MIT: Lighter-Than-Air Vehicle

Citation: Newman, D (2009). Lighter-Than-Air Vehicle: *CDIO Knowledge Library*, Cambridge, Mass: CDIO Global Initiative, www.cdio.org

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1. Project Overview (1 page)

1.1. Overall goal or purpose

As a team, design and construct a lighter-than-air (LTA) vehicle, often referred to as a "blimp". This project is used as a microcosm to represent many aspects of real world project design, construction, test and operation in the real world. The goals are both technical and societal. Most first-year engineering students nowadays have never built a major hands-on project, so it is an excellent introduction to aerospace engineering, especially since a lighter-than-air vehicle is much easier to control than an airplane, given that its lift does not depend on its velocity.

1.2. Societal context and relevance

Aerospace projects are almost always team efforts, and this project is an excellent introduction to teamwork. It also duplicates many aspects of the design/build process used in industry and government: preliminary and critical design reviews, opportunities for test flights and evaluations, and a competitive "fly-off".

1.3. Integration (e.g., where project fits in a course, program, or curriculum)

The project is the final experience in a freshman-level class that introduces the students to aeronautics. It also provides preparation in communication for their future classes: The preliminary and critical design reviews give the students experience in oral presentations, and the students also prepare two written reports.

1.4. Description (e.g., complexity, duration, group size and number, budget)

Participate in a lighter-than-air race, and as a team design and construct a vehicle that is:

- Stable
- Controllable
- Reliable
- Able to carry a payload
- Fast
- Aesthetically pleasing and an elegant design

Students work in teams of 6 for 10 weeks to accomplish the assigned task. The project costs $4045, of which $3860 is for reusable components.

1.5. Learning activities and tasks (brief summary)

Design, build, and fly a lighter-than-air vehicle. Students prepare for two formal design reviews:

Preliminary Design Review (PDR)

Objectives

- Describe the design process to arrive at proposed vehicle layout
- Provide justification for the selected design

- Preliminary analysis of selected design's performance
- Roadmap to arrive at finished product
- Convey technical ability and confidence that you will get the job done
- e.g., to justify funding from a supporter

Completed Design Review (CDR)

Objectives

- Describe the detailed design of the vehicle
- Layout and analysis
- Major modifications since PDR
- Present and discuss at least one built prototype component or subsystem
- Convey that you can overcome any issues that remain and will have a working vehicle on trial day

2. Learning Objectives (1 page)

2.1. Technical objectives (e.g., basic math, science and engineering knowledge, skills, processes and procedures)

Design, Build, Test and Operate a lighter-than-air vehicle.
Calculate lift and drag for blimps to evaluate aerodynamic designs.
Design a radio-control system
Evaluate the tradeoff between maneuverability and stability in aerospace systems

2.2. CDIO outcomes (e.g., personal and professional skills and attributes teamwork, communication, conceiving, designing, implementing and operating skills)

2.1.5 Solution and Recommendation
2.3.4 Trade-offs, Judgment and Balance in Resolution
2.4.7 Time and Resource Management
3.1.x Teamwork Skills
4.3.2 Defining Function, Goals, and Architecture
4.4.1 The Design Process
4.5.5 Test, Verification, Validation and Certification
4.6.2 Training and Operations

3. Student Instructions

3.1. Project description (e.g., brief description of project purpose and context)

To participate in a lighter-than-air race, as a team design and construct vehicle that is:

- Stable
- Controllable
- Reliable
- Able to carry a payload
- Fast
- Aesthetically pleasing and an elegant design

3.2. Learning objectives

- Design, Build, Test and Operate a lighter-than-air vehicle.
- Calculate lift and drag for blimps to evaluate aerodynamic designs.
- Design a radio-control system
- Evaluate the tradeoff between maneuverability and stability in aerospace systems

3.3. Learning activities including specific procedures, tasks, etc.

Attachment: LTA Student Notes.doc (7 pages)

3.4. Assessment criteria and standards

Students are assessed in a Preliminary Design Review and Critical Design Review and conduct peer evaluations of their teammates.

3.5. Equipment, tools, supplies and/or materials

- Balsa wood
- Large & small motors
- Propellers
- Radio control electronics
- Servos
- String
- Epoxy, glue, tape, other adhesives
- Weather balloons or 600 gm lift/balloon
- Helium Gas

3.6. Safety and risk mitigation procedures

None beyond "normal" shop safety procedures for any tools used. Helium may need to be properly stored (*e.g.*, with metal cap and secured from tipping) depending on size of cylinder used.

3.7. Deliverables (e.g., products, oral and written reports, and/or reflective journals)

In addition to the vehicle itself, the students submit a final report and a portfolio of their work throughout the project

4. Instructor Guide

4.1. Commentary on conducting the project keyed to the Student Instructions

Attachment: LTA Instructor Notes.doc (13 pages)

4.2. Team Organization and Management suggestions (e.g., number of groups and group size, initial organization, and ongoing management)

6 teams of 5-6 students. Each team is given the task of deciding its own organization & management structure.

4.3. Assessment

4.3.1. Criteria (e.g., to judge the quality of student products, processes, or performances relative to the learning outcomes and activities)

4.3.2. Methods and materials (e.g., rubrics for oral/written reflection methods, peer/team self-evaluation, assignments, lab reports, and standard quizzes embedded in the learning activities)

Student peer evaluation forms (LTA Instructor Notes.doc, pages 13-14)

5. Resources

5.1. Budget (e.g., recurring and non-recurring expenses)

Reusable materials to support 6 teams: $3,860 capital expense
Consumables: $185/year
(see LTA Instructor Notes.doc, page 12, for full breakdown)

5.2. Equipment and tools

Small hand tools: Xacto knives, small clamps, thin saws, sandpaper.

5.3. Materials and supplies (e.g., reusable and consumable including hazardous materials)

Adhesives: Wood glues, spray adhesive, glue sticks, superglue
Consumable materials: Balsa wood, Saran wrap, large plastic bags, helium
Reusable materials: Electric motors, servos, RC controllers, batteries, battery chargers, propellers, weather balloons
(see LTA instructor Notes.doc pp. 3-12)

5.4. Staffing (e.g., describe particular skills and scope of commitment)

1 faculty, 2 undergraduate teaching assistants

5.5. Spaces (e.g., minimum feasible space requirements per student or per student team, whether space is dedicated or used only during student activity, and use of space for design, build, operate, and storage)

One workbench per team for building. Race course is 160m long x 8m high.

5.6. Other resources (e.g., computer hardware and software)

Text: Newman, *Introduction to Aerospace Engineering and Design*

6. Safety and Risk Mitigation

6.1. Operational safety

Some care needs to be taken during testing and race to keep moving propellers away from people (especially if flying at head-height).

