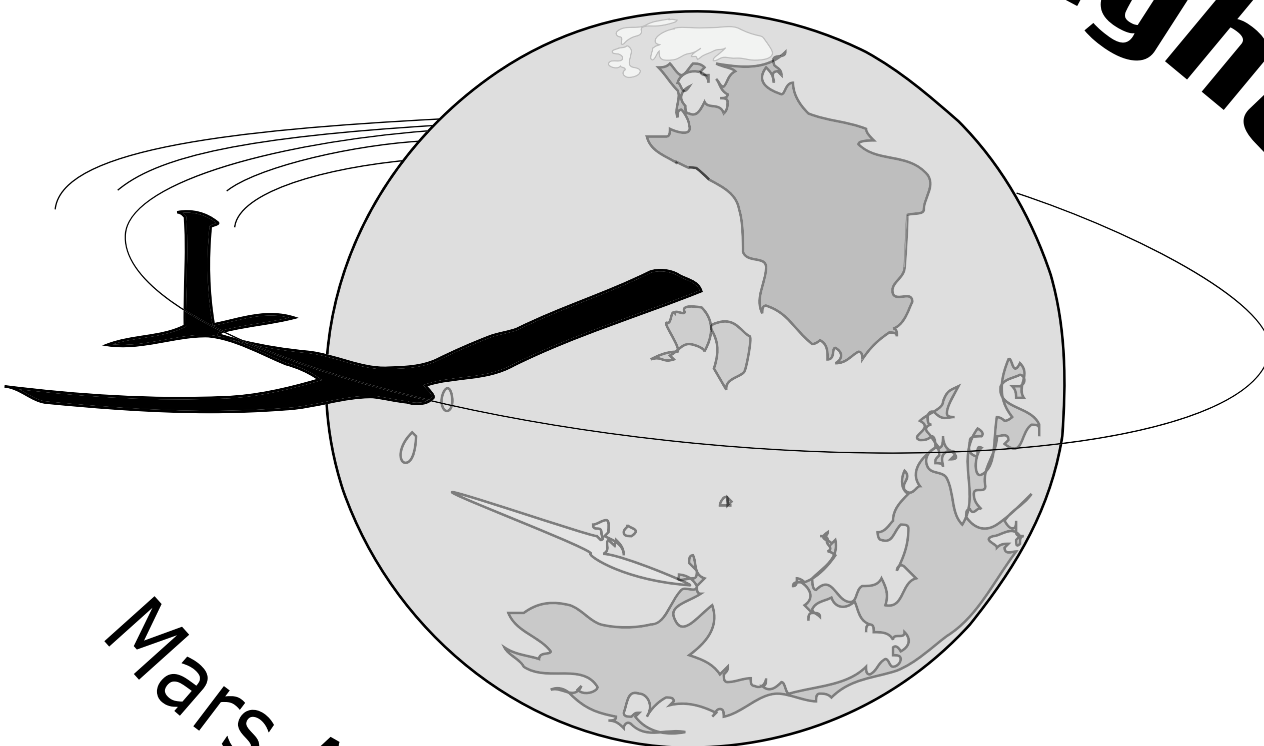
Planetary Flight



Mars Airplane Design

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Planetary Flight

Mars Airplane Design

Teacher's Edition

A Problem-based Learning Approach

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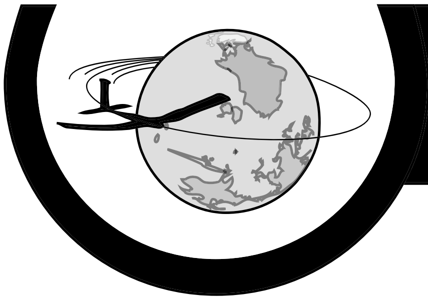

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PDF Files

Using This Web Site

This web site is structured so that the informal learner as well as a formal student in grades 5 through 12 can enjoy the concepts, skills and processes involved in designing an airplane to fly on Mars. The user is given the design specifications for a Mars airplane that will fly through the atmosphere of Mars collecting scientific data about the planet's geology, atmosphere, hydrology and geography. The user gathers the pertinent information needed to design such an airplane from the web site: text materials, animations, graphics, web chats (live and archived), on-line Q & A and links to other sites. The user designs an airplane by choosing from a series of parts: fuselage, tail section, propulsion system, wings. The program then assembles these parts into a Mars airplane, and provides the learner with an evaluation of the design's flight characteristics. There is not <u>one</u> best design, but there are some designs that will be better suited than others to not only successfully fly, but also be able to perform the scientific tests required. Regardless of the depth to which the user decides to delve into the information found on this web site, much can be learned about aeronautics as well as the planet Mars.

Teachers can make use of this web site in different ways. It can be used as:

- an independent study project with a small group of students or an individual student
- a whole class project with the class divided into specialty teams which research one aspect of the design specifications
- a whole class project with student teams competing to win the contract for the proposal

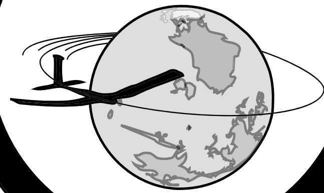
It can be used by one's students in the minimalist of ways: students simply survey the site, examining only what interests them, moving on to the interactive segment where they can select from a variety of aircraft parts to assemble a Mars airplane.

To maximize the potential for this web site, teachers are encouraged to use the Problem-based Learning (PBL) approach found within the instructional print materials. All the information needed by the students to solve the problem: answers to the essential questions, aeronautical science, atmospheric implications on flight, aeronautical design concepts, to name a few, are found on the web site.

The print material is structured so that it provides the teacher with the following:

- an overview of the airplane design problem
- a "step-by-step" guide to implementing this on-line project in the classroom
- all student handouts
- assessment features
- instructional activities
- additional resources

The Team at NASA Quest hope you, the classroom teacher, find this web site and its Problem-based Learning (PBL) instructional component to be a valuable asset to your classroom instruction.



Problem-based Learning in Brief

Problem-based Learning (PBL) is an instructional methodology that uses a carefully designed, open-ended problem to prompt students into a "real world" type investigation. Through immersion into such a problem, students experience the following:

- learn to research and collect information
- hone their critical thinking processes
- develop their collaborative skills
- advance their skills in the problem solving process
- improve their communication skills
- familiarize themselves with the technological design process

This problem, "Designing a Mars Airplane", is designed so that students will meet learning objectives while covering science content. The material correlates to the National Standards for Science, Technology, Mathematics and Reading/Language Arts (A delineation of these is found in the Appendices of the print material, "Correlation to the National Standards".). As students grapple with the problem: the critical knowledge questions that need to be answered, the aeronautical science knowledge that needs to be understood and applied, the atmospheric conditions which affect flight, and aeronautical design concepts; they work toward becoming better prepared to work in a rapidly changing global marketplace.

The Scenario and the Problem

In order to gather more and greater amounts of information about Mars, its geology, geography, possible hydrology, and atmosphere, scientists wish to fly an autonomous aircraft with a scientific instrument payload above the surface of Mars for as long as aerodynamically possible. This aircraft must fit into the spacecraft which will carry to Mars. Its own cargo space will only be allowed to hold 5 kg of scientific instrumentation which will gather the scientific data on Mars' atmosphere, geology, and geography.

> *Note: Although in actuality, for such an aircraft to fit into its designated container for stowage during space flight, its wings must be folded in its packaging. Upon deployment within Mars' upper atmosphere, its wings would then be required to unfold. It must also be able to withstand supersonic flight speed as it prepares for level flight while falling through Mars' atmosphere. This however will not be the crux of this problem. The main problem on which to concentrate will be that of how flight can be achieved in an atmosphere such as Mars.*

It is imperative that this aircraft be capable of flight within the atmosphere of Mars. Such flight is different from the atmospheric flight conditions that prevail here on Earth. The many differences between the two atmospheres will have major impacts on flight characteristics of any standard Earth-bound aircraft if it attempts a flight on Mars.

Before students can successfully engage in the complex concepts involved in such a flight they must have a solid understanding of the basic principles of atmospheric flight. The readings and Web references provided at this site are intended to offer students the information needed to solve the design problem. If additional basic aeronautical information is needed as a review, then it is recommended that your students be engaged with the educational CD-ROM ***Exploring Aeronautics*** available through NASA CORE at 216-774-1051 or fax 216-774-2144.

(Anticipated) Student Outcomes

These are the skills, concepts and processes that are intended to spring out of this Problem-based Learning experience. We have identified only the science concepts for the anticipated learning outcomes. The assessment section will assist you in identifying the processes that the students will utilize during the exploration.

Students will:

Understand the following aeronautical principles:

- Four forces: weight, lift, thrust, drag
- Reynold's number
- Airflow
- Density of air
- Speed of airflow
- Chord of the aircraft's wing
- Attached and separated flow
- Aspect ratio and lift
- Wing design: straight, swept
- Effects of control surfaces on flight
- What the tail section provides for flight

Understand the following atmospheric principles:

- Density of the atmosphere at various altitudes
- Atmospheric pressure at various altitudes
- Gravitational pull
- Atmospheric composition and its effects on propulsion systems

Learn how to compute and analyze aeronautical data such as:

- Reynold's number
- Lift/Drag ratios
- Coefficient of Lift

Compare the atmospheric differences of Earth and Mars

Compare the aeronautical differences of flight on Mars and Earth

Understand and use the technology design process

PBL and Mars Airplane Overview

The Problem-Based Learning process for this Mars Airplane Design will follow the steps delineated below. Use the guidesheets found in the Portable Document File (PDF) *Student Handouts, Instructional Activities* and *Student Assessments* to assist in this PBL process.

1. Introduce the problem to your students (Student Handout #1: Call for Proposals).

2. Define the situation and the roles the students are to play.

3. Have the students (individually, small groups, whole class) define the problem statement in their own words and phrase it as a question. (Student Handout #3: Defining the Problem)

4. Based upon their experience and prior knowledge, have the students (individually, small groups, whole class) list what knowledge they already have that would help them solve the problem. (Student Handout #4: Processing Through the Problem)

5. Next, have the students list in the form of a question what knowledge they need to acquire in order to solve this problem. This list becomes what is known as the "Essential Questions" that must be answered in order to be successful in this design process. *Note: A list of anticipated essential questions is provided for the teacher to use as a quick reference and potential guidance for the teacher to use with the students.*

6. For each essential question given, the students need to determine how each question will be answered ("How can we find out about it?"). This becomes the basis for developing their Research Action Plan. (Student Handout #5: Research Action Plan)

7. To assist you, the teacher, in ensuring that certain skills, concepts and processes are acquired a list of anticipated student outcomes has been provided.

8. The students use the information found on the web site as well as other noted resources to implement their Research Action Plan.

9. Also available, a series of instructional activities designed to assist students in exploring and acquiring the knowledge and understandings needed for successful completion of this project. These are optional and should be employed only if needed during the learning process. These are found in the PDF (Portable Document File) of the *Instructional Activities* section.

10. For your convenience there are a series of assessments designed to ascertain whether the students are truly acquiring the skills, concepts and processes needed to successfully design an airplane that will fly on Mars. Included are quizzes for evaluating the students’ acquisition of the technology design process, and aeronautical and atmospheric concepts. A rubric is also available for the evaluation of their final written report and their oral presentation. These are to be found in the PDF section *Student Assessments*.

11. Included also in the PDF section is a Learning/Reading Center set of materials to be used in conjunction with the tradebook Are We Moving to Mars? by Anne Schraff.

Implementing the Problem-based Learning Approach

Step 1: Introducing the Problem

Have students meet the problem by accessing the following web sites or accessing printouts from the following web sites, and reading about the NASA announcement for a Mars aircraft to be flown in 2003.

ABC News URL:

www.abcnews.go.com/ABC2000/abc2000science/marsplane/980720.html

Wired News URL:

www.wired.com/news/technology/0,1282,14708.00.html

Then distribute, read and discuss Student Handout #1: The Call for Proposals.

Step 2: The Scenario and Student Roles

Students will act as aeronautical researchers and aeronautical engineers throughout this scenario. They will need to research the basics of Earth-bound aeronautics and then see how these aeronautical principles apply in the atmosphere of Mars. Knowing how these principles act differently within Mars' atmosphere, will affect ultimately the design of the aircraft. They will then take the role of an aeronautical engineer and examine the different types of aircraft parts and how these are predicted to function within the atmosphere of Mars. They will make design decisions based upon these predictions.

Student Handout #2: Mars Airplane Design Specifications

Step 3: Crafting the Problem Statement

Based upon the students' work with Student Handout #1: The Call for Proposals and the web site references, they collaborate to derive a detailed definition of the problem. Use the Student Handout #3: Defining the Problem: The Problem Statement, and have students work in small teams or as a whole class to come up with this problem statement. Below are examples of what some these problem statements could be.

Examples:

What kind of aircraft design will meet the required aeronautical and scientific specifications for successful flight on Mars?

Given the type of atmosphere that is found on Mars, what type of airplane design will be able to fly and take as payload the required scientific equipment for study of Mars?

What kind of wing shape, fuselage shape and size, tail section shape and propulsion system will give the maximum flight characteristics necessary for a flight on Mars that will accomplish the scientific missions required?

What's the best kind of wing, fuselage, tail and propulsion system for an aircraft to use to fly in Mars' atmosphere with a scientific payload?

For an aircraft to fly in Mars' atmosphere with a full scientific payload, what is the best wing shape, fuselage shape, tail shape and propulsion system?

Step 4: Developing Their Essential Questions

Use Student Handout #4: Processing Through the Problem to assist them as they work in their teams to delineate the important information they need to know in order to successfully solve the design problem. Below are lists of Essential Questions that are anticipated to be generated by the students. The concepts embedded in the questions are repeated in other questions so as to give the teacher a broad range of question samples.

<u>Mars Atmospheric Questions</u>

- What is the gravity on Mars and how does that affect the four forces?
- What is the composition of the atmosphere on Mars?
- What is the atmospheric pressure on Mars and how would that affect flight?
- What are the general effects of the Mars' atmosphere on flight?
- What is the effect of Mars' gravity on weight and payload?
- What is the effect of the density of Mars' air on flight?
- What is the difference in the air/atmosphere of Mars' upper atmosphere and lower atmosphere?
- Would there be a difference between Mars' upper and lower atmosphere in an airplane's ability to fly?
- How does the atmosphere of Mars affect the performance of a typical propulsion system (jet engine, propeller, rocket engine)?

<u>Aeronautical Design Questions</u>

- Which wing shapes are better for reconnaissance flying (long, high-flying)?
- What type of propulsion system is the most efficient for reconnaissance flight?
- Would it be best if the fuselage is just big enough to hold the payload, transmitting equipment and propulsion system, that is only as big as it needs to be?
- How effective will the tail section be in directing the airplane's course being that the atmosphere of Mars is different from Earth's?

Aeronautical Questions

- How does atmospheric pressure affect flight?
- Does the density of the air affect how the air flows around an airplane?
- How does the shape of an airplane’s wings affect the four forces (weight, lift, thrust and drag)
- What kinds of propulsion systems and fuels can be used to power airplanes?
- Can a regular jet engine be used to power an airplane on Mars? Why or why not?
- How well would a commercial jetliner fly on Mars?
- How well would a small, propeller airplane fly on Mars?
- How well would a remote-controlled, model airplane fly on Mars?
- How important is the tail section of an airplane?
- What is the best (most efficient) airspeed at which reconnaissance flights are made?
- How does airspeed affect how air flows around a wing to generate lift?
- What are the forces that affect flight (weight, lift, thrust, drag)?

