steel tubing,
> What they have made must do for me
> They have done their work, I
> Carry on with mine, I am not alone, there are
> Eight of us flying here.[16]

On landing, his mind turns again to those engineers of flight: 'tell my comrades in the Ryan works at San Diego / that their work was good / Our engine held out / their work has no flaws.' Brecht was suggesting that by now the rampant individualism inherent in the early days of powered flight was waning; rather than empowering the flyer, aircraft were superseding the individual. It was a technological narrative even the strongest personality could not resist.

In 1926, the year before Lindbergh's flight, Antoine de Saint-Exupéry landed a job with the company that would become Aéropostale, flying the mail first from Toulouse to Alicante, then extending the route south to Casablanca, Dakar, and on by the shortest route across the Atlantic to South America. It was the making of his reputation as a flier, and a writer, too; and yet it is remarkable how little he seems to have been interested in the technical details of the aircraft he piloted, and crashed; indeed, a recent biographer called him 'the world's greatest Luddite aviator'.[17] Even when Saint-Exupéry devotes a chapter of *Terre des hommes* to aircraft, they remain abstract and unidentified, a means to an end in fact; the flight of the self:

> The more perfect machines become, the more they are invisible behind their function . . . Once we were in contact with a complex workshop. Today we forget the revolving of the engine. It is at last fulfilling its function, which is to revolve just as a heart goes on beating, and we pay no attention to out heart. The tool no longer absorbs out attention.[18]

In 1943, to escape a grim exile in New York, Saint-Exupéry managed to get back into active service with a French squadron, under the command of the USAF, flying Lockheed P-38s. At that time, the machine more commonly known as the Lightning was the fastest fighter in service and had the widest operational range. Twelve metres (38 feet) long, with a wingspan of 17 metres (52 feet), the Lightning was powered by two Allison V17 twelve-cylinder water-cooled engines, each developing 1,475 hp, allowing it to fly faster and higher than most enemy aircraft.

Furthermore, it was the only fighter to be fitted with five weapons – four 12 mm Browning M2 machine-guns and a 20 mm AN-M2 cannon – mounted together in the nose, which lent it great accuracy. The Germans called it the 'Fork-Tailed Devil', the Japanese 'Two Aircraft with One Pilot'; for the poet Gregory Corso it was one of 'the doves of war'.[19]

More than 10,000 were built, but the machines given to the French were barely serviceable; 'war-weary, non-airworthy craft', and for a flyer like Saint-Exupéry, used to flying instinctively, they were a handful, far more complex than the machines with which he had made his name. To his dismay, there were more than 200 dials and controls to monitor; the two engines were linked to six different fuel tanks and, to provide emergency speed, the engines were fitted with a supercharger boost, which would haul the large aircraft to 725 km/h (450 mph). By then his girth was thickening, and he

The Lockheed P-38 Lightning was an advanced design for its time, with a full-vision canopy, tricycle landing gear, turbo-superchargers and formidable armament.

was so crocked by his numerous injuries that he could barely make it into the cramped cockpit. To make matters even more uncomfortable, his plane's heating system was inoperative, and he found the complexities of the flight control system hard to divine: in August 1943 he wrote off a P-38 when he forgot to prime the braking system prior to landing on a short airstrip. Shortly after this accident, he wrote, but never sent, a letter: 'I have just made several flights on a P-38. It's a lovely machine. I would have been happy to have had such a present for my twentieth birthday'; but as the letter continues, however, he turns on the Lightning:

> If I am killed in action, I could not care less. Or if I succumb to a fit of rage over these flying torpedoes which no longer bear any relation to flying and which turn the pilot amid his dials and his buttons into a kind of chief accountant . . . But if I come out alive from this 'necessary and

Antoine de Saint-Exupéry, in the cockpit of his Lightning, 1943.

> thankless job', there will only be one question so far as I'm concerned: what can one, what must one say to men.[20]

He knew, as did so many of his comrades, that now the voice of the individual could barely be heard over the roar of the Lightning's propellers, the wail of the War machine.

Uncouth Arts

In 1949 the reclusive British millionaire Henry Kremer, 'a small alert figure, painfully shy', who having made his fortune from fibreglass and plastics now maintained a 'single-minded concern for developing new materials', offered a prize in his own name to be awarded for the first human-powered aircraft to fly a figure of eight course around two pylons half a mile apart; the tight figure of eight circuit offered an infinitely difficult challenge.[21] The prize was originally set at £5,000 and confined to British machines, but as the years passed numerous attempts were made, but with no winners. In 1969 Kremer doubled the prize and opened it to entries from the 'rest of the World'; within eight years, the purse had reached £50,000.

On 23 August 1977, as the early morning sun climbed over Shafter Airport, California, a flimsy transparent structure weighing only 35 kg (70 lb) was gently placed on the runway. Designed by Paul MacCready, a Californian glider expert, the Condor was constructed from thin aluminium tubes covered with Mylar, a thin plastic film made by Dupont, and braced with stainless steel wires. The propeller sat at the back of the plane and was balanced by a stabilizer carried on a long boom at the front; the leading edges of the wings were made of corrugated cardboard and styrene foam. Its pilot, Bryan Allen, a professional cyclist and hang-glider enthusiast, sat semi-reclined, with both hands free: one hand held a handle that controlled both vertical and lateral movement, the other manipulated a lever located beside the seat that controlled wires to twist the wing for turns.

MacCready had only conceived the idea of designing a human-powered aircraft in the summer of 1976. After building several models to test the structure, he and his team began constructing the first complete aircraft in October, the first proving flight, which lasted 40 seconds, taking place on Boxing Day. Throughout the first part of 1977 modifications steadily improved control and efficiency; now, on this late summer day, Allen took to the air at 7.30 a.m. and landed 7 minutes 27 seconds later, having covered the official circuit of 1,850 m (1.15 miles), at a flight speed between 10 and 11 mph. At full flight, Allen's pedalling developed one-third of a horsepower. Two years later the same team created the Gossamer Albatross, another contraption with a similar weight and wingspan, this time to meet the Kremer prize committee's challenge for the first human-powered flight across the English Channel. That flight took almost three hours and covered more than 32 km (20 miles), winning the new prize of £100,000, at the time the largest in aviation history.

Human-powered flight has its origins in a myth about wanting to return home over the water; an escape into nostalgia. The great inventor Daedalus, having created a labyrinth in which to imprison the Cretan Minotaur, given Ariadne the thread to find her way through it, and executed for Pasiphaë the notorious wooden cow is, in a sixteenth-century translation of Ovid's *Metamorphoses*, 'now tired of liuing like a banisht man and prisoner and longs in his heart to see his natiue Clime'. To flee from the island, he turns his mind to secret projects:

to vncoth Arts he bent the force of all his wits
To alter natures course by craft. And orderly he knits
A rowe of fethers one by one, beginning with the short,
And ouermatching still eche quill with one of longer sort
. . . Then fastned he with Flax
The middle quilles, and ioyned in the lowest sort with Wax.
And when he thus had finisht them, a little he them bent
In compasse, that the verie Birdes they full might represent.[22]

Icarus, of course, ignores his father's precise instruction to keep close to the surface of the sea, and his flying too close to the sun melts the glue holding his wings together. He comes unstuck over the Aegean.

The Gossamer Albatross under test, 1980.

Begun at MIT in the mid-1980s, 'Project Daedalus' was perhaps an attempt to react against some of the more outlandish precepts of the Gossamer aircraft; in particular, the fact that in August 1980 MacCready's team used the radiation that melted Icarus' wings to fuel more than 16,000 solar cells in the wing fabric of a bizarre-looking scaled-down version of the Albatross, and so cause a 3 hp engine to turn a 7 foot propeller. The plane, bizarrely named Penguin, and piloted by a featherweight pilot, Janice Brown, managed to fly two miles across Edwards Air Force Base, California, before landing on the desert floor. The goal of 'Project Daedalus' was quite simply to break, in an entertainingly public manner, the endurance record for human-powered flight, by taking off from Crete and heading to Santorini, 118 km (72 miles) away over the water. The flight was flawless until the pilot, Steve Bussolari, began to tire. As he approached the shore and turned into the northern wind, the ground speed began to drop until the aircraft was almost stationary; after an agonizing holding pattern, Daedalus crashed into the beach, in turn splintering the graphite in the tail boom and ultimately breaking the wing.

