Primary Two-Seater Development Problems

Dr. Jozsef Gedeon
Technical University

Budapest, Hungary

Presented at the XVIIth OSTIV Congress
Paderborn, Germany
May, 1981

ABSTRACT

An important aspect of gliding in common with other forms of flying, concerns pilot selection and elementary flying training. A training system capable of meeting this demand is to be based on a productive and easy-to-fly two-seater. Conflicting requirements for good performance, low weight, "primary" handling, etc. may be reconciled only partially and after careful consideration. The motorglider has some significant advantages while economically a multi-purpose utilization scheme is to be preferred.

NOTATION

b	wing span	[m]
c_y	lift coefficient	
f_o	undamped eigenfrequency	[1/s]
k	stick resp. pedal displacement	[mm]
n	normal load factor	
q	dynamic pressure	[Pa]
w	updraft	[m/s]
F	stick rsp. pedal force	[N]
G	power spectral density	[m^3/s^2]
L	(integral) scale of turbulence	[m]
M	degree of maneuverability	[1/s]
S	wing area	[m^2]
$\bar{S}$	degree of stability	[1/s]
T_1	time constant (rolling and directional)	[s]
V	airspeed	[m/s, km/h]
W	airplane mass	[kg]
	glide ratio	
λ	eigenvalue	
σ	standard deviation	[m/s]
ω_o	undamped circular eigenfrequency	[rad/s]
ω_x	rolling angular velocity	[rad/s, °/s]
Ω	reduced circular frequency	[rad/m]
ζ	damping ratio	

SUBSCRIPTS

a	longitudinal short period
c	for aileron
e	for elevator
p	longitudinal phugoid
x	rolling mode
y	yawing mode
w	atmospheric turbulence
D	Dutch-roll mode

SUPERSCRIPT

$*$	steady state maximum

INTRODUCTION

Gliding isn't,and probably never will be, an activity exerting a sustantial direct influence on a national economy. On the other hand, it isn't a cheap private hobby either,within reach of almost everybody, like swimming or angling. Practical problems resulting from this are manifold: aviation fuel tax,politics, gliding site authorization refusal, complaints about weekend flying noise, etc. It is therefore only common sense to give preference to those gliding activities having close connections to productive lines of the national economy.

A primary candidate for such a preference is elementary flight training. Airlines, agricultural and military flying, the aircraft industry, air traffic control, etc., are all integral parts of our present-day economic system with a continuous need for reliable men and women with some practical flying experience. Gliding is able to meet all these demands for selection and primary instruction reliably and more economically(1).

Present methods of dual gliding instruction are essentially a product of the late forties. They were cast in the moulds of the then contemporary technology. Since then several major innovations have resulted in new sailplane types of vastly improved performance, suggesting new flight tactics. These types are, however, difficult to land and expensive to buy. The motorglider is also here to stay and offers some new possibilities in instruction.

The general syllabus of elementary flight instruction has changed very little. But now classical primary two-seater types are being phased out everywhere due to wear and obsolescence. New types on the market now possess some quite different characteristics dictated by the glass and carbon-fibre/plastics technology and by the general desire for increased performance. Some time ago Lindermann (2) posed the fundamental question: what must we change? Shall we alter the training syllabus to accomodate new types (including perhaps the motorgliders) or should some design parameters be changed to produce the modern equivalent of time-proven primary two-seater types?

This paper is intended to contribute to this line of thought. It is hoped that by a more general and thorough analysis some new aspects may come to light to facilitate a better solution to this all-important problem.

MARKET RESEARCH

1. Training Demand

In order to address the basic training philosophy, let us look at the volume and character of the demand to be met. Elementary gliding training is compulsory for prospective sailplane pilots. It is also to be recommended for the primary training phase of airline, military, and general aviation pilots. In short, it is good for every responsible post connected with flying activities. From this point of view a rough estimate of future training capacity required can be worked out.

Present-day census and forecasting puts the probable number of the total world commercial airliner fleet at some 7,000-8,000 units for the next decade(3). Serving them may require about 20,000-30,000 pilots and respective flight engineers. General aviation, military flying, etc., may double or triple this number. The amount of would-be glider pilots is hard to forecast, but it is also considerable. In short, a training capacity requiring about 2-3,000 two-seaters is to be maintained.

2. Training System

Flying is an activity of dual character, requiring theoretical background as well as practical skills. Elementary flight instruction should be balanced between classroom work and practical flying. It is also highly desirable to introduce the pupil to the self-discipline and voluntary teamwork necessary for safe and efficient flying. In the following, statements and descriptions of activities apply strictly to the instruction of teen-age pupils, men and women in say their thrities requiring sometimes a slightly different individual treatment.

The fundamental unit of training capacity is the number of sites or take-off/landing strips available. Secondary basic assets are the launching aids available: winches, tow-planes and self-launching motorgliders. The number of movements realizable per strip depends on them. A good two-drum winch with quick cable retrieving gives 100-130 starts per day if an efficient flight organization can make use of them. Strip capacity using aero-tow depends largely on the number of tow-planes. But the flying circus type activity used in competitions, with a dozen or so tow-planes - even if it could be afforded - cannot be recommended for training. It would be too demanding on student pilots, resulting in high accident risk and lowering of pupil receptivity. In general, productivity per strip as expressed in number of flights is greater for winch-launching, however, aero-tow gives more flying hours.

Self-launching motorgliders are the most flexible of all categories. The frequency of start/landing movements is limited only by air traffic safety, and flight duration by the fuel capacity of the plane.

Flying instruction can be organized as a general club (i.e. week-end) activity or in courses. Both of them have their respective advantages and drawbacks. Normal club flying can perhaps give slightly better personal selection and character forming at the price of a little lower flying efficiency and occasional stagnations.

