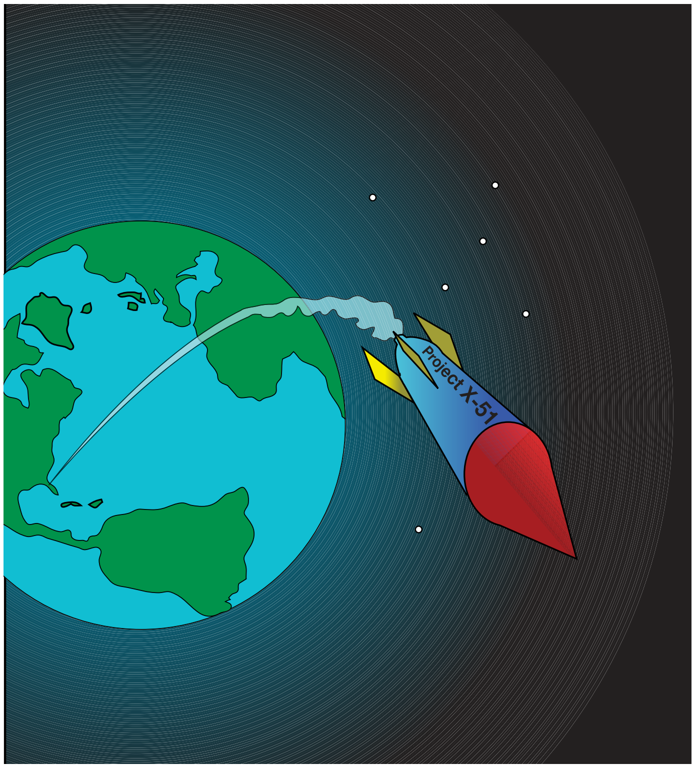


Rocket Activity

Project X-51

Objective

To apply rocket principles and design, construct, test, and launch a water rocket using a real-world problem-solving simulation.

Description

Teams of students will form rocket companies and compete in a commercial endeavor to construct rockets capable of launching payloads, astronaut crews, and even space tourists to Earth orbit. Through a strong interdisciplinary approach, balancing science with technology, engineering, and mathematics,

National Science Content Standards

Unifying Concepts and Processes
- Evidence, models, and explanation
- Change, constancy, and measurement

Science as Inquiry
- Abilities necessary to do scientific inquiry

Physical Science
- Position and motion of objects
- Motions and forces

Science and Technology
- Abilities of technological design

Science in Personal and Social Perspectives
- Risks and benefits
- Science and technology in local challenges

National Mathematics Content Standards
- Number and Operations
- Geometry
- Measurement
- Data Analysis and Probability

National Mathematics Process Standards
- Problem Solving
- Reasoning and Proof
- Communication
- Connections
- Representations

Materials

(All supplies need to be available for each group.)
- 2-liter soft drink bottle
- 1-liter water bottle
- 1 1” long by 3/4” diameter PVC segment
- Aluminum soft drink can
- Scrap cardboard, poster board, and tag board
- Large cardboard panels (about 3X1 feet) for silhouettes
- Duct tape
- Masking tape
- Glue stick
- Low-temperature glue gun
- Modeling clay
- Plastic grocery bag or garbage bag
- String
- Art supplies

(The following are needed for launch day.)
- Water rocket launcher (see page 109)
- Eye protection
- Altitude tracker (see page 80)
- Tape measure
- Water

they will develop a budget, purchase construction materials, and track expenditures while designing and constructing their rocket. They will then have to test the rocket for stability and fill out specification sheets. Finally, the teams will launch their rockets and conduct a cost/benefit (altitude vs. cost) ratio.

Management

Prior to this project students should have the opportunity to design, construct, and launch water rockets using different water volumes and pressures to see the effect these variables have on the altitude. Students should also become proficient in altitude tracking. (See article on page 141.) Doing so will prepare them to employ Newton's laws of motion to maximize the flight properties of their rockets.

Divide your students into teams of three. They will form competing rocket companies in a request for proposal, issued by NASA. Their objective is to construct the best payload/crew/space tourist orbital transport rocket. The team will select roles for each member: Project Manager, Budget Director, and Design and Launch Director. One of the student pages that follows contains badges for each student. The back side of the badges explain the duties for each job. Take digital head shot pictures of each student and print them. Have students trim the pictures and paste them on to their badges prior to laminating them.

