REVIEW of
HUMAN POWERED FLIGHT
to 1990

Chris Roper

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The creation of this review came about as a result of David Gordon Wilson of the International Human Powered Vehicle Association contacting the Royal Aeronautical Society to see if any of the RAeS members were interested in writing about the airborne side of the human-powered-vehicle story.

The intention was, and still is, that this piece will form part of a book, with other sections on the bikes and the boats and the submarines.

Although both these organisations caused me to start on this work, it is, in its present form, my own.

It is an overview of as many aircraft as I have been able to trace, and, with its glossary, its list of records and its list of references, hopefully of interest to anyone regardless of their present knowledge of the subject, their technical background or their likely involvement in the pursuit.

It is not a design or construction manual, but lessons can be learned from the planes reviewed.

In particular I have tried to pass on some of the lessons learnt from my own experience in the design and construction of my aeroplane where I encountered problems other than the technical ones.

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INTRODUCTION

This is the story of human powered flight during the time when the length of flights has increased from a lesser distance than could be jumped to a further distance than can be swum.

As far as we know, no member of our species has been endowed with wings or been lighter than air. Hence, flight has only been possible with the assistance of some sort of artificially constructed device.

The construction of every successful device, as the following account shows, has necessitated a great depth of involvement in the technicalities, the nuts and the bolts (or the wax and the feathers). For this reason, much of what follows is concerned with such technicalities. But it should not be forgotten that the most important formula is HPF > HPA Human-powered-flight is more than just a human-powered-aircraft. Flight is the object: the machinery is just one of the things which enable this to happen. Not only has a high professional level of engineering always been required to build a plane which will achieve flight, but also other skills have been needed.

MINIMISING POWER REQUIRED

When most people think of “horsepower”, they naturally think it is better to produce more. This was particularly so in the 1950s, (the decade of “Big is beautiful”). But the major aim of every HPA designer was, and still is, to make flight as easy as possible for the pilot(s), i.e. to minimise the power required from them. Hence when we who are involved in HPF hear the word “horsepower”, we think in terms of requiring less. This aligns with ecological thinking of 1990, since it is now realised that our planet will remain habitable only if the total power produced becomes less. The designers and builders will hopefully make only a small amount of power necessary. Of course, when it comes to flying, performance will improve still further if the pilot pedals harder.

TOPICS & ERRORS

There have been many accounts of human powered flight, as partially listed in the bibliography. I have tried to focus on those topics which I feel have not been sufficiently covered in these other writings, but you are encouraged to study them to get a fuller picture of the technical detail and for reports on flight experience.

In preparation for this writing the references are to the earliest available data. Any error or omission should be notified to the publishers or the author. Throughout, I have tried to show what human powered flight has felt like “from the inside”, particularly during the early days in Britain, the days of the Beatles.

MANY ASPECTS

What has all too often been overlooked is how many aspects there are to human powered flight. This review won’t tell you all you need to know to conceive, design, build and fly an HPA, but hopefully it will convey a little about some of the things about HPF that you didn’t think you needed to ask about.

OPINIONS

The views expressed are solely those of the author, and not of any organisation of which he happens to be a member.

Review of Human Powered Flight to 1990

BLANCHARD'S BALLOON

Jean-Pierre Blanchard was one of the pioneers of the hot air balloon, (invented in 1783 by the Montgolfier brothers). His most significant contribution to human-powered aeronautics was his use of a propeller, manually rotated, mounted on a balloon. Using this he was able to exert some limited control in the speed and direction of flight.

DEGEN'S BALLOON 1808

Jakob Degen of Vienna appears to have obtained most if not all of his lift from a balloon beneath which he was suspended together with a pair of devices, one on each side of him. These had the appearance of umbrellas but their use was more like parachutes. Once airborne, he had some control of his altitude, by tugging down on a bar connected to the centre of each of these, the perimeter being fixed to a framework.

Degen, a ribbon-maker and later a clock-maker, is of interest if only because reports of his performances omitting the fact that a balloon was involved reached Sir George Cayley. Hence Cayley, the inventor of the aeroplane, was encouraged to continue his researches. Perhaps the first and only "use" of person powered flight for over 100 years!

THE PEUGEOT PRIZE

In 1912, Robert Peugeot of France offered a prize for the first flight of a distance of 10 metres (33 feet). There were many attempts at this, and Peugeot gave several consolation prizes, some of them for distances less than the long-jump record of the time which was 7.61 metres, (Peter O'Connor in Dublin 5 Aug 1901), but the prize was not won for nine years.

POULAIN/FARMAN

A machine was built by the Farman company and pedalled by Gabriel Poulain over the specified distance in both directions early on the morning of 9th July 1921 with Robert Peugeot watching, with a distance of 11.98 metres. That same month, the long-jump record was reset at 7.69 metres by Edwin Gourdin on 23rd July 1921 in Cambridge Massachusetts, a city later to be associated with rather longer distances!
(As the home of Chrysalis, Monarch, Light Eagle and Daedalus)
(Guinness Track & Field Athletics 1986, Guinness Superlatives)
The Poulain Farman machine was undoubtedly a human-powered-vehicle. It was a biplane with a span of 20 feet and a wing-area of 132 square feet, (i.e. larger than some wings built for the purpose of true human powered flight in the 1960s). There was a fairing around the person and bicycle. There was no propeller and there were apparently no aerodynamic controls. The total weight was 201 lbs.

The lifting force, (lift) produced by a wing is mainly a function of the area of the wing(s), the density of the air, the speed of the wing relative to the air and the shape of the wing section. The other factor is the viscosity of the air, (see Reynolds' number in Glossary).

The section shape and its angle relative to the motion determines the factor C_l or "lift coefficient" in the formula

$$L = C_l \times r/2 \times V^2 \times S$$

Where L = lift, r = air density, V = velocity and S = area.

C_l is a pure number (dimensionless), hence if one converts to a different system of units its value is unaltered.

In round terms, one might assume that Poulain's wings achieved a lift coefficient of 1. Assuming also the typical sea-level value of air-mass-density of 1/420 in the ft/lb/sec system, and knowing the wing area and the weight that was needed to be lifted, one may state:

$$210 = 1 \times 1/840 \times V^2 \times 132$$

Which gives V = 36 ft/sec or 25 mph

However, to have travelled 11.98 metres (39.3 feet), he would have needed to be moving faster than this when leaving the ground. A rough estimate of this extra necessary speed can be made by assuming a glide-ratio of 5/1, (typical for hang-gliders), that is he could have travelled 39.3 feet forward while losing 39.3/5 (= 7.9) feet in altitude whilst maintaining the same speed. The extra energy needed is the same as that needed to climb this height. The calculation is done most simply by converting the forward speed into its equivalent height using

Height = $1/2 \times g \times V^2 = 1/2 \times 32.2 \times 37^2 = 19.9$ ft

Hence total equivalent height is 19.9 + 7.9 = 27.8 ft
Which is equivalent to a speed of half g times the square root of 27.8 = 42 ft/sec (29 mph).

Hence, assuming a lift coefficient of unity this would imply a flying speed of 25 mph, and if we assume a glide-ratio of 5 then Poulain would have needed to achieve 29 mph just before take-off to provide the momentum to carry through the air over the distance.

Poulain was a racing cyclist and an experienced pilot

Is it a bike? is it a plane? No, it was a machine which had been optimised over nine years purely for the purpose of winning the Peugeot prize, and was demonstrably the appropriate vehicle for the purpose. Poulain and the Farman company succeeded with this simple layout against a competition of machines with flapping wings and propellers, some of them being tricycles or having other appendages adding to the weight and drag. There is no record of anyone else operating this machine, or of whether it was stable or whether Poulain personally had gradually to acquire the specific knack of controlling it.

Clearly, without some sort of drive when airborne, one will not get very much further than this, but note that all those of the early aircraft which intended unaided take-off, and some of the later ones, used drive to the ground-wheel as well as to the propeller.

LIPPISCH 1929

Dr Alexander Lippisch, a prolific designer of sailplanes and other aircraft, built an ornithopter (see Glossary) in 1929. This was always launched like a glider (Lippisch 1960).

The principle Lippisch used relied on the wings twisting during the flapping cycle.

In general, on an aircraft the centre of pressure of the lift will not remain on the axis of the spar during flight. This offset loading will tend to warp the wing. On almost every other aeroplane this is a problem which must be overcome, usually by making the wing structure stiff enough to resist this torsion. But on this aeroplane, Lippisch tried to make use of this effect; the extra, and different, forces on the wing during the downstroke would hopefully warp it more.

Hence, the effect of the wing flapping would propel the plane on the same principle as a fish's tail propels a fish.

However, for one reason or another it did not work. Perhaps the wing was too torsionally stiff - again the opposite of what is unfortunately more common.

Lippisch added flexible extensions behind the trailing edge and it was then found that flapping of the wings slightly prolonged the flights, but he could not understand the still disappointing results until he realised that the pilot, Hans Werner Krause, was not really pulling very hard, and didn't see the point of it. He then offered to pay Krause's rail fare to see his girl friend for the weekend, if he were to fly from the usual launch point over a specified puddle about 300 yards away. The course was covered on the first attempt.

MUSKELFLUG INSITUT

In 1935, the Institute of Muscle-Powered-Flight (Muskelflug-Institut) was set up within the Gesellschaft Polytechnic, Frankfurt. Oskar Ursinus, director saw as the prime question the determination of power available.

A prize was offered for the first flight in Germany over a 1 km course. The data from his tests on muscle-power were made available to designers in 1936. Unfortunately no further research could be carried out by the Institute because of the onset of war.

MUFLI

This was the only relatively successful contender for the prize offered by the Muskelflug-Institut. Helmut Haessler finalised his design in 1935. His estimate of the available power was too high.

Eventually, since the results of the tests from the Institut were not published he and a colleague Franz Villinger performed their own tests on human-power by having one cyclist tow another who read a spring balance on the handlebars attached to the tow-line.

"It was not realised until our own tests and those of the Muscle Flight Institute, which was founded later, had been done, that the earlier data gave more than double the actual power." (Villinger 1960)

None of these human-power data mention the weight of the person producing it.

Franz Villinger and Helmut Haessler were both experienced in aircraft through their employment at Junkers.

The neatness of the configuration and the similarity to a sailplane conceal some subtle points. The length of the drive is very short and the propeller-support-pylon and wing do not interfere as they do on some later machines. The frontal area is desirably low, although this meant that it was most awkward for the pilot to get into or out of the Mufli.

TOTAL ENERGY COST OF POWER TRANSMISSION SYSTEM

Haesller argues that the effective total drive efficiency is high (Haesller 1961).
To calculate the total energy "cost", he summates four items.

Namely, the weight of the drive mechanism, the weight of its supporting structure, power losses in the drive, and power losses in the propeller.

According to his argument, if one assumes that the pylon would have been there anyway to act as king-post (Glossary), which it might have been, and that the drive mechanism was very efficient, which it probably was not, then this analysis shows the Mufli system to be a good design compared with others.

Such an analysis does not really go far enough however, as he does not consider the aerodynamic effects, i.e. the drag of the pylon (see SUMPAC and Jupiter). On some designs, e.g. Puffin, Linnet, the drive-train greatly constrains the fuselage design, hence the relative advantage of the Mufli layout could be even more than Haessler claims.

In 1977, Professor Hidemasa Kimura, of Nihon University writing about their Linnet wrote, "The basic form of the Linnet series embodied the original beauty which was unparalleled. What was wrong [with the Linnet] was that a torque shaft measuring about four meters long was needed to transmit the power of the pilot from the pedal to the propeller because the propeller was located at the tail end. The vibration of the shaft, which was witnessed in the initial phase of the program, was solved by increasing its outer diameter. The shaft, however, could not be elongated beyond reasonable limits. This made it impossible to elongate the moment arm of the tail. [The tail volume ratio of the horizontal tail was 0.305 for the I model and 0.334 for the II model.] Such structural deficiency brought on insufficient longitudinal stability, which caused the pilot constantly to pay his exclusive attention to the maintenance of longitudinal trim. It was not easy to attend to the delicate manoeuvring of the airplane while pedalling with both feet at full power simultaneously. There were many cases in which the airplane prematurely hit the ground as a result of a loss of foot power caused by excessive attention to piloting. The pilots for the past series of man powered flights were chosen from among students who held private pilot licenses for airplanes or gliders."

Here Kimura is showing how much the drive-train is dictating. Also he is pointing out the benefit of a stable aeroplane to reduce the pilot's work. See Gossamer Condor and Chrysalis, and Bryan Allen's comments on these two, having flown both.

LONGITUDINAL (PITCH) CONTROL & STABILITY

See foregoing paragraphs, sections on Puffin, Jupiter, Wright, and "longitudinal" in glossary.

As originally built, both wing panels twisted and the tailplane stayed fixed. This proved over-sensitive and Mufli pitch behaviour was such that a conventional moving elevator was built for later flights.

Lateral control (see Glossary) was by both entire wing-panels moving. With two bracing wires beneath the wing, this needed only a simple mechanism. There are no reports of turns, but the aircraft made 120 flights, hence one assumes lateral control was effective enough for straight flights.

Construction was of spruce and cedar as used for aircraft of that time, and the aerofoil section was Gottingen 535, a highly cambered section intended for gliders, which is aimed at producing high lift, but not at extensive

Aviette Contest France.

Photographer unknown.
RAeS HPAG archive.

Franz Villinger and Helmut Haessler's *Muffli*.

Photographer unknown.
RAeS HPAG archive.

Enea Bossi in the cockpit of *Pedaliante*.

Photographer unknown.
RAeS HPAG archive.

laminar flow.

The drive belt was cloth which needed frequent tightening.

The first officially recorded flight of the Mufli was at 11.10 am on 29th August 1935 in Frankfurt with Herr Duennebeil as pilot, but the author heard Villinger in London in the 1960s say that the first flights had been made by him and Haessler. The longest recorded flight was on the 4th July 1937. This was 779 yards, and for this the Institut gave a consolation prize. Villinger wrote in 1961 that this had been achieved in "near ideal conditions" (Villinger 1961).

This aircraft was to influence British theorists and designers in the 1950s and 1960s. Compare the propeller position and general glider-type layout. It was the only HPA known to have flown.

See HVS for a Villinger design forty-eight years later.

HANS SEEHASE

This man built an aircraft for the same competition. There is no record of this plane having taken off. However it is of interest because of many of its design features.

The wing structure was aluminium alloy tube with widely spaced ribs and an all fabric covering, in order to reduce weight even at the expense of increased drag. This principle was ignored by other designers for 42 years, perhaps because the plane was deficient in other ways, notably a clearly inefficient propeller. Perhaps if the Seehase design had been sound all over and it had flown, then others might have adopted a hang-glider type of wing earlier than the Condor.

The principle of the transmission system has never been used on any other project. Chain from the pedals drove a layshaft (intermediate shaft). This had two cranks on it as if it were the crankshaft of a two-cylinder motorcar. The con-rods did not go to pistons, but to another similar crankshaft. This second crankshaft is the propeller shaft, which as usual was at right angles to the layshaft. Theoretically it doesn't work, because the con-rods have to change length during the cycle. Seehase made it work on the ground by incorporating rubber buffers, as did Wilson later (see below). Gearing in the chain drive to the layshaft can be readily adjusted.

PEDALIANTE

Enea Bossi, an Italian aircraft designer, started his research into HPF in the 1930s by fitting a propeller onto a tricycle. This proved to be an unstable vehicle and he erroneously believed that an HPF with only one propeller would also be unstable hence his choice of wing-mounted contra-rotating propellers with the accompanying complicated drive.

The Pedaliante was of conventional glider configuration and construction, and with a span of 58 ft, area of 250 square feet and weight of 220 lbs.

It is generally agreed that this aircraft made many dozen flights after towed launches. There has been much dispute as to whether it ever took off under the pedal-power of the pilot alone. There is no record of official observation of it having done so. If it did, it would of course have been a world-first, preceding SUMPAC by thirty-five years. Some of the arguments for and against the validity of Bossi's claim to have done so are presented by Sherwin (1976).

In the period from 1958 to November 1961, one knew that the Pedaliante "might have done", and this mirrored most people's expectations about whether their own projects would ever work, or indeed whether HPF would ever be possible. Yes it's true, we really did say "Yes, but will it fly?"

Neither of these pre-war aircraft had ailerons, yet all the early British HPA used such devices to attempt to get lateral control.

AUGUST RASPET

Credited by many as the first major instigator of revival of interest in HPF. A paper by Raspet was published by the Mississippi Academy of Sciences in 1952.

In the 1950s, tests on boundary-layer (see Glossary) control were being done for proposed use on aeroplanes of many types. In at least one case an engined-aircraft was modified by having a sleeve added over a short part of the wing span. This sleeve was very accurately made to a mirror finish. Then small holes were drilled in the surface through which suction was applied in flight. The objective was that the boundary-layer would be constantly sucked away thereby preventing transition to a turbulent boundary-layer.

It was thought by some that this principle could have relevance to HPF, it being considered that HPF was not quite possible with ordinary wings but that it might just be made possible with the reduced wing drag resulting from a totally laminar (see Glossary) boundary layer, controlled by suction. Amongst these were August Raspet of Mississippi and Professor T. R. F. Nonweiler of the U. K. (Glasgow, Belfast & Cranfield).

B. S. SHENSTONE, T. R. F. NONWEILER

The renaissance of interest in human powered flight which arose in the UK in the 1950s, culminating in the figure-eight prize offer which marked the end of the decade, was further stimulated and given direction by the writings and other activity of these two. Beverley Shenstone was Chief Engineer of British European Airways, and Terence Nonweiler was on the staff of Queen's University Belfast.

The March 1956 issue of the Canadian Aeronautical Journal carried Shenstone's "The problem of the very light weight highly-efficient aeroplane." In October 1958 Nonweiler boldly chose the title "The Man-Powered Aircraft" for his piece published by the Journal of the Royal Aeronautical Society.

The MAN-POWERED AIRCRAFT COMMITTEE, (MAPAC)

Shenstone, Nonweiler and five other eminent enthusiasts met in Cranfield in January 1957 and formed this ad hoc committee with the purposes of reviewing relevant literature, assessing the prospects of HPF and promoting its realisation.

It was the opinion of its members and of most other aeronauts that flight powered by muscle power alone was only questionably possible. Haessler and Villinger's Mufli, 1935, had always been towed into the air and other claims were mythical or unsubstantiated.

Shenstone was to be an active member of the MAPAC and its successor for over twenty years. Prof G. M. Lilley, an early member of MAPAC, remains active, and became an aero-engine in 1977 when he flew Gossamer Condor on one of its last flights.

EMIEL HARTMAN

In England in 1958 an ornithopter was built by a glider-repairer who followed the rough sketches of Emiel Hartman, a sculptor. It used a mechanical linkage to provide the necessary twisting of the wings during the flapping cycle. Only towed flights were made, but the builder told the author in 1961 that by flapping the wings, forward progress had been made on the ground. In common with the earlier and more successful Lippisch machine the downstroke was assisted with springs, which became tautened on the upstroke. It would appear that its one good feature was that the natural frequency of oscillation of the wings, with the springs used, was the same as the usual human rowing cadence. This was also equal to the frequency calculated to be correct for aerodynamic propulsion. Various researchers had observed a range of insects and birds. Extrapolating from these observations, they hypothethised a flying creature of the weight of one person plus machine, and found that, conveniently, the frequency comfortable to rowers is what one would expect to find used on a successful flapping-wing HPA.

DANIEL PERKINS

Daniel Perkins was a civil servant, an engineer working at the Royal Aircraft Establishment at Cardington. This was at the time Britain's biggest experimental airship facility. Perkins decided to build an inflatable wing HPA. His first test was a propeller driven trolley and since the rider of this heavy crude trolley could accelerate to 14 mph, Perkins concluded that all was well with the drive and propeller system. Transmission was a rope belt.

However, having built the plane, they found that this could only be pedalled to 14 mph, the same speed as the test-trolley. Perkins took the wing off. Same result, 14 mph maximum, even though the rider was now in a streamline shaped pod, and the total weight was much less than the test-trolley.

The configuration was a pod and tail-boom fuselage (the first such built), and a parasol wing (see Glossary).

Various tests and modifications including a virtual rebuild did not improve this ground-speed.

Perkins became convinced that the efficiency of his propeller was adversely affected by proximity to the ground, and that this explained the apparent 14 mph barrier.

However he persisted (see Reluctant Phoenix).

ROYAL AERONAUTICAL SOCIETY MAN POWERED AIRCRAFT GROUP, (RAeS MPAG)

In October 1959 this group of the society was formed, having been proposed by, and essentially consisting of (ex-)members of the MAPAC. Meetings were then held at the Society's offices, as they are to this day. The name was changed to "Human Powered Aircraft Group" in 1988 in recognition of the many successful flights by women pilots.

S. S. WILSON

This Oxford University lecturer described his HPA transmission test-rig to the RAeS MPAG on 17th March 1961. Wilson appreciated that HPA drives have a heavy peak torque and low speed compared with most machines, and that a 1% improvement in drive efficiency is as effective in reducing the power required from the pilot as a saving of 2 pounds of weight. The power output from pedals is cyclic, with a burst of power as each leg pushes down, but it is preferable for the propeller to run at a constant speed. The transmission system can reduce these variations in power by an effective change in gear-ratio during the cycle, for instance with non-circular chain-sprockets or belt-wheels.

The drive being tested was mounted in the rig and a further power transmission of known high efficiency linked the shaft back to the pedals. This mechanism was then strained when static so that the load in the drive was as it would be when in use. The rig was driven & the power to drive it measured.

A flexible shaft showed the highest efficiency found, 99%. In use, this might cushion out cyclic-power-variations by absorbing part of the energy supplied as each foot goes down and resupplying this to the propeller during the remainder of the cycle. (Strictly, of course, this is stored energy).

Wilson quoted 98.5% for chain drive, but declared chains to be untwistable! Chains impose less load on the supporting structure than belts, which unless toothed are less efficient.

A double-crank system (as Seehase) with a 1 1/2 inch crank length was made to work using rubber bushes, and showed an efficiency of 96.5%.

Wilson recommended the use of self-aligning-bearings throughout an HPA drive system because of the flexibility of the supporting structure, and their lesser friction. He quoted a coefficient of friction of 0.001 for self-aligning bearings and 0.0015 for single-row bearings. Needle rollers were not recommended.

Tyres need 5 hours running in to reduce rolling resistance which decreases with temperature.

REDUCTION OF CYCLIC VARIATIONS

Four methods of reducing cyclic variations are:

1/ Elliptical sprocket as mentioned by Wilson and used on Musculair.
2/ Energy stored in drive path as suggested by Wilson's flexible shaft.
3/ Energy stored outside drive path, such as Bradshaw spring, as proposed for Jupiter.
4/ Weighted propeller tips to provide a flywheel effect. Builders have never used this last principle presumably because they felt that the extra weight was not worthwhile.

TRANSMISSION SYSTEMS IN FLIGHT

It should be remembered that actual conditions can never be duplicated by ground-rig tests. Such tests as those of S. S. Wilson are of value as are those of the manufacturers or a group's own ground-rig-tests; but experience has shown that flexure of the airframe in flight has affected the performance of the transmission.

HENRY KREMER

In November 1959, Henry Kremer, an industrialist, offered a prize of £5,000 for the first man-powered flight. £5,000 then was equivalent to around £50,000 Sterling 1990 or to 1990 US$100,000. That sum would have bought a moderate size house. The money was donated to the RAeS and the rules, composed by the MPAG were published in the February 1960 Journal of the Society (JRAeS). The winner would have to demonstrate that sustainable flight after an unassisted take-off was being achieved, and that left and right turns and moderate climbs could be flown, both with or into any wind. To fly a figure of eight course, with a minimum of ten feet height at start and finish, necessitates all those manoeuvres. This was the original Kremer Prize course. Entry was restricted to the British Commonwealth. Henry Kremer has continued to sponsor competitions ever since (two are current in 1990). Henry Kremer is a quiet spoken man of few, well chosen, words. His views on the rules for each competition, as well as his generosity, have influenced the progress of human powered flight as much as anybody. Even with regard to the Daedalus flight, which one might have thought had nothing to do with Henry Kremer, (the course having been established a few thousand years earlier!), Professor Mark Drela, co-designer, said that the flight would not have been possible but for the experience that members of their team had gathered while flying Kremer courses.

On February 19th 1967, the purse was doubled and the competition made international. Also in 1967, the "Slalom" competitions were started, effectively for a figure "S" around three pylons. There were first, second and third prizes of £2,500, £1,500 and £1,000 for the Slalom competition, but it had no entrants and was finally withdrawn

In 1973 the Kremer figure "8" prize was increased to £50,000, more than covering the rate of inflation.

Accounts of the Kremer World Speed Competition, and the two current Kremer competitions follow later in this review.

Henry Kremer was himself the recipient of awards when in 1986 he was made an Honorary Companion of the Royal Aeronautical Society and was awarded the prestigious Gold Medal of the Federation Aeronautique International at their annual conference in Sydney, Australia on 10th October 1988.

Kremer has led technological developments in industry for over 50 years. These developments include the first chipboard and the first usable remote-control bomb-defuser.

EFFECT OF FIRST KREMER PRIZE

No review of human powered flight which covers this period is complete without a description of at least one of the large number of eager but inexperienced pioneers.

ALAN STEWART was building human-powered-ornithopters before 1959, and was still making attempts in 1979. In fact these were all unsuccessful, although one glided once. He was perhaps the most persistent and notorious of the many young men of this period who had more optimism than aeronautical knowledge.

The passage that follows shows the technical level of many of the enthusiasts of this period, and illustrates the organisational problems faced by anyone operating in the real world such as Stewart's village, Greenhill. It illustrates the strength of audacious pioneering despite the mockery of the neighbours which is one of the necessary attributes.

Perhaps the main lesson to be learned here is that on any project which is seen as bizarre, as HPF still is, it is necessary to develop a technique for coping with the curious.

"My ornithopter grew and before long it was too big to be contained in the wash-house so I had to take my secret hobby outside in the yard where critical eyes could see. Man-powered flight might be taken seriously by the influential men on the Kremer committee [sic] but the people of Greenhill would be harder to convince of its worth.

"It wasn't long before someone leaned over the garden wall.

" 'What's that you're making then?'

"I tried to avoid giving a straightforward answer in the hope he would go away, but others appeared asking the same question.

" 'An aeroplane', I admitted at last, hoping that would get rid of them.

" 'Get away! You are having us on.'

" 'You never are! Come on, tell us what you are making '

" 'An aeroplane', I repeated, preparing to meet their

An example of the many enthusiastic attempts & press accounts criticism with thick skin.

"At first they were puzzled. People didn't make aeroplanes in their backyards.

" 'It's a practical joke!', grinned one at last, believing he had the answer. The others looked questioningly at me.

"I nodded. If they cared to think it was a joke, I wasn't stopping them.

"But as time went on, the people of Greenhill got to hear of the Kremer Prize and began to take me seriously. £5,000 was no joke." (Stewart 1980)

A better answer might have been something along the lines of Dr Paul MacCready's reply 18 years later to similar questioning at a time when he was as yet unsuccessful. (See Gossamer Condor.)

However, it wasn't Alan Stewart who lost out during a later series of questions, this time from the press -

"The film sequence was carefully arranged... I was told to pedal as though really going somewhere. At a given signal I was to stop pedalling. This was a cue for the interviewer to duck under the wing and have a little chat with me.

"...I began to pedal until the wings began to fan up and down... the cameraman signalled me to stop and the interviewer came forwards, ducking smilingly under the wing to ask his first prepared question.

" 'Tell me, Mr Stewart, don't you think this is all rather dangerous?'

"But although I had stopped pedalling, the wings hadn't quiet finished. They came steadily down to conclude the final beat. The main spar hit the interviewer on the head with such force that he fell to his knees.

" 'It is a bit', I had to confess." (Stewart 1980)

PRESS ACCOUNTS c1960

It was the less well-considered designs which were most written about and pictured in the daily press of this period, and the reporters found no shortage of material. Their vocabulary and accuracy however seemed to be more limited. Every overweight and under-wingspanned machine was pedalled "furiously", and every run was "an attempt on the Kremer Prize". In fact there was no official entry during the 1960s.

ROUGH ESTIMATE OF POWER REQUIRED

Sir Isaac Newton, Alan Stewart and those journalists in common did not understand the principle of the wing. Newton thought a wing worked by pushing air downwards. Since a propeller works by pushing air backwards, this would seem a reasonable assumption.

A propeller creates a jet of backward moving air, but a wing creates a vortex around itself. A vortex is swirling fluid, as seen when a bath empties. At each wing-tip the vortex persists, and the wing leaves in its wake a pair of vortices. Thus the total vortex system is horseshoe shaped. At certain altitudes these trailing vortices give rise to observable vapour trails. These vortices are necessary for lift and will be present no matter how "perfectly" the wing is made. The creation of these vortices absorbs energy, and for efficient flight will be as small as possible.

The beneficial effect of the vortex, the lift, acts all along the span so for the same vortex strength, the long wing produces more lift for the same energy. Hence, to generate the same lift a longer wing will need to generate a smaller vortex than a short wing, and will require less power from the pilot or engine. That is why success comes to HPAs with long wings. This energy loss manifests itself on the plane as a drag-force known as "induced drag".

Added to the energy absorbed by this vortex generation will be the power which would be necessary to push the plane forward even if no lift were being generated. This is reduced by making it a smooth or "streamlined" shape, as for any vehicle. In practice it usually turns out that these two components of required power are of the same order of magnitude. Some optimisation procedures aim to make them equal

The magnitude of this required power can be estimated at various degrees of sophistication as the project proceeds, but a rough estimate good enough to check the viability of a proposed design can be obtained as follows, from knowledge of three values and two empirical constants:

Total weight W lbs
Wing span b ft
Wing area S sq ft
Empirical constant 700
Empirical constant 1

V, the speed at which you might expect to fly is found from:

$$V^2 = (700 \times W) / (S)$$

P, the total power required is found from:

$$P = (1 \times W \times S \times V) / (b^2)$$

HENRY Kremer, like Leonardo da Vinci. believed that man should be able to fly using the power of his muscles. Although an ingenious inventor, such a feat was beyond him so he promoted the ancient dream by offering cash prizes and development grants for the first person to achieve it.

Henry Kremer was born was born in Dvinsk (now Dau gavpils) Latvia on May 8, 1907. His parents emigrated to England after World War I and Henry was educated in Britain and Switzerland, becoming a British citizen. His parents started a small plywood and chip-board fabrication business. Their son joined the firm in 1927 and proved to be brilliant at devising new materials and methods of making them. By the time World War II broke out, he held a number of patents, including those for the plywood process used to build the de Havilland Mosquito bomber. In 1941 he developed a process for making a plywood substitute from sawdust, wood shavings and resin.

Structural moulded boards replaced natural timber, which was then unobtainable, and were used in the war effort and later commercially. This was the first product of its type in Britain and it grew into the chipboard industry. In 1953 he produced a process of making glass fibres which were chopped and assembled with adhesive and, when used with epoxy resin. formed strong structural material. This process, initially only for defence purposes, is now used commercially for most reinforced plastics work. Without the resin it is now well known as fibreglass insulation. Henry Kremer founded Microcell in 1951 and subsequently expanded it into the Laser group of companies. In 1954 In a patent, kept as secret for some years, Mr Kremer described the invention of coating short glass fibres with aluminium. This was entitled Rapid Blooming Window and replaced the original window of aluminium foil, being lighter, easier to deploy and staying in the air longer. Dispensers were developed by Microcell for use on the RAF V bombers. which threw out bundles of 2 inch lengths of the fibres. In 1959 Experiments were carried out on behalf of the Royal Aircraft Establishment on void free radomes to produce better performance for radars. The successful methods of manufacture were put into widespread use in industry.

Since working with de Havilland, Kremer had maintained his interest in aviation, and he was also very interested in physical fitness. Both subjects were closely connected with Robert Graham's project to develop a human-powered aircraft, and from time to time Graham informed Kremer of the progress of the MAPAC and its successor committee of the Royal Aeronautical Society. One day in 1959, Kremer, Graham, H. G. Bennison, Fred East, and Air Commodore Bryan Hatfield stopped for lunch at the Cambridge Hotel in Camberley after touring one of Microcell's factories. The group was in a jovial mood because of a successful merger, and Graham spoke enthusiastically about human-powered flight. "Man could fly," he told the other men. "If only someone would put up a prize for it, say about five thousand pounds."

"I'll put up five thousand pounds," Henry Kremer volunteered immediately. The astonished and delighted Graham turned to his companions and verified that they had heard Kremer's offer. Bennison confirmed it and offered to put a plaque on the lunch table if anything ever came of it. That was the beginning of the Kremer Prize. The prize was announced in November 1959, and a letter signed by Robert Graham in the Royal Aeronautical Society Journal for January 1960 stated that the award would be made for "The first successful flight of a British designed, built, and flown Man-Powered Aircraft, such flight to take place within the British Commonwealth, under conditions laid down by the Royal Aeronautical Society."

Over the next 27 years Kremer's personal sponsorship led to the construction of many aircraft, short flights. completion of a figure-of-eight course and the spectacular Channel crossing in 1979. During that period his sponsorship amounted to more than £150,000. He realised that this was the first real step in human-powered flight and gave the Royal Aeronautical Society a further £100,000 prize money to encourage the design of more robust and practical aircraft. A speed competition was devised which became an outstanding success. with the fifth and final winner completing the 1,500 metre course at a speed of 44kph.

There is over £150,000 still to be won in Kremer prizes. In 1969 Mr Kremer conducted experiments on electro viscous fluids, in conjunction with defence departments and Sheffield University. such fluids are now in wide use in industry for controlling power eg in clutches. In 1974 Mr Kremer took over the concept of the Wheelbarrow for approaching suspected bomb situations in Northern Ireland and produced the first useable version. Production was assigned to another company. Although his man-powered flight competition attracted widespread interest and publicity.

Kremer was a self-effacing man who avoided the limelight. It is doubtful that human powered flight would have been achieved and developed to the extent it has been without the encouragement and support of Henry Kremer.

The Royal Aeronautical Society honoured him with Companionship in 1975. and in 1988 the Federation Atronautique Internationale presented him with its highest award. the Gold Air Medal. and later made him a Companion of Honour of the FAI.

Henry Kremer died at his home in Israel on April 8 1992 aged 84. He was survived his wife Norah, two sons and two daughters.

Born 8th May1907, died 8th April 1992
Companion of the RAeS 1975
The Paul Tissandier Diploma 1978
The FAI Gold Air Medal 1987

This was compiled from the following sources: 1. Notes and citations held at the RAeS library. 2. An obituary written by Frank Low (Chairman of the HPAG). 3.The Gossamer Odyssey by Morton Grosser.
Photographer unknown.
RAeS HPAG archive.

This equation gives the value of P in the units of ft lb/sec.

550 ft lb/sec = 1 HP (One horsepower)

This rough estimate method assumes a lift coefficient of 1.2, ground effect factor of 0.80, pilot weight of 165 lbs, ratio of induced drag to total drag of 0.43, propulsive efficiency of 0.85. These are typical values for HPA. The ground effect factor mentioned will only apply near the ground; more power will be needed to fly higher. The propulsive efficiency figure mentioned here is intended to cover both the mechanical transmission and the propeller.

This estimate is good enough to show that most of the "planes" shown in the press of the 1960s on the ground were almost certain to stay there.

EXAMPLE

Stewart-1976 Span 30 feet, Weight 250 lbs, Area 180 sq ft

$V^2 = (700 \times 250) / (180) = 972$
$V = 31$ ft/sec = 21 mph
$P = (250 \times 180 \times 31) / (30 \times 30) = 1076$ ft lb / sec

POWER AVAILABLE

The power that a person can produce depends on how long they have to produce it for, but however brief the flight, some time will be spent under exertion during the take-off run, say a total of half a minute. A person of average fitness can produce no more than 385 ft lb/sec for this time, and 1076 is clearly more than 385.

Making the same calculation for Mufli and Daedalus, and comparing with more sophisticated estimates:

Aircraft	**Weight**	**Span**	**Wing Area**	**Rough Estimate**		**Precise Values**	
	W (lb.)	b (ft.)	S (sq. ft.)	V	P	V	P
Mufli	245	44	104	41	534	41	456
Daedalus	247	112	332	23	150	23	149

Precise values from (Sherwin 1971) and (Langford 1989).

The rough estimation method is only suggested for use in estimating the likely success of a proposed design at the "back-of-envelope" stage, or on first sight if only weight, span and area are known. For the classical method see (Glauert 1948).

John McIntyre writes "Yes, a rough estimate of induced drag is useful to start with. To get it accurate later on, refinements will include considering the flexural and torsional deflection of the wing. The load distribution on the wing in straight flight is as you would expect from classical theory, except that the flexural deflection of the wing causes inward rotation of the local lift vectors. This reduces the lift of the wing and the aircraft must fly slightly faster than predicted - for an accurate solution, some iteration is necessary."

PUBLIC ATTITUDES 1959

Were typified by those of Alan Stewart's neighbours portrayed above. The spaceships of fiction foretold real spaceships with reasonable accuracy. But in 1959 most people did not know what a human powered aircraft would look like. Those who responded actively to Henry Kremer's challenge did not know what one would look like either, but that did not worry them as it did others. The ability to conceptualise the not-yet-existent, an essential talent for creators, does not appear to be universal. After the prize announcement, "man powered flight" to the majority of people meant "you have to do a figure eight".

RAeS GRANTS for HPA DEVELOPMENTS in the UK

The First True Flights SUMPAC

In June 1960 a grant-fund was set up to which Henry Kremer among others contributed. This fund still exists in 1990. An applicant for a grant must show primarily that the proposal is likely to lead to the development of human-powered-flight. In theory, grants are open to anyone who intends to research some aspect of the subject rather than build or modify an aeroplane, but such a grant has never been made. The applicant is asked to present a comprehensive assessment of the project, covering many relevant aspects to show that it will not falter for want of any essential ingredient. Also one is expected to have made the initial design decisions and show for instance the flight-envelope. The preparation of the grant application itself is thus useful in ensuring that one has not ignored anything of importance. (The PROGRAM section of this review, below, may hopefully serve a similar purpose.)

The grant is not intended to cover the entire cost, and one must anticipate needing to defray expenses occurring while awaiting final approval. These grants have been instrumental in making several projects possible in the UK.

FIRST RAeS LECTURES on HPF

The Royal Aeronautical Society held several lectures on the subject of HPF around 1960. Here and there in the Lecture Theatre one would be able to see little knots of people feverishly taking notes; these were the rival groups. The lectures were often published a few months later (see Bibliography), but we wanted the information straight away.

The RAeS HPAG continues to provide this service; typically now there is one event a year with a varying number of speakers. Many are reports of experience with HPF. Any prizes won during the year are presented.

THE FIRST TRUE FLIGHTS SUMPAC

It was in the spring of 1960, in the middle of their last term as undergraduates at Southampton University that three students Alan Lassiere, Anne Marsden and David Williams became interested in building an HPA. Marsden was happy with its name being the acronym for Southampton University Man Powered Aircraft, i.e. SUMPAC. The author remembers Susan Roper's comments on this name as "Aren't they lucky they don't have to think up a name for their aeroplane, they've got one automatically"- (nothing about "man" v "person").

The first Kremer Prize had been announced the previous November. The trio had to get their final exams out of the way, and then for the rest of 1960 they investigated possibilities, did tests and drew designs. "We spent ages talking about it before we got started", said Williams.

There was very little relevant additional knowledge, materials or experience available in 1960 that had not been available in 1935, and during these 25 years no HPA had flown. The SUMPAC's successful predecessor was the Mufli.

The team soon grew beyond the three leaders to include several undergraduates with varying amounts of involvement and commitment. Initial tests of power available were made by people being timed running upstairs; but, after a recumbent pilot position had been chosen, a rig was built for this purpose. The groups main aim was to get flying as soon as possible, hence the choice of a conventional single seat monoplane. Three main decisions needed to be made with regard to the wing, namely planform, section and method of construction. Today we would add a fourth, the method to be used for lateral control, but in 1960, since ailerons clearly worked for other aeroplanes, they were adopted.

PLANFORM was based on flying at 10 feet to comply with the rules of the figure-eight course. A span of 80 feet was chosen. Their analysis showed that a larger span would require less power, but be more difficult to turn.

AEROFOIL SECTION Aeronautical research had been more concerned with speeds of around the speed of sound than around the speed of a push-bike. The NACA 6 series aerofoils had been designed by the United States National Advisory Committee on Aeronautics, (now well known for its space exploits as NASA), for use at high subsonic speeds, i.e. speeds just below the speed of sound. In tunnel tests at high Reynolds' numbers, it had been shown that over a large part of the area on these sections the flow was laminar. The group extrapolated beyond the tested range to a section of high camber, 65_3-818.

The 6 signifies the series, the 5 is a measure of the position of maximum thickness and the pressure distribution, (65_3-818 is thickest further forward), the 8 is a measure of the camber (compare with Jupiter, Toucan and Linnet sections), the 18 signifies a thickness of 18% of the chord.

TEST-SECTION To prove the method of construction a test-section of wing was made. This had a "span" of 7 feet, to suit the wind-tunnel, and a chord of 3 feet, being the average of the expected chord on the plane. All construction was done as if it were to be part of the actual aeroplane.

The primary structure was a spruce girder box-spar (two spars linked with other structure to form a box shape). All the spruce was bought in with a thickness of 1/8th inch. The four spar booms which formed the corners of the box were laminated from 1 inch by 1/8th inch strips, some of the laminations being balsa. At the transport joints, the duralumin fittings, also 1/8th inch thick were bonded between laminations. The strips making up the vertical sides of the box were similarly incorporated. The two spars so built were then supported at the required twist and the remainder of the structure added. More spruce strips completed the top and bottom of the box-spar. Ribs were of girder construction with spruce booms and spaced at 9 inches. A true profile near the nose was maintained with a closer spacing in this area. The front 20% of this structure was skinned with 1/16th inch thick balsa, and balsa caps were added to the ribs. The trailing edge was spruce.

The details of this construction principle were arrived at from experience with the test-wing. The test-wing exhibited laminar-flow on tunnel tests, and proved structurally sound when loaded. When loaded beyond the expected flight-loads, failure first occurred in the transport-joint fitting, not in the bonding of this to the spruce. The wing was covered with doped parachute nylon.

TUNNEL TESTS Three tests were conducted. The wing-test-specimen, the propeller, and a model of the aircraft. The wing-test-specimen displayed laminar-flow satisfactorily. The propeller, which had adjustable tips, performed as expected.

INTERFERENCE DRAG However the drag of the model was excessive. It was discovered that this extra drag was being caused at the junction between the wing and the pylon. According to these wind-tunnel observations, this interference drag accounted for 2 out of a total of 7 pounds.

With a bluff section, such as a cylinder or sphere, the flow can be expected to separate somewhere on the downstream half of the section. In this region, as one proceeds in the direction of the flow, the cross section is decreasing. To avoid separation a gradual taper is needed as on aerofoils. If two aerofoils are adjacent at right angles to each other, as a conventional fin and tailplane, or as the SUMPAC wing and pylon, then the tendency for separation to occur is augmented. The pylon was thick enough for the pilot’s head, the wing section was thick and their regions of decreasing thickness were adjacent. Separation was observed to be occurring on the tunnel-model at this place. The shape was adjusted to reduce this effect. This could not be done in an ideal manner because building was too far advanced and such a fairing would have been within the sweep of the propeller blades.

1961 Construction started in January. The group were awarded a grant from the RAeS MPAG in February. The plane was transported to Lasham, an airfield in Southern England greatly used by sailplanes, in September.

DEREK PIGGOT was the Chief Flying Instructor at Lasham, and became SUMPAC test-pilot. The first flight was on November 9th. Even with his experience he reported that landing was more difficult than taking off.

AIRFRAME PROBLEMS The dampness of the hangar warped the nose-skinning and slackened the nylon. This meant that extra coats of cellulose dope were added to try to maintain tautness. The tubular framework supporting the pedals and nosewheel collapsed on early ground runs and was replaced with a light-alloy-sheet structure. The original fin was replaced with one of twice the area. The steel transmission belt slipped and stretched.

FLYING SUMPAC, the gear-ratio between the wheel and the propeller was adjusted before each flight to suit the anticipated wind-speed, but even so the pilot often found that the wheel was slipping. When speed has increased to the stage that the weight of the plane is nearly all carried by the wings then there will be very little grip because the pressure on the wheel has been lifted. On SUMPAC when the wheel slipped it then became essential to continue to accelerate to full take-off speed, thrust coming from the propeller.

Early flights were made at too steep an attitude (i.e. the nose was too high) until Piggot became accustomed to the controls and to the plane. The longest flight was 650 yards. Turns were attempted, with 80 degrees the best achieved. SUMPAC made a total of 40 flights. Some of the later flights were under tow or with the assistance of a model-aeroplane engine. Instrumentation was a Cosim variometer.

ALAN LASSIERE at IMPERIAL COLLEGE, the LONDON GROUP

At the beginning of 1963 after 14 months at Lasham, Lassiere, one of the original three, took the plane to Imperial College to develop it to a hopefully improved performance. The wing was left untouched, the fuselage was virtually rebuilt. The new transmission was by fabric belt, the new forward structure all of light-alloy sheet. The pylon was reshaped to avoid the separation mentioned above. The fuselage was covered with Melinex, (for “Melinex” see Glossary). These modifications took twice as long as the original designing and building.

