Model Rockets and Engineering Design

Summary: Students will gain experience with polymer matrix fiber composites, composite production, and the tradeoffs inherent in the engineering design process by designing, building and launching their own model rocket. Composite materials are created via hand layup and vacuum assisted resin transfer (VARTM). Students gain valuable experience in design, teamwork, working with a variety of tools, and following complex instructions. For the instructor, a starting familiarity with VARTM is helpful. A starting familiarity with model rockets is helpful but (I promise) not necessary. The project is best done in groups of 3-4 students and can be structured as a competition.

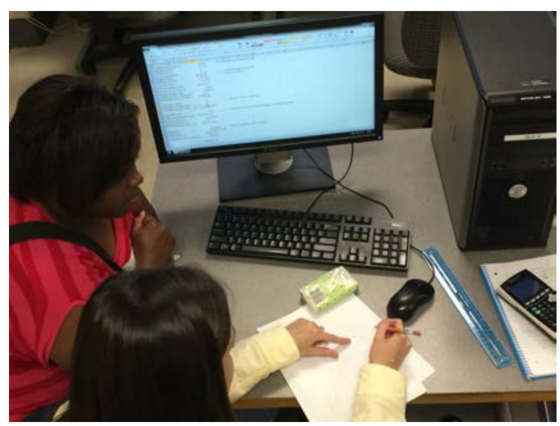
Time period: 1-3 hours per day for five days

Age group: High school (can easily be adapted for undergraduate students)

Resources included in this package:

- Powerpoint slides: Introduction to Composite Materials, Introduction to Rocketry and Project Description
- Excel spreadsheet: rocket height and cost calculations
- Handouts: team rocket design worksheet, rocket assembly instructions
- SolidWorks instructions: step-by-step guide to creating a nose cone
- Rocket height recording and judging sheet

Day 1: Introduction and Rocket Design



Introduce the students to composite materials and model rockets. Describe the project. Break students into groups and have them use the Excel spreadsheet to consider the impact of different design choices on the weight and cost of their rocket. At the end of a set time, they will need to have completely filled out the design sheet. With high school students, it is helpful to have some instructors or undergraduate students circulating while the teams deliberate to keep them on the right track and make sure their design choices are meeting all of the constraints. Students will need about an hour to design their rockets.

Materials:

- Powerpoint slides: *Introduction to Composite Materials, Introduction to Rocketry and Project Description*
- Excel spreadsheet: rocket height and cost calculations
- Computers (one per team)
- Printouts: Team rocket design sheet

Source: Dr. Amber Genau, University of Alabama at Birmingham (2021) https://nanohub.org/resources/35070

- Rulers
- Writing utensils

Adaptation for undergraduate students: If you are doing this activity with undergraduate students and have enough time, make them do the calculations themselves instead of providing the Excel spreadsheet. Ask for at least three different design options, and an explanation of why they selected their final design.

Optional activity: Have each group describe and defend their design choices. One member of the group should stand up and give a small presentation about what choices they made and why. This activity can be included in the competition by having the participants vote for the group that made the most convincing presentation.

Optional activity: In the real world, prices change and there are sometimes shortages of raw materials. Tell the students that (for example) three of the groups have elected to use a body tube made of carbon fiber, but a worldwide shortage of carbon fiber has resulted in only one carbon fiber body tube being available. Initially the cost factor for this material was 3x. Now, because of supply and demand, the one available tube will do to whichever group is willing to pay the most for it. Give the affected groups a few minutes to discuss how much the material is worth to them, and then auction it off to the highest bidder.

<u>Day 2: Creating the Composite Materials [and Nose Cones]</u>

Today the students will create their composite components based on their design choices from Day 1 using hand lay-up and vacuum assisted resin transfer (VARTM). It is possible to make either the body tubes or the fins or both from composite materials. Originally we did both, but found that removing the body tubes from the mandrels was difficult, so later changed to only making the fins and using the cardboard body tubes provided with the kits.

For the fins: A sheet of woven fabric large enough to accommodate all of the group's fins should be laid flat on a sheet of thick plastic or glass that has been sprayed with release compound. If the fabric is rather thin, layer two pieces on top of each other (the final product should be rigid). Each group receives a paper cup of epoxy and hardener mixed in appropriate amounts that they must stir well and then brush onto their fabric using a disposable paint brush. Make sure the fabric is completely saturated with resin. When finished, a piece of plastic is laid over the top and secured with tape all the way around. Plastic tubing is used to attach a vacuum pump, which pulls out air bubbles and further forces the resin into the fibers. Let the composite materials cure overnight with the vacuum pump running.

For the body tube: Use a piece of steel tube with the appropriate outer diameter as a mandrel and braided fiber sleeve of appropriate length. Make sure the diameter of the finished product will have exactly the same inner diameter of the kit-supplied tubes, in order for the internal components of the motor mount to fit correctly. Plastic bagging and tape can be used to improvise a vacuum chamber around the mandrel.

