Chapter 1

The Dreamers and Philosophers

Throughout the reign of the human animal on Earth, it has been human nature to be dissatisfied with one's lot in life. It is not a matter of being unhappy with one's life but rather yearning to do more. All human beings are taught that improving one's self is a necessary part of living. To most people, satisfaction comes from increasing their knowledge of the world around them or improving their skills. To others, doing what no one has done before is a necessary life enhancement. To some this means traveling over the ground faster than the cheetah. To others it means taking to the waters and sailing around the world. To still others it means swimming with the fish under the sea. One of the most intriguing desires of humankind is to fly with the birds.

Perhaps the most famous of those who dreamed of flying is Leonardo da Vinci (1452–1519), who made elaborate sketches of flying machines with which he fantasized flying like a bird. The problem with most of da Vinci's machines is that they were *too much* like birds. This drawback was not unique to da Vinci, for many other designs for a flying apparatus had wings that flapped and were called "ornithopters." One of da Vinci's sketches was for an "aerial screw" that would provide lift. When people finally took to the skies, although they had learned much from the birds, the machines they used did not resemble these creatures. Early aircraft did indeed use an airscrew, but they used it for propulsion and instead used fixed wings for lift. When aircraft construction technology improved, the early, boxy aircraft became more aerodynamic, with sweeping wings and smooth surfaces. The airscrew became the modern propeller, and at that point aircraft really began to look like birds.

Much of the dreaming of early humans was limited by their knowledge of the universe. They never dreamed of traveling to the moon and other planets because they did not know that these were places to go to. They knew of them only as points of light in the night sky. But from the moment that humankind understood the nature of the moon and the planets, it did not take very long before the dreamers wrote of traveling through space. One well-known writer, Jules Verne, wrote his first novel, *Five Weeks in a Balloon,* in 1863. Later Verne graduated to space travel with the publication of *From the Earth to the Moon* in 1865 and *Around the Moon* in 1870.

Not everyone was content with merely dreaming, and some actually took to the air. In 1783 brothers Joseph and Etienne Montgolfier successfully left the bounds of the Earth and flew in a hot-air balloon. Flying short distances produced an extreme thrill, but it was clear that a free balloon had a long way to go before becoming a practical mode of transportation. The dreamers imagined engines attached to the free balloon to ensure its path in the sky. Of course these dreamers predicted the invention of the dirigible.

Communications

Flying has always intrigued people, more because of the thrill and daring of it than its practicality. Communications, the roots of electronics, was for the most part born of necessity. Primitive tribes communicated with smoke and flags. Cave dwellers practiced written communications by drawing on the walls of their caves. With the invention of the printing press in the mid-fifteenth century, written communications got a large boost. Before the moveable-type printing press, books had to be either hand copied by scribes or printed from very expensive woodcut plates. Only the elite could afford printed materials. After the invention of the printing press, however, thousands of readers could share in religious scriptures, news, science, and the opinions of others. When electricity entered the communications arena, instant communications over long distances became a reality.

Although the thought of talking to someone a thousand miles away was intriguing, the telegraph opened up new vistas for other businesses. The railroad, for example, could not operate efficiently without the telegraph. Other businesses could expand over large geographic areas and operate as one company when tied together with the telegraph. The stock exchange could buy and sell for an entire nation with orders telegraphed to the trading floor. Some industries, such as steel, received ore from one part of the country, refined the ore with coal from another part, and shipped the product to yet another part. The dreamers envisioned huge operations spanning the entire country and delivering products to millions of consumers. In a country the size of the United States, rapid communications and efficient, well-organized transportation systems were necessary to create a single, world-class economy.

The telegraph did not reach consumers directly, in that consumers did not have a telegraph key and a sounder in their homes that they could use to communicate directly with friends and relatives. The consumer would write an outgoing message and drop it off at the local telegraph office, while a courier delivered incoming messages from the telegraph office. Telegraphy required considerable skill, and the telegraph network connected only the company's offices. However, because there were plenty of telegraph offices, the consumer could send and receive messages from the nearby "Western Union" office.

Those with vision knew that for personal communications to be really successful, a consumer should be able to communicate directly with anyone from home without the need to learn the Morse code.

