TOOLKIT FOR INFORMAL EDUCATORS

Background Science

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BACKGROUND SCIENCE

Gravity

When you jump, your legs push you into the air. What brings you back down?

In December 1903, Orville Wright flew his four-cylinder engine-powered Wright Flyer a mere 120 feet (36.58 m). What brought the first manned and powered airplane back to the ground?

About 400 years ago, Italian scientist Galileo Galilei watched four tiny dots in his telescope circle around Jupiter. What was keeping those moons traveling around the planet?

If you are thinking gravity, you are right! So how does gravity work? How do airplanes defy **gravity** and stay in the air?

Did you know that people were flying long before the Wright Brothers? On October 15, 1783 (220 years before the Wright Flyer), J.F. Pilatre de Rozier flew over eighty feet (24.38 m) into the sky above Paris, France. He then comfortably returned to the ground. How did he do it? He used a force that opposes gravity. Watch the smoke from a fire or the steam from a tea kettle and you will notice that heated air rises. De Rozier was able to heat the air inside a hot air balloon so that it became less dense than air and floated upward. But the Wrights used a different forces to oppose gravity: **Lift** and **Thrust**!

Airplanes are much denser than air and unlike a hot air balloon, do not need heated air to fly. Instead, the forces of lift and thrust help an airplane to overcome the force of gravity. When an airplane engine is turned off and the plane is at rest, it is the force of gravity that keeps the airplane firmly on the ground. Gravity is the invisible force of attraction between any two objects. It is a force that depends on the size and distance of the two objects. An object with a very large mass, like a star or planet, exerts a very strong gravitational force on objects that are nearby and exerts a lesser force on objects that are farther away.

Seventy-five years after Galileo's discovery, the English physicist Sir Isaac Newton developed the three laws of motion. In his writings, Newton used the Latin word gravitas which would later be changed to the term gravity. He also developed a mathematical way to measure gravity called the law of universal gravitation.

All objects that have mass have a gravitational field. Scientists have even been able to detect the gravitational field of objects with a very small mass. Most objects in our lives do not have a gravitational field large enough to have a noticeable effect (unlike a magnetic field, where the effect is clearly visible even with very small magnets). We can feel the earth's gravitational field pulling us toward the ground. The moon and the sun's gravitational fields control the ocean's tides. The sun's gravitational field keeps the earth in its orbit.

Newton's Laws of Motion

1. Every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it.
2. The relationship between an object's mass (m), its acceleration (a), and the applied force (F) is F=ma. Acceleration and force are vectors. In this law, the direction of the force vector is the same as the direction of the acceleration vector.
3. For every action there is an equal and opposite reaction.

Common Misconceptions:

Galileo discovered that due to gravity, freely falling objects fall at the same rate of acceleration, regardless of their mass. Astronauts on the 1971 Apollo 15 mission to the Moon were able to confirm Galileo's findings. The astronauts showed that on the surface of the Moon, where there is an absence of air to create drag, items of different mass fall at the same rate. An astronaut stood on the Moon's surface and dropped a feather and a hammer. Both objects slowly dropped and landed on the Moon soil at the same time.

Many people hold the misconception that lighter items fall more slowly than heavier items. This misconception is reinforced by the fact that many light items have more surface area and do not move through air as easily. The surface area to mass ratio, along with the orientation of the object as it falls, are what determine how quickly or slowly an object will fall. Air resistance, or drag, keeps items with more surface area—like a feather—from falling as fast as items with less surface area—like a hammer.

Flight Facts: Gravity

- As a way to recognize Newton for all his work, the science community named the unit for measuring force after him. Force is equal to the mass of an object multiplied by an acceleration rate. One Newton is equal to 1 kilogram multiplied by 1 m/s^2.
- An apple falls to the earth with the force of about one Newton. A little girl has around 500 Newtons of gravitational force trying to hold her to the ground. The force of gravity on a 1936 Stearman wooden biplane is about 8,943 Newtons. Imagine the force of 2.2 million Newtons on a fully loaded Boeing 787-8!
- A Quicktime video of the falling object demonstration conducted by the Apollo 15 astronauts can be viewed at http://www.hq.nasa.gov/alsj/a15/a15v.1672206.mov.
- Gravity causes the tides. Gravity is the force that keeps the Moon in orbit around Earth. But did you know the Moon pulls on the Earth too? The closer two objects are, the more pulling force they have on each other. The Earth has solid land and liquid oceans. Whatever portion of the Earth is closest to the Moon is more strongly affected by the Moon's gravity. The water there rises in a bulge,

causing the sea to rise in a high tide. In order for there to be a high tide somewhere on Earth, there must be a low tide somewhere else. The relationship between gravity and tides is fascinating. To learn more, find a book or website about the tides.

