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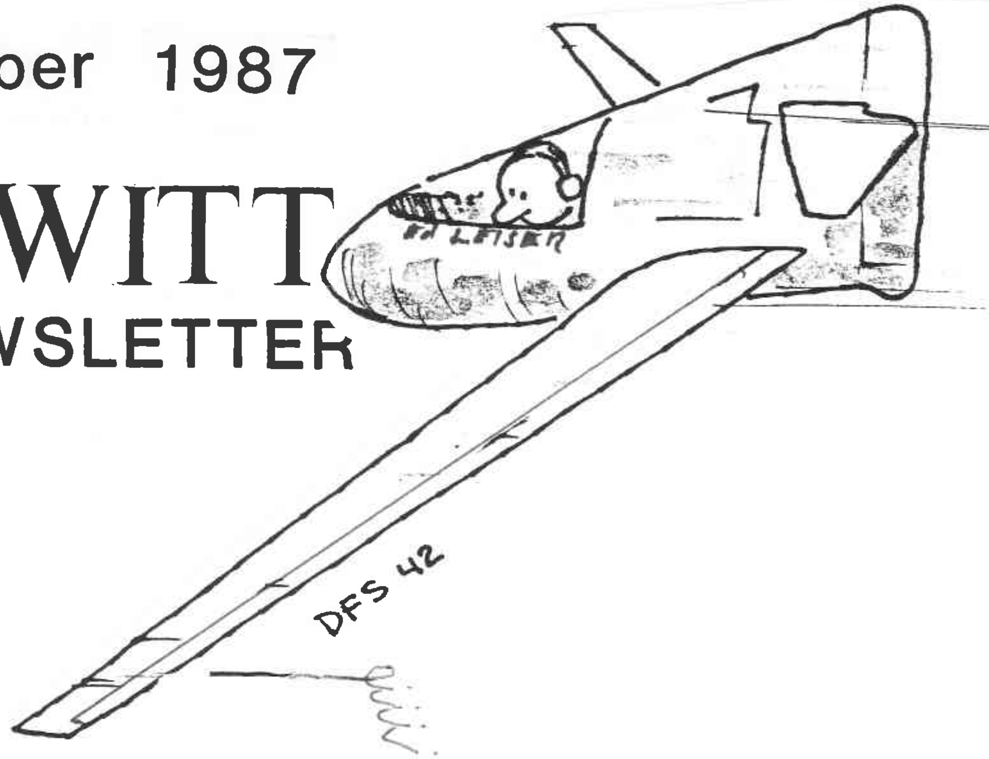

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STRETCHING YOUR *OWN* WINGS

by Norm Corwin

An introduction to building and flying sailplanes
from the Eastern Region of the Sailplane Homebuilders Association, March 1984

"You have not lived until you have built your own sailplane and flown it." So wrote a builder who recently finished and flew a sailplane of his own design. Have you thought of building your own wings? Of climbing and turning and touching down again in an aircraft created by the careful actions of your own mind and hands? Read on! This introduction is for you.

This is the time to ask lots of questions

Building an aircraft is a large undertaking. Take time to explore the options. A builder who presses forward against the gnawing sense of building the wrong type of sailplane for his use, or against the dismay of a type of construction he doesn't enjoy, usually gives in to discouragement and stops. Why not?

To avoid disillusionment, let's look at some basic questions that call for attention at the start.

What's my real purpose?

Why do I want to do this? Because I love to build and to sense the accomplishment as an aircraft is born under my hands? Because building, as well as flying, is a way of interacting with the forces of nature, as I form and connect the parts that are becoming a flying ship? Is it because I want my own aircraft, available when I am free to use it? Is it because this is one of the cheapest ways to get into the air regularly?

If you find real joy in building, one of the more challenging designs may be for you. If your main concern is to get possession of a flyable aircraft, look toward the simpler, faster-to-build types. And also check the prices on used aircraft, including used homebuilts, which often cost little more than the cost of building your own. Even more money can be saved at times by buying and repairing damaged sailplanes, or by buying and completing unfinished homebuilt projects.

Would you consider designing your own sailplane? The satisfaction this can bring is immense, and so is the investment of thought and effort. To design and build when you have never built an aircraft before is only for a few, but it has been done.

If you want to understand design and construction (perhaps to design your own next time), building your first sailplane is an engaging process of learning. As each part or connection is made, keep asking yourself, "Why is it shaped this way? How do I know I can trust it?"

What resources do I have for building?

Take stock of resources before you choose a project. There is a wide range of options when you decide what to build. Which can you handle best?

Building space is a basic factor, especially since sailplanes have long wings. Some designs for homebuilders keep the wing sections shorter by using a distinct center section and two outer sections. Do you need this?

Is there room enough to work around the wing or fuselage, and get at it from all sides? And–oh, yes!–are there doors or windows you can use to take the aircraft out of the work area?

Consider your own mechanical skills, and the available guidance from experienced builders. What about available tools? Most builders need to include the cost of some new tools as part of the cost of the project.

Available time and money must be assessed, of course. Beyond that, take a look at yourself. Are you a person who can follow through over a long period of time? Can you organize, so that you can get materials in advance of when you need them? Can you systematically make smaller parts and then bring them together into a larger assembly, like a rudder or landing gear? Will the people around you (spouses especially) bear with you, encourage you, or even help?

Should you have a partner or work as a team? This often makes all the difference–provided the partners have compatible ideas about what each is to contribute, who owns the finished project, and how it is to be flown.

Resources for flying

Before we look at specific choices, ask yourself where and how you intend to fly. Homebuilt designs are available for the competition pilot as well as the low-timer. Build something you can fly comfortably. If you are not a pilot, try to get your training and license before you finish your sailplane.

Are good flying fields close by, are towing services available (aerotow or winch), and is there a soaring club or a group which likes to help when someone plans a cross-country and may need a retrieve? What kind of weather and soaring conditions will you deal with?

When you ask all of these questions, does the whole thing seem discouraging? No one said it would be easy. But let's look at the range of sailplanes available to build. If you are serious, you may find something that suits your needs even better than you expected.

Types of homebuilt sailplanes

Racers, motorgliders, flying wings, vintage reproductions, very simple ships for the beginning builder and pilot–you name it. Almost every type you can think of is available for the homebuilder.

Some have very high performance (shown by a high lift/drag ratio). They demand experienced pilots and can be used for long flights and serious competition. They demand precision construction. Of course, all aircraft demand careful construction, but there are many moderate-performance types that are less critical for builder and pilot. Some are specifically designed for beginning builders and (or) novice fliers.

The self-launching sailplane sets the pilot free from dependence on towplanes or winches. These sailplanes have small engines, and often clever arrangements to reduce drag when the engine is not in use (such as feathering or folding props, or retractable engines). The powerplant increases cost and complexity and usually degrades performance. But the pilot is free to fly without help, and free to scout and find lift before shutting the power down. Some can be restarted in the air. Some are designed to take off from paved runways only; be sure to consider where you intend to fly from.

Some aircraft, often called motorgliders, can be flown continuously under power. They double as sport or cross-country aircraft when the soaring is poor, and they can fly home at the end of a soaring cross-country trip. The weight and drag of powerplant and fuel exact a price in gliding performance, resulting in a dual-purpose aircraft which is also a compromise.

Nearly every type of construction used in aircraft factories is also used by homebuilders. Choosing a project means deciding which types of materials and processes you will work with.

