COURSE READINGS

Course Title: Flying Cars and the Future of Transportation

Pointful Education LLC

POINTFUL EDUCATION

Instructors' Guide

Course Title: Flying Cars and the Future of Transportation

Course Description: This course introduces students to the newest and most cutting edge futuristic transportation technologies out there. Students gain familiarity with the history of transportation development and understand a framework with which to evaluate new transportation modes. Then the course dives into 10 different technologies on the horizon. Students examine the technologies, the pros and cons of each mode, and explore potential career paths in these emerging fields.

Note: The below readings are simply the reading texts for each module/unit, but do not include images, embedded videos, podcast, other multimedia, interactive activities, discussion prompts, and assessments that are part of the full online course. Please email contact@pointfuleducation.com to get access to the full course demo in your organization's LMS.

Module 1: Introduction to the Future of Transportation:

Module Description	How different would your life be if your only alternative to walking to your destination was to saddle up a horse and ride there? Before steam engines, when horse transportation was your best option, people probably didn't give it much thought. People saddled up their horses or jumped in their wagons. That was just life! It's only because we now know the convenience of cars and airplanes that the idea of only being able to take a horse seems painfully slow, horribly uncomfortable, and woefully inefficient. What will people 100 years from now say about the transportation of our era? How much more speedy, efficient and safe will transportation be then? This module aims to answer those questions. It will start by reviewing the history of transportation and how key inventions of transportation modes led to big changes in society. It takes a look at where we stand today, including problems with our current infrastructure and transportation systems. Finally, the module introduces some of the newest emerging transportation technologies like flying cars, hyperloop, and driverless cars, just to name a few.
Reading #1	**Making Walking Easier** Think about your shoes, for just a minute. You probably don't give them too much thought throughout the day. They are just something you wear. Think about if you had to walk around without them during the winter or in the blistering heat of summer. Feet coverings were among the first, prehistoric inventions designed to make foot transportation a little more comfortable. Other ancient innovations include skis and snowshoes.[1] **Roads** As people carried goods to and from places, tracks were naturally created at places where many people traveled. When animals became domesticated (which historians estimate to be around 4000 BC[2]), tracks started to widen and flatten even more. Animals provided much needed labor and helped create civilizations. Now people could do more than just hunt. They could trade, travel, and communicate more than ever.

Around the 4th or 5th millennium BC, animal drawn vehicles, like chariots, were on the roads[3]. This created an even better way to get goods to and from places.

Horses, donkeys, and oxen were the main modes of road transportation for thousands of years. The automobile was invented in Europe at the end of the 19th century, but it was the early 20th century when American companies started to mass produce automobiles, that the population started to adopt cars.

As cars use became more widespread, roads also became wider to allow cars to pass each other. Roads were paved to prevent dust and small rocks from flying up. People began to live farther away from city centers because they were able to commute from their homes in the suburbs to work in the cities easily. An entire **infrastructure**, which is structures and facilities needed for the operation of society, was developed to accommodate street traffic. Highways and interstate connected cities and states. People became more independent and less collective.

Rail

Rail transportation dates back about 500 years ago to when man or animals moved coal from mines down to rivers via wooden rails. [3]

Modern rails appeared in the 1820s in England. They used steam powered locomotive engines. These rails and engines were the first practical mechanized form of land transportation. Railroads also became the first means of land rapid transit.[3]

People and good were now able to get across countries and even across continents faster than ever before. More travel meant more communication both within countries and between countries.

Water

Primitive boats date back all the way to the stone age.[3] As civilizations developed, water vessels became more expansive and larger to accommodate trade and war. People and nature were the primary sources of power for boats until the steam engine.

The steam engine, which appeared during the industrial revolution, was quickly utilized by boats and the first steam boat was invented in 1769. Also during the industrial revolution, inland canals were built by England and the United States before railroads became widespread.

Although primarily a military vessel, submarines also influenced transportation. For the armed forces, submarines enabled sneak attacks in the enemy's waters. Outside of warfare, submarines also expanded our knowledge of the deep ocean.

Air

When you think of air transportation, what comes to mind first? Probably an airplane. But before airplanes came along, hot air balloons enabled a way for humans to really get a

	bird's eye view. But, of course, it was truly the airplane that revolutionized air travel. The Wright brother had their first sustained, controlled flight in 1903[4]. Only a couple years later, the first helicopter was invented by French inventor, Paul Cornu. It only flew about 2 feet and stayed airborne for only 20 seconds, but it laid the framework for future rotor crafts like drones and flying cars.[2] **Space** Humanity went even faster and even higher during the latter half of the 20th century. The former Soviet Union amazed the world with their launch of the first satellite, Sputnik, and then again as they sent Yuri Gagaran into space. Not wanting to be left behind in space exploration, the United States also made significant progress in space exploration and rocket development. Perhaps their crowning achievement was the Apollo 11 mission to the moon in 1969.[5] **References** 1. Origin of Snowshoeing. (n.d.). Retrieved January 01, 2018, from http://snowshoes.com/learn/article/origin-of-snowshoeing 2. Nguyen, T. (n.d.). From Horses to Rocket Ships: A Brief History of Getting Around. Retrieved December 30, 2017, from https://www.thoughtco.com/history-of-transportation-4067885 3. History of transport. (2017, December 30). Retrieved December 30, 2017, from https://en.wikipedia.org/wiki/History_of_transport 4. History.com Staff. (2009). Wright Brothers. Retrieved January 01, 2018, from http://www.history.com/topics/inventions/wright-brothers 5. Loff, S. (2015, April 17). Apollo 11 Mission Overview. Retrieved January 01, 2018, from https://www.nasa.gov/mission_pages/apollo/missions/apollo11.html
Reading #2	**Technology Adoption Curve** Do you use Netflix, Snapchat, or Pinterest? If you do, then you are considered one of the innovators along the **technology adoption curve**.[1] The technology adoption curve is a theory about how people use and implement new technologies. It divides users into five categories: • Innovators- these are the first to adopt a new technology. • Early adopters- adopt new technology once the innovators adopt the technology • Early majority- this group is a little more cautious and will adopt it once there is a clear benefit to using it • Late majority- this group is a bit more skeptical and tend to adopt it only when the majority does or when pressured into doing so • Laggards- are often reluctant to change and often only adopt when something becomes mainstream or traditional[2] Maybe you're thinking, “Wait- an innovator? That's not me. All my friends were on

	Snapchat/Pinterest or used Netflix way before me." While that may be true, compared to the entire US, with 323 million people, or the world as a whole, with some 7 billion people, using any one of those three technologies would make you an innovator. Your position on the technology adaptation curve could change as the population studied changes. So while looking at the world as a whole, you are an innovator, but while looking at the population of your school, you may be in the early or late majority category. **Moving Along the Curve** What causes technologies to move along the adaptation curve? For example, how will Netflix move from being adopted by early innovators to early adopters? The answer there lies in the adoption the preceding technologies. Since Netflix is dependent on the internet, it will never be adopted by those who haven't adopted the internet until they adopt the internet. It is also dependent on a screen, like a tv or tablet. If a person or group of people haven't adopted screens, they won't adopt Netflix. This is a critical concept for the transportation technologies we will discuss in this module. Driverless cars, for example, are unlikely to pop up in places where people still use domestic animals as the primary mode of transportation. **Ubiquity** If something has ubiquity or is **ubiquitous**, it means it appears to be everywhere. When it comes to technology, ubiquity is influenced by a number of factors such as location, demographic, and benefit it provides. Take cars, for example. They may seem ubiquitous in the United States, but they are nonexistent among some Amazonian tribes. Keep these concepts of adoption and ubiquity in mind throughout the course as we go through new and emerging technologies. **References** 1. (2016, June 27). The Adoption Curve for 26 Technologies Across the 7.4B Human Population. Retrieved January 01, 2018, from https://humanizing.tech/the-adoption-curve-for-26-technologies-across-the-7-4b-human-population-a4d45dca6714 2. (n.d.). The 5 Stages of Technology Adoption. Retrieved January 01, 2018, from https://ondigitalmarketing.com/learn/odm/foundations/5-customer-segments-technology-adoption/
Reading #3	**Traffic Costs** Have you ever been stuck in traffic? What were you feeling? Annoyed? Angry? Maybe anxious that you were going to be late?

Traffic is a huge time waster. American drivers wasted 6.9 billion hours stuck in traffic in 2014.[1]

Not only does traffic cost us time, it costs us money too. It costs us $160 billion per year. On an individual level, that's $960 per typical motorist. By 2020 those number are expected to rise to at 8.3 billion hours and $192 billion.[1]

Cutting down on time spent stuck in traffic is one of the big goals of many emerging transportation technologies. Driverless cars, flying cars, personal rapid transit, hyperloop, delivery drones, and even jetpacks all use traffic reduction as a big reason why their new technology will benefit society. They each outline in different ways solutions to the problem. Some call for getting people to places faster collectively, others take a more individual, streamlined approach.

Auto Fatalities

Every day six teens, ages 16-19, die from auto accidents.[2]

In the U.S. 37,000 people die in auto accidents each year. Most of those accidents happen because people get behind the wheel in while in conditions not fit for driving or are not paying attention. [2]

Many of the new technologies were will cover in this course are working to make our commutes safer by taking control away from the unpredictable driver. Autonomous, or self-driving vehicles, are touted by supporters as being much safer because autonomous vehicles are not subject to distractions, unlike humans.

Parking

What happens to cars, trucks, buses, and planes when they are not in use? Well, they have to be put somewhere and that “somewhere” takes up a lot of space. Vehicles sit idly in lots, garages, and driveways.

Future transportation technologies might be able to free up some of the space taken up by parked vehicles and put to other uses. Like traffic, some of the transportation methods we will cover aim to solve the parking problem by providing better systems of mass transit. Others are more individual but cut down on parking by decreasing vehicle size and/or making public personal transportation work more efficiently.

Pollution

It's no secret that our current forms of transportation cause major pollution issues. High amounts of carbon dioxide (CO_2) released from fossil fuels leads to smog. Smog reduces the amount of sunlight that reaches the earth, which in turn, affects plant growth. The decrease in air quality can lead to respiratory problems. More CO_2 also contributes to melting polar icecaps. This raises the sea level and causes problems for both animals and

	humans in coastal areas. Nearly every method of transportation we will cover is working to find a pollution solution. Many are working to use alternatives to fossil fuels, and others are looking to burn fuel much more efficiently. Our current transportation system has problems. Finding solutions to these problems is a major opportunity and challenge for our generation and is what makes new technologies worth pursuing. **References** 1. Dooley, E. (n.d.). Here's How Much Time Americans Waste in Traffic. Retrieved January 01, 2018, from http://abcnews.go.com/US/time-americans-waste-traffic/story?id=33313765 2. Motor Vehicle Safety. (2017, October 16). Retrieved January 01, 2018, from https://www.cdc.gov/motorvehiclesafety/teen_drivers/teendrivers_factsheet.html
Reading #4	Are you wondering which modes of transportation we're going to cover in this course? Well, here's a list and a brief description of the exciting things to come. **Driverless cars**- also known as autonomous cars or self-driving cars. These are cars capable of getting around without a human driver involved in most of the process. This is such an exciting and involved future technology that we are going to devote two modules to driverless cars. One module will focus more on the technology and the other will focus on the implications to society. Flying cars- imagine being able to fly over rush hour traffic. That's dream could be a reality with flying cars, or **vertical take-off and landing** (VTOL) vehicles. Not only do they bypass traffic, they also don't require the extensive runway that airplanes require. **Hyperloop**- this proposed method of transportation involves magnetic levitation and low pressure tubes to reduce friction and get a crowd of people to their destination faster than cars and even airplanes. **Jetpack**- these devices are warn on the back like a backpack and provide thrust and lift to get the wearer off the ground. You've probably seen them on tv or maybe even in person at something like a sporting event. We'll talk about whether there's a future for them in our every-day lives. **Supercavitation**- think that the future of transportation is limited to the land and air? Think again! Supercavitation which takes an object and encloses it in a bubble which reduces drag in the water, is another mode worth investigating. We'll talk about why some people think that a submarine may get you from California to China faster than an airplane! Supersonic jets- **supersonic speed** is anything faster than the speed of sound and up to Mach 5. In our module on supersonic jets, we'll cover the supersonic jets that zoomed through the sky at the end of last century and the beginning of this century. We will look at companies working to bring us back to supersonic speeds.

	Drones- these are autonomous and remote controlled vehicles. You've probably seen them around; they are becoming more and more popular. We'll look at how they could serve delivery businesses and other sectors of the economy as well. **PRT-** this stands for personal rapid transit. It's a form of public transportation that uses small automated vehicles on specially built guideways. This would take the convenience of public transportation and the privacy and point-to-point capability of personal transportation to create an alternative for getting from place to place. This module will also look at other ways of getting from place to place like Segways, monowheels and motorcycle/car hybrids. **Space travel**- in this module we'll explore rockets and emerging reusable rockets. We will look at how reusable rockets could change the future of space travel. We'll also look at a few companies working to make this possible. **Interstellar travel**- this is space travel beyond our solar system. We'll investigate what makes interstellar such a daunting task and proposed theories for making it happen.
Reading #5	**<u>Evaluation Process</u>** When you use a new product for the first time, how do you decide if you like it or not? You're likely thinking, “well, it depends on the product.” That is very true. You're likely to use different criteria when evaluating a new phone than you use when evaluating a new bed, for example. How it feels when you lie down on it is likely high on your list of criteria for a bed, but probably not on your list for a phone! Like all products and technologies, these modes of transportation we will cover in this course also need to stand up to a framework of evaluation to determine whether they are viable or not. Here's what a framework for evaluating a proposed method of transportation might look like: **<u>Cost</u>** This considers factors like whether or not a consumer has to buy the entire system (like a car) in order to take full use of it or whether they can pay per use (like a taxi or bus). Other factors to consider with cost are how the new technology compares in prices to more traditional modes of transportation. For example, how much more will it cost to ride on a supersonic jet versus a traditional jetliner. Tax money is another issue. If the public is going to have to fund a system which requires a specific infrastructure, the impact to tax payers is something to consider. **<u>Environmental Impact</u>** This goes beyond the question of whether it cause more or less pollution (although that certainly is a big consideration). We also have to consider whether it calls for natural resources and how we will extract those resources. Another consideration is what building the infrastructure will do to the environment.

	Safety Is it safe for the rider or user? Is it safe for those around the system? Another component that will be largely unique to future modes of transportation is if the user's information is secure, or if it's subject to hacking. Finally, what about the safety of building and other structures? If the system collides with a building or structure, is the building likely to collapse? This would endanger all the people inside the building as well as anyone around it. **Technology** Remember our discussion from the section on the adoption curve. A new technology is only going to be as ubiquitous as the technology preceding it. If that technology doesn't even exist yet (like with interstellar travel), then it's likely going to be a lot more work to make the technology work in the first place, and then even more work on top of that to make it ubiquitous. **User Experience** If a technology is aiming to be part of everyday society, it really does not matter how fancy it is if people hate using it. Think about how often you'd use a public transportation system that seemed to require an advanced degree just to figure out how to tell the system where you want to go! Or if it was cold and hard inside the vehicle. Or if it required extensive changes to your regular schedule to make it possible to use. Consider how you would feel using each of the technologies we will cover. This is such an exciting time in history. It's been decades since a new mode of transportation really changed society the way cars and airplanes have changed it. But as you'll see, there are some promising technologies that could have a tremendous impact on our lives and you just might get to see those changes happen in your lifetime.

POINTFUL EDUCATION

Module 2: Flying Cars

Module Description	From fiberglass cars with wings strapped to the top to vehicles looking like they came straight out of a science fiction movie, the concept of flying cars has evolved with time and technology. In this module we will explore and understand what a Vertical Takeoff and Landing ("VTOL") vehicle is, the history of flying cars, current flying car projects, the pros and cons of such vehicles, and careers in the field of VTOL technology.
Reading #1	**The Right Time** Almost as soon as cars became mainstream, engineers and forward thinkers started dreaming up how to make cars fly. Now, over 100 years and over 80 attempts later, many technological developments are coming together at just the right time to make this generation's engineers believe that flying cars will be here in the near future. Improvements in lightweight materials, fuel efficiency, and battery storage, among many other technologies are making this possible. Watch this video of The Lilium Jet's maiden voyage to see just how close engineers are to making flying cars a part of normal life. **VTOL** Key to understanding flying cars, is the concept of VTOL vehicles. **VTOL** stands for vertical takeoff and landing, and it refers to aircrafts that can take off and land vertically.[1] Vertical take-off and landing vehicles are the focus of many current flying car undertakings because the ability to take-off and land vertically means there is no need for an extensive runway. This space-saving feature allows more flexibility and freedom than traditional airplanes. And by utilizing airspace, it frees up and/or bypasses road congestion caused by a high volume of cars. **Helicopters** You may be more familiar with VTOLs than you think. If you have ever seen a helicopter take off or land, then you have witnessed a vertical takeoff and landing vehicle in action. A helicopter is a type of VTOL vehicle known as a **rotorcraft**. A rotorcraft lifts by using rotor blades spinning around a central mast. A helicopter's ability to fly depends largely on two principles: 1. First, is **airfoil**. An airfoil is any surface that is designed to aid in lifting or controlling an aircraft by making use of air currents. In the case of a helicopter, this refers to the rotor blades. 2. Second, helicopters use a **turboshaft** engine to rotate the blades. Those two components- airfoil technology and the turboshaft engine- are of primary interest to developing flying cars because they are what make the vertical take-off and landing possible. **Helicopter Limitations** However, there is a reason we do not have a bunch of helicopters parked in our garages. Flying car engineers are working to overcome some of the limitations associated with helicopters. These limitations include:

1. The cost: Helicopters are very expensive to operate. The cost to fuel a helicopter is much more expensive than the cost of a car. The helicopter body is also more expensive to produce than a car. Helicopters can cost anywhere from $250,000 to $1.7 million, while an average new car is around $30,000. [2]
2. Inability to significantly vary the size: Some cars are designed to fit 2 people. Other cars are designed to fit up to 8 people. This ability to scale a car to be small or large is not easily accomplished with helicopters. Furthermore, both small and large cars can fit on a driveway or in a parking spot. The same cannot be said of a helicopter. They are much too large to fit into our modern lifestyle.
3. Speed: Although faster than cars, helicopters are slower than airplanes. This makes taking a helicopter instead of an airplane impractical for long-distance travel.
4. Difficulty to operate: Obtaining a license to operate a car is relatively easy and inexpensive. In fact, many high schools offer a driver's education course. Certification to become a helicopter pilot takes over 35 hours of ground instruction and at least 35 hours of flight time, at a much higher expense than a driver's ed course.[3]

It is these 4 limitations to helicopters - cost, inability to vary the size, speed, and difficultly to operate - that we will distinguish flying cars. As you will see, some of the flying cars we will discuss seek to improve on one of these issues, others all four.

References

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2. T. (2016, November 12). How Much Does a Helicopter Cost? Retrieved January 09, 2018, from https://owlcation.com/misc/How-much-does-a-Helicopter-cost
3. Becoming A Helicopter Pilot. (n.d.). Retrieved January 09, 2018, from http://www.autorotate.org/PHPAInfo/BecomingAHelicopterPilot.aspx

Reading #2

Early Attempts

Currently, there are about 80 patents on file at the United States Patent and Trademark Office for different kinds of flying cars. [1] Examining some of the earlier attempts will help us further understand what current engineers are trying to improve upon with their own flying cars.

Curtiss Autoplane

In 1917, Glen Curtiss debuted his "Autoplane" at the Pan-American Aeronautical Exposition. [2] With an aluminum body, plastic windows, and a heater for passengers, the autoplane was aiming to be more comfortable than the airplanes of the time. When World War I started, and development halted and the project never resumed. Although it was built and designed to supposedly fly, the Autoplane never flew. [1]

Sky Flivver

Almost 10 years later, in 1926 Henry Ford built the Sky Flivver. [3] Although more plane-like, than car- like, the Sky Flivver had the public excited by the prospect of personal flying vehicles. The Sky Flivver was small. So small in fact, it could fit in Ford's office, which was one of his

specifications. In 1928, a distance-record breaking test was undertaken. Unfortunately, an engine stoppage occurred, causing the Flivver to go down and with it, the pilot, Harry Brooks. The Flivver washed up, but the pilot's body was never found. The pilot and Ford were friends, and the wreck upset Ford to the point that production of the Sky Flivver stopped.

ConVairCar

In 1947 brought perhaps one of the most literal interpretations of the flying car. Henry Dreyfuss's ConVairCar featured a fiberglass car body and wing and engine module on the roof. Two prototypes were built. The first, body was destroyed during a demonstration flight when a low fuel situation forced the vehicle into an emergency landing. A second prototype was built, but the enthusiasm was no longer there. The ConVairCar never went into production. [(4)]

Ryan X-13

Also during the 1950s, the armed forces became highly interested in VTOL technology. Considering how large and vulnerable airbases can be, it is not hard to see why vertical take off and landing vehicles with their space-saving, low profile setup areas were highly appealing to this sector. The X-13 was the aircraft funded by the Air Force to achieve vertical take-off and landing. To take off, the launch bed was elevated vertically, allowing the X-13 to hang from suspended cables with a partially retractable hook. The pilot would then increase the throttle until the hook lifted off the cable, sped up vertically, then switched over to forward flight. Things became considerably more difficult when it came to landing. Because the airframe obstructed the pilot's view, it was very difficult for the pilot to judge the distance from the ground and resulted in lots of radio communication with someone below the aircraft. Competing programs cut the funding for the program, and the X-13 flew for the last time on September 30, 1957.[(5)] It pioneering thrust vectoring system became a crucial component to combat aircraft by the end of the twentieth century.

