Pedal Powered Airplane

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Construction of the “Marathon Eagle” continued in 1992. The main emphasis this year was on mold construction and detail component design. The goal of the project is still to fly 26 miles in one hour at an altitude of 15 feet. The course consists of a five mile closed loop. A competition flight is timed from a dead stop at the starting line. Since it is a closed course, the minimum turn radius becomes important in establishing the cruising speed. The fifth “Kremer Contest” set up by the Royal Aeronautical Society established the requirements (of 26 miles in one hour over the five mile closed loop) that the “Marathon Eagle” hopes to conquer. As of 1992 no groups have attempted the course which was first established in the fall of 1989.

As of November 1992 the aircraft is 70% complete. It is hoped that I will be flying the aircraft before the summer of 1993. The majority of the work on the “Eagle” is done at my shop at home which makes it difficult for groups to work on the project. I have been training in preparation for the flight and have recently demonstrated 0.48 horsepower for 30 minutes on a stationary bike. The actual horsepower for flying should be between 0.40 and 0.45. Plans do include training other pilots; however, I currently have a total of 3 hours of airtime accumulated in my 9th through 11th man-powered aircraft, which should reduce the flying risk for “Marathon Eagle”. The 10th aircraft, which accumulated the most flying time is shown in Figure 1, on the following page.

The final configuration is an all cantilever, high wing design with a 15% chord aileron and all flying tail surfaces. The pilot sits upright in a standard bicycling position. The fuselage has a floating flap on the back 20% of the airfoil, to minimize sideslip drag. The main wheel is fully powered and is capable of retracting into the fuselage.

The airfoil redesign, which occurred in late 1991, required that all of the middle wing templates be scrapped. The airfoil was modified on the lower surface to eliminate early transition, which was caused by Gortler vortices on the concave surface. The redesigned airfoil was 2% thicker than the earlier 1990 design.

The wing spars had been completed and were found to be stiffer than anticipated for the 70 foot span design. Since the spars were stiffness designed, the resulting ultimate was estimated at 5 g’s. A span stretch to 85 feet was decided on to counteract the lower surface wing drag increase. The increased span, at constant wing area, lowered the induced drag, bringing the power required below 0.40 horsepower at 26 m.p.h. The thicker airfoil allowed a root chord reduction from 31 to 25 inches which resulted in an aspect ratio of 50 for the 85 foot span version. The aircraft will also fly with the 70 foot span with increased maneuverability at a slightly higher speed and power level. The