6.2. Governing policies and regulations (e.g., governmental and institutional)

N/A

7. Other information, for example:

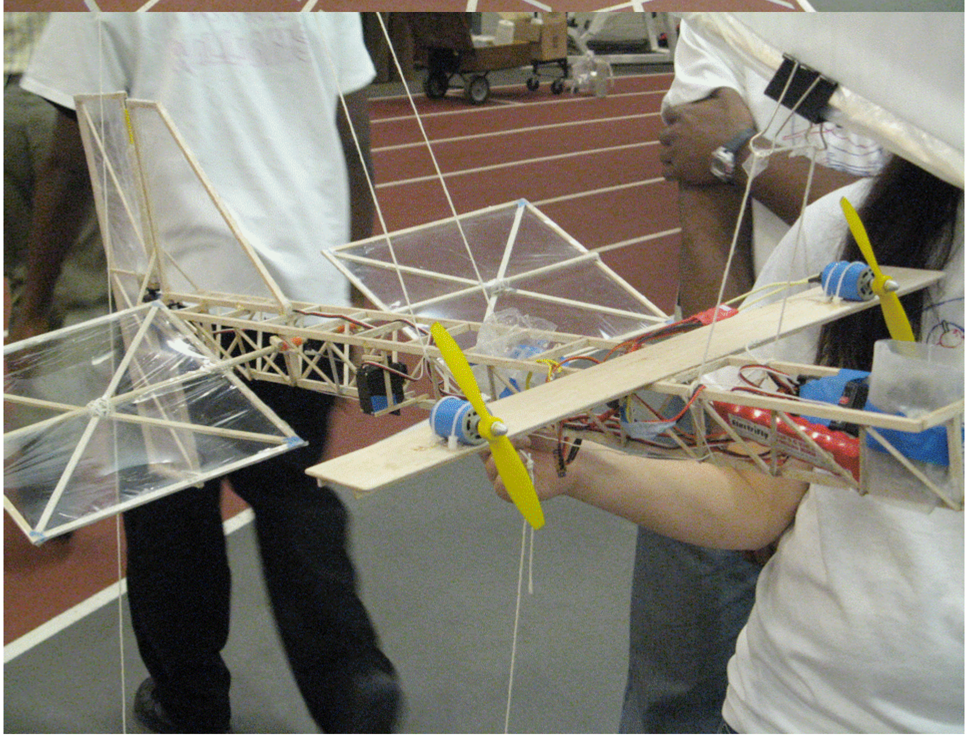
7.1. Possible variations in the project

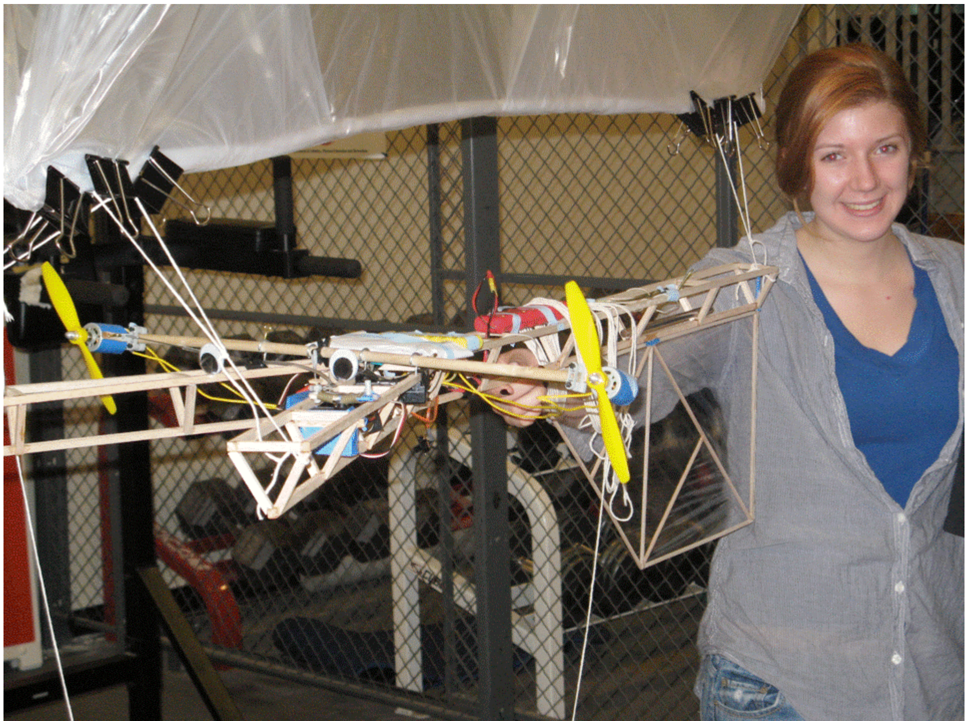
Attach RF camera to student vehicles for Remote-Operated-Vehicle event on race day: students fly vehicles from behind barricade using remote control and video display (see final 3 photos).

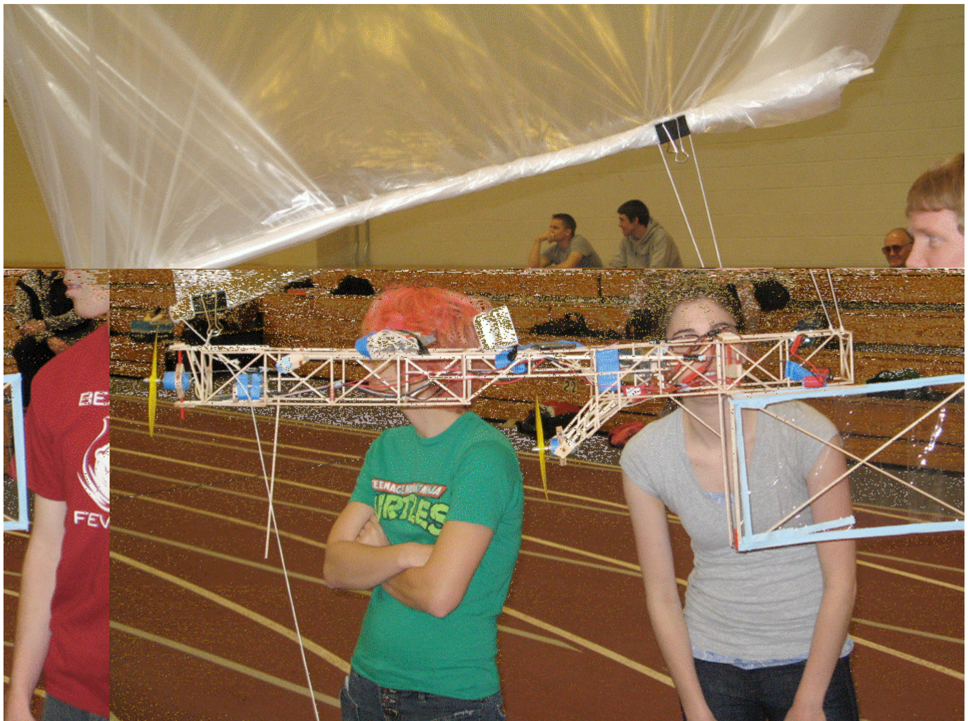
7.2. Supplementary multi-media and other resources

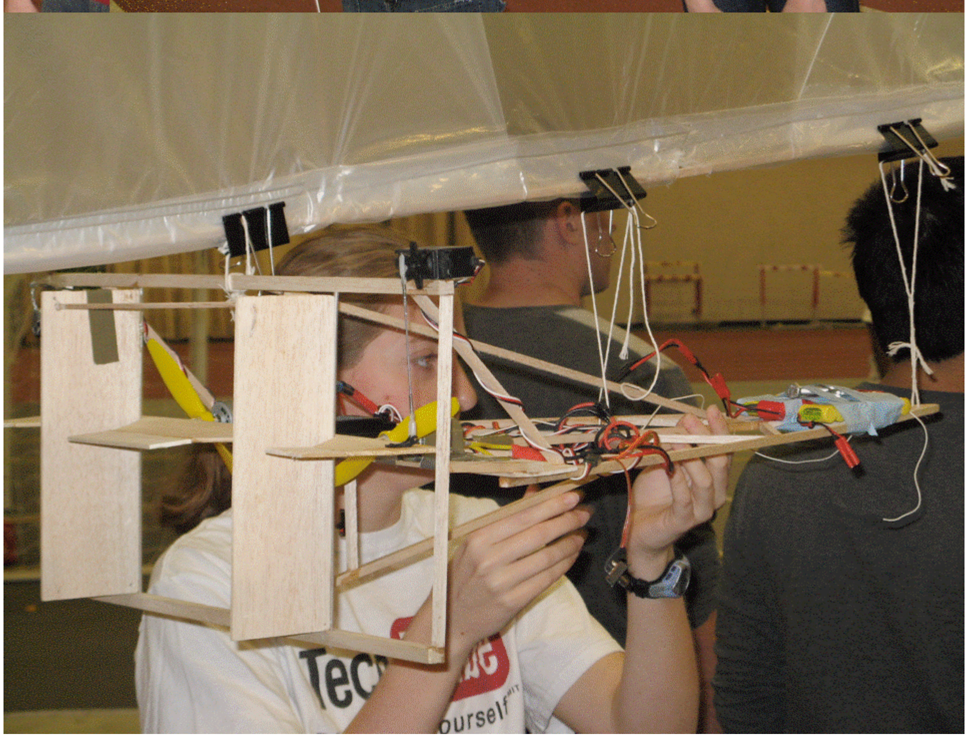
7.3. Sample student products from previous iterations of the project

