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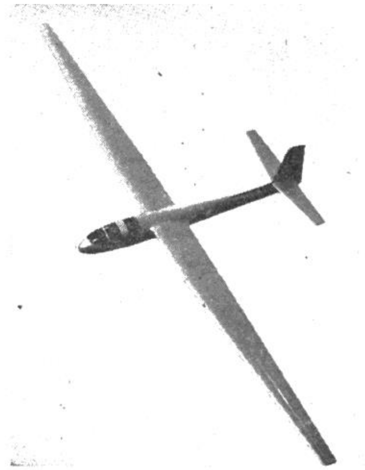


Motorless Flight in the Stratosphere

Compiled by BETSY WOODWARD. *Publications Committee, "Organisation Scientifique et Technique Internationale du Vol à Voile"—(O.S.T.I.V.)*

AT the 6th OSTIV Congress, St. Yan, France, in July, 1956, a symposium on "The Stratospheric Sailplane" was held during a joint session of the Meteorological and Technical Sessions. The primary speakers were Dr. Joachim Kuettner, Mr. Victor Saudek and Ing. R. Cartier.

Flying in mountain lee waves, sailplanes have reached the stratosphere, and above, over the Sierra Nevada in California. A dozen flights have been made above the 40,000-ft. (12 km.) level; the highest obtained was 44,500 ft. At this altitude the sailplane was rising 700 ft./min. (3.5 m./sec.) but was forced to leave the lift area as the maximum height without pressurization had been reached.

It appears that flights to 60,000-70,000 ft. are possible and it has been proposed that sailplanes provide the least expensive and most satisfactory means of exploring the atmosphere at these levels.

Several flights above 30,000 ft. have been made in such waves in various parts of the World (notably France, New Zealand and Austria) but the best-known and explored is the Sierra Wave (or Bishop Wave) in California. During the Sierra Wave Project and the Mountain Wave/Jet Stream Project, centred at Bishop,* California and sponsored by the Geophysics Research Division (GRD) of the U.S. Air Force Cambridge Research Center, considerable meteorological data was obtained.

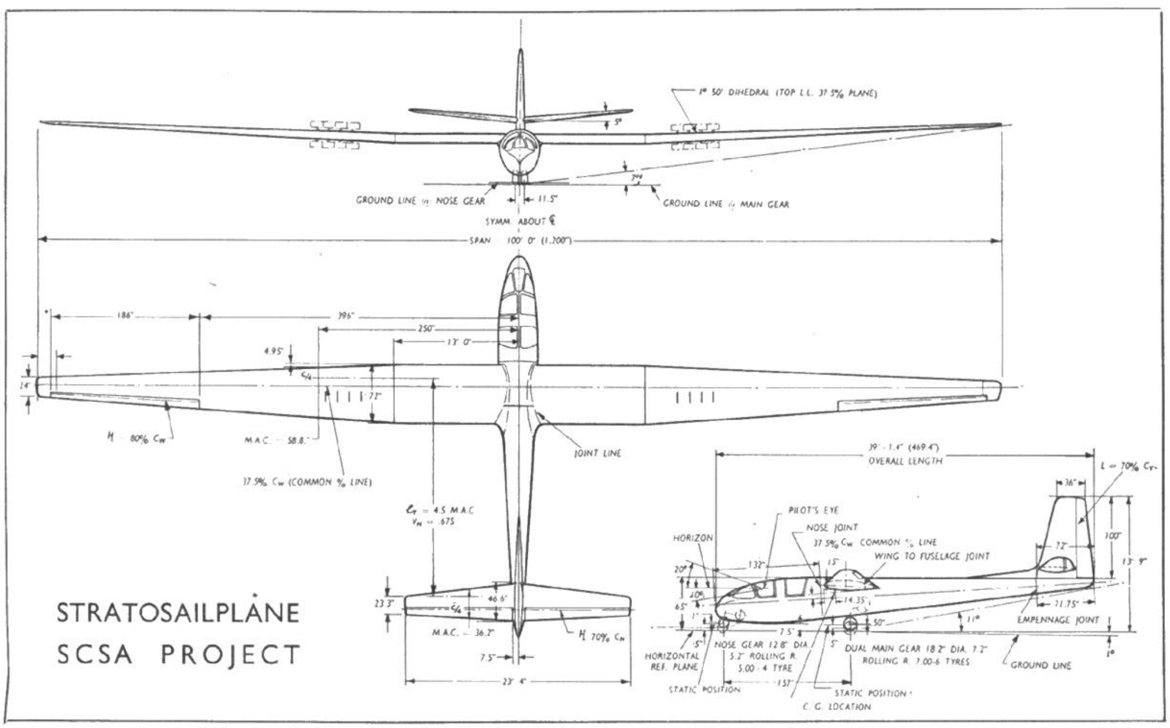
Dr. Joachim Kuettner of GRD has summarized the meteorological problems which must be considered when designing a high-altitude sailplane.

Temperature

A primary problem of sustained sailplane flights above 35,000 ft. (10.7 km.) is the extreme cold. The outside temperature reaches a minimum at the tropopause; under Sierra Wave conditions of the south-westerly type 35,000 to 39,000 ft. is a good average for the height of the "trop," which, however, can drop as low as 25,000 ft. (7.6 km.) after the passage of the associated cold front. Outside temperatures of −76° C. (−105° F.) have been recorded on several flights and the inside temperature (of the instrument panel) has been −46° C. (−50° F.). Under these conditions most of the standard instrumentation and the dry batteries, not to mention the crew itself, are severely affected. So are many of the vital parts of the glider, such as the spoilers and dive-brakes. When the latter become inoperative due to low temperatures, descent from a height between 40,000 and 45,000 ft. (12.3-13.8 km.) can be a major problem. The updraught area at this level is very wide and useful downdraughts are not found either upwind or downwind of the area. One must therefore descend by increasing the sinking speed of the sailplane. Lacking operative spoilers, the pilot has to achieve this by increasing the forward speed. However, with a modern high-performance glider of the "flat-polar" type, sufficient sink may only be obtainable at too high a speed.