Topic Links:

- Legend of the Sky: The Wright Brothers
- Legend of the Sky: Sir Isaac Newton
- Legend of the Sky: J.F. Pilatre de Rozier
- Newton's Laws of Motion
- Apollo 15 space mission (1971)
- Ocean tides

Background Science: Lift

Lift is the force that opposes gravity. Flight is possible only when the force of lift is strong enough to overcome the downward force of gravity. Lift is created with moving air and an **airfoil.**

Most airplanes have wings that are shaped like an airfoil, which has a curved top surface and a flat bottom surface. Scientists have two explanations of how lift is created by an airfoil.

One explanation is that the curved top surface of the airfoil causes the air traveling above the wing to take a longer path. The longer path means the air above the airfoil must travel faster than the air below it. Faster moving air is lower in pressure than slower moving air. The slower moving air, with greater pressure, pushes the underside of the airfoil up into the faster air flow. According to **Bernoulli's Principle**, the differences in **air pressure** between the bottom and top of the wing pushes the wing up. When the force of lift is greater than the force of gravity on that object, then that object takes flight.

A compatible explanation is that as air moves over and underneath the airfoil, it is directed downward by the trailing edge of the wing. This is called a downwash. Newton's laws state that there must be an equal and opposite reaction to the downward force of the air, which forces the wing upward, and creates lift.

Imagine keeping a balloon off the ground by squirting it with a squirt gun. When the water bounces off the bottom of the balloon (action), the balloon goes higher (reaction). If you want the balloon to stay up, you must constantly squirt it. You are creating lift with your squirts of water by forcing a collision between the water and the balloon. A plane's engine moves it forward, causing a collision between the wing and the air. This collision, combined with the shape of the airfoil, creates downwash. The equal and opposite force from the downwash creates upward lift on the wing.

Flight Facts: Lift

- Early aircraft had airfoils that were inspired by the wings of birds and fins of sharks. The profile of the seagull's wing shows the familiar shape of an airfoil. The bird can use its wing muscles to adjust the angle of its wings, either increasing or decreasing the amount of lift that it wants. Even the most modern airplanes are not able to do that...yet.
- The powerful swing of a shark's rear caudal fin propels the shark forward through the water. To keep its head from dropping, the shark's wing-like pectoral fin generates lift and keeps the shark's body on a horizontal plane.

Topic Links:

- Legend of the Sky: Daniel Bernoulli
- Airfoils and hydrofoils
- Bird wings
- Shark fins

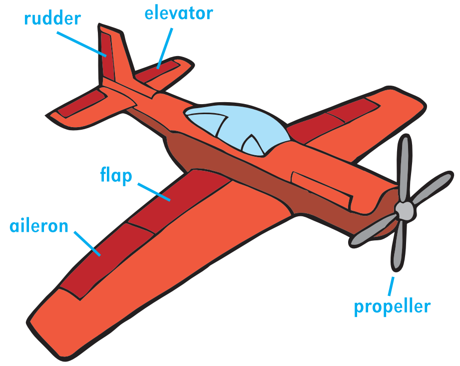
Background Science: Drag

Drag is the force of resistance caused by air on anything trying to move through it. If you have ever held your hand out the window of a moving car and felt the air pushing against it, you have experienced drag.

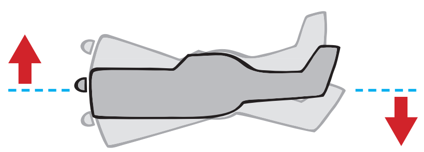
When an airplane moves through the air, drag is created when the airplane moves the air in front of it. The air then fills in the empty space left behind the airplane, which causes the air to pull—or slow—the airplane. In order for an airplane to fly, the force of thrust must overcome the drag.