Materials:

- Woven fibers of glass, carbon, mixed, and/or Kevlar: flat and/or sleeve
- Two-part resin epoxy and hardener (recommended: West Marine 105 Epoxy with 206 Slow Hardener)
- Disposable mixing containers, stir sticks, paint brushes, disposable gloves
- Safety glasses
- Bagging material, tape, tubing, and vacuum pump(s)

Optional activity: Have students use CAD software to create a model of a nose cone and 3D print it, rather than using the nose cone provided with the rocket kits. With the help of an undergraduate student (or two) who is familiar with the CAD program being used, student groups can be walked through the process of creating an appropriate STL file in around 20 minutes. We find it easiest to have the files printed in our university machine shop, rather than having the students do that themselves, in order for the nose cones to be ready by Day 4. A step-by-step guide to creating the nose cone files using SolidWorks is included in this package. Students can tweak the shape and dimensions to their preference, as long as the bottom part which will slide into the body tube remains the same.

<u>Day 3: Building the Rockets</u>

Today students will assemble their rockets using the composite parts they created on Day 2 and pieces from Estes Big Bertha or Baby Bertha kit (these kits are essentially the same except for the length of the body tube). Each group should have sufficient workspace (at least half a lab table) in a well-ventilated room. A version of instructions modified from the original kit instructions are included with this package, based on years of experience with students building rockets with composite components. The build process takes around two hours for most groups.

Materials:

- Rocket kits with unnecessary parts removed [Estes Big Bertha or Baby Bertha]
- Revised printed directions
- Composite parts from Day 2
- Wood glue
- Two-part epoxy, wooden stir sticks, mixing cups, gloves
- Foam blocks (to hold fins at correct angles while glue is drying)
- Rulers
- Pens, Permanent markers
- Heavy shears for cutting composites
- Sandpaper



Day 4: Decorating the Rockets

The appearance of the rockets is an important component of the competition. If people don't like the way a product looks, they're unlikely to buy it. Provide the students with paint or instruct them to bring it from home. Markers, glitter, and stickers can also be used. This usually takes 45 minutes to an hour. Use the time to finish any construction that didn't get done yesterday, attach the nose cones and/or parachutes if necessary, and double check the following:

- Are the fins sturdily attached? They shouldn't be loose or move back and forth.
- Does the rocket have a launch lug? Is the hole clear of paint and glue? This small piece is attached at the end of the build process and easy for students to forget. A piece of drinking straw can be used to replace a missing lug.
- Does the nose cone pass the two-finger test? The nose cone should not fall out on its own but should be loose enough that you can pull it out of the body tube using only

your thumb and pointer finger. If it's too tight, use sandpaper to reduce the diameter. If it's too loose, use masking tape around the base to increase the diameter slightly.

Materials:

- Paint (spray paint or acrylics both work well)
- Brushes
- Paper towels
- Masking tape
- Sandpaper

Day 5: Launching the Rockets

Today the students will launch their creations. An empty soccer or football field is ideal for this; a large empty parking lot can be used in a pinch. Whenever possible, we invite members of a local model rocketry club to come help with the launch as their knowledge helps the process go more smoothly. Eventually, we built our own multi-rocket launch device, thanks to our department's lab technician and resident electrician. We originally chose B6-2 motors, which are relatively low powered, especially given the large size and heaviness of these rockets. Later, on the recommendation of our rocket club expert, we started including C6-5 rockets. Now, we start with B6-2 or B6-4 engines (difference being a 2 or 4 second delay between the end of the boost charge and the initiation of the ejection charge) and end with a C6-5 for the wow-factor. With the B motors, the rockets go up to a maximum of around 300 feet, with the C motors they can reach heights around 800 feet. Each team gets three launches. The motors and ignition tabs should be placed into the rockets just before launch. Make sure the field is clear and do a proper countdown before each launch! Students will need to repack their parachute with fresh wadding paper after each launch. Have student volunteers go to the edge of the launch field with the altitude finders to calculate the height of each launch. Make sure they understand the trigonometry they need to do to convert their measurements into heights.

We like to invite the students' family and friends to watch the launch and celebrate afterwards with a barbeque lunch. The winners of the rocket competition are announced during lunch, as determined by a combination of maximum height attained, flight characteristics, cost, and appearance (see included judging sheet). We have also sometimes invited university media relations and local press to the launch, creating positive publicity for the program and the department.

Materials:

- Model rocket launching apparatus [launch kits available from Estes; can also be homemade]
- Rocket engines [Recommended: B6-2, B6-4, or C6-5]
- Wadding paper
- Altitude finder (2x) [available from Estes]
- Duct tape (for on-the-field repairs)
- Prizes!

Source: Dr. Amber Genau, University of Alabama at Birmingham (2021) https://nanohub.org/resources/35070





Source: Dr. Amber Genau, University of Alabama at Birmingham (2021) https://nanohub.org/resources/35070