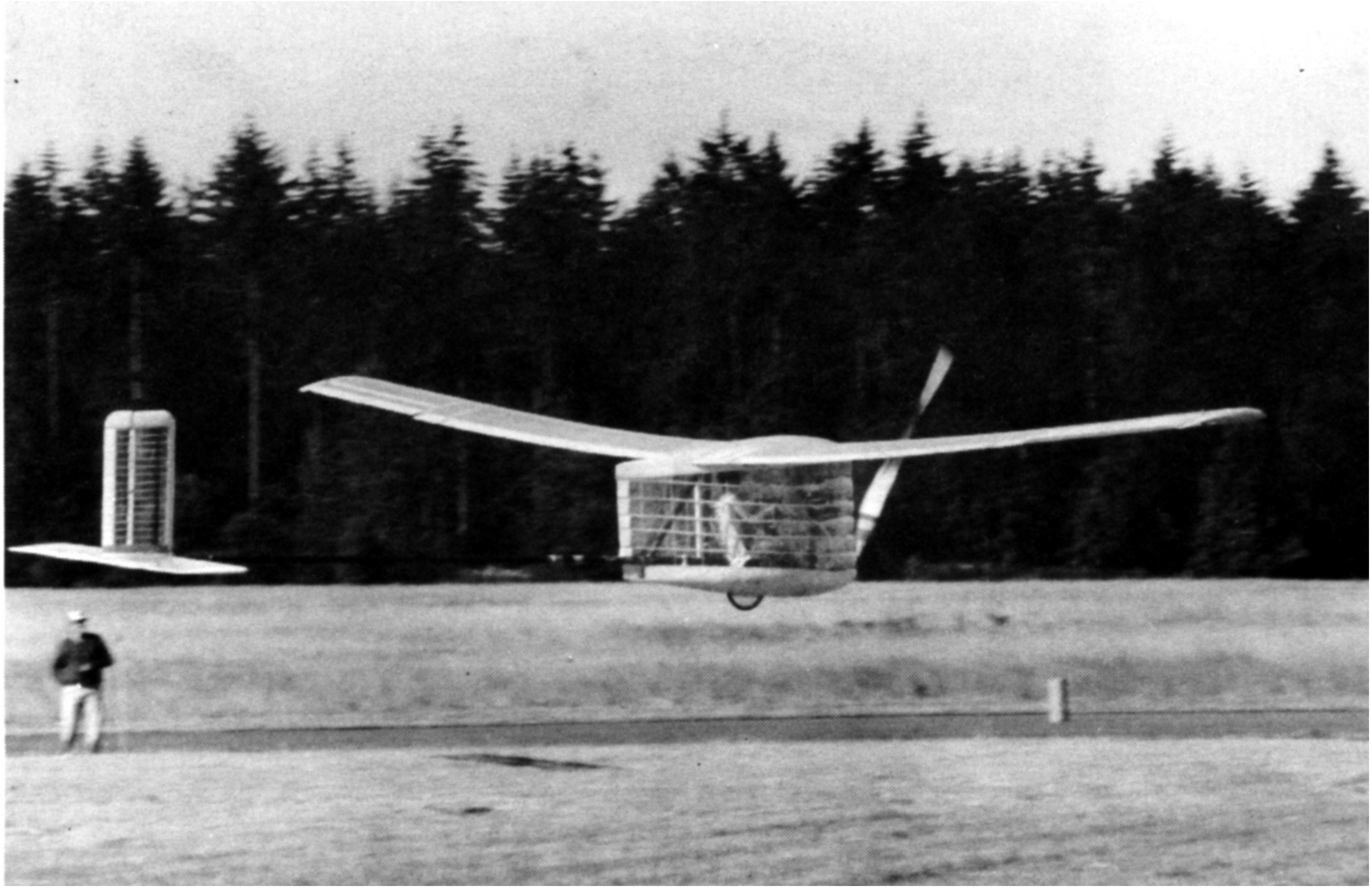

Figure 1. Man Eagle

shorter span version should be well suited for a lighter pilot, which is typical for these aircraft. My projected flying weight is between 170 and 180 pounds. The center region had to be redesigned to incorporate the smaller wing chord while still maintaining constant lift across the wing junction. The final wing deflection, for the 85 foot span version, should still be around 36 inches under 1 g load.

The airfoil and jig templates for the full wingspan are now complete. The airfoils are defined every 6 inches for contour accuracy. An example of this mold construction technique is shown (below) in Figure 2.

