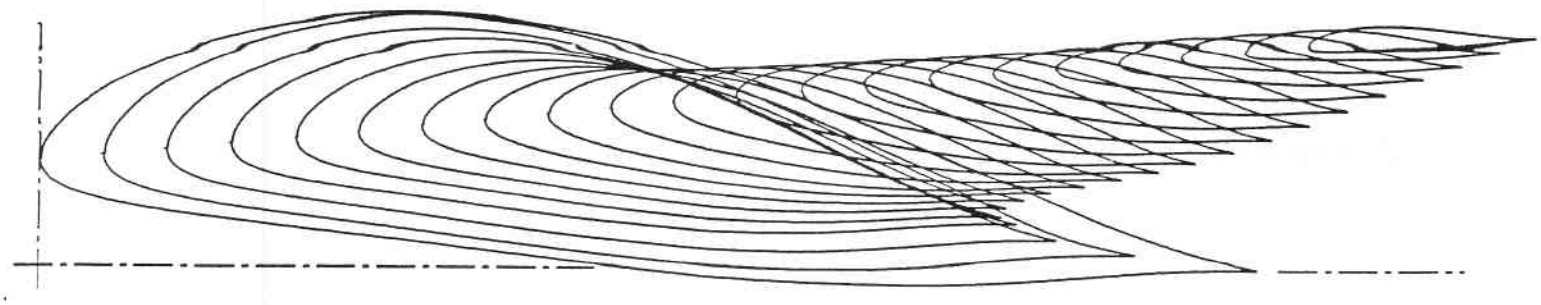
NUMBER 32 FEBRUARY 1989

TWITT NEWSLETTER

F. Marc de Piolenc, Editor and Publisher



SCHAPEL AIRCRAFT COMPANY

TWITT
(The Wing Is The Thing)
PO Box 20430
El Cajon, CA 92021
USA

The numbers in the upper right corner of your label indicate the last issue of your current subscription,

NEXT TWITT MEETING: Saturday, 18 February 1989, beginning at 1330 hours. As always, the location is Hangar A-4, Gillespie Field, El Cajon, California

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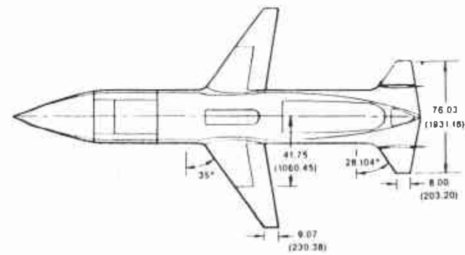
MINUTES OF THE 21 JANUARY 1989 TWITT MEETING