For airplane makers, drag requires serious consideration. At high speeds, drag can even be strong enough to tear an airplane apart. Drag slows the aircraft down making flights longer and even more expensive. Large engines are required to overcome the force of drag and propel the aircraft forward. These heavy engines need strong structural supports throughout the aircraft and require huge amounts of costly fuel. If it sounds like drag is nothing but bad, consider this: without drag, controlling an airplane would not be possible.

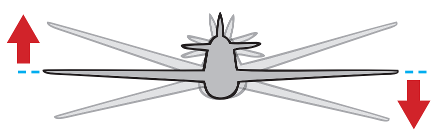
A skydiver relies on drag to fill her parachute, which increases the air resistance and slows her fall. Drag is also necessary for a pilot's controls to work properly. By increasing the drag on specific parts of the plane, small flaps called ailerons, elevators, and rudders make it possible for the pilot to control the flight of the airplane. No drag, no control!



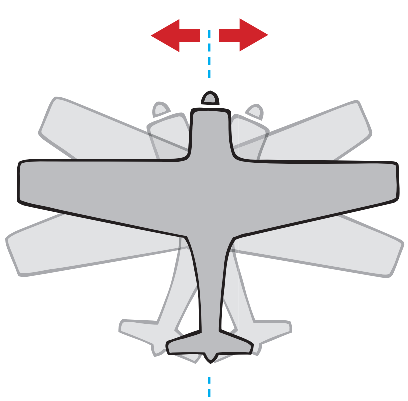
Pitch: The elevators are on the tail of the aircraft. Elevators make the nose of the airplane pitch up or down. If you raise the elevator, the tail drops down and the plane pitches up. If you lower the elevator, the tail comes up and the plane pitches down.



Roll: There is an aileron on the back edge of each wing. Ailerons make the plane roll side to side, which dips each wing up or down. By moving the ailerons in opposite directions, you can make the plane roll.



Yaw: The rudder makes the airplane yaw, which turns the nose of the airplane toward the right or left. If you move the rudder to the right, the plane yaws the right. If you move the rudder to the left, the plane yaws to the left. To make the plane turn, you must roll and yaw at the same time.



Common Misconceptions:

Many people are confused about the effects of gravity and drag on falling objects. While this misconception was addressed in the ***Gravity*** section, since this is such a common source of confusion, the information is repeated again below.

Many people hold the misconception that lighter items fall slower than heavy items. This misconception is reinforced by the fact that many light items have more surface area and do not move through air as easily. The surface area to mass ratio, along with the orientation of the object as it falls, are what determine how quickly or slowly an object will fall. Air resistance, or drag, keeps items with more surface area—like a feather—from falling as fast as items with less surface area—like a hammer.

Flight Facts: Drag

- Nature's design for flight is even better than any airplane ever made. Birds have a flight control system that manages drag, conserves energy, and provides the next meal. By bringing its wings close to its body at the beginning of each flap, a robin reduces drag for more efficient flight. A spotted harrier opens its wings wide to increase drag and slowly fly over open fields looking for its prey.

Topic Links:

- Bird flight
- Flight controls (ailerons, elevators, and rudder)
- Flight movement (roll, pitch, and yaw)
- Skydiving

Thrust

Thrust is the force that pushes an airplane forward and allows enough air to run above and below the wing in order to create lift. Developing thrust was the final hurdle for the early pioneers of flight in getting aircraft off the ground. Thrust is the force that opposes drag and can be achieved be either pulling or pushing the airplane in a forward direction.

Without an engine, airplanes are unable to produce their own thrust. Planes without engines are called gliders, sailplanes, or hang gliders. These engine-less planes are able to glide if there are special upward winds called thermals or if the plane gets a tow to a higher altitude by an engine-powered airplane.

Thrust can be produced in a number of ways. Birds, bats, and insects flap their wings and sharks swing their tails to create thrust. The four main ways modern airplanes produce thrust are propellers, rockets, jet turbine engines, and ramjet engines.

Propeller: A propeller is made of rotating blades, each one shaped like an airfoil. The rotating blades convert the engine's power into forward thrust. Propellers can push or pull the aircraft along, depending on how the blades are angled and which direction the propeller is turning.