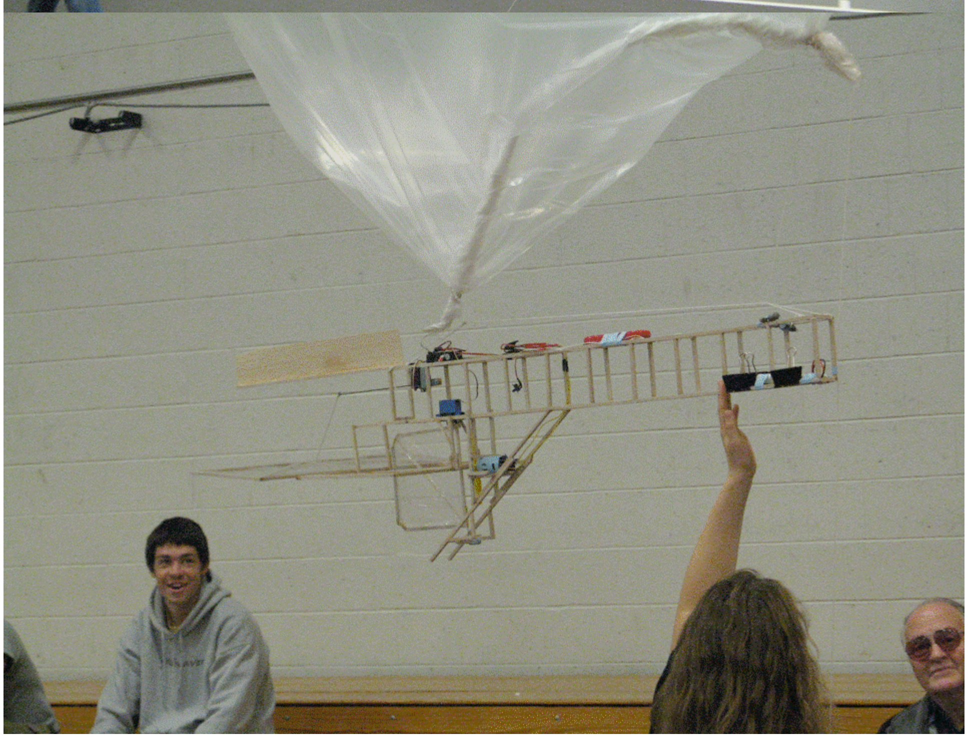
Photos of completed vehicles and race:

