The Handling Characteristics of High Performance Sailplanes

It has long been apparent that there is a wide divergence of opinion between pilots as to what would constitute ideal handling characteristics in a high performance sailplane; they are all in reasonable agreement as to what is required in the way of performance since this can be relatively simply and accurately described in terms of figures, but handling characteristics are not so easily measured in exact terms and tend to be described qualitatively by the pilot, hence he has full play for his own opinions and fads. Small wonder then that designers find it difficult to meet every pilot's requirements, nevertheless some come much nearer to it than others.

This article is an attempt to show the width of this variation by asking various pilots to put down their views on what they want, and say where they think there is greatest scope for improvement in modern sailplanes in general.

Before going on to the various views it is pertinent to run through the more important headings under which handling can conveniently be described.

Fore and aft stability and manoeuvrability

These are probably the most important handling characteristics of a sailplane since deficiencies in these respects may be not only unpleasant but actually unsafe. The most important criteria are:

a) Static longitudinal stability which is the tendency for the sailplane to return to the trimmed speed after a disturbance in pitch. It is measured both stick fixed and stick free.

b) Manoeuvrability (or static longitudinal stability in curved flight paths).

The effect of these characteristics from the pilot's point of view are as follows:

A sailplane which has static longitudinal stability stick fixed will have a stick position which varies with speed in the natural sense, i.e. to maintain higher speeds the stick has to be moved further forward and vice versa. The amount of movement to cover the speed range must obviously not be greater than the space between the pilot and the instrument panel and it may well be very small or nil. The amount of this movement is a measure of the degree of static stick fixed stability.

Static longitudinal stability stick free is measured by the stick force necessary to change speed and is positive if a push force holds an increased speed and a pull force holds a lower speed.

In pitching manoeuvres at a selected speed, the change in stick position and stick force for change in the rate of pitch define the *stick fixed* and *stick free* longitudinal manoeuvrabilities respectively. The rate of pitch is most easily obtained by measuring the applied normal acceleration or "G". Thus stick free manoeuvrability shows up as stick force per applied "G" and stick fixed manoeuvrability as stick movement per applied "G".

In addition to the above characteristics, the elevator will also be assessed from the point of view of response and effectiveness.

Whereas the static longitudinal stability of a sailplane refers to its *tendency* to return to the trimmed speed after a disturbance in pitch, the nature of the subsequent motion is determined by the dynamic longitudinal stability. There are two possible motions: one is a long-period oscillation (about 15 seconds for one cycle), usually termed the "phugoid", whilst the other has a much shorter period. The phugoid may be damped, may continue indefinitely with the same amplitude, or the amplitude may tend to increase. These effects may also be different stick free and stick fixed. But in practice the motion is so slow that for sailplanes of conventional configuration the characteristics of the phugoid are of little concern to the pilot. The short-period oscillation is rarely noticeable in practice being usually well damped.

Ailerons

The basic purpose of ailerons is to produce an adequate rate of roll leading into a turn at all speeds, with stick forces which are satisfactory to the pilot. In producing this roll, ailerons almost inevitably produce more drag on the upgoing wing than on the downgoing (aileron drag) so that the machine yaws against the direction in which the turn is being initiated. This adverse yaw must be corrected with the rudder.

Like the elevator the ailerons will also be assessed on response and effectiveness, but in addition they will be required to harmonise with the elevator so that movements of the control column either lateral or longitudinal require forces of the same order and also produce results of comparable degree.

Rudder

The rudder has special functions during take-off and landing in a cross wind but once in flight its only purpose is to counteract adverse yaw. A useful additional characteristic which may be present is roll with yaw, i.e. left rudder produces a roll to the left and consequently a turn to the left and vice versa. If roll with yaw is present the sailplane is easy to steer with the rudder alone leaving the hands free during straight non-manoeuvring flight.