The project takes approximately two weeks to complete and includes a daily schedule of tasks. Students may need additional time to complete daily tasks and keep on schedule.

Collect all building materials and copy all reproducibles before beginning the activity. Make several copies of the order forms and blank checks for each group.

Allow enough time on the first day for students to read and discuss all sheets and determine how the sheets apply to the project schedule. Focus on the student score sheet to make sure students understand the criteria used to assess their performance.

By the end of the first day, teams should have decided on the roles each member will play, the name of the company, and started their rocket design.

Background

From the beginning of the space program, rockets, spacecraft, spacesuits, launch platforms, and much more have been built by contractors. The responsibility of the National Aeronautics and Space Administration has been to manage the exploration of the atmosphere and space. When a particular space mission is decided upon, requests for proposals are issued to American industry to build the hardware. Corporate teams propose designs for rockets, space capsules, or whatever else NASA needs for its mission. After a competitive process, the winning corporation is chosen and money is awarded to begin construction. Often, when very large contracts are awarded, the winning companies will select other companies as subcontractors to build component systems. This contracting strategy has worked successfully for NASA for more than 50 years.

Now, NASA is looking to promote new space industries with the capabilities of constructing, launching, and controlling their own rockets. NASA looks forward to contracting with these companies to transport supplies and crew to the International Space Station, permitting NASA to concentrate on the large missions that will push outward the frontiers of space.

Procedure

Refer to the student sheets and the project schedule for details on specific tasks and when they should be performed. The project schedule calls for teacher demonstration on how to make nose cones on day 3 and how to determine the center of pressure and center of mass on day 6.

Discussion

- What did you learn about running a company? How might you have done things differently? What was the most difficult part of the two weeks? What do you understand now that you were not sure or aware of before?
- Why is NASA supporting the development of private launch vehicles?

Assessment

Base the assessment of team performance on their documentation: Project Journal, Silhouette, and Launch Results. Refer to the Project X-51 Score Sheet for details.