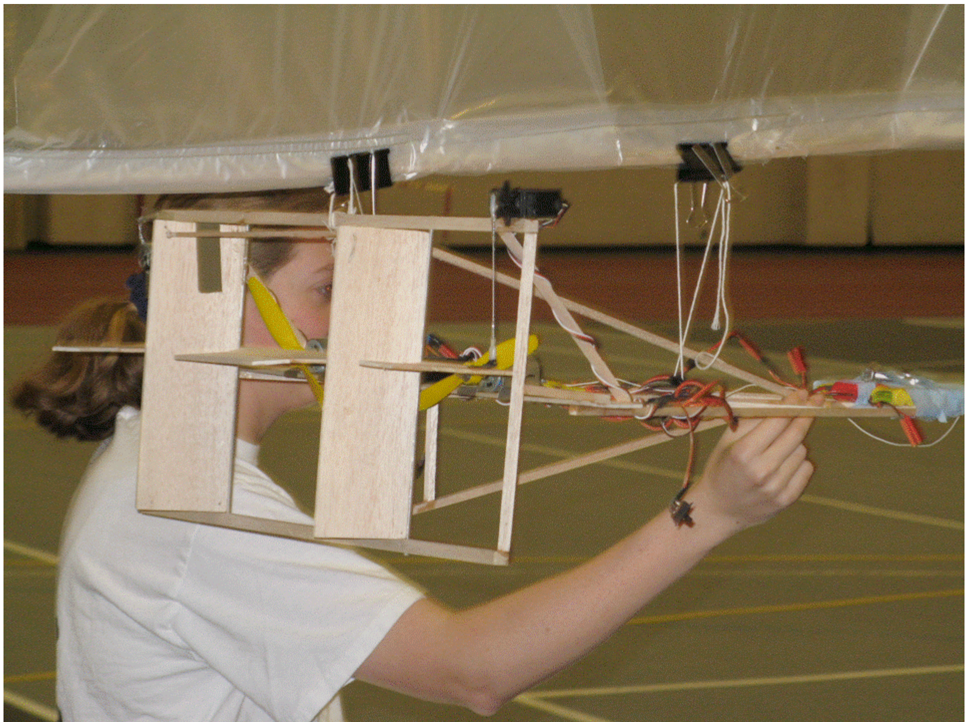


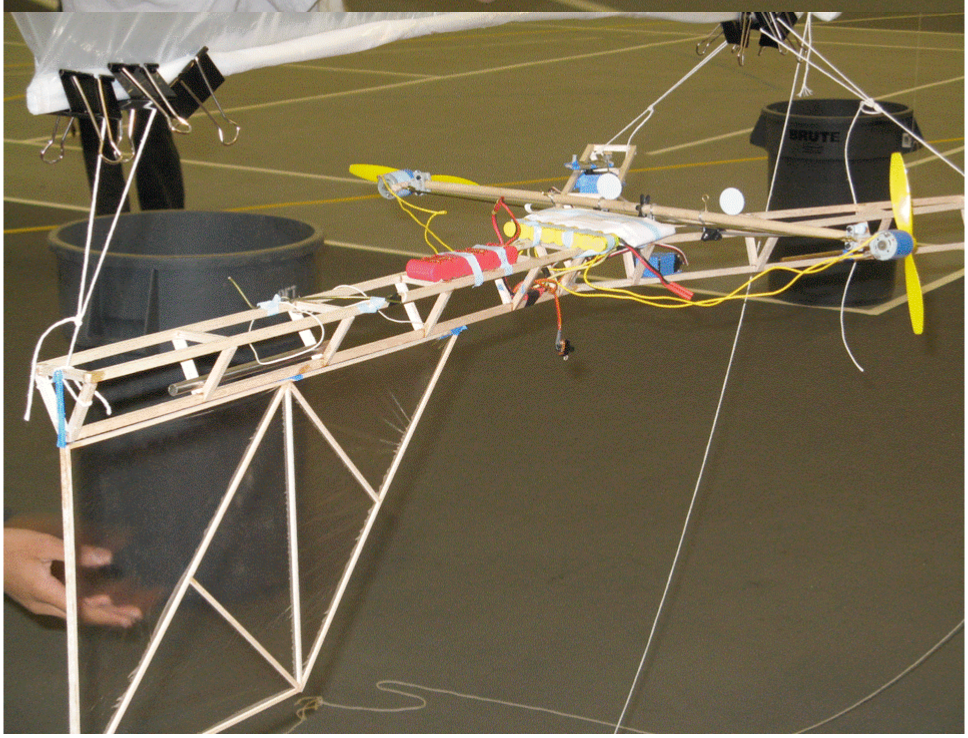








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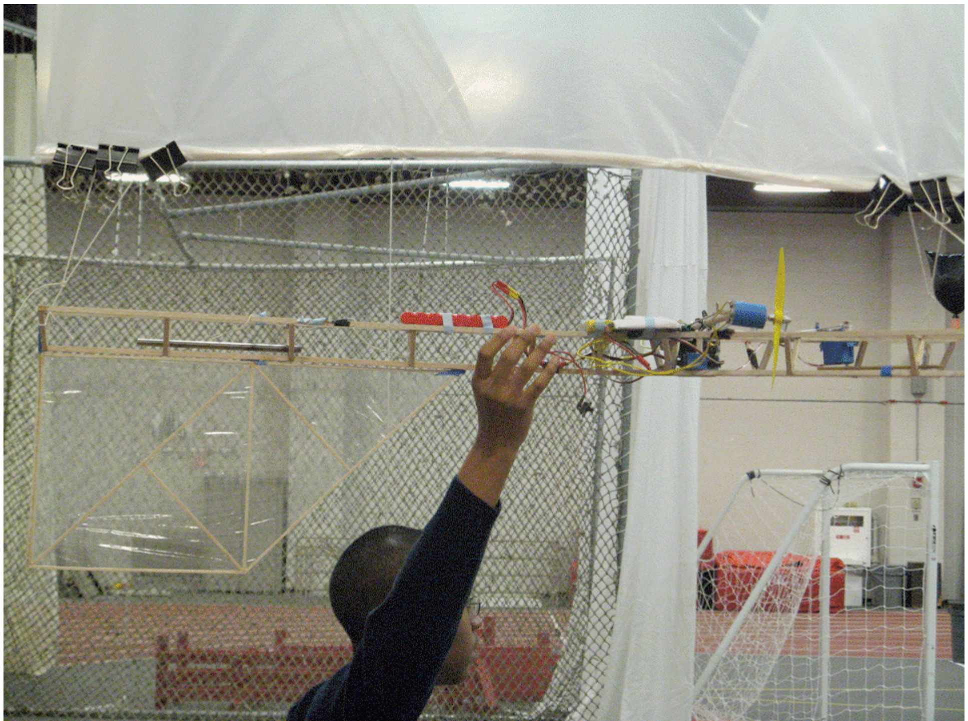
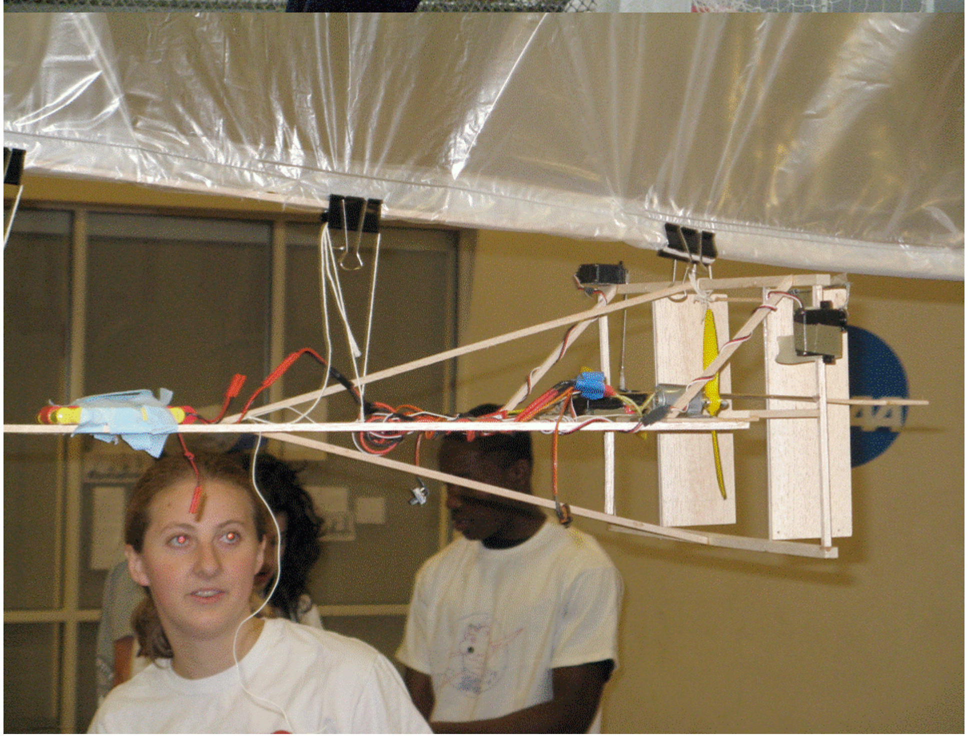





CADET
INSTRUCTOR


CAM1
DVR
CAMERA
OUTPUT

Lighter Than Air Vehicle - Notes for Students

Objective

To participate in a lighter-than-air race, as a Team design and construct vehicle that is:

- Stable
- Controllable
- Reliable
- Able to carry a payload
- Fast
- Aesthetically pleasing and an elegant design

Judging Criteria

• Score: (Time x Cost)/ Payload Mass Fraction
  – Each balloon costs 2 units
  – Each Motor/Propeller costs 1 unit
  – Each Servo costs 1/2 unit
• Formula may be updated depending on choice of balloons TBD
• Reliability - Most successful course completions (combination of test flight + race days)
• Aesthetics - Most creative and elegant design

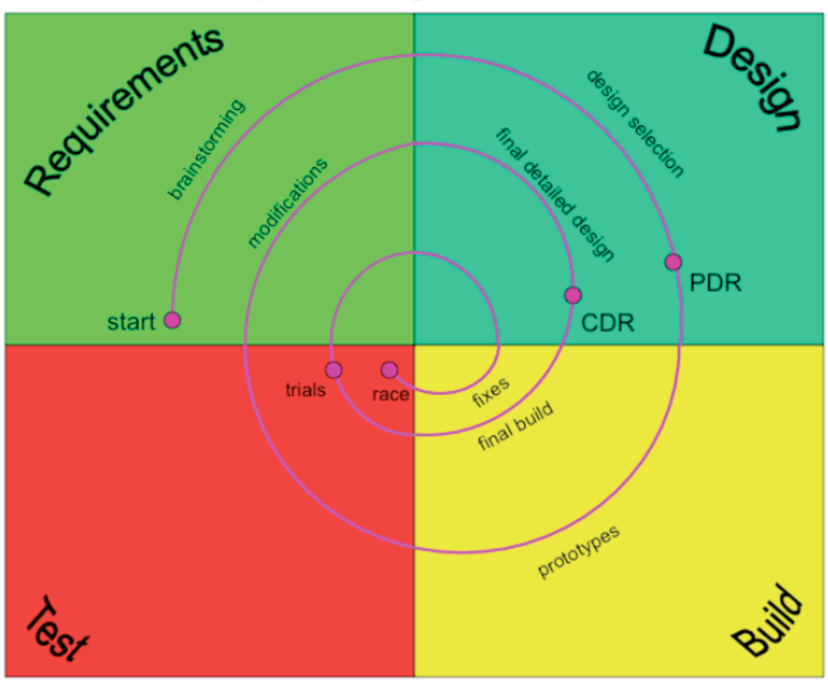
Constraints

- Payload will be a sack filled with standard weights. Payload must be detachable from vehicle.
- Maximum of 2 balloons per vehicle
- Minimum of 2 pilots per team
- Only "standard" materials may be used unless special permission is given in advance
- During "official" flights, vehicles may not be touched, and no force may be exerted via tether string.
- We may introduce a teleoperation exercise, so allow some room to mount a forward facing TV camera on your vehicles.

Standard Materials

- Balsa wood
- Large & small motor sizes
- Propellers
- Radio control electronics
- Servos
- String
- Epoxy, glue, tape, other adhesives
- Weather balloons or 600 gm lift/balloon
- Helium Gas

Spiral Design Process



Initial Steps

- Get acquainted, set ground rules, meeting times, choose team name
- Identify the key design parameters: Balloon layout, Number of motors, Etc…
- Brainstorm and sketch concepts
    - No filtering or critiquing of designs at this point
- Identify strengths and weaknesses
- Down select to several likely contenders
- Review + / -´s in more detail and formally select final design

Product Design Matrix

		Design Solutions			
Requirement	Importance	A	B	C	D
speed	6	5			
weight	8	7			
noise level	4	2			
Totals		94			

Project Schedule

- Week 1 - Start Project
- Week 3 - PDR; hand in portfolios
- Week 6 - CDR
- Week 8 - Initial Flight Opportunity (cage)
- Week 9 - Official Test Flight Day (write test flight reports)
- Week 10 - Race Day
- Week 10 - Awards Ceremony and Course Wrap-up (final LTA reports and portfolios due)

Preliminary Design Review (PDR)