Stalling characteristics

Stalling is very important in a sailplane since the greater part of every flight is spent at or near the stall in circling flight and often in turbulent conditions. Significant points from the pilot's point of view are stall warning, i.e. the onset of buffet or vibration before the stall is reached, the behaviour both in straight and turning flight at the stall, and the effectiveness of the controls at and past the stall.

Spinning

The most important characteristic under this heading is the ability to recover quickly and easily.

Airbrake characteristics

Airbrakes provide the pilot with a basic safety feature if they are capable of limiting the terminal velocity of the sailplane to a figure below its maximum permissible speed; they are also essential for glide ratio control for landing. Other points that interest a pilot are the change of trim they produce and the tendency or otherwise to remain shut or open.

Cockpit assessment and layout

Though not really belonging under the title of handling the assessment of the cockpit is usually included and there are several points in this area which are the subject of different opinion.

Such items as view, position of controls, position of instrument panel and comfort are all relevant.

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Individual Views – Part I

by Commander H.C.N. Goodhart, R.N.

(Note: Commander Goodhart is a private owner-competition pilot interested in maximum performance. He has a total of just over 2500 hours, most of which is in fighter type aircraft and about 400 of which has been in gliders. He is the holder of a number of British gliding-records and won the two-seat International Championship at St-Yan, France, 1956.)

The handling characteristics of a high performance sailplane are particularly interesting in that the requirements differ appreciably from those of any other type of aircraft. The reason for this becomes obvious when one analyses the normal technique of flying.

In circling flight a sailplane is flown in a speed bracket which no other aeroplane approaches except during take-off and landing. It is frequently operated at these speeds in very turbulent air and furthermore it is usually engaged at this time in doing steep turns. Controllability at very slow speed is clearly essential, and, due to the very large span relative to the weight this is not easy.

The other important difference between a glider and any other aircraft is the constantly varying conditions under which it is flown. Speed is varied throughout cruising flights to get the optimum performance; angle of bank and hence applied "G" are varied continuously during circling in order to remain central in the thermal.

It is this constant variation of speed or applied "G" which is the key to those features of fore and aft stability and manoeuvrability which make a sailplane pleasant to fly. Both speed and "G" should be able to be varied using only the lightest reasonable stick forces, it is then unnecessary to re-trim except for the grossest variations and the sailplane becomes lightly and easily controlled at the whim of its pilot. Of course the small stick forces required must be in the same sense. This states in so many words that both the static stability and manoeuvrability, stick free, must be positive but low.

The importance of getting this stick free stability and manoeuvrability right cannot be over emphasised; I think it is safe to say that this is the primary key to all pleasant handling characteristics. Nothing is more infuriating than a "ham-fisted" sailplane in which every change of speed or "G" can only be achieved at the expense of heavy stick forces which must be trimmed out after, or even during each change.

Another annoying feature of excessive stability is the reaction of the machine to changes of airspeed such as occur on entering or leaving a thermal. High stick free stability means that the aircraft will pitch strongly nose up when the air speed increases and vice versa, which is of course the one thing one wants to avoid as one enters a thermal.

I do not want unstable sailplanes but I hate them to be too stable. The argument that excessive stability is nice when flying blind in a rough cloud is pure nonsense. One is flying the machine, not being flown by it and the light stick forces associated with a reasonable degree of stability are entirely sufficient to make blind flying easy.

An additional disadvantage of excessive stability is the performance penalty engendered by the excessive sailplane area necessary for this stability. With this in mind, should we not tend towards the minimum reasonable stability?

Ailerons

Having got these fore and aft stabilities right, the next item is the aileron control. High rate of roll is a very useful item and a reasonable figure is under 4 seconds from 45° to 45°; however, rate of roll itself is not enough, the stick force necessary to produce it must be reasonable and in harmony with the fore and aft stick forces.

Lateral stick forces should build up progressively with the stick displacement (it very frequently does not) and rate of roll should build up similarly. If this is achieved the ailerons will be very pleasant to handle indeed and will feel crisp and effective.