The first airplanes were built largely of wood, and wood remains popular. Modern glues make wood construction easier and more reliable. Another early construction method was steel tubing. Not too many sailplane designs use steel tube today, although it makes a strong and light structure. It is usually joined by welding.

Fabric covering is often used on wood and steel tube aircraft, although some wood aircraft are entirely covered with plywood. Modern dacron fabrics are durable, and current techniques require little or no stitching or sewing.

Sheet aluminum is now the standard material in most aircraft factories. Many homebuilt sailplanes also use it. Homebuilders who lack experience with sheet aluminum frequently find out that with some practice they like it, and do it well. The classic practice of riveting with a rivet gun and a helper holding a bucking bar has been supplemented with new methods. "Pop rivets" are installed with a simple squeeze tool by one person, with no noise. And metal bonding techniques using epoxy cement are the main fastening method in several homebuilt designs.

"Fiber Reinforced Plastic" (FRP) refers to the use of fiberglass cloth or other fibers such as Kevlar or carbon held in the desired orientation and shape by a resin (epoxy of polyester) which is hardened by mixing with a hardener or catalyst. When such material is combined with plastic foam or honeycomb for shape and a certain degree of stiffness, the resultant structure may be referred to as "composite," although the term is loosely used to cover a variety of construction techniques in which more than one material is involved. In the simplest form, a piece of plastic foam is cut to the shape of a wing, and then fiberglass cloth and epoxy resin is laid over the over the foam core. When the epoxy hardens, the wing is sanded and finished. Small parts or major structures can be built this way, and the smooth and precise shapes that make good sailplanes are practical with this method. Composite construction is now widely used in the homebuilding of aircraft, although it does have certain drawbacks, which should be recognized: it is difficult to finish properly, and some builders have had strong allergic reactions to epoxies, even in the new low-toxicity forms. Builders must use proper safety techniques at all times so that their sensitivities do not develop. Once a sensitivity appears it is almost impossible for the person to continue to work with this material.

Most commercial competition sailplanes are composite, although the methods are more complex than those described here, involving the use of precise molds and temperature control.

Many homebuilt sailplanes use a combination of these methods, but usually one predominates. Nearly all aircraft use metal for hinges, reinforcement at attachment points, and control system parts. Any builder should expect to saw, file, and drill some steel or aluminum parts. Bending of metal for these parts may be necessary. If welding is needed, the builder can do the rest of the work and take the parts to a qualified welder, if he is not able to do the welding himself.

With this background, you can proceed on a fascinating task–look at the specific designs available and mentally "try them on for size." Perhaps you can see some finished examples or even fly one. Whenever possible, talk to builders or pilots of designs that interest you. Gather written and published information and study it. *Do not* commit yourself to the first thing that looks good, or buy the cheapest set of plans because of the price. You will live with your decision a long time, and exploring the possibilities before you are committed is captivating fun.

Plans or kits?

When your decision starts to become firm, get a look at the plans you will need to work from. Only when you have studied the plans and satisfied yourself that the information you need is there and that you can understand it, should you commit yourself. Perhaps you can borrow plans at this stage, but don't go ahead with building just because you may have already paid for plans.

Not only plans, but parts, materials kits, and prefabricated kits are available–in all degrees up to "49%." The FAA requires that the builder complete over half (51%) of the project himself, if the aircraft is to be approved as "Experimental-Amateur Built." This sets a limit on the completeness of a kit. (This requirement does not apply to ultra-light aircraft, which do not require FAA approval.)

Building from plans alone may be the cheapest way to go, and it allows great satisfaction to the builder who has done the whole job himself. It requires the builder to locate and acquire all parts and materials himself. This takes time–and it's a great way to learn what's available and why the designer used the materials specified.

Many times parts or assemblies for an aircraft are available for purchase. This may be for the convenience of the builder, or because the required methods are not available to most homebuilders. If the designer is not the supplier, it's worth checking to see if the designer has given approval to the supplier. Lack of approval means the buyer must evaluate the parts entirely on his own.

"Materials kits" are sometimes available, frequently from supply houses which also sell aircraft materials individually. These kits may be for a complete aircraft or part of it, or they may be for certain classes of materials, such as wood kits, hardware kits, or composite materials kits. Manufactured parts, such as wheels and brakes, may be included–the possible combinations are endless, and new ones are always appearing. Materials kits save the builder the effort of locating and ordering individual items and also avoid the need to buy a large piece of material when only a small piece is needed. Of course every builder spoils a few pieces, and the kit may not have enough extra to allow a second (or third) try.

Keep in mind that many supply houses will sell materials in small quantities for homebuilders and that many builders save money by trading and scrounging and by employing used but airworthy items.

The fastest way to build a sailplane is by using one of the kits which include preformed parts and structures and usually include most of what is needed to finish the aircraft. Some claim to include everything but the paint (they don't know what color you want). In some cases, so much has already been done that the designer has conferred with the FAA to be sure that the kit does not violate the 51% rule.

Frequently these kits are offered by small firms (sometimes part time operations) which have designed the aircraft and prepared the kit. Tooling (molds, forming blocks, drilling jigs, etc.) has been made, and plans and instructions prepared. This approach can save the builder the need to make his own tooling. It allows the use of drag-reducing shapes that are difficult for the homebuilder to achieve and allows the use of sophisticated processes beyond the capacity of the home workshop.

Such comprehensive kits are often more costly than other approaches to homebuilding, but many offer a higher performance sailplane and can be seen as a less expensive way to higher performance. Speed and simplicity of building are attractive features, and kits for the less-skilled pilot are available.

A purchaser should verify that aircraft have been built and test-flown from the *kit* he is interested in. There have been some cases in which a prototype has been flown, but problems developed in preparing the kit-built version. Builders working from partial kits have had to modify sections of the aircraft already completed. Worse yet, some sellers have disappeared from the scene leaving kit orders partially unfilled. In many cases kit aircraft cannot be completed from the plans alone, and these builders have been unable to finish. There are many sellers with fine records, but the buyer should always have his eyes open. Obviously, we can't give specific recommendations or warnings here.

How much does it cost?

The cry for a cheap sailplane reverberates through the land, but alas!-the only cheap ones are usually not airworthy. Building costs vary a lot; there are designs that can be built for a few thousand dollars, and others will cost over ten thousand to complete. The designer's intent to keep costs low is a key factor, and the lowest cost usually goes with lower performance.

What else will you need besides plans and materials? -Tools? Instruments? Professional welding or machining? Radio? Trailer? Parachute? All of these things are part of the cost. But they are not all needed at the start. In fact, the cost-especially the cost per year-for homebuilding depends a lot on how much you buy (compared to how much you make yourself) and how quickly you build.

Getting a good estimate of the cost requires careful investigation and evaluation. Most published figures can be regarded as bare minimums. Inflation raises prices regularly. Unexpected savings come by trading work, parts, and materials. Purchasing completed parts and assemblies adds to the cost. Building from plans allows purchasing materials a little at a time, which can reduce the cost per year and allow taking advantage of bargain opportunities. If you're in a hurry, be sure you have the cash to lay on the line at the start.

You can see that building is an individual process, and that costs depend on the individual approach. Probably the most we can say in general is that any sailplane will cost a few thousand dollars before it's in the air. How many dollars will depend on the type you build and how you approach your building. If an engine is included, the minimum cost per new engine is a thousand dollars, and most are more. The cost of the accessories will vary greatly with the sophistication of the design and its intended use.

How long will it take?

Anxious to get it finished and fly it? Many are, but others are happy to take a little longer, enjoy the process, and do more of their own work. If you can ask someone who has built the same sailplane you are considering, don't just ask how many months or hours it took. There are some other questions.