This machine, the design of Mark Drela, a young professor of aeronautics, also made use of Mylar to cover the internal structures, but its frame, compounded from Kevlar, a material created for the moon landings, was more recognizably that of a conventional, but very light, aircraft. The fuselage pod was suspended beneath a 8.8 m (29 ft) boom, which supported an 3.35 m (11 ft) propeller turning at about 105 revolutions per minute. Each turn of the pedals was translated by gearboxes into one and a half revolutions of the propeller, and a bell crank enabled Bussolari to adjust the propeller's pitch during flight: low pitch for power on take-off, high pitch for endurance during cruise. He manoeuvred the rudder and elevator with a small control stick in his right hand. Except for a few metal screws, everything in the airplane was handcrafted and meticulously measured, even the 31 kg (68.5 lb) of glue that held together much of the machine of was weighed.

In order to achieve their goals, these designers made use of advanced weight-saving composites, and sophisticated aerodynamic modelling techniques. Yet at the heart of each of the machines was an older, less unfamiliar technology: the bicycle. Seven years prior to the Wright brothers' first flight in December 1903, James Howard Means argued in an editorial for the *Aeronautical Annual* that the bicycle and the flying machine were inevitably connected: 'To learn to wheel one must learn to balance. To learn to fly one must learn to balance.' Even then it was recognized that bicycles and aircraft would have an inherent instability in common, and might share technologies. In August 1896 Otto Lilienthal, the German gliding pioneer who would die a few days later of head injuries sustained testing a rudder modification to one of his devices, wrote a letter to Means to congratulate him on this insight: 'I think that your consideration on the development between the flying machine and the bicycle . . . is excellent . . . I am sure the flying apparatus will have a similar development.' Most remarkable, perhaps, was the perspicacity of the editor of the *Binghamton Republican* who had predicted in June 1896 that the invention of a successful airplane might well be the work of bicycle makers. 'The flying machine will not be in the same shape, or at all in the style of the numerous kinds of cycles, but the study to produce a light, swift machine is likely to lead to an evolution in which wings will play a conspicuous part.'[23]

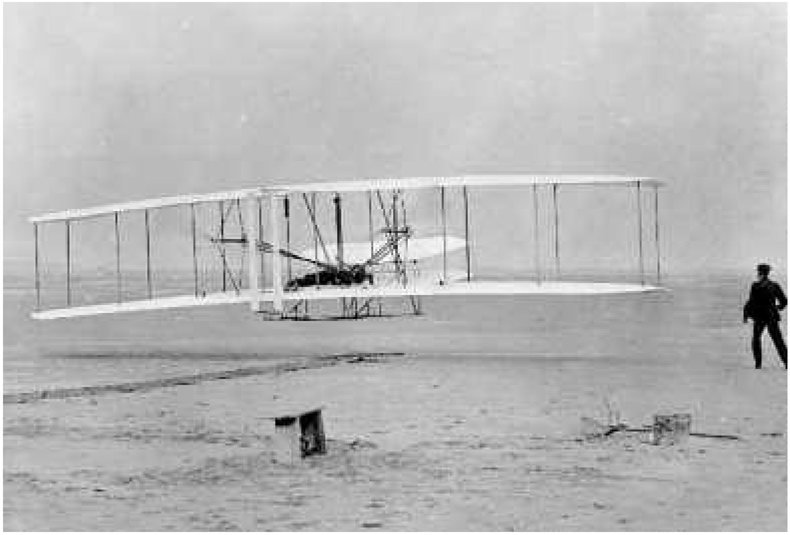
At this time, in Dayton, Ohio, the Wright brothers – their very surname implying some kind of craft – were living among hollow metal tubes, spoked wheels, chain drives and whatever else it required to construct efficient velocipedes that weighed and cost as little as possible. They also happened to be moved by flight. When they first expressed formal interest in flight by writing to the Smithsonian Institution in 1899 for a reading list on aeronautics, their business was robust. By way of reply, the brothers received a brief bibliography, the contents of which – books and pamphlets then available, including the works of Lilienthal, whose glider designs had made over 4,000 successful flights, L. P. Mouillard, S. P. Langley and Octave Chanute – they sought out and studied. In due course they contacted Chanute, a Chicago-based civil engineer and aeronautical authority, whose book *Progress in Flying Machines* (1894) had become the standard work in the field of aeronautics. Their correspondence would lead to a significant personal and technical relationship between the two brothers and the then famous engineer and inventor.

The Wrights' first ambition was to build a man-carrying kite. After consulting Chanute, and the US Weather Bureau for a suitable location, they settled on a sand bar between Albemarle Sound and the Atlantic Ocean at Kitty Hawk, North Carolina, where stiff sea breezes and soft sand dunes combined to offer perfect conditions for experiments; where Kill Devil Hills, more than 30 metres (100 ft) high with a ten-degree slope, proved ideal as a test range; and where the mosquitoes and the ticks bit them hard. The brothers built their first glider and took it down to Kitty Hawk in the autumn of 1900, where they flew it like a kite controlled by two ropes. Built on the basis of data obtained from the writings of Lilienthal and Chanute, this glider flew on a rope with a 23 kg (50 lb) payload of chains. Encouraged by these efforts, the Wrights returned to Dayton, keen to build a larger glider, which would be flown at Kitty Hawk in the presence of Chanute in late 1901; this, however, proved an embarrassing failure. It was during these trials that the Wrights became convinced that the works of Chanute and Lilienthal contained fundamental flaws, and so they embarked on their own basic experimentation on the optimum shape of aerofoils.

During the winter of 1902–3 they built, in their bicycle shop, a crude wind tunnel; it was fashioned from an old soapbox. From this, they obtained their first experimental confirmation that the data they had been relying on was incorrect. Galvanized, they built a large and more efficient wind tunnel with its airstream propelled by a single-cylinder petrol engine, and now experimented with some two hundred wing shapes. At this point they felt confident in the design of a new glider that would depart radically from earlier technologies of stability and control. This device made more than a thousand flights, far surpassing the previous achievements of Chanute and Lilienthal. Satisifed with their own data, they now determined to build a powered glider; for the remainder of 1903 the bicycle business would be neglected.

The biggest problem still remaining was the means of propulsion. Having designed and built an engine for their wind tunnel, with the help of the mechanic Charles Taylor they now designed and built a lightweight motor that embodied such advanced engineering as direct fuel injection into the cylinders, the use of aluminium, and water cooling. It weighed only 77 kg (170 lb) and delivered between 12 and 16 hp. In developing a propulsion mechanism, the brothers relied on wind tunnels and books on marine engineering; drawing on their earlier bicycle fabrications, they bodged together a crude chain drive to carry power from the engine to the two counter-rotating propellers at the rear of the machine, one chain being crossed to give better rotation.[24]

Having spent much of the autumn at Kitty Hawk tweaking the machine, and waiting for ideal conditions, on the morning of 17 December 1903 Orville took the controls and made four flights,



the longest of 59 seconds and covering 259 m (850 ft). In due course, the poetry of their flight emerged:

> O sinewy silver biplane, nudging the wind's withers!
> There, from Kill Devils [*sic*] Hills at Kitty Hawk
> Two brothers in their twinship left the dune;
> Warping the gale, the Wright windwrestlers veered
> Capeward, then blading the wind's flank, banked and spun
> What ciphers risen from prophetic script,
> What marathons new-set between the stars![25]

Hart Crane's lines are strangely duplicitous as they draw attention to the strangely recurrent aspect of the two brothers' achievement, and of their 'twinship': their close relationship, naturally, is at issue, as well as the dual structure of their amazing machine, the Wright Flier, a bi-plane, derived, predictably enough, from the bi-cycle.

The moment of flight, Kill Devil Hills, 17 December 1903.