Ailerons should suffer no appreciable loss of effectiveness near the stall nor should any snatch be present. Effectiveness should in fact be maintained well below the stall.

Rudder

The rudder's main job is to conteract aileron drag. The test for the rudder is, therefore, it's ability to keep the ball in the middle when full aileron is applied. Foot loads in doing so should not be more than comfortable and equally, should not be too light. Lightening of the rudder forces in side slips frequently occurs but is not a very serious item; in spins it may even lock over, but, provided the foot loads to centralise it are small this can be ignored.

I am strongly in favour of good roll with yaw characteristics so that the machine may be easily flown hands-off in straight flight when both hands are needed for other things, e. g. pouring out the coffee.

Stalling

It is essential that the machine shall have no tendency to wing drop at stall in straight or turning flight and there must be some warning of the approach of the stall. However, this must not occur at speeds in excess of 1—2 knots above the stall. This is a rather severe requirement since the onset of stall warning is unpredictable. In general, stall warning in the form of buffet at too great a margin above the stall is indicative of aerodynamic troubles which are causing a loss of low speed performance.

All controls should remain effective at and past the stall.

Airbrakes

The value of terminal velocity airbrakes lies not so much in their speed limiting capabilities as in their extreme effectiveness in small field landings. The prospect of finding myself relying on T.V. brakes to avoid exceeding the maximum permissable A.S.I. I find very remote. However, the size of brakes necessary for this purpose is just about right to provide the maximum margin for error in touching down at a preselected point, and the prospect of my needing all this margin is very far from remote.

It is important that airbrakes shall tend to stay open when opened and shall have a really good lock to keep them shut when shut. Force to operate must be reasonably light, but changes in the force are not important as one puts the lever where one wants and takes no notice of the force necessary to do so. Changes of trim with movement of brakes should be kept to a minimum, particularly at high speeds.

Cockpit

Comfort in a sailplane is highly important as one frequently has to sit in one position for 6—8 hours. If cramp is to be avoided it is essential that the seat shall provide even support over a large area of one's thighs in addition to the piece one normally sits on. It is also essential that there shall be adequate leg lenght available. I find, and I have heard other pilots say, that shortage of leg length produces severe knee pains after two or three hours flying.

A feature which seems to be getting steadily worse in some modern sailplanes is the ability to see out. Canopies have got more cramped in the interests of low drag and it has become quite impossible to see downwards in level flight. For competition purposes this feature is annoying since it is difficult to cross a starting line accurately when one cannot see either end of it and it is still more difficult to waste a minimum of distance on making a turn on a triangular or out and return flight.

Another minor feature of cockpits is instrument presentation. Why instruments are not installed so that they face the pilot has always been a mystery to me. All pilots of aeroplanes have always put up with vast amounts of parallax error in attempting to read their instruments. Either the instrument makers should drag their heads out of the sand and put the dials on their instruments sloping back at about 20° (this gives them an ideal opportunity to install good instrument lighting too) or if they are determined to ignore the basic requirement for a good instrument then the instrument should be mounted at an angle in the panel. Existing gyro instruments cannot be so mounted which is annoying, though they could be easily modified to allow this.

Conclusion

That then covers the main features of what I would consider an ideal sailplane—provided the performance was of world beater standard. Many pilots will disagree on nearly every point and most will disagree on some points, but even if all agreed I doubt if anyone will ever build a sailplane which could measure up exactly to the requirements. To do so would necessitate starting whith a really good design and then setting up a vast testing programme to develope the machine. Somebody would then have to pay for this testing and development which brings us back to perhaps the most important feature of a sailplane which, though it scarcely comes under the heading of handling, is, of course, cost; so instead of asking for perfection let us hope that one designer can get somewhere near it at the first shot and give us adequate handling and performance at the lowest possible price.

Individual Views – Part II

By F. G. Irving

(Note: Mr. Irving has about 400 hours on gliders, zero hours power. He is a member of BGA No. 1 Flight Test Group, Lasham, England.)