There is the question of style-how hard did he push to finish, and did he add any individual touches or make changes in the design? These things take a lot of building and thinking time. What experience did he have? Was this his first aircraft, and did he have building skills and knowledge of aircraft before starting? If not, he had a lot of basic learning to mix in with the building. That's rewarding, but it's not fast. If he had the skills and experience, and you don't, use a multiplier on his time to estimate your own.

Designers tend to give bare minimum figures on how long it takes to build their design. They should be regarded as the actual construction time needed by a very experienced builder with the designer nearby for consultation. Assume that no time has been allowed to become familiar with the plans, set up the shop, struggle with the questions that will come up, or evaluate honestly whether a part that isn't really perfect should be used or scrapped. And there's no time allowed in the estimates to stand and admire a finished structure, show off the project to your friends, consult with advisors, or sit in the cockpit of the half-completed fuselage and plan (you wouldn't dream a bit, would you?) about climbing in that first thermal. Occasionally a designer gives a more careful, conservative estimate. And some just give enthusiastic guesses.

If you know how many hours it will take, can you translate that into years? Suppose you choose a simple design, and the designer says 400 hours. You are a beginner, and you estimate 800. That's 16 hours a week for a year. Will you be flying in a year? Perhaps, but if you have family, school, a more than bare-minimum job, any other interests-in other words, if you're like most of us, you can expect 2 or 3 calendar years to go by. They can be very absorbing and rewarding years-probably more so if you don't torture yourself with unreasonable expectations.

Sources and resources

No one really builds and airplane by himself or herself. There are organized groups to help, and you'll be amazed at how interested and helpful the people around you will be. Some will think you're crazy, but they seem to admire your daring spirit.

Designers! We can't thank them enough, since most do their work as a labor of love and never begin to earn enough by selling plans or parts to compensate for the hours they invest. Most designers are available to answer questions by phone or mail, or they see that someone else is. Of course they don't like to hear a lot of ideas about changing the design from people who don't understand how to do it. But they want you to build a good aircraft and fly it safely. They are a great resource.

Organizations: a few of the most basic are listed here. They make up a large part of the information stream in homebuilding and soaring. They will lead you to other sources that will help with your specific needs. And they help organize supply sources and facilitate contacts between builders and regulatory bodies. Not every home-builder belongs, but most rely on these organizations and contribute to our common interests through them.

The **Sailplane Homebuilders Association** is a group of enthusiasts trying to help each other and to promote the sport. Our stated purpose is: *To foster progress in sailplane design and construction which will produce the highest return in performance and safety for a given investment by the builder. We encourage innovation and builder cooperation as a means of achieving our goal.* The degree of participation by persons with distinguished records in aviation is amazing. Annual workshops have become a great source of help to builders, and the newsletter *S.H.A.p. Talk* brings guidance and information on new designs. A design contest focused the SHA effort to stimulate new designs for the homebuilder. There are only a few hundred members, so your voice can be heard in this group. For membership, contact

Sailplane Homebuilders Assn.
490 Broad Ave.
Leonia, NJ 07605

The SHA is a division of the **Soaring Society of America**, which is the master association for organizing and promoting soaring in the U.S. Information, contest sponsorship, safety and training promotion, representation of soaring with the FAA, record and badge certification–its functions are comprehensive, to say the least. *Soaring* magazine covers the gamut, with many articles of interest to homebuilders. Our SHA bylaws require that at least 90% of our members also be members of SSA, so we encourage you to join. The address is

Soaring Society of America
Box E
Hobbs, NM 88241)

The **Vintage Sailplane Association**, also a division of the Soaring Society, is the organization for those with an interest in restoring and flying historic sailplanes. This group holds informal flying meets, publishes the newsletter the *Bungee Cord*, collects and preserves information on the history of sailplanes and soaring, and has plans available for those who want to build one of the old designs.

Vintage Sailplane Association
3103 Tudor Road
Waldorf, MD 20601 ($10 per year)

The **Experimental Aircraft Association** started nearly 30 years ago as a small organization of homebuilders and is now the leading sport aviation organization in the U.S., with affiliates and sister organizations around the world. Since the soaring movement has its own organizations, EAA does not stress soaring. But soaring enthusiasts participate on an equal basis. EAA has hundreds of chapters around the country, and this direct participation with other builders and enthusiasts is a great resource. Many chapters have EAA Designees: these are experienced people who can give specific advice on building and who will inspect projects under construction for airworthiness (although they are under no obligation to "sign off" or assume responsibility for the structural integrity of your aircraft). The magazine *Sport Aviation* includes building advice and articles on new designs; much of this is applicable to soaring. EAA is a very effective voice with the FAA and with state regulatory bodies.

Experimental Aircraft Association
Wittman Airfield
Oshkosh, WI 54903-2591 ($25 per year)

Publications! There's lots of helpful material, but no single guidebook that says it all. In addition to the journals of the organizations just listed, here are some good sources of information, in two rough categories:

Aerodynamics and design

Harry Hurt, *Aerodynamics for Naval Aviators*, a classic text available through Sporty's Pilot Shop, Batavia, OH 45103-9747

Donald R. Crawford, *A Practical Guide to Airplane Performance and Design* ($20 postpaid to Crawford Aviation, P.O. Box 1262-SA, Torrance, CA 90505), a clear, step-by-step nomagram approach to preliminary design.

David Thurston, *Design for Flying* (McGraw-Hill), an excellent study of design from the pilot's viewpoint.

The *American Soaring Handbook* (series), *Sailplane Aerodynamics* (vol. 9), available from SSA, $4.50 per chapter/volume. This series is not directed specifically at homebuilders, but it deals with many issues of interest. See additional suggestions below.

Alex Strojnik, *Low Power Laminar Aircraft Design*, 2nd ed. ($19.50 + $4 airmail, Strojnik, 2337 E. Manhattan, Tempe, AZ 85282), an introduction to the process of getting the most out of light sailplanes.

SSA, the November 1983 issue of *Soaring*, which is the 1983 SSA Sailplane Directory; it describes and pictures a vast array of sailplanes, including many for which plans or kits are available.

Aircraft construction

Tony Bingelis, *The Sportplane Builder* ($17.95 + $2 postage from Bingelis, 8509 Greenflint Lane, Austin, TX 78759). This is a priceless collection of Tony's articles on every aspect of homebuilding from his columns in *Sport Aviation*. The book is directed toward powered aircraft but is useful for anyone working on any type of aircraft.

Aircraft Inspection and Repair and Aircraft Alterations, issued by the FAA as Advisory Circular 43.13-1A & 2. Order from the U.S. Supt. of Documents or (the faster way) from Aviation Maintenance Publishers, 211 S. 4th St., Basin, WY 82410. About $13. Homebuilt aircraft are not strictly required to follow the standards of this book, but it is a manual of good practice with a lot of safety experience behind it.

Basic Glider Criteria (U.S. Government Printing Office, FAA publication 050-011-00004-6), the basic guide to strength criteria and physical testing methods for gliders built in America.

Strojnik, *Low Power Laminar Aircraft Structures* (companion book to his volume on aerodynamics, also $19.50 + postage to the author)

EAA, a new series on construction (to replace an older classic set), starting with one on wood construction ($8.70 to EAA Aviation Foundation, Wittman Airfield, Oshkosh, WI 54903-3065)

Jack Lambie, *Building and Flying Sailplanes and Gliders*. The publisher no longer lists this book, which was published in 1980 at $6.95. Some aviation book suppliers still list it. Includes chapters on construction materials and design, plans and kits, and tuning your glider.