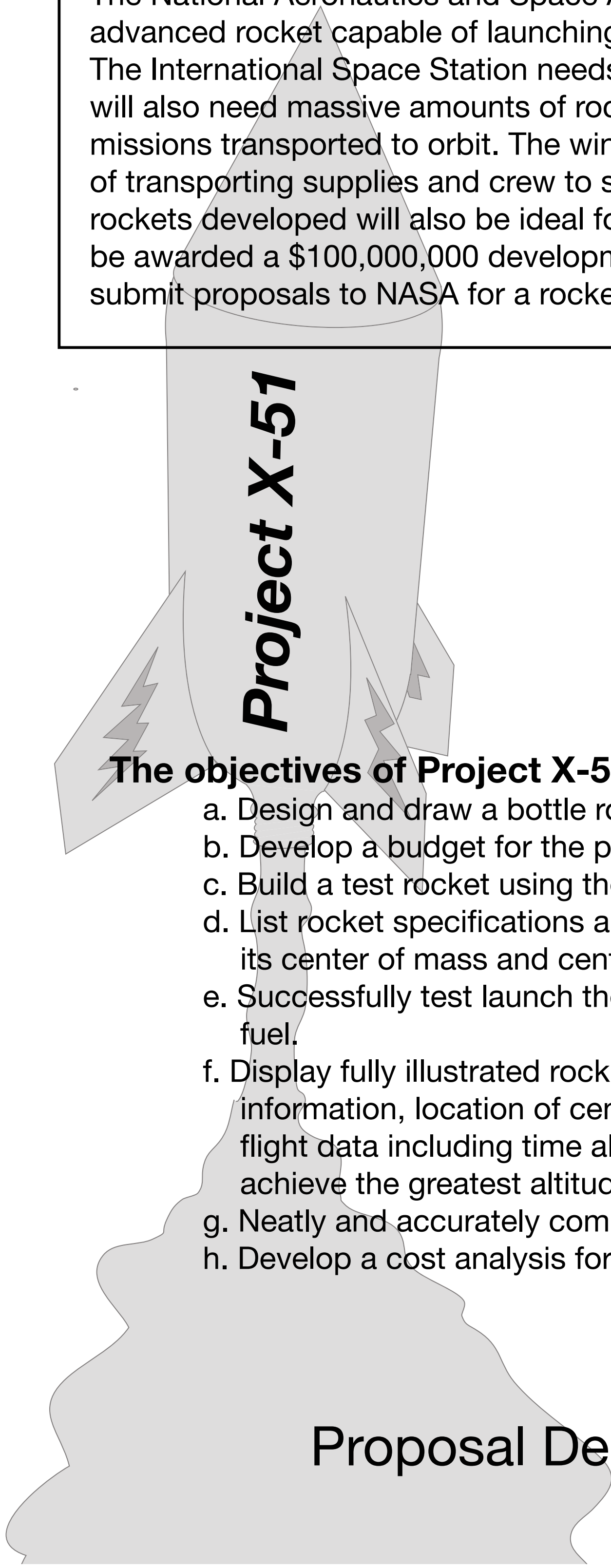
Extensions

- Large space missions often require a wide range of subcontractors across the United States to provide the expertise needed to build the launch and vehicle systems. Learn about the contributions contractors in your state make towards the exploration of outer space. A good place to start is with the Space Grant Consortium for your state. Consortium members (colleges and universities) promote space research and educational activities in their home states and work with local space industries. The following website contains an interactive listing of Space Grant programs by state:

  http://www.nasa.gov/offices/education/programs/national/spacegrant/home/Space_Grant_Directors.html

Request for Proposal

The National Aeronautics and Space Administration is seeking competitive bids for an advanced rocket capable of launching large payloads and crew to Earth orbit at low cost. The International Space Station needs continual crew and cargo resupply flights. NASA will also need massive amounts of rocket fuel and other supplies for furure deep space missions transported to orbit. The winning company will design and test a rocket capable of transporting supplies and crew to space at the best cost. As an added bonus, the rockets developed will also be ideal for use in space tourism. The winning company will be awarded a $100,000,000 development contract. Interested companies are invited to submit proposals to NASA for a rocket capable of meeting the objectives below.



The objectives of Project X-51 are:

a. Design and draw a bottle rocket plan to scale.
b. Develop a budget for the project and stay within the allotted funds.
c. Build a test rocket using the budget and plans developed by the team.
d. List rocket specifications and evaluate the rocket's stability by determining its center of mass and center of pressure and by conducting a string test.
e. Successfully test launch the rocket with a 250 gram payload of simulated fuel.
f. Display fully illustrated rocket designs in class. Include dimensional information, location of center of mass and center of pressure, and actual flight data including time aloft and altitude reached. Launch the rocket to achieve the greatest altitude.
g. Neatly and accurately complete a rocket journal.
h. Develop a cost analysis for the rocket and justify its economic benefits.

Proposal Deadline: Two (2) weeks

Project Schedule

Project X-51 Schedule

Day 1

- Form rocket companies.
- Pick company officers.
- Brainstorm ideas for design and budget.
- Sketch preliminary rocket design.

Project X-51 Schedule

Day 2

- Develop materials and budget list.
- Develop scale drawing.

Project X-51 Schedule

Day 3

- Demonstration: nose cone construction.
- Issue materials and begin construction.

Project X-51 Schedule

Day 4

- Continue construction.

Project X-51 Schedule

Day 5

- Continue construction.

Project X-51 Schedule

Day 6

- Demonstration: Find center of mass and center of pressure.
- Introduce rocket silhouette construction and begin rocket analysis.

Project X-51 Schedule

Day 7

- Finish silhouette construction and complete prelaunch analysis. Hang silhouette.
- Perform swing test.

Project X-51 Schedule

Day 8

- Launch Day!

Project X-51 Schedule

Day 9

- Complete post launch results, silhouette documentation.
- Prepare journal for collection.
- Documentation and journal due at beginning of class tomorrow.

Project X-51 Checklist

Project Grading:

50% Documentation - See Project Journal below. Must be complete and neat.
25% Proper display and documentation of rocket silhouette.
25% Launch data - Measurements, accuracy, and completeness.

Project Awards:

USA will award exploration contracts to the companies with the top three rocket designs based on the above criteria. The awards are valued at:

First	$100,000,000
Second	$ 50,000,000
Third	$ 30,000,000

Project Journal:

Check off items as you complete them.

- [ ] 1. Creative cover with members' names, date, project number and company name.
- [ ] 2. Certificate of Assumed Name (registration of the name of your business).
- [ ] 3. Scale drawing of rocket plans. Clearly indicate scale. Label: Top, Side, and End views.
- [ ] 4. Budget Projection.
- [ ] 5. Balance Sheet.
- [ ] 6. Canceled checks. Staple checks on a page in ascending numerical order (3 to a page).
- [ ] 7. Pre-Launch Analysis
- [ ] 8. Rocket Launch Day Log.
- [ ] 9. Score Sheet (part 3).