In the sense that one is trying to define an ideal, these notes should be written on the assumption that one is so wealthy as to be able to afford a completely tailor-made glider, designed precisely to a personal specification. On the basis of such an assumption, it is not particularly difficult to state what one would like. I have attempted to do so below and I imagine that Commander Goodhart adopted the same point of view.

In practice, very few individuals can indulge themselves to this extent, and even so they do not often find themselves completely satisfied. Most of us have to be content with a standard production machine, often in conjunction with other pilots, either as a small group owning the machine or as members of a club. Under such circumstances, one's ideals must be somewhat modified. The concessions which usually have to be accepted are mentioned in the last paragraph.

Longitudinal Stability and Manœuvrability

Stick-fixed longitudinal stability is usually of minor importance provided the other requirements are satisfied, since the pilot is not particularly sensitive to stick position in steady flight. However, it should be remembered that stick-fixed stability depends on the external geometry and centre of gravity position of the glider; other things being equal, it is dependent on the size of the tailplane-and-elevator. Once a glider is built, the stick-fixed stability cannot be easily altered.

Stick-free stability is of great importance, since the pilot senses stick forces quite readily. This should be moderate—a rather vague expression to which, I regret, I cannot attach precise figures. On the one hand it should be possible to leave the machine to its own devices for reasonable periods (e.g. when grappling with maps) without large errors in speed developing. I am prepared to accept re-trimming when entering a thermal or when changing speed by, say, five knots or so in straight flight. It is not, after all, a great effort to do so, although something better than the usual trimmer lever would be pleasant. This stick-free stability should be obtained by aerodynamic means, the elevator being as nearly completely mass-balanced as possible. Otherwise, the inertia effects due to small gusts become unpleasant.

Stick-force per "G" should also be moderate; if it is too low, the machine tends to feel rather "twitchy", particularly during aero-towing, whilst the results of too high a value are obvious. Again, one can only set very wide limits in the absence of measured values. One pound per "G" is too low, whilst 20 pounds per "G" is far to high.

Adequate damping in pitch and elevator effectiveness are very desirable.

I have flown a machine whose stick-fixed and stick-free stabilities were small but positive. Due to a rather small horizontal tail, the damping and elevator effectiveness were both very poor, so that one has an unpleasant sensation of being more nearly a spectator, rather than the controller, of the glider's manœuvres. Again, data is lacking which would enable one to quote desirable values, but these criteria might well decide the size of the horizontal tail.

Ailerons

I entirely agree with Commander Goodhart, so there is no point in repeating what he has already said.

In addition, I would naturally like ailerons which do not produce adverse yaw. There must be no danger of devices, such as nose balances, causing over-balance at high speeds.

Rudder

See Commander Goodhart's comments.

Stall

Likewise.

Airbrakes

In addition to Commander Goodhart's requirements, I would like to add a further suggestion. Whilst brakes which have to be held open at high speeds are infuriating, there might be merit in arranging them so as to have a slight closing tendency up to a speed slightly in excess of the normal aero-towing speed with a slight sucking-out tendency at higher speeds.

Any buffet produced by the brakes should be small.

The Production Glider

A glider produced in series has to be designed to cater for a reasonable range of pilot weights. Since the longitudinal stability and control are effected by the centre of gravity position it is usually found that if ballast is not to be carried and if reasonable stability is to be maintained at the aft-most C. of G. position, then a heavy pilot will tend to complain of excessive stick-free stability and stick force per "G". The solution is for each pilot to have his personal ballast, provided, of course, that the C. of G. is kept within the permitted limits. This is satisfactory if an individual or a small group owns the machine but it is not acceptable, to my mind, for club operation. This suggests that, whilst club members probably have to accept that a communal glider cannot fit their individual tastes, the glider should be designed so that the private owner can achieve a reasonable approximation to his desires by ballasting and without exceeding any limitations.

