ANTARES

A Self-Starting Silent Super Sailplane

by Ir. L.M.M. Boermans

The Antares is the first high-performance electrically powered self-launching sailplane in the world. A small, powerful electric engine enables the 20-meter span sailplane to take off and climb silently and rapidly to the intended height, where the engine and propeller are retracted and soaring flight begins — with 56:1 performance.

Prologue

Some years ago Dipl.-Ing. Axel Lange, working on the DG-800 at DG Flugzeugbau in Germany, got the idea to develop a self-launching high-performance sailplane with an electric engine. He started his own company Lange Flugzeugbau GmbH on a former military airfield near Zweibrücken, and built up a network of internationally renowned specialists (see The Antares Design Team, below) to combine their expertise for this project.

Since May 1999 a flying testbed — a 20-meter-span modified DG-800 named Lf-20E (Figure 2) — has been used to test the engine and propeller, the hydraulic systems for the retractable propulsion system and landing gear, and the electronic management system. The tests fully confirm the performance expectations and system reliability. In the meantime, a new factory has been built and preparations for the production of the Antares prototype are underway.

Electric propulsion system

The brushless electric motor (Figure 3) is compact and powerful; with the propeller it weighs 68 lbs and produces 56 hp with 90% efficiency. With only two bearings and no electronic components on the rotary part, the engine is practically maintenance-free (TBO is 1000 hrs, sufficient for 10,000 launches). Power is transmitted to a slow-running (1500 rpm) large-diameter (2-meter) propeller of 83% efficiency, which enables the test sailplane to launch and climb at an initial rate of 900 fpm with sound emission less than 40 dB — nearly silent. The powerful, lightweight nickel-metal-hydride batteries, located on rails in the inner wings, enable a total climb height of 5700' (in one or several climbs). They are cooled by a venting system that also removes gasses in case of malfunction.

The process of deploying and starting the engine, or stopping and retracting it, as well as controlling the power is very simple with a one-lever control system (Figure 4). The electronic management system ensures optimal and safe operation of the engine and batteries.

In summary, the propulsion system is reliable, safe, compact, powerful, quiet and vibration-free — a development that, until recently, was considered unlikely.

Design of the Antares

At the start of the design, only some main dimensions of the wing and fuselage were specified by Mr. Lange. The wing areas of the 18m and 20m span wings — offered in one package by means of removable wingtip sections — were determined on the basis of weight estimations, leading to favorable wing loadings. As a result, the aspect ratios were specified; this worked because cross-country performance calculations with several weather models (i.e. combinations of strong, weak, large and small thermals) showed that the optimum of the aspect ratios is very flat.

The main dimensions of the fuselage were determined on the basis of crashworthiness measures. A three-view drawing of the Antares, to be described next in more detail, is shown in Figure 5.