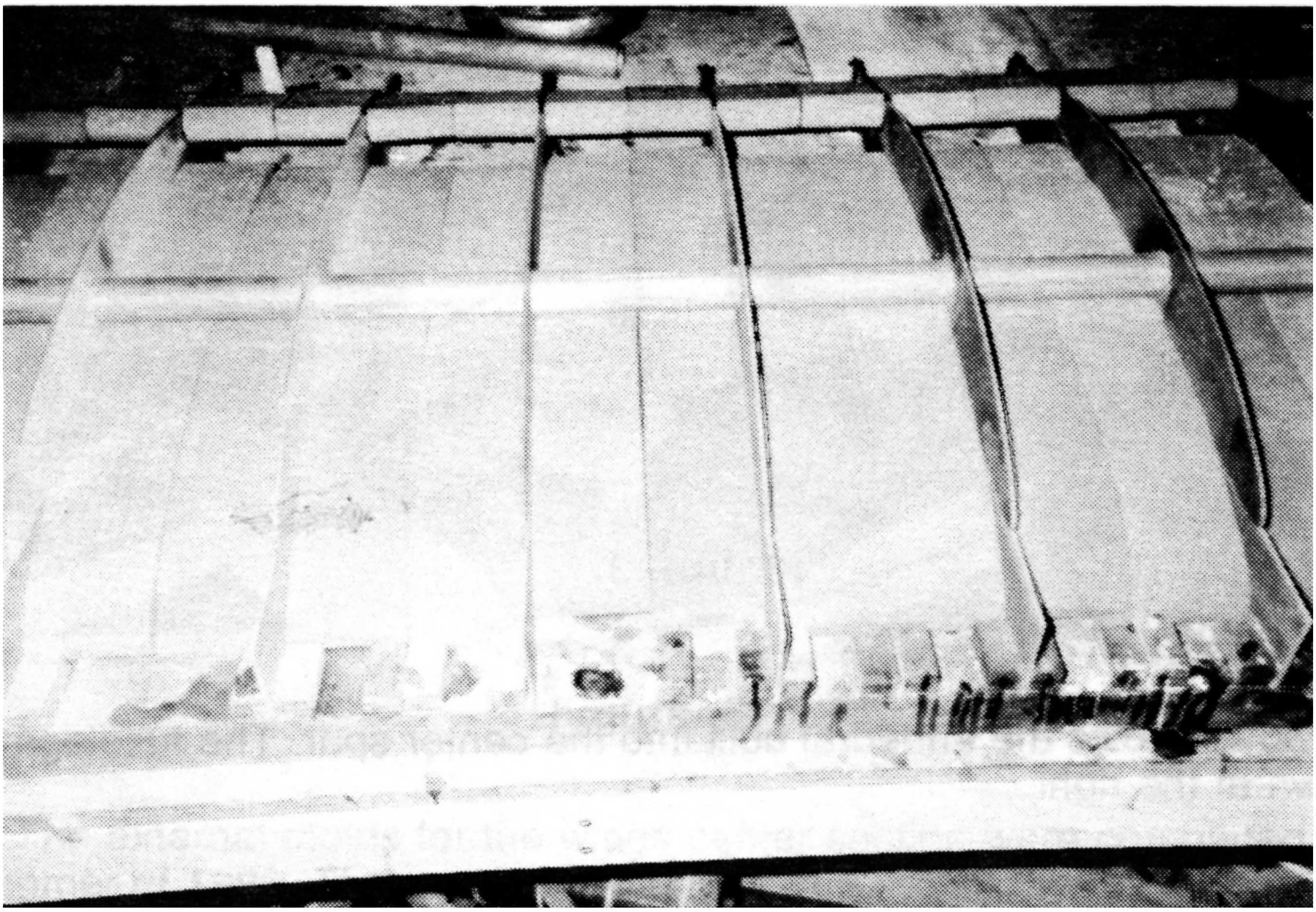

Figure 2. Wing mould construction

The aileron is shown in the background under construction. The shear and wing twist were incorporated into the jig templates to match tha “actual” spar deflections in the zero load condition. The center wing plug was completed in the summer of 1992 and was displayed at the F.R.I. projects exhibit, at the Museum of Flight, along with the fuselage and tail molds. The assembled carbon spar structure was also displayed along with a one-tenth scale model of the “Marathon Eagle”. The display was featured in a Seattle Times article, and Channel 11 news. The Boeing News also carried a story on the project. Figure 3. (on the following page) shows the center wing mold, fuselage frame and wing spars.