The first step toward a personal communications system was taken when Alexander Graham Bell invented the telephone in 1876. But his telephone instrument was only a small part of the system that we take for granted today. If we replaced the telegraph with a telephone and used the same wires and telegraph offices, the result would be an unworkable system. In order for two customers to communicate by telephone, both parties would have to be at the telegraph (now telephone) office at the same moment. The telephone required an entirely new concept. Installing a telephone in every home required an infrastructure of wires and switching systems way beyond that used by the telegraph company. Every telephone in the system had to be capable of being connected to every other telephone, and many users had to be able to communicate without interference and with a fast connection. The telegraph companies had an infrastructure, but their "subscribers" were only the companies' own offices. If each telegraph office served a community of, say, several thousand souls, to provide each citizen with their own connection would mean the infrastructure would have to be increased by a factor of several thousand. In fact, the technologies used for the early telephone systems were quite different from those for the existing telegraph.

The revenue potential of the telephone was tremendous. Virtually everyone in the country would be a customer. Consequentially, money was spent on a system of telephone "central offices" connected with trunk lines, and the United States was wired from coast to coast. The United States was not the only nation to discover wired communications, and similar situations existed in all the developed nations of the world and many of their colonies.

Of course we all know the final result of modern electronic communications. Citizens of the industrialized world have gained access to all sorts of personal, wireless, communications devices that provide not only worldwide voice communications but also a broad spectrum of data. The modern telecommunications company is a huge worldwide conglomerate that is involved in wired, wireless, and space-based communications.

It is interesting to note that some fifty years after the invention of the telephone, the aviation industry required a coast-to-coast infrastructure of hubs (central offices), connected with airways (trunk lines) and terminating at an airport (local telephone distribution), to be successful. When the aviation infrastructure was designed, the success of the system depended on telephone, telegraph, and teleprinter communications. Where wired communication was not available or reliable, radio communication was used. Just as for the railroad industry, aviation would not be successful without long-distance communications.

Making Money with Wireless Communications

Heinrich Hertz (1857–1894) experimented with invisible waves, properly known as electromagnetic waves, which became known as "Hertzian" waves. He demonstrated several phenomena over distances of several meters, and he showed that the invisible signals could be transmitted through the air and used for wireless communications. What prevented the waves from traveling hundreds of meters? Thousands? Even millions? The reason was that the signals became weaker as the distance separating the transmitter and receiver increased. The received signal power decreased by the square of the distance. Whatever power could be received at one kilometer (km) was only one-fourth of that at two kilometers. How great a distance could be achieved by using more transmitter power or more sensitive receivers? A highly educated scientist, James Clerk Maxwell (1831–1879), had written defining equations for electromagnetic waves when Hertz was a young lad of seven. If Maxwell's equations were right, and modern science has shown they are, there are no limitations to the distances Hertzian waves can span.

Although a number of scientists were experimenting with Hertzian waves, none would become as well known as Guglielmo Marconi, for good reasons. Marconi's goal was to use Hertzian waves for two-way communications between ships at sea and distant outposts. Marconi made improved transmitters, perfected more sensitive receivers, and experimented extensively.

Marconi's vision for wireless was point-to-point communications for hire. This was more similar to the telegraph than to the telephone and would require the consumer to go to a Marconi wireless office and send what amounted to a wireless telegraph message. Since there would be no wires connecting Marconi wireless offices, the message could go directly to any Marconi facility. This could be offices worldwide, including ships at sea. Marconi exploited the safety advantages of wireless for ships and remote outposts in his quest for financial backing. Wireless did not require an expensive or expansive network with switching hubs, which was a very expensive component of the telephone system.

Even before the *Titanic,* wireless equipment was installed on ships for safety reasons. But after the *Titanic* disaster, the importance of wireless communications for ships at sea was all too evident. In the case of the *Titanic,* the wireless messages from the stricken ship went unheeded. After the *Titanic* disaster, wireless operation was taken more seriously.

During the early part of the twentieth century, the business of carrying passengers from Europe to the United States was growing. Many of the passengers were not traveling on limited budgets, so quite a bit of luxury was found on the high seas. In addition to providing safety, wireless aboard a ship was a potential gold mine. The wealthy passengers would impress their friends by sending greetings from international waters. Although Marconi is recognized as a scientist and an inventor, his major goal was to make money, and he certainly succeeded.