To descend downwind may necessitate flight through thick cloud layers and the effect of the low temperatures on many instruments and on the power supply enhances the danger of blind flight. On March 29, 1955, during the first high-altitude flight of the Schweizer 2-25, the spoilers and the turn-and-bank indicator failed at 40,000 ft. Penetration upwind over the Sierra for more than 10 miles beyond the crestline did not give any sink. In fact the glider was being carried upwards when flying at about 90 m.p.h. (145 km.p.h.) indicated. Flying in the opposite direction cirrus layers were encountered. At this

* Sixty miles north of Mount Whitney.



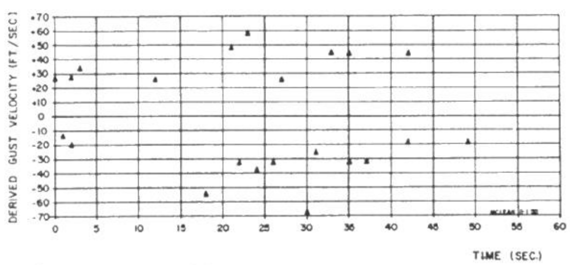


Fig. 1. Severe turbulence measured in rotor-cloud area by flight analyser of B-29 over Bishop, California, at 17,500 feet, April 1, 1955. Derived vertical gust velocities (NACA formula) in excess of $\pm$ 30 feet per second occurred 13 times within 50 seconds; the maximum gust measured was 69 ft./sec. negative.

point the airspeed indicator stopped working. An old German gyro, modified for attitude and bank, remained operative and was used. Emerging from cloud just east of the White Mountains and 20 miles downwind from Bishop, penetration toward the Bishop Airport proved almost impossible even from an altitude of over 35,000 ft. (10.7 km.). Below 20,000 ft. (5.9 km.) an indicated speed of 110 m.p.h. (177 km.p.h.) was required to brush over the crest of the White Mountains.

On another occasion, when at 43,000 ft. (13.1 km.), three factors aggravated the situation. First, the spoilers locked due to low temperatures, secondly, the oxygen exhaust-valve froze, and finally the rate of ascent was only 100 ft./min. (0.5 m./sec.), indicating a long flight if the 44,000-ft. level was to be passed. Descent was started but was so slow that the half-hour above 41,000 ft. on this day may have been close to the safe limit.

The wide range of temperature variation which is encountered on a flight is especially bad. During the tow, records showed inside temperatures of 92° F. (33° C.), even with full ventilation. Cockpit temperatures dropped to between −30° F. (−34° C.) and −50° F. (−45° C.). On the descent there was a reversal of inside and outside temperature. The temperature span inside the cockpit may reach as much as 150° F. (over 80° C.).

Turbulence

While the lift encountered in the wave proper is, in general, extremely smooth, excessive turbulence can be encountered in the rotor zone (up to about 20,000 ft. = about 6 km.). To record $+4$ to $+6g$ and -2 or $-3g$ on the accelerometer while on tow in this area is not uncommon. The area downwind and below the first rotor-cloud is generally wildly agitated, with a maximum of turbulence near the cloud base and its leading edge. On April 1, 1955, a day not considered particularly turbulent by wave flight standards, the B-29 which was assigned to the Jet Stream Project, flew for about an hour over Bishop between 10,000 and 20,000 ft. (3 and 6 km.). Evaluation of the flight analyser record shows severe turbulence at 17,500 ft. (5.3 km.) (Fig. 1).

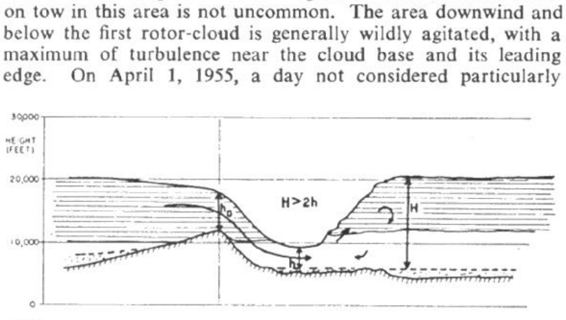


Fig. 2. Hypothetical airflow in the rotor-cloud. Upper picture: "breaking hydraulic jump" with severe turbulence. Lower picture: more common cases of "undular hydraulic jump." A temperature inversion replaces the free surface.

On April 25, 1955, when flying the Project's Pratt-Read sailplane which is stressed for $10g$, pilot Larry Edgar entered a small cloud puff at 14,000 ft. (4.3 km.) that had rapidly formed in front of the main rotor-cloud. Structural failure of the glider occurred and Edgar landed by parachute. He estimates entering the cloud with about 65 knots (120 km.p.h.) indicated. Unless the sailplane makes a high-speed stall, an acceleration of $10g$ requires a minimal airspeed of $\sqrt{10}$ times the stalling speed (which had been previously measured, for the Pratt-Read, to be slightly below 40 knots). It must then be expected that the airspeed increased to over 120 knots, perhaps 150 knots (about 270 km.p.h.). The corresponding true gust velocity would lie somewhere between 90 and 150 ft./sec. with a vertical component of the same order.

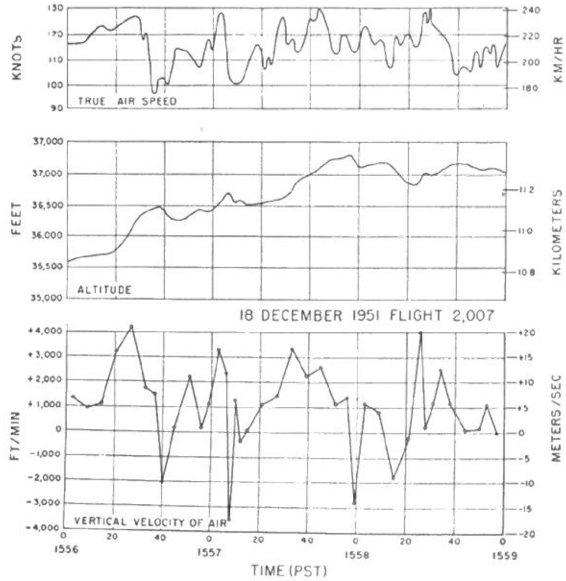


Fig. 3. Indicated altitude, rate of climb and airspeed *vs* time during a portion of a flight on December 18, 1951, when high-altitude turbulence was encountered.