Figure 3. Showing the wing spar and wing centre section mould

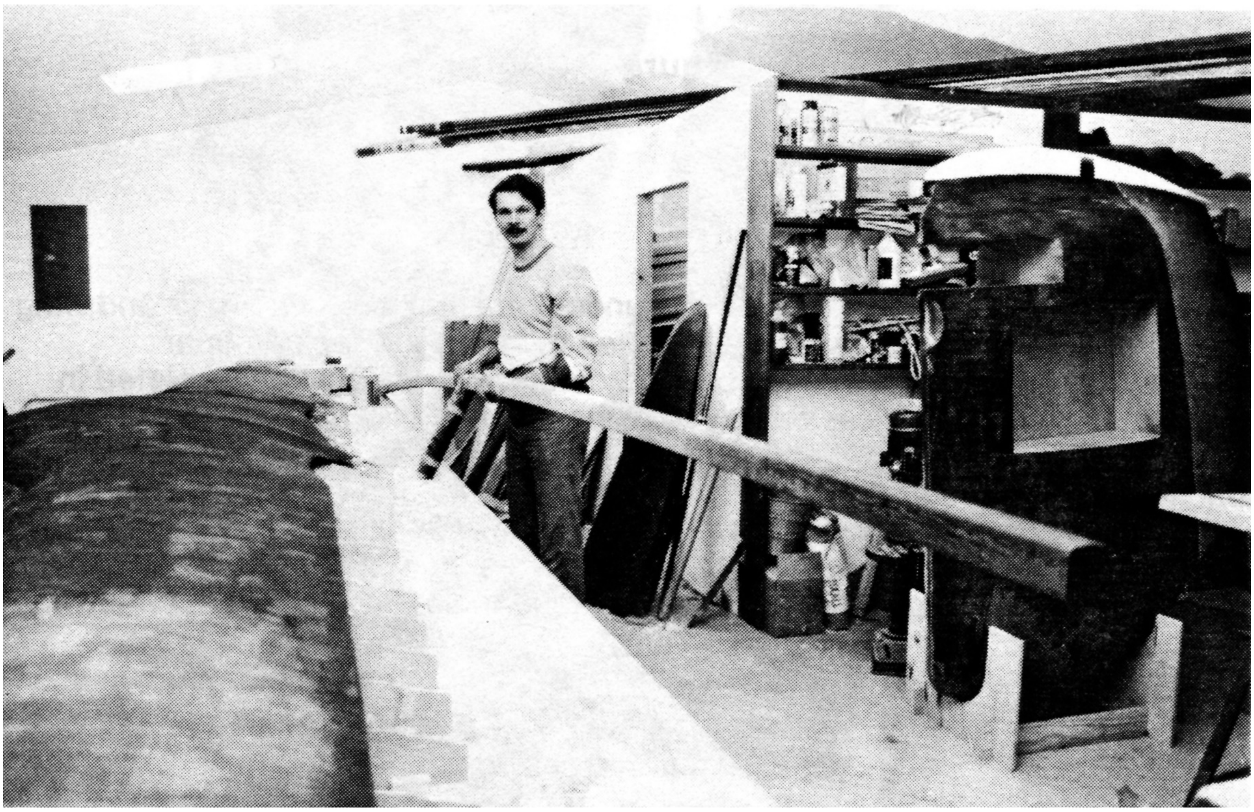

Figure 4. Showing the anhedral built into the centre spar. The fuselage mould is shown on the right

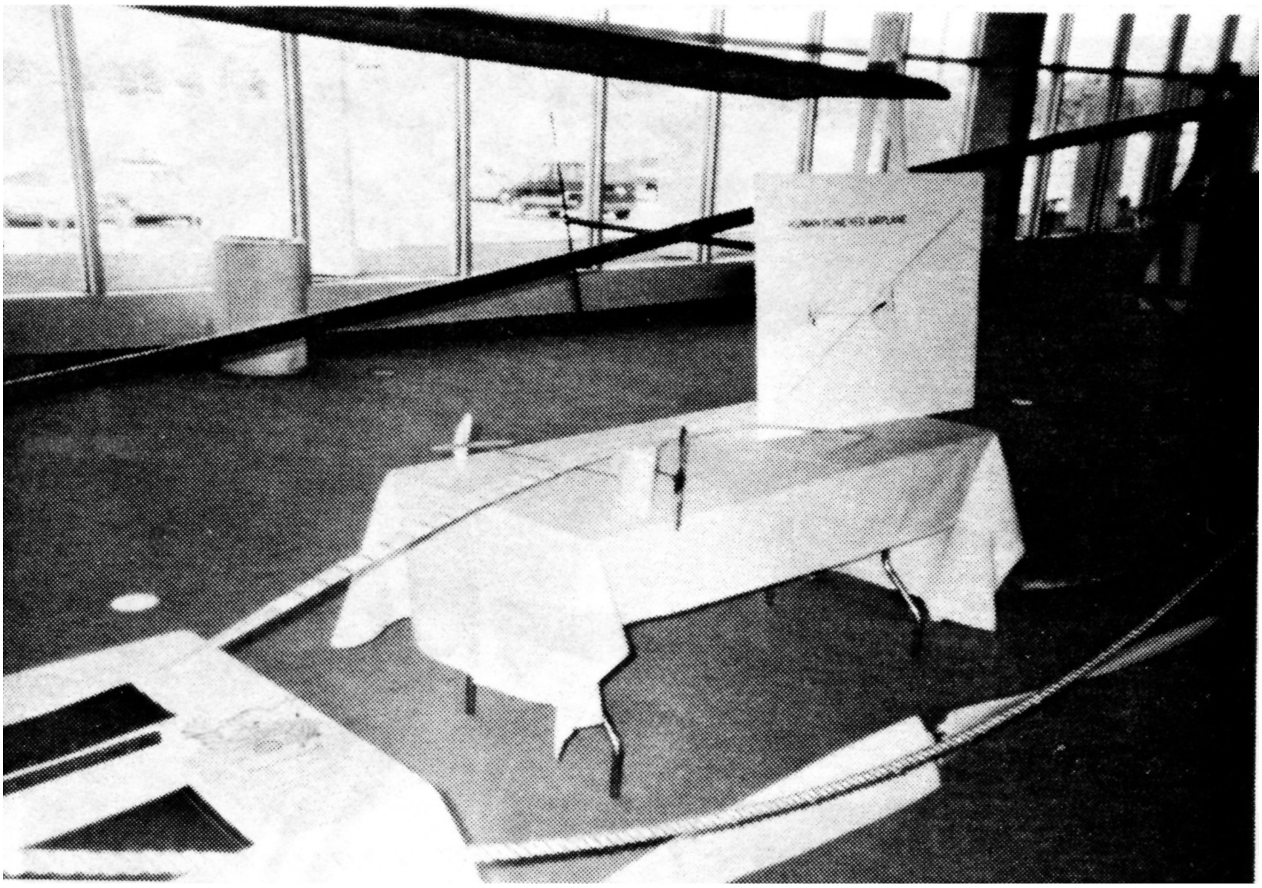

Figure 4. Shows the one tenth scale model while on display at the May 16th 1992 Flight Research Institute projects display at the museum of flight.