Getting Ready to Fly

During the last part of the nineteenth century and the very early part of the twentieth, serious experimentation in flying machines was taking place. The curious-looking ornithopters with their flapping wings were long gone, and free balloons were used only for sport. Experimenters were beginning to craft designs with fixed wings. One pioneer, Otto Lilienthal, made more than two thousand successful flights in a variety of gliders but unfortunately lost his life when one of his gliders crashed. However, he left behind valuable data on the design of wings.

During the period leading up to the advent of powered flight, scientists knew quite a bit about air but not much about the atmosphere. They knew the nature of air at the surface of the Earth, but what it was like at higher altitudes was still mostly a mystery. Scientists knew our Earth was shrouded with an atmosphere that gravity held in place. They also knew the characteristics of gasses and could easily calculate the density of air at various altitudes. The temperature of the atmosphere, particularly at higher altitudes, was not well known and actually has a lot to do with the motion of the air at these heights.

The atmosphere determines our weather, but at the end of the nineteenth century very little was known of weather fundamentals. Of course, no one knew what existed above 36,000 feet, what we today call the *stratosphere.* For early attempts to fly, this did not matter because all of the early flying experiments took place in the lower strata of the atmosphere, which people knew much more about. Surprisingly, more of our early knowledge of the atmosphere came from radio operators rather than aircraft operators. They discovered that the atmosphere played an important role not only in the flight of aircraft, but also in the propagation of radio signals. Electronics would play a role in the history of aviation once again.

Around the turn of the century, scientists believed it would be possible to generate lift and fly a heavier-than-air craft. Of course, like so many objectives, possibility is one thing, and practicability is another. On the other hand, if accurate scientific data indicate that something is impossible, then pursuing that thing is a waste of time.

At the end of the nineteenth century, electronics and aviation were at essentially the same stage. In aviation, people had flown, but scientists were convinced that the impractical, powered, heavier-than-air craft could fly. In wireless communications, Marconi had communicated with radio, but not at distances that would make it valuable, such as spanning the oceans. But Maxwell's equations predicted that it was possible. The theorists had their say, and it was now up to the pragmatists to create viable machines. Little did these early pragmatists know that their ventures would become the basis of the powerful aerospace industry of the mid-twentieth century and one day permit humans to travel to the moon.

In a historical discussion of the role of electronics in the evolution of flight, we must abandon the term *electronics* for the early stories. At the end of the nineteenth century, the word "electronics" was unknown because the role of the electron was not known. The equivalent stage in aviation would be not to know that it is air that holds up aircraft. That was never the case, however, because people can see and feel air, so there was never any question as to what held aircraft up. It is fascinating to realize that electric lights illuminated city streets and citizens were riding the streets in electrified trains and ascending to the tops of high buildings in elevators—all without a full understanding of the physics of electricity. Unlike air, the elusiveness of the electron was that it could not be seen or felt. It took nearly the first quarter of the twentieth century to fully define the electron.

In electrical engineering, a clear division of the disciplines was beginning to appear. One was electrical and the other was wireless. Eventually there would be electrical engineers and radio engineers. The electrical part included motors, lighting, heating, and the generation and distribution of the energy these devices required. Wireless, or radio, was more abstract and futuristic.

The Brothers Wright and Guglielmo Marconi

At the dawn of the twentieth century, the world was waiting for visionary inventors to implement practical applications for scientific theory. The work of Guglielmo Marconi and of Wilbur and Orville Wright was very similar in that it perfected what many others had only started. The difference is that Marconi's work applied a well-publicized scientific theory—that of Hertzian waves. The Wrights' work was based more on empirical data than scientific theory. In addition, the Wrights and Marconi fully intended to commercialize their respective fields, and they did. As the twentieth century opened, the efforts of the Wrights and Marconi would affect the world forever.

It is interesting to note that Marconi shared the Nobel Prize for his practical application of Hertzian waves. The Wright brothers, however, were never awarded a Nobel Prize despite the importance of their efforts. It is true that the Wrights did not discover any previously unknown scientific truth. They did not invent the wing, and they were not the first to fly or design a powered aircraft. Clearly, if birds could fly, so could people; thus one could argue that the Wrights only learned what the birds already knew. But Marconi did not make any fundamental scientific discoveries, either. Maxwell had already written the defining equations, and Oliver Heaviside refined those equations and wrote them in a more understandable form. Hertz had demonstrated his waves for short distances. But since no human or animal had communicated using Hertzian waves before the time of Hertz, communicating over any significant distance would be a first. Therefore, Marconi and not the Wrights received the Nobel Prize.