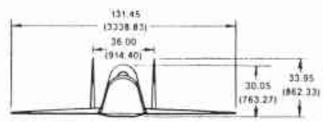
Present were Bob Fronius, June Wiberg, Doug Fronius, Jim Neiswonger, Doug Babb, John Chalmers, Vic and Anita Millman, Emil Kremzier, Fred Blanton, "Tuto" Figueroa, Klaus Savier, Ed Lockhart, Bill McCaffrey, Gregg Kendall, Harald Buettner, Andy Kecskes, Jerry Blumenthal, Ralph Wilcox, Phil Burgers and Bevan Iredell. Bob Fronius opened the meeting by calling on a visitor, Fred Blanton, to introduce himself. He came down from the San Francisco Bay area to attend the TWITT meeting. Bob noted that this day was the anniversary of Eugene Ely's first landing on the converted cruiser *Pennsylvania*, only eight years after the Wright brothers' exploit at Kitty Hawk. Your Editor, as usual, was attending a meeting of his Reserve unit and compiled these notes from audio tapes of the meeting. Bob displayed some of the balsa models built from scratch by members of the John Street Aeronautical Society, an eminent group which meets only over the New Year holiday to quaff champagne, fire acetylene cannon and advance the state of the aeronautical art. Many of the designs were tailless, though some of the tailed designs flew well too. Ed Lockhart rose and presented several of the airplanes at Bob's request. Bob then proceeded to introduce his son Doug, the featured speaker, an employee of Teledyne Ryan and member of their Special Projects group. Doug's topic was the three unmanned aircraft projects currently in the works at Ryan. Although none of them is tailless, they are unusual and represent the concerted efforts of many San Diego engineers. The mainstay of Ryan's business is the Firebee, originally developed as a subsonic target drone in the late Fifties. This work led smoothly into very advanced unmanned reconnaissance aircraft developed during the Vietnam war, including the *Compass Arrow* which was flown from South Vietnam clear over Peking and back. That program was mothballed after the US pulled out of Vietnam. This machine and another high altitude, long range machine, the *Compass Cope,* were built for the US military. One of the programs Doug discussed, the Model 324, was developed for Egypt to use for reconnaissance of Libya. The model 410 is designed for runway takeoff and a longer range than the 324, making it cheaper to operate than the 324. Tests of the 410 as a manned airplane were recently concluded and the machine was being reconverted to RPV form. It can fly for 24 hours if 200 of the 300 pounds of payload are traded for fuel. The nosewheel alone is retractable, primarily to clear the field of view of the sensors in the payload bay. The design is modular; the machine is designed to be easily dismantled for transport. This project is company funded. Price is about $400,000. The machine has several operating modes, including real-time video (maximum range to the ground control station would then be 100 miles). The machine can fly a programmed flight path, or the autopilot parameters can be reset remotely in real time. Doug showed a short videotape of the 410 in flight. Test flights were flown at Holtville, a former (WW2) pilot training field. The Model 324 is the most mature of the current projects. The original contract was signed in 1984, and the aircraft flew for the first time in 1986. The first machines have been delivered to Egypt. A Ryan team will accompany these machines to see them through their initial deployment. The airframe was built of Kevlar/epoxy by Scaled Composites, Inc. at Mojave. Engineering and final assembly took place at Ryan in San Diego. A videotape on the 324 followed. The salient feature of the 324 is its support system—including a multi-axle, all-wheel-drive transport and launch vehicle—designed for operation from unprepared sites. The whole system fits in a C–130 transport. The airplane is launched with the aid of a booster and recovered by parachute. Turnaround time is about three hours if a new booster and a packed parachute are both immediately available. The Model 350 is an outgrowth of pressure exerted by Congress on the Navy in the wake of the capture of a US pilot by Syrian forces on a recon flight over Lebanon. The idea is to launch the RPV from a carrier based manned airplane in flight, and to recover it in flight. The 350 is a variant of the 324 designed to be air-launchable from a wide variety of aircraft, including tactical fighters. Two other companies are competing for the same contract. Ryan funded a project to demonstrate air-launch of a 324 variant. The aircraft was completed in 58 days, Skunk-Works style. The team that built the airplane included TWITTs Robbie Grove and Ralph Wilcox. The million-dollar effort resulted in a "textbook" launch. Doug showed an unedited flight test tape of the 350 prototype. A short Q&A session followed. Bob then showed the ESPN videotape on human powered vehicles which was

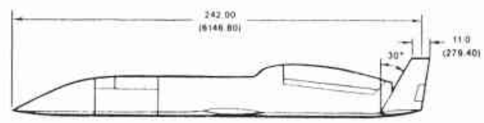
AIR VEHICLE

GENERAL DATA:

WING:	
AREA	2.230 SQ METERS (24.00 SQ FT)
ASPECT RATIO	5.00
HORIZONTAL STABILIZER:	
AREA	1.095 SQ METERS (11.78 SQ FT)
ASPECT RATIO	3.41
VERTICAL FINS:	
AREA (EACH)	0.368 SQ METERS (3.96 SQ FT)
ASPECT RATIO	1.80
POWER PLANT:	
(1) TCAE MODEL 373-8C TURBO JET ENGINE	
THRUST	4,270 NEWTONS (960 LBS)
WEIGHT:	
DRY WEIGHT	619.7 KG (1366 LBS)
GROSS WEIGHT	1068.8 KG (2356 LBS)
PAYLOAD:	115 KG (250 LBS)







MODEL 324

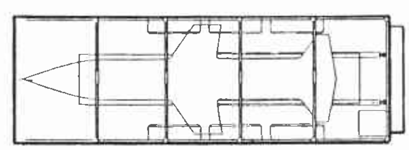
LAUNCH RECOVERY VEHICLE

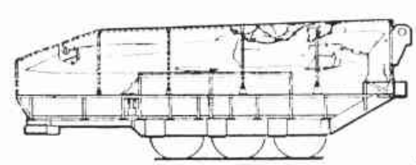
LRV GENERAL SPECIFICATIONS

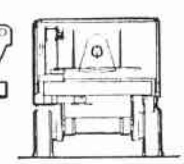
OVER ROAD CONFIGURATION	
SPEED (MAXIMUM SPEED)	84 KPH (52 MPH)
RANGE ⁹ 50 MPH	6 HOURS
WEIGHT — TRACTOR	10,368.2 KGM (22,862 LBS)
TRAILER/AIR VEHICLE	7,609.1 KGM (16,778 LBS)