No matter which one of the organization forms is preferred, practical flight instruction - after a short introduction in the theory of flight, followed perhaps by an examination - proceeds as follows. The pupil is taught in the following sequence:

- straight glides;
- turns;
- take-off and landing;
- circuit planning;
- cable breaks, spinning, etc.

The first solo flights complete the first instruction phase. The training syllabus of the second phase, up to say C level, isn't as universally standardized as the first one, so we will not discuss it in detail.

The main working tool of the instructor for his job is the two-seater. High productivity and handling qualities as good as possible are perhaps the most valuable features sought in a training glider. Let us see how they can be obtained.

GENERAL ARRANGEMENT AND BASIC PARAMETERS

1. Historical Review

How much the mode of gliding instruction depends on starting aids can be clearly seen on the evolution of the two-seater as we know it today. Early types of two-seaters existed in the twenties (4,5). Nevertheless, solo instruction doing slides and hops dominated the scene because chain-fashion bungee starting of heavy tow-seaters was too demanding on manpower. Winch launching and later aero-tow opened the way for dual instruction.

Examining the evolution of basic design parameters, very interesting development trends can be observed(4-10) (see also Figs. 1-4). Types marked with squares on the figures are intended mainly for ab initio work. They are characterized by low weight, low-to-medium span and moderate wing loading. Their best glide ratios are also mostly on the low side. As against this, high performance types, indicated by triangles on the pictures, boast high glide ratios but at the price of high weight, long span and heavy wing loading. Multi-purpose types, marked with circles, are in between, but nowadays they tend more to the heavy competition machines.

Wing span seems to be one of the most stationary parameters. According to Fig. 1, if we exclude a few special designs, early types had b = 13-20 m, while now the scatter is b = 15-18 m. Flying weight, as shown in Fig. 2, is increasing steadily. In the thirties, it was from 370 to 460 kg while we now have W = 470-630 kg for sailplanes and 590-720 kg for motorgliders. In Fig. 3 W/S is plotted proportional to $\sqrt{W/S}$, showing the increase of airspeed for constant lift coefficients. Here again, a monotonic increase over the years is observed, with motorgliders (shown in full figures) occupying the higher levels. Early ab initio two-seaters had a best glide ratio of 14-24/1. Now they are claiming 23-25/1 to 26-39/1. Motorgliders are more modest with 25-30/1. The practical significance of these trends for instructional work is as follows:

Improving the glide ratio adds to productivity. But what is its price? Looking at the pictures, a steady diminishing of the number of specialized primary two-seaters from about 1963 is observed. Their place is being taken by dual-purpose designs (i.e. essentially high-performance machines without special gadgets). The most significant alteration is the increase of weight.

Now, the classical primary may be defined as a relatively light and cheap plane which is exceptionally forgiving of pilot error and efficient in winch launching. High weight and wing loading combined with long span are no good for regular, all-day winch launching. A good mobile winch of 75-95 kW (100-130HP) power can reliably handle gliders up to say 450 kg and 22-25 kg/m^2 wing loading. In addition, there is the problem of cable breaks. A steady hand, good judgement and some experience are required to tackle an emergency situation at low altitude in a fast glider with long span and a good glide ratio.

2. Mode of Starting

The cheapest and quickest way to get the glider to a given height is by winch, while aero-tow is best for finding thermals. The motorglider goes a step further, assuring altitude maintenance for an indefinite time even without updrafts. We have seen that at the beginning the pupil is taught straight glides and later, turns. In this phase of the training the productivity of circuit flying at say 200 to 400 m is poor; a substantial part of the flying time being lost for unaided piloting attempts by the pupil. In this part of the instruction curriculum and for spinning, winch-launching is at a disadvantage.

In 1960, the late Professor Landmann introduced his La 17 motorglider to the author as a "primary two-seater with infinite glide ratio." This is the way we have to look at the motorglider for ab-initio work. In this respect, for productivity, it is to be preferred over pure sailplanes but only if it is up to the demands in every other respect.

When we have to chose between winch-launching and aero-tow, the selection is most strongly influenced by availability and by economics.

3. Which Way to Go?

Now we have seen the problem as posed e.g. by Lindemann(2) from a slightly different aspect. He is advocating a motor-glider course, with transition before the first solo stage to an appropriate modern two-seater sailplane and aero-tow. More generally, one has to choose between a specialized training two-seater, a general-purpose sailplane and a motorglider. Then there is also the problem of retaining or abandoning the winch.

To begin with, a very modern and effective two-seater motorglider of about 16 m span could be conceived meeting every requirement for productivity. Cruical problem areas in this design would be noise and flying qualities.

Not long ago the author undertook an investigation of the limits of noise abatement and environmental protection possibilities for motorgliders in the form of a feasibility study for a solar-powered plane(11). But series production of even a partial SPP is still a long way off; economically, more than technically. In the meantime, we have to work with special silencers and low Mach number propeller designs (see e.g.(12)) in order not to paralyze our flying, especially on week-ends.

Some aspects of the flight handling improvement problem for motorgliders are common with modern high-performance general-purpose, two-seater sailplanes. In both cases we have to deal first with the inertia problem aggravated by high wing loading, long span and perhaps by some other special circumstances.

Bad handling or faults readily tolerated in high-performance sailplanes can exclude an otherwise quite sound design from being good for ab-initio training. In order to get a clear understanding of the work to be done, let us review the essentials of the flight handling improvement problem. It is necessary to see if high wing loading, greater weight and span relative to the "auxiliary" engine of the motorglider are compatible with the high level of protection against pilot errors and ease of handling so necessary for the novice pilot.

HANDLING CRITERIA

1. General Remarks

In this respect the best is only just good enough for ab-initio training. The design and development of first class flying qualities for a sailplane is now as much of an art as a science. Basic rules of airplane motion and controllability are well understood. Types designed in line with them can be developed and refined by expert flight test work and sound judgement to the point of meeting the demands of practically every good sailplane pilot.