SUMPAC was taken to West Malling in 1965. Unfortunately before any improvement in performance could be noticed, a flight on 12th November 1965 ended in disaster. John Pratt, chosen for his cycling ability was aboard.

Having flown fifty yards, Pratt found himself at 30 feet in a stalled aeroplane, perhaps due to a gust. One wing hit the ground first, breaking it; then the fuselage hit, causing further damage. John Pratt was not injured, but the airframe was considered beyond repair.

SUMPAC then became the first HPA to be displayed at the Shuttleworth Collection of historic aircraft.

PUFFIN

Within a week of SUMPAC's first take-off, there were two HPA flying in England. Puffin first flew on 16th Nov 1961. The report in "Flight", of this event concluded *"... an attempt on the Kremer Prize appears to be imminent."* This is what was generally believed: at the time the words appeared superfluous and self-evident (and annoying to rivals, at least one of whom could remember them 28 years later). But 16 years were to pass before the figure-eight was flown.

Hatfield, within 80 miles of Southampton, was the home of the De Havilland Aircraft Company Ltd. Frank Vann, structural engineer, John Wimpenny, aerodynamicist and other employees of this company trod a path remarkably similar to that of the Southampton graduates described above. With the approval of Geoffrey de Havilland the Hatfield Man-Powered Aircraft Club was formed.

Care and attention went into the design and construction of Puffin as would be expected from people in the aircraft industry working on a full-size aircraft.

SIMILARITIES between Puffin I and SUMPAC:

No unproved aerodynamic concepts, such as flapping wings.

Single-seat monoplane. Bicycle-style pedals. 9 ft diameter propeller. Puffin I wing span 84 ft (SUMPAC 80), wing-area 330 sq ft (SUMPAC 300). Main material, wood. Driven bicycle-type ground wheel. Conventional control surfaces, operated by bicycle-handlebar-type pilot's control. Control system linkage by lightweight cable. Empty weight 118 kg (128 kg).

DIFFERENCES between Puffin I and SUMPAC:

On Puffin, pilot position upright. Propeller behind tail. Transmission by bevel-gear and shaft. Stressed-skin wing-structure.

Group members were workers in the aircraft industry. Approached the design of their HPA with an experienced and sophisticated attitude.

This Hatfield group had support from the firm, including dry hangarage. Members lived in or close to Hatfield, where the plane was built and flown.

On SUMPAC, pilot position recumbent. Propeller on pylon. Transmission by steel belt. Box-girder wing-structure.

Group members were graduates and undergraduates. A thorough theoretical optimisation was conducted before finalising design, but this was the first aeroplane by the designers. Simple effective techniques were used.

The group had the use of a University laboratory for building, a heated space with a firm flat floor. But at Lasham, conditions were not so comfortable, and the airfield was at a distance from members homes.

In 1990, the relative merits of upright and recumbent are still debated. And propeller positions, transmission systems and principals of wing-structure are still as chosen by one or other of these two early groups. Both had input from the knowledge and ideas assembled and disseminated by the RAeS MPAG.

CONFIGURATION: John Wimpenny said *"We didn't make the fuselage that fancy shape for the sake if it, but in order to accommodate the transmission tube."* See above (Mufli) where the effects of propeller position are discussed. This layout also led to a very short aeroplane, (see also Linnet). A single-crew layout was chosen "to reduce the work required in the very arduous task of producing an aircraft of this nature."

TESTS: A wing test-section was mounted on legs in the open air. On a day when the wind-strength was appropriate, the flow over this section was investigated. It was felt that this would avoid the turbulence associated with wind-tunnels or the vibration associated with car-roof mounted models. Structural tests on the wing test-section suggested increasing the size of the internal vertical struts. A transmission rig was useful in demonstrating the efficiency of the drive and for checking prospective pilots' power output. A fuselage structural test-piece was made;

a few feet of typical proposed rear-fuselage at full-scale. This proved the integrity of monocoque balsa design, (see monocoque in Glossary). The pilot-support structure was a magnesium tube framework.

Wing root (centre) aerofoil for Puffin I was a Wortmann section modified by making the bottom flat. Tip section was a NACA 4 figure section.

CONSTRUCTION All of the fuselage and tail and most of the wing on Puffin I was balsa wood. The sub-structure, the fuselage frames and wing ribs were all built of balsa sheet or strip. Puffin I in flight is seen with a straight wing. The wing-spars were built with a pre-calculated downward curve such that they would become straight when loaded. These spars were then sprung into the wing-jigs which were straight. Then the balsa skin was added. This meant that the skin was not stressed by the bending loads. This skin was a single thickness of 1/16th inch balsa with the grain at 45 degrees to the span. Large panels were first assembled from the 4 inch width produced for model aircraft. Then this panel was glued onto the structure. This operation was done by as large a team of people as could get close enough to work at once, so that it could be accomplished before the glue went off. This resulted in an excessive weight of glue. Projected wing-weight estimate was 39.4 lb, but the actual wings weighed 63 lb. The completed wings were carried by hand a mile from the De Havilland Apprentice Training School to one of the main Hatfield Hangars. Here everything was glued together. No way could Puffin I be transported.

During the flying stage it was found that the balsa skin had warped after a few months. The wing-surface profile was no longer smooth, and this was increasing the profile drag. Now, the front cockpit canopy of Puffin was removable to let the pilot in. To make an airtight seal around this canopy, the group had used a few feet of “Cling”. This is a proprietary draught excluder intended for the doors and windows of houses. It is a strip of sponge with adhesive on one side. It is lightweight and the obvious choice for this application, and this little detail is hardly worthy of mention except that it provided the solution to the wing-skin warping problem. Strips of this same soft foam, (quite different from the rigid foams used in later years for secondary structures), were stuck on the wing following the position of every rib, which were at 4 inch pitch. The wing was then re-covered with Melinex above these strips. This provided a smooth surface, although not strictly the same aerofoil shape since it was now 3/16 inch bigger all round.

TRANSMISSION: The group sought advice from Dunlop Ltd with regard to a tyre for the aircraft. This firm responded by offering to make the whole wheel and the bevel-gear box, which was entirely satisfactory. The long shaft from the pedals to the propeller was originally made by laminating 1/64th balsa around a mandrel. There was no way of adjusting the ratio of wheel to propeller revolutions, as there was on SUMPAC and later Jupiter. Effective tuning of this for take-off had to be done by adjusting the pitch of the propeller. Wheel-slip was encountered with Puffin but was no great embarrassment. Perhaps because of the lesser power-requirement of Puffin the technique of building up ground speed, holding some weight on the wheel, and then “popping up”, was more easily done.

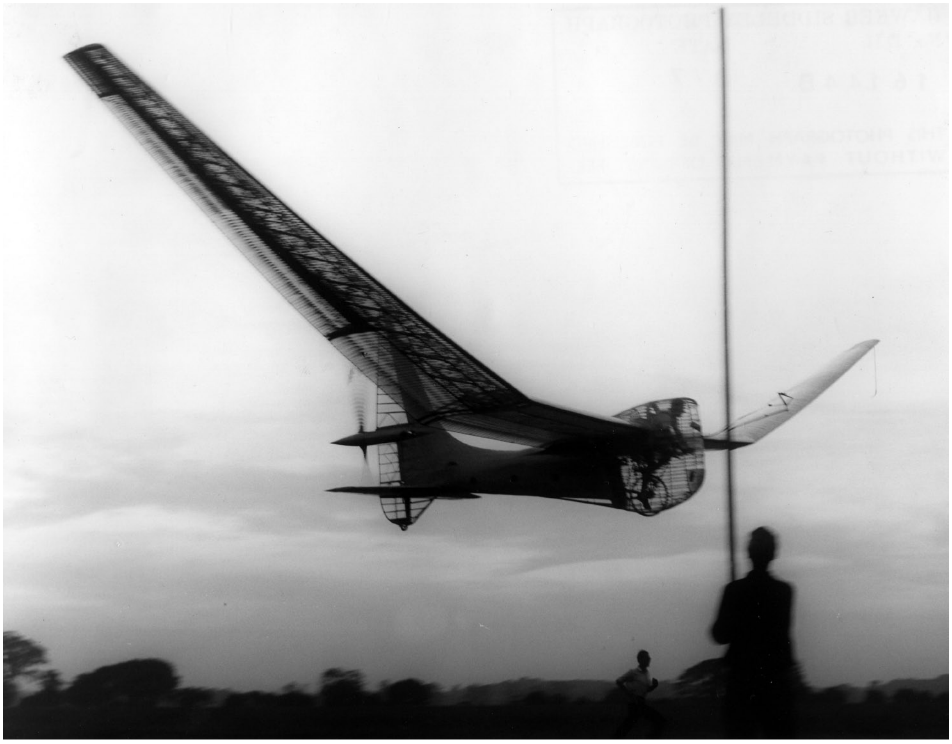
On Puffin, the pilot was leaning further forward than a bicyclist, and was restrained by a harness. This was to relieve the hands of all weight, and arrange the centre of gravity correctly. With concentric wheel and pedals, similar to the author’s 1960 design, the position of the feet is of course constrained. This imposes a restriction on positioning of the major items: wing, pilot, wheel. There would appear to be an implicit hazard in this arrangement of the pilot being thrown forward over the wheel in a bad landing. The layout was such that, statically, with the weight on the wheel, the aircraft would start to rock forward at an angle of 15 degrees from the horizontal. To surmount this, the Puffin group added a strut protruding forward for the purpose of absorbing impact in such an eventuality. (On Jupiter, the author positioned the main wheel well forward of the centre of gravity in order to avoid such a nose-over. However this had the disadvantage of too much weight on the tail-wheel.)

Fortunately no such nose-over has ever occurred during the many heavy landings of planes using this system and the Stork used and further developed this layout.

The plane was built in just over a year by November 1961. It first rolled out on the evening of 15th of November when a book of birds was consulted to see which it most closely resembled. You can see a design on your drawing board, you can see the plane when it is being built, but you never see what it really looks like till you get it outside. A puffin it was. In contrast to the many days of ground-runs of SUMPAC, Puffin lifted off the next day, and it didn’t require as much puffin’ as its contemporary. A horizon reference bar was mounted well in front of the nose and this proved excellent, particularly when the other instruments were also mounted here so the pilot only needed to look in one place. John Wimpenny found that it was better to maintain constant speed than try to maintain constant attitude.

SUMPAC flown by Derek Piggot.

Photo British European Airways.
RAeS HPAG archive.



John Wimpenny flying *Puffin*.

Photo de Havilland Aircraft.
RAeS HPAG archive.

Flight tests included drag measurements by towing via a spring balance. The pilot found this adversely affected stability and spring-balance-towing was terminated as soon as the measurements had been obtained. Drag was found to be 30% above estimate before the foam-rubber sponge as described above was added. In a further attempt to reduce drag, all control hinge-lines were sealed. A wheel brake was added and the mid-span skids removed. A pedal revolution meter was fitted linked to two coloured lights, red and green. A shining red light meant "pedal faster".

It was 39 year-old John Wimpenny, one of the initiators and designers who did most of the flying and who exceeded the 779 yards of Mufli with a straight line flight of 993 yards which was well independently observed since delegates to an IATA conference happened to be at de Havilland's at the time.

The photograph of Wimpenny in the plane with the front fairing removed and a big smile on his face was on the cover of the next day's tabloids with headline "Puff, Puff, Puffin!" It was presumably assumed that the readers of these daily papers could sometimes manage words of two syllables, but not with the names of two people. Understandably, others in the group wondered why it was only J. W. who was mentioned.

Sustained turns, however remained elusive, since, as for SUMPAC, pilot effort had to be directed mostly towards turning the pedals. With either remote-control or an engine, the pilot would only have to concentrate on either controlling or pedalling. As with SUMPAC, the Puffin group added a model-aeroplane engine, and turns up to 270 degrees were flown. Angle of bank was between 5 and 10 degrees. The group were able to make a demonstration flight for the benefit of the spouses and relatives of group members as some recompense for the many hours that the members had been away from them and with the project.

(Much of this information is from notes taken by Susan Roper at RAeS MPAG meetings in 1962 & 1963 (Clear-Hill, Wimpenny)

PUFFIN II

With a cyclist at the controls in April 1963, Puffin I crashed. The entire wing and fuselage were destroyed.

Using the salvaged propeller and gearbox, the plane was redesigned to a span of 93 feet and an area of 390 sq ft.

Dr Wortmann sent the group a selection of his aerofoil section ordinates and test-results. All these had been specifically designed for HPA. The group selected FX 63-137. This section, although giving good ratios of lift to drag at the speeds and incidences encountered by HPA, produces a high lift moment (see below for comments by John Potter and others on this section). On the ribs for the new wing, allowance was made for the thickness of sponge strips as added to the first plane. Much attention was paid to getting a good surface.

The fuselage was almost identical, but the wing structure was now a box-girder, with spruce for the booms and balsa for the top and bottom diagonals. The rib-pitch of 4 inches was retained. The empty weight was 140 lb.

The first flight of Puffin II was on 27th Aug 1962. Results were not as good as had been hoped. Little more was achieved in turns, and none in distance. A wide variety of ingenious lateral control devices was tried. A pair of spoilers was added at each wing-tip (4 in all). These would be opened on one side only to pull that wing back.

The Puffin II had differential ailerons, as commonly used on gliders, where the up-moving aileron usually travels more than the down-going. A range of ratios was tried on Puffin II with deflections up to 70 degrees up and 10 degrees down.

HINDSIGHT Commenting, in 1989, on the lack of improvement, John Wimpenny attributed the disappointing performance of the Mk II partly to the fact that the increase in wingspan without additional tail area led to directional control difficulties. Control, he says must always be resolved first, before trying for duration. (An engineer, not an operator speaking.)

Any of today's home-computers will show that the ordinate points on FX 63-137 do not lie in a smooth curve. In 1989, Professor M. Drela, using his advanced aerofoil design program (see Daedalus), found that the section produced more drag than the early wind-tunnel tests would indicate. On hearing of this, John Wimpenny considered that this also would help to explain the disappointing performance.

In the author's opinion, if Puffin II had not suffered from this handicap, perhaps by using a different section, then it would have easily outperformed his own Jupiter, and this would have influenced the design of those machines which followed, such as Stork, since they might have tended to follow Puffin.

LIVERPUFFIN

The Puffin II hit a concrete runway-light post in April 1969 and the group at Hatfield handed over all the remains to Dr K Sherwin of Liverpool University. The wing structure was mendable, and the transmission and propeller were salvageable.

Sherwin's approach was not to aim for the Kremer prize or for record distances, but instead to work towards a type of HPA which could be flown on days that were not absolutely flat calm, and for a simpler less expensive machine that could nevertheless leave the ground. Lippisch, mentioned above, agreed in the 1960s with this view. New, outside Japan, (see Linnet), was the idea of a student project initiated and led by the University staff.

STAFF LED UNIVERSITY PROJECTS

The difficulties which are met when trying to encourage undergraduates to work creatively and as a team are discussed by Sherwin (1976):

"On their own the students were quite happy to discuss these [agreed] findings in general terms but were not prepared to use them as a basis for decisions regarding [design].."

and -

"It was difficult... to persuade students to make the transition from innovation to detail. All too often...students would come forward with an idea but without any details or anything written. When told to quantify their idea they would go away only to change the idea for something 'better' and later present this, again without anything on paper."

And on the subject of take-overs after discussions with John Potter and Frederick To:

"Unless one is offered a complete man-powered aircraft that requires only a small amount of repair work before it can be flown, it is much better to start such a project from scratch, particularly in view of the enthusiasm that should be generated by a complete project."

The same wing section was built up again on top of the salvaged spar using hot-wire-cut polystyrene. Solid blocks were obtained large enough to form the nose of the wing. The outside profile was cut, then most of the middle cut away. This avoids the labour of many ribs and the difficulty of forming a sheet material around the nose accurately. Thus Sherwin pioneered the system later used on Light Eagle and Daedalus. Sherwin then cut circular holes in these nose-forms, an arguably bad move, because accuracy of shape was lost.

This was the first HPA to fly with a pod and tail-boom. The original Puffin propeller was mounted behind the pod, with thus a much shorter transmission. Control was by rudder only.

Span, in the spirit of Sherwin's endeavour for a simple plane was cut to 64 feet which gave an area of 305 feet. The weight of LiverPuffin was 140 lbs. First flight was on the 18th of March 1972. No long flights are recorded.

SINGAPORE Later Sherwin joined the staff of a University in Singapore and with the benefit of his Liverpool experience persevered with the idea of student projects.

The year-batch was split into two groups, with the idea that each build an HPA. Some raw materials were provided.

One of the aeroplanes flew and the other did not.

McAVOY If the rules for a competition stated that the HPA must have a three wheeled undercarriage, the span must be not more than 54 feet, the pilot must be unfaired, the tail unit must be an annulus surrounding the propeller which must have four blades, then entrants might well produce machines very much like that of James M. McAvoy of Georgia Tech. Otherwise, why attempt so many innovations on one design?

McAvoy's wing area was 289 sq ft and the weight was no more than 126 lb, typical of the areas and weights of contemporary successful machines. He had used an aluminium and balsa structure and the drive was by bevel gears and a shaft. McAvoy was an aeronautical engineering student and it would appear that his design was sound. Unfortunately there was no opportunity to tell how many of his novel features would have worked, because the machine rolled over when 50 yards into its first attempted take-off run and the damage was severe enough as to preclude further attempts.

VINE

S. W. Vine of Krugersdorp, Transvaal, South Africa was an expert glider pilot who also had engineering experience. His HPA had a layout similar to that of a single seater engined aircraft. The propeller, small by HPA standards, was driven by both hands and feet. The wing section is quoted (Reay 1977) as a modified Gottingen 535 but photographs indicate a slimmer section. Weight was 205 lbs with a wingspan of 40 feet and an area of 220 sq. ft.

POLITICS & the SPORT of HPF

The Kremer figure-eight competition was at this time open to citizens of the British Commonwealth only. When Vine started building his plane in 1961 he was just such a citizen, but it had been decided by the powers that be in his country that on 31st May 1962, South Africa would quit from the British Commonwealth.

On the 17th May, with a fortnight of political eligibility remaining, the plane was complete, but the weather highly unsuitable, being windy and gusty. Vine decided to have a go. Accounts of the flight remind the author of one of the flights of Jupiter ten years later: take-off into the stiff breeze: satisfactory straight flight for several hundred yards: gust lifts plane: pilot loses control: plane crashes.

Mr Vine, although 70 years old, survived uninjured. Unfortunately the aircraft was destroyed, and this was its first and last flight.

Presumably otherwise he could have transported it the 150 miles from Randfontein into neighbouring Botswana, then Bechuanaland, to regain Kremer eligibility.

RELUCTANT PHOENIX

Daniel Perkins, who had built several inflatable HPA which had not flown, (see above), met with success with his design of the Reluctant Phoenix, the first inflatable to fly.

This plane was designed to fly very low, so that the height was a fraction of the chord of the wing, (see ground-effect in Glossary). Perkins had made some tests, and found a symmetrical aerofoil to be appropriate.

To quote Frederick To (Aerospace June/July 1985) and (Society of Automotive Engineers Inc.) "The aircraft was a delta flying-wing with a wingspan of 31 feet and an empty weight of 39 lb. The envelope of the wing was made of polyurethane-coated nylon fabric. Due to the high power requirement for cruise, the aircraft was limited to short hops under man-power as it was being flight tested inside an 800 ft long airship hangar. About 90 flights were made. Reluctant Phoenix was successful in that it could be folded away and transported in the back of a small station wagon. It also survived many crashes without requiring repairs as the aircraft merely bounced when in collision with the ground. Shortly after Perkins's death the Reluctant Phoenix was handed over [to Frederick To], who immediately recognised the advantages of the system".

This author visited Fred To and heard him praise the neatness of the design of the Reluctant Phoenix. The seat-frame was similar to the chassis of a recumbent road HPV, the pilot's control bar being below the knees. See Phoenix.

LINNET I, II, III, and IV

This series of early successful aircraft were all student projects built at the The Research Institute of Science and Technology, Nihon University, Japan, under the leadership of Professor Hidemasa Kimura. The project was "... conceived in 1961 soon after the news of Britain's SUMPAC and Puffin were received. April 1963 marked the beginning of the first year of research," which entailed "A device to measure the power generated." A propeller driven trolley was built at Nihon, to prove the possibility of take-off without wheel-drive. "The second year was devoted to operations research to determine the optimum airframe dimensions, weight, aerodynamic characteristics and other factors to make flight possible. The basic form of the airframe was defined on the basis of the research. The third year marked a transition to detail design and manufacturing." The long-awaited airplane was rolled out in February 1966.

"On 25th February 1966, our dear Linnet, with Munetaka Okamiya at the controls, lifted wheels off ground for the first time..."

"Because of his aerial feat, Mr Okamiya became the first Japanese who was able to walk on the ground, swim at sea and fly in the air using his own power." (Kimura 1977).

HPF > HPA But Okamiya had not needed a machine which had taken three years of research by a University Institute of Science and Technology in order to do his walking or his swimming. Human powered flight has only been made a reality by engineering. But human powered flight is not the same as engineering. The Linnet I is in the author's opinion the best looking HPA ever built, but as Kimura's remark implies, its purpose is to enable flight, not just to look pretty.

1960s The early Nihon aircraft LINNET I, II, III, and IV

Linnet I was the first HPA to fly without having to carry the weight of a wheel drive in the air, but the longest flight was only 47 yards.

Transmission on the Linnet series was by bevel gear and shaft (see Mufli for a discussion of the transmission and pitch control of Linnet). The single wing spar was spruce, the ribs balsa . This framework was covered with styrene-paper, about which Kimura enthuses

"...a thin sheet made by rolling styrol-resins at a thickness of about 0.5 mm [0.02 inch]. Such material is light and effective in enhancing the rigidity of the airframe. It is also smooth in outer surface finish, a quality which is far superior to that of Britain's Melinex whose surface is slackened like a wet paper screen..."

Achieving an accurate profile shape without excessive weight is indeed one of the key points on an HPA. Kimura's criticism of polyester film is particularly valid when applied to areas of high curvature or double curvature. Looking at the fuselage-pods of many HPA one can see that the shape has been determined by the designer's knowledge at the outset that it would be made of polyester film supported by a framework. This constraint did not apply to the Linnet fuselages which helps to account for their elegant appearance and reasonably accurate profiles. On the wing, the styrene paper covering was apparently alone in providing any torsional rigidity.

Kimura again "...subsequent models continued at a pace of one airplane every year except for the period during which the University was embroiled in faculty-students disputes."

Data for all the Linnets are shown in the table.

For subsequent activity at Nihon see Egret.

MALLIGA

Polystyrene sheet was a material also much used by Josef Malliga, but here the similarity with the Linnet series ends. In 1967 Josef Malliga was a pilot in the Austrian Air Force.

This man designed the Malliga and built it on his own. Even the aerofoil section was his own design. Wing spar was aluminium tube with ribs and skin of expanded polystyrene foam (EPS). The ribs were capped with plywood strips.

The pilot's feet are at the same height as the propeller hub, which is just behind the pod, and transmission is via bevel gears at the pedals, and a shaft straight back to the propeller. This layout necessitates a tall undercarriage. The wheel was not driven. (Tony Paxton of England made a machine of similar layout, but the Paxton machine made no flights.)

Wing span was originally 65 ft with a weight of 113 lb.

After some towed flights, the first pilot-powered flights were in the autumn of 1967 with distances of up to 150 yards.

To improve performance the span was increased to 85 ft and the propeller diameter increased from 6 1/2 ft to 9 ft. This led to flights of up to 380 yards.

PROPELLER EFFICIENCY

Josef Malliga's increase in propeller diameter will have helped because efficiency increases with diameter.

Propeller efficiency is usually quoted as a percentage; (90% is a figure that might be assumed for a good HPA propeller). What this means in physical reality is that 10% of the energy arriving at the propeller hub is being wasted on pushing the air backwards and in creating turbulence in the wake. The other 90% of the energy is pushing the aircraft forward. It is perhaps easiest initially to think in terms of trying to reduce the inefficiency, that is to reduce the energy loss.

The thrust produced must at least equal the drag of the aircraft. Knowing the values of diameter, speed and thrust one can immediately state there will be an energy loss which can be calculated from momentum theory, even if the propeller is perfect in all other respects. Its only imperfection, hypothetically, is that it does not have infinite diameter. The efficiency so calculated is known as the 'ideal efficiency', the energy loss is known as the 'induced loss'.

The propeller with ideal efficiency will have an ideal distribution of thrust along the blade. In practice this will not be the case.

Here is a simplified approximate method of calculating induced loss. This is for first estimates only. K is a factor to allow for non-ideal thrust distribution, which has been found to be of the order of 2.

Given Diameter D ft, Velocity V ft/sec and thrust T lbs,

Induced loss = $K \times (188 \times T)/(V^2 \times D^2)$

Using this to estimate the improvement on the Malliga due to propeller diameter change alone, making the same assumptions about thrust and velocity for both diameters:

The length of flights achieved indicate that the power required was of the order of 0.5 HP or 275 ft lb/sec.

Let us assume a velocity of 20 mph or 30 ft/sec. This is based on known flying speeds of other HPA of similar wing areas.

Since Power = Drag × Velocity, drag = 275/30 = 9 lb

Hence thrust must be 9 lb

With D = 6.5, V = 30, T = 9
induced loss = $2 \times (188 \times 9)/(30 \times 30 \times 6.5 \times 6.5) = 0.08 = 8$ %

With D = 9.0, V = 30, T = 9
induced loss = $2 \times (188 \times 9)/(30 \times 30 \times 9.0 \times 9.0) = 0.04 = 4$ %

An efficiency increase of 4%

So there is therefore 4% less power is needed

Four percent may not seem like very much, but it is only by saving a few percent wherever one can that flight becomes possible or flights become longer.

The factor K will effectively be reduced with a “minimum induced-loss” propeller. It will never be less than one.

In the above case, actual propeller efficiency will be less than 96% because of the energy lost by the drag of the blades, and other losses.

See (Sherwin 1971) for a method of blade element analysis or (Glauert 1948) for classical theory.
Ernst Schoberl has plotted the propeller diameters required to provide 85% or 89% efficiency for a range of flying speeds. (Schoberl 1987). These plots were drawn in 1987, when HPA had developed to the point that less propeller thrust was required than at the time of the Malliga; they confirm that a diameter increase of the order of magnitude made by Josef Malliga provide an efficiency benefit of 4%.

VENTILATION Ventilation is always a problem on HPAs. When the author’s mother first saw the project drawing of Jupiter she asked “How is the poor chap going to breathe?” The author made the mistake of thinking this was nonsense, being more concerned with sealing every gap to reduce drag. On wheel driven machines there is inevitably a leak source around the wheel as on many road HPVs. However, on all the early British machines, holes had to be cut to provide fresh air, the air leaking in around the wheel not being in the right place. Later HPAs show sophistication in the breathing tubes with the Daedalus being a good example; the inlet was carefully positioned and the duct shaped to minimise energy loss.

VENTILATION, COOLING & DE-MISTING METHODS have included:

* Doble Glazing
* Proprietary de-mister
* Vent Duct
* Use of non-perspiring pilot during taxiing
* Sun-shade above pilot

On the Malliga, ventilation was provided by the simple expedient of extending the fairing only to the pilot’s shoulders, leaving the head in fresh air.

One could say that the weight-cost of ventilation-provision would be a credit. (Some flights on Light Eagle and Daedalus were made without the pilot's door).

MALLIGA LATERAL CONTROL In the shorter wing configuration, Malliga used rotating wing-tips together with tip-spoilers. The tubular spar presumably provided a convenient hinge-system for the rotating tips. Such devices have the advantage of generating less torque on the wing-spar than ailerons.
With the longer wing, to quote Sherwin 1976
"...conventional ailerons which operate in a differential manner, being linked to both the aileron control and rudder control. With aileron control being exercised to keep the aircraft level the ailerons operate in a conventional manner. However, when making turns with the rudder, the aileron at the inner wing tip moves to a vertical position and acts as a drag brake to aid the turn. The modifications were completed by mid 1972." It sounds as though Malliga was on the right track! (see Gossamer).

SM-OX see table of types.

"MAN POWERED FLIGHT" So titled, the first book on the subject, was written by Dr Keith Sherwin of the University of Liverpool, England, in 1971, (see Bibliography). Published by the publishers of "Aeromodeller". Ron Moulton, editor of this magazine, later served excellently as Chairman of the RAeS MPAG And later the Chrysalis HPA was built as a "scaled-up model". The book marks the start of the link between the two pursuits.

OTTAWA Czerwinski developed a new method of strong lightweight construction for HPA (Czerwinski 1967). This uses a framework of aluminium tubes. The joints are made by lashing with glassfibre. This principle was used by the Dumbo/Mercury, and heralded the use of lashed tubes of more modern materials. A two-seater aircraft with two propellers was designed using this constructional system. The author knows of no record of flight trials.

DUMBO/MERCURY

P. K. Green, W. F. Ball and M. J. Rudd were employed at BAC Weybridge, UK. This airfield is of interest, having been built on the famous Brooklands race-track, and was the home of the Vickers-Armstrong Aircraft Company, now part of BAC. It is south of London, not far from Farnborough.

The project started early in 1966. The aim of the designers was to increase wingspan without increasing weight. They considered that much of the weight on a wing is there only as structure to resist the loads, particularly torsional loads which occur when ailerons are used. They estimated that by eliminating ailerons, a 120 ft wing could be built for the same weight as the 80 ft wings of SUMPAC or Puffin. For lateral control the whole wing twisted from the root.

In 1967 they learnt of the Czerwinski method of joining light alloy tubes as developed by the Ottawa group (JRAeS Jan 1967) and decided on this method of construction. Test-pieces of wing-spar (but without the enveloping secondary structure), the proposed transmission system and the innovatory wing-hinges were tested with practical help from the company. These hinges were not the simple affairs of the Mufli because this was a fully cantilevered wing.

A recumbent pilot position was chosen, and a tail mounted propeller. With a shaft to the propeller, the rear part of the plane was like a neater version of the Puffin, having all moving surfaces.

Construction started in mid 1968. As for Puffin 1, the wing spar was built curved so that it would straighten out in flight. The spar and the fuselage frame were girder-principle, built up from light alloy tubes etch-milled down to a thickness of 0.010. The etch-milling was done by the company.

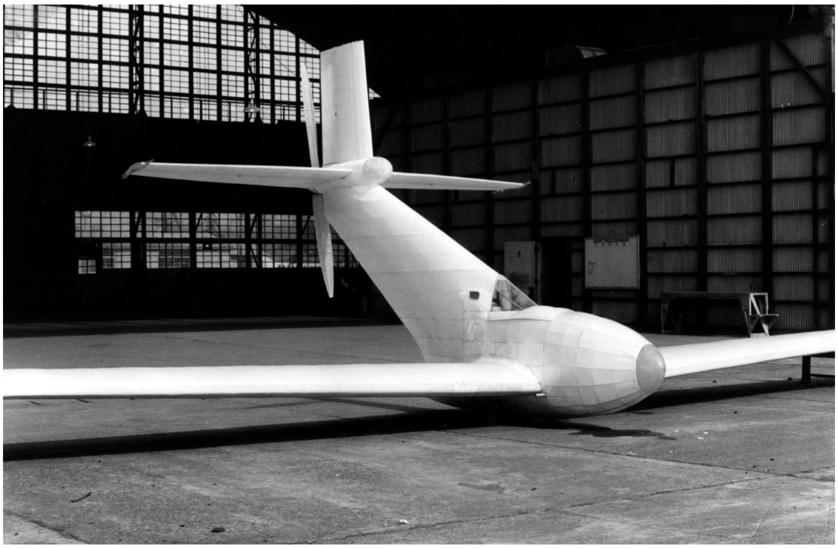
Etch-milling involves chemicals of a strength which take it out of the realm of "kitchen-table" processes. However, using suitable precautions, later groups devised their own equipment. (See Gossamer Condor & Monarch).

The parts for the secondary structure were made in member's homes. Each elaborate built-up-balsa-strip fuselage frame was quite a piece of work in itself, but the individual ideas of each member are apparent in these, as in the wing ribs. It appeared to the author when he viewed the machine that not as much loving-care had gone into the nose-skinning as had gone into the components. The wing was not a smooth shape and the associated high profile-drag must have offset the advantage of reduced induced drag from the enormous span.

Dumbo was originally covered in transparent Melinex; close scrutiny of the photograph in Sherwin's 1971 book

Reluctant Phoenix.

Photographer unknown.
RAeS HPAG archive.



Nihon University *Linnet I*.
Picture taken by Mr. Hiroshi Seo.

Mallaga flying.

Photo Foto Hruby.

(page 116) is needed to see that it was covered. The same photo is in Reay’s book with caption *“uncovered!”*
When built, the centre of gravity was found to be further aft than required for stability. This meant that ballast had to be added, and it was at the nose that it was needed, so there was not much moment arm to help.
First flight, with Chris Lovell, cyclist and glider pilot in Dumbo’s rather cramped cockpit was on 18th September 1971. The name “Dumbo” was a joke which stuck, because someone thought it looked like an elephant with big flapping ears because the wings were so flexible.
Performance of Dumbo was disappointing considering its wingspan, and there were only a few short flights at Weybridge, partly for lack of pilots. Dumbo was found to be directionally unstable.
The plane was taken over in April 1974 by John Potter who had gained experience restoring and flying Jupiter. He refurbished the wing and renamed the plane Mercury, but it did not perform much better than it had at Weybridge. First flight as Mercury was July 1974. Potter gives some tips for ground-handling and hangar-storage in his account (Potter 1975).

NORTHROP INSTITUTE of TECHNOLOGY

Malcolm Smith of NIT, Los Angeles, USA, and 200 students were building a two-seater MPA in 1972. This would have had a wing of 78 ft span and 288 sq ft area. Using a Mylar/Honeycomb sandwich they hoped for a very low wing weight and an accurate manifestation of a modified Wortmann section.
The proposed crew were pilot Rose M. Licher and an athlete Scott Claypool.

MAYFLY

This unfortunately named machine was from the author’s viewpoint, *“the other Essex project”*, (Southend and Woodford being two towns in the English county of Essex, 40 miles along the Thames from each other). There were several other similarities with Jupiter. The wing foil section was identical (NACA 65_3 - 618), and the wing structure was similar. On both projects, the building work took much longer than first estimated, there being several optimistically forecast completion dates which did not materialise. Beverley Shenstone used to visit and encourage both groups, sometimes on the same day. Neither project met with success while in Essex. The first Southend design incorporated a tubular wing-spar. This design was not awarded a RAeS grant. The first Woodford, Essex design incorporated a tubular tail-boom. In 1961 this was not awarded a grant either. The Melinex used on both machines was aluminised, rather than the more commonly used clear plastic.
The original Mayfly design was by Brian Kerry, an aerodynamicist working at the then Aviation Traders company.
Kerry’s design was in 1960, that is before any human had flown. This design was modified by other group members, and after comments from members of the RAeS MPAG committee. The front view of the fuselage was, in its final form, rectangular, to accommodate the two crew side-by-side. Wingspan was 90 feet and area 405 sq. ft.
Construction started in the summer of 1961 with completion estimated for May 1962. As it transpired the first attempted flight was in July 1965. The Mayfly did not fly, although some observers claim they saw light under the wheels on some runs.
Layout and control surfaces were as a conventional glider. The propeller was on a pylon at the nose. The wing structure was a single spruce and ply spar, with a nose torsion box of 1/16th balsa with the grain in line with the span, (cf Puffin I diagonal grain and Jupiter 2 ply diagonal balsa skin). Drive to the propeller from the two recumbent crew was by twisted chain. Mayfly had a nosewheel, and the main wheel was driven.
With its silver covering, in Shenstone’s words it “looks just like an aeroplane”, and it had been built following the same principles as the other sixties British planes. Yet it did not take off, despite an airline pilot and racing cyclist sitting side-by-side and doing their best on ground runs. Here are some possible reasons: The many modifications to the design of parts of the plane, such as widening of the cabin during the building, precluded a neat result. The wing was warped, and there was insufficient spirit left after all that time to rebuild it, which is understandable considering the labour-intensive construction methods used at the time. The transmission system involved 3 bearings in-line at the pedals with insufficiently rigid support.
Other problems included: finding money for insurance premium: difficulty with rigging due to a redundant structure (too many points needed to line up at once and not all of them did): cg not being where intended: and difficulty for the crew to get in and out without damaging the fairing.
Brian Kerry says (1989) “We were all very young at the time and with hindsight, there are some things we

would have done differently, but I believe that the two-seat concept is worth pursuing.” No help had come from the firm, and there were no experienced people frequently around, or anyone “keeping a fatherly eye”, as he implied had been the case at Southampton (SUMPAC) and Hatfield (Puffin), although he agreed with the author that Beverley Shenstone had to a certain extent fulfilled this role.

As for group-structure he said that “we were not just a loose assembly of people but the group structure was a bit weak.” He spoke of the difficulties of keeping people motivated in a project which goes on for years. Much of the construction depended on voluntary help from local aero modellers putting in long hours. Towards the end, motivation dropped off, the team broke down and when the end wall of the Nissen hut at Southend, in which the derigged plane was stored, collapsed in 1967, causing damage to all three wing-sections, the heart of the group finally went out.

However, Kerry considers that the fundamental design of the Mayfly was as sound as any of its contemporaries.

The propeller, designed by Brian Kerry and made by Martyn Pressnell was salvaged and used on Toucan.

THE AUTHOR’S SUBJECTIVE ACCOUNT of JUPITER

One of the first things I was taught at school was that I had spelt my surname wrong. To prove teacher wrong took twenty-four hours. I took my birth-certificate to school the next day to show that I had spelt it right.

Another thing I was taught at school was that in order to fly by your own power you would need arm muscles six feet (two metres) thick. To prove teacher wrong in this instance took twenty-seven years and the help of a lot of other people.

MOTIVATION I have always been interested in off-beat vehicles. In 1947, when I was 10 years old, I made what was effectively a skateboard. Unfortunately this was hampered by a fifth wheel in front for steering, and was much too long. When cycling down and up the valleys of Berkshire in my early teens, it often occurred to me, when about to descend a hill, how good it would be to be able to cut across in a straight line through the air to the top of the next hill.

PREVIOUS EXPERIENCE I was an aircraft engineering apprentice from 1953 to 1958, and a design draughtsman until 1961, thereby gaining experience in many departments of aircraft-manufacturing firms, both in the technical offices concerned with design of airframes (not engines) and in workshops. With the possibility of sometime building an HPA in mind even then, I wanted to get experience in one of the offices concerned with production (analogous to the builder, rather than the architect, of a house. Quantity production is not necessarily implied; the ‘production’ departments are busy on prototypes as well). However it was generally considered necessary for an apprentice to be versed either in design or in production, but not both, so I was never worked in a production department.

My main hobby was building canoes and then paddling them. These were all made with a spruce framework onto which was stretched a canvas skin. (Fibreglass was being used by others for some sailing dinghies). In one of these canoes I travelled down the Thames from home, and then around the coast and across to France, camping overnight on the way.

1950s The 1950s in Britain were a time of expansion. The Festival of Britain in 1951 showed that the nation had got its breath back after the war. For the first time ever there was a ‘youth culture’ exemplified by rock-and-roll, and there was the money to buy gramophone records, teddy-boy clothes and motor-bikes. The power of youth was increasing and in 1958, as conscription for two years of ‘National Service’ (the draft) ended, many males suddenly discovered that they had two years of unexpected freedom.

1959 In 1959 I was feeling that I would like to attempt something more original than another canoe and was wondering whether to build a human-powered submarine or a human-powered aircraft, and had started calculations and sketches for the former.

Nobody offered a prize for a human-powered submarine in 1959, but I can remember being at home in my parents’ suburban house where I lived, one lunchtime that November, and turned on the wireless to hear, as the valves warmed up, ‘...businessman has offered a prize of five thousand pounds for the first man powered flight. Our next broadcast .... ‘.

I wasn’t interested in their next broadcast, and suddenly I wasn’t interested in submarines either. I reached for my slide-rule and started to calculate how much wing area would be needed.

At this time I was more ignorant about what an HPA would look like than anyone reading this, although within a few months I began to get to hear of Mufli and Pedaliante through the RAeS MPAG. The details of the first Kremer Prize were not published for two months. I made a mistake that was consistently made by many people for several years, namely to suppose that anything that could fly would be able to get round the figure-eight course.

I was a 22-year-old with no tools but those I built canoes with, and those I shaved with. I did have a Higher National Certificate in Aeronautics, and I was full of optimism. I even convinced myself that my ignorance on the subject of engines was almost an advantage on a plane that would not have one! Muscle-powered-flight had never been accomplished and maybe it would never be, but if anyone was going to, it might as well be me.

1960 There was another big event in my life in 1959. I met Susan Jones, later to become Susan Roper. This was three weeks after the Kremer announcement. Before long I had to tell her 'Look, I am building an aeroplane', 'I will help' she replied. I was 22, she was 19; we thought it would take two years. As it transpired she devoted eight years of her life to me and to the project. We married in 1963.

INITIAL DECISIONS

It never occurred to me that any type of aircraft other than a monoplane would be the appropriate layout. A cycling attitude for the pilot was chosen because it would require no experimentation. Bicycles work. You can take a dynamo drive off the wheel. I would take the propeller drive off in a similar way. However, there was no point in the weight of two big bike wheels and centre-of-gravity calculations of my first sketches showed the wheel position to be interfering with where the pilot's feet should be. To make the pedals and wheels concentric as in the "penny-farthing" bicycles seemed to solve this, and my 1960 design had this feature. This dictates a minimum wheel size for the feet to clear the fairing (see fairing in Glossary) and the fairing to clear the ground. During various re-thinks, this layout for the front end remained.

My brother Geoffrey and I conducted some tests bicycling up and down a hill to determine power-output and air-resistance of the unfaired cyclist. The strengths of a few wood/glue/wood joints were tested. My job at this time was design draughtsman for metal aeroplanes. I needed to fill out the gaps in what I would need to know. At about this time, (early 1960), I visited "The Cycle Show", an annual event in London, to see if there was anything which might be relevant. On one of the trade stalls were displayed a number of samples of chain. 'Do you have a chain that twists?', I asked. 'Our chains do not twist' was the emphatic reply of the salesman. I then took hold of one end of the yard long sample of 8 mm pitch chain with my right hand and of the other end with my left hand - and twisted - easily. I looked at the salesman. 'Our chains do not twist' he repeated in exactly the same tone of voice. The drive chain for Jupiter was therefore acquired through a stockist, rather than direct from the manufacturer. This chain is about a third the weight of bicycle chain. I made, by hand, an 8 mm chain-wheel and sprocket to suit my bicycle and road-tested it for a year, before it showed signs of wear.

OPTIMISATION

There are various methods of arriving at the best size of wing and of making the other quantitative design decisions. In 1990 it is common to set up a computer program, but this will often be preceded by one of the more primitive techniques. I saw that the most important thing was to so arrange matters so that the pilot would not have to pedal harder than necessary. The job was to find the combination of span, area and other parameters which would produce the lowest value of power required. Thus the power-required would be the parameter which would be optimised. All these things that are being varied are numerically definable, and at this stage exist only hypothetically. But the final sizes chosen will be translated into concrete reality.

I would list a set of values, sufficient to define the size and the general shape of the aeroplane, seeing always that each value was within practical constraints, and then calculate the result, namely the required power with that set of dimensions. Then one of them would be varied and the process repeated.

In order to do this one needs a set of assumptions, for instance as to the manner in which increasing the size of the wing will increase the weight. I made the best estimate that I could, which at that time was based mostly on guesswork. No-one knew for sure how much a 60 ft HPA wing would weigh, or even how much less it would weigh than an 80 ft HPA wing.

Although I had studied aerodynamics, there was a certain amount of guesswork here as well, because although the principles of flight were to be the same as for any conventional aircraft, the expected profile drag could not be accurately predicted, since flight would be outside the range of Reynolds' Numbers which had previously been of interest.

AEROFOIL SECTION

The aerofoil section chosen for the wing was NACA 65_3-618 which seemed to be the most appropriate. I boldly extrapolated the published drag figures down to the relevant Reynolds' number. The second 6 denotes camber, and of the sections of various camber for which ordinates had been calculated and test results published, this was the most cambered section. It did occur to me perhaps to try to squeeze a little more lift out of the wing by adding another 2% camber (2% of the chord, over the length of the chord). This would have meant extrapolating beyond the published data. I decided against this, because I preferred to stay with what had been proven and because down-ailerons would be adding yet more camber still. Meanwhile the Southampton group had done just this, but they knew that they could tunnel-test their own section.

FIRST WING TEST SPECIMEN

One of my colleagues at work suggested making a test-section of wing, a few feet of span, at full scale. Making this would serve many purposes, provide an estimate of the likely weight of an entire wing, demonstrate and provide practice on a form of construction with a good enough surface profile shape and give an indication of feasibility in general. I discovered that thin wood just doesn't seem to stay where you put it, and this is particularly the case when it is covered and doped. The shape was awful. This was clearly an aspect of the project that would need further attention if a laminar-flow aerofoil was going to be used, and for a while I considered basing the design on another wing section."