The external molds for the wings center section were completed during the summer of 1992. The molds were built with a flange on the leading and trailing edges to align the final wing halves on assembly. The external molds were built using polyester resin. A tooling polyester gelcoat was applied over the plug so that the fiberglass cloth would not show through on the inside of the mold. Three layers of fiberglass cloth were applied to the outside of the gelcoat after it was partially setup. A 0.5 inch urethane foam core was applied to add stiffness. Two more layers of fiberglass cloth sealed the core in and produced a rigid box structure. Each half of the center mold weighs over 60 pounds and posed a considerable handling problem for one person. Final sanding of the inside of the external molds was required due to 0.003 inch waves that formed on the plug mold during the external mold layup. This is common when plugs are built from ribs and a single layer of glass cloth. An improvement to the technique would have been to offset the templates, in the plug mold, and build a thicker fiberglass surface. Figure 6. (on the following page) shows both sides of the external molds for the vertical tail.

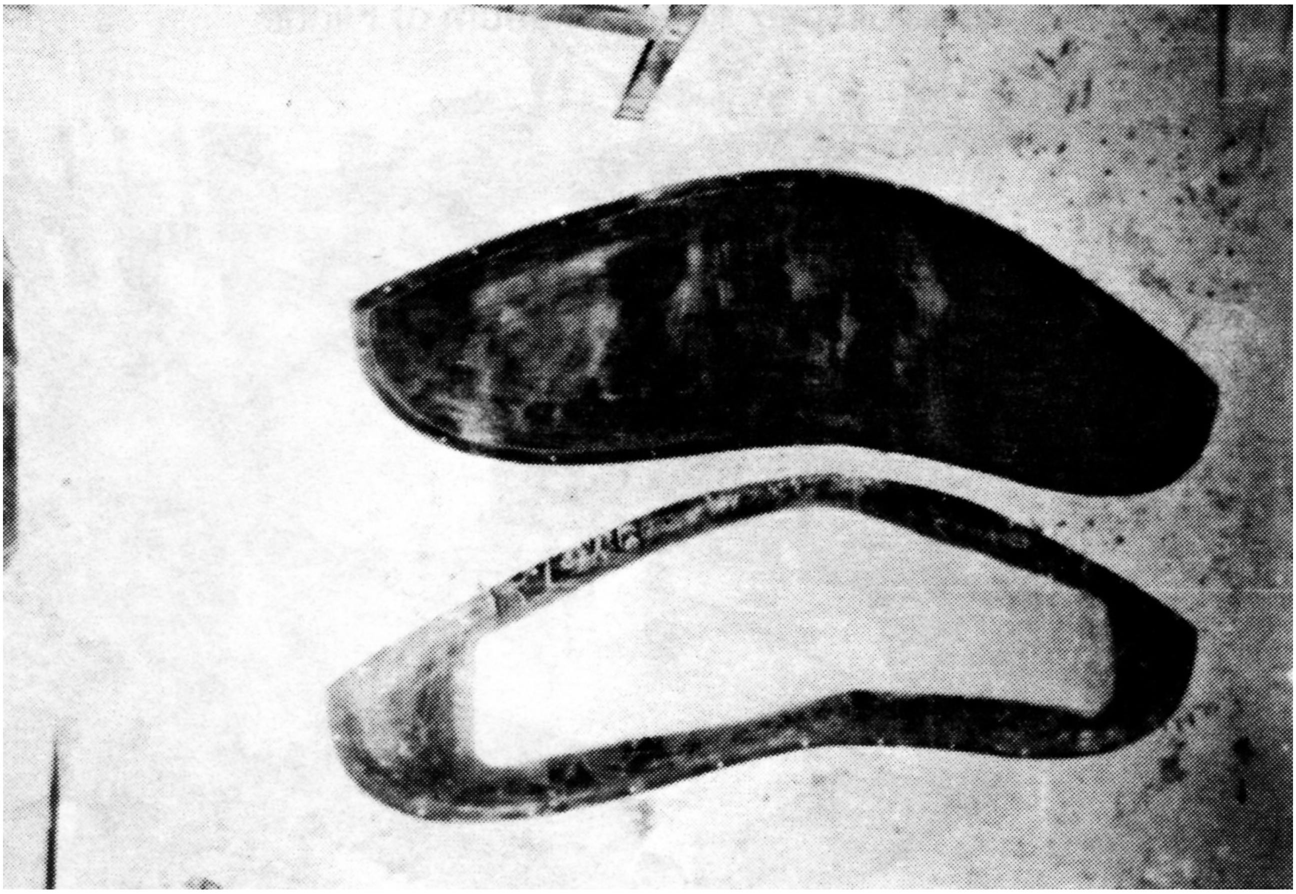

Figure 6.

