WRIGHTSTUFF-AIRCRAFT

<u>For grade Level(s)</u>

Middle School grades 6-8
High School grades 9/10 and 11/12

<u>Suggested Time</u>

MESA period: 3-5 weeks of daily 50 min. sessions
MESA afterschool: 4 total sessions of 60-90 min periods
MESA Saturday: 2 Saturdays for a total of 8 hours

<u>Purpose</u>

The purpose of this unit is to reinforce or introduce the engineering design process to MESA students, while introducing them to the principle of flight and aircraft design. Students will be prepared to build and fly a model aircraft that will sustain a long flight time in MESA Day competition.

<u>Objectives</u>

At the end of the unit students will;

- Know the parts of the design cycle and relate them to aircraft design and construction
- Critically analyze the design and construction in relation to the flight mission
- Solve problems related to flight, lift and drag
- Solve problems related to balance and torque
- Solve problems related to angles
- Understand the practical applications of the design process for students and engineers.

<u>Standards Addressed</u>

<u>Common Core and NGSS</u> **<u>Common Core Mathematics</u>**

Ratios and Proportional Relationships 6. RP
3. Use ratio and rate reasoning to solve real-world and mathematical problems, e.g. by reasoning about tables of equivalent ratios, tape diagrams, or equations.
3c.Find a percent of a quantity as a rate per 100 (e.g., 30% of a quantity means 30/100 times the quantity); solve problems involving finding the whole given a part and the percentage .

Grade 6

Expressions and Equations 6. EE
6. Use variables to represent numbers and write expressions and when solving real-world or mathematical problems;

understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set.

Grade 6
Geometry 6.G
Solve real-world and mathematical problems involving area, surface area, and volume.

Grade 7
Ratios and Proportional Relationship 7. Rp
Analyze proportional relationships and use them to solve real-world and mathematical problems.

Expressions and Equations 7.EE
2. Understand that rewriting an expression in different forms in a problem context can shed light on the problem and how the quantities are related. For example, a + 0.05a = 1.05a means that “increase of 5%” is the same as “multiply by 1.05”

4. Use variables to represent quantities in a real-world or mathematical problem. And construct simple equations and inequalities solve problems by reasoning about the quantities

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Geometry 7.G
1. Solve problems involving scale drawing of geometric figures, including computing actual lengths and areas from a scale drawing at a different scale.

6. Solve real-world and mathematical problems involving area.
Volume, surface are of two and three-dimensional objects composed of triangles, quadrilateral, polygons, cubes, and right prism.

Grade 8
Expressions and Equations 8.EE

1. Know and apply the properties of integer exponents to generate equivalent numerical expressions. For example; $3^{(2\ -5)} = 3^{-3} = 1/3^3 = 1/27$.

Statistics and probability 8. SP
Investigate patterns of association in bivariate data

1. Construct and interpret scatter plots for bivariate measurement data to investigate patterns of association between two quantities. Describe patterns such as clustering outlies, positive or negative associations, linear or non-linear associations.
2. Know that straight lines are widely used to model relationships between two quantitative variables. For scatter plots that suggest a linear relationship, informally fit a straight line, and points to the straight ling

Higher Common Core Mathematics
Algebra 1- A1
Quantities N- Q
Reason quantitatively and use units to solve problems.

1- Use units as a way to understand problems and t guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

Seeing Structure in Expressions in A-SSE
Write expressions in equivalent forms to solve problems.
3-Choose and produce an equivalent form of an expression t reveal and explain properties of the quantity represented by the expression.

Statistics and Probability
Interpreting Categorical and Quantitative Data S-ID
1-Represent data with plots on the real number line (dot plots, histograms, and box plots.)

Make geometric constructions. G-CO
12-Make geometric constructions using a variety of tools and methods (compass, and straight edge, sting,

reflective device, paper folding, dynamic geometric software, etc.).