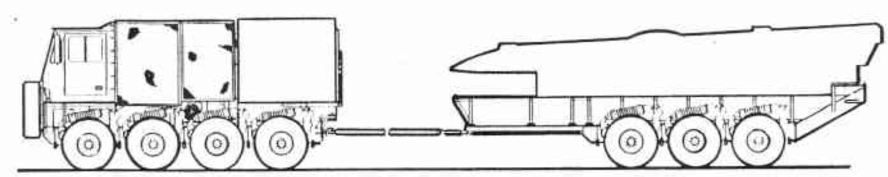
POWER UNIT
- 8V92/A DETROIT DEISEL ENGINE
  - 400 BHP (298 KN) AT 2,100 RPM
- ALL-WHEEL HYDRAULIC DRIVE W/LEVELING
- TRAILER-POWER ASSISTED

HANDLING CAPABILITIES
- CENTRAL TIRE INFLATION SYSTEM
- ENVIRONMENT CONTROL SYSTEM (CAB & GCTSS)
- AC GENERATOR — 25 KW









the raffle prize. Ed Lockhart won the drawing and became the videotape's owner.

FEBRUARY SPEAKER

On 18 February we will feature Phillip Burgers, aerodynamicist and founding member of TWITT. Phil came to this country from Argentina, where flying wing designer Dr. Reimar Horten has lived since shortly after WW 2. Phil met and befriended Dr. Horten, visited him at his home in Cordoba province, and came away with numerous insights into the aerodynamics of flying wings and much of Dr. Horten's collection of original drawings and other technical material. As a result, Phil probably knows more about the Horten designs—over twenty successful types—and the thinking behind them than anyone in North America, with the possible exception of Jan Scott in Virginia. His talk will, not surprisingly, concern itself primarily with the Horten machines, but will also cover the gamut of aerodynamic considerations related to tailless airplanes. Be there if you can.

ABOUT OUR COVER AND OTHER MATTERS

Marc de Piolenc

As he promised, Rod Schapel came through with information on his beautiful SA-882, featured in this issue. Our cover illustration is a drawing of the airfoil sections at various stations along the 882's wing, and their relation to each other. It appears that camber, thickness and incidence change spanwise, suggesting a fairly sophisticated aerodynamic design. Drawing courtesy Schapel Aircraft.

In order to fulfill its goal of spreading technical information on flying wings and tailless aircraft, TWITT needs to build and make available several databases, including an index of the Newsletter, a bibliography of material on tailless machines, a list of sources other than TWITT for that material and a listing of material in the TWITT library in sortable/retrievable form. I have designed a database structure for the library listing and the bibliography, using dBase II under CP/M. This can easily be converted to IBM disk format to run under dBase III, III+ or IV under MS-DOS. What's needed are volunteers with access to IBM or IBM-compatible computers who are willing to do data entry. No programming at any level is required. I'm back in school, working on my BSME, and I simply don't have the time. HELP!

Some of you have expressed interest in how the Newsletter is put together, so here goes. First I prepare the text files (minutes, articles, etc.) using Wordstar under CP/M on my Kaypro 4 portable computer. Then I translate the files into IBM PC disk format, concatenate them into a single text file and take the disk to a service bureau where I use an IBM-compatible computer running Xerox Ventura Publisher, a typesetting program, to lay out the Newsletter. Once I have it right on screen, the Newsletter master is printed on a Postscript laser printer. Photos and drawings are then pasted into spaces reserved for them and the pasteup is delivered to the printer. Bob Fronius and June Wiberg staple, address, stamp and mail the printed copies. The process now requires three computers (including the Polymorphic 8813 I use to maintain the mailing list), three operating systems, two floppy diskettes, three sets of text files, four software packages, considerable care and a lot of time. I've been trying for some time to find an IBM-compatible computer with the right combination of performance and price, but the variation in both, and lack of time to pursue the search, has hindered me. I am reluctant to simply plunk down money for a cheap AT clone, because of the certainty that it won't have the performance I need two years from now and will have zero resale value at that time.