Rocket: A rocket engine is the only engine type that does not require outside air to operate. Rocket engines burn a fuel to create thrust, pushing hot exhaust out a nozzle at the back of the engine. Rockets can even operate in space, where there is no air at all!

Jet Turbine: Jet turbine engines push air through the blades of a spinning turbine, which compresses the air. Fuel is then combined with the air and ignited. When the fuel burns, it rapidly expands from liquid to a gas and is forced out the rear of the engine. As the gas is forced out the back of the engine, the airplane is pushed forward.

Ramjet: A ramjet engine is similar to a jet turbine, except it has no moving parts. Ramjets only work after the aircraft is already moving quickly, so the aircraft initially needs another source of thrust. Once the aircraft is moving quickly, air is forced into the front opening of the engine at a high speed, which compresses the air. Inside the engine, fuel is injected, mixed with the compressed air, and ignited. As the fuel burns, the exhaust explodes out the nozzle at the rear of the engine, which creates thrust. Ramjet engines are usually lighter than jet turbine engines, which makes them ideal for supersonic flight. Ramjet engines are also used for missiles and some types of space craft.

GOING GREEN

The Boeing 787 Dreamliner and the Airbus A380 both are built with super-efficient, gas-sipping jet turbine engines. Compared to similar aircraft, the 787 uses twenty percent less fuel and reduces emissions of both carbon dioxide and nitrogen oxides. The A380 uses seventeen percent less fuel per passenger seat. The 787 and A380 engines are also quieter, both inside and outside of the planes. This greatly reduces these planes' noise footprints.

Newton's Third Law of Motion

"All forces occur in pairs, and these two forces are equal in magnitude and opposite in direction."

A girl and a boy are standing on skateboards. When the girl pushes the boy, both skaters move away from each other with a force equal to that of the push. A jet engine works using the same concept. The fuel burns and leaves the back of the engine with a huge force. The jet engine and everything connected to it move in the opposite direction with the same amount of force.

Flight Facts: Thrust

- December 17, 1903: Orville Wright flew the Wright Flyer into the history books. The longest of the three flights of the Wright Flyer was 196 feet (59.74 m). The Flyer gained an altitude of only about 10 feet (3.05 m) above the ground. The entire flight only lasted 21 seconds. The entire flight could have easily taken place inside the body of a Boeing 747 airplane.
- Did you know the Wright Brothers were NOT the first people to fly? What makes Orville Wright's 1903 flight historic was his was the first engine-powered, human flight. We have reports from China that as many as 2,500 years ago, people were using wind and wings to sail through the air! The glider or sailplane has been around for a long time. The pioneer of sailplanes may have been Lu Ban, a fifth-century B.C.E. Chinese philosopher.
- Harrier military aircraft are called V/STOL (Vertical/Short Take-Off and Landing) jets. They use jet turbine engines for forward thrust, just like a standard jet. But what makes these planes special is their ability to change the direction of their jet nozzles. When they land and take off, their jets can be pointed straight down, allowing the jump jet to lift straight off from the ground. Harriers can even hover like a hummingbird.
- An airplane propeller is like a twisted wing. If you look closely at the shape of a propeller, it should look familiar. It is the shape of an airfoil, just like a wing! There is one difference between a wing and a propeller – the propeller is perpendicular to the ground. While a wing's airfoil creates lift to keep the airplane flying, the propeller's airfoils instead create thrust and move the airplane forward.
- In order to provide the thrust needed for travel, the Boeing 787 burns about 1 gallon (3.79 liters) and the Airbus 380 burns about 1.27 gallons (4.81 liters) of fuel per passenger seat per 100 miles (160.93 km) traveled.

Topic Links:

- Legend of the Sky: Sir Frank Whittle and Dr. Hans Von Ohain
- Legend of the Sky: Orville Wright
- Propellers
- Gliders, sailplanes, and hang gliders
- Harrier V/STOL jump jets
- Engine types (propeller, rocket, jet turbine, and ramjet)
- Newton's Third Law of Motion

Airplane Design

What colors and patterns are most restful to weary travelers? What shapes and lighting will make passengers feel most comfortable? These questions and many others were examined by the interior designers who designed the cabin of the new Boeing 787 Dreamliner and the Airbus A380.

