ELECTRONICS IN THE WEST

THE FIRST FIFTY YEARS

JANE MORGAN

ABOUT THE AUTHOR: Born in Montana and raised in Berkeley, California, Jane Morgan graduated from the University of Southern California and worked as an advertising copywriter in San Francisco before joining the first class of officers to be commissioned in the Women's Auxiliary Army Corps. She was in command of the initial WAC contingent sent to England in 1943 and was with the first group of WAC's to land in Normandy. Subsequently, she served in Intelligence in Europe for more than two years.

After the war she married an engineer and became interested in the men who had made electronics possible. She has written a biography of Lee de Forest and continues today to study and write in the field of electronics history while serving on the Board of Advisors of the Foothill Electronics Museum to be built at Foothill College on the San Francisco Peninsula.

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BY
JANE MORGAN

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"Five hundred feet up and running level"

ELECTRONICS IN THE WEST

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PREFACE

In this book Jane Morgan tells the little-known story of the men responsible for the growth of electronics in the San Francisco Bay Area. These were young Western engineers and scientists, able and creative, who felt that they had something original to contribute to electronics. They exchanged ideas, often assisted each other. Remarkably versatile, they combined technical competence and design skill with inventiveness. Even after their initial success, they could still be found in their shops and laboratories working side by side with their technicians; they also frequently served as their own salesmen and their own business managers, as well as their own janitors. These men were content to start simply and to build up an operation through its own success, growing with it all the while. Their satisfactions came from doing something new, something that was their own, and from doing it in their own way.

During recent years the San Francisco Bay Area developed rather suddenly into one of the major centers of electronics research and industry in the United States. To those who knew the background it seemed a natural evolution in a region that has been the scene of radio and electronics pioneering since early in the century.

Today, it remains an area in which young people may follow the pattern set by these Western pioneers. It is still possible to start simply—yes, even in a garage—and develop an idea or an invention to a point of success. Opportunities are unlimited and the atmosphere even more favorable than it was during the fifty years which this book so ably covers.

FREDERICK E. TERMAN

Stanford University
September, 1967

FOREWORD

This book is the culmination of a project undertaken over a period of years to document and preserve the story of the development of electronics in the West, particularly in the San Francisco Bay Area.

It had its beginning at the New Almaden Museum, founded by Douglas and Constance Perham in New Almaden, California. This facility became a valuable educational resource for the schools of Santa Clara County, containing a unique collection of electronics materials that could not be replaced.

Also aware of the value of this collection was a group of radio pioneers who, with other business and professional men, formed the Perham Foundation in 1959 to insure the future preservation of these privately owned archives and artifacts. Eventually, the Foundation acquired the artifacts, and steps were then taken to provide a permanent, public museum in which to display them.

In the meantime, Graham Sullivan, who was in charge of the National Defense Education Act programs in the California State Department of Education, became interested in the project. He worked with John Satterstrom of the County Office of Education to obtain National Defense Education Act funds with which to purchase the electronics archives of the New Almaden Museum and to prepare them for school and public use. Then Mrs. Jane Morgan was engaged to write this book.

Foothill College has now provided an ideal location for the permanent housing of the Perham collection on its campus in Los Altos Hills, California. With the cooperation of the Perham Foundation, plans are under way to build the Foothill Electronics Museum in 1968. The original New Almaden Museum materials will form the nucleus of an ever-expanding electronics collection and library. Additional materials are now being received by the college from both national and local electronics companies, as well as from individuals. Mrs. Lee de Forest and Mrs. Alan B. Du Mont have recently donated extensive archives and artifacts from their late husbands' collections.

Field trips to the Foothill Electronics Museum will be an important educational activity related to the use of this book for classroom purposes. In turn, the book will furnish illuminating background material to the public, to whom the college museum will be open. Indeed, the book will serve as an easy introductory step for the uninitiated of all ages into the world of electronics.

I wish to express my appreciation to all those who have made this project possible, and especially to Mrs. Morgan for her interest and untiring efforts in unearthing the source material and writing this valuable history which relates, for the first time in book form, the important contributions of the pioneers in electronics in this part of the West.

C. R. TIMPANY, *Superintendent*
Santa Clara County Schools

June, 1967
San Jose, California

AUTHOR'S NOTE

Far from attempting to be a definitive history of the incredible growth of electronics, even within a limited geographical area, this book has taken the easier and more delightful approach of strolling through these first fifty years as a tourist, stopping to visit a man here, a landmark there. The amount of time spent with each person may not always be in proportion to his importance, but perhaps in proportion to his appeal to a young reader, or even because we happened to find him at home! It is hoped that the many deserving men who should, but do not, find themselves, their inventions, or their companies within these pages will be understanding and know that such omissions were not premeditated. Like other tourists, I had to leave the country regretfully, knowing I had not explored it fully.

I should like to acknowledge my gratitude to the following: C. R. Timpany, whose background in science as well as his dedication to serving the educational needs of his community made him alert to the need of such a book, and of writing it while the pioneers and their materials were still available; Leonard F. Fuller, who acted as technical advisor, and without whose almost constant help I could not have written a single chapter; John Satterstrom of the Santa Clara County Office of Education, who, as supervisor of the project, skillfully and patiently guided it for more than three years; Haraden Pratt, whose research for the book provided much of its documentation; E. A. Rasmussen and Douglas Perham for materials prepared by them for the County; Mrs. Margie Downey, Mrs. Gertrude Owler, and Mrs. Phyllis Dillman for their individual contributions in preparing the manuscript for publication; Earl Goddard, chairman of the History Committee of the San Francisco Section of the Institute of Electrical and Electronics Engineers; the members of the Board of Directors of the Perham Foundation; and the Reverend Arthur D. Spearman of the University of Santa Clara.

