LEARNING GOALS: After the completion of this workshop, students will understand:

1. How airplanes fly
2. Bernoulli’s principle
3. How to control an airplane, and use of mathematics to calculate average distance traveled.

CONCEIVE – What do I wish to accomplish through this project?

This stage involves guiding students in defining the goals of the project, then helping them develop conceptual, technical and action plans to meet those goals while considering the technology, knowledge, and skills that apply. This guidance is provided in the form of Essential Questions that use student’s preconceptions, and misperceptions then move them toward a deeper and more realistic understanding of the process and skills needed to complete the project.

ESSENTIAL QUESTIONS:

1. How do airplanes fly?
2. What components are necessary to achieve lift and control of an airplane?

DESIGN - How will I accomplish the project?

This stage focuses on creating the plans, drawings and algorithms that describe the product, process or system that will be implemented.

http://www.midwestproducts.com/store/product/e0a83f56-9ef4-4c91-b7a7-9e3576d89375/Delta_Dart_Class_Pack_-_Supplies_35_students.aspx

We purchased kits from Midwest products for students to construct a Delta Dart model airplane that is powered by using a rubber band.

Instructions on building the plane are included in the kits. A .pdf of instructions is also included.

NOTES: There are instructional materials included with kits. See Appendix A. Discuss Why Airplanes Fly? Section before you start the project.

IMPLEMENT - From an idea to a product!

This stage refers to the transformation of the design into a product. It includes hardware, manufacturing, software coding, testing and validation.

NOTES: See above. Building instructions included with kit. After the students have built their planes and are flying them. Then discuss design changes or corrections they would make to fly differently, straighter, etc.

If time permits you can also include a worksheet that allows them to measure their planes flight path over a series of flights and calculate the average distance traveled.

This includes some mathematics into the workshop.

OPERATE – Does it work the way I planned?

This stage uses the built product, process or system to satisfy the intended goal.
If the plane is flying poorly or making diving turns into the ground, correct this by installing trim tabs. Trim tab ailerons can be made of stiff typewriter paper measuring ¾” x 2” and use a glue stick to apply them on the edge of the back wings. (an illustration is included in instruction #27 Appendix 2). They can also add horizontal stabilizers (see instruction#28) or add a tab to the tail fin as a rudder to collect hard, tight turns.

NOTES:

RESOURCES NEEDED – What equipment and supplies do I need?

http://www.midwestproducts.com/store/product/e0a83f56-9ef4-4c91-b7a7-9e3576d89375/Delta_Dart_Class_Pack_-_Supplies_35_students.aspx

In addition you will need:

- A piece of corrugated cardboard or drywall or wall board approximately 12” x 15” to serve as a work pad.
- Wood glue
- A glue stick
- Straight pins
- Scotch tape
- Scissors
- A hobby knife or razor blade (depending on age group)

SET-UP

See above supplies needed.

<table>
<thead>
<tr>
<th>Colorado State Standards - High School</th>
<th>21st Century Skills</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Physical Science</td>
<td>Concepts and skills students master:</td>
</tr>
<tr>
<td></td>
<td>1. Newton's laws of motion and gravitation describe the relationships among forces acting on and between objects, their masses, and changes in their motion - but have limitations.</td>
</tr>
<tr>
<td></td>
<td>5. Energy exists in many forms such as mechanical, chemical, electrical, radiant, thermal, and nuclear, that can be quantified and experimentally determined</td>
</tr>
<tr>
<td></td>
<td>Inquiry Questions:</td>
</tr>
<tr>
<td></td>
<td>1. What factors can be measured to determine the amount of energy associated with an object?</td>
</tr>
<tr>
<td></td>
<td>2. What are the most common forms of energy in our physical world?</td>
</tr>
<tr>
<td></td>
<td>3. What makes an energy form renewable or nonrenewable?</td>
</tr>
<tr>
<td></td>
<td>4. What makes some forms of energy hard to measure?</td>
</tr>
</tbody>
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<table>
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<tr>
<th>Colorado State Standards – 8th Grade</th>
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<tbody>
<tr>
<td>1. Physical Science</td>
<td>Concepts and skills students master:</td>
</tr>
<tr>
<td></td>
<td>1. Identify and calculate the direction and</td>
</tr>
<tr>
<td></td>
<td>Inquiry Questions:</td>
</tr>
</tbody>
</table>
The magnitude of forces that act on an object, and explain the results in the object's change of motion

1. What relationships exists among force, mass, speed, and acceleration?
2. What evidence indicates a force has acted on a system? Is it possible for a force to act on a system without having an effect?

