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THE ULTRALIGHT SAILPLANE

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SUMMARY

The increasing cost of traditional soaring has lead to a search for less expensive alternatives. During the past decade, the rise in the popularity of hang gliding, together with advances made in other branches of ultralight weight aircraft design (e.g., human powered aircraft), has demonstrated the possibility of development of a "new" category of soaring device - the "ultralight sailplane." As presently envisioned, the ultralight sailplane is intermediate in size, cost and performance between current hang gliders (defined here as a "sailplane" having a foot launch/landing capability) and the lower end of the traditional sailplane spectrum (as represented by the Schweizer 1-26, "Duster" and "Woodstock"). In the design of an ultralight sailplane, safety, low cost and operational simplicity are emphasized at the expense of absolute performance. The present paper presents an overview of the design requirements for an ultralight sailplane. It is concluded that by a judicious combination of the technologies of hang gliding, human powered flight, conventional soaring and motor gliding, an operationally and economically viable class of ultralight, self-launching sailplanes can be developed.

INTRODUCTION

The purpose of the present paper is to summarize and place in context the technical design trade-offs, performance potential and operational characteristics of a category of ultralight sailplanes which would combine several desireable characteristics of present hang gliders, sailplanes and motorgliders into a viable, low-cost alternative or supplement to all three. There are few modern examples of the ultralight sailplane envisioned here, and a central purpose of this paper is to establish the existence of an "ecological niche" for such devices.

The remarkable rise in the popularity of hang gliding during the past decade has paralleled an increase in both cost and regulation of traditional sport aviation (powered and unpowered). This has lead to a rebirth in interest in a range of ultra-light weight sport aircraft. The wretched safety record and generally low performance (by modern sailplane standards) of hang gliders has resulted in substantial controversy within organizations like the Soaring Society of America (SSA) regarding the wisdom and desireability of associating themselves in any way with the vital new sport of "ultralight soaring." To many participants in traditional soaring, the term "ultralight sailplane" is taken as synonymous with the explitive "hang glider," which conjures visions of wretched wood and fabric (or bamboo and plastic) anachronisms. This lack of discrimination among the possible types of ultra-light weight soaring devices is unfortunate and is as wrong-headed as considering "soaring" to be synonymous with fiberglass racing sailplanes and contest flying.

Despite its obvious liabilities, hang gliding has several attractive features, not least of which are low cost and simplicity (both in construction and in operation). In view of its advantages, and a surprisingly benign regulatory environment, hang gliding has gone its own way, largely oblivious to the outcries of its critics. Progress has been rapid and separate organizations have been formed to provide goals and a measure of self regualtion. At present, hang gliding is represented by the US Hang Glider Association (USHGA), its British counterpart, the BHGA, and, within the Federation Aeronautique Internationale (FAI), by the Commission International du Voile' Libre (CIVL).

Several authorities (including the FAA) have attempted to define the term hang glider and identify it as only one element of a larger "ultralight" matrix. Attempts to rigorously define classes of vehicles whose development is at a rudimentary stage are often inadequate and frequently degenerate into a sort of pointless legal exercise. Regarding the problem of "disassociating" the hang glider from other types of soaring device, it must be acknowledged that all but the crudest of modern hang gliders are capable of soaring under favorable conditions, and there appears to be no satisfactory way to ignore these devices when discussing the broad spectrum of possible soaring activities.

Despite the difficulty of formulating adequate general defintions, the following simple morphology is considered adequate for purposes of the subsequent discussion:

Hang Glider - An airplane whose dominant mode of flight is gliding or soaring, wherein the pilots legs serve as the primary launching and/or landing gear.

Ultralight Sailplane - Any "lightweight" (by Schweizer 1-26 standards) sailplane capable of steady controlled flight at a (zero wind) minimum speed below 15 m/s ($\sim$30kt).

SOURCES

While few modern examples of the sort of ultralight sailplane to be discussed here exist, its possible development must draw heavily on the wealth of data and experience gained in other branches of low-speed and motorless flight. Prior to discussing the prospects for synthesizing this information into a "new" whole, it is advisable to indicate some sources of such information.

A definitive technical history of soaring, charting its evolution from the notions of Cayley and Rayleigh, through the experiments of Lilienthal and the Wrights, the early experience at the Wasserküppe, and the fundamental transition which occurred as ridge soaring gave way to cross-country thermal and wave soaring, has yet to be written. Along the way, the classic ultralight sailplane (perhaps epitomized by the Darmstadt D28 "Windspiel") was discarded as competition sailplane performance rose to its present dramatic levels. Serious hang gliding died with Lilienthal. The brief summary of this evolution presented by Zacher (ref. 1) remains the single best semi-technical source of information on developments up to the advent of the current range of fiberglass sailplanes, and a popularized overview has been presented by Dwiggins (ref. 2). Modern sailplane developments are covered extensively in the various journals devoted in whole or part to soaring (e.g., Soaring, Sailplane and Gliding, AeroRevue, Technical Soaring). Possible future trends have been discussed recently in references 3 through 5.

The history and technology of hang gliding has been documented in several sources (refs. 6, 7, 8) and an excellent survey article by MacCready (ref. 9) describes technical and operational trends for a range of unpowered hang glider type vechicles. Developments in this branch of ultralight aviation have been very rapid and the interested reader should consult publications specifically devoted to this sport (e.g., Hang Glider, nee' Ground Skimmer; Glider Rider). Perhaps the most important development in "hang gliding" since publication of ref. 9 has been the rapid rise of powered (self launching) hang gliders (ref.7), both rigid and flexible winged.

