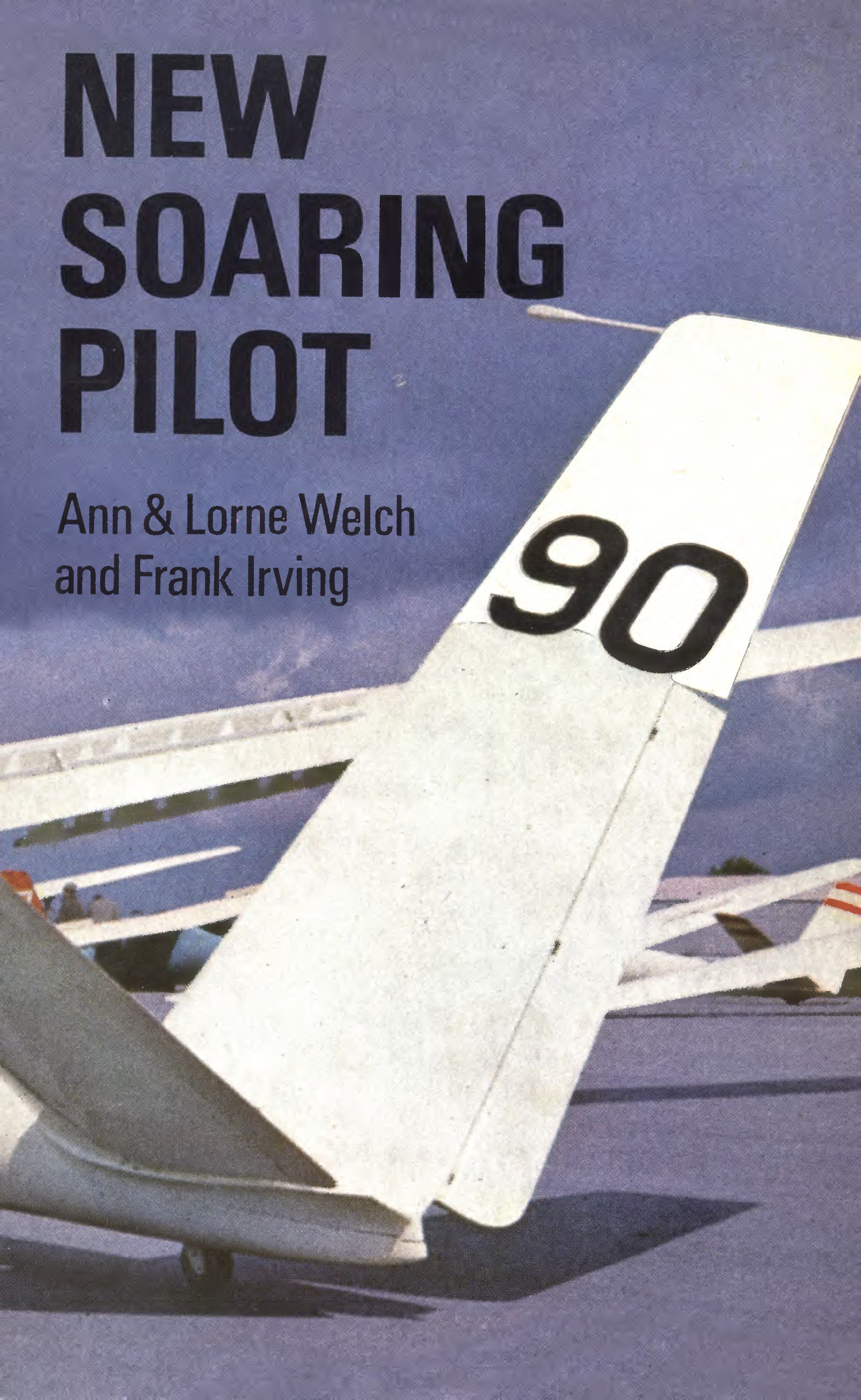
NEW SOARING PILOT

Ann & Lorne Welch
and Frank Irving



NEW SOARING PILOT

Soaring combines advanced technology, physical dexterity and the fascination of a complicated puzzle. Each flight involves self-discovery and self-mastery, and affords great pleasure while stretching physical and mental processes to the limit. It is a rapidly evolving sport which still gives opportunities for great experiment and new ideas. The authors have taken a foremost part in the development of British gliding, and this book is the result of many years close co-operation in operating gliders in many countries. Their object is to discuss fully the modern glider and the technique of using it. In its first form, their book *The Soaring Pilot* quickly became a standard text. Now it is so thoroughly replanned as to deserve a new title. Full account has been taken of developments in every sphere of gliding with particular emphasis on competition flying and its equipment and techniques. There are entirely new chapters on Flight Limitations, Circling Technique, Wave Soaring, Championship Flying and Physiological Considerations; new Appendices include Compass Swinging, Radio Notes, Task Setting, Rules of the Air. Undoubtedly one of the most comprehensive yet lively manuals of flying that exists.

Photograph by Ann Welch

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NEW SOARING PILOT

To Wally

ANN and LORNE WELCH
and
FRANK IRVING

from Welch

JOHN MURRAY

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To

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AUTHORS' NOTE

The preface, Chapters 1, 2, 3, 4, 5 and 15, and Appendices 9, 10, 11 and 15 are written by Frank Irving. Chapters 6, 7, 8, 9, 10, 11, 12, 13, 14, 16 and 17, and Appendices 4, 6, 7 and 8 were written by Ann and Lorne Welch. The remaining Appendices were written jointly or were contributed. The drawings are by the authors.