The mould construction techniques were similar for all the moulds. Figure 7 above shows the horizontal tail female mould. The alignment bolts used for part assembly can bee seen on the mould flanges

The outboard wing plugs are currently (Dec. 1992) being built. These are 24 feet long and contain the 15% chord aileron, which has a 20 foot span. The right outboard plug mold is shown in Figure 8. (below). Foam is being applied to the aileron. The center wing external mold can be seen on the left side of the photo.

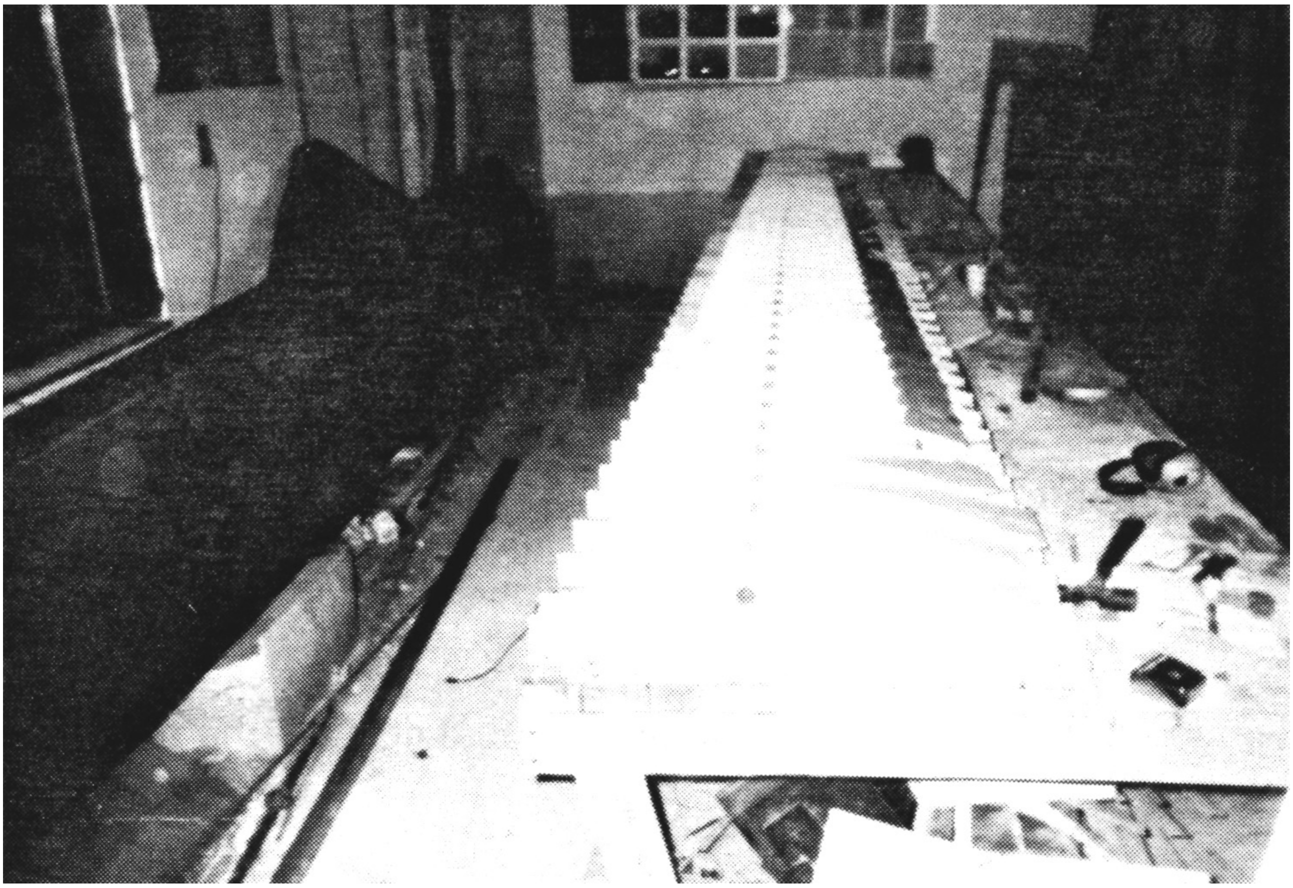

Figure 8.