Many of the men included in the book gave generously of their time in interviews and in editing their own stories. I am particularly indebted to Mrs. Lee de Forest, George Everson, Mrs. Earle Ennis, Phillip Ennis, Mrs. Philo T. Farnsworth,

Mrs. Laura Farnsworth Player, Mrs. Geneve Shaffer Parsons, and Mrs. Russell Varian for source material.

A special word of praise goes to Edwin Ingalls, who did the illustrations and coordinated the art work of Robert Tamara, Urban Wallace, and John Henshaw.

The book is dedicated to my family in appreciation of the indulgence and technical help of my husband, the unfailing support of my mother, and the forbearance and cooperation of my teen-aged daughters.

JANE MORGAN

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INTRODUCTION

On the morning of May 5, 1961, a strange, tense silence hung over the nation. In homes, mothers told small children to hush. In offices, typewriters were still. On the West Coast, families still in their bathrobes sat together around their radios and television sets, in quiet concern. Many were praying.

At 9:34 A.M. Eastern Standard Time, Alan Shepard had left the earth in a brilliant flame of fire, the first American to rocket out into space. As the seconds of silence stretched into minutes, millions of Americans and others all around the world wondered, "How has he weathered that terrific blast-off?" "Are the automatic controls in the spaceship working properly?" "Other rockets have exploded on their way up . . ." The tension grew.

At 9:38 A.M. came the voice of Alan Shepard, awe-inspired, as he looked down upon the bright globe 116½ miles beneath him, "What a beautiful sight!" Thus began the Space Age for Americans.

Besides the courage and training of the astronaut, there were many scientific achievements making this first U.S. space journey possible. Flight engineers, rocket pioneers, chemists, doctors, metallurgists, mathematicians – a whole army of skilled men saw their efforts crowned with success that morning. Alan Shepard in describing his trip referred to "we" rather than "I."

Basic to the work of all the scientists of the Space Age are the tools of electronics. The instruments that guide the spaceships, report the condition of each astronaut's heart and temperature, enable us to see and hear them, and bring them back to a specific landing spot in the huge ocean – all these instruments are electronic. Space travel would be impossible without electronics.

What is electronics? If you look up the word electronics in the dictionary, choose a fairly recent one, because until about 25 years ago the word wasn't even in the dictionary. Today the electronics industry is one of the largest in our nation.

Electronics is the study of electricity as it applies to electron tubes, transistors, and other such devices which control the flow of electrons. Many electronic products contain electron tubes similar to the tubes found in a radio or TV set. In some electronic devices, the work of these vacuum tubes is done by transistors, as in a transistor radio.

Some electron tubes are as small as the tip of your finger. Others, like those used in atom smashers, may be nine feet tall. Until recently, the electron tube was the "heart" of every electronic device. This marvelous invention made possible the development of many wonders we now take for granted, such as radio, color television, long-distance telephones, talking motion pictures, electronic computers, tape recorders, and photoelectric eyes that open doors for us. Most of the technological advances of today depend upon electronics. The first three-element vacuum tube has certainly changed our way of life. Scientists promise us even greater changes tomorrow. The time we live in is, indeed, an Electronics Age.

About 40 years after the electron tube appeared, the transistor was invented. Transistors and similar devices can often be used instead of tubes and can be made much, much smaller. The electrons in these tiny transistors behave somewhat as they do in tubes, but are moving through solids, rather than through a vacuum or a gas. These "solid state" devices with their speed, durability, light weight, and small size are making an entirely new range of products possible.

When did the Electronics Age begin? Even before the turn of the century, a few men were studying and experimenting in what we now call electronics. But in 1912, in a little cottage in Palo Alto, Lee de Forest, an American inventor, made a world-changing discovery. He had already invented, in 1906, the original three-element electron tube, which he called an audion. This was successfully in use as a detector to "catch" the electrical signals of the wireless telegraph as it sent its dot-and-dash Morse code messages through space. But these electrical impulses coming in on the antennas were often weak and hard to detect. For years, de Forest and other scientists and engineers had been trying to devise a way in which to amplify or increase these currents.

One summer day in 1912, de Forest and his assistants connected the tubes in a new way and achieved a remarkable amplification. It was so good that when they dropped a handkerchief a few inches from a telephone transmitter, there was a loud thud in the earphones! A few months later they discovered that these tubes could also be used to generate, or create, electromagnetic waves.

The ability of the tube both to amplify weak electrical currents and to generate radio waves made the tube one of the most important inventions in history. It opened a new era of science and technology. Its inventor, de Forest, is recognized as the "Father of Electronics."

When it was discovered that de Forest's electron tube could amplify communication signals, the telephone, radio, and wireless telegraph companies soon adapted the tube to their systems. Gradually scientists and engineers in many different fields found that this tube opened up endless possibilities when it was further improved with their own research and skills. Some brilliant but unsuccessful inventions of past geniuses, such as the computer or "brain" designed by the Englishman, Charles Babbage, nearly a hundred years before, could now be made to function.