Step 5: Performing Research and Instructional Activities

As students use the web site to find the answers to their Essential Questions, the following activities can be interspersed among their research when and where applicable. The following instructional materials do not necessarily have to be used in order for the students to gain the full benefit of this Problem-based Learning unit. They can be used to assist in illustrating aspects of aeronautical knowledge.

Activity 1: The Aspect Ratio of Wings
Students learn how the length and width of a wing can affect the amount of drag it generates.

Activity 2: Graphing the Four Forces
Students acquire a simplified version of how the forces of weight, lift, thrust and drag can be graphed.

Activity 3: Don't Let it Weigh You Down!
Students are introduced to the importance of lift versus weight in determining payload for lighter-than-air aircraft.

Activity 4: Know All the Angles
Students work with simulated wind tunnel data to determine the coefficient of lift.

Activity 5: Expressing Rules for Atmospheric Pressure
This contains a few mathematical problems that ask the 9 – 12 grade students to write exponential equations regarding atmospheric pressure at different altitudes.

Step 6: Design and Refine the Prototype

Once students have adequately researched their essential questions and the teacher believes the students are able to reflect intelligently upon their information it is time to allow the students to actually choose prototype designs. They do so by accessing the web site's section: "Design a Mars Airplane". Here students mix and match various airplane parts and structures to design a prototype. If their research has been performed thoroughly, the students should be able to eliminate the more obvious prototype designs that could not achieve successful flight on Mars. Do not allow the students to test their ideas at this time. They are to first review the selections available and discuss the remaining possibilities within their group.

After said process of elimination, the students will next need to decide which of the remaining features when combined would provide one of the more successful prototypes that meets the design specifications. Before proceeding they must complete Student Handout #7: Designing a Prototype of the Mars Airplane.

Once Student Handout #7 is complete, students should be allowed to proceed to test their prototype by using the web site section: Design a Mars Airplane. During this time the teacher decides how many iterations the students should be allowed before the teacher calls the scientific conference. Students are then given time to prepare their written proposal and their oral presentation of said proposal.

Step 7: Presentation of Proposals

Acting as a scientific community, students present their written reports summarizing the knowledge they acquired and the prototype their research produced. They must defend their work in front of their colleagues.

Any disagreements can be quelled by returning to the web site section "Design a Mars Airplane" to ascertain any other possibilities. The teacher can also use the experts' explanations found in the Appendices to assist in substantiating any claims.

Student Assessment

You will find in the PDF file *Student Assessment* an array of assessments that can be utilized within the context of the Problem-based Learning format. The assessments vary from concept quizzes to processes checks to rubrics. No need to use them all. Simply pick and choose those which will be most applicable to how you will use these materials within your program.

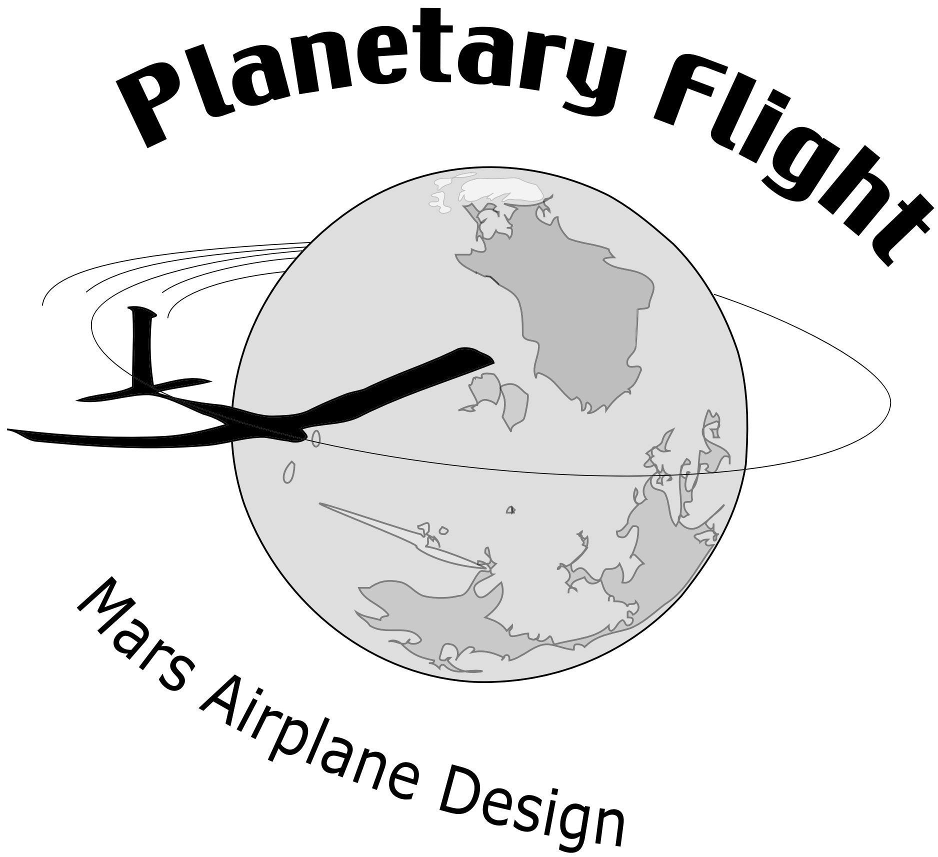
Below is a brief description of each. These can be printed from the PDF file *Student Assessment*.

- #1 Aeronautical Content Check
  Just a quiz to ascertain if students are picking up the underlying aeronautical principles involved in the problem.

- #2 Atmospheric Flight Comparison Chart
  This is an embedded assessment that will underscore if students understand the basics of how a planet's atmosphere affects flight.

- #3 Technology Design Process Check
  This is a quick assessment to ascertain recognition of the steps used in the design process.

- #4 Mars Airplane Design Proposal Rubric
  Use this rubric to score their written reports and oral presentations.

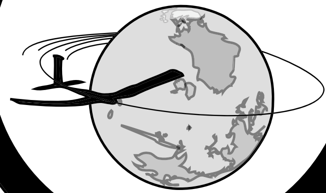


Appendices

The best choices for the Mars airplane (with explanations from the experts)

Additional Resources

Correlation to the National Standards
Science
Mathematics
Technology
Reading / Language Arts



Appendices

The Best Choices for a Mars Airplane Design (with explanations from the experts)

In this activity the students choose variables to come up with the best design for a Mars Airplane mission.

The best combination of choices is:

Elliptical Wing,
Fuel Oxidizer,
Propeller,
Sub-sonic
Full Payload

This plane would fly for the longest time (70 minutes) and the longest range (531-km).

Our experts comments:

<u>Steve Smith:</u>
The elliptical wing will minimize the drag generated by the tip vortex.
The sub-sonic choice produces less drag, which is very important in Mars's low-density atmosphere.

<u>Peter Gage:</u>
The fuel oxidizer is ideal for the atmosphere on Mars, which lacks Oxygen to burn hydrocarbons and is more efficient than batteries and solar power. (One complication with this "best" solution is that the technology is not currently available. Batteries and an electric motor would be more reliable, because the components are available now. The best performance on paper may not turn out to be the best in real life!)

The propeller is the best option for generating sub-sonic thrust.

Additional Resources

Teacher Web Sites

The Mars Airplane-NASA Langley Research Center
http://marsairplane.larc.nasa.gov
Celebrating the Human Spirit of Invention and Innovation with details about the Mars Landscape, History, and Future explorations (req. FLASH Plugin).

Ames Imaging Library Server-Digital Library
http://ails.arc.nasa.gov
AME-2 Mars Airplane starting the development sequence; Photographer: Tom Trower; Date: Nov 20, 1996

Power and On-Board Propulsion Technology Division
http://powerweb.lerc.nasa.gov
Home Projects Power Technologies Propulsion Technologies Research Technology Transfer Publications Feedback Organization Search;

Deep Space 2 Picture Gallery
http://nmp.jpl.nasa.gov
Presents a synopsis of a scientific Mars mission during which the Mars microphobes will collect data to determine the atmospheric density profile, the hardness and thermal conductivity of the soil, and if water ice is present below the Martian surface.

MARS AIRPLANE PACKAGE (MAP) PROCUREMENT
http://nais.nasa.gov/EPS/LaRC/Synopses/1-47-OCD/mod-01.html
General technical information concerning the technical specifications about the Mars airplane.

Taking Wing over Mars
http://www.abcnews.go.com/ABC2000/abc2000science/marsplane980720.html
News article detailing the mission proposed to coincide with the Kitty Hawk Centennial.

A Flight Plan for Mars
http://www.wired.com/news/technology/0,1282,14708,00.html”
News article detailing the general and background information about the Mars Airplane.

Additional Resources (continued)

Teacher Print Material

How to Use Problem-based Learning in the Classroom, Delisle, Robert. Association for Supervision and Curriculum Development, Alexandria, VA, 1997. ISBN: 0-87120-291-3.

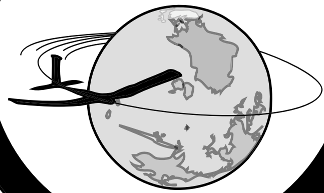
Mach 1 and Beyond, Reithmaier, Larry. Tab Books, Blue Ridge Summit, PA, 1995. ISBN: 0-07-052021-6.

Future Flight: The Next Generation of Aircraft Technology, Siuru, B. & Busick J. D. Tab Aero Books, Blue Ridge Summit, PA, 1994. ISBN: 0-8306-4376-1.

The Illustrated Guide to Aerodynamics, Smith, H. C. Tab Books, Blue Ridge Summit, PA, 1992. ISBN: 0-8306-3901-2

"Mars Air: How to build the first extraterrestrial airplane" Morton, Oliver. *Air and Space*,. December 1999/January 2000, pp. 34-42

"Designing a 'smart wing' for the Mars airplane", Kenwright, D. ***Grid****points,* Winter 1999, pp. 8-11.



Appendices

Correlation to the National Standards

Science

Mathematics

Reading / Language Arts

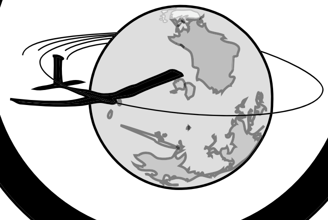
Correlation Matrix: National Science Standards Grades 9 -12

standard → / planetary flight ↓		Unifying concepts & procedures	Content Standard A Science as inquiry	Content Standard B Physical science	Content Standard C Life science	Content Standard D Earth & space science	Content Standard E Science & technology	Content Standard F Science in personal & social perspectives	Content Standard G History & nature of science
Web site Components	Atmospheric flight	S,EM,F		B2 B4			E1 E2	F6	G1 G2
Web site Components	Balloon flight	S,EM,F		B2 B4			E1 E2	F6	G3
Web site Components	Non-atmospheric flight	C,EM, F		B2 B4				F6	G1 G2
Web site Components	Mars facts	S					E1 E2		
Web site Components	Mars airplane specifications	EM,F					E1 E2	F6	
Web site Components	Design a Mars airplane	F	A1 A2	B4			E1 E2	F6	G1
PBL Projects	Student handouts #1-8	EM	A1 A2	B4			E1 E2	F6	G1
Instructional Print Materials – Instructional Activities	#1	EM,F					E1 E2		G1
Instructional Print Materials – Instructional Activities	#2	EM,		B4					G1
Instructional Print Materials – Instructional Activities	#3	EM, F		B4					G1
Instructional Print Materials – Instructional Activities	#4	EM, C, F		B4					G1
Instructional Print Materials – Instructional Activities	#5	S,EM, C							G1 G2
Instructional Print Materials	Mars learning & reading center	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Correlation Matrix: National Science Standards Grades 5 – 8

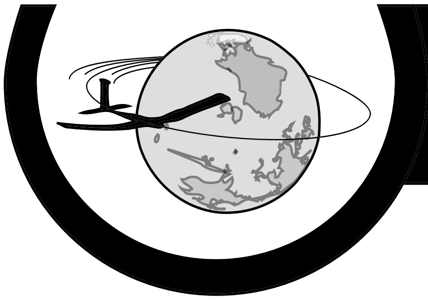
planetary flight ↓ / standard →		* Unifying concepts & procedures	Content Standard A Science as inquiry	Content Standard B Physical science	Content Standard C Life science	Content Standard D Earth & space science	Content Standard E Science & technology	Content Standard F Science in personal & social perspectives	Content Standard G History & nature of science
Web site Components	Atmospheric flight	S,EM,F		B1 B2 B3		D1	E1 E2	F4 F5	G1
Web site Components	Balloon flight	S,EM,F		B1 B2 B3		D1	E1 E2	F4 F5	G2
Web site Components	Non-atmospheric flight	C,EM, F		B1 B2 B3				F4 F5	
Web site Components	Mars facts	S					E1 E2		
Web site Components	Mars airplane specifications	EM,F					E1 E2		G1
Web site Components	Design a Mars airplane	F	A1 A2	B2 B3			E1 E2		G1
PBL Projects	Student handouts #1-8	EM	A1 A2	B1 B2 B3		D1	E1 E2	F4 F5	G1
Instructional Print Materials	Instructional Activities #1	EM,F					E1 E2		G1
Instructional Print Materials	Instructional Activities #2	EM,		B2					G1
Instructional Print Materials	Instructional Activities #3	EM, F		B2					G1
Instructional Print Materials	Instructional Activities #4	EM, C, F		B2					G1
Instructional Print Materials	Instructional Activities #5	S,EM, C		B1					
Instructional Print Materials	Mars learning & reading center	S, F							

* S = systems, order and organization C = change, consistency and measurement F = form and function
EM = evidence, models and explanation EE = evolution and equilibrium



Correlation Matrix: Standards for Mathematics Grades 5 – 8

Group	Web site components → / standard ↓	1 Mathematics as problem solving	2 Mathematics as communication	3 Mathematics as reasoning	4 Mathematical connections	5 Number and number relationship	6 Number systems and number theory	7 Computation and estimation	8 Patterns and functions	9 Algebra	10 Statistics	11 Probability	12 Geometry	13 Measurement
Web site Components	Atmospheric flight			★				★		★				
	Balloon flight			★				★		★				
	Non-atmospheric flight													
	Mars facts			★										
	Mars airplane specifications		★	★				★						
	Design a Mars airplane			★										
PBL Projects	Student handouts #1–8	★		★	★			★						
Instructional Print Materials – Instructional Activities	#1	★			★			★		★				★
	#2	★			★			★						★
	#3	★			★			★						★
	#4	★			★			★					★	
	#5													
Instructional Print Materials	Mars learning & reading center													



