THE DESIGN AND DEVELOPMENT OF THE SPRITE SAILPLANE, 1969 - 1980

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Presented at the XVIIth OSTIV Congress
Paderborn, Germany
May 1981

ABSTRACT

This paper describes the work done to build the first British glass fiber sailplane. The design was for the Club type of sailplane and benefitted from the analytical work carried out in the course of the design of the Sigma sailplane.

The design used the "high lift" wing section linked to an aspect ratio of 20. Wide use of computer programs took place and the design was optimized for cross country performance in weak thermal conditions achieved by superior thermalling performance.

The significant points in the design philosophy, flight testing, and soaring experience are recorded. The development of the sailplane was successful in taking the initial design that fell short of its performance target and, by fine tuning, raising the flight performance to current levels for this class of sailplane.

DESIGN AND DEVELOPMENT OF THE TORVA SPRITE SAILPLANE

BACKGROUND AND INTRODUCTION

The interest in the Club glider continues. The pages of the proceedings of the OSTIV Congress contain many references to design optimization. This paper describes such a sailplane, its design philosophy, the main difficulties in its development, and comments on the experience of flying it over some nine year.

The Club sailplane has never been defined. The concept is a low cost, easy to fly sailplane of acceptable performance. Low cost is an imprecise term; it does not say with what the cost is compared. "Acceptable performance" begs the question: is the performance acceptable to one pilot acceptable to another?

The Slingsby Aircraft Company closed in 1969 and left its workforce unemployed. As a competition pilot and instructor of many years experience, I was able to establish a small company, Torva Sailplanes Ltd., to employ some of those people to design and build a Club type of sailplane that I believed the market wanted. I built into the specification my own thoughts for the development of the Sport. The design was to have superior thermalling capability in temperate climates and an uncomplicated design.

J.L. Sellars joined the company as Technical Director. He had been associated with the Sigma Project at Slingsbys and was familiar with the work that had been done on that design. Later other ex-Slingsby people joined us, notably Norman Ellison and Harry Luck. We set about building the Torva Sport 15-meter sailplane - the first British designed and built glass fiber sailplane.

In all, three sailplanes were constructed. The Sport was flown by John Williamson in the 1971 British Nationals at Husbands Bosworth, and was later used for structural tests on the wings and forward fuselage. The Sport had a retractable undercarriage and wing trailing edge flaps .

The Sprite, of which two were built, was a simplified form of the Sport. We fitted a fixed undercarriage and removed the flaps. The wing incidence was increased and a small pneumatic wheel was fitted to the forward fuselage in place of a rubbing skid. These two sailplanes are still in service.

DESIGN CONCEPTS

As a designer and industrial engineer, I understood the need for volume in low cost production. As a manager, I appreciated the need for the sailplane to have as large a sale market as possible. We therefore introduced the concept of a family of three sailplanes within the one basic design. Considerable interest was aroused in the idea and I notice it is now common.

At Slingsbys, Sellars had seen the opportunity to advance sailplane performance in the lower speed range by use of the high lift wing section.

He pointed out that the two independent variables in sailplane performance were span and aspect ratio. Since span was fixed by the definition of the type of sailplane, he turned his attention to defining the aspect ratio for "Optimum Performance" measured by cross country speed using the McCready formulae in a range of thermal sizes and strengths.

He argued that a glider should be circled at its "Ideal Lift Coefficient" ($C_{l ms}$) which gives the minimum sinking speed in straight flight or any radius of turn. This lift coefficient is defined:

$$C_{l ms} = \sqrt{\frac{3\ A.C_{do}}{k}}$$

where A = Aspect ratio
C_{do} = Profile Drag
k = induced factor 1.05-1.10

Sellers went on to point out that it is necessary to have a safety margin of 15% in circling speed above the stall speed.

$$C_{l ms} = \frac{C_{l max}}{1.15}$$

The use of conventional sections having $C_{l max} = 1.4$ or so limits the aspect ratio to quite low values. As the aspect ratio rises, so does the wing loading; to get good thermalling performance may require C_l values above the capacity of the wing section.