Kuettner in the Schweizer 2-25 flew through the turbulent area a half-hour before and 5 miles north of the accident location. While attempting to keep the speed down to 45 m.p.h. (72 km.p.h.) by maintaining an increasing "nose-up" position, the airspeed reached 80 m.p.h. (129 km.p.h.) indicated, by which time control was lost due to a high-speed stall at about $4g$. After recovery the event repeated itself immediately with stronger intensity. Following short readings of 1,600 ft./min. (8 m./sec.) up, then 1,000 ft./min. (5 m./sec.) down, the speed increased from 45 to 90 m.p.h. (72 to 145 km.p.h.) in a matter of about 2 seconds in spite of the extreme nose-up position. At $4\frac{1}{2}g$ the ship again stalled.

Taking into account the decelerating action of the climb attitude, which is smaller than $1g$, and of the drag, the horizontal gust velocity encountered in the 2-25 must have reached about 60 m.p.h. (25 to 30 m./sec.). Considering the vertical and lateral components, the gust velocity could have been considerably higher. The load factor of the Pratt-Read must have reached the order of $15g$ if the gust encountered was about 85 knots (40 to 45 m./sec.). This is likely as it flew in the more violent section to the south. It thus appears that, under the special conditions illustrated in Fig. 2 (upper picture) gust velocities of 100 to 150 ft./sec. (30 to 45 m./sec.) might be experienced when crossing the leading edge of the roll cloud slightly above the level of the mountain crest.

Severe turbulence can be encountered near the tropopause. Fig. 3 shows indicated altitude, rate of climb and speed *vs*

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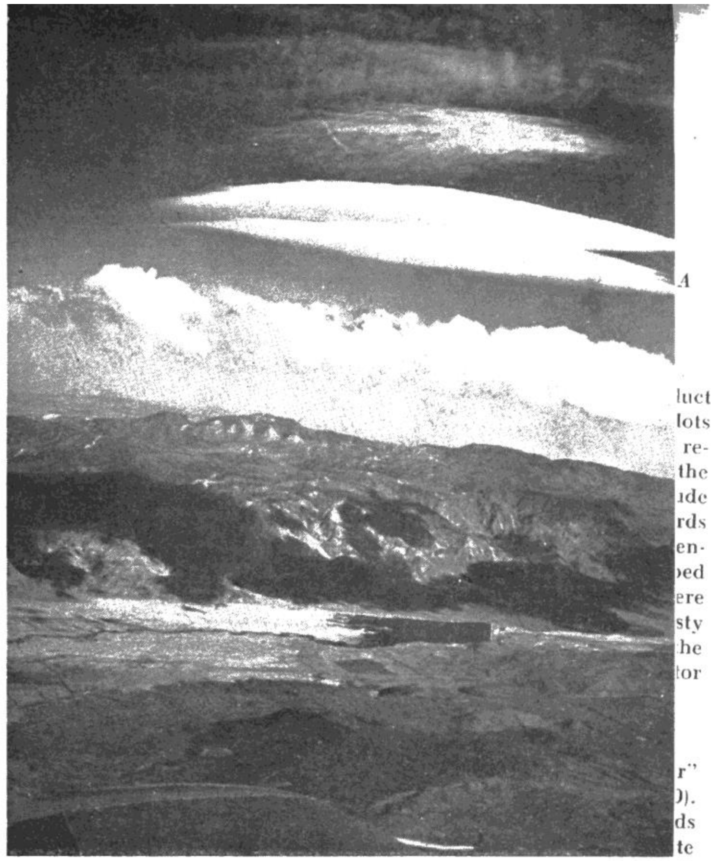

Photographed by Betsy Woodward from 20,000 feet when flying over the Sierra Nevada in California. The smooth cloud in the centre is a lenticular or wave cloud. Below is the rotor or roll cloud, an area generally associated with turbulence.

time for a portion of one flight when measured accelerations were $+3g$ and $-2.5g$ at an indicated speed of 60 m.p.h.

Performance Requirements

The maximum horizontal wind speed occurs in the jetstream in the neighbourhood of 35,000 ft. (about 11 km.) at Bishop, and under strong wave conditions averages approximately 100 knots (about 50 m./sec.). An indicated airspeed of 60 knots is necessary in order to retain position. To penetrate into the wind without losing a great deal of height, a sailplane with a flat polar is required. At 40,000 ft. the wind generally decreases, as does the vertical velocity. Minimum sink of the sailplane, instead of penetration, is now the prime requisite. At 45,000 ft. a sailplane, with a sinking speed of 2 ft./sec. at sea level, will have a true sinking speed of 4.2 ft./sec.

* * *

Mr. Victor Saudek, Project Supervisor, Sierra Wave Project, in his OSTIV paper discusses and describes the design features of two similar sailplanes proposed for meteorological research operations at altitudes above 60,000 ft. (18 km.). The designs presented here were prepared by the Southern California Soaring Association, Inc. (SCSA), under sub-contract from the University of California as part of the activities of the Mountain Wave Project which was sponsored by the Geophysics Research Division of the Air Research and Development Command of the U.S. Air Force.

A great part of the engineering work involved in these proposals was performed by personnel of the Del Mar Engineering Laboratories at their facilities at Los Angeles, California, under the direction of Mr. Bruce Del Mar.

High Altitude Exploratory Devices

The justification for the existence of soaring craft to ascend to or beyond, 65,000 ft. (20 km.) should be their ability to collect needed information that is otherwise practically unobtainable. In a broad sense the research sailplane is a calibrated instrument, a tool to perform its tasks in an effective manner and for a reasonable cost.

There are several ways to explore the atmosphere at the altitudes considered: these include balloon, aeroplane and rocket sounding devices, both manned and unmanned; and the sailplane.

The sailplane offers unique advantages which are reviewed here. It can be used to attain great heights by exploiting the very conditions that are being measured. It can remain at altitude for many hours and can there traverse the areas of interest either ranging afar or concentrating its search. Compared to the balloon, it is re-usable, can be directed and redirected through wind fields and has proved itself able to cope with very severe weather conditions. The sailplane can survey the fine structure of atmospheric motions at flight speeds slow enough to sense significant detail.

Aeroplanes capable of the considered high altitudes are expensive to build and to maintain, and the evaluation of the data obtained is complicated by varying thrusts and weights.