Sky Commuter

During the 1980s saw the creation of the Sky Commuter. Boeing engineers spent $6 million developing this particular flying car concept.[(4)] The flying car featured three road wheels for driving and takeoff/landing. Forward movement was to be provided by gas turbine engines. The engines were linked to each fan by helicopter-based drive shafts. Exhaust was to exit out the tail of the Sky Commuter. When this happened, it was thought to create a thrust which would cause forward movement. The Sky Commuter never made it past the prototype stage.

References

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	5. Ryan X-13 Vertijet. (2016, November 19). Retrieved January 09, 2018, from https://airandspace.si.edu/collection-objects/ryan-x-13-vertijet
Reading #3	Below are some Flying Car projects that are underway. Which one do you think sounds the most promising? **Uber Elevate** This century is also seeing its fair share of attempts to make flying cars commonplace. Uber is a location-based app that pairs riders with private drivers to enable riders to get where they want to go. However, Uber has no intentions of getting left behind as technology leaps forward. Uber is working toward building an electric VTOL aircraft that will function to shorten urban commutes. The project is called "Uber Elevate."[(1)] The goal is to strengthen and add to their already successful business strategy by connecting Uber Elevate riders with ground drivers to take them to their final destination. **Ehang** A Chinese company called Ehang is developing the Ehang 184. [(1)]Passengers enter their desired location and this autonomous aerial vehicle (or AAV) takes off on a medium-short distance flight. AAV means there is no pilot. Instead, the rider inputs their destination into a computer which is programmed to safely navigate take-off, flight, and landing. The Ehang 184 will be electric based which means no pollution will be released into the atmosphere. **TF-X** The Terrafugia's TF-X is another AAV in the works. Interestingly, the TF-X is meant to function both in the air and on the road. This VTOL vehicle would takeoff, fly and land completely autonomously, but drivers would be required to manually handle the roads, however. Unlike the Ehang, however, this particular AAV VTOL will use gasoline. The company is projecting to have a production version by 2025.[(1)] **Lilium Jet** We mentioned the Lilium Jet at the beginning of the module. This all-electric vehicle would transport riders from London to Paris, or Chicago to Detroit, in an hour. [(2)]To combat safety issues, the jet follows the concept of "ultra-redundancy," mean the components are independent, so that in the event of a single engine failure- or even multiple engine failures- the system can still land safely because there are so many "back-ups" so to speak. It will, however, require a pilot to drive. **Vahana and CityAirbus** The French company, Airbus has two key projects emerging in the flying car sector. Project Vahana is a single rider VTOL aircraft with AAV technology. It will also come with technology components like radar and lidar to detect obstacles. [(1)] Airbus is also developing a flying taxi system called CityAirbus. Multiple riders could book the CityAirbus using an app. Riders would then report to the nearest "helipad" to board CityAirbus.

	Cartivator "Cartivator," a project backed by the Japanese car company, Toyota, aims to use the flying car to light the Olympic flame in Tokyo for the 2020 Summer Olympics. [3] The flying car is known as "SkyDrive". Furthermore, Toyota hopes to use the flying cars to transport athletes between the Olympic village and various venues around the area using AAVs. **References** 1. Muoio, D. (2017, February 06). Uber is just one company interested in 'flying cars' - here are 5 others. Retrieved January 09, 2018, from http://www.businessinsider.com/companies-invest-flying-cars-2017-2 2. Lilium. (n.d.). Retrieved January 09, 2018, from https://lilium.com/ 3. Wong, E. B. (2017, June 03). Toyota-supported flying car hopes to light the Tokyo 2020 Olympic flam. Retrieved January 09, 2018, from https://www.reuters.com/article/us-olympics-tokyo-flying-car/toyota-supported-flying-car-hopes-to-light-the-tokyo-2020-olympic-flame-idUSKBN18U0E3
Reading #4	Without a doubt, flying cars would have major benefits. However, like most technology, there could be significant drawbacks as well. Let's explore some of the pros and cons of the proposed flying cars. **Flying Car Pros** **Economy**: First, let us consider the impact flying cars would have on the economy. The commercialization of VTOL vehicles would create a number of jobs and add more positions in existing fields for the economy. Depending on the type of VTOL vehicle these jobs might include: aerospace manufacturers; tech developers; a variety of engineers, specialized mechanics; electricians; VTOL pilots; infrastructure planners, developers, and technicians; and many more. The creation of jobs is a definite potential benefit to the production and use of flying cars. **Cost of Housing**: Another potential benefit is bringing down the cost of housing in some cities. If VTOLs are able to make significant improvements to commute time, then housing close to major cities might not be at such a premium. People would be able to live farther away from where they work and not have to sacrifice so much time to the commute. **Complementary to Airplane and Auto Industries**: It is also unlikely that these VTOLs would wipe out the airplane or auto industries either. Most of the VTOL aircrafts would be limited to short, urban routes due to batteries needing to be recharged. Provided gasoline prices stay at a reasonable cost, massive commercial airlines will still remain more cost-effective for years to come for long-distance and international travel. The automobile industry would still be necessary as well. The best solution for short distances that require a vehicle is still going to be a car. Furthermore, cars and mass-transit systems, like buses, are still going to be the most cost-effective solution for the majority of people. This will hold true at least until production becomes mainstream enough to be able to produce flying cars at a reasonable cost for consumers. **More Connections**: meeting face to face would be easier than ever before. This interpersonal

communication could strengthen businesses, families, and distant communities as people come together and learn from one another. Furthermore, flying cars could connect people to job opportunities that were previously not an option due to their geographical proximity.

Time: Flying cars would give commuters a significant portion of time back, increasing overall human productivity.

Electric-powered Vehicles: One of the big problems facing the world today is trying to remedy the consequences of pollution. Many flying car companies seek to deliver an Eco-friendly solution and have found going electric to be the answer. Rather than burning fuel to power the engine, and thereby creating pollution, the motor would be electric. Not only does this mean no carbon emissions from the engine, it also means that there would be less noise pollution because they would be quieter.

Flying Car Cons

Potential Job Losses: The aspect of future technology that may cause some to lose their jobs is actually not unique to flying cars. A potential job challenger is driver-less technology. Driver-less technology is already being put into practice by airplanes, trucks, and cars. This could negatively affect the pay scale of drivers and pilots as technology replaces or reduces their skills.

Use of Rare Metals: However, eliminating emissions is just one aspect of the improving the environment. One of the concerns about electric cars is that the electronics throughout the car uses rare metals. It's possible that rare metals would be necessary for VTOL vehicles as well. Rare metals are only available in small amounts and are usually found in inconvenient places. It usually requires destructive mining to get to these sources. However, by recycling old electronics, we can help limit the amount of mining necessary.

Impact on Wildlife: Another important consideration is the impact more flying vehicles would have on wildlife, particularly birds. The majority of cases where birds hit airplanes happens at an altitude lower than 500 feet.[1] Since most VTOL vehicles will fly lower than airplanes, this is a considerable issue. Not only could this kill wildlife, this could harm or even kill those riding the aircraft.

Safety Concerns: Which brings us to safety concerns, of which there are many. For one, most buildings are designed to withstand a car crashing into it on the ground without greatly compromising the structural security. Buildings are not designed with aircraft collisions in mind. A toppling building is a threat to those in the building as well as those around it.

Emergencies: Furthermore, most roads in the United States are designed to be wide enough for cars to pull over. This is particularly convenient in the event of an emergency. In an aircraft, an immediate landing may not be possible due to the circumstances and people below the vehicle. There is a great deal of uncertainty around emergency procedures for flying cars.

Traffic in the Air: One of the major problems VTOLs seek to alleviate is traffic. However, there is no system in place to regulate the speed and flow of low flying, VTOLS. More vehicles in the air

	could mean more traffic which could slow down air travel time. Thus, we'd be taking one traffic situation and simply replacing it with another, airborne situation. **Regulation and Logistics**: The logistics and rules of the sky would need to be clear and universal, especially if flying cars lead to an increase in international travel. Issues such as if two different companies have an aircraft traveling and the two vehicles intersect somewhere, which vehicle has the right of way? Rules and regulations would need to be in place for VTOLs to become more common place. **Malfunctions**: One of the big concerns that is on many peoples' minds as engineers seek to make all vehicles more autonomous is what happens if the autonomous technology malfunctions or fails altogether. This is especially worrisome in a VTOL because, as stated earlier, crash landings impact not only the rider, but anyone and anything below the vehicle. **Impact on Societal Classes**: It is likely that for the first few years, perhaps decades, some of these vehicles will only be available to those who can afford it. For that reason, the lives of the rich could improve, but not the life of the middle and lower classes, thus dividing the classes further. However, many technologies that start out only accessible to the rich (the first cell phone in the 80's was $5,000![2]), but over time, improvements in technologies and production can bring the cost down to make it accessible across economic classes. **References** 1. The first mobile phone call was placed 40 years ago today. (n.d.). Retrieved January 09, 2018, from http://www.foxnews.com/tech/2013/04/03/first-mobile-phone-call-was-placed-40-years-ago-today.html 2. AviationKnowledge. (n.d.). Retrieved January 09, 2018, from http://aviationknowledge.wikidot.com/aviation:air-safety-bird-strikes
Reading #5	**Careers** For those interested the future of VTOLs, there are a variety of career options to investigate. Currently, Lilium has a number of positions open for those interested in developing and improving the Lilium Jet. Support positions include: public relations rep, accountants, recruiters, and others. [1] For those interested in being more directly involved in the technology and development aspect, the company is looking for: software engineers, calculation engineers, mechanical engineers, and electrical technicians to name a few. All the available positions are listed on their website under “careers.” [1] Lilium is not the only company hiring in the industry. Terrafugia and Airbus also have listings on their websites for vacant positions.[2,3] One common need throughout all companies is the need for skilled engineers. The requirements for these positions range from a bachelor's degree to a doctorate degree depending on the position level and the particular skill set. **STEM** This need for engineers is one of the reasons public schools from elementary through high

school are putting such an emphasis on science, technology, engineering, and math or STEM learning. Schools today are realizing how crucial these positions are to solving some of our world's problems like traffic and environmental concerns, and are working to provide those who will enter the workforce to solve these problems with the best background possible. So even before a student sets foot on a college campus, he or she can prepare to be a part of the science and technology industries by taking advantage of the classes and programs offered at the high school level and in communities.

Internships and Nanodegrees

For those who would like to experience work-life at a VTOL company while still in college, many of the companies offer internships. These internships, although competitive would allow you to experience the day to day life of working in the company before you graduate from college.

Another interesting pathway to consider is Udacity's Fly Car Nanodegree Program which will open in 2018. According to the website, "Our curriculum will initially focus on the basics of autonomous flight including motion planning, state estimation, control, and perception. But over the course of two terms, students will gain an understanding of the bigger picture of autonomous flight as part of the air transportation system, and especially the challenges of safe and reliable autonomous flight. They will develop skills in systems integration through hands-on projects that include both flight simulation and the option to deploy code on a small drone. Our students will develop the software skills and conceptual understanding necessary to build a flight system for an autonomous flight vehicle that can reliably complete complex missions in urban environments." [(4)]

This is an exciting industry to be a part of, and from what we've learned in this module, it is only going to grow.

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Module 3: Driverless Car Technology

Module Description	Self-driving cars are coming. In fact, in some places, they are already on the streets. In this module, we are going to examine the technology behind self-driving cars. We will examine how sensors in cars "see" an object and respond accordingly, as well as how fleets of driverless cars learn from each other, through a process called machine learning, by driving millions of miles on the road. And finally, we will investigate what the future hold for those perusing a career in the industry.
Reading #1	**Introduction** Let's begin by understanding what we mean when we say "self-driving car." **Self -driving cars** are also known as autonomous cars, robotic cars, or driver-less cars. All these names refer to cars that utilize robotics in order to navigate and sense the environment around the vehicle without human input. Or at least that's the capability of a level 5 driver-less car. Driver-less cars range in their autonomous abilities beginning with level 0, with no automation, up to level 5, which is a completely autonomous vehicle. (1) **Level 0** At level zero, there is **no automation**. Even if the car has warning systems or monitoring systems to alert the driver of a possible collision, it is still considered level 0. This is because, aside from setting off visual or auditory warnings, the car is still completely under the driver's control. If the driver must monitor and actively drive the whole time and the car cannot take over under any situation, then it is a level zero car. **Level 1** A level one car has one or more autonomous features and uses **driver assistance.** It may able to control speed or steering- but not both simultaneously. The driver must still monitor the drive the entire time. **Level 2** At level two there is **partial automation**. Some luxury car companies are currently producing vehicles that can control both speed and steering at the same time. An active driver is still needed behind the wheel at all times to monitor what the other cars are doing and what is going on in the environment. **Level 3** Level three cars provide **conditional autonomy**. At this level of autonomy is based on the condition of the road or situation. The car will handle driving as long as conditions are optimal, but once the system recognizing an upcoming problem, it is going to notify the driver to intervene. Some companies are choosing to completely skip this level. We'll explore why this is later, but see if you can think of some good reasons why companies like Ford and Volvo are planning to bypass this level. Could it be dangerous or risky for a human to take over with short notice? **Level 4** Many car companies are currently targeting level 4, or **high autonomy**. At level 4, no driver handling is needed. The car will stop on its own if there are any dangerous system failures and

	the driver does not interfere first. Ford and Volvo have each said that a level 4 car will be available by 2021. [1] Whether that means for ride-sharing or to the general public remains to be seen, but it's clear that it's coming soon! **Level 5** At level 5 we have truly driver-less or **fully autonomous** cars. The car can safely make appropriate driving decisions in all weather conditions and under variable conditions. While it may not seem like a big distinction between level 4 and level 5, it is a big technological project to be able to pull that off. As of 2017, no company has specifically said when or if they will achieve a level 5 self-driving car.[1] Many speculate that it is still decades away. **References** 1. Aaron Cole | The Car Connection. (2017, February 21). What are the different levels of self-driving cars? Retrieved January 10, 2018, from https://www.washingtonpost.com/cars/what-are-the-different-levels-of-self-driving-cars/2017/02/21/444a2a80-f877-11e6-aa1e-5f735ee31334_story.html?utm_term=.03b3bd12ae33
Reading #2	Let's start by looking at some of the key hardware technologies that go into making a driverless car possible. **Sonar** First, let's look at **sonar**. Sonar stands for sound navigating and ranging. It uses sound waves to detect and measure the distance of objects**.** This is similar to echolocation, which is how animals like bats, dolphins, and whales navigate. It wasn't until after World War One that humans began to use sonar. The first application was for submarines. Sonar was a break-through for submarine warfare. Sound travels so much better underwater than light or radio waves. You can imagine the welcome relief it was to have a way to detect objects while deep underwater. Level zero cars sometimes use this technology for parking assistance. They use ultrasonic waves which is why drivers can't hear anything until it triggers the warning system. **Radar** After World War II, came the development of **radar**. Radar, or radio direction and ranging, uses radio waves to measure distance. Whereas sonar only works at a range of about 5 meters, radar can detect and track objects as far as 200 meters away. And we use radar... a lot! It has a long operating distance and it can operate in cloudy weather conditions and at night. Police officers use it to track a car's speed, airports use it to control air traffic, and meteorologists use it to predict the weather. Radar is great, and it certainly is useful for driver-less car technology. For example, a car with adaptive cruise control uses radar sensors to sense the distance of the car in front and adapt speed accordingly. But it has its limitations.

For one, it doesn't allow the detection of small objects, it also can't give us the precise image of an object. For example, it couldn't tell us if an upcoming object is a street sign or a pedestrian. Without knowing exactly what an object is, the driver-less system can't predict the movement or react appropriately.

LiDAR

So how does LiDAR work? Like we mentioned before, LiDAR is similar to both sonar and radar, but it uses light instead of sound waves or radio waves.
First, laser signals are emitted. When the laser signals reach an object, the signal reflects from the obstacle and returns to the receiver. Finally, the position is calculated. There's an inner processor within the LiDAR system that saves each reflection point of a laser and creates a 3D image of the environment.

LiDAR is a lot like sonar. Except light is one million times faster than sound.[1]You've probably witnessed this first hand during a thunderstorm. First you see the lightening and then you hear the thunder seconds later. That sort of speed makes it possible for the LiDAR device to gather data from a huge number of laser pulses every second. As a result, info can be updated more often which leads to more precise data.

Drawbacks of LiDAR

It seems great- being able to generate precise 3D maps nearly instantaneously- and it is! LiDAR *is* great. But it's not perfect. For one, it's expensive. As of 2017, LiDAR units can cost as much as $80,000.[2] However, many companies are working hard to overcome this obstacle. Some, such as Pasadena-based startup company, Strobe, claim to have found a way to reduce the cost by 99% .[3] Overcoming that obstacle would be huge step toward making driverless cars available to the general public.

Another issue is extreme weather conditions. For example, a LiDAR system is nearly useless if enough snow covers the sensor. But like the expense problem, companies are hard at work to solve the bad weather problem. In fact, Google even put tiny windshield wipers on the sensor in an attempt to help visibility.[4] It's also important to note that radar and LiDAR aren't necessarily an either/or competition. Both help driver-less cars navigate. So provided a car has both radar and LiDAR capabilities, the car isn't totally without navigation if the LiDAR doesn't work.
Some experts argue that LiDAR isn't worth the expense. Instead, they are building cars that rely on multiple cameras, ultrasonic sensors, and radar. An on-board computer is used for processing the information.[5]

Digital Cameras

Digital cameras are another step in technology that has brought the development of self -driving cars that much closer to reality. Light from the scene comes streaming in through the camera's lens. It hits a sensor chip and is broken up into millions of pixels. Each pixel's brightness and color is converted into numeric form. The camera, although unable to provide a 3-D rendering, provide the “sight” for the cars, while the computer interprets what the cameras “see” by making sense of the numbers associated with each pixel.
Like all the other forms of technology we've looked at, digital cameras have drawbacks too. For one, a spray of mud will make even the most sophisticated camera blind. Though some companies have recognized this and put windshield wipers on these as well.

	For another, there is no calculation of depth. One of the great things about biological eyes is that we have two of them placed side by side. This lets us see depth. Because they create a two-dimensional representation of a three-dimensional world, we lose depth. In other words, while it may show what objects are around, it does not communicate how far away those objects are from the camera. This is why companies bring aboard other technology such as radar, to combat the lack of depth information. It will certainly be interesting to see which systems- those with or those without LiDAR- prove to be the safer, more capable driverless car system. **References** 1. LIDAR vs RADAR Comparison. Which System is Better for Automotive? (n.d.). Retrieved January 10, 2018, from http://www.archer-soft.com/en/blog/lidar-vs-radar-comparison-which-system-better-automotive 2. 5. (2017, May 09). An Introduction to LIDAR: The Key Self-Driving Car Sensor. Retrieved January 10, 2018, from https://news.voyage.auto/an-introduction-to-lidar-the-key-self-driving-car-sensor-a7e405590cff?gi=f053849a55ac 3. Davies, A. (2017, October 09). GM Buys a Laser Startup to Help It Deliver Your Self-Driving Car, ASAP. Retrieved January 10, 2018, from https://www.wired.com/story/gm-cruise-strobe-lidar/ 4. Hawkins, A. J. (2016, January 08). Google's self-driving cars are learning to deal with bad weather. Retrieved January 11, 2018, from https://www.theverge.com/2016/1/8/10738554/googles-driverless-cars-bad-weather-windshield-wipers 5. Autopilot. (n.d.). Retrieved January 10, 2018, from https://www.tesla.com/autopilot
Reading #3	Now let's move on to some software technologies that go into making a driverless car possible. **Computer Vision** Another crucial component to driverless cars is **computer vision**. Computer vision, or machine vision as it is also known, is a field of study that focuses on advancing machines' abilities to interpret an image or series of images. For example, it is not enough for a driver-less car to recognize that there is an object in the road. The driver-less car must be able to distinguish whether it is a paper bag that can be run over, or big rock that should be avoided. **Deep Learning** So how does a computer go from recognizing that there is an object to correctly identifying that object? The answer lies in a concept called **deep learning**. Deep learning is "a subfield of machine learning concerned with algorithms inspired by the structure and function of the brain called artificial neural networks."[(1)] That's a hefty definition to take in! **Algorithm** Let's start by understanding what an **algorithm** is. An algorithm is a set rules used to solve a problem. As related to computer science, an algorithm is a set of rules or procedures programmed into a computer to enable the computer to solve particular problems. Just about every task performed by a computer uses an algorithm. And driver-less technology is no different.

	Deep learning is inspired by how we learn. A child learns to correctly identify objects by seeing it in a variety of situations, environments, positions, etc. So, step one to teaching a computer to see is by feeding the computer system a wide variety of images. Thanks to a project called Imagenet, computer scientists are able to feed millions of pictures to the computer. The project took millions of digital photos uploaded to the internet, and with the help of tens of thousands of workers, analyzed and classified them using plain English words. [2] After enough exposure to a particular object, the computer is able to recognize it in real situations. Then, thanks to layers and layers of algorithms, the computer can respond based on how it classified the object. As deep learning improves, driverless cars will rely on data just as much as they rely on fuel. Although they will require extreme amounts of data, they will also *produce* vast amounts of data. As cars and roads provide more data, the result will be safer streets and more streamlined traffic. **References** 1. What is Deep Learning? (2016, September 22). Retrieved January 10, 2018, from https://machinelearningmastery.com/what-is-deep-learning/ 2. LIPSON, H. (2017). *DRIVERLESS: intelligent cars and the road ahead*. S.l.: MIT PRESS
Reading #5	Driverless technology is going to impact the truck driving industry. Let's take a look at what is predicted to change in this sector of the economy as driverless technology develops. **Platooning** What would you think if you saw two 18-wheeled trucks driving with less than 10 yards between them, each going about 70 miles per hour? Would that make you nervous? That may soon become not only the norm, but actually quite safe. Pairing trucks apart by 30-50 feet is called **platooning**.[1] Race car drivers and cyclists know that they can save fuel or energy by tucking in close to the rider or driver in front of them. The same is true for trucks. A truck tucked into the slipstream of another truck will save 10% of its fuel.[1] That might seem like a great deal for the second truck and not so great for the first, but actually both trucks benefit from the smoother airflow that platooning creates. The first truck will actually burn 5% less fuel when platooning with another truck.[1] Since self-driving trucks are still in the future, companies are working to make platooning safe for truck drivers to do. Companies are using cameras, reflective light scanning, and radar to make platooning safe. Researchers are working on safety issues such as how fast platooning trucks should travel, where it should be permitted, and what to do if drivers try to cut in between platooning trucks. **Technology of Self-Driving Trucks** Forward facing cameras, radar, accelerometers, and lidar are key technologies behind driverless truck technology. Inside the cab is the crucial computer. The computer crunches the vast

amount of data from the sensors and puts it through algorithms which adjust breaking and and steering to compensate for the truck's weight.