Thus, if the lift coefficient could be increased, the thermal performance would improve and the higher wing loading would provide a better glide angle at higher speeds. However, this was not thought to be possible over the low drag range of the available sections. This range is defined:

$$\frac{\text{Max low drag speed}}{\text{Stalling Speed}} = \sqrt{\frac{C_{l max}}{C_l \text{ at lower end of drag bucket}}}$$

for the conventional section this approximated to:

$$= \sqrt{\frac{1.4}{0.1}} = 3.75$$

In a Club glider the emphasis is on the ease of thermalling, not racing; this speed ratio could be replaced without any significant fall in pilot enjoyment.

Once the rate of climb is known then the best speed to fly between thermals is easily derived from the Polar Curve.

A further 5 kts are added as a margin and the maximum low drag speed can be defined for each span and aspect ratio.

The conclusion was that a wing section $C_{l max}$ of 1.75 at an aspect ratio of 20 was the optimum value. There was the added advantage of "Structural Compaction" that favored higher strength materials, and this was achieved at the same time as improved circling performance. A good cruise performance was possible if the sailplane was flown below 70 to 80 kts.

These conclusions are demonstrated in Figures 1 and 2. Figure 1 shows the now familiar comparison of climbing performance within the formalized Goodhart Standard Thermal (Ref. 1 and 2). Were other formats to be used, the relationship would be retained but the climb rates would change.

Figure 2 shows how this theory works out in a cross country flight. The cross country speed of the Sprite and a datum glider of the time were compared

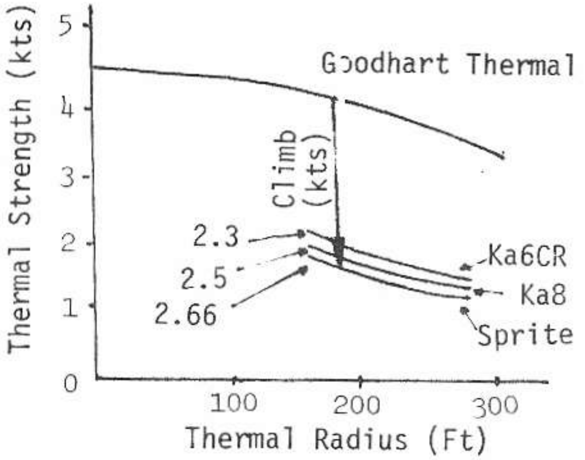

Fig. 1 Sailplane Thermal Climb Comparison

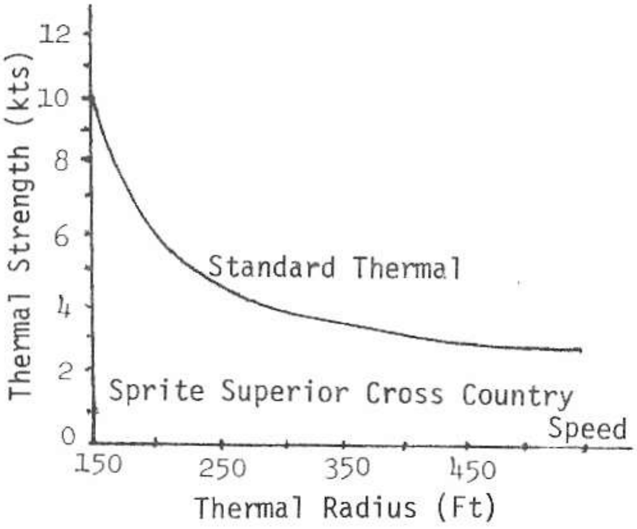

Fig. 2 Exchange Curve for Cross Country Performance at 840 lbs

using the Sigma computer program. The maximum cross country speeds possible by the two gliders were compared in a wide range of thermal sizes and strengths. The line records the points where the cross country speed of the two gliders are the same. It follows that if conditions are weaker than this value, the Sprite will go faster by virtue of its superior thermalling ability. However, if the thermals are better than the point on the line suggests, the datum glider will go faster by virtue of its better glide angle at speed. This representation is sometimes known as an "Exchange Curve."

Figure 3 shows the relation between the optimal cross country flying speed and the maximum average cross country speed over the ground by the sailplane.