Badges

Each team member will be assigned specific tasks to help their team function successfully. All team members assist with design, construction, launch, and paperwork. Print the badges and fold them on the dashed lines. Take digital pictures of the teams and paste head shot prints inside the boxes on the front of the badges. Laminate the badges and provide string loops or clips for wearing them.

Cut Out

X-51

Design and Launch Director

Supervises design and construction of rocket. Directs others during launch.

- Submit neat copy of the rocket scale drawing.
- Conduct String Test.
- Record and submit neat copy of the Launch Day Log.
- Arrange for creative report cover.
- Complete silhouette information and display properly in room.
- Assist other team members as needed.

Cut Out

X-51

Budget Director

Keeps accurate account of money and expenses and pays bills. Must sign all checks.

- Arrange all canceled checks in ascending numerical order and staple three to a sheet of paper.
- Check over budget projection sheet. Be sure to show total project cost estimates.
- Check over balance sheet. Be sure columns are complete and indicate a positive or negative balance.
- Co-sign all checks.
- Complete part 3 of the score sheet.
- Assist other team members as needed.

Cut Out

X-51

Project Manager

Oversees the project. Keeps others on task. Only person who can communicate with the teacher.

- Make a neat copy of the team's Rocket Journal.
- Use appropriate labels as necessary.
- Check balance sheet and list of all materials used in rocket construction.
- Co-sign all checks.
- Assist other team members as needed.

State of: ______________________________

Certificate
of
Assumed Name

A filing fee of $50.00 must accompany this form.
Make out the check to “Registrar.”

Filing Date: ____________ **, 20** _____

Project Number: [ ]

State the exact assumed name under which the business will be be conducted:

____

List the name of the officers of the business:

Project Manager ______________________

Budget Director ______________________

Design and Launch Director ______________________

Describe the product of your business:

Project X-51 Budget

Your team will be given a budget of $1,000,000. Use the money wisely, plan well, and keep accurate records of all expenditures. Once your money runs out, you will operate in the “red.” This will count against your team score. If you are broke at the time of the launch, you will be unable to purchase rocket fuel. You will then be forced to launch with compressed air only. You may purchase only as much rocket fuel as you can afford at the time of the launch.

All materials not purchased from the listed subcontractors will be assessed an import duty tax of 20% of the market value. Materials not on the subcontractors list will be assessed an Originality Tax of $5,000.00 per item.

A project delay penalty fee will be assessed for not working on task, lacking materials, etc. The maximum penalty is $300,000 per day.

Approved Subcontractor List		
Subcontractor	**Item**	**Market Price**
Bottle Engine Corporation	2-liter bottle/launch guide 1-liter bottle/launch guide	$200,000 $150,000
Aluminum Cans Ltd.	Can	$ 50,000
International Paper Products	Cardboard - 1 sheet Tagboard - 1 sheet Colored paper - 3 sheets Crepe paper - 1 strip Silhouette panel - 1 sheet	$ 25,000 $ 30,000 $ 40,000 $ 10,000 $100,000
International Tape and Glue Co.	Duct tape (50 cm strip) Masking tape (100 cm strip) Glue stick	$ 50,000 $ 50,000 $ 20,000
Aqua Rocket Fuel Service	1 ml	$ 300
Strings, Inc.	1 m	$ 5,000
Plastic Sheet Goods	1 bag	$ 5,000
Common Earth Corporation	Modeling clay - 100 gm	$ 5,000
NASA Launch Port (rental)	Launch	$100,000
NASA Consultation	Question	$ 1,000

Company Name: ________________

Project X-51 Purchase Order Form

Date: ____________, 20___ Check No. ________ P.O. No: ________

Supply Company Name: ________________

Items Ordered:	Quantity	Unit Price	Cost
		.	.
		.	.
		Total	.

Budget Director's Signature: ________________

Company Name: ________________

Project X-51 Purchase Order Form

Date: ____________, 20___ Check No. ________ P.O. No: ________

Supply Company Name: ________________

Items Ordered:	Quantity	Unit Price	Cost
		.	.
		.	.
		Total	.