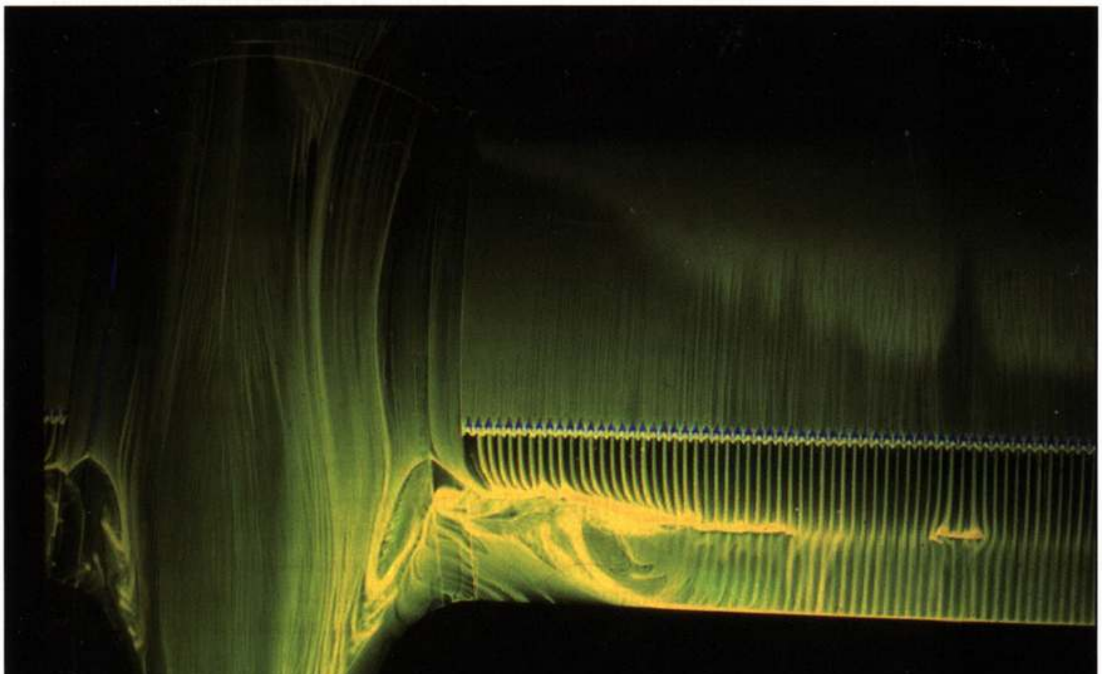
Wing

The wing contributes 90% to the total drag of the sailplane at low speeds (flying in thermals) and 65% at high speeds (flying to the next thermal). Hence, minimum wing drag is a prerequisite for high performance. At low speeds about 70% of the wing drag is induced drag and at high speed 80% is profile drag. These numbers indicate where attention has been focussed.

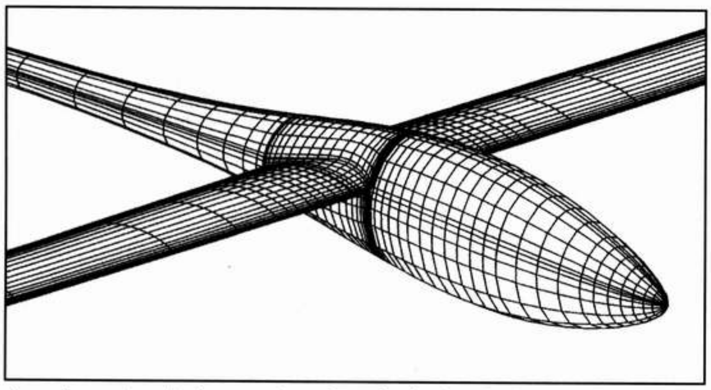
Minimum induced drag of planar high-aspect-ratio wings is realized with an elliptic planform. Because the surface of such a wing is curved both in chordwise and spanwise direction, production by hand is difficult. Therefore such wings are usually approximated by a multi-tapered planform. However, modern computer-controlled milling machines enable the production of complicated and accurate moulds, which allows a wing to be designed for real minimum induced drag. The wing airfoils (more about them later) are designed from the start with a camber-changing flap of 15% chord. Since the hinge line has to be straight, this determines the planform of a wing with elliptic chord distribution. The resulting gradual sweep of the leading edge is favorable for directional stability and flutter prevention.

A disadvantage of an elliptic wing is the narrow chord in the tip region; the corresponding low Reynolds numbers

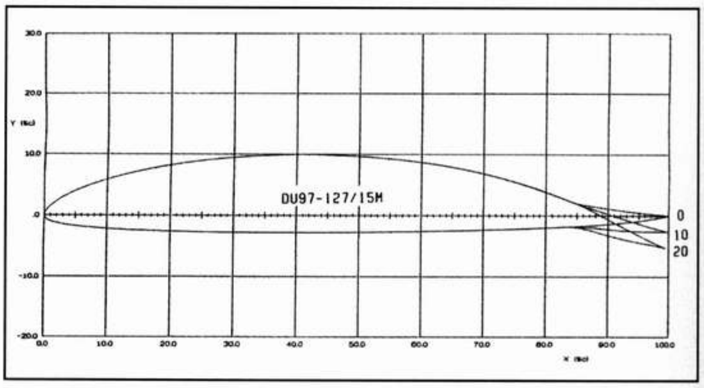
The flying testbed Lf-20E (a modified DG-800).