Driverless trucks also use a drive-by-wire box. The drive-by-wire box turn the computer's output into physical truck-control signals. To do so, it uses what is called electromechanical actuators which are mounted to the truck's mechanical steering, throttling, and breaking systems. There are also controls which can be pushed to turn of the automatic features of the truck in order for the driver to regain complete control if needed or wanted.

Redesigning Trucks

While many companies are focusing on how to convert traditional semi-trucks into autonomous vehicles, some are dreaming up completely different vehicles for transporting cargo. After all, if no human driver is needed, then that eliminates the need of a cab. Without a cab, the trailer portion can be adapted as well to fit the needs of various types of cargo more efficiently.

Read this brief article (http://bgr.com/2017/04/17/driverless-semi-truck-shipping/) to see what could be delivering cargo in the not-too-distant future.

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POINTFUL EDUCATION

Module 4: Driverless Cars in Society

Module Description	Self-driving car technology is advancing quickly. In some cities, there are already self-driving cars on the streets. But do we really need self-driving cars? Is society ready for self-driving cars? In this module, we will start by outlining the need for driverless vehicles by explaining some of the problems and drawbacks of the current human-operated world we currently live in. Then we are going to examine the pros and cons of driverless cars. We will look at the benefits and risks of several aspects of driverless cars, including safety, cybersecurity, mobility, cities, and jobs. We will examine social dilemmas and privacy issues associated with self-driving cars in society. By the end of this module, you will be able to examine both side of the issue of self-driving cars.
Reading #1	**Traffic Costs** "Yay! A traffic jam!" - No one ever In a long list of daily annoyances, sitting in traffic (especially when it's unexpected) is pretty near the top of the list as most annoying. American drivers wasted 6.9 billion hours stuck in traffic in 2014 (on average 42 hours per year per driver). That is a big number, and it represents a lot of wasted potential since productivity is limited while sitting in a car waiting to inch forward. In terms of dollars and cents, traffic congestion costs us $160 billion. On an individual level, that's $960 per typical motorist. To make things even worse, those numbers are *not* projected to decrease. By 2020 those number are expected to rise to at 8.3 billion hours and $192 billion.(1) And the bad news doesn't stop there. **Auto Fatalities** Have you heard about the high schools who are holding "mock car crashes?"(2) The idea is to give students a chance to see the consequences of impaired and distracted driving by using student and teacher actors as well as law enforcement and emergency medical professionals to simulate the scene of a car crash. While you may or may not agree with this method, the fact that auto accidents are the leading cause of death for teens, certainly warrants extra attention. Every day six teens, ages 16-19, die from auto accidents.(3) In the U.S. 37,000 people die in auto accidents each year.(4) The majority of those accidents are NOT happening because a car suddenly blew up without any warning. No, the majority of those happen because people drink alcohol and drive, try to drive while distracted, or while drowsy. In short, most of those accidents are happening because people are getting behind the wheel while in conditions not fit for driving or are not paying attention.(4) **Parking**

	What happens after we finally get through traffic and avoid collisions? We get out of our cars and our cars sit idly in lots, garages, and driveways. Unfortunately, cars cannot disappear and reappear whenever we need them. Which means, there must be a spot for all the cars that are not on the roads. Think of how many venues- like arenas and stadiums- where the parking lots are even bigger than the actual building! If you look across the entire world, there are 1 billion cars, and they sit idle in parking lots 95% of the time, requiring massive amounts of space for parking spaces in homes, suburbs, and cities.[5] **Solutions** In the past, the solution to the problem has been to adapt the car to the driver. Drivers get stuck in traffic- give them better surround sound, comfier seats, climate control, and a dvd player for the kiddos in the back. Drivers make mistakes- give them seatbelts, air bags, and a sturdier car frame. But maybe there is another solution. And maybe that solution is to take the human driver completely out of the picture. **References** 1. Dooley, E. (n.d.). Here's How Much Time Americans Waste in Traffic. Retrieved January 12, 2018, from http://abcnews.go.com/US/time-americans-waste-traffic/story?id=33313765 2. R. (2017, April 19). Students Hope to Raise Awareness Through Mock Car Crash. Retrieved January 12, 2018, from https://bhsregister.com/students-hope-raise-awareness-mock-car-crash/ 3. Motor Vehicle Safety. (2017, October 16). Retrieved January 12, 2018, from https://www.cdc.gov/motorvehiclesafety/teen_drivers/teendrivers_factsheet.html 4. Research Note: 2016 Fatal Motor Vehicle Crashes: Overview. (n.d.). Retrieved January 12, 2018, from https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812456 5. Want to know why Uber and automation really matter? Here's your answer. (n.d.). Retrieved January 12, 2018, from http://fortune.com/2016/03/13/cars-parked-95-percent-of-time/
Reading #2	**Distraction** Do you think you are/would be a safe driver? Do you think you can tune out distractions? How about your ability to multitask? Take this demo to measure your distractibility. (We'll wait!) http://www.nytimes.com/interactive/2010/06/07/technology/20100607-distraction-filtering-demo.html What was your score with 2 distractions? What was your score with 6 distractions? Write your answers in the box below: How did you do? What Stanford University researchers found was that high multitaskers do not handle multiple distractions well. This has an interesting implication for the world of self-driving cars. Human error is the leading cause of auto accidents.[1] This includes recognition errors (approx. 41%), decision errors

(33%), performance errors (11%), non-performance errors (7%), and other human errors (8%). One of the factors associated with decision errors is distraction.

Problems with Driver Assistance

Researchers are finding that mere driver assistance lulls people into a false sense of security. They stop paying attention. They become distracted to the point that they are so engaged in the other activity they are doing, they lose contextual awareness. [(6)]As a result, when forced to grab the wheel, they are less capable of taking over safely.

In fact, after a "napping incident," Google's Waymo project decided that it was best not to ask the drivers to interfere at all. In fact, the only two drive controls on their Chrysler Pacifica minivans are buttons for starting a ride and for telling the vehicle to pull over at the soonest opportunity.[(2)]

Driverless Car Safety

Let's quickly review the definition of a **self-driving car** (also called a driverless car or autonomous car): a car that utilizes robotics in order to navigate and sense the environment around the vehicle without human input.

This idea of giving as little control to "human drivers" is the growing consensus among driverless car developers. The statistics back up the idea. The Eno Center for Transportation estimated in 2013 that if 90% of the cars in the US were autonomous, it would prevent 4.2 million accidents and save roughly 20,000 lives per year (the number of driving related deaths would drop from over 32,000 per year to less than 12,000!)[(3)]

What could make driverless cars so much safer? For one, driverless cars have 360 degrees of visibility. That alone is something no human has. Second, driverless cars are not operating under the **4 Ds**: **drunk, distracted, drowsy, or drugged**. Finally, they are programmed to respond in the safest way.

But how do we know we've arrived at the level where computer drivers are safer than human drivers? Some say that self-driving cars should not be legal until they are 100% reliable. If that's the case, than self-driving cars will never be legal. There are no perfectly reliable operating systems.

Some experts suggest that to be legal, a self-driving car must be twice as safe as the average human driver. That translates to an acceptable failure metric for the car to be on average, one accident every 400,000 miles it drives.[(4)]

Adapting to Human Drivers

It would probably be easiest to develop driverless cars if we all woke up tomorrow and driving was prohibited. Then all cars on the road would be driverless and would be able to almost perfectly predict what the driverless cars around it are going to do at any moment. But that is not the case. Currently (and into the foreseeable future), driverless cars are sharing the road with unpredictable human drivers.

	Hive Mind Another advantage of self-driving cars is that they have a "**hive mind**." In other words, the cars share knowledge. When one car learns a new safety measure, or encounters a new situation, the information learned can be distributed to all cars using that software. This means that the same mistake is less likely to be made by multiple cars. In fact, as of late 2017, Google's driverless car company Waymo has completed 4 million miles driven by its driverless car fleet. That's the equivalent of an average American driving for 300 years![5] **References** 1. Research Note: 2016 Fatal Motor Vehicle Crashes: Overview. (n.d.). Retrieved January 12, 2018, from https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812456 2. Dave;, P. (2017, October 31). Google ditched autopilot driving feature after test user napped behind. Retrieved January 12, 2018, from https://www.reuters.com/article/us-alphabet-autos-self-driving/google-ditched-autopilot-driving-feature-after-test-user-napped-behind-wheel-idUSKBN1D00MD 3. Mearian, L. (2013, October 24). Self-driving cars could save more than 21,700 lives, $450B a year. Retrieved January 12, 2018, from https://www.computerworld.com/article/2486635/emerging-technology/self-driving-cars-could-save-more-than-21-700-lives-450b-a-year.html 4. LIPSON, H. (2017). DRIVERLESS: intelligent cars and the road ahead. S.l.: MIT PRESS 5. Team, W. (2017, November 27). Waymo's fleet reaches 4 million self-driven miles – Waymo – Medium. Retrieved January 12, 2018, from https://medium.com/waymo/waymos-fleet-reaches-4-million-self-driven-miles-b28f32de495a
Reading #3	**Social Dilemma** How DO programmers program a car to respond safely in a given situation? Is it to avoid harm to the passenger? To avoid the least amount of property damage? Or is it to avoid harming the least number of people? When asked if, as a pedestrian, they would want driverless cars that are programmed to avoid harming a single passenger or avoid harming a group of pedestrians? People generally responded that they want the car to avoid harming a group of pedestrians. However, when asked if they would ride in this type of car, people said no! This is called a **social dilemma**. Who lives and who dies in complicated and unforeseen scenarios is a question that could keep some people from adopting driverless cars. Understandably, some may be hesitant to get in a car not knowing whether or not that car is programmed to sacrifice them in order to save others and in which situations. Driverless car makers, however, insist that such scenarios are increasingly rare because they are focused on developing the safest car possible, not the most ethical car. The truth, however, is the self-driving car's software must quantify the value of human and animal life. And that makes people uncomfortable.

Reading #4	**<u>Robojacking</u>** What if you were sitting in your self-driving car when all of the sudden a small gang stood in front of your car and refused to move? Your car would be frozen since it would be programmed to not run into people. If there was no manual overdrive option on the car, you would have no way of speeding off to safety. **Robojacking** is the hijacking of an autonomous machine, in this case, a driverless car. And it is just one way hackers and criminals could take advantage of self-driving cars. Other ways hackers will be able to "attack" self-driving car is by breaching and compromising data from car sensors, digital maps, and operating systems. With the self-driving car needing to update its information, like maps, there must be a way to verify that the information is secure, authentic, and certified. **<u>Privacy</u>** Related to the risk of cyber-attacks is the issue of privacy. If the data of everything the car "sees" is being stored, then that data can be retrieved by police, for example. If a crime is reported in a particular area and the police are looking for a suspect, the police could find which cars were in the area around the time of the incident and investigate whether or not the cars "saw" something in particular. While that may be a potential benefit- solving crimes- that also raises the question of privacy. How would you feel knowing that, given there are enough driverless cars on the road, you (and everyone else) is nearly always being recorded and every move tracked? Who would have access to the data and how would it be used? The issue of privacy is definitely something to consider, but it assumes that the data on self-driving cars will be recorded and saved. That is a hurdle in and of itself. All those cars having all that information recorded and stored would require a HUGE amount of physical storage to keep all that information. Plus it would require a system for archiving and retrieval. Perhaps information will only be kept for a certain amount of time and is then deleted to make room for new information. Cameras on the car could take pictures of its passengers or pedestrians. Those pictures could be sent to the government for face recognition. Or those pictures could be sent to marketing departments. Marketers would get a clear idea of what people are using and wearing and at what ages. An important point to consider, however, is that most Americans are already walking around with a device capable of tracking their every move. Cellphones do just that. For most people, the convenience, security, and connection of having a cellphone outweighs the fact that to complete an incoming call, cellphone companies must know the carrier's location. **<u>Legislation</u>** Passengers of self-driving cars would need some sort of privacy protection. At the very least,

	everyone should know what data is being collected and who will have access to that data. At least that's what Senators Markey and Blumenthal believe. They have introduced The Security and Privacy in Your Car Act (SPY act). This piece of legislation would direct National Highway Traffic Administration and Federal Trade Commission to establish federal standards of security and privacy. It would also establish a rating system known as "cyber dashboard" that would inform consumers as to how well the vehicle protects security and privacy beyond the minimum requirements. [1] **References** 1. Sens. Markey, Blumenthal Introduce Legislation to Protect Drivers from Auto Security, Privacy Risks with Standards &. (2015, July 21). Retrieved January 12, 2018, from https://www.markey.senate.gov/news/press-releases/sens-markey-blumenthal-introduce-legislation-to-protect-drivers-from-auto-security-privacy-risks-with-standards-and-cyber-dashboard-rating-system
Reading #5	Today's high school students are going to be tomorrow's engineers, coders, designers, and business and government leaders. So it is important that you start thinking about the implications and effects of driverless cars. There are going to be pros and cons, positives and negatives, risks and opportunities. And they aren't going to line up perfectly… ok we have 10 positives and 9 negatives so we should do it! The world isn't that clear cut, so a thoughtful approach needs to be taken. Additionally, it's important to think through **second order effects**; that is outcomes that are a result of the first decision, but not necessarily intended. For example, with driverless cars, we have explained that it could reduce highway deaths significantly, which is a good thing. But did you know that a lot of organ transplants come from people that die in car crashes? So people waiting in a hospital for a new heart, liver, or kidney, are going to have to wait even longer if self-driving cars are used by a large percentage of the population. That's one example of a second order effect, and it's important to think about other changes that will ripple through the economy and society with driverless cars. **Mobility** The elderly, the blind, and the disabled are three key groups that would likely experience an increase in quality of life if they were able to use driverless cars. They would have more mobility, independence, and potentially more opportunities to work and contribute to society. While more mobility may be great for some, for others it may encourage them to drive instead of walk or ride a bike. This could mean poorer health for others. **Productivity** As we mentioned in the first section, there is a huge amount of time and money lost sitting in traffic by Americans every year. What if that time could be turned into productive time? Rather than watching the road, the person who previously was driving the car could now be working, reading, studying, sleeping, or (if we are honest with ourselves) playing on their phone. This freed up time could mean that people will liver farther from work or school and have longer commutes. And it could be a big bonus to the economy if people spent that time working rather than simply driving. **Driverless Trucks**

Trucking is one of the largest single employers in the United States, with almost 2 million jobs. Unfortunately for those 2 million drivers, the trucking industry is likely going to be one of the first sectors to use the technology. After all, a trucking company does not have to pay a self-driving car a salary, healthcare, and other benefits. One way to help those who face job-loss would be for job training to provide new skills for drivers so the drivers can transition into new jobs at similar wages. The impact of driverless technology on trucking is an example of disruption, which is a radical change in an industry. A disruption typically involves the introduction of a new product or service (in this case, driverless transportation) that creates a new market. There are new jobs created (driverless car engineers), while others are lost (such as truck drivers).

Implementing self-driving trucks could also provide many benefits including lower costs and less fuel use, resulting in fewer carbon emissions. This is done through **drafting**, or platooning, which is when a group of trucks drive close to the truck in front of them to reduce wind resistance and save fuel. Watch the video below about how Volvo is testing this with a fleet of trucks in Europe:
https://www.youtube.com/watch?time_continue=3&v=lx9EFJ6qgZc

City Changes

Not only will people and their jobs potentially change, but cities too. In order to help cars "see," cities are going to have to make things like lane painting and sign painting a priority. Streets will narrow since less human error means no more need to make lanes and streets wide to account for a margin of error the way they do today.

The Regional Plan Association has developed a timeline to help streamline and integrate driverless cars into our cities. Although the developers admit it makes some assumptions about the technology and implementation that may not play out as anticipated, it still provides an organized approach to ease cities into the transition of a new era of transportation.
Phase one spans from 2017-2022. During this phase, automated features continue to improve in cars and become less expensive. Car companies pair up with transportation network companies like Uber and Lyft to test driverless cars with drivers still behind the wheel. Greater use of on-demand driving services will increase during this time as well.
Phase two spans from 2022-2027. During this time, self-driving trucks will revolutionize the freight system and make sending and receiving goods much less expensive. Costs to ride share will plummet as driverless vehicles take over the task. Particularly interesting during this proposed era is the development of loading zones to accommodate freight and on-demand services.

During phase three (2027-2040), things get really interesting. Conversion to driverless cars for light duty vehicles increase from a projected 15% in 2030 to 75% by 2040. Because driverless cars are able to "talk" to each other, they are more flexibly and dynamically routed, so the need for road space decreases. Less road space opens up the potential for more bike lanes or other areas. Charging stations start to appear for all the electric vehicles now on the road.

Finally from 2040 and beyond, infrastructure such as traffic lights are removed since driverless cars are able to fully communicate with each other. Over 1 million acres are freed up because the need for parking is so drastically reduced. The space can be used for affordable housing,

	open space, or other beneficial uses to communities. Transit companies us driverless technology to increase flexibility to provide services in low density areas and during off-peak hours. People regain commute time to use for work or leisure. And perhaps the best part of all, vehicle crashes fall by 90%. Now that all sounds wonderful and smooth. But that only happens IF officials plan accordingly and IF cities reinvest in evolving transportation systems, and IF technology works according to plan. And those are all really big ifs! After looking at just some of the issues associated with bringing driverless cars into society, it should be pretty clear that the impact of such a turning point in technology could be a once-in-a-lifetime change to society, similar to the introduction of the (human-driven) automobile. At this point though, there seem to more questions than answers, though many people are working hard to overcome the problems and risks to make it a reality. There will likely be lost jobs as well as new career opportunities. These issues will be figured out in the coming years and decades. You will have an important voice in these debates and discussions in your communities, on social media, and in your schools.

Module 5: Drones

Module Description	They take photos, spray pesticides, rescue swimmers, and deliver packages. They survey damage, explore new land, and occasionally, they hit someone in the face. Yikes! They are aerial drones. And even though they don't move people from place to place, drones are still an emerging transportation technology that will grow in importance in the years to come. This module will explain what drones are and how they are different from other aircraft. It will provide an introduction to how drones fly, are controlled, and operate autonomously. The module will examine the impact drones have on jobs today and future jobs involving drones. We will examine some of the current uses for drones and their safety. By the end of the module, you will be able to formulate an opinion about drone use, and explain whether or not you think they do more harm or good for the world.
Reading #1	Unmanned aerial vehicles, aerial drones, unmanned aerial systems, flying cars, flying passenger drones, remote-controlled planes... these terms are enough to make anyone's head spin trying to figure out what each one means. Let's break down some of the more applicable terms and definitions for this module. **What is a Drone** A **drone**, simply put, is an unmanned aircraft.[1] Drones and **unmanned aerial vehicles** (UAV) are terms that are often used interchangeably. Drones differ from helicopters and planes in that there is no pilot operating from within the drone. Instead, the pilot is generally operating from the ground. Drones differ from remote controlled planes in that they have some autonomous capability. Autonomous meaning, the vehicle is capable of flying and navigating by itself without the pilot

	actively controlling it for some period of time. **<u>Common Drone Uses</u>** Drones are not meant for carrying passengers, unlike flying cars. Drones do, however, transport things like small packages, supplies, food deliveries, cameras for filming. Amazon has started experimenting with drone delivery in some areas. The advantage to this is that it is less expensive than paying to have it shipped and delivered by traditional methods. After a disaster, drones can deliver supplies and survey the area without the same dangers associated with putting a human on the ground to do the job. Imagine how fast your pizza could arrive if the deliverer was a drone! The drone would be able to bypass traffic and get to your location much quicker than someone driving a car. Drones are ideal for filming live events such as concerts or press conferences. Their ability to hover above a crowd means closer, more direct footage. Also, since they do not have to be tethered to a line like a camera without a drone, they are free moving. This means they can back up, move closer, go higher, go lower, or do just about whatever is necessary to get the best footage. We will discuss these applications and more in sections to come. **<u>References</u>** 1. What is drone (unmanned aerial vehicle, UAV)? - Definition from WhatIs.com. (n.d.). Retrieved January 14, 2018, from http://internetofthingsagenda.techtarget.com/definition/drone
Reading #2	This section will review some of the key components and technology in drones. **Rotors** How does a drone go from sitting on the ground to hovering hundreds of feet in the air? Let's take a look at some physics: Most drones use **rotors** to control their flight. A rotor works a lot like a fan. As the blades rotate, they push the air down. In response, the air pushes up on the rotors. To fly, the force of air must be greater than the pull of gravity. (Note: for this section, we are focusing on 'quadcopter' drones, or drones with 4 rotors that provide lift. These are the most common drones, and different than larger military drones, which fly more like airplanes). **<u>Thrust</u>** To climb higher, whomever is controlling the drone increases the **thrust,** or speed of the rotors so that the upward force is greater than the weight of the drone. To come down, the thrust must decrease so the net force is downward. To hover, the thrust must be equal to the gravitational force pulling down on the drone. Manually controlling each individual rotor would be extremely difficult. Luckily computers take

away some of that difficulty. Drones today are equipped with some fantastic technology features.