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PREFACE

This book is largely concerned with technology, for the glider is essentially a product of this technological age. The pilot must therefore learn the appropriate mechanical skills which, as we try to show, probably encompass a greater proportion of the process of soaring than the newcomer to the sport might imagine. But this is not to say that soaring has been reduced to a drill for operating the controls and pressing buttons: these are merely means to an end, and since soaring occurs in a very variable and subtle element—not without its dangers—there is plenty of scope for art and inspiration. Our object is to try to render soaring a little easier, by demonstrating that all the actions involved in a given situation are amenable to a logical approach.

However, the pilot has a large element of choice in arranging the situations, since he is not just a passive spectator. Each small section of a flight is usually a fairly straightforward matter, but inspiration is often involved in taking advantage of the weather or the terrain. The successful pilot conducts his flight with the inspired logic of a composer making splendid music from a series of simple phrases.

In such circumstances, the technology becomes quite unobtrusive. As Antoine de Saint-Exupéry wrote: '. . . precisely because it is perfect, the machine dissembles its own existence instead of forcing itself upon our notice. And thus, also, the realities of nature resume their pride of place. It is not with metal that the pilot is in contact. Contrary to the vulgar illusion, it is thanks to the metal and by virtues of it, that the pilot rediscovers nature. As I have already said, the machine does not isolate man from the great problems of nature but plunges him more deeply into them.' This was written in the context of flying powered aeroplanes, but those who love soaring will recognize its general truth.

This, then, is the glider: a machine of great elegance, cleverly fashioned from wood, metal or fibres so as to cause the least possible disturbance to the air it traverses. Its behaviour is quite complicated and to exploit it to the full is not particularly easy. In this book, we try to explain most of those characteristics which are of interest to the pilot, indicating their relevance to the process of soaring. It is as well to point out at this stage that soaring is essentially a practical matter: there is no substitute for flying and putting the book-learning into practice until the control of the machine becomes instinctive and 'it dissembles its own existence'. It also follows that, whilst the designer of a good glider is unlikely to achieve great riches on earth, he can be content in the knowledge that he has contributed something to the sum of human happiness.

Each individual has his own idea of the enjoyable soaring flight: for some it is the exercise of a somewhat esoteric logic with the aim of surpassing others in speed or distance; or it may be the solitude and beauty; or simply, escape from a desk. But all satisfying flights have one feature in common: they involve taking decisions. As Dr Johnson might have said: 'Nothing concentrates a man's mind so wonderfully as the knowledge that he is ten minutes from a forced landing.' We hope that this book will be of some help in making the right decisions and thus contribute to the enjoyment of soaring.

Chapter 1

SOARING PROGRESS

Soaring as a sport is less than fifty years old, and represents as yet an infinitesimal fragment of human experience. Various writers have observed that perhaps man's age-old yearning to fly has been overrated in that the construction of a glider was technically feasible some two centuries ago but did not come to fruition until quite recently. Be that as it may, a few tens of thousands of men have now experienced the unique pleasures, beauties, triumphs and frustrations of soaring, finding satisfaction in its subtle blend of art and science.

This book is primarily concerned with the science (or, more exactly, the technology) of soaring but first it is useful to consider how soaring has developed, not so much in terms of personalities and outstanding flights but rather in terms of the techniques which made these flights possible.

A little soaring occurred towards the end of the nineteenth and at the beginning of the present century, not so much as an end in itself, but as incidental to the development of flying machines. The names of Lilienthal, Wright, Pilcher and many others are rightly venerated as befits brave pioneers of flying. The first sporting gliding took place just before the First World War at the Wasserkuppe, but Kronfeld does not relate whether any real soaring occurred. However, it demonstrated the value of the site, and when Oskar Ursinus put on his famous hat in 1920 and started a campaign to stimulate soaring, it was there that his centre took shape. The first few annual meetings produced rapid progress in pure slope soaring, from flights of a few seconds in 1920, of twenty minutes in 1921, to over three hours in 1922. By then, soaring was being attempted at other hill-sites in Germany and the celebrated meeting took place at Itford, Sussex, which saw comparable flights but produced little real result.

The requirements for a suitable glider were now becoming clear and machines were built, which, although crude by modern standards, were far cleaner than the contemporary aeroplanes. Stagnation then rapidly set in, and although the design of gliders continued to improve, enthusiasm for pure hill-soaring tended to flag. In some measure this was due to the prevailing meteorological opinion on thermals; one writer declared that '... the wind varies so much in speed and direction that, owing to the resultant turbulence, the extent to which we can make use of up currents is very limited. The vertical wind forces are also not strong enough to enable one to soar by means of vertical currents alone.... Tests usually show a lift of only 1 metre/sec.... The skill of our pilots and the manoeuvrability of our sailplanes are not, however, such that we are able to stay in the narrow columns of rising air and gain height by means of tight circles as the birds seem able to do. In view of this, it appears that man will never be able to soar for any length of time with the help of thermal up-currents....' Thus scientifically discouraged, soaring pilots became hill-bound and frustrated, their outlet being occasional short cross-country flights performed by hopping from one hill to the next.

The first major technical development which effectively set soaring free from hills was the variometer of Lippisch and Kronfeld in 1928. A reasonably skilled pilot of today can soar in thermals without instruments, but usually only because he can relate the feel of the glider in the thermal to his previous experience with a variometer, and he has considerable understanding of the nature of a thermal. In the absence of such experience, the variometer became a key to an understanding of all types of vertical motion in the atmosphere. In 1929, Kronfeld climbed to over 6000 ft in a thunderstorm, landing 90 miles away. His glider, the Wien, was highly refined by any standards, but the lack of blind-flying instruments and airbrakes rendered such a flight dangerous. Progress was then rapid: Wolf Hirth flew in clear-air thermals at Elmira, N.Y.; in 1930 and by 1932 German pilots had carried out enough cloud flying, often indulging in spiral dives, to realize that machines specially designed for cloud flying were vital. Enthusiasm in other countries was greatly stimulated by such feats. In England, the British Gliding Association was formed in 1929, and Kronfeld made some excellent demonstration flights in 1930. By 1933 pilots at the London Gliding Club at Dunstable were regularly soaring in thermals.

