NOTES FOR THE CLASSROOM TEACHER

Please read this first!

Most of us know that flight is an engaging topic and that activities involving simple flying models, are always extremely popular with students. However, before trying any of the AeroLab activities, we strongly suggest that you review these notes, written especially for teachers who may be new to using simple model airplanes to teach basic concepts in physical science.

A primary goal in creating the AeroLab activities was to use inexpensive, readily available foam and balsa models for stable and reliable platforms to permit students to better control the variables present in any experiment. Paper airplanes, while fun, have limited utility in the science classroom because their flying characteristics vary widely from flight to flight.

These lessons were developed by experienced middle school teachers and have been field-tested in several states through a series of workshops supported by the Alcoa Foundation. The process enabled us to refine them and make them more useful for classroom teachers. We encourage you to become part of this process by contacting us if you have questions or suggestions that will help us improve future editions of the AeroLab materials.

We want these lessons to be as relevant and user-friendly as possible, which is why we welcome your comments. We hope you will send us ideas for lesson updates or new activities you develop, so we can enrich the program and further increase student achievement in math and physical science. Please send us your ideas at this email address: aerolab@mansfieldct.org

As a final note, we hope you will forgive us if our presentation style is a little more informal than those you are accustomed to seeing in commercially-produced videos. AeroLab is an instructional video intended for teachers and students. It was created around the activities we regularly feature in our workshops with teachers. We had no interest in creating a production in a style different from the presentation we offer to our workshop audiences.

About Science Standards and Inquiry-Based Instruction

As you know, the "No Child Left Behind" legislation recently passed by Congress mandated that each state test children in science, beginning in the year 2008. Physical science will be one of the areas tested, but because each state determines its own science framework and standards, the grade level for physical science will vary from state to state. The AeroLab activities you chose will depend on the objectives outlined in your state standards, the scope and sequence expectations in your school district and, of course, the needs of your students.

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We have created several lessons using the Jetstream to promote inquiry-based instruction for your students. To help you get started, we present these lessons *prescriptively,* as "guided inquiry." However, as you become comfortable using the model with students, we encourage you to make the lessons as open-ended and inquiry-based as your instructional objectives and time will allow. As experienced science teachers, we know that there is a tension between state-wide standardized testing and inquiry-based instruction, and we hope to help you and your students strike a balance between these two important but sometimes contradictory goals.

To this end, all of the lessons (including the suggested quizzes) can be modified in any way you wish before producing hard copies for your students. For example, we have tried to include sufficient background in the science for each lesson as appropriate, but if you find that it gives your students too much information for an inquiry-based experience, delete the text from the copies they will receive.

Lesson Order

The core math and science activities can be found in four lessons featuring the "Pylon Racer": Speed, Potential Energy, Weight and Drag. We have provided suggested quiz items for these lessons to reproduce and use with your students as you wish.

The remaining lessons are offered as enrichment and additional inquiry-based activities for your students. The video "Total Control" is an introduction to a unit from *Inventing Flight,* a multi-disciplinary curriculum written by the authors to celebrate the Centennial of the Wright Brothers' achievements in 2003. This ten-minute video is included online as preparation for the foam plate glider (FPG-9) activity. The video was made available, courtesy of ThinkTV, of Dayton, Ohio, the local PBS affiliate that produced the curriculum. Copies of the curriculum may be obtained by contacting the Agency for Instructional Technology at **www.ait.net**

The final activity, Building a Skystreak, is included purely for fun. Although, the activity has limited utility as a science lesson, students love the experience of flying a simple free-flight model outdoors. A successful flight requires patience and finesse, but the project is definitely rewarding as a culminating activity for a unit on flight.

Science "Tutorials"

Teaching the physics of flight is sometimes counter-intuitive, so to help your students, we have included several science "tutorials", also courtesy of ThinkTV and *Inventing Flight*. These short, three or four-minute segments were created to illustrate the relevant concepts and we think you will find that they will be a useful introduction or review to the lessons. In addition, we have included more science background below, including notes on why flat wings fly.

Thinkers, Not Modelers

The Academy of Model Aeronautics interest in promoting these activities is not to make modelers of students, but to help make *thinkers* of students. Building a simple flying machine is an act of the imagination involving creativity and craftsmanship. Flying it well requires careful observation, making adjustments where necessary to control variables.