"Passenger well-being, on both an emotional and physical level, relies heavily on collaborative and research-orientated design practices. In designing the highly-anticipated 787 Dreamliner, Teague and Boeing employed a variety of design research techniques to determine the needs and desires of commercial travelers the world over. Defining and responding to the collective needs and desires of air travelers fueled the design process, permitting new, unconventional ideas to flourish and succeed in an industry renowned for strict standards. The results surpassed expectations."

- John Barratt,
CEO of Teague, the interior designing firm for the Dreamliner.

Soft, relaxing, roomy, and comfortable are not normal ways of describing the flying experience. Yet when passengers board the Boeing 787 Dreamliner, these are some of the words Boeing hopes passengers will use to describe their flying experience aboard the aircraft. Years of research and passenger input have gone into making the Dreamliner a "dream come true" for passengers. From wider seats and larger windows to quieter toilets, every passenger is promised a unique and top-notch flying experience.

At the heart of this experience is the airplane's interior lighting. The goal of the designers was to use a combination of lofty arches and a "sky effect" to give the passengers a sense of spaciousness. The "sky effect" is supposed makes the ceiling of the airplane look like a blue sky. The "sky effect" is achieved by shining a series of light-emitting diodes (LEDs), onto the curved interior surfaces of the airplane.

What is a light-emitting diode (LED)?

A light-emitting diode or LED is a new kind of lighting device that has a number of advantages for airplane interiors over standard incandescent and fluorescent lights. LEDs

1. LEDs produce more light than incandescent bulbs.

   Advantage? When needed, the inside of the airplane can be brighter than ever before.

2. LEDs can shine a single color light.

   Advantage? The inside of the airplane can change color depending on what effect is desired. Would you like sunset or sunrise?

3. LEDs are difficult to damage.

   Advantage? Fewer lights will be damaged by turbulence or clumsy ground crews.

4. LEDs have an extremely long life span.

   Advantage? Nobody likes to change light bulbs. LEDs burn longer, are more efficient, and are better for the environment.

5. LEDs can be very small and work very well when dimming is needed.

   Advantage? Lights can be placed in tight areas. They take up less space. They can dim or brighten quickly.

GOING GREEN

The Boeing 787 Dreamliner and the Airbus A380 both use efficient LED lights throughout their cabins. LEDs last three times longer than fluorescent tubes and fifty times longer than incandescent bulbs.

Lighting effects do not begin and end in the entry hall of the Dreamliner. LED lighting throughout the cabin gives the flight attendants the ability to change day to night, and then back to day with a simple touch of the controls. With their ability to dim, LED lighting can even be programmed to simulate dusk and dawn, so passengers will begin to sense the time to sleep or wake up without sudden changes in light. The ability to mimic natural day cycles will help reduce jet lag for passengers flying on long-haul flights.

Passengers will notice that the windows are larger and do not have shades. With a simple touch of a control pad near the window, passengers will be able to progressively dim their windows.

Experts have thought about every moment during a flight and how lighting can help enhance the experience. They even thought about how food looks under different colors of light.

Flight Facts: Airplane Design

The emotion triggered by a color depends on a person's nationality, past experiences, and, sometimes, personal preference. However, studies have shown that specific colors and color combinations can psychologically affect the majority of people, regardless of their culture or past.

Topic Links:

- Lighting and jet lag
- Color psychology
- LEDs

International Teamwork

In order to construct the Boeing 787 Dreamliner, Boeing employees traveled around the globe in search of partners. In the end, they formed the most far-reaching international development team in the history of commercial aviation.

Unlike the partnerships of the past, in which suppliers made parts and systems to fulfill a Boeing design, the new project asked a higher level of involvement and commitment from other companies. Boeing decided to share the responsibility for design and development, as well as manufacturing. This meant higher risks, because Boeing would need to entrust others with the work they only trusted themselves to do in the past. But it also guaranteed that in order to take part in the team, partners would need to be the very best in their field. In the end, partners in eleven different countries across four continents were selected to build parts and design systems that would all fit together into one airplane. The final assembly point was chosen—the Boeing Everett Plant in Washington, U.S.A.—and the challenge of figuring out how to transport all these separate parts to one place began.

Distances traveled by some of the Boeing 787 parts from the international partners to the final assembly plant in Everett, Washington, U.S.A.