Men all over the world became aware that there was a special magic in this modern Aladdin's lamp; it could extend the range of their own physical senses. At first, the electron tube was used to "hear" the human voice and music coming from a distance. Later, it was used to "see," as in television, electron microscopes, and photoelectric cells. And now the tube can "feel" and measure extremely small changes, such as in temperature or in the smoothness of metal, changes which are impossible for the human touch to detect. We have electronic instruments that can "taste" and "smell" which are invaluable to manufacturers of foods and chemicals. And electronic devices do all this sensing far more accurately and rapidly than we can.

What is the significance of the Electronics Age? To understand the place of electronics in our civilization, perhaps we should take a long look backward. For centuries, men did everything either by hand or with the help of horses or other work animals. Then, about 200 years ago, men began to invent machines to do the work instead of using their muscles. With the invention of steam engines, and later, gasoline engines and electric motors, men could lift, cut, and move heavy material with little effort.

To see what happens when we substitute machines for muscles, let us imagine that we are hiking up a steep road on a hot day. It seems to take a lot of energy just to keep moving ahead. Suddenly, a car whizzes past us, 60 miles an hour. How much of his own energy does it take for the driver to move himself and his heavy automobile? Just the touch of his toe on the gas pedal!

The invention of machines brought power, and with this new power, men began to travel in new ways; first by train, then automobile, then above the ground in an airplane.

The Machine Age also meant that, with a machine, one man could do the work of many. This brought an increase in productivity. Everyone could have more manufactured goods, more comforts, more leisure time. A man no longer had to work 14 hours a day for a bare living. Increasing numbers of people, rather than just a privileged few, were able to have an education.

In the Machine Age, when we replaced several men with a machine, we left one man with the machine to operate it. With the coming of the Electronics Age, we are replacing even the man who is operating the machine, for his work can now be done with automatic, electronic controls. And we are restyling the machine itself with electronic parts, so that it produces better products, faster. Thus electronic devices are lifting our standard of living even higher than did machines.

By extending the range of our senses, electronics has made us explorers of space. We have put on "seven league boots" and are striding out into the universe. Electronics, with its communications satellites, world-wide television, and space travel, has brought us closer to our neighbors around the earth, and perhaps soon to others on some distant planets! We have devised far-ranging weapons, aimed and guided electronically, which are so devastating that they are forcing us, if not to love our neighbors, at least to try to live cooperatively with them.

The Machine Age brought about such changes that it was called the Industrial Revolution. Some 50 years ago the Electronics Age started another revolution in our way of life. It is still going on all around us. Those who live in the San Francisco Bay Area are actually at one of its headquarters. De Forest's discoveries in Palo Alto in 1912 gave electronics a tremendous push, like breaking a log jam in a river. And in the Bay Area, ever since, adventurers in this field like de Forest have continued to make important "breakthroughs" or advances; it has become one of the largest centers of electronics manufacturing and research in the world.

If we trace the growth of electronics in this region, we will have a good idea of how it developed in the rest of the nation. It was man's search for better ways to communicate over water and over long distances on land that led to invention and application of important early electronic devices. Our story can appropriately begin with the first ship-to-shore wireless telegraph, or electromagnetic wave, messages received in the United States, an event which occurred in San Francisco.

"Sherman is sighted"

Chapter I

WIRELESS WAVES AND A WILD WELCOME

Looking around San Francisco early in August, 1899, the casual observer would have seen nothing unusual. The little cable cars clanged their way noisily up the steep hills. Children hiked off to school, the girls in ankle-length dresses, the boys in short pants and long stockings.

The fathers went downtown to their offices, some driving horses, others on the electric trolley cars. There were no automobiles in the streets, for these were rare. There were only a few hundred in all of America.

The mothers swept the front steps of their houses, many of which were built wall-to-wall, with no space in between. The housewives chatted together, as they waited for the vegetable man. Although it had been 23 years since the first practical telephone had been developed in 1876, there were very few telephones in private homes. And, of course, no radios. So, much of the news was passed about from neighbor to neighbor.

From around the corner came the hoarse cry, "Vegetables!" and something that sounded like "Fresh froo da day!" Then the vegetable wagon appeared. The old horse pulled the heavy load slowly, his hooves beating out a dull clip-clop on the stone street. The women gathered around, as usual, to make their purchases.

But this was a special August, this August in 1899, and hardly anyone talked about the food, nor even about whether the chill August fog would lift by afternoon.

"Well, Mrs. Coonley," said the vegetable man, as he put her potatoes in the scales, "it won't be long now till you'll have your boy home from the war, safe and sound. I hear tell that all our California soldiers have already left the Philippine Islands on the *Sherman*. She's a good, fast ship."

"Yes," smiled Mrs. Coonley. "Some reports say the *Sherman* might be here by the 24th, but my husband says the old-time skippers figure that, even with good weather, they could never make it by then. They think it will be the 26th at the very earliest."

"I'm on the committee that's going to cook breakfast for all the soldiers and their relatives at the Ferry Building," said Mrs. Flanagan, one of Mrs. Coonley's neighbors, worriedly, "and I declare I don't know how we're going to buy the food and prepare it for about 2,000 people when we won't even know what day to cook it until the men are actually here!"

