AEROSPACE PALACE ACADEMY, NIGERIA
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LESSON 61: STAR WARS

May the 4th be with you, or may the force be with you if you are reading this at a later date. Like many science fiction stories, Star Wars is a fun way for people to imagine what advanced technology might look like and how that same technology might work. While science fiction is just that–fiction–it uses a lot of concepts based on reality and ideas that can be applied to future engineering projects. Star Wars is a great example of this: while the popular stories set in a galaxy far, far away may be mystical and far-flung, a lot of the vehicles in the Star Wars universe demonstrate engineering principles used in real-world aerospace design.

Next Generation Science Standards (NGSS):

- Discipline: Engineering, Technology, and applications of science.
- Crosscutting Concept: Structure and function.
- Science & Engineering Practice: Asking questions and defining problems.

GRADES K-2

NGSS: Engineering Design: Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.

One example of nonfiction, or real, technology is a new spacecraft that NASA (National Aeronautics and Space Administration) is developing called the Orion. The Orion spacecraft is designed to travel into orbit and beyond. This means, perhaps, a trip to Mars and back!

So, what are some examples of technology ideas in Star Wars that could help improve the design of the Orion spacecraft? You may not know this, but there are a lot of tiny particles in space called *cosmic rays* that can damage a spacecraft and harm people. This is a problem. Some of these particles are made up of stuff, or matter, while others are composed of electromagnetic energy. In Star Wars, the spacecraft have strong hulls and shields. Could this be helpful?

The short answer is yes, some sort of protection is very helpful. Currently, scientists and engineers don't know exactly what effects deep space particles will have on people. So they are constantly experimenting with different materials for hulls and chemical coatings for the outside that will protect both the people and the spacecraft.

GRADES K-2 (CONTINUED)

In the case of protecting people and spacecraft, the shields in Star Wars sure would be nice. While we're not quite there yet, this idea has certainly inspired scientists to try and develop similar technologies. This is one way in which one person's imagination in the form of books and movies has helped to inspire real-life engineers and scientists.

What other questions do you have about protecting people and spacecraft for deep-space travel? Do you have any ideas or observations about the problem as described here?

Suggested Activity: Ask students to draw a model of their own idea for a spaceship. Encourage students to label the different parts of their design and to write a short description. Ask students to think about the problem of space particles, and then ask them to add on some sort of additional protection system to their model.

GRADES 3-5

NGSS: Engineering Design: Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

In addition to shields to protect the spacecraft and its inhabitants from cosmic rays and other hazards, another staple of science fiction is artificial gravity. "Artificial gravity" is especially useful when filming movies because it is so difficult to film zero-gravity scenes convincingly.

In Star Wars, the question of artificial gravity is not even brought up; it is simply assumed. One can do this with fiction: the main purpose is to tell the story about the characters and what they do, not dwell on the technical working details of the things they use.

What, exactly, is gravity? While the answer is probably beyond the reach of elementary school students, they are all familiar with its effects: it pulls things *down*. In fact, *down* is pretty much defined as the direction in which things fall when they are not supported. (You may, as an aside, use a globe to point out that "down" at the North Pole and "down" at the South Pole are in exactly the opposite directions from each other.)

How would a spacecraft create artificial gravity? It turns out that our understanding of gravity as a force (what causes it and how it might be controlled) is embarrassingly weak. The only way we know of to "create" gravity right now is to have a tremendous amount of mass right next to you, exerting a gravitational force in the same way that planets and other celestial bodies do. Of course, this isn't of any practical use for spacecraft; even if we could

GRADES 3-5 (CONTINUED)