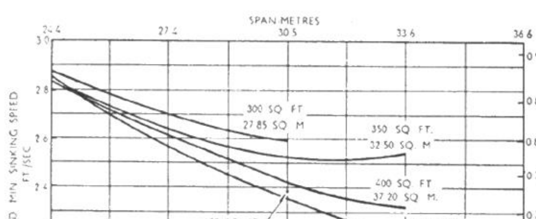

Fig. 4. Comparative performance of stratosailplane with a 2,000-lb. fuselage: Indicated minimum sinking speed vs wing span for various wing areas.

Rocket sondes are extremely expensive, short-lived and, due to their enormous speed, are not suited for detecting wave forms and other textural details of the air flow.

Thus, it may be seen that the stratosailplane has a rightful place in the arsenal of high-altitude research vehicles.

The Cabin of the SCSA Stratosailplane

Since the cabin is the "payload" its size and weight define, to a great degree, the remainder of the aircraft. A crew of two, pilot and scientist-observer, would be carried in tandem. As the cabin is a self-contained unit and houses a great many sensitive instruments, it is not only feasible to construct it as a capsule, it is obvious that there is much to be gained if it is made easily detachable from the rest of the aircraft.

For good measure, it provides an effective means for escape from a damaged or uncontrollable aircraft at high altitude. In the latter case the cabin, with its oxygen system attached, can be jettisoned from the airframe; it would then deploy a stabilizing parachute so that the crew can jump at a lower, safer, altitude. The lightened cabin might even be relatively intact after it strikes the ground so that salvage of equipment should be worthwhile.

Cabin structure is all metal except for the seals and special clear acrylic windows (Plexiglas, which is made to be quite opaque to ultra-violet radiations). The flush-riveted formed aluminium-alloy skin (24 ST3) is supported by Z-shaped frames in the conventional manner. All seams are rendered pressure-tight by using a suitable caulking compound. The transparent canopy is formed of seven pieces of clear plastic, none larger than the maximum recommended for pressure cabins.

Research instrumentation, oxygen equipment, extra rolls of film, flight panels, food, water and other crew necessities are provided. Altogether, about 845 pounds (385 kg.) of useful load, including the crew, are carried (does not include fixed equipment; crew's instruments, radio, batteries).

Cabin oxygenation and pressurization may be achieved by liquid oxygen boilers or by compressed gas. Liquid oxygen is the lightest and in many ways the better system but, should liquid oxygen be difficult to obtain in practice, gaseous oxygen may be stowed in cylinders in the aft fuselage.

Duration of a flight will depend upon several factors: (a) Time required to conduct a typical exploration. (b) The tightness of the cabin (to reduce the amount of make-up gas). (c) The amount of oxygen that can be conveniently carried. A flight to 60,000 ft. (18.3 km.) is expected to have a duration of 5½ to 8 hours.

To seal the cabin against leaks the following design features were adhered to. The only doors through pressurized walls are the crew entry doors. They are to be sturdily designed and are sealed by means of inflated pneumatic tubes between the doors and the frames. These would be pumped to sealing pressure when the crew is inside the cabin.

All control cables and shafts have been designed for rotary instead of longitudinal sliding glands so that a tight seal can be maintained with very low control friction.

By maintaining a cabin atmosphere of 75% oxygen at 65,000 ft. (20 km.) the breathing conditions in the cabin would be equivalent to 10,000 ft. (3 km.) Three p.s.i. (155 mm. Hg) pressure-drop across the walls of the cabin is proposed and corresponds to a cabin pressure altitude of 32,840 ft. (10 km.). Carbon dioxide should be kept below 2% by circulating cabin air past porous bags of NaOH so that $NaCO_3$ will be formed. The moisture released by this reaction and by the crew's breathing should be absorbed by suitable surface active agents such as silica gel. Some water will be absorbed by the almost completely dry oxygen provided.

Emergency oxygen and a T-1 suit pressurization will be provided by a separate direct pressurized oxygen supply source of sufficient capacity to permit the crew to descend quickly to a safer altitude should oxygen or cabin failure occur.

The amount of the oxygen supply is determined by these calculations. A leakage and overflow average loss of oxygen is estimated at 0.5 cubic ft./min. (236 cc./sec.) for a period of 8 hours. This is many times more than the crew consumes, even with great activity. The cabin has a volume of about 112 ft.^{3} (3.18 m.^{3}). By pre-oxygenating and providing 265 ft.^{3} (7.77 m.^{3}) of oxygen at standard atmosphere and pressure, at least 8 hours of flight should be realized.

Performance Requirements for Stratosailplanes

As the minimum rate of sink, and also the forward speed, increases with altitude it would be necessary for a sailplane to have a nominal "sea-level" (i.e., standard atmosphere) minimum sink of 2.5 ft./sec. (0.76 m./sec.) in order to remain in a vertical air current of 9 ft./sec. (2.74 m./sec.) at 65,000 ft. (20 km.), or 2 ft./sec. (0.61 m./sec.) if the vertical current is 7.4 ft./sec. (2.26 m./sec.).

An analysis of sailplane size (which is a prime cost factor) was prepared. A fuselage gross weight of 2,000 lb. (908 kg.) was assumed, based on cabin and payload plus tailcone and empennage weights. A chart (Fig. 4) was prepared on relative rather than accurate bases, but it is reasonably close to the final, more exact computations.

Particulars of the two craft chosen to bracket the range are in the accompanying table.

Three important features require elaboration:—

1. The limiting Mach number of .63 to .65 is due to the rather thick wings called for to keep the spars deep and thus wing weight reasonably low. Such Mach numbers may be achieved at 70,000 ft. (21.5 km.) with an indicated airspeed of about 89 knots (164 km.p.h.). The problem of attaining altitudes much in excess of 70,000 ft. thus involves transonic complications as well as vigorous up-currents.

2. Any increase in size above the 120-ft. (36.6 m.) wing span sailplane (which is 3 ft. longer than the Douglas DC-7 wing) means a disproportionate increase in ground handling problems, already severe compared to the 100-ft. span machine.