Appendices

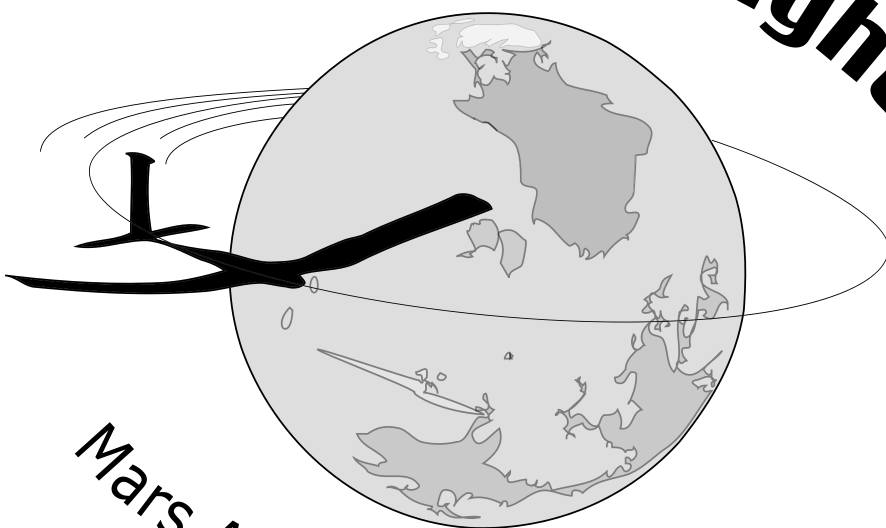
Correlation Matrix: Standards for Mathematics Grades 9 – 12

Group	Web site components	1 Mathematics as problem solving	2 Mathematics as communication	3 Mathematics as reasoning	4 Mathematical connections	5 Algebra	6 Functions	7 Geometry from a synthetic perspective	8 Geometry from an algebraic perspective	9 Trigonometry	10 Statistics	11 Probability	12 Discrete mathematics	13 Conceptual underpinnings of calculus	14 Mathematical structure
Web site Components	Atmospheric flight			✪		✪									
Web site Components	Balloon flight			✪		✪									
Web site Components	Non-atmospheric flight														
Web site Components	Mars facts														
Web site Components	Mars airplane specifications		✪	✪											
Web site Components	Design a Mars airplane			✪											
PBL Projects	Student handouts #1–8	✪		✪	✪										
Instructional Print Materials – Instructional Activities	#1	✪			✪	✪									
Instructional Print Materials – Instructional Activities	#2	✪			✪										
Instructional Print Materials – Instructional Activities	#3	✪			✪										
Instructional Print Materials – Instructional Activities	#4	✪			✪										
Instructional Print Materials – Instructional Activities	#5	✪				✪	✪		✪						
Instructional Print Materials	Mars learning & reading center														

Correlation Matrix: Standards for the English Language Arts Grades 5–8 and 9–12

standard → / Web site components ↓		Web site Components: Atmospheric flight	Balloon flight	Non-atmospheric flight	Mars facts	Mars airplane specifications	Design a Mars airplane	PBL Projects: Student handouts #1–8	Instructional Print Materials: Instructional Activities #1	#2	#3	#4	#5	Mars learning & reading center
1	Students read a wide range of print and nonprint texts to build an understanding of texts, of themselves, and of the cultures of the United States and the world; to acquire new information; to respond to the needs and demands of society and the workplace; and for personal fulfillment. Among these texts are fiction and nonfiction, classic and contemporary works.													
2	Students read a wide range of literature from many periods in many genres to build an understanding of the many dimension (e.g., philosophical, ethical, aesthetic) of human experience.													
3	Students apply a wide range of strategies to comprehend, interpret, evaluate, and appreciate texts. They draw on their prior experience, their interactions with other readers and writers, their knowledge of word meaning and of other texts, their word identification strategies, and their understanding of textual features (e.g., sound-letter correspondence, sentence structure, context, graphics).	►	►	►	►									►
4	Students adjust their use of spoken, written, and visual language (e.g., conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.													►
5	Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences for a variety of purposes.													►
6	Students apply knowledge of language structure, language conventions (e.g., spelling and punctuation), media techniques, figurative language, and genre to create, critique, and discuss print and nonprint texts.													►
7	Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g., print and non-print texts, artifacts, people) to communicate their discoveries in ways that suit their purpose and audience.							►						►
8	Students use a variety of technological and informational resources (e.g., libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.	►	►	►	►		►							►
9	Students develop an understanding of and respect for diversity in language use, patterns, and dialects across cultures, ethnic groups, geographic regions, and social roles.													
10	Students whose first language is not English make use of their first language to develop competency in the English language arts and to develop understanding of content across the curriculum.													
11	Students participate as knowledgeable, reflective, creative, and critical members of a variety of literacy communities.	►	►	►	►	►	►	►						►
12	Students use spoken, written and visual language to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information.)	►	►	►	►	►	►	►						►

Planetary Flight



Mars Airplane Design

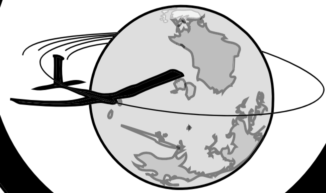
PDF Files

Student Handouts
#1 The Call for Proposals
#2 Mars Airplane Design Specifications
#3 Defining the Problem: The Problem Statement
#4 Processing Through the Problem
#5 Research Action Plan
#6 Project Checklist
#7 Design a Mars Airplane Prototype
#8 Design Proposal Guidelines: Written Report & Oral Presentation

Student Assessments
#1 Aeronautical Content Check
#2 Atmospheric Flight Comparison Chart
#3 Technology Design Process Check
#4 Mars Airplane Design Proposal Presentation Rubric

Instructional Activities
Activity 1: Aspect Ratio of Wings
Activity 2: Graphing the Four Forces
Activity 3: Don’t Let It Weigh You Down!
Activity 4: Know All the Angles
Activity 5: Expressing Rules for Atmospheric Pressure
(Grades 9 – 12 math)

Note to teachers*: The handouts found in this file correspond to the material referenced in the Teacher’s Edition section offered online.*



Student Handout #1: The Call for Proposals

The National Aeronautics and Space Administration is implementing a call for proposals for micro-missions to Mars in which model airplanes will be employed to perform scientific data-gathering expeditions.

In order to gather more and greater amounts of information about Mars, its geology, geography, hydrology and atmosphere, scientists wish to fly a robot-controlled model aircraft above the surface of Mars for as long as aerodynamically possible, with a scientific instrument payload aboard. This aircraft must fit into the spacecraft which will carry it into an orbit around Mars. This aircraft must then be capable of deployment from its space capsule while entering Mars' atmosphere at supersonic rates of speed. This aircraft must be able to hold and employ scientific instrumentation during its flight. It must be capable of flying within the Martian atmosphere between altitudes of 5,000 and 30,000 feet. Prolonged, sustained and controlled flight characteristics are highly desirable.

Design specifications and payload specifications to be released soon.

Student Handout #1: The Call for Proposals

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Design specifications and payload specifications to be released soon.

Student Handout #2: Mars Airplane Design Specifications

Context

As part of the process for the scientific exploration of other planets, researchers will use aircraft to survey large areas of the planet. Instruments on the airplane will analyze samples from varied regions of the atmosphere and they will perform remote sensing surveys of the planet's surface. To gain a greater understanding of Mars, an airplane needs to be designed to meet the needs of such an unmanned scientific expedition.

Need

Since the atmosphere of Mars is distinctly different from that of Earth, consideration needs to be given to a fixed wing aircraft design that will fly in such an atmosphere, and be able to carry and use a scientific payload.

Design Brief

Design a fixed wing airplane that is capable of sustained, powered, controlled flight in the atmosphere of Mars carrying a scientific payload with a mass of at least 2 kg.

1. The aircraft must be able to carry a scientific payload of 2 kg and include 3 of the following experimental equipment (Note: Weight is in Earth units.):

    - Atmospheric Indicators (air pressure, air temperature, turbulence, composition, density, electromagnetic survey) 1.0 kg
    - Magnetometer (low altitude aeromagnetic survey) 1.25 kg
    - NIR Spectrometer (near infrared spectroscopy full range imaging) 1.0 kg
    - Point Spectrometer (boresighted spectroscopy to remotely determine surface mineralogy for limited baseline capability) 1.0 kg
    - High Resolution Camera (10 cm resolution) 0.75 kg
    - Context Video Camera (1 – 3 meter resolution) 1.0 kg

Student Handout #2:
Mars Airplane Design Specifications

2. Aircraft must be of a fixed wing design.

3. Aircraft must have sustained, controlled flight in Mars' atmosphere for minimum 15 minutes. You should carry as much payload as possible with a minimum duration of 30 minutes.

4. Propulsion system must be functional within the Mars atmosphere.

5. Must be able to withstand airspeeds of approximately 700 m.p.h. with an average airspeed range of 300 m.p.h. – 400 m.p.h.

<u>People</u>

You will work in teams of _____ in roles assigned by your teacher functioning as aeronautical researcher, aeronautical engineer, designer, fabricator and evaluator.

<u>Tools/Machines</u>

You will use a computer connected to the Internet, a resource library and other aeronautical engineers and researchers in the field to research the aeronautical information, to assist in the design process and to test your model.

<u>Materials</u>

You will use the research information found on this web site and other links to assist you in your decisions prior to virtually constructing and testing your model in the section "Design Your Mars Airplane".

<u>Energy</u>

You may use the energy generated by your group's collective brain power to develop this design and the "virtual engines" found on the web site to provide the thrust for your model.

Student Handout #2: Mars Airplane Design Specifications

<u>Capital (Money)</u>

Your team will have enough of a research budget to complete the work as assigned.

<u>Time</u>

You have ___ class sessions as assigned by your teacher to devote to research, design, virtual model construction, model evaluation, design revision and final evaluation. Be prepared to present your report to your colleagues upon project completion.

<u>Reporting</u>

Use the format provided by your teacher. Note the best working model and drawings of successful and unsuccessful designs. Explain why some models were more successful than others.

Student Handout #3: Defining the Problem: The Problem Statement

Directions: You have now been introduced to the concepts surrounding an airplane flight within the atmosphere of Mars, have read the Call for Proposals and been briefed on the Design Specifications. As assigned by your teacher, develop a problem statement that considers only the aeronautical challenges. Your teacher will coach you as to what a well crafted problem statement should consider. Brainstorm a few possible problem statements below and then choose one for refinement. Be prepared to discuss the strengths of your problem statement.

Student Handout #4:
Processing Through the Problem

Directions: After your group or class has reached agreement on the Problem Statement for the Mars Airplane Design Problem, continue with the following steps:

Step 1: Develop a list of questions below about what your team ALREADY KNOWS about Mars, its atmosphere, aeronautics and airplane structure and function.

Step 2: Develop a list of questions below about what your team will NEED TO KNOW about Mars, its atmosphere, aeronautics and airplane structure and function.

Student Handout #4: Processing Through the Problem

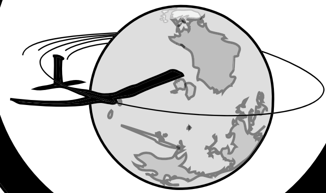
Directions: After your group or class has reached agreement on the Problem Statement for the Mars Airplane Design Problem, continue with the following step:

Step 3: Choose appropriate category names and organize your questions into these categories. Use as many categories as you believe is best for grouping the questions.

Category 1: ______________________

Category 2: _______________________

Category 3: _______________________



Student Handout #5: Research Action Plan

Directions: You now have a list of what you already know to help you solve the problem. You also have a list of questions for which you need to find the answers. To get answers to these questions you will need to do some research. With your team list the steps you will need to take to get all the information you will need. Below write each step and include what resources you will use and who will be responsible for each action.

Step #	**Action to be taken**	**Resources to be used**	**Person(s) responsible**

Student Handout #6: Project Checklist

Directions: This checklist serves as an overview of what you and your team will be responsible for during this design problem. Use this guidesheet to track your progress.

Task **Assignments / Assessments**	**Due Date**	**Completed/** **Score**
Student Handout #4 Processing Through the Problem	___________	___________
Student Handout #5 Research Action Plan	___________	___________
Student Handout #6 Project Checklist	___________	___________
Student Handout # 7 Design and Refine Mars Airplane Prototype	___________	___________
Student Handout # 8 Design Proposal Guidelines: Written Report and Oral Presentation	___________	___________
Student Assessment # 1 Aeronautical Content Check	___________	___________
Student Assessment # 2 Atmospheric Flight Comparison Chart	___________	___________
Student Assessment # 3 Technology Design Process Check	___________	___________

Student Handout #6: Project Checklist

Directions: This checklist serves as an overview of what you and your team will be responsible for during this design problem. Use this guidesheet to track your progress.

Task Assignments / Assessments	Due Date	Completed/ Score
Optional Activities:		
Activity #1 Aspect Ratio of Wings	___________	___________
Activity #2 Graphing the Four Forces	___________	___________
Activity #3 Don’t Let it Weigh You Down!	___________	___________
Activity #4 Know All the Angles	___________	___________

Student Handout #7: Design and Refine Mars Airplane Prototype

Directions: After answering your Essential Questions through research, you are now ready to apply your knowledge. Discuss with your team members what the research suggests for a successful design. Answer the questions below as you develop the prototype.

1. Based upon your research, draw a diagram (on a separate sheet of paper) of the type of wing the Mars Airplane should have. Include a cross section view and a top view.
2. In a paragraph explain why the wings should have this design.
3. Based upon your research, draw a diagram (on a separate sheet of paper) of the type of fuselage the Mars Airplane should have. Include a side view and a top view.
4. In a paragraph explain why the fuselage should have this design.
5. Based upon your research, draw a diagram (on a separate sheet of paper) of the type of tail section the Mars Airplane should have. Include 2 different views.
6. In a paragraph explain why the tail section should have this design.

Student Handout #7: Design and Refine Mars Airplane Prototype

7. Based upon your research, draw a diagram (on a separate sheet of paper) of the type of propulsion system the Mars Airplane should have. Include a cross section in one of the 2 views.

8. In a paragraph explain why the propulsion system should have this design.

9. Based upon your research, list and diagram (on another sheet of paper) any other design ideas that would be beneficial to the Mars Airplane that helps it to meet the specifications.

10. On a separate sheet of paper, draw a diagram of your complete Mars Airplane prototype.

11. Using the Planetary Flight web site section “Design a Mars Airplane”, select the parts for the airplane that most resemble the parts your team has selected. Print out or copy on a separate sheet of paper this design.

12. Using the Planetary Flight web site section “Design a Mars Airplane”, test this design. Record your findings below.

Student Handout #7: Design and Refine Mars Airplane Prototype

13. Based upon your findings, list below what design characteristics of your prototype would be changed to improve its performance. Explain the scientific reasoning that supports such a design change.

14. On a separate sheet of paper, draw your new design based upon your findings.

15. Using the Planetary Flight web site section "Design a Mars Airplane", select the parts for the airplane that most resemble the parts your team has selected for its new design. Print out or copy on a separate sheet of paper this new design.

16. Using the Planetary Flight web site section "Design a Mars Airplane", test this design. Record your findings below.

17. Reflect upon this experience.

Student Handout #8: Design Proposal Presentation Guidelines: Written Report and Oral Presentation

Directions: Follow the outline given below when developing your research team's written report. Use the same information when presenting your findings to the class.

- Introduction to report
- Essential Questions with answers
- List the steps in your team's Research Action Plan
- Diagram with labels of the proposed design
- Scientific explanations for this chosen design
  - Include references or sources of scientific information
- Performance evaluation of your design
  - Include scientific explanations
- If given additional time and resources explain any further improvements which the team would propose to make to the design
  - Include scientific explanations
  - Include diagram with labels of the new design
- List any additional questions that if there were more time and resources were available would need to be answered. Organize them into categories.
- List any changes your team would make to their Research Action Plan if your team could solve this design problem again from the beginning.