Downtown, it certainly wasn't "business as usual," either. The mayor announced that there would be a three-day holiday, to begin as soon as the troops landed. Prominent leaders put aside their regular work and threw themselves into plans for the biggest celebration San Francisco had ever staged. They decided to raise $50,000, asking everyone to contribute, to show the heroes from the Spanish-American War "how proud their home folks were of them."

The Chinese merchants donated over $5,000. One of them gave all the Fourth of July fireworks in his warehouse. Actresses and actors put on special performances, day and night, and turned the money over to the welcome-home fund.

The Pacific Incandescent Lamp Company was hired to prepare a "grand electrical display," using 10,000 electric lights. These incandescent light bulbs had been invented 20 years before by Thomas Edison, but were not yet used to light the streets in San Francisco. Some streets were lit with gas, others with arc lights. Hardly any homes had electric lights; people used either gas lights, kerosene lanterns, or candles. Nor were there such things as battery flashlights. If walking or riding a bicycle after dark, one would take along a kerosene lantern.

But now, for three wonderful nights, downtown San Francisco was going to be ablaze with lights! The electricians outlined the Ferry Building tower and the City Hall with the bright bulbs. Strings of them were stretched across Market Street in rows overhead, from the waterfront to Larkin Street, along the route where the soldiers would march. The festivities were to start out on the water, with "a grand naval parade" as soon as the *Sherman* came through the Golden Gate. Every craft that could float, big and little, was to join the huge transport and escort her into the Bay.

Besides a breakfast the first day, a banquet was planned for the soldiers, knowing how good "home cooking" would taste after a year of living on battlefields in a foreign country. But *when* would they come? If only they were arriving by train.

Then the telegraph operators along the route could tap out their Morse code signals, and the wires could carry the news faster than any train could go. But how could a ship send a message?

For years the United States Navy had experimented with wigwagging flags and flashing lights. But these could be seen only for short distances and were no good at all in the fog.

The Navy had begun to equip its shore stations along the coast with carrier pigeons. In the event an enemy ship were sighted, a pigeon could be released to fly to the next station up the shoreline, with a message on a tiny band wrapped around its leg. This was considered a great step forward. A newspaper, in reporting it, said, "Homing pigeons have come to be regarded as valuable additions to our military force."

But there were no homing pigeons on the *Sherman*.

Then a group of men in San Francisco had an inspiration. There was (and still is) a lightship anchored outside the Golden Gate, about nine miles from the shore. Lightship No. 70, called the *San Francisco* was equipped with a strong light as a guide for all ships heading for the San Francisco Bay. Often the incoming ships would anchor near the lightship and wait for daylight or calmer seas before attempting to pass through the narrow Golden Gate. Anyone on the lightship would of course be able to sight the *Sherman* long before she would be ready to enter the Bay.

The idea that came to the group of men was this: They had heard that Guglielmo Marconi, an Italian, had been sending messages without wires, in England. In March that very year, he had succeeded in transmitting a Morse code signal 30 miles across the English Channel. Just two years before, in 1897, he had received an American patent for his system, but he had not yet brought his equipment to the United States. Why not try installing something like Marconi's wireless on the lightship *San Francisco?* Then, when the *Sherman* came within view, a man on the lightship could send the message instantly to the shore. This would give the celebration planners hours of advance notice.

One of the men was George Otis Mitchell, a physics teacher at the Girl's High School in San Francisco. He had been experimenting with wireless telegraphy and had demonstrated his devices to an expert telegraph operator, Charles M. Fisher. Fisher was impressed and told Frederick J. Samuels, director of the J. D. Spreckels and Brothers Company. Soon others became interested: Lewis McKisick, the Western Union Circuit Manager at Sacramento; Frank Brodi, of the California Electrical Works; and Henry J. Wolters, chief engineer of the Claus Spreckels Building. Samuels approached one of the San Francisco newspapers, *The Call*. Would they be willing to support the venture? *The Call*, seeing a chance for a news "scoop," eagerly agreed.

It was more easily said than done.

For weeks the men worked on their wireless system. They had to design and make many of their own parts, as such things were not sold in stores. There was uncertainty about the actual details of Marconi's apparatus. The basic elements were a transmitter and a receiver. The transmitter produced electromagnetic, or radio, waves. The receiver reacted to these waves as they came through space and changed them into signals. These signals were recorded in dots and dashes, inked automatically by a pen, on a moving paper tape.

Very little was known about wireless waves in 1899. It was only 11 years since they had first been produced and detected, or "caught," with a receiver, by a German named Heinrich Hertz. So important was his apparatus (really, a radio set), and what he learned about the waves, that scientists named them Hertzian waves in his honor. Some years later, we began to call them radio waves. They are the ones your radio or television picks up.

Perhaps this is a good place to go back in time to some other men who came before Hertz, for without their work, Hertz couldn't have done his.

The first, Michael Faraday, was an English physicist who was fascinated with electricity and magnets. Like other scientists of his day, he wondered if it would be possible to get electricity from a magnet. Since electricity could make a magnet, could a magnet make electricity? From around 1820, he experimented in his laboratory, off and on for about ten years, using such things as batteries, galvanometers, coils of wire, and, of course, magnets. Success came in 1831 when he moved an iron bar magnet through a coil of wire, just as you might pass a pencil through the hollow center of a large wire spring. He discovered that this action induced, or produced, a pulse of current in the wire! He noticed that the pulse of current occurred *only* right after either the coil or the magnet was moved, and would die down unless the coil or magnet was moved again. It didn't seem to matter which was moved; you could get a pulse of electricity by moving a coiled wire past a magnet, or a magnet past a coiled wire. After further experiments he came to the momentous conclusion that it was the *changing* magnetism in the coil that induced the current.