Accelerometer and Altimeter

An **accelerometer** keeps the drone flying at the right acceleration. In fact, some heavy duty drones can withstand wind gusts of 50 miles per hour![1] An **altimeter** lets the drone know what- you guessed it- altitude the drone is flying. And that's not all the features on some high end drones. There are also camera, radar, and laser, to name a few features.

Algorithms and Deep Learning

A drone knows it needs to correct something because it has been programmed with **algorithms**. Algorithms are a set of rules or procedures to follow when solving a particular problem or calculation. So if the wind begins to blow while a drone is in flight, a certain algorithm leads the drone to making the necessary corrections to maintain flight.

Until recently, a global positioning system or (GPS) was crucial to drone flight. GPS is a system of computers, satellites, and receivers that are able to determine the latitude and longitude of a receiver. In the case of unmanned aviation, they relay the position of the aerial vehicle.

The problem with using GPS is that it is not available in all areas of the world. To work around this problem, deep learning is being utilized in drone technology. **Deep learning** enables a computer to learn by observing. The computer learns to recognize an object through seeing thousands or millions of photos of the object from every angle and in different lighting or situations. Algorithms are programmed into the computer to instruct the drone on how to proceed once it identifies an object.

Object Detection

A team from Nvidia believe that the answer to autonomous aerial vehicles is **deep learning**. Deep learning is a process used to teach machines to recognize objects.

Now, back to how this applies to aerial drones. Places where drones would be helpful are often places that are not GPS friendly. Knowing this, the engineers decided to test their drone in a difficult to manage forest. Figuring, if they could get the drone to fly autonomously through a dense forest, it could fly almost anywhere.

The team from Nvidia "trained" their drone by using image datasets captured by researchers in the Alps and the pacific northwest. The team tested their drone in the Seattle area. The team successfully trained the drone to fly through 1 km (.62 miles) going 3 meters per second. This sort of success leaves engineers hopeful that deep learning is the answer to autonomous flight. [2]

References

1. How Do Drones Work? (n.d.). Retrieved January 14, 2018, from http://time.com/3769831/this-is-how-drones-work/
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POINTFUL EDUCATION

Reading #3	**<u>Drone Uses</u>** Drones are still in their infancy. Society is only beginning to realize some of the applications drone use could have in the world. Here area few jobs that a drone could do or, in some cases, are already doing: **<u>Pesticide application</u>** When a human applies pesticides, he or she has to be extremely careful since it involves applying chemicals to reduce bugs in crops. It usually involves layers of protective clothing while working in the hot sun. Even when an airplane is used to apply pesticides (called "crop dusting"), it's still a dangerous job for a human. Crop dusting has the highest accident rate in general aviation.(1) Drones not only do the job more efficiently and accurately thanks to their technology, but safer as well. **<u>Aerial photography</u>** Whether flying over a celebrity's house, an active volcano, or beautiful landscapes, drones are being used for all kinds of aerial photography projects. They are much cheaper and easier for photographers to use than having to rent a plane or helicopter. **<u>Life guard</u>** On average, it takes a human lifeguard about 90 seconds to reach a person in trouble. It takes a drone about 30 seconds.(2)Although not able to jump in and save a person, the drone is able to deploy a flotation device for the victim. In fact, in early 2018, drones were used to help rescue some teenage surfers in Australia. Read about that story here. And saving drowning victims is not the only beach service a drone provide. In California, drones are also used to check for sharks. **<u>Spotting poachers</u>** At Chitwan National park in Nepal, drones patrol the skies reveal poachers below, on the ground. And it's working. Endangered species populations are on the rise, and reported incidences of poaching are on the decline. **<u>Disaster Zone Inspection</u>** Investigating a disaster zone is dangerous for humans. A drone, on the other hand, can assess the scene from near ground level without having to walk through unstable buildings, rubble, and down power lines. It can also easily climb higher to get a better vantage point. **<u>Delivery</u>** Whether it's bringing your Amazon order in less than 15 minutes(3) or a pizza hot from the oven, drone delivery has huge potential commercial use for drones.

	While delivering packages and pizzas might come to mind first when thinking about deliveries, there are other, potentially life-saving deliveries that drones can make as well. A company called Zipline in East Africa, for example, is using drones to make regularly schedule blood deliveries as well as emergency deliveries. The local children call them "sky ambulances", and these sky ambulances have made over 400 emergency deliveries saving many, many lives.[4] In Switzerland, Matternet has been approved to make deliveries between hospitals, clinics, and labs. This means that highly important items like blood tests and diagnostics can be delivered in a half hour. Drones can also access disaster areas much more safely and quickly than humans. For this reason, drones are an excellent option for sending emergency supplies and essentials. **Environmental Benefits** As a benefit to the environment, drones are replacing some gasoline-guzzling machines on farms and in agriculture. This reduces emissions in the air. Furthermore, when used for activities like delivery, not only does it reduce emissions, it also lessens traffic. Other benefits to the environment include being able to fly over solar farms, detect pipeline leaks, and for tracking emissions. **References** 1. Murray, R. (n.d.). How Drones Will Replace Humans in the Workplace. Retrieved January 14, 2018, from http://abcnews.go.com/Lifestyle/drones-replace-humans-workplace/story?id=24890351 2. Newman, L. H. (2015, March 24). Lifeguard Drones Deliver Help to Drowning Victims in 30 Seconds. Retrieved January 14, 2018, from http://www.slate.com/blogs/future_tense/2015/03/24/lifeguard_drone_test_in_chile_by_green_solution_and_x_cam.html 3. Watch Amazon's Prime Air Complete Its First Drone Delivery. (n.d.). Retrieved January 14, 2018, from http://fortune.com/2016/12/14/amazon-prime-air-delivery/ 4. Rinaudo, K. (n.d.). How we're using drones to deliver blood and save lives. Retrieved January 14, 2018, from https://www.ted.com/talks/keller_rinaudo_how_we_re_using_drones_to_deliver_blood_and_save_lives/transcript
Reading #4	**Security Issues** We've covered the benefits, now it's time to look at some of the risks associated with drones. For one, there are security issues. It is also not too difficult to hack into most drones. If this happens to a company drone, any information stored on the drone could be exposed. This could mean leakage of trade secrets and network data, for example. A drone has also crashed in front of the white house, and in many cases drones are flown too close to airplanes and helicopters.[1]

Privacy

Then there are privacy issues. Many drones come equipped with a camera. The opportunity to harass, stalk, humiliate, and blackmail is that much easier when the harasser can invade personal space or property and easily obtain images.

Drone Harm

It's not just their pilots that can cause mayhem. The drones themselves have harmed people as well. During a festival in Virginia, a drone being used to record video crashed into the stands, injuring several people in attendance. One also has impacted sensitive environmental area, as one man crashed his drone into a famous hot spring in Yellowstone National Park.[(1)]

Drug Smuggling

Drones are also being caught carrying drugs. This is a problem particularly at the border between Mexico and The US. Police have caught drones smuggling hard drugs across country lines.[(2)] Listen to the following radio segment from NPR about how prisons are working to keep out drug-smuggling drones.

Regulations

The government is trying to limit the dangers drones pose by enacting various laws. For example, drones are not supposed to fly higher than 400 feet. There are also no-fly zones such as near airports. In some states, it's illegal to stalk with a drone.

Not everyone is in favor of those laws. Some worry they will stifle innovation and commerce. Others feel some of the regulations are unnecessary. For example, if people live in a place where they have “reasonable right to privacy,” does there need to be a separate law in place governing drones and privacy issues?

Drone Delivery Issues

Although Amazon Prime Air has demonstrated the capability of using drones for package delivery, there are some associated concerns. For example, the drone could damage a person or piece of property, it could be “hacked”, or someone could tamper with it upon delivery.

And the rules and regulations regarding drone delivery are far from in place, at lest in the U.S. This is one of the biggest hurdles Amazon has faced with instituting Amazon Prime Air. The FAA has kept tight restrictions on the testing area for Amazon Prime Air. That is why some of the testing and delivery has happened in other countries such as Canada and the U.K.[(3)]

Furthermore, if more and more companies use drone technology, it could create air traffic chaos with potentially thousands of drones flying daily. Finally, it might be relatively easy to deliver a package via drone onto someone's front lawn, but how about an apartment on the nineteenth floor?

Summary

Clearly the way forward with drone use is not perfectly mapped yet. Drone manufacturers, delivery companies like Amazon, and other users like photographers will need to work with government

	officials (mostly in the Federal Aviation Administration or "FAA") to promote rules that will ensure safety and privacy, while allowing new ideas to be tested and used. **References** 1. Conner Forrest | March 20, 2015, 5:00 AM PST. (n.d.). 12 drone disasters that show why the FAA hates drones. Retrieved January 14, 2018, from https://www.techrepublic.com/article/12-drone-disasters-that-show-why-the-faa-hates-drones/ 2. Dinan, S. (2017, August 20). Drones become latest tool drug cartels use to smuggle drugs into U.S. Retrieved January 14, 2018, from https://www.washingtontimes.com/news/2017/aug/20/mexican-drug-cartels-using-drones-to-smuggle-heroi/ 3. Oswald, E. (2017, May 03). Here's everything you need to know about Amazon's drone delivery project, Prime Air. Retrieved January 14, 2018, from https://www.digitaltrends.com/cool-tech/amazon-prime-air-delivery-drones-history-progress/
Reading #5	**Potential Careers in Drones** Does the idea of using a drone AND being paid sound too good to be true? Well, you can do just that. Here are 3 jobs for those skilled at using drones: • Aerial photographer: landscapes, sporting events, and real estate properties are just a few things you can get stunning photographs of using a drone. • Inspection jobs: drones are perfect for inspecting electrical lines, remote substations, cell towers and for helping insurance companies inspect claims. And those are only a few potential inspection jobs. • Engineers: Amazon's Prime Air group (the group attempting to make delivery drones a reality) is growing and in need of many types of engineers to assist in drone development, including software development, security, and electrical engineering.[(1)] **Drone Development** If developing drones is more in line with your interests then this might interest you. "The Association for Unmanned Vehicle Systems International's AUVSI Foundation has also worked with several universities to develop educational programs in unmanned systems and robotics for high school and four-year college/university undergrad and graduate students. According to the foundation (www.auvsifoundation.org), participating students are frequently offered internships and employment opportunities while still in school."[(2)] **Internship** Would you like to have an internship and gain legitimate experience while in high school? Insitu, Inc. is a manufacturer, designer, and service provider of unmanned aircraft systems offers such internships. High schoolers apply directly to their schools, and the school selects the candidate

they feel would benefit the most. Here is a link to Insitu's website: https://insitu.com/about/insitucareers

College Level Preparation

Colleges and universities are beginning to offer programs specifically to prepare students to enter the unmanned aerial sector. For example, Kansas State University -Salina has created a UAS option degree to focus on drone development. Coursework focuses on computer science, electronic and mechanical engineering with unmanned systems. "We won't have graduates for two to three years," says Kurt Barnhart, associate dean of research and engagement and executive director of the Applied Aviation Research Center, which oversees the university's UAS program office. "Our current program graduates operators, analysts, and technicians and they're being recruited by all industry sectors. We have one-hundred percent placement right out of school." Barnhart says that students currently make $60,000 to $80,000 which is a pretty high starting salary.[3]

Military Opportunities

The military is another recruiter looking for UAV pilots. Drone work within the military potentially has more serious consequences than some of the other drone fields, and would require a cool head and the ability to analyze aerial data.[4]

Experts predict that as laws and rules get sorted out and more drones enter society, this field is going to explode with job openings. Now is truly a great time to start learning more about drones.

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2. STEM Education & Robotics. (n.d.). Retrieved January 14, 2018, from http://www.auvsifoundation.org/stem-education-robotics
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4. Luckwaldt, A. (n.d.). Air Force Unmanned Aerial Vehicle Operator Career Profile. Retrieved January 14, 2018, from https://www.thebalance.com/career-profile-air-force-unmanned-aerial-vehicle-operator-2356488

Module 6: Hyperloop

Module Description	So you need to get from Los Angeles to Las Vegas. You could take a car and be there in about six to eight hours. You could take a plane and get there in a little over an hour. Or perhaps in the not-too-distant future, you could take the Hyperloop and get there in a whopping thirty minutes. This module is all about the proposed Hyperloop and vactrain concept. Starting with the technology, the module will explain what a vactrain is and a bit about the physics behind it. Second, it will investigate whether the concept of Hyperloop is actually practical, given costs and current state of technology. Third, the module will examine the risks associated with such a system. After having looked at the technology and hurdles behind the system, the module will take a look at the current state of Hyperloop development and what the future holds. Finally, the module goes over careers and opportunities in the vactrain sector.
Reading #1	**Vactrain History** Ten years ago, no one had ever heard the term "Hyperloop." Now, due to its increasing media attention, it is being discussed around the world. However, **vactrains**, which use magnetic levitation and pressurized air and is the technology behind the Hyperloop, dates back to 1799. During this time, inventor George Medhurst proposed moving goods through cast-iron pipes via air pressure. He actually built a railway station in London that relied on pressurized air.(1) And Medhurst's railway was not the last of its kind. The mid 1850's saw the development of several more pneumatic, or pressurized air, railways. American rocket pioneer, Robert Goddard designed a train that would go from Boston to New York in a mere 12 minutes. Although the train system was never built, it was the original vactrain system, combining magnetic levitation and a vacuum-sealed tunnel.(2) Others have also proposed similar systems. MIT designed a vacuum-tube train system in the early 1990s which also would have used magnetic tracks. In the early 2000s, a company called ET3 designed a system using car-sized pods that would travel in pneumatic, elevated tubes using magnetic levitation.(3) All of these earlier developments bring us closer to the origination of what is called "The Hyperloop." **Hyperloop and its Key Technologies** In 2013, Elon Musk, an entrepreneur and CEO of Tesla and Space X, shared a 58 page paper outlining his research for the Hyperloop, a system he claimed would be faster and cheaper than a high speed train(4). (Note: though this paper is not required reading and somewhat technical, it is recommended to take a look - it addresses many topics of this module and will help you succeed in this module!) Then he made the research public and essentially told everyone to go ahead and build it! There are currently two main front runners who have taken on that challenge- Hyperloop Transportation Technologies and Hyperloop One, in addition to other companies such as Arrivo and TransPod. Musk's transportation system would use tubes where the air has been pumped out to create a vacuum-like environment. This is known as **pneumatic tube transportation**. It is the same technology used by banks when someone pulls up to the drive through to deposit a check. They

open a canister, place the check inside, and send it back through the pneumatic tube which, like a vacuum, sucks up the canister and returns it to the teller. Or maybe this scene from the 1971 movie, Willy Wonka and the Chocolate Factory, will help make the concept clear!

Back to Hyperloop, large pods would travel through these near-vacuum tubes at speeds of over 700 miles per hour.[5] While the pressurized tube system would be one aspect of the technology, **air canister** skis would be another crucial component. The air canister skis would push up on the pods, causing them to levitate. It is the same concept that allows pucks to glide over an air hockey table. The levitation would lessen drag even more which is how the pods would reach such high speeds.

There are two companies, Hyperloop One and Hyperloop Transportation Technologies, which are considered the front runners in the race to build the first viable Hyperloop system.[6] Rather than air canister skis, both companies are using **magnetic levitation** to levitate the pods. In their approach, pod-side magnets repel a passive track, creating levitation.[7]

This is a type of magnetic levitation known as passive magnetic levitation. Magnetic levitation works because magnets have two poles, the north pole and the south pole. When you have two magnets, the south pole of one will be attracted to the north pole of the other. On the other hand, the same poles on different magnets will repel one another.

To get the pods moving, thrust is generated from linear motors. With **drag** greatly reduced from the near-vacuum like tubes and the levitating pods eliminating **friction**, conditions are optimal for generating fast speeds. Speeds of approximately 670 miles per hour, to be more precise. As a reminder from science class, friction is the rubbing between solid objects remains constant. Drag is the resistance to the motion of an object through the air and increases with speed.

Cleaner Form of Transportation?

Another noteworthy feature is the potential for being a form of cleaner transportation than cars, trains, and airplanes. Many Hyperloop designs aim to be as eco-friendly as possible. Hyperloop One claims their system will draw power from "whichever energy sources are available along the route. If that means solar and wind, then the entire system is 100% carbon free." [8]

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Reading #2

Hyperloop is inexpensive and it works! Or at least that is what Hyperloop enthusiasts believe.

Hyperloop One Test

Hyperloop developers would have a hard time raising a single penny more if it starts to look like the technology itself does not even work. Luckily for supporters and investors, the developers are out to prove that it does work. In July of 2017 Hyperloop One tested a full-scale hyperloop on its test track. The track was 500 meters long and the pod was able to get going to almost 200 miles per hour.

The test in July 2017 was a big victory for Hyperloop One. It traveled 4.5 times further, achieved 2.7 times more speed, and experienced 3.5 times more horsepower than any prior test.[1] While the speeds were not the 600+ miles per hour max that the company claims Hyperloop can reach, nevertheless, the company feels this validates that the science is there; that given the proper amount of track to gain speed, Hyperloop could reach such speeds. It also validates the technology- a vacuum-like tunnel and magnetic levitation enable very fast transportation. Or at least Hyperloop One believes it does.

Hyperloop Criticisms

Skeptics, true to nature, remain skeptical. One of the biggest criticisms is how an average human body can handle accelerating to nearly 700 miles per hour in such a short time without a serious case of motion sickness. Critics argue that the only way to do that is to make sure the track is pretty straight because changes in acceleration/deceleration is what will trigger motion sickness.[2]

However, the earth is not flat in too many places. There are hills and mountains to climb and descend nearly everywhere. To maintain a flat, constant track would require lots of expensive drilling.

Nevertheless, Hyperloop One maintains that riders will feel just as comfortable riding the Hyperloop as they would riding in an airplane.

Hyperloop Cost Comparison

In addition to its high speeds, one of the major benefits that Hyperloop is supposed to provide is a low-cost travel option. According to Hyperloop One's website, “High-speed rail and maglev trains require power along the entire track. As a result, the track costs more to build and more to operate. Hyperloop One achieves better performance for less cost.”[3]

	Ticket costs are also projected to be lower than other means of transportation. For a plane ride from Los Angeles, California to Las Vegas, Nevada costs about $125 (depending on day and time of year). The same trip would cost approximately $89 by bullet train. Hyperloop estimates that a ride from Los Angeles to Las Vegas will cost about $60. That definitely gives the price advantage to Hyperloop. Skeptics are not so sure about that. While those involved with the project estimate that the cost will be two-thirds the cost of a high speed rail, experts argue that the project could be upwards of $100 billion.[4] That is well over twice the cost of high speed rails! And it is MUCH higher than the original proposed cost from LA to San Francisco which was $6 billion. If the skeptics are right, and the prices end up being astronomically higher than predicted, that expense is likely going to translate to much higher ticket costs than projected. The cost for transporting freight may not give Hyperloop much advantage either. For one, the max speeds are only obtained during straight shots. The train will have to slow down to turn. The heavier the freight, the slower the train will have to go to turn. Furthermore, the proposed routes are fixed points. Trucks would still need to transport freight to its final destination. This could potentially eliminate any advantage Hyperloop's speed gave it. Hyperloop would also lack the flexibility of air shipping which can shift routes to match demand for moving high-value, low-weight goods. In short, supporters say it will be fast and inexpensive. Critics say it won't be as fast as projected and will cost much more than estimated. Which group proves right will likely, ironically, depend on future testing and funding. **References** 1. Hawkins, A. J. (2017, August 02). The hyperloop just had its fastest test yet, nearly hitting 200 mph. Retrieved January 15, 2018, from https://www.theverge.com/2017/8/2/16080070/hyperloop-one-fastest-test-192-mph 2. Akpan, N. (2016, May 11). Can our bodies handle the hyperloop? Retrieved January 15, 2018, from https://www.pbs.org/newshour/science/is-traveling-on-hyperloop-a-ticket-to-puke-city 3. Facts & Frequently Asked Questions. (n.d.). Retrieved January 15, 2018, from https://hyperloop-one.com/facts-frequently-asked-questions 4. Follett, A. (2016, July 26). Scientist Lays Out 5 Huge Problems With Elon Musk's Hyperloop [VIDEO]. Retrieved January 15, 2018, from http://dailycaller.com/2016/07/26/scientist-lays-out-5-huge-problems-with-elon-musks-hyperloop-video/
Reading #3	**Hyperloop Risks** How safe do you feel when you get on an airplane? Do you even think about the risks of flying, or do you just walk through security, board the plane, and put on your headphones, hardly paying attention to the safety briefing? Hyperloop developers hope riders will have that sort of safe and secure feeling when riding the Hyperloop.

Terrorism

History shows that terrorist take advantage of mass transit systems for terrorist attacks. The fact that large groups of people congregate in a relatively small area makes mass transit systems high targets for terrorists. For that reason, Hyperloop One proposes the same high security checks airports employ before boarding an airplane. However, the system will supposedly go much faster at a hyperloop station because pods will be coming and go so much more frequently and systematically than airplanes.

Pylons and Structural Safety

Safety within the station, does not necessarily translate to safety outside the station.
The **pylons** (structural support towers) which will be built to support the hyperloop system, may still be targets. And there is no indication that there will be guards standing watch at each pylon.

Pylons are also the proposed solution for problems related to thermal expansion, which is what happens when steel gets hot. As well as the solution to earthquakes since the tube is not rigidly fixed at any point. According to Musk, inside each pylon could be two lateral dampers and one vertical damper.[1] The dampers are devices that would absorb seismic activity.