Flow pattern on a wing-fuselage combination showing flow separation at the junction, and vortices behind zig-zag tape.



Aerodynamic calculations (panel method) for the fuselage design.



The basic airfoil section of the Antares wing.

are unfavorable for the other drag contribution: profile drag. This problem was solved by applying a super-elliptic (over-elliptic) planform and sweeping back the trailing edge of the removable tip sections at the 20m span version. Calculations show that the ideal minimum induced drag is realized within a negligible 0.1%, while achieving low profile drag.

Induced drag can be further reduced by bending the wing upward; most efficient in this respect is the application of winglets. Since the improvement in induced drag should more than outweigh the loss due to winglet profile drag, yielding the maximum net drag reduction, the design of winglets is a tidbit for an aerodynamicist. Windtunnel tests and flight tests have shown that the design procedure developed in Delft is successful. Both for the 18m and 20m span wing, winglets have been designed that reduce the induced drag by the theoretically maximum amount possible. The winglet profile drag predominates only at very high flight speeds — beyond the practical speed range.

Much attention has been devoted to designing airfoils with minimum profile drag by keeping the boundary layer on the upper- and lower-surface laminar as far aft as possible, and at the same time looking for the thinnest airfoil that produces a certain range of lift coefficients. Due to sophisticated computer programs and experience built up in the excellent Delft Low-Speed-Low-Turbulence windtunnel, an airfoil could be designed that is only 12.7% thin (Figure 6). Wind tunnel tests proved that laminar flow on the lower surface at the high-speed zero-degrees flap setting extends up to 95% of the chord (i.e. onto the flap) and that the flexible slot sealing does not disturb the laminar flow. At the high-speed low-lift coefficients this is the longest laminar flow extent possible. To avoid subsequent separation of the laminar flow and consequently an increase in drag, the laminar boundary layer is artificially made turbulent at 95% chord by pneumatic turbulators, i.e. by blowing air through small spanwise-spaced holes. The hollow flap is the channel for the blowing air; the air enters the flap via a small NACA inlet. This boundary layer control system acts like a turbulator with self-adjusting thickness and is an improvement on the well-known zigzag-tape turbulator developed at Delft in 1981 for sailplane applications.

On the upper surface of the airfoil the boundary layer is laminar up to 75% chord. This extent is limited by the occurrence of flow separation on the flap and consequently bad handling characteristics when flying in thermals, where the angle of attack varies constantly. Wind tunnel tests showed that the present airfoil has no problems of this kind, and that the drag at all flap deflections is the lowest of all sailplane airfoils ever tested in Delft.

The upper surface of this excellent basic airfoil has been modified in the inner and outer wing where the Reynolds numbers are different. Special low-drag airfoils have been designed for the winglet too; the flow situation is such that their lower surface is completely laminar while on the upper surface a zigzag-tape turbulator is needed to avoid a detrimental laminar separation bubble.

Much attention was given to the wing-fuselage junction. Due to crossflow caused by the fuselage, the angle of attack in the wing root region increases considerably at low speed and decreases at high speed, and the complicated flow in this area is always turbulent. The inner wing airfoil, designed for laminar flow, is not suitable here: the chordwise position of transition — where the laminar boundary layer turns turbulent — moves forward in the direction of the fuselage, both on the upper and lower surface, and early flow separation occurs at the wing root (as shown in Figure 7). The drag due to these wing-fuselage interference effects increases the sink speed.