create and control that much mass, it would make the spaceship impossible to maneuver. We do not know of any other ways to create gravity (notice that this is not the same thing as saying that no other way exists—Einstein's Theory of General Relativity *could be* wrong about this, although it most likely is not) but it's possible that as scientists learn more about the root causes of gravity, we will discover ways to manipulate it. For now, we can at least *simulate* gravity in space using the "centrifugal force" which results from spinning something around. This is the same force which pushes you into your seat on a rollercoaster or pushes you to the side of a car if it goes around a corner quickly. If we were to construct a round spacecraft, spinning the vehicle would create a sort of artificial gravity that pulled objects to the outside of the spacecraft. Some science fiction spaceships use this: they have large sections that rotate and create an artificial gravity against their outer surface. In fact, this effect was tested on a real spacecraft during the Gemini 11 mission of 1966. The astronauts aboard this mission, Charles "Pete" Conrad and Richard "Dick" Gordon, tethered their space capsule to an unmanned spacecraft (the Agena Target Vehicle) and put the two spacecraft into a slow rotation. Due to some technical difficulties, the astronauts were not able to create much artificial gravity–they achieved about 0.005 G, or 1/200th of our standard gravity on the Earth's surface–but it was enough to demonstrate the concept of creating simulated gravity. You can see some archival footage of this experiment in the following video, starting about 11 minutes in. You may notice some wild gyrations of the two spacecraft as the tether goes slack and snaps taut; this is the problem that complicated the experiment and prevented the astronauts from creating a stronger simulated gravity force.

Suggested Activity: Create some "artificial gravity" of you own by filling a bucket half-full of water. You can then swing the bucket in a vertical circle over your head and down beside you. The water does not fall out of the bucket because the "artificial gravity" (or centrifugal force) from the bucket's motion overcomes the Earth's gravity pulling the water down. (If you have not done this before, you may want to practice outside beforehand).

GRADES 6-8

NGSS: Engineering Design: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

GRADES 6-8 (CONTINUED)

One of the most beloved characters from the Star Wars universe is R2-D2, the plucky little Astromech droid that appears throughout the franchise to save the day. R2-D2 and his spiritual successor BB-8 perform a lot of functions as sort of robotic assistants, but one of their most interesting roles is aboard spacecraft. When starpilots strap into small vehicles–from Obi-Wan Kenobi's Jedi starfighter to Poe Dameron's X-wing–they are always joined by a robotic companion, who rides along and helps with navigation, repairs, communication, and situational awareness. We never see starfighters operating without these robotic assistants; in fact, we can probably conclude that the droids form an integral part of the spacecraft.

This might sound pretty far-fetched, but robotics plays an increasingly important role in how modern aircraft and spacecraft are designed and flown. Of course, we don't have cute droids rolling around and beeping at us, but we do have autonomous (meaning self-reliant, or robotic) systems which allow pilots and astronauts to fly safely and successfully. These systems are collectively called *avionics*, and they range from simple GPS systems to complete autopilots that can navigate and fly vehicles all by themselves.

You may or may not know this, but most airliners are actually flown by autopilots for most of the flight. The autopilot is a computer system–much like a droid–that analyzes how the plane is flying and makes inputs to the controls to keep it flying in the right direction. Early autopilot systems could only handle simple tasks like keeping the airplane flying in a straight line, so human pilots would still have to perform most of the maneuvers. However, modern autopilots can climb, descend, turn in different directions, and even follow directions from a GPS. Today, the only parts of a flight where a pilot is required are takeoff and landing – but even that is changing! The new generation of autopilot systems being developed for aircraft will allow them to land themselves. Similarly, most spacecraft are designed to fly autonomously. In fact, a Russian vehicle called the Buran once flew an entire flight–launch, orbiting the earth, and landing like an airplane–without any humans on board at all.

Another droid-like technology which engineers are currently developing is advanced diagnostic tools for aircraft and spacecraft to use in-flight. Currently, aircraft and spacecraft must be routinely inspected to make sure that there are no parts which have cracked, worn down, or otherwise broken. This can take weeks or months and cost millions of dollars. However, thanks to so-called "smart materials" with built-in electronic sensors, these vehicles may soon be able to monitor their own health as they fly. Just as

GRADES 6-8 (CONTINUED)

R2-D2 can tell Luke Skywalker when parts of his X-wing have been disabled, today's pilots may soon have their aircraft itself tell them when parts of it are broken or in need of maintenance. Some engineers are even looking at materials which can "heal," allowing damaged vehicles to fix themselves as they fly along.

There are plenty of other "sci-fi" capabilities which the avionics systems of aircraft and spacecraft employ. These include navigation (voice-activated GPS), communication (Automatic Dependent Surveillance Broadcast, or ADSB systems), management of complex vehicle systems (Full Authority Digital Engine Controls, or FADEC), and more. Perhaps you can think of further droid abilities which could help real-world pilots and astronauts!

GRADES 9-12

NGSS: Engineering Design: 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.

