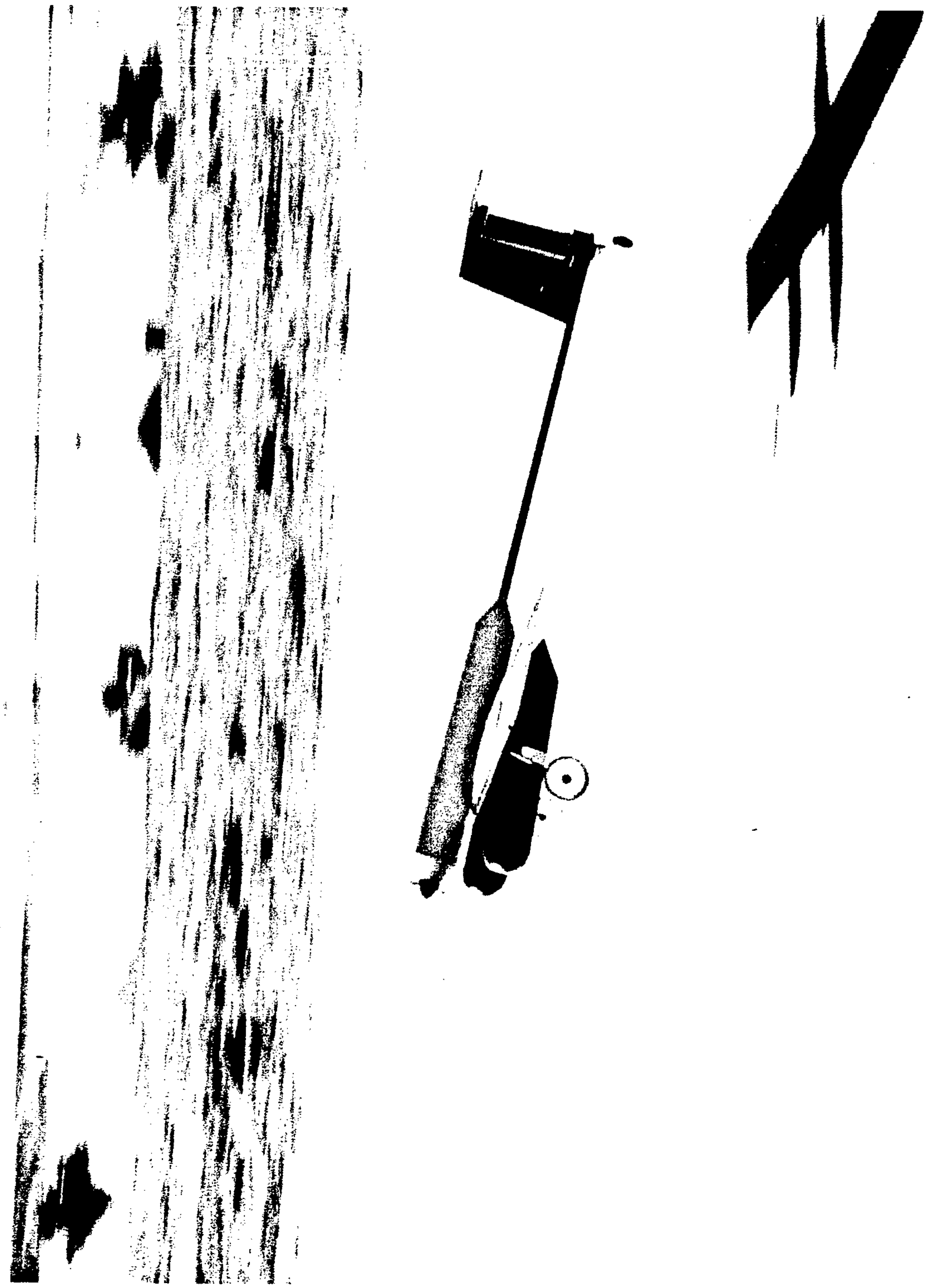
American Institute of Aeronautics and Astronautics

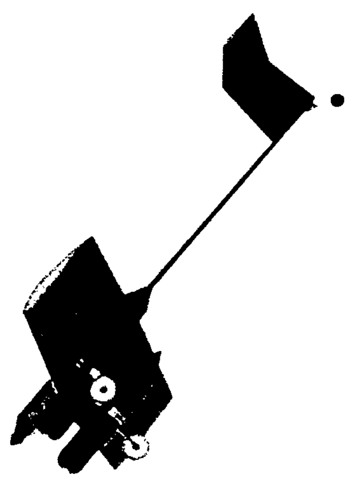
AIAA Cessna/ONR
Student Design/Build/Fly Competition

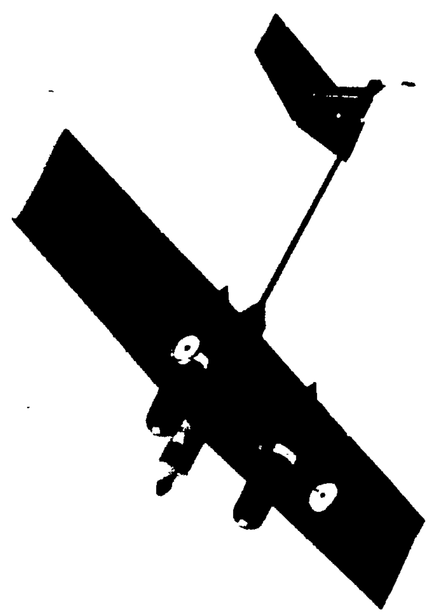
TEAM T.L.A.R.
FLIGHT PHOTOS

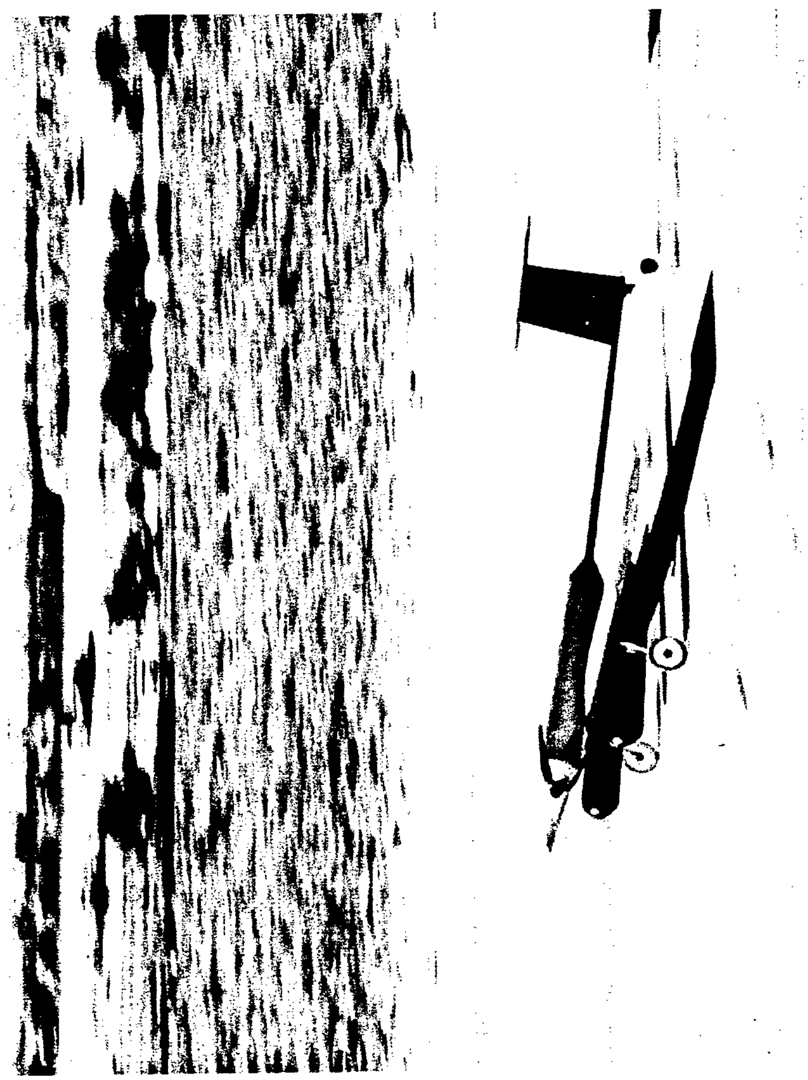
DESIGN AND DEVELOPMENT TEAM:

Andrew Mye
Joshua T. Hu
Annie Powers
Kari Goulard
John Taylor









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Aeronautics and Astronautics

AIAA Foundation/Cessna Aircraft/ONR
Student Design/Build/Fly Competition

Design Report: Proposal Phase

Submitted By:

The University of California, San Diego
AIAA Student Chapter Competition Team

March 13th, 2000

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i. Table of Contents

1. Executive Summary

1.1 Design process

As this was UCSD's first year entering a competition of this nature, we realized that the first step was to decide on a basic design. We started by looking at last year's designs, visiting hobby shops, as well as a local airfield for model planes. Visiting the airfield turned out to be the most informative, since we were able to view the plane not only on the ground but as well as in flight. As fortune would have it, we viewed a plane that had similar dimensions and thereby had a template from which to spawn our own design. Following careful analysis of the scoring procedure we determined that four liters would be a sufficient payload. This prediction allowed us to proceed with design alternatives, which would promote speed without sacrificing payload capabilities.

The initial design included a biplane configuration with dual motors. We soon realized that this configuration would not suffice due to high drag and difficulty of construction. Following this realization we considered a single wing, dual motor configuration. This design alternative would allow us to utilize the idea of placing the payload into nacelles along with the motors. These pods were located on the wings at a distance that would allow enough clearance for the propellers.

Further alterations to the design occurred when we researched propulsion systems. This research revealed that motors with sufficient thrust capabilities to propel a single engine design exist. With this knowledge we decided to vary the design to a configuration that would accommodate a central pod flanked by two nacelles on the wings.

The fuselage would consist of the central nacelle, while the two outboard nacelles would contain the cargo. This design would permit us to carry the predetermined payload and, thus became our working design. At this point we were free to begin considering possible designs for the other components, such as the nacelles, and horizontal/vertical stabilizers, etc....

1.2 Design Tools

Through extensive research and recommendations from storeowners, several programs and computational tools were discovered. Tools employed during the process included:

- Virtual Motor Test Stand (Aveox):
  The ability to vary parameters such as motor model and power input (batteries) aided in determining an effective propulsion system.

- Microsoft Excel:
  Excel was found to be extremely useful throughout the entire design process. Spreadsheets for Rated Aircraft Cost, moment, Lift (takeoff and flight), power and plan form (area and wing loading) calculations were generated via Excel.

- VirtualFoil (Hanley Innovations):
  This program allowed comparison between various airfoil characteristics. Examples of this include C_d and C_m versus Angle of Attack, Polar plots, velocity and pressure distributions and C_p versus Chord position.

- Macfoil:
  Obtained printouts of airfoils with the necessary chord length. These printouts were used as templates for hot wire cutting of blue foam.

2. Management Summary

2.1 Management Architecture

The UCSD project team consisted of 12 undergraduates with diverse backgrounds. Team member profiles are shown below.

Name	Year	Major	Experience
Andrew Mye (Project Manager)	Senior	Mechanical	AutoCad, knowledge of composite materials, machining, programming
Greg Tengan	Senior	Mechanical	AutoCad, programming
Franky Choi (Chapter Vice President)	Senior	Aerospace	Aerospace Structures, Aerodynamics
Brian Faz (Treasurer)	Senior	Mechanical	Fundraising, programming
Kari Goulard	Senior	Mechanical	Pro-Engineering Software
Samantha Infeld	Senior	Aerospace	Aerospace Structures, Aerodynamics, AIAA Chair
Jocelyn Lo	Junior	Mechanical	
Yishai Mendelson	Senior	Aerospace	Aerospace Structures, Aerodynamics
Annie Powers	Freshman	Aerospace	Fundraising, AIAA Secretary
Josephine Sheng	Junior	Electrical	Fundraising, AIAA Council Representative
John Taylor	Junior	Mechanical	Project Coordination, programming
Joshua Hu (Chapter President)	Senior	Aerospace	AUVSI Design Competition, AIAA Chair, fundraising, programming

During one of the initial meetings a decision was made to divide the group into various subgroups, each with it's own chair. These subgroups include wings/stabilizers, cargo pods/boom, landing gear, electrical, and fundraising. Weekly meetings allowed the team to discuss component interfaces, ideas, roadblocks encountered and possible alternatives. This management structure enabled everyone to choose a role that they felt comfortable with and thus ensured quality. In addition, this structure was conducive to timely completion of each subgroup's particular responsibility. These responsibilities are as follows:

- The wings/stabilizers subgroup began by comparing a range of airfoils. Through use of these comparisons an airfoil was decided upon, an E214, which satisfied the preliminary estimations for necessary lift and drag characteristics. As the specifications of the design (i.e. weight, placement of components, etc...) became available, the necessary calculations, such as the wing loading and pitching moment about the center of gravity, were completed. The wings/stabilizers subgroup consisted of Josh, Franky, Jocelyn, Yishai, and Greg.

- The cargo pods/boom subgroup focused on designing the cargo/motor pods and the boom. They researched possible designs for the pods and boom and also dealt with the calculations to determine the particular component's strength requirements. In addition, this group also investigated what types of connections to the wings would provide the best stability. This subgroup included Andrew, Kari, and Brian.