Other SSA American Soaring Handbooks: Chapter 7, *Equipment I-Instruments and Oxygen*; Chpt. 8, *Equipment II-Radio, Rope & Wire*, and Chpt. 10, *Maintenance and Repairs*. (Chpt. 10 seems to be based largely on Advisory Circular 43.13, above, and is limited to topics of interest to sailplane people.)

Finally, consider writing for the catalogues of two major suppliers of aircraft materials for homebuilding. Both are compendia of important information about hardware and materials: $4 to Wicks Aircraft Supply, 410 Pine St., Highland, IL 62249 (refundable with $35 order) and $4 to Aircraft Spruce & Specialty Co., P.O. Box 424, Fullerton, CA 92632 (also refundable with $35 order).

Advertisements are very helpful, and the journals listed above will do a fine job of guiding you to most of the plans, kits, parts suppliers and information sources available. Note that most of the advertisers are responsible, but the journals and associations themselves are in no position to verify the claims of the advertisers or the accuracy of any complaints they may receive. The buyer's good judgment is still required.

You take it from here...

If building your own saiplane sounds like an invigorating challenge, go to it! For many of us, it is the experience of a lifetime. Join us and share it.

A note from the Sailplane Hon
Region: this pamphlet has been
to the world of homebuilt sailpla
your questions, but if there are s
about, please let us know. If you
topics or points that should have
revised edition is expected, and
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To Choose An Airfoil

By Capt. Will D. Mitchell (EAA 85466)
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THE SOUL OF the homebuilt movement is the desire to design something better. Yet many designers are reluctant to choose the optimum airfoil, relying instead upon the well proven Clark Y or NACA 23015. And indeed, the selection of an airfoil should not be undertaken lightly. One should have excellent reasons for choosing any particular section. One should consider many factors that vary widely with various aircraft. For help, I highly recommend the comprehensive and highly understandable book, "Theory of Wing Sections" sold by EAA. It's a classic worth several times the cost.

Your airplane is shaped by what you want it to do. The Breezy has its purpose, and its unique shape. The Pitts Biplane has another purpose and shape. Rivets has yet another. In each case, the shape is dictated by what the designer wanted the plane to do — and "shape" includes the wing. Let's consider a small, fast, cross country, two-seater — and choose an airfoil for it.

First, we must list the "desires" that will shape our airplane.

CRUISE SPEED — 180 mph
STALL SPEED — 55 mph
GROSS WEIGHT — 900 lbs.
FUEL WEIGHT — 150 lbs.
WING CHORD — 4 feet
WING AREA — To be found, based on stall speed.

Since the plane is to be fast, the wing is chosen for low drag during cruise; that's one parameter. Any airplane should have docile stall characteristics, unless designed for acrobatics or possibly for racing; that's a second one. A cross country bird ought to be a fast climber from two standpoints: it should reach altitude quickly, and should do so at a fast forward speed. We don't want to choose a wing that has excellent climb characteristics, but has to fly slowly to achieve them. That's a third consideration. So, to the "desires" list, we add:

BEST RATE OF CLIMB SPEED — 90 mph or more.

To start, we determine wing area. Stall speed determines wing area, and vice versa. Other factors are weight (actually the load on the wings) and the coefficient of lift. It can be a mistake to pick too low a stall speed, for then the plane rides rougher in bouncy air, and passengers become greener.

One formula for Wing Area is:

$$A = \frac{390.6\ L}{V^2\ C_l} \qquad \text{where:}$$

A is wing Area, in square feet (called S for surface in some texts)

L is Lift. In 1-G flight, lift equals weight (900 lbs.)

V^2 is Velocity squared. This is stall speed squared ($55^2 = 3025$)

C_l is Coefficient of Lift, found in "Theory of Wing Sections". A typical figure for unflapped wings is 1.25. This is less than the C_l for a wing section, due to wing tip effects. Since this bird has no flaps, we will start with 1.25.

390.6 is a constant that accounts for Air Mass Density, and also converts fps to mph. Putting numbers into the formula, we find wing area.

$$A = \frac{390.6 \times 900}{3025 \times 1.25} = 93 \text{ square feet.}$$

This gives a wing loading of $\frac{900}{93}$ or about 10 pounds per square foot, which is reasonable.

As an aside, let's compute the benefit of half span split flaps. Use the same formula, except use a C_l of 1.75, and solve for velocity. Use a 93 square foot wing.

$$V^2 = \frac{390.6 \times 900}{93 \times 1.75} = 2160. \text{ Taking the square root,}$$

V = 46.5 mph.

Thus, full span flaps would reduce stall speed by 8.5 mph, and ½ span flaps would reduce stall speed by roughly 4.25 mph. There are more efficient flaps than split flaps, of course.

We want to minimize the drag coefficient at cruise speed. Looking in "Theory of Wing Sections" we can find a drag coefficient for any lift coefficient, on a particular airfoil. So we need to find the lift coefficient at cruise speed. We use the same formula again, turned around via algebra:

$$C_l \text{ (design)} = \frac{390.6\ L}{V^2\ A}$$

In this case V^2 = cruise speed squared, ($180^2 = 32400$)

Lift is still lift, but let's use average flying weight for average cruise conditions. This is gross weight minus half the fuel (900 - 75 = 825)

Wing area is, of course, 93 square feet.

$$C_l \text{ (design)} = \frac{390.6 \times 825}{32400 \times 93} = 0.11$$

We will look for minimum drag at a lift coefficient of about 0.11. But this is at sea level, and much of our flying will be around 10,000 feet. In this case the Air Mass Density changes, and the 390.6 figure changes to 527.9.

Still using an Indicated Airspeed of 180 mph, we find:

$$C_l \text{ (design)} = \frac{527.9 \times 825}{32400 \times 93} = 0.14.$$

We are looking for a section with minimum drag between 0.11 and 0.14 lift coefficients.

Since airfoil data is presented at various Reynolds Numbers, we must compute Reynolds Number to know which lines of the graphs to use.

RN = 779.8 V C where:

V is still Velocity, in mph

C is wing chord in inches. Let's say we want a 48" chord.

At cruise, RN = 779.8 x 180 x 48 or 6,700,000.

At stall, RN = 779.8 x 55 x 48 or 2,100,000.

When looking in the graphs, we'll use the nearest values, 3 million for stall, and 6 million for cruise characteristics.

We must also consider the stall. The amount of curvature in the peak of the Lift curve gives us an indication. Sharp curve, sharp stall! Now, we are talking about generalities, and what is sharp to me might be gentle to you. So, let's talk in terms of known airfoils. The Clark Y is docile, and the NACA 23015 is pretty mean, in my opinion. You should form your opinion, based on facts and experiences you've had.

To measure curvature, use a plastic drafting triangle with a right angle on it. Position the triangle as in the drawing, so it touches the lift curve at two points. Then measure the space between the points of tangency. The wider the space, the gentler the stall. Measure the space in terms of degrees of angle of attack, and use this data for a "figure of merit".

We must consider the climb and the glide. Any airplane climbs at the fastest rate and glides the farthest when the ratio $\frac{\text{Lift}}{\text{Drag}}$ is highest. And when a plane is flying at its ceiling, this ratio is also at its maximum value. To find this L/D ratio, we could start dividing C_l by C_d all along the curve and find the largest values, but there is a simpler way.