About this time, the third and so far final form of useful upcurrent was discovered: the standing wave. Nehring had flown in an 'evening thermal' in 1926, a phenomenon which was misunderstood for another twenty years or so, and may well have been the beginning of a wave. In 1933, Deutschmann and Hirth flew Grunau Babys to 4600 ft in the Moazagotl wave in Silesia, and in 1937 a height of 7000 ft was attained near the Long Mynd, Shropshire. Waves are now known to be very common in this country and, following the experiences of glider pilots, have been the subject of intensive study by meteorologists.

During the few years before the Second World War, skill in thermal soaring and cloud flying progressively improved; distances became hundreds of miles and heights tens of thousands of feet. Broadly speaking, the exterior appearance of gliders did not alter greatly during the 1930s, although they became much stronger in order to withstand large gust loads and stability and control were improved. They were no longer designed to give the lowest minimum sinking speed, but to travel as fast as possible on thermal cross-country flights, so that wing loadings became higher. Reliable blind-flying instruments also became available. There was another outstanding technical development: speed-limiting air-brakes. The terminal velocity of a clean glider is about 300 or 350 knots, a quite impossible speed for it to withstand. Given speed-limiting brakes which would reduce the terminal velocity to 100 knots or so, the spiral dive lost much of its danger and pilots could go cloud flying with infinitely greater security. The Second World War bequeathed three assets to post-war soaring in the form of synthetic waterproof glues, a vast fund of knowledge of the properties and design of low-drag aerofoils, and a generation of pilots who were accustomed to the handling qualities of powered aircraft or who had gained experience of modern test-flying methods. There were also minor pickings in the form of cheap instruments and parachutes.

Shortly after the war, a large number of Olympias were built by Elliotts of Newbury, by redesigning the pre-war

Jacobs Meise to satisfy British Civil Airworthiness Requirements. Many of these machines are still in use. There was a similar reliance on pre-war German designs elsewhere in Europe, and variants of the Grunau Baby and Weihe were built in several countries.

The next generation of glider designs also relied on the example of pre-war Germany. Types such as the Slingsby Sky and the Air 100 were recognizably descended from the Weihe, although with higher wing loadings and more effective airbrakes. A major stimulus to glider design came from the USA, in the form of the Ross-Johnson RJ-5 of 1950. By the use of the then novel low-drag NACA wing sections, and careful attention to detailed finish, a glide angle of nearly 1 in 40 was achieved, and this machine was the subject of detailed investigation by Dr August Raspet who continued to pursue 'low-loss aerodynamics' until his untimely death. Following the example of the RJ-5, other designers were quick to adopt low-drag wing-sections and more accurate profiles. In the UK, the Skylark series (Fig. 1) were typical of this trend, using thick gaboon plywood as wing covering in an attempt to reduce the waviness commonly associated with the thinner birch of previous designs.

The low-drag NACA wing sections were not specifically designed for low-speed operation, although the thicker members of the series had useful properties for glider application. The next revolution came from Germany, where R. Eppler and F. X. Wortmann initiated the design of special sections particularly suited to gliders. In particular, they were intended to operate at high lift coefficients (see Chapter 3) without an undue increase in drag. One of the earlier machines to embody these ideas was the Phönix of 1957. In the interests of maintaining accurate profiles, this machine was largely built from glass fibre and resin. Although not particularly successful as a contest aircraft, this type displayed the merits of these special aerofoils and the advantage of accurate contours. Its successors, such as the ASW-12 (Fig. 2) and the Kestrel, are production aircraft which represent the current development of these themes. They also illustrate a further trend, that of reducing the extra-to-wing drag as much as