1961 DIRECTION? Initially, these various items of work such as tests, calculations and finding what chain and other necessities were available were not well co-ordinated. When RAeS grants towards HPF projects were announced in mid 1960, I started to prepare an application for one of these. The grant application forms of that time requested information on many relevant aspects of the project, some of which I had considered insufficiently, if at all. Thus I was encouraged to consider the project as a whole, rather than just parts of it.

TAIL-BOOM DESIGN & APPLY FOR GRANT My 1961 design, the 'Hodgess Roper', showed a span of sixty feet, an area of 200 sq. ft, and the pilot without a fairing, although I wrote that this could always be added later. On the drawing, the propeller was just aft of the wing, and from behind the propeller hub extended an aluminium tube, at the aft end of which the tail surfaces and a skid were fixed. As far as I know (1990), this was the first drawing of a propeller concentric with a tail-boom; although the design published by Beverley Shenstone in 1957 showed the propeller in a similar position but around a more normal fuselage. The time-estimates which I quoted in the grant application were little more than guesswork. The grant was not awarded, but the experience of having made the application was useful. I continued to refine the design, and to make tests. Also I attended all of the RAeS lectures on the subject of HPF.

PROPELLER and TAILPLANE I decided to make the propeller first. I felt that being the smallest component it committed me the least. Also I felt that if I could make this complex shape then I could certainly produce the simpler shaped components. It was quite satisfying to see the blades swing.

In the front room of Susan's flat a jig of 2 inch by 4 inch timber was erected for the construction of the tailplane. This jig was subsequently used for the other tail components. Susan was helping with the construction, working to a high level of accuracy.

1962 TUBE ORDERED The aluminium tube that I needed for the tail-boom, 2.5 inch diameter and 0.022 inch wall thickness, was not a standard size, but British Aluminium Co. Ltd quoted me 19 pounds 6 shillings and eight pence for 4 lengths of 17 feet. This was ordered in November 1961 and arrived in January 1962. It was the most expensive item up till then.

TAIL to BOOM The tail components were completed and assembled to one of these lengths in my father's garden, taking up half the lawn. One of my sisters boldly declared that any aeroplane which you needed to pedal would not be so good as one that you did not have to pedal. To a greater or lesser extent my other 4 siblings gave occasional help, and tolerated the monopoly of the lawn. The work was being done mostly by me with assistance from Susan.

Despite the domestic surroundings, I was working as I would on any aeroplane. A record was kept of the weight of each part, and test pieces had indicated that each part would be strong enough to withstand the loads which I estimated would be applied in flight.

Looking back, I can see that I was excessively aping standard aircraft practice, for instance ball-race-pulleys were used for the control surface hinges. Another mistake was an over-elaborate detail design. The tailplane tips were built up like half a model-aircraft fuselage with their own frames and stringers.

SIR STUART MALLINSON CBE DSO MC JP DL It began to occur to my father that there was not going to be room for the wings in his garden, and he contacted Sir Stuart Mallinson who was one of the more colourful characters of an otherwise dormitory suburb. His grandfather had started the Mallinson plywood factory, which had flourished, and Sir Stuart had a large estate bordering Epping Forest. He was a prolific benefactor and interested in sport and in enterprise. A part of his estate was open for Scouts to camp in, and he was allowing Christine Truman the free-run of his tennis-court.

Sir Stuart was invited to view the tail on the lawn. He was impressed. He would provide spruce for the wing-spars and advice on how to use it, and he offered the use of a double garage for construction. In August 1962, Susan and I carried the components there.

REDESIGN WING The new surroundings elicited a new approach from me, and I began to re-appraise the design. I was now free to think wing. I took advantage of accounts of SUMPAC and Puffin, and I now had the experience of the tail fitted to the boom.

ANOTHER WING-TEST-PIECE The first job at Sir Stuart's was to make another wing-test-specimen. This was of 3 ft span with the same 5 ft chord and the same taper as at the centre of the proposed wing. After many amendments this proved satisfactory in all respects. We developed the technique used on Puffin of using sponge under the Melinex. The weight was less than estimated. Crude timber girder extensions to the spar at each end made a thirty foot bridge, the wing-specimen being the centre-section of the bridge. Thus the specimen could be tested structurally. On first tests the joint fittings to the extensions, which were to the design of the transport-joint fittings of the actual wing, tore away from the spar. Mallinson's (Sir Stuart's firm) made up some special sheets of birch ply bonded to light alloy. The fittings were cut from these sheets and then glued to the spruce booms using wood glue. These held.

However there was one thing that those working in Sir Stuart's garage could do, and those in his plywood factory couldn't. That was to make balsa-plywood. We heard from members of their technical department that the Puffin group had approached them with just that request, and Mallinson's said it couldn't be done. Puffin I wing was skinned with a single thickness of balsa. This involved the complication of a two-cell torsion-box, the grain of the wood being different in each, so that torsion in either sense would be resisted. We had already been using our home-made balsa ply on the tail-components of the 1961 design. The details of how to make such panels and other techniques used are described more fully in 'Aero Modeller' (Roper 1973). I used the data from the weight of the test-specimen, and each part of it, to re-optimise the wing, and to finally establish Jupiter's wing dimensions.

The actual weight of the wing was in excess of the value estimated from this test-specimen. To a considerable extent this was because we could not control the weight of glue on a large assembly so readily as on the test-piece; for on a large assembly there is an urgency to get the whole area wetted in a certain time. John Potter quite rightly blames the Woodford people for this (Potter 1973).

COMPUTER The ordinates for each of the 55 rib stations along the wing were calculated by a colleague of my brother John Roper who, on the staff of Manchester University at the time, had access to one of the few computers in the country. My brother offered other computer-help, but I didn't know what other questions it could answer. Writing programs and even the range of programs that could be written were mysteries known only to a few. Optimisation was done by calculating a series of values by slide-rule, and plotting graphs. The prop design was particularly tedious and took 3 weeks use of log. tables.

CONSTRUCT WING Spruce and balsa were ordered and we launched into the construction of the wing. This had a main spar at 40% chord, with spruce booms and balsa-ply web. Skinning with balsa-ply between there and a front spar at 7% chord completed the torsion box. The nose forward of this was skinned with spanwise grain balsa. Ribs forward of the spar were of 1/16 inch balsa-sheet and were stacked in a pack 20 inches high and sanded to profile together. Aft ribs were balsa girder construction. The only jig used for the wing was an 18 ft long bench.

The spars, skin panels and the five sections of the wing were all made on this bench.

HELPERS at WOODFORD, ESSEX I came to adopt a policy of inviting someone to join us only if they could demonstrate an ability to perform at least one relevant task better than anyone else in the group. Susan and I had help with construction from John Bowan, Martin Gelling, David Green, Victor Hurran, Eric Gilbert, Helen Kuczinska, Geoffrey Roper and Jennifer Roper. Victor Hurran, who was a student at the City University, London at the time, was able to make an analysis of the aircraft's flight dynamics, with other students including Dave Newby. This counted as part of their course and they used the college's computer. The result was that a dihedral of 5 degrees was recommended for stability. Alan Vincent, an ex-colleague of mine, gave design advice from a prospective pilot's viewpoint. On one occasion he took Susan and me in a light aircraft to West Malling, one of the airfields we were considering.

1963 REDESIGN FUSELAGE

In January 1963 I redesigned the fuselage. The existing tail components and the propeller were to be modified to suit. I discovered that a propeller, efficient under the flight conditions of the new design, could be made by adding 9 inches to the tip of each blade. The lower part of the old fin became the upper fin on the new configuration. The original ball-race bearing is still there at the top of the fin. At this stage the original tailplane was incorporated, but before flight this was replaced. Tube as bought for the boom was ideal for the pylon structure.

I realised that the pitching moment of inertia on an HPA was likely to be considerably smaller than the moments of inertia about the other two axes. In the belief, at the time, that flight-dynamics would be improved if this disparity was minimised I drew Jupiter with a long fuselage.

In deciding the wing position relative to the fuselage, there were three considerations:

In a 5 degree bank, the wheel must be lowest point.
The lower the wing, the more beneficial ground effect.
Interference drag must be minimised.

INTERFERENCE DRAG Having heard of the problems SUMPAC had encountered with interference drag at the pylon to wing junction, I gave very careful attention to this area. In our case the top of the canopy would also be above the wing. It was arranged that at no point would the region behind maximum thickness on any two of these components coincide. The base of the pylon has greater chord than has most of its length; not, as it might appear, for structural reasons but so that for the thickness necessary for chain clearance a section of lesser thickness ratio may be employed.

The small pod at the top of the pylon could have fulfilled its task of fairing the top of the transmission without protruding forward of the pylon. However, drawn like that it looked hideous, and a few square inches of area were added for aesthetics.

The shape of the front fairing was dictated by my choice of a cyclist attitude pilot, and this was faired in to a glider-style rear fuselage in a functional manner. The point of inflexion of the "S" curve so formed was arranged to coincide with the joint of the fairing.

The rear-fuselage was designed with stringers along the sides and top to split the Melinex panels down to a size which would not flap, and to keep the Melinex away from the struts. They would also reduce the effective strut-length of these members. Because of a misunderstanding these stringers were eventually assembled inside the struts.

The lower fin neatly houses the tailwheel and reduces the torsion applied to the rear-fuselage under rudder loads, by partially balancing the load from the upper fin. It was proportioned so that rear-fuselage torsion resulting from side-load on the tailwheel had the same magnitude as in the rudder-applied case.

VISIT BY PRESIDENT RAeS Susan had kept us in touch with the RAeS MPAG, and in February 1962 it was arranged that Beverley Shenstone would visit. This was his year as President of the Society. I couldn't believe it. He came. He was impressed. "That looks more like an aeroplane", he said, looking at my drawing board. This despite the fact that the scheme of having the propeller concentric on the fuselage, as originally proposed by him for HPA in 1957 had been abandoned. He saw the pack of wing-nose-ribs which was declining in height as we took them off the top for assembly to the spars, - indicating progress.

GRANT We applied for a grant from RAeS MPAG funds for completion of Jupiter, to my 1963 design. We were successful. In total, nine increments of £100 were claimed. On each occasion we had to justify past expenditure. There was minimal delay, because of the system of delegation then in use. Many materials were given free by the manufacturers, and Sir Stuart was providing space, heating and lighting.

Wing construction continued during that year.

In 1964 I turned my mind to the details of the transmission, and this and the seat frame were made. There are four rotating parts. The pedals and wheel are concentric, and a chain from the pedals drives the layshaft at a gear-ratio of 2/1. From the layshaft a chain twists up to the propeller shaft and another chain takes the drive back to the wheel. This all worked satisfactorily when a spring-tensioner had been added to the propeller chain. The layshaft was arranged to rotate at double pedal speed in order that a Bradshaw spring could be incorporated.

BRADSHAW SPRING This is a device to reduce the cyclic variations in torque. A crank on the layshaft is connected to a spring. This spring will be loaded while either of the feet are at the front and will unload, returning its energy, to help carry the feet over the top and bottom of the stroke. On Jupiter the shaft was made to suit the fitting of such a crank, but no arm or spring was ever fitted.

Manufacture of some of the transmission components and the brazing of the seat frame were done outside by specialist firms. The rear-fuselage structure was made and by July 1964 we were able to invite Mr Shenstone to witness testing of the transmission system. He sat and pedalled it himself and the propeller spun and rustled the leaves on the trees of Sir Stuart's famous arboretum. Wing construction was complete by the end of 1964.

1965 CONTROLS I had considered all the possible combinations of pilot-hand-movements to correspond with each of the control-surfaces. It annoyed me that the only logical one was a copy of the Puffin. Already the nose looked like that aeroplane, and I would have liked to show some originality. I rigged the controls so that rudder operation is in the same sense as the steering of a bicycle. Later I learnt that the Hatfield group had followed an aircraft-rudder-bar, which is the opposite way. Another innovation was to make only part of the length of the elevator twist-grip movable. I felt that this would enable more precise control. I couldn't imagine applying aileron and not inadvertently applying elevator without a fixed part of the hand-grip to hold onto.

Aileron linkage was designed with two options. The first was a simple linkage so that one aileron moved up the same amount as the other moved down (Max. +17 degrees, -17 degrees). The other option was to have one move up and the other not move (+45 degrees, -0 degrees). This would involve restraining springs. John Potter did not like the idea of springs and only the simple system was used.

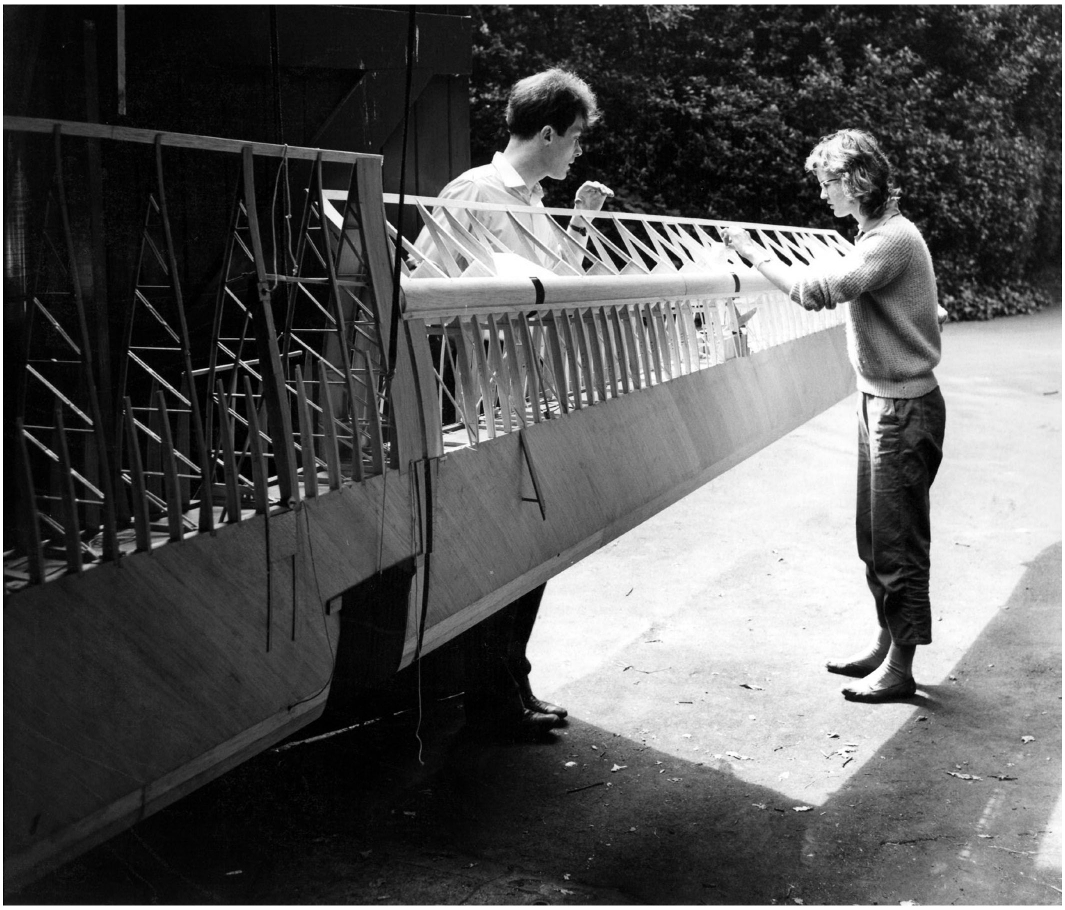
The control bar and some of the control linkage was completed at Woodford, Essex. All the balsa hoops for the cockpit canopy were made and this was partially assembled.

At this time, it seemed evident that Jupiter would fly. It also seemed evident that it was unlikely to fly the Kremer figure-eight circuit since it was similar to others that had not done so. However I was confident that since there were so many "measures" such as altitude, turning ability, duration and rate of climb, that there would be one at which my design would excel, but couldn't then specify which of these. As things turned out, John Potter decided to go for distance, and made a record. The plane was also recognised as having the most accurately made wing-profile. I hadn't seen the other wings and assumed they were being made as accurately as ours.

VISITORS Some visitors to the workshop treated the partly-built aircraft as though it was more fragile than it really was, but sadly that didn't make up for the others! Bitter experience showed that usually there is a complete lack of appreciation of what can be handled and how; in particular, that a half-built component is more vulnerable than it will be when complete. 'Friendly' photographers assumed a divine right to anything and were amongst the worst. No malice was involved, and therefore further damage was often done when they tried to 'just put the bit back again'.

Notices were found to be useless, verbal requests little better. One trick that was found to work quite well was to realise that they will handle something, and to hand them an old test piece.

In order to help prevent ourselves from blundering into anything that mattered, we had been found it worthwhile to arrange a few inches of scrap wood jutting out from any component so that one only snapped this stick off if passing too close. Use of these sticks provided the clue to the most effective guard against visitor-damage. A few more were added, typically along the span, and it really did work like magic in keeping anyone off. Present someone with a component in its assembly jig, and they would always reach forward and feel it. Fix a few two foot lengths of 1/8th inch square balsa projecting from it, and although they were perfectly capable of reaching past these spikes, experience showed that they just didn't. Surprisingly, it works.



Chris and Susan Roper working on the wing of *Jupiter*.

Photo Kenneth Bray. RAeS HPAG archive.

Chris and Susan Roper with the fuselage of *Jupiter*.

Photo Kenneth Bray. RAeS HPAG archive.

The authors subjective account Jupiter

This was my experience in Sir Stuart's garages. It is true that the spike principle is effective in minimising damage both from constructors clumsiness and from outsiders. However it is clear that at best this is only part of the answer to a problem that I failed to solve. Another recommendation, which again is only part of the answer, is to acquire a trailer at an early stage and use it to store any parts not being worked on. You're going to need a trailer eventually anyway.

1966 Another of the mistakes I was making was not to realise to what extent skills other than engineering were needed.

EXPONENTIAL "PROGRESS" It was around this time that work started to slow down. Half of what remained to be done was being done each year. On this basis it would take forever. The reasons for this were all organisational, not technical:

NO AIRFIELD The authorities at various airfields were contacted. In some cases they even said 'Yes, bring it here', but the plane was not ready at that time, and we could give no definite date when it would be. In other cases hangar rent was prohibitive. It was realised that a grass field would not be adequate.

NOT ENOUGH PEOPLE During 1963 and 1964, over half of an aircraft was built with not much more than one person working normal hours. If we count this as equivalent to 1 1/4 people, this implies 10,000 hours total construction time. Figures of the same order were quoted by members of both the Puffin and the Toucan groups. Thus the basis on which the work had been progressing could be said to have been satisfactory, if it could have continued. At this rate construction would have been completed during 1966. However, the time involved in making arrangements for a move was not now (1965 onwards) being spent on construction. It was also felt, at the time, that more people, conversant with the project, would be needed during and after any move.

LACK OF FINANCE From 1963 onwards, Sir Stuart had provided building space, and materials had been donated by firms or bought from the RAeS MPAG grant. Domestically, Susan had been the sole breadwinner, thus supporting me, but this had meant that money available for luxuries amounted to little more than the cover price of "The Observers Book of Astronomy". There was no money or hope of money to cover moving and flying expenses, nor the additional domestic costs this might incur, although we had gone as far as obtaining a small caravan and locating this close to an airfield at which we had been given permission to operate the aircraft. However the airfield circumstances changed, and the caravan was towed back to Woodford, Essex.

MORALE 'Oh, I would never have the patience, I am surprised you have', was a remark often made by someone seeing the amount of work involved. Logically, it can be inferred that the magnitude of the speaker's surprise would have been less if morale had started to drop after two years rather than after three years.

But it wasn't so much patience running out as losing a sense of direction. I was motivated to make the spars and ribs because I could see that these would form the wing. I was motivated to make the wing because I could see that this would fit to the fuselage. But there is no incentive to complete the construction unless it can be seen that there are the airfield arrangements ready for the next step - flying.

Love blinds, but I have heard Susan described as a very sensible person. Her support, right up to helping arrange the handover demonstrated an exceptional strength of character and level of commitment. But she also, after so many years of the lifestyle we had chosen was feeling and showing the strain. The strain of thinking up answers to 'When is it going to fly', alone would have been too much for many others, over that length of time.

1967 PROGRESS EXPONENTIAL

1968 DISASTERS 1968 was a year of disasters. One of these was that I was injured in an accident. The 5th February 1968 was the last day I worked on Jupiter until much later.

LOOKING FOR TAKERS Susan and I realised that the best chance for the aircraft was for someone to take over. She wrote to the RAeS Journal and "Flight International" and arranged for them to publish "... should anyone wish to save the project will he contact .. Roper."

1969 Beverley Shenstone (ex-president RAeS) wrote on 1st January 1969 '... I am very sorry to hear of the difficulties and vicissitudes that you have had to bear... ... It appears to me that what you are doing to enable some other person or group to take over the project is the correct thing to do..' and '..write about your aircraft. Describe the technical design, with reasons for decisions made. Discuss the main problems which arose, both technical and organisational. Point out for the benefit of others, things to avoid and things of positive importance.'

Various people showed interest until they appreciated that a take-over would involve them taking it away. One group and one individual visited the garage in January, but declined the offer.

FIRE In June a fire broke out and destroyed part of the machine. From this time on, not being so well stored, the remains further deteriorated.”

1970 JOHN POTTER new management

Flight Lieutenant John Potter MA RAF had contacted the Royal Aeronautical Society asking about HPF and learnt of the plight of Jupiter. A plane without a group. Well, actually the plane was in almost as bad a state as the group. He arranged to meet Sir Stuart and myself at Woodford, Essex to see the hardware.

Number one, chronologically, in the actions for which he deserves special credit is having the imagination to see a heap of rubble and think ‘I am going to transform that into an aeroplane’.

As I saw it then, my options were to allow this man to turn it into a static exhibit at best, or to let it carry on rotting; so I chose the former.

MY FEELINGS (with hindsight) about the HANDOVER

Jupiter was to become the only HPA which performed better after being handed over to new leadership. Is this a point for me to be proud of?

Yes, insofar as John could generally follow drawings originally prepared only for myself.

Yes, insofar as it meant that as mentioned above, Jupiter became in some ways the first non-experimental HPA.

No, since if the mistakes I made had been different ones, the original group could have seen the project through.

I had built the fuselage big enough for my 6 ft 2 inch self, but realised that others have more flying skill. While being sole leader of the project, my intention had been that when it came to flying, that at the moment of take-off the pilot would become the boss. Thus you are flying your aeroplane. It is one system, maybe not the best, but the decision on my part to adopt this policy had partially prepared me for relinquishing control.

HALTON GROUP

On arrival at Halton John and I dumped all the components in the canoe-club shed. The task of convincing others that here there was a worthwhile project began.

Sir Stuart Mallinson wrote to Air Commodore Weighill, the commanding officer at Halton.

“ When Flight Lieutenant John Potter came here, he took away what was left over from a fire of an aeroplane built by Hodgess Roper.

“ .. worked in two of my garages building what he hoped...

“Unfortunately, after 5 1/2 years he had an accident which prevented him for over a year doing anything, and after some 6 1/2 to 7 years a fire broke out and destroyed part of the machine. It is quite impossible for him in his condition to carry on or replace, and eventually he apparently arranged for it to be taken over to your Base. I think there is no question that Hodgess Roper had a good idea and there was a reasonable prospect that he might have been successful...

“I hope it may be possible for you to encourage the finishing of this machine.

“Stuart Mallinson

SUPPORT from ROYAL AIR FORCE

In much the same way as at Woodford, Essex, the plane was moved step by step into better premises. At one time it occupied the only room at Halton College which had access without going around twisting corridors. This was necessary because of the length of the wings.

Other staff, Mrs Potter, and the more senior apprentices became interested, joined the Halton group and helped with the repair and later with the flying operations.

PROJECT MANAGEMENT John’s policy was that if anyone turned up, then he would find them something to do. I took a friend with me to Halton on one occasion and they were promptly given the task of making sanding blocks. In this way, if a person persisted they could then proceed to other tasks, if they didn’t, then at least they had done something. As the group built up, he was able to delegate entire components, and 3/4 of the work of restoration was done in 20 weeks. (Potter 1973)

DESIGN John worked to the detail-working-drawings that I had prepared at Woodford, Essex for my own use. Occasionally I was asked to resolve an ambiguity on one of these or to explain some note that was not clear. It was in doing this that my interest in the project was re-awakened. I made a few new drawings or new copies of old ones.

NEW ELEVATOR The original tailplane and elevator needed replacing, and I took the opportunity of a redesign here, in consultation with John. The new surface was all-moving, had a higher aspect-ratio and was positioned slightly further aft. This component was built at Woodford, Essex in 1971. The original control linkage was retained. Unfortunately this led to flying problems, a small movement at the control bar having too much effect.

I had made outrigger wheels and fitted these just inboard of the ailerons. John decided to dispense with these and they were not used in flight. I feel that this was probably the right decision. The Puffin I outriggers had been removed after early flights. However on Toucan, outriggers at 40% of the semi-span had proved satisfactory.

The Halton group finalised the detail design of the aileron control linkage, and made and fitted these parts.

Much of the trailing edge had warped because of damp storage. This would increase induced drag because the lift distribution would be affected. Looking at it another way, in flight each warp would create its own little additional trailing vortex. So, a lot of the trailing edge was cut away and replaced. The outer wing sections were found to be in good condition and were left with the original blue Melinex covering which Susan and I had put on at Woodford, Essex. The other three sections needed various repairs and were then covered in John's choice of aluminised Melinex.

FUSELAGE TORSIONAL STIFFNESS When the plane was nearly assembled, I noticed that it was very easy to move the top of the fin from side to side because the rear-fuselage is easily twistable. This didn't seem right, but apparently didn't matter, being less critical than wing torsional stiffness. Ironically, it was partly because of the observed low torsional stiffness of the tail-boom that I had rejected it.

HALTON GRASS

Halton is a grass airfield. When the aeroplane was in one piece, John tried some runs there, but was finding that the tail was staying on the grass and with only a small wheel, that end was being alarmingly shaken. Hence he moved the aeroplane twenty miles to RAF Benson. This meant that during all the flight trials, people from Halton had first to make this journey.

During the first runs on the Benson concrete runways the tail still would not lift. Then John found that all that was needed was more speed. This is due to the constraints of this type of layout with the concentric wheel and pedals, affecting the centre-of-gravity position relative to the mainwheel (see Puffin). On Jupiter, more weight is on the tailwheel than one wants for take-off.

I arrived at Halton on February 10th 1972 with a list of a few jobs which I considered needed doing before the plane was airworthy, to be informed that Jupiter had flown the previous day, twice. Three more flights were made on the 13th. On the last of these the wheel buckled on landing. I had seen none of these flights, and it was not until after the 25th February that I was able to write

A LETTER TO MY BROTHER.

28th February 1972
Dear Geoffrey

A great shame you couldn't be there on Friday (25th). Actually we only just managed to get a flight as by the time we had put the wheel back on and a new chain and got it outside it, was nearing darkness.

I believe I told you the wheel was damaged on the fifth landing, and the people at Halton had only just repaired it and took it to the aerodrome with me on Friday.

When we had put the wheel back - a task which was accomplished not without my local knowledge of the particular machinery - it was discovered that the wheel-drive chain had also been damaged during the landing, but luckily we had a spare length and the special tools at Benson. So this was then trimmed to the exact number of links and fitted.

(The old chain which had made five flights was cut up and a short length given to several of those who had helped with the project.)

We then opened the hangar doors, having got clearance to use the runway, and seeing that the weather was calm enough and trundled the machine outside, the wingtips just clearing the sides of the doors of the hangar which could take a Concorde. Taxi to end of runway, and you wish you had taken a taxi because you get more puffed out running alongside than the pilot who can cycle the machine at ten miles an hour with very little effort. Surprisingly, since the aeroplane only has two wheels like a bicycle this can be done without the assistance of anyone at the wingtip to hold it level because aileron becomes effective at quite an early speed, but assistance is required to help turn sharp corners on the ground since the wheels don't swivel to steer. So, having got to the end of the runway you have to point the plane in the right direction. There were only three of us there - John Potter, Ernie Moore and myself on Friday, which is the minimum, one inside and two ground assistants for handling and to put the cockpit hood on which is quite a knack as it has to mate up in several places at once. Having fulfilled these tasks, I was going to act as timekeeper of the flight, and Ernie as photographer. Two youths leaning against the enclosing fence of the aerodrome thought fit at this stage to shout to us "You'll never fly".

On our first attempt that day we actually didn't, this was because I hadn't grasped the fact mentioned above re wing tip holding. I as wing tip holder had held on far too long as I ran alongside whereas I should have let go when the aircraft reached walking pace. All my previous wing tip holding had been with gliders. Ernie claims that it took off and he could see daylight under the wheel while I was still holding the tip. He may well be right, it turns out that the pilot finds it not clear to tell whether he is still on or just off the ground, and on this occasion the feel was further complicated by me holding on. I was looking forward and forty feet from the wheel all the time, and it was beginning to get dark.

We waited for John P to get his breath back before making another attempt. Meanwhile I was thinking that if what I had just witnessed was flying then it was a bit low.

This time he reached flying speed much quicker and when he left the ground there was no doubt at all that he was going up. What impressed me most was the rate of climb, particularly as my calculations had shown and I had read in several places that this would be a most difficult manoeuvre. The aircraft then levelled out to a height well above our heads and giving us the illusion of hovering. Then John must have given an extra burst of energy because the machine once more started to climb and then went off into the distance. Then I realised that I hadn't pressed the stopwatch.

It certainly was a sight worth seeing. The day's events had very much taken the form of going up to a bicycle, fixing the wheel and the chain and then just wheeling it out of the shed and pedalling it into the sky.

I have up to now felt insulted when the machine has been described as a "flying bicycle" rather than as an aeroplane, but once airborne the size is apparently lost amongst the vastness of the sky, and what has happened is that he's pedalled and its flown. It is a Flying Bicycle.

He landed and we ran to the aircraft, and he commented on some minor adjustments we had made to the instruments.

I felt that watching the flight was a worthwhile recompense for having travelled to Halton, travelled from there to Benson, worked on the wheel and the chain and done quite a lot of running along the side of the runway. The true cost, of course, is all those, but multiplied by you-name-it and then put a nought on the end, or two noughts. And whether I feel it was worth this true cost I can't say. Thinking about it since, sometimes I feel I can't say yes and sometimes I feel that I definitely can't say no.'

Geoffrey, to whom this letter was sent, came to Benson in June of that year and observed the record-distance flight. As it happened he had the aggravation of a minor car-accident on the way. I asked him (1990) whether he felt it was worth it. 'Yes, definitely', he replied.

Two more flights were made on the 27th February, and three more on the 1st March.

By the end of 19th March, twenty five flights had been made, the longest about a quarter of a mile.

FLYING ATTITUDE John Potter had made several flights before having the opportunity to observe one from the outside. It was Ernie Moore who gave him this opportunity, by making a few flights. Based on his observations, John was able to establish the best speed and attitude-in-pitch for Jupiter. Following this, flights were of longer duration as they were less exhausting.

TAKE-OFF It was found that aileron became effective at 5 knots, rudder at 8, but the tail did not lift until 13 knots. After this point, John recommends holding the acceleration steady. He later analysed the optimum pedalling effort during the ground-roll in order to be the least exhausted at the point of take-off (Potter 1975). However this analysis omits that the relevant quantity is anaerobic energy. Such an analysis will be vital for take-off from water.

CHAIN TENSIONER It took some time to locate the source of an occasional loud banging noise that was occurring during flight. I discovered that on the ground this could be cured by holding my thumb against the moving chain as John pedalled, and we deduced that the propeller drive chain was sometimes jumping a tooth. Halton group members fitted a spring-loaded tensioner.

DEMONSTRATION FLIGHT

PLANNING The Community Relations Officer at RAF Benson arranged a press-conference for a Sunday, always a good move, namely March 19th. This was to include a demonstration flight. As mentioned in the foregoing letter, I had been impressed by the flight-pattern of holding one height for a while, and then doing a further climb. I discussed this with John, who for most flights had been inside. We agreed to do this during the demonstration flight since with the capabilities of the aircraft as it then was, this was one of the most impressive series of manoeuvres that could be done.

The first flight that day was disappointingly brief, as was the second. By the time the aeroplane was repositioned for another attempt, the wind had sprung up.

Take-off into wind is considerably easier in Jupiter, thus conserving the pilot's energy. John was able to start the series of manoeuvres we had planned. As it happened, just as John started the second climb, the plane met a gust with the result that the climb was much more impressive than we had expected. The effect of the gust was to increase the effective airspeed, and the plane climbed like a kite, the mass of the aircraft being the "string". John levelled out, and for a while held a straight course.

Then a second gust hit the plane, this time from the side. The effect of the gust and the wind-shear put the aircraft out of control

Suddenly I noticed that Jupiter looked different, but it had a familiar appearance. Somewhere I had seen that view before. It took me a few milliseconds to remember that it was on my drawing-board that I had seen that view. It was a front elevation - spot on. Jupiter was heading straight for my bit of grass, it was out of control and losing height. Luckily I had thought out the appropriate response for just such an eventuality. I dropped to the ground. The rationale is that the wing will pass over you. It did.

Seconds later I was on my feet and observing the heavy landing, wing-tip first. I was in line with the wing at this moment and observed it to be deflected into a curve I would not have thought possible, but nothing broke on the wing. A second later the fuselage came down with a thud and its height was reduced to a dimension that was surely not enough to house a living John Potter.

It was a worrying few seconds until Tony Gilchrist and I reached the cockpit and tore away at the fairing, to find John all in one piece.

"Actually, that wasn't supposed to happen", said John for the benefit of the pressmen who were arriving.

It had been Tony who had installed the aileron control linkage, and since it was failure of the lateral controls which had occurred, he promptly checked to see if it was the linkage that had been at fault. It was not so. Photographs show the controls at full deflection during the descent.

DAMAGE "On inspection later it was found that damage was only to the wheel, the cockpit canopy and a dozen spruce to spruce glue joints on the top and bottom of the portion of the fuselage under the wing.

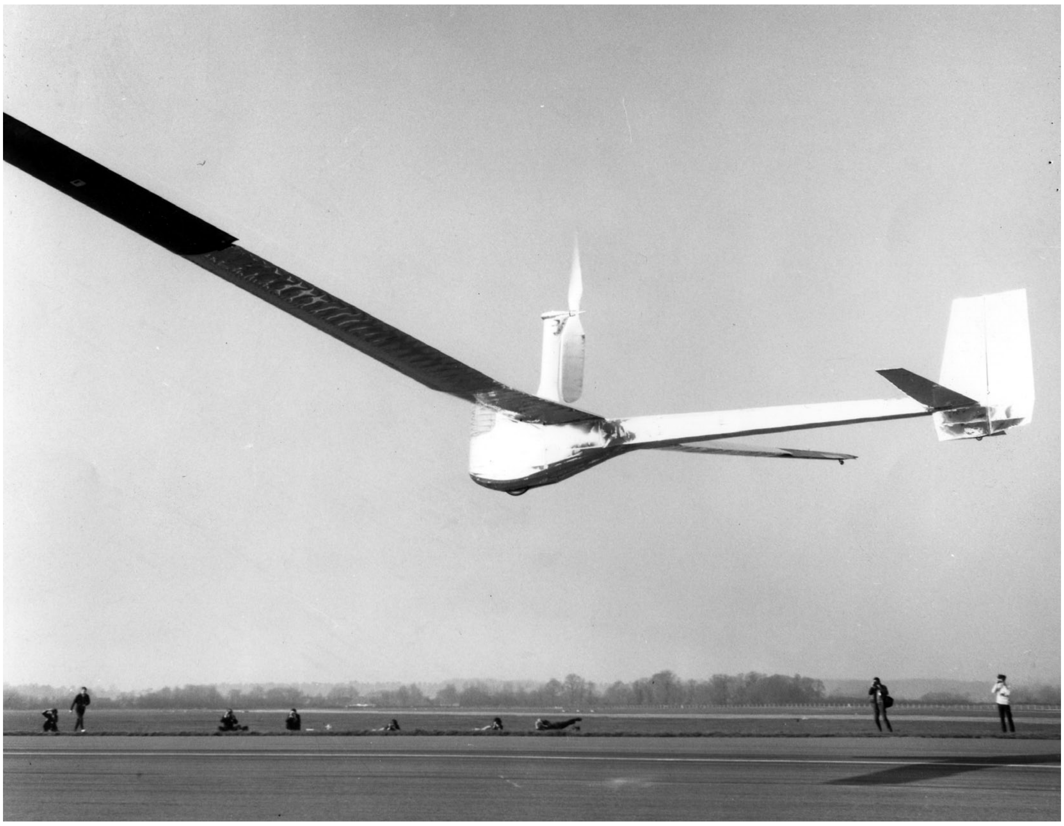
'IT'S DOWN, LET'S KICK IT' Journalists at Benson 1972, who would not have deigned to touch it when it stood majestically in one piece, swarmed forward to have a prod after Jupiter was seen to crash-land. There was already damage which turned out to take six weeks to repair. We didn't want any more. I was the only civilian in the group who was present at the time, and the only person who made any attempt to defend the aeroplane from this aggression.

The Royal Air Force had been invaluable in enabling John Potter to restore and fly the machine, (Seven years later the RAF helped Gossamer Albatross), but my belief in the benefits of national armed forces in general had been declining for several years and took another downward turn when observing their inaction while our aeroplane was being attacked.

This demonstration received greater exposure than that of any other aircraft prototype except the Concorde, but as is usual, some of the descriptions were imaginative. One photograph showing Tony Gilchrist and myself running is captioned "..as running sightseers keep pace with it ..".

Flt Lt A J Gilchrist was effectively the chief maintenance engineer, and as I remember, I had some sort of connection.

NAME During this much publicised flight the aircraft still did not have a name. The previous evening I had thought up two; both retained the tradition of the first vowel being "U". "Unicorn" because the pylon is like the single horn of this mythical beast, and because it was now flying from Benson, the home of the Queen's flight, and the Unicorn is one of her symbols. "Jupiter", after the planet, astronomy being one of my hobbies at the time.



John Potter flying *Jupiter* at RAF Benson

RAeS HPAG archive.

John Potter in *Jupiter*

RAeS HPAG archive.

I had once managed to see this planet in the daytime without binoculars (we couldn't afford binoculars); it can be done if you know just where to look. This had reminded me of the discovery of the planet Uranus in 1781. Herschel first observed this through a telescope, then realised that it can be seen without such aid. Similarly, flight was first made only with the aid of engines (or winches), and now we were doing it without. I wasn't calling it "Uranus" and John didn't like "Unicorn" so that settled it.
REPAIRS "On most trips to Benson, the Halton group would need to do some minor repair in addition to any flying, though not as extensive as after the landing of the 19th March. As a result the aircraft was gradually getting heavier.
MIST The inside of the cockpit used to mist up, and John double glazed a small area for forward vision, and cut some slits. It was necessary for the pilot to do some physical warming-up exercises before a flight. This would mean that the screen would become misted during taxiing. To obviate this John developed the technique of a "cold pilot" and a "hot pilot". The cold pilot who had not warmed up and was not perspiring would taxi the plane to the end of the runway.
INSTRUMENT To indicate attitude in pitch, John Potter added a mercury-switch controlling a red and a green light, powered by a hearing-aid battery. On test it was found that the best attitude was when the green light was blinking. The pilot could tell which light was shining without turning the head. This has been recognised by people outside the Jupiter project as a significant innovation. It certainly made a lot of difference to the actual performance of the aeroplane.

RECORD DISTANCE

By May 1972, John had learnt exactly what speed to fly at for minimum power and how to take-off with minimum energy, and he had done a lot of cycle training. He had told me he was going to give up smoking.

"But you don't smoke", I replied.

"Oh, I smoke about one a week", he said.

"It became clear to both of us that Jupiter was not capable of the figure-eight course. Arguably the power-requirements were too high for the climbs and distance alone. Having to do turns made it out of the question.

What was worth attempting was a new distance record. The length of the Benson runway had been covered several times, and on the evening of June 29th 1972, John Potter was observed to fly 1171 yards.

The configuration in which it established the distance record was the 1963 design from my drawing-board with only the addition of the chain-tensioner and the instrumentation.

We established another 'First' by carrying payload on an HPA, namely printed envelopes stamped 'Worlds First Man-Powered AirMail, Jupiter, 1972'. These philatelic covers were sold to collectors, and raised funds for the RAF Museum.

CRANWELL In 1974 John transported Jupiter to Cranwell, where it hangared alongside the Dumbo/Mercury which he also acquired, but no great success was achieved with either of these planes at this airfield.

In 1978 the Jupiter was retired to the Shuttleworth Collection and remained there until 1982 along with Toucan.

THAMESMEAD FESTIVAL of HUMAN POWER 1984

This was a weekend meeting of HPVs of land, sea and air.
The Jupiter was on static display and the only aircraft, since no current HPA was in Britain at this time. The purple Melinex on the outer wing-panels and ailerons was still drum-tight 19 years after Susan and I had glued it on (maybe only ten years after John had retensioned it). The propeller still spun. Festival-goers enjoyed sitting in it between HPV races.

MAIN LESSONS LEARNED

What I did right:

Design. Used the conventional answer whenever there was one; and if there was not, then thoroughly bench-tested the new idea before incorporation into the airframe.

Organisational. After it became impossible to continue at Woodford, Essex, I handed over as soon as I could.

What I did wrong:

Design. The structural design of the wing to fuselage junction, though satisfactory, could have been neater and lighter. This is one of the ways in which the Stork aircraft was better than Jupiter.

Organisational. There could have been contact with other HPA groups. During most of the time that Jupiter was at Woodford, Essex, we were located not far from SUMPAC (London) & Toucan (Herts). As it was, with no such contact, the sense of isolation was contributory to loss of morale. Links with other groups might also have helped solve the other organisational problems.

Made plenty of other mistakes as mentioned above.

What John Potter did right:

Took the opportunity of taking over in the first place.

Organised the best use of all the facilities that he had available, or could make available, to restore and fly the plane. This included, at the flying stage, intensive use of the "facilities" of the aeroplane itself and his own legs.

What John Potter did wrong:

During re-building, no components were weighed.

There are a few details of the Jupiter which are badly constructed. Most noticeable is the wrinkled covering of the rear-fuselage. This could have been avoided by more consultation with me. In general the standard of construction of the Woodford-built parts is higher.

With regards to flying, as he realised himself and wrote (to me) in 1973

"I hope we shall be able to conduct our (further) trials in a rather more professional manner than we had time for last year (1972). It was all rather a rush, and I am surprised we achieved our results in a very short space of time,"

"But they were great results."

AUTHOR'S 1973 DESIGN, THE 'CHIGWELL'

My next design never flew. It was based on what I misguidedly thought to be the best points of Jupiter and the best points of Puffin II. My February 1973 drawing shows a span of 80 ft, area 380 sq ft, much of it constant chord for ease of construction. Ailerons moving up only and tip spoilers. Upright pilot. Twisted chain transmission to 10 ft propeller mounted behind tip of fin. No rudder.

It was designed to take off from grass.

All moving tailplane, also at tip of fin. Primary structure as Puffin II/LiverPuffin. Secondary structure balsa and EPS. With its low wing position, tapering rear-fuse and "T" tail it looked like a jet transport, and had enormous fuselage wetted area.

Optimisation was based on turning flight.

Constructional test-pieces made. Propeller built by Mike Knight of Essex Gliding Club. Ergonometer made.

METAL CHAINS CAN TWIST - OFFICIAL

Lack of sufficient appropriate support ended the project, but not before I had written to the Application Services Manager of Renold Ltd with regard to use of their chain 51308/01 (aluminium, fits bike sprockets).

He replied '...we confirm that this chain will twist through 90 degrees over 54 inches and although adequate for the loading figures given [cruise 75 lb, climb 144 lb, ultimate 352 lb], we are concerned with the effect of the twist and reverse twist under load conditions and suggest that the system be tested before any flights take place. Also the chain should be visually checked at regular intervals to confirm that the security of the chain parts is still intact.

[It can be arranged that there is no reverse twist, and if there is any, that it is on the slack side.]

Effective lubrication is most important. The lubricant must penetrate between the pin and bush and pin and roller, and to achieve this we suggest dipping into a bath of good quality light machine oil prior to assembly, and re-lubricating regularly.'

1975 Frank Vann, John Potter and the author met in May 1975 to consider a new project, but collectively there was not enough enthusiasm at the time for this to proceed."

BRIERLEY'S COMPETITION

In February 1971, Mr Frank Brierley offered a prize of £5 worth of groceries per month for life to the first person to cross from the roof of his Peterborough supermarket to the other bank of the river Nene. This amounts to traversing 140 ft to a grass bank 20 ft lower than the roof, from a standing start. A road bridge is conveniently situated for spectators.

The rules include "No gliding allowed", yet all entrants so far have made the first test of their wings on the actual course, presumably relying on the 20 ft height of the launch point, and only hoping to make forward progress if also descending, just as gliders.

The fact all entries so far have been clearly underwinged is no bar to a serious entry. To be successful, it would appear that this course would need a very special configuration.

WRIGHT

Of the three HPA to fly in the spring of 1972, the Wright was the only one which was not the result of a take-over.

It was the first successful British one-person project.

Peter Wright had trained on carbon fibre fabrication at Rolls-Royce, and was an active glider-pilot.

Wright started to design for quick construction in October 1969. A figure of 500 hours construction time is quoted for this aircraft.