Geometric Measurement and Dimension G-GMD
4-Identify the shapes of two-dimensional cross-sections of three dimensional objects, and identify three-dimensional objects by rotations of two-dimensional objects.

Modeling with Geometry G-MG
3-Apply geometric methods to solve design problems (e.g. designing an object or structure to satisfy physical constraints or minimize cost, working with typographical grid systems based on ratios.)

Next Generation Science Standards
Physical Science PS

MS-PS2-2- Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and on the mass of the object. [Clarification Statement: Emphasis is and on balanced (Newton's first law) and unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton's second law) frame of reference and specification of units.

HS-PS2-1-Analyze data to support the claim that newton's second law of motion describes the mathematical relations among the net force on a macroscopic object, its mass, and its acceleration. Analyzing data using tools, technologies, and/ or models to make valid and reliable scientific claims or determine an optimal design solution.

Engineering Design

MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit potential solutions.

MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well the meet the criteria and constrains of the problem.

MS-ETS-3 Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

HS-ETS1-2 Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

Assessment

Students will be evaluated through the following methods;

- Assessment work sheets
- Oral presentations with rubrics
- Lab reports with rubrics
- Project testing and evaluation

Additional Resources

www.physicsclassroom.com
www.grc.nasa.gov/WWW/k-12/airplane/short.html
www.modelaircraft.org/education/edpacket.aspx

Background

The first evidence of man wanting to fly was a coin from about 3500 BC depicting a man flying on an eagle's back. About 1000 BC, the Chinese invented kites which carried men to scout troops. The first step to modern aeronautical engineering was Leonardo da Vinci's designs about 1500. In 1799 Sir George Cayley invented the concept of fixed wing aircraft and followed that by building and flying a successful model glider. In 1903 the Wright brothers flew the first heavier than air, manned, engine powered airplane. Since then aircraft development, design and manufacturing has progressed rapidly. Long distance travel is now dominated by commercial aircraft. There are still problems to be solved-fuel economy, safety, passenger comfort, crew fatigue, take-off and landing reliability, manufacturing costs and plane longevity. For example, the addition of winglets on the wing tips significantly reduced drag and , therefore, saved much fuel.

Benefit to Society

Aircraft is now the major form of long distance travel. It is used for people, cargo, scientific experiments, hurricane watching, hospital, news watch, mail, firefighting, traffic watching, and the military. The next generation (there's always a new innovation that advances the aircraft status) is the use of pilotless aircraft. With that change came the need for safety assurances, new flying space regulations, privacy protection and less pollution. Today's commercial aircraft, i.e. Boeing and Airbus, are less reliant on pilots during long flights and are more fuel efficient. The passengers generally are more comfortable and the fatality rate is low. There trips are quick, clean, relatively inexpensive, allowing more time at the flight terminus. A trip from LA to NY takes about 5-8 hours while a train requires 3+ days.

Engineering Design Process/ Module Content

Engineers have to create solutions to a problem. The solution must fit into the given constraints the problem. In the MESA program, we learn to engineer solutions that can relate to real work problems. The use of the engineering design process contextualizes this problem solving approach for students.

This unit is organized around the steps in the engineering cycle. Define the problem, investigate, plan, create, evaluate and then start the process all over again until a valid competition ready project is created. The unit begins with an introductory activity that leads to students into the challenge to be addressed.

Organization of the Module Content

Introduction

- Build a foam plate glider (FPG-9) as an ice breaker.
  (www.modelaircraft.org/education/fpg-9aspx)

Define the Problem

- Read the specification closely to define the requirements including constraints to be met when your product, process, or system is designed. For example; wingspan limit? , propeller size? , material? And etc.

Investigate

- Research glider/ propeller model aircraft on the web or other sources.