The earliest flight was in one direction only, but in Crane's account the brothers 'banked and spun', perhaps implying that the impetus driving the venture was financial as much as technological. A recent critic has put it neutrally: 'the pioneering voyage has a commercial *raison d'être*, which does not invalidate the pilots' heroism, but objectifies it, and so demonstrates how the lone hero must interact with the impersonal forces of society'.[26] But for the Wright brothers the social interaction became increasingly rare:

> As the flights got longer,
> the Wright brothers got backers,
> engaged in lawsuits,
> lay in their beds at night sleepless with the whine of phantom
> millions, worse than the mosquitoes at Kitty Hawk.[27]

Though they continued to make flights in the two years following the triumph at Kill Devil Hills, they did so with as little publicity as possible; by late 1905, with the patents still pending, the elder brother, Wilbur, was increasingly anxious that their aircraft might be easily copied if it were seen in public at all. Consequently, for almost three years, until May 1908, the Wrights neither flew their machines nor permitted strangers to view them. Geoffrey de Havilland recalled that, in the years following it, their 'epoch-making first flight was almost secret':

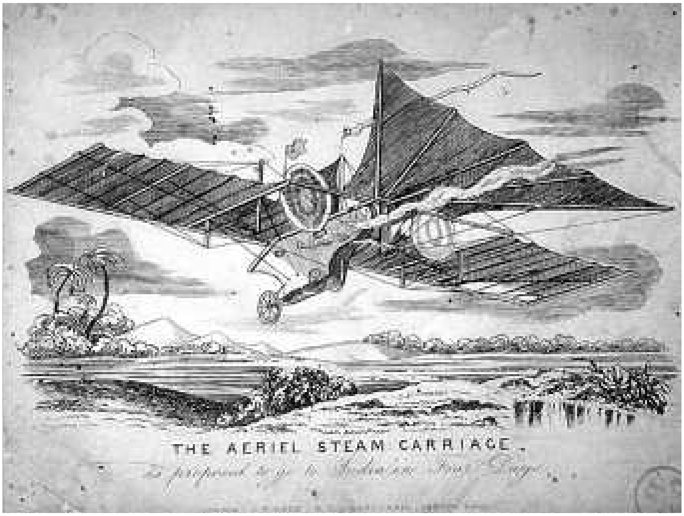
> The world heard little about the early exploits of the Wright Brothers, but by 1906 or 1907 word began to filter through to people who were interested in such things that men like Santos-Dumont, Blériot, Voisin, Pelterie and Farman in France, and Cody, Roe and Dunne in England, were meeting with success and were actually making short hops.[28]

These hops would soon lengthen into great leaps forward; in 1909 Blériot, so single-mindedly, would fly across the Channel in a monoplane: the Wrights' secrecy forced interested parties to develop alternative designs, often more sophisticated than their own. While the European public was impressed when it finally saw the Wright Flier at Le Mans in August 1908, many of the designers de Havilland mentions were already looking beyond its configuration, since, despite the 'extraordinary thrilling beauty' of the machine Henry James saw, its technologies – rail-launched, propellers driven by sprocket and chain, forward elevators, wing warping and unpredictable flight characteristics – were resolutely of the nineteenth century. This is the nub: the Wright Flier, the first powered aircraft, looks nothing like the aircraft that were to follow it, yet they in turn do recall the designs of earlier objects that barely left the drawing board.

Flying Objects

In late April 1843 *The Times* carried a report, originating in the *Glasgow Constitutional*, concerning a flight made by Professor Geolls, 'a foreigner', in a hitherto unidentified flying machine. Having described the preparation, take-off and early part of the flight from 'Dumbuck' hill, the correspondent coolly reported that, while over the Ayrshire coast, three steam pipes simultaneously fractured, causing the craft to lose power suddenly and plunge into the water, where the shaken Professor was rescued by a passing steamer.

For once the editors of *The Times* had been taken in by a hoax, one typical of the many circulating at the time intended to ridicule the 'dumb buck' William Henson, a Somerset lace-maker, whose design for the 'Aeriel' was, nevertheless, the prototype of a modern aeroplane.[29]



The previous year Henson's ambitions for what was later styled the 'Aeriel Steamer' or the 'Aeriel Steam Carriage' had materialized in patent No. 9,478, for which provisional protection was granted. A complete specification with drawings was filed on 28 March 1843, under the title of 'Locomotive Apparatus for Air, Land and Water', and referring in particular to 'Certain Improvements in Locomotive Apparatus and Machinery for conveying Letters, Goods and Passengers from Place to Place through the Air, etc.' He proceeded to describe the contraption as

> an apparatus so constructed as to offer a very extended surface or plane of a light yet strong construction, which will have the same relation to the general machine which the extended wings of a bird have to the body when a bird is skimming in the air; but in place of the movement or power for onward progress being obtained by movement of the extended surface or plane, as is the case with the wings of birds, I apply

A contemporary engraving of William Henson's 'Aeriel Steam Carriage' (1843).

> suitable paddle wheels or other proper mechanical propellers worked by a steam or other sufficiently light engine.

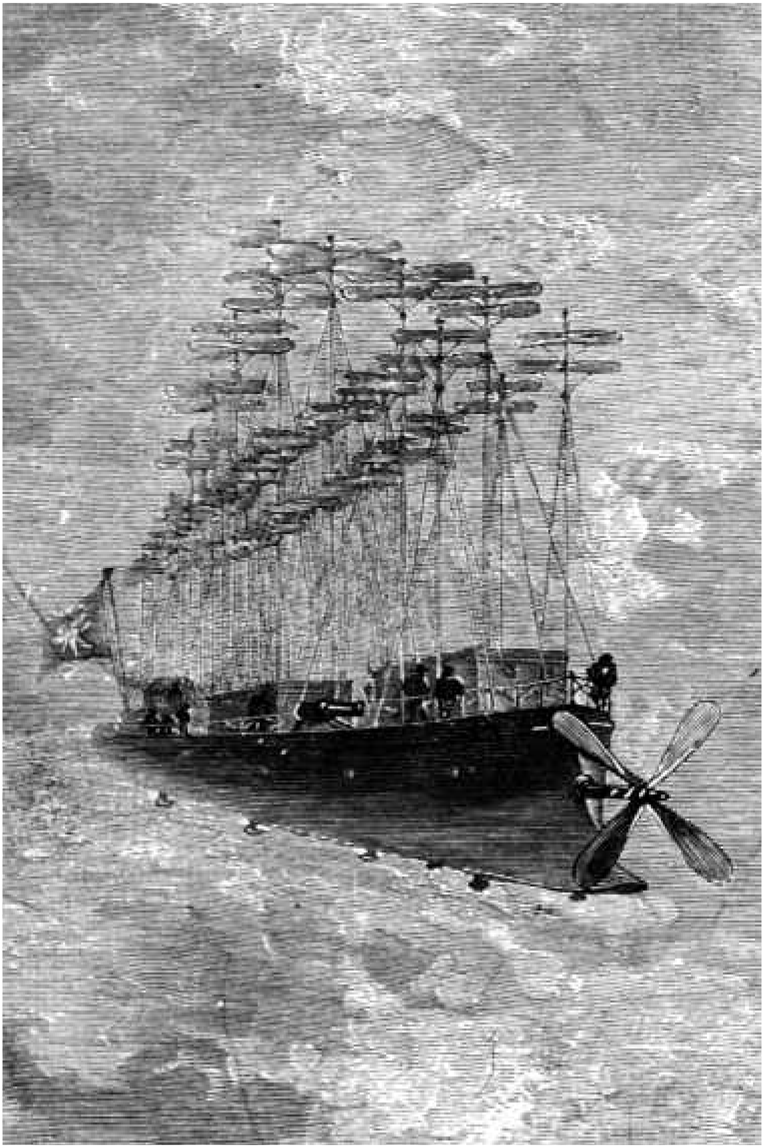
He envisaged a huge monoplane, the large rectangular wings of which, spanning some 45 m (150 ft), were not flat surfaces but instead were curved on the tops and undersides, and formed by wooden ribs attached to spars – hollow cylinders that gradually tapered to the ends – and then covered with fabric. Braced with wires, internally and externally, these wings carried two contra-rotating six-bladed propellers, driven by a compact steam engine capable of delivering 25 to 30 horsepower. The machine would weigh 3,000 pounds and for every half pound of weight would have one square foot of surface – a wing surface of 4,500 square feet, a horizontal tail surface of 1,500 square feet. Henson's flight control system worked by means of a web-shaped slab tail-plane and a pilot-controlled vertical rudder. The landing gear was fixed in a tricycle arrangement beneath the cabin, which was slung directly under the wing.

