

The Design and Development of the Sprite Sailplane 1969-1980

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Background and Introduction

The interest in the "Club" glider continues. The pages of the proceedings of the OSTIV Congresses, contain many references to design optimisation. 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 years.

The "Club" sailplane has never been defined. It is a concept of a low cost, easy to fly sailplane of acceptable performance. Low cost is an imprecise term, for 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? Only time will tell.

In 1969 I established a small company Torva Sailplanes Ltd to design and build a "Club" type of Sailplane that I believed the market wanted. The sailplane was to have superior thermalling capability in temperate climates and to be of uncomplicated design. With J.L. Sellars as Technical Director, Norman Ellison and Harry Luck, we set about building the Torva Sport 15 metre sailplane - the first British designed and built Glass Fibre Sailplane.

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

The Sprite, of which two were built, was a simplified version having fixed undercarriage and no 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.

Fig. 1 shows the General Arrangement, and Table 1 gives dimensions and performance data.

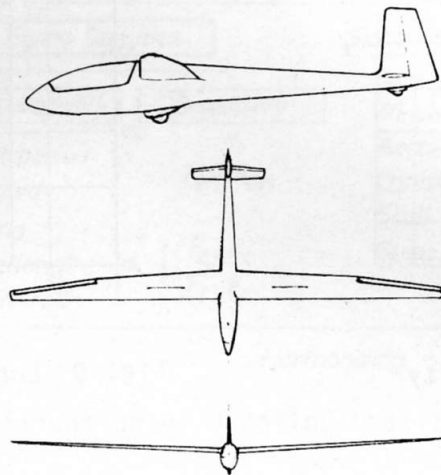


Fig. 1 General Arrangement Drawing.

Table 1

General	
Span	15.0 m 49.2 ft
Wing Area	11.3 m ² 121.5 ft ²
Aspect Ratio	20
Wing Taper	0.35
Dihedral	3.0°
Wing Twist	-2.0°
Aileron Chord/Wing Chord	20%
Empty Weight	273 kg 600 lb
Max. Weight	378 kg 830 lb
Horizontal tail	
Tail Area	1.06 m ² 11.35 ft ²
Tail Span	2.5 m 8.25 ft
Tail Arm	4.05 m 13.33 ft
Tail Volume	0.5
Tab Chord/Tail Chord	20%
Vertical tail	
Fin Span	1.27 m 4.15 ft
Fin Area	0.97 m ² 10.40 ft ²
Fin Arm	4.17 m 13.67 ft
Fin Volume	0.024
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 Sect.	0.43 m ² 4.6 ft ²
Wetted Area	10.0 m ² 108 ft ²
Centre of Gravity	9.3 in to 14.3 in (236 mm to 368 mm) aft of wing L.E.
Operating Speeds etc.	
Winch Launch	65 kt 120 km/hr
Aerotow	80 kt 148 km/hr
Rough Air	80 kt 148 km/hr
Never Exceed	117 kt 216 km/hr
Stall Speed	34 kt 63 km/hr
Min. Sink	1.1 kt 0.57 m/sec
Max. L/D	38:1
Max. L/D Speed	46 kt 85 km/hr
Design Load Factors on Ultimate	+8.25 -5.0

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 wide a sale 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 that it is now common.

Sellars 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 deciding the Aspect Ratio for "Optimum Performance" measured by cross country speed using the "Macready" formulae in a range of thermal sizes and strengths. He argued that a glider should be circled at its "Ideal Lift Coefficient" (C_{lms}) which gives the minimum sinking speed in straight flight or any radius of turn, equal to

$$C_{lms} = \sqrt{\frac{3 A C_{do}}{k}}$$

where A = Aspect ratio

C_{do} = Profile Drag
= induced factor
1.05-1.10

In addition it is necessary to have a safety margin in circling speed above the stall speed of some 15%, so that

$$C_{lms} = \frac{C_{lmax}}{1.32}$$

The use of conventional sections having $C_{1max} = 1.4$ or so limits the Aspect Ratio to quite low values. As the aspect ratio rises, so does the wing loading and to get a good thermal performance may require C_1 values above the capacity of the wing section.

It was found that a section C_{1max} of 1.75, allowing an Aspect Ratio of 20, was the optimum value. There was the added advantage of "Structural Compaction" that favoured 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.

To demonstrate these conclusions Fig. 2 and 3 have been drawn up. Fig. 2 shows the now familiar comparison of climbing performance within the formalised Goodhart Standard Thermal. (Ref. 1, 2.) Were other formats to be used, the relationship would be retained but the climb rates would change.

Fig. 3 shows how this theory works out in a Cross Country Flight. The Cross Country speeds of the Sprite and of a datum glider of the time were compared, using the Sigma computer programme, in a wide range of thermal

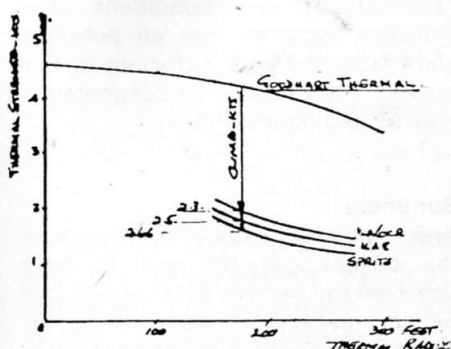


Fig. 2 Sailplane Thermal Climb Comparison.