There are quite a number of requirements to be met, so let us start with a short classification of them (see Fig. 5). Design of handling and control begins with the so-called basic flying qualities, i.e. with stability, maneuverability and sensitivity in the longitudinal and lateral mode in straight glide. In this phase, longitudinal and lateral motion can be treated separately and even the eigenmodes of the motion (respectively the sensitivity of the elevator, aileron and rudder) may be singled out.

Having put the elementary flying qualities in order, investigation of the complex motions, such as turns, start and landing, stalls, spins, etc. can be dealt with. Pilot comfort problems and human engineering aspects concerning secondary controls and instruments complete the picture.

Correct assessment of the flying qualities has its particular problems because we can't calculate or measure the "qualities" proper, only the parameters affecting them. The current mode of tackling this problem is by statistical evaluation of the pilot rating e.g. according to the Cooper-scale(13). This method, based on simulator and variable-stability airplane test runs, has been in use effectively for a long time for high-performance airplane work. Adaptation of the Cooper rating to sailplanes is possible and even confidence limits on mean pilot ratings can be established(14). Thus, for want of a better direct method, Cooper-Harper ratings will be accepted as the scale of flying qualities.

2. Elementary Flying Qualities

The characteristic equation obtained by solving the linearized airplane equations of motion in a straight glide reads (see e.g.(15,16)):

For the longitudinal motion (in factorized form):

$$(\lambda^2+2\zeta_a\omega_{oa}\lambda+\omega_{oa}^2)(\lambda^2+2\zeta_p\omega_{op}\lambda+\omega_{op}^2)=0 \qquad (1)$$

For the lateral motion:

$$(\lambda+\frac{1}{T_{4x}})(\lambda+\frac{1}{T_{4y}})(\lambda^2+2\zeta_D\omega_{oD}\lambda+\omega_{oD}^2)=0 \qquad (2)$$

Sailplane handling quality literature is far from being unanimous in the assessment of basic longitudianl criteria (see e.g.(17-30)). Some of the early concepts (e.g.(17)) stressed the possible importance of horizon angle (i.e. pitch angle and its gradient). Modern instructing techniques have put an end to this problem. Along with general theoretical(20-23,25,27-29) and flight test(18,19,30) work, there are the following fundamental concepts for longitudinal criteria development.

a. Assessment of the static margin (e.g.(19,30)). Some authors(19) are for higher static stability while the former preference for reduced static stability has also re-emerged (30). More of this later.

b. Simulator and variable stability aircraft work(31,32) resulted in Cooper rating graphs as a function of undamped short period frequency and damping ratio like Fig. 6. Shomber and Gertsen combined this also with sensitivity type parameters(32).

c. Position and shape of iso-opinion boundaries may be interpreted as pilot preference for medium values for the degree of stability(24,25)

$$\bar{B} = \omega_{oa} \exp\left[\frac{\zeta_a}{\sqrt{1-\zeta_a^2}} \operatorname{arctg} \frac{\sqrt{1-\zeta_a^2}}{\zeta_a}\right] \quad [s^{-1}] \qquad (3)$$

and for the degree of maneuverability

$$M = \frac{\omega_0 \sqrt{1-\zeta_a^2}}{\operatorname{arctg}\left(-\frac{\sqrt{1-\zeta_a^2}}{\zeta_a}\right)} \quad [s^{-1}] \qquad (4)$$

These seemingly different approaches are compatible except for the reduced static stability case.

Flight mechanics has taught us that short period frequency and damping ratio depends on the static margin(15,16). Stick fixed static stability can be calculated from stick deflexion plotted as a function of lift coefficient for different C.G. positions(16)(Fig. 7). If we can fly the sailplane throughout its speed range with fixed, neutral trim position, stick free static stability may be calculated from stick force - $1/c_y$ graphs (29) (Fig. 8). f_{oa}-ζ_a values in the optimal range according to Fig. 6 may be obtained for sailplanes of light fuselage design and with a static margin of about 15-30%. But advocates of reduced static stability want no more than, say, 3-5%. Which one of the two opinions is right?

Due to aeroelastic effects, the static stability of sailplanes may diminish considerably in the high-speed range(22,27). The author has also flown a prototype having, for his weight, a slightly negative static margin above 80 km/h. There were no controllability problems in normal circuit flying and in aero-tow in fair weather. But, it needed oversteering, and in the pull-up after termination of spins caution had to be taken not to overstress it because of the sluggish elevator response. In short, it was not pleasant to fly even for an experienced pilot and for the beginner it could become dangerous.

It is not the increase of maneuverability designers are looking for in reduced stability commercial aircraft designs. Advantages claimed for them include only savings in weight and fuel due to decrease of tail volume and trim moment relative to trim drag(3,35). True, there are reduced/negative stability military high maneuverability CCV designs but only thru use of auxilary surfaces ahead of the CG(34). Sailplanes can't afford such drag producing extras. And all modern reduced stability airplanes feature autostabilization fly-by-wire control systems(33,34).

The q-feel, all important in turbulent conditions, is given by the stick force and stick displacement gradients. There are different techniques for measuring them(8,9,18,19,30). Characteristics of a good design may turn out like those shown in Fig. 9. Low friction and lost motion complete the picture(30).

All the desirable characteristics mentioned above do not contain any size or gross weight problem except that of a little tailoring of hinge moment characteristics to suit our needs(21,26,28). Longitudinal handling of modern high performance two-seaters may be comparable in all aspects to the classical primaries.

