The History of the Twentieth Century
Episode 47
"Icarus Rising"
Transcript

[music: fanfare]

Daedalus was a legendary craftsman of ancient Greek myth. It was said that he designed the Labyrinth on Crete, where King Minos kept the Minotaur. Unfortunately for Daedalus, since he was now the only person who knew the passage through the Labyrinth, King Minos imprisoned Daedalus and his young son Icarus in a tower, so that he could not tell what he knew to anyone else.

Daedalus and Icarus could not leave the tower, because it was guarded. And even if they could, Crete was an island, and they would not be permitted to board a ship. Since escape by land or by sea was impossible, Daedalus constructed wings made of feathers secured with wax. For himself and his son. They would escape the tower and the island, although Daedalus warned his son not to fly too close to the sea, lest the feathers get wet, nor too close to the sun, lest the wax melt. Then they took off from the tower and flew over the sea toward mainland Greece.

You already know the rest of the story. Young Icarus, intoxicated with the thrill of flight, swooped and soared and tried ever more daring maneuvers until, forgetting his father's warning, he flew too close to the sun. The wax melted, the feathers fell off, and Icarus plunged to his death in a portion of the Aegean known to this day as the Icarian Sea.

Welcome to the History of the Twentieth Century.

[music: opening theme]

Episode 47. Icarus Rising.

The myth of Icarus persisted past the fall of the ancient world, and it remains one of the most well known and compelling of the old myths. If you go online right now and do an image search under Icarus, you will find depictions of this ill-fated youth from the ancient world through the Renaissance and the Age of Enlightenment through Romanticism and into modern times, including cartoons, anime, and video games.

The image of a man with wings, soaring high into the sky, has been a compelling one throughout the history of Western culture. No one wonders how, in the thrill of the moment, Icarus could

have forgotten the dangers, and of course, this legend is one more example of how teenage boys are the same in all centuries, and in all cultures.

There are basically three kinds of human artifact that can lift themselves off the ground and fly freely into the air, and humans have known about all three of them for a long time. The first is the rocket, which originated in China. The Chinese invented gunpowder, somewhere around the year 850. By the year 950, gunpowder was being put into bamboo tubes and used to launch flaming naphtha at enemies in war, an early form of flamethrower. Later, larger tubes were used to launch gravel and stones at enemy soldiers, the ancestor of the cannon. As these weapons got more powerful, poles were attached to the tubes, so that the soldiers firing them could brace the weapons against the recoil. By the year 1200, someone had gotten the idea of turning the tube around and sticking the pole into the ground, then firing the tube, causing it to launch into the air, and the rocket was invented. The first known use of rockets for military purposes was recorded in 1232.

The second type is the airfoil, which has been known since prehistoric times, most famously the Indigenous Australian "boomerang." Non-returning boomerangs can be used as weapons in hunting. More familiar to Westerners is the returning boomerang, which can be made and thrown so that it follows an elliptical path back to the thrower. These are more often used for sport and recreation than for hunting. But the returning boomerang is, in a very real sense, the earliest known example of controlled flight. Various forms of aerodynamically stable throwing sticks would be invented independently in other cultures around the world over the centuries that followed.

During the Middle Ages, Chinese and Europeans independently invented pull string helicopters. These are those little toys where you wrap a string around a stick that has a propeller attached at the top. You pull the string quickly, causing the stick to rotate, and the toy rises into the air, and then drifts elegantly back to earth as the spin slows down. These were popular children's toys seven hundred years ago, and they remain popular today, if the internet is any indication.

The third type is the balloon. The earliest known lighter-than-air balloons were Chinese "sky lanterns," which are a lightweight paper and bamboo shell, open at the bottom, with a candle mounted inside to provide both light and heated air. These have been in use in China for signaling at night and for festival celebrations since at least the third century. It appears that Portuguese mariners and traders brought the technology home, since sky lanterns begin appearing at festivals in Portugal by the early sixteenth century.