PDF Files–Student Assessment #1

Aeronautical Content Check

Directions: Answer each question below.

1. Explain just how practical it really is to use a balloon to carry the scientific instruments needed to study the surface of Mars from the air.

2. The amount of lift generated by an aircraft depends on what 3 factors?

3. Explain the reasons why a standard jet engine would not be a good choice for a propulsion system on an aircraft designed to fly in atmosphere of Mars.

4. The amount of drag depends on what 4 factors?

PDF Files-Student Assessment #1

Aeronautical Content Check

5. List the four forces that affect flight.

6. List 3 ways in which the atmosphere of Mars is different from the earth's atmosphere.

7. Explain how the differences in atmosphere between Mars and the Earth will affect each of the four forces.

PDF Files–Student Assessment #1 Key

Aeronautical Content Check

1. Explain just how practical it really is to use a balloon to carry the scientific instruments needed to study the surface of Mars from the air.

   The Earth's atmosphere has greater density than the atmosphere of Mars. Since the buoyancy force on an object in the Earth's atmosphere is not very great, a balloon would have to be very large and made of extremely lightweight material to get the buoyant force needed to generate enough lift to carry the payload of scientific instruments. Also, the balloon could not be adequately controlled as it would drift with the winds which are quite forceful.

2. The amount of lift generated by an aircraft depends on what 3 factors?

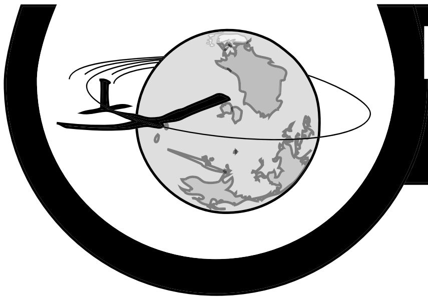
   A) details of the shape of the wing, including angle of attack
   B) size of the wing
   C) dynamic pressure (density and speed)

3. Explain the reasons why a standard jet engine would not be a good choice for a propulsion system on an aircraft designed to fly in atmosphere of Mars.

   A jet engine relies on plenty of oxygen in the air to mix with the fuel in order to create combustion. The atmosphere of Mars does not have nearly enough oxygen to create combustion. A jet engine could be used, but it would have to be modified so it can carry its own oxygen source to combine with the fuel for combustion.

4. The amount of drag depends on what 4 factors?

   A) size of the aircraft
   B) details of the shape and smoothness of the aircraft and wings
   C) the lifting efficiency of the wing, related to aspect ratio
   D) dynamic pressure (density and speed)



PDF Files–Student Assessment #1 Key

Aeronautical Content Check

5. List the four forces that affect flight.

   A) Lift
   B) Weight
   C) Thrust
   D) Drag

6. List 3 ways in which the atmosphere of Mars is different from the Earth's atmosphere.

   Answers will vary, more than 3 are given below:

   A) Greater differences in air temperature between night and day on Mars compared to Earth.
   B) Mars' air is saturated 100% at night and undersaturated during the day (humidity)
   C) Mars' air pressure is 100 times less than the air pressure on Earth.
   D) Mars' atmosphere is made up of 95% carbon dioxide with no oxygen compared to the Earth's atmosphere which has 78% nitrogen and 21% oxygen.
   E) Gravity on Mars is less than Earth's (Though not usually considered "atmospheric" since it has an effect on flight this could be allowed as an answer.)

7. Explain how the differences in atmosphere between Mars and the Earth will affect each of the four forces.

   Answers will vary.

   A) Lift
   - *Lower air density means that the aircraft will have fewer molecules available to generate lift*
   - *Less gravity means that the aircraft needs to generate only 40% of the lift it normally would on Earth.*

   B) Weight
   - *Less gravity means that the aircraft needs to generate only 40% of the lift it normally would on Earth.*
   - *Less gravity also means that the Mars airplane could be made of heavier materials or carry a greater payload (provided all other atmospheric factors were the same between the Earth and Mars.)*

PDF Files–Student Assessment #1 Key

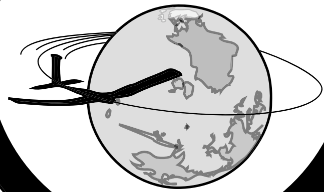
Aeronautical Content Check

7. Explain how the differences in atmosphere between Mars and the Earth will affect each of the four forces.

   Answers will vary.

   C) Thrust
   - *No oxygen on Mars will require a different type of propulsion system or modifications to what is common on Earth.*
   - *Lower air density means that the propellers have fewer molecules available to the propeller for it to produce thrust.*

   D) Drag
   - *Extremely strong winds will make control a problem and create additional drag that will slow the aircraft's flight speed.*
   - *Fewer molecules mean that the aircraft will be travelling at very fast speeds (transonic to supersonic). Air flows differently around an aircraft during different flight regimes (speeds: subsonic, transonic, supersonic, hypersonic). During transonic speeds greater pressure drag is generated than at lower (slower) speeds.*

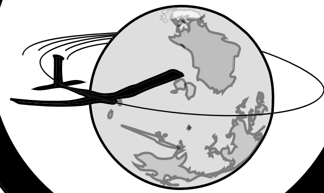


PDF Files–Student Assessment #2

Atmospheric Flight Comparison Chart

Directions: After researching the differences between the Earth's atmosphere and Mars' atmosphere, complete the chart below. List what the differences are and describe the effect this atmospheric difference would have on flight.

Atmospheric Condition	On Earth	On Mars	Effect on Flight
air pressure			
temperature			
gases present			
humidity			
air density			
wind			
gravity			

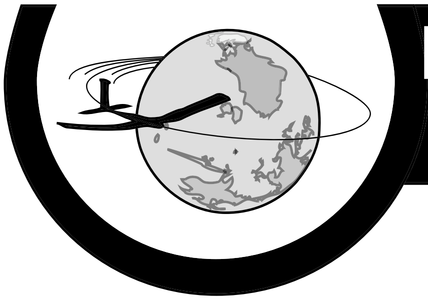


PDF Files–Student Assessment #2 Key

Atmospheric Flight Comparison Chart

Directions: After researching the differences between the earth's atmosphere and Mars' atmosphere, complete the chart below. List what the differences are and describe the effect this atmospheric difference would have on flight.

Atmospheric Condition	On Earth	On Mars	Effect on Flight
air pressure	*1,013.0 millibars*	*7.5 millibars*	*Fewer gas molecules on Mars with which to generate lift or for a propeller to produce thrust.*
temperature	*-88 – 57.7 Celsius*	*-125 - 22 Celsius*	*Colder temperatures can cause damage to an airplane's structure.*
gases present	*78% nitrogen 21% oxygen 1% argon*	*95% carbon dioxide 3% nitrogen 1.6% argon*	*Propulsion system cannot use oxygen from atmosphere for combustion. Must bring its own or not use oxygen*
humidity	*varies*	*100% night undersaturated during day*	*Night increase drag Day drag would decrease*
air density	*1.2256*	*0.0155*	*Fewer gas molecules on Mars with which to generate lift or for a propeller to produce thrust.*
wind	*mild to gale*	*strong*	*Will affect ability to control flight*
gravity	*9.8*	*3.0*	*38% that of Earth's, Mars airplane needs to generate only 40% of lift that it would generate on Earth*



PDF Files–Student Assessment #3

Technology Design Process Check

Part 1

Directions: From the list below, choose the steps that best describe the process used in technology design. Place a check next to the 6 steps.

______ State the hypothesis.

______ Test the consequences.

______ Evaluate the solution and its consequences.

______ Propose designs.

______ Put into action a suggested solution.

______ Choose between alternative (different) solutions.

______ Observe the results.

______ Identify a problem.

______ Communicate the problem, process and solution.

______ Design the experiment.

Part 2

Directions: Place the 6 steps you checked above into a sequential order below that reflects the process used in technology design.

1.

2.

3.

4.

5.

6.

PDF Files–Student Assessment #3 Key

Technology Design Process Check

Part 1

Directions: From the list below, choose the steps that best describe the process used in technology design. Place a check next to the 6 steps.

_____ State the hypothesis.

_____ Test the consequences.

__✓__ Evaluate the solution and its consequences.

__✓__ Propose designs.

__✓__ Put into action a suggested solution.

__✓__ Choose between alternative (different) solutions.

_____ Observe the results.

__✓__ Identify a problem

__✓__ Communicate the problem, process and solution.

_____ Design the experiment.

Part 2

Directions: Place the 6 steps you checked above into a sequential order below that reflects the process used in technology design.

1. *Identify a problem.*

2. *Propose designs.*

3. *Choose between alternative solutions.*

4. *Put into action a suggested solution.*

5. *Evaluate the solution and its consequences.*

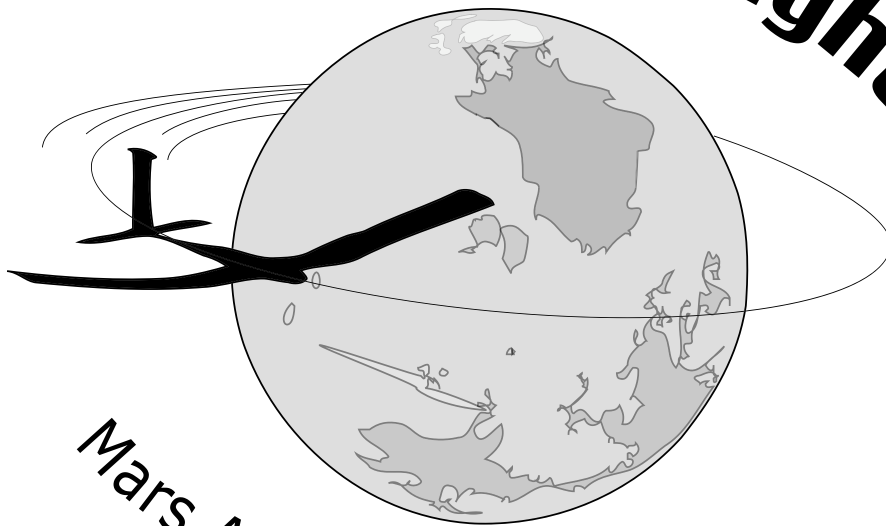
6. *Communicate the problem, process and solution.*

PDF Files–Student Assessment #4

Mars Airplane Design Presentation Rubric

Points	Technical Thought	Scientific Thought	Presentation Organization	Oral Presentation
50-45	The solution reveals a firm understanding of the technology involved and the design features. Offers the most viable solution.	Complete understanding of scientific concepts extensively researched w/excellent sources cited. Proper and effective use of scientific vocabulary and terminology.	Presentation demonstrates excellent organization and preparedness. Is clear, concise with effective application of scientific topic.	Engaging presentation, well supported by use of multi-sensory aids. Scientific content effectively communicated to peers.
44-40	The solution reveals that most technical principles are recognized and understood. Offers solution that satisfies specifications.	Good understanding of scientific concepts, well researched with a variety of sources cited. Adequate use of scientific vocabulary and terminology.	Presentation demonstrates good organization and advanced preparation. Has clarity and remains on topic most of time. Makes good use of scientific topic.	Interesting and confident presentation supported by multi-sensory aids. Scientific content adequately communicated to peers.
39-35	The solution reveals that a few technical principles are recognized and understood. Offers solutions that satisfy the specifications in a basic way.	Acceptable understanding of scientific concepts adequately researched w/some sources cited. Adequate use of scientific terms.	Acceptable presentation with some organization present and adequate preparation. Fairly clear and remains on topic most of the time. Makes adequate use of scientific topic.	Acceptable presentation with some use of aids. Only modestly effective in communicating science content to peers.
34-30	The solution reveals that few technical principles are recognized or necessarily understood. Offers solutions that marginally satisfy the specifications.	Lacks understanding of most scientific concepts with minimal research evident. Incorrect use of most scientific terms.	Presentation shows little clarity and organization with minimal preparation. Poor use of scientific topic.	Marginally acceptable presentation with poor to no use of some aids. Mostly ineffective in communicating science content to peers.
29-25	The solution reveals that most technical principles are not recognized or understood. Offers solutions that fail to satisfy the specifications.	Lacks understanding of basic scientific concepts with little research evident. Incorrect use of basic scientific terms.	Poor presentation lacks clarity and organization with little preparation. Poor to confused use of scientific topic.	Poor presentation, little to no use of aids. Does not communicate science content to peers.

Planetary Flight



Mars Airplane Design

Instructional Activities

Activity #1
Aspect Ratio of Wings

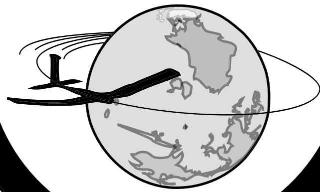
Activity #2
Graphing the Four Forces

Activity #3
Don't Let it Weigh You Down!

Activity #4
Know All the Angles

Activity #5
Expressing Rules for Atmospheric Pressure
(Grades 9 – 12 math)

Note to teachers: *The activities found in this file correspond to the material referenced in the Teacher's Edition section offered online.*



Activity 1: The Aspect Ratio of Wings

Review: As air flows over and under a wing, we know from research that the air flowing over the top flows faster than the air that flows under the wing. We also know from Bernoulli's Principle that the air that flows faster applies less pressure to the surface it is flowing over. Therefore, since the air flowing over the top of a wing has less pressure (because it is flowing faster), the air pressure on top is less than underneath the wing. The higher air pressure on the bottom "lifts" the wing.

Background: When engineers design a new airplane, the size and shape of the wings are a very important issue. Wings provide the majority of the lift for the airplane, but they also cause drag. Remember that drag is a force that opposes the thrust force. Engineers are always trying to find ways to increase lift and reduce drag caused by the wings.

In addition to flowing faster, the air that flows over the top of the wing also tends to flow inward, toward the fuselage. The air that flows over the bottom is flowing more slowly and tends to flow outward toward the wing's tip. As these two airflows meet along the trailing edge of the wing, they form a rotating column of air that extends from the wing tip. This is called a wing-tip vortex.

If they are lucky, passengers riding behind the wing of an airplane can sometimes see a wing-tip vortex - particularly if they are flying in the morning or on a slightly humid day. It looks like a long, slim whirlwind that extends out and behind the tip of the wing.

Unfortunately, while a wing-tip vortex is interesting to watch, the same characteristics of the airflow that create wing-tip vortices (the plural of vortex is vortices) also create drag.

Activity 1: The Aspect Ratio of Wings

Teacher - Led Exercise

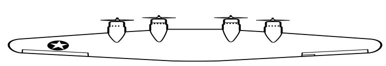
Directions: In their efforts to increase lift and reduce drag, engineers use a mathematical formula called the "aspect ratio". The "aspect ratio" is simply a comparison between the length and width of the wing:

$$\frac{\text{length of the wing}}{\text{width of the wing}} = \text{aspect ratio}$$

Experiments have shown that a wing built with a greater aspect ratio tends to create less drag than a wing built with a lesser aspect ratio - even when their area remains the same!

Examine the three wings drawn below, calculate the area and aspect ratio of each wing, and fill in the following table. Then, rank the wings according to the drag that each will create, given their aspect ratios. Rank the wing with the least drag, number 1 and the greatest amount of drag, number 3.