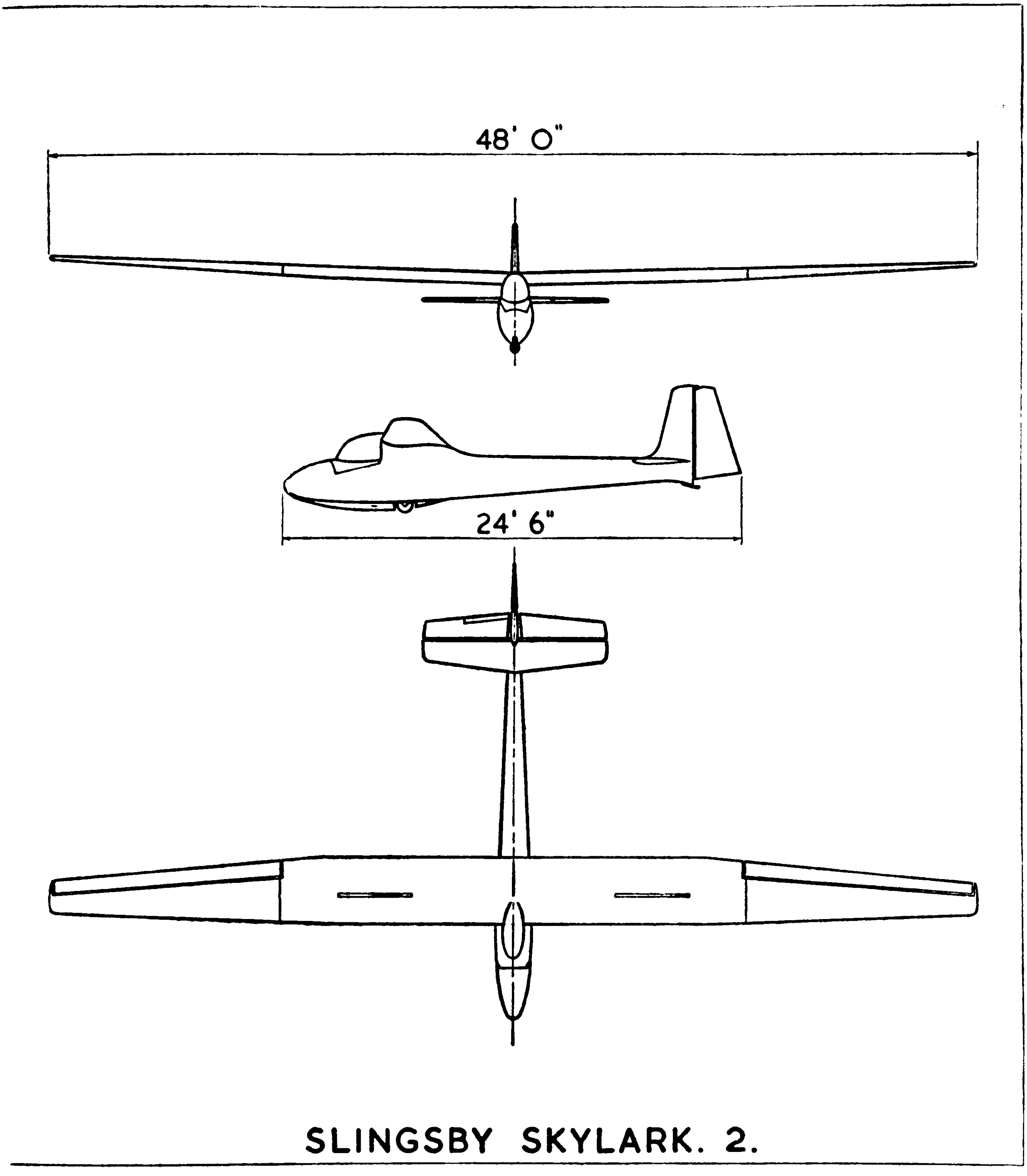

Fig. 1 General arrangement of Slingsby Skylark II.

possible. This drag arises from the fuselage and the tail, and is associated with the need to house the pilot in adequate comfort and to provide acceptable longitudinal stability and control. Ideas on 'adequate comfort' were radically revised when the

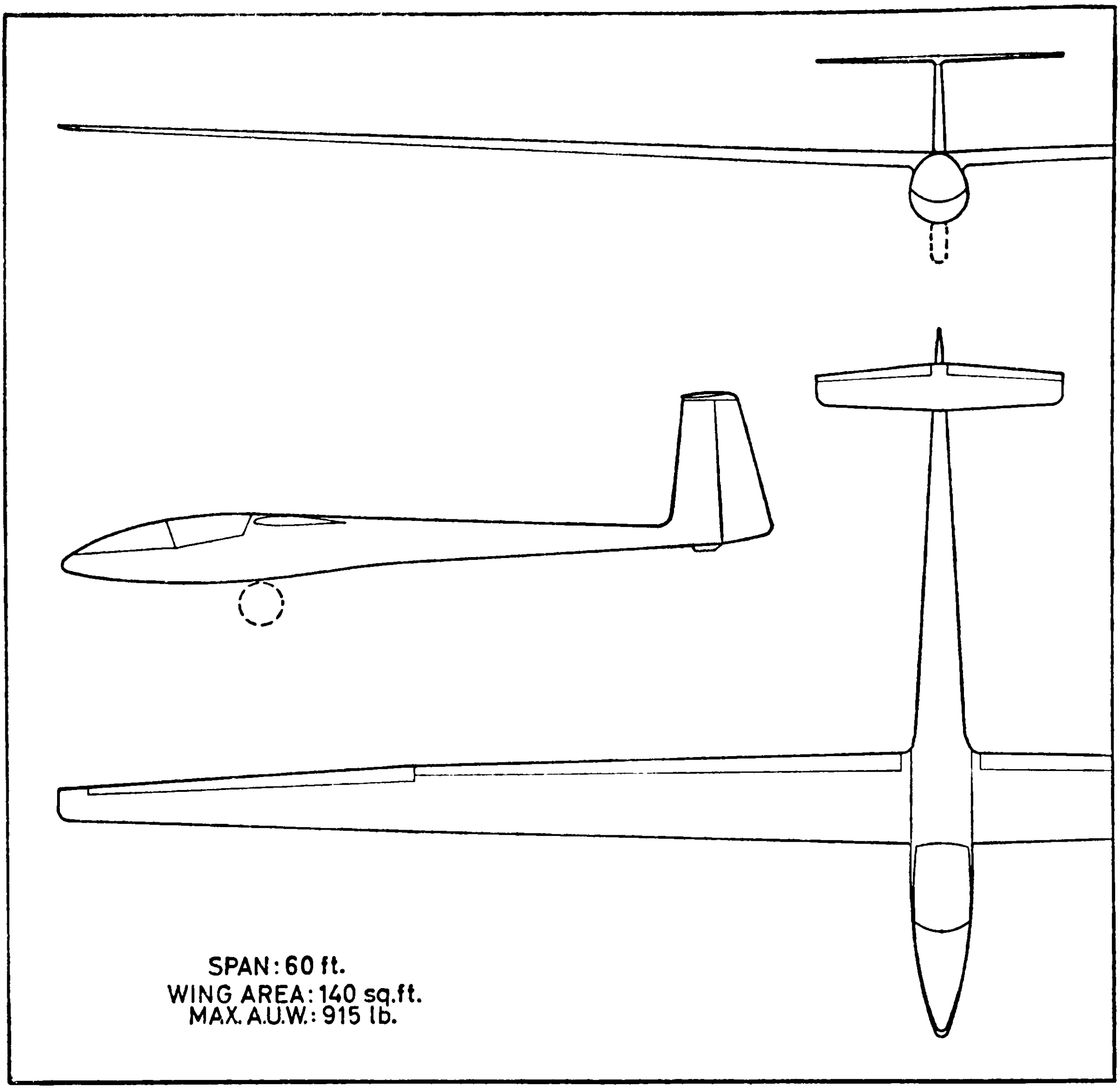

Fig. 2 The ASW-12, a production version of the D-36, which was the outstanding machine of the 1965 World Gliding Championships. The structure is a glass-fibre/balsa sandwich.