In the year 1709, a Brazilian-born Portuguese priest, Bartolomeu Lourenço de Gusmão, tried to sell the King of Portugal on the idea of funding a hot air balloon big enough to carry human beings. As a proof of concept, he built a small demonstration balloon, made of paper, attached to a small brazier in which he lit a fire. Of course paper and fire don't get along very well, and the early prototypes tended to burst into flames during the demonstration, which was kind of

embarrassing. De Gusmão would go on to build a more successful demonstration model that rose up into the air before the King and his court. Of course, a flaming object floating around inside a building at a height too great for people to reach it can be a problem, too, and he was forced to move his experiments outdoors.

It seemed de Gusmão was on the right track, but he seems never to have gotten beyond small-scale demonstrations of the principle, for reasons that are unclear. By some accounts, he feared persecution by the Portuguese Inquisition, so he burned his notes and left the country for Spain, apparently because he didn't know they had an Inquisition, too. Or something.

I mention these early inventions to make the point that it was well known as early as the Renaissance that there were human-built devices capable of flying through the air. To a person with sufficient knowledge and insight, it should have been clear even then that the invention of a machine capable of carrying human beings on a controlled flight had been reduced to a mere engineering problem. It was not now a question of theory, but of materials and machinery.

One person of the era who had a lot of knowledge and insight was the Renaissance Italian thinker Leonardo da Vinci. I hardly need explain who da Vinci is. You already know that he was a genius in many different fields, the quintessential "Renaissance Man." You probably also know he was interested in flight, and sketched designs for flying machines. He spent a lot of his time studying birds, and based his work on the concept of mimicking the flapping wings of birds, which is unfortunate, because that's a dead end, as far as human flight is concerned. Birds can fly by flapping their wings because birds are small and light. Human beings are just plain too big to get the power-to-weight ratio necessary to fly by flapping their arms, no matter how ingenious a wing device you might build to assist them.

This fact, that humans cannot possibly fly just by flapping their arms, had been worked out to a mathematical certainty within a hundred years after da Vinci's death. Sorry, Icarus. But in spite of that absolute assurance that it was a dead end, inventors would persist in trying to build flapping wing flying devices for another 250 years. And I'm sorry to say, this fixation on imitating birds probably had the effect of delaying the development of powered flight, maybe by decades.

The first manned flight would take place in Paris in 1783, and the vehicle would be a balloon. A year earlier, a struggling businessman in the paper trade named Joseph Montgolfier was staring at his fireplace in Avignon, watching the embers fly up the chimney, when he began to wonder if it would be possible to harness that updraft. He was pretty good with his hands, and he had soon put together a lightweight cubical wooden framework with taffeta fabric stretched over five of the six sides. He caught some smoke in it, and *voilà,* it rose to the ceiling.

He wrote at once to his brother Etienne, another struggling businessman, asking him to send more taffeta and promising to astonish him. Etienne complied, was astonished, and their work together began. The following month, December 1782, they had launched a hot air balloon

outdoors, in front of witnesses. They spent most of 1783 perfecting their design, eventually ditching the taffeta in favor of a material made of linen backed with paper. This material was manufactured for them by a wallpaper maker, which may explain the amazingly ornate look of the Montgolfier brothers' balloons—they've been described as giant flying Fabergé eggs, and that's an apt description.

But the Montgolfier brothers were craftsmen, not scientists. They had written to the French Royal Academy of the Sciences, offering to demonstrate their balloon, touting its scientific and military potential, but the Academy ignored them. By the summer of 1783, though, as their public experiments continued, and began to attract the attention of the press, the French government queried the Academy on the Montgolfiers' work. The Academy pondered this, and concluded that while the Montgolfiers were on the right track, the Academy felt that hydrogen gas seemed a more promising way to provide lift.

And the Academy knew what they were talking about. Seventeen years earlier, the British scientist Henry Cavendish had discovered a gas that he called "inflammable air." This was well known to the Academy, since one of its members was the greatest French scientist of the age and future victim of Revolutionary justice, Antoine Lavoisier. Lavoisier had confirmed Cavendish's work, had developed the theory of combustion, and was also the scientist who, in that very year of 1783 had proposed the name "hydrogen," that we use to describe this gas today—it comes from Greek and means "water generator," because when you burn it, you get water. So, these Academy guys, they know what they're talking about. Hydrogen gas is only about one tenth the density of air, so that's a lot of lift; it's more lift than you can get from hot air, and it works cold, which means you don't have to carry an open flame along in your balloon.