The NASA web site contains much of the aircraft science and math that is applicable to this program. (http://www.grc.nasa.gov/WWW/k-12/airplane/short.html) This site is a clickable index. Pick your subject and a click shows the Power Point and description. (NASA Aerodynamics Index is attached)

- Review the reverent mathematics and science with students (the complexity and depth science background and is at the instructor's discretion).
  - Newton's three laws of motion, torque, forces and torque, and equilibrium.
  - Area, volume, acceleration, ratios, and geometry
  - Identify how aircraft is constructed and what are the key parts and how does an aircraft fly? Thrust, lift, drag etc.
- Introduce MESA students to the engineering design cycle.
- There are many online resources to do this including, the teach engineering resource (http//www/teachengineering.org/engrdesignprocess.php) and the science buddies website (http//www.sciencebuddies.org/engineering-design-process/engineering-design-process-steps-shtml). And the NASA web site (http//www.nasa.gov/audience/foreducators/plantgrowth/reference/Eng Design 5-12.html)
- Have the students create their own design notebooks. MESA students will use the journal to document the information gathering process they engaged in and any relevant information that will prepare them for designing and building their competition ready package. The logbook can also follow throughout the different stages of the project. Regular entries into notebook/journal are an essential part pf this unit/project.
  (http//www.sciencebuddies.org/blog/2010/01/labnotebooks.php).

Planning and Brainstorming

At this point the students should get experience building a small glider (~7 inch wingspan). A huge variety of plans can be found by "googling" "*plans for balsawood gliders".* The airplane building students can also search "*rubber powered flying model airplanes".* A few examples include;
http://www.amaflightschool.org/diy
http://www.4p8.com/eric.brasseur/glider2.html
http://www.theplanpage.com/months/2406/recordhlg.html
http://www.rubber-power.com/make-it.htm

After building and testing their small models, the team brainstorms the possible designs for the competition glider/airplane. They pick the best two or three ideas, and Design and build their Prototypes. Design means they draw the construction plans.

Prototype and Testing

After designing the prototype(s) must be built and tested. Good detailed records must be kept so the same mistakes are not continually repeated. Testing conditions need to be changed (wing locations, wing design, dihedral angles, aspect ratio, center of gravity, trim and etc.) Several tries at each condition are needed since one test is not adequate for data reliability. Not only is the design and construction important but the launch technique also needs to be developed and tested.

Analysis

After the prototype testing, the results are analyzed and the group selects the best potential design for their competition model. Using data tables from the notebook with all the information such as wing span, location of center of gravity, glider weight, angle of launch, and flying time and plotting the key information on graphs will enable clear visuals on how the glider/plane performed. Then modify the design to correct the defects that prevent them from their reaching their goal. The engineering cycle is now repeated until the glider/plane achieves the flying time goal repeatedly and consistently. The designs and construction must be regularly checked against the MESA specifications so the product doesn't drift into reject range.
http//:www.mesa.ucop.edu/mesa_day_rules.html.

Compete

If the final model meets the teams goals and the MESA specifications and does so repeatedly then it is ready for competition. If a drawing is required make sure it is complete in every detail.

Pacing Guide

Although Advisors can structure their lessons as they see fit, below is the suggested pacing guide for this module.

ACTIVITY	APPROXIMATE TIME
Introduction	
Foam Plate Glider (FPG-9) Discuss how to control the glider and answer the work sheet in the packet.	1-2 class periods
Define the problem	
Read the MESA rules and discuss what are the goals and the constrictions. Summarize in the journal.	1 class period
Investigation	
Research gliders or rubber powered model airplanes on line. After the students identify potential plans have them build a small (~7 inch wingspan) glider to get a feel for working with balsa and flying. Followup with the physics and math of flying, designing, and building the aircraft. Investigation reflection in log. The students answer quizzes available in the NASA lessons.	5-8 45 min. class periods
Planning and Brainstorming	
Overview of the Engineering Cycle and math. Students brainstorm ideas (in logs) and select	3-4 class periods

most probable routes to aircraft meeting specs.
Draw preliminary design selections.