Wilbur Wright was born on April 16, 1867, on a farm near New Castle, Indiana. Wilbur's younger brother, Orville, was born in Dayton, Ohio, on August 19, 1871. The brothers' father was a bishop in the United Brethren Church. Neither brother earned a high school diploma. Although Wilbur had finished his prescribed courses, he decided that he did not need a diploma, so he elected not to attend graduation exercises. Orville also attended high school but decided to take only those courses he liked; unfortunately, they did not lead to a diploma.

Mechanical devices fascinated the brothers. Orville started a printing business with a press of his own manufacture. Later he published a newspaper with Wilbur as the editor. In 1892 the brothers started a bicycle sales and rental business and eventually sold bicycles of their own design and manufacture. Flying intrigued Orville and Wilbur. Off and on for about three years—from Lilienthal's death in 1896 to around 1899—the Wrights read scientific publications on aeronautics. In spite of their lack of diplomas, they quickly assimilated the available knowledge about aeronautics and in 1899 experimented with a large bi-wing kite.

After consulting the United States Weather Bureau, the Wrights selected a narrow strip of sand on the Atlantic Ocean. They were looking for an open area that provided the benefits of a prevailing wind. The site they selected was the beach called Kill Devil Hill near Kitty Hawk, North Carolina. In a letter of August 18, 1900, the weather bureau informed the brothers that the beach at Kitty Hawk generally afforded a steady wind of 10 to 20 miles per hour. That same year the Wright brothers tested an unpowered glider at Kitty Hawk. They demonstrated the ability to control the glider, and they also learned that the information provided by the weather bureau was not accurate. On the Wrights' first trip, the winds at Kitty Hawk were more than 25 miles per hour.

Encouraged by their success of 1900, the brothers returned to Kitty Hawk in 1901 with a larger glider. On this second trip the brothers from the fields of Ohio were introduced to what those who live on the shore of the North Atlantic know only too well: eighty-five-mile-per-hour winds from a winter storm. This interruption lasted for several days, after which the Wrights' experimentation continued.

Wireless and Marconi

Guglielmo Marconi was born on April 25, 1874, to a wealthy family in Bologna, Italy. He was educated at the family's estate by private tutors and later studied at the University of Bologna but, like the Wrights with their high school diplomas, never received a degree. Marconi was a quick learner and grasped complex ideas with ease. He was fascinated by Hertzian waves and, in the same spirit as the Wrights, read all he could on the subject. At the age of twenty, he set up a transmitter and receiver and transmitted wireless signals a greater distance than anyone else had done at that time.

Like the Wrights, Marconi was an astute businessman and approached the Italian government for financial backing to develop practical applications of Hertzian waves. When the government turned him down, Guglielmo traveled to England to seek the necessary funds. His change of venue paid off, and in 1897 he started the Marconi Wireless Company, Limited, with the financial assistance of the British government. About this time Marconi received the first patent—his famous number 7,777—from the English patent office for a wireless device. One of the first contracts awarded to the fledgling wireless company was for the installation of wireless stations in lighthouses along the English coast. During this time Marconi succeeded in spanning the English Channel with Hertzian waves—a distance of eighty-five miles.

During these early days of the Marconi Wireless Company, wireless stations were installed in both lighthouses and lightships. During an unusually bad storm, the Goodwin Sands lightship was seriously damaged by heavy seas. By the use of wireless, a rescue team was dispatched to the ship to prevent any loss of life. Although this rescue was from a stationary lightship, it was clear that wireless would play an important role in saving lives—first, on ships on the high seas and later in aircraft.

Marconi continually strove to cross ever-greater distances with Hertzian waves. According to Maxwell's equations, the transmitter's power, the antenna's effectiveness, and the receiver's ability to intercept faint signals were the only limits to the distances the waves could span. Marconi's goal was to cross the Atlantic Ocean with wireless signals.

Nikola Tesla, the brilliant but eccentric scientist and inventor, was convinced that Hertzian waves had no boundaries. In his February, 1901, article, "Talking with the Planets," in *Colliers Weekly* he suggested that Hertzian waves could be used to communicate with Mars. Tesla's concern was not with the ability of Hertzian waves to span the enormous distance but with the Martians' ability to understand the Morse code. Tesla, who was predisposed to showmanship, often criticized Marconi. Although Tesla was successful in working with alternating-current machines and dabbled extensively in wireless, he did not produce any useful inventions in that area. When others performed some demonstration of wireless, Tesla claimed to have thought of the same idea earlier. If Tesla had been alive when the first pictures from Mars were transmitted with Hertzian waves, he would probably have claimed that he had had the same idea nearly a hundred years ago.