The ailerons are designed to be Up only due to the large aft camber built into the cruise airfoil. Deflecting the aileron down would increase the drag substantially, with little gain in lift. Separate aileron molds are required for construction. Plans call for the aileron construction to include using 45 degree biased carbon cloth for the skin surface. This will provide additional stiffness in torsion which aids the aileron effectiveness. As with the tail surfaces, all contol linkages and cables are inside the structure for minimum drag. The controls are activated internally using a jeweler's chain and small reduction sprockets at each surface. This allows the cables to move further, reducing the required load and minimizing the effect of cable stretch.

Trial demonstration of the carbon skin secondary structure is complete. All of the carbon mat has been purchased (100 yards). The wing uses 1 ounce carbon mat which has a styrene spray applied. The spray allows the fibers to be handled after they are wetout with epoxy. The following procedure is used to layup the skins in the molds:

1. The mat is wetout on a Teflon vacuum table.

2. A vacuum is applied and the mat is sqeegeed to remove excess resin (this process produces a glue to fiber ratio of 80%).

3. The next step is to layup a piece of dry carbon mat over the 80% sheet.

4. The two sheets are then placed under a vacuum and resqeegeed (this brings the original sheet down to 60% glue ratio).

5. The first sheet is now ready to be put into a mold and the second sheet is placed onto the Teflon with the process repeating.

6. Before the carbon mat is placed into the mold, a white layer of polyurethane paint is sprayed into the mold and allowed to dry.

7. The carbon mat is added along with a pre-cut sheet of 0.125 inch foam. (this is vacuum bagged until dry)

8. The final piece of carbon mat is brought to 60% glue ratio and added over the foam.

9. A vacuum is applied and the skin is allowed to dry.

10. The wing spars are attached to the wing skins with foam ribs every 12 inches. (the wing skin doubles the torsional rigiity of the square spars)

The projected skin weight is still 15 pounds.

The foam for all of the secondary structure has been pre-cut and is ready for skin assembly. The foam was cut to 0.125 inch thick sheets on a cutting table built for the project by Dale Schubert. The foam was initially cut into 24 by 48 inch sheets. The cutter produced sheets with a variation of only 0.005 inches the whole sheet. The foam panels will be cut to fit the local mold shape prior to assembly in the external molds. Figure 9. (below) shows the flexibility of the 1/8 th foam core sheets.

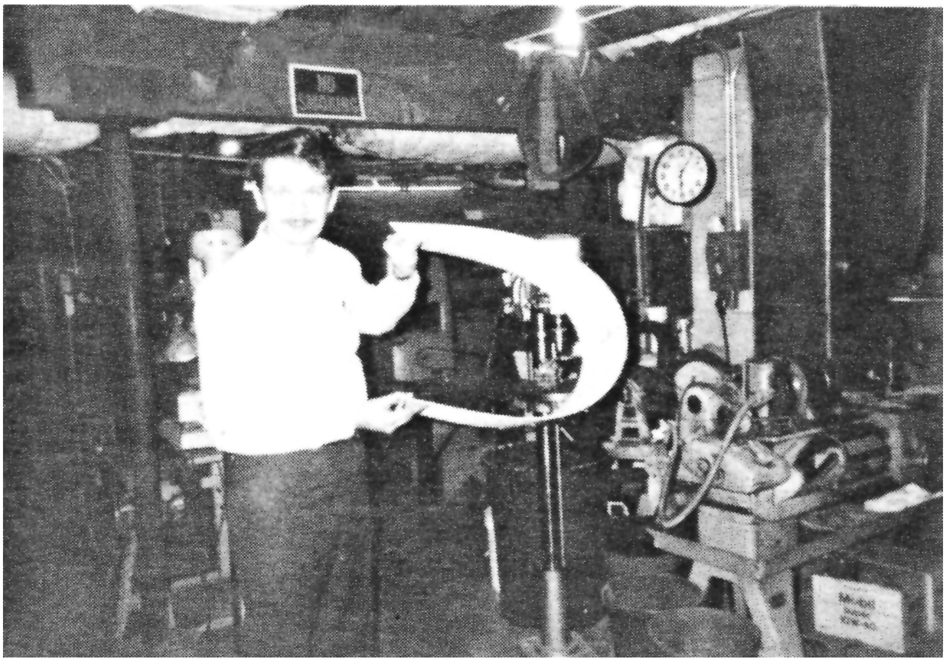

Figure 9.

Work on the retractable and driven landing gear is under way. A detail design drawing of the mechanism has been completed. The mechanism consists of an aluminum hub and bearing set with an armature made from a balsa wood core surrounded by a carbon laminate. Figure 10. (below) shows the balsa core for the landing gear strut on the wheel. The strut is shown in the "down" position. The upper arm is latched at the top to hold the wheel in position for take-off and landing.