In order to get this machine off the ground, however, funding was required; and the first stage was the creation of a limited company. Henson, along with John Stringfellow, an engineer specializing in weaving machines, Frederick Marriott, then resident at Chard, who would become a well-known journalist in California and would build his own dirigible, the Avitor, and a lawyer, D. E. Colombine, formed a partnership to secure the patent and to construct the machine. The involvement of J. A. Roebuck, then MP for Bath and who sponsored the company's necessary incorporation under an Act of Parliament, served to attract some attention in the press. But Colombine, although responsible for the legal work connected with the patent, was also an experienced publicist, and he commissioned and circulated many illustrations of the proposed machine – now coming to resemble a flying wheelbarrow – in flight over London, the Channel, the coast of France, the Pyramids and China. A pamphlet appeared, entitled *The Full Particulars of the Aeriel Steam Carriage which is intended to convey Passengers, Troops and Government Despatches to China and India, in a Few Days*, containing most of the information that served as the basis for contemporary newspaper articles and proclaiming that the machine, 'the result of years of labour and study, presents a wonderful instance of the adaptation of laws long since proved to the scientific world combined with established principles so judiciously and carefully arranged, as to produce a discovery perfect in all its parts and alike in harmony with the laws of Nature and of science'. Not surprisingly, faced with such vaunting claims, the press became hostile and, despite the construction of several models that Henson vainly attempted to make fly, the project foundered shortly afterwards and he emigrated to New Jersey.[30]

Yet the main features of his design were to be found incorporated, in one way or another, in the majority of aircraft during the early years of successful flight. However bizarrely, Henson assimilated nearly all the available knowledge of his time and applied it most ingeniously in the design of the 'first aeroplane project'. Of course, his approach was not by way of practical full-scale experiments with gliding machines or wind-tunnels – the method by which the Wrights ultimately achieved their flight. Had funds emerged, Henson would apparently have been content to construct a machine from the drawing board, and then provide it with the propulsive power that was known to be essential. Fifty years on, another procedure applied: it was of little use to apply power until an airframe had been built that could be piloted in the air. The irony is that a flying machine that never left the drawing board was more influential, in terms of the 'look' and 'form' of later aircraft, than the Wrights' successful design. Indeed, as competitors to the brothers struggled to get their machines airborne, alternatives were being taken seriously whose provenance was far more fictional than Henson's grand project.

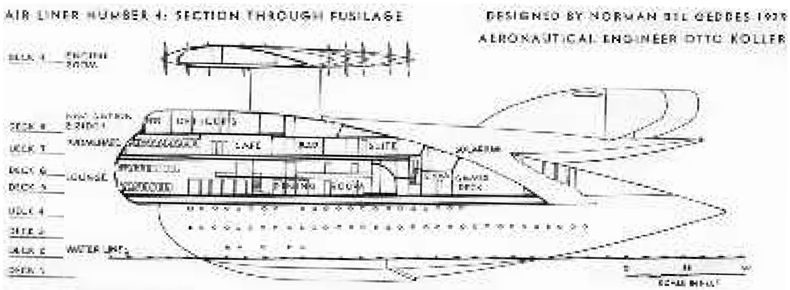
'The future is for the flying machine', proclaimed Santos-Dumont, who in 1906 had become the first man in Europe to fly in a powered aircraft. He was alluding to the pronouncement made by the great inventor hero of Jules Verne's novel *Robur Le Conquérant* (1886), a work which, the Brazilian aviator often claimed, had first caused him to devote his life to aeronautics.[31] Early in the book Verne provides a brief history of nineteenth-century flying machines, consisting of 'some with wings or screws, others with inclined planes, imagined, created, constructed, perfected', but each 'ready to do their work, once there came to be applied to thereby some inventor a motor of adequate power and excessive lightness'. Included in the list, of course, is 'the Englishman Henson, with his system of inclined planes and screws worked by steam'; without his and all the other attempts and experiments of his predecessors, it is clear that Robur could not have conceived 'so perfect an apparatus' as the *Albatross*, an *aeronef* or heavier than air machine. As the novel begins this has made a series of mysterious appearances, leading to reports of aerial trumpets in the heavens and flashes of light in the night sky over Europe and America.[32]

The *Albatross* is constructed on a platform a hundred feet long and twelve feet wide; a ship's deck in fact, with a projecting prow, so that at first glance it might indeed have been called 'a clipper with thirty-seven masts': hence, the English translation as *The Clipper of the Clouds*. Distributed along its deck are thirty-seven vertical shafts (fifteen along each side, and seven, more elevated, in the centre), each bearing two propellers, not very large in diameter, but rotating at tremendous speed. In front and behind are



An engraving of the 'Albatross' from the 1895 edition of Jules Verne's *Robur le Conquerant* (1886).

another two propellers, each with four blades, and of much larger diameter than the verticals; all of the shafts were powered by the still mysterious force of electricity. As young men, Geoffrey de Havilland and his brother were also inspired by this visionary design: ‘in our enthusiasm we made numerous drawings and got as far as writing to the makers of electric fans to ask about the thrust and horsepower required’.[33] Perhaps most extraordinary of all was the state of the technology used to create the framework and hull of the *Albatross*, since it seems that ‘unsized paper, with the sheets impregnated with dextrin and starch and squeezed in hydraulic presses, will form a material as hard as steel’, but one which, at the same time, is light and incombustible, qualities ‘not to be despised in an apparatus flying at great heights’. Of course, this design for a paper flying machine exists in the farthest realms of possibility; that is, only on paper. Verne was aware of this since, although he had checked the viability of the design with his engineer friend Badoureau, he told his publisher, ‘between you and me, I advise you never to get in a machine like this one’.[34] Indeed, the chapter that sets out the technical aspects of the *Albatross* is subtitled ‘One that engineers, designers and other scientists would do well to skip’. And yet, rather than ignoring it, fliers and designers drew on, or at least coincided with some its inspiring technological suggestions. Boeing, for instance, developing the 747 in the late 1960s, and needing to shed as much weight as possible from the original design, turned to Nomex, a highly flameproof chemically impregnated paper (once again developed by Dupont, the company involved in the Gossamer aircraft), which until then had been used only for internal structures. As in Robur’s *Albatross*, the material was used externally; all the fairings, where the massive wing joins the fuselage, were formed from specially treated paper.



It seems that any design, however unlikely, was worthy of consideration and investigation; before Boeing's engineers began to work on 'the big plane exercise'– the project that would lead to the 747 – their required reading was *Horizons* (1932), Norman Bel Geddes's collection of futuristic transport designs. In it he claimed that, for a number of years, he had been working on plans for a big plane: 'not "big" for the sake of being big', neither 'mad or foolish', but 'sound in every particular', the very idea of the intercontinental airliner of 1940.[35] With the assistance of the German aeronautical engineer Otto Koller, designer of the Pfalz aircraft, so effective in the circuses flying over the trenches fifteen years earlier, he proposed Air Liner Number 4, a tailless, V-winged flying-boat, capable of carrying a total of 606 persons (451 passengers and a crew of 155). It would have had a total wingspan of 528 ft, and on the water would have been supported by two massive pontoons 104 ft apart, 235 ft long and 60 ft high, designed 'substantially as the hull of a yacht, in order to withstand tremendous pounding when the plane rests on a rough sea.' As a means of visual comparison, Bel Geddes suggested that

> if it were possible to stand her upon one wing tip against the Washington Monument, she would lack only 23 feet of reaching the top.

Cross-section of Air Liner Number 4, designed by Norman Bel Geddes and first published in *Horizons* (1932).

> Or imagine that the Public Library was removed from its site in Bryant Park at Forty-second Street and Fifth Avenue, New York. The plane could then settle comfortably in the park with a clearance of about 35 feet all around.