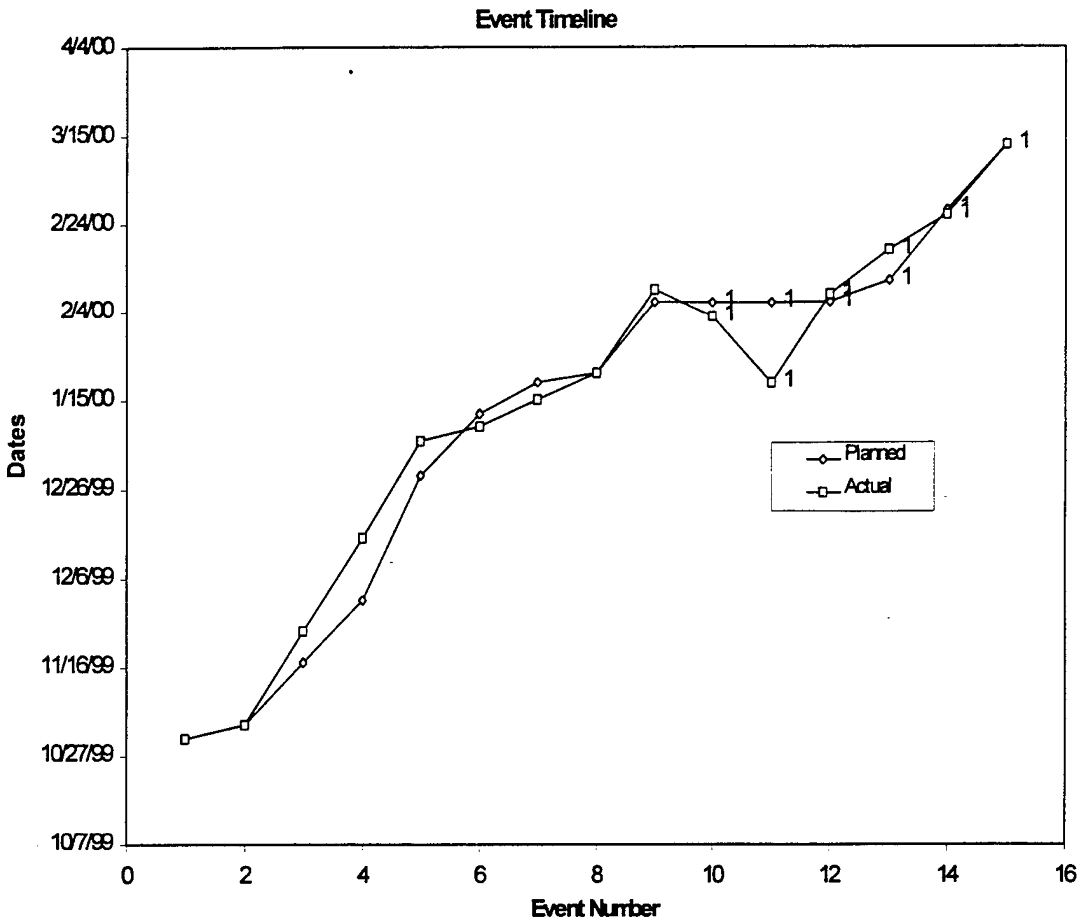
- The landing gear subgroup's main responsibility was to develop a landing gear structure. This group worked closely with the pods group to devise a means to attach the structure to the airframe. The landing gear subgroup consisted of Andrew and Brian.

- The electrical subgroup, headed by Josephine, took care of the wiring of the motor, servos, batteries, and onboard radio receiver. In addition, calculations with respect to necessary voltage and amperage were part of this group's responsibilities.

- The fundraising subgroup sought out possible sponsors and acquired both sponsorship and accepted donated components. Those involved in the fundraising aspect of the project included Andrew, Josh, Annie, and Brian.

2.2 Task Scheduling

During the month of October, the group decided upon a schedule of completion dates. Each subgroup was expected to complete tasks by a certain deadline. The following chart (Figure 1) depicts the planned and actual date of completion (D.O.C.) of each major event. Through teamwork and communication we were able to overcome the problems encountered due to inexperience. Andrew, Brian and Josh's leadership skills pulled the team together when things seemed overwhelming and motivated the group to get the tasks accomplished.



Event		Planned D.O.C.	Actual D.O.C.
1.	Submitted Notice of Intent to Compete	10/31/1999	10/31/1999
2.	Conceptual Design FOM's chosen and ranked	11/3/1999	11/3/1999
3.	Conceptual Design finalized	11/17/1999	11/24/1999
4.	Preliminary Design finalized	12/1/1999	12/15/1999
5.	Detailed Design completed	12/29/1999	1/6/2000
6.	Obtained sponsorship for the project	1/12/2000	1/9/2000
7.	Acquired materials and parts for construction	1/10/2000	1/13/2000
8.	Construction started	1/21/2000	1/21/2000
9.	Wings completed	2/6/2000	2/9/2000
10.	Pods completed	2/6/2000	2/3/2000
11.	Boom completed	2/6/2000	1/19/2000
12.	Landing Gear completed	2/6/2000	2/8/2000
13.	Final assembly of aircraft	2/11/2000	2/18/2000
14.	1st test flight of aircraft	2/27/2000	2/26/2000
15.	Completion of Proposal Phase Report	3/1/2000	3/5/2000

Figure 1: Dates of Completion

3. Conceptual Design

3.1 Design Parameters

In order to ensure safety, stability, structural integrity and quality performance several design parameters were selected. Design parameters that were considered during the design stages included:

- *Undercarriage design:*
  The design of the landing gear was considered to be important due to the impact energy encountered during landing. Ground handling is another factor that is affected by the landing gear configuration.

- *Nacelle shape and location:*
  The shape of the nacelles, heretofore referred to as Pods, was carefully thought out because of its impact on drag and other flight characteristics. The location of the pods also played a critical role in calculating the center of gravity and, thus had a considerable impact on the overall flight stability. This parameter would be used in determining the location and functional requirements of the undercarriage.

- *Payload access:*
  Scores earned during the flight periods are dependent on speed of flight and loading/unloading of cargo. The team realized that optimization of the loading/unloading phases would have allow for a better score. This, therefore, affected the location of the cargo pods.

- *Inter-component attachments:*
  The interfaces between components such as the pods and the wings, landing gear and spar and wing section joiners demanded careful consideration. These locations would give rise to stress concentration factors that needed to be neutralized so as to promote structural integrity.

3.2 Figures of Merit

The Figures of Merit, along with ranking, established during the Conceptual Design period are as follows:

- *(1) Lift Characteristics):*
  The flight score is determined by the payload capacity of the design, therefore the lift characteristics were of the utmost importance. This criterion was of critical importance while considering the airfoil and shape of external structures.

- *(2) Efficiency of Payload Loading and Unloading:*
  Since time is of the essence during the competition, efficiency of payload loading and unloading was a major consideration. This particular FOM had a big impact on the placement and dimensions of many integral components, especially the cargo pods.

- *(3) Durability (structural):*
  Taking into consideration the high wind conditions we attempted to construct an airframe that was not only light but also durable. With the understanding that these conditions would lead to bumpy landings and take-offs we made appropriate material choices.

- *(4) Ease of Fabrication:*
  Due to limited experience and time in the machine shop we chose structures and components that were easy to construct. The structures/components included the landing gear, spar and boom. This FOM made it very difficult to meet the functional requirements of each of the components.

- *(5) Availability and Cost Efficiency of Materials:*
  Establishing connections within the business community was an invaluable step in acquiring advice, monetary and material support. Obtaining financial assistance proved to be more difficult than we thought, therefore we were obligated to make cost and availability a major consideration throughout the entire design process.

3.3 Alternative Designs

- *Wing/Motor Basic Layout:*
  Initially, a biplane configuration with dual motors was considered because of the extra lift area it would provide. Although this satisfied FOM 1 it was not in compliance with FOM 4 and FOM 5. We also noted that a biplane configuration increased the drag significantly thereby increasing our power requirements. With this realization we began looking at simpler designs such as a single wing configuration with dual motors.

This configuration required that the plan form area be increased thereby sufficient lift would be attained. This design would satisfy FOM 1 without challenging the requirements of FOM's 4 and 5 would be satisfied. At this point in time we began to gather information on propulsion systems and discovered that single motors existed that could meet the requirements.

This discovery led us to consider a single wing/motor design. This not only met the requirements imposed by the FOM's but also decreased our overall cost and rated aircraft score.

The ranking of these design concepts is as follows:

Figures of Merit:	Lift	Payload	Durability	Fabrication	**R.A.C.**
Biplane	5	2	-	1	95.29
Single wing dual motors	4	2	-	2	74.78
Single wing single motor	4	2	-	3	68.69

- *Cargo Placement:*

  The placement of the cargo pods was dependent on the overall layout of the design. Once we decided on the single wing/motor arrangement, we noticed that the nacelles on the wings could serve as cargo pods. This would allow easy access to the payload and thus was in complete agreement with FOM 2.

- *Spar Design:*

  With the basic design of the airplane, and a good estimate of the weight, we could consider a spar design. We began by comparing the mechanical characteristics of tubular, I-beam and rectangular structures. They chose the I-beam structure due to its good strength-to-weight ratio.

- *Landing Gear:*

  In designing the landing gear, we searched for a configuration that would be durability, thus satisfying FOM 3. We looked at a torsional configuration, in which the structure's material would absorb the majority of the energy of impact. We immediately recognized the fact that this configuration would reduce the risk of damaging the airframe during landings.

- *Pod Design:*

  In considering the design of the pods, low aerodynamic drag was the first priority. We began by researching planes with external fuel tanks. This led us to the conclusion that a cylindrical shape would be best. Cylindrically shaped parts, with the use of a lathe, are easy to fabricate thus satisfying FOM 4.

- *Empennage:*

  To avoid the problem of downwash from the wing interfering with performance, a T-type empennage was chosen. This configuration would be easy to construct, consequently FOM 4 would be satisfied.

3.4 Design Selection

Selection of the final configuration was made after careful deliberation. We decided to elect the following design:

- Single wing
- Single motor
- Two cargo pods
- Motor/Battery pod
- Torsional landing gear configuration
- I-beam spar
- T-type empennage

4. Preliminary Design

4.1 Design Parameters Considered

Based on the requirements of the competition, the design parameters considered were:

- Aspect Ratio
- Power Capability
- Airfoil Design
- Tail Shapes
- Thrust-to-Weight Ratio
- Fuselage Shape and Size
- Desired Payload Capacity
- Landing Gear

Aspect ratio was a major consideration as it determines the ability of the plane to glide, affecting the thrust-to-weight ratio. An increased ratio would allow the airplane to require a shorter take-off distance. The airfoil design was extremely important as the purpose was to determine how to achieve the maximum possible lift for the given surface area and weight. The curvature of the airfoil affects both the pressure and velocity distribution, which in turn affects the control of the airplane.

The shape of the tail is another important characteristic in the handling of the airplane. The vertical, horizontal size and locations are key to obtaining the maximum maneuverability of the aircraft.

The desired payload capacity was also another key consideration. The maximum payload allowed would be ideal; however, this adds considerable additional weight, which in turn affects the maneuverability of the airplane, its velocity and lift, along with placing increased strain on the materials.

Power also played an important part in the preliminary design. The motor would need to be light, yet powerful, as it was deemed necessary for the plane too not only have a short take-off ration (less than 100 feet), but to have a rapid climb rate. In order to achieve such stringent requirements, the power capability was carefully determined and a suitable motor selected.

Landing gear required careful consideration; it, more than any other part, would need to be robust, as it would have to absorb the shock of landing again and again. Weak landing gear would result in failure of either the gear or a portion of the plane due to the sudden jolt of ground impact, perhaps even to the point of inability to repair within the allotted time.

4.2 Figures of Merit

- Construction Capability
- Structural Integrity
- Weight

- Payload Access
- Cost

Time and financial aspects were key to the final design. A complicated wing shape would require unreasonable time, not to mention the cost of producing such a design. Furthermore, simplicity allowed for the possibility of mistakes to be corrected in a reasonable amount of time and with minimal additional cost. The last argument in favor of a simple design is its robustness – a simple, solid wing would be able to take the hard jolt of landing and also support more weight than a complicated airfoil construction.

The structural integrity of the airplane and the weight were two considerations that were closely intertwined. It was important for the airplane to be robust, yet be light enough not to require more than a reasonable amount of power to maintain flight. Materials were considered mainly on the basis of their strength-to-weight ratio. The buffeting of winds during flight, possibility of rough landings, and the weight of the payload required that the airplane be able to withstand any and all such events as might occur during the course of the competition.

Finally, payload access was also a consideration. The time constraint of the competition requires quick removal/insertion of the payload. Location of the pods on the airplane and the ability for ground members to access them would increase the amount of time spent in the air by the plane.

4.3 Analytic Methods

4.3.1 VisualFoil

Visual foil was used to compare airfoils and their defining characteristics. This program allowed us to make polar plots, plots of velocity and pressure distributions, moment and pressure coefficients versus angle of attack (AOA), and moment versus AOA. These plots were extremely helpful in choosing an airfoil.

4.3.2 Aveox Virtual Test Stand

We used this program to compare the different battery, motor and propeller dimension combinations. We found this to be helpful when deciding on the propulsion system.

4. Preliminary Determination of Features

Initially, designs were brainstormed and critiqued with consideration of applicability to come later. Immediately, several design considerations to be investigated were separated from the pile: single-wing versus biplane, dual versus single motor, high versus low wing, number of pods, and so on.

4.1 Airfoil

The competition requirements determined the wingspan of the aircraft, leaving only a few design parameters that could be changed by the contestants. Among these were the aspect ration, the airfoil design, and the decision between a biplane and single-wing. The additional wing of the biplane would provide a great increase in lift. However, the complications involved with the design of such an airplane, as the necessity for an additional non-payload fuselage caused this idea to be rejected.

The next consideration was that of a high wing versus a low wing. A low wing was decided upon as the landing gear could easily be incorporated, and would allow for more support for the pods, as opposed to them being suspended from a high wing. A sweep of zero degrees was chosen because of fabrication difficulty concerns.

4.2 Tail

The empennage of existing RC aircraft was carefully considered when determining the final design. Initially, the horizontal stabilizers were located at the base of the tail, as is the case with many commercial and most of the local RC aircraft. The decision to move to a "T-Tail" design was based on concerns from down wash of the wing. The finalized area of the tail came out to be 264 in^2.

4.3 Motor

It was felt that the main points of consideration for the capability for the motor were the climb rate and takeoff distance. Based on previous research and the final design, a thrust-to-weight ratio of around 0.5 would be ideal.