Polish Zefir and Foka appeared in 1960, demonstrating that a very reclining posture was, surprisingly, quite acceptable even if initially somewhat disconcerting. Likewise, it is not too difficult to arrange the size of the tail surfaces and the centre of gravity position of the aircraft so as to keep the 'trim drag' as low as possible.

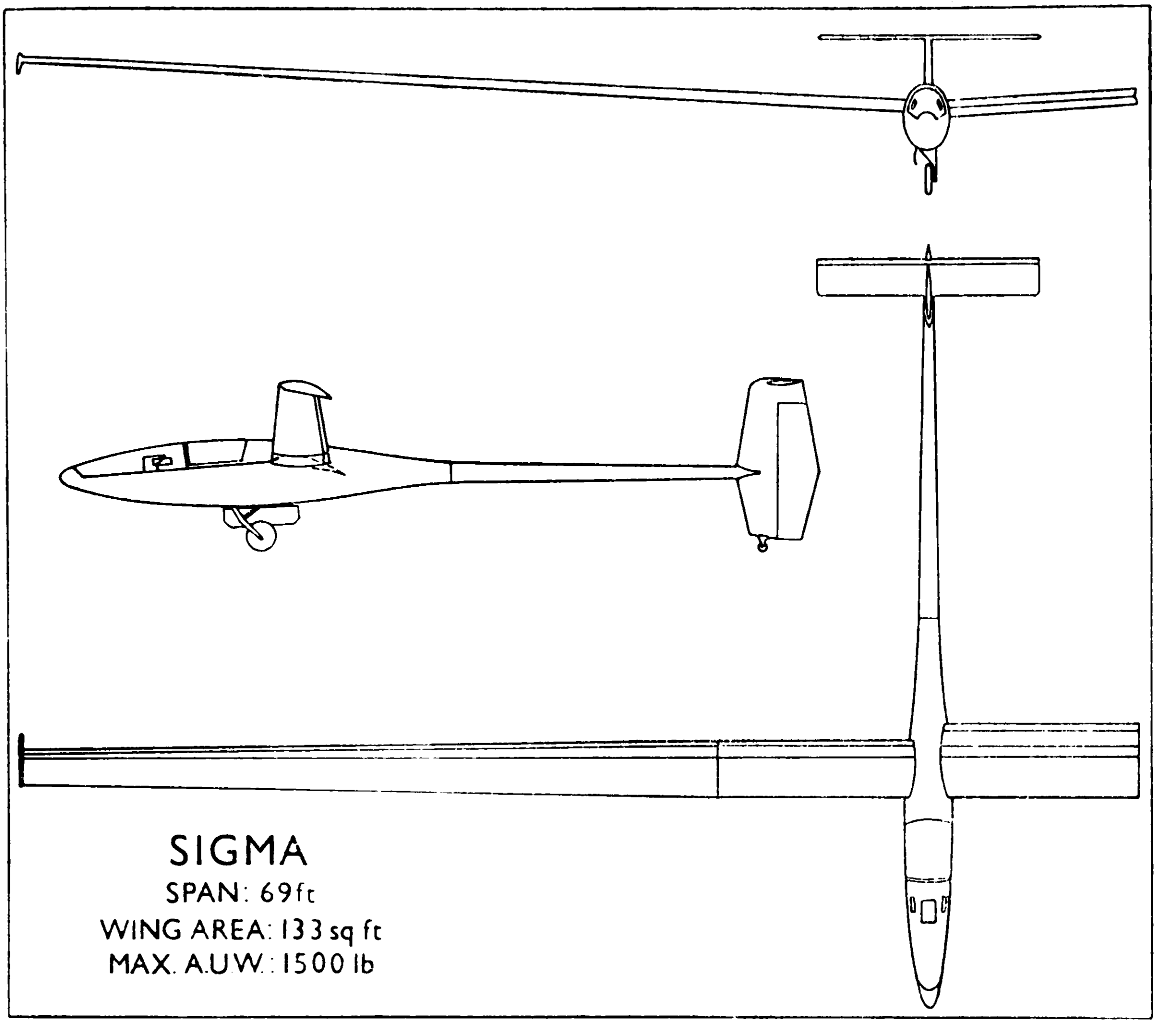

Fig. 3 The Sigma is a new British glider with a variable area wing. For circling flight, flaps increase the wing area by 35% to produce a clean, highly cambered wing. The estimated best glide angle, flaps in, is about 50:1 at 55 knots.

The outcome of such endeavours is that the extra-to-wing profile drag of a modern machine is about 60% of that of the wing (again, see Chapter 3), and there is doubtless room for further improvement by arranging for extensive laminar boundary layer on the front fuselage and suitable shaping of the rear fuselage to minimize the drag due to the turbulent boundary layer.

Glass-fibre construction is now widely used; it gives a superb finish and the difficulties introduced by its low stiffness have been largely overcome. Gliders such as Sisu and the HP-14 have shown that an excellent finish can also be obtained on a metal structure, and that assembly can be quite simple.