To haul the machine into the air, twenty 1,900 hp motors were to be mounted on an ‘auxiliary wing located above the main wing, 180 ft in length by 54 ft in width’. Six extra would be carried as spares, mounted on wheeled carriages: ‘by this arrangement it is possible to replace any disabled motor within five minutes. The disabled motor is run over to the machine shop where it can be immediately repaired.’

The plane would have cruised at the stately speed of 100 mph, at a height of only 5,000 feet but with a range of 7,500 miles. The accommodation, spread over nine decks, included 180 apartments, three kitchens, a restaurant for more than 200 people, three private dining-rooms capable of feeding 40 people apiece, an orchestra platform, a dance floor, six shuffleboard courts, a gym, separate solaria for men and women, a library, a writing room and a promenade deck. The crew would have included two telephone operators, 24 waiters, seven musicians, two masseuses, a manicurist and a gymnast. Perhaps realizing the questionable airworthiness of certain aspects of his design – not least its gross take-off weight of 570 tons – Bel Geddes states: ‘As a premise, one must accept the fact that the air liner I am going to describe will fly, and fly just as readily as any other plane. In fact, I have every reason to believe that it will fly much more smoothly than any plane that has yet been built’. However, to bolster further this wishful thinking, he points out that in the past Koller has developed ‘very favourable airfoils for wings and pontoons; streamlines for fuselage; and without exception, all of his planes have flown successfully’.

Despite the precise formulae that Bel Geddes provided in support of his proposed aircraft, there seems to be no absolute form for such designs. Le Corbusier observes, for instance, that 'it would seem "rationally" that the airplane should have a single and unique form. Not at all. There is a differentiation of "harmonies" arising from an individuality which is not to be gainsaid (creation) and resulting in diversified organizations of shape and structure.'[36] Underneath, he prints a photograph of an experimental aircraft designed by the Italian engineer Luigi Stipa, which in appearance resembled a winged dustbin. Perhaps such formal criticism is irrelevant when the only objective is that a given machine should fly freely. Yet the desire to identify style and grace in flying objects is difficult to deny. In the opening moments of *The First of the Few* (1942), Leslie Howard's stirring film account of the life of the Spitfire designer, R. J. Mitchell, it is suggested he was driven only by a desire to create an aircraft that bore no resemblance to the ungainly machines that had been lumbering into the sky

An experimental monoplane with tubular 'venturi' fuselage, conceived by the Italian engineer Luigi Stipa in 1931.

throughout the 1920s; simply, to create an aircraft that could be regarded a piece of functional sculpture. Certainly, its conception is appreciated by 'Rembrandt', one of the real-life RAF pilots featured in the film who, in a lull during the Battle of Britain, admits that he can't 'see a Spit in the air without getting a kick out of it'. As an art student, he is able to appreciate the distinctive line of its wing, and the fact that, although a warplane, it is also an 'artistic job'. Others have suggested that the aircraft's parabolic wing profile is 'as elegant as a Brancusi'; the perfect compromise of its 'small clean fuselage / slim curved wings' making this plane 'British Bauhaus'.[37] Yet the famous wing of the Spitfire, tapered from broad to narrow to distribute stress, was also designed to be just short enough to allow the plane to make tight turns and pull out of steep dives. It was certainly beautiful, but its shape was determined, ultimately, by Mitchell's grasp of aerodynamics, rather than aesthetics.

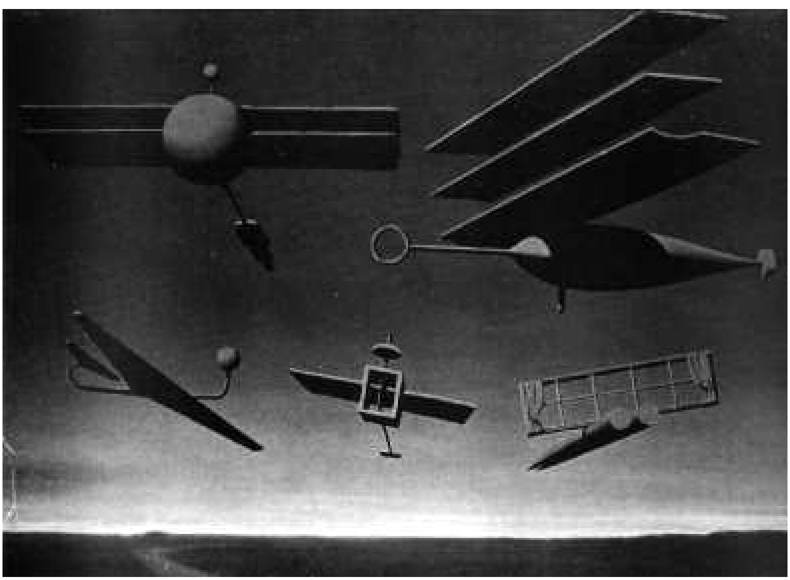
The converse, of course, is that sometimes technological determinants can render design bizarre rather than beautiful, as in the case of the Blohm und Voss BV 141. In 1937, the year after the Spitfire's first flight, the German Air Ministry (RLM) invited detailed tenders for a new kind of aircraft that would reflect the experiences of the Condor Legion in Spain. These had confirmed the role the Luftwaffe would play in the new strategy of Blitzkrieg: the belief that tank brigades followed closely by motorized troops could make sweeping advances against a conventionally disposed opponent only if that enemy were first pulverized by strategic bombing. The specification, therefore, was a specialist single-engined reconnaissance aircraft with optimum visibility for its crew of three, and which would have a secondary role in supporting army ground units by dropping smoke screens and directing artillery fire.

The Supermarine Spitfire first flew in 1937, and quickly established itself as a masterpiece of aeronautical design.

One of the most serious contenders, the BV 141, was designed by Richard Vogt for Blohm and Voss, a Hamburg-based aircraft company that had been in existence for only five years, a subsidiary of the long-established shipbuilding firm of the same name. Newly appointed, Vogt recognized the challenge and resolved to be daring. In the earliest stages of his research for the commission, it had become clear that conventionally symmetrical airframes might adversely affect the reconnaissance tasks for which the aircraft was intended. His subsequent conjecture was that an asymmetrical craft might perform the role as well as, if not better than, more conservative designs and ensure maximum visibility, both forward (for ground attack) and down (for reconaissance). Hence the aircraft's design was finalized: Vogt placed the crew in a split-level, streamlined pod, shaped like the thorax of a hornet, which projected a

The Blohm and Voss BV141, an asymmetrical prototype designed in 1937.

short distance fore and aft of the wing, but well to the right of the centre line. Just to the left of this glazed cabin, parallel with it, was a long tapering, cylindrical fuselage on which was mounted a radial engine at its front, blending into a conventional tail at the back. At first the Air Ministry officials were sceptical and wary of such an audacious design, but Ernst Udet, the newly appointed head of the Technical Bureau, encouraged Vogt to build a prototype, obliging the Ministry to take a closer look. Once they had flown in it, though, pilots and officials alike were won over by the responsive and forgiving handling of the strange aircraft; Vogt's design theory was vindicated in practice, because having the weight and drag of the cockpit adjacent to the fuselage perfectly countered the torque generated by the single propeller. By January 1940 the Air Ministry was making grandiose production plans. However, the Luftwaffe, its clients, clearly thought the machine



René Magritte, *Le Drapeau Noir* (1937).