An initial design considered consisted of a dual-motor system. This would supply the much-appreciated extra thrust, increasing the velocity of the plane in-transit, decreasing the take-off distance, and increasing the climb rate – all ideal situations. However, it was determined that the competition-imposed penalty was undesirable, the price unreasonable, and that equipment had been found that would greatly reduce the weight of the airplane.

It was decided to use an Aveox 1415 3Y motor running off thirty-six battery cells, turning a 16 in. diameter propeller. The total thrust was determined to be 221 oz. The placement for the motor was at the logical location of the front of the fuselage, which doubled as the center pod.

4.4 Pods

Most of the initial designs considered only two pods, with the capability to hold two liters of water each. This was considered a good balance between the weight of the pods and the desire to transport as much water as possible during each flight. The pods would be located equidistant from the center of the wings. This design was ideal for the dual-motor design.

The single-motor design required some modifications – the least not being the fact that it would be necessary to position the motor at the center of the wings, requiring a fuselage located there to house the motor. This determined that either a single pod could be used, as the fuselage could logically and efficiently double as a pod, or three with the center fuselage and two pods on the wings. It was determined that the power of the motor and strength-to-weight ration was sufficient support for three pods. The two pods on the outer wings are located 10 inches from the fuselage centerline. Further details of the pods are included in the detail design section.

5. Detail Design

5.1 Performance Data

Upon completion of our design the task of gathering data was undertaken. We have estimated 95.04 Watt–hrs, average power of approximately 712.8 watts. Other flight data is in the process of being gathered and determined and evaluated.

5.2 Final Configuration

The final configuration of the plane consisted of a high-wing, single motor, three nacelle design. The undercarriage was based on our initial torsional hypothesis, the boom was purchased from a local composites company and the T-type configuration was chosen for the empennage.

5.2.1 Wing

The final design of the wing followed from much careful consideration of the flight characteristics that it would impart. The plan form area was 1176 in^2, slightly tapered from 15 to 13 inches of chord and single piece construction. We chose an Eppler 214 as our airfoil as it met all of our lift, drag, and other flight characteristics quite well.

5.2.2 Nacelles

The location of the payload nacelles was at a distance of 10 inches from the centerline of the entire structure. This had a large impact on the placement of the undercarriage because of its obvious impact on stresses experienced during landings. The fuselage consisted of the motor/battery pod and was aptly located in center of the symmetric structure. These nacelles were all 21 inches long and 4 inches in diameter.

5.2.3 Undercarriage

The initial design of the landing gear was judged to be the easiest and most effective configuration. The placement was, for structural integrity reasons, chosen to be just outboard of the payload nacelles. The forces experienced during landings were at their highest value at the payload nacelle locations. This forced us to place the gear as close to the cargo pods as possible. This distance was chosen to be at a distance of 11 inches from the centerline of the plane.

5.2.4 Empennage

Located at a distance of 38 inches from the trailing edge of the wing, the T-type configuration for the empennage would allow for good flight handling characteristics. The boom, which was attached directly to the vertical stabilizer, was a carbon fiber tube of approximately 2 oz. The area of the empennage was 88 in^2 and the horizontal stabilizer was 22 inches long. We chose a symmetric airfoil, which was tapered from 9 inches to 7 inches.

6. Manufacturing Plan

6.1 Manufacturing Processes

The manufacturing processes involved in the construction of a model airplane utilize various materials. These include foam, wood, lightweight metal, plastics, composite materials and combinations of them all. Model airplanes tend to be combinations of the above. We encountered many planes that utilized combinations of wood, foam, plastics and metal.
Such planes used:

1. Wood as ribs and fuselages
2. Plastic as wing skins
3. Metal in places that demanded strength
4. Foam as wing/empennage cores
5. Composites as stiffeners and strengtheners

We decided that the best approach was to employ combinations of these. The individual components and their respective functional requirements would dictate what the best choice of materials would be.

6.2 Figures of Merit

The following figures of merit were used to compare the competing concepts during the manufacturing process:

- Machining skill level required (1)
  Due to few of us having machining this became one of the critical FOM's

- Material availability (2)
  The availability of materials was of great importance for several components.

- Material cost (3)
  Cost of materials caused great concern due to our small working budget.

- Required time for fabrication (4)
  Timely completion of parts would allow for room for error.

- Weight of material (5)
  The weight of the entire structure would play an important role in the performance of the design.

6.3 Material Selection and Fabrication Process

6.3.1 Wings and Empennage

The wing, vertical and horizontal stabilizers were constructed from a combination of blue foam and glass fiber. The 2 lb/ft^2 blue foam made for an excellent core due to it's light weight and surprising stiffness. Once the core was cut out we installed the necessary hard points and servos so that we could proceed to encase the entire structure in 2oz bi-directional glass fiber.

The process of cutting the foam is quite similar to what is done for surfboard foam cores. In order to cut the foam we needed to make full-scale templates with the plots obtained from the MacFoil program. Two plots of each were needed in order to create templates for the top and bottom faces of the wing. We then attached the plots to Formica so that we could cut down to where the top and bottom lines of the airfoil were exposed. The templates were then attached directly to the foam. Once attached, we utilized a wire bow with a voltage applied across opposite ends so as to heat the wire up to an appropriate temperature. The templates were used as guides for the wire as it was run through the blue foam. The bottom edge was cut first so as to ensure accuracy, then the top edge was cut in the same manner, except this time with the top template attached to the foam.

Once this was completed we installed quarter inch thick marine grade plywood in the foam to act as attachment points for the pods and landing gear. The spar was then installed at the 30% chord line where the wing was thickest. The next step was to lay the glass fiber on Mylar and evenly coat the fiber with an epoxy. We then proceeded to lay the Mylar and glass on the wing in the proper orientation. At this point we put the wing in a vacuum bag so as to ensure even and smooth adhesion of the glass to the foam and hard points.

The final step in the manufacturing of the wings was to cut out the control surfaces. The control surfaces were then reattached with the use of a high strength tape to acts as a hinge. This process was repeated for the empennage structures with the only difference being the location of the hard points and the servos and a strip of carbon to add stiffness.

6.3.2 Pods

The pods for the payload and the motor/batteries were comprised entirely of glass fiber. Marine grade plywood was utilized again as material for attachment to wings. Care was taken not to cut the fibers, which would lessen the strength dramatically.

The construction process began with the production of a wooden plug on a wood lathe. Three molds of the plug were made for each pod. These molds provided a template in which to place the glass fibers. We then proceeded to incorporate the attachment points.

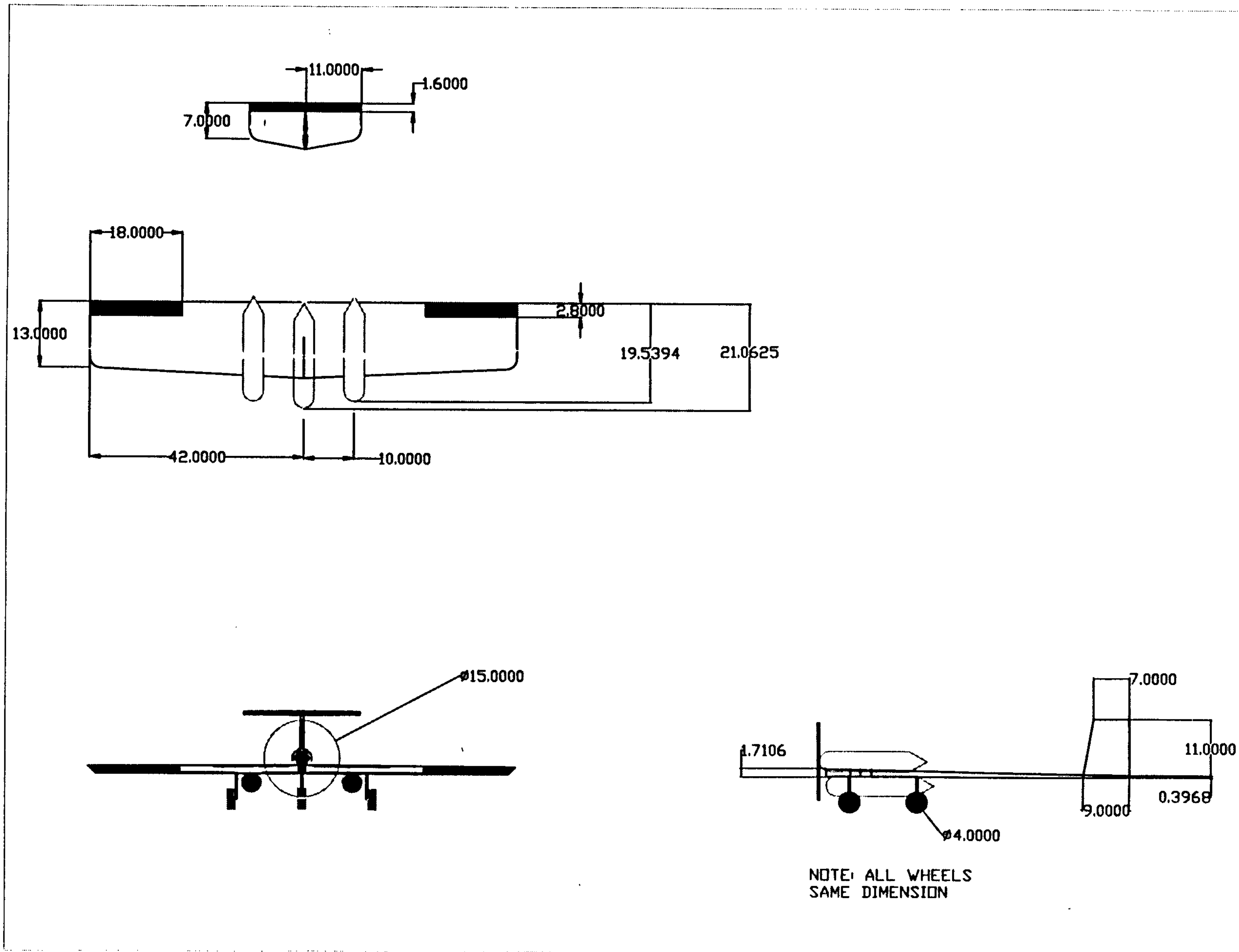
6.3.4 Undercarriage

Then landing gear structure consisted of a combination of .25 inch diameter steel piano wire and marine grade plywood. This torsional system allowed for easy construction without sacrificing durability and weight.

The production of this component included machining blocks of wood in the proper dimensions and gluing them together. A notch was made in the center at .25 inch depth to accommodate the wire. Brackets were then screwed in to prevent the wire from breaking free. The wheels for the plane were made of aluminum with a rubber O-ring that acted as a tire.