Lateral criteria may look a little different from this. There is, first of all, the rolling mode. A resume of basic simulator work as reported by O'Hara(31)is shown in Fig. 10. Interpretation of the results for sailplane design is unambigious(25). The degree of stability in this mode is(24):

$$\bar{B} = \frac{1}{T_{1x}} \quad [s^{-1}] \qquad (5)$$

while the degree of maneuverability in the case of short T_{1x} values is to good approximation:

$$M \cong \omega_x^* \quad [s^{-1}] \tag{6}$$

With typical sailplane T_{1x} values ranging from about 0.06 to 0.15 s, handling quality in the rolling mode turns out to depend practically alone on the steady rate of roll ω_x^*. Aileron power for the usual, (i.e. flap type) aileron designs is limited in terms of

$$\chi_x = \frac{b\,\omega_x}{2V} \tag{7}$$

being proportional to the tangent of wing tip helix angle. A good sailplane may achieve about χ_x^* = 0.18-0.20. At V-72 km/h = 20 m/s, the best glide speed range for the classical primaries, the higher value gives ω_x^*=32.8-28.7 o/s for b = 14-16 m, relative to ω_x^*=25.5-22.9 °/s for b = 18-20 m of the high-performance designs. But a comparison at the same speed is unfair to modern designs. By calculating for V = 90 km/h = 25 m/s, the rolling rate goes up to ω_x^*=31.8-23.6 o/s for b = 18-20 m.

Thus, the rolling rate, (i.e. maneuverability in time, lost by the greater span may be roughly compensated by higher wing loading for good penetration. But this is not a full value compensation. In an emergency landing situation or in entering thermals, maneuverability in space (i.e. the distance necessary for the execution of a maneuver) counts as much. In this respect we have to register a loss of 20-22%, making the high-performance machine more demanding on the pilot. We may have an even larger difference because of the longer T_{1x} values due to an increased radius of gyration of heavier wings.

Aileron feel may be evaluated using force-gradient, displacement-gradient graphs as functions of V^2 (Fig. 11). Here too, new high-performance machines turn out heavier.

About the same may be said regarding the yawing mode and rudder feel. Likewise, the undamped frequency ω_{oD} and damping ration ζ_D for the Dutch-roll mode are also decreasing requiring more subconscious mental work for the pilot. In short, for the lateral modes there is no possibility of full compensation of size and weight relative to wing loading effects. All the designer can do is to reduce radii of gyration as much as possible.

3. Complex Motions

Deterioration of lateral parameters are influencing the execution of turns, start in aero-tow, etc. accordingly. In this respect the spin problem would deserve a separate full investigation. While the increase of span is beneficial in increasing the period, (i.e. in decreasing the rate of yaw and roll, higher moments of inertia and reduced damping ratio may lead to qualitative changes in the character of the spin.

By the way, the detrimental effects of an out-of-limits rearward C.G. position can't be cancelled by increasing the static stability, (i.e. by the tail volume, alone). Practical experience has taught us to respect conservative C.G. boundaries even if static stability would be satisfactory in the off-limits case.

Motorgliders are exposed to the inertia problems to a still higher degree than sailplanes. Types mounting the propeller or even the engine about the fuselage may have radii of gyration quite extreme by sailplane standards. Some of the newer designs intended for training have reverted to mounting the engine in the nose of the fuselage. While satisfactory from the handling dynamics point of view, this is, detrimental to really good glide ratios. An acceptable compromise might be to have an engine, buried in the fuselage behind the pilot, driving a pusher propeller on the fuselage boom behind the wing trailing edge. A canard layout might be another solution to the problem.

FATIGUE AND WEAR

1. Service Load Spectra

Primary two-seaters are not articles of fashion for a few seasons but workhorses of daily club activity expected to last for a dozen or so years and for several thousand flying hours respectively. Fatigue design problems peculiar to the type are the demand for a near-airliner service life and the complex nature of service load spectra.

Fatigue design, testing and operating control of sailplanes has to be based on a flight program related to mission analysis appropriate to the type, climate and to prospective users. Fatigue life is given in terms of flying hours for high-performance sailplanes (e.g.(45)). Flight profile analysis for training two-seaters indicates a substantial influence of the number of take-offs and landings on fatigue damage(36,37,40,43). It is therefore advisable to calculate fatigue life in flying hours and starts, e.g. in the form of normal hours(37,40).

At present there is no standard flight program and load calculation method for fatigue life determination. This is partly advantageous because of individual requirements and partly not, because there is no possibility for direct comparison between different types.

The most reliable load calculation method presently available for stochastic (e.g. atmospheric turbulence) load determination uses power spectral methods(42) and aeroelastic element procedures(44). The power spectral density function for atmospheric turbulence, as given by von Karman, reads:

$$G_w(\Omega) = \sigma_w^2 \frac{L}{\pi} \frac{1 + \frac{8}{3}(1.339\Omega L)^2}{\left[1 + (1.339\Omega L)^2\right]^{11/6}} \qquad (8)$$

Below say 600-800 m the Lockheed-Georgia formula can be recommended(38):

$$G_w(\Omega) = \sigma_w^2 \frac{0.8\,L}{(1 + \Omega L)^{1.8}} \qquad (9)$$

Using modern servo-control techniques it is possible to simulate atmospheric turbulence forces on the glider but for economic reasons it is normal to run the fatigue tests on appropriate multi-level sinusoidal blocks. For these, load level crossing statistics are needed. It is possible to measure them directly in flight, to calculate them from the power spectra, and there is also an approximate method for their direct calculation (39). But caution should be taken not to put full trust in them because single-parameter statistics give only a very incomplete picture of broad-band stochastic processes. Realistic fatigue damage calculation needs a range-mean analysis or still better the so-called rainflow or pagoda-roof method(41).

2. Fatigue Design and Testing

Provided a standard flight program may be found, the fatigue life of an airplane structure depends on:

- choice of material;
- magnitude of stress concentration factors;
- correct technology;
- nominal stress levels, etc.

Are there any significant differences in one of these factors between classical primaries and high-performance new designs?

Industrial production of wooden gliders practically came to an end several years ago. As regards light metal versus composites, the former may have advantages in uniformity and in the amount of service experience accumulated against possibly greater development possibilities of the latter.