Faraday was the first to produce electricity with a magnet. At almost the same time, an American professor, Joseph Henry, also discovered how to do this. Both he and Faraday built many marvelous devices using induced current. This is the way almost all of our electricity is produced (with generators, machines having large magnets) and distributed (with magnetic devices called transformers). There are also a number of other ways to produce electricity. For example, by chemical means, as is done in electric flashlights. Or by light, shining it on certain light-sensitive materials in photoelectric cells, such as those that are used to open doors automatically. However, the amount of electricity created in these ways is tiny in comparison to that produced magnetically, almost as a candle compares to the sun. More than 99 percent of the electric energy used today is produced by generators. Faraday's discovery in 1831 that electricity could be generated with magnets and wires is one of the greatest electrical discoveries of all time.

Faraday's experiments led him to ask some questions. "What really happens in the space around a magnet when magnetic forces are present? How fast does magnetic force move through space? Does it move in waves? Is it like light?" He exchanged letters about his theories with a young Scottish professor, James Clerk Maxwell. Maxwell was a mathematician, and with measurements and calculations he concluded in 1873 (some 40 years after Faraday's first successful experiments!) that Faraday's ideas were sound. Light was indeed an electromagnetic wave, and all electromagnetic waves moved through space with the speed of light. Maxwell published his equations, and these were what inspired the German physicist, Hertz, in 1888 to build equipment that would actually send and receive these waves.

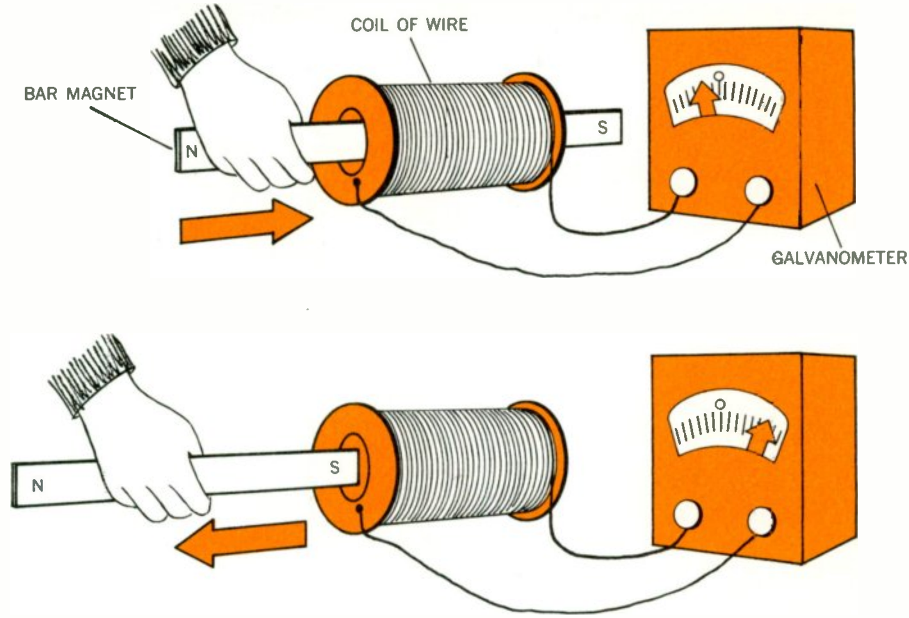
Hertz placed two brass rods, a few feet long, end to end, in a straight line. He left a small gap between the two ends where the rods would have come together. A spark coil (similar to the ignition coil in an automobile) sent current flowing back and forth between the rods; sparks jumped across the gap. Electrical disturbances then traveled out in all directions, like ripples in a pond when you throw a rock in it, only these moved as fast as light (186,000 miles per second).

Hertz then bent a wire into a loop, a few inches in diameter. He didn't quite close the loop tight, but left a tiny gap between the ends. He placed this loop a few feet from the brass rods. When the spark jumped between the gap in the brass rods, it caused another spark to leap across the gap in the loop. He then tried putting the loop in another room, behind a closed door. Its little spark still responded to the big spark between the rods.

"It is not without astonishment," he wrote, "that one sees the sparks appear inside a closed room."