Prototypes

The first prototype(s) are built and tested. Several variables need to be evaluated such as aspect ratio, weight, launch conditions, and etc. Repeat tests to establish data reliability. Enter data directly into logs. — 3-5 periods

Analysis

Analyze the prototype results and select the competition design, build and fly it repeatedly and make the final trim adjustments until it is competition ready. — 3-5 periods.

Compete. ***GOOD LUCK!***

WRIGHTSTUFF-AIRCRAFT

Aerodynamics Index

Glenn Research Center

Here is a list of all the topics available from the Beginner's Guide to Aerodynamics (BGA) site. Clicking on the title will deliver a page with a slide and a scientific explanation of the contents. Click on the word "Animated" for the animated version of selected pages. If the number and variety of pages seems too intimidating, consider taking one of our Guided Tours through the web site.

Another method for reaching students, teachers and lifelong learners is the use of **Distance Learning**. While preparing presentations for students, many Power Point files have been developed for the Digital Learning Network using information from the BGA. Another group of Power Point presentations has been prepared concerning the exploration of space. Students and teachers are encouraged to copy the Power Point files to their own computers and to modify them as desired for their own presentations. We have also created a home page for all of our movies featuring Wilbur and Orville Wright.

* Animation files can be large (average 350K bytes)
** Java Applet

STUDENT ACTIVITIES

NASA Glenn History and Missions
Activities
FoilSim Activities
Basic Aerodynamics Activities
Aerospace Lesson Plans
Cross-Word Puzzle Activity
Airplane Gallery

SCIENCE FUNDAMENTALS

Three Phases of Matter
Newton's Laws of Motion ..Movie
Newton's First Law - Inertia
Newton's Second Law - Force
Newton's Third Law - Action & Reaction
Torques (Moments)
Forces and Torques
Equilibrium - 2 Forces
Equilibrium - 3 Forces
Equilibrium - 2 Torques

MATH FUNDAMENTALS

Functions
Rectangular and Polar Coordinates
Area
Volume
Displacement, Velocity, Acceleration
Angular Displacement, Velocity, Acceleration
Scalars and Vectors
Comparing Two Scalars - Ratio

AIRPLANE PARTS

Airplane Parts Definitions
Fuselage
Turbine Engines
Wing Geometry Definitions ..Interactive**
Winglets
Elevator..Movie..Interactive**
Aileron..Movie..Interactive**
Rudder..Movie..Interactive**
Spoilers ..Interactive**
Flaps and Slats ..Interactive**
Stabilator ..Interactive**
Pitot-Static Tube - Speedometer

AIRCRAFT FORCES

Four Forces on an Airplane ..Movie
What is Weight? ..Movie
What is Lift? ..Movie
What is Drag? ..Movie
What is Thrust? ..Movie
Lift to Drag Ratio
Thrust to Weight Ratio
Excess Thrust (Thrust - Drag)
Forces in a Climb
Vectored Thrust
Airplane Cruise - Balanced Forces
Trimmed Aircraft
Momentum Effects
Density Effects ..Interactive**
Velocity Effects ..Interactive**

AERODYNAMICS

Aerodynamic Forces

WRIGHTSTUFF-AIRCRAFT

Comparing Two Vectors
Vector Addition
Vector Components
Trigonometry
Sine-Cosine-Tangent
Ratios in Triangles
Pythagorean Theorem..Interactive**

ANALYSIS

Conservation of Mass
Conservation of Momentum
Conservation of Energy
Euler Equations
Bernoulli's Equation
Navier-Stokes Equations
Lift of Rotating Cylinder ..Interactive**
Ideal Lift on Spinning Ball ..Interactive**
Ideal Flow Around Spinning Ball ..Interactive**
Conformal Mapping... Interactive **

STATIC GASES

Animated Gas Lab...Animated
Gas Properties Definitions
Equation of State (Ideal Gas)
Specific Heats - cp and cv
Boyle's Law...Animated
Charles and Gay-Lussac's Law...Animated
Specific Volume
Kinetic Theory of Gases