Relevance & Application:

1. Engineers take forces into account when designing moving objects such as car tires, roller coasters, and rockets.
2. Vehicles and their propulsion systems are designed by analyzing the forces that act on the vehicle.

| Colorado State Standards – 7th Grade | N/A |
| Colorado State Standards – 6th Grade | N/A |
| Colorado State Standards – 5th Grade | N/A |
| Colorado State Standards – 4th Grade | 21st Century Skills |
| Colorado State Standards – 3rd Grade | 21st Century Skills |

<table>
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<th>Supply</th>
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<td><a href="http://www.midwestproducts.com/store/product/e0a83f56-9ef4-4c91-b7a7-9e3576d89375/Delta_Dart_Class_Pack_-_Supplies_35_students.aspx">http://www.midwestproducts.com/store/product/e0a83f56-9ef4-4c91-b7a7-9e3576d89375/Delta_Dart_Class_Pack_-_Supplies_35_students.aspx</a></td>
<td>$49.99 for 35 kits</td>
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</table>

Total | $1.48 per student |

* 3-4 staff recommended
Introduction

This manual begins with a class planning aid, relates a short history of aviation, answers the question "Why Do Planes Fly?" by explaining Bernoulli's Principle, examines the forces of lift, thrust, gravity, and drag, considers the problem of stability in flight, and deals with control surfaces. It also contains a wealth of curriculum enhancement activities that may be used to adapt the material to your particular instructional needs. Vocabulary and bibliography sections complete this teaching tool.
This manual presents a concept centered, activity based complement to the educator's particular curriculum. A nominal 5 class period schedule is suggested. This, of course, may be varied greatly depending upon the grade level and subject being taught. Draw from the curriculum enhancement activities, vocabulary, and suggested reading sections to further adapt the module to your unique curriculum needs.

1st Period  
Present an overview of the laboratory. Chart a timeline of aviation history.

2nd Period  
Lecture on the scientific principles involved in flight. Class discussion of how the same forces at work on a model affect the airliner the students fly in. Distribute just the instructions and plan. Suggest that the students look for structural components of their model's design that enhance lift, stability, and control.

3rd Period  
Distribution of building supplies and parts. Construction begins.

4th Period  
Completion of construction. Set aside models for adhesive to cure. Ask students for their estimates of their model's performance relative to duration of flight, altitude, distance, payload carrying ability, and flightpath.

5th Period  
Flight of models. Compare students' predictions of their performance with actual flight. Time aloft may be recorded to add a competitive atmosphere. Discuss and perform modifications to the models to affect performance. Sum up.
The pioneers of aviation experimented with models to understand what it took to achieve flight, just as we will with our models. What do you think are some advantages of the use of models over full sized prototypes?

Leonardo da Vinci

Late in the 1400's, Leonardo da Vinci drew the designs for a variety of flying machines, including the ornithopter and the helicopter. His work, however, was quite secret, and did not influence the development of these aircraft, as the drawings remained unpublished until late in the nineteenth century.

Da Vinci's notebooks contained some 150 sketches of flying machines which might have advanced the course of aviation history, had it been known.

Montgolfier Brothers

The first successful man-carrying free flight occurred over Paris in 1783. Carrying two Frenchmen, the Montgolfier's balloon traveled more than five miles across the city in some twenty-five minutes.

Soon after this flight, balloons and ballooning became a craze that spread throughout the civilized world. This excitement soon led to experiments with heavier-than-air flying machines.

Sir George Cayley, The Father of Aerial Navigation

In the early 1800's, Sir George Cayley of England discovered the principles which form the foundation for modern aeronautics. His work with model airplanes and full-scale airplanes replaced the flapping wings of the ornithopter with affixed wing glider. These aircraft introduced the forces of lift, thrust, and drag.

Cayley's model experiments uncovered the importance of control surfaces and stabilizers that are essential to today's aircrafts.

William Samuel Henson

In 1845, W. S. Henson published his design for a monoplane "Aerial Steam Carriage". Although the full-scale machine was never built, his designs and testing of models led to the eventual development of powered airplanes.
Felix DuTemple

In 1857, DuTemple patented his design for the first airplane device that rose into the air under its own power (hot air). The design had been tested successfully with a scale model. His design included a tractor propeller, swept-forward wing and tail, and retractable landing gear.