Place the 45° part of the drafting triangle so it slants upward to the right, just touching the Lift:Drag curve for the right Reynolds Number. See Fig. 2. The point where it touches the curve is the point to compute L/D maximum.

Also notice the value of C_l at that point. Substituting back into the original formula, you can find the airspeed that gives that C_l. This is roughly the best rate of climb speed, and the best glide speed for the airplane. There are other factors, such as propwash, drag of the fuselage and tail, lift of the tail, etc. But this gives us an idea of what to expect.

For example, on the NACA 4415 which is just like the Clark Y, the triangle touches the 6 million RN curve at a lift coefficient of 1.05. The drag coefficient is .0084. Therefore, L/D is 1.05/0.0084 or 125.

And to find the best rate of climb speed, or glide speed:

$$V^2 = \frac{390.6 \times 900}{93 \times 1.05} = 3600$$ exactly. Taking the square root, V = 60 mph. That corresponds nicely with most Clark Y aircraft; they glide and climb well at 60 mph.

We would like to climb out at 90 mph with no undue drag penalty. Let's go into this same formula again and find a lift coefficient to look for. ($90^2 = 8100$)

$$C_l = \frac{390.6 \times 900}{8100 \times 93} = 0.47.$$ So, we would like to have the L/D (maximum) to occur near this C_l, or at a lower one if possible, for a faster climb speed.

This plane has no flaps, for there is simply no room. But it can use an alternative I've never seen exploited — the Drag Bucket.

Look at the L/D curve for a laminar airfoil, such as the 65_4321. (Fig. 2). The deep dip between lift coefficients −0.1 and +0.7 is called the drag bucket. But how can it substitute for flaps?

One function of flaps is to steepen the glide path. Actually, the drag bucket acts more like a set of automatic spoilers, and does the same thing. On the glide slope, if you keep your speed high enough, the lift coefficient will be less than 0.7, and the drag will be rather low. But if you slow the plane down until the lift coefficient reaches 0.8, the drag shoots up dramatically. Thus you have a set of spoilers that deploy automatically at a certain airspeed — in effect. Then when the drag increases, the L/D ratio goes to pot, and you descend more rapidly. If the airfoil has a sharp drag bucket, changing speed only a few mph makes a large difference in the glide path.

Some laminar flow wings have a bad reputation due to this drag bucket. The airplanes do very well until about time to land, then all of a sudden the bottom drops out, and your passenger is clutching his chest and watching your red face. This happens when the drag bucket extends up to rather high lift coefficients, as in Fig. 2. When you start to flare, you are still inside the bucket. But if you flare a bit too abruptly, or pass through the right speed during the flare, you fall out of the bucket, and the L/D ratio embarrasses you. So, we will choose a drag bucket that stays in the lower C_l range (higher airspeeds). Then during the landing flare, we will already be in the higher drag range that is more predictable.

With rough wings, or those with rivet heads sticking out all over the leading edge, laminar flow is impossible to obtain — thus no drag bucket. Notice the "standard roughness" curve in Fig. 2. This airplane will naturally use the super slick Foam/Dynel/Epoxy technique, and the airfoil will be carefully constructed. So, we can disregard the "standard roughness" curves.

So, in summary, for this particular airplane **only**, we want:

1. Lowest practical drag at lift coefficients of 0.11 to 0.14, for high speed.
2. Smooth stall, better than the NACA 23015 has.
3. High value for the Lift/Drag ratio, for good climb rate and good glide ratio.
4. L/D (maximum) to occur at about 0.5 lift coefficient, for high speed climb.
5. Airfoil thick enough for strength. Let's say a stress analysis dictates 15% or more.
6. High maximum lift coefficient, for slow stall and landing speeds.
7. Moment coefficient near zero. This reduces trim drag, for the tail doesn't have as much pitching moment from the wing to overcome. This also reduces the torsion loads on the wing and allows lighter construction. Values from 0 to -0.05 are fine.

By just looking at airfoil designations, we can eliminate many sections out of hand. Consider the hypothetical airfoil 65_4321. The "4" is the design lift coefficient, the "3" is the range of the drag bucket either side of the "4" and the "21" is the % thickness of the airfoil. Looking at our summary, we can eliminate any airfoil with the last two digits less than 15. And, we probably want the third and fourth digits to be 2s. This last statement applied only to the 6-series sections, but they are the laminar flow airfoils that most probably fit our needs. There are others, of course.

AIRFOIL	DRAG AT DESIGN C_l	STALL MERIT	LIFT/DRAG	C_l FOR BEST CLIMB/GLIDE	C_l MAX	C_m AT DESIGN C_l
4415	.0068	6 plus	125	1.05	1.42	−.095
23015	.0062	3	114	1.20	1.50	−.003
63_2215	.0047	1.6	101	.055	1.43	−.03
63_2415	.0053	2.1	123	0.8	1.52	−.07
63_2615	.0053	2.1	133	0.9	1.46	−.11
64_2215	.0049	2.0	100	0.5	1.39	−.03
64_2415	.0050	3.1	136	0.7	1.48	−.07
65_2215	.0043	2.4	113	0.58	1.42	−.035
65_2415	.0043	2.4	128	0.7	1.44	−.06
66_2215	.0036	2.1	103	0.5	1.42	−.03
67,1-215	.0035	0.5	98	0.4	1.43	−.046
747A315	.0048	5.1	120	0.7	1.22	−.012
747A415	.0059	6.0	143	0.75	1.32	−.03
GA(W)-1	.0070	3.0	86	1.0	1.76	−.12

Now for value judgments. We'll underline the data that are acceptable. The strongest criteria is low drag, which eliminates all but four sections. Of these, one has a poor stall. Another climbs best at a rather slow speed. There are two left, the 66_2215 and the 65_2215, just what we predicted. We choose the former for this particular airplane, due to its lower drag and faster climb speed. Both have about the same stall speed. The other has a slightly nicer stall, and a slightly higher rate of climb.

The GA(W)-1 did not fare too well, but it was not really designed for this sort of work. If you care to run the same comparison, but using "standard roughness" lines, you will find that the GA(W)-1 is an excellent section for its purpose. This section was computer designed for a C_l (design) of 0.4, and low drag through C_l values up to 1.0. The max C_l is about 2.0 at high RN values. The 1.76 value quoted above is for RN = 2.7 million and mach 0.28.

The GA(W)-1 was not designed for laminar flow; instead lift and gentle stall were optimized, considering that construction roughness and bug spots often keep the flow over the wing turbulent. Certainly if you plan on rivet heads all over the wing, or a fairly rough covering, look hard at the GA(W)-1 and its successors we all hope will follow.

For a trainer, the 747A415 might be promising. It has a superbly gentle stall, high rate of climb at a fairly slow speed, and a slow stall speed. Yet, it will move out rather well too. We'd have to do some calculating to see, but it looks like a good one for several popular custom airplanes.

If you are particularly interested in sailplanes, consider one other parameter. Find the highest value for the ratio $\frac{\text{LIFT}^3}{\text{DRAG}^2}$ for each candidate airfoil. This ratio is the highest just above the point where L/D is the highest, so find L/D (max) first and then increase C_l by about 10% to 15% to find the point to start looking.

The airfoil with the best L^3/D^2 ratio will descend at the lowest rate. Why not just use the L/D ratio which gives the best glide ratio? Consider this:

The Boeing 707 has an excellent glide ratio, nearly 20 to 1. This is better than a couple types of sailplanes, but the 707 would make a lousy sailplane, even if it could turn sharply enough to stay inside a thermal. When gliding, power off, the 707 must hold an airspeed of nearly Mach 1, and it is descending at about 3000 feet per minute. But since it is traveling so fast, it covers a tremendous amount of ground, and has an excellent glide ratio. The problem is, how could the 707 use a 200 foot per minute thermal? Or even a 2000 fpm boomer? It is descending at 3000 fpm.