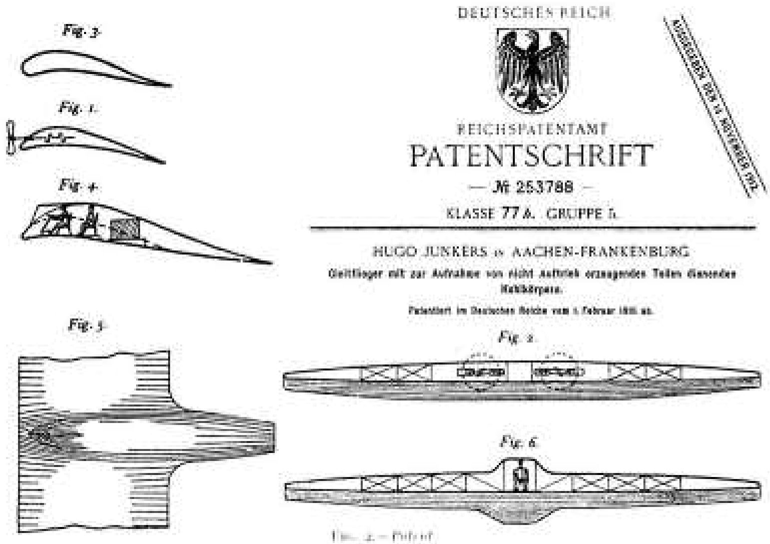
too unorthodox in appearance to be taken seriously for a combat role, and it blocked plans for production.[38]

Roughly contemporaneously with the first flights of the Spitfire and the BV 141, René Magritte completed *Le Drapeau Noir* (1937), an oil painting depicting a night sky, cast in grim gunmetallic tones and filled with objects moving in several directions. Later, after the Second World War, Magritte wrote to André Breton and claimed that the painting 'gave a foretaste of the terror of flying machines, and I'm not proud of it'.[39] Perhaps, in retrospect, his decision to figure the aircraft through a variety of domestic objects – coat hangers, hooks, bobbins, candles, shelves and curtained window frames – gives rise to a certain diffuseness, a promiscuity of vision. The title might seem to imply an act of piracy, the raising of a black flag; or even the announcement of the execution of a death sentence. One of the best accounts of the painting suggests that 'it contains the notion of a visitation from another planet worthy of Mack Sennett, but it also brings to mind the eerie hysterical swooping of bats, and the aerial battles of demons in Bosch's *Temptations*'.[40] Yet as well as entertaining such arcane possibilities, the canvas raises a curious technical question: what precisely is it that makes these formal combinations of shapes and objects instantly recognizable as flying machines? Perhaps Magritte was implying the paranoia of a continent whose people, preparing for the inevitable war, saw heavily armed aircraft massing everywhere they looked, and especially when standing anxiously at the windows of their homes. Or is it that the basic shape of aircraft, developed by trial and error over the previous four decades or so, was now so fixed in the public imagination as to be clichéd. It is curious that while the flying objects flagged here are so predictable in their aerial symmetry and connote recognizable machines – monoplanes, biplanes, 'triple-deckers' – the BV 141, although constructed and successfully flown, was unthinkable. In its technologically advanced asymmetry, it looked unnatural; an object that could never fly like a bird, even in one's wildest imaginings.

Framing the Future

In 1923 Hugo Junkers, a German academic turned industrialist who had made his fortune from the invention of a domestic water-heater, was invited to address the Royal Aeronautical Society in London. The most influential aircraft designer of the age, this 63-year-old former Professor of Thermodynamics and Mechanical Engineering at Aachen University – he resigned his post in 1912 – claimed to see in his invitation 'an effort at renewing the ties of a genuine humanity which desires to extinguish the sad traces of devastating war by hoisting the flag of peaceful competition'. The reaction of some distinguished members to his talk, however, was not as constructive as Junkers might have hoped. Frederick Handley-Page, whose firm produced the 0/100, the first British bomber to fly over German positions on the Western Front, took to the floor after the lecture to describe how he had once witnessed the crash landing of a Junkers. The force of the impact caused its fuselage to shear just behind the K painted on its side, so that all he could decipher was the word JUNK – a word which, Handley-Page claimed, encapsulated the Professor's achievements in aeronautical engineering.[41]

Junkers's researches began shortly after the Wrights' European tours of 1908 and 1909 had aroused in this middle-aged man an obsessive interest in the structures of flying machines, to the extent that he added an aviation research centre to his bath water-heater factory at Dessau. Applying the metallurgical expertise he had gained making boilers, and making use of the accidental discovery in 1909 by the German company Durener Metallwerke



of duralumin, an aluminium alloy containing a little copper and magnesium, Junkers devised a means of constructing aircraft out of such new compounds. Furthermore, in 1910, he patented a design for a flying wing, the Nurflügel; although the extraordinary, modern-looking machine went unbuilt, this patent is the first recorded design of a thick, self-supporting wing. Its basic structural principles led, five years later, to the J.1, a small monoplane powered by a 120 hp Mercedes engine and intended as a scout. This was not simply the first all-metal aircraft, but also featured the first practical cantilevered wing, attached to the fuselage without any of the external bracing wires and struts that typified its competitors, designs against which Leslie Howard's characterization of Mitchell would rail. Its top speed of 170 km/h (105 mph) was agonizingly slow compared with the nervy fabric-covered biplanes of the day, and so it found favour with neither

Hugo Junkers's patent for a flying wing, 1910.

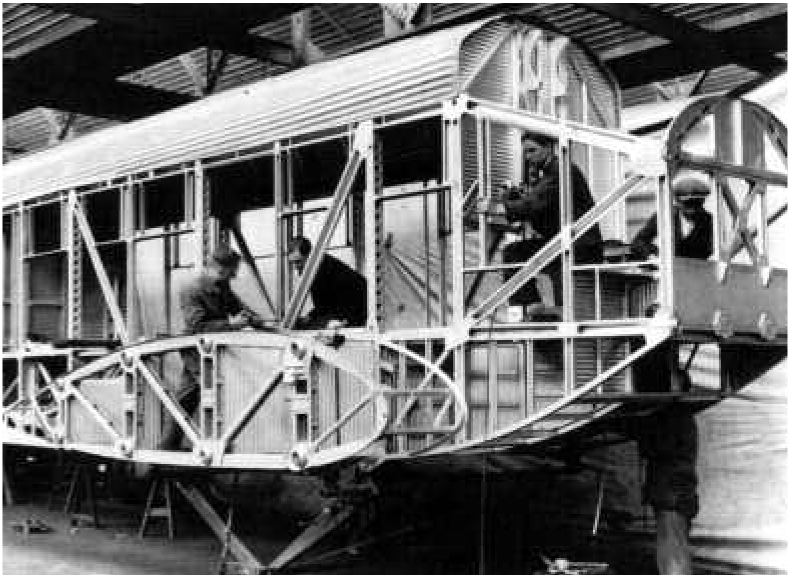
pilots nor the German air force, who refused to commission it. Nor did British designers have a better opinion: a machine captured on the Western Front in 1918 was exhibited at to the Agricultural Hall in Islington, London, to the general amusement of the British aeronautical fraternity.

Junkers, however, persevered with his radical designs, now benefiting from the development of more powerful engines, and in 1917 the German Air Service bought his J.4, a two-seat biplane built largely of duralumin, ribbed for added strength, the corrugations running from nose to tail to minimize drag. Though the machine was unwieldy, German airmen liked it for the protection it afforded them. Since it was intended to be a ‘trench strafer’, and so subjected to heavy small-arms fire, sheet-steel enclosed the cockpits, engine and fuel tank. Before the end of the war Junkers’s firm, in collaboration with Fokker, had built nearly 400 military

The four-engine Junkers G38 was the biggest landplane of its time. It had a twin fuselage and seats in the wings giving a unique forward view; a veritable Nurflügel.

aircraft, including two more significant warplanes, the J.9 and J.10, both all-metal cantilevered monoplanes with wings that were attached unconventionally to the underside of the fuselage, and which in the event of a crash landing would hit the ground first, so absorbing some of the impact. After the Armistice, Junkers devoted himself solely to passenger aircraft. A new company, the Junkers-Flugzeugwerke, was established in June 1919 and its first new design, the F.19, a monoplane with an enclosed cabin, and seat-belts for its four passengers, set the standard for post-war air transport. By 1925 Junkers machines had carried about 100,000 people over a total distance of three million miles.[42]

Elsewhere, flight engineering was following an alternative course and an aircraft construction was, in the main, a question of 'a delicate assembly of timber, piano wire, and doped fabric'.[43] Sir Geoffrey de Havilland's first aircraft was typical of the time, but also of the aircraft he would continue to make in the years following the Great War. Airframes were formed out of many components joined together by glueing, pinning or bolting to form a strong but light structure, which was then braced with numerous tensioned wires and the aerodynamic surfaces covered with good fabric such as varnished silk or rubberized, waterproof linen fabric. In 1923 one of de Havilland's machines, the DH.50, was entered for a civil airliner competition at Göteborg, Sweden. Its main rival, flown by Hermann Goering, was the Junkers J.10 monoplane, solidly metal. De Havilland later described his own machine as 'a successful effort to produce a four-seater cabin aircraft at really low cost and upkeep'; in reality it was cheap, flimsy and unpredictable in its handling. Yet the DH.50 won the competition with 999 marks out of a possible 1,000, the company representative identifying his machine's superiority in the fact that there was 'no thin, perishable material whatever in it. Robust wood members and good metal



fishplates throughout. Proved in all climates, and any carpenter can repair it.'[44] Such rough and ready construction would disappear within the decade, to be replaced by an all-metal 'stressed skin' or monocoque structure, in which the metal wrapped around the airframe bears the major part of the structural loads.