ADDITION TO THE LIBRARY

Shvyetz, A.I. and Shvyetz, I.T.: *Aerodynamika Nyesushchikh Form* (Kiev: Golovnoye Izdatyelstvo Izdatyelskovo Obyedinyenia "Vishcha Shkola," 1985)

The title, if memory serves, means *Aerodynamics of Unusual Shapes*. Bruce Carmichael gave the book to TWITT.

LETTERS

Wants SB-13 Plans

Kenneth J. Carpenter of Providence, Rhode Island writes:

I am a subscriber to *RC/Soaring Digest*. In the September '88 issue, there was an article on your SB-13 flying wing; what a beautiful craft!!!

I am quite interested in flying wings and am in the process of building the Cortina flying wing. I would be very grateful if you could send me information on subscribing to your newsletter and plans for the SB-13.

P.S. I still have no idea how to make a foam SB-13 wing! *[Neither do we—Ed.]*

Yours truly,

Kenneth J. Carpenter

Unfortunately, TWITT cannot claim credit for the SB-13, developed by the Akaflieg Braunschweig, a university-based aeronautical club in West Germany. Some information on it has appeared in past issues of our Newsletter, and there's more to come as soon as your Editor can translate it.

Prefers Pioneer II to AV 36

Syd Hall of Nevada City, California wrote to subscribe to this Letter, and added:

Yes, I am the same fellow who built the only AV 36 (for Fred Jukich) built in the US and I like Marske's Pioneer II better. The AV-36 fights to go at its design speed, so to fly it faster requires forward stick, etc., while the Pioneer is neutrally stable, and it stays where you put it, slow or fast. But my new bird should be even better. Wish I lived closer to El Cajon.

Syd Hall

Keep us informed of progress on your bird. Come to think of it, how about a three-view, some specs...

Aussie AV 60

Dear Sir

Well I have No. 30 on my knee. On page 6, Syd Hall says 21 dollars will cover back issues and Charles Pearson says that 15 will cover. 36 total.

Who am I. Well, I have many Fauvel plans and an AV-60 in the hangar half complete. The Marske Pioneer is a good machine, maybe not as good as claimed. There is one for sale here. Flies well and does hold position in thermals full of machines. Fred Hornville had a Backstrom Plank and there were several here. Now it appears that its stall is something.

Page 8 is interesting. EAA printed the information and I had a University Book Card. We got A.R. Weyl from the magazines and photocopied them. I sent several copies to the US, but I could not get the whole page in the machine, rather like your pages. The rest of the magazine was poor. Anyway, wherever they came from, A.R. Weyl did a good job.

Many flying wing drawings are available in Canada from maybe

CDX Aviation Sales
11343-104th St.
Edmonton, Alberta

I am sure he has a different name too. Look up your Canadian phone numbers. I may have covered enough for now. Cheers.

Alan Lewis
Paddington, NSW
Australia

Back issues still cost $.75 each, but the number available keeps going up. Our A.R. Weyl material consists of second generation reduced photocopies. The "originals," the bound journals from which they were copied, are yellowed, brittle and generally hard to handle, but they can be found in the San Diego area. Who is selling the Pioneer? May we have pictures of your AV 60 project?

SDSU AIAA Student Chapter Needs Speakers

Dear Mr. Fronius:

The San Diego State University student chapter of the American Institute of Aeronautics and Astronautics (AIAA) would be very interested in having you as a guest speaker to our group on a topic of your choice.

The AIAA Student Branch is a pre-professional organization which meets regularly to promote the interests of engineering students in the aerospace field. Our weekly meetings are on Thursdays form 11:00 am to 12:15 pm.

We are presently constructing our calendar for the 1988-89 Academic Year. We look forward to receiving two tentative dates convenient for you so that we may structure our schedule to best accomodate your needs. Please choose dates from the enclosed list.

Sincerely,

Marty Stanton, Vice President

Other San Diego area TWITTs may want to offer their expertise and experience to the very active SDSU chapter. Their number is (619) 265-6074.

TWITT Origins Revealed [?]

For historical interest, we reproduce the following letter from Syd Hall, which appeared in the September 1975 Soaring.