For the 707, our L^3/D^2 ratio is not so good, but the L/D ratio is excellent. Further, both ratios reach their maximums at high speeds, which increases the turning radius. For sailplanes, we want the two ratios to both be high, and we want them to occur at high values of C_l, to keep airspeed down. If the bird is to be used for cross country flying, however, the L/D ratio should be best at lower values of C_l, so the speed will be higher while traveling from one thermal to another.

Always the compromise, but that's the way it is in aerodynamics.

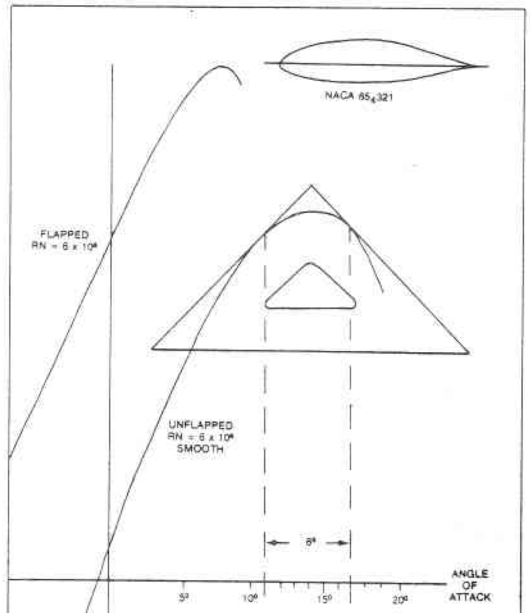


FIGURE 1

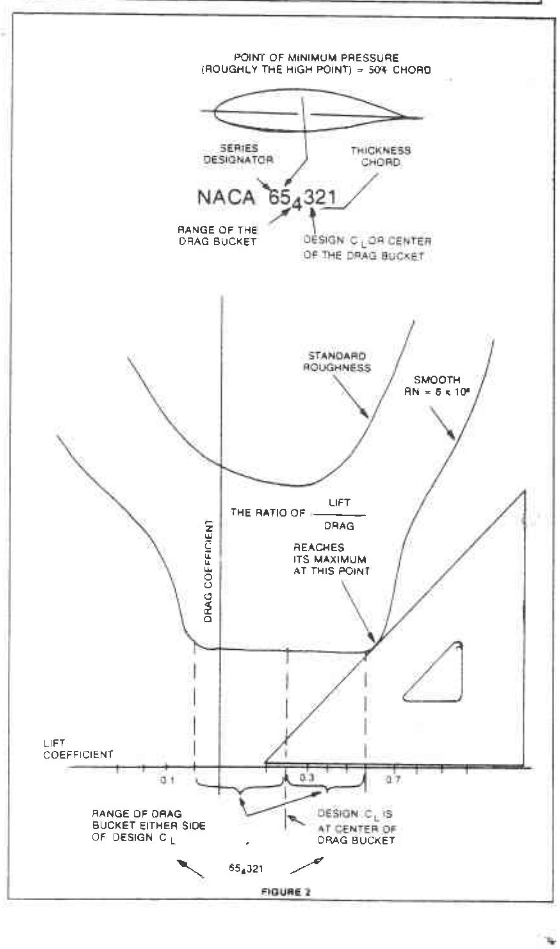
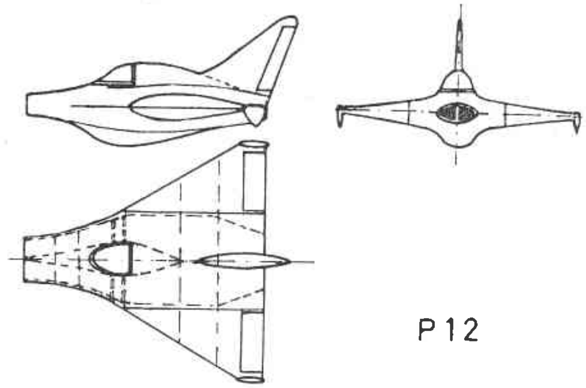
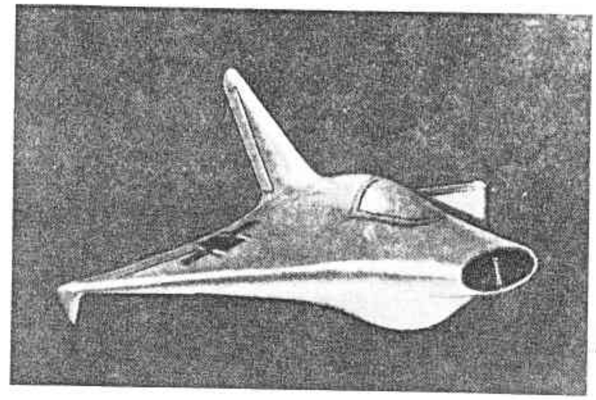


FIGURE 2





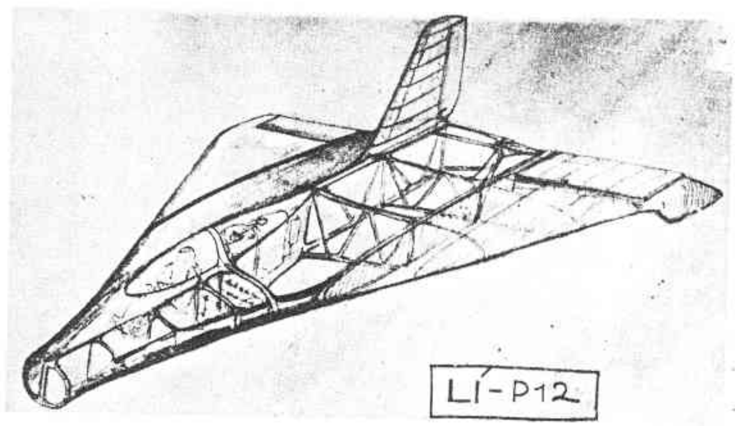


Abb. 84 Projekt P 12, a) Übersicht (Rekonstruktion), b) Modellfoto, c) Darstellung des Antriebs.