6.3.5 Spar

The spar was constructed of a combination of carbon tow and end-grain balsa in an I-beam configuration. The balsa was cut into 3-inch square parts and then glued together. Then a groove was cut into top to make room for the 2K-carbon tow, which would provide strength and stiffness. The entire structure was then inserted into a groove in the wing at the 30 % chord line. This line was the thickest point of the airfoil and thus would provide enough room to accommodate the spar. The spar was then sanded down so that it was flush with the airfoil surface.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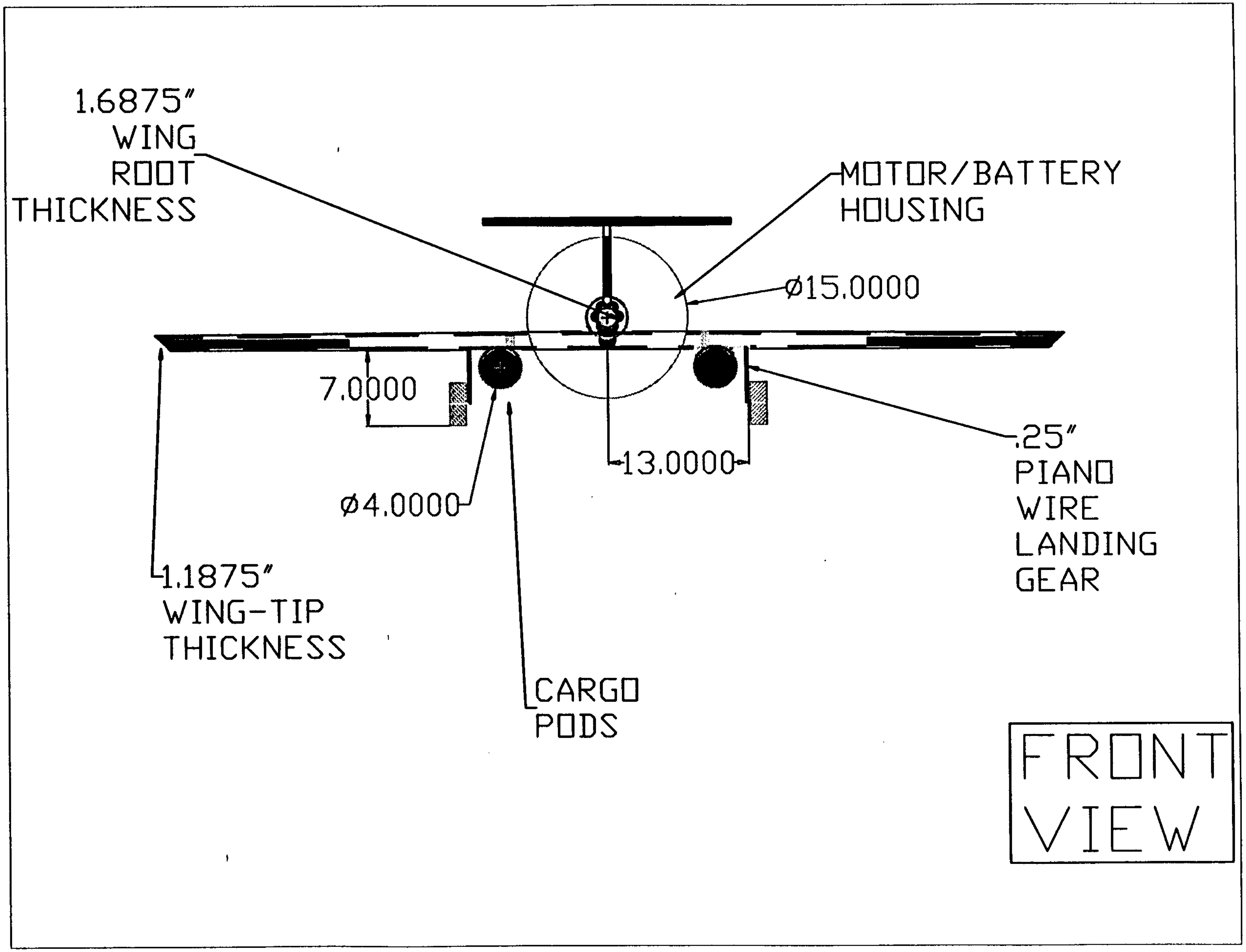
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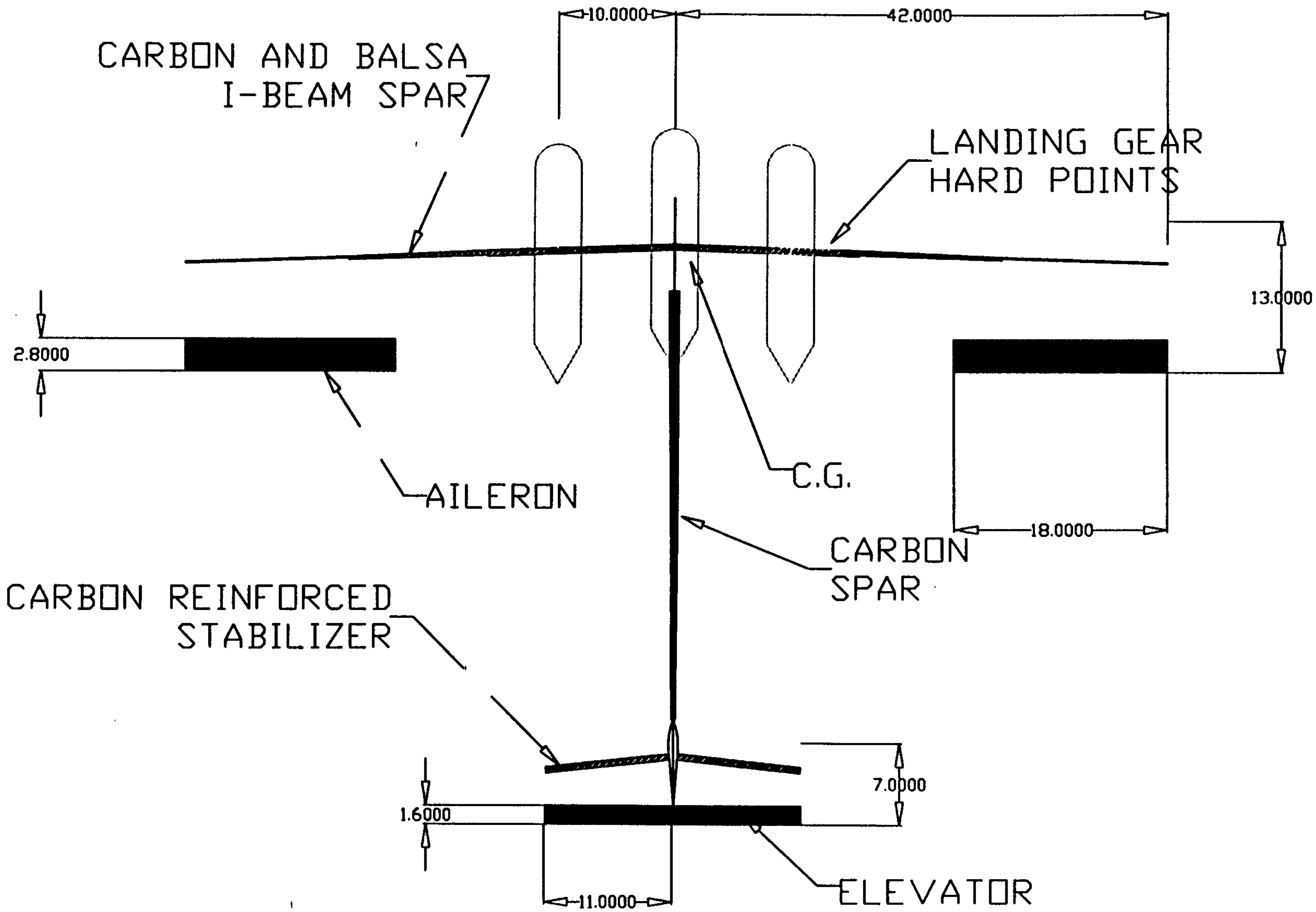
CARGO PODS
FRONT VIEW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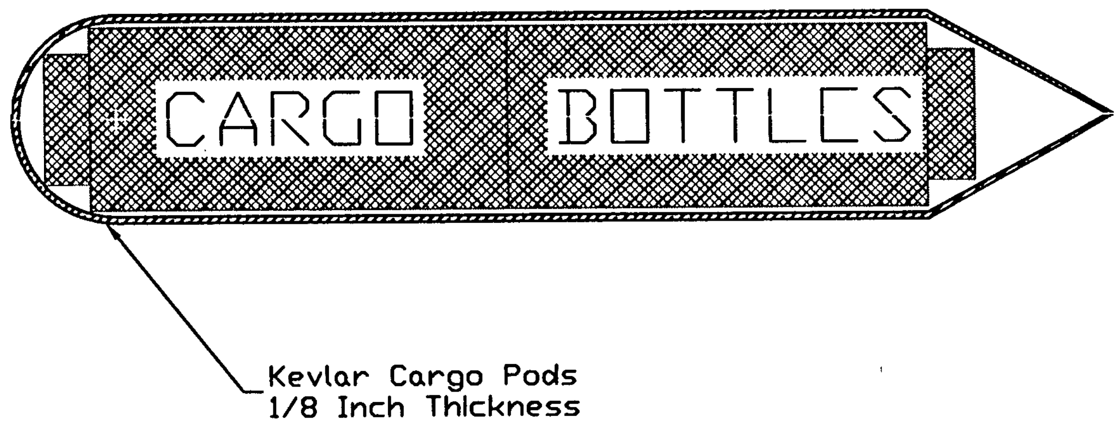
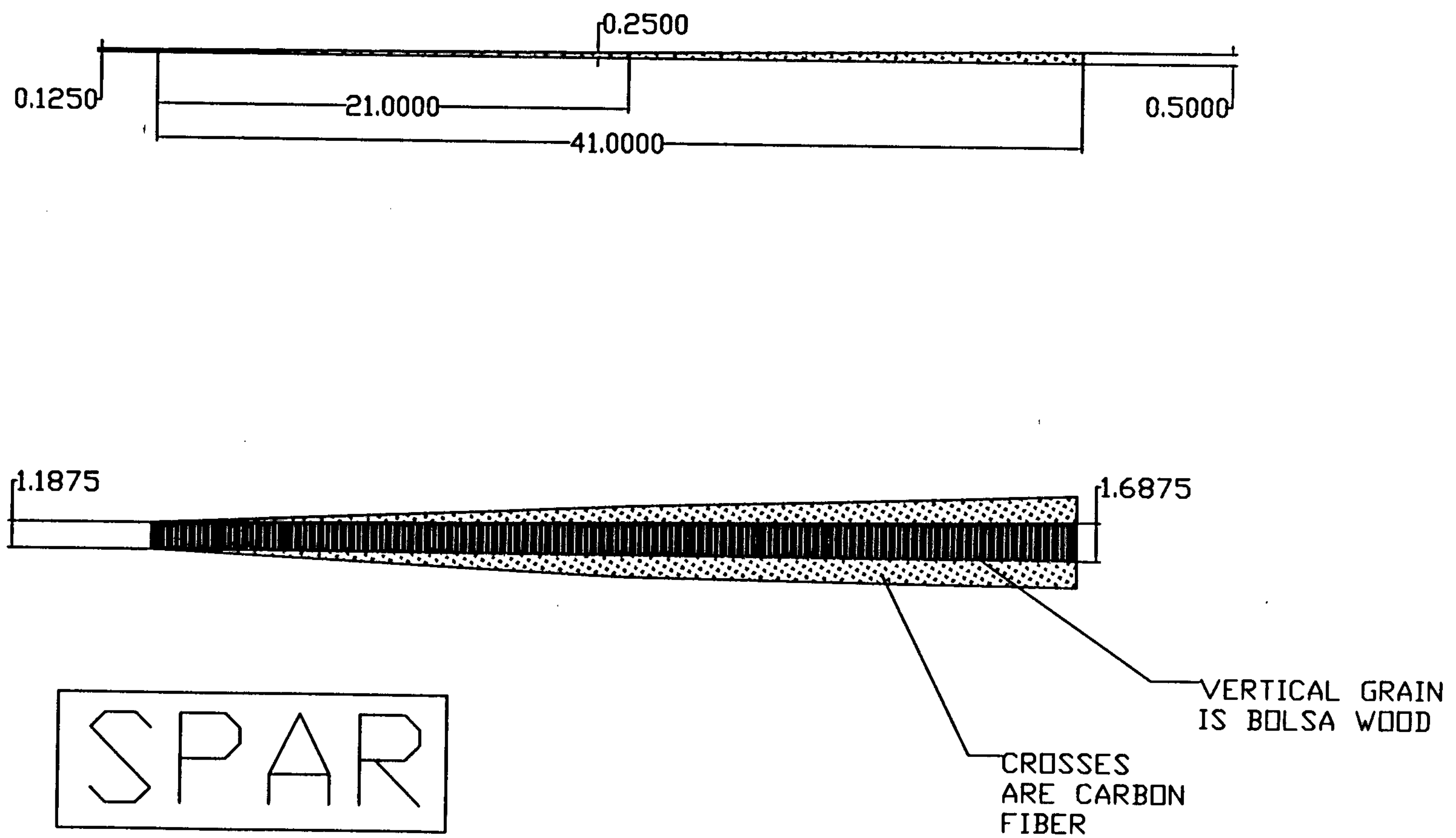
BOTTOM VIEW

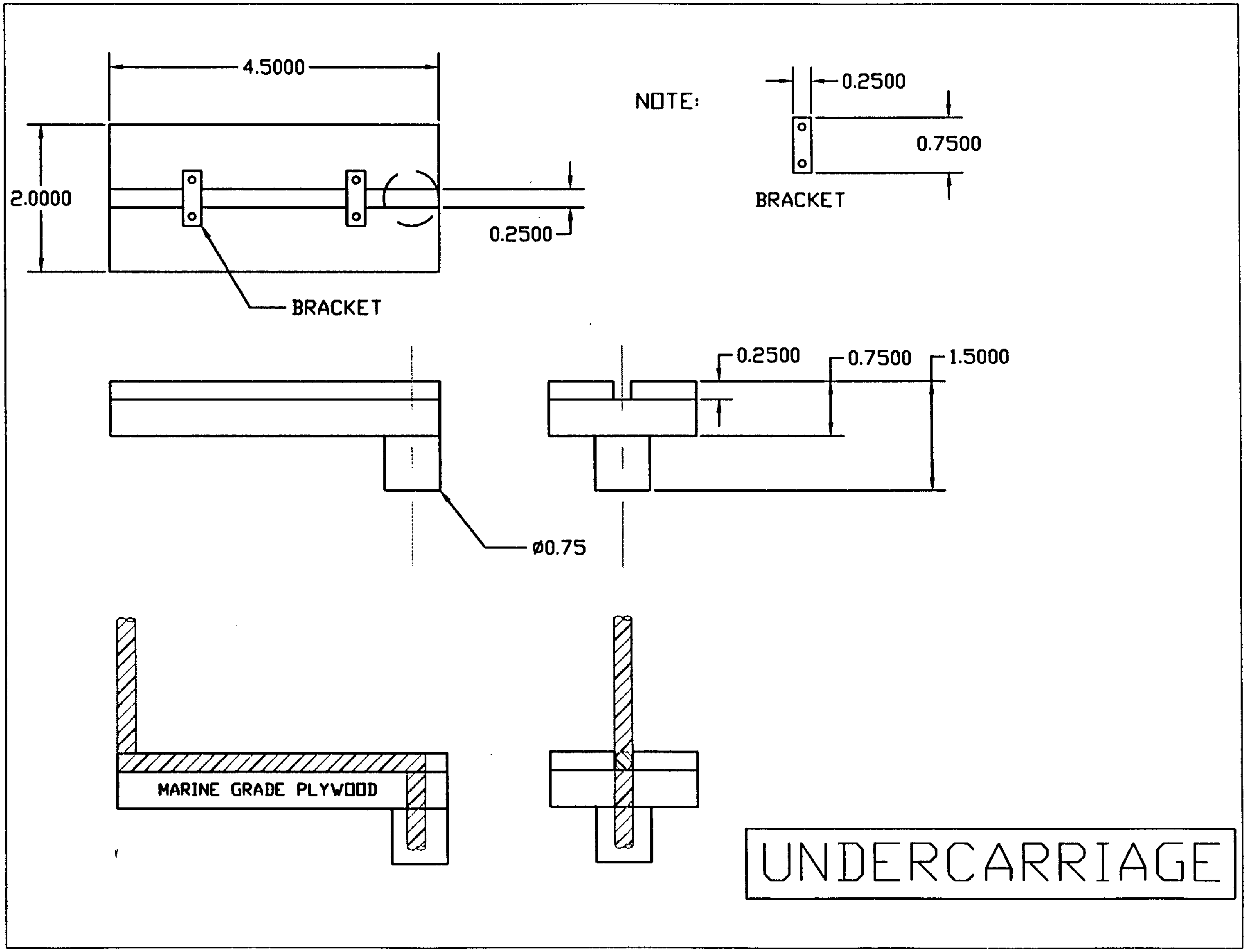


CARGO PODS

REFER TO CARBON LAYOUT SCHEDULE
FOR ACTUAL DIMENSION



SPAR



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American Institute of
Aeronautics and Astronautics

AIAA Foundation/Cessna Aircraft/ONR
Student Design/Build/Fly Competition

Design Report: Addendum Phase

Submitted By:

The University of California, San Diego
AIAA Student Chapter Competition Team

April 1, 2000

American Institute of Aeronautics and Astronautics

UCSD

AIAA Cessna/ONR Student Design/Build/Fly Competition

TEAM T.L.A.R. ADDENDUM PHASE REPORT

DESIGN AND DEVELOPMENT TEAM:

Andrew Mye
Joshua T. Hu
Annie Powers
Kari Goulard
John Taylor

i. Table of Contents

C2) VisualFoil Plot of Surface Velocity for Eppler 214

C3) VisualFoil Plot of Surface Pressure Distribution For Eppler 214

C4) VisualFoil Plot Pressure Coefficient for Eppler 214

C5) MacFoil Plot of Airfoil Template For Wing Tip for Eppler 214

II) Photo Gallery

7. LESSONS LEARNED

7.1 Major Areas of Enlightenment

Throughout the design process many important lessons were learned and much valuable experience was gained. Due to the various backgrounds and personal knowledge of each team member, lessons were learned from each other via teamwork. These included experiences with electronics, composite materials, machining techniques, use of various computer programs, teamwork skills and power supply systems. The most important lessons learned through entering a competition such as this include:

- ***Early start***

Establishing a management structure and starting the design process as early as possible allows room for error and alterations in design. Beginning early allows for time to acquire materials, sponsorship, equipment and financing thus avoiding complications due to lack of time and unavailability of necessities. Establishing a conceptual design dictates what equipment, materials and amount of money is needed and therefore should be one of the first things to be decided upon.