Budget Director's Signature: ________________

Company Name: ________________

Project X-51 Purchase Order Form

Date: ____________, 20___ Check No. ________ P.O. No: ________

Supply Company Name: ________________

Items Ordered:	Quantity	Unit Price	Cost
		.	.
		.	.
		Total	.

Budget Director's Signature: ________________

Project X-51 Budget Projection

Company Name: ______________________________

Record below all expenses your company expects to incur in the design, construction, and launch of your rocket.

Item	Supplier	Quantity	Unit Cost:	Total Cost:
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.

Projected Total Cost ______________ .

Keep this stub for your records

Check No:

Date: , 20

To:

For:

Amount:
$

Company Name:

Check No.

Date: , 20

Pay to the Order of:

$

Dollars

National Space Bank

Project Manager Signature:

Budget Director Signature:

For:

⑆30109932 ⑆ 0295110⑈175

Keep this stub for your records

Check No:

Date: , 20

To:

For:

Amount:
$

Company Name:

Check No.

Date: , 20

Pay to the Order of:

$

Dollars

National Space Bank

Project Manager Signature:

Budget Director Signature:

For:

⑆30109932 ⑆ 0295110⑈175

Keep this stub for your records

Check No:

Date: , 20

To:

For:

Amount:
$

Company Name:

Check No.

Date: , 20

Pay to the Order of:

$

Dollars

National Space Bank

Project Manager Signature:

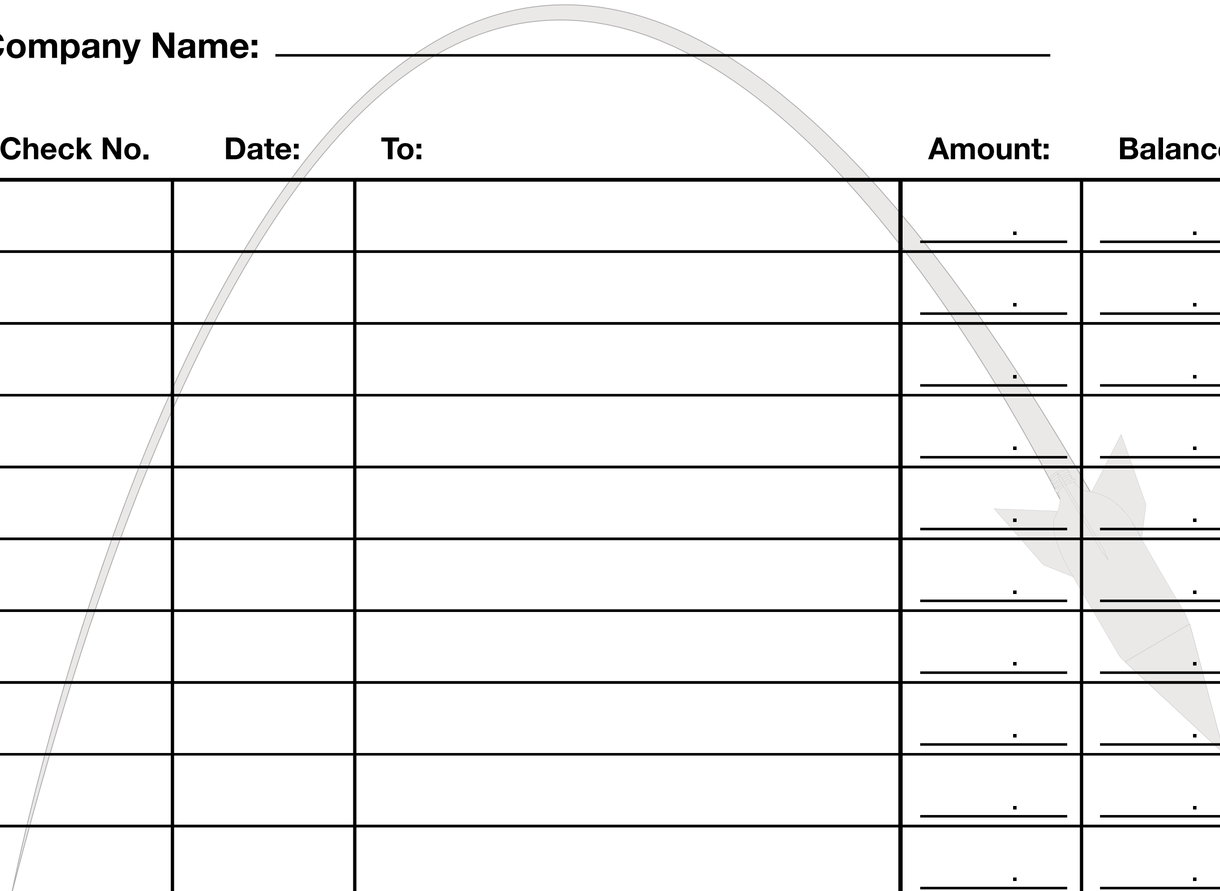
Budget Director Signature:

For:

⑆30109932 ⑆ 0295110⑈175

Project X-51 Balance Sheet

Company Name: ______________________________



Check No.	Date:	To:	Amount:	Balance:
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.
			.	.