The result of these advances is that, if we regard the best gliding angle as a good measure of overall aerodynamic efficiency, gliders have been improving at a rate of somewhere between two and three per cent per annum. As is usual in any technology, it has not always been clear how the next improvement can be achieved. At present, one can argue that without discovering some new law of nature there is little prospect of reducing the drag of wings much further and fuselages cannot be made much slimmer unless high performance gliding is restricted to the wee folk. Obviously, there is some minor cleaning-up to be done, but what then? As Chapter 3 indicates, the design of a glider involves a compromise between the ability to perform slow circles when climbing in thermals and the ability to cruise at high speeds in straight flight. It seems very likely that the machine can be caused to perform more efficiently in both regimes of flight by using a variable-chord and variable-camber wing. Some efforts have been made in this direction already (e.g., the BJ-3 in South Africa) using standard Fowler-type flaps. But the design of special wings and flaps holds out the promise of a machine which will have a high lift coefficient for circling flight, coupled with a rather higher wing loading than is usual today, and an even higher wing loading in the cruise configuration (Fig. 3): A great deal of mechanical ingenuity is involved, but there is no reason to suppose that the rate of improvement will slacken for some time yet.

A relatively small improvement in the pilot's ability to find and use thermals has a much more significant effect on cross-country performance than hard-won aerodynamic and structural advances. Over the last few years, various instruments for locating thermals and displaying rates of climb have been proposed, but none have reached a practical stage other than the electric variometer and various types of computer. Thermal location by means of temperature or electrical charge gradients has been singularly unsuccessful. One possibility, within the scope of current technology, is the infra-red location of thermal sources, and another is the detection of thermals by laser techniques. At present, both developments are very expensive and not readily available even to the well-endowed experimenter, but this situation could change quite quickly.

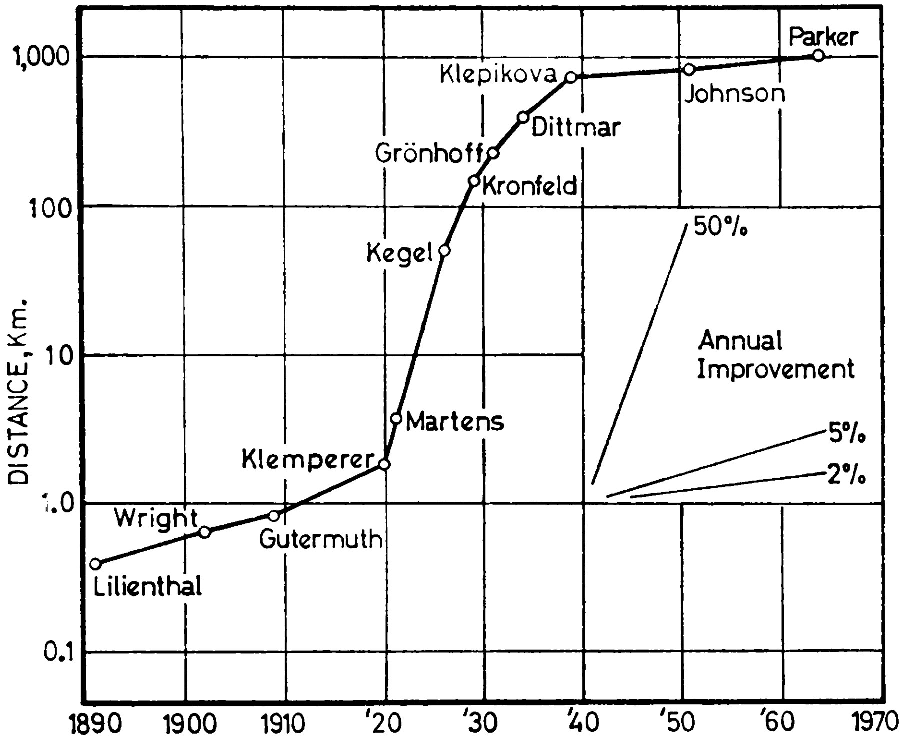

Fig. 4 Progress in soaring, as illustrated by significant distance flights.

All things considered, there is still much scope for technological advance, even if one eschews ideas such as building solar cells into the wing surfaces. With the possible exception of variable-chord wings, we seem to be getting into the realms of diminishing returns, and it is becoming debatable whether pilots, outside World Championships, will regard expensive electronic aids as contributing enough to the fun. In the nature of things, they probably will.

Fig. 4 illustrates the progress in soaring, in terms of significant distance flights. Some very meritorious flights have been omitted if they have no noticeable effect on the overall trend. The distance scale is logarithmic, and hence any straight line sloping upwards to the right represents a constant percentage rate of improvement per year on a compound-interest basis as indicated by the lines on the right of the diagram. The spectacular rate of improvement in the '20s and '30s is immediately apparent, as is the relatively slow rate thereafter. It is probably fair to say that the greatest advances were associated with a rapidly increasing knowledge of how to put soaring weather to good account, particularly after the invention of the variometer, rather than to improvements in the gliders themselves. It is very significant that the considerable improvements in glider design since the war are quite invisible on the basis of this diagram. Of course, one has to be careful in looking at logarithmic plots: a considerable improvement in distance, measured in kilometres, looks very small towards the upper end of the diagram. Moreover, distance is not the only measure of progress in soaring.

It is therefore difficult to know whether to end this chapter on a note of gloom or of hope. One can argue that something very like stagnation has set in and that further improvement will be dearly bought, as we have already suggested. One can also look at the experience in other areas of technological effort: when the rate of advance falls off, somebody invents a completely new technique (jet engines replacing propellers, for example) and a further era of improvement occurs. It is by no means clear how the new technique in soaring will arise, but this may simply indicate a lack of imagination on the part of the writer. Perhaps the ability to locate thermals really is the advance to be pursued and perhaps its effect will be as great as that of the variometer nearly forty years ago.