We believe in inquiry-based learning, what we call the "art of fine play," - activities that give students more practice in observation, data-gathering, forming hypotheses/making predictions – all while having fun. All learning is a process and we hope these lessons will help you and your students as your journey continues. After you view the lessons and the Science Tutorials from Arconic, check the "Classroom Management Tips" below and additional background information if needed. If you have questions, we are always available by email and phone to provide assistance. Have fun!

Jon Hand
Art Ellis
Gordon Schimmel, Ed.D.

Classroom Management Tips

Because AeroLab is a creative "work-in-progress," some important information inevitably is overlooked. Therefore, we offer an additional list of miscellaneous Teacher Tips to simplify your work and avoid classroom management issues before they occur. As we receive comments and suggestions from classroom teachers, we will add them to this list to make doing these units easier for you and more successful for your students.

1. Have students write their names on planes for easy retrieval.

2. Storage is a problem in most classrooms. An easy solution is to tie string across the room and hang the planes from it using paper clips.

3. Special notes on

Building: On occasion, the Jetstream fuselage is smaller than the housing on the motor hook. If the motor is loose, the motor will wobble when running, resulting in an erratic flight. To be safe we suggest that you shim the motor with a small piece of scrap balsa to ensure a tight fit.

Winding: Lessons featuring the Jetstream are conducted using 1000 turns on the motor (200 rotations of a 5:1 winder). Three *very important* things need to happen to avoid prematurely breaking rubber motors:

> First, all motors *must be lubricated* with *Armor-All* or *Sun-of-a-Gun*; an un-lubricated motor will overheat during winding, causing the motor to break prematurely.
>
> Second, when students wind a motor, it is *imperative* that they begin moving in towards the motor hook between 600 and 700 turns (120 to 140 rotations of a 5:1 winder); doing so relieves the stress on the motor as the final turns are added.
>
> Third, make sure students position the winder, the rubber motor and the fuselage of the plane in a straight line, along the same axis; winding a rubber motor at an angle also over-stresses the motor. In summary, motors must be lubricated and wound properly to avoid premature breakage.

Flying: problems with Jetstream launch most often occur when students do not point the plane slightly outward, away from the pylon. The tether should be tight, the propeller released first, followed by release of the plane. If the plane lacks power, shorten the rubber motor.

4. When timing the Jetstream, say "time" as the plane lifts off the floor. The liftoff point is lap "zero".

6. Students with long hair should tie it back to avoid getting caught in the motor.

7. Helicopter lesson: a reminder that all measurements should be taken from the same location on the helicopter. The bottom of the shaft is probably the best.

Science Concepts and Principles

Why do Flat Wings Fly? A Word about Newton and Bernoulli: Although the Wright Brothers never considered Daniel Bernoulli's theory when inventing the first flying machine, it was generally understood by those investigating flight in the late 19th Century that cambered (curved) wings were more efficient than flat wings.

Bernoulli, whose work was based on Newton's, observed that the pressure of a fluid is lower when it is moving faster. This means that slower moving fluids have higher pressure. In general, Bernoulli's Principle applies to flight in the following manner: Air passes faster over the top of a cambered wing, resulting in lower pressure. Therefore, cambered wings lift more easily than flat wings. In addition, camber reduces drag, having another positive effect on lift.

However, many of today's textbooks and general references incorrectly credit Bernoulli's Principle as the *only explanation* of lift, an explanation that is incomplete. Newton's Third Law of equal and opposite forces must also be considered. A wing (cambered or flat) also *deflects air downward because of its angle of attack,* creating the reaction force of lift. Proof of the power of Newton's third law is found in all AeroLab lessons that make use of simple, flat-winged airplanes.

Newton's 1st Law: *Every object remains in a state of rest or uniform motion in a straight line unless acted upon by an outside force.* Planes at rest remain at rest. Planes in motion will remain in motion in a straight line (unless acted upon by an outside force.) Things keep doing what they were doing until interrupted.

Newton's 2nd Law: Force = mass x acceleration (F=ma)
When a force acts upon a body it accelerates that body in the direction of the force. The acceleration produced is proportional to the force and inversely proportional to the mass of the body.

A net force (thrust) applied to an airplane causes acceleration. Planes move in the direction they are pushed or pulled. It is easy to push or pull lighter planes; it is harder to change the velocity of massive planes. Planes accelerate more quickly when a greater force is used.

F=ma is easily illustrated by the "Pylon Racer" in the Weight lesson. For instance, it is possible to calculate thrust by attaching a Newton meter to a stationary plane with 1000 turns, and then calculate the acceleration of a plane if its mass is known. Lighter planes are easier to accelerate.