Airframe life for all-metal semi-monocoque sailplanes is limited practically by the durability of such built-up details as spar joints, bolt fastenings, etc (see e.g. (40)). Substituting forged designs for them would give substantial improvements but there are heavy financial arguments against it. The designer has some more freedom in the detail design for joints and fittings in composite structurtes but more responsibility, too. In short, basically there is no inherent disadvantage in fatigure sensitivity for modern composite structures.

Present-day very long service lives of commercial aircraft are invariably connected with fail-safe design and inspection procedures. There are also concepts for adapting them to all-metal sailplane structures (39). Sorry to say, composite structures, while basically very sound from the crack propagation point of view, are not well suited for magnetic or active acoustic crack detection methods. Non-destructive inspection of defects in laminates, too, is now possible by interferometric holography. The high price of the equipment may however preclude its use for sailplanes, especiallly for periodical service life extension checks.

3. Wear, Corrosion and Weathering

The usual fatigue test doesn't cover such internal items as control runs, etc. In fact, conservative dimensioning can make them quite reliable from the fatigue point of view, but control system backlash due to wear may be a nuisance. Corrosion or weathering should present no serious problems if a good corrosion inhibitor for the metal parts relative to an effective UV protection for the laminates is applied and maintained.

MULTI-PURPOSE UTILIZATION

Modern GRP and CRP two-seater sailplanes are used for training as well as for advanced soaring. Except for a few experimental designs (e.g. the SB-10), nearly all new types belong to this dual purpose category. As we have seen, for lateral handling, size and wing loading effects can't be fully compensated but the scheme may work for training in aero-tow on a spacious airfield.

Motorgliders are offering still more possibilities in standardization. In addition to doubling in the training and soaring role, they may be exquisite for fair weather personal air tourism. Present-day undercarriage designs are not very satisfactory for easy ground handling by the pilot alone. Attention to this problem has been directed by Wolf Hirth (4) but the last word hasn't been spoken as yet.

CONCLUSION

Modern high-performance two-seaters are here to stay. The need for standardization on a few types requires them to be used for instruction purposes, too. Fundamental handling problems in the lateral modes due to size and inertia effects can't be eliminated fully even by carefull design. Modern instruction methods have to compensate for the rest.

Productivity and good flying qualities should be backed by a long service life, preferably permitting fail-safe licensing and operation. Motorgliders have many advantages as regards multi-purpose utilization but there are also some additional problems regarding their universal use.

REFERENCES

1. de Lange, L.A., "The Value of Gliding and Soaring for the Training of Airline and Military Pilots," OSTIV Publication III, 1954, PP. 99-105.
2. Lindemann, E., "La double command de demain...avec quoi?," Aero Revue 1979, No. 12, Dez., pp. 734-735.
3. Swihart, J.M., "The Next Generation of Commercial Aircraft, the Technological Imperative," ICAS-80-0.2, 12th Congress of the International Council of the Aeronautical Sciences, Munich, 1980.
4. Hirth, W., "Handbuch des Segelfliegens," Stuttgart, 1938.
5. Shenstone, B.S., "Two-seat Sailplanes," OSTIV Publication II, 1952, pp. 570-81.
6. The World's Sailplanes, published by OSTIV, Berne, 1958.
7. The World's Sailplanes, Volume II, published by OSTIV, Zurich, 1963.
8. Zacher, H., "Flugeigenschaftsuntersuchungen an 14 Segelflugzeugen," FFM Bericht Nr. 40, 1960.
9. Rade, M., Weishaupt, P., Zacher, H., "Flugeigenscheftsprüfung von doppelsitsigen Segelfulgseugen in OSTIV-Kurs Varese," 1973.
10. 50 Jahre Motorsegler. 5. Deutscher Motorseglerwettbewerb 8. Juni-15, Juni 1974 auf Burg Feuerstein, Herausgeber, Rudolf Muller.
11. Gedeon, J., "Some Thoughts on the Feasibility of a Solar-Powered Plane," Technical Soaring, Vol. 6, No. 1, Sept. 1980, pp. 11-17.
12. Masefield, O.L.P., "Status of a European Joint Research Program into Light Aircraft Noise," Proceedings XI Congress of the International Council of the Aeronautical Sciences, Vol. 1, Lisbon, 1978, pp. 199-206.
13. Cooper, G.E., Harper, R.P., "The Use of Pilot Rating in the Evaluation of Aircraft Handling Qualities," NASA TN D-5153, 1969.
14. Gedeon, J., "The Statistical Treatment of Pilot-Opinions on Flying Qualities," ICAS Paper No. 68-17, Munchen. [illegible]

15. Etkin, B., "Dynamics of Flight," New York, 1959.

16. Perkins, C.D. (ed.), Flight Test Manual, Vol. 11, Stability and Control, London, 1959.

17. Eörsi Nagy, L., "Evaluation of the Training Glider Design Competition 1948 from New Point of View," (in Hungarian), OMRE Repülőtud, Közl, No. 1, 1949, Febr.

18. Zacher, H., "Vorschläge zur Zahlenmäsigen Erfassung von Flugeigenschaften," OSTIV Publication III, 1954, pp. 21-31.

19. Gedeon, J., "Statische Längsstabilitätsmessungen an Segelflugzeugen," OSTIV Publication VI,1960

20. Lehmann, W. "Ein Beitrag zu den Flugeigenschaften der Segelflugzeuge", Aero Rev., April 1963, pp. 197-204 and OSTIV-Public. VII, 1963.

21. Irving, F.G., "All Moving Tailplanes," Aero Revue, Juli 1963, pp. 395-399 and OSTIV-Publ. VII, 1963.

22. Labuc, T. Skrzydlewaski, S., "The Effect of Wing Twist Distortion of Glider Static Longitudinal Stability with Stick Fixed," OSTIV Publication IX, 1965.