Rocket Measurements for Scale Drawing

Project No. ____________

Date: ____________ , 20 ____

Company Name: ______________________________________

Use metric measurements to measure and record the data in the blanks below.
Be sure to accurately measure all objects that are constant (such as bottles) and those you will control (like the size and design of fins). If additional data lines are needed, use the back of this sheet. Mark "NA" in columns that don't apply to the object being measured. For example, diameter and circumference do not apply to fin measurement.

Object	Length	Width	Diameter	Circumference

Using graph paper, draw side, top, and bottom views of your rocket to scale (1 square = 2cm), based on the measurements recorded above. Attach your drawings to this paper. If you make changes during construction, your scale drawing and measurement sheet should reflect them.

Company Name: ______________________________

Project X-51 Scale Drawing

Scale: 1 square = 2 centimeters

Rocket Stability Determination
(Swing Test)

A rocket that flies straight through the air is said to be *stable*. A rocket that veers off course or tumbles is said to be *unstable*. Whether a rocket is stable or unstable depends upon its design.

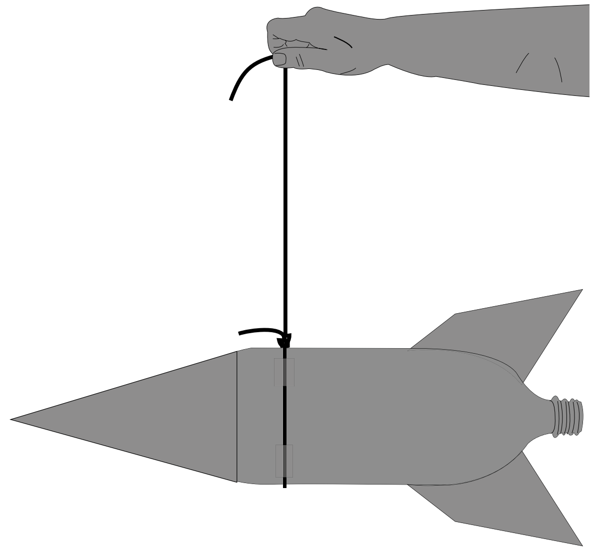
All rockets have two "centers." The first is the *center of mass*. This is a point about which the rocket balances. The picture to the right shows a rocket suspended from a string. The rocket is hanging horizontal. That means that it is balanced. The string is positioned exactly beneath the rocket's center of mass. (This rocket looks like it should really hang with its tail section downward. What you can't see in the picture is a mass of clay placed in the rocket's nose cone. This gives the left side as much mass as the right side. Hence, the rocket balances.)

The center of mass is important to a rocket. If the rocket is unstable, it will tumble around the center of mass in flight the way a stick tumbles when you toss it.

The other "center" of a rocket is the *center of pressure*. This is a point in the shape of the rocket where half of the surface area of the rocket is on one side and half on the other. The center of pressure is different from the center of mass in that its position is not affected by what is inside the rocket. It is only based on the rocket's shape.

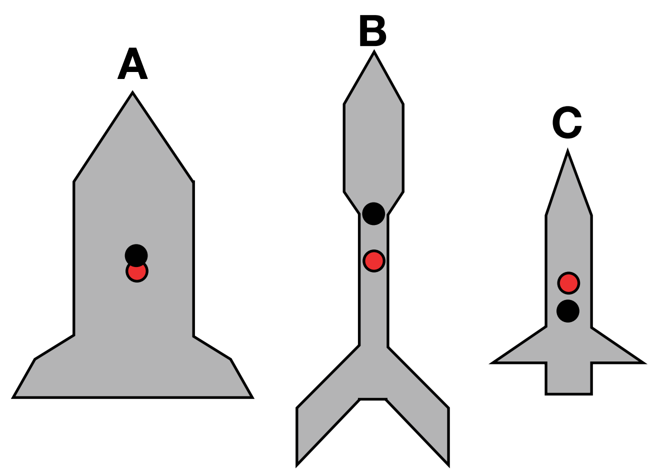
Air strikes the surface of the rocket as the rocket moves. You know what this is like. If you stick your arm outside a car window when it is moving, you feel pressure from the air striking your arm. The center of pressure of a rocket is the middle point. Half of the total pressure on the rocket is on one side of the point and half on the other.