Some engineers raise their eyebrows in skepticism about the feasibility of this pylon and damper plan. Engineer Kristen Ray said, "A simple damper will not suffice for the major seismic activity potential in the San Francisco and Los Angeles areas with a structure that needs to keep such exact tolerances due to the high speeds."[2]

Tube Stability

Another potential issue is the thickness of the tube. If a crack or breach happened, disaster would strike. Dr. Phil Mason, a former Cornell University explained that, "... a single breach in the Hyperloop would probably kill everybody else in the Hyperloop because air would rush into the tube at about the speed of sound."[3]

Hyperloop Claims

So the solution, according to Hyperloop One, is to build thick, strong tubes made of steel and tubes and pods that can withstand sudden pressure changes.[4] Although that sounds reassuring, it raises the question: won't that make the construction extremely expensive? After all, the pylons and dampers are going to have to support extremely thick tubes, not just in optimal conditions, but in extreme weather and natural disasters too.

One safety feature Hyperloop One claims they will have is the ability to section off parts of the route. That way, in theory, they could limit problems to just one area. Furthermore, the company plans to build sensors to notify of any problems or air breaches.

Furthermore, all Hyperloop One pods will be autonomous. This eliminates driver-related errors.

A final safety win for the Hyperloop is that unlike railroads, there will be no other vehicles or pedestrians crossing the Hyperloop's track. This means no potentially fatal collisions with other forms of transportation or pedestrians.

	While it does seem that Hyperloop developers are taking the safety issues seriously and developing plans to deal with the issues, for most critics, only proof, not just words, will do. **References** 1. Here's Why The Hyperloop Would Withstand An Earthquake (At Least In Theory). (2013, August 13). Retrieved January 15, 2018, from https://www.webpronews.com/heres-why-the-hyperloop-would-withstand-an-earthquake-at-least-in-theory-2013-08/ 2. What are the biggest challenges, in terms of those that are technical, political, and those involving land-use issues, to Elon Musk's Hyperloop, and to what degree is it feasible? (n.d.). Retrieved January 15, 2018, from https://www.quora.com/What-are-the-biggest-challenges-in-terms-of-those-that-are-technical-political-and-those-involving-land-use-issues-to-Elon-Musks-Hyperloop-and-to-what-degree-is-it-feasible 3. Pring-Mill, D., Majumdar, D., Mills, C., Fontaine, R., & Kliman, D. (n.d.). Hyperloop Projects May Be Uniquely Vulnerable to Terrorism. Retrieved January 15, 2018, from http://nationalinterest.org/feature/hyperloop-projects-may-be-uniquely-vulnerable-terrorism-21781 4. Facts & Frequently Asked Questions. (n.d.). Retrieved January 15, 2018, from https://hyperloop-one.com/facts-frequently-asked-questions
Reading #5	t is a bit amazing to think that prior to 2013, hardly anyone was talking about vactrains as a viable mode of transportation. Elon Musk had not written his 57 page white paper outlining the technology. Hyperloop One and Hyperloop Transportation Technologies did not even exist. **Hyperloop Teams Expanding** Now, not only do those companies exist, they are actively looking for people to join their teams. Hyperloop One has a list of available positions on its website (https://hyperloop-one.com/careers). They also have engineering and non-engineering internships for college students. Hyperloop Transportation Technologies has more of a tell-us-about-yourself-and-we'll-see-where-we-can-find-a-place-for-you type approach. To get a better sense of the company, Hyperloop One has a 60- Second Team Profile Series on their Youtube channel. Videos feature a welding engineer, the director of manufacturing, director of accounting, test engineer, and many more. **Career Preparation** Although it may seem a far way off to be employed by a company like Hyperloop One, there are things you can do now to prepare. Interestingly, for the position of vehicles control and dynamics engineer, there is a need for people who have experience with creating manned or unmanned vehicles or drones. So while flying drones may feel like just a past time, it could actually help you gain some real experience as you figure out what you like or do not like about how it works and think critically about how it could be better. Sometimes innovations like Hyperloop seem like something better suited for science fiction movies. But then someone actually stands up and builds it, and it changes the world.

POINTFUL EDUCATION

Module 7: Jetpacks

Module Description	Does the idea of blasting off the ground with nothing but a mini rocket on your back thrill you? If so, then it is likely you have dreamed of using a jetpack. And you are not the first to dream of it. People have been asking for decades, "where is my jetpack?" Some big companies are asking this question as well. In late 2017, the giant company Boeing, which makes jumbo jets, offered a $2 million prize to anyone who can produce an "easy to use, personal flying device."[1] This module will define what a "jetpack" is and how it differs from other forms of technology. Second, it will identify technological advances that have contributed to the emergence of jetpacks. Third, the module will look at historical creations as well as modern jetpacks and how they operate. Next we will discuss the risks and limitations associated with jetpacks. This will bring us to a discussion about whether or not jetpacks will be used as a regular means of transportation. Finally, we will examine an existing company that develops jetpacks. **References** 1. Hawkins, A. J. (2017, September 26). Boeing will give $2 million to anyone who can build a functional jetpack. Retrieved January 15, 2018, from https://www.theverge.com/2017/9/26/16362868/boeing-go-fly-prize-jetpack-competition
Reading #1	For anyone that has ever had a dream they could fly, you know the exhilaration that comes from realizing 1. You aren't plummeting to your death and 2. That flying is *awesome!* Now imagine if you did not have to be asleep to fly but could do it anytime and anywhere you wanted. That's the fantasy behind jetpacks. A **jetpack** is a device worn like a backpack that enables the wearer to travel through the air by using jet propulsion. **Jet Engines** To get an idea of how a jetpack works, let's first look at how a jet engine works. A **jet engine** converts high-energy liquid fuel into a powerful thrust, or powerful force. It uses a chemical reaction called **combustion** in which it burns fuel with oxygen in the air to release an energy that powers the jet, or in this case, the jetpack. The terms rocket pack or rocket belt are often used interchangeably with jetpack. Obviously, jets and rockets are *not* the same thing, so technically speaking, a rocket pack/ rocket belt is not the same thing as a jetpack. **Rockets** To find out what makes a jetpack different from a rocket pack, let's find out how a **rocket** works. For a rocket to work, **exhaust gases** (gases emitted from the combustion of fuels) come out of the engine nozzle at high speeds. This pushes the rocket upward. So far a jet engine and a rocket engine are not too crucially different from one another. The main difference is that jets intake oxygen from the air to burn fuel. Rockets carry their own oxygen.

	That is why rockets, but not jets, can travel into space. A rocket carries the oxygen with it, so that even if there is no oxygen- like in outer space- the rocket can still work.[1] Throughout this module, we will look at both jetpacks and rocket packs since the overall idea is the same. Both aim to provide a way for users to strap a device on their bodies to fly through the air. This is different from other futurist transportation ideas such as hover boards or flying cars, both of which require a device you ride *in* or *on*. **Hydrojet Pack** Sitting somewhere in the middle between jetpacks and other forms of transportation is a **hydrojet pack**. These recreational devices have become increasingly popular over the past five years or so. Hydrojet packs are powered by water. A forceful amount of water shoots out the bottom of the rider's pack propelling the rider over 20 feet in the air. A force that strong requires a great deal of water. More water than a person could carry in a pack. Instead, a jet ski or similar device sucks up the water through a hose. The hose shoots the water into the pack which lifts the rider high above the water. So even though the rider is tethered by the hose, the ride can go on for quite a while since the rides are usually in an ocean or lake which has a near endless supply of water for the activity. And people love it! **References** 1. Propulsion. (n.d.). Retrieved January 15, 2018, from http://www.qrg.northwestern.edu/projects/vss/docs/propulsion/3-how-is-rocket-propulsion-different-from-jet.html
Reading #2	We can access a near infinite amount of information on a device we carry around in our pocket. We use that same device to connect to people halfway around the world. We have medicine which has nearly wiped out diseases that were killing us mere decades ago. Despite all these amazing advances, or perhaps because of them, people still ask “where's my jetpack?” If we can do all those things listed above, why can't we strap ourselves to a device and fly anywhere we want, any time we want? **Small Rocket Lift Devices** A lot of the development in the jetpack or rocket belt technology has happened because of the US army's interest in the technology. Although there interest in “**Small Rocket Lift Devices**” (SRLD) has been less about getting out of traffic jams, and more about things like overcoming minefields, reconnaissance, and crossing rivers.[1] In the 1960s, the army began working with Wendell Moore of Bell Aerosystems to create a SRLD. Moore created the Bell Rocket Belt. **Jet Pack Chemistry** The belt features a glass-plastic corset which holds three cylinders, two of **hydrogen peroxide** and one of compressed **nitrogen** in the middle. When the operator opens the regulator valve, the compressed nitrogen moves out of the center cylinder and displaces the hydrogen peroxide. They hydrogen peroxide is piped to the gas generator.

	In the generator, it comes in contact with the catalyst. A **catalyst** is a substance that increases the rate of a chemical reaction without undergoing any permanent change itself. In the case of the Bell Rocket Pack, the catalyst was a silver plate covered with a thin layer of samarium nitrate. Then the hydrogen decomposes. The result of the decomposition is a mixture of steam and oxygen gas. The gases travels through two pipes to the jet nozzles. First the gases constrict and then they are allowed to expand. This accelerates them to supersonic speed and creates reactive thrust. The thrust lifts the pilot into the air... for only about 20 seconds. Furthermore, the noise is so loud that protective ear wear is necessary. Given these limitations, it is not too hard to see why the army lost interest in the project. That's not to say they haven't been a complete waste of time for science. In 1994 NASA introduced the Simplified Aid for EVA Rescue or SAFER.[2] It's a propulsive backpack used when astronauts become untethered during spacewalks. All subsequent rocket belts have their foundation in the Bell Rocket Design and have been merely tweaked from there. **Rocket Packs vs. Jetpacks** As discussed in the previous section, there is a fundamental difference between packs which use rocket technology and packs which use jet technology. Jetpacks, as opposed to rocket packs, depend on the intake of oxygen from the air. In traditional models, these packs use a small turbofan and divides the air into two flows. One flow goes into the combustion chamber, the other flow bypasses the engine, then mixes with the hot turbine gases. This air cools the turbine gases. In the upper part of the engine, the exhaust divides between two pipes which lead to jet nozzles. Turbojet packs use kerosene-based fuel. The results in terms of flight time, height, and overall efficiency, are much better. The problem with jet technology is that it is more expensive and complex to build. Some models have added wings to achieve even better results. In the next section, we will take a closer look at how some of these more contemporary models work. **References** 1. The World's First Jetpack Was Built In The 1950s. (2013, September 08). Retrieved January 15, 2018, from http://knowledgenuts.com/2013/09/08/the-worlds-first-jetpack-was-built-in-the-1950s/ 2. Greene, N. (n.d.). Astronauts Wear a JetPack in Space for Safety. Retrieved January 15, 2018, from https://www.thoughtco.com/simplified-aid-for-eva-rescue-safer-3073499
Reading #3	If our heart is set on wearing a jetpack in this lifetime, you may be in luck. There are still engineers and inventors working to improve jetpack technology. **Inventor Yves Rossy**

In the 2000's, a Swiss pilot name Yves Rossy has flown his incredible jetpack with wings over the English Channel, over the Swiss Alps, and attempted to cross the Straight of Gibraltar with it, but had to make crash landing into the water. (He was fine.) He even flew next to the Emirates A380!

His personal flying devices uses four small jet engines.[1] Being able to fit four small jet engines on a wearable pack is a technological advancement that has made modern jetpacks more efficient. With so much hot exhaust coming from four jet engines, Rossy wears a thermal resistant suit, similar to what a racecar driver would wear.

One of the amazing things about Rossy's flights is how he is able to fly horizontally. To do this, first he rides in an airplane up to the necessary altitude. As he prepares to jump out of the plane, he ignites the jet engines using an electronic starter. The starter enables all four engines to start at the same time.

After which, he immediately jumps out of the plane with the wings still folded at a hinge in the middle. The wings open during his free-fall. The aerodynamic wings help him fly horizontally for several minutes. A parachute helps him land once his kerosene-based fuel gets low.

JB-10 Jetpack

If you have $250,000 and you are unsure how to spend it, you are in luck! That is the cost of the JB-10, a jetpack developed by JetPack Aviation. If that's a little out of your price range (or a lot!) don't despair- you can still take jetpack pilot lessons and learn to fly one in about three hours. [2]

The JB-10 is truly a modern creation. It uses sensors like gyroscopes and accelerometers to monitor the wearer's flight. Being able to use these sensors is in many ways due to smartphone development. With the development of the smartphone, such sensors went from thousands of dollars to mere cents in costs.[3] Such sensors allows technology to do much of the monitoring that, in the past, had to be done by the pilot.

In order to improve on jetpack technology of the past, the JB-9, the predecessor to the JB-10, made it possible for one engine to rotate in the opposite direction of the other. This counteracts rather than magnifies torque effects which makes the jetpack wearer a more controlled flight.

Modern jetpacks show that advances in one area of technology often trickle down to other areas.

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Reading #4	We have touched on a few of the limitations to jetpack technology in previous sections, but now we are going to get down to the nitty gritty. What is the problem with jetpacks and rocket belts? Why don't we all have one? **<u>Rocketbelt Limitations</u>** Let us look first at the rocket belt. Like we mentioned before, rocket belts have not changed much over the past few decades. Their flight time is still limited to under a minute, fuel still remains expensive, and they still do not fly high enough to have a back-up parachute. The problem with rocket belts can really be summed up in two points. 1. Humans are not meant to fly. Nothing about our bodies is aerodynamic. Our bodies are essentially useless weight once we get up to the sky. Weight that must somehow be lifted off the ground. 2. Gravity is always (literally) pulling us down. Because rocket belts require the pilot to carry all the necessary fuel, the pack cannot be too heavy. If it's too heavy, even more fuel is needed to overcome gravity. More fuel means a heavier pack. Heavier packs need more fuel. It's a vicious cycle. One that leaves rocket belts at a flight time of less than a minute. Spending money on a device that only gets you thirty seconds of travel time is unpractical. This is why rocket belts have been largely limited to theatrical presentations. **<u>Jetpack Limitations</u>** Jetpacks, although more efficient, have their limitations as well. They still burn up quite a bit of fuel to get lift. More fuel burned means more money. This makes them expensive and thereby impractical for the majority of people. Safety is another issue with personal flying devices is the additional awareness required to navigate. In a car, a driver must be aware of what is going on behind, in front, and on either side of him. What is going on above or below is rarely a concern. In the sky, however, there are all sides and angles to be aware of and monitor. This translates to more potential dangers. Another safety issue what happens in the event of a malfunction. Because jetpacks are used mostly in highly controlled and monitored situations, there have not been too many disasters involving jetpacks. However, if there were hundreds or thousands of jetpack out on a daily basis with no one monitoring other than the pilot, it is likely that would drastically change for the worse. When a car malfunctions, most of the time, the driver can pull over and deal with the inconvenience. If a jetpack malfunctions, say the engine goes out, that could mean a free fall to the ground. Backup engines are not feasible at this point because that would make the weight of the pack heavier, which as we learned, requires even more fuel. Parachutes may be useless as well depending on the altitude of the flight (and add even more weight). Even if all the issues above become resolved soon and the jetpack business starts booming seemingly overnight, there is still the lack of control in the sky. There are other aircraft to consider such as planes, helicopters, and pretty soon drones and flying cars! There is wildlife in

	the sky. There would need to be rules to follow in the sky, just like on the street to keep people as safe as possible. That system could take years to figure out. Despite all these limitations, some still feel the jetpack is the vehicle of the future.
Reading #5	**<u>Martin Aircraft Company</u>** Located in New Zealand, the Martin Aircraft Company is one of the world leaders in jetpack development. Although it started quite humbly in the garage of Glen Martin in 1981, by 2010, The Martin Jetpack had been named one of Time Magazine's top 50 inventions.[1] At that point, first responders began showing interest in the product and the company began to realize the life-saving potential the jetpack had. **<u>Life-Saving Potential</u>** Some of the ways the company feels the Martin Jetpack can be used to save lives includes: • Accessing difficult to reach places • Being loaded onto a truck or trailer; thereby eliminating the time required to call in and wait for air support to arrive on the scene. • Supply delivery • Reconnaissance (in other words, scoping things out ahead of time) Although to look at The Martin Jetpack, you may wonder if they are pushing the limit of what is actually considered a "jetpack" a bit.[2] The device is made not so much with a backpack style, but rather something meant to be stepped into. It features a roll cage and a shock absorbent undercarriage. Features one typically does not associate with jetpacks, but nevertheless have usefulness for the device. The Martin Jetpack is designed to be both safest and lightest aircraft. It is made of lightweight composite material and uses automotive fuel for lift. Automotive fuel, although available in most parts of the world, it is neither clean nor renewable. The company is, however, pursuing other forms of fuel. **<u>Additional Uses</u>** Although the company seems particularly enthusiastic about the life-saving potential of the jetpack, the company also proposes some other uses for it. For example, capturing aerial film and photography, inspecting pipelines and powerlines, inspecting superstructures like communication towers and pylons, and in the agricultural industry. A counterargument is that while these are all worthwhile uses, they could also be done cheaper and more safely by using remote-controlled drones. For the Martin Aircraft Company, they feel the biggest limitation to making the Martin Jetpack available for personal use is not the technology, but rather the regulations required to make it (and other flying and/or autonomous vehicles) part of society.

	Whether or not jetpacks will ever become a regular part of transportation is debatable. But whether or not you believe in the potential of jetpacks, you have to applaud the visionaries who see beyond what is happening today and, instead, look to what could be in the future. **References** 1. Saporito, B. (2010, November 11). The 50 Best Inventions of 2010. Retrieved January 15, 2018, from http://content.time.com/time/specials/packages/article/0,28804,2029497_2030622_2029786,00.html 2. Jetpack, M. (n.d.). Martin Jetpack. Retrieved January 15, 2018, from http://www.martinjetpack.com/

Module 8: Supersonic Jets

Module Description	When the Concorde was retired in 2003 with no successor, it left some people scratching their heads wondering what went wrong. Was it the crash of 2000? Was it the cost? Was it the boom? Or was it something else? Why did we fly faster than the speed of sound for 30 years and then... slow down? This module will look at supersonic travel technology. It will examine how supersonic jets differ from traditional jet liners. Then the module will explain the "sonic boom" phenomenon. With this foundation, the module will then look at the technology, costs, operations, and demise of the Concorde. Next it will examine the pros and cons of supersonic jets in general and whether or not it is realistic to expect supersonic intercontinental flights. Finally, the module concludes with a look at companies developing supersonic jets as well as career opportunities within the aerospace industry.
Reading #1	**Regimes of Speed** Imagine jetting off from New York to London in the morning, surprising a friend for her birthday, then jumping *back* on a plane to be home in time to hit an evening Broadway show. All in the same day! Seems incredible, right? Well, when you travel at supersonic speed, or faster than the speed of sound, it's possible. And up until 2003, people were actually traveling that way. **Supersonic speed** is speed faster than the speed of sound, which travels at about 768 miles per hour. When comparing speed to the speed of sound, we use Mach numbers. A **Mach number** is the ratio of the speed of an object to the speed of sound. If something is traveling at twice the speed of sound that would be Mach 2, or 1,536 miles per hour (2 X 768) for example. Supersonic is one of the regimes of speed. The four regimes are[(1)]: 1. **Subsonic**: this is speed slower than the speed of sound, or slower than Mach 1. Today's airliners all fly at subsonic speeds, on average about 575 miles per hour when in flight. 2. **Transonic**: this is speed at about Mach 1. 3. **Supersonic**: like mentioned before, supersonic speed is faster than the speed of sound. It ranges from Mach 1 to Mach 5. 4. **Hypersonic**: Any speed faster than Mach 5, or five times the speed of sound. Launched vehicles fly at hypersonic speeds while in Earth's upper atmosphere. **Aeuronautics** **Aeronautics** is the study of the science of flight. It is thanks to aeronautics that we have figured out how to make jets fly faster at supersonic speeds. Supersonic jets are actually similar to subsonic jets in a number of ways. First, both require oxygen from the air, so air is sucked in with a fan. Next, a compressor, which is made with many blades attached to a shaft, raises the air pressure. The blades spin at high speed to

	compress the air. Third, the compressed air is sprayed with fuel before a spark ignites the mixture. While burning, the gases begin to expand. Finally, they blast out of the nozzle in the back of the jet. The gases blasting out of the back provide thrust for the jet to move forward. **Afterburners and Intakes** The differences are mainly in design and the use of afterburners. **Afterburners** inject fuel directly into the exhaust stream coming out of the jet, and then burns it by using the remaining oxygen. Because gases are able to heat up and expand further, this increases **thrust** by more than 50%. More thrust means more forward force. **Intakes** are responsible for taking in the air for internal combustion.[2] Often the engine of a supersonic jet will sit right behind the intakes, which not only capture the air like a regular jet engine, but also slow and increase the pressure of the air. Positioning the engine right behind the intakes means the air flow does not have to change directions. Another difference has to do with the look of the intakes themselves. The intakes are also longer and have sharp edges. Some can even change their geometry in order to handle the air coming in at supersonic speeds. This enables them to slow down the air, which is also traveling at supersonic speeds. The intakes also have a smaller capture area to minimize drag. **Supersonic Jet Design** Supersonic jets look different as well. Supersonic aircraft generally has a more pointed nose and special wing shapes. The delta or swept wing shape and pointed nose help reduce drag. Supersonic jets are also generally made of lightweight material like titanium whereas traditional airliners are made of composite materials. **References** 1. Pike, J. (n.d.). Flight Regimes. Retrieved January 15, 2018, from https://www.globalsecurity.org/military/systems/aircraft/intro-regimes.htm 2. Tedeschi, D. (2002, November 01). How Things Work: Supersonic Inlets. Retrieved January 15, 2018, from https://www.airspacemag.com/military-aviation/how-things-work-supersonic-inlets-35428453/
Reading #2	**Sonic Boom** A **sonic boom** is a loud noise created by supersonic aircraft. The sound can be heard by a person on the ground when the aircraft flies overhead. When a jet flies at supersonic speed, the air around it reacts like a fluid. Think about it like a boat moving through water. As the jet travels through the air, the air molecules are disrupted, just like the water around a boat. The molecules are pushed aside with great force which forms a shock-wave, similar to the wave created by the front of a boat moving through water. The shock wave creates a cone of pressurized air. The pressure builds and is sharply released once the air returns to normal. The release of pressure after the buildup is the sonic boom. It is kind of like a balloon bursting when pricked by a pin. The sharp release of pressure creates the loud pop of a balloon.