23. Morelli, P., "On the Dynamic Response of Sailplanes to Longitudinal Maneuvers," OSTIV Publication IX, 1965.

24. Gedeon, J., "Messzahlen und Methode für die Berechnung und Kontrolle der dynamischen Flugeigenschaften von Segelflugzeugen," OSTIV Publication IX, 1965.

25. Gedeon, J., "Statistical Aspects of Handling Criteria Research,." OSTIV Publication X, 1968.

26. Sandauer, J., " Dynamic Characteristics of a Sailplane with All-moving Tail," OSTIV Publication XII, 1972.

27. Morelli, P., Nuccio, P., "Main Static Aeroelastic Effects on Sailplane Longitudinal Stability and Control," OSTIC Publication XIV, 1976.

28. Duranti, P., "The Longitundinal Dynamic Behaviour of Sailplanes as affected by Mass Balancing of the Control System," OSTIV Publication XIV, 1976.

29. Bennet, G., Enevoldson, E., Gera, J., Patton, J., "Pilot Evaluation of Sailplane Handling Qualities," Technical Soaring, Vol. V, No. 4, June 1980, pp 3-14.

30. Higgins, H.C., "The Light Touch," Technical Soaring, Vol. VI, No. 2, Dec. 1980, pp. 35-41.

31. O'Hara, F, "Handling Criteria," Journal of the Royal Aeronautical Society, Vol. 71, April 1967.

32. Shomber, H.A., Gertsen, W.M., "Longitudinal Handling Qualities Criteria: An Evaluation," Journal of Aircraft, Vol. 4, No. 4, July-Aug. 1967, pp. 371-376.

33. O'Hara, F., "Stability Augmentation in Aircraft Design," ICAS Paper No. 70-24, Roma, 1970.

34. Rediess, H.A., "Impacts of Advanced Control Concepts on Aircraft Design," ICAS-80-0.4, 12th Congress of the International Council of the Aeronautical Sciences, Munich, 1980.

35. Mooij, H. A., "Flying Qualities Criteria for Advanced Control Technology Transports," ICAS-80-05.2, Proceedings 12th Congress of the International Council of the Aeronautical Sciences, Munich, 1980, pp. 202--208.

36. Gedeon, J., "Belastungmessungen bei der landung von Segelflugzeugen," OSTIV Publication V, 1958.

37. RACZ, E., Gedeon, J., "Der Ermüdungversuch eines Ganzmetall-Schulsegelflugzeuges," OSTIV Publication IX, 1965.

38. Firebough, J.M., "Evaluations of a Spectral Gust Model Using VGH and V-G Flight Data," Journal of Aircraft, Vol. 4, No. 6, Nov-Dec, 1967, pp. 518-525.

39. Gedeon, J., "Improvements in Fatigue Testing of Sailplanes," OSTIV Publication XI, 1970.

40. Gedeon, J., Kálmán, Gy., "Service Life Extension Possibilities by Fatigue Tests on Used Gliders," OSTIV Publication XIV, 1976.

41. Watson, P., Dabell, B.J., "Cycle Counting and Fatigue Damage," Journal of the Society of Environmental Engineers, Sept., 1976, pp. 3--8.

42. Laudanski, L.M., "Elementry stochastyczey dynamiki szybowca," in Polish, Rzeszow, 1978.

43. Esson, G.P., Patching, C.A., "Fatigue Life Considerations for Gliders Operated in Australia," Aero Revue 1979, No. 10, October, pp. 637-640.

44. Mai, U.H., "Application of a Low-frequency Aeroelastic Element Method to the Harmonic Gust Response Analysis of a Flexible Airplane, XVI OSTIV Congress, 1978, to be published.

45. Nyström, S., "A Fatigue Test on a Sailplane Wing," XVI Ostiv Congress, 1978, to be published.

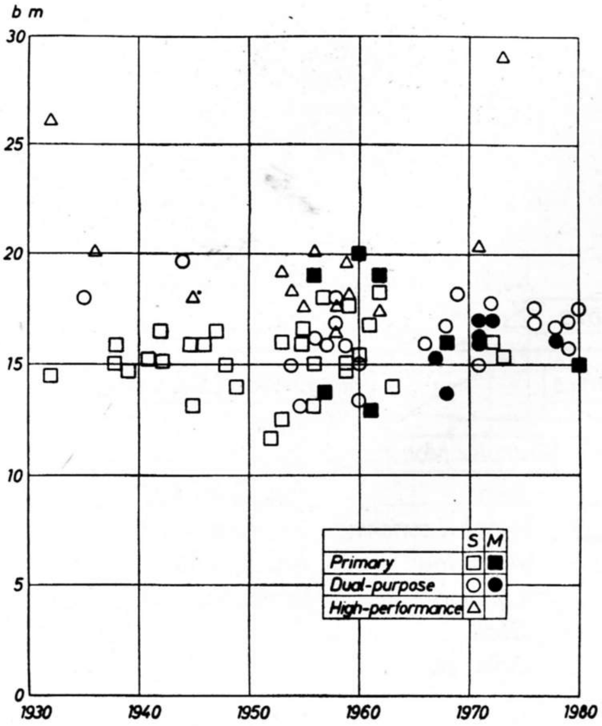

Fig. 1 Trends in the Span of Two-Seaters (S=Sailplane, M=Motorglider)