Laser guns are something of a staple in science fiction stories. They suffer from some real-world problems, though, which may prevent them from becoming practical hand-held weapons for a long time. A laser gun—and indeed most modern weapons—operates by depositing enough energy in a small enough spot quickly enough that the target cannot dissipate it in time. A flying bullet dispenses kinetic energy; a conventional explosive sends chemical energy; a nuclear explosive uses nuclear energy; and a laser transmits electromagnetic energy. All that energy needs to come from somewhere, though, and it is difficult to concentrate the required amount of energy into a weapon small enough and light enough to be held safely by a person. Sending such an intense beam of radiation through the atmosphere will also disrupt the molecules of the various components of the air, heating them up and breaking them down into their constituent atoms, ions, and electrons.

The notoriously bad aim of the Star Wars storm troopers follows an ancient literary trope. It makes what may be its first appearance in Homer's Odyssey where, halfway through Book 22, the goddess Minerva disrupts the suitors' aim as they throw their spears at Odysseus (also known by his Latin name "Ulysses") and his men while allowing the latter to have full effect on the suitors.

GRADES 9-12 (CONTINUED)

Just like laser guns and bad guys who can't aim them, so-called "warp drives" are a classic sci-fi cliché, and Star Wars–with its frequent use of hyperdrives and light-speed travel–is no exception. Warp drives may seem like a silly idea, but they actually represent an important way of dealing with the biggest hurdle to interstellar travel–the massive distances involved–and one which might not be as crazy as it first seems.

After nearly 70 years, manned spaceflight is now almost routine. Hundreds of astronauts have been to space and back, and since 2000, a rotating crew of at least 3 astronauts has permanently inhabited the International Space Station (ISS). Why, then, have we not sent humans any farther than the moon? The reasons are complicated, but physically at least, the biggest challenge is the sheer magnitude of the distances involved. When NASA sent astronauts to the moon during the Apollo program of the 1960s and 70s, it took them about four days to make the trip of about 39,000 kilometers. Our next destination beyond the moon will be Mars–about 225 million kilometers away, which will take astronauts 3-4 *months*. You can already see how long it takes to get anywhere in space–and these are our two closest neighbors! With current technology, sending humans much farther than Mars becomes infeasible–the travel time to get anywhere beyond our solar system would exceed a human lifespan. (Some science fiction stories get around this hurdle by considering *colony ships*—spaceships with whole colonies of people who live on them for generations.) The closest star to our Sun, Proxima Centauri, is 4.2 light-years away (remember, a light-year, which is the distance light can travel in a year, is about ten million *million* kilometers). To put that in perspective, Mars and the Moon are 0.000024 light-years and 0.000000004 light-years away, respectively–meaning that even nearby stars are billions of times farther than we've ever travelled. It's easy to see that these distances are well beyond what human beings could traverse with current technology. Further complicating issues is the fact that travel above lightspeed, or even at lightspeed, is likely to be impossible due to fundamental limits of physics. This is where the idea of a warp drive comes in. As mentioned earlier, warp drives were imagined by science fiction writers as a convenient work-around to these problems without addressing any of the real science behind how they might work. However, in a generation of scientists who grew up watching science fiction shows, some have decided to try to put the concept on a sound theoretical footing.

GRADES 9-12 (CONTINUED)

Although we now expect that it is impossible for an object to move faster than the speed of light, there are no known limits on how quickly space itself can expand and contract. In theory, if we can contract the space in front of us and expand the space behind us, we should be able to move forward–a concept known as the *Alcubierre Drive*, after the physicist who conceived the idea. This might be hard to wrap your head around, but imagine a surfer riding a wave: the surfer isn't moving locally, but is rather riding a small bubble of water which is being pushed forward by a wave. This is the concept of an Alcubierre drive: moving through space in a small bubble that is pushed by disturbances in spacetime. This idea is still *very* far from becoming practical; we know that it should be physically possible, but we have no idea whether or not it is something that can be feasibly implemented on a spacecraft. Right now, scientists–including some at NASA's Johnson Space Center in Houston–are doing experiments to evaluate the idea.

It's likely that some kind of warp drive, if it ever becomes real, will be necessary for humans to ever travel to other stars but for right now, they're a great example of how art and science influence each other.

Sixty Years Ago in the Space Race:

May 1, 1958: As a result of experiments on Explorer I and Explorer III, American scientists announced the discovery of the Van Allen radiation belts surrounding the Earth.