Good sources of information on related areas of ultralight aircraft development (e.g., human powered aircraft) are contained in refs. 10 through 12. Specific background information for the present paper has been published in references 3, 8, 13 through 16. To place the subsequent discussion in quantitative perspective, the characateristics of tweleve ultralight aircraft and small sailplanes are presented in Table 1.

PRELIMINARY ANAYLSIS

In order to discuss the specific design requirements for an "ultralight sailplane" which could represent a true alternative to either the traditional sailplane or the modern hang glider, it is necessary to examine the possible performance ranges of existing low-speed "aircraft." For this purpose it is instructive to examine the variation of maximum aerodynamic efficiency (maximum lift-drag ratio) with the flight speed at which these values are achieved for aircraft operating below 40m/s ($\sim$80kt). Such a plot, with the apparent (approximate) bounds of the feasible indicated, is shown in Figure 1.

Lift-drag ratio by itself is not an adequate index of soaring performance, and Figure 2 has therefore been prepared to show the approximate ranges of minimum sink rate as functions of horizontal speed for some of the same categories of device shown in Figure 1. The foot launching capability limitation on cross-country speed for hang gliders is clearly shown in Figure 2.

Figures 1 and 2 show that there exists a rather large void area between the performance ranges of current hang gliders and sailplanes. This is presumably the performance range or "ecological niche'" of the ultralight sailplane. While Figures 1 and 2 provide few clues to the size-performance-cost trade-offs in ultralight design, they remain instructive of the general nature of the performance spectrum to be investigated. As in Nature, if a vacant niche' exists, and good reasons for filling it exist, it will be filled - by new genera or species as necessary.

"Good" reasons for filling the ultralight niche' can be readily identified on the basis of an analysis of cost and operational penalties of traditional soaring and the performance limitations of hang gliders. Detailed cost-performance comparisons for sailplanes are always controversial, and a full discussion of the many factors involved is far beyond the scope of the present paper. However, two brief articles by Sharp (ref. 17) and Bell (ref. 18) present interesting insights into the problem of the spiralling cost of traditional soaring, and allow one to make the following observations:

1. Initial equipment cost (airframe, instruments, trailer) is a substantial portion of the cost of soaring and probably looms largest to the average pilot contemplating a first purchase.

2. There is a direct relation (with possible substantial scatter around the mean) between sailplane cost, empty weight and performance increase. Bell's analysis (ref. 18) supports the intuitive conclusion that the cost-performance relation is non-linear, with cost increasing ever more rapidly with increasing performance.

3. Over several years of utilization, the overall cost per hour of soaring dominates the cost consciousness of the enthusiast. These costs are stongly influenced (for those who neither crash nor travel frequently to national contests) by:

   a. The requirements for aero towing (either its direct cost or the problem of availability limiting sailplane utilization).

   b. Factors associated with fixed base operations (hangaring, tie-down, travel).

There are obvious options and alternatives to the above. Homebuilding can reduce airframe costs substantially. However, many lower cost/performance sailplanes for which plans or kits are presently available suffer from a level of structural complexity which limits their appeal to homebuilders due to the large amount of construction time involved. Further, these aircraft, once built, remain traditional sailplanes carrying the full burden of operating costs associated with any performance level sailplane (fiberglass or otherwise). In principle, motor gliders (or self launching sailplanes) could reduce direct operating costs (e.g., towing, outlandings), and increase utilization. Motor gliding has not yet become a popular alternative in this country, due to a number of factors besides the philosophical difficulties of mating an engine to a "motorless" soaring machine. If soaring performance comparable to unpowered equivalents is sought (e.g., PIK 20E, Motor Nimbus), equipment cost becomes very high. If simplicity or cost reduction is sought in a conventional sailplane weight vehicle, power requirements become excessive and/or performance deteriorates dramatically. All too frequently, a device resembling the mooncalf off-spring of a dalliance between a Piper "Cherokee" and a Ka6 results. Finally, commerical motor glider development has been plagued for decades by the problem of availability of low-cost, reliable, light-weight, licensable engines.

Current hang gliding (powered or unpowered) may provide an alternative to sailplane soaring for some, but many more conservative individuals are put-off by the safety record of the sport, the apparent flimsiness of the equipment, and the lack of suitable instruction or flying sites in their area. Extremely light weight structures and ultra-low speeds are intrinsic characteristics of the hang glider, the resulting compromises in performance and crash protection made in exchange for the freedom and low cost of basic foot launched hang gliding being cheerfully accepted by its proponents. To many accustomed to 1-26 durability and performance, hang gliding is no alternative at all.

The latest bold extrapolation in hang gliding involves fitting "anything airworthy" with a "chainsaw" engine. This development has caused very serious concern, even among many of those who have been stout advocates of basic hang gliding. The sometimes crude, often unenlightened "cut-and-try" nature of some of these retrofits to marginal or inappropriate airframes seems a sure route to disaster. The obvious appeal is undeniable, however.

It should also be noted here that several designs for "low-cost" sailplanes have recently appeared. Only two of these, however, (the powered version of "Monerai" and the American "Eaglet", cf. Table 1) seriously address both the problems of reducing airframe cost (through reduced size and complexity) and operating cost (by incorporating a self launching capability). Both the "Eaglet" and the "Monerai" remain relatively sophisticated by contemplated ultralight standards and their appeal as a true alternative to conventional sailplanes remains to be fully demonstrated.