	Smaller sailplane	Larger sailplane
Number of seats ..	2	2
Wing span	100 ft. (30.5 m.)	120 ft. (36.6 m.)
Wing area	452 ft.^{2} (42 m.^{2})	600 ft.^{2} (55.8 m.^{2})
Gross weight.. ..	3,250 lb. (1,470 kg.)	3,700 lb. (1,675 kg.)
Min. rate of descent..	2.3 ft./sec. at 42 knots (0.7 m./sec.)	2.0 ft./sec. at 40 knots (0.61 m./sec.)
Total useful load ..	845 lb. (383 kg.)	845 lb. (383 kg.)
Max. design speed ..	160 knots or Mach .63	160 knots or Mach .63
Max. glide ratio ..	34 at 49 knots (87 km./hr.)	36 at 46 knots (82 km./hr.)
Wing aspect ratio ..	22.1	24
Wing loading ..	7.2 lb./ft.^{2} (36 kg./m^2)	6.2 lb./ft.^{2} (29.3 kg./m.^{2})

3. It will be noticed that the wing loadings and aspect ratios are somewhat greater than for most sporting sailplanes. This permits penetration of wind fields of up to 200 knots (370 km.p.h.) which may be found between about 20,000 and 45,000 ft. (6 and 14 km.) during mature waves. The ability to drive through such strong winds without undue loss of altitude may not only mean a successful flight, it could also mean avoidance of the turbulent rotor zone.

General Arrangements and Design Details

In order to achieve more predictable results and costs, emphasis was placed upon stability, high performance and conservative conventional design. The same cabin is used for both configurations and is shown in Fig. 5. Control surfaces are actuated by steel cables which are fitted with tension-control devices to compensate for temperature effects.

Wing and tail flutter are influenced by true air speeds, and since these speeds are fairly high at altitude, statically balanced ailerons, elevators and rudder are indicated; these may even be fabric-covered structures to reduce their mass.

The temptation to equip these stratosailplanes with a Vee tail was overcome by computations which proved that, for equal stability and controllability, the conventional tail produced less drag. The chosen tail areas times their moments are high to ensure adequate stability in violent turbulence.

Landing-gear design is based on requirements for good ground handling characteristics under turbulent take-off and landing conditions. The main gear is set aft of the centre of gravity to ensure good directional control, since take-offs and landings may be made under strong wind conditions. This gear comprises a pair of wheels, side-by-side, on a single oleo strut; it is retracted and extended electrically. Power for these actuations can be made up by a wind-driven generator during tow and let-down. The main gear is provided with wheel-brakes. When the main gear is down a small tail-skid under the rudder is extended to protect the aft fuselage at high angles of attack.

A single electrically retractable nose-wheel is set so that the wings are at a low lift attitude when the craft is on its wheels. For tie down, the nose-wheel may be retracted. The nose-wheel is steerable (sailplanes with this feature are very easy to handle during take-off and roll out).

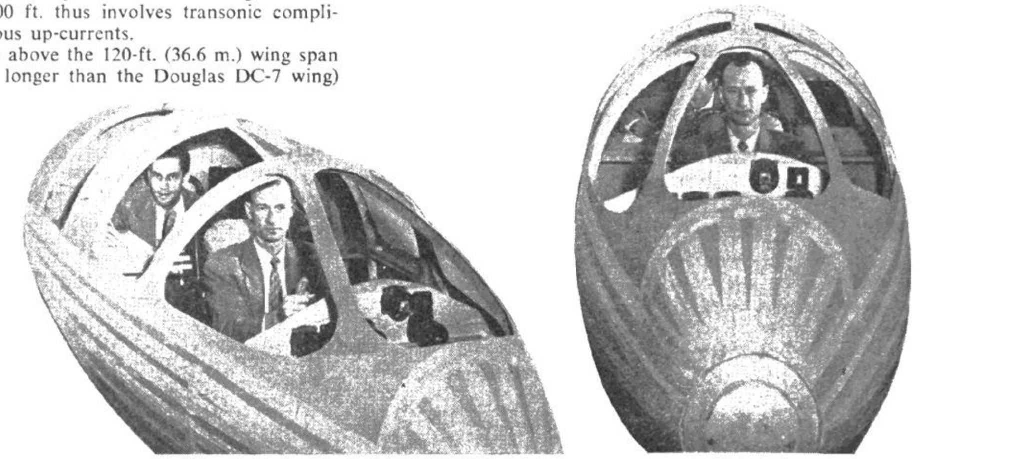

Fig. 5. Two views of a mock-up of the cabin of the stratosailplane designed by the Southern California Soaring Association, Inc.

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THE aerodynamic factors which influence the dimensions and performance of the proposed sailplane were first computed on a comparative, rather than an accurate, basis. These were developed somewhat concurrently with the arrangement design of the craft and are conservative. After the two boundary configurations were selected from the comparative data, a more rigorous performance analysis was made of each of these. Both kinds of analyses are discussed here briefly.

The probable variations of weight of wings were calculated in relation to the span and area. The weight of the fuselage and tail were estimated at 2,000 lb. (908 kg.) based upon payload and structural computations. From these, the comparative performances shown by Fig. 4 were produced. Size selection was based upon practical aspect ratio and gross weight; both of these factors dominate preliminary cost computations.

The smaller design was originally chosen as the best probable overall stratosailplane, and the preliminary S.C.S.A. Report No. 2 dealt only with this. When it appeared that a still lower minimum sinking velocity would be of great advantage, especially to attain higher altitudes, the analysis of the larger machine was added and the final report was revised accordingly. An even larger craft could be built, but the curves (Fig. 4) are quite flat already at the 120-ft. (36.6-m.) span; the handling requirements and costs increase disproportionately for small performance gain beyond this point.

The selection of the airfoil was reduced to an analysis of four candidate sections of the N.A.C.A. low-drag series: 63_3-618, 64_3-618, 63_3-418 and 64_3-418, plus one popular conventional curve, the N.A.C.A. 4418, for comparison. In all cases the 18% thickness sections were chosen to reduce wing weight by providing room for deep spars. The minimum drag coefficients are not significantly greater than for slimmer airfoils. The wing outer panels have an airfoil thickness taper from 18% to 12%; the whole wing averages 17%. The airfoils are compared in Fig. 6.