THE ATMOSPHERE

Interactive Atmosphere Simulator
The Atmosphere
Air Properties Definitions
Air Pressure
Air Temperature
Air Density
Air Viscosity ..Interactive**
Earth Model - Imperial Units
Earth Model - Metric Units
Mars Model - Imperial Units
Mars Model - Metric Units
Relative Velocity - Ground Reference .. Interactive**
Relative Velocity - Aircraft Reference
Cross Winds
Updrafts and Downdrafts
Lightning Strike

SPEED REGIMES

SoundWave Interactive Simulator

Dynamic Pressure
Center of Pressure - cp
Aerodynamic Center
Similarity Parameters ..Interactive**
Reynolds Number..Interactive**
Boundary Layer
Mass Flow Rate
Definition of Streamlines

THRUST

Beginner's Guide to Propulsion
EngineSim Interactive Simulator
Thrust Equation

WEIGHT

Determining Aircraft Weight
Center of Gravity - cg ..Movie
Aircraft Center of Gravity - cg
Weight Equation ..Movie

LIFT

FoilSim III Interactive Simulator
Bernoulli and Newton
Objects with Lift ..Interactive**
Lift from Flow Turning ..Interactive**
Shed Vorticity
Equal Transit Theory ..Interactive**
Skipping Stone Theory ..Interactive**
Half Venturi Theory ..Interactive**
Factors That Affect Lift
Shape Effects on Lift ..Interactive**
Size Effects on Lift ..Interactive**
Inclination Effects on Lift ..Interactive**
Downwash Effects on Lift
Lift Equation..Movie
Lift Coefficient

DRAG

Factors That Affect Drag
Shape Effects on Drag
Drag on a Sphere...Animated
Size Effects on Drag
Inclination Effects on Drag
Drag Measurement
Induced Drag Coefficient
Drag Equation..Movie
Drag Coefficient

GLIDERS

Gliders
Paper Airplanes..Plans

WRIGHTSTUFF-AIRCRAFT

Compressible Aerodynamics
Mach Number..Interactive**
Speed of Sound ..Interactive**
Subsonic
Transonic
Supersonic
High Supersonic
Hypersonic
Re-Entry
Mach Calculator

OBJECT MOTION

DropSim Interactive Simulator
Basic Object Motion
Object Motion Due to a Side Force
Ballistic Flight..Interactive**
Falling Objects - Newton's First Law
Motion of Free Falling Object
Free Fall without Air Resistance
Falling Object with Air Resistance
Terminal Velocity..Interactive**
Flight with Drag..Interactive**
Ballisitic Flight Calculator

AIRCRAFT MOTION

RangeGames Interactive Simulator
Simplified Aircraft Motion
Aircraft Motion - Newton's First Law
Aircraft Motion - Newton's Second Law
Aircraft Translations
Aircraft Rotations
Roll..Movie..Animated
Pitch..Movie..Animated
Yaw..Movie..Animated
Banking Turns
Range - Constant Velocity
Maximum Flight Time
Range Summary

Fun with Gliders
Space Shuttle as a Glider
Three Forces on a Glider
Glide Angle
Vector Balance of Forces - Glider
Glider Trajectory Problem

MODEL ROCKETS

Beginner's Guide to Model Rockets
RocketModeler Interactive Simulator

KITES

Beginner's Guide to Kites
KiteModeler Interactive Simulator

WIND TUNNELS

Beginner's Guide to Wind Tunnels
TunnelSim Interactive Simulator

SPORTS

Baseball Home Page
HitModeler Interactive Simulator
HitModeler Weather Interactive Simulator
CurveBall Student Interactive Simulator
CurveBall Expert Interactive Simulator
Soccer Home Page
SoccerNASA Interactive Simulator

MISCELLANEOUS

Wright Brothers Aircraft
Let's be Specific
Venus Airfoil