Depending upon the design of the rocket, the center of mass and the center of pressure can be in different places. When the center of mass is in front of the center of pressure (towards the nose end), the rocket is stable. When the center of pressure is towards the front, the rocket is unstable.



When designing a stable rocket, the center of mass must be to the front and the center of pressure must be to the rear.

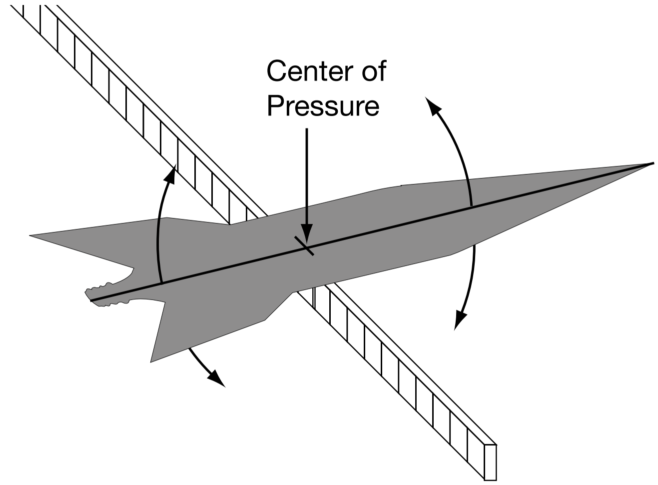
A simple way to accomplish stability is to place fins at the rear of the rocket and place extra mass in the nose. Look at the rockets below. One of them is stable and the others are not. The center of mass is shown with a back dot. The center of pressure is shown with a red dot. Which rocket will fly on course?



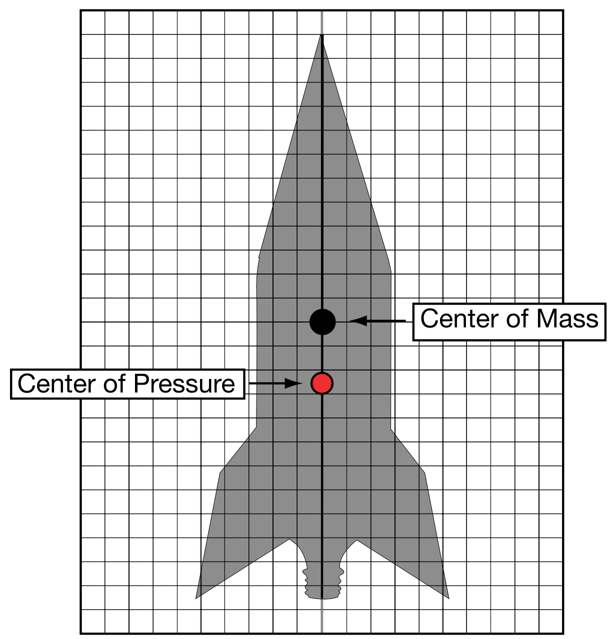
Rocket B is the most stable rocket. Rocket C will definitely tumble in flight. Rocket A will probably fly on a crooked path. Any cross winds encountered by the rocket as it climbs will cause it to go off course.

How to Determine Your Rocket's Stability

1. Draw a scale diagram of your rocket on the graph paper. Make it exactly like the shape of your rocket as seen from the side.
2. Tie a string loop snugly around your rocket so that you have one long end to hold. Except for the water needed for launch, your rocket should be set up exactly as it will be during launch.
2. Slide the loop until the rocket hangs horizontally. When it hangs horizontally, the string is at the rocket's center of mass. Mark that spot in the middle of your rocket on the scale diagram. Use a black dot.
3. Cut out a silhouette of your rocket from a piece of cardboard. Make it <u>exactly the same shape and size</u> of your rocket as seen from the side.
4. Balance the silhouette on the edge of a ruler. The center of pressure of your rocket is where the ruler is located. Mark that spot in the middle of your rocket on the scale diagram. Use a red dot.
5. If the center of pressure is before (towards the rocket's nose) the center of mass, add some additional clay to the rocket OR increase the size of the fins. Repeat the tests until the center of mass is in front.
6. Verify your design results by conducting a swing test. Balance the rocket again with the string. Use a couple of pieces of masking tape to hold the string loop in position.
7. Stand in a clear area and slowly start the rocket swinging in a circle. If the rocket is really stable, it will swing with its nose forward and the tail to the back.