And the race was on, craftsmen versus scientists. In June of 1783, the Montgolfier brothers built a 35-foot diameter unmanned balloon and launched it 3,000 feet into the air. It traveled two miles across the southern French countryside, gracefully descending to a soft landing. Flush with success, the brothers headed to Paris. In Paris, at that same time, another member of the Academy of Sciences, Jacques Charles, was raising money to experiment with balloons filled with hydrogen. The tricky part here was developing a system of generating hydrogen gas in the quantities that would be necessary to fill a balloon. No one had ever done that before.

In August, Charles, in collaboration with two brothers named Robert, manufactured a 12-foot diameter balloon made of fabric coated with rubber, which was then a new and exotic material. They filled it with hydrogen, and launched it from the Champs de Mars. The balloon was smaller than the Montgolfier balloon, but the extra lift that came from the hydrogen was enough to keep it in the air a full 45 minutes. It traveled 15 miles, pursued by a few hardy spectators who followed it on horseback in the rain, before the balloon descended to the countryside, purportedly because of a tear in the fabric, although it would be hard to tell, because the local farmers, terrified by the sight of a giant sphere descending into their fields, attacked it with pitchforks.

Among the spectators at that day's demonstration were Charles's friend and fellow scientist, and also the American minister to France, Dr. Benjamin Franklin, along with his teenage sidekick, John Quincy Adams. While the experiment was a success, one spectator is reported to have asked, "But of what possible use is it?" And Franklin famously retorted, "Of what use is a newborn baby?"

But don't count out the Montgolfier brothers yet. The news of Charles's success spurred them onward. Three weeks later, they launched a test balloon at Versailles. Among the spectators that time were the King and Queen of France (and future victims of Revolutionary justice), Louis XVI and Marie Antoinette.

This flight had three passengers, a sheep, a duck, and a rooster. Which is interesting, because it kind of reminds you of the early spaceflight tests in the United States and the Soviet Union, when they launched dogs and chimpanzees, doesn't it? The sheep was supposed to be a stand-in for a human being, and I guess the duck was sort of an experimental control, since ducks can fly, maybe they were looking to see if there was some unknown ill effect of altitude that would harm a sheep but which a duck might be immune to. Just don't ask me what the rooster was all about. As it happened, the liftoff was shaky, owing to strong winds, which alarmed the animals, and led to the sheep stepping on the rooster, but otherwise, the passengers suffered no ill effects otherwise despite rising to an altitude of 1,500 feet.

In October, the Montgolfiers built their biggest balloon yet and tested it tied to a tether with Etienne riding, although neither of the Montgolfier brothers would ride the balloon when it was finally tested in free flight. That honor would go to two other members of their team. That flight took place on November 21, 1783; one year and seventeen days after Joseph had his fireplace inspiration back in Avignon. The flight was a success in spite of a wind gust that tore the balloon while the Montgolfiers were setting it up. Women volunteers from the crowd were recruited to sew the tear shut, and off the balloon went, on a 25-minute voyage over a distance of about five miles. Also among the spectators that day: Dr. Benjamin Franklin.

And so the Montgolfier brothers win the credit for the first manned flight. But don't forget Jacques Charles, who launched his own hydrogen balloon flight just ten days later, on December 1. He may have lost the race, but he presented the world with a superior technology, not only because it used hydrogen, but with a gondola instead of a simple basket, and a pressure relief valve to protect the balloon from bursting. Charles also took a barometer and a thermometer along to use to make observations during the flight. He had this small green balloon on hand that he planned to release first to test the wind. When he saw Etienne Montgolfier in the crowd of spectators, he graciously handed him the test balloon and said, "It is for you, sir, to show us the way to the heavens."

Charles toasted the crowd as he and Nicolas-Louis Robert took off. They flew at an altitude of about 2,000 feet for two hours, and covered a distance of about 25 miles before the balloon

drifted slowly to the ground, at which point it dawned on Charles that he could fly for a little longer if he kicked Robert out of the balloon, so he did. He was then able to climb to the amazing altitude of 9,000 feet, high enough that his fingers got numb from the cold and he experienced ear pain from the rapid change in pressure. But he was able to land the balloon without further difficulty.