Another difficulty, rather beyond the scope of these comments, relates to Airworthiness Requirements. These must recognise that different pilots have different conceptions of what constitutes a pleasant glider to fly. They must therefore allow considerable scope, whilst laying down the essential features conducive to safety. Those who draft requirements have the difficult task of preserving both scope and safety.

These considerations suggest that efforts should be made to collect numerical data specifying pilots' opinions of what they want. It might eventually be possible to evolve a "Recommended Practices" manual, giving manufacturers guidance on those features which contribute to the operational efficiency of a glider.

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Individual Views – Part III

By D. H. J. Ince

Although the art of designing sailplanes for maximum performance has now reached an advanced stage, much less effort has been directed towards improving their handling characteristics. Unfortunately there is a tendency to produce too many new designs—with the accent on performance—and to devote insufficient development time to each. As a result the handling suffers. For this, the pilots are largely to blame; manufacturers must live and they know that we, so selective in our buyings, have an almost abnormal lack of sales resistance to a "new model". Worse still, we have not yet been able to agree amongst ourselves and establish a standard in handling characteristics for their guidance.

Longitudinal stability

In the first article of this series Nick Goodhart described the environment against which handling characteristics should be established and he has painted a very real picture of affairs on a good, reliable and possibly, rough, thermal day. Under these conditions one wants to be able to vary speed and g with the lightest possible forces and if possible without retrimming—stability is of virtually no importance. There are, however, many other conditions to satisfay, in particular one thinks of wave flying, weak thermals, and conditions late in a good thermal day, not forgetting the problem of pilot fatigue during a long day's flying—here stability is increasingly important, manoevrablity less so.

Hence the compromise—in my view positive stick free static stability and, putting a figure to it, such that the stick force to change speed from any trimmed value within the usable speed range should lie between 1½ to 2½ lb per 10 kt. This order of stick free static stability necessitates a trimmer of sufficiently high gear to cover the usable speed range in one continuous hand movement without, and this is important, requiring use of the hand which holds the control column.

As regards stick force per g, I am in favour of putting a bob weight in the elevator circuit to reduce this substantially to zero. The stick force gradient must not of course be negative at any combination of g and EAS. Ideally one wants zero stick force per g when circling in thermals (with a maximum of say 1 lb per g) and an increasingly positive stick force per g for higher values of 8 and EAS reaching 3 to 5 lb/g at the limits of the flight envelope. It is of course important that the acceleration on freeing the stick in a dive, when trimmed to normal circling speeds, does not exceed the limiting value. This combination may be impossible to satisfy in practice—nevertheless it is a target at which to aim.

Before introducing any bob weights to satisfay stick force/g requirements, it is important that the elevator should be mass balanced as closely as possible about its own hinge line. An out-of-balance elevator produces an unpleasant effect in rough air due to the changes in hinge moment with normal acceleration.

Insufficient feel in pitch can make an aircraft difficult and tiring to fly. By this I mean the following: suppose an aircraft is flying trimmed at a steady speed. If the stick is displaced by an amount which equals a small change in speed, then the force required to displace it must be a reasonable proportion, say 50 to 80 %, of that required to hold the new speed once it has been attained.

Other factors concerning longitudinal stability and control are that the stick fixed static stability is relatively unimportant; it should be small and positive but can be zero and even slightly negative without disturbing the pilot. The manoevrability stick fixed is also unimportant but should probably be small and positive. The point here is that one flies an aircraft by force, and not by displacement of the controls.

Ailerons

Ideally, the ailerons should produce very high rates of roll throughout the cruising speed range and should produce no adverse yaw due to aileron drag. The traditional method of measuring aileron effectiveness is based on the time taken to reverse a 45° banked turn at 1,4 Vs (using the most favourable combination of ailerons and rudder) and on this basis surely anything more than 5 seconds is quite unacceptable, *regardless of span;* 2 to 2½ seconds being the ideal at which to aim. Assuming the longitudinal stability situation already described, lateral stick forces must be as light as possible and provided that they increase progessively with displacement I would set no lower limit to their value. This implies not only close aerodynamic balancing but means that any minor defects in aileron control will show themselves more readily. For example it is important to avoid aileron overbalance with angular acceleration in roll, change of lateral trim with slip or skid, and any measurable lateral control force to hold a steady turn.