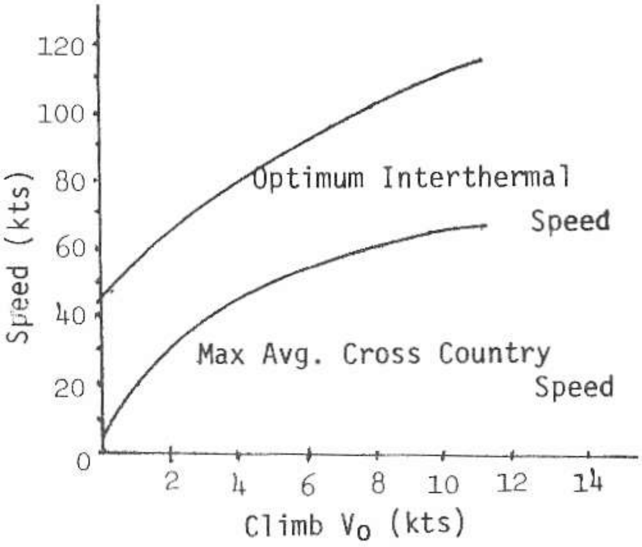

Fig. 3 Interthermal Speed and Average Cross Country Speed

SELECTION OF WING SECTION

A high lift section designed by Dr. Wortmann was chosen. As there was no data for the modifications that Sellars proposed, we made up a flapped model and tested it in the Imperial College London wind tunnel (Ref. 3). The results were satisfactory and indicated a $C_{l\max}$ in excess of 1.6 with zero flap and a R_e of 10^6.

FUSELAGE FORM

Glass Reinforced Plastic had been selected as this allowed the structure to conform closely to the mathematical shape required for minimum fuselage drag. The forward fuselage section conformed to a cubic equation, while the rear of the fuselage was elliptical.

To produce a smooth transition from one form to the other required care. Manual drafting methods would not give the necessary accuracy, so it was decided to use the Computer Aided Design Center facilities recently established at Cambridge. Their "Multipatch" program was used after further development by them.

DEVELOPMENT RECORD

The man hours required to carry out the design and construction of the prototype sailplane were estimated as follows:

Activity	Designer	Draftsmen	Works	Sub-contract
Preliminary Research	280	400	168	253
Prototype Design	1040	680	–	–
Prototype Mfr.	–	–	2500	756
Certification	400	560	1050	336
Totals: 8422	1720	1640	3718	1344

The Sprite first flew in February 1972 and I then commenced the test flying program for B.G.A. Certification. The development phase of any new aircraft is often uncertain and, at times, extended. The Sprite flew well but there were a number of points that needed attention in the area of pilot comfort and instrumentation. In addition, there were three unusual points that I feel I should mention.

LONDITUDINAL STABILITY

In the course of the flight testing to establish the center of gravity limits and the stabiity criteria for the sailplane, it was noted that the londitudinal stability was divergent, i.e., unstable at speeds above 80 kts.

This was due to a resonant oscillation between the fuselage structure and the elevator circuit. The frequency was 0.67 hz, but the elevator circuit contained no damping. Springs were fitted to the elevator push rod; this took out the pitching oscillation, but the stick loads were too high. Softer springs were fitted and the oscillation was again damped, but the stick forces remained light.

DIRECTIONAL CONTROL

The rudder cables were carried through flexible outer sleeves under the cockpit seat. Under load, the friction of the cable in the sleeve rose significantly. This had the double effect of indicating a very heavy rudder and providing a slow response in sideslip, suggesting rudder lock.

At first it was thought that the loads were induced aerodynamically and a dorsal fin was fitted. Apart from disfiguring the sailplane this had no noticable effect at all. When the rudder cables were removed from these sleeves and run over pullys, the improvement was marked. The dorsal fin was removed.

UNDERCARRIAGE

A rubber suspension was fitted to the undercarriage and this worked well. The Sprite design had a small forward pneumatic wheel in place of a skid and a steel spring at the tail. On two occasions when landing on metalled runways, a violent pitching oscillation was set up that was not only most unpleasant, but also uncontrollable. Two fore and aft periods of motion were experienced before the front tire burst, thus breaking the loop.

The front tire was replaced by a rubbing strip, while the tail skid was removed and a semi-embedded 200 x 50 mm wheel fitted. Both appearance and ground handling were improved.

PERFORMANCE IMPROVEMENT

This activity consumes by far the greatest proportion of the time in developing a new design. Thus, it is often left to the first owner to add the fine finish and sealing of the structure that gives the edge to the sailplane.