The Montgolfiers may have won the race to launch the first balloon flight, but Charles won the technology competition. The superior lift of hydrogen gas made it the preferred technology for the next 170 years, although hot air balloons would make a comeback in the latter part of the twentieth century, as modern, lightweight, reliable propane burners made hot air balloons safer and easier to fly.

[music: *Roman Carnival Overture*]

During the nineteenth century, ballooning would become an entertainment for the wealthy. Balloons would be used for atmospheric research, climbing as high as four miles into the air, once equipment had been developed to supply the passengers with oxygen for the flight.

They would also be used for military purposes. Just a few weeks after observing the first manned flights, Benjamin Franklin wrote, “Five thousand balloons, capable of raising two men each, could not cost more than five ships of the line; and where is the prince who can afford so to cover his country with troops for its defense as that 10,000 men descending from the clouds might not in many places do an infinite deal of mischief before a force could be brought together to repel them?”

But the real military value of balloons would be for reconnaissance. The French used reconnaissance balloons during the Revolutionary wars, although Napoleon found them to be not worth the trouble and discontinued them. During the American Civil War, the US Army used balloons for reconnaissance purposes, improving on the idea by adding a telegraph line so that the observers in the balloon could report their observations to the ground in real time. But again, balloons were deemed too troublesome and their use was discontinued in 1863. Balloons were used to send mail into and out of Paris when that city was under siege by the Prussians in 1870 and 1871. And by 1899, enough people were talking about the possibility of dropping bombs from balloons that the subject came up during the Hague peace conference of that year, as we saw back in episode 30.

Dirigible balloons, that is to say, balloons that can be steered, would develop through the second half of the nineteenth century. Most of these use propellers to drive and steer the airship. Early models were powered in a variety of ways, including hand cranking and steam engines, but eventually, internal combustion engines would become the standard, for reasons we’ll take a closer look at in a little bit.

In 1891, a 52-year old German aristocrat and army officer, General Ferdinand Adolf Heinrich August Graf von Zeppelin, retired from the military and took up the manufacture of airships. Zeppelin's new idea was an airship with a rigid frame, which would hold multiple bags of hydrogen gas, and to which the engines and the passenger compartment could be rigidly attached. Zeppelin's first successful test flight was in 1900, but over the next few years, his ships would suffer accidents and he would have difficulty raising money. But eventually, his work began to attract public attention in Germany and became a source of national pride. By 1909, Zeppelin was taking paying passengers on pleasure cruises, and by 1912, the German military was taking an interest in his work.

By the way, the name zeppelin technically refers to airships manufactured by the Zeppelin company, although the name has come to be used generically for any dirigible with a rigid frame, or sometimes just as a synonym for "dirigible."

And before we leave the subject of dirigibles, I need to mention Alberto Santos-Dumont. Santos-Dumont was born in 1873 in Brazil, in a town then called Palmira, but today called Santos-Dumont. He was born into a family that had grown very wealthy from the booming coffee trade. In 1891, the year Alberto turned 18, and also the year General Graf Zeppelin retired from the German Army, Alberto's father was thrown from a horse and seriously injured. He sold his plantation and traveled to France to seek medical care. Alberto came with him. In France, he became a fan of the proto-science fiction writer Jules Verne, studied physics and chemistry, and developed a fascination for balloons. He began by paying for balloon rides, and enjoyed the experience so much he soon found it would be cheaper to indulge himself by building his own balloon rather than keep on paying to ride in someone else's.

By 1899, the now 25-year old Alberto had his own airship hangar and equipment to manufacture hydrogen gas, and was experimenting with dirigibles. In 1901, he became a sensation in Paris and a national hero in Brazil after winning a ₣100,000 prize for becoming the first to fly from the Parc Saint Cloud to the Eiffel Tower and back again in thirty minutes, which works out to an average speed of about 14 mph. Alberto gave half the prize to his crew, and donated the other half to charity. He became the toast of Paris. Parisians called him *le petit Santos* and his signature Panama hat became all the rage.