Chapter 2

GLIDER DESIGN AND ASSESSMENT

This chapter is written from the point of view of the soaring pilot who is concerned with flying a satisfactory glider, either as a private owner or a member of a club. It does not deal with one-off specialized designs although these obviously have a valuable function in stimulating progress and training designers. Nor will structural design be specifically mentioned, except when it is involved in other considerations. It is hoped that a theme will emerge from this chapter: that whilst performance is important, since it is the *raison d'être* of the glider, it is not all-important. Good aerodynamic performance is only one of the attributes of a satisfactory glider, since the overall performance may be regarded as a synthesis in which the qualities of the glider and the skill of the pilot are combined. The nature of soaring flight is such that the skill of the pilot is still, and doubtless always will be, of prime importance and it follows that a 'good' glider is one which enables him to apply his skill to the best advantage. Safety, comfort, simplicity, pleasant flying characteristics, ease of ground handling and maintenance all contribute to this and are just as essential as a good polar curve. All too often does one encounter designs to which immense care and ingenuity have been applied to minimize the aerodynamic losses, but which fall short of being practical soaring machines due to a neglect of this principle.

Whilst good aerodynamic design can hardly be said to be easy, it is essentially a fairly straightforward technical problem, but translating it into good engineering is quite difficult. This difficulty is not peculiar to glider design, of course, but applies to almost any useful man-made object from pots and pans to motorcars and airliners and much has been written on both the practical and philosophical aspects of the matter. It will suffice to observe here that apart from being a competent engineer, the glider designer must be able to visualize the various circumstances in which his machine will be used, he must be able to scan previous experience with a discerning eye, rejecting what was found to be bad, and he should ideally have at his disposal some of that ill-defined attribute called inspiration. Then he may be able to produce a machine in which the pilot will instinctively feel happy at first acquaintance and which he will rapidly come to regard subconsciously as an extension of himself.

Although the best aerodynamic layout may be somewhat varied to suit local conditions, the qualities of a glider which lead to this happy result do not differ from one country to another so much as is commonly supposed, since glider pilots are of much the same physical and mental characteristics the world over. This chapter is therefore devoted to examining some of those features of glider design which directly affect the pilot and to presenting some opinions of the authors, who are strongly inclined to the view that refined aerodynamics, good handling, comfort and mechanical reliability are not mutually incompatible. There are also some notes on the assessment of the flying qualities of a glider.

COCKPIT LAYOUT

Since the pilot hopes to spend many hours at a time sitting in the cockpit, its comfort and convenience are obviously vital. Unfortunately, the human frame does not conform to a standard specification, so that the cockpit must be large enough for a big man without losing sight of those of slighter build—in both the literal and figurative senses. Ideally, the rudder pedals would be adjustable and the seat position would be variable, both horizontally and vertically. In practice, cost dictates a simpler arrangement and the pilot usually has to adjust the seat by means of cushions. It is well worth having a specially tailored seat cushion giving proper support under the thighs, since few things are more trying than paralysis due to excessive bearing pressure on the seat during a long flight. Various seating positions have been tried, from the prone pilot looking downwards, through the bolt-upright to a psychiatrist's-couch reclining posture, the more extreme positions being unhappy compromises between comfort, view and small frontal area. The current tendency is to reduce the frontal area of the fuselage as much as possible by placing the pilot in a near-horizontal supine attitude. Given a suitably shaped seat and sufficient elbow-room, this position can be very comfortable, but it does involve problems in providing adequate pilot restraint by means of the harness and a good forward view. The conventional 4-strap harness is not entirely satisfactory since a supine pilot can easily slide forwards through it, but a safe and comfortable substitute has yet to be provided. Contouring of the seat is often a weak point of cockpit design. Various diagrams of the 'average man' are available showing the hinge points of the conventional body (and—gruesome thought—the centres of gravity and weights of its various members), but they should be regarded as giving only the roughest guide. The only real test of cockpit comfort is made by causing pilots of different shapes and sizes to sit in it.

The width of the cockpit is frequently inadequate, since it seems to assume that a lightly-clad slender figure is prepared to sit precisely on the centre-line for long periods. Another two or three inches of width may increase the drag by some small amount but will prevent the sense of frustration which attends sitting on an inaccessible packet of cigarettes. These may seem small matters, perhaps expressed rather facetiously, but the effect on one's peace of mind and body during a long flight is very real.

It goes without saying that the primary controls should come readily to hand and foot and should be movable through their full travels without any sensation of discomfort or strain. Similar requirement apply to the secondary controls, and in this respect cockpit layouts are often unsatisfactory. The airbrake lever, for example, frequently causes discomfort to the left leg and it may even lead to a restriction of the stick travel in this sense. An airbrake lever which folds towards the cockpit side can be very satisfactory. Another important control is the tow-release knob, painted yellow according to the airworthiness requirements and located near the left-hand corner of the instrument panel. Since failure to release may lead to great danger, it is quite apparent that this control must be plainly visible, easily reached, and of such size and shape that it can be grasped by a gloved hand so as to apply a large pull-force. All this is quite obvious, but one still encounters machines with release knobs between or under the pilot's legs, or in a dark corner under the instrument panel, perhaps only an inch in diameter, sometimes painted black. If there is more than one tow hook, the same knob must operate both simultaneously.

The pilot must be able to reach the adjustment knob of the altimeter and operate switches. In some modern designs it is not particularly easy to reach the instrument panel, and it may be necessary to locate such controls elsewhere. In a perfect world, the de-misting arrangements for the inside of the canopy would be so good that the pilot would never need to wipe it. Unfortunately, they often fall short of this standard, so it must be possible for the pilot to reach enough of the canopy for him to maintain a good view, even if the extreme front mists up.