In view of the preceeding discussion, it appears that the ecological niche' for a safe, ultralight, low-cost sailplane indeed exists and is not adequately filled by other available types of soaring equipment. As hang gliding matures and the cost of traditional soaring continues to increase, it seems unlikely that overlap between the two sports will occur (thus leaving the ultralight niche' intact), and the requirements for the ultralight alternative will increase. If the favorable prognosis for the ultralight sailplane is valid, why do so few examples of this type of machine exist at present?

The reasons for the "vacancy" in the ultralight sailplane niche' have several historical roots, but it may be conjectured that basically its time has not yet come (or returned). Soaring in the US (unlike Europe) is not a major branch of sport aviation. Potential domestic manufacturers of conventional sailplanes are faced with a limited market and the huge expense of complying with existing airworthiness certification requirements. Ultralights like the "Windspiel" became "obsolete" in the early 1930's, and domestic sailplane designers have remained enthralled with the challenges of developing high performance racing sailplanes (or more affordable imitations) ever since. The low priority of soaring due to its limited commercial potential has also resulted in a lack of the research necessary to maintain a strong modern data base from which designs can compete efficiently with European (largely German) manufacturers.

As racing sailplane performance and cost have spiralled upward together, an alternative presented itself on the extreme low end of the soaring spectrum in the form of a rebirth in interest in hang gliding. Here, at least, no technology gap existed between domestic and foreign manufacturers. In the absence of any direct government regulations on hang gliding, this turn from the sublime to the ridiculous has flourished. Hang gliding development has brought with it a whole new set of challenges to designers, and remarkable progress has been made very largely on a cut-and-try basis. As developments on both ends of the soaring spectrum mature and stabilize, the time may again become ripe to turn attention to the middle range of ultralight sailplanes, and a class of machines as different from the "Windspiel" as the Rogallo is from the box kite may emerge.

Regardless of the route future soaring developments take, it appears that there is a valid place for an ultralight sailplane in the overall scheme. It can be argued that both the "Eaglet" and "Monerai" are commendable half measures of what may eventually be possible, and a large gap still remains between these machines and the 1-26 on one side and the motorized Mitchell Wing (ref. 19) on the other. The technology exists to design a good ultralight and the last stumbling block to its early realization appears to be lack of a definite goal for its development. Ann Welch's article (ref. 15), advocating establishment of an internationally recognized "Ultralight Class" (100 kg empty weight limit) for record and competition purposes, discusses what may be wanted, provided the rules are not too confining, and the resulting machines represent clear alternatives to either present hang gliders or pseudo-racing sailplanes.

AN ULTRALIGHT SAILPLANE

On the basis of the preceding discussion it is now possible to define in more detail the concept and design requirements of a "typical" ultralight sailplane.

Concept

This light weight (empty weight less than about 1300 N~300 lbs.) sailplane is intended for local and limited cross-country soaring. The aircraft may be suitable for home construction from a limited number of prefabricated components. Launching is to be by means of other than aero towing (e.g., bungee, winch or self-launched by an air restartable engine).

Design Priorities

In order of importance:

1. Safety (benevolent launch and flight characteristics, no unusual demands on pilot skill, adequate strucutral strength and controlability over the entire flight envelope, crash protection for the pilot).

2. Simplicity (in both construction and operation).

3. "Low cost" (in both construction and operation).

4. Performance (adequate mild thermal soaring capability, adequate penetration into winds up to 15 m/s ~ 30 kt).

Additional Constraints

1. The machine should be transportable on nothing more elaborate than a simple boat type trailer, towed by a compact car.

2. The machine should break down into components which allow convenient storage at the owner's residence.

3. There should be minimum requirements for, or limitation due to, special launching sites (e.g., a hill of sufficient slope and height).

4. No completely adequate airworthiness standards (U.S. or international) presently exist for this category of ultralight aircraft. Until such standards are formulated, the OSTIV Airworthiness Standards for Sailplanes should be used as a guide.

A tentative concept for the type of machine which might meet these requirements is shown in Figure 3, together with an existing "first generation" version.

TECHNICAL CONSIDERATIONS

A detailed technical discussion of ultralight design trade-offs is beyond the space limitations of the present paper. Such a study is in preparation by the author, and, in the interim, some additional technical references up-dating those in ref. 8 are presented. Although absolute performance is not the primary design goal of the ultralight sailplane, it remains necessary to examine carefully several areas of performance compromise involved in meeting primary design objectives (e.g., safety, low-cost, simplicity).

Aerodynamic Requirements

In general, sailplane aerodynamic preliminary design optimization is performed assuming a "glider" operating in rectilinear flight, with central emphasis placed on the achievement of a high lift-to-drag ratio (minimum glide angle) at a "desired" forward speed. Around this pivot point in the performance polar, low sink rates at both low (for climb) and high (cross-country) speeds are juggled until a satisfactory "racer" has been defined. If thermal soaring is envisioned, only towards the end of the analysis is sink rate in a banked turn seriously considered. It has recently been argued by Eppler (ref. 20) and Irving (ref. 21) that emphasis on analysis of the rectilinear portion of the glide may lead to non-optimum sizing (selection of wing area and aspect ratio) of 15m span sailplanes which must both thermal efficiently and achieve good high speed performance. Under a variety of conditions (ballast levels and thermal models assumed), a racing sailplane optimized for minimum sink rate in a turn and a high forward speed in the region around 2-3 m/s rate of sink should have a somewhat lower than customary aspect ratio. In the 15 m examples considered, this means larger area. In these examples, absolute rectilinear L/D suffers somewhat, but average cross-country speed (in the MacCready sense) increases.