Distances from Everett	In miles (mi.)	In kilometers (km)
Australia	7,908	12,727
Italy	5,627	9,056
South Korea	5,272	8,484
Germany	5,252	8,452
Japan	4,769	7,675
United Kingdom	4,734	7,619
Sweden	4,658	7,496
Canada	168	270

Boeing has stated that the final assembly time for the Boeing 787 Dreamliner will be a remarkable three days. This short assembly time is only possible if the parts that arrive at the Boeing Everett Plant are ready for assembly. This meant that traditional forms of shipping needed to be rethought as well. The major structural components of the Dreamliner are built in Japan, Italy, Kansas, and South Carolina. Boeing had to design and build an airplane that could carry the major structure components of another airplane. The result is a flying flat-bed truck of sorts – the Dreamlifter. The Dreamlifter is a modified Boeing 747 that has a hump-shaped back, no windows, and a tail that swings on a huge hinge to open the plane for cargo loading. The Dreamlifter is an engineering marvel, and its only job is to transport the parts for the Boeing 787.

Flight Facts: International Teamwork

- At only three days, the final assembly time for the Boeing 787 Dreamliner will be the fastest in commercial aviation history. This will be an amazing achievement, but it is not the fastest airplane assembly time on record. There were times during WWII that the Boeing Everett Plant produced sixteen B-17 bombers every day.
- The Boeing Everett Plant is the largest building (by volume) in the world. The building covers 98.3 acres (39.95 hectares) and is about nine stories tall. The building has over one million light bulbs.
- Global partners in Sweden, Germany, France, the United Kingdom, and Italy are providing the following Boeing 787 parts: Landing gear, engines, fuselage, doors, brakes, seats, tubing, ducts, and wiring.
- Global partners in Japan, South Korea, and Australia are providing the following Boeing 787 parts: Tires, sound system, lavatories, wing tips, landing gear, and vertical tail assembly.
- Global partners in the United States of America and Canada are providing the following Boeing 787 parts: Lighting, electronics, water systems, seats, sidewalls, escape slides, electronics, software, displays, hydraulics, flight deck, fuel gauge, lighting, engines, and windows.

Topic Links:

- International teamwork
- Geography and distance
- Aircraft assembly
- Boeing 787 Dreamliner and Boeing Dreamlifter

Materials Science—Composites

There are three main types of materials strength that all materials possess:

- **Compressive Strength:** The maximum amount of compression (squishing, crunching, etc.) that a material can handle before it fails. An example of compressive strength is stomping on an aluminum soda can.
- **Tensile Strength:** The maximum amount of loading that a material can handle before it fails. Some materials will stretch before breaking. An example of tensile strength is piling pennies on top of a paper towel until the towel tears.
- **Shear Strength:** The maximum amount of stress along a plane that a material can handle before it fails. An example of shear strength is tearing a piece of fabric into strips. Shear strength can be measure across the width, length, and diagonal of a material.

What are composite materials?

A **composite** is a combination of two or more different ingredients. When combined, the features of each ingredient are shared and the composite benefits beyond the individual parts. In a composite, there must be reinforcement, which provides the structure, and a matrix ingredient, which is the binding agent.

There are a variety of different types of composite materials. Composites found in the layers of plywood are called fiber reinforced polymers (FRP). Super strong composites may contain metal matrix composites (MMC). Composites designed to withstand heat may include glass reinforced plastics (GRP). There is a new type of cement that has ceramic matrix composites (CMC) as an ingredient. There are even OMCACs—organic matrix/ceramic aggregate composites. OMCACs can be found in nature, such as the shiny surface on some shells, which is called nacre or mother of pearl.

Carbon fiber composites have become popular because of their combined properties of low weight and high strength.

What is a carbon fiber composite?

In Greek mythology, Icarus' father molded him a pair of wings out of feathers and wax. The combination of organic fibers in the feathers with the wax binding agent created one of the first stories of human flight. Icarus was warned by his father not to fly too close to the sun, or too close to the ocean, for fear that his fragile wings would melt or dissolve. Alas, Icarus flew too high, his wings melted, and he plummeted into the sea. Fortunately, today's composites can withstand both high temperatures and corrosion from humidity. Although modern composites are much more advanced than Icarus' feathers and wax, carbon fiber composites are made out of similar basic ingredients: fibers and resin.