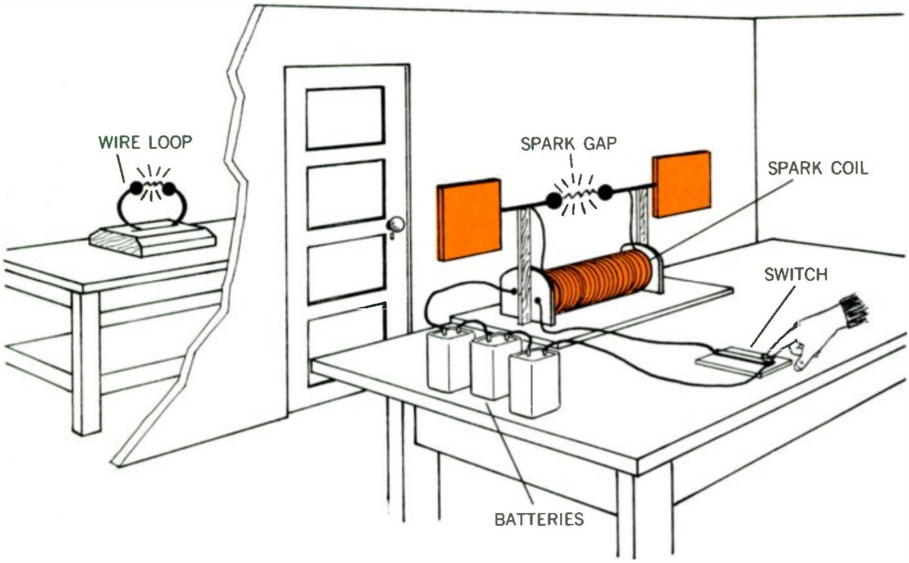
Guglielmo Marconi was just 20 years old when he happened to read about Hertz's experiments in an electrical journal in 1894, six years after Hertz had done them. The young Italian was fascinated. Electromagnetic waves leaping through space. They were man-made and could be man-controlled. Marconi was struck with an idea. Why not use them to send Morse code dot-and-dash signals, by transmitting the waves in long and short intervals? If the spark was strong enough, surely one could send a message farther than just a room away! (It is quite possible that other men were also pursuing this idea, but none did it with the persistent zeal and eventual success of Marconi.)

Marconi was so excited that he began designing that very day. What resulted after months of work was his own unique wireless sending set and a receiver system that was much more sensitive than Hertz's loop. A French physicist, Edouard Branly, had demonstrated that metal filings in a glass tube would cohere, or stick together, when an electromagnetic wave hit them, thus making a conducting path for electric current.



Electricity generated by a moving magnet in a simple but significant experiment of Faraday. While the magnet is in motion, a pulse of electricity is registered on the measuring instrument. Later, Faraday used magnets and coils to generate electricity continuously, leading the way to the electric power of the present day.

Guglielmo Marconi (right) visited a fellow pioneer, the Reverend Richard H. Bell, at Santa Clara College in October, 1933. (See Ch. III.)



Using equipment similar to this, Heinrich Hertz became the first to build an apparatus that would generate and receive radio waves. It was Hertz's experiments which led Marconi to develop his wireless telegraph system.

A wireless telegraph message sent August 23, 1899, from the San Francisco lightship to a station in the Cliff House restaurant building overlooking the Pacific was the first ship-to-shore wireless transmission to be received in the United States.

Marconi adapted this in a receiver in which the filings cohered and decohered with each wireless signal, thereby sending electrical impulses in rhythm with the short and long intervals of the Morse code message.

Marconi experimented with a great variety of antennas of various shapes, sizes, and materials, always connecting one to the transmitter and another to the receiver. Each antenna was also connected to the ground. He finally concluded that the best type was a tall, vertical, wire antenna. (It has been said that these upward-reaching wires got their name from the antennas, or feelers, of an insect, and it does seem appropriate.)

By constantly improving his equipment, Marconi was able to receive the waves over longer and longer distances–through his house, across the garden, then over a nearby hill, and finally, by December, 1895, he was sending messages a mile and a half away! Marconi now felt confident of his invention. Wireless telegraphy was on its way! By skillfully drawing upon the discoveries of others, and adding his own devices, Marconi achieved something none of them had done. He had built a wireless communication system which scientists could see promised to be practical over long distances, something of which Faraday, Maxwell, and Hertz could hardly have dreamed.

(It is interesting to note that in this same year a man named Alexander Popov was working in Russia on wireless communication. He had succeeded only in detecting flashes of lightning, but was later to develop a complete system, and to be hailed by his countrymen as the first to do this.)

In 1899, four years after his first successful "long" distance transmission near his home, Marconi was still experimenting and improving his apparatus in Europe. News of Marconi's progress had reached the United States, but the American public wasn't at all sure whether to believe his claims. One San Francisco newspaper even hinted that he was a fake, and referred to him as "Macaroni." The method certainly had yet to be proved to the average man in the street.

It was at this point in history that the team of men in San Francisco decided to try to build a wireless telegraph system. They felt that if it were successful, it would accomplish two goals. It would meet an important, immediate need for communication in the city, notifying people in advance of the arrival of the *Sherman*, bringing home the California soldiers. It would also prove in the United States what Marconi was trying to prove in England: wireless telegraphy was not just an inventor's toy, but rather a valuable and unique means of putting people in touch with each other, wherever they were, on land or sea, in darkness or fog—instantly. *The Call* saw this as a chance to demonstrate wireless as a practical tool, and at the same time triumph over their rival newspapers. It was an alluring prospect.

Their first trials were made between the nineteenth floor of the Claus Spreckels Building, downtown, and Telegraph Hill, about a mile and a half away. However, the sparks from the electric trolley wires caused magnetic disturbances, and interfered with the spark signals from their sending set.

After trying other locations, they finally moved out to the beach. They put the receiver in the basement of the Cliff House, overlooking the ocean and the Golden Gate. (The Cliff House you see today is not the original building, which burned down; but today's Cliff House is on the same spot.) Then they installed the transmitter on the lightship *San Francisco*, anchored outside the Golden Gate.

Their apparatus was crude and fairly simple. The messages were sometimes indistinct, but nevertheless they were clear enough to be understood. Each day they worked to get things adjusted better.