And the story is told that a little while later, Alberto had lunch with his friend, the noted watchmaker Louis Cartier. At the lunch he complained about the difficulty of timing himself during his famous thirty minute airship flight, because it was tricky to pull out a pocket watch while you needed two hands on the controls of your airship. He challenged Cartier to develop a timepiece that could be checked even when your hands are busy. Cartier developed a wristwatch with a leather strap that could be buckled around the wrist.

Now, wristwatches had been worn by women for some time now, but not by men. Real men carried pocket watches, watches that you have to pull out of a pocket and fiddle with, if you want

to know what time it is. That was manly. A watch on the wrist was effeminate. But wristwatches had come into to use in the military by the end of the 19th century, where they were sometimes called “campaign watches.” There are obvious advantages in issuing wristwatches to soldiers: you can coordinate movement with greater precision, and soldiers on a battlefield, like aviators in a dirigible, need to be able to check the time quickly and easily, even when their hands are busy. The military use of the wristwatch would make it become more and more familiar to a new generation of young men until, by the end of the Great War, they had become an accepted part of male civilian attire as well.

In other words, once men learned that you could still kill people, even if you did have a watch strapped to your wrist, well, that made it perfectly acceptable and manly. By 1920, you were likely to spot a campaign watch or two at any gathering of men, especially if there were younger men. They caught on rapidly after that, and by 1930, the pocket watch had all but disappeared.

[music*: Gymnopédie no. 1*]

I mentioned airfoils at the beginning of the episode, and now it’s time to go into the subject of airfoil flight in a vehicle heavier than air. Airplanes, in other words. That’s a longer story that I need to defer to next week’s episode, but I want to finish up this week’s episode by taking a short look at the internal combustion engine, because it is a crucial step in the development of a practical airplane, not to mention in the development of a practical automobile.

As I mentioned all the way back in episode one, the coal-fired steam engine is what powered the advances of the nineteenth century. You can think of a steam engine as an external combustion engine. A steam engine uses heat to boil water in a closed container, creating pressurized steam. The pressure of the steam is then converted into work, often by pushing a piston. It is an external combustion engine because the combustion that produces the heat that pressurizes the steam occurs outside the container that holds the steam.

People were experimenting with primitive steam engines by the early Roman Empire, but the first practical steam engines were developed in Britain in the 18th century. Steam engines were first developed for industrial purposes, and powered the Industrial Revolution. Steam engines were also, particularly in those early days, very heavy and not terribly efficient. Only a portion of the heat generated by the combustion goes to make the steam. The rest of the heat energy released is wasted. Early steam engines were only 1 or 2 per cent efficient.

But as steam engines developed in the 19th century, they became more and more efficient, perhaps 10% efficient by the end of the century, but this was at the cost of making them bigger and adding additional equipment, which made them heavier. So when you talk about steam vehicles, you are mostly talking about railroad locomotives, very large vehicles that pull very large loads, and require tracks because they are too heavy to roll on the ground. Inventors have been experimenting with steam vehicles that could run on roads for as long as they were experimenting with rail locomotives, but those vehicles were more curiosities than anything else.

By the later 19th century, steam automobiles were becoming more practical, but larger machines for many passengers—steam busses, really—were a more appropriate use than automobiles as we would come to know them.

Needless to say, a steam-powered airplane sounds like a dubious concept. But there were people experimenting with them by the late 19th century, as you will see next week, and, who knows, it might have become practical someday. But we will never know, because the internal combustion engine became available first. Perhaps you can already guess the difference between the steam engine and the internal combustion engine. In the internal combustion engine, combustion takes place right in the piston cylinder, meaning that the energy released in the combustion is entirely contained, which makes the engine potentially much more efficient.

Obviously, you can't use coal in an engine like this. The earliest versions of internal combustion engines began appearing in the late eighteenth century, and used gases for fuel, either hydrogen gas or natural gas. Early engines were two-stroke engines, meaning combustion occurs every piston cycle, and they were no more efficient than steam engines.