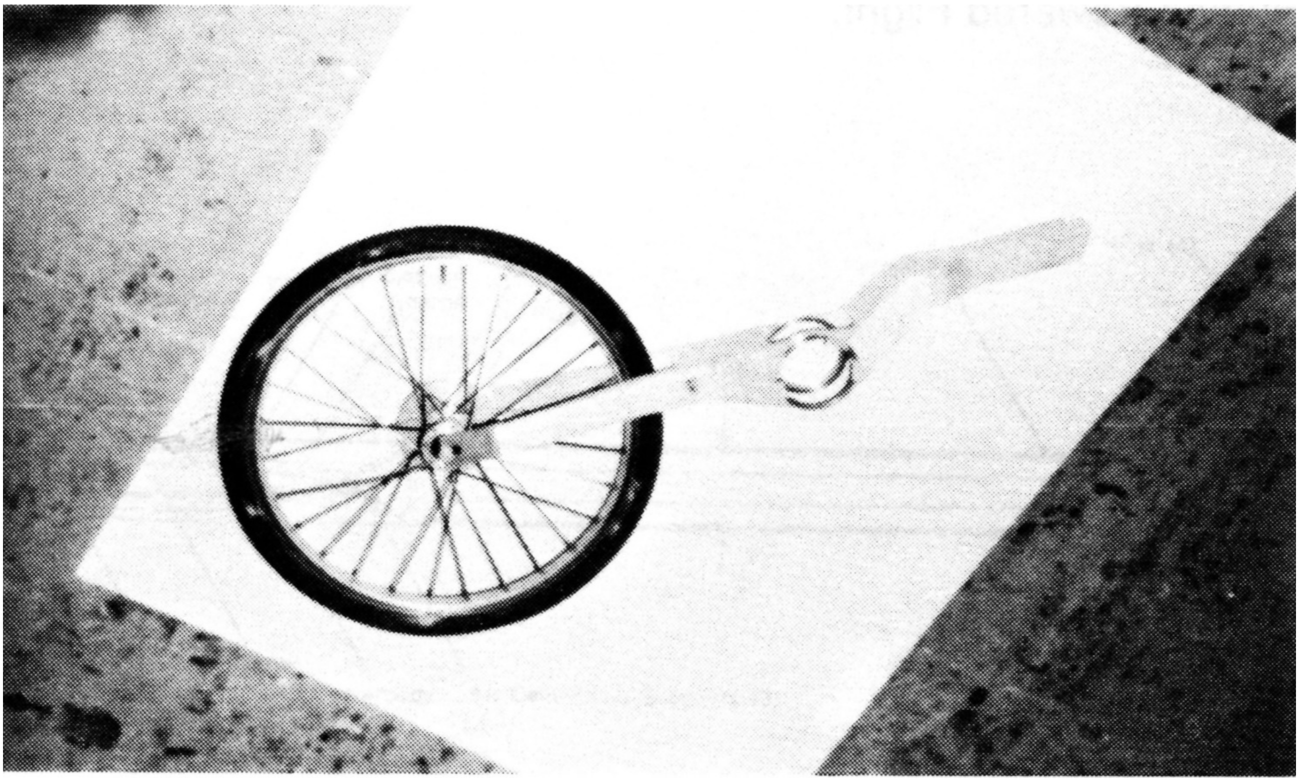

Figure 10.

The mechanism is designed to handle a 3 g landing with a 500 pound side load at the wheel. The retractable gear bearings are concentric with the pedal axis so that the wheel can be powered at all positions. A ratchet is located on the wheel so that power will only be applied to the wheel below 18 miles per hour. Above this speed the gearing transfers power to the propeller. This technique gives a lower gearing ratio for initial takeoff and prevents shock loads, to the propeller and drive train, from occurring during landing.

The propeller is now complete and the drive shaft and bearing hardware have been sent to England for final assembly with the propeller.

The drive train consists of a 0.25 inch pitch twisted chain from the pedals to the prop shaft. A study is underway concerning the low inertia of the drive train. The uneven power output of the pilot produces pulses to the propeller which generates a series of shed wakes. This reduces the overall efficiency of the problem. The pulses can be smoothed using an elliptical sprocket at the pedals. The amount of ellipticity will be determined by calculating the final inertia of the system and simulating it with a low weight flywheel on an ergometer.

After the moulds are complete, final assembly should proceed with rapid visible progress.

As a footnote Mr Henry Kremer died in the spring of 1992. Since he was the sole sponsor of human powered flight contests, I suspect this will be the Royal Aeronautical Society's final contest for human powered flight. I have been working on human powered aircraft since 1976 and have built a total of 12 aircraft, including the "Marathon Eagle" My dealings with the Royal Aeronautical Society has given me much respect for their willingness and drive to pursue this field of human powered flight.