For somewhat different reasons, the ultralight sailplane presents the same two-point optimization problem confronted by the classic thermal soaring racer, with rectilinear maximum L/D being of importance only insofar as it reflects minimum sink rate (at an arbitrary bank angle) and high speed (penetration) capability. High speed penetration capability is basically a safety objective, and only secondarily a desireable performance objective in the ultralight. Minimum sink rate is the fundamental <u>performance</u> objective. An indication of banked turn performance is shown in Figure 4.

Unfortunately, the banked turn, minimum sink rate, optimum sizing problem is a great deal more complex than the simple rectilinear flight problem. For further discussions, the papers by Marsden (ref 22, 23) and Cone (ref. 24), in addition to those by Eppler (ref. 20) and Irving (ref. 21), should be consulted. Any serious ultralight design must also consult the report by Shenstone and Scott-Hall (ref. 25).

While ultralight detailed aerodynamic wing design should follow conventional sailplane practice (although aspect ratios may be substantially lower), the selection of suitable airfoil sections presents a major problem due to the general lack of experimental data for appropriate sections optimized at sufficiently low Reynolds number. Existing data is surveyed in refs. 26 through 34. The airfoil selection and design problem is further complicated by the strong coupling between high-lift/low-drag aerodynamic and simple, light weight wing structural requirements. Modern laminar sailplane sections are generally inapplicable to an airplane wherein the structure is unlikely to support laminar flow much beyond 30-40% of the wing chord. In this light, the experience with sailplanes of 1930-40 vintage (refs. 25, 27) provide a far better guide to airfoil selection and performance than do those of the 1970's.

Aerodynamically, the ultralight is an excellent candidate for a fully flapped wing (preferably involving flaps with a high degree of Fowler motion). Unfortunately, this desirable feature directly conflicts with the simplicity requirement, and cannot be advised for early generations of such aircraft. Further data on this topic can be found in references 35 through 39.

Aerodynamic Constraints

The basic first order equations of sailplane motion (cf. refs. 22, 24, 40) show that both minimum sink rate and maximum L/D are (for equal weight vehicles) most powerfully influenced by wing span. High speed performance is largely one of profile/parasite (viscous dependent) drag which increases as the square of the flight speed. Further, whereas weight and/or wing loading increase helps high speed performance, it seriously erodes minimum sink performance. Overall, then, for a racing sailplane the trend should be towards large span (to regain low-speed performance) and high wing loading and extreme aerodynamic "cleanliness" to maximize high speed performance. In addition, a better match between desired low- and high-speed performance can be had by use of flaps.

This simplistic view ignores important aspects of the low-speed thermalling (banked turn) mode, however; these effects may be particularly important in attempts to transfer the above recipe to an ultralight. Increasing span leads to increasing wing weight. Drag cleanup and flaps are contrary to structural simplicity. Most important is the "low-speed turn problem" which puts the ultralight in closer kinship with the vulture and the HPA than the racing sailplane, and may ultimately establish a practical upper bound on wing span, just as aeroelastic effects at high speed ultimately limit the span of high-performance sailplanes.

In a steady turn, the radius is a purely kinematic function proportional to the square of the sailplane's velocity and the reciprocal of the tangent of the bank angle. For an ultralight type vehicle (vulture, hang glider), the normal thermalling speed may be decreased to the point where the wing span becomes a significant percentage of the turn radius. As discussed in refs. 41-43, this situation results in substantial gradients of velocity (and hence dynamic pressure and Reynolds number) across the span, and a corresponding distortion of the untrimmed span loading accompanied by an outboard shift in the center of lift which tends to steepen the turn. To counteract this overbanking tendency, powerful trimming devices (ailerons and rudder) and dihedral are required, and/or the bank angle or wing span must be limited. Regardless of other precautions, the depressed Reynolds number over the inboard semi-span during a turn may aggravate any tendency towards tip stall with the danger of a subsequent spin. The vulture's solution to this problem (ref. 24) is worth noting, since it represents a marvelous example of the coupling between structural strength/stiffness, high-lift aerodynamics and minimization of trim drag.

Structures and Weight

Surprisingly little good information on ultralight structural techniques exists. The best sources relate to human powered aircraft, the structures of which are generally complex. Of all the aspects of ultralight development, structural weight reduction and simplification are in most need of major effort. The author's favorite sources on these topics are references 44 through 48.

Launching

Provision of an alternative to aero towing for launching an ultralight sailplane is central to the operational simplicity concept. The success of the motorized hang glider makes the notion of a motorized self-launching ultralight sailplane an attractive idea. The key to success here lies in availability of reliable "engines" (internal combustion or otherwise). It should also be noted that either the canard or the flying wing configuration seem natural for a powered ultralight due to the ease of low drag integration of an engine into the design. Some information on suitable engine/propeller combinations are contained in references 49 and 50.

CONCLUSIONS

An evaluation of the requirements for an inexpensive alternative to conventional soaring has shown that an "ecological niche'" apparently exists for an ultralight sailplane intermediate in performance and weight between modern hang gliders and traditional sport sailplanes. There appear to be no serious constraints on the ecomonic or operational viability of such a device. Four factors appear to be central to progress towards its early realization:

1. Development of simple structural techniques for minimum time and cost construction of wings of adequate aerodynamic quality, strength and stiffness.

2. Availability of reliable, light weight, low powered and low-cost engines to provide a self launching capability, and/or development of "minimum" non-aero tow launching methods.