Carbon fiber composites are a composite—or an inseparable combination—of carbon fibers and polymer epoxy resin, which is a liquid that hardens into a plastic with the help of high temperatures and/or specific hardening chemicals. Carbon fiber composites can be made in a variety of ways, including cold press, hot press, chill plate, and dry impregnation process.

Carbon fiber composites can be found in many consumer products. A trip down the sporting goods aisle will feature carbon fiber composite baseball bats, golf club shafts, fishing rods, archery bows and arrows, bicycle frames, hockey sticks, canoe and kayak paddles, skateboards, surfboards, and even the interior components of some basketball shoes. Carbon fiber composites are featured in many modern military aircraft, Formula One race cars, some yachts, and special edition cars from manufacturers including Porsche, Mitsubishi, Maybach, Chevrolet, Ford, and Bentley. The Boeing 787 and

Airbus 380 commercial aircrafts also feature carbon fiber composites in their structures and major components.

How are carbon fiber composites manufactured?

One process for creating carbon fiber composites is similar to the creation of acrylic fabrics. It all begins with extremely fine carbon filaments, which can be many times thinner than the diameter of a single human hair. The filaments are twisted into fibers called threads. These threads are then woven together and mixed with epoxy resin, which is basically a liquid resin that hardens with the help of high heat or special chemicals. This creates a material called a tape. The tape is wound on spindles which are placed on a machine called a prepregger. The prepregger is like a huge, mechanical loom that pulls tape from multiple spindles and weaves them together using a series of combs. The resulting woven mat is mixed with polymer epoxy resin, pressed in a mold, and cooked under high heat and high pressure in an industrial oven called an autoclave.

Why are composite materials used to build airplanes?

Historically, most commercial aircraft have been made mostly from aluminum. The composite most used on the new Boeing 787 Dreamliner is a carbon fiber reinforced polymer (CFRP) while the Airbus A380 uses CFRP and GLARE, an aluminum and fiberglass composite. The new CFRP material has replaced many of the aluminum structures on the Boeing 787 for the following reasons:

1. CFRP is lighter. The Dreamliner still has some aluminum parts, but it is twenty percent lighter than an all-aluminum airplane of the same size.
2. CFRP is stronger. In tests, CFRPs were pulled, twisted, torn, flattened, cracked, and punctured, and in all tests the composites were proved to be as strong, if not stronger than the aluminum.
3. This increased strength in the fuselage allows for the cabin to be pressurized at the equivalent of 6,000 ft. (1.83 km). The stronger fuselage also allowed for the construction of larger windows. Carbon fiber composites are much more resistant to corrosion than aluminum, allowing for an increased level of humidity to be sustained in the passenger cabin. Pressurizing the cabin and humidifying the air helps travelers to feel better and arrive at their destinations refreshed and relaxed.
4. CFRP is more durable. Airplanes are asked to fly through a variety of difficult conditions that cause wear on aluminum parts. Extreme temperatures weaken the metal over time and the salty air above the oceans can create rust on metal surfaces. Composites will make airplanes more reliable and keep maintenance costs down.
5. CFRP is more resistant to high temperatures. Not only is CFRP stronger than aluminum at average temperatures, when the heat goes up, the difference in strength increases. As aluminum gets hotter, it becomes more malleable, which means that it can change shape. This effect occurs at a much lesser degree in composites.
6. CFRP can be molded into large pieces. Aluminum airplanes were made out of large pieces of aluminum that were held together with thousands of rivets. The seams and rivets on aluminum airplanes create drag. The Boeing 787 Dreamliner has as much as 50,000 fewer fasteners than on an aluminum airplane of the same size. With larger pieces and fewer seams between parts, there are far fewer places for weak spots, adding to the overall safety of the airplane.

GOING GREEN

Composites help create a more efficient aircraft – less weight reduces the cost of taking off and landing, less fuel usage while flying, greater load capacity, and longer range. Since it is twenty percent lighter than other aircraft its size, the Dreamliner will save around twenty percent on fuel! This means fewer emissions and harmful impacts on the environment.