Yet the British aircraft industry continued to develop technologies beyond the mainstream. Take the de Havilland Mosquito, developed in the late 1930s as a high-speed unarmed bomber swift enough to avoid interception by even the fast enemy fighter. For various reasons – not least a shortage of metal – it was built of wood by skilled cabinet-makers mobilized from Britain's furniture industry. Its wings were constructed with inner and outer skins of plywood bonded by strong glue to spanwise spruce lengths; the fuselage was made of plywood sandwich with a core of balsa wood, the material often used by aeromodellers. Light alloy and

Junkers Ju-52 under construction, showing the tubular steel airframe which would provide the aircraft with much of its strength.

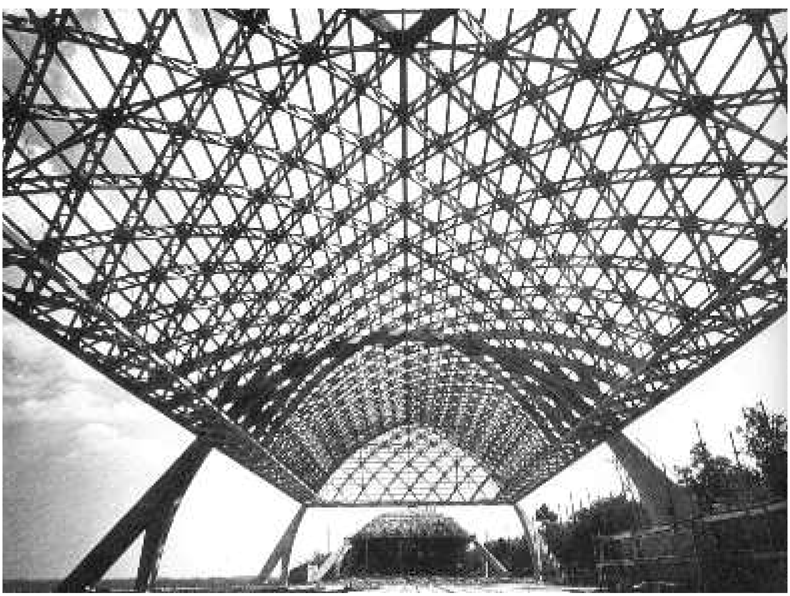
steel fittings were used as joints at the main stress areas and the airframe was covered by fabric. The aircraft, popularly known as ‘The Wooden Wonder’, was extraordinarily resilient: flak shrapnel and bullets that would have shattered a metal structure merely holed the timber frame, leaving the machine airworthy. Its losses – only one per 2,000 sorties – were among the lowest in the RAF during the war. A serving pilot wrote a paean to the plane and its makers:

> The Mosquito represents all that is finest in aeronautical design. It is an aeroplane that could only have been conceived in this country, and combines the British genius for building a practical and straightforward

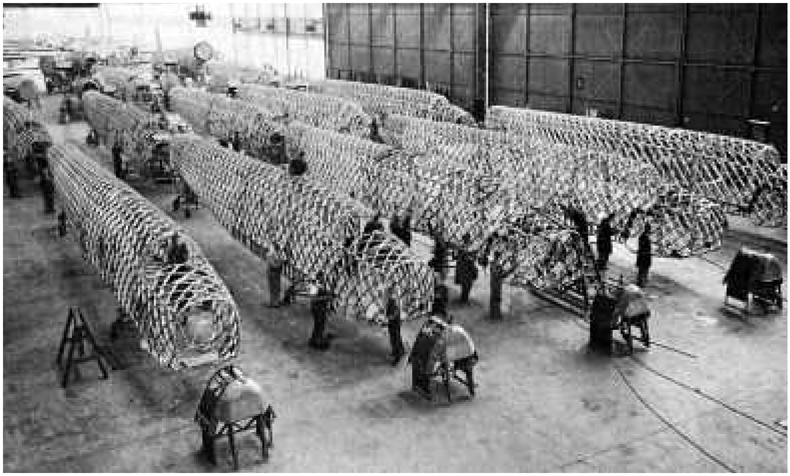
De Havilland Mosquito light bomber, which would enjoy the lowest loss rate of any RAF Bomber Command aircraft during the Second World War.

> machine with the typical de Havilland flair for producing a first-rate aeroplane that looks right and is right.[45]

The other distinctive construction technique used in the design of certain British bombers was the geodetic form of lattice-work, developed by Barnes Wallis out of his awareness of new developments in airships and hangar building. A 'geodesic' is the shortest line that can be drawn between two points on a curved surface; hence, the massive arched hangars Pier Luigi Nervi constructed for Mussolini's air force in the 1930s depended on a geodetic metal lattice for their strength and durability. Wallis, seeing that an aircraft could be made with equally regular surface curvature all over, developed a metal basketwork in which the entire airframe was assembled from quite small geodetic members pinned together

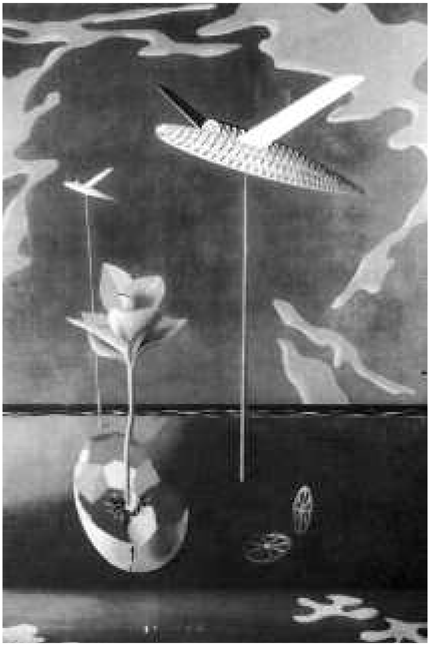


Piero Luigi Nervi, Aircraft Hangar, 1940, Orbetello, Italy.



at the joints. The first two types of such a design were the Wellesley and Wellington bombers, the latter in particular having such structural integrity that it gained a reputation for bringing crews back from situations that, in conventionally constructed machines, would have seen them dead. Its distinctiveness even emerged into contemporary painting. *Analysis of Easter*, a canvas painted in 1940 by John Armstrong (an associate of Paul Nash, and the costume designer for Sir Alexander Korda's 1936 film, *Things to Come*), seems to imply the resurrective capabilities of such aircraft. Suspended over a pestilent void on thin sticks, and towering above a flower recently sprouted from a broken Easter egg-shell, two flying objects aspire towards gassy clouds. Their wings are tilted up at a curious angle and seem about to commence a synchronized downstroke; but before the image becomes too irrational, the familiar shape to which they are attached comes into focus – the latticed fuselage of the Wellington, which by early 1940 was the mainstay of Bomber Command, and which had given hope to the crews prepared to sacrifice all for the

Vickers's Wellington production line in 1940, showing the geodesic construction of the aircraft's fuselage.



defence of King and Country. In 1980 Prince Charles cited Wallis's geodetic construction as an example of a British technology that had received insufficient recognition abroad.[46] However, though strong, the difficulty of its manufacture, and the fact that it could only ever be covered by fabric, meant that it was of limited value in the new world of aircraft design that emerged from the ruins of Nazi Germany.