3. Establishment of suitable goals for ultralight sailplane performance and design (e.g., national or international recognition of an Ultralight Class for record or competition purposes).

4. Clarification of the relationship of hang gliding (powered or unpowered), ultralight sailplanes and government (FAA) regulation. Whether regulated by the government or not, a suitable set of airworthiness standards for "ultralights" needs to be developed.

As a final thought, it can be argued that the single most important factor which made the modern hang glider renaissance flourish as it has was the structural and aerodynamic model presented at the outset by the Rogallo wing. The utter simplicity of this concept completely outweighed its very modest performance. As it turned out, this performance was quite good enough to launch a new sport and its supporting industry. The great progress in hang gliding since a few visionaries began diving off sand dunes in bamboo and plastic monstrosities has been accomplished very largely by cut-and-try, further tribute to the basic simplicity of the initial concept. It now remains for some individual to make the same sort of creative leap which could usher in the modern ultralight sailplane.

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Table 1. Aircraft Characteristics

Type	Wing Span m (ft)	Wing Area $m^2(ft^2)$	Aspect Ratio	Weights Empty N (lb)	Weights Loaded* N (lb)	Wing* Loading N/m^2(psf)	Estimate L/D max.	Ref.
Schweizer 1-26	12.2 (40.0)	14.87 (160.0)	10.0	1826 (410)	2628 (590)	176.6 (3.69)	21.6	51
Darmstadt D28b "Windspiel"	12.0 (39.4)	11.4 (122.6)	12.6	704 (158)	1506 (338)	132 (2.76)	23.5	1, 53, 54
Maupin "Woodstock"	11.9 (39.0)	9.73 (104.7)	14.5	1047 (235)	1849 (415)	190 (3.96)	24	52, 55
Hall "Vector I"	10.4 (34.0)	11.6 (125)	9.25	668 (150)	1470 (330)	127 (2.64)	17	52, 56
Monett "Monerai"	11.2 (36.7)	7.3 (78.5)	17.2	1025 (320)	1826 (410)	250 (5.22)	30	52, 57
Haig/American "Eaglet"	11.0 (36.0)	6.7 (72.0)	18.0	713 (160)	1515 (340)	226 (4.72)	26.5	52, 58, 59
Marske "Monarch	12.8 (42.0)	17.3 (185)	9.5	980 (220)	1782 (400)	103 (2.15)	20	52
Hill "Super-floater"	9.76 (32.0)	12.3 (132)	7.8	401 (90)	1203 (270)	98 (2.05)	12	52, 62
Mitchell Wing	10.4 (34.0)	12.6 (136)	8.5	347 (78)	1149 (258)	91 (1.90)	14	52, 60
Aviafibre Canard 2FL	13.5 (44.4)	9.1 (98)	20	423 (95)	1225 (275)	94 (1.96)	28	61
Bennett "Phoenix 8"	11.3 (37.1)	17.9 (193)	7.15	254 (57)	1056 (237)	59 (1.23)	8	62, 64
Nihon U. "Stork B"	21.0 (68.9)	21.7 (233.5)	20.3	354 (79.4)	1155 (259.4)	53 (1.11)	28	12, 63

*Weight assumes pilot plus equipment weight of 800 N $\sim$ 180 lb.