Objectives

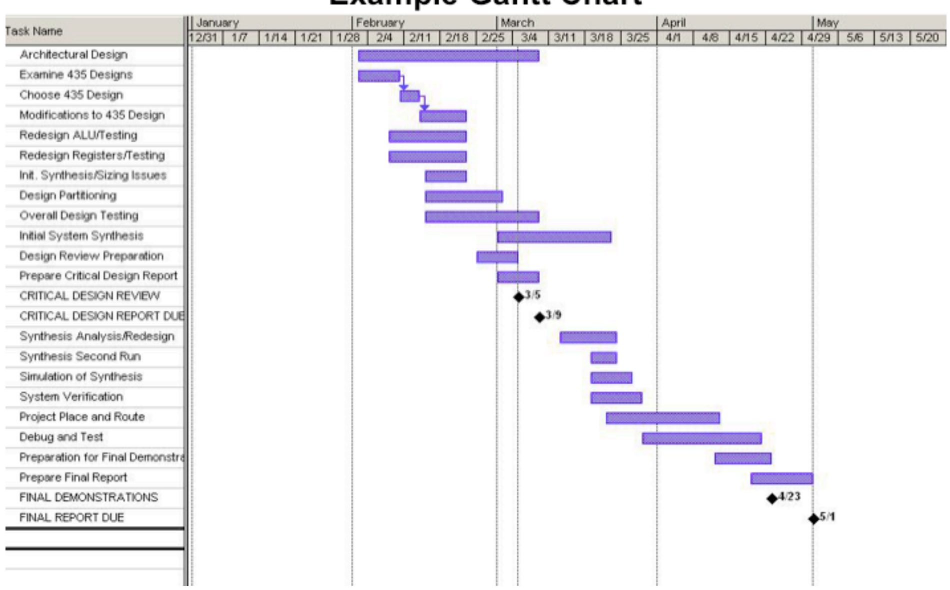
- Describe the design process to arrive at proposed vehicle layout
- Provide justification for the selected design
- Preliminary analysis of selected design´s performance
- Roadmap to arrive at finished product

- Bottom line: Convey technical ability and confidence that you will get the job done
    - e.g., to justify funding from a supporter

Elements

- Introduction, Team name, Team members
- Discussion and analysis of proposed designs
- Selection of proposed design
- Schematic of selected design
    - Approximate layout, balloons, propulsion, attitude control
- Analysis
    - He volume, mass estimates, drag & thrust estimates
    - Number and placement of motors & propellers
    - Number, size, and placement of batteries and electronics
    - Method of attitude control and maneuvering
    - Expected vehicle velocity and endurance
- Request and justification for additional materials (if necessary)
- Timeline construction and testing

Example Gantt Chart



Completed Design Review (CDR)

Objectives

- Describe the detailed design of the vehicle
    - Layout and analysis

    - Major modifications since PDR
- Present and discuss at least one built prototype component or subsystem
- Convey that you can overcome any issues that remain and will have a working vehicle on trial day

Elements

- Introduction, team name, team members and roles in the project
- Introduction of the final design
- Scale drawing of final design (at least a dimensioned 3-view)
- Control system details
- Aerodynamics analysis
- Other analysis (structural, construction, major concerns, etc.)
- Timeline for construction and test
- Conclusion

Presentation Logistics

- 10 minutes/team – (8 min. presentation, 1 min. Q&A, 1 min. turnover)
- PowerPoint presentations must be emailed or delivered on CD by 8 a.m. of the day of the presentation.
- Each team member must actively participate in either the PDR or CDR presentation (i.e. speaking role)
- Presentations will be evaluated and graded by the teaching staff, using scoring sheets. Content of the sheets will be made available to students before the presentations.

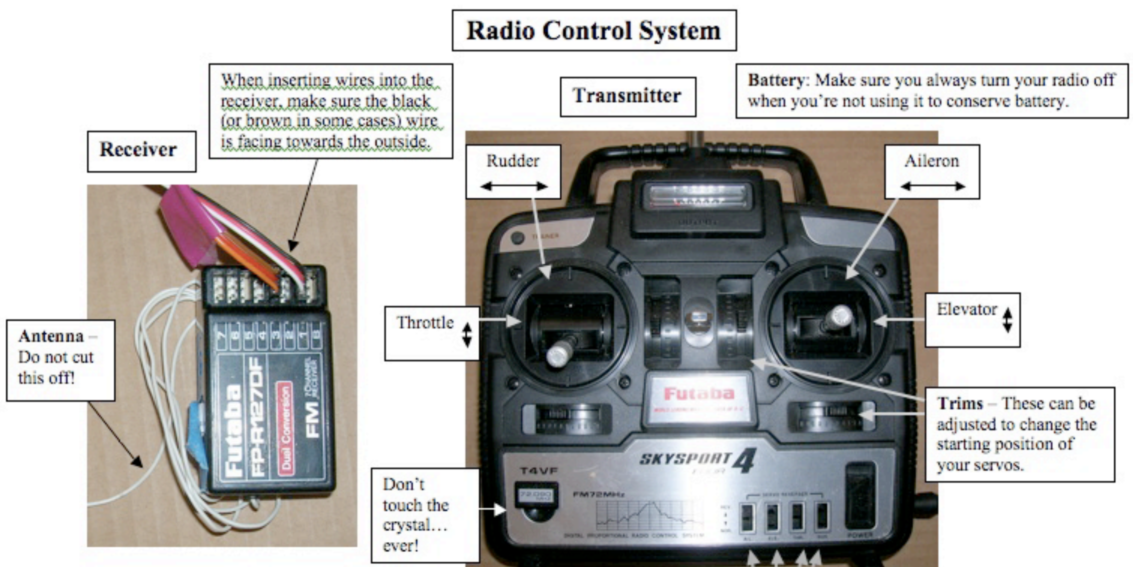
Teamwork

- Effective teams do not just happen – they take work
- Open lines of communication are critical
- Methods for arriving at decisions should be clear and acceptable
    - Strive for consensus
- Everyone should have clear responsibilities
    - And follow through on the team
- Note your contributions in your Personal Design Portfolio

LTA Design Hints

- It is easy to make a blimp that float
- It is not easy to make a blimp go where you want it to
- Stability: Able to maintain altitude and attitude without control input
- Controllability: Able to dictate direction of movement and rotation

Electronic Specifications



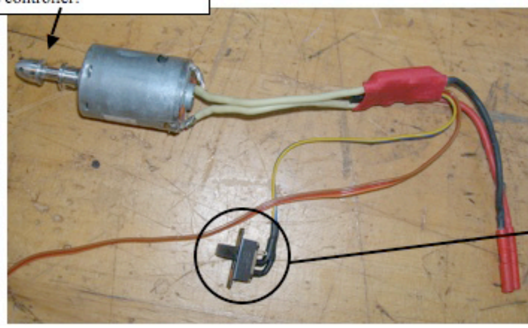
Key for matching Receiver Ports, Transmitter Controls, and Reversers:

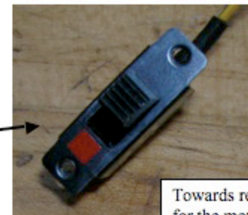
Receiver Port	Transmitter Control Location/Movement	Transmitter Reverser
1	Right Control/ Left-Right	Aileron
2	Right Control/ Up-Down	Elevator
3	Left Control/ Up-Down	Throttle
4	Left Control/ Left-Right	Rudder
5	None	None
6	None	None
7	Right Control/ Left-Right	Aileron

Reversers: These switches reverse meaning of the directionality of the corresponding control on the transmitter. If the motor is off when the throttle is up, switching the corresponding reverser will make the motor off when the throttle is down, and on when it is up. (It will not work for making the motor switch from forward to reverse.)
If a servo moves clockwise when you push the controller left, switching the corresponding reverser will make ithe servo move counter-clockwise when you push the controller left.

Motor

Always take the propeller off before practicing work with the controller!





Towards red is on for the motor switch.

The 9.6V battery can power the receiver and the motor, and eliminates the need (and extra weight) or the smaller battery to power just the receiver.

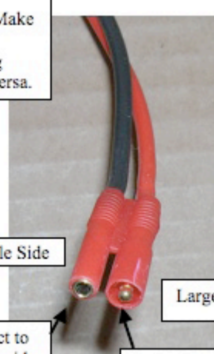
Procedure for turning the motor on and off:
ON:
1. Begin with everything off
2. Connect the battery (red connectors)
3. Turn the transmitter on
4. Turn on the motor switch (to red)
5. Move the control on the transmitter forward to turn on.

OFF:
1. Move the control all the way down so the motor is off
2. Turn the motor switch off (to black)
3. Turn the transmitter off
4. Disconnect the battery

Motor Control: The left control on the transmitter is best to use with the motor since it is on a gimble and not spring-loaded. To use the right control (up-down) for motor, put a rubber band around it to hold it in the off position unless force is applied.

Connecting Wires

The connectors for the batteries must <u>always</u> be connected properly or sparks will fly. Make sure the large-male side is connected to a corresponding small-female side and vice-versa.