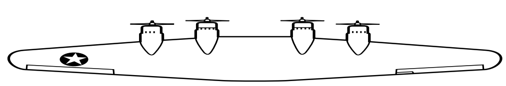
Wing "A"



5 units

20 units

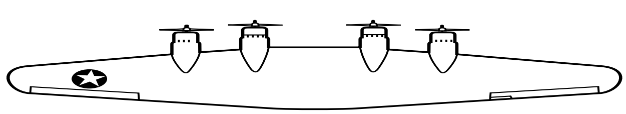
Wing "B"



4 units

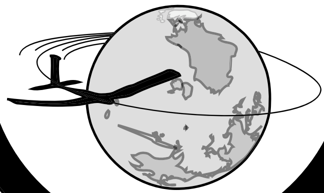
25 units

Wing "C"



2 units

50 units



Activity 1: The Aspect Ratio of Wings

Wing	length	width	area	aspect ratio	drag ranking
A					
B					
C					

Activity 1: The Aspect Ratio of Wings

Exercise 2

Step 1: Create and draw your own wings below and give each the same area of 200 square units.

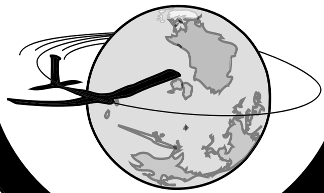
Wing A **Wing B**

Step 2: Label the length and width of each wing.

Step 3: Calculate the aspect ratio for each wing and fill in the table below. Don't forget to include the units!

Wing	length	width	area	aspect ratio	drag ranking
A					
B					

Step 4: Rank the wings according to the drag that each will create, given their aspect ratios. Rank the wing with the least drag, number 1 and the one with the greatest amount of drag, number 2.



Activity 1: The Aspect Ratio of Wings

Teacher – Led Exercise Key

Wing "A": *length: 20 units* *width: 5 units*

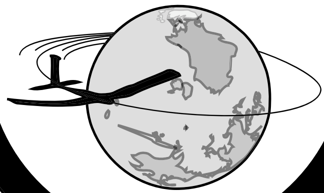
Wing "B": *length: 25 units* *width: 4 units*

Wing "C": *length: 50 units* *width: 2 units*

Wing	length	width	area	aspect ratio	drag ranking
A	*20 units*	*5 units*	*100 square units*	*4*	*3*
B	*25 units*	*4 units*	*100 square units*	*6 R1*	*2*
C	*50 units*	*2 units*	*100 square units*	*25*	*1*

Even though each wing has the same area, 100 square units, Wing "C" has the greatest aspect ratio, and Wing "A" has the least aspect ratio. This implies that Wing "A" creates more drag than Wing "C".

Maybe you've wondered why sailplanes and gliders have long, slim wings. Since they don't have engines to provide thrust, their wing shape helps to provide the greatest amount of lift with the least amount of drag.



Activity 1: The Aspect Ratio of Wings

Exercise 1- Key

Step 1: Possible wing dimensions and aspect ratios:

length = 9 width = 8 aspect ratio = 1 R1
length = 12 width = 6 aspect ratio = 2
length = 36 width = 2 aspect ratio = 18
length = 24 width = 3 aspect ratio = 8
length = 18 width = 4 aspect ratio = 4 R2

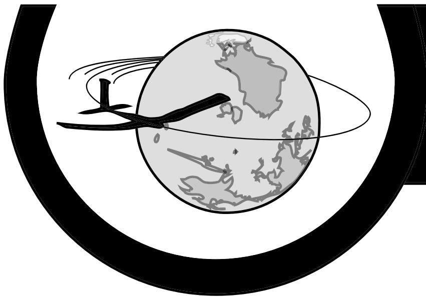
Wing	length	width	area	aspect ratio	drag ranking
A	*9 units*	*8 units*	*72 square units*	*1R1*	*2*
B	*12 units*	*6 units*	*72 square units*	*2*	*1*

Exercise 2- Key

Step 1: *Possible wing dimensions and aspect ratios:*

length = 100 width = 2 aspect ratio = 50
length = 50 width = 4 aspect ratio = 12 R2
length = 20 width = 10 aspect ratio = 2
length = 25 width = 8 aspect ratio = 3 R1

Wing	length	width	area	aspect ratio	drag ranking
A	*100 units*	*2 units*	*200 square units*	*50*	*1*
B	*20 units*	*10 units*	*200 square units*	*2*	*2*



Activity 2: Graphing the Four Forces

Background: The concept of force can be effectively represented on a graph using the Cartesian coordinate system. By representing four of the aeronautical forces (lift, drag, thrust, weight) on a graph, students can visualize both parts of the definition of force: magnitude and direction.

This lesson concentrates on the actual representation of the four forces on a graph. If, after combining the four forces, the net force is plotted in the upper right quadrant of the graph, then we will draw the conclusion that the airplane is able to fly.

Directions: Have students examine the graph on the following page. Point out that lift is "<u>up</u> toward the top of the paper", weight is "<u>down</u> toward the bottom of the paper", thrust is "<u>forward</u> toward the right of the paper" and drag is "<u>back</u> toward the left of the paper".

Using the magnitudes below, follow the steps and plot your points on the graph on the previous page.

Weight	**3 units**
Lift	**7 units**
Drag	**2 units**
Thrust	**5 units**

The forces can be plotted in any order. For example:

Step 1: Start at the origin (center of graph) and count down three squares (for Weight). Plot a small dot.

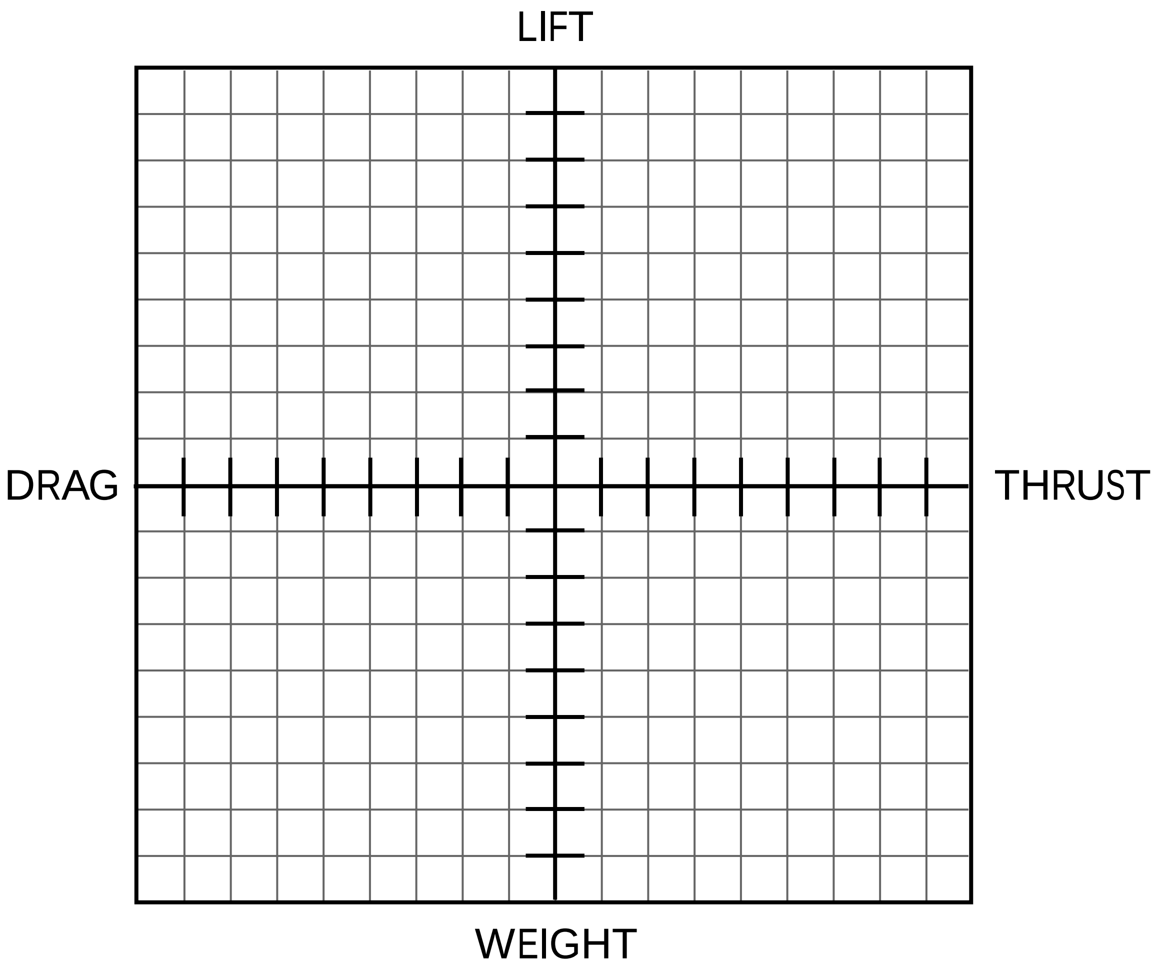
Step 2: From that small dot (do not start again from the origin!) count up seven squares (for Lift). Plot another small dot.

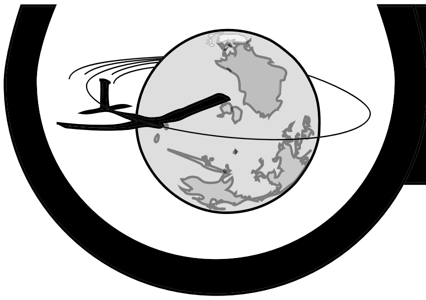
Step 3: From that small dot (do not start again from the origin!) count to the left two squares (for Drag). Plot another dot.

Step 4: From that small dot (do not start again from the origin!) count to the right 5 squares (for Thrust). Plot a large dot. This is the representation of the net force.

See the graphs on the page 9 for guidance, then continue.

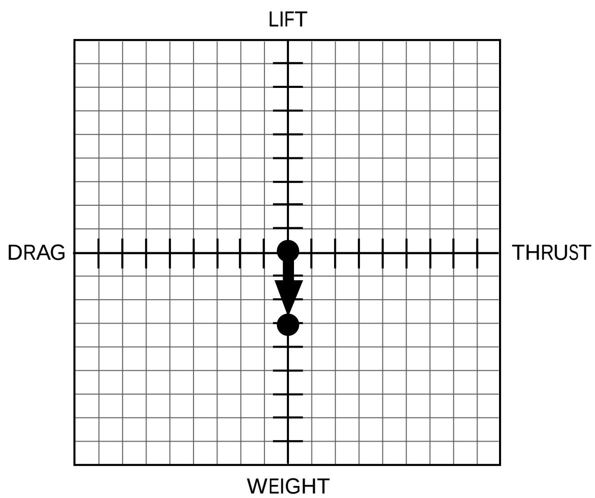
Activity 2: Graphing the Four Forces



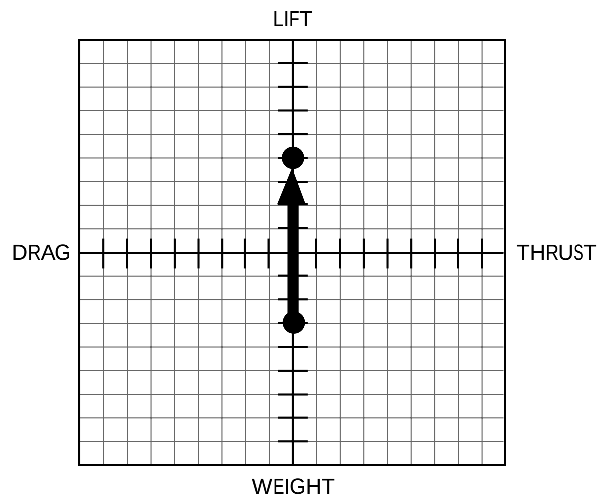


Activity 2: Graphing the Four Forces

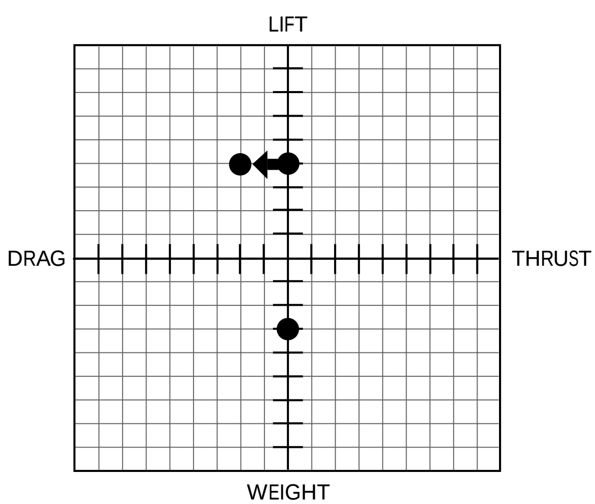
Step 1: Down 3



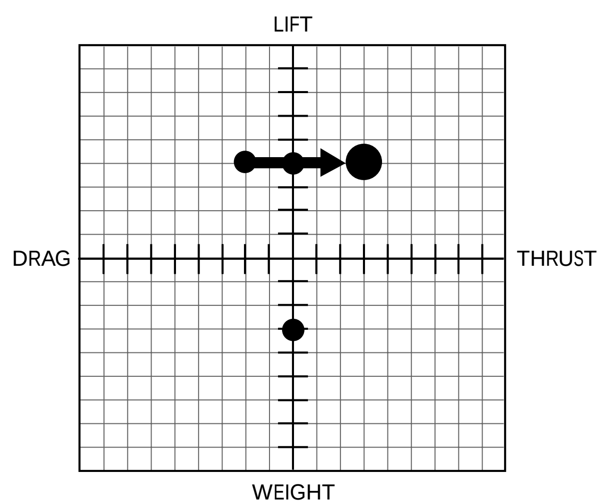
Step 2: Up 7



Step 3: Left 2



Step 4: Right 5



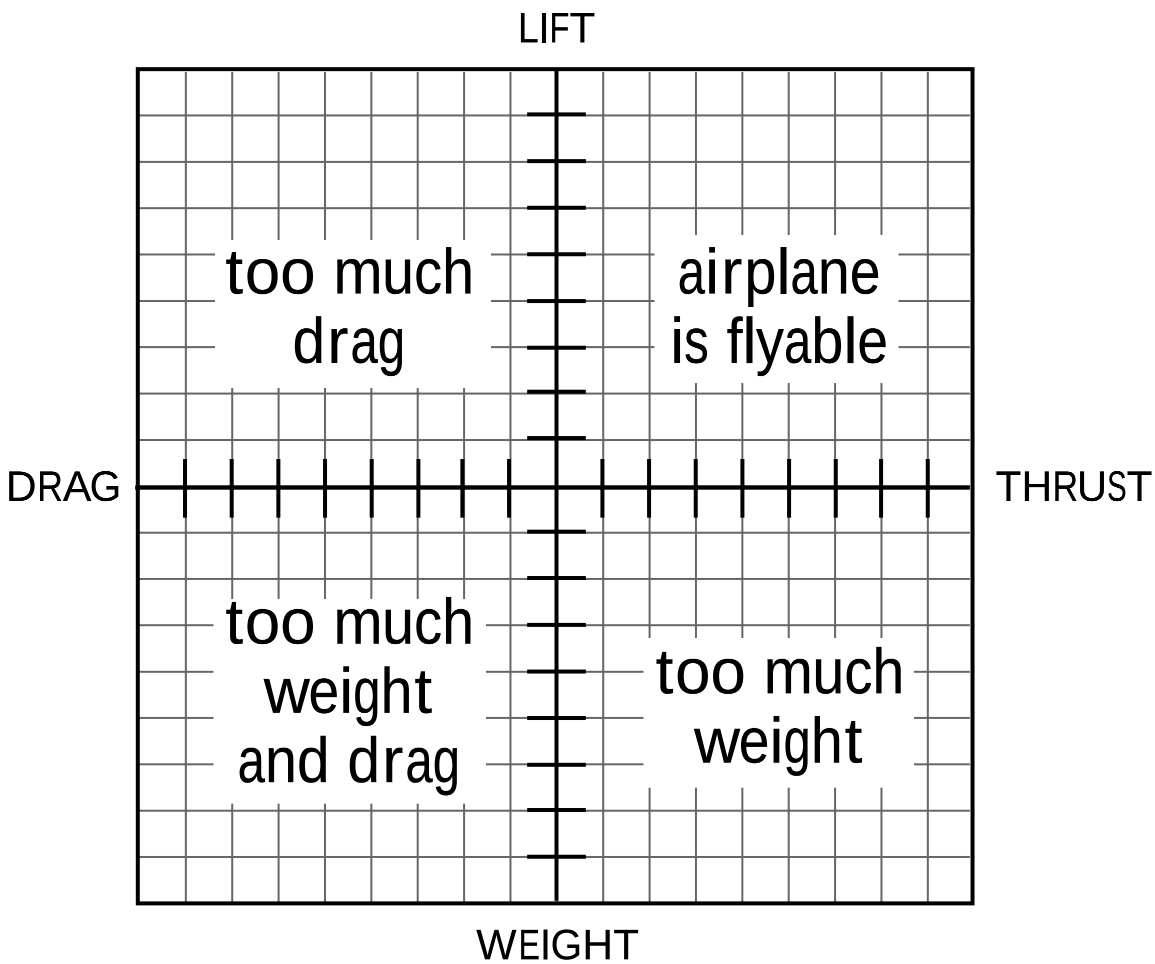
Step 5: Determine whether or not the airplane is flyable.