After building a powerful transmitting station at Poldhu in Cornwall, England, Marconi set sail for the coast of Canada at St. Johns, Newfoundland, and arrived on December 6, 1901. He did not publicize his attempt to span the Atlantic. Although he had achieved a certain amount of notoriety for his previous experiments, where he had covered a distance of 250 miles, the North Atlantic was eight times wider, so Marconi was not certain that he would succeed. In spite of Tesla's suggestion that Hertzian waves could reach Mars, Marconi was not sure they could even span the Atlantic.

Marconi also faced another problem. If Maxwell's equations were correct, radio waves traveled in straight lines. To span the Atlantic, however, the waves would have to follow the Earth's curved surface. But Marconi had already spanned nearly 250 miles over the curvature of the Earth. If the experiment worked, he would have no explanation for his success. Another three decades would pass before scientists would understand the ionosphere and thus be able to explain the secrets of long-distance, wireless communication.

With the help of his two assistants, Marconi assembled the wireless equipment and made ready for the experiments. A large, nine-foot kite was to support the "aerial" (antenna). After the wire antenna was attached, the kite was launched, and the stiff Atlantic Ocean winds, the same winds that bedeviled the Wrights, tore the kite from the wire and sent it out to sea. Expecting trouble more from too little wind than too much, Marconi brought a balloon, which he inflated with hydrogen. After reaching the limits of the antenna wire, the balloon broke away and was lost at sea. The following day, December 12, 1901, Marconi and his two assistants launched yet another kite. The blustery winds made it difficult for the three to control the kite, but they successfully launched it and raised the receiving antenna to a height of four hundred feet.

Marconi cabled his transmitting station in Poldhu and requested the transmission of the three dots, the Morse letter *S*. Sitting in an old barracks building on a bluff overlooking the North Atlantic on a cold December day in 1901, Marconi strained to hear the faint clicking in the headphones. After a while, Marconi—a bit weary from the trials of the previous days—gave the headset to his assistant, the only other person in the barracks. "See what you can hear, Mr. Kemp." Kemp donned the headphones and after a few minutes said, "Yes, there it is!" The distinct clicking of the three dots! The historic moment was shared by only two—Marconi and Kemp. Hertzian waves had spanned the Atlantic.

The Wrights Prepare to Fly

The Wrights arrived at Kitty Hawk in September, 1903, on their fourth trip, but this time they brought along a powered aircraft. After a few months of tackling problems with the aircraft, they were ready for a powered flight. The Wrights had spent the past year working out problems associated with their glider experiments. They had generated new lift data to replace those published by the aeronautical journals of the day. They had thoroughly analyzed the calculations for their aircraft and were absolutely sure it would fly. They were so sure that they tossed a coin to see which of the two brothers would be the first person to take off and land in a controlled, heavier-than-air craft. Orville won the toss.

Exactly two years and five days after Marconi's history-making event and about nine hundred miles south on the same ocean shore, Orville Wright, lying prone, was about to be the first person to fly an airplane. Orville flew for 12 seconds over a distance of 120 feet. The brothers made four flights that day, the longest being made by Wilbur, who achieved a distance of 852 feet and a duration of 50 seconds.

There are a number of interesting parallels between the work of the Wrights and Marconi. First, all these men were young when they made their historic debuts. Wilbur was 36, oldest of the group, Orville was 32, and Marconi was 27. Because the history-making events were the result of years of preparation, these men were all in their twenties when most of the work was done. All of them had a similar goal, making the world a smaller place, by air travel or by radio waves.

The turn of the century was marked by a great deal of discovery, and much of it was done by very young men. Perhaps one of the most significant events was the publication of the special theory of relativity by a twenty-six-year-old German physicist, Albert Einstein. Although Einstein is usually associated with his theories of relativity, he won a Nobel Prize for his discovery of the photoelectric effect, an important step in our understanding of the electron. This trend of discovery would not die out. The pioneers of the newly created aviation and wireless fields, although primarily very young men, also included older men, including the Wrights and Marconi, who continued to work as they aged. There were women, too, such as the aviators Harriet Quimby, Bessica Raiche, and Blanche Stuart Scott, and we should not forget them, but for various reasons it was ambitious and courageous young men who dominated the aviation and wireless fields.