- ***Intricacies of design process***

The team as a whole, especially the underclassmen, was exposed to a "real world" design process. Techniques gained through taking the required design courses allowed the upperclassmen of the team to make necessary decisions and to guide the underclassmen. The major difference between projects undertaken in a classroom setting and this type of project was the fact that we were solely responsible for problems that arose. This showed us the value of self-reliance and making judgement calls based on our knowledge gained through classroom instruction.

- ***Theoretical vs. Actual***

The theoretical flight and physical characteristics of the T.L.A.R. differed from the actual characteristics. These characteristics include the location of the C.G., angle of incidence and, therefore, necessary thrust for optimum performance. The differences were found to be due to the machining processes used and using published values for weight (composites). In addition, more material was used for strengthening high stress points than was originally deemed necessary. The realization of these differences forced us to note the importance of testing the completed design. Testing also gave the team insight into what needed to be improved and/or redesigned in order to achieve satisfactory performance.

- ***Knowledge of model aircraft***

Although one of the team members had experience with RC model cars none had previous exposure to RC model airplanes. This entire experience has allowed the team as whole to understand the attraction to these recreational toys. Each individual was also able to apply knowledge gained via classes to a real world endeavor. Members of the team with little to no background of basic aerodynamics received a crash course in this field and will no doubt benefit from the experience.

7.2 Final Configuration vs. Proposal Design

The fact that this was UCSD's first time competing in such an event, alterations in the design were necessary. Several changes were made to the various components of the T.L.A.R. due to the need for higher strength, better design ideas being generated, availability of material and ease of access and/or replacement. Initial flight-testing and analysis of flight performance data illustrated the need to make changes. Although changes were necessary, the proposal design was an excellent representation of our final configuration. The following are component-wise breakdowns of deviations from the proposal design:

- ***PODS***

The motor and cargo pods were constructed from 2-oz kevlar and epoxy. We made a wooden plug on a wood lathe and then cut one end off and split the body into two halves. These three parts were used to create molds out of hydrocal plaster in which we could lay the kevlar fiber. Once the kevlar was wetted with epoxy and opposing edges were trimmed the two halves were pinned together. This type of joint is commonly referred to as a lap joint. The original plan was to use a strip of marine grade plywood to acts as the joiner between the two halves.

The length of the motor/fuselage pod was extended because the C.G. was located 2 inches closer to the trailing edge than originally planned. This made the total length of the fuselage 28 inches as opposed to 21 inches. This also allowed room for the battery pack to be moved in order to accommodate the other equipment stored within the fuselage. One other benefit of this was that when the battery pack became hot it would not heat the other equipment, therefore reducing the chance of damaging the controller and receiver.

The method of attaching the cargo pods to the wings was also reconsidered. The team came up with the idea of using an aluminum strap to support the front of the pod. This made the fabrication process easier because it allowed us to avoid using wooden hard points as attachments. The use of aluminum straps also decreased the overall weight while maintaining the structural integrity of the kevlar pods.

- ***STABILIZERS***

The stabilizers were altered slightly to attain the required the +1.25 angle of incidence. The height of the vertical stabilizer was shortened from 11 inches to 10 inches. In order to obtain the necessary angle of incidence material was removed from the trailing edge so as to cant the horizontal stabilizer in our favor. This method helped reduce the weight further and attain good flight handling characteristics for our pilot.

- ***LANDING GEAR***

The modification to the forward landing gear was based on undesirable aspects of the original fabrication process. During the initial testing phase we noticed that the gear bent in several places and ultimately deformed and therefore needed to be modified. The .25 inch diameter piano wire, comprised entirely of 1095 cold rolled steel, is quite hard and strong. In order to attain the desired shape a heating process was utilized. This fabrication process reduced the strength while increasing the ductility of the metal, allowing us to bend it. In order to regain strength, an annealing and tempering cycle was used. This did not achieve complete return to the original strength and resulted in the deforming that was unacceptable.

In order to obtain the required strength we had to bend the wire cold, which would leave residual stress. Tempering the steel in a conventional oven at 700°F for 15 minutes helped alleviate the residual stress. We then proceeded to test the landing gear and found it to be quite strong and stiff and therefore suitable.

The team saw that it was necessary to add a tail wheel instead of the original configuration. This was necessary because the original design was not conducive to ground handling and stability during landing and taxiing. The tail wheel was purchased at local hobby store along with 3/32 piano wire to attach it to the boom. In addition, a connection to the rudder was fabricated thereby making ground handling quite smooth and efficient.

- ***WHEELS***

Substituting aluminum wheels for rubber wheels purchased at a local hobby store would reduce the overall weight of the design. This decision led to the fabrication of an aluminum rim into which a rubber o-ring could be placed to provide traction. The aluminum rim was then covered with blue MonoKote so as to reduce drag.

- ***PROPULSION SYSTEM***

The propulsion system was changed because it was determined that an AVEOX 1412 3Y motor would provide more than enough power. Switching to this motor would reduce the amount of power drained from the battery, which would allow for more sorties flown during the flight times. The importance of power management considerations would also be somewhat reduced.

- ***BOOM***

The proposal phase incorporated the use of a carbon fiber boom which was to be purchased from a local company. The dimensions of the boom did not fit our needs and therefore we decide to choose a glass fiber tube. This tube was then reinforced with 2k carbon fiber tow so as to provide stiffness and increased strength.

7.3 Possible Areas of Improvement

The team felt very confident with the design and could come up with very few areas for improvement. These areas are as follows:

- ***BRAKING SYSTEM***

Installation of a braking system was an issue that was noticed following the initial flight-testing phase. Following touchdown, T.L.A.R. rolled, on average, approximately 100 feet. This was cause of much concern considering the time necessary to taxi back to the starting line which would consume precious time and power. The idea of installing a braking system was considered but quickly dismissed due to the lack of necessary time to acquire the equipment.

- ***INTEGRATION OF MOTOR AND CARGO PODS***

Combining the motor and cargo pods would reduce the weight of the structure and decrease the drag. This configuration would require careful consideration when the necessity of quick load/unload is of the essence. The strength of the spar and the wing joiners would have to be optimized in order to support the centering of the weight. This design would make establishing the location of the C.G. easier.

- ***SHOCK ABSORBERS***

The landing gear system would have benefited from the use of shock absorbers. The use of absorbers would reduce the risk of collateral damage during landings. This design idea could possibly lead to an increase in payload capability.

7.4 Final Flight Performance Data:

Weight: 22.1 lbs

Turning radius: 25 ft

Angle of Incidence (AOI): 1.25 relative to 10" stab

Avg. Speed: 70 mph

Power: 1800 peak
718 avg.

Amp: 50A peak
18 avg.

Volt: ~36 volts under load

Peak Thrust = 82.2 Watts/ lb.

8. RATED AIRCRAFT COST

RATED AIRCRAFT COST **(RAC) = A*MEW+B*REP+C*MFHR**

A = $100/lb
B = $1/watt
C = $20/hour

MEW = Manufacturer's Empty Weight (lb)
REP = Rated Engine Power (watts)
MFHR = Manufacturing Man Hours (hours)

MEW = Total weight – Battery Pack Weight – Payload weight
= 22.1 lb – (79/16) lb – 10.27 lb
= 6.89 lb

REP = Number of motors * 50 Amps * 1.2 Volts/cell * Number of cells
= 1 * 50 Amps * 1.2 Volts/cell * 36 cells
= 2160 watts

WBS Number and Type	Scoring Values	Design Description
#1-Wings	5 hr/wing + 4hr/sq. ft Projected Area (PA)	Single Wing Design PA=1176 ft^2
#2-Fuselage and/or Pods	5 hr/body + 4hr/ft of length	Two 21" Cargo Pods 28" Fuselage
#3-Empenage	5 hr (basic) + 5 hr/Vertical Surface + 10 hr/Horizontal Surface	One Vertical Surface One Horizontal Surface
#4-Flight Systems	5 hr (basic) +1 hr/Servo	Four Servos
#5-Propulsion Systems	5 hr/Motor + 5 hr/propeller	One propeller

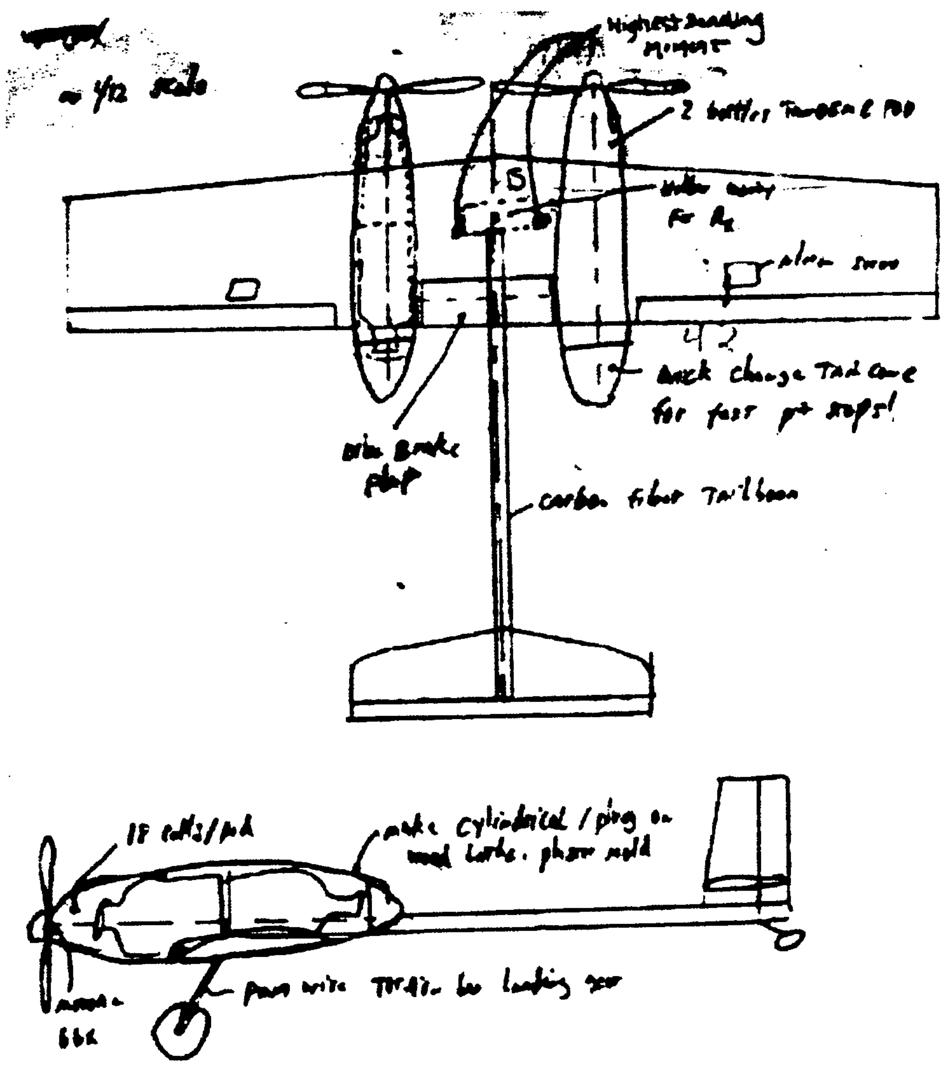
MFHR = Wing + Fuselage & Pod + Empenage + Flight System + Propulsion System
= (5+ 4*[1176/144])+([3*5]+4*[104.5/12])+(5+5+10)+(5+4)+([5*1]+[5*1])
= 126.49 hours

A * MEW = ($100/lb) * (6.89 lb) = $689
B * REP = ($1/watt) * (2160 watts) = $2160
C * MFHR = ($20/hour) * (126.49 hours) = $2529.8