If it was otherwise impossible to achieve a satisfactory rate of roll I would be prepared to accept some aileron drag provided that it was comfortably within the capacity of the rudder to correct.

Finally, the ailerons must be effective in the correct sense down to and preferably below the stall. If necessary to obtain satisfactory ailerons I would be prepared to accept some aileron snatch at 1 or 2 kt above the stalling speed.

Rudder

When designed for use with my ideal ailerons the rudder should be heavy, and I mean heavy, by sailplane standards, with good self centering. Frankly, I would not mind additional spring feel in order to obtain a centering force for normal circling flight of the order of say 50 lb at full travel.

Assuming that there was some aileron drag, or even worse, that the aileron power was inadequate, I would prefer somewhat lighter rudder forces, although still heavier than it is the case on most sailplanes. Not more than about 50 % of the rudder travel should be required to counterbalance the aileron drag at full deflection.

In both cases rudder loads for recovery from a spin must not be excessive.

Although rudder locking and lightening of rudder forces in a sideslip are relatively unimportant neither should occur in

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a properly designed sailplane. Good roll with yaw characteristicts are of course highly desirable.

Stalling

There must be little or no tendency for a wing drop at the stall either in straight or turning flight; also there must be no large or violent nose down pitch.

Ideally onset of buffet together with a rapid increase in both stick fixed and stick free stability should occur 2 or 3 kt above the stall and the elevator should be practically on its stops at the stall. Slight aileron snatch would be acceptable as a stall warning in the absence of buffet.

These remarks apply equally with airbrakes open or closed.

Spinning

It is only necessary to stress here that the recovery from the spin must be easy, rapid and straightforward. The recovery, whether it occurs automatically or is pilot initiated must in no sense approach the limits of the flight envelope.

If the aircraft can be spun indefinitely there must be no tendency for a prolonged spin to flatten or lead in any other respect to difficulties in recovery.

These conditions apply with airbrakes open or closed.

Airbrakes

Although one may feel personally that airbrakes may have no application as terminal velocity "limiters" it is important again to remember that this year's new model may be flown by relatively inexperienced pilots in the not too distante future. Admittedly it requires skill and determination to achieve a truly vertical dive, nevertheless this is a reasonable design case and yet there are examples of failure to meet it.

For most of us however the away landing is the more stringent and frequent occasion and here it is essential that the brakes provide a sufficiently wide range of glide path control and a means of reducing the float as well. Some airbrakes are bad in the latter respect and nothing is worse than to find oneself floating on and on across a small and somewhat rough field with full airbrake and little sign of deceleration!

Cockpit

There is a dreadful tendency to seat the pilot in such a way that his frontal area is minimum and then to enclose him in the smallest possible box. I am quite sure that the loss of pilot performance thus achieved far more than offsets the marginal gain in aircraft efficiency. There must be a wealth of data available to designers on cockpit layout and pilot positioning. Let's then consider these points alone:

1. There is a relationship between the relative height of the seat and rudder pedals and the inclination of the seat back—it is frequently ignored.

2. Adjustable seat backs and rudder pedals which can be adjusted in flight are much easier and cheaper to engineer than might appear at first sight and they help to cater for different sizes of human being. Furthermore it is a very great comfort to be able to stretch one's legs during a long flight.

3. Cockpit canopies must be arranged so that one does not look forward through them at an acute angle otherwise difficulties arise with internal reflections, and in rain the view becomes quite hopeless. The transparency must be carried as far down the sides of the cockpit as practicable. Clear vision panels must be mounted so as to provide a view forward and slightly downward as close to the line of flight as possible. Some rearward view is highly desirable—particularly in busy thermals.