He got clean away from glider or model-aircraft structures and pioneered the use of carbon-fibre on HPAs, using this material to reinforce EPS and PVC rigid foams, and also for diagonal taping. Pilot-support and transmission frame were welded mild steel tube. The transport joints were arranged so that the transmission could be tested inside the available workspace.

The Wright had the largest wing area yet of 486 sq ft and an empty weight of 95 lb. Flights were done with fixed elevator, the tricycle undercarriage being set to give take-off incidence. This was done to reduce pilot workload. There was only the rudder to think about apart from pedalling. Take-off was found to be easy, and flights of up to 300 yards were made.

Initially the CG was too far aft. Another problem was that in flight the vertical chain jumped off the top sprocket - exactly as on its contemporary, Jupiter. The transmission was, in principle, similar on both planes, although the proportionate length of chain-runs very different. The Wright propeller was 3-bladed and behind the tail.

In 1973 extensions on the wing-tips of the Wright increased the span to 85 ft and the area to 521 sq. ft. It was proposed to move the propeller to a nose mounted pylon, and to fit a 10 ft propeller.

MICRON

Wright's second aeroplane. By contrast, this had a wing area of only 134 sq ft on a 76 ft span. Material was glass fibre reinforcing a variety of foams, PVC, polyurethane and polystyrene. Construction took 200 hours up to February 1976. It was finished, then converted to a single-seat high performance sailplane which it continued to be for several years with the Buckminster Gliding Club.

TOUCAN

Martyn Pressnell, who had previous experience in the aircraft industry, with the Southend Mayfly group, and with aeromodelling writes,

"By 1965 it was apparent that the current single seat machines would not be able to achieve the performance necessary for the figure of eight course. Consequently in September of that year four employees of the Handley Page Aircraft Company at Radlett in Hertfordshire founded the 'Hertfordshire Pedal Aeronauts', under the leadership of their chairman Martyn Pressnell. Their object was to investigate the problems of man powered flight, and to obtain the support of the Company and the RAeS, to enable the group to build a second generation man powered aircraft."

"The early work of the group was concerned with a technical evaluation, and it soon became apparent that they could not expect to achieve a significant improvement by designing another single seater of the current type. The decision was taken in the true Handley Page spirit, to design a large machine powered by two men, which was to prove to be the biggest man powered aircraft constructed and flown in pursuit of the then current Kremer prizes."

"Initially the design studied had a wing span of 100 feet, but before construction began this was increased to 123 feet, In its later modified version the wing span became 139 feet, or about the same as a Boeing 707 airliner.

In December 1966 a technical summary of the proposals was submitted to the RAeS, and this was enthusiastically received by the Man Powered Flight Committee then under the chairmanship of the late Mr. Robert Graham CBE. FIMechE. FRAeS."

"The size of the group had been steadily increased up to twenty, and with financial assistance assured in addition to members regular subscriptions, construction work commenced in April 1967. The total construction effort for the aircraft alone amounted to more than 20,000 man-hours, and as an entirely voluntary spare time occupation, this phase of the work spread over five years to 1972. The major problems, apart from the innovation and development of construction techniques, were concerned with the organisation of manpower and materials. Many members were doing this type of work for the first time, and many mistakes were made and corrected in the course of achieving the high quality of workmanship necessary for success."

"Initially construction took place in a private garage, but in order to make the big assemblies it was essential to have a larger workspace. Thus in 1969 work on the aircraft almost came to a halt while members built and equipped their own workshop on the Handley Page airfield at Radlett. This was originally two prefabricated bungalows some twenty years old. When erected and redecorated these provided an excellent, light and airy workshop measuring 66 feet by 21 feet. A 250 yard trench was dug in order to bring in power, and a large lathe was acquired from the Company."

"In February 1970 the Handley Page company went into liquidation after sixty years as an aircraft constructor. Many of the members of the group left the area, and for a time the future of the project was in jeopardy. However through the kind co-operation of the receiver, Kenneth Cork, Gully and Co., and Wingate Investments Ltd., the group were permitted access to the workshop and subsequently to have the use of part of a hangar, and latterly the use of the airfield for flight trials. The group were also indebted to Messrs. Humbrol for the gift of adhesives, I.C.I. for the gift of Melinex covering film and others for the provision of materials on favourable terms. The group were also indebted to Eastern Electricity for their assistance in solving the power supply problem after 1970. The group were rewarded in some measure, when on 23rd December 1972 Toucan I made the world's first flight of a two seat man powered aircraft, covering a distance of 68 yards. The weather conditions at the time were cold, overcast and flat calm. The pilot who had received a little gliding experience previously, was Bryan Bowen and the crewman was Derek May."

Never mind 'two can', now it was 'two did'!

Pressnell continues

"A variety of mechanical, structural and other development problems remained to be solved. Following modifications to the wing incidence, dihedral and power transmission system, Toucan I was ready to resume flying on the evening of 3 July 1973. There was a slight headwind of about 3 ft/sec angled 15 degrees across the runway at Radlett. Toucan I took off and climbed to about 18 feet altitude, and flew in a stable and well controlled manner. It landed safely on the runway after covering a measured distance of 700 yards, and was airborne for approximately one minute and twenty seconds. A second flight was made of 340 yards, both flights terminating because of lack of oxygen in the cockpit and the high airborne pedalling rate, which exhausted the crew."

"Serious damage occurred to the starboard wing in an accident, and for the remainder of 1973 and most of 1974 the aircraft was undergoing repairs. The opportunity was taken to increase the wingspan by introducing a central 16 feet extension, as well as rectifying the other defects mentioned. On completion the machine was renamed Toucan II, and flight testing continued until September 1978. Several dozen flights were achieved ranging up to 500 yards, and throughout its long career it proved to be a stable and controllable aircraft in straight flight. Although it could be controlled adequately in a cross wind up to 3 ft/sec notwithstanding its slow lateral response, turns were not attempted because of the potential risks involved in landing off the paved runway. The wing was badly damaged on two further occasions because of inadequacy in the strength and impact absorption of the outrigger wheels. This problem was cured by the introduction of flexible plastic tube outriggers, and in 1978 taxying on grass was inadvertently accomplished without mishap."

"It became necessary for the Hertfordshire Pedal Aeronauts to leave Radlett airfield because of redevelopment in October 1978. Realising the difficulty of rehousing the project at another airfield and with due regard to the age of the aircraft, the decision was taken to present Toucan II to the Shuttleworth Collection where it was for a time handsomely exhibited alongside its forebear SUMPAC. The library at Old Warden was handed a set of working drawings and technical data referring to the project."

"It is doubtful if the full potential of the two seat machine has been realised by this single successful project. The anticipated advantages include better power to weight ratio, improved power continuity particularly when the pilot is engrossed in flying, and improved aerodynamic ground effect associated with the high span. These advantages were evident on Toucan on certain occasions. However the sheer size of the two seater and the relative frailty of the wings presented numerous problems. The group considered that this, allied to the elusive proper combination of calm weather, aircraft serviceability, and human willpower, made for protracted progress."

Description of Toucan II

Toucan II is a fixed wing monoplane of 139 ft span, 29 ft in overall length and 13.5 ft in height. It was powered by two men sitting in tandem in conventional cycling attitudes, with the crewman in front and the pilot behind. Both men pedalled on cranks which transmitted the effort through light alloy chains to the main wheel for ground propulsion. When airborne the power was transmitted through a torque shaft in the rear fuselage to a 10 ft diameter propeller mounted behind the tail.

The empty weight of the aircraft is 241 lb, and with the crew onboard it weighed 550 lb. The wing area is 696 sq. ft and its aspect ratio is 27.8. The flying speed was 18 to 20 mph.

Wing section selected was NACA 63_3-618, similar to that used on several previous machines but with the centre of pressure and the greatest depth further forward. It was not expected that extensive laminar flow would be achieved, and Martyn said (1989), "Maybe we would have done better with a turbulent flow section.

Wing primary structure was a spruce spar, torsion being carried by a lattice box of spruce strip. The fuselage frame was conventional aircraft riveted light-alloy sheet, of 30 gauge. This proved light and satisfactorily supported both crew. For the first time in Britain, foam plastic sheet was the main skinning material (see Linnet)

Pressnell continues,

"Materials used in the construction included large quantities of balsa wood and expanded polystyrene, as well as spruce mainspars and longerons, thin aluminium alloy sheet, titanium, and nylon cord. Melinex, a transparent plastic film, was used to cover the airframe and was shrunk drum tight by being warmed. Accurate construction depended on the use of flat surfaces, as with model aeroplanes. The tools employed included razor blades, pins and pegs as well as the more usual wood and metalworking tools.

Airborne control of the aircraft was achieved by an all moving tailplane and by slot lip ailerons set in the outer wings. These ailerons provided co-ordinated roll and yaw, and at extreme deflection provided a strong yawing effect obviating the need for a conventional rudder.

It was appreciated by the group that the wake of a rudder, when deflected would have interfered with the tail-mounted propeller.

A single main wheel of 16 inches diameter, fitted with a (2 inch) balloon tyre absorbed normal landing impacts. The nose wheel permitted the machine to take up a nose-down ground attitude. Thus the wing produced little lift during taxying, which improved traction through the main wheel and enabled the aircraft to be accelerated above flying speed on the ground. On raising the nose the machine was able to zoom to a modest altitude. This ground angle also assisted braking the aircraft on landing, which was achieved with two bicycle brakes, one on each wheel. In flight the wing tips deflected upwards about 8 feet which together with the built-in dihedral angle, ensured that the tips were not close to the ground. At take off the wing tips were steadied by running handlers, and on landing small outrigger wheels were provided under each wing to stabilise the aircraft."

The Hertfordshire Pedal Aeronauts

The group was organised on broadly democratic lines, with elected executive officers guided by two committees to consider design and administrative matters. The committees operated within a framework of agreed rules, which fixed their constitution and member's rights and responsibilities. It was a non profit making private organisation with a membership fee set at £0.50.

The group was founded in 1965 by Martyn Pressnell, Reginald Lambert, Christopher Dudfield and Gordon McGregor, all colleagues in the technical departments of the Handley Page aircraft company. Their colleagues in the company, their families and friends, actively encouraged the enterprise. In addition to completing the initial technical evaluation, the founders expanded the group and guided it in the early construction and organisational phases. The membership was drawn from inside and outside the company, and embraced a diversity of practical, technical and professional skills.

The pilot Bryan Bowen and the crewman Derek May were not practising athletes, but kept fit by cycling frequently. The pilot learned to glide ab initio with the London Gliding Club at Dunstable as a preliminary to flying the man powered aircraft, and experienced no difficulty in coming to terms with it.

Nihon University *Stork A* flying at Narashino runway.

Picture taken by Mr. Hiroshi Seo

TOUCAN I airborne at Radlett Airfield where its best flight covered a distance of 700 yards (640 m) in July 1973. It is the only two-seat aeroplane to have flown to date, and the modified aircraft *TOUCAN II* is the largest machine to be constructed, with a wingspan of 139 ft (42.37 m).

The enthusiasm for the project was found to be self generating when it was under way, most members regarding the pursuit as a challenging hobby. The Kremer Prizes, while giving strong initial impetus and a long term goal, were thus found to be augmented by this more immediate reward.

Group Officers,
M. S. Pressnell BSc. CEng. FRAeS. (Chairman)
P. R. Sladden BSc. (Vice Chairman)
P. L. Jones BSc. CEng. MRAeS. (Secretary)
R. E. Harris BSc. (Treasurer)

On Toucan a vane-operated air-speed-indicator was fitted. The pilot would see one of three coloured lights according to the airspeed.

Martyn Pressnell is now Vice-Chairman of the RAeS MPAG.
See Table of Types for details of this and other aircraft.

NIHON UNIVERSITY (continued)

At Nihon University progress continued, as described by Prof. Kimura, “In 1972, a well equipped runway, 620 meters in length and 30 meters in width was completed along with a hangar in the precincts of [Nihon University]. The research base for HPA was moved out there. At the same time, model changes were carried out. The new series was named the ‘Egret’, which was supposed to fly better than the ‘Linnet’.”

EGRET

Prof. Kimura continues, “The major changes incorporated in the Egret series featured the introduction of a belt drive to shorten the power transmission system. This was made possible by putting up a pylon for the propeller right behind the cockpit, as seen in the SUMPAC and Jupiter.” (Kimura 1977). (See Mufli for discussion of length of transmission.)

Three Egrets were built, still following the pattern of one HPA per year from Nihon University. For details see Table.

Kimura continues, “The 1975 student team was composed wholly of enthusiasts who had been helping their seniors with the manufacture of HPA since their freshman days. The team had as its leader an expert designer named Junji Ishii. I decided that I could entrust them with the task of undertaking drastic model changes. We confidently crowned the new model with the name of the “Stork” which is something of a flier.”

STORK

The distance flown by Stork was ten times anything previously flown at Nihon, and almost twice the distance of its predecessor Jupiter.

STORK’S IMPROVEMENTS ON JUPITER

The control bar support is arranged to make it much easier for the pilot to get in or out, and this arrangement on the Stork probably made rigging easier. On Jupiter the control bar is supported sideways from the nose of the wing. This meant that the fuselage on its own could never be rigged for testing the transmission; the centre section of the wing needed to be there as well.

Since on Jupiter none of the balsa plywood actually forms the profile, the Melinex being held away from the wood by the sponge, there is no reason for the balsa-plywood-torque-box to be any special shape. A logical developmental step is to simplify and lighten, and to make this a square box as was done on the Stork, which led to a more efficient wing.

The elevator is positioned behind the fin on the Stork. As well as making the elevator more effective, having a longer moment-arm, it again simplifies and lightens. This component can be in one piece.

RIGGING The author is reminded that there are rigging implications here too. It is important to have a pre-thought-out system for the order in which the components are assembled. It must be borne in mind that the machine when half-rigged will not balance. On at least one occasion with Jupiter, during rigging, the fuselage tipped over because of the uneven weight at that stage. When it was a wing-tip that it “landed” on, then it only needed picking up. When it was the elevator tip, then this component was damaged. With the Stork’s improved layout, the elevator can more easily be attached last and detached first.

Other improvements, apart from those details to be expected in any series development, are the castoring tail-wheel and a proper ventilation system. With less power required, the pilot was able to think about turning; and flights involving turns were at least comparable with the best turning performance shown by Puffin II.

On 2nd January 1977, Stork was officially observed to fly 2290 yards, exceeding Jupiter’s 1171 yards, and thereby becoming the holder of the World Distance Record.

IBIS

Nihon’s 1978 aeroplane, followed the same general configuration except that the wing was mounted lower. Ibis was a slightly smaller plane, and its performance less.

DRAGONFLY

Roger Hardy, who had flown Jupiter, designed and built two versions of his Dragonfly in Prestwick, Scotland.

Hardy’s approach was to make his only innovation the fact that there were no innovations. The Dragonfly was the sort of neat looking plane you feel you want to make a model of. It had a smaller wing-area than its predecessors and used the Wortmann aerofoil section FX 63-137. There was a side-door for the pilot, unusual at the time. Ailerons moved up only.

The Dragonfly made some short flights in early 1975, but Hardy went onto his second version in the February. It was estimated that the plane would fly at 28 ft/sec with a lift coefficient of 1.15 and a pedal cadence of 70 rpm. He recorded his hours spent on this one-person venture. Design took 1,000 hours and construction 1,610 hours, being comprised of wing 740, aileron 60, fuselage 200, tailplane 40, fin 80, pylon and propeller 80, covering 180, mechanism 160 and final assembly 70 hours. This was all within a period of 22 weeks. No drawings were made. Roll-out was on 30th July 1975.

Problems then arose. The spar buckled, resulting in two weeks of repair work, and the propeller flexed, hitting the pylon. There was damage to the rear-fuselage from ground-handling. The cg intended as 38% m.a.c was found to be at 25% m.a.c. This necessitated 4 lb of ballast in the tail. In February 1976 he had notice to quit the hangar, the aircraft not having flown by this time, for lack of elevator power.

LONGITUDINAL TRIM Flying characteristics are affected by the position of the centre of gravity (cg) relative to the wing, just as take-off and landing are affected by this position relative to the wing and to the wheel(s).

Which part of the wing? The mean aerodynamic chord (m.a.c.) is the convenient reference against which to quantify trim. It is the “average” chord-line, defined by a formula which recognises the fact that those parts of the wing with greater chord have a greater effect on pitching moment per unit area; (m.a.c.)% × span = integral of (chord)% along span.

AVIETTE

The word “aviette” is literally French for “small aeroplane”, and usually refers to the class of flying bicycles of the twenties which typically had ground-drive only. By contrast, Monsieur Hurel’s 1976 aircraft had an 137 feet span and a 12 feet diameter propeller.

On the Aviette, Hurel used an aerodynamic solution to a structural problem. As explained above (see Lippisch), it is important that the wings of aircraft do not warp or twist uncontrollably. The obvious answer to this is either to stiffen the internal structure to resist torsion, or to arrange external bracing wires to do the same job. However, on this plane stabilising surfaces were attached on mini-tail-booms behind each outer wing. Just as the effect of a tailplane is to tend to return the entire aircraft to a level attitude from a non-level attitude, so the effect of these surfaces is to tend to hold the wing-tips at a constant angle relative to the airflow. The conventional constructional techniques of the time were used, materials being spruce, balsa and Melinex.

The Aviette flew at Le Bourget, largely through national recognition of the designer’s contribution to industry throughout his working life.

In 1974 the Aviette recorded flights of 1100 yards

BURD

BURD, The Biplane Ultralight Research Device, was the first attempt at HPF by students at the Massachusetts Institute of Technology, Cambridge, MA, USA (MIT). They chose the configuration of a two-seater canard biplane, with the propeller mounted behind the fin. Span was 63 ft with a total wing area of 640 sq ft of FX 61-163 section. Spoilers were incorporated for lateral control. Spar was laminated balsa.

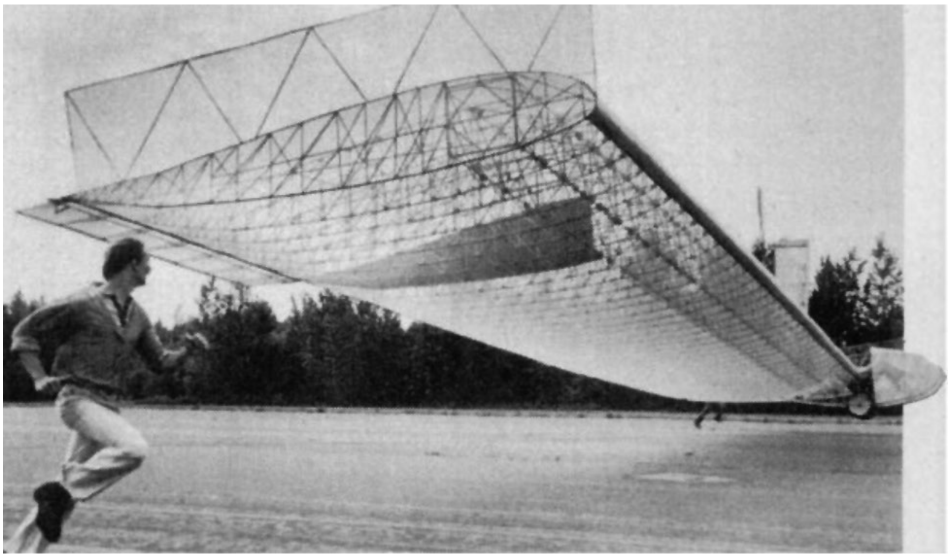
Considerable structural analysis of many of the primary and secondary components of the BURD were performed by Paul Hooper and Robert Peterson. However the capability of the wing to resist being bent forward was neglected, with the result that the wings of this promising two-seat biplane collapsed forward during rotation on its first flight-attempt in 1972.

WING RIBS The students had been very concerned with details, particularly the wing-ribs, but neglected the fact that the main loading on these derives from the tension of the wing-covering when it is shrunk taut, rather than the theoretically calculable air pressure loads applied during flight, and hence these secondary components can only be tested by a full-scale wing-test-section as mentioned above.
Ribs on BURD were, as was usual at the time, of balsa-strip girder construction.
It has been said that there is no such thing as a perfect rib, and that there are lots of ways to make ribs. Questions to ask when choosing a method of rib construction are:

1/ How long are they going to take to make? (there are a lot of them)
2/ How long are they going to take to line-up and fix to the spar and trailing edge?
3/ Are they going to be easy to fix the covering to? (particularly if there is reverse camber)
4/ Is the rib-cap (the strip of material which follows the curve of the profile) going to remain attached to the rest of the rib? (particularly awkward if carbon caps are on foam ribs.)
5/ Will they resist the effect of the Melinex, if used, being shrunk taut? (unlike flight-loads, this load is applied even when the plane is stored)
6/ And, lastly, are they light enough, strong enough and the right shape?

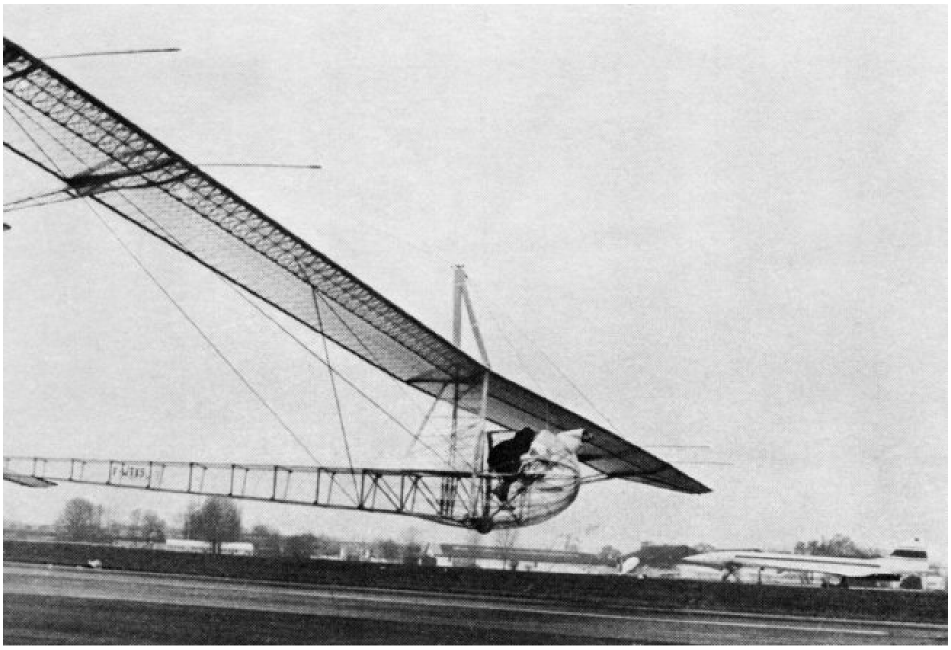
The BURD II was built between 1974 and 1976 to the same shape but from different materials. The wing-spars were foam and graphite-epoxy, which resulted in the weight being 112 lb compared with the 130 of the Mk 1. However this plane could not be made to fly, even when, years later different students dusted it off and added model-aeroplane engines. This attempt however, led to the successful Chrysalis (see below), which in turn led to other aircraft from the same academy.

Perhaps the main lesson to be learned form the BURD project is to not be deterred by lack of early success.



Wayne Bliesner's first aircraft, *Seattle Slow 1*, in towed flight at Bellingham Airfield, Washington on 18th August 1976. Wayne was a Junior at the University of Washington when he started to build the aircraft. This design was a flying wing with a minimum flight speed of 12 mph. The main structure included aluminium tube brazed truss work with balsa wood ribs and a mylar skin. The large wing design allowed the pilot to sit partially inside the wing reducing the fuselage requirements. The prop was mounted on a tower to minimise prop wash effects. Only one tow flight occurred with the takeoff at 12 MPH and a controlled flight up to 10 feet altitude. The hanger where this vehicle was initially assembled was in use so a makeshift hanger was built at Bellingham Airfield. The aircraft was destroyed when a storm collapsed the new hanger.

Taras Kiceniuk's *Icarus* flying at Shafter airport in 1976.



Monsieur Hurel's *Aviette* flying at Le Bourget.
In 1974 it made several flights of 1100 yards.

OLYMPIAN ZB 1

This was a one-man venture by Joe Zinno, an ex-pilot. The first HPA to fly in the continent of North America, the Olympian ZB 1 made its first flight on 21st April 1976. Reay observes that there many similarities between this aircraft and Jupiter (Reay 1977). There are also many differences:

	Olympian ZB 1	**Jupiter**
Aerofoil	Wortmann	NACA
Continent of origin of aerofoil	Europe	N. America
Lateral control	Rudder only	Conventional
Fuselage	Pod and boom	Glider-type
Length	18 ft	30 ft
Pedal-type	Treadle	Rotational
Rudder-control	One-hand	Both-hands
Wing-position	Mid-wing	High-wing
Wing-nose Material	E.P.S.	Balsa
Success in completion by originator	Yes	No

ICARUS

Taras Kiceniuk's Icarus aircraft was flying in the Mojave Desert of Southern California in the same year that the MacCready team were using this space to fly their Gossamer Condor; at one time the two planes shared a hangar. As on the Condor, materials were alloy tube, foam and Mylar.

The propeller on the Icarus was concentric around the tail-boom; it was the first time that an aircraft with this scheme had been completed. Taras Kiceniuk, who helped with the Gossamer Albatross, was later part of the prize-winning Bionic Bat team, which adopted a similar propeller position. The author started to construct an aeroplane with such a layout (see above) and this system is used on the current Airglow. The weight per inch of the carbon-fibre 4 inch diameter propeller final drive shaft on Airglow is the same as that of Jupiter which was of aluminium and only 1 inch diameter. Such a scheme was considered for Daedalus, and then rejected.

Icarus had a very low wing; so low that on take-off it would have been influenced by the type of ground-effect which becomes significant when the height is a fraction of the chord. The Reluctant Phoenix appeared to benefit from this, but on Icarus, take off was only possible if the aircraft was towed (See Dumbo/Mercury and HVS)

Fabrication technique of the wing was hot-wire cutting from solid blocks of foam, as used on LiverPuffin and later the Light Eagle and Daedalus.

BLIESNER SERIES

Wayne Bliesner has designed built and flown a bewildering number of HPA, producing about one new aircraft or new variant each year. This prolific enthusiast has had the benefit of membership of the Flight Research Institute, Seattle, Washington, USA. This institute has assisted various forms of flight research and aerodynamic research including the Alcor Program where a pressurised glider explores the waves in the lee of mountains; and a project which tested improvements in the drag-reduction of an Olympic 4-place Bobsled. Membership is open to all, but employment with the Boeing Company is required for use of some of the facilities of the institute.

Bliesner's first three aircraft only made flights under tow.

After the successful flight of the fourth, there followed a series of planes using the same elliptic spruce-spar wing. Various propeller positions and tail arrangements were tried during this time.

Airplane 8 was also known as Man-Eagle 1. It is at this point that Bliesner decided to aim for speed. He designed a new aerofoil, and built a new wing with a carbon spar. This wing was progressively trimmed, and the Man-Eagle variants had different spans as well as different fuselage arrangements. Stored-energy was used on Man-Eagle 3 (Bliesner 10). Man-Eagle 4 had a sophisticated shape pod and is comparable with Pelargos 3.

Bliesner 1 Bliesner was a student at the University of Washington when in 1975 he built his first HPA. This was a flying-wing design. The wingspar was a girder of brazed aluminium tubes, the ribs balsa. Propeller was on a pylon above the pod. The plane was designed to fly at 12 mph, as indeed it did, but only when towed. Unfortunately before further flight tests could be made, a storm destroyed the temporary hangar and the aircraft with it.

Bliesner 2 Of the hardware, only the propeller was salvaged from the first plane. Of the design, the low-wing position was retained, as was the pylon-mounted propeller and the principle of a brazed-tube spar. This was a conventional layout with a recumbent pilot and glider-type rear-fuselage. This aircraft made flights in 1977, but again only under tow.

Bliesner 3 A new wing was built for the 1978 trials. This was of elliptic planform, spruce spar and foam ribs. The fuselage was designed around the possibility of a water-landing, with pilot access from the top, and a hopefully ditching-proof lower part. This plane made many tow-assisted flights, on the last of which it crashed after stalling at a height of 20 feet.

Bliesner 4 "The wing was rebuilt to its original shape and a new fuselage with better contoured surface was constructed. The wing was left low with the pilot sitting on the wooden spar. Drive train problems on the previous aircraft led to the decision to run the propeller on a short pylon at the front of the fuselage.

"A debate had occurred for several years as to whether it was better to put the propeller in front where it saw clean flow but the fuselage or pylon suffered from the propeller wash penalty or to put the propeller behind in the fuselage wake but with no resulting propeller wash penalty."

"The configuration was moved to Arlington airport where a hangar allowed partial assembly. A large unused runway was available for flight tests. This proved to be an ideal site for straight line flight. This aircraft became the first [of his] configurations to be pedalled off the ground without tow assistance, and several short flights of up to 100 yards were achieved.

Bliesner 5 "News of the English Channel crossing [(see Gossamer Albatross)] and the fact that carbon fibre was now available led to the decision to make another design improvement" (Flight Research Institute. Status Report 1987-8)

The 1980 fuselage which characterised the "5" incorporated a carbon structure, a new propeller and an upright seat. It had two wheels side-by-side in front so that unlike most HPA it was stable when standing on the runway. This made it easier for one person alone to manage it on the ground. Flight distance increases up to a mile were attributed mainly to the new propeller. There were many occasions when the aircraft was assembled, taxied out to the field and flown with only the pilot around. Bliesner had not expected that this could be done, but having discovered that it could, decided to retain this capability in later designs: but he did this later with single wheel aeroplanes.

The upright pilot position was considered to be the major cause of a nose-over, when the aircraft was blown into a ditch while taxying, and it was decided to revert to a recumbent pilot position for pilot safety. (Four years later the Monarch team suffered a similar crash while on the ground, and adopted a recumbent position for their new fuselage.)

Bliesner 6 First of the series with a high wing; this feature was retained thereafter. Pilot was recumbent, as mentioned. The propeller was in front, as before, but the lower fuselage necessitated a short pylon. This variant only made a few hops before the failure of a wing to fuselage joint which had been hastily put together led to the destruction of the fuselage.

Bliesner 7 This 1981 aircraft was the last to use the wooden wing. Three actions were taken to reduce interference drag: the propeller was moved up to be pylon-mounted: the fuselage-wing junction carefully faired: and a "V" tail built.

It was found that the tail-boom flexibility considerably reduced the effectiveness of the tail (See later Light-Eagle, where this phenomenon is studied). Also, "the high thrust line required large pitch adjustments when the pilot power varied during flight". (This effect had concerned the author when designing Jupiter, which had a pylon-mounted propeller, but in flight on that machine it was found that any variations in pedalling rate led to changes in speed only, not in attitude. It was not a concern for the pilot of that aircraft).

Flight tests on this plane were terminated so that a new wing could be fitted. This new configuration, the Bliesner 8, which was named Man-Eagle is described later.

SUMMARY of BLIESNER AIRPLANES 3 to 7

In all cases the wing was 80 feet span, 300 sq ft with spruce spar.

Lateral control was conventional.
Unless specified in the table, seat was recumbent, tail was conventional on boom.

Mk	Year	Special features	Wing position	Propeller position	Flight results	Reason for termination
3	1978	Waterproof pod	Low	Short pylon behind pod	Towed only	Crashed
4	1979	Better faired pod	Low	Short pylon at nose	100 yards	Desire to improve
5	1980	Upright Seat, Twin wheels, New propeller	Low	Nose	1 mile	Crashed during ground crew taxi
6	1980		High	Short pylon at nose	A few hops	Crash.
7	1981	" V " tail	High	Long pylon	Initial tests	New wing ready.

See account of Speed Competition for later Bliesner aeroplanes, and his Man Eagle series.

PHILIPS

Two HPAs were designed and built by Ron Philips, a cycle enthusiast of Humberside, England in the mid 1970s. The Philips Mk I had a span of 80 ft and a weight of 190 lb. The Mk II, a two-seater, made some flights under tow.

VERSTRAETE/MASSCHELIN Bros

This Belgian trio made and flew two elegant machines contemporary with the Aviette. They had to be transported to France to fly at Calais-Marck airport because the Belgian authorities would not grant a permit to fly. The flights were remarkable for the altitude gained (about 15 feet) and the performance on a base adjacent to the sea where wind is both fierce and gusting. Wingspan was 85 feet and weight 117 lb.

NEWBURY MANFLIER

In the mid 1970s, when the first few British aircraft had flown but failed to win the figure-eight prize, people were looking for new approaches. Rear Admiral H C N Goodhart CB, a champion glider pilot with other aeronautical experience, had the idea of increasing the span without increasing the weight of the wing, by distributing the load along its span. In 1975 he designed the Newbury Manflier with two pilots seventy feet apart, each in their own fuselage. When the author saw this machine under construction, it looked to him like two Jupiter's tip-to-tip, the wing having a span of 138 feet, an area of 198 square feet and a Wortmann aerofoil section.

The control system was simply an elevator for each pilot. To yaw (right or left), one pilot pedals harder; to roll, one applies up-elevator; to pitch, both apply up-elevator. There were no ailerons, and both fins were fixed.

The structure was similar to the earlier British machines except that the wing spar was a plywood tube for torsional stiffness and shear, with spruce upper and lower booms. Drive was by chains to propellers on pylons, one for each pilot, who were in upright cyclist positions. This aeroplane had the widest undercarriage of any aircraft ever, and could only operate from a very wide runway.

The Newbury Manflier first flew in 1979 at Greenham Common, England which was available at the time. It demonstrated that a satisfactory command system was possible for this configuration. Surprisingly, what worked best was for each pilot to look after his own end. No captain, or "coach" on the ground, which were the other two options that Nick Goodhart had considered.

Other problems were however more significant. One of these was structural. For a simple cantilever wing, it has been found satisfactory to calculate the loads to be expected during cruise, and then by applying a constant factor along the span to make allowance for all contingencies such as gusts or manoeuvres. However the effect of localised gusts which affect only part of the wing cannot be allowed for in this simple way. HPA operating close to the ground, and having large wing spans are probably more susceptible to these localised gusts than other types of aircraft, and little is currently known about such gusts. A local gust will be more serious for a wire-braced wing or a wing of unconventional loading such as the Newbury Manflier than for a cantilever.

On this topic, though not specifically about the Newbury Manflier, John McIntyre writes, "Localised gusts are a big problem for HPA - this is probably what broke the Daedalus wing at Santorini. Prediction of deflection failure mode for a wing with a single bracing wire, such as Daedalus or Airglow, in gust/manouevring is difficult - the problem is non-linear, requiring iteration for an accurate solution".

In the author's opinion this could have affected the Newbury Manflier but Nick Goodhart disagrees:

Goodhart writes

"The aircraft, suffered a wing spar fracture due to bad construction and lack of fuselage torsional stiffness due to bad design. After repair the wing spar proved entirely satisfactory and took up exactly the predicted shape in flight indicating that the loadings were as anticipated."

"The project was terminated soon after the first (two) flights had been achieved as the hangar and runway at Greenham Common became unavailable."

GOSSAMER CONDOR

Until now, all human powered aircraft had followed the glider and the bicycle. There had been nothing really new since the 1935 Mufli of Haesller and Villinger. Designers had added to this by copying wheel drive from the bicycle, which meant unnecessary weight once airborne. HPA had flown in straight lines, but the Mufli had flown in a straight line. Every time the straight line got a little longer we got excited, but the 2290 yards of the Stork compared with the 779 yards of Mufli? In forty years one expects more progress than that. And no HPA could repeatably demonstrate controlled sustainable turns. There must be a better way.

As this account shows, the quantum leap in HPA progress made by the Gossamer series occurred through a combination of novel ideas and thorough analysis, as well as iteration through flight testing and modifications.

In 1976 experienced glider-pilot and aerodynamicist Dr Paul MacCready decided to follow the hang-glider concept. His first calculations showed that with a much larger wing area than other HPA, flying speed could be brought so low that the drag of wire-bracing would be permissible. Also, at this low speed, wheel drive for take-off would not be needed.

PASADENA VERSION MacCready decided that as a first step he would make the simplest possible machine to just fly and prove the principle. This would look like no other aeroplane, in fact it would look like no other thing at all. It consisted of 12 ft lengths of 2 inch diameter aluminium tube and a network of wires. If it didn't work, MacCready didn't want to be laughed at; if it did work he wanted to keep it secret. So if anyone asked what "that" was he replied "This is a work-of-art. It portrays the meddling of government in the affairs of citizens". This first test aircraft flew just once in the car park of the Pasadena Rose Bowl, California, near where it had been made by Jack Lambie.

MOJAVE VERSION The first real aeroplane had a single surface Mylar covered aerofoil, the aluminium spar tube at the leading edge with a second tube near the trailing edge, no pilot fairing, but otherwise the general configuration of the later versions. First flight was by the designer's son Parker MacCready at midday on 26th December 1976 in the Mojave desert. This was a 40 second flight, already exceeding the durations of many previous HPA. The plane was named Gossamer Condor to draw attention to the condor, an endangered species of bird native to the locality. This had a wing-span of 96 ft and an area of 1100 sq ft. Longer flights were made and enough experience gained to show that the plane could not be made to turn. Also it was unstable, but the motions were so slow that all pilots could cope with this. Initially, the canard stabiliser only worked as an elevator to control pitch. Later it was made to bank, so that it would "pull the plane round by the nose."

SHAFTER VERSION An improved version flew at Shafter airport, California in March 1977. Shafter had calmer weather at this time of year, and nearby lived Vern and Maude Oldershaw, Sam Duran, Bryan Allen and Bill Richardson. The team were able to draw on Dr Chester Kyle's experience with human-powered road vehicles. A special aerofoil was designed by Dr Peter Lissaman. This had a low pitching moment and moderate concavities.

At this stage it would seem that the plane was never quite the same shape on any two flights as a variety of lateral control surfaces were tried out. Spoilers were tried, then a forward rudder, then an aft rudder. The banking canard stabiliser on its own was insufficient.

Before long, the Gossamer Condor's total time in the air had exceeded that of all other HPA put together. Minor

December 26th 1976: Parker MacCready making the first 40 second flight in the Gossamer Condor at Mojave airport. It covered 469 feet (143 meters) at an altitude of 3 feet. Photo Anton Higgs. RAeS HPAG archive.

Bryan Allen flying the *Gossamer Condor* for the press at Shafter airport after winning the Kremer prize in August 1977. Photo Don Monroe. RAeS HPAG archive.

crashes were frequent; if the spar broke the pilot would jump out, so as to land feet-first and to reduce the weight on the plane. If anything broke it was rebuilt better. The Condor was evolving from the initial contraption into a sophisticated flying machine.

While the team were still searching for a method of making the plane turn controllably, it was so severely damaged as to require a rebuild.

They promptly started thinking about what improvements to incorporate in the next version. Many wings are built with a twist such that at each wing-tip the angle of attack is the same as at the other tip, but different from the angle of attack at the centre of the wing. This is known as wash-out or wash-in. While discussing wash-out for the new design to replace the damaged machine, it occurred to someone that if the wing had wash-out on one side and wash-in on the other then it would turn.

That was it! This and all other HPA until then had done little more than straight flights, unsuccessfully trying all sorts of lateral-control-devices except, until then, this wing-warping which, in fact, was the system which the Wright brothers had used. But a bright idea is not enough: MacCready then had to calculate how much twist would be required.

The new version incorporated a lever in the cockpit which when operated pulled on the rigging wires which twisted each wing. The system worked as hoped for in flight. The pilot retained the use of the banking stabiliser for small corrections and the wing-twist was used both to initiate and to hold a steady turn.

With Bryan Allen as pilot, an attempt was soon made on the Kremer figure of eight course with a prize of £50,000 to be won. On the first attempt the wake from a passing crop-duster plane put the aeroplane out of action.

On Bryan's next attempt on the 23rd August 1977 the course was completed. The first Kremer Prize, that had been known as the Kremer Prize for eighteen years had been won.

The Gossamer Condor was now flown for the fun of it by all members of the team and others including Professor Geoffrey Lilley of Southampton, England.

KREMER CROSS CHANNEL COMPETITION

Henry Kremer's response to the first figure-eight flight was promptly to propose a new challenge, and the rules for the Channel crossing were drafted by a sub-committee led by Ron Moulton. Also there was to be a new figure-eight competition, restricted to entrants from any country other than that of the first winner.

As mentioned above, after the first flights of SUMPAC and Puffin, it was generally thought that it would be a short time before the figure eight was flown. This was not what happened.

When a competition was announced with the course being the English Channel, then it was generally thought that it would be a long time before this course was flown, if it ever was. "22 miles?", "Impossible!". Again, this is not what happened.

GOSSAMER ALBATROSS

The project started in October 1977 as a development of the Condor. New materials would lighten the weight. The technique of producing carbon-fibre tubes was developed. Although carbon-fibre had been used for some time, and composite tube structures were used for instance for fishing-rods, this was the first time that carbon was used on tubes of the proportion that we now think of as HPA spar proportions. Kevlar, another material taken for granted today, was used on an HPA first on the Albatross.

The wing surface profile was improved by having closer spaced ribs. The wing area was reduced to suit a higher speed. First flight of the Albatross was at Shafter in July 1978.

HPF > HPA Human powered flight entails more than just a human powered aircraft. MacCready was realising that the organisational problems involved were such that sponsorship would be needed. In March 1979 the Du Pont Company, makers of most of the materials of the plane, agreed to be chief sponsor. The publicity generated by MacCready's ingenious use of their new material Kevlar resulted in millions of pounds of extra business for the firm.

Organisational tasks included: transport to England of the plane and two back-up planes, test-flying these over land, obtaining boats, studying navigation, providing communications and making arrangements for the team during the trip which might last several months waiting for the right weather.

The aeroplane was refined but was still not indicating the capability of crossing the English Channel, as Bryan Allen's best duration was 18 minutes. It was considered that inefficiency in the propeller was holding them back. With help from the Chrysalis team (see below), Gossamer Albatross soon had a new propeller, and in April 1979

Allen's duration improved from 18 minutes to 69 minutes, and he was not exhausted. He landed only to let Kirk Giboney have a flight.

At this time, the intention was that the next stage would consist of some practice flights over water, but in a way that at the time seemed to the team to be magic, with the aid of test pilots and Royal Air Force authorities whom they had never met, transport to England had been arranged for the very next day in a Royal Air Force Hercules. So the overwater testing was skipped.

It was some weeks before the weather was right but on the 12th June 1979 at 5.51 am the Gossamer Condor with Bryan Allen aboard headed out to sea, with the many escort boats. Half way across the plane met a headwind. It had been anticipated that the first attempt might not get all the way, hence the spare aeroplanes, but Allen kept pedalling.

Although France can be seen from the top of the Dover cliffs, it cannot be seen from the beach. This means that for almost half the trip Bryan Allen was pedalling apparently to nowhere, but following MacCready in the pilot boat. Then comes the moment when it can be realised that the blur on the horizon is the continent, which gradually gets firmer.

The headwind was getting stronger and when barely three miles from Cap Gris Nez, Allen felt he could go on no longer and it was decided to abort the flight. The first move was made in the pre-planned procedure, namely climb to the height of a fishing-rod ready to be hooked up for a tow from a fast rubber dinghy. Surprisingly, he found that at this greater height he was able to proceed, so he never made the hook-up and flew all the way under his own power, arriving at 8.40 am, feeling that he could not have gone another 100 yards. But the Channel had been crossed, and the prize won by a superhuman effort, the equivalent of a marathon race in the air.

Back in England to collect the reserve aircraft, MacCready kindly invited all those known to be interested in HPF in England to view these aeroplanes; and he then related the background to the achievement (See Gossamer Odyssey).

CHRYSALIS

The project started when some MIT students tried to fly BURD II with the assistance of model aircraft engines in November 1978. This resulted in a smashed BURD, but the experience sparked new ideas, and Harold Youngren, Bob Parks, John Langford, Hyong Bang and Mark Drela decided in early December 1978 to design and build a new machine.

This had to be flying by May 1979 when these final-year students were due to graduate. Other objectives were, a maximum 75 ft wingspan so as to fit the hangar, and a plane able to be flown by anyone and easy to repair.

These objectives led logically to the choice of a wire-braced biplane. The usual theoretical optimisation process was performed to finalise dimensions, and to decide the control system an 1/8th scale flying-scale-model was made. In its final control configuration, with developed control techniques, it was possible to fly this radio-controlled model in turns as tight as 2 1/2 spans in radius. As a result of these model tests it was decided to adopt conventional controls and wing-warping for the full-size plane. A test-section of wing was made and resulted in several important changes in design and constructional details. The team developed a method of anchoring the bracing wire 36% more efficient than that used on the Gossamer Condor. The Czerwinski method of joining the aluminium tubes was used.

The project was officially recognised by MIT and funded. More students joined the team to help with construction. Professor E. Eugene Larrabee's minimum induced loss propeller design process was used.

In March 1979, Larrabee met Paul MacCready who suspected that the propeller on the Gossamer Albatross could use some improvement. Guppy Youngren designed a propeller for Albatross using Larrabee's method and sent the plans to MacCready.