Dear Sir:

I have subscribed to *Soaring* for over 20 years but for most of that time have been unable to fly as much as I'd like for financial reasons. For the past few years I have almost dropped my membership but the hope grew that cross-fertilization from hang gliders might bend some articles my way. This has not happened yet. I am subscribing this year with the conviction that if something other than the glass slippers and lead sleds don't make the pages of *Soaring*, this will be my last year because a $ 15,000 glider is not where it's at with my income. Likewise, the Rogallo and other kites do nothing for me since that is not soaring—nor is it smart.

I feel there is a growing movement toward less costly birds that can remain airborne but which may never win a thing. These may come from Stan Hall's column or from Jim Marske's *Monarch* or Klaus Hill's *Superfloater* and *Fledgling*. They may also come out of the past with something like an updated Grunau or Bowlus *Baby Albatross*. (Pete Bowers might do us all a favor by giving details of the old good birds.)

My conviction is that *the wing is the thing* [italics ours—Ed]. The Apgar article (*Soaring*, July '74) on Jim Marske's flying wing did not dampen me too much because it was clear that it had been modified. This plane has now been rebuilt and *Soaring* would be fair if you would recheck it. You might also do an update on the *Monarch* which is pretty nearly the solution.

Syd Hall

IS THIS YOUR LAST ISSUE?

Beginning with Newsletter Number 21, mailing labels have had on them a four-digit code for the year and month of the last newsletter the subscriber will receive under his current subscription. If your label reads "8901," for example, your last Newsletter will be this one. Please check your label now, and take the time to renew if your subscription is nearly expired. While we're at it, let us remind you that all back issues are still available at $ .75 apiece. Subscriptions still cost $ 15.00 per year. Payment must be in US Dollars.

SCHAPEL SA–882 FLYING WING

The SA-882 is a flying wing which was designed and built to research the overall aerodynamics, control, and flying characteristics of a tailless airplane configuration.

Construction of the Schapel Flying Wing utilizes advanced composite materials. Unlike most "proof of concept" airplanes, the Schapel Wing was constructed in female molds to assure accurate contours and permit better control of structural weight. Epoxy-Glass and P.V.C. foam is the primary structural method. The Schapel Wing is powered by a turbocharged Mazda, 2-chamber, rotary engine. The 3-bladed propeller is ground adjustable and is driven by a 40-inch long drive shaft. Propeller speed reduction is accomplished by a helical gear speed reducer.

PRELIMINARY SPECIFICATIONS

GROSS WEIGHT, LB	1984
EMPTY WEIGHT, LB	1372
USEFUL LOAD, LB	612
MAXIMUM FUEL, GAL	57
WING SPAN, FT	34
WING AREA, FT^2	160
ASPECT RATIO	7.23
SEATS (2-SEATS OPTIONAL)	1
ENGINE, MAZDA 2-CHAMBER ROTARY, HORSEPOWER (OPTIONAL ENGINES AVAILABLE)	180