4. Cockpit and canopy must be sealed to exclude all draughts. Suitable ventilation must also be provided to avoid misting up inside the canopy.

5. One spends hours fumbling at the quite inaccessible rear of instrument panels. There is no reason why these should not be fully exposed to view when the canopy is off or open.

6. Most high performance sailplanes become festooned, to a lesser or greater extend, with radio, oxygen and electrical equipment. It is important to take this into account at the design stage, otherwise these items start finding their way into the cockpit to the detriment of its occupant.

Conclusions

To summarise my views on handling characteristics—considerable improvements could be achieved if we in the gliding movement would establish our requirements and encourage the manufacturers to concentrate on fewer designs with longer development.

I have attempted to put a few figures to some of my ideas in the hope of encouraging others to disagree and do likewise, thus eventually we may see a set of recommendations, *not requirements,* for the guidance of designers.

I cannot accept the view that quantitative handling standards are impossible to establish. Are we so individualistic, not to say wealthy, that each of us must have a sailplane designed to his own requirements? Surely all of us would be willing to surrender something in the knowledge that the overall standard was being raised? We know that familiarity with any aircraft will blind us to its faults as we adjust our flying habits accordingly. How many of our ideas are just prejudices created by the aircraft we fly?

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Individual Views – Part IV

by P. F. Bikle

Note: Mr. Bikle has about 950 hours in gliders, 320 of these on cross country, contest or record flights, and 600 hours power. He is the present holder of the World Class D-1 record of 55.02 m.p.h. for speed around a 200 km triangular course and holds number seven F. A. I. Diamond C award.

As I see it, everyone wants a machine that is easy to fly. This requires a reasonable degree of stability and light, powerful controls which enable the pilot to do what he wants when he wants to do it. Most pilots agree that a particular airplane flies well or that it doesn't; the divergence which seems to exist when pilots state their opinion about sailplanes in general usually arises from attempts to select certain parameters and establish numerical yardsticks to define the area of desirable characteristics. The difficulty here is that the validity of these yardsticks is influenced by a number of other factors in the design of the sailplane.

High performance sailplanes are no different than other aircraft in this respect except that the designer is perhaps under greater pressure to compromise the ease of flying to make some slight gains in performance. An uncomfortable cockpit or poor visibility will make even the best sailplane difficult to fly. Awkward placement of the controls will dictate a different level of acceptable forces. But, on the other hand, the ability of the high performance sailplane to achieve its purpose has a rather important influence on the pilot's opinion of the ease of flying. There is nothing like an additional five points on the L/D scale to make a difficult contest flight easier and a few feet per minute less sink has been known, on certain occasions, to more than offset the lack of a linear stick force gradient.

Every good aircraft is based on design compromises. Overall performance is usually considered a compromise between good low speed performance, adequate structure, and ability to land in small fields. Handling characteristics should be included in the same way, and all balanced together to derive a total performance factor on which to base design compromises.

Cockpit assessment not only should be included in a discussion of handling characteristics but should be high on the list. Provisions must be made for comfort of pilots of different physical proportions. Little compromise can be made in visibility, and it goes without saying that the controls need to be in a convenient location and the instruments easy to see. Friction in the controls must be low, or even the best aerodynamic control arrangement will be unsatisfactory. For example, one 40/1 sailplane that I have flown recently had excellent performance, and good stability and control. Yet the designers effort to reduce frontal area by placing the pilot in a semi-reclining position has seriously compromised these good features because the pilot can not see the ground without banking and because the controls are uncomfortable to operate despite forces which are well within the acceptable range for a more conventional seating arrangement. The result is a sailplane that is not easy to fly even though it measures up very well to the parameters used to define satisfactory handling characteristics.