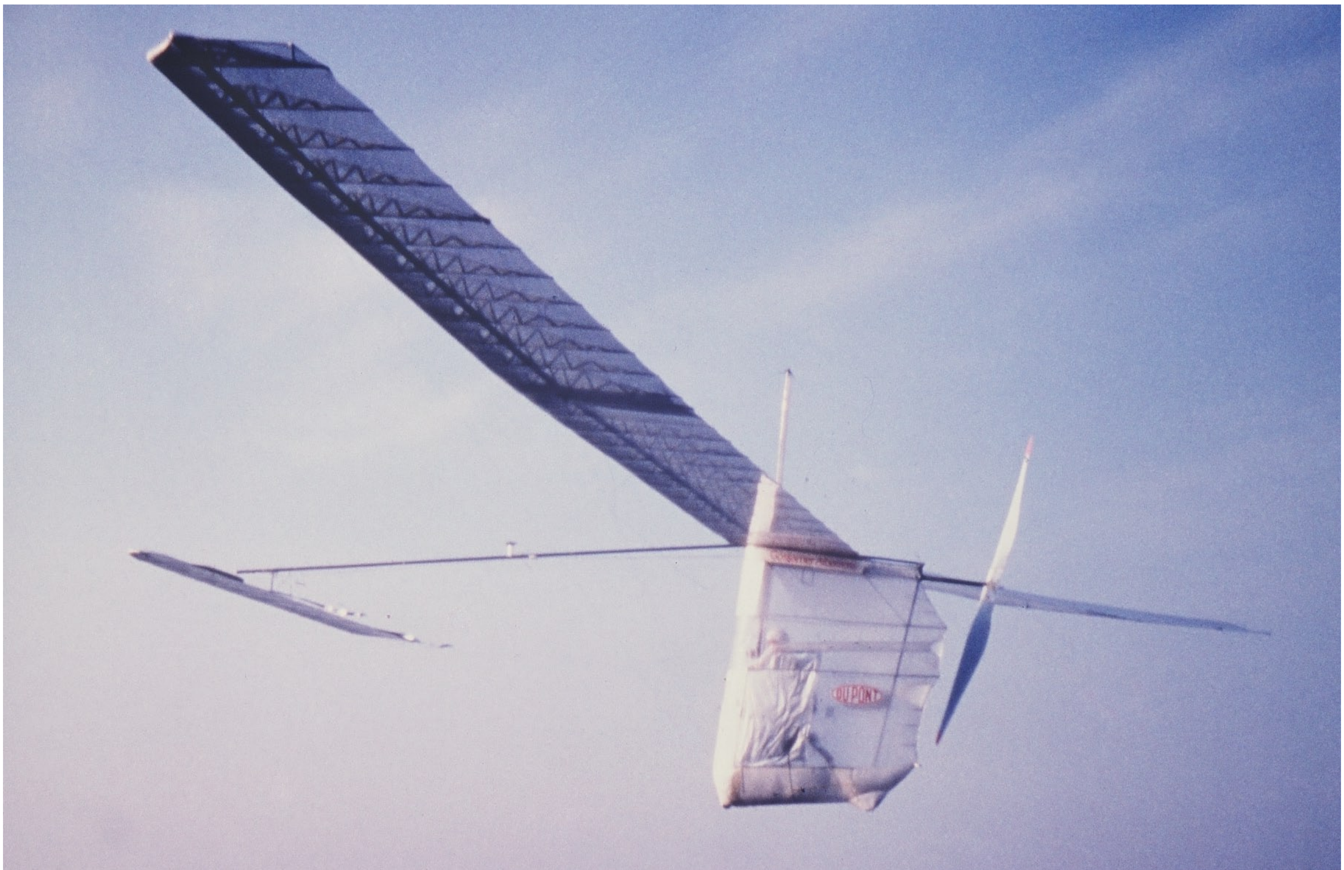
A few weeks later MacCready was able to help the Chrysalis project by supplying the Mylar, an essential item which the team could not obtain elsewhere.

Construction took 3 times the originally estimated number of person-hours, but the plane was built in 91 days, and when nearly complete, proceeded for 72 hours round the clock.

Chrysalis made two flights on the 5th June 1979, the first day it had left the hangar. Within 3 weeks it was making 120 degree turns. One major modification was the addition of a fairing at the aft of the pod to lower wing junction. See interference drag in SUMPAC above.

Chrysalis provided recreational flying for 44 pilots, some inexperienced, and one very experienced: Bryan Allen, just back from flying to France. He found Chrysalis to require less power than Condor for cruise although more for climb and particularly that it was a more stable aeroplane.

May 10th 1979. *Gossamer Albatross* making the required 2 minute demonstration flight at RAF Manston. (Its longest flight that day was 9 minutes 24 seconds.) Photo Ron Moulton. RAeS HPAG archive.



12th June 1979. Bryan Allen flying *Gossamer Albatross* across the channel to win the Kremer Cross Channel Competition. Photo Ron Moulton. RAeS HPAG archive.

MiLan
There was no new aircraft at Nihon University from March 1978 to December 1981, when the MiLan'81 first flew. This was a totally new configuration, an almost rectangular high wing to which were attached twin tail booms with the propeller between them just behind the pod. A large number of bracing wires from the top of a kingpost to the wing and from the wing to near the small wheel. The pilot was upright. This aircraft flew 645 yards. A similar plane, the MiLan'82, flew on the 16th Oct 1982. Cruising speed was 12 mph. The twin booms were far enough apart for a 14 ft propeller.

PHOENIX
Frederick To, an architect, made a film about HPF called "The Last Challenge" in 1974. He started building Solar One with the help and advice of David Williams (see SUMPAC), in 1977. In 1978, Solar One became the world's first solar-powered-aircraft. In this same year he began considering inflatable HPAs, seeing the advantage of portability and less vulnerability. He acquired the Reluctant Phoenix, and followed several of Perkins' techniques, including the elevon hinge system, in the design of his own inflatable, the Phoenix.

Wanting to use Melinex, rather than traditional balloon fabric, To first had to develop a system for bonding this material (F. To Aerospace June 1985), enabling the "T" joints to be made. Built like a flying airbed, there are a quarter of a mile of such joints between the skin and the vertical webs. F. To chose a rectangular configuration, to maintain constant skin tension and Reynolds' number along the span, a flying wing configuration, because otherwise the inherent simplicity of rigging and transportation would be lost, winglets to enhance ground effect, and a span of 100 ft with 16.7 ft a chord. He estimated a weight of 85 lb and power requirement of 1/3rd HP. He realised that cable operated controls would be out of the question because he anticipated the wing stretching 9 inches when inflated. Operation was by model aircraft servos and radio control, 4 servos to each elevon.

Work on construction of this largest ever HPA wing took place in a suburban house in a room 12 ft by 26 ft. The workbench was just longer than the chord. The material was fed across spanwise as it was worked on.

Wind-tunnel tests at Imperial College, London showed that the winglets reduced induced drag by a quarter. They also showed that the profile drag would be ten times more than for a smooth shape of the same section, whereas To had assumed a factor of only 1.25 in his power-required estimate. The model's profile replicated the series of flats and curves to be expected on the inflated shape. By this time, construction of the actual wing was advanced. Frank Irving of Imperial College suggested a series of hoops, with the outer skin above them, and these were used on the plane. Performance indicated their effectiveness.

Eventually inflation could be done in 20 minutes and deflation 30, but the first few times it took much longer than this. Phoenix could be carried deflated on a car-roof-rack. Fred To said the most awkward thing to transport was the propeller.

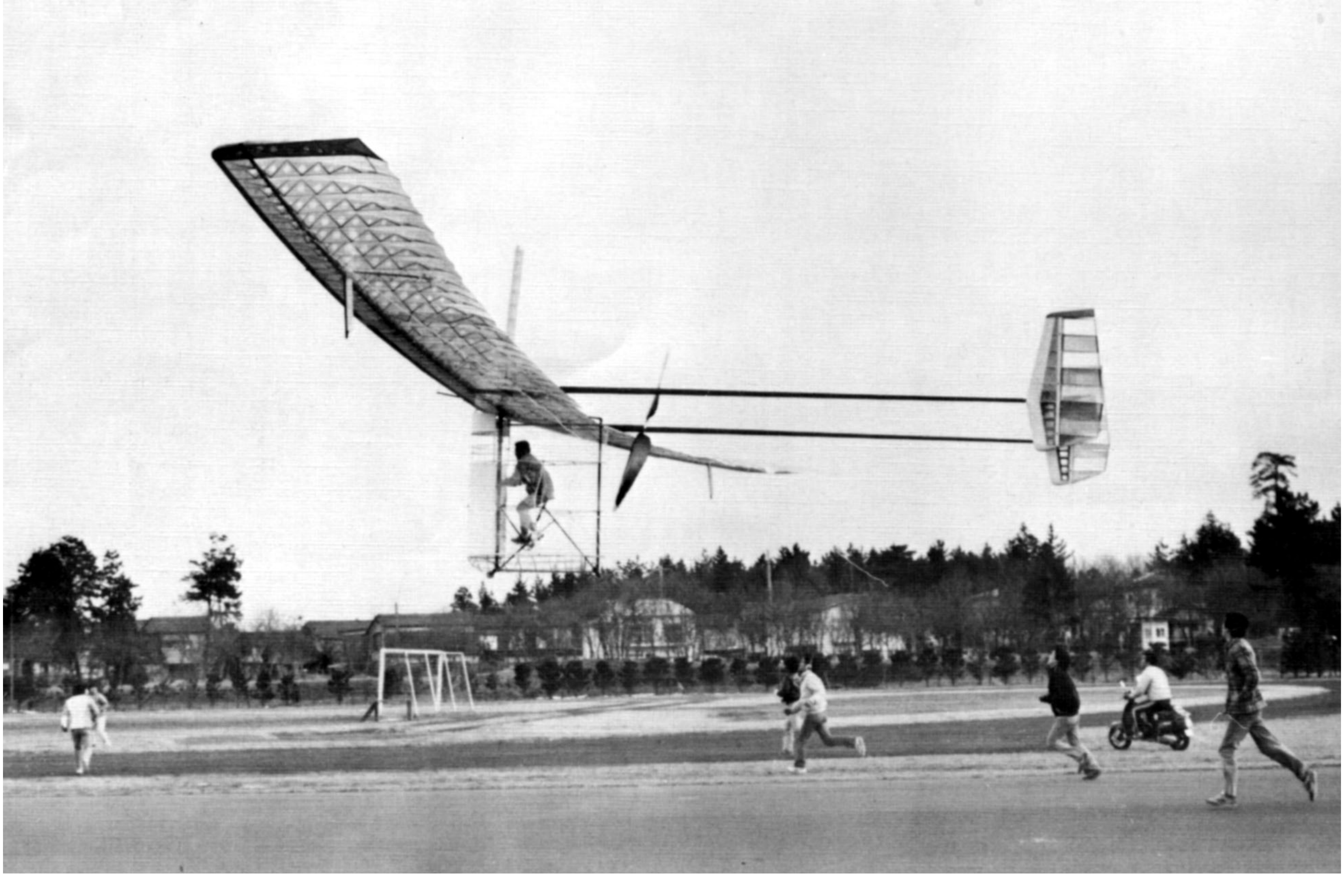
On 28th March 1982, it was planned that Ian Parker would make the first test-flight inside the 600 ft warehouse where it had been rigged. However Ian Parker thought better of this, and took it outside and took off. The weight was 105 lb, but there was 200 lb of air inside the wing which had to be accelerated during the take-off run. Control was adequate and flights were made by all group-members, but no great distances were covered.

In May 1982, Barry Jacobson took over the Phoenix, intending to reduce its thickness to make it more manageable.

A prize of £10,000 was still available in 1980 for this course. The first figure-eight had been flown by Bryan Allen in the Gossamer Condor, in the USA. The rules stated that an entrant for the competition must be from a different country. The competition was to close at the end of June 1984. Three aircraft raced to beat this date, and each other.

HVS
The HVS was designed by Hutter, Villinger and Schule. Franz Villinger had been responsible for the Mufli 48 years previously. Wolfgang Hutter had designed gliders and Wilhelm Schule had constructed airframes. With the experience of the designers, and with backing from industry a neat and sophisticated-looking plane resulted. However it would appear that this was another disappointing low-wing aeroplane. The longest distance flown being little more than that of the Mufli. Achievement of the HVS has been to operate in high winds; speeds greater than 21 mph (the plane's cruising speed) have been quoted. (Aero Modeller, Aug 1983).

ADJUSTMENTS would have been difficult to make on the HVS. The "V" tail precludes adjustment of vertical or horizontal tail area; and the canopy fits pilots of only one height.



Nihon University *MiLan'81* in flight.

Ian Parker flying Fred To's *Phoenix*. Photo Fred To.

On this plane, the pilot operated non-rotating pedals to drive an adjustable pitch propeller. The drive mechanism was complex, entailing cable runs to the pylon where there are chains to contra rotating flywheels on the prop-shaft. With a cantilever wing of 54 ft span and a carbon-fibre structure, the HVS first flew on 12th March 1983.
The HVS was designed and built before the setting of the Kremer World Speed Competition, yet its cruise speed of 21 mph was just in the range to make it a contender had it been more successful.

PELARGOS II
In 1980, Max Horlacher the head of a small company which worked with composites, hoped to build a plane which his son, then eleven, could fly and which could be entered for the Kremer figure eight competition. His first plane, Pelargos I, did not take off, and although he blames this partly on the fact that his son had put on too much weight, he decided to call in assistance for his next design.
Fritz Dubs, an aerodynamicist from Zurich who collaborated on the Pelargos II pointed out that the aerofoil section must be changed to be suitable for the very low speed at which they intended to fly the new plane.
The firm of Reichhold Chemie AG supported the project by supplying the synthetic materials used. It is noteworthy that the wing-ribs and other secondary structural items on this aircraft were made from carbon, compared with the more usual and cheaper foam sheet construction. Other unusual structural features were a rigid strut and a light rear-spar. This rear-spar, as well as stiffening the wing generally was also made to serve as a place on which to make the joint between the sheets of Mylar, the greatest available width being six feet, and the chord of the wing over eight feet.
It might seem that the wing could have been covered by using the width spanwise, and forming the joints on ribs; but if “tensilised” Mylar was used than this would explain their procedure. Tensilised Mylar shrinks more in one direction than the other when warmed. If correctly oriented, it will provide a better approximation to the rib shape between the ribs.
The propeller was 12 feet in diameter, one of the largest used. For ease of construction, a rectangular shape was chosen for almost everything else. This aeroplane was one of the first to be easily transportable in sections. The constructors benefited from Horlacher’s business experience, and the lessons learned on the plane were, in turn, useful to the business, as well as an advertisement for them and for Reichhold. Once the Pelargos II was constructed, it was put on display at a trade show in March 1983, but did not make its first flight until seven months later, because of difficulties in finding a satisfactory transmission system. A Cardan type universal joint was one of the options considered for this.
On January 20th 1984 Horlacher wrote to the RAeS to enter for the Kremer figure eight competition. Max Horlacher knew that there was competition both from the HVS and from Rochelt’s Musculair. He wrote in June 1983 “I do not grudge the German team its success up to now. Both the aeroplanes are distinctive. One could be curious which will be successful”.
The Pelargos II first flew in December 1983. On a later flight it covered a distance of 1100 yards.

MUSCULAIR I
Was built by Holger Rochelt and Gunter Rochelt, and designed by Gunter Rochelt, Ing. Ernst Schoberl and Dr.Ing. Heinz Eder. Gunter Rochelt had previously built a successful and radical solar-powered-aircraft. This human-powered-aeroplane was not built with the intention of winning a Kremer Prize. It was built with the intention of winning two Kremer Prizes. But it didn’t. It won three of them!
Although there are many difficulties in the design of an HPA, one of the ways in which it is easier than for most other classes of aeroplane is that one has generally needed to only consider a narrow speed range. But Ernst Schoberl in his optimisation process aimed to find a shape which would be suitable both for the figure-eight course and for the speed course (see next page), and it would be piloted by Holger Rochelt who was not particularly athletic.
As can be seen from the table, the wing area of 173 sq ft was one of the smallest used on an HPA, and contrasts with the 760 sq ft of the Condor, the only other plane to fly a figure eight. A conventional configuration was chosen, with the propeller behind the tail, the drive shaft being the length of the tail boom. This propeller had previously been used on the solar-powered-plane.
Spar construction was by laying-up cloth onto a rectangular block of foam: firstly diagonal weave all round, then spanwise strips top and bottom. Ribs were foam sheet, and the wing was skinned at the nose area, then covered in Melinex. The torsional stiffness deriving from the box-spar and the Melinex covering was found to be insufficient and it was found necessary to involve the “C” shape nose skinning in the task of load-carrying. This

was done by adding diagonally-braced carbon-fibre rovings and effectively changing the "C" to a "D", thus forming a closed box.

The plane was built in three months and made its first flight, as yet without cockpit fairing, at the end of May 1984. Within two weeks, on 18th June 1984, Holger Rochelt made a figure-eight flight.

One Kremer prize for the Rochelts, the second ever figure-eight in HPF.

Musculair I story continues later.

The Kremer World Speed Competition

AIMS In the early 1980s there was much discussion by the committee of the then called Man-Powered-Aircraft-Group of the RAeS about where we go from here, whether the time was ripe for another competition, and if so what form of competition. The figure eight had been flown. The English Channel had been crossed, and hence in some ways the hopes of 1957, and of centuries before, had been more than realised.

However,

1/ muscle-powered-flight was still impractical,
2/ flying was restricted to freak calm weather, and
3/ the aircraft were of monstrous size. Apart from the obvious need for improvement in these ways there were also the hopes of
4/ initiating a sport,
5/ maintaining the momentum of development,
6/ continuing to encourage the pursuit of excellence, which was seen to imply high-technology,
7/ tending towards enabling the man-in-the-street to be the man-in-the-air, which was seen to imply low-technology, &
8/ prizes being awarded on a wider basis than previously.

SETTING-UP

With these aims in view, a working group, the majority of whom had designed successful HPAs, was formed under the chairmanship of Nick Goodhart. A speed competition was chosen as the most likely event to promote as many as possible of the above facets of HPF, and the course was carefully planned in the usual way as being just beyond possibility at the current state-of-the-art. Henry Kremer was approached for the financial support which he most generously provided.

TROPHY

Also Henry Kremer had observed, when in the auction rooms of Christie's of London, an impressive bronze sculpture of a winged man striving forward with eyes determinedly fixed on the horizon. Seeing this as representing progress in human-powered-flight he promptly acquired it and presented it to the RAeS, and it now became The Kremer Trophy.

Inscribed "L. ALLioT", it is of unknown origin. A replica of the trophy was presented to each successive winner, along with a share of the prize money.

The spirit of the competition was, with the foregoing eight points in mind, to aim for maximum speed around a circular mile. It was believed by some that the development of stored-energy (see glossary) might be one path towards a more practical vehicle, although anything taking a long time to wind up was seen as impractical, hence a rule allowing a maximum of 10 minutes for storing energy. At that time, there was no experience of stored energy on HPA since the bungee launches of Mufli 47 years previously.

The rules were drafted by Martyn Pressnell and after full discussion in committee, were approved by the Society's council, and published on 4th May 1983 by the Society.

RESPONSE

The response was overwhelmingly fast compared with other competitions, as the following narrative shows.

THE RACE

The fastest previous plane, Jupiter, flew at 20 mph. This is equivalent to a mile in three minutes. But to win the first prize of £20,000 this speed must be exceeded around a triangular course. To win a subsequent prize, an entrant must improve on the previous time by 5%. And subsequent prizes are only £5,000. Hence there is a big incentive to be the first. After that, a faster speed is needed for less money.

The Chrysalis team and the Gossamer Condor team had co-operated in 1979. It was a Chrysalis designed propeller that had crossed the English Channel, and it was Condor Mylar that covered the vast areas of the wings of the Chrysalis biplane.

In 1983, with news of a new competition, they saw each other as potential rivals. At a meeting in February Paul MacCready, Condor initiator, declared that he would not be competing, but this was met with scepticism by John Langford and others at MIT who had been involved with Chrysalis.

4 MAY 1983 Royal Aeronautical Society Human Powered Aircraft Group, the competition's organisers, announce the rules. Following the publication of these rules, both Langford and MacCready promptly indicate to the organisers their intention to enter the speed competition.

5 MAY 1983 Langford and some of the old Chrysalis team at MIT hold the first design meeting for the aircraft they will call the Monarch. They decide to build a very simple machine, just capable of a 3 minute time.

27 MAY 1983 The old Chrysalis foam-slicer is dug up and restored. The first Monarch parts are made.

28 MAY 1983 MacCready's team, which includes some of the Condor people, start to design their entry for the Kremer World Speed Competition, which will be called the Bionic Bat or Gossamer Swift. These people have the experience of many Condor aircraft, and they have the carbon-fibre technology which they developed.

MAY 1983 Wayne Bliesner starts to add a twisted-rubber energy storage system to his Man-Eagle. This plane had already flown the previous year and is fast and controllable.

14 JUNE 1983 Knowledge of Monarch becomes public.

27 JUNE 1983 Construction of Bionic Bat starts.

10 JULY 1983 Knowledge of Bionic Bat becomes public.

4 AUGUST 1983 Monarch rolls out - and rolls over, causing damage to the airframe.

14 AUGUST 1983 Repaired Monarch makes first flight. This students aeroplane is made from aluminium tubes and plastic foam, but carries ingenious energy-storage gear enabling pilot to control motor assistance during "play-back" in flight.

20 AUGUST 1983 Bionic Bat makes first flight. Seen casually from a distance, Bat looks similar to Monarch. But pilot seating, propeller position and wing bracing all differ between the contesting machines.

23 SEPTEMBER 1983 Monarch crashes on development-flight. Fuselage wrecked.

25 SEPTEMBER 1983 Bionic Bat flies course in 2 minutes 39 seconds. Claim is submitted to organisers. Monarch team know they will never beat this by 5%.

13 OCTOBER 1983 Parker MacCready, Bionic Bat pilot, invited by John Langford to describe his experiences to Monarch team.

15 OCTOBER 1983 Monarch team store their aeroplane away and start to redesign the fuselage, which had been a source of problems anyway. Pilot seating will now be recumbent, same as Bat. New version will have variable pitch propeller, an important item when motor assistance is used (see Monarch).

23 NOVEMBER 1983 RAeS disallow the Bionic Bat claim for technical reasons concerned with energy storage.

DECEMBER 1983 A few parts made for Monarch variable pitch prop

JANUARY 1984 Bionic Bat is being modified with a new electrical system, 5 lb heavier. Parker MacCready continues to practice the course with this new system.

Gunter Rochelt starts construction of Musculair. This will not use stored energy, being powered only by Holger Rochelt for prize attempts. Man-Eagle is modified to use electrical system.

FEBRUARY 1984 New Monarch fuselage being built secretly, road-testing at night.

29 FEBRUARY 1984 Paul MacCready declares he will dispense with stored energy, and modify wing instead. Span will be increased from 48 to 55.5 ft.

4 APRIL 1984 Langford's new fuselage completed. Plane flies again renamed as Monarch B.

APRIL 1984 MacCready new motorless variant flies as Gossamer Swift.

3 MAY 1984 Pilot Frank Scarabino attempts to fly Monarch B around the course, but new variable-pitch propeller is wrongly set. Attempt aborted.

5 MAY 1984 Scarabino tries again. Crosswind ends flight.

6 MAY 1984 Scarabino completes course - in 3 minutes 0.43

7 MAY 1984 Another attempt with the Monarch B, but Scarabino lands from exhaustion part way around. Scarabino rests for 3 days.

11 MAY 1984 Monarch B team prepare for another attempt. The official observer watches click to denote the commencement of the 10 minute storage period. Frank Scarabino starts to pedal to charge up the batteries. If more than ten minutes are spent on the ground then this excess time gets added to the flight time. The ten minutes are coming to an end when a door zipper jams, the struggle to unsnag this causes precious seconds delay, and Frank takes off 5 seconds late. To get the prize he will now have to fly the course in 2 minutes 55. He climbs to clear the required height of two meters at the starting line and heads for the first turn which is at the end of a runway on Laurence G. Hanscom Field, Bedford, MA. He clears the two markers which represent the short side of the triangle and straightens up for the half mile stretch past the MassPort Civil Terminal, continuing past the control tower towards the last turn. With the new electrical system on Monarch he can ration the amount of charge coming out of the batteries. The idea is that the batteries, his legs and three minutes all get exhausted at the same time - except, there is five seconds to be made up. It isn't just leg work. It isn't even just leg work and also flying a plane as well. The electrical system is another thing to have to think about. On the last turn he opens the "throttle" slightly to get more help from the motor. Now to straighten up for the last quarter mile stretch over the runway and the climb to two meters at the end. Monarch B crosses the line 2 minutes 50 seconds after crossing it the first time; he has made up the five-second-late start. A time of 2 minutes 55.72 seconds is recorded. The Monarch B team have won the £20,000 first prize.

John Langford will be able to take his pick of the replicas of the Kremer Trophy. The Monarch team retire from the race, considering that their plane has done the best it ever will. But while others compete for subsequent prizes, they have a longer course in mind - see below.

JUNE 1984 Paul MacCready decides to use stored energy after all. The team prepare an improved system that uses the motor as the generator. This means only one item and less weight to carry. But the increased span remains.

19 JUNE 1984 Holger Rochelt takes Musculair round the figure-eight course, winning the prize for that competition. Now the Musculair can be refined for the speed course. A time of only 4 minutes 5 seconds for the figure-eight shows the potential of this plane.

JULY 1984 Bionic Bat with new motor and 55 ft wingspan rolls out and makes practice flights. This aeroplane was built from carbon-fibre tube by professionals, and has been refined over several variants.

But the electric motor only has an on/off switch.

18 JULY 1984 Parker MacCready flies course in 2 minutes 43 seconds, gaining second prize of £5,000 with the Bionic Bat. The length actually flown to clear the marked out triangle depended on how wide a turn each pilot made, but it can be considered as nominally a mile. On this basis Parker's speed was 22 mph.

3 AUG 1984 Musculair gets round speed course in 2 minutes 45 seconds, an improvement on Monarch's time of more than 5%. Rochelt hasn't heard of the Bionic Bat success and thinks he has second prize.

AUG 1984 Continual training and refinements of the plane including reducing tail area improve the Musculair performance.

21 AUGUST 1984 Holger Rochelt completes course in 2 minutes 31 seconds. Speed based on a nominal mile is 24 mph.

NOVEMBER 1984 MacCready makes no more major changes to the aeroplane but calls in pilot Bryan Allen, who pedalled the Condors on their prize winning flights.

2 DECEMBER 1984 Bryan Allen clocks time of 2 minutes 23 seconds, improvement on the previous record is 5.8%. A nominal-mile-speed of 25 mph. The second time that the Bionic Bat has earned a prize.

FEBRUARY 1985 Musculair is severely damaged in road accident.

1985 Rochelts and Schoberl decide to design and build new plane specifically for speed course. No energy-storage will be used. Good aerodynamics, neat structure and accurate wing-profile. Elliptic chain-wheel. During this summer Wayne Bliesner, who has been training hard and improving his energy-storage-system makes eight attempts on the course. It is now necessary to complete the course in 2 minutes 15 seconds. He can't quite get round in the required time.

AUGUST 1985 Musculair II nearly complete. Rochelts bring plane to England, hoping to fly at Milton Keynes festival. Musculair II completed at Cranfield, but weather precludes flight. Plane displayed indoors at Milton Keynes.

1 OCTOBER 1985 Holger Rochelt flies Musculair II round speed course in 2 minutes 21 seconds. This is the fastest yet, beating the Bat's 2:23, but not beating it by the required 5%.

2 OCTOBER 1985 For today's record attempt, Holger warms up for two hours and is psychologically prepared by an experienced bike-racer. He beats his yesterday's record by an amazing 19 seconds, covering the course in 2 minutes 2 seconds, thereby qualifying for a Kremer prize, the Rochelt family's third award.

This time represents a nominal-mile-speed 30 mph, a 15% improvement on the previous winner, 50% better than original target at start of competition.

1986 RAeS close competition, but course still recognised by FAI for speed records

SPEED COMPETITION SUMMARY OF RESULTS

Compare the table below, showing dates of first flights and prizes for this competition, with the fact that after the announcement of the first Kremer Competition, the figure eight, it was 2 years before the first flights of SUMPAC and Puffin, and 18 years and 25 years respectively before prizes were won by the Gossamer Condor and the Musculair I.

Review of Human Powered Flight to 1990

Aircraft	Project Starts	Pilot	Date of the prize flight	Time	Percent improvement	Speed based on mile			
				secs	%	mph	knots	ft/sec	m/sec
Initial goal	4 May 1983			180		20	17	29	9
Monarch B	May 1983	Frank Scarabino	11 May 1984	175.7	(2.39)	20	18	30	9
Bionic Bat	May 1983	Parker MacCready	18 Jul 1984	163.3	7.06	22	19	32	10
Musculair I	Mar 1984	Holger Rochelt	21 Aug 1984	151.4	7.29	24	21	35	11
Bionic Bat	May 1983	Bryan Allen	2 Dec 1984	143.1	5.48	25	22	37	11
Musculair II	Feb 1985	Holger Rochelt	2 Oct 1985	122.0	14.74	30	26	43	13

And as it transpired all of the eight basic criteria mentioned above were satisfied and hence it was a successful competition, as the following points show:

1/ muscle-powered-flight had been impractical.
The Musculair II was able to perform at air-shows.

2/ flying had been restricted to freak calm weather.
There was not as much progress as might have been expected from the usual rule that a faster aircraft can operate in stronger winds. John Langford of the Monarch team reported “Weather was always a problem. - Final weather checks were made at Hanscom about 3:30 am, and a go/no go decision made about 4:00. - The aircraft was never taken out in winds higher than about 4 mph although gusts of up to 9 mph were recorded during some flights. Long turns and Kremer courses were not attempted in winds above about 1 mph. Flying was usually completed by 7:00 am.”, and “The Monarch is clearly a transitional aircraft. It is no longer a fragile gargantuan and yet neither is it a ‘practical’ ultralight aircraft in any sense of the concept”. (Langford 1984).

Compare the flying usage of its predecessor the Chrysalis which was half the speed of Monarch, yet its first flight was in a wind of 8 mph. (Chrysalis was in fact the slowest aircraft ever to fly). Langford wrote “Eight pilots made 24 flights on June 24 [1979]. Thereafter, the aircraft was rolled out whenever the weather was good and people wanted to go. When the weather remained calm, the sessions extended far into the morning; one day in July a record 11 pilots made 56 flights in Chrysalis. This particular session concluded when the wind speed consistently exceeded flight speed, but not before the aircraft demonstrated hovering and even backward flight.” (AIAA Student Journal Spring 1981).

3/ the aircraft had been of monstrous size. Seeing Musculair II, the author was impressed particularly by the compactness of the plane and the speed with which it could be rigged. The wingspans and areas shown in the Table indicate the size of HPA of this period in general.

4/ initiating a sport.
What could more define sport than two teams competing and alternately creating new world speed records. The records were accepted by the FAI. Seen from outside, the prize-flights were more pilot-oriented, although the differences between the machines made the contest far from a “class-design”.

5/ maintaining the momentum of development.
The table above shows in how few years the performance of HPA was increased during this competition. John Langford compares the race to be the first winner in the speed competition with the race of 23 years previously “The contest between the Monarch and the Bionic Bat played out an old and familiar contest that first occurred in the race between students at Southampton (SUMPAC) and professionals at de Havilland (Puffin) to make the first human-powered flight in Britain. As in the 1961 race, the students triumphed in 1984.”

And in both contests, both the students and the professionals were eventually beaten by projects initiated by families:

Roper (Chris & Susan, Jupiter) 1972
MacCready (Paul & Parker, Gossamer Condor) 1977
and Rochelt (Gunter & Holger, Musculair II) 1985

MIT *Monarch B* in flight.

Bionic Bat flying over the take off and landing height marker.
Photo Don Monroe.

6/ continuing to encourage the pursuit of excellence, which was seen to imply high-technology.
The Musculair II with custom-aerofoil, carbon structure and monocoque wings was a quantum jump ahead of anything that had previously flown. The aerodynamic merits of this design were demonstrated not only by its making the biggest increase in speed, but also that this was without using stored energy.

7/ tending towards enabling the man-in-the-street to be the man-in-the-air, which was seen to imply low-technology.
This might appear to be incompatible with 6, yet in fact the competition promoted development in both directions. Monarch, the first winner was built with little more equipment than the box that the light-alloy tubes were delivered in, and the cost of the project was estimated at $6760 net ($2375 of this being energy-storage costs). See Monarch, and (Langford 1984).

8/ prizes being awarded on a wider basis than previously.
All the prizes went to people who had built and flown aircraft before, and the five prizes went in only three directions. However this aspect showed improvement as did all the others.

The competition was closed in 1986 when the committee felt that no further significant improvements in flight speed were probable and the Kremer funds could more usefully be deployed in other ways.

BATTERIES

Was anything learnt about stored energy that could be used in HPA or in human-powered-vehicles in general? The author had hoped that maybe something would be learnt towards a practical energy-regenerative braking system for bicycles. The kinetic energy would not be wasted in just heating up the brake-blocks and rims, but put into storage where it would boost acceleration when the rider restarted. Such a scheme would be appreciated by cyclists particularly the professional cyclist-couriers of London.

The various options for energy-storage were seriously analysed by the entrants and the conclusions were that the only two viable systems were batteries or twisted rubber, and that a third viable option was to omit energy-storage altogether. Hence only these systems were tested.

Anyone thinking of organising a competition which allows stored-energy should know that when applied to batteries the word “uncharged” must be carefully defined. The organisers consulted with many battery experts at Government research institutions and there is a supplement to the rules on this point. The first claim for a speed record was disallowed for technical reasons but in so doing initiated the establishment of a universal standard for discharge of batteries when employed for stored energy.

Various innovative systems were developed by both the Bionic Bat team and the Monarch team to charge in ten minutes and discharge in less than three, without losing efficiency on either occasion or carrying a heavy battery. Also developed was the ability to use the dynamo as the motor, and to enable the pilot to monitor the assistance from storage without requiring so much concentration as to detract from flying and pedalling ability. Details of these are in (Cowley 1985) and (Langford 1984)

REPORTS

Goodhart surveyed the competition at a symposium of the RAeS when several prizes and trophies were presented (RAeS MPAG Dec 1985). (See also Gremmer 1985).

FUTURE

Since then, a further vindication of the competition is that people from all the three teams who made official entries, who in fact were all winners, gained experience enabling them to go on to (1/) Daedalus, (2/ and 4/) a battery operated full-scale-model pterodactyl to test evolutionary theory and star in a film, and (3/ and 5/) a delta-wing single-place aircraft somewhat between a glider and a hang-glider.

Later developments in rare-earth motors and fast charge batteries indicate that both the Bionic Bat team and the Monarch team were on the threshold of new progress in electric power as an aid to HPA. Model aircraft have proven the point over and over in the late 1980’s and the Paris, France to Manston, England flight by solar power by MacCready with Solar Challenger heralded yet another benchmark in electric power for very light aircraft.

MONARCH A & B

Chrysalis designers Mark Drela and John Langford had been intending to build another aeroplane. They had made sketches and even chosen a name. Monarch is named after the monarch butterfly, the next stage after a chrysalis.

Hearing of the Kremer World Speed Competition, Drela and Langford proportioned and optimised this new plane for it. This meant a much smaller machine than their previous one.

With a team comprising Scott Clinton, Juan Cruz, Mark Drela, Steve Finberg, John Flynn, Whitney Hammett, Geoffrey Landis, Barbara Langford, John Langford, Tom Roberts, Frank Scarabino and Rick Sheppe, this aeroplane was flying within 88 days of start of construction.

Constructional techniques were similar to those used for Chrysalis, although the layout was very different.

Unusual on the Monarch was the wheel drive system.

On an HPA wheel with chain-drive like a bicycle, the number of times the chain makes a complete circuit during take-off is in two figures. When in flight it is a nuisance, turning the wheel for no reason. Why then does the wheel-drive-chain need to be endless? The Monarch team realised it didn't and built their wheel drive accordingly on the principle of a glider launching winch.

Considerable sophisticated analysis went into the sizing of this aircraft. An early design decision was to use a simple structure and an ingenious electrical system.

For a comprehensive & detailed account of a project from conception to the winning of a Kremer prize, John Langford describes the Monarch in his thesis (Langford 1984).

The plane is also further mentioned above in the narrative of the speed competition.

BIONIC BAT/GOSSAMER SWIFT

Team members were Bryan Allen, Bob Boucher, James D Burke, Martyn Cowley, Adam Curtin, Bob Curtin, Bill Dodson, Roy Haggard, Lance Inoue, Parker MacCready, Paul MacCready, Tyler MacCready, Ray Morgan, Taras Kiceniuk, Les King and Roger Sinsheimer.

The Bionic Bat was yet another aeroplane from the MacCready stable to win a Kremer prize, this time in the speed competition, and this time two prizes, (see above). This plane was in fact the first to complete the circuit in the specified time of three minutes but was disqualified because of technicalities of the energy-storage.

Configuration was a recumbent pilot in pod under a high wing. Propeller was concentric around the tail-boom just behind the pod, as on the Icarus. Such a design was vindicated when, on flight tests, the drag was less than estimated. The team consider that this may have been caused by the effect of the propeller in reducing the drag of the fuselage.

Electrical storage was by Astro samarium cobalt Astro 40 DC electric motor/generator and a battery of 16 Nickel-Cadmium rechargeable cells returning an overall storage system efficiency of 20%.

The approach to pilot safety differed widely from that of the early large Condors, where the pilot would jump out if anything broke. On the Bionic Bat, the structure was designed to not break, and the pilot strapped in.

FLIGHT ENVELOPE

The wings were designed to carry 3g or minus 1g. Minus 1g represents inverted flight. The Bionic Bat never actually flew upside down, but it was strong enough to have been able to. For safety, a flight envelope is drawn to include actual anticipated manoeuvres well inside it.

The fuselage was designed to withstand a 4g vertical landing load or a 6g head-on load. The wheel was designed to withstand 1g aft from braking with a 0.7g simultaneous side-load. The nose wheel was designed for 1.5g vertically with a 0.7g side load. The maximum airspeed catered for by the structure was 50 mph. The design manoeuvring speed was 40 mph. This is the maximum speed for which the structure permits full control deflection. Stall at 1g, i.e normal flight was anticipated as 25 mph (see Flight Envelope in Glossary).

The next step was to decide on the lightest type of structure which could carry these loads. Wire bracing, as used on many machines, enables a lighter wing spar, but at the expense of extra drag. That means more power from the pilot. An optimisation procedure will indicate whether a cantilever wing or a wire-braced wing will lead to a lower power-requirement. In the case of Bionic Bat, the unusual answer was that the very short strut characteristic of the Bat would be best. (This choice may also have been influenced by consideration of ease of assembly and rigging).

Materials used were carbon-fibre tubes. Tubes are most efficient when of large diameter and thin wall. The spar tube on this plane is nearly the depth of the wing, and so thin that it would buckle locally unless supported. Some support would be provided "free" by the wing ribs, without any extra weight, but in addition internal discs were added midway between ribs. The tail-boom tube had to be stabilised externally, since control cables ran inside. Another method of tube stabilisation considered by the team, but not used, is to stabilise externally with a layer of Nomex honeycomb, then a layer of Kevlar to form a sandwich, as used on HPV road vehicle fairings and the Challenger aircraft. In order to protect the pilot from carbon splinters, tubes in the area of the pilot were wrapped with bonded-on Kevlar cloth which does not splinter if broken. Fore and aft loads on the wing of the Bat were carried by what was effectively a horizontal "I" beam. The tube-spar was one boom, the trailing-edge-member the other, with the Mylar covering acting as the web (for free again) and the ribs being the stiffeners.

WING AERODYNAMICS

A section to suit this plane was derived from Robert H. Liebeck's LH 110 aerofoil. The wing area was changed several times during flight trials.

BIONIC BAT VARIANTS

Date	Span	Area	Weight	Motor	Generator	Course time	
	ft	sq ft	lb			seconds	
Aug 1983	41.9	110	76	2	1		
Sep 1983	48.0	134	84	1	1	159	
Jan 1984	48.0	134	89	1	1	161	
Apr 1984	55.5	149	66	0	0		The Gossamer Swift
Jul 1984	55.5	149	72	1		163.3	Parker MacCready Second Speed Prize
Dec 1984	55.5	149	72	1		142.1	Bryan Allen Fourth Speed Prize

Control surface areas also varied. The April 1984 variant had a larger propeller diameter. Roy Haggard also piloted the Bat.

EFFECT OF MOTOR ASSISTANCE

Martin Cowley writes, "An advantage is a constant speed effect, if the pilot relaxes his pedalling, the motor provides a larger proportion of the power required to fly. If the pilot increases output, the motor reduces its contribution. However, this is a mixed benefit, as it now becomes difficult to 'add power' merely by pedalling harder"

On the Monarch B, the use of a variable pitch propeller enabled this to be overcome. Total power output was controlled by varying the pitch of the propeller. The pilot put in some of this power, and the motor provided the remainder.

Gossamer Swift, the April 1984 variant, was without the complication of energy storage and compliance with the competition rule relating to energy storage that this involved. However, the team returned to the use of electrics with a single motor which also served as the generator. (cf Musculair II which used no energy storage).

Bionic Bat is also further mentioned above in the narrative of the speed competition.

With more training and some refinements to the airframe, Holger was ready for the next competition. But the speed he now needed to fly at to get a prize had been increased by 16%, because meanwhile two prizes had been won. Original target was 180 seconds. Now, to get a prize, Holger must pedal round the course in less than 155.12 seconds.

He did it in 151.38 seconds with no motor assistance. The Rochelts had considered using stored energy, then decided that it was a wasteful impediment.

PASSENGER FLIGHT

Holger's sister, Katrin Rochelt weighed 62 lb, the same as the plane. A makeshift seat was taped to the back of the main fuselage vertical tube. She climbed in behind her brother and she held on tight. Musculair took off and made a flight of 550 yards, reaching a height of 16 ft with the wings deflecting considerably more than usual. The incredibly modest Holger, winning pilot for three Kremer awards said later, "I just had to pedal a little harder".

Bionic Bat then cut 8 seconds off Musculair's time, but before the Rochelts could beat this latest record and bring the trophy back home once more to Germany, Musculair was seriously damaged in a road accident, so they decided to build another plane.

MUSCULAIR II

This aircraft was brought to England when nearly complete, in the hope of flying at the Milton Keynes 1985 "Zapple" Festival of Human Power. Final details of construction were done at Cranfield College, and the plane was brought and displayed indoors at the festival, but bad weather precluded flights.

Aerodynamically optimised by Ernst Schoberl, and test flown by Holger Rochelt and Peer Frank, with project management by Gunter Rochelt, this plane was advanced for its time. It was designed to fly the speed course in two minutes. Schoberl writes that design and construction of Musculair II was relatively simple since the team "merely" had to adapt proven concepts for the new conditions (another modest man talking).

WING

The section was derived from the Wortmann section FX 76 MP by Dieter Althaus at the University of Stuttgart to suit the particular Reynolds' number and lift coefficient anticipated.

Musculair I had experienced torsional problems. As described it had needed to be stiffened by the addition of rovings. For the II the team opted to skin the wing all over with a fibreglass/foam/fibreglass sandwich. This would also hopefully produce an accurate surface finish. The wing surface did indeed look incredible, as though it had been carved out of a block of aluminium. Performance indicated its good characteristics, but it suffered an imperfection as mentioned below (See Cyclair). The upper skin dimpled between the ribs in flight except at the spar position where the spar restrained it. Thus, in a chordwise direction, there was not a smooth curve. Schoberl considers that without this defect, an even greater extent of laminar flow could have been achieved.

The main area of the fuselage fairing used the same material as the wing-covering, but moulded to double curvature. The shape had been arranged so that the windscreen was single curvature, this is lighter and enables a better view (the author copied this concept in the design of the Bluebell III road vehicle). On Musculair II the windscreen was removed for pilot access, and then taped in place.

Musculair II had carefully shaped wing-tips to reduce induced drag, and a non-circular chainwheel which Schoberl claims improved power output by about 5%. All details on the plane were neat, ingenious and light. It could be rigged in 10 minutes. The team were seen to be in good spirits and not exhausted at the completion of construction.

The plane was more tricky to fly than the I, but on October 2nd, Gunter flew it around the speed circuit in 2 minutes 2 seconds, winning the fifth and final Kremer Speed Prize. Also recognised by the FAI, the Musculair II is currently the holder of the World Speed Record.

Gunter Rochelt offered to produce copies of Musculair II for sale at $ 25,000.

MAN-EAGLE

In 1982 Wayne Bliesner, who had previously built and flown several HPA, (see above) was perfecting a new wing design. He set up an optimisation computer-program which indicated that a span of 110 ft would be best. He then modified the FX 63-137 aerofoil to suit the conditions of flight, naming the new section WBT3134, which in theory at least has considerably better characteristics. This wing as originally designed was intended for long distance flight. This wing was built, using a carbon-fibre tube spar, rib-spacing of 3 inches and fitted to his existing Bliesner 7 fuselage complete with its V tail.

Tests showed that the flow over the wing was laminar back to 65% on the upper surface. Bliesner advises that the utmost care must be taken on the wing surface.

The wing tip deflection was fifteen feet, and it became clear that this had to be reduced. This was first cut to 74 feet and then to 63 feet. The resulting aircraft, the Man-Eagle 2 was found to require much more power to fly than would be expected of measurements made of the drag. This difference was traced to losses in the drive and also because the propeller had not been designed to be compatible to the reduced wingspan and was operating in a stalled condition. In particular it was not absorbing peak power.