Because the 63_3-618 airfoil has a suitably low C_D at the minimum sinking velocity (at $C_L = 1.1$) and does not show an undesirably sharp drag increase at high lift coefficients, it was the curve finally selected. There was an effort to get information on the 63_3-818 because of its probable low drag at a higher lift coefficient, as the code number indicates (it is more deeply cambered), but no wind-tunnel data were available and the practical difference in sailplane sinking velocity between these two curves would probably have been negligible.

The 65 and 66 series of airfoils were not considered because of their increased sensitivity to surface condition, a situation that is liable to be less perfect during a research programme than during a soaring contest. For this same reason the performance analysis did not consider the full effect of the "bucket" in the drag curve. Instead, since the "bucket" is seldom achieved except in good wind-tunnels, the drag curve was "faired" in accordance with standard practice. Much time and money has been spent in the quest of the elusive "bucket," and only by means of the most unusual and artificial schemes has it ever been realized, and then for only one flight! There is some evidence that the sailplane RJ-5 may actually have the "bucket" characteristic (it uses a 65 series airfoil). If it does, it is possible that the S.C.S.A.'s proposed sailplanes should do as well, at least for a while. The resulting performance would be excellent propaganda material, but there

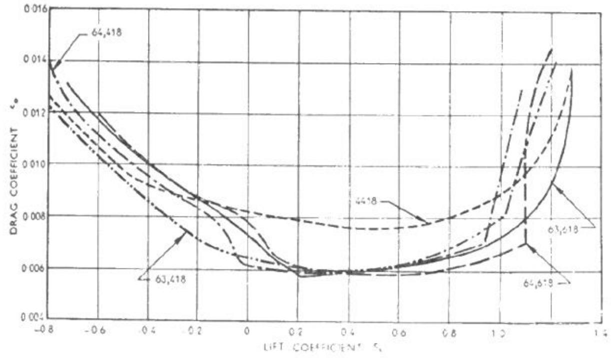

Fig. 6. Drag coefficient vs lift coefficient for various airfoil sections.

Photo: Betsy Woodward

A mature mountain wave over the Owens Valley, formed by the Sierra Nevada. The cloud reaches to about 40,000 feet.

is reason to believe that the wing will become too wavy to produce such performance after flight experience has been gained in rough wave conditions. Accordingly, the design was made conservative enough to provide adequate performance for high flights without depending on this drag anomaly.

Another unusual consideration was applied to the adjustment of both of the sailplanes' performances: the Reynolds No. for the wing and the whole craft was determined on the basis of the kinematic viscosity of the atmosphere at 45,000 ft. (14 km.). It is on the basis of the "45,000-ft. Reynolds No." that the performances shown in Fig. 7 were computed. The true

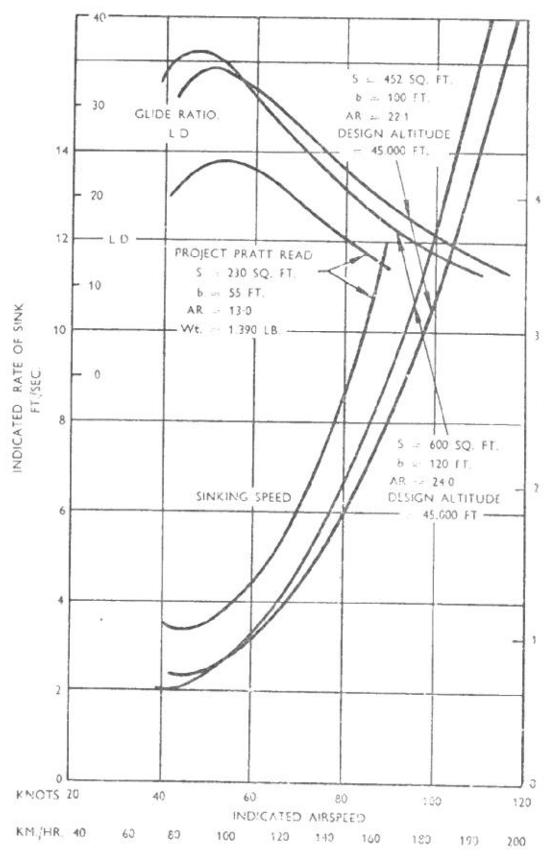

Fig. 7. Performance curves of the Pratt-Read sailplane and the proposed stratosailplane with a span of 100 ft. and 120 ft. and at a design altitude of 45,000 ft.

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sea-level performance of the Pratt-Read sailplane that holds the present World's absolute altitude record is shown for comparison.

The aspect ratios chosen and the wing loadings are comparatively high, but little is gained by reducing these except in the region of lower spans (Fig. 4). Before a noticeable decrease in sinking speed is achieved by lower aspect ratio, the glide ratio is markedly impaired and thus the necessary ability to penetrate through strong winds is effectively lost. To point this up, Pratt-Read and Schweizer TG3 sailplanes have flown waves with wing loadings of 6 lb./ft.^{2} (29.2 kg./m.^{2}) and aspect ratios of only 13. There have been flights when these craft needed higher glide ratios (more aspect ratio); and the forward speed, in some conditions, was quite marginal at 80 knots (147 km.p.h.) indicated. The better high-speed performance of the Schweizer 2.25 (aspect ratio: 18) in the Sierra Wave was very welcome.

The calculations for the performances shown on Fig. 7 utilized the following:—

The profile drag of the wing was corrected for skin joints and spoiler and aileron gaps. (As calculated, it constitutes approximately 70% of the total parasite drag of the machine.) The actual exposed wing area was then used in arriving at the total wing profile drag, which allows for variations due to angle of attack. Accordingly, the span efficiency factor was found by the formula

$$\frac{1}{\pi AR_e} = \frac{1}{\pi AR_u} + \theta a_0 v \quad \text{(from NACA TR 572)}$$

which corrects for taper ratio, aspect ratio and twist.

The drag of the fuselage was assessed by conventional calculations using well-known coefficients and techniques. The total exposed wetted area of the fuselage was determined and multiplied by a drag coefficient based on Reynolds No., fineness ratio and surface condition. No variation of drag with angle of attack was considered.

The tail surfaces were treated in a similar manner. The profile drag coefficient for aerodynamically smooth airfoils was adjusted for Reynolds No., surface condition and control surface gaps. Tail induced drag was included.