We've already seen the growth of the petroleum industry in the 19th century. As the extraction and distilling of petroleum became more widespread, gasoline became readily available. Gasoline, however, does not make a good household fuel, like, say, kerosene, because gasoline is volatile, it produces dangerous fumes, it is potentially explosive, and it is prone to producing unpleasant by-products like soot and carbon monoxide when you burn it, unless the fuel-to-air mixture is carefully controlled. Hence, there was not much of a market for gasoline, and oil companies often simply threw it away, perhaps dumping it in a nearby river. Just thinking about that makes me cringe.

The development of the carburetor made it possible to burn gasoline in an internal combustion engine, because carburetors provide that careful control of the fuel-to-air mixture I was talking about. Later in the 19th century, the four-stroke engine began to appear. In this design, combustion only occurs every other piston cycle. In-between, the piston expels the combustion products from the previous combustion, and then draws in the fuel/air mixture, and then compresses it before the next combustion. It may seem counterintuitive to think that a cylinder that only fires every other cycle would be more efficient than a cylinder that fires every cycle, but in fact, it is. The extra power you get by compressing the fuel and air mixture before igniting it more than makes up for the fact that now you need more cylinders because each cylinder is only firing half as often. The four-stroke internal combustion engine easily beats the steam engine in efficiency, and now that gasoline has become readily available, it quickly became the fuel of choice.

These innovations happened piecemeal, over many years, so it's difficult to point to one inventor and say that person is responsible. But many of these innovations were appearing in Germany. Two German engineers named Nikolaus August Otto and Eugen Langen produced the first

practical four-stroke engine, which won a prize at the 1867 Paris Exposition. Gottlieb Daimler would later develop this concept into an early automobile. Working at the same time, another German engineer named Karl Benz would market the very first commercial automobile, albeit with a two-stroke engine. Benz would later upgrade his design to use the new four-stroke technology, and the Daimler and Benz companies would become rivals.

In 1893, a French-born German engineer named Rudolf Diesel patented the Diesel engine, which differs from other internal combustion engines in that it achieves much higher compression, which makes the engine more efficient. Higher compression means higher temperatures in the cylinder, which means that Diesel engines do not require a spark, and can operate using fuels less volatile, and therefore less dangerous, than gasoline, even vegetable oil, as Diesel himself demonstrated at the 1900 Paris Exposition. Diesel engines by their nature also tend to be more rugged and last longer than gasoline engines.

Internal combustion engines were first used in static applications, to turn a pulley to do useful work. They were especially useful for farmers, because they were smaller and more practical than steam engines. Their continued development made the automobile practical, and later, the airplane. Later still, portable internal combustion engines made possible power tools like lawn mowers and chainsaws, that could be carried and operated by one person. Try to imagine a steam-powered chain saw, and that should give you an idea of why the internal combustion engine was revolutionary.

We'll have to stop there for today, but I hope you'll join me next week on *The History of the Twentieth Century* as we take up the development of airfoils and fixed wing aircraft and how, after many ups and downs, literally, the problems of heavier than air flight are finally solved by two bicycle manufacturers from Dayton, Ohio, who would become the first people to fly an aircraft, at a remote location, in front of just three witnesses, and then struggle for years afterward to convince the rest of the world that it actually happened. That's next week, on The History of the Twentieth Century.

And I'm going to post a supplemental episode later this week, a reading of the 1870-ish American poem "Darius Green and His Flying Machine," because I find it amusing, and hopefully it gives you some perspective on the public attitude toward people who experimented with flying machines in the late 19th century.

Oh, and one more thing. In case you were wondering, the Daimler company designed a new model car in 1901, which was named Mercedes at the suggestion of a customer, a wealthy Austrian who used Daimler cars for a racing team he owned. "Mercedes" was his daughter's nickname. The success of the model, coupled with the fact that Daimler Motors had sold a French company the use of the "Daimler" brand name in France led to "Mercedes" becoming the brand name of Daimler automobiles. In 1909, Daimler trademarked a three-pointed star in a circle to represent the brand. In 1926, Daimler Motors and Benz Motors would merge to form

Daimler-Benz. And because of that earlier contractual concession of the name “Daimler,” the new company’s automobile division would be called Mercedes-Benz. That name, and the three-pointed star, are still used by Daimler’s automotive division to this day.

[music:closing theme]