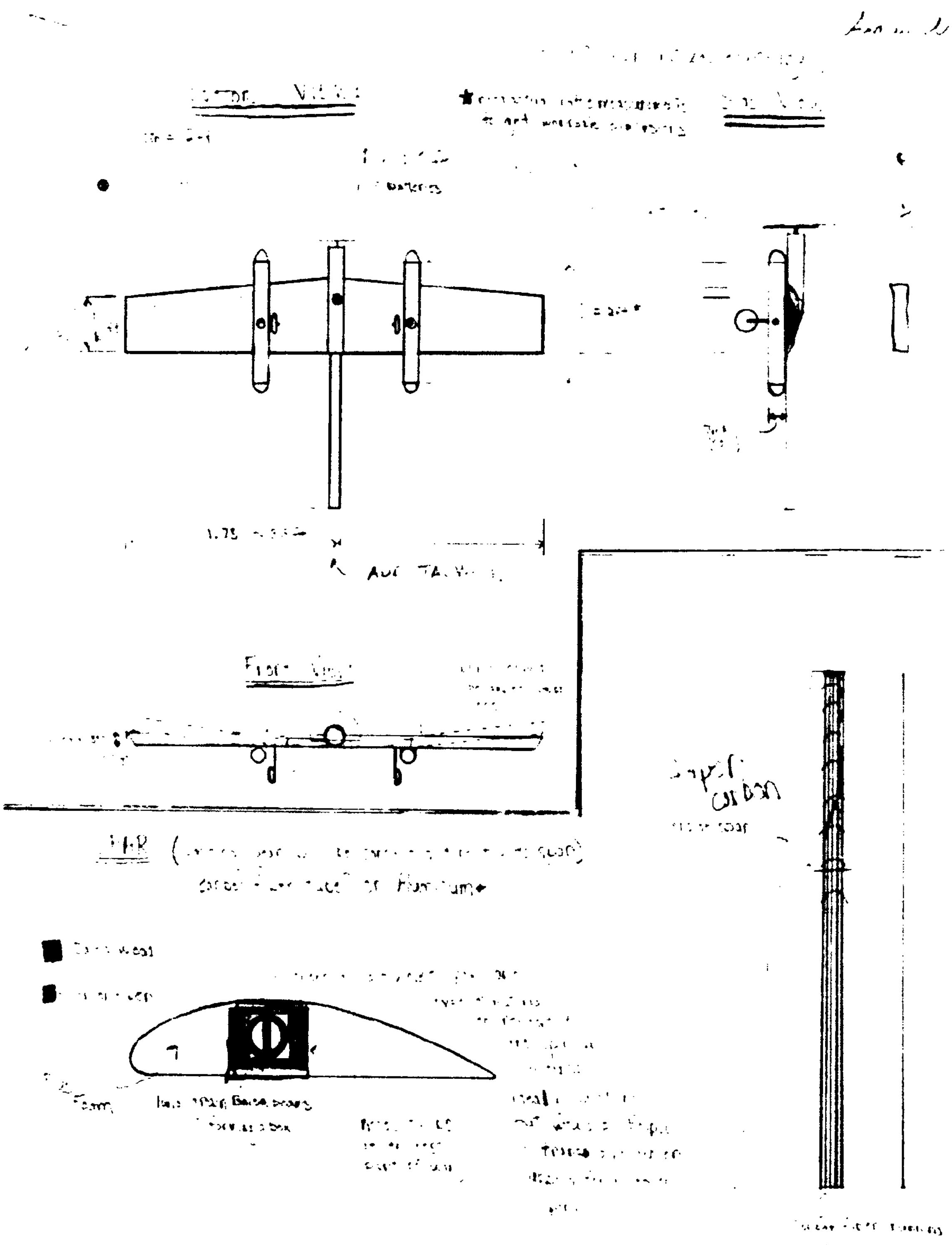
RAC = (A*MEW+B*REP+C*MFHR) * (1/1000)
= ($689 + $2160 + $2529.8) * (1/1000)
= **$5.3788**

Appendix

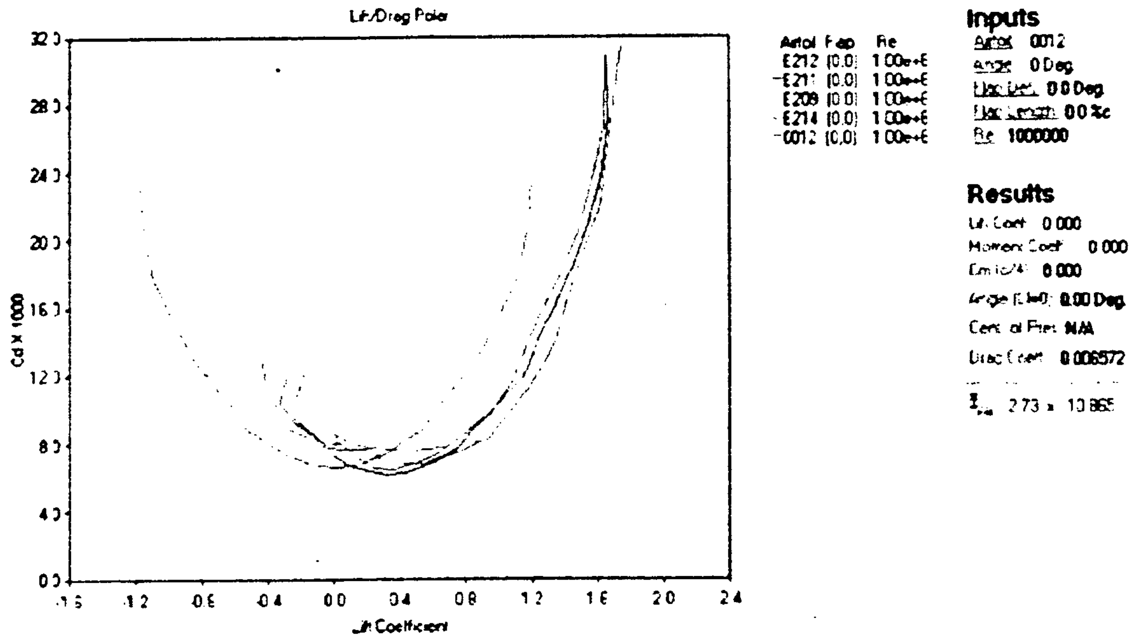
I) Table of Figures:



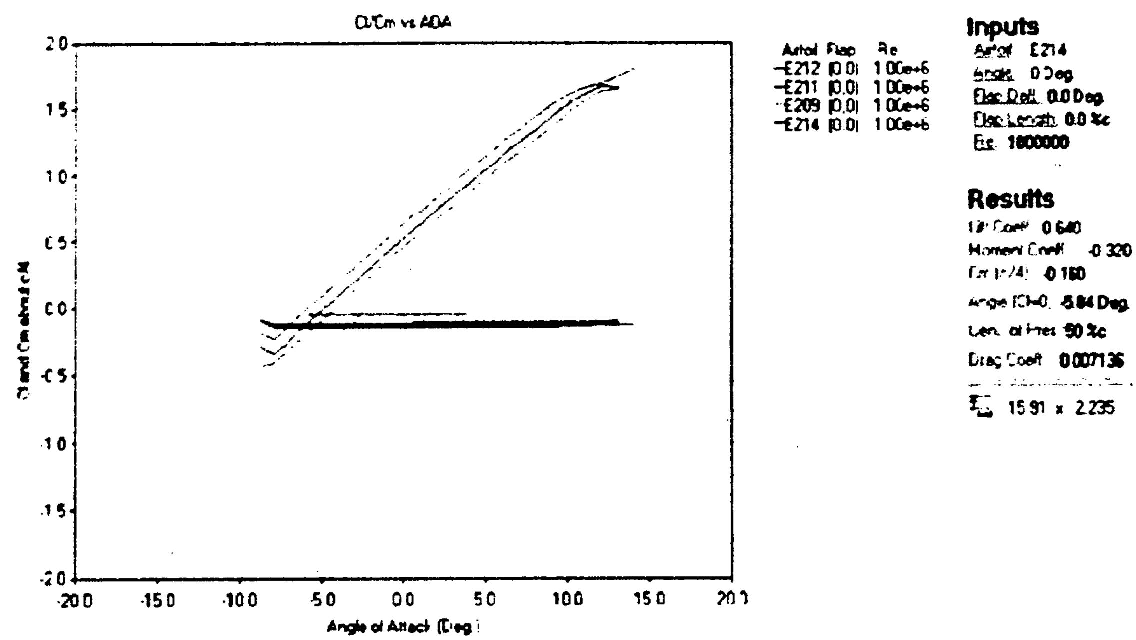
A.1 Dual Motor Single Wing Design Configuration



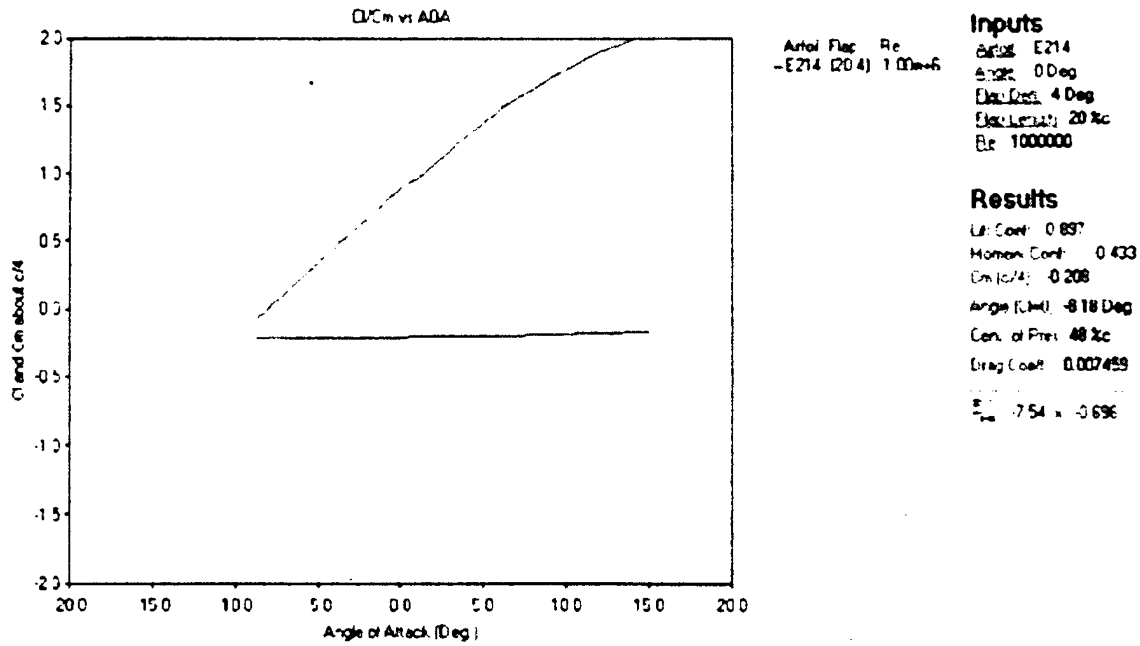
A.2 Single Motor Single Wing Design Configuration



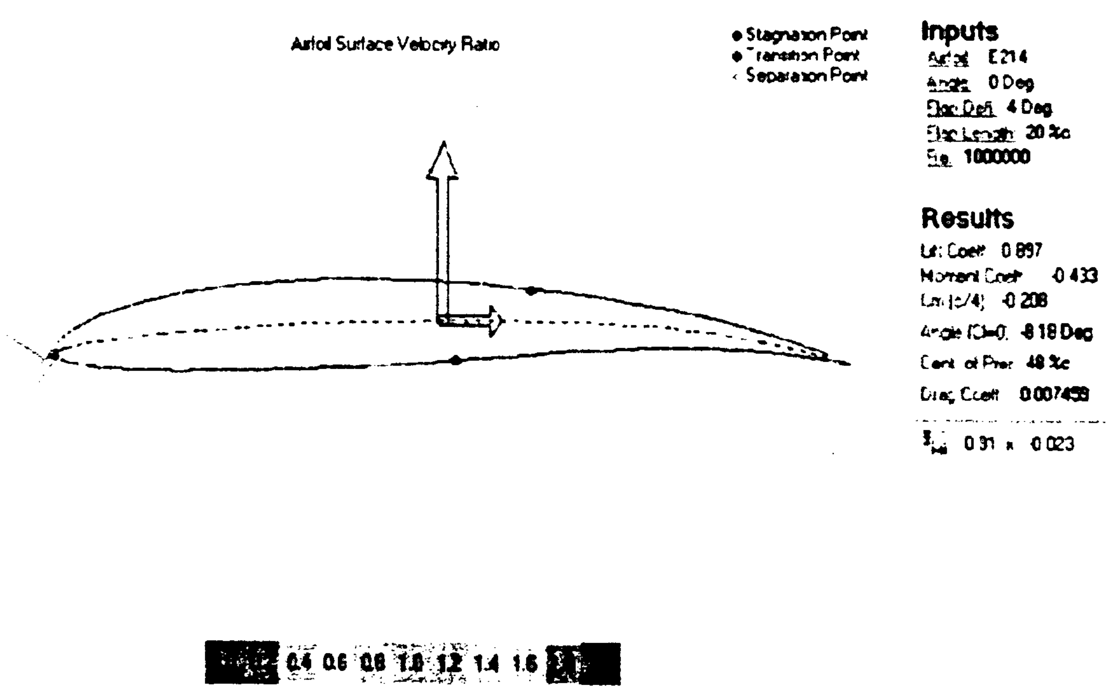
B.1 Polar Plots for Various Airfoils (VisualFoil)



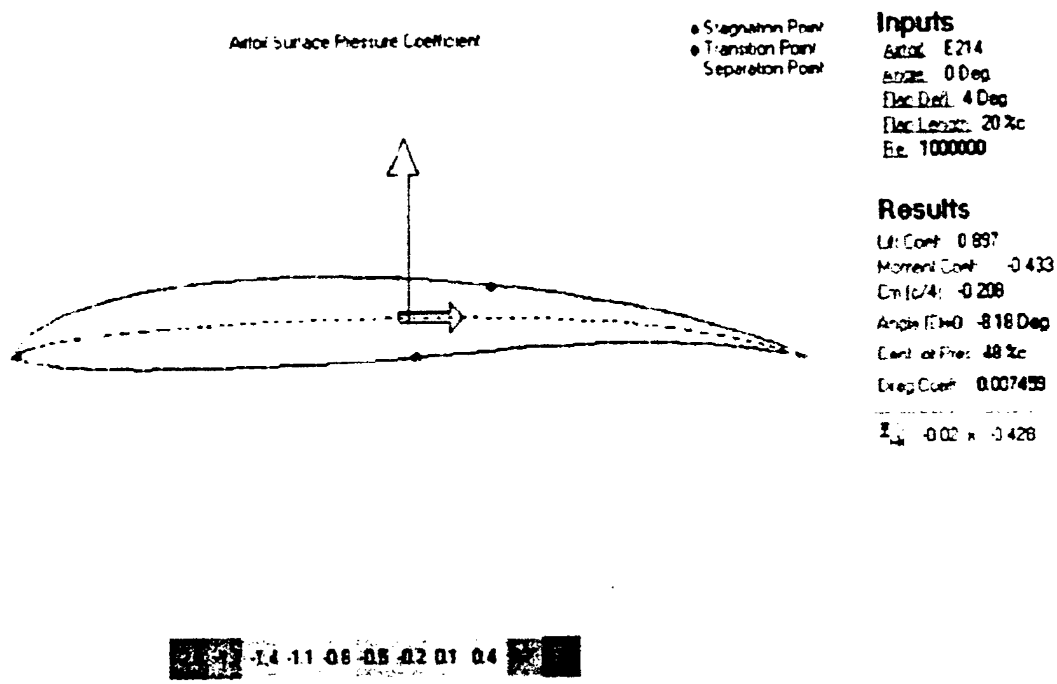
B.2 Lift vs Drag Coefficients vs Angle of Attack
For Various Airfoils (VisualFoil)