'Operation Paperclip', the Allied undertaking to absorb Germany's scientific expertise, took effect the moment the European war was over. As soon as the surrender was signed, teams of British and American experts swooped into Germany, and, picking through the remains of the Reich's war machine, were astonished by what they discovered. De Havilland's design chief, Ronald Bishop

John Armstrong, *Analysis of Easter* (1940).

(responsible for the Mosquito), visited the Messerschmitt plant at Oberammergau, Bavaria, and was stunned at the sophisticated nature of the prototypes he saw: the Me 262, a twin-jet fighter-bomber and by general agreement the finest airframe of the war; the Me 264, a large four-engined, long-range jet bomber, intended to attack America; and Projekt 1007, which Messerschmitt claimed could carry a large load at 885 km/h (550 mph) for almost 7,250 km (4,500 miles), and which would heavily influence Bishop's next design, the ill-fated passenger jet, the Comet. The British engine designer Roy Fedden gloomily reported that 'Germany possessed aeronautical research and test equipment in advance of anything existing in this country or America at the present time'; and representatives of US firms, such as Boeing, were equally amazed at the advanced airframe technology.[47]

George Schairer, the Seattle company's chief aerodynamicist, then working on a jet bomber for the USAF, was assigned to the aeronautical research institute at Braunschweig, where he came across drawings of swept-wing aircraft and wind tunnel data relating to them. He questioned Adolf Büsemann, one of the institute's aerodynamicists, who quickly responded: 'Don't you remember? Rome? Volta Scientific Conference in 1935? You remember my paper on supersonic aerodynamics? . . . No one paid any attention.'[48] In October 1935, Büsemann, a young engineer, had presented a paper on the 'arrow wing', a futuristic concept which argued that if the wings of a plane could be swept back, they might fall within the shockwave cone streaming from the nose of the craft, and so would thus have less drag than straight wings. Although this theory would, within a decade, provide the means by which aircraft could be built to fly faster than sound, Büsemann's calculations attracted little interest at the conference; indeed one of the organizers, General Arturo Crocco, facetiously sketched 'Busemann's aircraft' on the

back of a menu; it had sweptback wings, a sweptback tail and a sweptback propeller to match. But in another part of the future Axis, Germany, Büsemann's theory of airframes would be taken much more seriously. There the Luftwaffe was experimenting eagerly with a number of provocative aircraft designs and his work eventually caught the attention of Woldemar Voigt, the senior designer at Messerschmitt. In 1942 Voigt decided to try out Büsemann's idea in an experimental jet referred to as 'Projekt 1101', the wings of which were to be angled back sharply, in marked contrast to the barely swept wings on the Me 262 he was then developing. Work on Projekt 1101 continued sporadically, with Voigt unable to give it his full attention owing to his involvement with the 262. However, wind-tunnel tests on models of the swept-wing jet were so promising that in 1944 Voigt had commenced development of a research

X-5 experimental 'variable geometry' aircraft.

plane with variable wings that could be repositioned in flight; it was this machine that was captured by the Allies in 1945, and which led to the development of the Bell X-5 experimental aircraft.

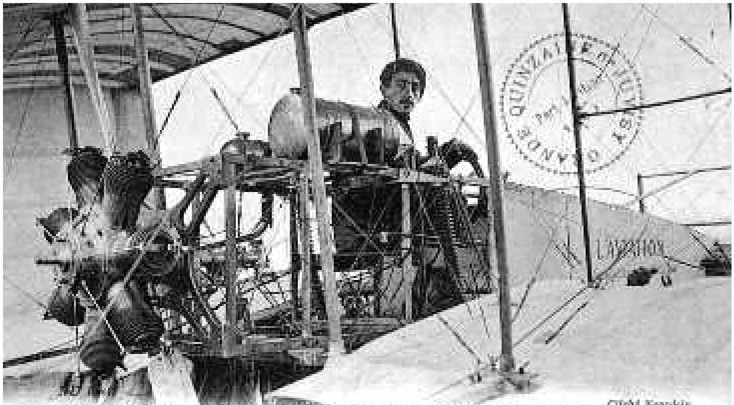
Having absorbed much of this advanced research, George Schairer returned from Germany in August 1945 and set out to redesign Boeing's jet bomber as a swept-wing design. By November a radical design had emerged for a machine that would be known, eventually, as the B-47 Stratojet; a silver machine with long razor-thin wings, sweeping back from each side of the fuselage at an angle so sharp that, seen from above or below, it did, indeed, give the profile of an arrowhead; wings under which were slung, in four bullet-shaped pods, six turbojet engines to propel this bomber at 600 mph through the thin air at higher altitude to deliver its atomic weapon at the heart of the enemy. The B-47 would exert as great an influence on future developments in military aviation as any machine since Blériot's monoplane; but its sleek form and sophisticated airframe would also lead directly to an aircraft that would alter the world of air transport even more radically.

In mid-May 1954 a large aircraft painted in a sickly livery of yellow and brown was rolled out of a hangar at the Boeing plant in Seattle. The Dash 80 prototype, a swept-wing jet-powered military

The Boeing B-47 Stratojet bomber, the mainstay of the US nuclear strike force by the early 1950s.

transport, and in-flight refueller, was intended to complement the B-47 bomber, the aircraft on which its airframe was largely based. When she launched it, by swinging a champagne bottle at a cage that fractured the glass but stopped it short of the aircraft's delicate aluminium skin, Bertha Boeing, the wife of the founder of the company, exclaimed 'I christen thee airplane of tomorrow.'[49] Within a few months the USAF had ordered a substantial number of the tankers, but the airlines were less than interested in the Dash 80, which they felt was too obviously a by-product of military procurement. The project languished until, pushed by the Pan-Am chairman, Juan Trippe, Boeing's management sanctioned the construction of a revised model, the 707, slightly larger and with more powerful engines that would allow it to fly non-stop across the Atlantic, delivering 120 passengers at a time into the jet age, at the speed of a nuclear bomber.

A Boeing 707-320, in service with Lufthansa in the early 1960s.



Cliché Neurdein

GRANDE SEMAINE D'AVIATION DE LA CHAMPAGNE (Août 1909).

PAULHAN sur Biplan cellulaire Voisin, Moteur rotatif Gnome, classé : 3e dans le Grand Prix de Champagne,
178 par 133 kil. 676 ; 3e dans le Prix d'Altitude, par 90 mètres ; 8e dans le Prix de Vitesse, en 32' 49" 4/5.

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1 It is reported that Chavez's last words, 'whose meaning cannot be interpreted, were: *Non, non, je ne meurs pas … meurs pas*.' See John Berger, *G* (London, 1972), p. 209.

2 'Quando volai per la prima volta coll'aviatore Bielovucic, io sentii il petto aprirsi come un gran buco ove tutto l'azzurro del cielo deliziosamente s'ingolfava liscio fresco e torrenziale. Alla sensualità lenta stemperata, delle passeggiate nel sole e nei fiori, dovete preferire il massaggio feroce e colorante del vento impazzito.' F. T. Marinetti, *Teoria e invenzione futurista*, ed. Luciano De Maria (Milan, 1968), p. 116.

3 'Ecco che cosa mi disse l'elica turbinante, mentre filavo a duecento metri sopra i possenti fumaiuoli di Milano. E l'elica soggiunse . . . ' Marinetti, *Teoria e invenzione futurista*, p. 41.

4 'N'est-ce pas une âme en effet cet infiniment petit par rapport à l'ensemble de l'avion, par son imponderabilité même quand elle tourne à des folles vitesses, par sa fonction quand elle passe invisible dans l'éther azuré? Âme par sa contexture même, car elle exhale souvent sa vie dans un heurt délicat, maintes fois elle expire dans une caresse.' Lucien Chauvière, 'La Construction de l'hélice', in his *L'aéronautique pendant la Guerre Mondiale* (Paris, 1919), p. 198.

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6 'J'ai pu enfin attacher le bourdonnement à sa cause, à ce petit insecte qui trépidait là-haut, sans doute à bien deux milles mètres de hauteur; je le voyais bruire.' Marcel Proust, *À la recherche du temps perdu*, ed. Jean-Yves Tadié (Paris, 1999) p. 1908.

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