Small Female Side

Large Male Side

Must connect to a large-male side

Must connect to a small-female side

Re-wiring/ Connecting Wires:
It is acceptable to solder wires, but you must <u>always</u> keep the color convention! i.e. <u>always</u> connect black to black and red to red.

Servo Info

Tips for connecting servos:
*Secure the servo using 2sided carpet tape.
*Wrap the servo in masking tape and then connect it using apoxy
*Use small wood screws t
*Drill holes in the wood and use tie-wraps

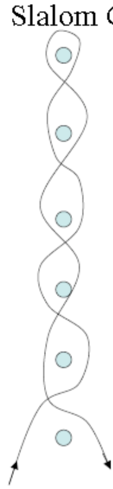
Lighter Than Air Vehicle - Notes for Instructors

Comments from instructor:

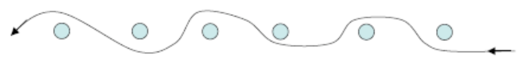
1) I now include cost as a factor in the LTA project. Previously, vehicles were scored just on speed and payload capacity. I feel that introducing cost gives the students a more real-life experience. The cost was calculated according to the number of balloons, motors and servos that were used. I continue to experiment with the formula used to calculate the success of the project, in order to encourage students to use fewer balloons and make their LTAs more maneuverable. This year, two teams were able to design their LTAs to use only one balloon. Most teams used only two.
2) I introduced a third LTA flight opportunity in 2005 and have retained it as a permanent feature of the LTA project. Previously, there was an initial flight day, when teams could see whether or not their designs actually flew. They then had a week to make repairs and changes prior to the race day a week later. Students often asked if they could test their new designs over the intervening weekend, but we could not support this either in terms of getting the use of the gym or providing the supervisory personnel. Also, the price of balloons (now up to $15) was not trivial. Last year, we started using a new technique to tie off the balloons, which resulted in far fewer balloon bursts during deflation, so we could reuse balloons. Also, given the cost factor, teams limited their balloon use to one-, two- or three-balloon vehicles, so fewer balloons were used overall. In 2007, only two balloons were lost! I feel that if redesign is part of the learning objectives, then students should have a chance to test their redesigns before the final race.
3) I introduced concepts of test flight into the LTA project in 2005 and have retained this in 2006. Taking advantage of the extra flight day, I created special slalom courses to test the horizontal and vertical maneuverability of the vehicles. In a lecture before this test flight day, I introduced the students to concepts of test flight, including Cooper-Harper ratings. The students had to write test flight reports for their vehicles, including CH ratings for horizontal and vertical maneuverability. Student response seemed extremely positive.
4) I eliminated the “demolition derby” at the end of race day. While many students in previous years enjoyed crashing their vehicles into one another, I felt that with all our emphasis on reusing balloons, this activity would send the wrong message to students.

Slalom Race Course

Top View
Horizontal Control
Slalom Course



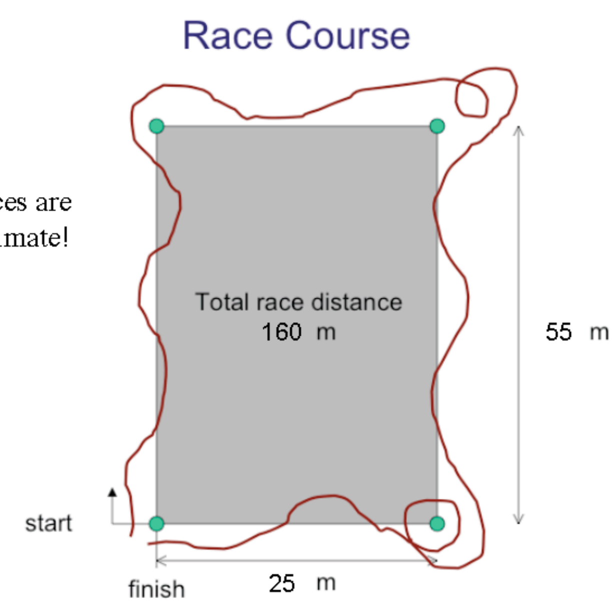
Side View
Vertical Control
Slalom Course



<u>Controllability Test Flight Slalom Courses</u>

(Class will use Cooper-Harper test flight rating system to evaluate controllability.)

Note:
Distances are
approximate!



Electronic Specs

Servos:
Futaba standard S-148 servos; 1.3 oz wt; dimensions 40x20x35 mm.
Torque: approx. 44.4 (in-oz) 3.2 (kg-cm) @ 4.8 v. Range of motion: +- 60 deg.

Futaba 7-channel receiver:
1.5 oz (42.5 g); dimensions 62 x 33 x 22 mm; current drain 14 ma @ 4.8 volts.

Receiver Battery:
4.8V NiCd pack, 500 mah capacity; dimensions 50 x 29 x 29 mm
NOTE: this battery is primarily used for pre-flight (non-motor) testing; the electronic speed control (ESC) provides the proper electrical voltage for the motors, the receiver, and servos.

Rechargeable NiCd battery for the electric motors (flights): 8 cell, 600 mah pack, 5 1/2 ounces.

Motors:
Large S-600 electric motor with Graupner 7x3 propeller, electronic speed control: all up weight appr. 6.88 ounces
Smaller S-400 electric motor with Graupner 6x3 propeller, electronic speed control; all up weight appr. 3 1/2 ounces

The source of the figures is a commercial performance program, E-Calc. These figures are computed analytically assuming an 8 cell 500 mah battery pack, Nickel Cadmiums, and are very close to actual empirical data. What's more important here are the current drains of the motors at various thrust levels.

Graupner Speed 400, #1794; 6x3 propeller

Current [amps static]	thrust, [ounces]
2	2.5
3	3.4
4	4.3
5	5.4
7	6.5
9	7.6
10	8.8

Graupner Speed 600, #3301; 7x3 propeller

Current [amps static]	thrust, [ounces]
2	4.6
3	5.8
5	7.2
8	8.8
10	10.5
13	12.3
14.2	16

Other weight contributors: propellers (@ 1 oz); electronic speed controls (@ 1/2 oz); 3 conductor wiring; and electrical connectors.

1. Vehicle construction

The LTAs' basic structures are made from 36" long sheet and strip balsa wood. Dick Perdichizzi orders a standard supply of wood from Lone Star Balsa in Lubbock, Texas. The wood dimensions vary and here's a representative listing:

Balsa sheet: 1/16", 3/32" and 1/8" thick balsa sheet, 3" x 36"
Balsa strip: 1/8" square, 3/16" square, ¼" square; 1/8" x 3/16", 1/8" x ¼"

It may be worthwhile to standardize on the strip stock provided, as well as to impose some sort of materials' limit for each team. Setting constraints may inhibit experimentation and creativity, but stimulate more pre-planning prior to actual construction starts.

An excellent local “quick reaction” source for supplies is Pearl Art & Craft in Central Square. They have a large supply of balsa wood, thin saws, adhesives, and useful Xacto hand tools of various kinds. Pearl gives academic discounts if requested.

Adhesives needed are aliphatic wood glue (Elmer’s Carpenter’s Glue), 5-minute epoxy, medium viscosity cyanoacrylate superglue, superglue spray accelerator, solid glue sticks, and 3M77 spray contact cement.
The wood glues, 5-minute epoxies, glue sticks, and spray contact cement can be purchased at Pearl, Economy Hardware (also in Central Square), or any Home Depot. The c/a superglues can be mail-ordered from a variety of on-line sources (Hobby Lobby, Tower Hobbies) or picked up at Alex’s R/C Hobby Shop, 129 Belmont St., Belmont, MA (phone 617 484-3780). Alex’s store hours are 11am-8pm, Tuesday-Friday, 10am-6pm Saturday, closed Sunday and Monday. Alex Lob occasionally takes vacation days so it’s wise to call in advance before making a special trip for supplies. He can order any special order items needed and it’s a good idea to support our local suppliers – a vanishing species without which we’d be suffering.

Other handy construction equipment: long steel construction pins (available from Alex’s or Pearl), small clamps, thin saws, and sandpaper in medium and fine grades. Thin thread is useful for wrapping/and reinforcing wood joints.