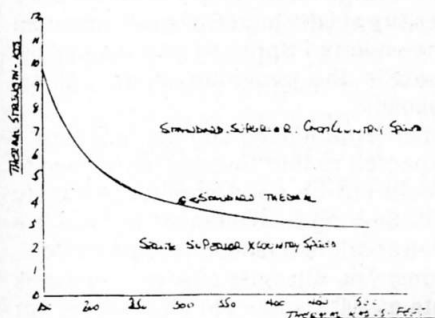
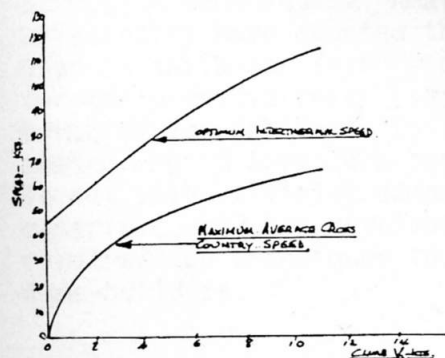


Fig. 3 Exchange Curve for Cross Country Performance.

sizes and strengths. The line records the strengths where the cross country speeds of the two gliders are the same. It follows that if conditions are weaker the Sprite will go faster by virtue of its superior thermalling ability. However if the thermals are better the datum glider will go faster by virtue of its better glide angle at speed. This representation is sometimes known as an "Exchange Curve".

Fig. 4 shows the relation between the optimal cross country flying speed and the maximum average cross country speed over the ground by the sailplane.

Fig. 4 Interthermal Speed and Average Cross Country speed.



Selection of Wing Section

A modified Wortmann high lift section was chosen. As there were no data for the proposed modifications, we made up a flapped model and tested it in the Imperial College wind tunnel (Ref. 3). The results were satisfactory and indicated a $C_{1 \max}$ 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 development by "Multipatch" programme the recently established Computer Aided Design Centre at Cambridge the "Multipatch" programme developed by the recently established Computer Aided Design Centre at Cambridge.

Development Record

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

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

The Sprite first flew in February 1972, and the test flying for B.G.A. Certification was then commenced. 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. They were concerned with pilot comfort and instrumentation. In addition there were three unusual points that should be mentioned.

Longitudinal Stability. In the course of the flight testing to establish the centre of gravity limits and the stability criteria for the sailplane, it was noted that the longitudinal 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 therefore fitted to the elevator push

rod and this was found to take out the pitching oscillation but the stick loads were too high. Softer springs were therefore 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 side slip 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 noticeable effect. When the rudder cables were removed from these sleeves and run over pulleys, 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 forward small pneumatic wheel in place of a skid, and a steel spring at the tail. On two occasions when landing on metallised runways, a violent pitching oscillation was set up that was not only most unpleasant but was also uncontrollable. Two fore and aft periods of motion were experienced be-

fore the front tyre burst thus breaking the loop.

The front tyre 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, and it is thus often left to the first owner to add the fine finish and the sealing the structure that gives the edge to the sailplane.

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 was reduced. The wheel well was sealed by fitting a larger wheel fairing and adding a flexible leathercloth panel between the rigid fairing and the wheel cover.

The Sailplane was now much less noisy, but it was still not silent. It was found that a significant source of noise was 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 and 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 were a source of difficulty for they tended to suck out in flight. On investigation it was found that although the system locked over centre, the airbrake was some distance from the lock and was therefore capable of lifting under reversed movement. Some slight deflections of the supporting airframe structure amplified this effect. The overcentre 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 but one day it was 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 stabilised 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_1 value of 1.65 was achieved. Comparison flights with other types of sailplanes showed that the Polar (Fig. 5) was as good as and in some cases superior to other designs of the time.

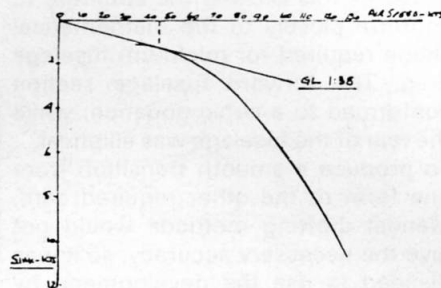


Fig. 5 Polar Curve (830 lb.)

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 Fig. 4. This ability allowed the sailplane to start soaring earlier in the day and to last longer in the evening. Until the aileron control geometry was corrected the glide angle was disappointing, but since then the Sprite has proved to be an effective soaring machine many cross country flights having been carried out in weak conditions. In competitive conditions the cross country performance has been satisfactory, the ability to climb away from low levels having given added pilot confidence.

The high speed performance was thought to be a difficulty 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 – very 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 be said to have achieved the performance targets that Sellars and I set for it when we started. There is no doubt in my mind that the wing section was well chosen.

The design of a wing with little drag penalty at very high C_1 values has been shown in the Sprite to give 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. Soaring achievement is mostly a matter of the quality of the pilots 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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