Alphonse Penaud

In 1870, Alphonse Penaud began experimenting with model airplanes powered by twisted rubber bands. His model "planophones" had raised wing tips and a negatively positioned tail plane. Some even incorporated a vertical rudder which added stability.

A few years later, Penaud proposed using a new method of instantaneous photography to record the actions of birds' wings in flight.

Entienne-Jules Marey

Late in the 1800's, Marey put Penaud's photography methods into practice. The resulting photographs allowed man to study the birds' motions of flight in great detail.

Later, Marey studied airflow by photographing the smoke displaced in a wind tunnel by different shapes. These studies eventually led to the development of airfoil designs to create better lift.

Otto Lilienthal

By 1891, Lilienthal had built and flown the first of several successful gliders. In 1896, Lilienthal flew the first hang glider himself, with movable wing tips that were powered by a small carbonic acid gas motor.

Lilienthal was the first person to study gliding flight scientifically, and is regarded as the "greatest pioneer" of the late 1800's. His successful manned flights inspired a great deal of future glider pilots, including Wilbur & Orville Wright.

Wilbur & Orville Wright

The Wright brothers began studying aviation in 1899. They built their first glider in 1900, and for several years, they conducted test flights at Kitty Hawk.

Throughout these test flights, the Wright brothers managed to control the pitch, the yaw and the roll of their gliders. They went on to make the world's first powered, sustained and controlled airplane flight in 1903.

By 1905, they had built and flown the first practical flying machine which could be banked, turned and circled with ease. This plane, the "Flyer III", could fly for over half an hour.
Why Do Airplanes Fly?

The same scientific principles apply to why a model airplane flies as they do to a full size airplane. The same forces are at work upon each, and they must be managed in order to achieve flight.

The Four Forces

- **Lift**: The energy of air on the top and bottom of the wing create LIFT which keeps the airplane UP.
- **Thrust**: The pulling power of the propeller and the strength of the motor creates THRUST which pulls the airplane FORWARD.
- **Gravity**: The mass of the airplane is acted upon by GRAVITY which pulls the plane DOWN toward the earth's surface.
- **Drag**: The displacement of the air by the plane itself, and the friction of the plane's surfaces against the air create DRAG which holds the airplanes BACK.

It is relatively easy to see how most of these forces work. For example, the more streamlined the airplane is, the less DRAG we have. The lighter the mass of the airplane, the less effect GRAVITY will have.

We can see how the engine and propeller must overcome the force of DRAG. But, how can the force of LIFT overcome the force of GRAVITY?

**Bernoulli's Principle** - states that the air pressure will decrease as the speed of the air increases.

When the wings of an airplane are pulled through the air (by the motor and propeller) they create LIFT. This "LIFT" is actually a "bulge" in the flow of air, which occurs when the air travels more rapidly over the top of the wing, creating a low pressure area. A high pressure area is created below the wing.

The shape of the wing is called an airfoil. There are many different airfoils that create LIFT. The shape of the airfoil will also affect the DRAG.
So far, we have learned the basics of how to keep an aircraft UP in the air, and moving FORWARD. Next, we must consider how to control the aircraft so that it is STABLE in its forward flight, and capable of making controlled banks, turns, and circles. The control surfaces of an aircraft allow this type of controlled movement.

### Stability

VERTICAL & HORIZONTAL CONTROL SURFACES are important to the stability of the aircraft. These surfaces at the tail of the aircraft act like feathers on an arrow to keep the nose pointed in the direction of travel, and to keep the wings at the correct angle of attack.

Both the rudder and the stabilizer on an aircraft help to increase the stability.

Another factor that increases the stability of an airplane is the dihedral of the wings. Dihedral is the angle at which the wings are inclined upwards when the airplane is viewed head on.

A horizontal line (dashed line) is included in these illustrations to help to see the dihedral angle of these three variations.

### Center of Gravity

The center of gravity, or CG, is the point where the yaw, pitch, and roll axis intersect. (See next page.) On most airplanes, the CG is slightly forward to achieve the most stability in normal, level flight, after a proper launch.

If the CG is too far to the rear, the airplane will stall in flight.

To correct this, add mass to the nose.

If the CG is too far forward, the airplane will dive.

To correct this, add mass to the tail.
Controlled Movements

Because airplanes are often in a position where "up" and "down" are meaningless words, there are three special terms used to describe an airplane's movements - *yaw*, *pitch*, and *roll*.

**Yaw** . . . movements to the left or right.
**Pitch** . . . movements up or down.
**Roll** . . . . bank (to the) left or right.

The illustration shows the axis on which each of these movements is made.