About sundown, they would bring in the long wire antennas at both sending and receiving stations, for fear a storm might blow up in the night and destroy them. One evening, shortly after five o'clock, Charles Fisher was taking down his antenna from between the masts of the lightship. A thick haze was settling over the ocean. It was growing dark.

Suddenly there was a cry from one of the crew. "The *Sherman!*" And there, like some great white ghost, the *Sherman's* hull appeared, as though suspended in the mist.

Frantically, Fisher put up his antenna again. Controlling his excitement, he sat down and carefully tapped out the message on his telegraph key. "*SHERMAN* IS SIGHTED. *SHERMAN* IS SIGHTED."

All the while, he kept thinking, "They've probably gone home by now, and there's no one to hear my signals!"

But the conscientious fellows at the Cliff House were still there, taking advantage of an off-duty hour to try some improvements on the receiving set. They were surprised to hear a clicking in the instrument, which they thought must be some chance electrical disturbance. But the clicking continued. Fisher must be sending! Faintly, but unmistakably, the signals wrote themselves out:

"*SHERMAN* IS SIGHTED."

"Hurray! Get *The Call* on the telephone!"

This was the newspaper's cue to fire a cannon from the top of the Spreckels Building. "Buroom!" The noise was heard for miles. *The Call* then quickly posted the news in its street-floor windows, as did other newspapers. According to *The Call*, its cannon was answered by another cannon from the *San Francisco Chronicle*, followed by the ear-splitting blast of a steam siren from the *San Francisco Examiner*. The Union Iron Works turned on its piercing closing-time whistle—and left it on!

It took a minute or two for people to remember that this was the way the transport's arrival was to be announced. Then, as though an orchestra conductor had brought down his baton, everything in San Francisco that could whistle, shriek, ring, or bang went off at once. Bells, sirens, and guns, from churches, factories, and forts, made such a wild and enormous racket, it's a wonder the soldiers out on the ocean on the *Sherman* or the men on the lightship didn't hear it. (Fisher had to wait for four days to learn whether any of his messages had been received. Henry Wolters came out in a tugboat on August 27 with the happy report that *all* the dispatches had been received. Delighted, the men continued their lightship wireless experiments until the 10th of September!)

It was almost six o'clock. Streetcars laden with homeward-bound crowds stopped and everyone poured back downtown, yelling with joy and blowing horns which they purchased from peddlers who seemed to appear from nowhere. Dignified businessmen in derby hats and walking canes were caught up and carried along in the milling mob. Fashionable, wasp-waisted ladies had their huge plumed and flowered hats knocked off—and just laughed. Bonfires were lit. Songs were sung. One of the favorites was, "There'll Be a Hot Time in the Old Town Tonight." After many months, California's boys were at last safely home from the war. San Franciscans were releasing all their pent-up strain and worry with one continuous, hilarious whoop.

While the city rejoiced over the good news, reporters raced out in tugboats to get more news. Finally finding the troop transport in the murky darkness, they called out, "Welcome back!" The soldiers crowded up on the decks, eager to talk with the newsmen. When they heard of the reception planned for them, they cheered until they were hoarse. The officials arranged with the commanding officer and the ship's captain to wait until afternoon the next day before coming into the Bay. The mayor, dignitaries, and all the committees would have time to prepare, including Mrs. Flanagan and the others who were to cook the soldiers' homecoming breakfast.

The following day, August 24, 1899, *The Call* ran banner headlines across its front page: "CALIFORNIA HEROES HOME FROM THE PHILIPPINES." The second headline proclaimed, "Ahead of All Others The Call Heralds Their Approach to the City by the First Use on This Coast of Wireless Telegraphy." (*The Call's* claim of being "ahead" was not acknowledged by her rival San Francisco papers. Each paper announced the next day that *its* noisy signal had been the one to alert the city. The *Sherman* passed the lightship at 5:15 P.M., according to the lightship's log. However, the wireless message could not be sent until the antenna had been reinstalled. Meanwhile, the *Sherman* approached the shoreline and was presumably sighted by the lookout station which telephoned the news to the city. If so, this and *The Call* message could have reached the papers within minutes of each other, and thus *The Call's* scoop was not as great as had been hoped for.)