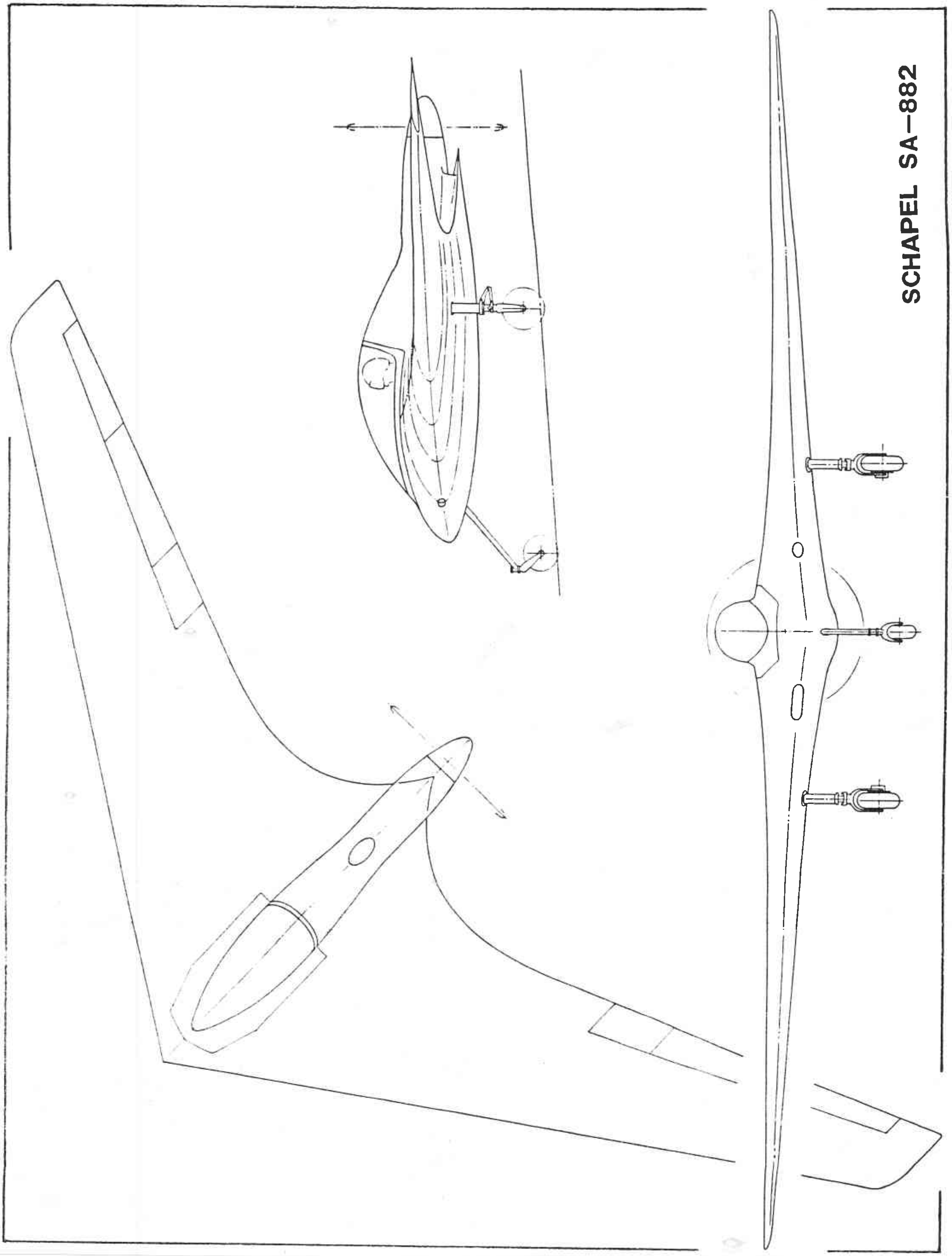
CONSTRUCTION: ADVANCED COMPOSITE MATERIALS UTILIZING EPOXY-GLASS-P.V.C. FOAM SANDWICH METHOD

ESTIMATED PERFORMANCE

MAXIMUM SPEED AT SEA LEVEL, MPH	223
MAXIMUM SPEED AT 20,000 FT, MPH	256
ECONOMY SPEED AT 20,000 FT, MPH	192
RANGE AT ECONOMY SPEED, STATUTE MILES	1013
STALL SPEED AT SEA LEVEL, MPH	67
TAKEOFF DISTANCE OVER 50' OBSTACLE, FT	1205
LANDING DISTANCE OVER 50' OBSTACLE, FT	1732
MAXIMUM RATE OF CLIMB AT SEA LEVEL, FT/MIN	1505
MAXIMUM ENDURANCE, HOURS	5.3

DESIGNED & CONSTRUCTED BY

SCHAPEL AIRCRAFT COMPANY
P.O. BOX 60039, RENO, NV 89506
(702) 972-8937


SCHAPEL SA-882

This is the *iterative process of "conceptual design" and "synthesis" for which the* professionals write Synthesis Programs to scan literally hundreds of possible parameter combinations in a systematic manner.

There are other design aspects affecting a flying wing transport. Passengers require cabin pressurization. A wing does not lend itself efficiently to that unless we adopt a fuselage again and then have a tailless "hybrid" instead. For the latter, the wing geometry constraints mentioned above are avoided, and the requirement to separate fuel from passenger containment is met (for military airplanes this is normally not a problem.) A possible application could be for a naval deck launched aircraft which usually is constrained in span and length by deck spotting and elevator size. It may turn out that the length of a tailless meets these criteria better, while the wing can be folded in the usual manner.

Operators like to order stretched or shrunk versions to match their route and payload demands, or simply for anticipated growth. This can be done relatively easy with a fuselage by adding or deleting sections of constant crossection forward and aft of the wing root to maintain the CG range for stability, and the main landing gear position aft of it. To do something similar in the spanwise direction is much more difficult, to say the least. The maximum bending moment of the inboard panel would be exceeded if outboard area is added. Also, CG limits must be held within a trimable range. The loading ramp should preferably be located between the main gears, although tip-loading also has been suggested but requires mobile ground-based loading equipment.