To prevent the entry of water and cold draughts the cockpit must be properly sealed with the canopy closed, and ventilation should be deliberate rather than fortuitous. In the small space of a cockpit, really good ventilation and de-misting is difficult to achieve, and can account for enough drag to be just significant. In order to avoid spoiling the flow over the front fuselage, a pitot-type intake at the nose is undesirable, and the current trend is to provide a flush intake further aft, where the boundary layer has become turbulent. A suitable position would be just aft of the cockpit. The air must then be carefully ducted to suitable points in the cockpit, and should be exhausted in an orderly fashion. At least one clear-vision panel must be installed in such a position that the pilot has sufficient view to land the machine even if the rest of the canopy is covered with water or ice.

Sufficient space should be provided to stow all the miscellaneous property carried by the pilot, such as maps, computers, food and drink. It also follows that the cockpit floor should be continuous so that such articles cannot fall into the control mechanism. The bottom of the stick should also be faired to the floor and seat by means of a suitable flexible gaiter.

A completely detachable cockpit canopy, as opposed to one which is hinged, has considerable nuisance value and is liable to be easily damaged. The method of securing the canopy must be positive and arranged so that it cannot be inadvertently undone, but on the other hand it should be possible to jettison the whole canopy in emergency and, if need be, a handle fixed to the fuselage should be provided above the instrument panel to assist the pilot in baling-out. All projections which might cause injury to the pilot in the event of an accident must be adequately padded.

The provision of adequate forward visibility is not easy when the pilot is lying almost flat and the perspex of the canopy blends smoothly into the lines of the front fuselage. It seems that pilots are prepared to sacrifice some convenience for performance. But it is rather easy to diminish the safety as well as the convenience, and one finds some machines in which the pilot's line of sight makes such a flat angle with the perspex that, for all practical purposes, he has little view straight ahead. When circling in a thermal, lack of forward view is of less consequence than might be thought, since one is usually looking somewhat sideways. In straight flight, particularly on tow or when landing, it becomes unpleasant and somewhat hazardous.

DETAILS

One of the more familiar sights at a gliding club is a group of members pushing a glider to the launching point. Whilst such exercise is doubtless very salutary, it is often rendered unnecessarily difficult by the failure of the designer to provide proper handling points. Glider pilots are long-suffering, and have become hardened to being confronted by a tailplane bearing the legend 'NO HANDLING', but without any constructive suggestion. Sometimes one finds a small hole in the rear fuselage, apparently designed to do violence to the human hand and wrist. The only really satisfactory arrangement is a proper lifting bar: for club purposes, its drag is a small price for the convenience, whilst the purist can always take it out and stow it in the luggage locker.

In addition to Mr Stout's famous dictum 'Simplicate and add more lightness', there is another which seems to be particularly relevant to glider design: 'You cannot make control cable pulleys too big.' One still finds pulleys about one inch in diameter, usually in dark corners where it is difficult to inspect the cable. They are far too small. Furthermore, it is a fallacy to suppose that the pulley size can be reduced if it only deflects the cable through a small angle. It is strongly suggested that a pulley taking 10 cwt cable should not be less than $2\frac{1}{2}$ in. diameter. By far the best solution is to avoid the use of cables and pulleys by using push-pull rods wherever possible. They are heavier, but far more reliable and convenient.

It should also go without saying that turnbuckles should be readily accessible for adjustment and that main rigging pins should have handles. Unless they are taper-pins, rigging and de-rigging with a mallet is undesirable. Experience shows that control circuits containing levers working at short centres are unsatisfactory, since the loads tend to be high, the rate of wear of pivots correspondingly great and the effect of backlash much more noticeable.

FLYING QUALITIES: LONGITUDINAL STABILITY AND CONTROL

One of the major improvements in sailplane design in recent years has been in the provision of greatly improved stability and control; indeed one marvels at the courage of those early pilots who flew in turbulent clouds in gliders whose flying characteristics would now be quite unacceptable, with inadequate instruments and no airbrakes.

Longitudinal stability and control was placed on a sound practical basis largely by the work of Gates and Lyon in this country. Plenty of data is available, and there is no difficulty in obtaining satisfactory longitudinal characteristics. As explained in Chapter 5, a conventional glider may be just acceptable with zero stick-fixed stability, provided that the stick-free stability is still positive, and for a glider whose stick-free neutral point is aft of the stick-fixed neutral point this condition may well determine the aftmost position of the centre of gravity. Once a glider has been built, the stick-fixed neutral point position cannot be easily modified but the stick-free neutral point can be readily altered (see Chapter 5 for an

Ann and Lorne Welch need no introduction to the gliding world: there must be few aspects of gliding in Britain with which they have not been involved. Both learnt to fly first on powered aircraft in the 'thirties and then turned to gliding. Ann was an ATA ferry pilot in the 1939–45 war and Lorne first an RAF instructor and then a POW after being shot down in a bombing raid. Ann has run many National Competitions and has managed the British Team in 8 World Championships. She was the Director of the 1965 World Championships at South Cerney, Gloucestershire and in 1968 was awarded the OBE for services to gliding. She holds the British Women's National Goal record of 328 miles. Lorne has flown in 4 World Championships, was Chief Instructor of the Surrey Club for four years and has test flown the prototypes of most British gliders since the war. With Frank Irving he holds the British Two-Seater Distance of 264 miles. Gliding runs in the family: one daughter is also a glider pilot.

Frank Irving is Senior Lecturer and Assistant Director of the Aeronautics Department at Imperial College, and is responsible for the design of their supersonic wind-tunnels. He started gliding at Redhill in 1947, and now holds the Gold 'C' and one Diamond. With Lorne Welch he is a member of the Board of 'Operation Sigma', concerned with the construction of a very advanced variable-geometry glider.

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