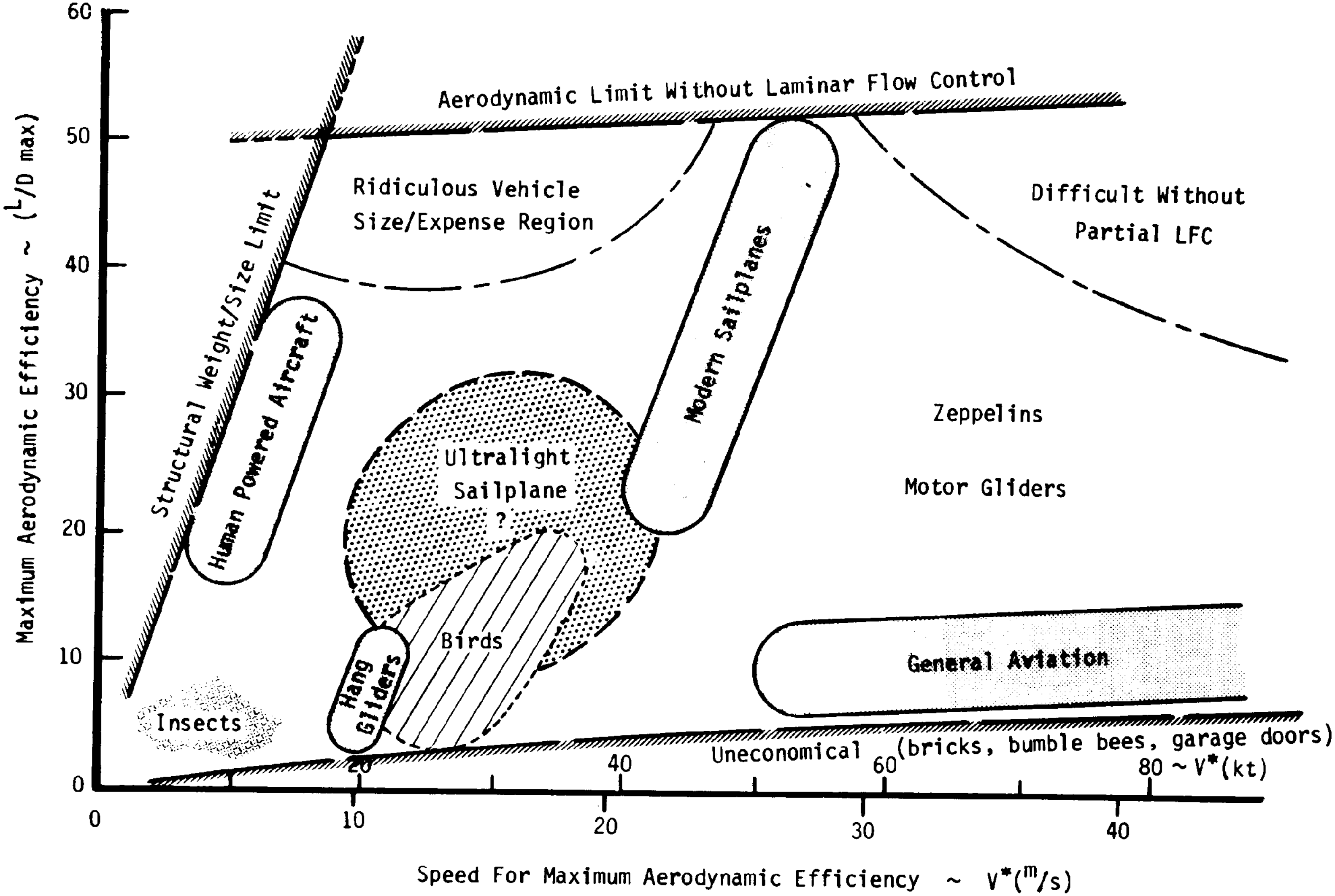


FIGURE 1. APPROXIMATE BOUNDARIES OF THE FEASIBLE/ECONOMICAL LOW-SPEED FLIGHT SPECTRUM

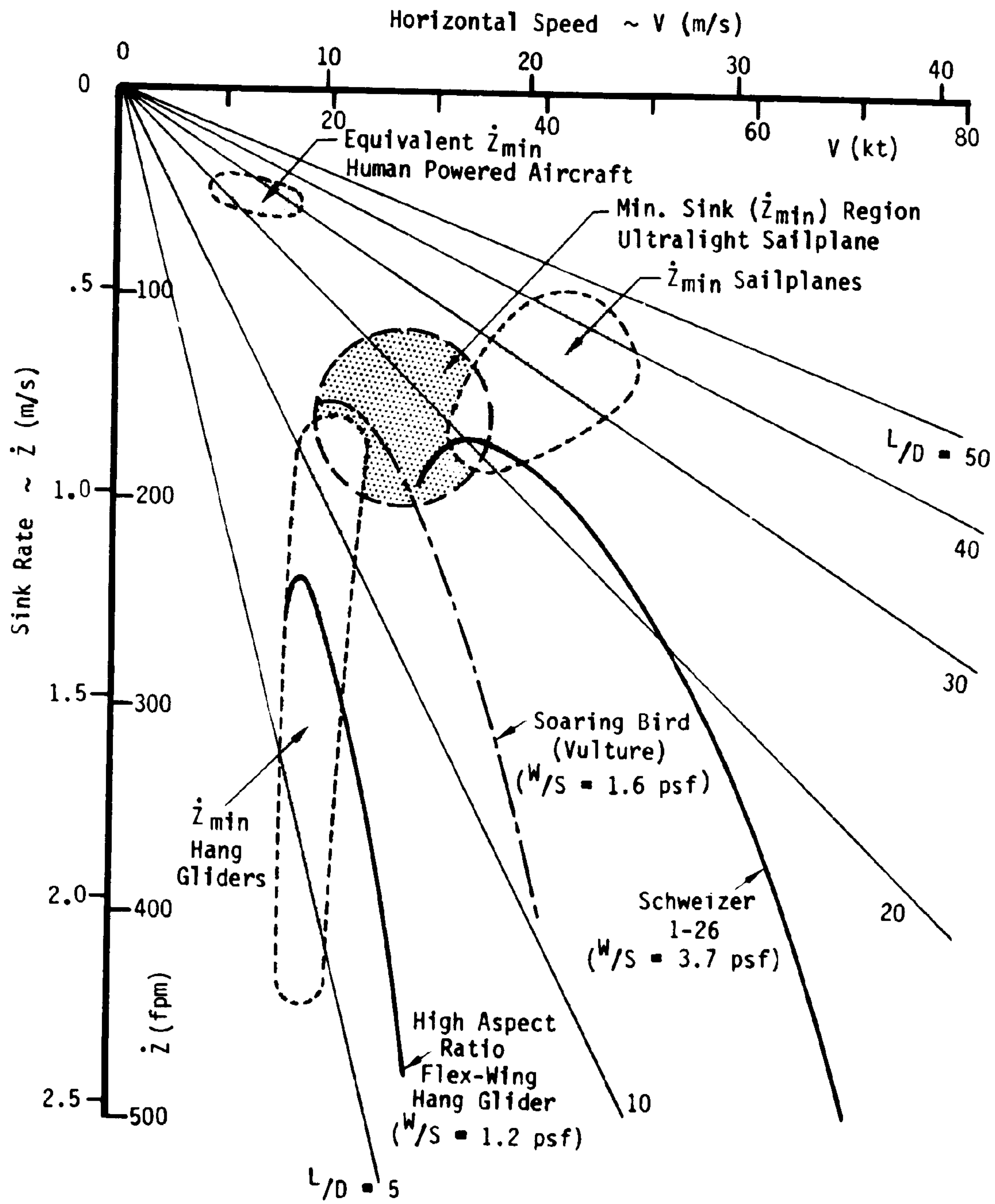
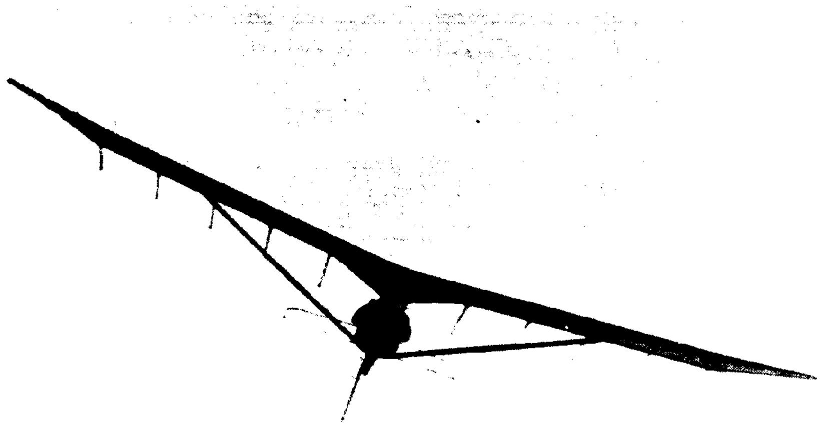