The classic arguments that always must be examined on a case-by-case basis, are: 1) the limited use of high-lift devices for take-off and landing due to their pitching moments and limited elevon power to trim these, could dictate the wing area; 2) the effect of elevon deflection on span loading; the Horten bell-shaped distribution mitigates these effects for incompressible flow and a rigid wing. However, structural deformation and/or compressibility effects must also be considered.

The real intriguing aspects of the "span loader" are of a structural nature[1]. Intheory, it would be possible to achieve the compensation of air and inertia loads in 1g flight, such that shear and bending moment are zero. Then, the remaining transient gust loads, torsion and ground loads would design the wing strength and stiffness. (...remember B.Rutan's Voyager take-off ?)

So, it appears that there are places and no places for the superiority of a flying wing. Applications worth considering are sailplanes and military long range or endurance

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[1] NASA TP 1625 (1980), T.A.Toll, Parametric Study of Variation in Cargo-Airplane Performance Related to Progression from Current to Spanloader Designs.

aircraft and RPV's. The latest sailplane is the SB-13 of the Akaflieg Braunschweig in Graphite construction with an aspect ratio of 19.6 which resulted in short chord lengths, in turn necessitating a small fuselage for the pilot as for the Horten IV. Hence, strictly speaking, it is a "tailless"[2]. L/D, sink rate and other performance details have not yet been published but could be fairly easily calculated.

CANARDS & Co.

"Unconventional" as the canard popularly may be termed, it nevertheless belongs to the same "two surface" family as the conventional, or even the biplane, and as such they were treated by Ludwig Prandtl and Max Munk almost seven decades ago.

From a drag and L/D viewpoint, a comprehensive analysis was published by T. McGeer and A.Kroo[3] concluding that "the drag of the aft-tailed system remains about 5/6 (83%) of the Canard's over a wide speed range...for the same trimmed $C_{L max}$" and "Thus, the conventional arrangement has a fundamental advantage among naturally stable lifting systems; an alternative arrangement could only be competitive in an application that permitted some offsetting economy in the overall layout of the airframe".

These "side benefits" can be decisive, e.g. in the form of structural weight reductions arising from high canard up-loads during a max. g pull-out, which are opposed to the fore-body inertia loads and hence relieve the bending moments on the forward fuselage. Wing lift is reduced by the amount the canard lifts, hence wing bending moments are reduced in the same proportion, and the weight of the fuselage wing attach bulkheads, reacting the wing root bending moment, will be lighter. In other cases, a smaller combat aircraft for less material, power and fuel required might result from the canard layout, even if its drag *coefficents* are the same or slightly higher. In fact, a better area distribution resulting in lower wave drag is occasionally claimed.

The canard arrangement may be chosen to make an airplane stall-proof by letting the canard surface stall before severe wing pitch-up or stall[4]. This is achieved by selecting a canard section with low $C_{L max}$ or leading edge modification, and the proper incidence.

It would seem that the canard has an inherent advantage during take-off: it "lifts" the nose wheel off, as compared to the conventional tail which pulls "down" to produce

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2 Aerokurier, 5/1988, Nurfluegel-Renaissance ?

3 Journal of Aircraft, Nov. 1983 p.983, A Fundamental Comparison of Canard and Conventional Configurations.

4 (1) SAE Paper 850865, T.W.Feistel, Interdependence of Parameters Important to the Design of Subsonic Canard-Configured Aircraft.
(2) Journal of Aeronautical Sciences, Dec.1942, p.523, J.V.Foa, Proportioning a "Canard" Airplane for Longitudinal Stability and Safety Against Stall.

rotation, but this feature by itself hardly justifies its selection. For fighters, the combination of thrust vectoring plus canard, to modulate or trim the thrust moments, offers synergistic benefits for the entire mission profile including take-off and landing.