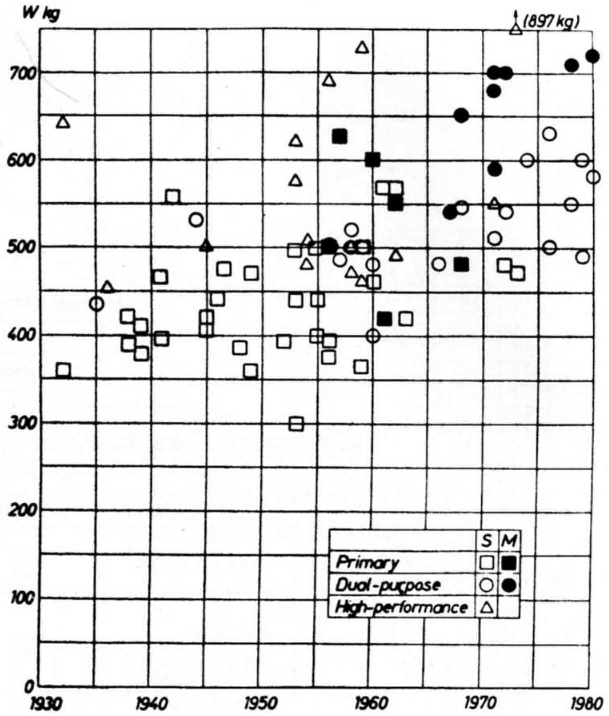

Fig. 2 Trends in the Weight of Two-Seaters

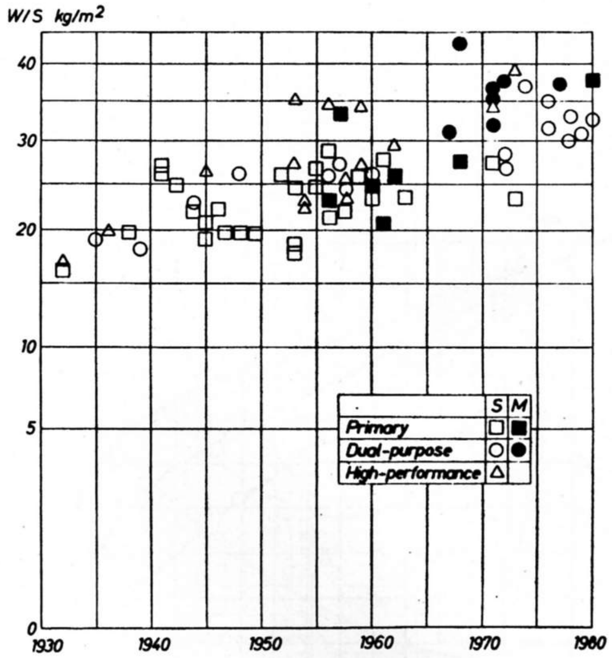

Fig. 3 Trends in the Wing Loading of Two-Seaters

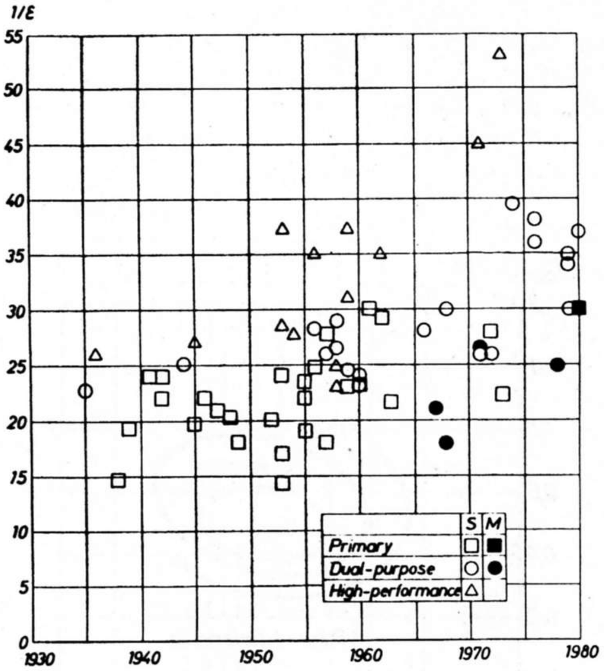

Fig. 4 Trends in the Best Glide Ratio of Two-Seaters

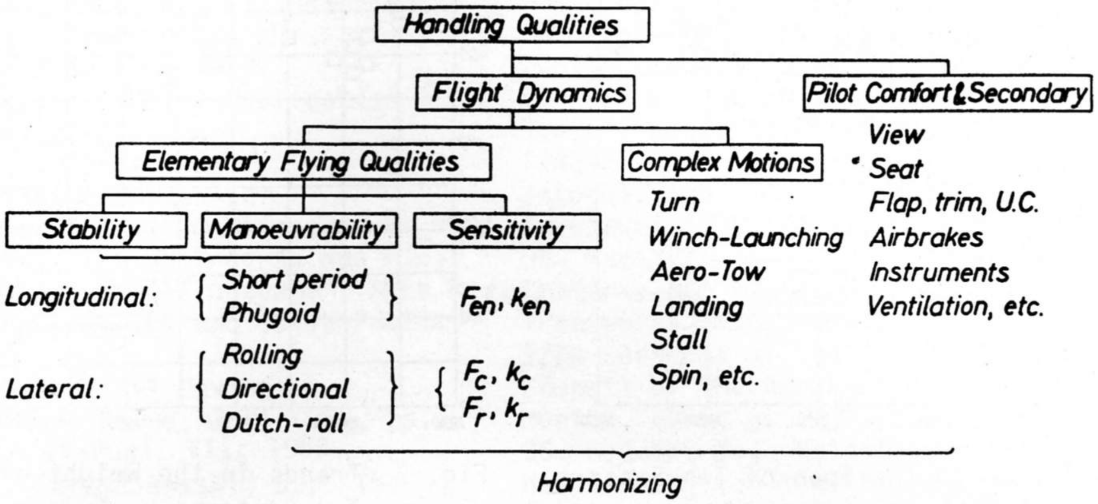

Fig. 5 Classification of Handling Quality Requirements

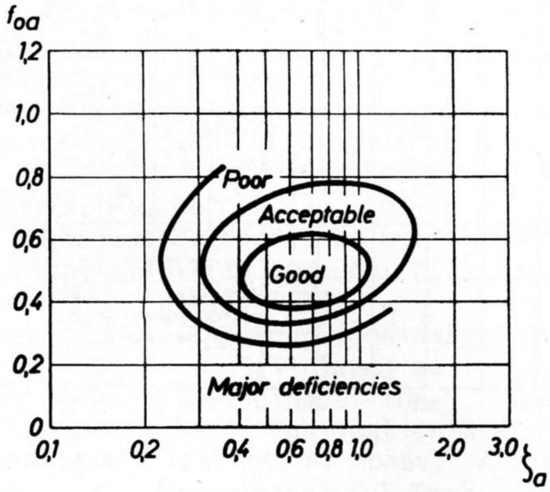

Fig. 6 Pilot Opinion on Short Period Frequency and Damping (after O'Hara(33) resp. Shomber & Gertsen(32))