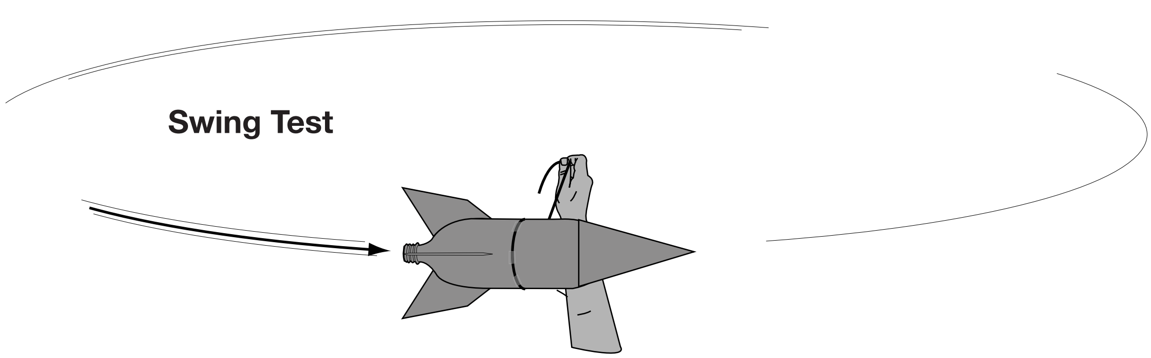


Scale Diagram



In flight, the rocket will try to tumble around its center of mass. If the center of pressure is properly placed, the rocket will fly straight instead. More air pressure will be exerted on the lower end of the rocket than on the upper end. This keeps the lower end down and the nose pointed up!

Swing Test



Project X-51

-00:00:10

Pre-Launch Analysis

Company Name: ______________________ **Project No.** [ ]

Project Manager: ______________________

Design and Launch Director: ______________________

Budget Director: ______________________

Rocket Specifications

Total Mass: ________ g

Total Length: ________ cm

Width (widest part): ________ cm

Circumference: ________ cm

Number of Fins: ________

Length of Nose Cone: ________ cm

Volume of Rocket Fuel (H_20) to be used on launch day: ________ ml

---

Rocket Stability

	Center of Mass (CM)	**Center of Pressure (CP)**
Distance from Nose:	________ cm	________ cm
Distance from Tail:	________ cm	________ cm

Distance of CM from CP: ________ cm

Did your rocket pass the String Test? ________

Flight Day Log

Date: ____________, 20_____

Project No. [   ]

Time: ____________________

Company Name: ______________________________________

Launch Director: ______________________________________

Weather Conditions: ____

____

Wind Speed: ___________ mph Wind Direction: ______________

Air Temperature: ________ °C

Launch Location: ____

Launch Angle (degrees): __________________ Launch Direction: ___________

Fuel (Water) Volume: _________ ml Pressure: ________ psi

Altitude Reached: ___________ m

Evaluate your rocket's performance:

Recommendations for future flights:

Project X-51 Score Sheet

Total Score: [ ]

Project No. ____________

Date: ____________ , 20____

Company Name ______________________

Part 1: Documentation = 50% of project grade

Neatness ____________ Completeness ____________

Accuracy ____________ Order ____________

On Time ____________ Score: [ ]

Part II: Silhouette = 25% of project grade

Neatness ____________ Completeness ____________

Accuracy ____________ Proper balance ____________

Correct use of labels Score: [ ]

Part III: Launch Results = 25% of project grade (teams complete this section)

a. Rocket Altitude ____________ Rank ____________

b. Expenditures and Penalty Fees ____________
(Check total from Balance Sheet)

c. Final Balance ____________
(New Balance on Balance Sheet)

d. Efficiency (Cost/meter) ____________
(Divide investment (b) by Rocket Altitude (a)

e. Contract Award ____________

f. Profit ____________
(Contract Award (e) minus Expenditures (b)

Score: [ ]