	Boom Carpet Although we only hear one sonic boom from a supersonic jet, there are actually two. The first happens when the nose reaches Mach 1 and the other when the tail of the jet passes. However, the boom does not happen once and then go quietly on its way at supersonic speeds. It "drags" the boom the entire time it flies over Mach 1. In other words, if there was a line of people from London to New York and a supersonic jet flew overhead, every person in the line would hear the boom. This narrow path below the aircraft where the boom can be heard is known as the "boom carpet".[1] Sonic booms have been known to break glass and disrupt people and wildlife. For that reason, supersonic flight is typically banned over land. Reducing the loudness from sonic booms is one of the big technological hurdles companies working on supersonic flight have to overcome. Luckily, scientists are able to use math to predict the boom's path, where they will hit, and how loud they might be. **References** 1. Dunbar, B. (2017, August 15). NASA Dryden Fact Sheet - Sonic Booms. Retrieved January 15, 2018, from https://www.nasa.gov/centers/armstrong/news/FactSheets/FS-016-DFRC.html
Reading #3	**Concorde** Today, a typical flight from New York to London takes about seven or eight hours. During your grandparent's, your parents', and perhaps even *your* lifetime, people had the ability from New York to London in only 3 and a half hours. These supersonic travel times were the magic of Concorde, a joint project between the United Kingdom and France. British Aerospace and the French firm Aerospatiale designed the airframe. Rolls-Royce and France's SNECMA developed the jet engines. These engines were zero-bypass engines, also known as turbojets. A **bypass ratio** is the ratio of air passed around a jet engine core to the air burned in the core. For a **turbojet engine**, all the air goes through the turbine. The result is a fast, but extremely poor fuel efficiency. In fact, the flight from London to New York on the Concorde used up 100 tons of fuel! To put that into modern day perspective, today's jumbo jet uses 44 tons for the same route. This high fuel usage was less of a concern when gas was a mere thirty cents per gallon. But those gas prices disappeared right around the time of Concorde's development. **Concorde Technology** The plane also sported a delta wing design. A **delta wing** is a shaped in the form of a triangle. Since delta wings are relatively thin, this keeps wave drag, which occurs at supersonic speed, down. Other technological innovation of Concorde include:

- variable engine air intake ramp system which was controlled by computers
- supercruise
- thrust-by-wire engines
- droop nose section (for better visibility)
- Mach 2.04 cruising speed
- Mainly aluminum construction
- Autopilot and autothrottle
- High pressure hydraulics
- Computerized complex air data

Concorde's Retirement

Although Concorde was time saving and even life-changing for business people who had to travel frequently, it was retired in 2003 with no successor to offer commercial supersonic flight. There were a variety of factors that contributed to the fleet's retirement:

1. **Cost:** Concorde was developed and built through funding provided by the United Kingdom and France's government. It cost tax payers approximately $1.5 billion. It was never economically viable. In the early days, a flight was roughly $1,500 one-way. By the early 2000s that price had risen to $7,000 and if you could find round-trip tickets for $10,000 that was considered a good deal.[1] These high costs were largely a result of the necessary specialized maintenance and ever-rising fuel prices.
2. **Safety:** Along the same lines, keeping Concorde safe was a challenge. Because it required specialized maintenance, it could only fly to airports with the tools and mechanical expertise to take care of it.
3. **Design Flaws:** Design flaws were put in the spotlight by the tragic accident of 2000. The oldest running Concorde burst into flames when it ran over a piece of debris which caused the fuel tank to ignite. Sadly, all 109 people aboard and four people on the ground were killed. The accident not only highlighted the jet's flaws, but also decreased the number of people wanting to fly.
4. **Noise pollution and environmental concerns:** discussed in the previous section, the sonic boom led many counties to ban overland supersonic flight. Furthermore, with as much fuel as Concorde guzzled, it was no friend to the environment.
5. **Terrorist attacks reducing plane travel:** The September 11, 2001 terrorist attacks lowered the number of people flying for the next few years.

All these factors contributed to the demise of Concorde. Although they may no longer be in service, they are available for viewing at Manchester Airport, Smithsonian National Air and Space Museum, the National Museum of Flight, and many other locations across the world.

References

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Reading #4	Read below and compare the pros and cons of supersonic jet travel. **<u>Supersonic Travel Benefits</u>** Having examined the Concorde, you should have an idea of some of the pros and cons associated with supersonic travel. Let's outline them a little more succinctly. Pros: • ***Faster travel***: this enables people to connect faster and more easily with one another. This also translates to more productivity in many cases. • ***More trips***: Since turn around for supersonic jets is so fast, the jet could, at least in theory, make more trips which would bring in more money. Of course this assumes that there is sufficient demand for supersonic travel to justify more trips. • ***Updated interiors***: not only would a fleet of new supersonic jets provide a new exterior to the look of a plane, but it would provide the opportunity to re-imagine the interior of a jet. • ***Technical innovation***: noise reduction, emissions reduction, and overall efficiency improvement are key components of supersonic research that will spill over and benefit all areas of aeronautics. • ***Competitive advantage***: with so many options for flight today, airlines are constantly on the lookout for ways to set themselves apart from other airlines. Being able to offer supersonic flight would definitely set those airlines apart. • ***Health benefits***: less time sitting on an airplane is a good thing, from a health standpoint. **<u>Supersonic Jet Risks</u>** Cons: • ***Environmental issues***: Burning fuel at such high rates does no favors to the environment. Not only does it contribute to pollution, but it also further depletes a nonrenewable energy source. • ***Ultraviolet (UV) radiation exposure***: Supersonic fly at a higher altitude compared to regular jetliners. The higher the altitude, the less protection there is from UV radiation. Whether or not that is canceled out by the less time spent in the air because of supersonic speeds remains debatable. • ***Noise pollution***: No matter how comfortable or fuel efficient developers make the supersonic jet, they will still have to contend with the sonic boom. • ***Expert training***: Supersonic jets are operationally different than traditional jetliners which means they require special skills and expert knowledge. • ***Special maintenance***: As was the case with Concorde, a supersonic jet will only be able to go where it can be sufficiently maintained. This may limit the number of airports where it can fly. • ***High investment cost***: Creating, developing, testing, and certifying a supersonic jet is not cheap. Combine that with the possibility that it will not go into operation, and it is not hard to imagine why some might be hesitant to put forth the necessary investment.

	• ***Uncertain demand***: Travelers today demand more than just short flight times. If a supersonic jet cannot meet the other requirements passengers have, there may not be sufficient demand. • ***Cost to tax payers***: If the project is subsidized by the government (like the Concorde was), that money has to come from somewhere. And that somewhere is the pockets of tax paying citizens. • ***Limited routes***: Currently, supersonic flight is limited to over-water in most places. This limits the routes that can benefit from supersonic travel. Airports would also need to be mostly those closest to oceans.
Reading #5	**<u>Future of Supersonic Travel</u>** Boom Technologies, Inc. poses the question "When you can get there in half the time, where will you go?" Boom Technologies is one of the companies with a purposed supersonic jet, which they call Boom. Although it may be called "Boom" the company claims that the sonic boom emitted by Boom will be thirty times quieter than Concorde's sonic boom.[(1)] According to Boom Technologies, the time for supersonic flight is now. They attribute a number of modern advances, such as composite fuselages and high temperature, (which have only recently been accepted by the Federal Aviation Administration for commercial flight) for making now the time to pursue supersonic flight. Boom's fuel consumption and emissions profile will match that of subsonic business class. The XB-1 Supersonic Demonstrator is scheduled to fly in December of 2018, and the company hopes to offer passenger flights in the early 2020s. Another company looking to bring back supersonic flight is The Aerion Corporation. Aerion is focused on smaller, private business jets. Their AS2 will fly up to Mach 1.5, or around 1,000 miles per hour. Over land, where it cannot fly at supersonic speeds, it will fly just under Mach 1 (Mach .95) without producing a boom. This is faster than any other commercial jet today. **<u>Suborbital Travel</u>** If for some reason, a supersonic jet seems yawnable, there is always Elon Musk's plans for suborbital rocket travel! Yes, he proposed to use reusable rockets to fly passengers between any two cities in under an hour.[(2)] As outrageous as the idea may seem, it is not a particularly new idea. The key difference between Musk's idea and others that involve suborbital travel, is the use of rockets. Most who have proposed suborbital travel have proposed using planes capable of flying at high altitudes. Whichever vehicle is used, it will not change the fact that this plan has some serious obstacles to overcome. Just the cost alone would be daunting. Add in the safety regulations that will undoubtedly be implemented, and the impact of acceleration and G-forces on a human body, and it will be a hard road for anyone brave enough to pursue making it happen. However, just because something is difficult, does that mean scientists and innovators should not pursue doing it? Even if it does not work out, their contributions to science, engineering, and creativity will impact the world in ways we cannot even imagine.

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Module 9: Personal Rapid Transit

Module Description	What does a small town in West Virginia, Heathrow Airport in London, and Masdar City, United Arab Emirates all have in common? They all use a transportation system known as personal rapid transit or PRT. In this module we are going to explore PRT and other exciting modes of personal transportation. This module will define and explain PRTs, as well as related terms. Then the module will discuss the similarities and differences between the PRT systems and existing modes of transportation. Next, the module will explore personal transporters and how they might fit in to the world of transportation. Finally, it will end with a look at how crossing a motorcycle with a car could, potentially, offer a solution to many transportation issues.
Reading #1	What is one of the most annoying parts of going downtown? If you said traffic, driving, navigating, or parking, you are not alone. Congested roads, limited parking, and trying to figure out where you are and where you need to be can make going downtown stressful, whether you are a passenger or a driver! **PRT Definition** **Personal Rapid Transit** (PRT) aims to alleviate all those stresses with an automated system which utilizes small vehicles, or **podcars**, on a specially designed guideways. A rider simply pays for the fare, selects the destination in the PRT's system, and boards the provided podcar. Then, the podcar whisks the rider directly to his/her final destination. There are no other stops along the way. **Guideways** The **guideways**, or tracks, allow for point-to-point efficiency because the stations are located off the main line. Instead of stopping on the main line, the guideways have many merge/diverge points that allow podcars to enter and exit the main line as needed. The guideways are also separated from other transportation systems, often above-ground, which means there is no stopping for pedestrian crossing, buses, etc. Because they are small, podcars offer the privacy of a car, but the convenience of public transportation. PRTs are a safe, energy efficient solution to public transportation. Because most are electric, there is no emissions. The podcars do not travel very fast, so there is little danger of traumatic collisions. Furthermore, because they are automated, human error is greatly reduced. Because they are automated, PRTs are also known as **Automated Transit Networks** (ATN).
Reading #2	**Pod Size** One of the biggest hurdles in figuring out a PRT is determining the pod size. In the USA, the average car carries 1.16 people. [(1)] In fact, most industrial countries have an average of fewer than 2 people per car. This low rider per car ratio is indicative of peoples' preference to not share a car with strangers. So does that mean pods should fit one person? What about if a small family wants to use the system? Or a single rider with a bike? If the pods accommodate such situations, will people be

turned off at the idea of potentially sharing a pod with strangers? Where is the happy medium between offering the privacy of a personal car, and the convenience of fitting a small group? These are not easy questions to answer. Most are built to accommodate a small group of approximately six people.

PRT Technologies and Terms

Most proposed PRT systems call for electric propulsion. **Propulsion** is the driving force that pushes a pod forward. To make the pods light, they are powered from the outside, as opposed to onboard batteries, though most include a small battery as emergency backup. This is more eco-friendly than traditional buses or cars. Furthermore, where a bus or light rail has a set schedule that runs even if no one is riding, the pods would have designated waiting spots where they would sit until needed by a passenger. This would save energy and be friendlier to the environment.

To navigate the tracks, most designs call for **vehicle-mounted switching**. Proponents of vehicle-mounted switching state that it is faster and allows pods to be closer together (the distance between two unmanned pods is called **headspace**.) compared to the distance between pods on a track switching system. Another benefit is that if a switch fails on one pod, it will not likely affect other pods.

However, there are supporters of **track switching** (what traditional railway systems use) who point out that while vehicle switching may simplify the tracks, track-switching simplifies the cars and involves fewer moving parts. Furthermore, since the parts would be on the track, they could be built for durability without worrying about size or weight.

PRT stations will be similar to subway stations but will operate on a smaller scale since the stations will only need to accommodate a small number of passengers at a time. One key difference, however, is that pods will not be located on the main lane. Rather, there will be sections connected to the main lane by the same junction.

PRT Systems vs. Buses

While we have spent most of the previous section pointing out the flaws of bus systems, there are actually people who feel that buses are the system to develop, not PRTs. It is a bold claim, considering all the traffic generated because buses have to stop, wait for people to load and unload, and collect individual fares.

Countries in Latin America have implemented the bus rapid transit system. The bus rapid transit (BRT) system lifts buses out of the ordinary flow of traffic and into segregated, high-speed lanes. Waiting for passengers to pay their fares disappears by utilizing fully-enclosed stations where passengers can pay before the bus even arrives. Bonus: this system is MUCH cheaper than PRT.

	Of course, you are left without the eco-friendly and privacy aspects of PRT which could mean that if built, it could be under-utilized if it turns out people value no emissions and privacy over the benefits of PRT. **References** 1. Personal rapid transit. (2018, May 29). Retrieved from https://en.wikipedia.org/wiki/Personal_rapid_transit
Reading #3	**Existing PRT Systems** Despite the convenience, and the many proposed systems, only a few PRTs actually exist. The oldest and most extensive is in Morgantown, West Virginia, which is on the campus of West Virginia University.[1] Other places include Heathrow Airport (London England); Suncheon, South Korea; and Masdar City, United Arab Emirates. Of these other ones, none of them exist quite the way proponents envision. Most are just alternatives to shuttles and/or automated people movers. PRT requires building an entirely new infrastructure, mainly all knew tracks and stations. Any system that requires a brand new infrastructure is going to be difficult to implement because building a new infrastructure takes money and resources. Buses, on the other hand, can just utilize the roads already built in a city which makes them a much cheaper form of public transportation for a city to implement. Listen to the podcast below from NPR talks about the PRT system at West Virginia.[2] **Above Ground** Furthermore, that infrastructure can be quite obtrusive, especially if built above ground. Chicago's elevated train or "L-train", for example, was built in the 1890's and would be much more expensive and difficult to build today. There is a reason it is one of the few cities in the U.S. with significant amount of above-ground track (Los Angeles, New York City, and Philadelphia are others). As mentioned before, many designs call for above-ground guideways in order to maximize efficiency. However, an above-ground system may be very noticeable and restrict views. However, many designers are coming up with designs that would blend the infrastructure into the cityscape as best as possible. PRT systems aim to be everything to everyone, as far as transportation options are concerned. Interestingly, this aim could prove to be a potential pitfall to the system. As more people use the system, it becomes less able to accommodate private or semi-private destination demands. This reduces it to more of a light-rail system, making multiple stops. But it would be unable to handle a rush-hour crowd. Perhaps rather than a cure-all, it is best to look at PRTs as a cure-some. Perhaps there are some areas that are better suited than others for the PRT system. For example, small to mid-sized cities that do not already have well-established transit system already. Other useful places are campuses, airports, and new cities.

	The system was a good fit for the city of Masdar because it was being built from scratch with the intention of discouraging private vehicles. For new cities, it also nearly eliminates the problem of disrupting surroundings. However, there are not many brand new cities built from scratch out there (at least not in the US). **PRT Systems vs. Driverless Cars** There is yet another obstacle in the way- driverless cars. Companies are actively developing and even implementing driverless cars already. Driverless cars offer all the benefits of the PRT system without the expensive infrastructure. In a driverless car, passengers would get the privacy, the ease of navigation, and the freedom to engage in other activities. Driverless cars even one-up the PRT systems because, unlike PRTs, a driverless car can take a passenger from his/her house to his/her exact destination every time. There is no need to figure out transportation to and from the closest station. Driverless cars fit in nicely with the road system already in place. Although modifications may be made to make the roads more driverless car-friendly, those changes can be made incrementally. Whereas a PRT system requires an entire infrastructure be built before a single vehicle can be utilized. **SkyTran** Before you give up on PRT, it's worth looking at the solution offered by a company called SkyTran.[3] SkyTran offers all the benefits of PRT namely, point-to-point travel, privacy, on-demand usage, and low emissions but doesn't come with a hefty price tag. One of the key differences with SkyTran and other systems is in the use of magnetic levitation. Electromagnets provide the thrust and the levitation for the systems "jet-like" pods. This allows for almost no emissions and very little energy to operate. Another separating factor is its guideway. As we discussed, most guideway systems are expensive and take a long time to build. But SkyTrans off-the shelf, "snap together" rails can be assembled quickly, easily, and with a much lower cost. **References** 1. https://transportation.wvu.edu/prt 2. Palca, J. (2016, October 03). A Revolution That Didn't Happen: Personal Rapid Transit. Retrieved from https://www.npr.org/2016/10/03/494569967/a-revolution-that-didnt-happen-personal-rapid-transit 3. http://www.skytran.com/
Reading #4	It should be pretty clear by now that building an entire infrastructure from scratch is an expensive, headache-inducing undertaking. On the other hand, finding parking for a car can be stressful too. And no one wants to sit around and wait for a bus. So what other ways are there to get from, say, a store downtown to a restaurant about a mile away in a crowded urban city? **Personal Transporters**

Hoping to be the answer to those problems are personal transporters. Personal transporters are compact, portable, electrically powered vehicles capable of transporting a single individual. Most personal transporters fall into one of four categories:

1. **Electric Kick Scooters:** these vehicles have two in-line wheels with a platform for the rider to stand on and handlebars for steering. Most fold up, making them conveniently transportable. To get it going, the rider just needs to twist the throttle. The Razor e-series are popular electric kick scooters as well as Speedway Mini 4 Pro.
2. **Self-balancing Scooters:** these differ from electric kick scooters in that the wheels are parallel instead of front and back. Examples in this category are Segways and Segway Mini products. Also fitting into this category are vehicles known as "hoverboards" sometimes referred to as "self-balancing boards." The unique feature with these devices are how they are controlled. Rather than using some sort of handlebars or control stick, the rider uses his or her weight to control all aspects of the board. Halo Rover and SwagTron T1 are some of the most popular hoverboards currently on the market.[1]
3. **Electric skateboards:** similar to the hoverboards in the category above, the rider controls the speed and direction of the board by shifting his/her weight. These devices, however, have a set of wheels in the front and another set of wheels in the back. Just like, well, a skateboard! Evolve GT Bamboo Street is an example of an electric skateboard.
4. **Self-balancing Unicycles:** like the name implies, these devices have just one wheel.

Let's examine how self balancing works. Self-balancing devices generally have tilt and speed sensors which detect revolutions per minute of the wheel(s). This information is sent to the **gyroscopes**, which are used to help maintain equilibirum, and speed control boards. When the gyroscopes and speed controls receive the rpm and tilt information, these pieces send the information on to the control board. The control board is where the processor computes the status of the board, and controls things like maximum speed. Examples of self-balancing unicycles include the Kingsong KS16S[2] and the IPS15.

Uni-Cub and Modobag

There are two more devices which really fit into the unofficial category of "great for the airport." They are the Honda Uni-Cub and the Modobag. The Uni-Cub allows the rider to sit on a bicycle-type saddle while cruising along at... less than 4 miles per hour. The website states these are designed for "barrier-free indoor environments."[3] So you may not see these out and about on the sidewalk. They are controlled by rider shifting his or her weight. The Uni-Cub is compact enough that riding on one does not make the rider feel like he/she is infringing on another's personal space.

Also zipping along in indoor environments might be the Modobag. The Modobag is rideable carry-on luggage with a handlebar for steering that can pop up and down. With a price tag of almost $1,400[4], it's likely only those who travel frequently will sport these devices.

All these devices are largely due to the affordability of the lithium-ion battery. The price of the lithium-ion battery fell over 80% between 2011 and 2017[5] which is why these sort of electric devices have seen a huge surge in development and utilization.

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Reading #5	**C-1** Would you rather drive a car or a motorcycle? Your answer is probably "it depends." It depends on the weather, where you're going, the type of terrain, how fast you need to get there, how far, etc. To be sure, each has their own pros and cons. Motorcycles can weave in and out of traffic, park in tight spaces, take up less room (which lowers overall traffic congestion), can go farther on less fuel, and are pretty fun to drive! On the downside, they are notoriously unstable, do not protect the rider from the elements, and lack the safety features of a car. Most cars, on the other hand, are fully-enclosed, have many safety features, steer easily, and are stable. On the downside, they take more fuel to run, require large parking spaces, and contribute to traffic and congestion. However, both provide the privacy and point-to-point travel that people want from transportation modes. What if you could get the best features of both in one vehicle? The Lit Motors C-1 is a cross between a motorcycle and a car.[1] It's like a motorcycle in that it has two wheels, is compact and narrow enough to allow the rider to weave in and out of traffic, and leans to turn. The C-1 is like a car in that it is all enclosed, has a reverse mode, and similar steering. With environmental concerns growing in the minds of the public, the C-1 runs on a rechargeable battery, not fossil fuels. **Gyroscopic Stability System** Where the C-1 really stands out from a traditional motorcycle is in its stability and safety. The vehicle features a patented gyroscopic stability system. The gyroscopes are controlled by the vehicle . This allows the C-1 to lean itslef into and out of turns, and stay upright when stopped or even in the event of a collision. The gyroscopic stability system brings the stability of a car to the two wheeled system of a motorcycle. Being enclosed enables the developers to add safety features traditionally found in cars. There are seatbelts, airbags, and a steel reinforced chassis. Climate control and a premium sound system are perks to this sort of enclosed set up too!