Another parallel between the work of Marconi and the Wrights was that at the time of their early experiments, none of them really understood the important role the atmosphere would play. Neither Marconi nor any other scientist of the time could explain why wireless signals followed the curvature of the Earth. Although the curved propagation of Marconi's trans-Atlantic signals had more to do with Earth's shape than its atmosphere, later experiments with shorter waves, done mostly by amateurs, revealed fantastic results. Strong signals from relatively low-powered amateur transmitters were received all around the globe but only at certain times. The behavior of Hertzian waves would lead to an improved understanding of the atmosphere. Short-wavelength wireless signals are propagated by the upper levels of the atmosphere, while the lower levels of the atmosphere contain Earth's weather, which was of prime importance to aviators. Aviation and wireless would be the impetus for most of the future atmospheric research, with the lower altitudes of interest to aviation and the higher altitudes of interest to wireless engineers.

Despite the complete success of their first powered flight in 1903, the Wrights did not make the progress that others did after that year. The quest for flight was alive and very well in Europe, and the Wrights' success was not well received there. In 1906 the first European, Santos-Dumont, repeated the Wrights' feat. But that was only a beginning. Names like Gabriel Voissin, Louis Blériot, and Frederick Handley-Page would become well known for their aviation achievements.

In the United States, the Wrights were no longer alone in their achievement. Glenn Curtiss won a prize offered by *Scientific American* magazine to fly on demand. The date chosen was July 4, 1908. Curtiss successfully flew a one-kilometer straight-line course with his aircraft, the *June Bug*. Luckily for Curtiss, the chosen path was not a closed one because the *June Bug* was barely controllable. Making a turn and returning to the starting point was not a part of the aircraft's capabilities. Curtiss, a motorcycle mechanic, built his own engines and became a name to reckon with in aircraft-engine manufacturing in future years.

Both Curtiss and the Wright brothers made a point of obtaining patent protection for their ideas. Ideally this would provide a handsome income for the use of the novel ideas that inventors developed. However, patents obtained in the very early history of a technology tend to become obsolete long before the patent expires. Unless an inventor can obtain a very broad patent on a technology that will not change, early patents tend not to be as valuable as more mature ones.

Curtiss and the Wrights became involved in patent battles beginning in 1909 even after the Wrights were warned about becoming entangled in such fights. It would have been better to allow the infringers to use the patent than attempt to profit from their illegal use by court action. What invariably happens in such situations is that the inventor is distracted from developing new patents because of the requirements of the legal action and falls behind in the technology. Moreover, at a later date the Wrights might have had an opportunity to use an important Curtiss patent. Potential legal action against Curtiss's earlier infringement is a powerful bargaining tool for the use of a newer Curtiss patent. The typical solution to such a problem is to cross-license both patents and move on. The patent battles stifled not only the progress of the Wrights and Curtiss but also of other experimenters in the United States, who feared being drawn into the fray. This was all to the advantage of European inventors, who pulled ahead in aviation technology in the period from 1903 to 1913.

As early as 1913, people were thinking of equipping aircraft with wireless. One of the stumbling blocks to achieving this was the marginal performance of the Wright aircraft and the Wrights' distraction because of the patent battles. The Wrights were believers in economical design, and their aircraft had just enough power to achieve the desired goal: lifting a pilot and a passenger. Clearly there was no excess power to allow the addition of wireless equipment.

In Europe the aviation world was moving ahead by leaps and bounds. Numerous new designs appeared and were well funded. In 1912 a French-designed Deperdussin smashed the 100-mile-per-hour barrier at 127 miles per hour. In 1913 American aircraft held only two international records while the French and some Germans held the majority. This situation persisted until the beginning of World War I and caused a serious setback in the U.S. aviation industry.

Government Regulation Calms the Chaos

The achievements of Marconi and the Wrights in the first years of the new century were harbingers of things to come. But both aircraft and wireless had a very long way to go before finding enough practical applications to make the industries profitable. The two fields attracted investors, engineers, scientists, and even a large number of amateurs. Although much work was needed, a cadre of bright, enthusiastic individuals worked diligently, and progress was rapid.