Flight Facts: Composites

- A composite does not have to be a building material. A composite can be anything that is made of two or more ingredients that when combined create something entirely new.
- Composites are being commonly used more and more. If an item needs to be strong, flexible, and lightweight, composites are either being used, have been tried, or will be used soon. Graphite composites are found in golf club shafts and sail boat masts. Thermoplastic composites include bullet-proof vests and hockey sticks. Laminate composites are used for some types of countertops. A high-performance composite material called Mallite is used in the body of Formula 1 racing cars.

Topic Links:

- Greek myth of Icarus
- Acrylic fabrics
- Weaving and textiles
- Composites in nature (mother of pearl)
- Composites in everyday consumer products
- Carbon fiber reinforced polymer (CFRP)

Careers in the Aviation Industry

DESIGNING AND BUILDING THE AIRCRAFT

AERONAUTICAL ENGINEER

Aeronautical engineers plan the design and construction of airplanes. These engineers face many challenges, such as how to increase speed and fuel efficiency and how to decrease drag, turbulence, and noise. These engineers need a background in mathematics, physics, mechanics, and material sciences.

CIVIL ENGINEER

Civil engineers are responsible for the design and development of airports, including runways, parking lots, and roads. These engineers need a background in design, drafting, mathematics, physics, and project management.

ELECTRICAL ENGINEER

Electrical engineers build power systems that improve the airplane's performance. They must have a background in mathematics, physics, electrical drawing, computers, aircraft electrical systems, and project management.

MECHANICAL ENGINEER

Mechanical engineers design parts to help the airplane move and fly, such as the machinery in a plane's landing gear and flaps and the fuel pumps that deliver fuel to a plane. They solve mechanical problems such as how to design the landing gear to withstand the impact of the landing. These engineers need a background in mathematics, mechanics, thermodynamics, drafting, and design.

INTERIOR DESIGNER

Interior designers develop the "look" for the interior cabin of an aircraft. The designer will choose everything from carpet and seats to linens and silverware. The interior designer may also choose the seat and galley configurations.

PSYCHOLOGIST

A psychologist may be able to provide a window into the mind of passengers, crew, and mechanics. By understanding how these people use the aircraft, the airplane can be designed to accommodate their needs and desires.

SCIENTIST

The scientists are responsible for the research and development of new airplane technologies. They design and test new materials so that airplanes continue to improve.

TECHNICIAN

Technicians have a working understand of the airplane. They are the drafters, analysts, designers, and planners that help build and maintain the airplanes.

MAINTAINING AND OPERATING THE AIRCRAFT

FLIGHT ATTENDANT

Flight attendants spend more time with the passengers than any other airline employee. Their job is to be sure you get to your destination as safely and comfortably as possible.

GROUND CREW

There are a variety of jobs considered as part of the ground crew. Some include drivers, conveyors, and the flagger who helps the airplanes taxi to and from their gates. The ground crew helps flights begin and end as safely as possible.

MAINTENANCE MECHANIC

Maintenance mechanics have the important job of checking every airplane before take-off. They are capable of troubleshooting problems and performing emergency repairs.

PILOT

Pilots do much more than just fly—they are responsible for overseeing flight plans, airplane maintenance, and flight safety.

SUPPORTING AIRPORT OPERATIONS

AIR TRAFFIC CONTROLLER

Controllers are the specialists who work at the control center of the airport and provide pilots with instructions, air traffic clearance, and flight conditions.

BAGGAGE HANDLER

Handlers are the men and women who load and unload passenger bags and cargo. They are responsible for sorting bags and ensuring they are on the correct flight.

METEOROLOGIST

Meteorologists analyze weather data and prepare weather reports. They help plan safe flight routes to avoid poor flying conditions.

SKYCAP

Skycaps are dedicated to passenger service. They assist with luggage at the curb and answer questions about the workings of the airport.

SECURITY

Security at airports has become one of the most important jobs in the industry. These agents are highly trained and are dedicated to airport and passenger safety. Federal Air Marshalls are law enforcement officers who go undercover as passengers on airplanes.

TICKET AGENT

Ticket agents are usually the first person the passenger meets at the airport. They are concerned with customer service and helping passengers make their flights on time.

Credits

The *Legends of Flight Informal Educator's Toolkit* was developed by Kristen Clapper Bergsman and Matthew Merritt for Pacific Science Center, under the direction of project manager Heather Gibbons.

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