At this point in the development of the Man-Eagle, the Kremer World Speed Competition was launched, and Bliesner decided to make his next variant suitable for this. The "V" tail of the previous designs was rejected. The new plane had a pod & boom fuselage with the propeller mounted in front. The pilot was recumbent, and the boom was low, with the fin above.

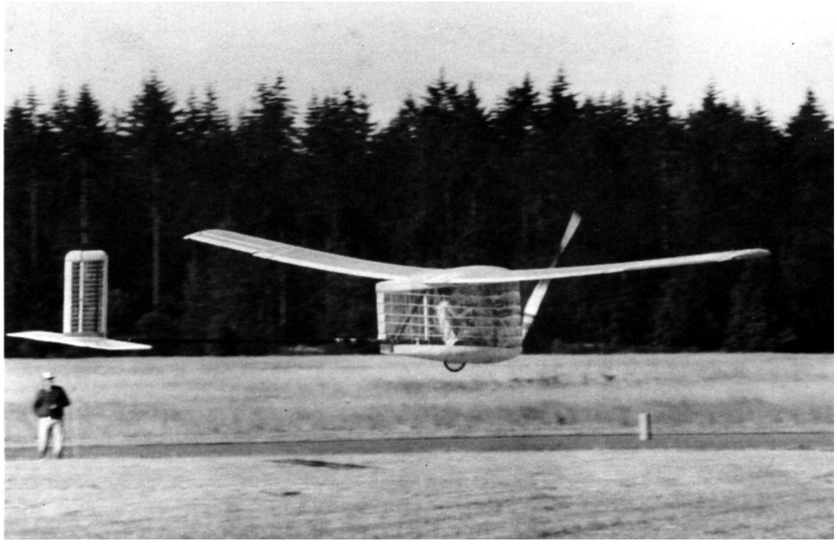
Experience with previous aircraft indicated the benefit of a propeller capable of absorbing peak power without stalling, and 3/4 of a horsepower was allowed for, in the new propeller.

Musculair I flying.

Photo Ernst Schoberl.
RAeS HPAG archive.

Musculair II flying.

Photographer unknown.



Wayne Bliesner flying *Man Eagle*.

Photographer unknown.

STORAGE SYSTEM

Wayne Bliesner first fitted a twisted-rubber energy-storage system, just like a rubber-powered model-aircraft. Propeller hub was in front and just above the pilot, so the strands of twisted rubber were above the head. Bliesner discarded this for safety reasons, not relishing the result of a strand snapping and whirling so close. He installed an electric system which was more reliable but not so efficient as the rubber (other aircraft have used twisted rubber, but housed inside the tail-boom see Swift).

PERFORMANCE

On some occasions, Wayne Bliesner took Man-Eagle out of the hangar alone, climbed in and made a flight completely single-handedly (as he had done with the Bliesner 5). As tests continued, a group of 2 or 3 ground crew provided a very safe and reliable combination.

To achieve a record performance, a pilot needs to train physically. This, he declares, is where he has found difficulty. If a pilot is chosen who is already athletic, then the project already stands a chance in a competition. If there is only yourself, and you are only averagely athletic, then you will need to give considerable time to training. Between 1983 and 1986 he developed his power output from that of an ‘average fit cyclist’ to a third of the way between this level and that of a ‘champion athlete’, but states that this diversion of effort did compromise the project.

The plane made hundreds of controlled flights during 1985, with a total flight time of over three hours, and on one occasion completed 90% of the speed course in 2 minutes 5 seconds. This was at a time when 2 minutes 16 was required for a prize.

Following the closure of the competition, Wayne Bliesner concentrated on streamlining the fuselage pod and produced a very smooth shape for the Man-Eagle 4.

MAN-EAGLE VARIANTS

In all cases the wing was of WBT3134 section, with a carbon spar. The fuselage used for Man-Eagle 1 was that of the Bliesner 7, but with a new propeller. The wingspan was successively reduced as shown. The wing position was high in all cases, and on Man-Eagle 4 was separated from the pod by a short strut.

Year	Man-Eagle	Wing span	Special features	Energy storage	Propeller position	Flight results
1982	1 (Bl-8)	110	V tail	None	Short pylon behind pod	Excessive wing deflection & difficult to control
1982	2A (Bl-9)	74	V tail	None	Short pylon behind pod	
1982	2B	63	V tail	None	Short pylon behind pod	Measured drag less than pilot’s assessment
1983	3A (Bl-10)	63	New prop and tail	Rubber	Nose	Easy to control
1984	3B	63		Electric	Nose	Turns flown and the speed course flown.
1986	4 (Bl-11)	63	Moulded pod and parasol wing	None	Co-axial on boom	

MAN-EAGLE 5 PROPOSALS

Paul Illian, also a member of the Flight Research Institute of Seattle has proposed a development of Man-Eagle. The fuselage shape would be computer generated.

everal HPA have been built with the propeller shaft at the same height as the pedal shaft. This has necessitated a high undercarriage, and some of these planes have not flown. To make this layout practical, he suggests a retractable undercarriage.

Illian’s other justified criticism of most past designs is that Mylar does not provide the correct profile shape between the ribs. It is also true that the glass-cloth stiffened foam sheet that has been used has not held its exact shape under load.

With Bliesner’s experience, and Illian’s new ideas, we could well be seeing a very interesting new HPA.

SWIFT series

These aircraft were built by students at Nihon University to compete for the Kremer World Speed Competition. Swift A had the configuration of a high-performance sailplane. The pilot was recumbent with the propeller on a pylon above the wing. Structure was carbon and foam.

The Swift B and the subsequent Swift C had configurations similar to Musculair. The transmission was twisted chain, 1/2 inch pitch Shimano bicycle chain. Many different chains have been used on a twisted drive for HPAs. Any chain will be able to accommodate a certain twist per length, but this Shimano was found to be excellent.

Innovative on this Japanese aircraft was the use of two skeins of rubber inside a larger-than-usual tail-boom to provide energy-storage after the principle of a model-aeroplane. 13 lbs of 1/4 inch model-aeroplane-rubber were used.

Pilot Koichi Nakamura said in 1990 that these aircraft were nice to fly and had good controllability; however no official entries were made for the speed competition.

NEW ZEALAND There have been three projects in New Zealand, all of unconventional configuration; two of the aeroplanes made flights under tow.

FROST EMMETT HPA 197? -1979 and 1984

The machine was partly constructed in the 1970s by John Frost.

The structure was aluminium tube with a maze of bracing wires and control was by wing-warping, similar to the Condors of the same period.

The wing was covered with Dacron, a heavier material than Melinex, and the wing-area was only a third of the Condor. Span was 80 ft with a wing area of 250 sq ft, and empty weight was 92.4 lb. Configuration was flying wing.

Frost died in 1979 before the craft was complete and the machine became the property of the Auckland branch of the RAeS. In 1983 it was handed over to University of Auckland.

UNIVERSITY OF AUCKLAND 1984

In 1984 Grant D. Shirreffs and Daniel S. Steinemann of the University of Auckland made a two-pronged attack on the problem of HPF. One was to complete and test the Emmett HPA and the other was to further develop the propeller design algorithm of Prof. Larrabee mentioned above.

Flight trials at RNZAF Base Auckland, Hobsonville, were made with the aircraft towed behind a car. The aircraft proved extremely difficult to fly. Lateral control was totally inadequate, and a wingtip dropping on take-off could not be corrected. Shirreffs reports, “This control mechanism would not be recommended for future HPA”. However he recognises that, “The structural design concept was arrived at simultaneously by MacCready and Frost...”

PROPELLER DESIGN

A Fortran computer-program was written for minimum induced loss propeller design. Shirreffs notes the difficulty in obtaining aerofoil data for angles of incidence beyond the stall. A listing of this program is in Shirreffs report to the University. (Report PME 84/041, Department of Mechanical Engineering, University of Auckland)

NZHPFG “ROYAL SPOONBILL” HPA 1983 to 1987

This ambitious design was for a three-seater aircraft, the pilots in separate pods, like the Newbury Manflier. Proposed wingspan for the “Royal Spoonbill” was 328 ft.

Robert Le Johnno-Johnson initiated the “New Zealand Human Powered Flight Group”, or “Squadron” in 1983. He applied to the RAeS for entry into Kremer Competitions on headed notepaper and challenged the Daedalus to a race.

The group built special workshop equipment including a vacuum-table for curing resin on Kevlar tubes and angle joints, but not all of the Royal Spoonbill ever existed as hardware. When the plane was quarter built in 1985, the workshop was vandalised. At this stage the group took the opportunity of a redesign.

However, the workshop was closed down and the squadron disbanded on 12th March 1987.

DON WALTHER 1982 to 1987

Don Walther of Christchurch, New Zealand was an ex-RNZAF-pilot. Between 1982 and 1987 he built a machine called the “Boffin Coffin.” This machine had a wingspan of 45 feet. The planform was unconventional, with a forward wing of 140 sq ft and a rear-wing of 120 sq ft. Weight was 126 lb, materials were resin-laminated aluminium-alloy sheet, EPS and Melinex. Pilot position was prone, i.e. head first. There was a shock absorber in the drive between the rear-wheel and the prop.

Flight trials were made at Wigram Air Base Christchurch with a car towing the plane. After the first flight, piloted by 65 year old Walther, he said, “When I took my eyes off the tiller and looked down I was looking down on the roof of the car. The aircraft came down very lightly, but I could hardly call it a controlled flight. It is a mystery just how much control there is with these ailerons on the front wing - how much they contributed to my safe landing and how much was pure luck...”

Even the three foot long main undercarriage leg survived this first landing, but after its second launch it landed tail-first causing damage. Further flight attempts were made in 1987 under pedal-power by younger pilots, Steven Preest and Trent Hiles.

Don Walther writes (January 1990), “The steady easterly breezes which blow over Wigram Airbase make it unsuitable for HP flights.”

Even in the hangar “The hangar doors had been left open and a blast of wind shot the machine backwards into a wall. I gave up repairing, as in any event, it received damage from time to time by people not familiar with the delicate nature of these aircraft.”

Walther abandoned the project in July 1988.

To date, the only human powered flight south of the equator has been the single flight of the Vine in Africa in 1962.

VERTIGO

Andrew Cranfield was working at Westland Helicopters, England in September 1980 when he started design of a human-powered helicopter. This had four rotor blades, two pairs contra-rotating. The pilot was on a bicycle-style seat frame above the blades in order to get the most ground effect. Rotor diameter was 79 ft, each blade having a 5 ft chord. Total lifting surface area thus amounted to 750 square feet. The coning angles at the root (the equivalent of dihedral) were set at 9 degrees and 6 degrees.

The blades would be operating at a ratio of height to diameter less than any previous helicopter. Experiment confirms theory that at a height to diameter ratio of 0.3 the power required is 70% of the power required when out of ground effect; but below this, the effect was unknown. Also to be considered, for helicopters operating indoors, is that the wake will circulate, not necessarily steadily, and thus effect a downwash on the aircraft. Estimates for the Vertigo based on extrapolated data for the beneficial ground-effect and ignoring wake-recicirculation indicated that the power-required to hover would be comparable with that of flying a fixed wing HPA.

A square torsion box spar was built for each blade. The top and bottom panels of the box being a carbon/honeycomb/carbon sandwich. The sides were foam sheet. The blades, conforming to a Lissaman section, were built on this in the same way as for a fixed wing, with foam ribs and Melinex skin. Rigging the blades was found to be awkward, as sixteen bolts held each joint and it was difficult to avoid damaging the foam sidewalls during this operation.

The initial transmission was by chain drive to a layshaft on which was mounted a single bevel gear. This bevel gear meshed with two others, each of which drove one of the rotor shafts. Control would be by pilot-weight movement as for a hang-glider.

On test there were two major problems: transmission and the effect of the blades passing each other.

The transmission system entailed the layshaft being on a cantilever bracket which was found to flex excessively in operation such that the bevel-gears did not mesh accurately. Also (as usual!), it was found that a chain tensioner was needed. At no point during the trials could the pilot exert his full power, because of transmission problems.

Each blade individually was tufted and showed a satisfactory flow-pattern. But, “As the blades approached on crossover, an aerodynamic interference caused the top rotor blades to pitch down and then flap down onto the lower blade.” And, “At the exact point of crossover, reverse flow was seen to take place momentarily on the lower rotor.”

The machine was tested with just the lower rotor fitted, and was seen to “skip around the floor” (Cranfield 1987).

Andrew Cranfield handed the machine over, and the new owner stiffened the transmission support considerably, but there are no authenticated reports of take-off.

This machine showed promise of leading to a successful helicopter, since the problems were identified and could hopefully have been obviated in a subsequent design.

THE DAEDALUS PROJECT

Pilot Frank Scarabino got his breath back after the prize winning flight of Monarch on May 11th 1984, and the team disassembled the plane. Then they all wondered "What next?"

Some of them had helped to make the last desperate attempt to get BURD to leave the ground. Many had been involved with both Chrysalis and Monarch or with all three machines. BURD could no more fly than could a caterpillar. They had been through the "Chrysalis" stage and on to the prize winning butterfly stage of the Monarch.

What could follow that? The next stage above emulating real living creatures must surely be nothing short of emulation of the gods, or the mythical heroes of ancient legend who consorted with them. The archetype of mythical fliers were the father and son team of Icarus and Daedalus.

Incredibly to readers of this book, it is probably true that most people still think HPF is impossible (see below), but "In his own subject every man knows that all discoveries are made and all errors corrected by those that ignore the 'climate of opinion' " C. S. Lewis. And by definition, most people think that myths never happened. But Drela and his colleagues are not most people. And maybe the original Daedalus did actually make the flight from Crete to the mainland of Greece. Could he possibly have done it then? Could it be done now? For a year, Mark Drela and fellow enthusiasts asked this question. Then they decided to find out for real.

PRELIMINARY ANALYSES May 1984 to April 1985

By the end of May, five of the Monarch team, Juan Cruz, Mark Drela, Steve Finberg, John Langford and Barbara Langford were studying charts of the Aegean and starting to calculate what sort of plane would be needed. They concluded that if the flight could be made, it would not be done in same sort of frantic rush as was used to get Monarch into the air, and it would not be done using the simple technology of MIT's three previous machines. Maybe, it was felt, it could not be done at all, and therefore it was proposed that a year be devoted to a feasibility study.

In February 1985 the Smithsonian Institution gave the group some initial backing on the basis of this proposal.

PHASE 1 April 1985 to April 1986 Feasibility Study

The official start of the Daedalus project with students at MIT making a preliminary design.

The only major difference between this first design and the eventual aeroplanes was the propeller position which was shown at this stage as behind the pod.

The classical Greek texts were studied in an attempt to pinpoint the route of Daedalus and Icarus.

A trip to Crete set up weather stations and made contact with authorities.

Efforts were made to get further sponsorship.

In the group's study of the likely power available, it was realised that up till then all experiments on the power that a human can output had not recorded the weight of the person producing it. Clearly a choice of pilot will be based, amongst other factors, on both power-output and weight.

STANDARD FOR MEASURING POWER REQUIREMENT

Drela showed mathematically that if an airframe has approximately half the weight of the pilot, then the power needed is directly proportional to the weight of the pilot. Therefore the parameter most relevant to pilot physical fitness is power-output per weight. Drela chose to quantify this in watts per kg.

This value could be expressed in ft lb/sec per lb weight. This reduces to ft/sec (implying 1g conditions). One could then get a feel for the magnitude of this parameter by comparing it with, for instance, how fast one can run up stairs. This is readily measured in ft/sec and is also equal to the person's power-output per weight. Watt-units become relevant if there is electrical-energy-storage. As a result of the Daedalus project, watts/Kg has become the standard measure of HPA power-requirement.

In April 1986 the group decided that a crossing of the Aegean was possible, but that technology would need to be developed, and that a prototype aeroplane would need to be built to determine the form of the final plane.

PHASE 2 April 1986 to April 1987

Michelob Light Eagle

With sponsorship from Anheuser Busch Inc, makers of “Michelob Light”, construction started on the Eagle. An Eagle is one of the trade marks of this company.

NEW AEROFOIL

Mark Drela had written a computer program which enables the design of aerofoils and which can accurately predict the performance at any Reynold’s Number. It is actually superior to a wind-tunnel test of a proposed section, because tunnels suffer from turbulence and interference from the tunnel walls and model supports. A series of sections was produced to suit the varying Reynolds numbers along the wing due to wing-taper.

WING PROFILE

A computer-driven foam-cutter was built, based on a hot-wire stretched between the pen-holders of two plotters. This was used not only to cut the ribs, but to cut the nose skinning panels from solid blocks. The wing sections never existed on paper either as lists of numbers or as drawings; the information came out of the design program onto disc, and this guided the cutter. The spar was three tubes aligned vertically, but this scheme was abandoned for the final design where the more usual single tube was used. Construction of Light Eagle took 15,000 hours work by 18 members of MIT.

PILOTS SELECTION, TRAINING & TESTING

Because of the sheer distance to be travelled on the cross-Aegean flight, pilots had to be selected on athletic stamina, based on a carefully set up test which measured heart-rate at 70% maximum oxygen uptake during prolonged exercise. Being athletes rather than pilots meant that they needed to be trained to fly. Many other projects, faced with a plane with a high power-requirement have asked the experienced pilot to step out, and asked a cyclist to step in - with disastrous consequences. On the Daedalus project the quality of the flying-training, and the piloting-ability acquired by those that flew the three aircraft is evident in that in all the flights made there were only two crashes, both in local weather conditions against which no amount of experience would have availed.

Like most HPA, both Eagle and Daedalus are single-seaters, and a flight simulator was built to familiarise pilots. Other than on the simulator which had the same seating as the aircraft, the pilots kept physically fit by training on upright unfaired bicycles.

DRINK

A special drink was developed by Ethan Nadel to refresh the pilots during flight. Nadel calculated how much fluid, glycogen and sodium would need to be replaced per hour, and found that no available drink would provide this. His own concoction was tested by the pilots on the ergometer and all who tried it could keep up a sufficient pedalling rate for six hours, except one who gave up after four hours because he had been sitting on the uncomfortable seat of the rig long enough, not because his legs were tired.

It must be mentioned that this was done in the spirit of engineering in order to find a satisfactory solution to a problem, not as pure research, since no comparative tests were done with other drinks.

JANUARY 1987 TEST FLIGHTS

The Eagle first flew in October 1986 at Hanscomb Field. The wingspan was then increased to 114 ft and the first series of Michelob Light Eagle test-flights were done at NASA Dryden during January 1987. On January 22nd with Glenn Tremml at the controls the distance record previously held by the Gossamer Albatross was reset at 36.5 miles. The World Distance Record for a female pilot was set at 10 miles by Lois McCallin, in 37 minutes 38 seconds. McCallin’s flight also established Duration-Female and Closed-Course-Distance and Closed-Course-Distance-Female records recognised by the FAI.

But the main purpose of these January 1987 flights was to gather data to guide the design of Daedalus itself.

LAMINAR FLOW

To discover whether the flow on the wing surface was laminar, the team used the following technique. Immediately prior to flight, the wing surface was painted with a powder/liquid mixture. As the liquid dried off, the type of flow could be detected by the streaks that remained. This was photographed during or immediately after flight. On the Eagle it was seen that the flow was indeed laminar in all the areas expected, including at some points on the lower surface where the Melinex had been deflected up to touch the carbon fibre spar, but not at the wing-tips. This turbulence at the wing tips was attributed to the coarseness of the texture of the foam skin-panels on the relatively sharp leading edge. Accordingly, a denser foam was used for Daedalus.

ATHLETIC LIMITS

The pilot's heart-rate and breathing-rate were recorded during these flights and results confirmed those obtained on the training-rigs and the simulator.

REQUIRED POWER

Attempts were made to determine how much power was needed to fly Light Eagle. These were not very conclusive.

It is notoriously difficult to use gliding angle as a measure, as any slight up gust will affect the results.

The other method used was to fit a strain gauge to the propeller shaft, and use readings from this in conjunction with recordings from the airspeed indicator and altimeter to determine power-required. Altimeter readings were necessary so that the power absorbed by any height increase during the test-period could be subtracted to obtain the net power for level flight. This system gave consistent results. Surprisingly perhaps, it even gave fairly consistent results when the mean height was varied between 10 ft and 25 ft. The best measure of required-power still seems to be the subjective estimate of pilots, backed up by the records of their heart-beats during prolonged flights after the effect of take-off on heart-rate has subsided. This can be quantified as a power value from the records of each pilot's performance on a ground-rig on the same day. One snag with this system was discovered later, when on any pilot's first Daedalus flight, there was an increase in heart-rate which was due to the excitement of flying the new plane.

AUTO-PILOT An attempt was made to make an autopilot, as had originally been envisaged for Daedalus. This did not prove possible because neither the artificial horizon display nor the sensors ever showed the degree of reliability necessary for autopilot operation, possibly because of a buildup of an electrostatic charge on the aircraft as it flew. This meant that the crossing of the Aegean would need to be made in daylight when there is more wind and turbulence.

PHASE 3 April 1987 to April 1988

DAEDALUS

The Daedalus airframe was considerably lighter than Eagle because it was designed to a lower load-factor, 1.75 g instead of 3g, and because a higher grade of carbon was used for the spar. There were no ailerons on Daedalus, whereas on Eagle the tip 12 ft had rotated. This more than offset the slightly heavier wing-skinning foam used. Parts for two Daedalus airframes were made simultaneously.

The United Technologies Corporation backed the project with $500,000, and there were many other sponsors.

AERO-ELASTICITY FLIGHT TESTS

A separate series of flight-tests was made with Light Eagle from December 1987 to March 1988. This research was aided by J. E. Murray of NASA-Dryden because one of the purposes of these tests was to gather information which could be useful in the design of a high altitude drone, which would operate at between 55,000 and 70,000 ft altitude. The flights were also invaluable pilot training for all the five Daedalus pilots Erik Schmidt, Frank Scioscia, Glenn Tremml, Greg Zack and Kanellos Kanelloppoulos.

A video recorder and a pair of mirrors were fitted to Light Eagle so that both wing-tips and the tail could be seen in one picture. The airframe was fitted with accelerometers, rate gyros and strain gauges to measure aircraft motion and wing and tail-boom bending. The computer that polled these sources 20 times a second weighed 2 lb and had a memory of half a megabyte. This system devised by the Daedalus team was recognised by NASA as providing good quality data. Each set of data was processed on a NASA mainframe the same day to give useful results for the next day's flying.

The Eagle has a long thin flexible tail-boom; on a plane like this, it is fairly obvious that if you waggle the elevator up and down fast enough, you won't move the plane, you'll just flex the boom. But that is just stating one of the problems that the Daedalus team set out to solve.

The natural frequencies of the pedalling-cadence, the structural flexure and the aircraft flight dynamics were known to be of the same order and would therefore be expected to interact. Therefore both the aircraft stability and the response to any control input could not be calculated using standard theory. Analysis of the stresses observed during tests showed that a drone with a similar structure to the Eagle could well survive the turbulence at the anticipated operating altitude. With regard to the involved flight dynamics question, the report on these tests found that the influence of aircraft flexibility and unsteady aerodynamics was greater than originally expected and concludes “The flight data collected so far may prove adequate for model validation, although special software will need to be written to handle the larger sets of equations of motion” (Zerweckh, Flotow & Murray, 1988).

Of direct relevance to the project was a study of the response of the aircraft to rudder only, to simulate Daedalus. It was observed that the aircraft moved into a turn satisfactorily, albeit with a 12 degree angle of sideslip. This was seen as confirming the decision to not have ailerons on the final plane, although at least one of the group considers that the lack of ailerons did play a part in the April 1988 accident.

The first flight of Daedalus 87 was in January 1988. Flight trials were satisfactory until a loss of control into spiral divergence resulted in a crash in February 1988. This was attributed to insufficient rudder movement because the control cables were stretching, and insufficient dihedral. The flight simulator proved useful in investigating how much more dihedral would be necessary, and it was seen as fortunate that the faults became evident before the plane was out over the sea. Construction work on the second airframe, Daedalus 88 was stepped up, incorporating the modifications and Daedalus 87 was repaired.

On 26th March 1988, the Hellenic Air Force transported all three aircraft to their Heraklion base on Crete. This conveniently has a runway pointing straight out to sea. Greek Navy ships stood by to escort Daedalus, the Greek National Tourist Organisation provided meals and lodgings to the team, and the Hellenic Industrial Development Bank helped to sponsor the epic flight.

THE CROSSING 23rd April 1988 It had been estimated that there were maybe 3 or 4 possible days a year when the weather would be suitable, and there had already been two of these just before arrival! The pilots were on a rota system. Each morning one would sit in Daedalus and wait to be told by Steven Bussolari that the weather wasn’t quite good enough today. Even if it was calm at Heraklion at that moment, reports from team members on the destination island of Santorini or from a yacht offshore or from Greek meteorologists would indicate unsuitable weather later on.

It is the 23rd April, the turn of Greek national cycling champion Kanellos Kanellopoulos to be in the pilot’s seat. The weather initially is ideal, with a 3 mph tailwind. Flight controller Steve Bussolari decides that the flight is on.

The Daedalus flight starts. The Heraklion runway ends at the top of a cliff, so Kanellos suddenly finds himself 130 ft up, but glides down to join the waiting escort boats. The speed of Daedalus, 15.4 mph is more than that of Gossamer Albatross on the English Channel crossing (12.1 mph). It has been so designed in order to make the distance in a short enough time for there to be a reasonable chance of the weather holding. The inflatables with their outboards are making a lot of wake just to keep pace, as photographs later show. The course has originally been planned as leaving from the Western tip of Crete, but this would involve too much flying close to coastlines with their associated turbulence. On the course chosen there is only the small island of Dia to detour around until the coast of Santorini is reached. Dia is passed after 26 minutes and all is well, but soon after this the altimeter fails. Bryan Allen had to fly the last five miles to France without altimeter. Kanellos has another sixty miles to fly without one. The morning is still cool and Kanellos is not drinking at the prescribed rate. Yes, the rate was prescribed because otherwise pilots tend to ignore drinking until dehydration started to impair performance. Suddenly a cargo vessel is seen sailing towards the flight path, but a Greek Navy boat heads this off. Kanellos pedals smoothly on, making Daedalus 88 the first HPA to lose sight of land, the first HPA to cover such a distance and then after 2 hours 48 minutes the new duration record holder.

The tops of the mountains of Santorini are seen first and then through the clear Greek air could be seen the whole island. Beautiful as it looks, the weather report radioed from the beach is not so cheering - an 8 mph wind, and in order to land into this wind, the plane will need to turn almost back on its current flight path. Thermals from the hot beach are causing turbulence. At 10.58 am, during this turn for a final approach parallel with the beach a gust lifts the plane and brings the groundspeed to virtually nil. A second gust from the side catches the rudder and snaps the tailboom. This momentarily causes full up-elevator deflection. The starboard wing is overloaded and snaps. Kanellos and the Daedalus 88 fuselage fall into the sea 20 feet from shore. He rips through the Mylar unharmed and with plenty of energy left to swim ashore, the whole trip done under his own power.

The local people are ecstatic, as are Kanellos and the rest of the team, and as indeed are HPA enthusiasts the world over when we hear the news and see the television pictures later that day. Journalists on the beach are baffled as to why the team should be pleased when their aeroplane is lying there, smashed up. The team are pleased

Ryan recumbent cycle paces *Daedalus 'A'* over the vast flats of Edwards air force base in California. Significantly, with experienced cyclists the aerodynamic efficiency of the human powered aircraft enables airscrew drive to match the effort required for the wheeled bicycle.

Photo Steve Finberg.
RAeS HPAG archive.

Daedalus on its way to Santorini.

Photo John McIntyre.

because they have accomplished what they have been planning for four years. Furthermore, because the project was a pursuit of the ultimate, the fact that the plane just completed the course before breaking up was proof that it was designed just right for its intended purpose.

The flight clearly was a success and must be recognised as such; however it is double-counting to claim both that it was a “success because Kanellos wasn’t exhausted” and a “success because the plane only just made it.”

RESULTS

The two national flags of Greece and the United States had flown side by side by the temporary hangar at Heraklion, showing that this was an endeavour supported by individuals and organisations, both private and public from both nations.

As mentioned above, the technology of Daedalus indicates the feasibility of high-altitude winged craft.

The Daedalus project led to a large number of technical reports, covering the wide range of topics studied. Some are mentioned in the bibliography including (Dorsey 1990), (McIntyre 1988) and (Langford August 1989). The last two authors accompanied the epic flight. Langford was project manager and his August 1989 publication lists many other references.

But, of course, for us HPA enthusiasts, or indeed for those with soul enough to appreciate the realisation of a classical myth, the flight needs no such apology. Sufficient that it happened.

VELAIR 88

Peer Frank of Stuttgart was a former glider pilot and racing cyclist. He had flown the Pelargos II and the Musculair II and with the Pelargos III had been involved with the aerodynamic side of the design and then flew the plane.

On leaving college in 1986, and starting to earn, he was able to afford to start his own project. Theoretical design and optimisation took place in 1986, using an Amiga computer, and construction started in May 1987 with the help of two friends. By October 1987 they had built the wing structure, designed using the “D” nose principle, and Peer Frank decided to strength-test it on the ground. It broke. In order to get flying in a reasonable time, it was repaired and reinforced by skinning over the entire wing, - the two cell concept. The rest of the plane was built and first flight was on the 9th August 1988 without any problem.

Exhaustion now caught up with Peer Frank, who had been designing and building the aircraft while also doing a full-time job. He realised that he was not a fit man. He decided to take time off at a cycle training camp to restore his health, but meanwhile he became seriously ill. In 1989 he had recovered sufficiently to make flights of up to 3390 yards, the length of the runway, with Velair 88.

VELAIR 89

This sophisticated aircraft has the usual pod and boom layout of the period, but is distinguished by the bean-shaped pod slung low from the wing to reduce interference drag. Lateral control which appears satisfactory so far is by rotating wing-tips actuated by model-aircraft servos.

It first flew on the 24th September 1989 and has already flown the length of the 3390 yard runway and made gentle turns. Velair, when developed should have a performance somewhere between that of Musculair II and Daedalus. The project continues.

BIRD MAN CUP ENTRANTS

It is reported that in the first week of December 1989, both entrants for this Japanese event flew from the same airfield on the same day. Both planes were built by teams based at motor-cycle factories.

One of them is a cantilever aircraft with pusher propeller. First test flights of this plane showed the wing not to be stiff enough in torsion, the wingspar being an “I” section beam. This was fixed by carbon fibre and foam reinforcements to the nose, transforming this into a torsion box.

The other has a configuration similar to Daedalus and a structure similar to Gossamer Albatross.

DA VINCI 3

Since the mid-eighties, students at California Polytechnic State University at San Luis Obispo have been working on the Da Vinci helicopter project.

The first versions refused to leave the floor of the basketball gymnasium where they were tested, but on the 10th December 1989, the Da Vinci 3 took off and hovered for eight seconds at a height of 8 inches powered by pilot Greg McNeil.

Project manager Neal Saiki claims that this makes the Da Vinci 3 the world's first human-powered-helicopter to take off. However similar claims have been made about the A Day Fly in Nihon and the Vertigo helicopter originally built by Andrew Cranfield in England in the mid-eighties.

The Da Vinci series of helicopters have a recumbent pilot below the rotors. There are bracing wires below the rotors only. These rig to a frame which rotates with the rotors and is apparently independent of the seat-frame. Drive is to two propellers, one at each rotor-tip. This is a spool-drive, similar in principle to the Monarch wheel-drive, thereby putting a limit on duration. At the current stage of development, it would appear that the pilot has no control over the craft except vertically. Drift is restrained by cords held by people on the ground.

The Da Vinci 3 incorporates improvements on the previous machine made by a team led by Saiki and Kyle Naydo, and included a weight reduction from 140 to 97 lbs, thinner rotor blades, a different arrangement of bracing wires, and a redesigned pilot support frame. The project continues.

CYCLAIR - A PROPOSED DESIGN

A design for long distance flight by Ernst Schoberl was presented to the 1987 OSTIV conference. With his experience in the design of the Musculairs, Schoberl recommends a self-centering sprung control bar, rear position propeller, chain drive with elliptical chainwheel, an autopilot, semirecumbent pilot and avoidance of Reynolds' numbers below 300,000.

His design showed fully sandwich covered wings with laminar flow aerofoil. The structure is a two-cell torsion box, with spar at thickest point. On the Musculair II, this structure led to turbulence just behind the spar because the presence of the spar affects the profile shape of the wing in flight. "Sandwich covering and carbon spar deform differently in flight." He claims that this can be avoided with a slightly flexible connection of the spar to the covering sandwich. Hopefully, then, the sandwich, though deforming slightly, will take up a smoothly curved shape from nose to trailing edge.

UNDER CONSTRUCTION (and sometimes under wraps)

NIHON The latest from Nihon University is the "Papillon" helicopter, with coaxial rotors of 65 ft and 98 ft diameter.

CAMBRIDGE UNIVERSITY, ENGLAND A student project under Dr Organ is "studying the feasibility of HPF." It would appear that they have chosen to aim for a high-performer at the first attempt, rather than follow the course of other Universities, and gain experience on a low-tech short-hopper first. This is against the advice of the author. May they prove me wrong!

LOUGHBOROUGH UNIVERSITY, ENGLAND By early 1990, progress reached the stage of production of a gearbox and a foam cutter. Aim is for a 1992 flight of an advanced aircraft after discussion with MIT.

BLIESNER XV Wayne Bliesner, mentioned above, is currently working on his fifteenth HPA, this time with sponsorship from a large aircraft-firm in Seattle.

ORNITHOPTER Bryn Bird of London England is currently constructing two prototypes of his ornithopter design. This project uses more modern materials and a larger wing area than any previous ornithopter attempt.

A. N. ANOTHER Not yet alright to publish, are details of a firm somewhere, taking human powered helicopters seriously.

AIRGLOW

Airglow was designed by John & Mark McIntyre of Cambridgeshire, England. John McIntyre has a degree in marine engineering, and accompanied the Daedalus on its epic flight. Mark McIntyre is a professional model-builder. The two brothers are both keen aero-modellers, and have constructed a wide variety of contraptions including a sail-propelled-bicycle and a hot-air-balloon which carried a camera.

But the author has seen that the quality of the construction evident in the family workshop is a far-cry from what the amateurishness of their boyhood projects might imply, while the same amount of enthusiasm and ingenuity is still present. They are working to a level of perfection in fabrication which is probably unprecedented in HPF. Any part which is not perfect is made again, and progress is not as swift as in some projects. At the time of Airglow's conception, no prize was on offer, so they were not in a race against anyone.

They have chosen to use a carbon-fibre structure, and first had to make the equipment to produce tubes from this material. They are prepared to pass on to other HPV constructors the benefit of their experience in composite construction, and have advised the Cambridge University HPA team, the Bluebell III road vehicle team and even a visitor from Nihon University.

John McIntyre writes, "The wingspan of Airglow is 86 feet, and area 254 square feet. The structure is similar to Daedalus. Carbon-fibre tube with styrofoam ribs. It was designed to withstand 3g, and on static test in September 1989, it proved satisfactory and the deflection was as predicted. Weight, based on the bits we have already weighed, will be of the order of 68 to 75 lbs. Wing section is DAI1335 and DAI1336, designed by Mark Drela for the Michelob Light Eagle. "The propeller is coaxial on the tailboom like Bionic Bat, and transmission is via bevel gears and a short length of untwisted 6 mm pitch chain."

In June 1990, the McIntyres realised that in order to get flying in the foreseeable future, their policy of perfection in workmanship could be compromised, particularly on a part which could later be replaced by a better one. In any event they were obliged to follow this course with respect to the windscreen since the material they really wanted was not available. They wanted to use a large single sheet of Melinex, but the windscreen was made from joined sheets of acetate.

The airframe was complete in July 1990, and tests were conducted to prove the control system which used a remote-control aircraft-model system except that instead of radio, the link between the pilot's control and the servos was by wires. The model servos proved satisfactory, and on one test were even able to provide a torque sufficient to overstress the control surface. This surface was replaced and calm weather was waited for.

On 20th July 1990 Airglow was assembled at Duxford airfield Cambridgeshire, England early in the morning. Seventeen year old Nick Weston was in the hot seat and for the first time an attempt was made to fly the plane. On the first run, quite a lot of the runway was covered at what seemed to be surely sufficient speed, but on the runway was where the plane stayed.

An adjustment was made to the elevator setting and on the second run Airglow made its first flight at 6 am. Three further flights were made, the longest being about a quarter of a mile.

Nick Weston reported that the power requirement was lower than he had expected and that he could have flown for much longer, he found it fairly easy to keep to a straight line and to hold the height between one and four feet.

Problems arose only after landing, when either the plane would roll onto the grass, or a wing-tip would touch ground and yaw the plane around uncontrollably. On the fourth landing, Airglow hit a bump on the grass and the shock damaged the seat mounting.

Apart form the make-shift parts mentioned above, on July 20th no door was fitted, and all the inspection panels were off, some with wires hanging out. The team plan to make more flights when the plane has been cleaned up in these respects, the control stick position changed, and strain gauges fitted to the drive shaft to measure the power used.

Meanwhile in Germany, Peer Frank is continuing to fly his Velair. When McIntyre phoned him to say "We flew this morning" Peer Frank replied, "So did I." This is probably the first time since the days of the speed-competition that two different pedal-planes have flown in Europe on the same day.

Peer Frank flying *Velair 88* at malmsheim

Photo Ben Russ.

Peer Frank flying *Velair 89*.

Photo Britta Bartsch.

Nick Weston flying *Airglow* at Duxford.

Photo Mark McIntyre.

SHARING DETAIL KNOWLEDGE

From the bibliography, Langford's 1984 thesis and many of the AeroModeller issues mentioned are particularly useful sources of practical information.

John McIntyre is preparing a manual on carbon-tube spar design and construction, and possibly further relevant literature of a practical nature.

Meeting other HPA enthusiasts is always worthwhile, either on an individual basis or through one of the organisations, RAeS, IHPVA etc, or events held by them. The author knows at first hand that on the Jupiter project, on the transmission system alone, the two major problems encountered could have been avoided by contact with contemporaneous groups. The Toucan group had devised a method of laterally testing a main wheel, and Peter Wright was also coping with chain-jumping.

Records of your own project will always be welcome, particularly if they contain data such as dates and weights. It is helpful if a member of the group takes photographs regularly. Consider deciding to end up with one photograph taken per week 'regardless', dated, and under your control. Cheap at the time - gold later.

Unfortunately, all too often, those projects which have not led to the aircraft flying have been insufficiently documented, when an account of the events and the suspected reason for the results (whether technical or organisational) could be a useful addition to the body of knowledge and would be recognised as such. Perkins' first aircraft did not fly, but encouraged others.

CONVENTIONAL, EXPERIMENTAL or CRANK APPROACH to DESIGN

"Conventional", here, means following what has worked before.

"Crank", here, means having one inspiration, then expending a lot of perspiration, regardless of whether the idea can be seen in practice to be working, or even whether it can be shown in theory that it may work.

"Experimental", here, means knowing the likely benefit of any new idea, before committing oneself too far.

But, when experimenting, how far is too far?
Here follow some opinions of a few others on this topic
John Langford wrote about Monarch, "Decisions about when and what to test were among the most debated issues on the project. We didn't always get it right: several problems which surfaced only in flight test (particularly the inadequacy of the original front landing gear) might have been avoided through increased testing. On the other hand, several major tests (particularly a proof-testing of the wing) that were originally planned were scrapped, with huge savings in time and no apparent adverse effects on the final design. Knowing when and what to test is clearly one of the finer arts of research and development" (my italics) (Langford 1984).

Several people's views
Keith Sherwin wrote, "... it is as permissible for the layman to dream up a design and then use existing data to check its correctness as it is for the expert to use a sophisticated theoretical approach to the problem. In fact the layman could find a new approach, which the expert with his deep involvement in the subject and the preconceived ideas that come with such involvement, may have missed. The layman only becomes a 'crank' if he proposes a new idea without considering all the implications or fails to check the validity of his proposed design either theoretically or experimentally." (Sherwin 1971).
N. A. V. Piercy wrote "progress in aeronautics is most rapid and reliable when theory & experiment join hand in hand" (1944)
Beverley Shenstone said "You can do calculations until you're blue in the face, but the only way to tell if it really works is to try it out", (communication to the author in 1965 with regard to the authors concern over the adequacy of the stiffness of the pylon on Jupiter, there being no standard method for calculating this).
The crank attitude is effectively a handicap, in that one is constrained to the first idea thought of. However one can also be handicapped by sticking too rigidly to convention, particularly if the conventional method manifestly

isn't getting people very far.

Perhaps the best course is to compare the conventional method with the new "crazy" method. This comparison will probably involve both calculations and practical tests. If the results of these calculations and tests show that the idea doesn't work, at least in the application intended, then the thing to do is console oneself by remembering that only one idea in ten is worth proceeding with, and either think of another nine, or go back to the old way. If the results of the first of these calculations and tests show the new way is promising, then do further tests to fully convince yourself and anyone else that it is better.

GROUP DYNAMICS

A gliding club typically exists on its own, and one often knows nothing about another member except that they come gliding. But for most of the HPA groups recorded above, particularly the successful ones, there has been some other group of which everyone is also a member. Let us call this the "parent-group." This has in the main been either a workplace, a university or a family. The fellow group members will have been known to each other in another context already.

Being committed to the parent-group, one will also tend to stay with the HPA group itself. One will know the capabilities and the foibles of one's fellows. The attitudes prevalent in the parent-group will tend to be implicitly accepted with respect to behaviour in the HPA group.

Building an HPA group from scratch would entail having to "invent" a lot of unwritten laws.

Probably what has happened has been that groups have just made use of a set of attitudes that exists without understanding it or being able to modify it or mend it when necessary. We have got away without knowing how the muscles work that power our planes, and without knowing how the groups work that build and operate them.

Amongst other things, you will need to decide a policy on whom to invite or admit to the group, perhaps following one of the principles exemplified above.

Personal motivation: building an HPA involves some laborious repetitive tasks, and until we have completely trained monkeys or computers to do it for us, we must consider how to keep morale up during the boring parts of the operation. Is a potential new member (or even yourself) likely to have appropriate attitudes long enough? Motivation may include - share of any prize, an opportunity to fly the plane, enjoying doing it, habit, wanting to get the thing built. It must be expected, understood and respected that the proportions of these will vary from person to person and from time to time.

Successful command structures have apparently varied from a single-leader-situation to a group of peers (to use the pejorative political words, from a dictatorship to anarchy), with every type of democracy inbetween. Presumably members have accepted each of these, either from what they were accustomed to in the parent-group or from quickly learning that this is the way things are done in this HPA group.

BRIEF REMINDER OF NEEDS

To build and fly an HPA your needs will include:

1/ A sound design
Originality is not important.
Aero, structural, and don't forget transmission.

2/ The tools to produce
The chief being heatable space, safe from inquisitive fingers, & for longer than you first estimate you will need.

3/ Funds
Engineers are accustomed to applying factors to applied loads. Remember to do the same for costs. Your costs will probably end up being 3 times your first estimate.

4/ Time
Total time needed will probably end up being 5 times your first estimate. Lack of experience tends to cause disbelief of this as well as a necessity to use a bigger number than 5.

Group Dynamics

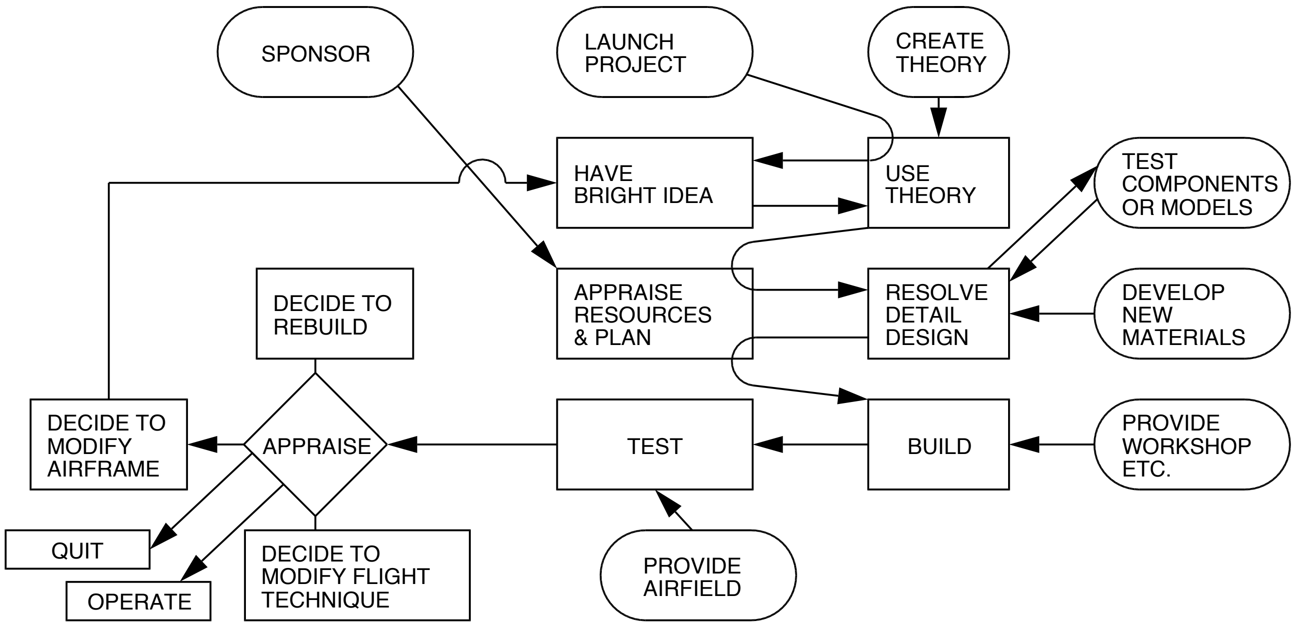
5/ People with a range of skills to do the work.