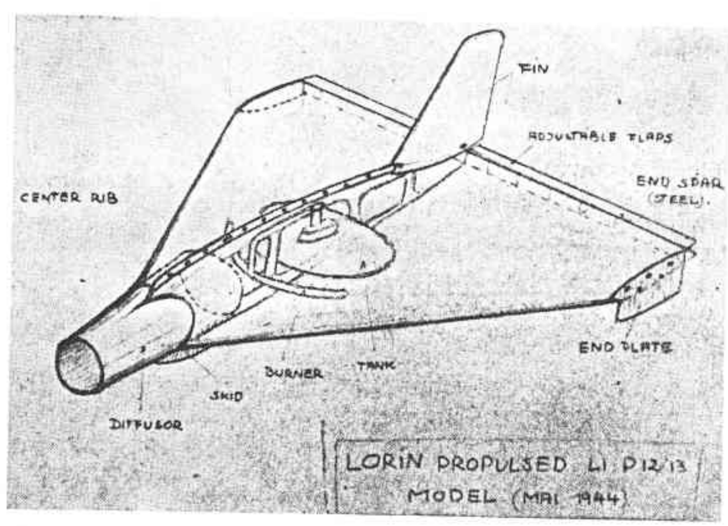


fig KLS Drawn by Karl Sanders

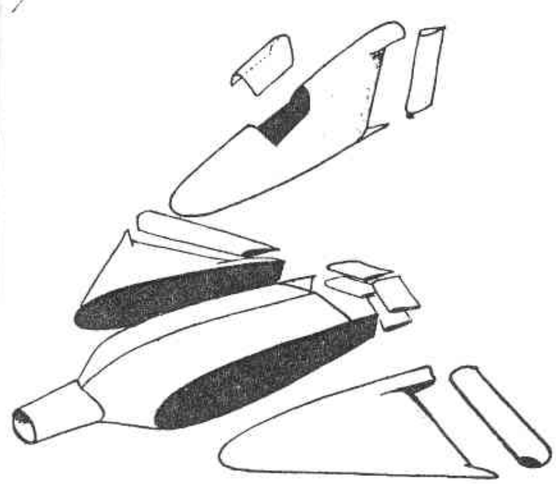


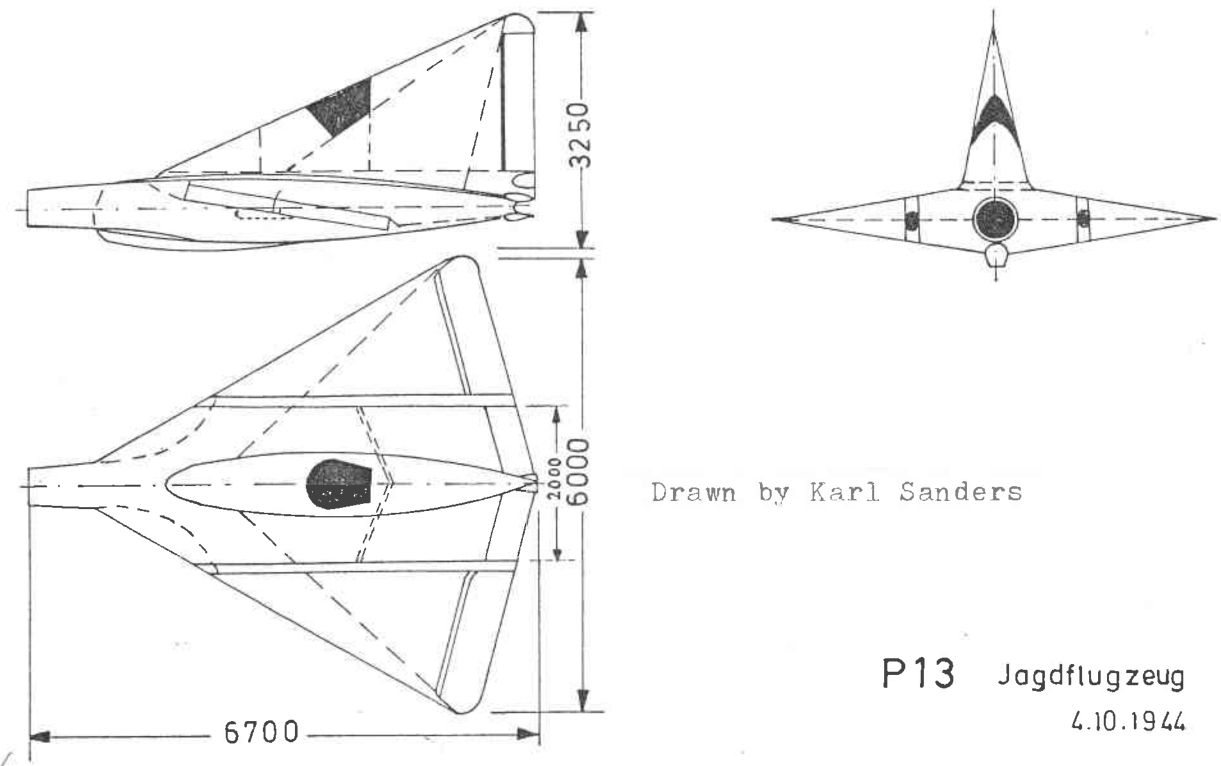
Abb. 85 Flugfähiges Triebflügelmodell Li P 12/13 (Skizze) (Mai 1944 und Weiterentwicklung zur P 13

Flying Wings at Tehachapi

If Robert Hoppe had had his flying wing at the Sailplane Homebuilders annual get together there would have been five flying wings present.

Klaus Savier flew his modified U-2, Don Mitchell displayed his newest design, Bernie Gross exhibited his "Deaf Hawk" and two unidentified men assembled the pre-molded Marske "Pioneer" pod.

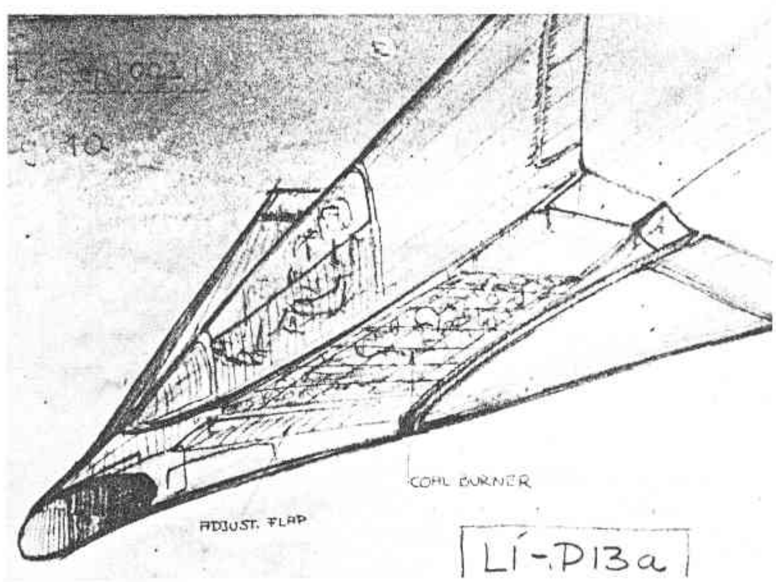
Labor Day weekend 1988 at Tehachapi will concentrate on flying wings as well as other homebuilt sailplanes.

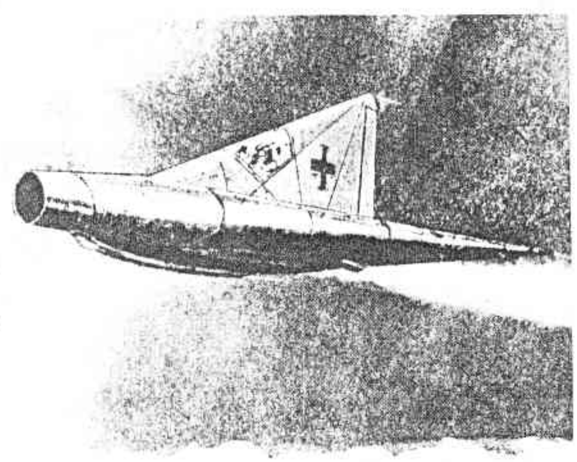


Drawn by Karl Sanders

Abb. 86 Staustrahljäger-Entwurf P 13 vom Juli 1944, a) Übersicht, b) Darstellung des Antriebs, c) Flugbildzeichnung.