Marconi's wireless signal was capable of sending messages using Morse code. This was fine for ships at sea, where a trained radio operator was on duty. It also found application for communications between distant outposts, such as between military installations and between European nations and their colonies. Here, too, trained radio operators were important. But for wireless to become practical and achieve its full potential, voice transmission was essential.

Marconi's wireless signal had another serious problem. His transmitters generated the required high-frequency waves using mechanical means. *Frequency* refers to the number of times the direction of an electrical current changes in one second. For example, in the United States, power supplies have a frequency of 60 Hertz, abbreviated 60 Hz. The unit of measure for frequency is the Hz, which was named in honor of Heinrich Hertz.

In Marconi's transmitters, an electric motor turned a device that opened and closed a switch in such a fashion that a spark was generated. Most people have heard a click or pop in a radio when a nearby light switch is turned on or off. This demonstrates that a spark signal can radiate as a Hertzian (now called radio) wave. Today's electronics engineers call this type of signal *noise.* This noise has no value.

Marconi's spark transmitter was essentially a noise generator. The frequencies of the waves it generated were not well defined. To understand what this means, consider the modern AM broadcast radio. The radio covers a frequency range from 540 kilohertz to 1,710 kilohertz. *Kilo* is the international prefix for 1,000; thus 540 kilohertz is 540,000 Hz. The abbreviation for kilo is the lowercase *k.* Therefore, the frequency range of our example is 540 kHz to 1,710 kHz. Our AM radio has a channel every 10 kHz, which means that there are 117 channels in the frequency range we are talking about. In this example, a *channel* is a band of frequencies that may be used for communications if they do not cause interference to users of other channels.

Marconi's wireless signal was not stable, which means that its frequency would wander around and move out its channel boundary. Furthermore, his spark-generated signal occupied many channels of 10 kHz each. Only about five signals like Marconi's could be assigned to a frequency range that today accommodates 117 channels. When Marconi ran his experiments, he encountered no problems with interference because his very crude signal was the only one on the air. Later, however, he experienced interference from his own wireless stations. When wireless stations owned by other companies—sometimes in other countries—eventually went on the air, serious problems erupted.

One growing group of wireless station owners consisted of amateur radio operators, who are also called "ham" radio operators. There are several different theories about how ham radio operators got their name. One theory is that, during early experiments in broadcasting, the amateur would "ham it up" to the amusement of nearby neighbors with radio receiving sets. To call this group "amateurs" is rather misleading and would be akin to calling the Wright brothers amateurs. To a certain extent the Wright brothers and the wireless amateurs were not professionals, as they were not being paid to perform research. No one was paying to fly somewhere by airplane . . . yet. No company was paying to advertise on a wireless station . . . yet. These aviation and wireless amateurs were learning, in many cases, more than the so-called professionals were. The amateurs did not need to get approval to perform an experiment; they just did it. Until there was a clear profit base, no one was going to pay for development work in wireless or aircraft. These aviation and wireless amateurs thus became the pioneers of their fields.

The explosive growth of wireless amateurs created serious interference problems. The number of amateur wireless operators in 1917 grew to four thousand, which by twenty-first-century standards is a very small number. During this time there were no regulations whatsoever. Those who wished to communicate by radio could build or buy equipment, concoct a call sign, and simply go the air on any wavelength of their choosing. With a growing interference problem, it became clear to commercial wireless stations, amateur wireless operators, and the government that the situation had to be improved. Two measures resulted from that realization: First, the federal government began to regulate wireless transmissions. Second, everyone's efforts focused on putting the spectrum-polluting spark transmitters off the air.

In 1909 a group of seven young teenage boys in the New York City area formed the Junior Wireless Club, Limited. The seven were also members of the Junior Aero Club, which was an organization of model-aircraft enthusiasts. The boys came together because of their interest in using wireless to control their model aircraft. Of course, at this time there was no wireless of any type in full-sized aircraft. The Junior Wireless Club grew in membership, and the interest of the club members began to lean more toward wireless communication and less toward aircraft. Many of the newer members were not as young as the charter members, so in 1911 the name of the club was changed to the Radio Club of America, as it remains today.