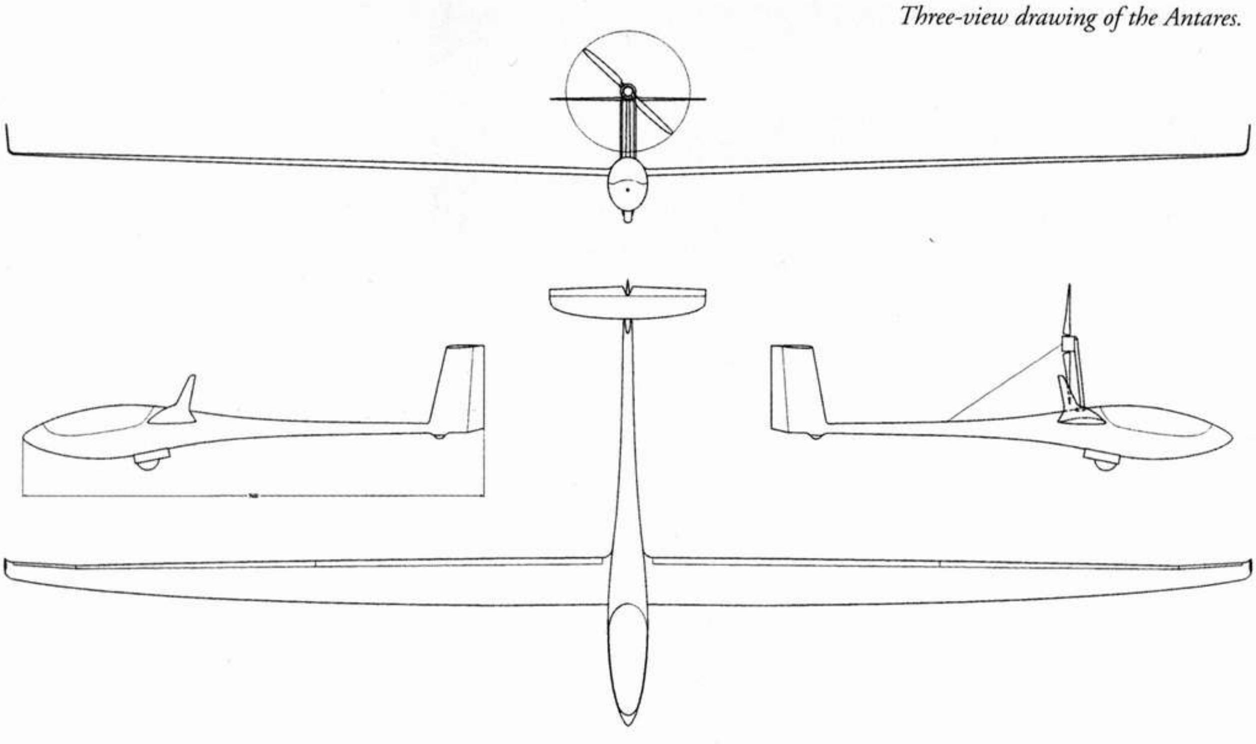
By using a unique aerodynamic design program (developed at Warsaw Technical University and in cooperation with Delft further refined and tuned for the design of winglets and wing-fuselage combinations) it turned out to be possible to design a wing root region where the boundary layer on the upper and lower surface remains laminar and does not separate early. This success has one possible disadvantage: since separated flow is absent the pilot will not be warned by vibration of an approaching stall. Flight tests will be needed to determine whether a stall-warning system is required. A few years ago such a system was developed in Delft and successfully flight-tested on the ASW-19X testbed sailplane.

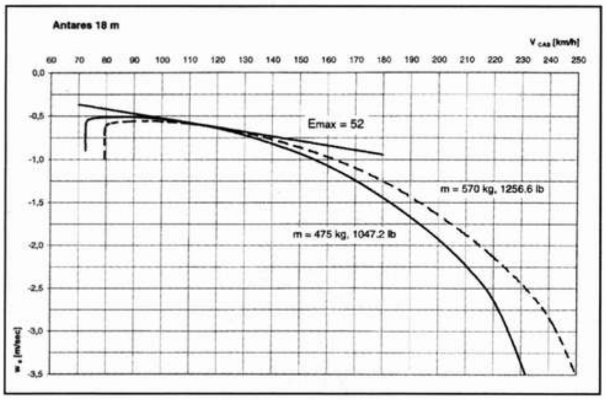
FUSELAGE

Again, windtunnel experience and computer programs (Figure 8) were the basic design tools. Over the years, fourteen wing-fuselage combinations have been wind-tunnel tested, providing valuable information about measures and ideas intended to reduce drag.