6/ Group-relevant items
Morale: will this be sustainable?
Leadership or democracy: variations on these can work if people know where they stand, who they are responsible to and what they are responsible for.
Are significant relevant attitudes to the project or to each other too disparate?

7/ Flying Area
Transport to.
A trailer can be used earlier for storing finished components.
Storage at.
Decide early on whether you reckon on having to rig each day.
Time on Runway.
Changes of circumstances at an airfield during the building period may necessitate flying elsewhere than from the airfield at which permission was originally granted.

PROGRAM

The diagram shows how progress is made in development.
To date, only the top three items shown ringed have happened in the absence of a specific project.



Completing any item enables one to move on to the next. The top three circled items are where starts have been made without an aeroplane existing. Henry Kremer SPONSORed initially when no planes existed. Dr Wortmann designed aerofoil sections in the absence of any existing plane, hence CREATING THEORY. The productive input of B. S. Shenstone, T. R. F. Nonweiler et al. in the late 1950s by collating and disseminating existing theory and adding to it, or the research done by the Muskelflug Institut, again in the absence of any aircraft, could be classed likewise. The organising of competitions and the other work of their successors at the R.Ae.S. can be classed as a combination of CREATING THEORY and SPONSORING.

Each item in the main loop, the rectangular boxes, will not only need to be done but will first need to be enabled. Theory needs to be created before it can be used, provision of building space will enable building (Circles represent enabling actions).

Historically, what has happened is that most such enabling actions have been in connection with a specific aircraft project. There have been few enabling actions, other than the top three, outside an existing project although this does happen often for other classes of aircraft. For instance no material has been developed for the use of HPF in general to enable BUILD, although there are many for aircraft in general, and even for model-aircraft.

However, once a project exists then work can be done not only on the actual items, but to enable any of the tasks on the main loop of the diagram. For instance Kanellos Kanellopoulos, Daedalus pilot, trained to pilot in order to enable TEST & OPERATE with not only a specific plane but a specific flight in mind.

Events which are exceptions or came close to being exceptions to the above generalities are:

A brief glimpse into the abyss of general ignorance

The Nihon runway. But this was not built solely for HPA.

S. S. Wilson at Oxford University, England. In the sixties Wilson tested the efficiency of transmission systems for HPA in general, and built a test-rig usable by any system. The publication of his results was a guide to the efficiency we might expect with any system, but at best it only confirmed the choice that each had made, and all transmission systems needed modification once installed in the actual airframe and used in flying conditions.

Co-operation between groups. But this has occurred only when both groups have had projects under way. Examples are between Ottawa and Dumbo, and between Chrysalis and Gossamer Albatross, not because one group has set up as a specialist supplier of whatever.

A BRIEF GLIMPSE INTO THE ABYSS OF GENERAL IGNORANCE

To get some idea of the general public's knowledge of HPF, the author started to conduct a small informal survey in December 1989. The general trend was clear after the first ten people questioned. All were picked at random in Covent Garden Central Market, London. Six were English. After a couple of dummy questions, each was asked

"What does the word "DAEDALUS" mean to you?", and then
"In your opinion has any person ever succeeded in flying by their own power?."
In answer to the first question, to six out of the ten, the word meant nothing, four said "Greek myth."
Out of these 4, 2 said yes to the second, but neither connected the name.
To the second question, 6 out of the 10 said that one human had flown.
The rest said none had. 2 of these 6 had said "Greek myth" to the first.
The most knowledgeable person questioned, a tourist, recounted the Greek myth in full, and remembered the 1986 flight but without connecting the two questions. The sum total of his knowledge was "..last ten yards, fell in water... across some channel... it must have been English Channel, that's what everyone goes for." This interviewee knew of no other human-powered-flight.
The other 5 positive answers, were "pedalled microlight", "a helicopter recently", "1 kilometre" and "Alberto Santos Dumont, c1900, French/Brazilian" twice.
The results of this questioning are mentioned here to remind those involved in HPF that we are surrounded by those who are not. (Santos-Dumont was the first to fit a petrol-engine to a balloon, 1898; after Giffard had fitted a steam-engine to a balloon in 1852).

RECENT THEORY ON LATERAL CONTROL

Although the Mufli had an all-moving-wing, many subsequent HPA reverted to simple ailerons. Although various other devices were tried out, no aircraft was able to perform turns until the Gossamer Albatross was fitted with warpable wings under the control of the pilot and a banking canard elevator (the drafters of the original Kremer prize had intended that it should be won only with a plane that could perform controlled turns).

Dr Paul Macready considered that this unorthodox method of lateral control was necessary because of the disproportionately high value of apparent mass compared with other aircraft. Apparent mass is the mass of air which needs to be accelerated whenever the wings start to bank. With a very light large wing, this mass can be more than that of the wings themselves. For comparison purposes, it is usual to calculate the mass of air inside a notional truncated-cone-shape whose cross-section at any point along the span of the wing is a circle of diameter equal to the chord.

However, more recently, Prof. Mark Drela has discovered from analysis that there is another parameter which is also highly significant in determining whether conventional ailerons will suffice for lateral control. This is the value obtained by dividing the span by the forward speed.

This parameter will be a guide to the response time to any lateral control input by the pilot.

It has the units of time and I am here calling it the Delay in REsponse to LAteral control input, or DRELA.

Examples are:

Aircraft	**Span**	**Speed**	**DRELA**	**System**	**Turning ability**
	b	V	b/V		
	feet	ft/sec	sec		
Typical glider	60	60	1	Turns	
Light aircraft	30	180	0.17	Turns	
Mufli	44	42	1.00	All moving wing	Straight flights only
SUMPAC	80	30	2.7	Ailerons	Slight turns
Jupiter	80	30	2.7	Ailerons	Straight flights only
Gossamer Condor	96	15	6.4	Wing warping	Turns
Musculair II	64	35	1.8	Ailerons	Turns
Light Eagle	114	23	4.7	Rotating tips	Turns
Daedalus	112	23	4.9	Rudder/sideslip	Slight turns

It must be borne in mind that only when the pilot can produce a sufficient reserve of power above the power required for straight flight will turns even be attempted. The Mufli and most of the early machines left little if any such available reserve.

The lateral control system used by each type that has flown is shown in the table.

Of the sixty-two types, six have used wing-warping.

YET TO BE DONE

"One of the attractions of person-powered-flight is that it is one of the few remaining fields where the action of a single person can have a significant effect.", and, "For most of the projections that we are discussing, in which we are looking 20 to 30 or more years ahead, perhaps the most surprising thing that could actually happen would be an absence of surprises."

Beverley Shenstone (JRAeS Aug 1968)

The current challenges and list of things that no-one has done yet (1991) include:

TAKE OFF FROM WATER

Calculations indicate that this is probably possible, but it presents new challenges to both the designer and the pilot (not to mention the "ground" crew).

From the pilot's viewpoint it would represent a sprint at the beginning of the flight. It is up to the designer to arrange things such that this does not absolutely exhaust the pilot. Let us assume that one uses the techniques of current human powered land-planes in the design whenever they are not obviously inapplicable, and just consider exactly what would have to replace the wheel. This could be a float, a hydrofoil or the hull itself, or more probably a combination.

At rest the weight must clearly be supported by water displacement, which will require no power from the pilot.

After take-off, all the weight must be carried by the wings, and land-planes have proved that this is possible. Probably during the take-off run the weight would be shared between the above three and the wing in a proportion that varied second by second. What is unknown is what the power-requirement during take-off would be at half take-off speed, which might be half of 16, i.e. 8 mph.

On land, pedalling along at this sort of speed is easy, but on water is a different matter, particularly since the pilot will also need to be accelerating. With engined seaplanes on take-off there is what is known as the “hump” speed, typically half to two thirds of take-off speed when the power requirement is a maximum. We could expect something similar, and it would appear that the take-off run must be short, because the pilot will be unable to sustain this “hump” power output for long. Having punched through this hump-speed it should become easier to accomplish the further acceleration necessary to reach take-off speed.

Bear in mind also that you’re going to come down onto water too. Any complicated sub-structure such as a series of stepped foils would need to be able to withstand the impact of landing at whatever angle the fallible human pilot and the vagaries of the weather cause them to be re-introduced to the water. Good luck!

A NOTE ON THE FEASIBILITY OF FLOATS FOR HUMAN POWERED AIRCRAFT

HULL and FLOAT CHARACTERISTICS

Peter G. Fielding writes, “A hull or float serves three major purposes:

a/ It must displace water so as to have buoyancy to support the weight of the aircraft when standing still. Conservative practice usually requires that the displacement of the float completely submerged should be 2 to 4 times the weight of the aircraft. The submerged volume is usually 40% to 60% of the product of the three overall dimensions. I.e. Block coefficient = 0.4 to 0.6.

b/ It must offer small resistance to motion at low speed so that a given amount of power will make it move fast enough to obtain a dynamic reaction from the water that will force it to rise out of the water and ride “On the Step” in a planing attitude.

c/ It must offer small resistance while planing so as to permit the aircraft to increase its speed beyond the stalling speed and leave the water. “It should be noted that conventional floatplanes have four times as much air drag as water resistance, and resistance to weight ratios of 0.15 to 0.2. At a first glance it would appear that water-based HPA of 200 lb all-up-weight would then have a water resistance of 30 to 40 lbs and a power requirement at 20 mph of 1.6 to 2.14 to overcome the water-resistance alone. This is way beyond the ability of the pilot to develop. However, HPA at this speed are already airborne, and just below this speed the weight carried by the water is just a few pounds. Accordingly it is necessary to look at the development of lift from static to stall in order to establish the actual displacement on which the weight to resistance parameter applies.”

Fielding has calculated the power required at various stages during the take-off run. For this analysis he assumes an aircraft of the dimensions of Musculair II but fitted with a two-foot-wide float. Data is available for the resistance to be expected from lifting floats, and he has extrapolated from this data into the range of interest. He warns “It will be recognised that the flight regime of human powered aircraft falls outside of any technical data available for conventional aircraft. In extrapolating existing data a number of liberties have been taken particularly the extrapolation of the weight to resistance versus Cv, in the very low speed range.” He finds that the maximum power-required occurs at half flying speed and is of the order of three-quarters of a horse-power, (half a kilowatt). It is possible to produce this for a short time. A full analysis must take into consideration the varying propeller efficiencies to be expected. A pilot can output a cruise-power continuously, and on top of this has a reserve of a certain amount of aerobic energy. During the middle of the take-off run the reserve will be tapped. For each second that one ft lb/second or one watt is needed, the reserve will be depleted by this amount. The real question is whether take-off can occur before all this reserve is gone.

MAKE HPF PRACTICAL

Most projects have been the fortunate recipients of free materials, workspaces, labour etc, so the true total cost is unknown. But by any estimate, there has yet to be an HPA where the "operating cost per seat mile" is a figure that an airline manager would want to report to the shareholders.

A significant forward step would be to make a reduction of cost and increase in practicality.

MAKE HPF LEAD SOMEWHERE

Perhaps make person-powered-flight "lead" somewhere other than the winning of prizes or for its own sake. Everyone the author has met who has been involved in the pursuit has been doing it primarily for its own sake, while being occasionally forced into pretending that there were other motives. One possibility here is:

There is a region of the upper atmosphere, too high for balloons, and too low for orbiting craft, where remotely-controlled solar-powered aircraft built with techniques first developed for human-powered-flight could fly. The Reynolds' numbers would be similar, the structures would be appropriate and the flight path envisaged is well above any cloud. Such drones could be useful for communications or the essential task of monitoring the atmosphere. Recent reports indicate that this application may be in the process of ceasing to be something yet to be done.

FIND BEST CONFIGURATION

The old controversy of upright versus recumbent pilot position has yet to be resolved. As John Langford put it in his fascinating account of the Monarch.

There were a number of basic design choices to be made, including:

Wing structure	Cantilevered versus wire braced
Tail	Aft versus canard
Seating	Vertical versus recumbent
Propeller	Tractor versus pusher

Even with these simple choices there are 16 possible configurations. Almost none of the choices are predetermined from an engineering point of view, and it is interesting to note that the Bionic Bat made different choices from Monarch in three of the four areas."

On pilot position, John Wimpenny asked in 1989 "We need to analyse for instance why road-cyclists invariably stand up off the saddle when climbing hills."

MAKE BEST USE OF POWER SOURCE

Dr Tony Evans, a member of the RAeS Human-Power Flight Committee, adds that the optimum method of extracting mechanical energy from the human power plant in the most efficient manner has not yet been determined and demands further study. Training methods, aspects of nutrition (pre-flight and in-flight) and control design are other areas which have been inadequately researched; and hence HPF offers as much to interest the sportsman, pilot, physiologist or ergonomist as it does the aerodynamicist.

FLAPPING-WING FLIGHT

All human-powered-flight to date has been by fixed wings, and to a much lesser extent, rotating wings. The early HPAs "imitated" gliders, the Condor series were "imitations" of hang-gliders and the Chrysalis was an "imitation" of a model aircraft; and of course many HPAs have been developments of or "imitations" of earlier HPAs. However no-one yet has successfully imitated a bird.

Dr J. M. V. Rayner of Bristol University, in a lecture sponsored by the RAeS HPAG, 6th Feb 1990 found only a limited number of solutions to the problem of developing a wing capable of sustaining and propelling an animal in the air. High speed cine-film and flow visualisation experiments show similarities in wing movements of flying animals, despite fundamentally different morphology. Human-powered flapping flight using the trunk and arm muscles alone would be impossible but at least hypothetical using also the hind limb muscles, given a favourable design.

Rayner observed two "gaits" used by birds. In the slower gait, lift is produced in the downstroke only and the wake is not two trailing-vortex-lines as with fixed wing aircraft or with birds when soaring. The two trailing vortices are observed to close after each downstroke and the wake is a series of closed-loop-vortices. In the faster gait, lift is constant and the wake is similar to that of a plane.

Each species has evolved its aspect ratio and wing-loading for a specific flight-pattern: speed, distance, soaring and so on. In some cases span is determined by practical constraints such as avoiding branches of trees.

WIND-SHEAR SOARING

Another way that the behaviour of birds can be emulated, but in this case without flapping, is to make use of the fact that windspeed varies with distance from the ground. Just as a water-mill makes use of the fact that the water in the river is moving relative to the bank so that it can continuously tap some of the energy, so, in theory, one should be able somehow to tap energy from the fact that the air at 30 ft is moving relative to the air at 10 ft. Such a system of flight might be cyclic, with the aircraft climbing and descending, but with a net energy gain on each cycle. Maybe a method of wind-shear soaring could be evolved for model-aircraft, but if this involved turns then planes such as HPA with larger spans might not be able to copy it. If you did invent a method, strictly, of course, it would not be true human-powered-flight because it would be partially wind-shear-powered.

This type of flight was considered by Dr Keith Sherwin (RAeS conference Dec 1986). The variation of wind near the ground is one of the topics in (Hucho, 1987).

In ordinary flight-patterns, on descending one re-enters a zone of less head-wind, and the need for more forward speed.

THE FOLLOWING COMPETITIONS ARE CURRENT

THE KREMER MARATHON COMPETITION This competition involves a distance of a nominal marathon course (approx. 26 miles), figures of eight, and must be accomplished within a set time.

THE KREMER SEAPLANE COMPETITION This competition involves take-off from water and a figure-eight within a set time.

For details of the two current Kremer competitions contact The Secretary, Human Powered Aircraft Group, Royal Aeronautical Society, 4 Hamilton Place, London W1V OBQ, United Kingdom.

JONATHAN EVENTS
The Championnat du Monde de Vol Musculaire (World Muscle-powered Flight Championships) are held annually in Paris. The first such Championships have been mainly for the amusement of spectators seeing the participants falling, together with their ill-conceived contraptions, into the water. However, it is possible that in future that genuine flying will be encouraged. Further details and entry forms from: JONATHAN - 52, rue Galilee - 75008 PARIS Tel. 16(1) 47 20 08 04

THE BOGNOR BIRDMAN RALLY
For those who still want to see people jumping off piers, the sixteenth annual Rally will retain its original charac-

ter, although even here serious entry is possible, the current longest flight from Bognor Pier being 190 ft by Harald Zimmer of Germany. Bognor is on the South coast of England. Contact N. R. B. Mark, telephone international code + 44243 864001 (from within UK, 0243 864001).

THE IGOR SIKORSKY HUMAN POWERED HELICOPTER COMPETITION
A Prize of $20,000 is to be awarded for the first to hover for one minute as well as fly a 10-meter square course at an altitude of at least three meters.

JAPANESE BIRD MAN CUP
Will possibly become an annual event. See BIRD MAN CUP above.

EXPLANATORY NOTES

Aircraft are listed in order of first flight. An aircraft is included in this table if it has been successful in flying when powered solely by the crew. Mufli always had assisted launches. All others, unless mentioned otherwise have taken off under contemporaneous muscle-power alone.
Machines which did not fly, but are of interest because they made a significant contribution to HPF by providing experience for those involved in the project or in other ways are mentioned in the main text.
The most original available source is quoted. It would be much appreciated if any errors or omissions were reported to the author or publishers for incorporation in any revision.

NAME In many cases, e.g. Linnet I any modifications to the plane after the first flight were not such as to affect any of the parameters listed below, and Linnet II was a complete rebuild. However with Toucan for instance, the aircraft was modified, in this case mainly by an increase in wingspan, sufficient that it was felt that a change to the name was appropriate. There was only one Toucan fuselage. Both Monarchs had the same wing but a new fuselage was built and it became the “B”. With the Condor series there were many modifications without a name-change. The choice of a name, is entered below in the style the chosen by the designer, e.g. MiLan ’82. However, if a second version is built, an “I” or “A” is added to the name of the first version, e.g. Puffin I, was originally known as Puffin. In some cases the same aircraft has had different names or has been known by the name of the group responsible for its construction or operation, see previous page.

WINGSPAN On some aircraft e.g. Velair 88, shaped tips were added after the initial construction for improved performance. Span increase on Velair 88 was just over a foot. In the table below, the larger value of span is quoted, in feet. For a helicopter, the figure quoted in this column is the rotor diameter. Unless specified a two-blade rotor is implied. Bionic Bat figures shown in the main table refer to the Dec 1984 variant. Development from Aug 1983 altered wing and other areas, etc (see separate table in Bionic Bat above).

AREA Square feet of wing area, or rotor area. For canard layouts, some authorities include the area of the foreplane.

SECTION The cross-section of the wing. The choice is between using an existing published shape, (as Gottingen 535 was used on the Mufli), or deciding that nothing appropriate exists and designing one’s own (as PF 25 was designed for the Velair 89). A possible compromise, as on SUMPAC, is to derive a section by extrapolating beyond the range of the published series.
Stork A the section at the root of the wing differs from that at the tip, and both sections are quoted below. In this way it differs, for instance, from its predecessor Jupiter, where the effect of different sections along the wing was obtained by building the wing with wash-out.
Dumbo/Mercury FX 68-M-180 ~ FX 68-M-160 ~ FX 68-M-140 .
Musculair II Wortmann FX 76 MP series modified by Dieter Althaus.

EMPTY WEIGHT The weight in lbs of the craft including any energy-storage equipment or refreshment containers.

STRUCTURE The main structural material. Typically this will be the material or combination of materials used

for the wing-spar. Abbreviations show the principle used.
WB = Wire-braced for Bending only. Usually this means a single wire below and a single wire above the wing. In this case the wing's torsional strength and stiffness will derive from internal structure.
WBT = Wire Braced for Torsion. This will involve a large number of wires.
Ca = Cantilever.
SS = Stressed Skin. On Musculair II, for instance, the wing-skin was stiff enough to withstand the torsional loads as well as provide an accurate shape. No HPA wing to date has been flown with a wing-structure where ALL the loads were carried by the skin.
IG = Internal Girder. The Puffin II wing spar was a rigid framework built up of lengths of balsa and spruce, balsa being predominant.
SQ = internal SQuare torsion-box. Balsa-plywood on Stork.
PT = Plywood Tube. Newbury Manflier, the first MPA with a tubular spar.
Musculair I wing torsion carried by the wing-nose-skin "C" completed into a "D" shaped box by diagonal rovings. Bionic Bat incorporated a short wing-to-fuselage brace.

DRIVE The transmission of power from the pilot to the propeller has always involved turning the drive at right angles. (So far no crew has sat sideways as on some HP boats). This column in the table indicates the engineering device employed for this purpose.
BGS = Bevel-Gear & Shaft.
T = Twisted.
Ch = Chain.
S = Shaft.
HVS transmission. See text relating to this aircraft.

CONFIGURATION
C = as Conventional engined aircraft or glider
B = as C except that rear fuselage is a tail-Boom.
* = see text referring to this aircraft and note below,
Newbury Manflier, two fuselages spaced apart on one wing.
Phoenix, wing with unfaired pilot frame below, no tail.
SEAT R = Recumbent. U = Upright.

PROPELLER POSITION Pylon = propeller is mounted behind top of a pylon, except on the Bliesner 4, where the prop was in front of the pylon.
Fin = mounted behind fin.
Pod = mounted behind pilot's pod.
Da Vinci helicopter. The rotor was above the pilot.

LATERAL CONTROL The method of steering the plane. Because this has been a problem, and a wide variety of systems have been employed, this topic warrants its own column. Lateral Control has always been accomplished (or attempted) by changing the shape of one or more of the aerodynamic surfaces, or by swivelling all or part of such a surface. Shape-changing has been done by a hinged portion such as a rudder as on the Wright, or by warping the wing as on the Monarch A. Swivelling, which affects the angle relative to the oncoming stream and hence the aerodynamic force experienced by the whole surface, was used on the Dumbo/Mercury. Both entire 60 ft wing-panels were moved by the pilot. Many planes use all-moving fins. Velair 89 & others use rotating wing-tips. This item in the table does not refer to the various types of handle or control column or bar which the pilot uses, nor to the system which forms a link between the pilot's input and the surface.

SPECIAL FEATURES & INNOVATION This column shows one of the novel or distinguishing characteristics of the type. See text for other innovative features of each type.

DATE FIRST FLIGHT First flight under muscle-power.

ACHIEVEMENTS One or two of its more notable flights.

DESIGNER The size of design teams has varied enormously, and a table of this type cannot include the names of all those who have contributed to the design decisions. Where known, others responsible are mentioned in the text.

PREVIOUS EXPERIENCE The entries in this column do reflect the fact that success has come in the main to those groups where at least one of the members has had previous aircraft experience or formal aeronautical education. However people with a variety of skills are needed by a project. As Paul MacCready said when offering the benefit of his English Channel experience to the then still only hopeful Daedalus team "Building the plane will be easy; the logistics will be the hard part." The word "industry" here denotes aircraft industry.

PLACE of ORIGIN This was the home of the project and not always where the flights were made. The identity of the parent-group may be mentioned in this column.

Abbreviation	**Refers to**
Bliesner 8, 9, 10, 11	See Man-Eagle 1, 2, 3, 4
Bossi/Bonomi	See Pedaliante
Dumbo	See Dumbo/Mercury
Eagle	See Light Eagle
Gossamer Swift	See Bionic Bat
Haessler/Villinger	See Mufli & HVS
Halton	See Jupiter
Hatfield MPAG	See Puffin
Hertfordshire Pedal Aeronauts	See Toucan
Hurel	See Aviette
HPAG	Denotes "Human Powered Aircraft Group"
London MPAG	See SUMPAC
MAPAC	Man-Powered Aircraft Committee, formed 1957. In 1959 became RAeS MPAG. In 1987 RAeS HPAG.
Michelob Light Eagle	See Light Eagle
Man-Eagle 1, 2, 3, 4.	See Bliesner 8, 9, 10, 11
MIT	See BURD, Chrysalis, Monarch, LightEagle, and Daedalus
Mercury	See Dumbo/Mercury
MPAG	Denotes "Man Powered Aircraft Group"
Muskelflug Institut	(German, Anglicised as "The Institute of Muscle Powered Flight")
Nihon	See Linnet, Egret, Stork, and MiLan.
RAeS	Royal Aeronautical Society
RAeS MPAG	Now RAeS HPAG
Southend	See Mayfly.
Southampton	See SUMPAC.
Weybridge MPAG	See Dumbo/Mercury.
Woodford MPAG	See Jupiter.

Aircraft Data

Name	Designer	Previous Experience	Place of Origin
Mufli	Helmut Haessler	Industry/glider pilot	Frankfurt, Germany
Pedaliante	Enea Bossi	Aircraft design	Italy
Sumpac	Marsden et al.	Graduates	Southampton Univ., UK
Puffin I	Wimpenny/Vann	Industry	c/o de Havilland, UK
Vine	S. W. Vine	Gliding/engineering	South Africa
Puffin II	Wimpenny/Vann	Puffin I	c/o de Havilland, UK
Reluctant Phoenix	D. Perkins	Civil servant	c/o RAE Cardington, UK
Linnet I	Prof. Kimura	Aeronautical engineer	c/o Nihon University, Japan
Linnet II	Kimura et al.	Linnet I	c/o Nihon University, Japan
Malliga	Josef Malliga	Jet pilot	Austria
SM-OX	Sato Maeda	Gliding	Japan
Linnet III	Kimura et al.	Linnet II	c/o Nihon University, Japan
Linnet IV	Kimura et al.	Linnet III	c/o Nihon University, Japan
Dumbo-Mercury	Phil Green et al.	Industry	c/o BAC Weybridge, U.K.
Wright	Peter Wright	Production engineer	Nottingham, England
Jupiter	Chris Roper	Industry	Woodford, Essex, England
LiverPuffin	Dr K Sherwin	?	c/o Liverpool University, UK
Toucan I	Pressnell et al.	Industry	c/o Handley Page Ltd., UK
Egret I	Kimura et al.	Linnet IV	c/o Nihon University, Japan
Egret II	Kimura et al.	Egret I	c/o Nihon University, Japan
Egret III	Kimura et al.	Egret II	c/o Nihon University, Japan
Aviette	Maurice Hurel	Aeronautical engineer	France
VMM	Verstraete/Masschelin/ Masschelin		Belgium
Toucan II	Pressnell et al.	Toucan I	Radlett, Herts, England
Dragonfly	Roger Hardy	Industry/Jupiter	Prestwick, Scotland
Stork A	J. Ishii et al.	Students	c/o Nihon University, Japan
Phillips	Ron Phillips		Humberside, England
Olympian ZB 1	Joseph Zinno	Pilot	North Kingstown, R. I., USA
Stork B	J. Ishii et al.	Stork A	c/o Nihon University, Japan
Gossamer Condor	Paul MacCready	Industry/gliders	California, USA
Icarus	Taras Kiceniuk	Student	California, USA
Ibis	Stork B	c/o Nihon University	Japan
Gossamer Albatross	Paul MacCready	Gossamer Condor	California, USA
Chrysalis	Parks/Youngren et al.	Students	c/o MIT, USA
Bliesner 4	Wayne T. Bliesner	Industry	Seattle, USA
Newbury Manflier	Nick Goodhart	Navy/gliders	Newbury, Berks, England
Bliesner 5	Wayne T. Bliesner	Bliesner 4	Seattle, USA
Bliesner 7	Wayne T. Bliesner	Bliesner 5	Seattle, USA
MiLan '81	Prof Nito et al.	Ibis	c/o Nihon University, Japan
Phoenix	Fred To	Solar-power a/c	Hampstead, London, England
Man-Eagle 1	Wayne T. Bliesner	Bliesner 7	Seattle, USA
MiLan '82	Prof Nito et al.	MiLan '81	c/o Nihon University, Japan
HVS	Hutter/Villinger/Schule	Mufli	Germany
Man-Eagle 3	Wayne T. Bliesner	Man-Eagle 1	Seattle, USA
Monarch A	Drela et al.	Chrysalis	c/o MIT, USA

Bionic Bat	Paul MacCready	Gossamer Albatross	California, USA
Monarch B	Drela et al.	Monarch A	c/o MIT, USA
Pelargos 2	Horlacher/Mohlin/Dubs	Pelargos I	Mohlin, Switzerland
Musculair I	Schoberl/Rochelt	Research/design	Munich, Germany
Pelargos 3	Horlacher/Mohlin/Frank	Pelargos 2	Mohlin, Switzerland
Musculair II	Schoberl/Rochelt	Musculair I	Munich, Germany
Man-Eagle 4	Wayne T. Bliesner	Man-Eagle 3	Seattle, USA
Light Eagle	Drela et al.	Monarch B	Michelob sponsored. c/o MIT, USA
Swift A	Prof Nito et al.	MiLan ‘82	c/o Nihon University, Japan
Swift B	Prof Nito et al.	Swift A	c/o Nihon University, Japan
Daedalus 87	Drela et al.	Light Eagle	c/o MIT, USA
Daedalus 88	Drela et al.	Light Eagle	c/o MIT, USA
Velair 88	Peer Frank	Musculair II	Stuttgart, Germany
Velair 89	Peer Frank	Velair 88	Stuttgart, Germany
Da Vinci 3	Neal Saiki et al.	Da Vinci 2	Cal. Poly., USA
Airglow	John McIntyre	Models	Cambridge, UK

* See Notes on page 111 to page 113

Aircraft Data

Name	Config.	Seat	Prop Position	Lateral Control	Special Features & Innovations
Mufli	C	R	Pylon	Moving wing	King-post = pylon
Pedaliante	C	R	Wing	Spoilers	Two propellers
Sumpac	C	R	Pylon	Ailerons	
Puffin I	C	U	Fin	Ailerons	
Vine	C	R	Nose	Ailerons	Hand and foot driven
Puffin II	C	U	Fin	Ailerons+various	
Reluctant Phoenix	D	R	Fin	Elevons	First inflatable
Linnet I	C	R	Fin	Ailerons	Foam-sheet-covered
Linnet II	C	U	Fin	Ailerons	
Malliga	BB R	Pod		Various	One-person-built
SM-OX	C	U	Fin	?	
Linnet III	C	U	Fin	Ailerons	
Linnet IV	C	U	Fin	Ailerons	
Dumbo-Mercury	C	R	Fin	Moving wing	
Wright	C	R	Fin	Rudder only	Elevator not used
Jupiter	C	U	Pylon	Ailerons	Balsa-plywood
LiverPuffin	B	U	Pod	Rudder only	First tail boom
Toucan I	C	UU	Fin	Slot lip ailerons	No rudder
Egret I	C	R	Pylon	Ailerons	
Egret II	C	R	Pylon	Ailerons	
Egret III	C	R	Pylon	Ailerons	
Aviette	C	U	Nose	Ailerons	Outrigger foils
Toucan II	C	UU	Fin	Slot-lip-ailerons	
Dragonfly	C	U	Pylon	Ailerons	"No innovations"
Stork A	C	U	Pylon	Ailerons	Easier pilot access
Phillips	BB	Pylon			
Olympian ZB 1	B	Pod	Pod	Rudder only	
Stork B	C	U	Pylon	Ailerons	Customised for pilot
Gossamer Condor	CN	R	Pod	Wingwarp+banking e/v	"Hang-glider"
Icarus	B	U	Pod	Rudder only	Very low wing
Ibis	C	U	Pylon	Ailerons	Mid-wing position
Gossamer Albatross	CN	U	Pod	Wingwarp+banking e/v	Carbon structure
Chrysalis	C	R	Nose	Rudder+wingwarp	Biplane
Bliesner 4	B	R	Pylon	Ailerons	
Newbury Manflier	*	U	Pylons	Each pilot had elevator only	Twin pod and boom
Bliesner 5	B	U	Nose	Ailerons	Two mainwheels
Bliesner 7	B	R	Pylon	Ailerons	
MiLan '81	BB	U	Pod	Wingwarp	
Phoenix	*	U	Nose	Elevons	Remote control
Man-Eagle 1	B	R	Pylon	Ailerons	" V " tail
MiLan '82	BB	U	Pod	Wingwarp	
HVS	B	R	Pylon	Pedals non-rotating	
Man-Eagle 3	B	R	Nose	Ailerons	Rubber-energy-storage
Monarch A	B	U	Nose	Wingwarp	Fast-build

Bionic Bat	B	R	Boom	Ailerons	Propeller around boom
Monarch B	B	R	Nose	Ailerons	
Pelargos 2	B	U	Nose	Rudder?	Carbon secondary structure
Musculair I	B	U	Aft	Ailerons	
Pelargos 3			Nose	Rudder	
Musculair II	B	R	Aft	Ailerons	Stressed-skin wing
Man-Eagle 4	B	R	Pod	Ailerons	Moulded fuse-fairing
Light Eagle	B	R	Nose	Moving tips	
Swift A	C	R	Pylon	Ailerons	
Swift B	B	U	Aft		
Daedalus 87	B	R	Nose	Rudder-only	
Daedalus 88	B	R	Nose	Rudder-only	
Velair 88	B	R	Aft	Ailerons	
Velair 89	B	R	Aft	Moving tips	
Da Vinci 3	H	R	*	None	
Airglow	B	R	Boom	Moving tips	

* See Notes on page 111 to page 113

Aircraft Data

Name	Wingspan	Wing area	Wing section	Weight	Structure	Drive
Mufli	44	104	Gottingen 535	80	Spruce, WB, SS	T belt
Pedaliante	58	250	NACA 23012	220	Wood, WB, SS	BGS
Sumpac	80	300	NACA 65_3-818	128	Spruce	IG T belt
Puffin I	84	330	Hybrid	118	Balsa/spruce SS	BGS
Vine	40	220	Gottingen 535?	205	Spruce?	WBT
Puffin II	93	390	FX 63-137	140	Balsa/spruce IG	BGS
Reluctant Phoenix	33	250	Symmetrical	38	Inflated nylon	
Linnet I	73	280	NACA 63_3-1218	111	Spruce/balsa? SS?	BGS
Linnet II	73	280	NACA 63_3-1218	98	Spruce/balsa? SS?	BGS
Malliga	65-85	262-~300	Malliga	113-126	Alum/EPS/plywood	BGS
SM-OX	72	291		121	S?	
Linnet III	83	325 110	NACA 8418-8415	110	Spruce/balsa? SS?	BGS
Linnet IV	83	325	NACA 8418	121	Spruce/balsa? SS?	BGS
Dumbo-Mercury	123	484	Wortmann *	178	Lashed alum. tube	BGS
Wright	71	486	FX 08-5-176	90	First carbon/EPS	Ch+S
Jupiter	80	300	NACA 65_3-618	146	Balsa/spruce SS	
LiverPuffin	64	305	FX 63-137	140	EPS on Puffin II	
Toucan I	123	600	NACA 65_3-618	209	Spruce/balsa IG	
Egret I	74	306	FX 61-184	125	?	Belt
Egret II	74	306	FX 61-184	123	?	Belt
Egret III	75	306	FX 61-184	134	?	Belt
Aviette	132	581		145	Spruce/balsa	
VMM	85	117				
Toucan II	139	696	NACA 65_3-618	241	Spruce/balsa	IG T Ch+S
Dragonfly	80	213	FX 63-167	95	Spruce/balsa	SQ
Stork A	69	226	FX 61-184~63-137	79	Spruce/balsa	T Ch
Phillips	80	95			Aluminium	SS
Olympian ZB 1	79	312	FX 63-137	150	Spruce/birch/balsa	
Stork B	69	226	FX 61-184~63-137	79	Balsa/spruce	T Ch
Gossamer Condor	96	760	Lissaman 7769	70	Alum. tubing	T Ch
Icarus	41	~250			Alum. tubing	T Ch
Ibis	64	194	FX 72-MS-150A	86		
Gossamer Albatross	96	500	Lissaman 7769	55	Carbon, WBT	T Ch
Chrysalis	72	748	Lissaman 7769	93	Alum. tubing, WBT	T Ch
Bliesner 4	80	300			Spruce/foam	Ca
Newbury Manflier	138	~600	Wortman	167	Spruce/balsa PT	T Ch
Bliesner 5	80	300			Spruce/foam	Ca
Bliesner 7	80	300			Spruce/foam	Ca
MiLan '81	82	403	NACA 4412	75	Carbon	Ca
Phoenix	100	1666	FX 77-W-153 [1]	105	Inflated	T Ch
Man-Eagle 1	110-63	324-200	WBT3134		Carbon	Ca
MiLan '82	82	457	NACA 4412	60	Carbon, WBT	
HVS	54	153	FX 63-137	110	Carbon	Ca *
Man-Eagle 3	63	200	WBT3134		Carbon	Ca
Monarch A	62	178	Lissaman 7769	68	Alum. tubing, WBR	T Ch
Bionic Bat	72*	149	Liebeck LH110	72	Carbon	T Ch

Monarch B	62	178	Lissaman 7769M	72	Alum. tubing	?
Pelargos 2	89	710	Dubs?	79	Carbon	
Musculair I	72	173	FX 76 MP series	62	Carbon	
Pelargos 3	73	213		95		WB
Musculair II	64	134	Wortmann *	55	Carbon	T Ch
Man-Eagle 4	63	200	WBT 31	34	Carbon	
Light Eagle	114	334	DAI 1335	92	Carbon	BGS
Swift A					Carbon	T Ch
Swift B					Carbon	T Ch
Daedalus 87	112	332	DAE-11	70	Carbon	BGS
Daedalus 88	112	332	DAE-11	70	Carbon	BGS
Velair 88	71	177	FX 63-137	78	Carbon	
Velair 89	76	182	PF 25	67	Carbon	
Da Vinci 3	100	97		98	Carbon, WB	Tip propellers
Airglow	86	254	DAI 1335	75	Carbon	BGS + chain

1. increased in thickness to 20%
* See Notes on page 111 to page 113

Aircraft Data

Name	First Flight	Flight Achievements
Mufli	Aug 1935	779 yards from bunjee launch
Pedaliante	1936	40 unaided flights?
Sumpac	9 Nov 1961	First independently observed unaided
Puffin I	16 Nov 1961	993 yards
Vine	17 May 1962	200 yards. One flight only.
Puffin II	27 Aug 1965	875 yards, height 17 feet, turns
Reluctant Phoenix	1965	Inside airship hangars,Cardington, UK
Linnet I	26 Feb 1966	47 yards, height 9 feet
Linnet II	19 Feb 1967	100 yards, height 5 feet
Malliga	Autumn 1967	380 yards, height 3 feet
SM-OX	24 Aug 1969	31 yards, height 6 feet
Linnet III	26 Mar 1970	34 yards
Linnet IV	13 Mar 1971	66 yards
Dumbo-Mercury	18 Sep 1971	
Wright	Feb 1972	300 yards at 4 feet
Jupiter	9 Feb 1972	1171 yards, 30 lb payload
LiverPuffin	18 Mar 1972	20 yards at 1 foot
Toucan I	23 Dec 1972	2 person, Bryan Bowen & Derek May
Egret I	28 Feb 1973	37 yards
Egret II	30 Oct 1973	168 yards
Egret III	16 Nov 1974	222 yards
Aviette	1974	1100 yards
VMM	1974	Heights of 15 ft
Toucan II	1974 until 1978	500 yards
Dragonfly	1975	Short flights
Stork A	12 Mar 1976	651 yards
Phillips	1976?	First female pilot
Olympian ZB 1	21 Apr 1976	First controlled flight in Americas
Stork B	24 Nov 1976	2290 yards
Gossamer Condor	26 Dec 1976	Kremer Figure-Eight Prize
Icarus	Aug 1977	Flights with towed launch
Ibis	11 Mar 1978	1300 yards
Gossamer Albatross	Jul 1978	Kremer Prize for first England to France
Chrysalis	5 Jun 1979	40 pilots, some inexperienced.
Bliesner 4	1979	100 yards
Newbury Manflier	Nov 1979	Pilot control tasks shared
Bliesner 5	1980	No ground crew. One mile flights.
Bliesner 7	1981	300 yards
MiLan '81	21 Dec 1981	645 yards
Phoenix	28 Mar 1982	Flew from sports grounds
Man-Eagle 1	1982	Short flights
MiLan '82	16 Oct 1982	2800 yards
HVS	12 Mar 1983	operated in 20 mph winds
Man-Eagle 3	1983	Kremer Speed Course
Monarch A	14 Aug 1983	29 Flights

Review of Human Powered Flight to 1990

Bionic Bat	Aug 1983	Kremer Speed Prize
Monarch B	2 Sep 1983	First Kremer Speed Prize
Pelargos 2	Dec 1983	1100 yards
Musculair I	May 1984	Two different Prizes, first passenger
Pelargos 3	May 1985	875 yards
Musculair II	Sep 1985	Kremer Speed Prize
Man-Eagle 4	1985	
Light Eagle	Oct 1986	37 miles. Onboard test equipment
Swift A		
Swift B		
Daedalus 87	Nov 1987	Extensive data-gathering
Daedalus 88	Mar 1988	74 miles. Recreated Daedalus myth
Velair 88	9 Aug 1988	3390 yards
Velair 89	24 Sep 1989	3390 yards
Da Vinci 3	10 Dec 1989	8 second flight not controlled by pilot
Airglow	20 Jul 1990	Quarter mile on first day

* See Notes on page 111 to page 113

GLOSSARY

Aircraft Data

The purpose of this glossary is to make the text comprehensible to readers new to the subject and give an indication of the meaning of the word in the context used. For more precise definitions, and the meaning of the word in a wider context, the reader is referred to the bibliography. Words shown in bold type are found elsewhere in the glossary.

AEROELASTIC Refers to the interaction between the flow and the deflections of the airframe caused by the flow.

ASPECT-RATIO is approximately equal to the ratio of span to chord. Geometric aspect ratio is defined as span/area. Effective aspect ratio is defined as follows. The actual induced drag in free air (away from the ground) has the same value as that predicted for an elliptically loaded wing of the same area and the effective aspect ratio. Effective aspect ratio will usually be from 0.9 to 1 times geometric aspect ratio.

BOUNDARY LAYER Region close to the surface past which fluid is flowing where velocity calculated according to inviscid flow theory will not apply. In this region, viscosity is of great importance. Adjacent to the surface, velocity is zero. It has been found that generally the flow pattern in this zone is one of two distinct types: laminar or turbulent. In laminar flow each particle proceeds downstream, hence the boundary layer is similar to "laminates" of material sliding over one another. In turbulent flow, the direction of each particle will not be so orderly. This absorbs more energy and hence creates more drag. Laminar flow over a substantial part of the surface can be achieved with an appropriate aerofoil accurately constructed.

CAMBER of aerofoil-section. For a single-surface foil, positive camber entails a convex upper surface and a concave lower surface. A foil of finite thickness can be considered, geometrically at least, as a cambered single-surface-foil clad with a symmetrical foil.

CANARD Smaller horizontal surface forward of mainplane.

CHORD Distance from leading-edge to trailing-edge of wing or other surface, or line between these two points.

COMPOSITE Form of construction, where fibres are impregnated with a liquid, which then sets hard. E.g. Fibreglass. Word is sometimes used to refer to any bonded construction as in the Mosquito aeroplane.

DIHEDRAL Angle of each semi-span to horizontal.

ELEVATOR Horizontal control-surface. Enables pitch control.

FAIRING Aircraft component whose function is to provide a smooth exterior shape.

FLIGHT ENVELOPE The range of speeds and maximum g forces for which the plane is designed. A graph of speed plotted against maximum g at each speed. This typically looks rather like an envelope with the flap open.

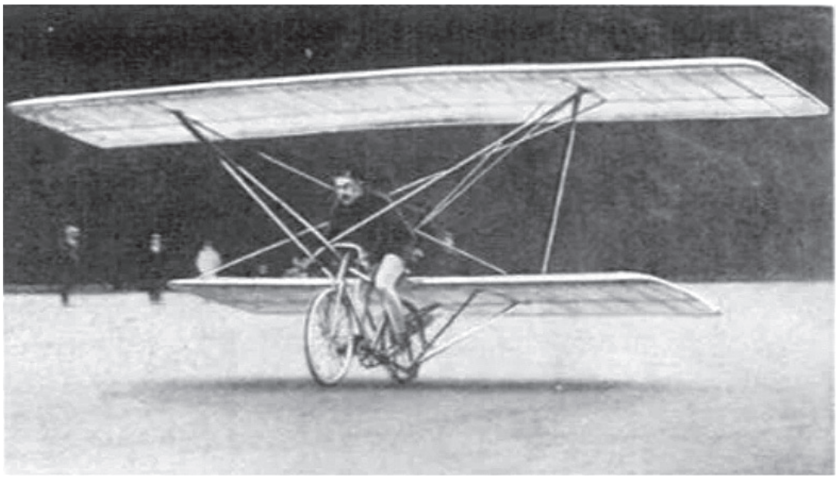
FLOW The motion of the air relative to the plane. Not quite the same as airspeed which is speed relative to a point far enough away from the path of the plane as to be in undisturbed air. Hence an air speed indicator, unless carefully positioned and calibrated, will at best give a rough guide.

g This is the magnitude of the acceleration due to gravity on the earth's surface. Aeronauts and astronauts use this value as a unit. So, if you experience 3g you feel three times as heavy, and the structure supporting you is subjected to three times as much load. This could happen for instance at the bottom of a loop in an aerobatic aeroplane if vertical acceleration were 2g. This would be vectorially additive to 1g from gravity.