We’ve been fairly liberal about letting 16.00 students use other construction supplies such as composite tubes (leftover from Unified) and thin sheet Depron plastic sheet (light weight, easy to cut, good for making horizontal and vertical stabilizers). We however should veto any proposed use of plastic or metal plug-together tube and socket assemblies, “Tinkertoy” style.

Thin plastic (Saran wrap or dry cleaning bag material) is useful for making lightweight aerodynamic surfaces. Solid glue sticks or spray contact cement are good adhesives for this usage.

Tips to minimize problems:

- Start buying supplies in November or December, well in advance of the class start. There’s no harm in starting early to accumulate needed supplies rather than later.
- Once the construction starts, the T As and staff need to conscientiously monitor the students’ progress to avoid crises if supplies or equipments suddenly run out.

2. Radio control equipment

For the 16.00 LTA event, the basic equipment suite includes the following:

- Futaba radio control transmitters and receivers
- Futaba “standard” digital servos, 2-3 per vehicle

- **Graupner Speed 400 and Speed 600 electric motors (available from Hobby Lobby, Brentwood, TN, www.hobby-lobby.com)**

SPEED 400 Electric Motors

For airplanes that weigh up to 25 oz., sailplanes to 45 oz. These are motors that consume from 35 to 75 Watts and about 6 to 10 Amps, have 2.3mm diameter prop shafts, are 27.6mm diameter, about 1-1/2" long, and weigh about 2.3 oz. Order 2.5mm Mounting Screws HLH8725.

SPEED 400 6V Motor

GR3321 Graupner **SPEED 400 6V Electric Motor ..... $ 7.90**

1 Add GR3321 to Cart **IN STOCK**

Motor weighs 2.55 oz.

SPEED 600 Electric Motors

For airplanes that weigh up to 50 oz, sailplanes to 70 oz. These are motors that consume from 130 to 300 Watts and about 15 to 30 Amps, have 3.2mm (1/8") diameter prop shafts, are 1-3/8" diameter, about 2-1/4" long, and weigh about 8 oz. Order HLH8730 Mounting Screws.

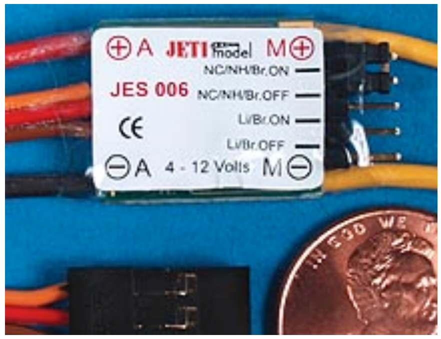
SPEED 600 9.6V Motor

Motor weighs 6.88 oz.

GR1786 Graupner **SPEED 600 9.6V Electric Motor ..... $ 18.50**

1 Add GR1786 to Cart **IN STOCK**

- Electronic speed controls (ESCs) to control the electric motors. Two different models are needed for the two different sized electric motors.



.7 x .6 x .2", .2 oz.

JES006 **Jeti 6 Amp Microprocessor Motor Controller ..... $ 23.90**

1 Add JES006 to Cart **IN STOCK**

1 x .75 x .3", .53 oz.

JES012 **Jeti 12 Amp Microprocessor Motor Controller ..... $ 33.70**

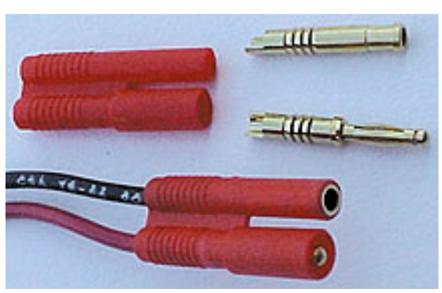
1 **IN STOCK**

Electronic speed controls are easily damaged (usually by improper electrical hookups) so adequate spares should be ordered in addition to a nominal supply on-hand. Each ESC needs the following electrical connections:

- The two heavier wires soldered directly to the back terminals of each motor. If reverse rotation is desired, these two wires should be reversed (this is the ONLY way to get reverse motor rotation!)
- A smaller gauge three-wire connection (as seen in the pictures) which connects to the receiver; this connector routes motor speed command signals from the receiver to the electric motor; and also provides 4.8V receiver and servo electrical power to the receiver, stepped down from the big motor batteries. Note the order of the wires to the three-wire connector: signal (orange), red (positive lead), and brown (ground).

The servo connectors should be inserted into the receiver with the ground wire oriented to the outside of the case, and any added extension wiring needs to observe the wiring sequence described.

- Nickel-cadmium rechargeable motor batteries – 8-cell, 600 milli-amp hours capacity. The current set of batteries on-hand, as of summer 07, may need replacements as these batteries have been used for several years and are not all in good shape. Good sources: www.cermark.com or www.batteriesamerica.com Order these as much in advance as possible. I'd recommend buying twice as many battery sets as the number of teams – so for 12 teams, order 24 battery sets. Unless these are ordered with connectors attached, the proper connectors will have to be soldered to the new batteries' wire leads.
- AC chargers for the Futaba transmitters - we have adequate numbers of these.
- Chargers for the motor batteries – two types at least.
    i. Ace Multi-Charge chargers can charge 6 battery packs simultaneously at independently set charge rates. Programming the chargers for the proper charge rate (60 ma for the 600 mah packs) and starting the chargers – requires some familiarity and expertise with the chargers; the instruction manuals should be consulted and I've found that having one person responsible for this important task helps logistics a lot (whereas trying to have individual teams do this is not a good use of time or people). This charger needs 15 hours (nominally) for a full batteries charged and available for flight days is VERY important – we have two or three of these chargers but they may be co-used by Unified – coordination is essential here to minimize conflicts!
    ii. Astro Flight peak detection chargers. We have three of these which are powered by a 12VDC power supply (or 12V lead acid battery). These are "smart" chargers which can be set to charge battery packs at various charge rates; I use 1C (600 ma) for the 600 mah packs and usually can get used packs charged in less than 10 minutes, at least the packs which are not fully discharged (which is rare in our LTA usage).
- Electrical connectors for the ESCs, motor battery packs, and chargers. We've standardized on Kavan connectors available from Hobby Lobby.



It's important to note the following:

i. Each plastic connector shell consists of a small and large diameter plastic housing.
ii. The two brass pins have a male and female fitting.
iii. Once the brass pins are pushed into the plastic connector, they are very difficult to remove.
iv. There's only ONE proper connector/pin order to get proper electric polarity – get it wrong and something will short.
    1. The T As from a previous year made up some nice tech illustrations that depict the proper sequence – some are posted upstairs in the mezzanine.
v. The proper wiring assembly sequence is to first push the electric wire through the plastic connector shell, going in on the knurled end; solder each wire to the brass pin; then pull the brass pin and wire back into the plastic connector.

Other needed equipment:

- Propeller adapters (2.3 and 3.2 mm) for propeller installation on the motor shafts
- 6x3, 6x4, or 7x3 nylon propellers – we've been using yellow Graupner propellers but APC electric propellers are also usable – although slightly more fragile than the Graupners.
- Small allen wrenches to fasten the propeller adapters to the motor shafts – these are easy to lose or misplace so it's a good idea to buy several (from Alex's or Hobby Lobby)
- 5.5 mm phone jacks are needed to connect charging batteries to the Ace Multi-Charge chargers; these can be purchased from Radio Shack.
- 3-conductor extension servo wire to provide long wire lengths for servos installed on the LTAs. This wire can be purchased from Alex's, Hobby Lobby, or Tower Hobbies. This type of wire is not commonly found in other retail outlets (Radio Shack for example) so it's wise to order this in advance.
- Control surface control horns. These can be bought in bulk from Hobby Lobby at a considerable savings over buying them one-two at a time.
- Control surface linkages. "Rod in nylon tube" Sullivan sets are easy to use and setup if the linkages run in straight lines from the servos to the control surfaces. Fishing line "pull-pull" connections are another good technique.
- Plastic or metal clevises to clip onto the control horns or servo arms, along with threaded (2-56) metal rods; Alex's stocks these routinely.