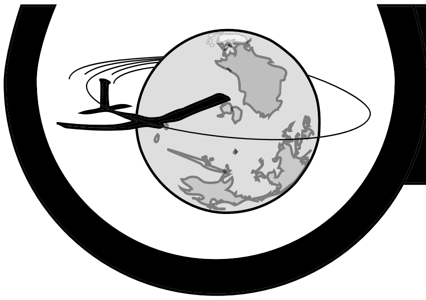
If the net force is plotted in the upper right quadrant, the airplane is flyable.

If the net force is plotted in the upper left quadrant, the airplane is not flyable - it has too much drag.

If the net force is plotted in the lower left quadrant, the airplane is not flyable - it has too much drag and weight.

If the net force is plotted in the lower right quadrant, the airplane is not flyable - it has too much weight.



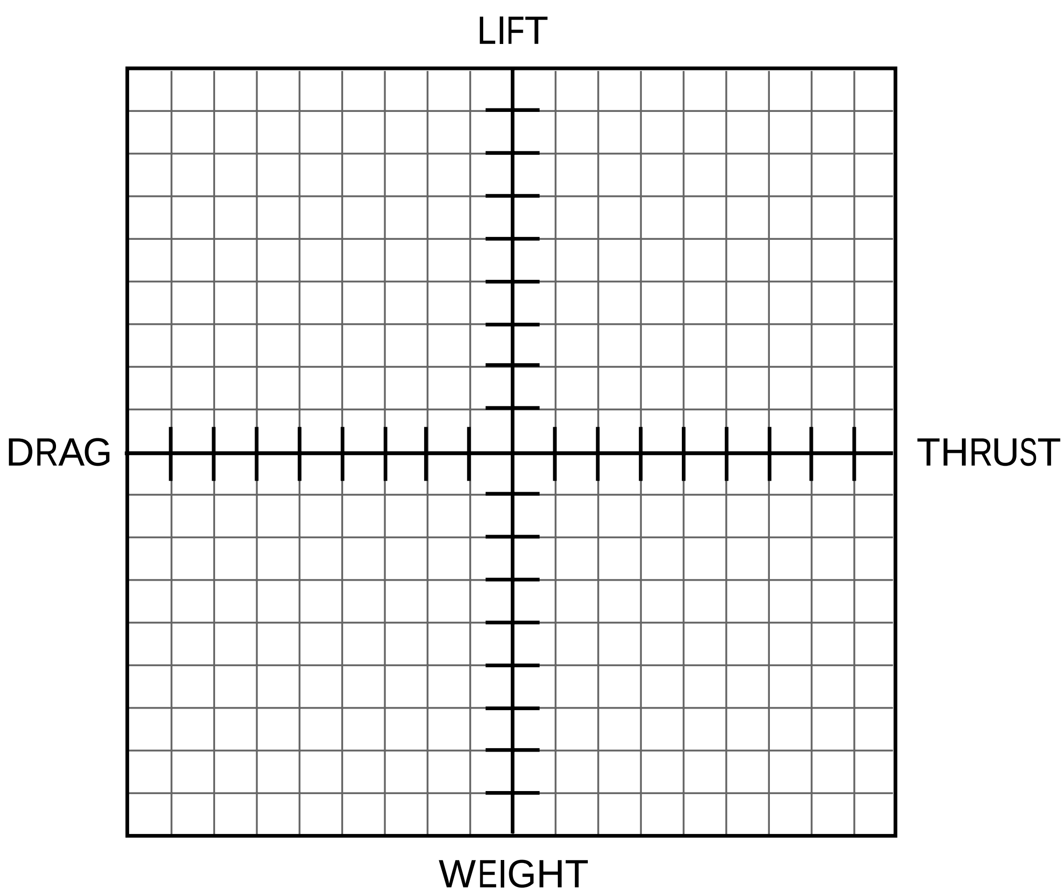


Activity 2: Graphing the Four Forces

Exercise 1

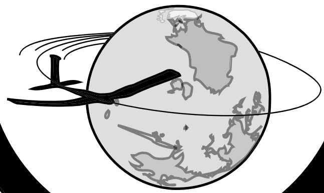
Directions: Use the steps from the previous example to plot the following magnitudes. After you plot the net force, make a decision about whether or not the airplane is flyable.

Weight	**4 units**
Lift	**10 units**
Drag	**2 units**
Thrust	**10 units**



Question 1: This plane is / is not flyable.

Question 2: If it is not, tell what force or forces are too great for the airplane to fly.

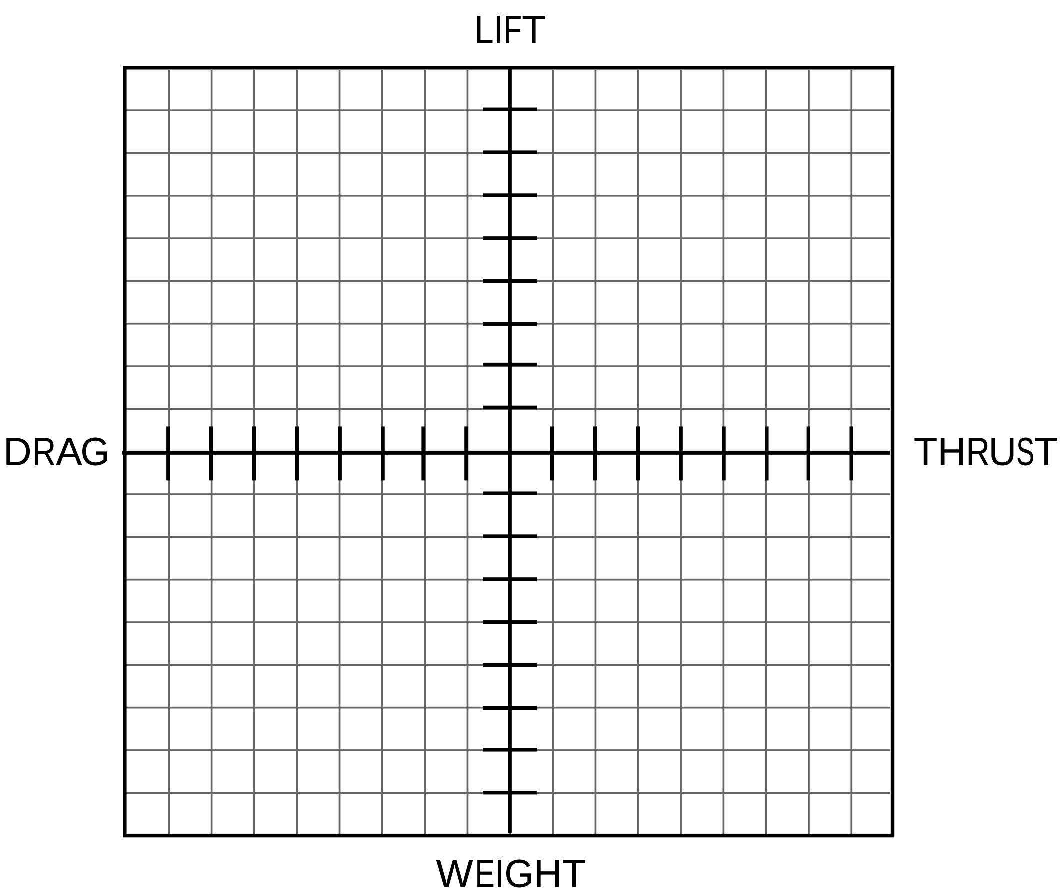


Activity 2: Graphing the Four Forces

Exercise 2

Directions: Use the steps from the previous example to plot the following magnitudes. After you plot the net force, make a decision about whether or not the airplane is flyable.

Weight	**8 units**
Lift	**4 units**
Drag	**6 units**
Thrust	**4 units**



Question 1: This plane is / is not flyable.

Question 2: If it is not, tell what force or forces are too great for the airplane to fly.

Activity 2: Graphing the Four Forces

Exercise 1 – Key

Starting at the origin:

the end of the weight arrow will be at (0,-4)
the end of the lift arrow will be at (0,6)
the end of the drag arrow will be at (-2,6)
the end of the thrust arrow will be at (8,6)

since (8,6) is in the upper right quadrant, the airplane is flyable

Note: the arrows may be drawn in any order, you will always end up at the same place!

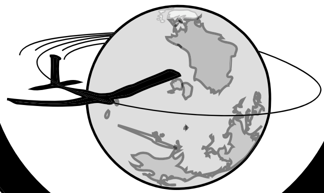
Exercise 2 – Key

Starting at the origin:

the end of the weight arrow will be at (0,-8)
the end of the lift arrow will be at (0,-4)
the end of the drag arrow will be at (-6,-4)
the end of the thrust arrow will be at (-2,-4)

since (-2,-4) is in the lower left quadrant, the airplane is not flyable

both weight and drag are too great



Activity 3: Don't Let It Weigh you Down!

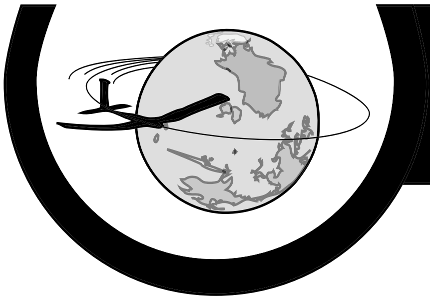
Background: When flying in a lighter-than-air balloon, the load you carry cannot weigh more than what the balloon can carry. Many years ago, through trial and error, methods were developed to accurately predict how much weight a balloon could carry. These methods use four measurements:

- the size of the inside of the balloon and how much gas it can carry - called the "volume" of the balloon
- how much the equipment weighs (including the balloon itself, ropes, gondola, and the gas)
- how much the aeronaut and passengers weigh
- the density of the gas

Say that you are an aeronaut who had planned to take your three cousins on a balloon ride to see the countryside from the air. You also planned to bring a picnic lunch to feed everyone (including yourself!) and, since it is cooler up in the air, you wanted to bring some blankets to keep everyone warm. Just when you had everything ready to go, your cousin from far away paid a surprise visit and wanted to go along also. Given all the facts below, can your cousin go along?

In preparation for the flight, you had calculated the total weight of all the people and equipment you expected to bring along. Your calculations were as follows:

Item	Weight
You (the aeronaut)	80 pounds
Cousin Susanne	65 pounds
Cousin Phil	70 pounds
Cousin Andrew	75 pounds
balloon	250 pounds
gondola	300 pounds
ropes and other equipment	50 pounds
lunch for four people	20 pounds
blankets for four people	8 pounds
Total	**918 pounds**



Activity 3: Don't Let It Weigh you Down!

Your balloon, with brilliant red, white and blue stripes, is as tall as a three-story building and can carry 89,000 cubic feet of gas. You can say that the volume of your balloon is 89,000 cubic feet. You also know from your study of chemistry that the density of helium is .011 pounds per cubic foot.

To calculate how many pounds your balloon could carry, you multiplied the density of the helium by the volume of the balloon.

Density of the helium = .011 pounds per cubic foot

Volume of the balloon = 89,000 cubic feet

.011 pounds per cubic foot X 89,000 cubic feet = 979 pounds

So, based on your calculations, you could carry 979 pounds on your flight. On the list above, where you totaled the weight of all the items you expected to carry, you expected to carry 918 pounds.

Would you be able to fly your three cousins, plus lunch and blankets on your balloon? Yes, because they weighed 918 pounds and you could carry 979!

But what about your cousin Bryant who wanted to come along? Bryant tells you that he weighs 85 pounds. You add Bryant's weight to the total weight of all the items you expected to carry:

918 pounds + 85 pounds = 1,003 pounds

Oh, no! Bryant cannot fly with you! Can you tell why?

That's right! The reason is that with the addition of Bryant the total weight of the items you want to carry becomes too big for the balloon you have.

What can you do so Bryant can go along? Well, you calculated that your balloon could carry 979 pounds. How much over that limit are you if Bryant comes along?

1,003 pounds - 979 pounds = 24 pounds

So, you must remove 24 pounds from your weight list. Obviously you cannot remove the people, the gondola, the balloon or the ropes and other equipment. What's left?

The total weight of the lunch and blankets is:

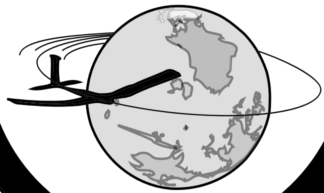
20 pounds + 8 pounds = 28 pounds

So, if you left the lunch and blankets at home, the total weight you need to carry is:

1,003 pounds - 28 pounds = 975 pounds

Without the lunch and blankets the total weight of 975 pounds is less than the 979-pound limit that your balloon can carry. You need to make a decision! Bryant may come along on the flight and the lunch and blankets stay home, or the lunch and blankets come along and Bryant stays home. What will you do?

Use the template on the following page to help you complete the exercises.

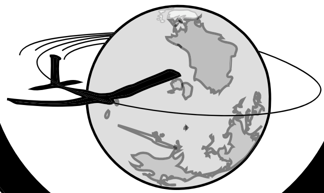


Activity 3: Don't Let It Weigh you Down!

Template

Step 1: Fill in the following weight list table. List the items you want to take along in the left-hand column, and the weight of each item in the right-hand column.

Item	Weight
Total	



Activity 3: Don't Let It Weigh you Down!

Step 2: Calculate the total weight your balloon can carry. Assume that you will fill your balloon with helium gas.