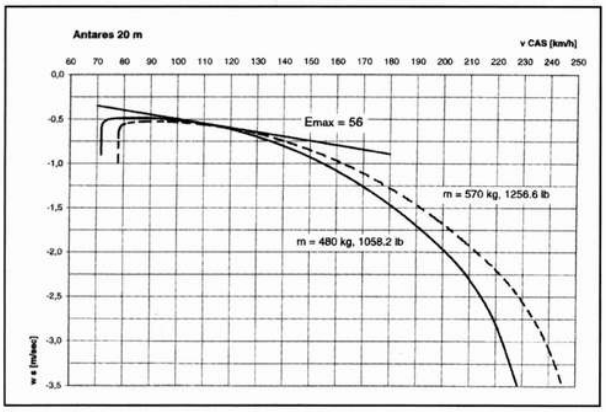
The many crash tests with sailplane cockpits and dummies, performed by TÜV Rheinland and the Fachhochschule Aachen, showed that a longer and higher cockpit – along with special construction

Three-view drawing of the Antares.



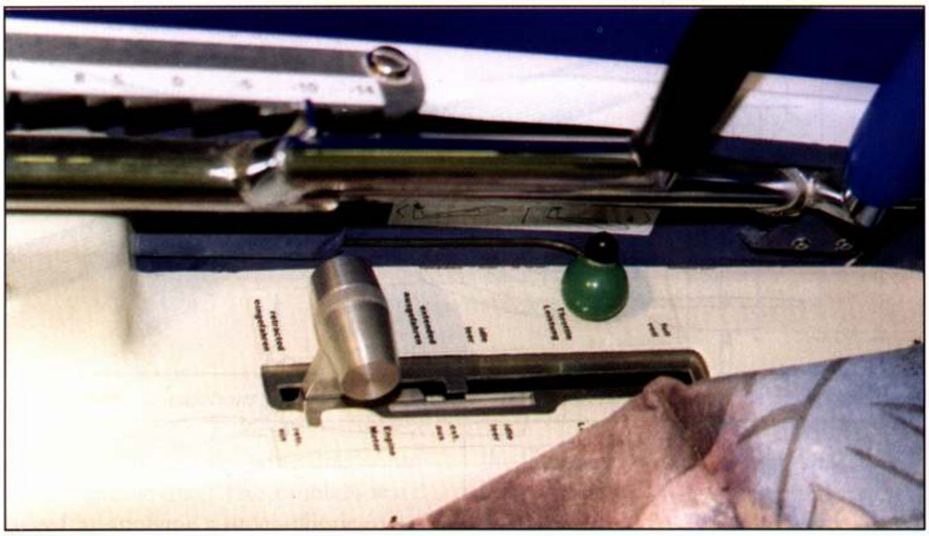


Performance of the Antares with 20m and 18m span.



TECHNICAL DATA FOR ANTARES

	18-meter span	20-meter span
Geometry		
Wing span	59 ft	65.6 ft
Wing area	128 sqft	135 sqft
Aspect ratio	27.2	31.7
Fuselage length	24.3ft	24.3ft
Fuselage height	4.7 ft	4.7 ft
Weight		
Empty Weight	893 lb	904 lb
Maximum weight	1256 lb	1256 lb
Waterballast	26.4 gal	26.4 gal
Minimum wingloading (154 lbs pilot & parachute)	8.1 psf	7.8 psf
Maximum wingloading	9.8 psf	9.3 psf
Gliding performance		
Best glide ratio	52:1	56:1
Minimum sink rate (at 1047 lb)	1.67 fps	1.58 fps
Stall speed (at 1047 lb)	39.4 kt	38.3 kt
Engine data		
Type	DC/DC brushless	
Power	57 hp	
Revolutions	1500 per min	
Engine-on performance (with lithium-ion batteries)		
Rate of climb (at 1102 lb)	860 fpm	
Rate of climb (at 1256 lb)	750 fpm	
Total height of climb (at 1102 lb)	9800 ft	
Total height of climb (at 1256 lb)	8200 ft	



The one-lever propulsion control system.