3. Preparation activities prior to class start

The general rule is – get started as early as possible to round up equipment, check out radios, etc. It's difficult, and usually more expensive, to remedy shortfalls when time is a pressing urgent issue. Overnight shipping is handy but very costly for small inexpensive items. Most of our suppliers will provide ac ademic discounts but this takes a little time to coordinate with the right people at the suppliers. In general, it's recommended SOP to start rounding up equipment and supplies in December and finish up the preps during IAP. Here are the key activities:

- Futaba transmitters (TX's) and receivers (RXs). TXs and RXs have to have matching crystals in order to operate properly, and there are several anomalous possibilities here. One is a missing RX or TX crystal. RX crystals can be easily ordered but due to FCC regulations, only certified repair techs can replace the TX crystals. So an important first step is to round up Futaba TXs and RXs and match them by frequencies to get matching pairs. Alex can order Futaba RX crystals if he doesn't have them on hand. At this time non-working transmitters (perhaps tampered with or obviously physically damaged) should be weeded out. Transmitter batteries can be load-tested to find if TX batteries are good or bad; I've usually repaired bad TX battery packs by removing and replacing individual bad NiCd cells. Cermark (www.cermark.com) or Batteries USA (www.batteriesusa.com) can provide replacement TX battery packs at a far cheaper cost than if ordered through Futaba, Tower, or retail.
- Servos and connectors. Usually most of the Futaba servos will need to have servo connectors (connecting to the receiver) installed as the students tend to cut off servo connectors. Dave Robertson has a good source for getting these servo connectors, much less expensive than from any other source. It usually takes me a dedicated evening or two to repair the wiring on 25-30 servos – production line techniques really pay off here rather than have individual students solder on connectors.
- Systems Testing of the Futaba radios. It's a good idea to check the primary output ports of the Futaba radios – a "live test" with servos attached and the receiver and transmitter powered up. The servos are pretty reliable and don't fail very often. The transmitters and receivers are another story and good troubleshooting is needed to determine whether system failure is due to a bad crystal (TX or RX), or a defective transmitter or receiver. Alex can order spare Futaba receivers and transmitters but allow extra time for this – the industry much prefers to sell complete radio systems, not individual components.
- Electronic speed controls. These are very vulnerable to failure due to misapplication of voltages; if the battery power to the ESC is inadvertently reversed, the ESC will immediately "go up in smoke". On-hand ESCs should be checked by hooking them up to a motor and verifying that they work - this takes time! As ESCs are pretty expensive, ordering them with an academic discount is a good idea and Hobby Lobby has been good in this respect. In the past, we've had two different types of ESCs, one for the lower current draw S-400s and a

bigger one for the S-600; it would save money to buy a single model ESC that is rated for the S-600s and would also work for the S-400s.

4. **Equipment and preparations for flight trials.**

- The 16.00 LTA project has evolved to having three flight sessions over at the Johnson indoor track area. Contact Sandy Lett slett@mit.edu to reserve the track area for the desired days – do this during IAP or earlier!
- Bottles of helium. Dick Perdichizzi orders these and we usually use up 2 ½ to 3 bottles per flying session. Dick has the proper sized wrenches and gas regulators that fit the gas bottles. An important note: be sure the shutoff valve on the gas bottle is closed when filling ops are complete – the shutoff valve alone, on the gas regulators, won't hold back the monatomic helium from leaking out.
- Dick also orders the weather balloons. I don't recall the lead time but there's no harm in ordering them early – don't wait until just before they're needed.
- Charging the motor batteries in advance. Using the Ace chargers that charge six motor batteries at a time, it's pretty easy to get all the batteries charged before a flight session. Coordinating these activities with Unified is essential as they are also big users of rechargeable batteries.
- Supplies needed for flight trial days:
    i. Spare motors, pre-wired with ESCs and ready to install.
    ii. Spare propellers and propeller adapters
    iii. Spare radio transmitters and receivers; pre-charged transmitter batteries
    iv. Lightweight line and smaller party balloons for lane markers. Caution: make sure the balloons are pretty good sized - big enough to carry the weight of the lightweight line. "Size matters".
    v. Large Bulldog clamps to pinch shut the balloons.
    vi. Moderately strong cotton or nylon line - balloon tethers.
    vii. Spare balsa wood and adhesives (super glue, 5 minute epoxy)
    viii. Power strips and as many peak chargers as can be rounded up. I've had as many as five chargers continuously in use during flight trials – as the students gather more experience with their LTAs, they tend to use up more of the battery charge so recharge times tend to get longer. A reasonable charge rate is 100% to 150% of the battery "C" rating; in other words, a 600 mah battery pack has a 0.6 amp "C" rating and can be charged at 0.6 to 0.9 amps without damage.
    ix. Lead weights and plastic sandwich bags – for use to hold ballast.
    x. Tools – screwdrivers in several sizes, razor blades, scissors.

xi. Electronic digital scales to weigh LTA structure weight.
xii. Spring scales to measure balloon buoyancy.
xiii. Electronic stopwatches
xiv. Masking tape
xv. Soldering iron, solder, “handy hands” fixture, spare servo wire
xvi. Portable megaphone

All the above supply items are a nuisance to carry to and from Johnson. I’ve borrowed my wife’s folding shopping cart and have been able to carry all the items above in one load – very convenient and much better than making multiple trips carrying individual items. I recommend buying one such foldable shopping cart – they’re not expensive and will save time and work.

Parts & Materials Budget

Desc	**Qty**	**Cost**	**Ext**	**Reusable?**
Futaba S-148 servo	15	$14.00	$210.00	y
Fitaba 7-ch receiver	6	$193.00	$1,158.00	y
Futaba transmitter	6	$220.00	$1,320.00	y
Receiver battery 4.8V NiCd	6	$15.00	$90.00	y
S-600 motor	6	$18.50	$111.00	y
Graupner 7x3 propeller	6	$4.20	$25.20	y
Jeti 12A motor controller	8	$33.70	$269.60	y
S-400 electric motor	6	$7.90	$47.40	y
Graupner 6x3 propeller	6	$3.60	$21.60	y
Jeti 6A motor controller	8	$23.90	$191.20	y
36" sheet & strip balsa			$0.00	
1/16, 3/32, 1/8" x 3"	3	$13.00	$39.00	
1/8" square, 3/16" square, 1/4" square	1	$15.00	$15.00	
Elmer's carpenter's glue			$0.00	
Superglue	10	$7.80	$78.00	
Superglue accelerant	3	$5.90	$17.70	
Ace Multi-Charge	1	$116.00	$116.00	y
Control surface control horns	6	$6.00	$36.00	
Weather balloons	20	$15.00	$300.00	y
		REUSABLE	$3,860.00	
		CONSUMABLE	$185.70	
		TOTAL	$4,045.70	

Self/Peer Reviews

- Students will receive an evaluation form
  - Intellectual Contribution (ideas, discussion, analysis)
  - Hands-on Contribution (drawing, construction, testing)
- Opportunity to assess your own effort relative to that of your peers
  - Confidential
  - Note significant team problems if they exist
- Uneven participation
- Unproductive team meetings
- Team member personality issues
  - Opportunity to praise good efforts by team members

Evaluation Form:

- First, write your own name in the first blank followed by your team members names in the consecutive blanks.
- On a scale from 1-5 grade your contribution and then that of your peers according to:

poor	below average	average	good	excellent
1	2	3	4	5

- Excellent (5) = makes original contributions to team; does extra work for the project. Spends extra time and effort on the project.
- Good (4) = does all jobs thoroughly and well; does all jobs without being asked. Attends all team meetings without being asked.
- Average (3) = does what is required; sometimes needs to be asked to work or to attend meetings.
- Below Average (2) = makes some contribution; often needs prodding. Misses a significant number of meetings.
- Poor (1) = has a negligible or even negative impact on team project.

- LTA Team Name:______________

- Intellectual Contribution:

Your Name __________________________
1 2 3 4 5

Name __________________________
1 2 3 4 5

Name __________________________
1 2 3 4 5

Name __________________________
1 2 3 4 5

Name __________________________

Name __________________________

	1	2	3	4	5	1	2	3	4	5

- LTA Vehicle Team Contribution:

Your Name ___________________________ Name ___________________________

1 2 3 4 5 1 2 3 4 5

Name ___________________________ Name ___________________________

1 2 3 4 5 1 2 3 4 5

Name ___________________________ Name ___________________________

1 2 3 4 5 1 2 3 4 5

- Special comments about teamwork or team members:___________________