Newton's 3rd Law: *For every action or force there is an equal and opposite reaction or force.*

Wings push down on air with the same force that the air pushes up. If a plane is flying at constant horizontal velocity, the weight is equal to the lift and the thrust equals drag.

Opposite forces are always equal unless the plane accelerates. Changes in velocity (magnitude or direction) indicate that forces are unbalanced.

Conservation of Energy: Energy cannot be created or destroyed. It can change from one form into another. Energy is conserved when winding the rubber-powered airplane. For example, chemical energy from food is transformed to mechanical energy when a person winds a propeller. The mechanical energy is transformed to potential energy, which is transformed to kinetic energy, once the plane is launched.

Potential and Kinetic Energy: Potential energy is stored energy. Gravitational potential can be easily calculated using the equation: Potential energy = mgh. (m = mass, g = the acceleration due to gravity or 9.8 m/s^2, and h = height above the ground) Kinetic energy is energy of motion. Kinetic energy = $1/2mv^2$. (m = mass and v = velocity) It can be calculated as well. When the rubber motor of a plane is wound, potential energy is stored. As the rubber motor unwinds, the potential energy is transformed to kinetic energy. Energy is measured in Joules.

Work: Work = Force x Distance. For example, work is measured in Joules. To calculate work, measure the thrust of the plane in Newtons by holding a plane in place and measuring the thrust of a motor wound to 1000 turns.

Power = work/time. Power is measured in Watts.

Conservation of Momentum: Momentum = MV. *In a system consisting of bodies on which no outside forces are acting; the total momentum of the system remains the same.* Momentum can be transferred from one object to another. In an interaction, the momentum lost by one mass equals the momentum gained by the other. Total Momentum before interaction = Total Momentum after. Imagine a plane that is flying. The momentum of the moving air in one direction is equal to the momentum of the moving plane in the other direction.

Gravity, Weight and Mass: *Any two bodies in the universe attract each other with a force that is directly proportional to their masses and inversely proportional to the square of their distance apart. (If the distance between two objects is doubled, the force of gravity falls to ¼ of its former value.)* Gravity is the attractive force between all objects and depends on the mass of objects and the distance between them! Weight = mass x acceleration due to gravity. A person will weigh less in a plane at 35,000 feet because the force of gravity is less. Mass is the amount of stuff in an object. A passenger will still have the same mass at 35,000 feet.

Centripetal Force: Centripetal force is the push or pull on a moving object toward the center of its curved path. As a plane banks and turns left or right, passengers experience centripetal force.

The Four Forces of Flight: A force is simply defined is a push or a pull. Drag and thrust are equal when a plane moves horizontally at constant velocity, and lift and weight are also equal. Changes in velocity (magnitude or direction) indicate that forces are unbalanced.

Friction: is the force that opposes the relative motion of two bodies in contact. Airplanes experience air resistance, or drag, as they fly.

Speed: Speed = Change in Distance / Change in Time. It is possible to calculate the speed of a model plane. Time how long is takes a plane to travel a known distance.

Acceleration: Acceleration is a change in velocity (or change in direction). A model plane with wheels, reaching take-off speed, will demonstrate how unbalanced forces result in acceleration. It is possible to calculate acceleration of a plane/kite/helicopter using this equation: Acceleration = Change in Velocity/Change in Time.

Some Suggestions for Inquiry-Based Activities

Variables
- How does rubber motor length affect flight time?
- How does trimming each propeller blade affect flight time?

Weight
- How does decreasing mass (by sanding) affect flight time?

Drag
- How does length of the yarn affect flight time?
- How does the location of the yarn affect flight time?

Center of Gravity
- How does wing position affect flight time? Measure the distance you move the wing in millimeters. For example, after marking the starting location, test what happens when you move the wing forward 3-mm, 6-mm etc…
- How is flight time affected by the addition of a penny at different locations?

FPG-9
- How can you modify the glider to fly the greatest distance? To right or left?

Additional Resources: *Inventing Flight,* a multi-disciplinary curriculum for upper elementary, middle and high schools students by the same authors, is available from the Agency for Instructional Technology www.ait.net.

AC Supply Co. – A vendor who knows the needs of AeroLab teachers with planes, winders and rubber motors. www.acsupplyco.com

Buildandfly.com is the website of the Academy of Model Aeronautics Education Committee. If you are looking for technical assistance on any lesson, or a local modeler to give a classroom presentation, this is the site for you.