It is important that the airplane has the proper center of gravity (straight and level flight has been achieved), before any of these movements are tried.

The rudder is made up of two parts. One part, the *vertical stabilizer or fin* is *NOT* movable. The other part of the rudder CAN be pivoted left or right to move the nose of the airplane left or right along the *yaw* axis.

Move rudder to the right - - - tail moves to left and nose moves to right.
Move rudder to the left - - - tail moves to right and nose moves to left.

The elevator is the movable surface on the *horizontal stabilizer*. The elevator can be pivoted up or down to move the nose of the airplane up or down along the *pitch* axis.

Move elevator up - - - tail moves down and nose moves up.
Move elevator down - - - tail moves up and nose moves down.

The *ailerons* are the movable surface on the *wing* of an airplane. It can be pivoted to control the up or down to control the *bank* of the airplane along the roll axis.

The two ailerons (left and right) will work together, moving in opposite directions to achieve banks or rolls.

Move Left Aileron Up or Right Aileron Down - - - Counter-clockwise bank or roll
Move Right Aileron Up or Left Aileron Down - - - Clockwise bank or roll
Curriculum Enhancement Activities

Early Elementary
* How many different kinds of airplanes do you know of?
* Tell the class about a vacation your family took on an airplane.
* In what ways does an airplane resemble a bird?
  Decorate your model airplane. Use felt tip marker pens, streamers, stickers, and your imagination.
* Make a mobile using several of the models.
  Arrange a field trip to the nearest airport.

Economics
* Suppose a new major commercial airport was to be built in a community. What economic impacts would there be?
* What if no airfreight were available? Consider the impacts on inventories, consumer prices, product diversity, and agribusiness.
* What would be the economic benefits of the proposed National Aerospace Plane?
* Has the Concorde been an economic success for Britain and France?
* Discuss the affects of airline "deregulation".
  Evaluate the prospects for air defense contractors to convert "swords into plowshares" in a post cold war era.

Geometry
* Measure the angle of dihedral in the wing of your model.
* What geometric shapes are there in the structure of your model? Are there particular attributes of some of these shapes that lend themselves to such design application?
* What is the total area of the lifting surfaces of your model?

Mathematics
* Calculate the average distance traveled and the average time aloft over a series of several flights of your model.
* Fly your model in an approximately straight line flightpath. By timing the flight and measuring the distance flown, you will have the data to compute the model's air speed. Do so in terms of miles per hour, kilometers per hour, and in knots.
* Calculate the aspect ratio of your model's wing.
Science

Contrast and compare the impact of the forces of lift, thrust, gravity, and drag upon an airplane and a rocket. With what techniques have these forces been managed in each vehicle’s design? Consider the combination of forces and their management in the design of a space plane which would take off and land horizontally from a conventional airport, yet travel in outer space.

Students have contributed ideas for experiments which have been conducted by astronauts in space. Discover what some of these experiments have shown.

Construct a series of 4 model aircraft of your own design. One is to maximize lift, one is to minimize lift, another is to maximize thrust, and one is to minimize drag, perhaps sacrificing performance relative to the management of the other 3 forces in each design. Evaluate their performance relative to distance traveled and time aloft.

The Balsa wood in your model was harvested from a rain forest in Ecuador. Describe the growth cycle of the Balsa tree. Why is Balsa wood so low in density? Report of “slash and burn” agriculture and its ecological impacts. Is Balsa harvesting a particularly harmful or a relatively benign activity?

Technology Education

Modify your plane to take off and/or land on water.

Design and construct a model aircraft which will transport a payload of 5 grams a distance of 20 meters.

Modify your model to maximize landing precision. Adjust the thrust and flightpath to land within a circle 1 meter in diameter whose center is 15 meters from the start of the model’s flight.

Construct a wind tunnel.

If your model was a hand launched glider, convert it to a propeller powered model, or vise versa. You will need to adjust the center of gravity accordingly to maintain proper flight characteristics.

Mass produce your model. Set up an efficient production line for its assembly, with an emphasis on quality control.

Add one half of one layer of toilet tissue to trailing edge of rudder, this additional area demonstrates the added effects of drag.

Vocabulary

Aerodynamics The study of the forces acting upon an object in motion through an atmosphere.

Aileron A movable hinged section on the trailing edge of an airplane’s wing used to control rolling movement.

Airfoil The cross-section shape of a wing taken at right angles to the wing span.

Airship A self-propelled, lighter-than-air craft which can be steered.