Although a reasonable degree of stability, particularly fore and aft, or at least a minimum tendency toward divergence is necessary, comments about handling characteristics tend to place more emphasis on this aspect than is warranted. While control is not entirely separable from stability, the important thing is control in the sense of the capability of the machine to respond to the pilot's wishes. Longitudinal control is usually more than adequate; lateral control is more of a problem—not that the ailerons are ineffective but more often because the rudder is not effective enough to compensate for the adverse yaw. This is particularly evident in many US sailplanes with short tails and relatively small vertical surfaces.

Sufficient control to roll the sailplane from a 45 degree left bank to a 45 degree right bank in 4 seconds is a significant numerical parameter that gives satisfactory roll performance. Of course this roll performance should extend down through the stall but some compromise is usually necessary as the stall is approached. The pilot cares little if the roll is achieved with the ailerons, with the rudder, or with both. As many high performance sailplanes are deficient in rolling performance because of inadequate rudder power, it is often possible to increase the response by decreasing "g" while rolling. This effectively reduces the adverse yaw and increases the roll rate.

Consideration of control positions and, particularly, control forces, is a source of much discussion, detailed analysis and selection of parameters to define desirable slopes and force gradients. Longitudinal characteristics appear to be the favorite for most of this work. It is pleasant to have a linear gradient and forces falling in the neighborhood of 3 to 7 pounds per "g" for maneuvering flight, but I find that I am concerned very little with these refinements and am quite happy so long as the forces are light and a pull force is required to slow up or increase "g", with a push force for the reverse. My only qualification to this is that the force required to exceed the structure limit should be appreciable, perhaps 30 pounds, so that the limit is not likely to be exceeded inadvertently. This applies particularly to high performance sailplanes because of the rapidity with which the speed builds up in a nose down attitude and the increased opportunity of overcontrolling at high speed.

If light forces are to be achieved, the aircraft must be capable of trimmed flight at some speed in the range of normal flying; otherwise, out of trim forces will completely mask the forces exerted for normal flying maneuvers. Trim devices need only be available on the longitudinal control. If forces are light, a simple bungee trimmer is adequate.

Slow speed flying characteristics are particularly important as the sailplane is flown so much of the time in the speed range just above the stall. Control is essential well into the stall region because of the turbulence often asso-

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ciated with soaring flight at these speeds. Newer high performance sailplanes have a little greater margin in this respect because of the drag characteristics of the laminar sections which require optimum speeds in thermals which provide a greater margin of speed above the stall. This is offset by a trend toward higher wing loadings placing greater emphasis on satisfactory stall characteristics for landing approaches. Stall warning in the form of a buffet at a speed slightly above the stall contributes much to easy flying and is a great aid in maintaining efficient thermal soaring speeds.

Perhaps the most important factor influencing ones opinion of the landing characteristics is the availability of adequate glide path control. Air brakes must be effective and produce negligible changes in trim as they are extended or retracted. Brakes which limit the terminal velocity to about 140 knots provide all the glide path control that is desired. Less effective brakes, which limit the speed in a 45 degree dive to 140 knots, give an acceptable degree of control on the approach but the more effective brakes are desirable. Recent experience flying a high performance sailplane fitted with a simple trailing edge flap which is used as a speed brake shows this to be an effective and simple approach to the problem. In this installation at least, the trim changes are very small. The flap is used in much the same manner as a spoiler with the pilot varying the position to control the flight path. Although the flaps permit slower speeds in the landing pattern, speed should be held at a normal approach speed as is done with spoilers or brakes because of the necessity of regaining speed if the flaps are retracted to stretch the glide. Besides providing very satisfactory glide path control, these flaps offer a number of secondary, but very desirable advantages. The flaps permit a more nose down attitude and better visibility for landing. Improved slow speed spiraling capability obtained at small flap deflections is another bonus offered by this arrangement. Use of the flaps for take-off also permits a lower angle of incidence for the wing.

As I compare these comments with those of Goodhart and Irving, I find that, although each of us has written of somewhat different aspects and has used different words, all are looking for the same qualities in a high performance sailplane.

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