– substantially improved crashworthiness. Aerodynamic calculations on the effect of cockpit extension revealed the surprising result that the drag did not increase. The reason is that although the wetted area does increase, the friction is less due to the lower pressure gradient. An increase in cockpit height, however, does increase drag. Very effective for low drag is a contraction of the fuselage behind the cockpit; but this contraction is limited by the occurrence of separated flow in case the fuselage is completely turbulent, i.e. when flying in rain.

Apart from crashworthiness and drag, the pilot's view during launch and landing and the prevention of wing drop during launch are essential elements in the design of the fuselage.

Since the flight speed of the Antares is controlled more by flap setting than by elevator deflection, the angle of attack of the fuselage varies only a few degrees. As a result, the overall shape of the fuselage could be fitted to the streamlines of the wing, thus minimizing the drag-increasing crossflow effects mentioned above. The shape of the cockpit section was derived from airfoils using a method to transform a two-dimensional body into a three-dimensional one with the same maximum flow velocity. Due to the small engine, the movable blades of the propeller and the compact hydraulically retractable landing gear, the contraction of the fuselage could be designed as if these elements were absent. Finally, a special requirement in shaping an aerodynamic body for low drag is that the curvature of the surface should be continuous in all directions; this guarantees a smooth pressure distribution and undisturbed boundary layer development.

Taking it all in all, the fuselage has been designed for minimum drag and maximum safety.

TAILPLANES

New airfoils have been designed for the horizontal and vertical tailplanes; they have laminar flow up to the elevator and rudder, where zigzag-tape prevents laminar separation bubbles that would increase drag and reduce rudder effectiveness. The problem in designing these airfoils was not so much the realization of low drag but the avoidance of loss of lift due to separated flow in cases of high angle of attack and rudder deflections (sideslip-, flare out- and cable break situations).

FINAL REMARKS

The calculated performance (Figure 9) shows an impressive glide ratio of 56:1 for the 20m span version and 52:1 for the 18m span wing. The revolutionary propulsion system has demonstrated its power, easy handling, extremely low noise and high reliability.

Recently, new lithium-ion batteries have been successfully tested that enable a formidable climb height of nearly 10,000'. They have an estimated lifetime of 10 years or 1,200 full-discharge cycles — 2,400 flights assuming half the available climb height is used. Recharge from full discharge should take about 8.5 hours and consume perhaps a dollar's worth of electricity.

The wing moulds (Figure 10) have been milled and look perfect. The fuselage moulds are being prepared. Flight tests of the prototype and the start of serial production are scheduled in 2001.

It has been great pleasure to design this special sailplane, using the best theoretical and experimental tools in order to realize ideas and find the best combination of safety and performance.

For further information, see the Antares website: www.lange-flugzeugbau.com.

THE ANTARES DESIGN TEAM

The electric engine and electronics were developed by professors Jeanneret and Vezzini of the Technical University in Biel, Switzerland. The large, slow-turning propeller was designed by Dr. M. Hepperle of the German Aerospace Center DLR in Braunschweig, Germany. Crashworthiness measures in the cockpit were developed by Dipl.-Ing. M. Sperber of TÜV Rheinland (crash tests) and Prof. W. Röger of the Fachhochschule Aachen, Germany. The author of this article, Loek Boermans, Associate Professor at Delft University of Technology, Faculty of Aerospace Engineering, did the aerodynamic design of the complete sailplane.

About the author: Loek Boermans (54) is Associate Professor in Low Speed Aerodynamics at Delft University of Technology, Faculty of Aerospace Engineering, The Netherlands.

His work is characterized by the development and use of theoretical methods (computer programs) and experimental tools (wind tunnels, free-flight experiments) for the aerodynamic design of aircraft. In this way he has contributed to the aerodynamic design of some 15 high-performance sailplanes and a few powered aircraft. Recent examples are the ASW-24, ASH-25, ASH-26, ASW-27, ASW-28, Ventus-2, DG-800, DG-1000, Albatros, Antares and the 6-seat cross-country and business aircraft Extra-400.

Since 1997 he has been President of OSTIV, the international scientific and technical organization for soaring.

Artist's impression of the Antares.

The revolutionary electric propulsion system.

The machine-milled moulds in the new factory building.