GROUND EFFECT This phrase of many meanings, all referring to the effect of the proximity of the ground on the vehicle. In the context of human-powered-flight there are at least five effects of the closeness of the ground.

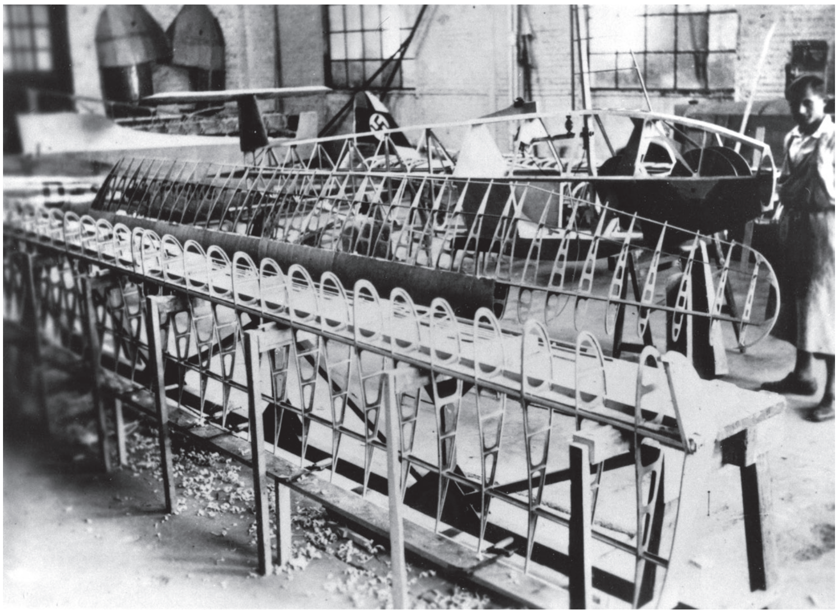
1/ One is beneficial and has the effect of reducing induced drag. This effect varies with the ratio of height to span and the observed effects are as predicted by classical theory, (Glauert 1948), but this is not the total effect because -

2/ there is another effect which will vary with the ratio of height to the wing chord and -



Aviette Contest France, November 1921: Prize-Winning flight made by Gabriel Poulain, earning 10,000 francs for his effort. Even more impressive: Poulain moved his winged bicycle at a full 30 mph before taking off, which Paul MacCready estimated took about three horsepower.

Photographer unknown.



Constructing *Mufli*.

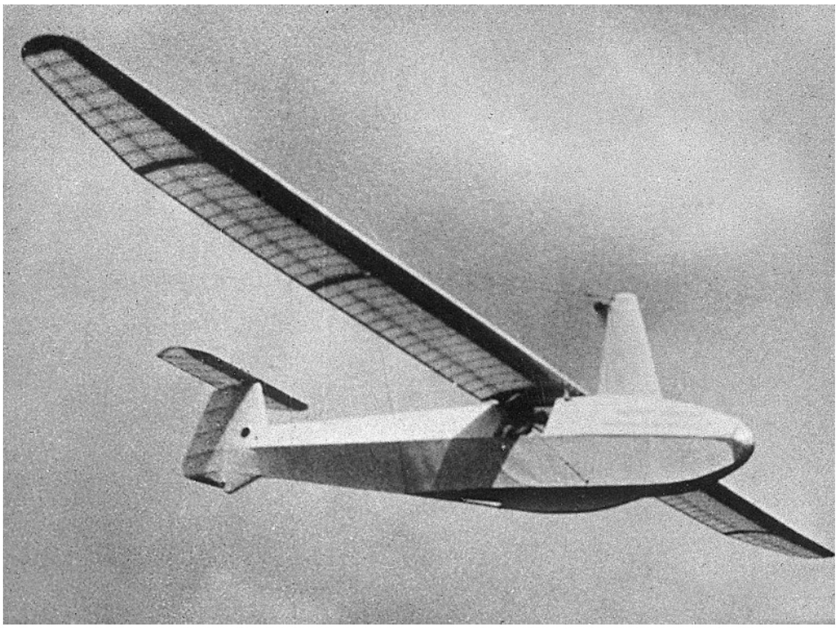
Photo RAeS HPAG archive.
Photographer unknown.

Pilot getting out of *Mufli*.

Photographer unknown.
RAeS HPAG archive.

Franz Villinger and Helmut Haessler with *Mufli*.

Photographer unknown.
RAeS HPAG archive.



Mufli in flight.

Photographer unknown.
RAeS HPAG archive.

Pedaliante.

Photographer unknown.

Ann Marsden one of the three designer-builders of *SUMPAC*.

Photo Ron Moulton.
RAeS HPAG archive.

SUMPAC and *Puffin I*.

Photo Ron Moulton.
RAeS HPAG archive.

Puffin I.

Photo de Havilland Aircraft.
RAeS HPAG archive.

Puffin I on the runway.

Photo de Havilland Aircraft
RAeS HPAG archive.

S. W. Vine of South Africa with his Human Powered Aircraft.

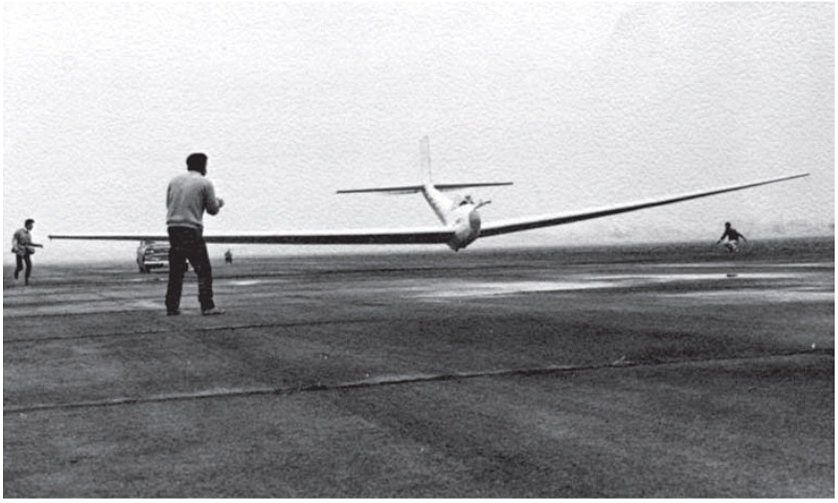
Photo S Vine.

Reluctant Phoenix.

Photographer unknown.
RAeS HPAG archive.

Nihon University *Linnet I* flying.

Picture taken by Mr. Hiroshi Seo.



Flight tests of *Linnet II*, 1967

Picture taken by Mr. Hiroshi Seo.

Malliga made a flight of 220 yards length at a height of 3 ft in the autumn of 1967 with Siegfried Puch, a gliding instructor at the controls. Since then flights of 400 yards have been achieved which is notable because of the comparatively small size of the aircraft since the wing span is 65 ft.

First take-off by the *Malliga* aircraft was in July 1967. The flight covered 150 yards at a height of 1-2 feet.

Photo Foto Hruby.

Sato-Maeda's *SM-OX* flew on many occasions in Japan.

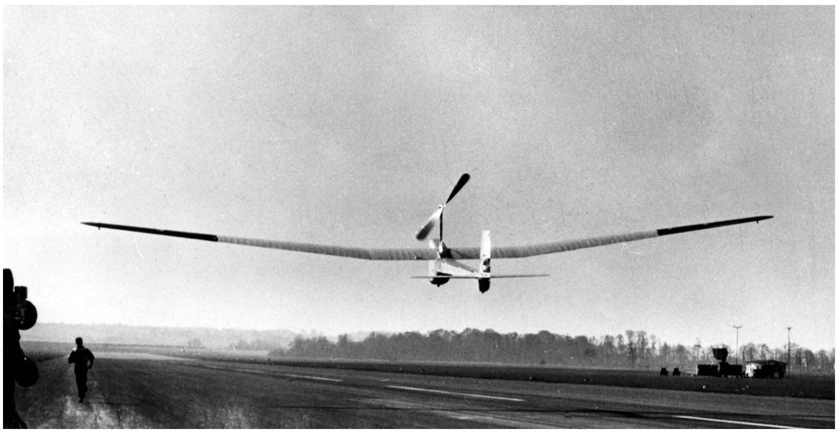
Photographer unknown.
RAeS HPAG archive.

Dumbo-Mercury at Waybridge.

Photo BAC.
RAeS HPAG archive.

Peter Wright's aircraft.

Photographer unknown.
RAeS HPAG archive.



Jupiter flying at RAF Benson.

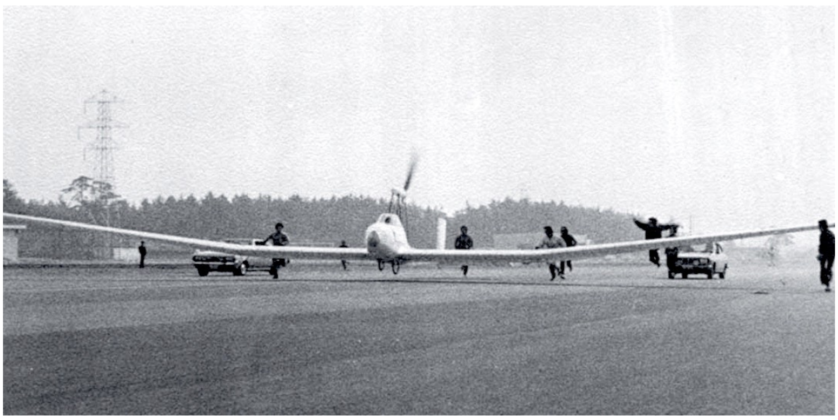
Photographer unknown.
RAeS HPAG archive.

LiverPuffin.

Photographer unknown.

TOUCAN.

Photo Ron Moulton.
RAeS HPAG archive.



Nihon University *Egrett I* flying.

Picture taken by Mr. Hiroshi Seo.

Nihon University *Egrett II* flying.

Picture taken by Mr. Hiroshi Seo.

Hurel *Aviette*.

Photo Ron Moulton.
RAeS HPAG archive.

Aviette. Jacques Martnache of M. Ae. C. de Paris made this latest entry in the contest for the Kremer Man-Powered-Aircraft prize for famous designer Maurice Hurel. Span 132 ft., area 581 sq. ft., weight, without pilot Jean-Pierre Thierard, about 140 lb. 10 ft. 6 in. prop weighs 30 oz. and will fly the Aviette at little more than 13 m.p.h. Magnificent balsa construction took three years, it was first flown, towed by a car with its 77-year old designer at the controls, in November 1973.

Photo Ron Moulton.
RAeS HPAG archive.

VMM
Belgians Paul and Stephan Masschelin, and Eric Verstraete, a racing cyclist have constructed five man powered machines and made many flights at Calais airport.

Photographer unknown.

Roger Hardy's *Dragonfly* in flight.

Photographer unknown.
RAeS HPAG archive.

Dragonfly.

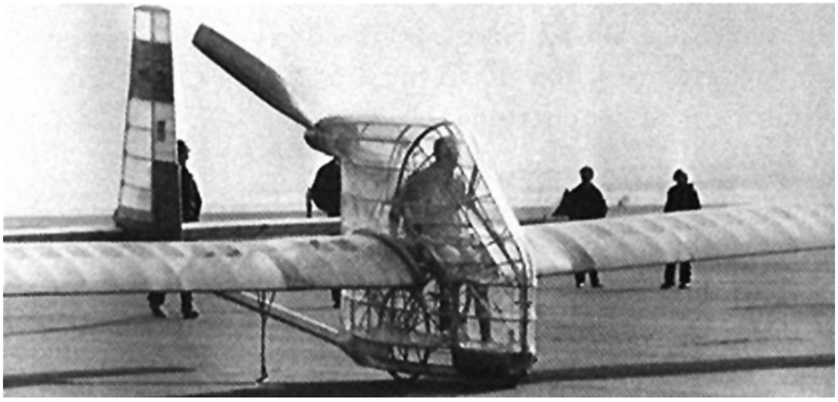
Photographer unknown.
RAeS HPAG archive.

Flight of the *Stork A* at Narashino runway.

Picture taken by Mr. Hiroshi Seo.

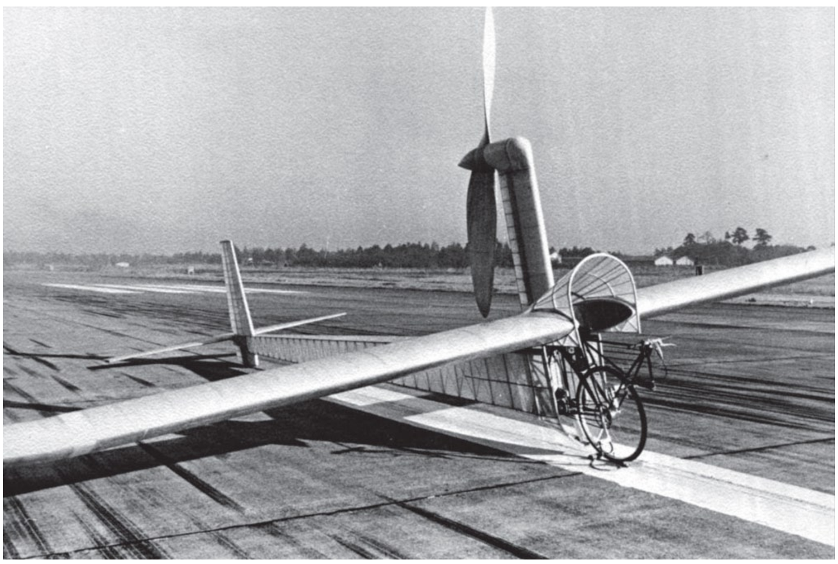
Phillips aircraft.
Two HPAs were designed and built by Ron Philips, a cycle enthusiast of Humberside, England in the mid 1970s. The Philips Mk I had a span of 80 ft and a weight of 190 lb. The Mk II, a two-seater, made some flights under tow.

Photographer unknown.



Olympian ZB 1 was designed and built by Lt.Col. Joe Zinno, USAF (Ret.) On his fourth try on 21 April 1976, at Quonset Point, RI. Zinno barely got off the ground for just a few seconds. The outside skin and overall design was Joe's - and was hand-made in Rhode Island. The propulsion and the cage was co-designed and fully built by his brother Clarence in Orlando Florida in his (then) garage at Tellson Place. Clarence loaded the bicycle-like cage onto the top of his Chrysler station wagon and drove it to Rhode Island where he and Joe mated it to the fuselage in 1976.

Photographer unknown.



The *Stork B* without cockpit canopy at Shimofusa Naval Air Base.

Picture taken by Mr. Hiroshi Seo.

Bryan Allen flying the *Gossamer Condor* for the press at Shafter airport after winning the Kremer prize in August 1977.

Photo Don Monroe.
RAeS HPAG archive.

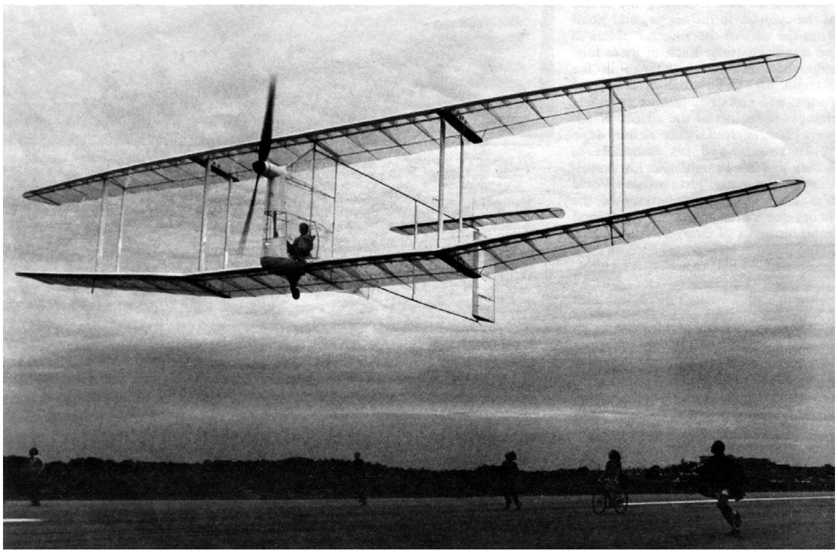
Taras Kiceniuk's Icarus flying at Shafter airport in 1976.

Photographer unknown.

Nihon University *Ibias A* flying.
The students at the Kimura laboratory of Nihon University began building the *Ibis* with hopes of capturing the Kremer figure of eight prize.
In 1980. Naito replaced the plane's spruce and balsa spar beam with CFRP and aluminium honeycomb. This was the first time that Nihon University used composite materials in an HPA structure.

The Ibis's longest flight was 1100 m and lasted 2 minutes and 15 seconds.

Picture taken by Mr. Hiroshi Seo.
RAeS HPAG archive.

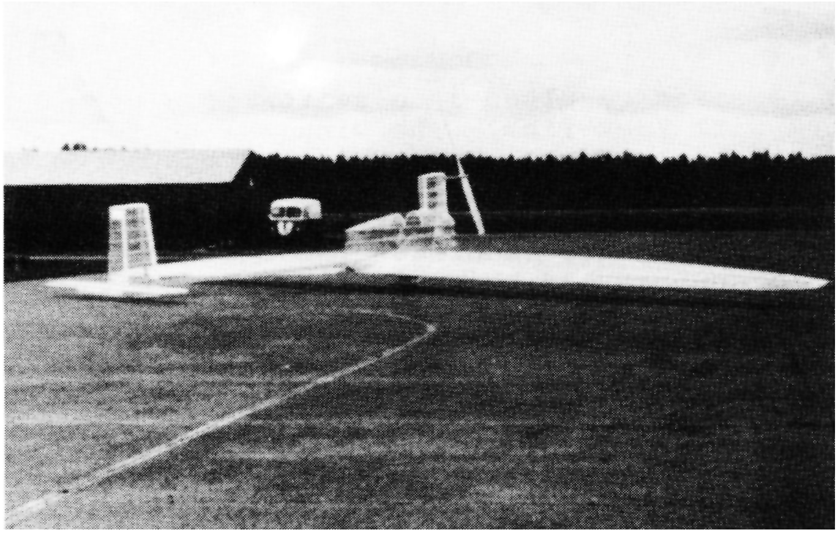


MIT *Chrysalis* flying.

Photo Bob Parks.

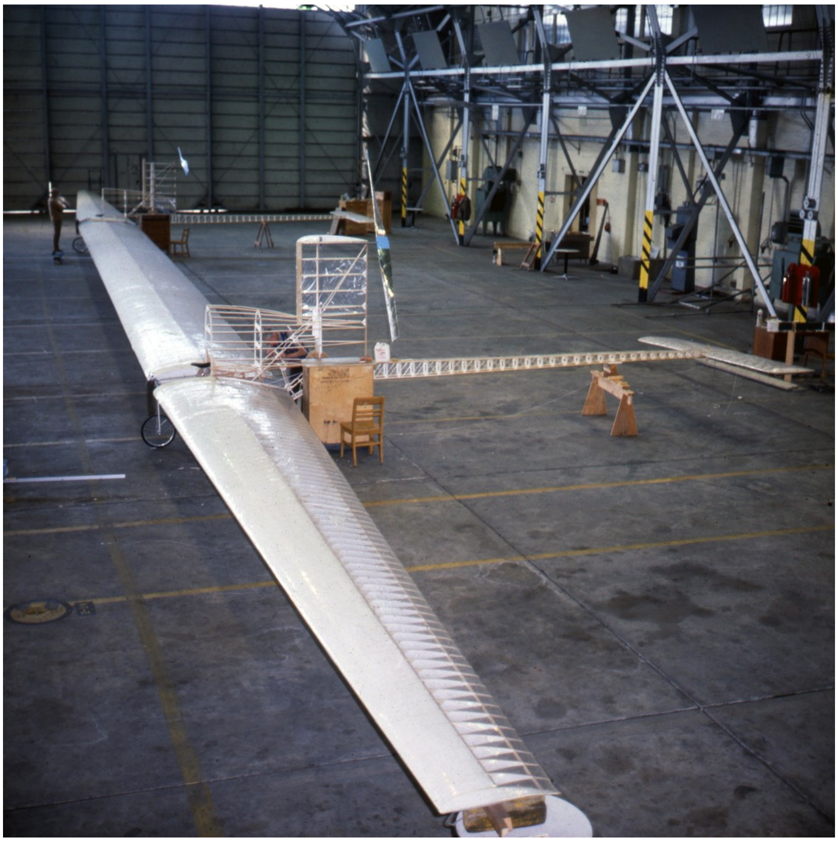
Gossamer Albatross just before takeoff.

Photo A. A. P. Lloyd.
RAeS HPAG archive.



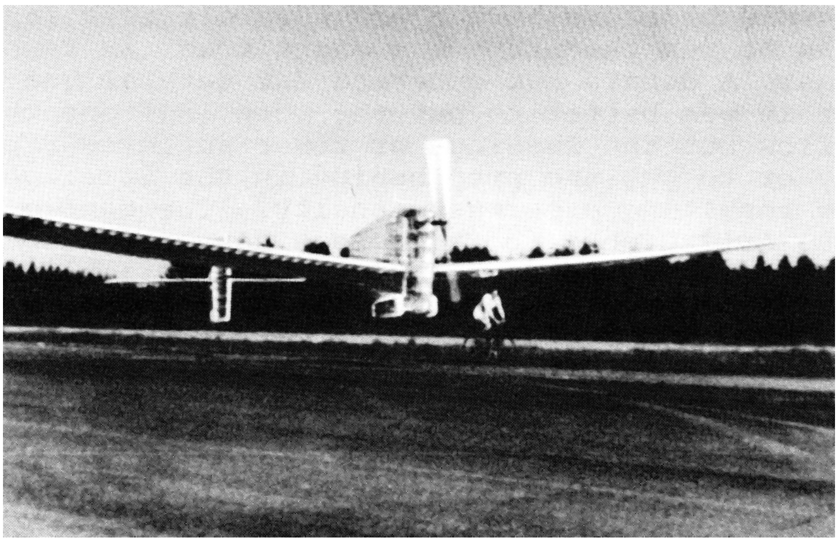
Wayne Bliesner's forth aircraft.

Photographer unknown.



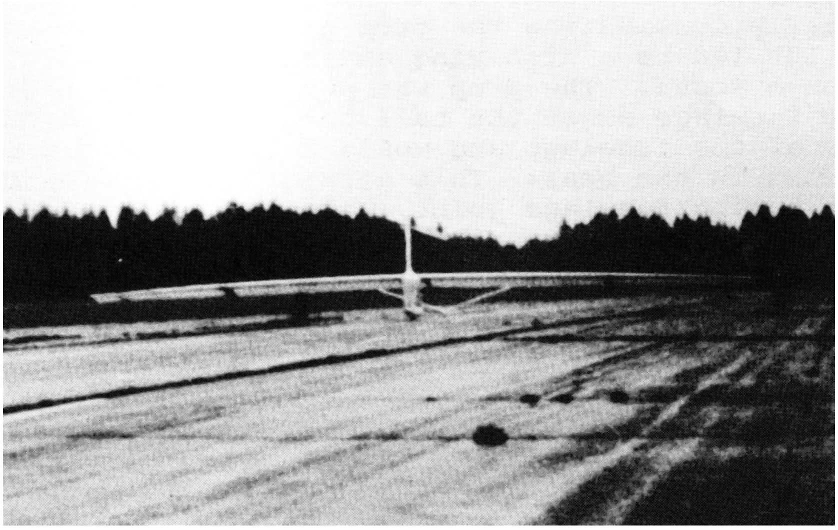
Nick Goodhart's *Newbury Manflyer*.

Photo Fred To.



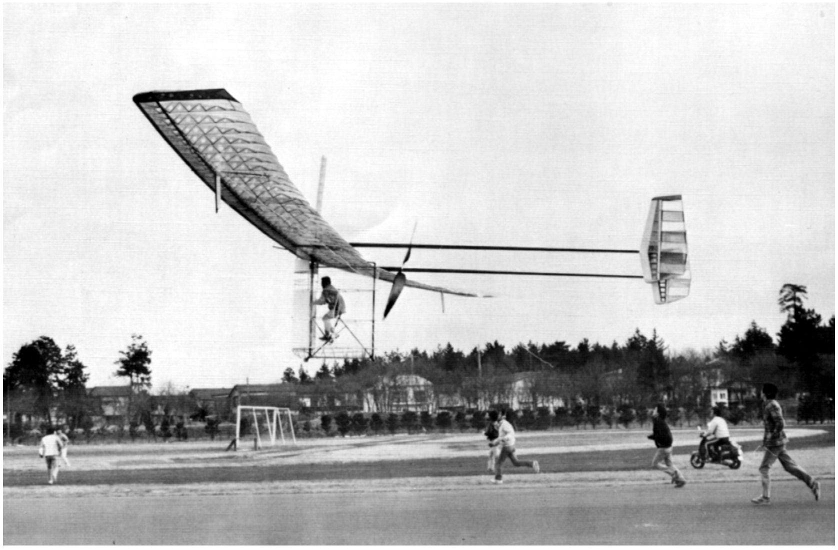
Wayne Bliesner's fifth aircraft.

Photographer unknown.



Wayne Bliesner's seventh aircraft.

Photographer unknown.



Nihon University *MiLan'81* in flight.

It was built by the Naito laboratory to win the Kremer prize for the first non-American aircraft to fly the figure of eight course. Both *MiLan'81 and MiLan'82* had wire braced tubular carbon fibre and styrofoam structures and hence a very low wing loading.

Photographer unknown.

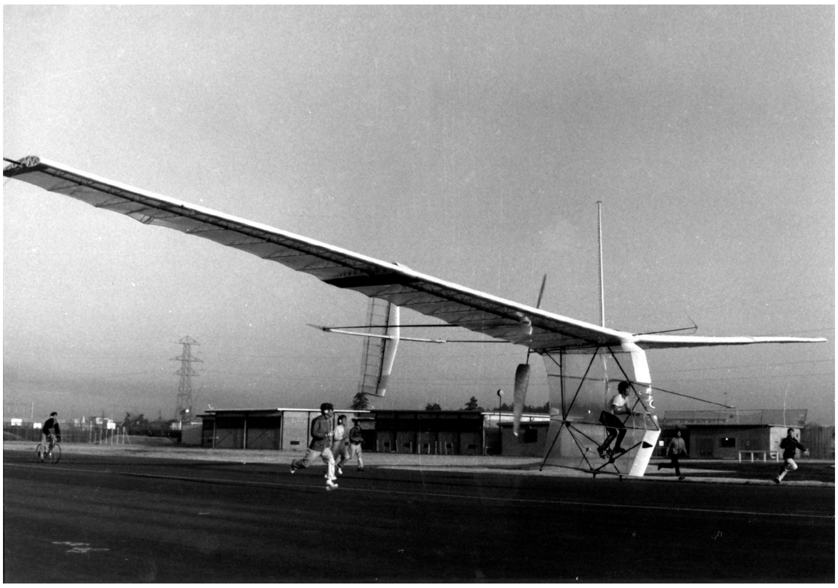
Ian Parker making the first successful flight of *Phoenix* at London Docklands.

Photo Fred To.

Wayne Bliesner's *Man Eagle I* flying.

Photographer unknown.

Wayne's Man Eagle aircraft made hundreds of flights, flew the Kremer speed prize triangle many times, but because he was working alone never quite flew it fast enough to keep up with the other teams and win a prize. Like Monarch and Bionic Bat they used electrical stored energy.



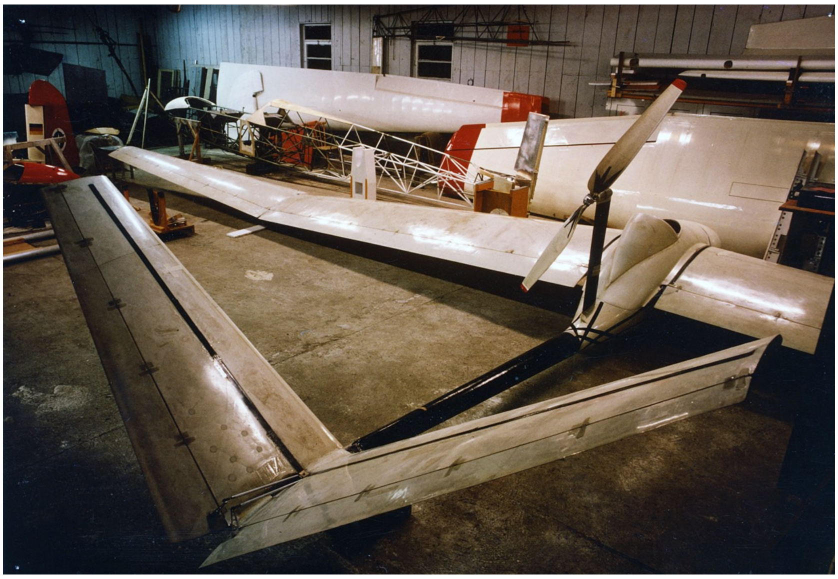
Masahi Suzuki flying the Nihon University *MiLan'82*.

Masahi Suzuki, one of the famous Suzuki brothers, tried for the Kremer prize in March 1983. but landed in the grass after flying 1500m from the starting point.

Photographer unknown.

HVS under construction.

Photographer unknown.



HVS.

Photographer unknown.

Wayne Bliesner's *Man Eagle II*.

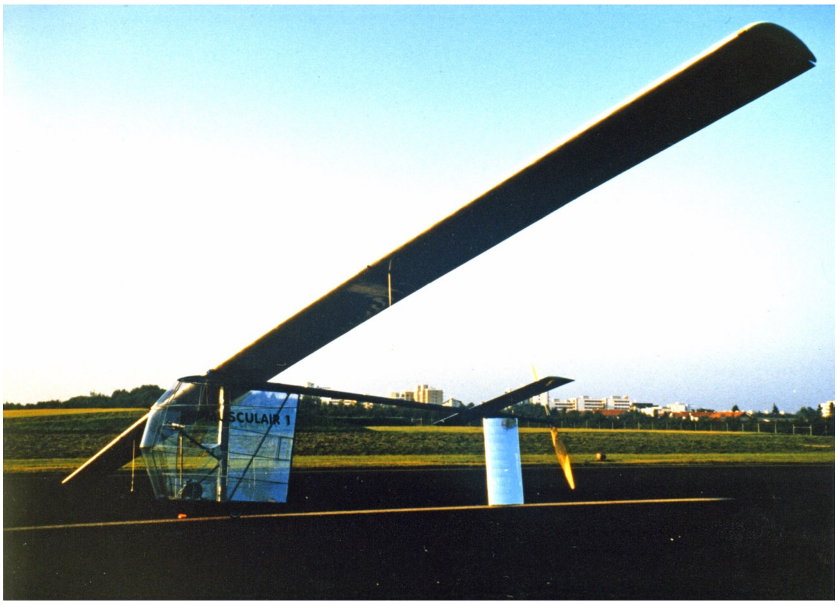
Photographer unknown.

MIT *Monarch B*.

Photographer unknown.

Peer Frank flying *Pelargos II* at Dübendorf CH.

Photographer unknown.



Musculair I.

Photo Ernst Schoberl.

Musculair II flying.

Photo Gregor Ruf.

MIT *Michelob Light Eagle*.

Photo Steve Finberg.
RAeS HPAG archive.

Nihon University *Swift A* in flight.

The *Swift A, B, and C* used rubber strip to store the pilot's energy.
The rubber motor provided half of the power needed for flight. All the Swift aircraft used model aircraft servos to control their ailerons and had winglets.
Swift A and B had 4 skeins of rubber inside their fuselages.
Swift C's rubber motor was divided into only two skeins that weighed 6 kg.

Photographer unknown.
RAeS HPAG archive.

Mark Drela with the MIT *Daedalus on the runway at Hiraklion airport*.

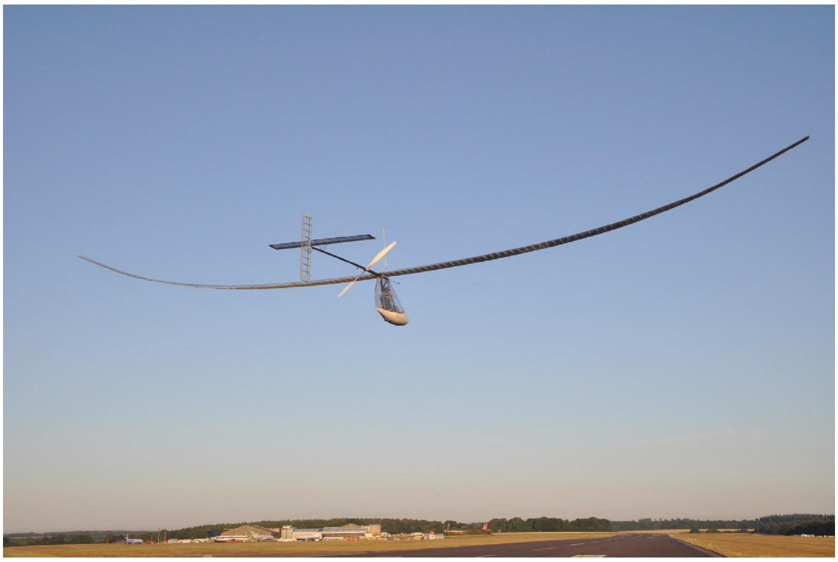
Photo Steve Finberg.
RAeS HPAG archive.

Velair 89 in flight.

Photo Peter Selinger.
RAeS HPAG archive.

The California Polytechnic *Da Vinci 3* human powered helicopter made an 8 second flight in 1989.

Photographer unknown.
RAeS HPAG archive.



Airglow flying at Lasham.

Photo Fred To.
RAeS HPAG archive.

3/ close to the ground one is flying in air which has small-scale turbulence due to the wind blowing over the ground, and

4/ the plane is operating in the region of wind-shear.

The second effect is employed by racing-cars to keep them on the ground and will in general not be beneficial to HPA although Perkins was able to arrange that this effect did increase lift on the Reluctant Phoenix which flew at about one wing thickness from the ground. At usual flying heights this effect will be smaller than the others.
The third effect will increase drag in a way not yet fully understood.

5/ Another effect is that, when close to the ground, the pilot will need to concentrate on not hitting it, thereby increasing the workload.

The total effect is that for each combination of pilot, aircraft, and wind and terrain there will be an optimum height at which it is easiest to fly.

HPA Human powered aircraft.

HPF Human powered flight.

HPV Human powered vehicle. In this context, land sea or air.

I BEAM A beam with cross-section like letter "I", it resists bending-loads, with an efficient use of material, but this shape is not rigid in torsion.

INDUCED DRAG typically accounts for about half the total drag of a wing. Induced drag is minimised with a large wing-span (most importantly), elliptic distribution of lift along the span, carefully designed tips or flying in formation as birds can be seen to do so that the flock effectively approximates to one wing of much larger span than each bird. If a wing is not of infinite span and if it is generating lift then it also generates trailing vortices. The direction of these is such as to produce a downwards velocity component at the wing, (downwash). Hence the wing is effectively operating in a region of sinking air, and so is "flying uphill." The power required to climb this "hill" can be expressed as speed × induced-drag.

KING-POST exterior structural post for supporting wires.

LAMINAR FLOW see boundary layer

LATERAL CONTROL Steering of the craft during turning, or indeed selecting not to turn & keeping straight and level.

LIFT MOMENT It has been found with most symmetrical aerofoil sections, that the centre of pressure will be at a distance of one quarter of the chord from the leading edge, regardless of the angle of incidence to the airflow. Hence the moment produced by the lift will be one quarter times the lift times the chord, if taken with reference to the leading edge, or it will be zero if taken with reference to the quarter chord point. Thus an all moving symmetrical tail-surface hinged at the quarter chord point will be easy to move.
However with a cambered or asymmetric section the centre of pressure moves when the incidence is changed, hence the lift moment will have a real and varying value which can have considerable magnitude. The designer may strive in designing the foil-section and the positioning of the spar to arrange that the lift-moment about the spar is small, but allowance must be made for all incidences and speeds. See Lippisch.

LONGITUDINAL CONTROL Enabling the pilot to select nose-up or down. (The German word for elevator literally translates as "high-rudder"), see "Tail-volume-ratio".

LAYSHAFT In a transmission system, this shaft receives drive from one medium (e.g. chain) and passes it on via another.

MELINEX ICI trade name for polyester film. See “Mylar”. A synthetic plastic sheet. It does appear to be the ideal material for the covering of HPA. However, Kimura considered (Nihon 1977), that a better shape can be achieved by 1/64 th inch thick styrene-paper or by “ganpi-shi” (a sort of Japanese paper).

MONOCOQUE The material which forms the profile shape also has the function of providing all of the rigidity and carrying all applied loads. Not quite the same as “Stressed Skin”.

MYLAR DuPont trade name for polyester film. See “melinex”.

OPTIMISATION Design procedure of considering various values of various relevant sizes and other parameters until the combination is found which is best or optimum.

ORNITHOPTER An aircraft with flapping wings.

PARASOL WING Wing above and clear of fuselage, but connected to it as a parasol is to its handle.

PITCH Rotation about lateral axis .

REYNOLDS’ NUMBER When studying the flow of water through pipes Reynolds discovered that the nature of the flow pattern depends on the radius of the pipe, the speed of the fluid and the viscosity of the fluid. If one multiplies the radius by the speed and then divides the product by the value of the viscosity, one arrives at a number. It might appear that such a number would only be of interest to the more statistically minded plumber, but not so! Reynolds’ important discovery was that if there were two different sets of conditions, then providing this number was the same for each, the two flow patterns would be the same. Furthermore, the same principle applies to all forms of flow, to any fluid and to any shape that the fluid is flowing inside or outside of, provided that the shape is the same in the two sets of conditions under comparison. Hence if we know how the flow around a shape behaved on test when the Reynolds’ number was, say one million (typical for HPF), and we know that on a proposed aircraft the wing will be operating at the same Reynolds’ number, (which may have been derived from different “ingredient” numbers to those of the test), then we can predict the flow around our wing. The viscosity of the fluid which flows around the shapes in which we are interested is such that the Reynolds’ number for a wing will be

N × the speed in ft/sec × the chord in feet.

N is 6993 at 0 degrees Celsius (32 F), & 6289 at 15 degrees Celsius (59 F); or 753 & 677 if using SI units.

For water the values are 52083 at 0 degrees Celsius and 81301 at 15 degrees; 5606 or 8751 if using SI units. Hence one can expect a hydrofoil to behave differently at different water-temperatures, whereas for air the effect of variation in temperature is not so marked (Glauert 1948).

ROLL Rotation about longitudinal axis.

SEPARATION BUBBLE Sometimes there may be observed by a riverbank a small region where the water is swirling rather than proceeding downstream. A similar situation can occur close to the surface of a wing, when the main flow has separated, leaving the bubble inside to swirl. The main flow will then re-attach further aft. Because of the reattachment, these bubbles are not easy to detect, but they will increase the drag, and an increase in incidence may cause the bubble to “burst”, i.e. the flow suddenly ceases to reattach, causing sudden changes in the flow pattern which typically will be a loss of lift. One method of avoiding these bubbles is to induce turbulent flow at a point forward of where the bubble would otherwise form. With things like this to watch out for, the design of an aerofoil is certainly no trivial task, but HPA designers have learnt to do it for themselves. If you don’t want to borrow someone else’s aerofoil, you can maybe borrow their computer program to tailor a shape suitable for your particular aeroplane.

SPAN (of aerofoil), distance from right tip to left tip.

STORED ENERGY in this context means energy stored by the crew, prior to flight, into some device. Theoretically, and as allowed by competition rules, this device can be of any nature. Historically three types have been used, the bungee, the battery or twisted rubber. The bungee, a length of stretched rubber fixed to stakes on the ground and to the aircraft nose, just aids take-off, like a catapult. The electric battery is charged by pedalling a dynamo while on the ground. The energy in the battery may be tapped at any stage of the flight. Wound up rubber as well known for model-aircraft was used by Wayne Bleisner and on the Stork series.

STRESSED SKIN The material which forms the profile shape also has the function of providing some of the rigidity, and carrying some of the applied loads. Not quite the same as "monocoque".

TAIL BOOM On most engined aircraft the rudder and other tail surfaces are fixed to the rear of the fuselage. However with a short fuselage or "pod" such as is sufficient to house one person this would mean that the tail surfaces would be too close to be effective. Hence on some HPF a tube, typically made of aluminium alloy or carbon extends aft from the pod for the mounting of the tail surfaces, and sometimes a tailwheel.

TAIL VOLUME RATIO A measure of the horizontal tail effective size and is defined as:

(horzl tail area × tail arm)/(wing area × mean chord)

(horzl tail area × tail arm) will have the units of area × length, namely the units of a volume. Similarly (wing area × mean chord) will have the units of a volume, hence "volume ratio". Tail arm is usually measured from aircraft centre of gravity to quarter chord point of tail. Sherwin suggests a value of 0.2 (Sherwin 1971). The Daedalus was able to get away with a small tail by dint of a very small pitching moment of inertia by concentrating all the fuselage weight close together. Bliesner suggests a static stability margin of 0.5. When flying, some pilots prefer to hold speed constant, others to hold attitude constant.

TORSION Torque. Combination of forces tending to twist.

WASH-IN, WASH-OUT Indicates that a wing is built twisted. With wash-out the tip will have a lower angle of attack than the root. With wash-in, a higher angle than the root (see Condor).

WIND-SHEAR Effect of wind variation with height from ground.

YAW Rotation about vertical axis.

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INDEX

Airglow, 88
Allen (Bryan), 55, 57, 58, 59
Aviette, 49
Bionic Bat, 66-70, 71, 75
Bird Man Cup, 87
Bird (Bryn), 88
Blanchard, 1
Bliesner, 52-54, 56, 74, 76, 77
Bognor, 109
Brierley, 52
Burd, 59
Cambridge, 97
Chrysalis, 68
Da Vinci, 96
Daedalus, 89, 92
Degen, 3
Drela, 73, 89, 104
Drink, 91
Dumbo, 27, 49
Egret, 57
Evans, 107
Flapping-wings, 108
Flight Envelope, 81
Glossary, 118
Goodhart, 64, 79
Gossamer Albatross, 66
Gossamer Condor, 65
Green, 27
Group Dynamics, 100
HVS, 70
Halton, 43
Hartman, 8
Hurel, 58
Interference Drag, 16, 39
Jonathan events, 109
Jones, 34
Jupiter, 30
Kanellopoulos, 92
Kimura, 5, 22, 24
Kremer, 10, 66, 72, 109
Langford, 73, 89, 99
Lassiere, 17
Lateral control, 26, 65, 113
Mayfly, 28
McAvoy, 22
Mercury, 27
MiLan, 69
Monarch, 73, 80
Mufli, 5
Musculair, 71, 75, 82
Muskelflug Institut, 5
New Zealand, 86
Newbury, 64
Nihon, 24, 56, 97
Nonweiler, 8
Northrop, 28
Olympian, 60
Passenger flight, 82
Paxton, 25
Pedaliante, 7
Pelargos, 70
Perkins, 9, 23
Peugeot prize, 3
Philips, 63
Phoenix, 69
Potter, 30, 43
Poulain, 3
Power required, 2, 12, 91
Pressnell, 29, 53
Propellers, 25
Puffin, 17
RAeS, 1, 9, 14
References, 122
Rochelt, 71
Roper, 30
SUMPAC, 15
Santorini, 93
Scarabino, 77
Schoberl, 71, 96
Shenstone, 8, 39, 42, 100
Sherwin, 21, 27, 100
Singapore, 22
Southend, 28
Smithsonian, 89
Stork, 57
Swift, 86

Lift coefficient, 3
Light Eagle, 89
Lilley, 8
Linnet, 24
Lippisch, 4
LiverPuffin, 21
Longitudinal control, 5
Loughborough, 97
MAPAC, 8
MIT, 59, 80, 89
Macready, 65, 75
Malliga, 25
Mallinson, 37
Man-Eagle, 84
Toucan, 53
Transmission, 5, 9, 40
Velair, 95
Ventilation, 26, 49
Verstralte, 63
Vertigo, 88
Villinger, 5, 70
Vine, 23
Water-take-off, 105, 109
Wilson, 9
Wind-shear soaring, 108
Wimpenny, 17
Wright, 52

Chris Roper
January 1991

Review of Human Powered Flight to 1990

Publishers note

This is a reprint of Chris Roper's book. He gave me the text on a floppy disk so that the text in this version is exactly as he wrote it. The only differences in the text and format are in the font used, text size, and page length.

But there are some differences. These are because I donated my copy to the RAeS HPAG archive so that I have had to work from memory when it comes to the font size and layout. (I hope to borrow a copy of the book so that I can correct the format and add things like the ISBN number.)

He produced the first addition by photocopying so all the images were in black and white and of low quality. In this addition they are in colour.

I have added a two page biography of Henry Kremer because without his generosity none of this would have happened, at least not in the way that it did.

This is version 1.1 released to the members of the BHPFC mailing list for comments and corrections. Be aware that the index is not yet corrected and is of no use!

A Shack 49 publication
John McIntyre February 21st 2022.