The following ultimate load factors (L.F.) would be used for this design :—

Condition	L.F.	L.F. with Gust Alleviation Allowance
Positive high angle of attack ..	10.0	12
Negative low angle of attack ..	−7.0	−8.4
Landing	4.0	4.0

The use of a gust-alleviation mechanism in the wings will permit an approximately 20% increase in load factor with negligible weight increase. This provides for "up aileron" deflection (both) as the wing bends up (positive high angle of attack) and "down aileron" as the wings bend down. It is accomplished by the arrangement of the aileron control cables near the upper and lower wing surfaces which are stretched unequally as the wings bend one way or the other.

Pressure loadings for the cabin are as follows:—

(a) Normal operating pressure differential ... ... 3.0 p.s.i. (155 mm. Hg)

(b) Maximum safety valve setting 3.2 p.s.i. (166 mm. Hg)

(c) Maximum test pressure ... 4.0 p.s.i. (207 mm. Hg)

(d) Ultimate design pressure ... 6.0 p.s.i. (310 mm. Hg)

The nose section canopy and doors are constructed of dural frames with formed acrylic plastic glass held at all edges by bonded sections of metal and fibreglass cloth. Extra safety margins will be used for these assemblies to assure their ruggedness at altitude.

The execution of a stratosailplane along the lines described here presents no unsurmountable engineering, manufacturing or operational problems. It does not ask special favours nor aerodynamic miracles. And, compared to the less specialized sporting sailplanes successfully used for high-altitude flights in the past, it should provide adequate comfort and safety for the crew and worthwhile returns from explorations of orographic lee wave and jet stream phenomena anywhere in the World.

Mr. Cartier then gave a description of the **Breguet stratospheric sailplane, S 10, which is presently under construction in** France. The sailplane, **which has a cabin diameter of** 1.10 metres (3.6 ft.), carries one pilot in prone position.

The wing, comprising a principal box spar and false rear spar carrying the hinged surfaces, is of wood. The covering is plywood up to the rear spar. The wing is in three sections; the central portion which is fixed to the fuselage by four fittings, and two outer portions, each linked to the centre section by four detachable bolts. The camber-changing flaps and the ailerons are slotted. Dive-brakes extend from the upper and lower surfaces of the wing.

The fuselage consists of three detachable sections: (1) the pressure cabin; (2) the centre section carrying the wing and the undercarriage; (3) the rear section carrying the tailplane and the tailwheel.

The pressure cabin (1) comprises:—

(a) The forward nose portion consisting of three hemispherical cupolas and a Plexiglass fairing. It is bolted on to the body of the cabin.

(b) The body of the cabin consists of a cylinder of plywood, fixed at its end to a wooden framework.

(c) The rear section of the box girder is constructed of stainless steel plate.

(d) A mounting comprising a cradle of corrugated sheet of AU 4G. It is fixed to the lower part of the rear framework and is supported by two struts (tension members) carried to the upper part of this same framework. It supports, in the plane of symmetry, a series of rollers on which rest the solid rails of the "stretcher" supporting the pilot.

The junctions are made pressure-tight by inflating pneumatic sealing tubes. Insulation is achieved by the three Plexiglass domes and by glass wool surrounding the body of the cabin.

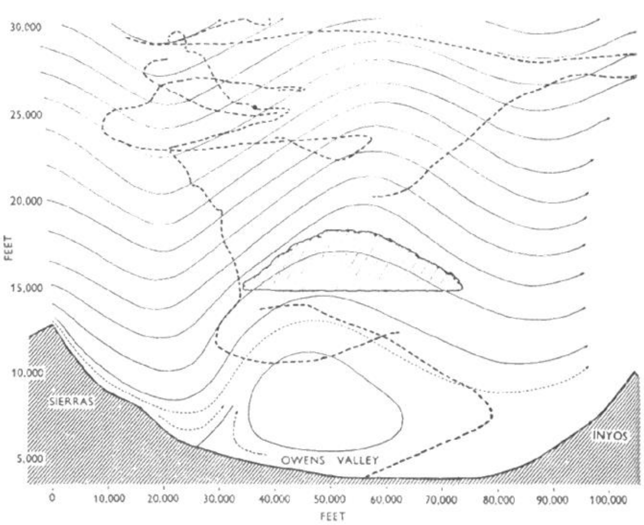
The centre section (2) is welded tubing, carrying the cabin, the wing, the undercarriage and the rear part of the fuselage.

The rear section (3) is of wood; it consists of 16 longitudinal stringers and a covering of plywood. The lower part of the fin springs from the construction of the fuselage.

The fixed tailplane (3) is in one piece; it is fixed on the lower part of the fin. The elevator is in two parts. The upper part of the fin is assembled by fittings to the lower part. The tail unit is of wood.

The undercarriage consists of a retractable wheel with shock-absorber and hydraulic brake, two retractable balancing units situated at the extremity of the wing-centre section, and a tail wheel.

The essential controls are operated by push-pull rods. The passage of the controls through the rear bulkhead of the cabin is brought about by concentric torsion tubes mounted on ball



A wave-pattern cross section showing the streamlines. The dotted line in this diagram is the path of the sailplane.