NOISE – Noise is a source of inefficiency. The Sprite was noisy. The cockpit area was sealed but the main flow of air was up through the wheel well and out through the rear of the wings to the airbrakes and ailerons. Sailcloth seals were therefore fitted to the push rod controls; leakage holes were sealed and the clearance at the extremes of the ailerons reduced. The wheel well was sealed by fitting a larger wheel fairing and adding a flexible leather/cloth panel between the rigid fairing and the wheel cover.

At that point the sailplane's noise level was reduced, but it was found that a significant source of noise was generated by the flow between the fuselage and the root of the all-moving tailplane panels. This area is cut away to allow the servo tab linkage to work; this induced a gentle "swish" dimension to the sailplane's flight.

WING CONTOUR - The surface was filled to achieve a roughness of less than 0.002" in a two inch gauge length.

AIRBRAKES - They were a source of difficulty as they tended to suck out in flight. On investigation, it was found that although the system locked overcenter, the airbrake was some way on from the lock and was therefore capable of lifting under reversed movement. Some slight deflections of the supporting airframe structure amplified this effect. The overcenter lock was therefore improved and the difficulty overcome.

AILERON COUPLING - Flight tests confirmed that the stalling speed at 37 kts was higher than expected. The cause was not clear and was put down to the all-up weight of the sailplane. One day I noticed that when the control column was in the fully aft position the ailerons were both raised above the trailing edge, while with the column fully forward the ailerons drooped. Clearly this action was having a degrading effect on the glide performance.

The ailerons are driven from a tree on the rear of the elevator push rod - a common layout at the time - and to do this the elevator rod is stabilized by a small vertical linkage from the floor of the fuselage shell.

The elevator push rod geometry was corrected by repositioning and lengthening this link to allow the ailerons to rise with increasing speed. The glide angle was much improved as was the stall. A wing max C_l value of 1.65 was achieved.

Comparison flights with other types of sailplanes showed that the polar (Fig. 4) was as good as and in some cases superior to other designs of the time.

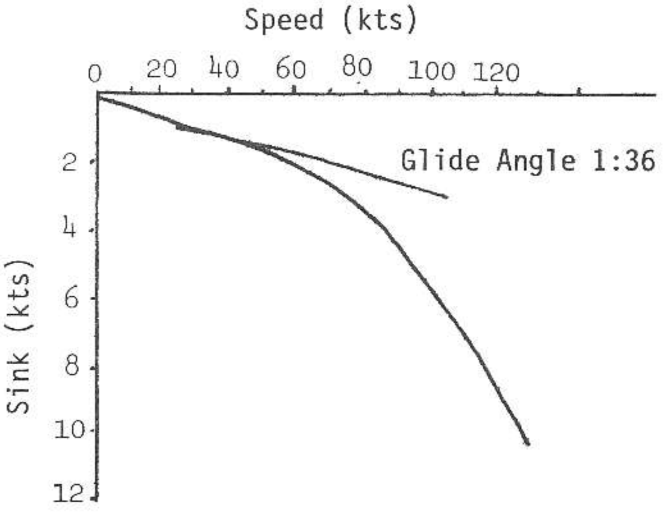

Fig. 4 Polar Curve: Sprite Sailplane, 830 lbs, W/S = 6.9 lbs/ft^2

CROSS COUNTRY EXPERIENCE

Early flights confirmed the ability of the design to climb well in thermals. At angles of bank between 30-40° the high lift coefficient worked well, and the design still outclimbs most sailplanes and reflects the situation shown in Figure 3. This ability allowed the sailplane to start soaring earlier in the day and to continue later in the evening.

Until the aileron geometry was corrected, the glide angle was disappointing, but since then many cross country flights have been carried out in weak conditions. In competitive conditions the cross country performance has been satisfactory.

In the North of England, hill and wave soaring is common, with sea breeze fronts in the summer months. The Sprite has proved to be an effective soaring machine. The ability to climb away from low levels has provided added pilot confidence.

The high speed performance was thought to be a problem when flying in high waves, but the improvements made in this area have produced an ability to make good progress against head winds of 30 kts and more – necessary in wave conditions. Dick Johnson suggests that an achieved glide ratio of 1:20 is sufficient to find the next thermal with an adequate degree of confidence (Ref. 4).

SUMMARY

After some ten years of development, the design can now be said to have achieved the performance targets that Sellars and I set for it when we started out on this program. There is no doubt in my mind that the wing section was well chosen.

The design of a wing with little drag penalty at these very high C_l values has been shown in the Sprite to provide a step forward in the evolution of the Club sailplane.