FIGURE 2. SINK RATE PERFORMANCE COMPARISON



KLAUS HILL "SUPERFLOATER"

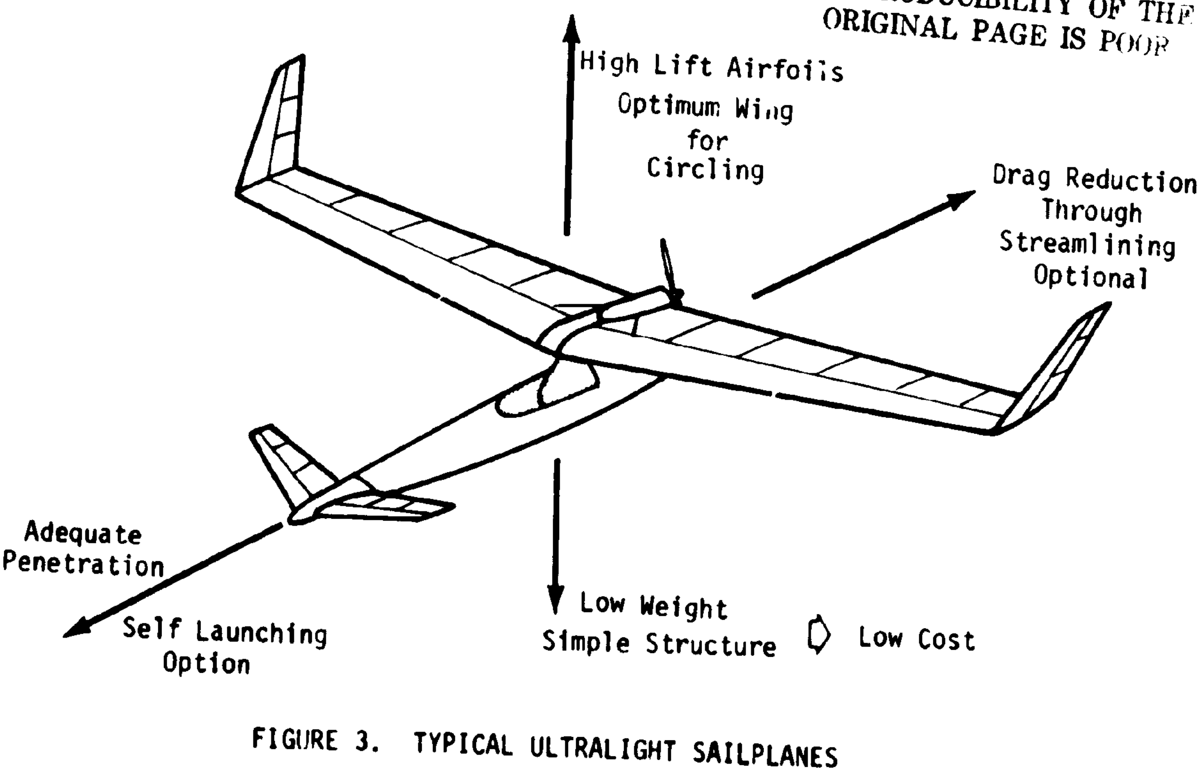


FIGURE 3. TYPICAL ULTRALIGHT SAILPLANES

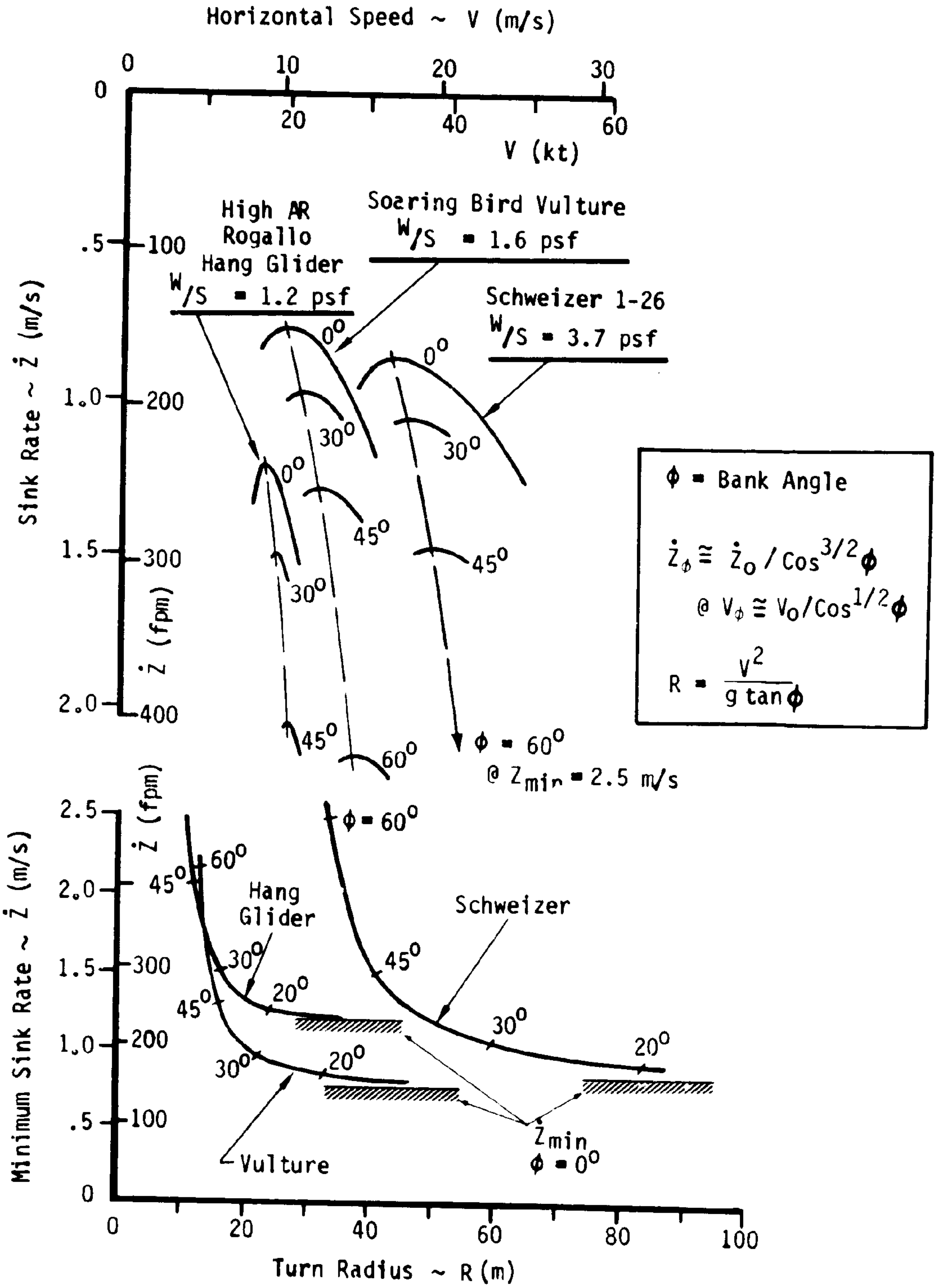


FIGURE 4. TYPICAL GLIDER TURN PERFORMANCE

N79-27081

ANALYTICAL AND SCALE MODEL RESEARCH AIMED AT IMPROVED HANG GLIDER DESIGN

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SUMMARY

A program of research on the aerodynamics, aeroelasticity, and stability of hang gliders has recently begun at Stanford University with support from NASA. The research consists of a theoretical analysis which attempts to predict aerodynamic characteristics using lifting surface theory and finite-element structural analysis as well as an experimental investigation using 1/5-scale elastically similar models in the NASA Ames 2 m x 3 m (7' x 10') wind tunnel. Experimental data will be compared with theoretical results in the development of a computer program which may be used in the design and evaluation of ultra-light gliders.

This paper describes the goals and general procedures of the investigation begun in January 1979.

INTRODUCTION

In recent years the performance and variety of hang glider designs have increased dramatically. Flight conditions and demands that are placed on hang gliders are very different from those encountered by older designs. Whereas lift-to-drag ratios of 3 were common not long ago, some present designs achieve glide ratios of close to 10 and have been flown cross