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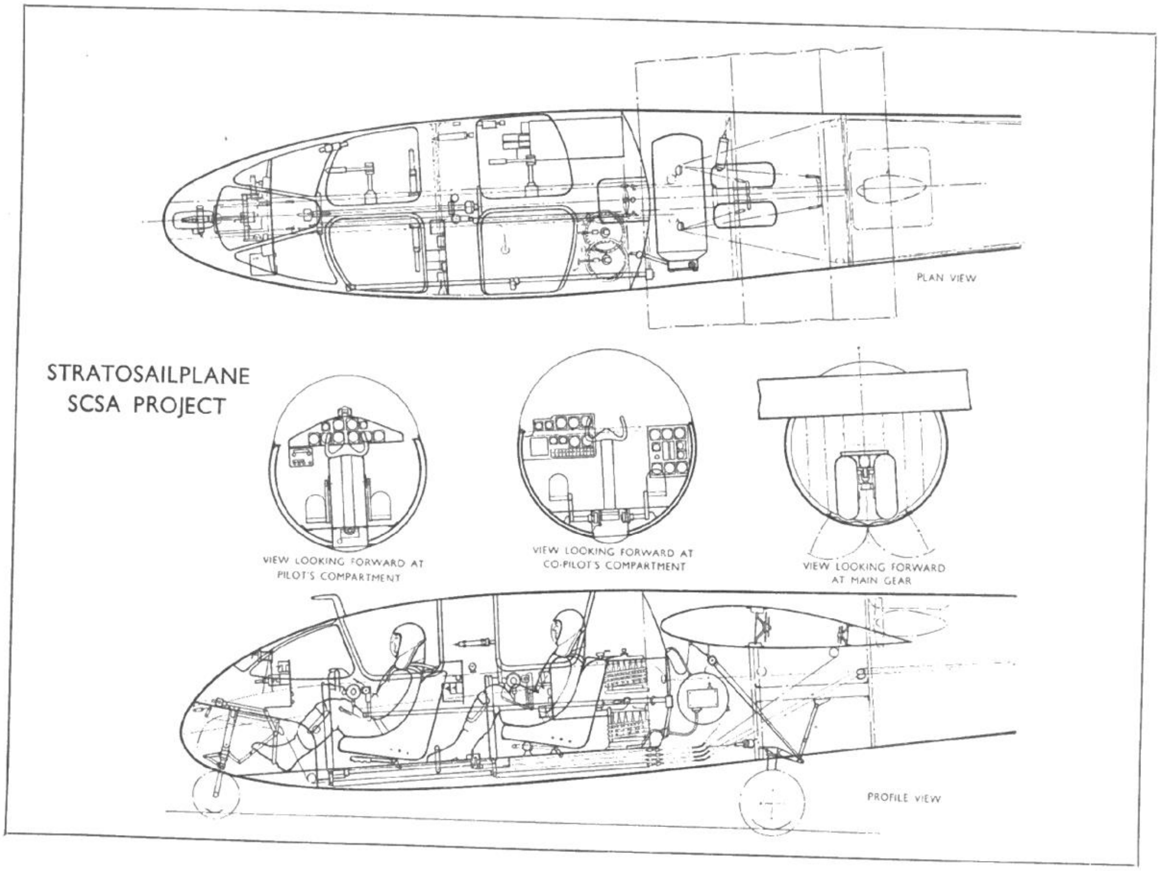


bearings, the pressure tightness of which is achieved by rubber joints.

Installation and Equipment

The compressing of the air for the cabin is obtained by a fan. The air then passes over "carbagel" which absorbs the water vapour, having come from the soda lime which absorbs the CO^2 and then is re-warmed by electric resistances. A supply of oxygen is assured by two bottles of 6.6 litres fixed under the stretcher.

An automatic valve, set to 0.260 kg./cm.², permits the air from the cabin to escape on the climb. On the descent, two clap-valves permit the air to re-enter the cabin, so avoiding all exterior pressure on the walls. Compensation for losses can be made, in case of emergency, by the supply of compressed air from a bottle.

Should the occasion arise for the pilot to abandon his aircraft, he can eject himself on his stretcher. An anti-spin parachute stabilizes the descent of the unit. In opening his parachute, the pilot breaks away from the stretcher-cupola unit.

CHARACTERISTICS.—Span, 24.20 m. (79.4 ft.); area, 41.70 m.² (450 sq. ft.); aspect ratio, 14; dihedral, 3°; length, 11.50 m. (37.7 ft.); fuselage cross-section, 1.10 × 1.10 m. (3.6 × 3.6 ft.).

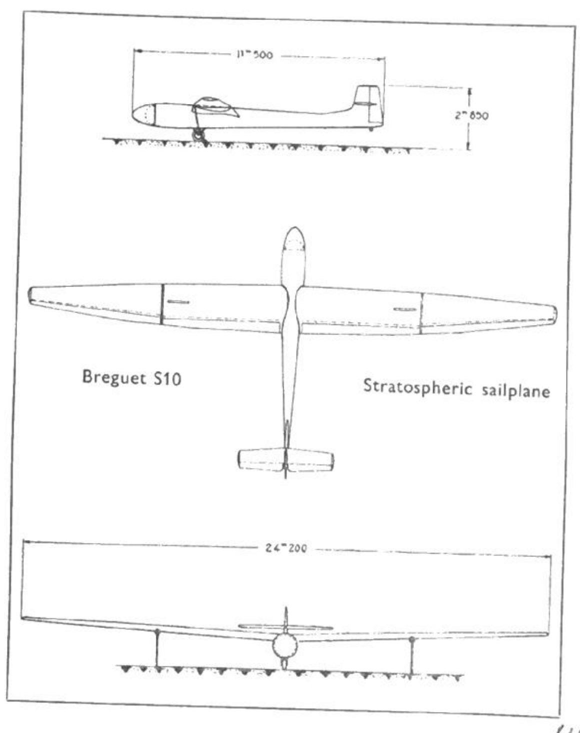
WEIGHT (estimated).—Structure, 604 kg. (1,330 lb.); equipment, 98 kg. (216 lb.); pilot and equipment, 83 kg. (183 lb.); total weight, 785 kg. (1,729 lb.); wing loading, 18.6 kg./m.² (3.81 lb./sq. ft.).

PERFORMANCE (estimated) at 785 kg. (1,729 lb.).—Min. sinking speed, 0.56 m./sec. at 70 km./h. (1.84 ft./sec. at 43.5 m.p.h.); sinking speed at 120 km./h., 1.56 m./sec. (74.6 m.p.h., 5.11 ft./sec.); sinking speed with 20° flap, 0.80 m./sec. at 54 km./h. (2.62 m./sec. at 33.6 m.p.h.); towing speed, 200 km./h. (124.3 m.p.h.); diving speed, 350 km./h. (217.5 m.p.h.).

* * *

After the above three papers were presented an informal discussion was held amongst those interested in the design and construction of a strato-sailplane.

Three years ago the Research and Development Command of the U.S. Air Force contracted four overseas manufacturers to make design studies of a strato-sailplane. While a number of the designers were present at the discussion, formal papers were not given at that time. One of the four was Slingsby Sailplanes, Ltd., Kirbymoorside, Yorkshire.



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