As an experienced competition pilot, I expected to find that the performance would not be good enough to satisfy me. But, soaring achievement is mostly a matter of the quality of the pilot's decisions. The absence of a very low sink rate at 100 kts has not worried me nor diminished my enjoyment of soaring: With the Sprite it has increased.

I should like to thank all the people who have helped in this project.

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2. Irving, F.G., "Computer Analysis of the Performance of 15-Meter Sailplane Using Thermals with Parabolic Velocity Distribution," OSTIV XI.
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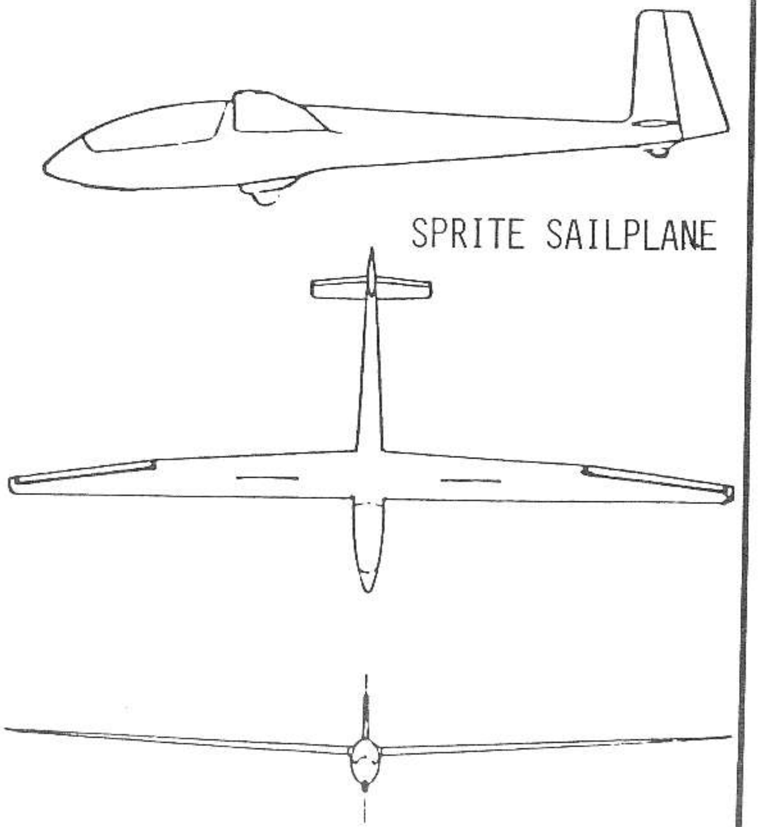
Span	15.0 m	49.2 ft
Wing Area	11.3 m^2	121.5 ft^2
Aspect Ratio	20	
Empty Weight	273 kg	600 lbs
Max Weight	378 kg	830 lbs
Wing Taper	0.35	
Dihedral	3.0°	
Wing Twist	-2.0°	
Aileron Chord/Wing Chord	20	
Horizontal Tail Arm	4.05 m	13.33 ft
Tail Volume	0.5	
Tail Area	1.06 m^2	11.35 ft^2
Tail Span	2.5 m	8.25 ft^2
Tab Chord/Tail Chord	20	
Vertical Tail Arm	4.17 m	13.67 ft^2
Fin Volume	0.024	
Fin Span	1.27 m	4.15 ft
Fin Area	0.97 m^2	10.40 ft^2
Rudder Chord/Fin Chord	50	
Fuselage Length	7.1 m	23.3 ft
Max Width	0.61 m	24.0 in
Max Depth	0.89 m	35.0 in
Area of Max. Cross Sec.	0.43 m	4.6 ft
Wetted Area	10.0 m^2	108 sq ft
Center of Gravity	9.3 in to 14.3 in (236 mm to 368 mm) aft of wing L.E.	



SPRITE SAILPLANE

Winch Launch	65 kts	120 kmhr	Never Exceed	117 kts	216 kmhr	Max L/D	38.1	
Aerotow	80 kts	148 kmhr	Stall Speed	34 kts	60 km/hr	Max L/D Speed	46 kts	85 km/hr
Rough Air	80 kts	148 kmhr	Min Sink	1.1 kts	63 km/hr			

Design Loads Factors on Ultimate +8.25 -5.0