	I-road Toyota is also thinking motorcycle-car hybrids could be the vehicle of the future. They have developed the i-road. Although similar to the C-1 in many ways such as using a rechargeable battery for power, being narrow and compact, fully-enclosed, leaning to turn, and car-like stability, safety features, and steering. It is a little different from the C-1 in a couple ways. For one, it features three wheels- two in the front and one in the back- instead of just two. For another, it only reaches speeds of about 30 miles per hour.[2] Whereas the C-1 reaches over 100 miles per hour.[3] For that reason, it is probably best suited for short trips around neighborhoods and cities. It is possible that in the future, you will see these hybrid motorcycle-cars as people realize they check many of the "must have" features of a vehicle off their list. **References** 1. http://litmotors.com/c1/ 2. https://www.chicagoautoshow.com/vehicles-on-display/2017/toyota/i-road/ 3. http://litmotors.com/faq/

POINTFUL EDUCATION

Module 10: Supercavitation

Module Description	In this module, we will get in the water and examine some of the futuristic transportation ideas in the sea. The focus of the module will be on the concept of supercavitation, which is a technology that has been around for decades, but has been sparsely used and has some serious challenges. Scientists are figuring out solutions to some of these challenges, which may lead to a resurgence in the use of this unique technology. In the final section, we will also review some other marine transportation modes that incorporate ideas that include autonomous control and clean energy.
Reading #1	**Density and Drag** Have you ever tried to run while in a pool? It is MUCH harder than running on land. When you run on land, you are running through air molecules which are much freer and loosely packed together compared to the molecules in the water. Air has a **density**, which is mass over volume, of only 1.225 kg/m^3 (or kilogram per cubic meter). When you are running through water, there are many more molecules more strongly and closely packed together. Water has a density of 1,000 kg/m^3. That's almost 800 times greater than the density of air! No wonder you have to work so much harder- there is a lot to push through.[(1)] **Drag** is the friction between an object and a gas or liquid. The drag is greater in water than air because there is more friction, or resistance due to the strongly linked, compact molecules. **Cavitation** Did you know that water can boil without the addition of heat? If the local pressure is lowered to the point that it is lower than the pressure of the water, bubbles or cavities of vapor will start to form, just like when you heat water to 100 degrees Celsius. **Cavitation** is the formation and collapse of these steam-filled cavities. The cavities collapse or implode when they move to a place where the local pressure is higher than the vapor pressure. This collapse triggers a shock wave. Cavitation happens around propellers. When a propeller rotates quickly, there is an area of low pressure generated on the blades. This low pressure causes cavitation. Repeated exposure to cavitation can actually damage the propellers. Therefore, scientists and engineers work to find a way to avoid cavitation and the corresponding damage. **Supercavitation** So far we have discussed two problems with moving through water: drag and cavitation. **Supercavitation** takes the bubble effect produced by cavitation, and encompasses an object within a bubble to reduce drag. Drag is reduced because instead of being in contact with water, which we know is denser, the object is in contact with a less dense vapor. The next few sections will look at supercavitation and its applications. **References**

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Reading #2	**Supercavitation Design** In theory, supercavitation could enable a vessel to reach speeds of 750 miles per hour- that's crazy fast for something moving through water![1] Let's now look at how engineers and scientists create supercavitation. The first step that must happen is for an object must be launched fast enough to generate cavitation. This is why torpedoes were among the first objects to be supercavitated; they are fast enough for the physics to work. Once you have an object moving fast enough (the actual speed needed depends on the size of the object—the larger the object, the faster it needs to go), the object creates a cavitation bubble at its nose. The nose is either flat or cone shaped, and features a cavitator. The **cavitator** is a sharp edge that generates the cavity. To enlarge or extend the bubble, generally, vents near the nose blow gas which expands the bubble over the entire object. The object can maintain supercavitation in one of two ways: 1. Achieving high enough speeds that the water vaporizes near the nose so that cavitation is continually initiated. This is known as **vaporous cavitation**. 2. Supplying gas to the cavity at the right pressure. This is known as **artificial cavitation**. Now that you have an idea of the technology and science behind supercavitation, let's look at how it has been and could be useful. **References** 1. Golson, J. (2017, June 03). How We Can Get Submarines to Travel at Supersonic Speed. Retrieved January 16, 2018, from https://www.wired.com/2014/08/how-we-can-get-submarines-to-travel-at-supersonic-speed/
Reading #3	**Supercavitation and Torpedoes** During the 1960s, the Soviets began developing a high speed torpedo. The goals was to create one capable of gliding through the water at speeds four to five times faster than traditional torpedoes.[1] The Shkval (Squall) was a supercavitation torpedo capable of speeding through the water at 230 miles per hour.[2] Designers gave the torpedo a blunt nose with a ring fitted around it. The ring acted as the cavitator, initiating supercavitation. A German-based defense company also used supercavitation when it developed a torpedo, called Barracuda, capable of reaching 250 miles per hour under water back in 2004. Iran also claims to have successfully tested a supercavitation torpedo, called Hoot, in May of 2017.[3]

The United States military has investigated some supercavitating torpedo projects as well. But due to the obstacles of supercavitation (which we will investigate later in the module), most torpedo projects have been shelved.

Supercavitation and Propellers

Propellers are another object that can be supercavitated. As we discussed earlier, cavitation damages propellers. However, when the propellers are wrapped in a supercavitating bubble that collapses *behind* the propeller, the result is a faster boat, thanks to the reduced friction.

Supercavitating propellers are uniquely wedge-shaped, a sharp leading edge (the cavitator), blunt tailing edge, and concave face. They also have cavities filled with water vapor and gases. These propellers are meant for use on high-speed boats- those moving at over 50 knots or higher- because these propellers are actually not efficient at slower speeds.[4]

Ghost

Juliet Marine Systems, Inc. has developed a boat that uses supercavitation in another way.[5] The ship features a two tube-like flotation devices (called **pontoons**) attached to struts. The tubes contain the engine, fuel, and most computing systems. This reduces vulnerability since those systems are protected by the water itself. The main cavity of the ship remains above the water. The propellers are attached to the front of the tubes. The propellers funnel air down through the struts which generate the supercavitation effect around the pontoons.

Once the ship starts going faster than 8 knots, the struts lift the main cabin of the ship above the water. This means that both the cabin and the pontoons have significantly less drag than traditional boats in water.

It is called the Ghost because thanks to its stainless steal and aluminum construction, it is nearly invisible to radar and sonar detection. It is designed with military use in mind. The Ghost is capable of missions including anti-surface warfare, anti-submarine warfare, and mine countermeasures.

Supercavitation and Liquid Membrane Technology

You may have noticed that we have not mentioned any supercavitated submarines. Getting a submarine to go fast enough to generate cavitation is one of the main problems. However, the Chinese claim to be on the path to supercavitating an entire submarine.[6]

To do so, a submarine first becomes submerged in water. Then, the submarine would shower itself in a liquid membrane all over the surface. The liquid membrane is said to cut down the minimum speed required to enable supercavitation.

Unlike the other examples of supercavitation we have investigated so far, the Chinese are looking at this not so much with military intentions, but rather civilian transport. If the technology works out, a submarine may get you across the ocean faster than an airplane!

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Reading #4

Supercavitation Difficulties

We're pretty sure that if engineers and scientists could develop a technology that had no negative tradeoffs whatsoever, we'd see a bunch of brilliant minds weeping with joy. But as it stands, no technology is without its drawbacks, and supercavitation is no exception.

Here's a break down of why supercavitation is not more common:

- **Limited range:** to achieve supercavitation, an object has to be moving fast enough to generate the bubble. Like we talked about in the first section, it is not easy to move through water, thanks to its resistance. Then, once the speed is achieved, it is difficult to maintain that speed for an extended amount of time. This means that the realistic range of a supercavitation object is limited.
- **Noisy:** with the Shkval torpedo, once the booster rocket ran out of fuel, the torpedo switched to a noisy hydrojet to keep going. Needless to say, the military has limited interest in noisy weaponry.
- **Cannot track target:** to track a target, a torpedo uses a sonar detector. Those detectors would need to be mounted on the cavitator, which for the way the Shkval was designed, was too small to fit on it. If the torpedo can't track the target, the only hope is for the target to stay put. Since a supercavitation torpedo is so fast, it actually could happen that the torpedo gets to the target before it's able to move, but it's still a drawback in warfare.
- **Environmental impact:** if submarines have to use rocket fuel the way that supercavitation torpedoes do, it would be devastating to marine life. All that rocket fuel exhaust would be dumped right into the ocean.
- **Pulsation:** sometimes during supercavitation, the bubble shrinks and expands. When the bubble shrinks, it can expose part of the object to the water. **Pulsation** is the continual expansion and shrinkage of the bubble that happens during supercavitation. If this happened to a submarine, anyone on board would be taking a very bumpy ride. This is a problem scientists at Penn State are working to overcome.[1]
- **Lack of steering:** To steer, control planes would have to pierce the bubble, producing great drag in the process. These planes would have to be extraordinarily strong otherwise they would break trying to move through the water at such high speeds.

	This means the submarine's trajectory is at the mercy of the bubble moving through the water. **Possible Breakthroughs** We have just listed quite a few hurdles to achieving supercavitation. It is worth mentioning that there is the possibility that these hurdles will be overcome and soon. Like we mentioned in the previous section, the Chinese claim their liquid membrane technology will lower the necessary speed and improve steering for supercavitation. The Russians are also rumored to have fixed many of the problems with the Shkval, like its limited range. However both the Chinese and Russian developments in this area are very new and not much is known at this time. One thing is clear, however, scientists have not given up on the promises of supercavitation! **References** 1. Messer, A. E. (n.d.). Innovative approach makes for a smoother ride. Retrieved January 16, 2018, from http://news.psu.edu/story/414720/2016/06/16/research/innovative-approach-makes-smoother-ride
Reading #5	We have spent the majority of this module looking at supercavitation. We'd be remiss, however, if we did not look at the future of maritime transportation on the whole. There are some key technological advancements that are spilling over into the future of maritime transportation. One of those is autonomous technology. **Autonomous Ships** Rolls-Royce is developing an autonomous ship. The company, which is working to become the market leader in power systems, have noticed the trend toward autonomous and unmanned transportation systems and is wasting no time in joining the trend. The company will create land-based control centers which will be able to monitor and control ships across the globe.(1) To do so, the company will use a combination of drone technology, holograms, and smart screens to help monitor the ships. The autonomous support tools include energy management, equipment monitoring, and predictive and remote maintenance. **Eco-Friendly Ships** Just like cars and airplanes are working to lessen their negative impact on the environment, so too are ships. MSC Cruises has placed an order with STX France, a boat design company, for two cruise ships which will be powered by liquefied natural gas or LNG. LNG reduces greenhouse gas emissions by 10%-20% compared to diesel and fuel oil and particulate emissions by over 50%. It also reduces the nitrogen oxide emissions by 50-80%. Nitrogen oxide is poisonous, so utilizing resources that reduce these emissions is definitely helpful to the environment. Plus, liquefied natural gas is a more economic source of energy compared to fuel oil and diesel.(2)

Other companies are creating ships that would utilize fuel cells, wind, and solar energy. For example, the Vindskip by design firm, Lade As, will feature a symmetrical airfoil-shaped hull.[3] This particular hull is designed to harness wind as propulsion. It would also use an LNG electrical propulsion system. As a result, this would create fuel savings of 60% and reduce carbon emissions by 80% compared to traditional ships.[4]

Conclusion

Whether is a submarine that gets you across the ocean in less time than a movie, an eco-friendly cruise ship, or a ship capable of navigating by itself, the future of maritime transportation is an exciting, evolving field.

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POINTFUL EDUCATION

Module 11: Space Travel

Module Description	Have you ever been to outer space? Do you know anyone who has been to outer space? Do you know *anyone* who knows someone who has been to outer space? We're guessing your answer is no. Why is it that nearly 50 years after man first walked on the moon that space travel remains so rare? In this module we will briefly discuss the history of space exploration and the benefits and cost associated. We'll also define words and terms related to rockets and space travel. Then we'll take a closer look at reusable rockets- how they would benefit the space industry and what challenges go into creating one. Next, we'll discuss companies that are developing commercial space travel. Finally, we'll explore careers in the space travel industry.
Reading #1	**Space Exploration Timeline** Before we dive into the heart of our module, let's take a look at some of the important events in space exploration history(1): October 3, 1942- Nazi Germany launched the V2 rocket, the first rocket to successfully reach the boundary of space (100 kilometers from the ground.) June 14, 1949- First monkey, Albert II goes to space. October 4, 1957 - The Soviet Union launched Sputnik, the first satellite to orbit the earth. April 12, 1961- Yuri Gagarin of the USSR became the first human in space. July 20, 1969- Neil Armstrong and Buzz Aldrin became the first humans to set foot on the moon during the Apollo 11 mission. Five more Apollo missions landed on the moon between 1969 and 1972. April 19, 1971- The USSR launched Salyut 1, the first space station. August 1977- Voyager 1, a probe, was launched. Voyager 1 is currently the farthest human made object from the earth. 1998- The US, Canada, Japan, Russia, and 11 European nations collaborate to create the international space station. April 28, 2001- American Dennis Tito became the first tourist in space by paying the Russian space program $20 million to be a crew member on an 8 day orbit in space. **Product Development** The past 60+ years of space study has benefited even those of us who have never left our planet. Here are some of the products that you may be familiar with that have their roots in space exploration(2): • Cordless tools

- cell phone cameras
- improved solar panels
- water purification systems
- light-emitting diodes (LED) technology

That is by no means an extensive list. But it does begin to show that the benefits of technological advancements associated with space exploration are not just for those few whom actually travel to space.

International Space Station

One of the greatest evidences as to what can happen thanks to an interest in space exploration is the International Space Station (ISS). Like the name suggests, an international partnership of space agencies work together to manage and provide elements of ISS. In order to achieve its goals and press onward, ISS has had to overcome political and economic strains. It is evidence of what can happen when countries unite under a common goal.

The findings and research conducted at the space station benefit the world at large as well. There have been over 1,800 investigations and over 1,000 experiments conducted on the ISS.[3] One of the benefits to the ISS is that they are able to better study the growth of proteins because gravity does not interfere with the uniform growth. By studying how it grows, scientists can understand how it works and potentially how to cure diseases that result.[3]

Satellites

Your daily life is greatly impacted by satellites. Knowing whether you need to take an umbrella before you head to school or to take shelter from an incoming hurricane, is largely thanks to satellite technology.

If you have a smartphone, then you definitely have satellites to thank. To give you an idea of just how critical communication satellites are to our everyday uses, in 1998 a single communications satellite went out. As a result, 30 million pagers stopped working, credit card payments couldn't go through, and National Public Radio went out in various location.[4] And that was nearly 20 years ago! The world has become even more dependent on satellites as the increase in internet usage has soared.

Economic Growth

Private companies interested in space exploration have come a long in the past one to two decades. These companies provide further jobs which stimulates the economy. As further opportunities presented by space become available, such as resource mining, colonizing, and tourism, more jobs will be created to manage these endeavors.

Popular culture

You don't have to be a scientist or astronaut to be inspired by space. Think about how many books, movies, songs, and art you've come across that use space as an inspiration. Stars, planets, constellations, space travel, and more provide a nearly endless supply of inspiration to creatives in a variety of industries.

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Reading #2

Dangers of Space Travel

"Anyone who sits on top of the largest hydrogen-oxygen fueled system in the world, knowing they're going to light the bottom, and doesn't get a little worried, does not fully understand the situation."

John Young, after being asked if he was nervous about making the first Space Shuttle flight in 1981.[1]

It is one thing to blast a rocket into the air. It's quite another to get it to go high enough and fast enough to make it into **orbit**. The engineering behind rockets requires absolute precision, even before blastoff. The slightest errors can have (and has had) terrible consequences. Then there's the challenge of getting that rocket's crew safely back to earth.

Health Challenges

And what is in store for those brave enough to blast off in a rocket? It's definitely not the same as heading off to a tropical resort here on earth. There's radiation for one. Astronauts take in about ten times more radiation compared to those on earth. The more exposure to radiation, the greater the chance of developing cancer. And the effects don't stop there. It can damage your nervous system with symptoms like worse cognitive function, poor motor function, and behavioral changes. Space radiation can also cause radiation sickness. Radiation sickness often causes causes nausea, vomiting, and fatigue.[2]

There's no fresh fruit and veggies. Instead, it's a diet of freeze dried food. And if you hate exercising, you'll really be miserable because exercising is a requirement to keep the muscles and bones from atrophying.[2]

Rocket Fuel and Costs

The great paradox of space travel is that to get farther, spacecrafts need more fuel. But carrying more fuel adds more weight. More weight requires more fuel to get off the ground and into space. More fuel means more weight. More weight means more fuel needed... and around and around the cycle goes. Until eventually, the weight of the added fuel needed to

	get to Mars, for example, cancels out the efficiency of adding on the extra fuel. This fuel problem is one of the key problems scientists and engineers are working on solving Another major problem is the cost. Developing a rocket, the material to build those rockets, fueling the rockets, training astronauts, monitoring missions... it all costs hundreds of millions to billions of dollars. As a point of reference, NASA's shuttle program cost a total of $209 billion dollars and made a total of 135 flights. This means that an average shuttle launch cost more than $1.5 billion.[3] When budget cuts come along and space programs get hit, development too takes a hit. This cost issue, is actually one that can be solved in a couple of ways or in a combination of ways. One way is to make space missions an international affair. Since it isn't likely that one country alone will be able to fund a crewed mission to Mars easily, pooling together resources- both monetary and scientific- would ease the monetary burden. Another potential solution is to make rockets reusable. We will look more closely at this concept in the next section. **<u>References</u>** 1. 21 Inspirational and Historic Space Quotes You Need to Know | Space Facts – Astronomy, the Solar System & Outer Space | All About Space Magazine. (n.d.). Retrieved December 29, 2017, from https://www.spaceanswers.com/space-exploration/20-inspirational-space-quotes-you-need-to-know/ 2. Gushanas, T. (2016, March 30). The Human Body in Space. Retrieved December 29, 2017, from https://www.nasa.gov/hrp/bodyinspace 3. Writer, M. W. (n.d.). NASA's Huge New Rocket May Cost $500 Million Per Launch. Retrieved December 29, 2017, from https://www.space.com/17556-giant-nasa-rocket-space-launch-cost.html
Reading #3	**<u>Rocket Science</u>** Have you ever heard the expression? "It's not rocket science!" Usually it's said when someone is explaining something that, compared to the science of rockets, is uncomplicated. Well, in this section we *are* going to explain rocket science! But hopefully in a way that is not too difficult to grasp. **Newton's Third Law of Motion** states that for every action, there is an equal and opposite reaction. For example, if you were to standing on a skateboard and you threw a bowling ball. The ball would move forward, and you would move backward. But because you are heavier than a bowling ball, you will not move much as the bowling ball. With a rocket, combustion of rocket fuel and an **oxidizer** causes hot exhaust gases which quickly exit out the back of the rocket. The equal and opposite reaction is that a thrust force happens on the engine mount. The thrust accelerates the rocket forward. **<u>Rocket Engines</u>** Rocket engines are unique from jet engines in that they do not use oxygen from the air. If rockets used oxygen from the air, they would not work in space since there is no oxygen in

space. Rockets carry both the fuel and oxidizing agent with them. Carrying the oxygen with it, allows a rocket to continue flying once it exits the atmosphere.

Why Reusable Rockets

Imagine if you had to buy a new car after every use. It didn't matter if that use was across the country or just to the grocery store. You had to buy a brand new car after every single use. Cars would be a rare luxury, as only the very wealthy would be able to afford to buy a new car after every use.

Fortunately, that is not the case. We can reuse our cars again and again. In fact, we can even buy a car that belonged to a previous owner. This ability to reuse cars is what makes them so affordable and widely used.

Rockets, on the other hand, have traditionally not be reusable. They are launched once, and all the expensive components used to create that rocket have essentially gone to waste after their initial use. If scientist could create a reusable rocket, the cost savings would be significant.[1]

Single Stage to Orbit Vehicle

The ideal situation would be to use a **single stage to orbit** (SSTO) vehicle. With a SSTO, a reusable launch vehicle would launch a payload into orbit, re-enter the earth's atmosphere, land, refuel, and repeat the process. Again, that's the ideal scenario.

Reusable Rocket Challenges

NASAS's Space Shuttle program attempted to recover and reuse the orbiter and solid rocket boosters. However, the cost to recover and refurbish the parts canceled out the money savings.[2] Also, there were some significant disasters that resulted in loss of life that made people question the safety and reliability of reusable rockets.

Rockets have to strike a delicate balance between the mass of fuel, support structures, and the payload itself. **Payload** is the rocket's carrying capacity for things like crew, cargo, scientific instruments, and other equipment. The United Launch Alliance looked into the feasibility of reusing rockets and found that that in order to work, it experienced a significant reduction in payload.[2]

Even if reusable rockets prove to be possible, it will probably take numerous successful launches for companies to be comfortable sending their expensive hardware and equipment up in a reusable rocket. After all, even a reusable rocket is still likely to cost millions of dollars per launch.[2] Companies are going to want to know that the millions they spend to pay for the launch and the cost of their expensive equipment is a sound investment.

Reusable Rocket Progress

These obstacles have not stopped SpaceX from working toward a reusable rocket. In March of 2017, SpaceX's Falcon 9 rocket successfully launched a rocket using a booster that had previously flown cargo to the astronauts living at the International Space Station.[3] This is a great step toward showing the feasibility of reusable rockets.