Shortly after the formation of the wireless club, the commerce committee of the U.S. Senate held hearings on a bill, S7243, to regulate radio communication. The proposed solution to the interference problem was to deny the use of wireless to all except government and commercial interests. This bill would have essentially eliminated all amateur radio experimentation. A committee from the Junior Wireless Club went to Washington to appeal to the Senate not to pass the bill. The club's president, fourteen-year-old W. E. D "Weddy" Stokes Jr. testified before the Senate committee; the bill was subsequently defeated. In 1912 a similar bill, the Alexander Wireless Bill, appeared in the Senate commerce committee, and again the radio club took action. This bill was killed in committee. In this year the membership of the club included many of the pioneers of the radio industry, including Edwin Armstrong.

There was no question, however, that some form of regulation was required if the wireless industry was ever to be successful. Beginning in 1912, the Department of Commerce began to issue licenses with call signs that stations had to use. The transmitter power was limited to one thousand watts, and amateurs were to operate on wavelengths of two hundred meters and shorter.

The whole arrangement was a sham. Two hundred meters sometimes meant 250 or 300 meters. One thousand watts easily stretched to two thousand. There was little enforcement, except for the most flagrant violations. However, this meant that, for the first time, there were some regulations. Also, the federal government established its jurisdiction over wireless transmissions. This ensured that only one set of guidelines for wireless existed throughout the country. However, the federal government had no monitoring and measuring equipment, and even if it did, it simply did not have the expertise to use it. Because the situation was so much better than before the regulations were enacted, however, most radio operators—amateur, military, and commercial—were happy. This situation persisted until April, 1917, when the United States declared war against Germany, and all amateur operations were halted.

The war ended on November 8, 1918, but the U.S. Navy liked the wartime situation of not having to share the radio spectrum with pesky amateur radio operators. The navy saw to it that amateur radio operations did not resume after the war. It took nearly a year of heavy lobbying by the American Radio Relay League, formed in 1914, and the Radio Club of America before the government permitted amateur radio operation to resume in October, 1919. This situation was an insult to the radio amateurs of the United States. The armed forces had benefited immensely from the skills of the amateur radio operators, yet after the war these amateurs found that the privileges that had enabled them to develop equipment and skills for the war effort were taken away from them.

The radio act of February 23, 1927, created the Federal Radio Commission. This commission had twenty field offices responsible for enforcing its regulations in its twenty "radio inspection districts." The districts covered the entire continental United States, the territories of Alaska and Hawaii, and the Caribbean Islands, Virgin Islands, and Puerto Rico. The Federal Radio Commission remained in operation until 1934, when the current Federal Communications Commission was formed by the Communications Act of that year. This new agency was—and remains—responsible for all telecommunications, both wired and wireless, in the United States.

A Similar Situation in the Aviation Industry

The Wrights were joined by other experimenters who developed their own ideas for aircraft and tried to improve on the Wright brothers' aircraft. Improved control was an important goal. The Wrights' first flights were in a straight line simply because the airplane was not able to turn. Increased power for the engines was crucial for increased payload and higher altitudes. Many people worked on these problems, and they made many improvements. The new names that appeared in the annals of aviation were Glenn Curtiss, Louis Blériot, Fredrick Handley-Page, Clyde Cessna, and Walter Beech, and these pioneers were by any standard just amateurs. Eventually their names would grace large companies that were certainly not run by amateurs.

In the early 1920s one did not need a license to fly. Anyone could buy or build an airplane and fly anywhere. There was some discussion of government regulation, but unlike wireless, where the problem obviously crosses state boundaries, the regulation of aircraft could be left to the states. Of course, one could argue that aircraft could cross state boundaries as easily as wireless signals. But it was also true that automobiles and even horse-drawn wagons could easily cross state boundaries, and these means of transportation were regulated by the states. A number of states and even some municipalities had already begun to regulate aircraft, so the federal government was satisfied to take a back seat.

On May 20, 1926, President Calvin Coolidge signed the Air Commerce Act into law. This bill establishes an aeronautics branch of the Department of Commerce. The branch was not only to regulate air commerce, but also to foster its development and safety. The aeronautics branch would regulate flying, license pilots, certify aircraft designs, develop navigation aids, create an airways system, and oversee many other activities. This was an important step in the development of the aviation industry, and it came not a moment too soon, as more states and municipalities were beginning to draft aviation regulations.

By 1927 the chaos of the aviation and radio industries had been brought under control by their respective governing agencies. Government money was helping to create federal airways, and the beginnings of an air transport industry were in evidence. Radio broadcasting was becoming very successful, and a tremendous amount of money was flowing into radio design and development. The time was right for the radio and aviation industries to become inseparably linked.

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