5-E CLASSROOM STEM ACTIVITY:
DESIGNING SPACESHIPS TO FIT THE MISSION: THE ORION VERSUS THE MILLENNIUM FALCON

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FROM RACE CARS TO ROCKETS

BY SUE HAMILTON

CHRIS HOFMANN
ENGINEERING TECHNICIAN
DEGREE: A&P LICENSE, ASSOCIATE DEGREE IN SPECIALIZED TECHNOLOGY
YEARS IN THE INDUSTRY: 5
STEM TYPE: MAKER AND PRODUCER

It is rocket science - but you don't have to be Einstein or earn several degrees in quantum physics to work in the space industry. A STEM career can take off on many different levels for candidates with diverse backgrounds in a rocket manufacturing company.

Meet Chris Hofmann, an engineering technician with Masten Space Systems, Inc., a company located in Mojave, Calif., which develops spacecraft, rocket propulsion hardware, and vertical landing software. Although he started working on race cars and airplanes, his goal was "to work on something bigger and faster." Chris' interest in the space program began early and growing up he remembers he "read every book, magazine, or other article I could get my hands on about the first big era of space exploration in the 60s."

His background as a race car mechanic gave Chris a head start in developing the skills and abilities he needed for a job in the space industry. While still in high school, Chris volunteered on a local professional stock car race team for the experience. He ended up loving it and moved to North Carolina to work for different NASCAR teams, eventually becoming car chief on an Xfinity series team. He worked in a lot of different roles, from building the race cars to serving as a pit crew member.

He eventually moved back home and attended the Pittsburgh Institute of Aeronautics to earn his Airframe and Powerplant (A&P) license. He got a job in Myrtle Beach, S.C., where he worked at a company that stripped planes, then repaired and refurbished them before sending them back to their airlines. His talent was quickly recognized, and Chris was promoted to a lead aircraft tech, which meant that he was responsible for creating a repair plan for each plane, managing the team of mechanics during that repair, and communicating with customers. As Chris explains, "It was a challenge, but it taught me a lot in a hurry and made me become a better leader. My time spent in NASCAR and understanding how to swiftly evaluate and repair race cars helped because I could adapt to anything that was thrown at me."

That ability to adapt came in handy when Chris was recruited by SpaceX and moved to Los Angeles. He started in aviation, then worked on the Merlin Vacuum engine for the second stage of their Falcon 9 rocket. He credits his mechanical skills, along with his troubleshooting abilities and "can-do" attitude for his success on these critical engines. As you can imagine, a career in rocket science isn't boring. "In my two years on the floor at SpaceX, I built over 20 engines, and one of them (used on the DISCOVR mission) is in orbit around the sun!" describes Chris.

When he was ready for a change, Chris found a great opportunity at Masten Space Systems, where he is now the crew chief on their Xodiac Rocket. In this role, he oversees all maintenance and upkeep on the rocket, runs and develops the engine shop, and sets up and manages their new Flight Operations building.

A degree is not mandatory for employment with Masten, but Chris does have an associate degree in specialized technology along with his A&P license. There are other skills that are essential for success, though. As Chris explains, "It's one thing to have the knowledge and do the job, but you can get a lot farther if you can discuss the how and why of what makes a solution better or worse. I find myself sitting down with the engineers a lot lately - they value my past experiences and deep, technical hands-on knowledge when trying to vet out ideas, tools, parts, designs, and manpower requirements."

Chris works with many other people in STEM roles at Masten. Besides all kinds of engineers, such as propulsion, electrical, and aerospace, there are computer-aided draftsmen, programmers, and other technicians. They all work together as a team to develop rockets for the aerospace and defense industries. "The most challenging part," he reports, "is when you have worked really hard for a test, and something unexpected fails ... but at the same time, being able to come back, take it apart, troubleshoot, and explain why we had a failure and prevent it from happening again is one of the best feelings."

The future of the space industry, according to Chris, will be in 3-D printing of tools, parts, and engines. "I think you will see a lot of advancement in printing design, quality, and what we can do (like the refinement of being able to print fittings and such) and that will lead the next revolution of space access." Three-dimensional printing will benefit long-term space missions by allowing manufacture of parts at the space station as easily as on the ground in a quick and efficient manner, according to NASA.

High school students interested in a career in the space industry are encouraged by Chris to investigate all of the smaller space companies in operation "where you can have a really awesome chance to get your hands dirty and learn something from the very start. There are tons of opportunities for people of all fields and backgrounds in the industry right now - and that will only keep going up, so never think you couldn't do it!"

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Here are some ideas for how high school teachers could use this story as a launching point for integrated STEM learning. Our activities follow the 5-E Learning Cycle Model.