country for 160 km (100 mi) at altitudes as high as 6000 m (19,000 ft.) (Ref. 1). In addition to (often turbulent) thermal flying, increased controllability has made limited aerobatic maneuvers possible. Several years ago the results of NASA wind tunnel studies of the Rogallo wing (Ref. 2-7) in the 1960's could be used to obtain some idea of the characteristics of new designs. Although not all flight regimes and relevant parameters were thoroughly investigated, the data that did exist proved useful. The hang glider has evolved, however, to the point that these original investigations can no longer be applied. The flight characteristics of modern hang gliders (Ref. 8) with spans extending to 31 m (36 ft.), aspect ratios from 5 to 7.6 and sails with low billow and sweep, cannot be estimated from these data for the high billow (4 - 5 degrees), low aspect ratio (2.5) "standards". Information on the aerodynamic characteristics of present designs is almost entirely qualitative, deduced from limited flight tests of new designs.

Many problems that have been encountered might have been prevented had such data been available. Pitch-down divergence at low angles of attack continues to be an important problem. Thirty percent of fatalities in 1976 involved full-luffing dives from altitudes in excess of 60 m (200 ft.) (Ref. 9) although recovery is theoretically possible in less than 15 m (50 ft.) (Ref. 10). Statistics from hang gliding accidents in 1977 and 1978 show that, despite a more