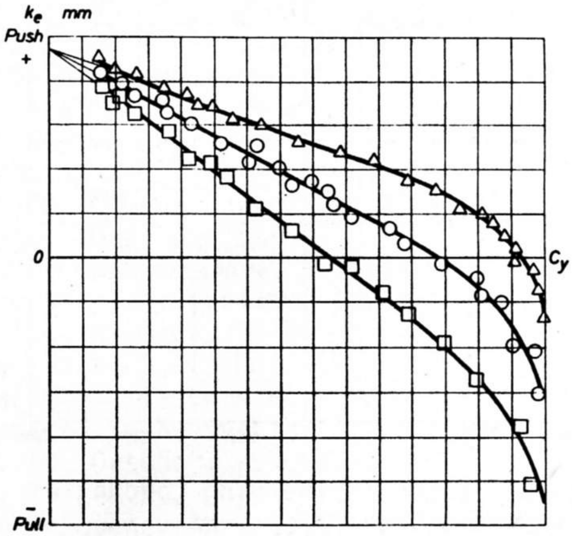

Fig. 7 Stick Fixed Static Longitudinal Stability

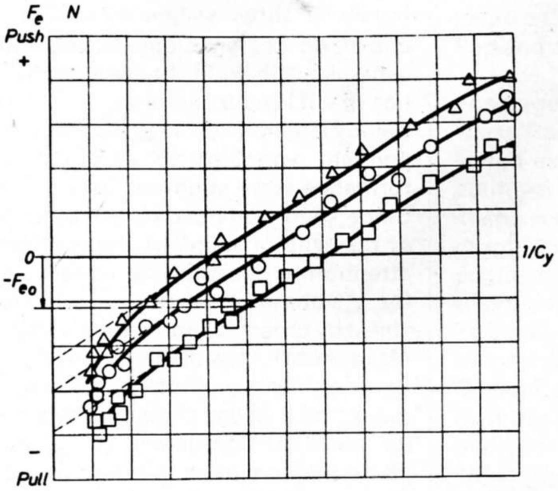

Fig. 8 Stick Free Static Longitudinal Stability

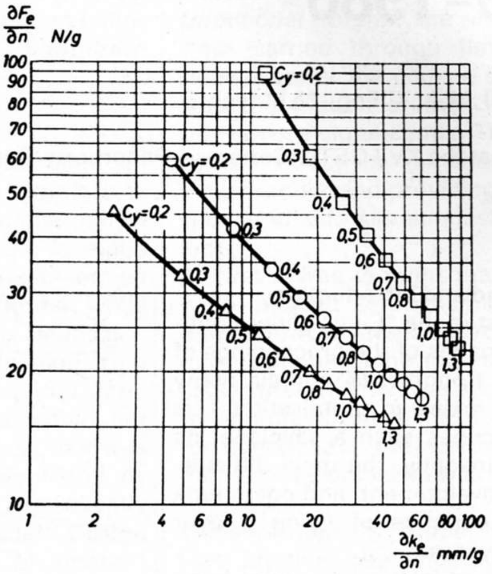

Fig. 9 Longitudinal Sensitivity

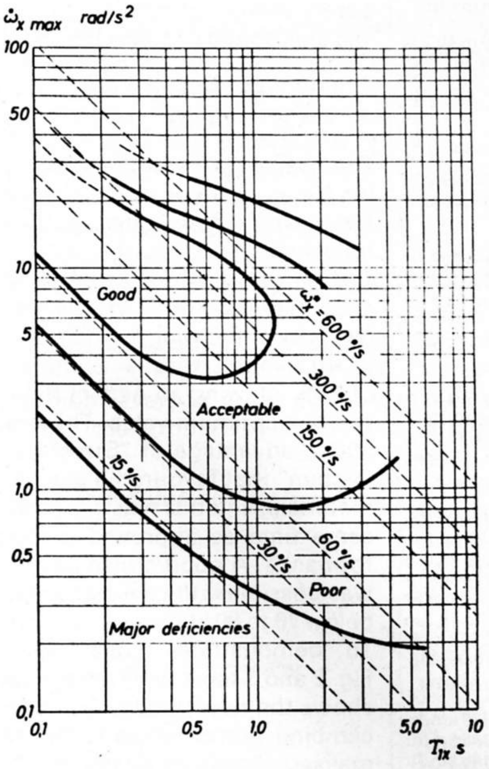

Fig. 10 Pilot Opinion on Rolling Mode (after O'Hara(31))

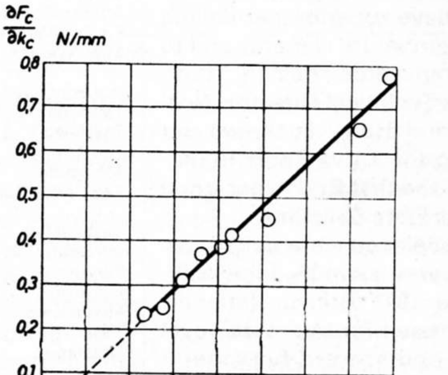

Fig. 11 Aileron Control Stiffness Plot