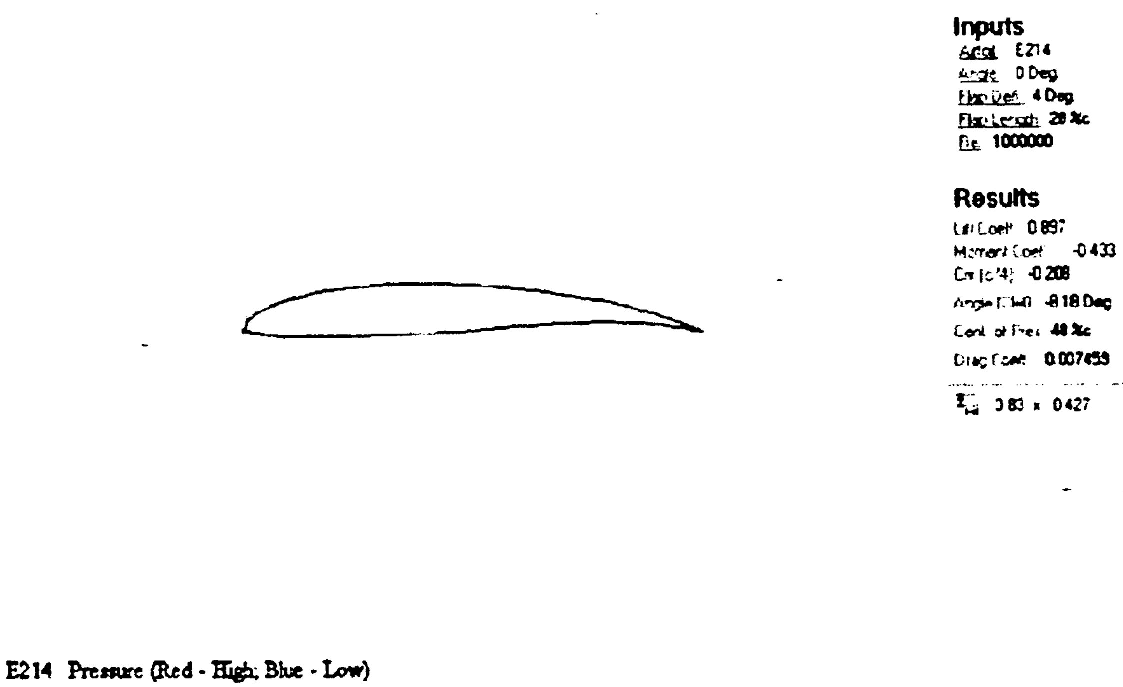
C.1 Lift and Moment Coefficients vs Angle of Attack
for Eppler 214 (VisualFoil)



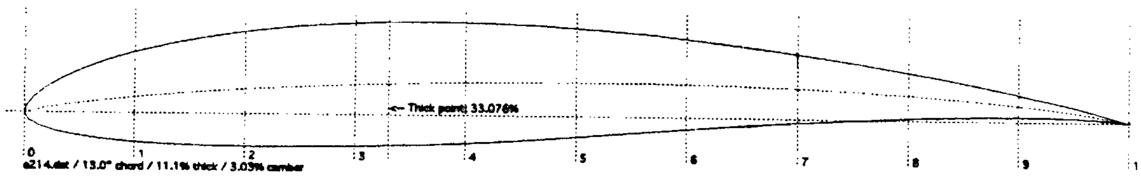
C.2 Surface Velocity for Eppler 214 (VisualFoil)



C.3 Surface Pressure Distribution for Eppler 214 (VisualFoil)



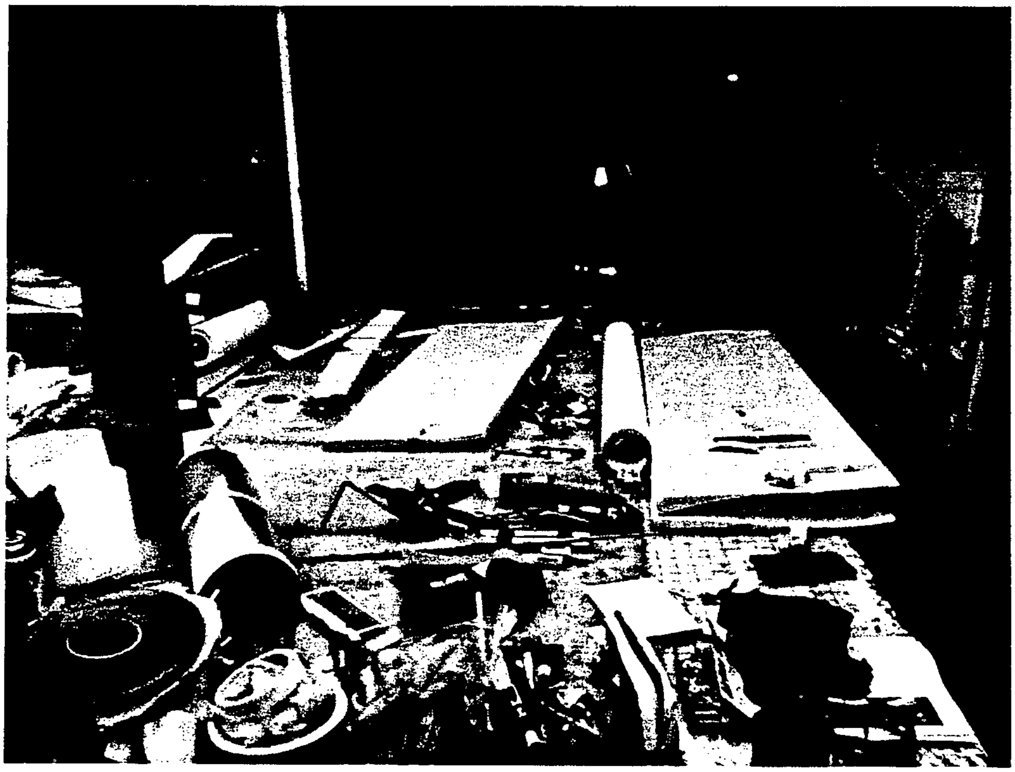
C.4 Pressure Coefficient for Eppler 214 (VisualFoil)



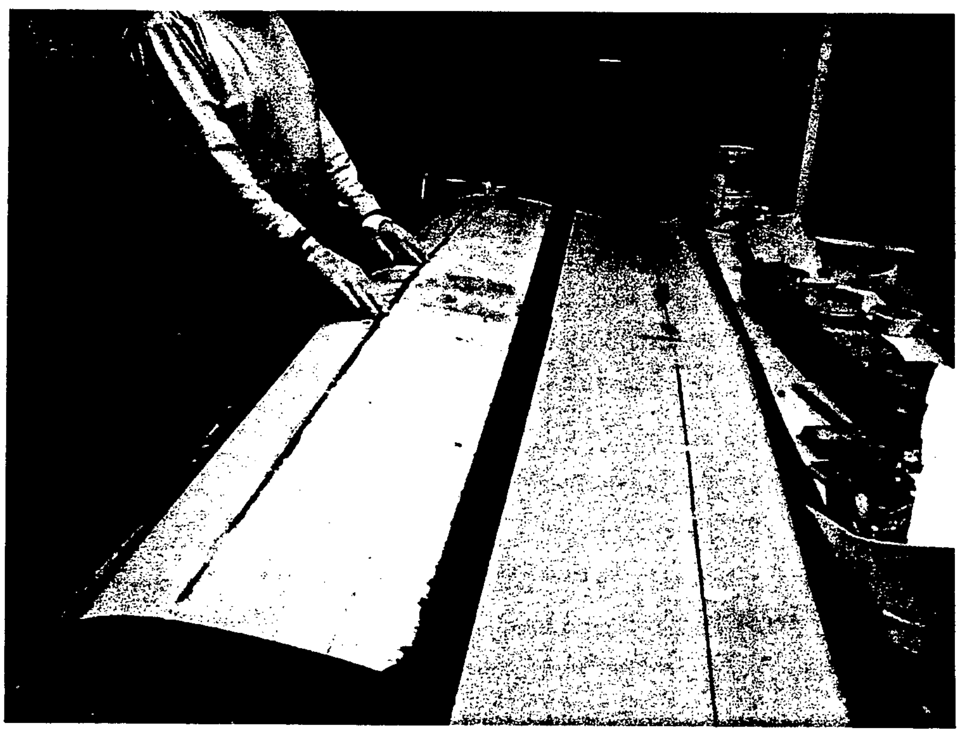
C.5 Airfoil Template for Wing Tip for Eppler 214 (MacFoil)

II) PHOTO GALLERY

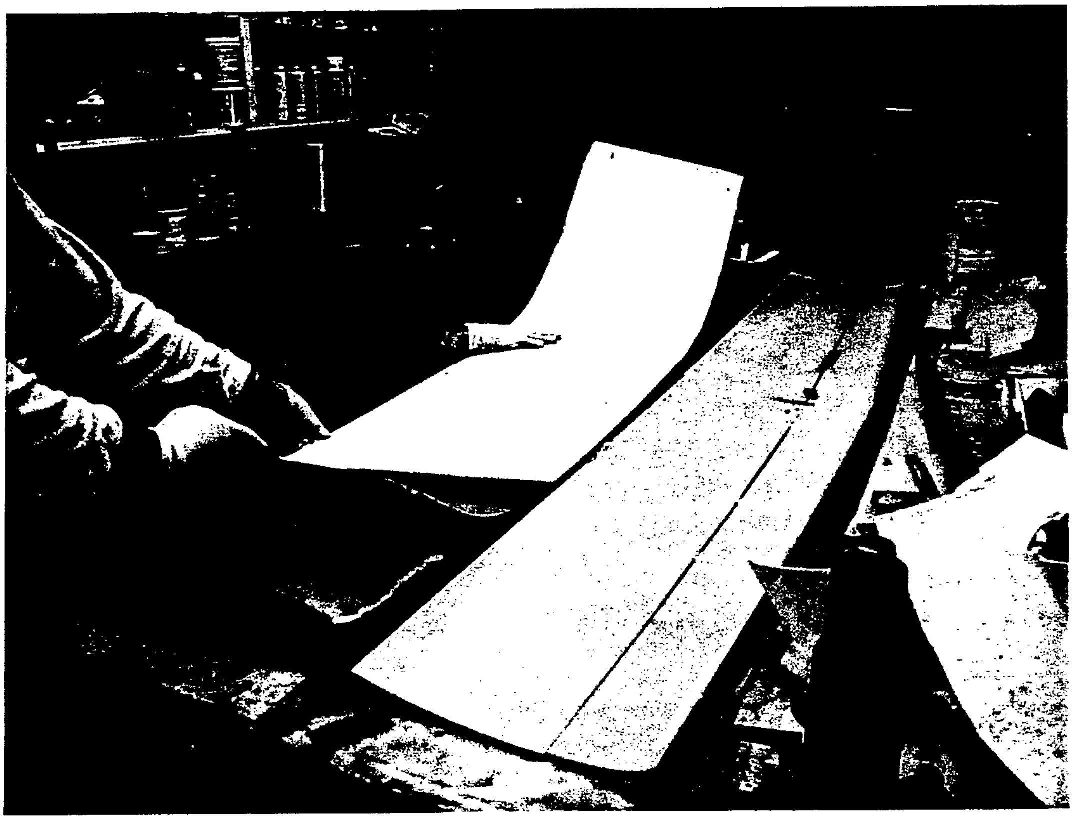
Andrew and John marking locations of spar on wing surface



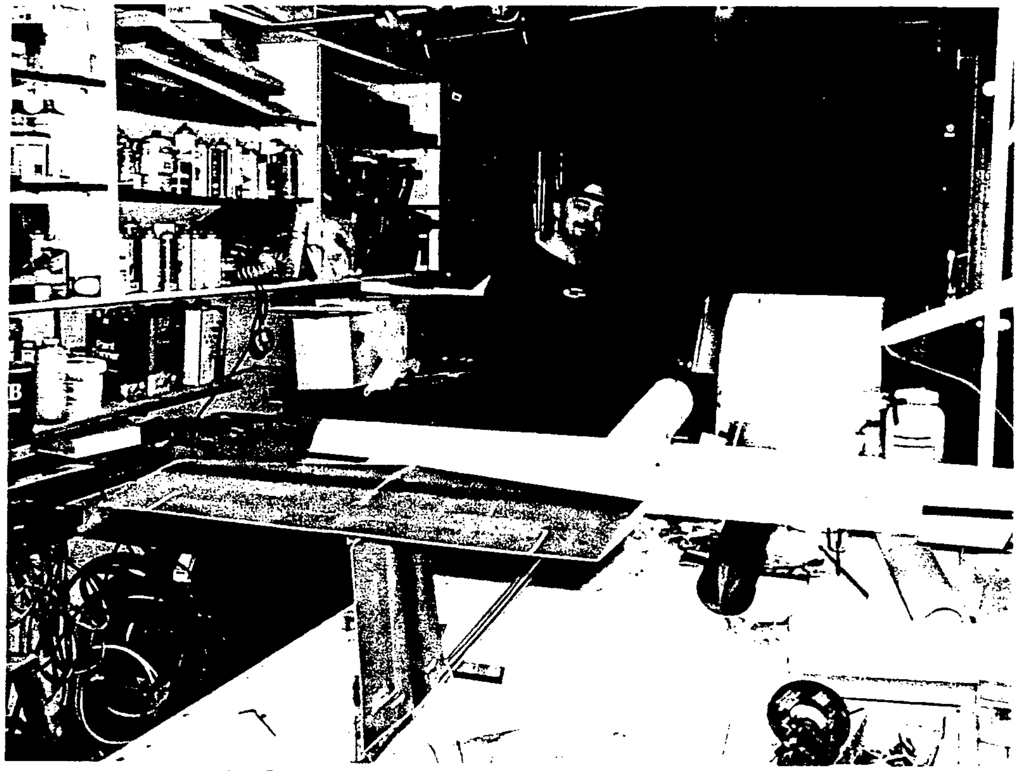
Work Bench with Rolls of Mylar and Blue Foam Cases