	SpaceX is also not the only company working toward reusable rockets. In the next section we will look at some of the companies working to make space travel more affordable. **References** 1. Whittington, M. R. (2017, May 30). Reusable rockets are the future of space travel. Retrieved January 02, 2018, from http://www.businessinsider.com/reusable-rockets-are-the-future-of-space-travel-2017-5 2. Hendricks, S. (2017, April 01). Elon Musk, SpaceX Fly Reusable Rocket to Space. Retrieved January 02, 2018, from http://bigthink.com/scotty-hendricks/one-small-step-for-spacex-one-giant-leap-for-inexpensive-space-flight 3. Writer, M. W. (n.d.). SpaceX Rocket Could Be 100-Percent Reusable by 2018, Elon Musk Says. Retrieved January 02, 2018, from https://www.space.com/36412-spacex-completely-reusable-rocket-elon-musk.html
Reading #4	**Government Programs and Small Enterprises** When The United States first put a man on the moon, it was through their government-funded program, NASA. In fact, in the previous century governments across the world were the driving force behind space travel and exploration. That, however, is changing as more private enterprises are popping up to usher in the future of space exploration. Why the shift? Well, like any complex issue, there are a series of answers behind that question. For one, there is a lack of consistency in priority for space programs between one presidential administration to another. This means that programs such as the Constellation Program which was established by President Bush in 2004 and aimed to get back to the moon by 2020 and Mars after that, get canceled under another president.[1] Another reason is money. These programs take billions and billions of dollars. These dollars have to come from somewhere, and where that money comes from is a challenge. More taxes and/or cutting other federally funded programs is rarely supported. This is where private companies come in to play. Some are backed by wealthy founders. Others are backed by outside investors. We will take a look at a closer look at a few of these businesses and their goals for space. **SpaceX** We have already touched on SpaceX and their strides in reusable rocket technology. They have put this technology to good use by sending cargo to the international space station. However, the company's ultimate goal is not just to make rockets more economical. Elon Musk, founder of SpaceX, wants to get humans on Mars. He's not talking about a quick jaunt to the planet and then back home to earth. He is looking at establishing a human colony on the planet. His reasoning is that as a species, humans have a much greater chance of survival if we are a multi-planetary species.[2] **Virgin Galactic**

	Another space travel company utilizing reusable rocket technology is Virgin Galactic. Though their ambitions are a bit different from SpaceX's. Galactic is looking to provide affordable suborbital voyages. Their reasoning for pursuing space is more about discovering the unknown. Their website reads, "Only through the exploration of the unknown can we continue to grow and evolve.... We still know so little about space and how our understanding of it can benefit life on our planet. What is clear is that the ability for more people to cross the final frontier of space will be key to human advancement."[3] Their rockets will take people into suborbital space, allowing for a zero gravity experience. In order to make landings safer and slower, the rockets will use a feathered-reentry system. This system uses a foldable boom tail that tilts up and causes the shuttle to slow down until it is low enough to use its wings. **Blue Origin** The final company we will look at is Blue Origin.[4] This company, which was founded by Jeff Bezos, who also founded Amazon, keeps a little quieter with their plans compared to the other two companies we've looked at. That does not mean they are not making impressive strides. Their reusable rocket, 'New Shepherd" made history with the first ever vertical landing from space. The New Shepherd features a pressurized capsule sits on top of a rocket booster. The two components launch vertically and accelerate for two and a half minutes until the engine cuts off. Then the capsule continues its journey to space. The booster free falls for a few minutes then performs an autonomous vertical landing. When the capsule is ready for landing, it deploys a parachute. Both the capsule and the boosters are meant for reuse.[5] Between these private enterprises and government programs, it is exciting to see the developments made toward space exploration and travel. **References** 1. R. (2017, February 27). Americans Will Never Make Mars A Priority. Why Should That Stop Us? Retrieved January 02, 2018, from https://fivethirtyeight.com/features/the-story-of-americas-space-age/ 2. Red means go: Elon Musk wants to colonize Mars. (n.d.). Retrieved January 02, 2018, from https://www.nbcnews.com/mach/space/elon-musk-makes-his-case-colonizing-mars-n655641 3. Why We Go. (n.d.). Retrieved January 02, 2018, from https://www.virgingalactic.com/why-we-go/ 4. https://www.blueorigin.com/ 5. Fishman, C. (2016, December 01). Is Jeff Bezos' Blue Origin the Future of Space Exploration? Retrieved January 02, 2018, from https://www.smithsonianmag.com/innovation/rocketeer-jeff-bezos-winner-smithsonians-technology-ingenuity-award-180961119/
Reading #5	Is a career in space travel in your future? We've broken up various careers in the industry according to their level of education/training:

Associates Degree or Technical Training[1]

- Avionics technician: installs, inspects, test, adjust, and repair avionics equipment
- Aerospace engineering technician: assist engineers in designing, creating and evaluating things like rockets and missiles
- Meteorological assistant: assist meteorologists and weather scientists by measuring weather and climate happenings to collect data

Bachelor's Degree[2]

- Atmospheric scientist: study weather conditions in space
- Aerospace engineer: design and construct rockets, missiles, and spacecraft
- Computer engineer: research and develop computer equipment used to collect data on earth and space
- Accountant: organize financial reports and track spending
- Public relations specialist: communicate the space program to the public

Doctorate Degree[2]

- Astronomer: study stars and space objects
- Physicist: study matter, energy, time and space

And that is just a list of jobs that are currently available. However, when looking forward into the future, there are a whole host of jobs and careers that don't even exist…yet. Click on the link below to read this article from Wired Magazine. Though written back in 2010, hypothesized on a number of futuristic space jobs, such as spaceport traffic control, Mars colony psychologist, and on-orbit refueling specialist: https://www.wired.com/2010/04/10-space-jobs-from-the-near-future/

While in High School

You certainly do not have to wait to start building your resume in space travel. NASA offers a variety of programs for high school students. There are internships, fellowships, scholarships, lectures, competitions, and workshops offered at the high school level. For more information, visit their website: https://www.nasa.gov/audience/forstudents/current-opps-index.html

If space travel is the industry for you, there are plenty of opportunities to utilize your talents. This is an exciting and growing field that could have an immense impact on the future of humanity.

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POINTFUL EDUCATION

Module 12: Interstellar Travel

Module Description	n 1903, the president of the Michigan Savings Bank advised Henry Ford's lawyer, Horace Rackham, NOT to invest in the Ford Motor Company. He said, "The horse is here to stay but the automobile is only a novelty – a fad."[1] It seems safe to say, the bank president was wrong. Very wrong. Today there are many scientists who look at interstellar travel and say it's only a matter of time before we travel there. Other scientists look at interstellar travel and say it will never happen. Which group will prove right? This module will identify the challenges to interstellar travel. It will explain need-to-know terms such as astronomical units, light speed, propulsion, and g-force. Then it will describe theories and the pros and cons of each theory in achieving interstellar travel. Then it will discuss the feasibility of an interstellar mission. By the end you will be able to make an informed prediction as to when, if ever, interstellar travel will be launched. **References** 1. Szczerba, R. J. (2015, January 09). 15 Worst Tech Predictions Of All Time. Retrieved January 01, 2018, from https://www.forbes.com/sites/robertszczerba/2015/01/05/15-worst-tech-predictions-of-all-time/#30c54c9d1299
Reading #1	**Long Way to Go** Imagine being part of the first ever interstellar exploration mission to an identified Earthlike planet. Imagine the view of a brand new planet as it fills up the viewport. It's more beautiful and amazing than you could ever imagine. So what is standing between you and this dream? In short- a whole lot of science, each and every step of the way. **Blast off** Overcoming gravity to launch into space takes a lot of fuel and a whole lot of money. Blasting a rover to Mars takes 200 million dollars.[1] Blasting off a large spaceship with all the necessary crew and equipment will take even more power... and even more money. **Propulsion** It takes 5-7 years for a satellite just to travel to the moons of Jupiter.[1] The planets scientists have identified as possibly habitable are much further from Earth than the moons of Jupiter. The planetary system Trappist-1, for example, would take 39 years to reach if we could travel at the speed of light.[2] Currently, we can't travel that fast. Not even close. It would take hundreds of thousands of years to get to Trappist-1 using current propulsion technology. **Navigation** The first thing to navigate around is all the debris orbiting the earth. There are over 4,000 satellites orbiting Earth and most of them are no longer functioning.[1] Collision with one of those satellites which travel at 17,500 miles per hour would have devastating consequences.[1]

Outside of earth's orbit, you would have to deal with meteors and cosmic dust, which could also wreak havoc on a ship going at light speed!

If you make it through the space minefield, there's still the issue of keeping on course. After all, Siri can't tell you where to go in space! Current transmissions to deep space would take hours[1]. Depending on the situation, the crew may not have hours to wait for navigation.

The Human Body

Without the protection of the Earth's atmosphere and magnetic field, space radiation can kill you. Furthermore, no gravity wreaks havoc on the body after a time. Even following an exercise regimen, crew members of the International Space Station (ISS) lost muscle volume and peak power after six months on ISS.[3]

Then there's the question of what kind of toll that would take on the human mind. No one knows the psychological effects that could come from an extended mission because no one has ever had to endure one. But it's safe to say that it would be mentally taxing being on a spacecraft for months, if not years at a time.

Furthermore, it's hard to predict what kind of microbes could exist on other planets that our bodies are not capable of fighting. What happened to the Native Americans when Europeans first started colonizing America is a bleak reminder that our bodies take time to adapt to foreign pathogens.

Necessities

Food and water aren't available at grocery stores in space. That means it would all have to come from the spacecraft itself. Growing food is very difficult with no gravity. Not to mention, it would take up a considerable amount of space on the spacecraft.

Current waste water filtration systems, like those used on the ISS, need maintenance. Sometimes they need new parts. It would be very difficult to anticipate all the maintenance and spare parts needed to make the water filtration work in deep space for the duration of an interstellar flight. Although, advancing technologies like 3D printing of spare parts may make this less of a challenge.

Landing

Even if the spacecraft did manage to get to a planet, scientists would have to know exactly what the gravity of that planet was like in order to safely land. Considering the speed that the spacecraft would likely be traveling at when it arrives at the planet, slowing it down without a crash landing would take precision.

This is just a sampling of the issues that scientists, engineers, and physicists must overcome to make interstellar travel happen. There are likely more problems that no one has even thought of too. Despite the immense problems, there are still scientists working to make interstellar travel happen.

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Reading #2	**Key Terms** Now that you understand what scientists are up against in figuring out interstellar travel, let's explore some helpful terms and concepts. **Interstellar and Interplanetary Travel** The best place to begin is probably with the definition for interstellar travel. **Interstellar travel** is traveling between stars or planetary systems. In other words, interstellar travel does not refer to traveling to the moon or Mars. That would be **interplanetary spaceflight**, or travel between planets of the solar system. **Astronomical Units** Because distances in space are so great, typical measurements that use here on earth, such as meters, miles, kilometers, etc. get too big too fast. So scientists use a different form of measurement when talking about distances in space. An **astronomical unit** (AU) is a unit of length used to measure distances within the solar system or other stars. One AU is about 93 million miles. It's also the distance from the earth to the sun.[(1)] **Light Years** Another unit commonly used to measure distances in space are light years. A **light year** is the distance light travels in a vacuum in one Julian calendar year (365.25 days). In terms of miles, it's about 5.9 trillion miles traveled in one year. In terms of seconds, it's about 186,000 miles traveled in one second.[(1)] **Gravity and G Force** Objects with mass are attracted to each other. This is known as **gravity**. Gravity is also the natural force that causes things to fall toward the earth. If you've ever accidentally dropped your phone and had the screen shatter, than you know that gravity is can have devastating consequences, even at 1 **g force**, or the force of gravity on earth. G force is acceleration that causes an object to experience a force acting in the opposite direction to the acceleration. At zero gs or no gravity, which what happens in space, the body begins to break down- muscles start to atrophy (deteriorate), bone loss happens, kidney stones, and even the heart stops working well. On the other end of the spectrum, high amounts of g force can be fatal if sustained for long periods of time. When astronauts take off in a rocket, they experience 3gs, but they are trained for this and also wear special suits. At around 9gs, most humans would black out as

	blood struggles to reach the brain.[2] 100 g would likely be fatal- even if experienced for only a second. What does this have to do with space? It's an important consideration for scientists to factor in as they calculate things like acceleration and deceleration. While a spacecraft may be able to accelerate in a way that does not cause considerable damage to the human body if done gradually, it becomes a different story if the spacecraft needs to suddenly decelerate to avoid a collision, for example. Now that you are familiar with some of the key terms associated with interstellar flight, let's look at some theories! **References** 1. Interstellar travel. (2018, January 01). Retrieved January 01, 2018, from https://en.wikipedia.org/wiki/Interstellar_travel#Propulsion 2. What g-force do astronauts experience during a rocket launch? | Space Facts – Astronomy, the Solar System & Outer Space | All About Space Magazine. (n.d.). Retrieved January 01, 2018, from https://www.spaceanswers.com/space-exploration/what-g-force-do-astronauts-experience-during-a-rocket-launch/
Reading #3	**Theories** It may surprise you to learn that terms like “warp drive” “hyper drive” “worm holes” and “interstellar ramjet” are not just the inventions of Hollywood silver screens or thrilling page turners. There is actually some evidence supporting the plausibility of each of these theories. Let's take a look at some of the more popular interstellar travel theories. **Space-time Shortcuts** One of the more popular theories that would shorten the distance between two places across the universe is wormholes. Wormholes are very popular in science fiction. They are mentioned in movies like *Star Trek*, *Deja-vu*, *Marvel Universe* movies, and *Interstellar* and books like *A Wrinkle in Time* and *Contact* as well as many other sci-fi works. Also known as an “Einstein-Rosen Bridge” (the two scientists who first proposed the theory), wormholes are like space-time tunnels. In theory, you would enter the wormhole in one location, and come out somewhere else in the universe.[1] Another popular shortcut through the universe is the theory of **warp drive**, a theory mentioned in *Star Trek* and *Star Wars* in particular. In warp drive, the gravitational fields of space are manipulated and “warped” in such a way that it shortens the distance between two points in the universe.[2] **Using Sails** Some scientists have theorized that energy from the universe could act as propulsion to push a spacecraft designed with a “sail” through the universe, similar to the way wind pushes a sailboat across the water. There are all kinds of proposed sail methods: solar, laser, maser, magnetic, and antimatter. Let's look at solar and laser, in particular.

	A **solar sail** would work by a large, thin sail that would get a push from sunlight. The sun gives off photons which have energy but no mass. A close pass by the sun could accelerate a spacecraft with a solar sail enough to the outer solar system or even Alpha Centauri, the nearest star system to us. A massive laser pointed at a **laser sail** would provide even further momentum than that of a solar sail. A laser would enable the photons to be focused enough that they provide even more energy than solar photons.[3] **Nuclear Propulsion** Inside an atom, is a nucleus consisting of positively charged protons and neutral neutrons, orbited by electrons. Protons, neutrons, and electrons, are collectively known as nucleons. When the bonds between the nucleons break, a large amount of energy is released. Nuclear propulsion is one of the proposed methods for propulsion that is more efficient and provides more thrust the chemical propulsion used in rockets today. **Nuclear fusion rockets** would harness the energy released when two nuclei combine. The sun and stars are fusion powered, and in theory, our rockets may soon be too. **Ramjet Propulsion** Finally, let's mention **Bussard's Ramjet** theory. This theory focuses on hydrogen fusion propulsion. For it to work, a large electromagnetic scoop collects interstellar hydrogen and then compress the hydrogen to create hydrogen fusion which would provide propulsion.[3] All of these theories aim to tackle two of the key problems associated with interstellar travel- distance and propulsion. In the next section, we will look at what each of these theories do well, and where the supporting science is lacking. **References** 1. Contributor, N. T. (n.d.). What is a Wormhole? Retrieved January 01, 2018, from https://www.space.com/20881-wormholes.html 2. An explanation of the Alcubierre-White Warp Drive | AsteronX. (2017, February 16). Retrieved January 01, 2018, from https://www.youtube.com/watch?v=Xlmdtf3UbmQ 3. Propulsion Ideas. (n.d.). Retrieved January 01, 2018, from https://tauzero.aero/making-progress/propulsion-ideas/
Reading #4	**Shortcut Methods Pros and Cons** The greatest benefit that shortcut methods, like wormholes and warp drive, provide is that that they shrink the distance between two locations. Since distance is a huge limiting factor to interstellar travel, this is a major benefit. However, each method is not without its drawbacks. Wormholes, for instance, are extremely unstable. They may only stay open for a fraction of a second. Speaking of fractions, it is thought that the beginnings of wormholes are a tiny of a fraction a centimeter in size.[1] And one more thing- we have never actually found a wormhole! At this point, they only exist in

theory. Although that theory is supported by many great scientists!) And creating man made wormholes would require "exotic matter" which scientists aren't even sure really exists.[1]

Warp drive too has some shortcomings to work through. For example, the shields necessary to keep a spacecraft safe during warp drive require technology that is well into our future. [2] And again, we would probably have to find that elusive black matter.[3]

Sail Pros and Cons

One good thing is we know that concept of sails work. We see them working on boats. There have also been instruments launched into space with sails for harnessing solar power.[4]

Another benefit is there is no need to carry the necessary fuel on the spacecraft because they are getting the necessary thrust from the sun or lasers. The proposed sails would also be much faster than conventional rockets, perhaps up to 30% of the speed of light.

Solar sails may be limited to our solar system or shortly beyond because the effect starts to diminish as the spacecraft gets farther away.

The most complex issue is building a sail capable of getting the kind of speed and distance necessary. The sail might have to be miles wide![5] Similarly, it would take a special laser that we just do not have yet. Although these technologies are probably a ways into the future, they work comfortably with the physical laws scientists already know.

Bussard's Ramjet Pros and Cons

Another theory that gets points for solving the fuel problem of interstellar travel is Bussard's Ramjet. Since it would be collecting hydrogen from space itself, then fusing the hydrogen, there's no need to bring unrealistic amounts of fuel on the spacecraft. Hydrogen fusion would also be much more efficient then the chemical propellants used on rockets.

Unfortunately, the necessary hydrogen fusion only occurs in the center of stars. Another issue is that the ramjet would likely cause drag. This would slow down the craft.[4]

Nuclear Propulsion

Of all the technologies, nuclear propulsion is probably the one scientists are closest to making a reality. Nuclear energy, whether through fusion, fission, or otherwise is more efficient and provides more thrust than conventional chemical propulsion.[6]

The most difficult part is creating a reactor that does not use more energy than it creates. Scientists have yet to figure out how to do that.[6] It also wouldn't get us as far or as fast as some of the other proposed theories.

In the next section, we will put all this together and discuss, given what we know, how we could make interstellar travel feasible.

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Reading #5

Having gone through just a handful of the technological and logistical challenges involved with interstellar travel, it's easy to think people should just forget it. In fact, there are many naysayers out there.

Cost

One of the biggest arguments raised by the opposition to interstellar travel is the enormous associated cost. Some economists predict an interstellar program could cost around 100 trillion dollars.[1] And that would be for an unmanned mission!

The costs for a manned mission would be even more expensive because of the necessities to keep people alive. Not to mention finding a way to make sure that g forces are optimal for travel AND destination. Even if we found a way to make people “sleep” through space, that would still be an enormous additional cost. That money could be spent on more pressing issues like pollution, for example, naysayers argue.

Humans are Fragile and Needy

Before modern medicine plagues and diseases devastated populations. If our bodies have a hard time fighting earth-born diseases, imagine how much more difficult it would be to find microbes and germs from other planets. We would know nothing about another planet's microbes without extensive research beforehand and if there was a harmful microbe scientists somehow missed in the research, it could have devastating consequences.

Like we mentioned earlier, humans need a lot of supplies. They would need air, food, water, health supplies, sleeping and living quarters, just to name a few. If any of those things were to cease to exist on an interstellar flight, well, so would people.

Too Risky

The final argument against interstellar travel that we'll discuss is the level of risk. Even if we were confident that we knew exactly what kind of microbes were on another planet, even if we had the propulsion figured out, and even if we found a way to carry along all the necessary

supplies... there is still the possibility that we could encounter something we did not prepare to encounter.

Imagine the devastation of something fatal happening to an entire multi-generational spacecraft. Space is too vast, too foreign, and too dangerous, the naysayers argue.

Given these arguments and the technology hurdles to overcome, you may be thinking interstellar travel is never going to happen and we should not bother. But let's take at some of the more compelling reasons for pursuing interstellar travel.

Beneficial Technology

A lot of the problems that would need to be solved to make manned interstellar travel happen would benefit life on earth if solved. For example, developing a more efficient, more powerful energy source. Or finding new ways to feed people in a limited amount of space. These and many others have direct applications to making life better for those remain on earth.

Multi-planetary Species

One of the most prominent theories about what happened to the dinosaurs is that the earth was hit by a devastating asteroid. Even if that theory turns out to be false, there is no reason why that couldn't happen to the earth in the future.

Even if a major asteroid doesn't hit the earth, scientists predict that the sun will expand to the point that it will no longer be possible to live on earth.[(2)] Of course that is billions of years into the future, however, yaysayers argue that just because it is far into the future, doesn't mean we shouldn't start working on a solution now.

One of those solutions is to become a multi-planetary species. The more planets humans inhabit, the more likely it is that the species will survive.

Cooperation

Interstellar travel is not a project for one country and one country alone. This will take the most brilliant minds across the globe working together for a common goal. Hopefully, working together will have beneficial consequences for international relations across the world.

Conclusion

There is a LOT of work to be done to make interstellar travel happen. It will take technology that hasn't even been created yet. It will take problem solving on a global scale. But as long as there are those daring enough to take on these challenges, interstellar travel just might be a possibility.

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