Inherent problem areas of the canard are its downwash and tip vortex shedding on the wing and the deleterious effects on its spanload distribution, induced drag and lateral-directional stability characteristics. But then, why is the SAAB Viggen so successful? This is a short-coupled canard (SCC) with its trailing edge located just at or behind and over the wing root leading edge, and acts as a local wing slat - a flow control device helping to maintain a nearly constant $C_{L max}$ over a range of high A.O.A. encountered in combat. The SCC concept was tested extensively at NASA and the NSRDC. Level flight cruise advantages were not specifically claimed by Viggen's proponent Hermann Behrbohm[5]. - There are of course also short-coupled tail-aft configurations, usually as an unavoidable result of an extreme far aft CG due to heavy engines in the back of the fuselage, typical for many combat aircraft. These tails work in a strong wing downwash gradient which is destabilizing; to compensate, the tail is made larger (and heavier). Now, the closeness of this larger tail to the wing causes its inboard region to work in the tail's upwash! Dragwise, this is not beneficial and a canard alternative could be studied for possible advantages.

A somewhat analogous situation can occur in a forward swept wing fighter design with the trailing edge coinciding with the end of the fuselage. The two possible locations for a horizontal tail are then a) on the vertical tail: not recommended for any maneuvering airplane because of wake immersion at high A.O.A., or b) in front of the wing: X-29 canard lay-out.

Combining a canard's best features results in a negative stability margin (SM) of about 10% MAC, i.e. the CG is 10% MAC behind the total configuration neutral point[6]. This CG location not only unloads the already highly loaded canard surface, but also closely combines highest trimmed $(L/D)_{max}$ and $C_{L max}$. This "natural instability" requires an "active" control system, i.e. FBW or FBL, something that is not yet economically available for sports and general aviation. Unstable canard deflection rates in combat maneuvers can reach ≥150 deg/sec., requiring stiff, heavy actuators, hydraulic pumps to provide high pressure and flow rates (HP), possibly with a high heat release needing a heat exchanger. Therefor, hydraulic system weight penalties for fighters limit the SM to about -15% !

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5 SAAB TN 60, (1965). Basic low speed aerodynamics of the short-coupled canard configuration of small aspect ratio.

6 Flight International, 23 Febr.1985, p.19, B.Burns, Canards,Design with Care.

A -SM can of course also be achieved in conventional tail-aft configurations; it's just a matter of CG location, wing location and tail size. Lifting tails can be obtained this way, and compete in several ways with canards, at least for combat aircraft.

The tri-surface arrangement is a true hybrid attempting to combine the best of two worlds. At least mathematically, it offers interesting ways to minimize drag due to lift of the total system[7]. But the extra complexity, especially of the control system, and possible weight and friction drag penalties cast a doubt over true, significant advantages over a clean conventional layout for the same design requirement.

CONCLUDING REMARKS.

The author has intentionally avoided to compare the performances of existing designs of the various types discussed in this paper. That has been done many times in aviation magazines and "letters to the editor"; it does not need one more time to leave readers confused. What really happens here is that these comparisons (unwillingly at that!) are always of oranges with apples. A valid comparison can only be made of designs meeting a common set of design requirements, such as for performance, common engine(s) or power, seating or payload, operating or life cycle cost, use of NLF sections, construction materials, etc. Comparisons of this kind are not easy, if at all, obtainable. Contest evaluation formulas consisting of a straight product expression (such as CAFE) are not conclusive for selecting a design concept. A concept evaluation criterion must be a ratio expression (e.g. payload x range / fuel load, within a specified speed bracket). The only thing a designer can do then, when designing a new airplane, is to investigate the alternatives in sufficient design and analytical detail to assure himself of having selected the best solution.

When making use of wind tunnel test data, make sure the data (primarily max. L/D, $C_{L_{opt}}$ and $C_{L_{max}}$) are presented for trimmed conditions and for the desired SM. As this is usually not the case, the total airplane moment coefficients (C_M) can easily be transferred to the CG (= "moment reference point") for the desired static margin, and then replotted. The trim point is always for the C_L (or AOA) and control deflection for which $C_M = 0$. Comparing trimmed to untrimmed data can be sobering !!

It is not sufficient to rate the drag of competing configurations by their trim drag increment ($\Delta C_{D_{trim}}$) alone. Since tail size is almost always involved, it is absolutely necessary to evaluate $(C_{D_{min\,tail}} + \Delta C_{D_{trim}}) \cdot S_{tail}$ instead. Even better is to compare $(C_{D_{min}} + C_{Di}) \cdot S$ of the complete configurations.

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7 AIAA Paper 87-2590, K.Goodrich, S.Sliwa , NASA L.R.C., Linear Optimum Trim Solution for Aircraft with Three Longitudinal Control Effectors