KLS





ALL ABOUT MOTORGLIDING

By Tasso Proppe

The FAA will eventually be unable to keep its stranglehold, when the tide of hanggliders spills over into the soarable areas of the flatlands, the desert. So far, they are still hopping off mountains, but those launch sites are becoming scarce. They are being closed down, because hanggliding, it turns out, is a spectator sport, and the spectators leave a trail of trash and debris behind, causing the land owner to stop the flyers from attracting this mess.

But there is another reason to move into the desert. The opportunities to catch a thermal from gliding off a mountain are depending on the coincidence of a number of things that have just to be right: wind speed and direction, to be there at the right time, and a temperature gradient that develops thermals. The latter parameter is nearly readily available in the desert, and neither the FAA nor anybody else would be able to muster enough policemen to enforce out-of-date regulations out there. All we need now is a means of getting into these thermals without the hampering GSE system. That will be a new brand of motorgliders, probably a more American breed (or kits made in Hong Kong or Communist China specifically for the American market and imported as plastic toys?). They will differ from the expensive ships that are now coming from Europe, also as toys, but for the rich only - instead of being tools to promote and further a sport that should be as popular as bicycling.

Let's look at the design parameters (or operational requirements, if you will):

These machines have to be slow, to be able to work thermals close to the ground when the diameters are very small, to have a low rate of sink in spite of a poor gliding angle, to take off from unimproved surfaces, dirt roads, dry lakes, and to minimize the overall power requirement.

They are parked disassembled on a light weight trailer alongside the home, trailered to the site, assembled by 2 to 3 people (one of them is the girl friend) in approx. 20 minutes, ready to fly.

They are home built from kits, consisting of preformed fiberglass composite and difficult to make metal parts (like weldments or the wheel) with only an average skill required to construct and assemble the rest.

They will take off on their own power, with a moderate rate of climb, loiter around 1000 ft. AGL at minimum power for zero sink (that's close to idle) and shut the engine down when they locate a lift area that provides more lift than their rate of sink with the engine off.

They will be able to re-start the engine on a moments notice, to pull out of a tight spot, to move across an inert area of no-lift, and to fly home when the thermals become too weak or quit altogether. This also holds when you are soaring the ridge of a mountain range where you want to get across a no-lift gap to the next range that promises to be soarable.

It means: 3 hrs. worth of fuel aboard, and a start system that's better than a lawn mower rip cord.

There are some additional criteria that may be prompted by my personal preference: I want to sit up front; I just cannot stand an engine blob to occupy my seat. It is not only a matter of field of view, safety, and all that; it is a matter of fun. This flying is for fun - and an engine in front of me spoils it. It is also a matter of noise during powered flight, but even with the engine in the rear, it still requires a muffler arrangement.

The machine should be able to take off without a wingtip runner. This does not mean that it should have a tricycle landing gear - just a central wheel and outriggers under the wings to stagger along until the ailerons take over. The gliding angle should be moderate, L/D around 20 in the interest of low weight and simplicity; that's more important. The engine replaces the excessive wing spans - I call this "adjustable" L/D.

Controls have to be tailored for positive authority close to stall. Soaring a slow airplane close to cliffs and Sierra rock protrusions calls for that. I have no use for roll-to-yaw combinations to eliminate rudder pedals for whatever the reason might be. Soaring the dust devils is even worse of a control problem, except if you loose control you don't hit the rocks right away; but with a certain amount of control authority, you keep the tumbling ship in a general spiral direction up, in competition with all kinds of junk: chewing gum wrappers, empty cigarette packets, and discarded government paperwork (I just had to get this in here).

October Program

The speaker for the October TWITT meeting will be Reg Finch. The subject will be the design of an aircraft for best performance. Comparison of conventional, carnard and flying wings; comparison of ease of construction of each type and flight qualities will be discussed.
Reg is an airline pilot, is flying a Varieze and is designing and building a composite motorglider.

Editor Up In A Blimp
Marc de Piolenc is working in Oregon on a blimp program. They hope to get type certification. The demands of the program prevented TWITT from receiving the minutes of the September meeting on time. TWITT will fimd a way to get a copy of them to you.

MINUTES OF TWITT MEETING, 19 SEPTEMBER 1987

This meeting began with a videotape showing the onset and development of flutter in the horizontal tail assembly of a light airplane. Several sequences, filmed in slow motion from different angles, made frightening viewing. This inspired the remark from Jerry Blumenthal that Boeing often used Convair's wind tunnel (with which he was associated) for flutter testing. The models, carefully built for dynamic similarity with the full-scale airplanes they represent, are tethered vertically in a vertical 8x12 wind tunnel. Piezoelectric sensors trigger gates that quickly close off the test section when divergent flutter is encountered. Convair is currently testing refinements to its wind tunnel using a 1/12 scale model of it! The blower blades of the model are hobby-shop items. Bob Fronius noted that there were four flying wings at Tehachapi, including Klaus Savier's very highly modified U-2, a new Mitchell design in wood and foam (how about some details, Don), a partly-built Marske kit and Bernie Gross' successful Marske Pioneer. Andy Kecskes displayed a Delta wing RC model sold by Top Flite, called "Holy Smoke .40," a very clean machine covered with the ever-popular Monokote. The model is fast and has a very high roll rate. It has no rudder. Access to the RC gear is through a belly panel, leaving the top surface of the airfoil clean. Next we saw a videotape of German origin on unusual aircraft. Film footage included shots of the Hortens 3, 4, 6 and 9, a tailless RC model and a Fauvel, model number unknown. A break followed, after which Karl Sanders took the floor. Before beginning his reminiscences on his wartime work with Alexander Lippisch, he noted that he had found articles on the electrostatic autopilot in the November 1972 and April 1974 issues of Aeronautics and Astronautics, the AIAA journal. He also noted for your Editor's benefit that the Naval Air Systems Command has a good deal of Horten and Lippisch material in its files. Karl's career began in 1942, when he went to work as a draftsman for Focke-Wulf in Bremen. While working there he came up with tailless fighter designs which he drew up (he refers to these sketches as "cartoons"). Eventually a letter he wrote to the Air Ministry was shown to Alexander Lippisch. Karl was transferred to a torpedo experiment station near Kiel, from which he could make free calls to Berlin. Hans Antz, an Air Ministry employee who had worked at CalTech before the war, helped him and in August of 1942 he began working for Lippisch at the Messerschmidt facility in Augsburg. [Karl noted in passing that Lippisch's first job was with a subsidiary of the Zeppelin company, building the giant Staaken bombers of WWI.] Messerschmidt had Lippisch and his 30-odd co-workers in a separate bungalow; he was a firebrand, a difficult man to get along with, and the Messerschmidt people were more comfortable with that arrangement. He was more an advocate of tailless airplanes than of flying wings, although some of his designs, notably the DFS 40, were very nearly all-wing aircraft. When Lippisch was transferred from Messerschmidt to an aeronautical research establishment in Vienna in 1943, Karl Sanders went with him, where he worked with Lippisch on some of his advanced projects which were never built, notably the P13 ramjet-powered fighter. In 1944 their facility was bombed out. At the end of the war, Lippisch was one of the many German scientists and engineers brought to the United States under Operation Paperclip. He worked secretly and in isolation for some time because he was technically an illegal immigrant, having been brought in without the knowledge or consent of the Immigration Service. Later, he and many others re-entered the country legally by being "laundered" through various US embassies in foreign countries. Summing up his impression of Lippisch, Karl noted that although Lippisch gave the appearance of a recluse, he actually enjoyed the limelight. He was a good, fluent speaker and an engaging writer. Karl illustrated his talk with many viewgraphs of Lippisch's designs, and contributed paper copies of all his illustrations to the TWITT library.