Wing w/ Spar embedded in it

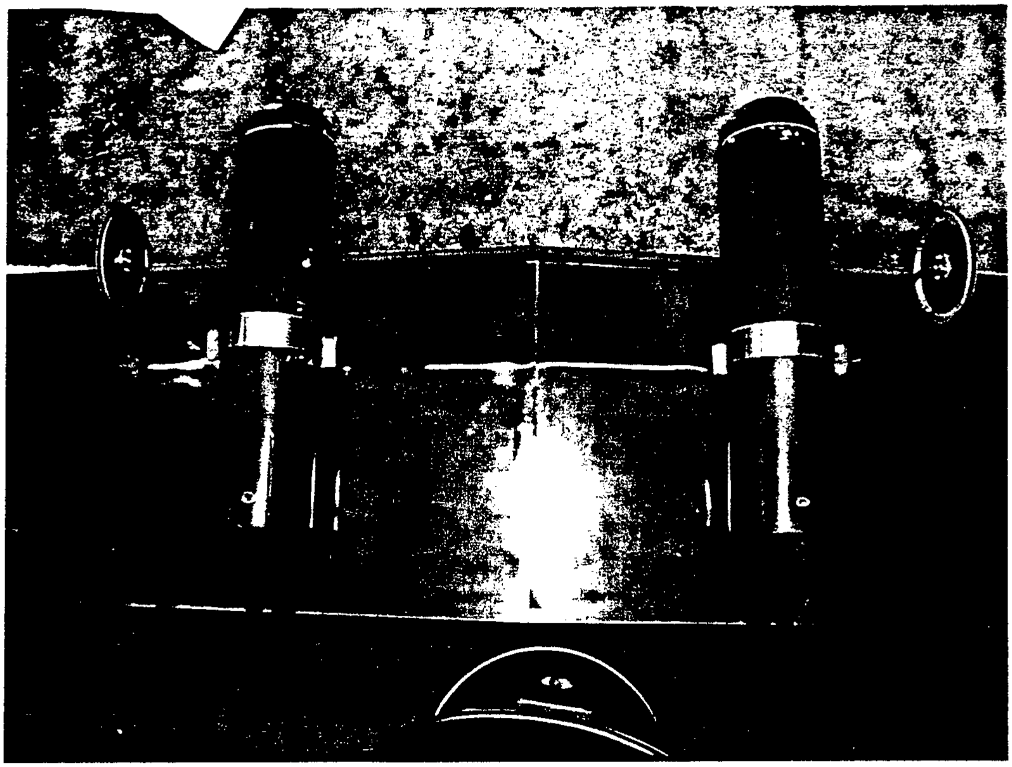


Andew and Greg laying Mylar on Wing

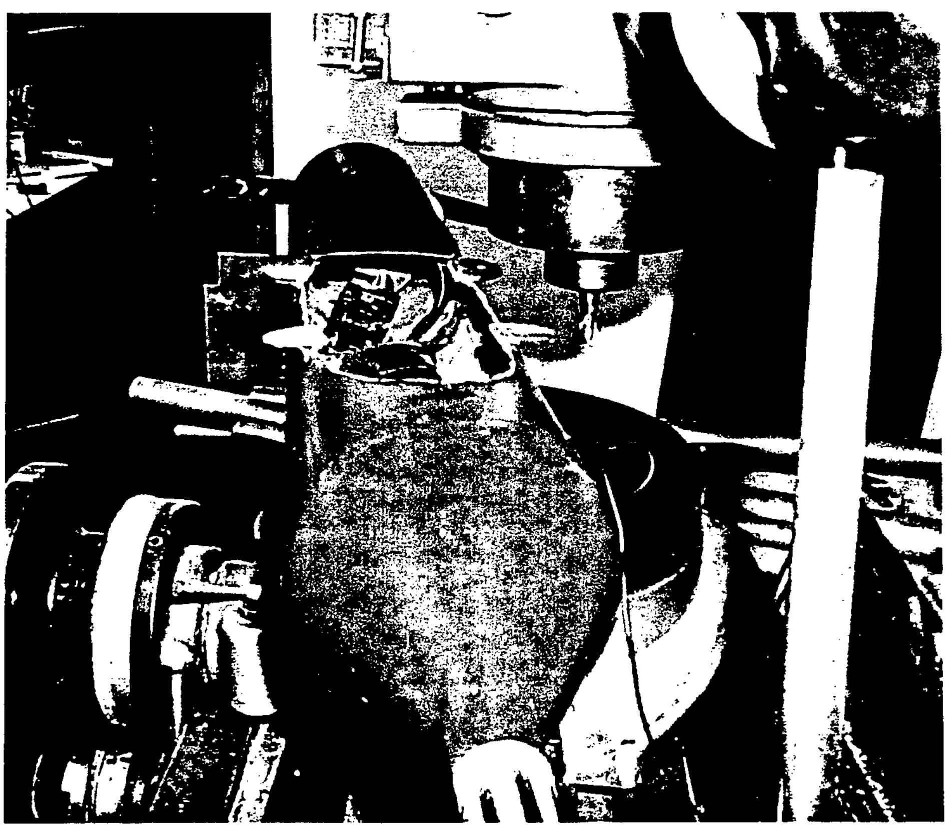


Andrew making sure vacuum bag is sealed

Photos of Final Configuration of T.L.A.R.

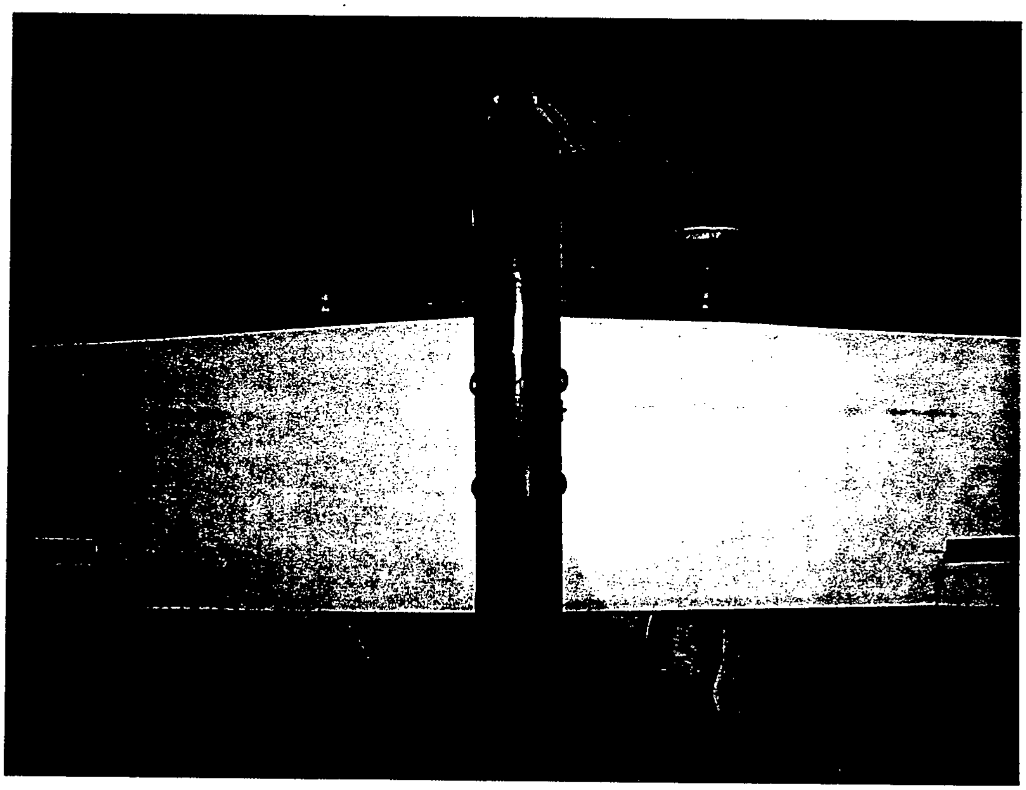


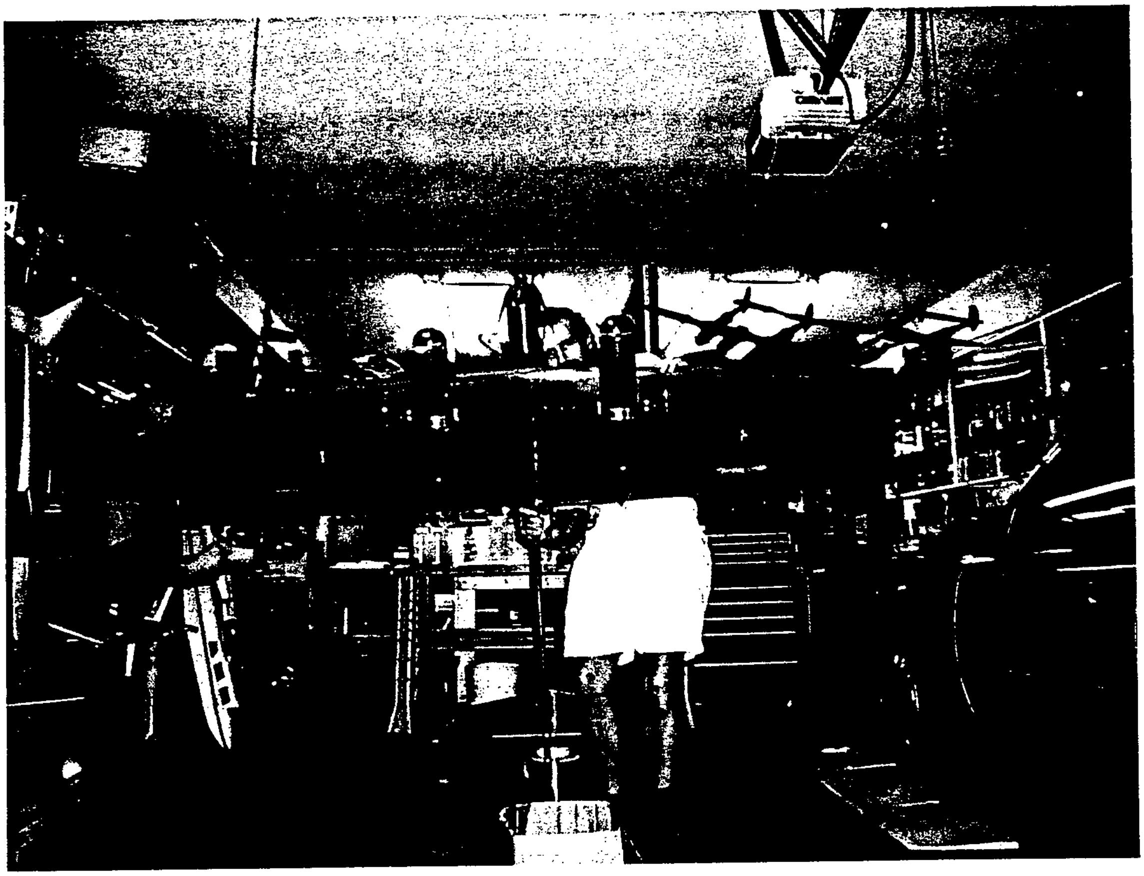
Cargo Pods



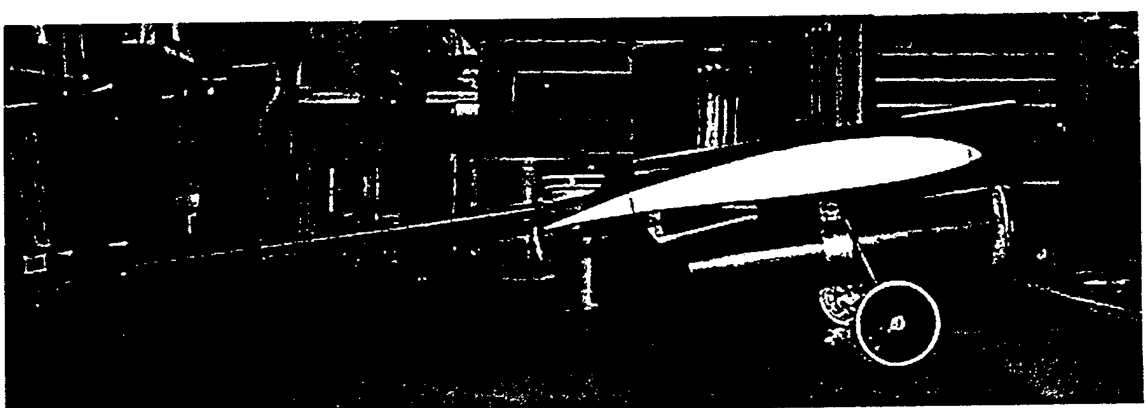
Fuselage/Motor Pod

T.L.A.R. with Josh and Andrew





Bottom view of T.L.A.R.



Side view of T.L.A.R.

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TEAM T.L.A.R. FLIGHT PHOTOS

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