Airspeed The speed of an aircraft relative to the air rather than to the ground.

Altimeter A device for measuring the relative altitude of an aircraft by measuring atmospheric pressure.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle of Attack</td>
<td>The angle at which a wing strikes the air stream.</td>
</tr>
<tr>
<td>Angle of Incidence</td>
<td>The angle of the wing in relation to an arbitrary line fore and aft in the fuselage.</td>
</tr>
<tr>
<td>Aspect Ratio</td>
<td>The relationship of the wing span to the wing chord, expressed numerically by the number of times the span can be divided by the chord.</td>
</tr>
<tr>
<td>Autogiro</td>
<td>An airplane which flies by virtue of freewheeling rotating wings set windmill fashion above the fuselage.</td>
</tr>
<tr>
<td>Bank</td>
<td>A turn made in flight with one wing tip lower than the other.</td>
</tr>
<tr>
<td>Camber</td>
<td>The curvature of the wing from the leading edge to the trailing edge.</td>
</tr>
<tr>
<td>Canard</td>
<td>An airplane designed to fly tail first.</td>
</tr>
<tr>
<td>Center of Gravity</td>
<td>The point through which the resultant forces of gravity act no matter how the body is oriented.</td>
</tr>
<tr>
<td>Center of Lift</td>
<td>The point at which the average of all lifting forces act.</td>
</tr>
<tr>
<td>Center of Pressure</td>
<td>The intersection of the resultant force with the plane of the chord of the lower surface. This center varies with the angle of incidence in a characteristic manner for every wing shape. The center is located for a given angle of incidence by giving its distance from the leading edge in percent of the chord length.</td>
</tr>
<tr>
<td>Chord</td>
<td>The width of a wing from leading edge to trailing edge.</td>
</tr>
<tr>
<td>Decalage</td>
<td>The difference between the angles of incidence of the wing and the stabilizer.</td>
</tr>
<tr>
<td>Dihedral</td>
<td>The upilt of wing panels toward the tips to increase stability in the roll axis.</td>
</tr>
<tr>
<td>Elevator</td>
<td>The hinged control section of the stabilizer used to induce a change in pitch.</td>
</tr>
<tr>
<td>Fin</td>
<td>The fixed forward portion of the vertical tail.</td>
</tr>
<tr>
<td>Fixture</td>
<td>A form for holding parts together for assembly.</td>
</tr>
<tr>
<td>Fuselage</td>
<td>The body of an airplane.</td>
</tr>
<tr>
<td>Glide</td>
<td>Sustained forward flight in which speed is maintained only by the loss of altitude.</td>
</tr>
<tr>
<td>Ground Speed</td>
<td>The speed of an aircraft relative to ground.</td>
</tr>
<tr>
<td>Induced Drag</td>
<td>The resistance of a wing to forward movement due to disturbance of the surrounding air and related to the lift produced by the wing.</td>
</tr>
<tr>
<td>Mass</td>
<td>The quantity of matter in a body.</td>
</tr>
<tr>
<td>Moment Arm</td>
<td>The distance from the center of gravity at which a force is applied.</td>
</tr>
<tr>
<td>Motor Stick</td>
<td>A strong wooden strip, often serving as a fuselage, used to support the rubber motor of a model airplane.</td>
</tr>
</tbody>
</table>
Ornithopter  An airplane that flies by flapping its wings in a bird-like fashion.

Parasitic Drag  Resistance to forward movement caused by non-lifting components of an airplane.

Parasol  An airplane with its wings mounted above the fuselage by struts or a pylon.

Pitch-Diameter-Ratio  The relationship between the propeller pitch and diameter, expressed as a mathematical proportion.

Propeller Pitch  The distance theoretically travelled by a propeller in one revolution.

Propeller Torque  The reactive force generated by a revolving propeller that tends to rotate an airplane in the direction counter to the direction or the propeller’s rotation.

Rudder  The moving part of an airplane’s vertical tail used to control movement on the yaw axis.

Spin  A prolonged stall in which an airplane rotates about its center of gravity while it descends.

Stability  The tendency of an airplane to return to level flight after having been disturbed by some force.

Stall  The complete loss of lift resulting from too steep an angle of attack.

Thermal  A rising column of relatively warm air.

Tip Loss  The reduction of lift near the tips of wings due to the leakage of high pressure air from beneath to the low pressure area above.

Undercamber  The concave curve on the underside of some airfoils.

Wing Loading  Ratio of lifting efficiency; weight of airplane \( \div \) area of the wings.

Suggested Readings