Density of the helium = .011 pounds per cubic foot

Volume of the balloon = ______________________cubic feet

.011 pounds per cubic foot X ___________ cubic feet = ________ pounds

Step 3: Determine whether the balloon can carry all of the items you want to take with you.

Is the total weight of all the items you want to carry greater than, less than, or equal to the weight the balloon can carry? Circle the correct answer.

	is less than	
__________________ pounds	is greater than	_______________ pounds
total weight of items	is equal to	weight balloon can carry

Will the balloon carry all of the items you want to take? ________ (yes/no)

Step 4: If your answer was "yes", then Bon Voyage!

If your answer was "no", then you need to go back to your Weight Table and figure out what can be left at home, then re-calculate your Weight Table and Step 3.

What are some other steps you could take to lighten the load?

Activity 3: Don't Let It Weigh you Down!

Exercises

1: Congratulations! You have just bought a brand new balloon! Your new balloon weighs 200 pounds, the gondola weighs 300 pounds and the ropes and other equipment, 75 pounds. You'd like to take your Aunt and Uncle along for a ride. Your Aunt weighs 110 pounds and your Uncle weighs 160 pounds. You weigh 90 pounds. Your Aunt's favorite candy is chocolate truffles, so you want to bring along a 5-pound box of candy for her. The volume of your balloon is 86,000 cubic feet. Can your balloon carry all the people, equipment and candy you want to carry?

2: The National Weather Service (NWS) often launches balloons to carry instruments into the atmosphere. One day, during mid-August, radar detects a huge storm brewing. The NWS needs to send a balloon up to help them figure out if the storm is really going to be as big as it appears. The balloon will not have any passengers - only instruments will be on board. The instruments weigh 335 pounds. The gondola weighs 105 pounds. Are there any other weights that you need? If so, go back to the very first example problem and choose what you need from the weight table. Next, decide what size balloon you need to launch the instruments.

3: You and a friend are going to give a birthday party for one of your classmates. You want to decorate with lots of balloons. You go to the store and buy a package of 100 different colored balloons. The volume of each balloon in the package is 9 cubic feet. How many pounds of helium must you buy to fill up all the balloons?

If the helium comes in 3-pound canisters, how many canisters must you buy?

Activity 3: Don't Let It Weigh you Down!

Exercises - Key

1: Congratulations! You have just bought a brand new balloon! Your new balloon weighs 200 pounds, the gondola weighs 300 pounds and the ropes and other equipment, 75 pounds. You'd like to take your Aunt and Uncle along for a ride. Your Aunt weighs 110 pounds and your Uncle weighs 160 pounds. You weigh 90 pounds. Your Aunt's favorite candy is chocolate truffles, so you want to bring along a 5-pound box of candy for her. The volume of your balloon is 86,000 cubic feet. Can your balloon carry all the people, equipment and candy you want to carry?

weight of all people, etc. = 940 pounds
.011 lbs/cubic foot X 86,000 cubic feet = 946 lbs
your balloon can carry everything

2: The National Weather Service (NWS) often launches balloons to carry instruments into the atmosphere. One day, during mid-August, radar detects a huge storm brewing. The NWS needs to send a balloon up to help them figure out if the storm is really going to be as big as it appears. The balloon will not have any passengers - only instruments will be on board. The instruments weigh 335 pounds. The gondola weighs 105 pounds. Are there any other weights that you need? If so, go back to the very first example problem and choose what you need from the weight table. Next, decide what size balloon you need to launch the instruments.

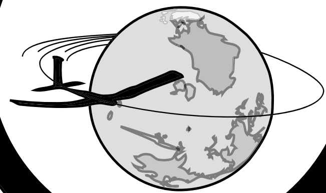
from example table: balloon = 250 lbs; ropes, etc. = 50 lbs
total weight = 740 lbs
740 lbs / .011 lbs/cubic foot = 67,273 cubic feet

3: You and a friend are going to give a birthday party for one of your classmates. You want to decorate with lots of balloons. You go to the store and buy a package of 100 different colored balloons. The volume of each balloon in the package is 9 cubic feet. How many pounds of helium must you buy to fill up all the balloons?

.011 lbs per cubic foot X 900 cubic feet = 9.9 lbs

If the helium comes in 3-pound canisters, how many canisters must you buy?

9.9 lbs / 3 lbs = 3.3 canisters - so you need to buy 4.



Activity 4: Know All the Angles

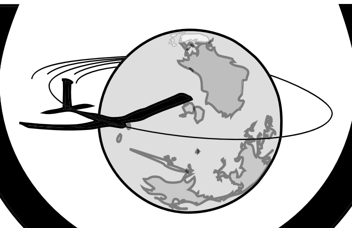
In July of 1901, the Wright Brothers were at Big Kill Devil Hill in North Carolina for more tests on their glider. On one day in particular, July 27th, there were many unsuccessful launches. The glider did get into the air, but it would stall. The stall occurred under the same circumstances for each flight. It happened when the glider slowed its speed. When its speed slowed, the pilot would increase the wing angle to compensate and maintain lift. At a certain critical point when the angle was very steep, the airflow over the top of the wing would become turbulent. This meant that the wing stopped generating lift.

When the brothers returned to Dayton, Ohio, for the winter, they needed to perform some experiments on the angle of attack for the 1901 glider. They used their own wind tunnel to test airfoil shapes.

One day, the boy who lived down the road from the Wright Brothers, young Martin Northrop, brought in a glider he had made and asked if the brothers would test his model. Marty wanted some test data so he could fly his glider more efficiently, and even improve his glider design. Marty had these questions about his glider:

- Which angle of attack would give the glider the greatest amount of lift?
- What cruising angle would be the most efficient for flight?
- What is the stall angle for his glider?

The Brothers agreed to help. They told Marty to return in a few days and they would have the data for him. When Marty returned, he received the results found on the data table on the next page. First, read the section "Understanding Wind Tunnel Test Results" carefully. Then, review the information found on the data table and the graphs. Finally, help Marty find the answers to his questions.



Activity 4: Know All the Angles

Marty Northrop's Glider Wind Tunnel Data Table

Run #	Point #	alpha (deg)	Lift (lbs)	Drag (lbs)	CL	CD	L/D
1	1	0	0.10	0.02	0.14	0.03	5.00
1	2	1	0.30	0.04	0.41	0.05	7.50
1	3	2	0.50	0.05	0.68	0.07	10.00
1	4	4	0.66	0.06	0.89	0.08	11.00
1	5	6	0.88	0.07	1.19	0.09	12.57
1	6	8	1.10	0.08	1.49	0.10	14.67
1	7	9	1.20	0.12	1.62	0.16	10.00
1	8	10	1.00	0.16	1.35	0.22	6.25
1	9	11	0.99	0.24	1.34	0.32	4.13
1	10	12	0.77	0.50	1.04	0.68	1.54
2	1	0	0.40	0.08	0.14	0.03	5.00
2	2	1	1.20	0.16	0.41	0.05	7.50
2	3	2	2.00	0.20	0.68	0.07	10.00
2	4	4	2.64	0.24	0.89	0.08	11.00
2	5	6	3.52	0.28	1.19	0.09	12.57
2	6	8	4.40	0.30	1.49	0.10	14.67
2	7	9	4.80	0.48	1.62	0.16	10.00
2	8	10	4.00	0.64	1.35	0.22	6.25
2	9	11	3.96	0.96	1.34	0.32	4.13
2	10	12	3.08	2.00	1.04	0.68	1.54

Activity 4: Know All the Angles

Understanding Wind Tunnel Test Results

Runs, Points, Angles, Lift and Drag

The type of wind tunnel test that was run would be called a "sweep test". The glider was run through the same test twice. During the test, the angle of attack of the glider was changed from 0 degrees through to 12 degrees. So for test 1 (Run # 1) there were actually 10 points in the test when data was taken (Point 1 through 10). The test was repeated (Run #2) and at 10 points in the test, data was taken (Point # 1 through 10). For each point in the test, the angle of attack for the glider was changed (alpha: degrees). At each point in the test, measurements were taken for lift and drag. At each point, the amount of lift was measured in pounds (Lift: lbs.) and the amount of drag was measured in pounds (Drag: lbs.).

For example, in Run #1, Point #2 with an angle of attack of 1 degree, Martin's glider generated 3 tenths of a pound of lift. It also created 4 one-hundredths of a pound of drag. Compare that to Run #1 at Point #8 with 10 degrees angle of attack when Martin's glider generated 1 pound of lift and created only 16-hundredths of a pound of drag.

Activity 4: Know All the Angles

Understanding Wind Tunnel Test Results

L over D (L/D)

The values of lift and drag are also shown as a ratio. We call it "L over D" (L/D). If the L/D number is high, then the design being tested can fly efficiently. When an airplane flies efficiently, it is creating the needed lift while creating little drag. This is important to flying because such an airplane can fly farther using less fuel.

The "L/D" column or last column on the right of the chart shows Lift divided by Drag. For example, look at the first line of data (Run #1 and Point #1):

.10 (Lift) **divided** by **.02** (drag) = **5.00** (L/D)

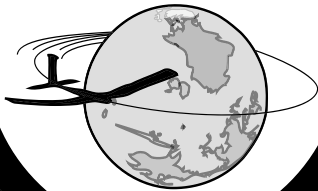
This ratio tells us how efficiently lift is being made. Let's look at four basic ways the lift and drag numbers could turn out in a test:

1. If the lift number is high and the drag number is low, then we say that L/D is high. That is a good thing!

2. If the lift number is high and the drag number is high, also, then we say that L/D is low and that the design is less efficient. That's not a very good thing! We would need to redesign the airplane to lower the drag number. Or, we can increase the thrust by putting on larger (and heavier) engines.

3. If the drag number is high and the lift number is low, then we say that the L/D is real low. That means the design is very inefficient. That is not a good thing!

4. If the lift number is low and the drag number is low, then we say that the L/D is low and that it is not an efficient design. That's not a very good thing! We would need to redesign the airplane to increase its lift.



Activity 4: Know All the Angles

Understanding Wind Tunnel Test Results

<u>Coefficient of Lift = CL</u>

Knowing the amount of lift and drag that is generated by the design being tested is important. Just knowing how much lift is made though is not enough. We need to know other things, too. The amount of lift that is made during a test depends on many things. Here are some examples:

1. A big wing makes more lift than a smaller wing.
2. Flying faster makes a wing produce more lift.
3. Air of greater density will be able to make more lift than air of lesser density.

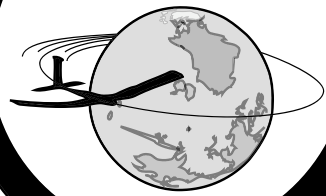
By combining all these variables into one number, researchers can compare test results more easily. This is done for lift by combining the following measurements:

1. Amount of lift (measured in pounds)
2. Wing area (measured in square feet)
3. Speed (measured in feet per second)

This one number is called the “coefficient of lift” or “CL”. The mathematical equation used to get this one number (CL) is given below:

$$\mathbf{CL} = \frac{\text{Lift}}{\text{Wing area} \ \mathbf{X} \ \text{air density} \ \mathbf{X} \ \text{speed} \ \mathbf{X} \ \text{speed} \ \mathbf{X} \ 0.5}$$

This number is used to compare the airplane’s flight performance without having to run more tests. This means, for example, that a small-scale model of the space shuttle being tested in a wind tunnel will have the same CL as the full-size shuttle flying through the upper atmosphere.



Activity 4: Know All the Angles

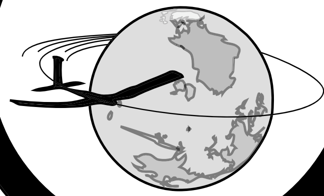
Understanding Wind Tunnel Test Results

<u>Coefficient of Drag = CD</u>

The CD is the coefficient of drag. It's another calculation that is very important in wind tunnel tests. The CD includes the same measurements as CL except it uses drag instead of lift. This number can be used to make comparisons in much the same way as the CL.

Researchers make greater use of CL and CD because they work with models when performing wind tunnel tests. By converting a lot of the data to numbers like CD, researchers can compare data more accurately. Researchers can compare data from different tests. They can compare data of models to full size aircraft. And they can compare data from different aircraft designs. Researchers can then make predictions about how the model will fly based upon the CL and the CD.

Now that you have some insight into what the data means, help Martin Northrop answer some questions using the data table and the graphs that show the results of the tests.



Activity 4: Know All the Angles

Activity Sheet # 1

Directions: Use the data table below to help Martin Northrop answer his questions.

Run #	Point #	alpha (deg)	Lift (lbs)	Drag (lbs)	CL	CD	L/D
1	1	0	0.10	0.02	0.14	0.03	5.00
1	2	1	0.30	0.04	0.41	0.05	7.50
1	3	2	0.50	0.05	0.68	0.07	10.00
1	4	4	0.66	0.06	0.89	0.08	11.00
1	5	6	0.88	0.07	1.19	0.09	12.57
1	6	8	1.10	0.08	1.49	0.10	14.67
1	7	9	1.20	0.12	1.62	0.16	10.00
1	8	10	1.00	0.16	1.35	0.22	6.25
1	9	11	0.99	0.24	1.34	0.32	4.13
1	10	12	0.77	0.50	1.04	0.68	1.54
2	1	0	0.40	0.08	0.14	0.03	5.00
2	2	1	1.20	0.16	0.41	0.05	7.50
2	3	2	2.00	0.20	0.68	0.07	10.00
2	4	4	2.64	0.24	0.89	0.08	11.00
2	5	6	3.52	0.28	1.19	0.09	12.57
2	6	8	4.40	0.30	1.49	0.10	14.67
2	7	9	4.80	0.48	1.62	0.16	10.00
2	8	10	4.00	0.64	1.35	0.22	6.25
2	9	11	3.96	0.96	1.34	0.32	4.13
2	10	12	3.08	2.00	1.04	0.68	1.54

1. For Test #1 looking at points #1 – 10, what is the difference in lift between the greatest weight and the lowest weight?

2. For Test #2 looking at points #1 – 10, what is the difference in drag between the lowest weight and the highest weight?

3. Which angle of attack (alpha) overall generated the greatest amount of lift?

4. Which angle of attack (alpha) overall generated the least amount of drag?

Activity Sheet # 1 (continued)

5. Which angle of attack (alpha) overall generated the lowest L/D?

6. Which angle of attack (alpha) overall generated the greatest L/D?

7. For Run #1, looking at Points # 1-10, find the greatest L/D. __________

8. For Run #1, looking at Points #1-10, give the number following the greatest L/D. __________

9. Using the information from questions 7 and 8, what is the angle of attack (alpha) at which the glider is not generating as much lift as it was before?

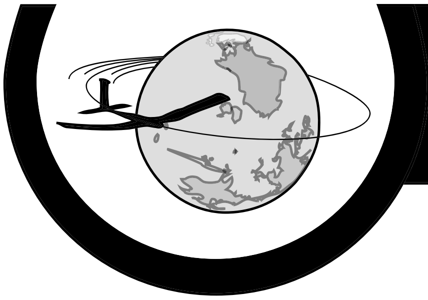
10. Overall, which angle of attack (alpha) generates the greatest CL?