Part 1: Engage

1. Have students read the *STEM Jobs* article "From Race Cars to Rockets—A Career Fueled by STEM."
2. Ask students: What jobs are available in the space industry? How has the role of NASA changed recently? What are some recent space flights that have happened? What rockets are planned to be launched in the future? Have you heard about the Orion?
3. Show the video about the Orion spaceship that can be found at edu.STEMjobs.com/teacher-resources.
4. Ask students: What is the purpose of the Orion? What is it being built to do and what kinds of missions will it go on? When will it be launched? What features does it have that are revolutionary? How does it compare to some of the Apollo rockets?
5. Have students read the article that can be found at edu.STEMjobs.com/teacher-resources.
6. Lead a discussion with your students: Think about imaginary spacecraft you've seen on T.V. or in movies. Which is your favorite and why? How do the imaginary spacecraft we see in popular media compare to an actual rocket like the Orion? What are the similarities and differences?

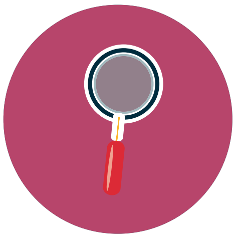
Part 2: Explore

Place the students in groups of 3-4 and give them the following prompt:

1. *Today you will be working in groups to compare the technical specifications of NASA's Orion to the imaginary spacecraft the Millennium Falcon from* Star Wars*. This will help us to understand how engineers design spacecraft by balancing tradeoffs and constraints and critically consider their intended purpose and needs. Your job will be to make a presentation (poster, PowerPoint, Google Slides, etc.) with your group that compares the two spacecraft in terms of as many attributes as you can come up with that you find important or interesting. Some suggestions include:*
   - *Size (length, width, height)*
   - *3-dimensional form and shape*
   - *Weight of spacecraft*
   - *Cargo held*
   - *Crew held*
   - *Habitable volume*
   - *Speed*
   - *Material*
   - *Engine and launch system*
   - *Armaments*
   - *Costs, including upkeep/maintenance*
2. *Helpful resources can be found at* edu.STEMjobs.com/teacher-resources.
3. *Your presentation should use important mathematical and scientific representations like tables, charts, statistics (ratios, rates, etc.), and drawn scale diagrams.*

Part 3: Explain

Have each student group present to the class, explaining the key attributes they contrasted between the two vessels. Ask each group why the two crafts are so different, and use this question to facilitate a discussion about how these vehicles are each designed with a unique purpose in mind. (The Orion is designed to do distant space exploration, while the Millennium Falcon is a cargo/smuggling ship.) These needs lead to different design considerations and technologies. Also highlight the mathematical and scientific representations each group used to compare the two ships, noting which ones are most informative and useful for understanding similarities and differences.



Part 4: Elaborate

1. Have students read the NASA article found at edu.STEMjobs.com/teacher-resources.

2. Have students work in their groups to design a craft either for (1) exploration of the surface of the moon, or (2) creating a human colony on Mars. Groups can choose which design to tackle, but ensure that both designs are addressed. Students must create a scale drawing of the craft on graph paper that includes all key measurements and materials. They must specify how many crew members and how much cargo the ship will hold, including supplies. They also must make a “factsheet” that gives key statistics of their vessel. Encourage students to conduct research on what each of these missions would involve and what ideas have already been generated for spacecraft to accomplish these purposes.

Part 5: Evaluate

1. Conclude the lesson by having students read and discuss the two articles on space vessels for deep space exploration that can be found at edu.STEMjobs.com/teacher-resources.

2. Have each student respond to the following prompt in their science journals: When designing a spaceship for interstellar travel like the Millennium Falcon, what are some key design considerations? How could a ship be successfully designed for this purpose? Do you think it will take 100 years? Do you think it’s worth the high price tag? Why or why not?

Standards Addressed:

Next Generation Science Standards

HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

Common Core State Standards – Math

MP3 Construct viable arguments and critique the reasoning of others.
MP4 Model with mathematics.
MP5 Use appropriate tools strategically.
G.MG.A.3 Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).

Texas Essential Knowledge and Skills – Science

Astronomy.2.H communicate valid conclusions in writing, oral presentations, and through collaborative projects
A.3.B communicate and apply scientific information extracted from various sources such as current events, news reports, published journal articles, and marketing materials
A.3.E describe the connection between astronomy and future careers
A.14.A identify and explain the contributions of human space flight and future plans and challenges

Texas Essential Knowledge and Skills – Math

G.10.B determine and describe how changes in the linear dimensions of a shape affect its perimeter, area, surface area, or volume, including proportional and non-proportional dimensional change
MMA.6.A use similarity, geometric transformations, symmetry, and perspective drawings to describe mathematical patterns and structure in architecture
MMA.6.B use scale factors with two-dimensional and three-dimensional objects to demonstrate proportional and non-proportional changes in surface area and volume as applied to fields