11. Overall, which angle of attack (alpha) generates the lowest CL?

12. Overall, which angle of attack (alpha) generates the greatest CD?

13. Overall, which angle of attack (alpha) generates the lowest CD?

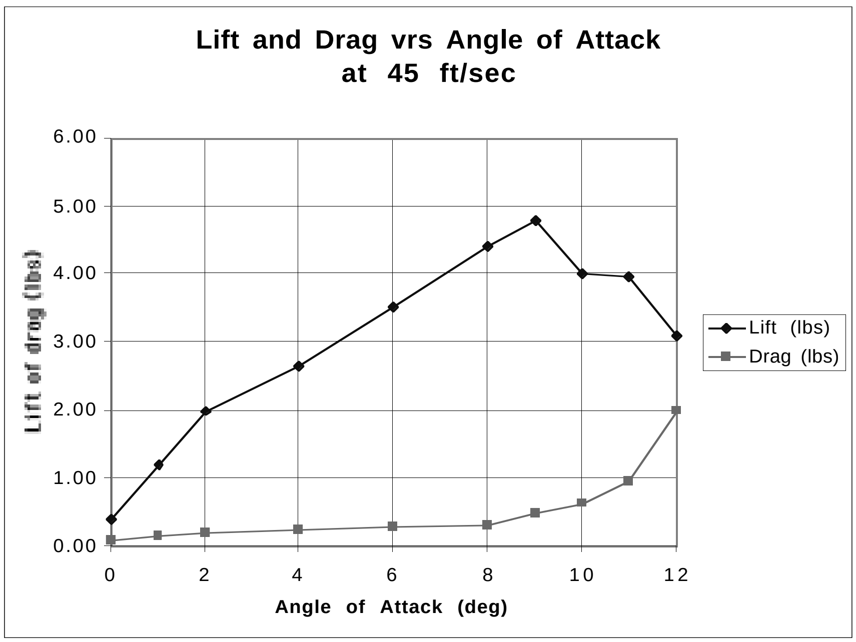
14. Overall, which angle of attack (alpha) do you think is the stall angle? Explain your reasoning. (Hint: Look over your answers for questions 7 – 12.)



Activity 4: Know All the Angles

Activity Sheet # 2

Directions: Use the graph below to help Martin Northrop answer his questions. This is a graph showing the data collected on Martin's glider. It displays the lift and the drag at different angles of attack when the glider is flying at 45 feet per second.



1. On the graph above, circle the point at which the most lift is being generated.

   A. How many pounds of lift are being generated? ____________

   B. What is the angle of attack? ____________

2. On the graph above, draw a box around the point at which the most drag is being generated.

   A. How many pounds of drag are being generated? ____________

   B. What is the angle of attack? ____________

3. List the 4 angles of attack during which the same amount of drag is being generated.

Activity Sheet # 2 (continued)

Directions: Use the graph from page 9 to help Martin Northrop answer his questions.

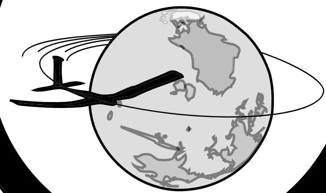
4. At which angle of attack does drag begin to steadily increase?

5. At which angle of attack does lift peak, and then begin to steadily decrease?

6. What do you think is happening between 9 and 10 degrees angle of attack?

7. A good cruise angle is one in which the design has the greatest difference between lift and drag. <u>Doing some subtraction, calculate which angle of attack would most likely be the most efficient cruise angle?</u> (Hint: you don't have to subtract the drag from lift of each angle of attack. Narrow the field, by looking for the biggest gap between lift and drag and then doing some subtraction.)

8. At which angle of attack does lift begin to steadily increase?



Activity 4: Know All the Angles

Activity Sheet # 1 – Key

Directions: Use the data table below to help Martin Northrop answer his questions.

Run #	Point #	alpha (deg)	Lift (lbs)	Drag (lbs)	CL	CD	L/D
1	1	0	0.10	0.02	0.14	0.03	5.00
1	2	1	0.30	0.04	0.41	0.05	7.50
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2	9	11	3.96	0.96	1.34	0.32	4.13
2	10	12	3.08	2.00	1.04	0.68	1.54

1. For Test #1 looking at points #1 – 10, what is the difference in lift between the greatest weight and the lowest weight?

   1.20 - .10 = 1.10

2. For Test #2 looking at points #1 – 10, what is the difference in drag between the lowest weight and the highest weight?

   4.80 - .40 = 4.40

3. Which angle of attack (alpha) overall generated the greatest amount of lift?

   9 degrees

4. Which angle of attack (alpha) overall generated the least amount of drag?

   0 degrees

Activity Sheet # 1 – Key (continued)

5. Which angle of attack (alpha) overall generated the lowest L/D?
   12 degrees

6. Which angle of attack (alpha) overall generated the greatest L/D?
   8 degrees

7. For Run #1, looking at Points # 1-10, find the greatest L/D. *14.67*

8. For Run #1, looking at Points #1-10, give the number following the greatest L/D. *10.00*

9. Using the information from questions 7 and 8, what is the angle of attack (alpha) at which the glider is not generating as much lift as it was before?
   9 degrees

10. Overall, which angle of attack (alpha) generates the greatest CL?
    9 degrees

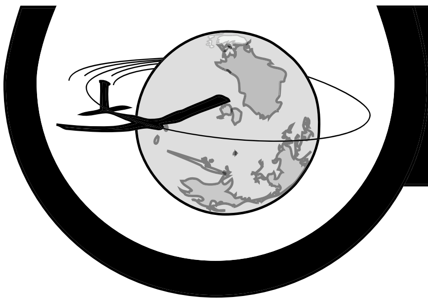
11. Overall, which angle of attack (alpha) generates the lowest CL?
    0 degrees

12. Overall, which angle of attack (alpha) generates the greatest CD?
    12 degrees

13. Overall, which angle of attack (alpha) generates the lowest CD?
    0 degrees

14. Overall, which angle of attack (alpha) do you think is the stall angle? Explain your reasoning. (Hint: Look over your answers for questions 7 – 12.)

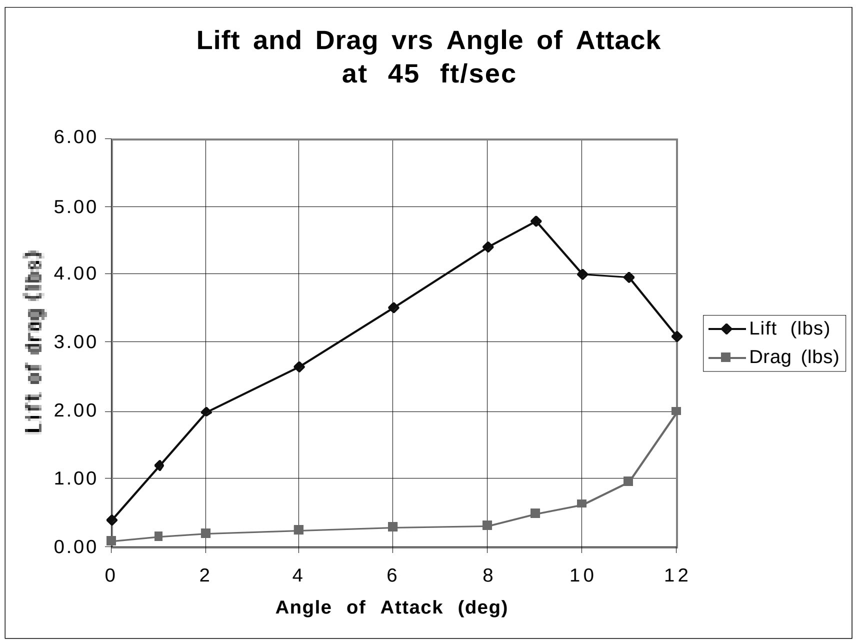
    9 degrees because the model being tested is increasingly generating lift until it gets to 9 degrees and then lift begins to steadily increase.



Activity 4: Know All the Angles

Activity Sheet # 2 – Key

Directions: Use the graph below to help Martin Northrop answer his questions. This is a graph showing the data collected on Martin's glider. It displays the lift and the drag at different angles of attack when the glider is flying at 45 feet per second.



1. On the graph above, circle the point at which the most lift is being generated.

   A. How many pounds of lift are being generated? *4.80*

   B. What is the angle of attack? *9 degrees*

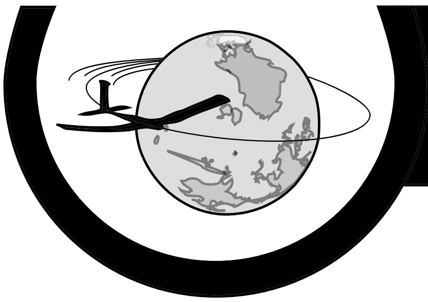
2. On the graph above, draw a box around the point at which the most drag is being generated.

   A. How many pounds of drag are being generated? *2.00*

   B. What is the angle of attack? *12 degrees*

3. List the 4 angles of attack during which the same amount of drag is being generated.

   2, 4, 6, 8



Activity Sheet # 2 – Key (continued)

Directions: Use the graph from page 9 to help Martin Northrop answer his questions.

4. At which angle of attack does drag begin to steadily increase?

   9 degrees

5. At which angle of attack does lift peak, and then begin to steadily decrease?

   9 degrees

6. What do you think is happening between 9 and 10 degrees angle of attack?

   The stall angle has been reached and lift is not being generated as greatly as before.

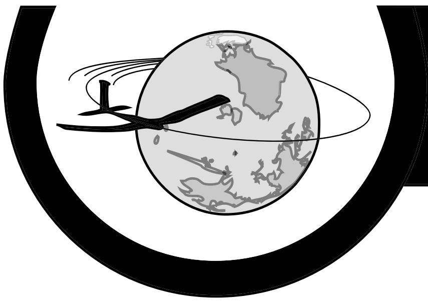
7. A good cruise angle is one in which the design has the greatest difference between lift and drag. <u>Doing some subtraction, calculate which angle of attack would most likely be the most efficient cruise angle?</u> (Hint: you don't have to subtract the drag from lift of each angle of attack. Narrow the field, by looking for the biggest gap between lift and drag and then doing some subtraction.)

<u>8 degrees</u>	*<u>9 degrees</u>*	*<u>10 degrees</u>*
4.40 L	*4.80 L*	*4.00 L*
-.30 D	*-.48 D*	*-.64 D*
4.10	*4.32*	*3.36*

   Somewhere between 8 and 9 degrees

8. At which angle of attack does lift begin to steadily increase?

   1 degree



Activity 5: Expressing Rules for Atmospheric Pressure

Directions: Solve the exponential equations given below to compute various atmospheric pressures.

Introduction

The early work that led to our understanding of the planetary motions and gave us the description of the solar system we know today would have been virtually impossible without the use of logarithms to reduce the labor of computations. Although computers and calculators have replaced logarithms as computational tools, logarithmic and exponential functions are still essential for the study of Earth's atmosphere and rocket propulsion.

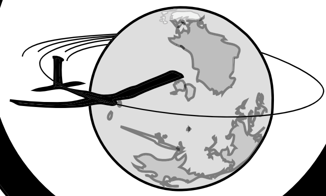
Problem 1

Experimentation and theory have shown that an approximate rule for atmospheric pressure at altitudes less than 80 km is the following: Standard atmospheric pressure, 1035 grams per square centimeter, is halved for each 5.8 km of vertical ascent.

A) Write a simple exponential equation to express this rule.

B) Compute the atmospheric pressure at an altitude of 40 km.

C) Find the altitude at which the pressure is 20% of standard atmospheric pressure.



Activity 5: Expressing Rules for Atmospheric Pressure

Directions: Solve the exponential equations given below to compute various atmospheric pressures.

Problem 2

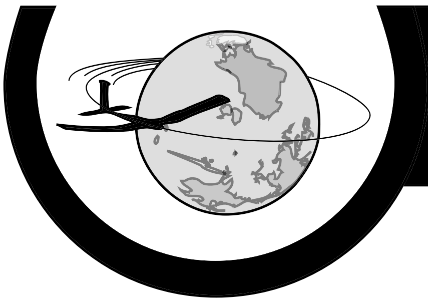
The rule for the variation of atmospheric pressure with height can be written:

$$\mathbf{P} = 1035\,(2)^{-h/5.8}$$

$$= 1035\,(2)^{-0.17h}$$

Atmospheric scientists often use this rule in one of its equivalent forms where the base is 10 or *e*, the base of the natural logarithms, instead of 2.

Find k_1 and k_2 so that $P = 1035\,(2)^{-0.17h} = 1035\,(10)^{-k_1 h} = 1035\,(e)^{-k_2 h}$



Activity 5: Expressing Rules for Atmospheric Pressure – Key

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Introduction

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A) Write a simple exponential equation to express this rule.

Solution

Letting **P** denote atmospheric pressure at altitudes less than 80 km and h the altitude in km, we have

$$\mathbf{P} = 1035\ (1/2)^{h/5.8}\ \text{g/cm}^2$$

B) Compute the atmospheric pressure at an altitude of 40 km.

Solution

From the equation of part A,

$$\begin{aligned} \mathbf{P} &= 1035\ (1/2)^{40/5.8}\ \text{g/cm}^2 \\ &= 1035\ (1/2)^{6.9}\ \text{g/cm}^2 \\ &= 1035\ (0.0084)\ \text{g/cm}^2 \\ &= 8.7\ \text{g/cm}^2 \end{aligned}$$

C) Find the altitude at which the pressure is 20% of standard atmospheric pressure.

Solution

Substituting in the equation of part A gives

$$(0.20)\,(1035) = (1035)\,(1/2)^{h/5.8}$$

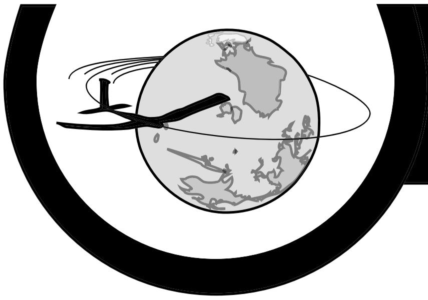
where h is in km, and so $(0.2) = (1/2)^{h/5.8}$

Now, taking logarithms,

$$\text{Log}\,(0.2) = \frac{h}{5.8}\ \log\,(0.5)$$

and

$$h = 5.8\,\frac{\log\,(0.2)}{\log\,(0.5)}\ \text{km} = 5.8\,(2.32)\ \text{km} = 13.5\ \text{km}$$



Activity 5: Expressing Rules for Atmospheric Pressure – Key

Directions: Solve the exponential equations given below to compute various atmospheric pressures.

Problem 2

The rule for the variation of atmospheric pressure with height can be written:

$$\mathbf{P} = 1035\,(2)^{-h/5.8}$$

$$= 1035\,(2)^{-0.17h}$$

Atmospheric scientists often use this rule in one of its equivalent forms where the base is 10 or *e*, the base of the natural logarithms, instead of 2.

Find k_1 and k_2 so that $P = 1035\,(2)^{-0.17h} = 1035\,(10)^{-k_1 h} = 1035\,(e)^{-k_2 h}$

Solution:

We need to find k_1 so that $2^{0.17} = 10^{k_1}$

Taking logarithms,

$0.17 \log 2 = k_1$ or $k_1 = (0.17)(0.301) = 0.051$

For k_2 we have $2^{0.17} = e^{k_2}$ or $k_2 = (0.17) \log_e 2 = (0.17)(0.693) = 0.12$