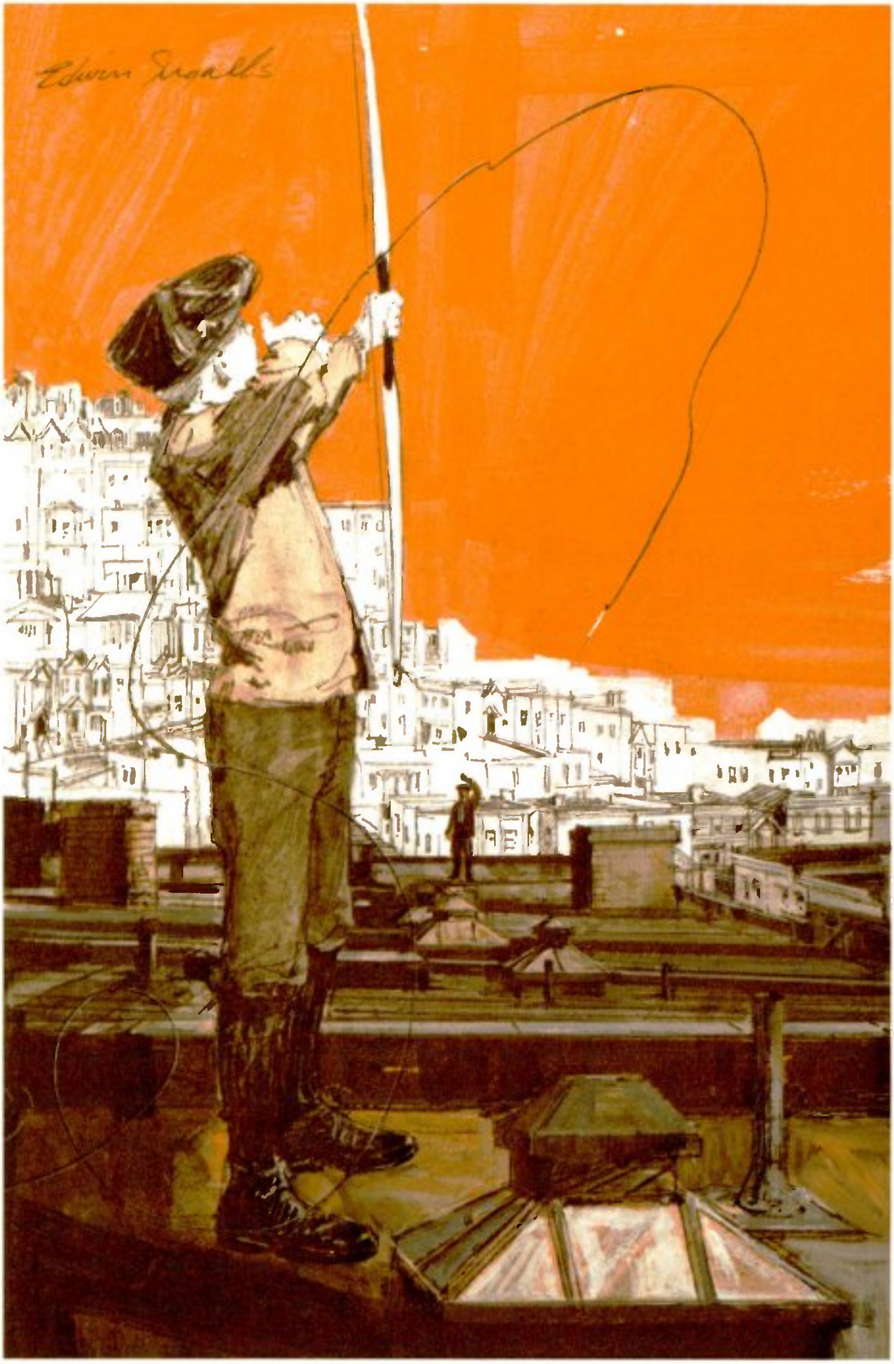
The faint dots and dashes whispering across space from the San Francisco lightship had set off a local roar that made history, both for its noise and its consequences. It was the first ship-to-shore wireless message to be received in San Francisco or on any American coast. (Later that year, on September 21, Marconi arrived in the United States and soon conducted his

first demonstrations in this country by sending messages between the steamer *Ponce* and the Navesink lighthouse in New Jersey.)

The Call's experiment marked the beginning in the United States of the use of wireless for reporting news. It helped to convince those skeptical of Marconi's work that ships offshore actually could reach each other or the shore with wireless telegraphy, a system that was to save countless ships and lives. But few could have guessed on that day that those weak dot-and-dash signals would eventually be developed into voice and music broadcasting. And who could have imagined that this first flirtation with these intriguing radiating waves was to lead men on, past the wonders of radio, into the new world of electronics?

Come to think of it, perhaps no one in that gay city in the "Gay Nineties" would have cared *that* day!

They had to develop imagination



Chapter II

RADIO PIONEERS—AGE TEN AND UP

During the first years of the new century, wireless telegraphy grew quite literally by leaps and bounds.

The month after the wireless message "*SHERMAN* IS SIGHTED" was flashed into San Francisco, Marconi came to America from England and successfully demonstrated his communication system on the Atlantic Coast, as mentioned in the previous chapter. Impressed by these experiments on both coasts, the United States Lighthouse Board asked Congress in June, 1900, for $25,000 to begin installation of wireless apparatus on lightships and lighthouses.

In December, 1901, Marconi sent a signal across the vast Atlantic Ocean, from England to Newfoundland. This was a tremendous leap—about 2,100 miles. It was not really a message, just three dots in code for the letter "S", repeated over and over. However, it spelled out a dramatic new possibility. Wireless telegraphy might be the long-needed answer to communication with ships not just close to shore but everywhere on the high seas.

In March, 1904, the U.S. Navy installed its first wireless station on the West Coast at Mare Island, at the Navy base on the north end of San Francisco Bay. And where on the base did they put the station? The wireless operator and his equipment were moved quite logically into a "communication" building—a carrier pigeon shed! Official records don't reveal whether the feathered messengers were first removed or not.

By 1908, the Navy had wireless stations along the entire Pacific Coast, including Alaska, where miners had struck rich gold deposits a few years before.

San Francisco was a "boom town" and the center of Pacific shipping activity. A host of companies claiming the ability to supply vessels with wireless sprang up between 1900 and 1912, as easily as the golden poppies blossomed on the Bay Area hills. Some were merely get-rich-quick organizations which didn't last. Others were sincere; they put the best equipment they knew how to make on the ships and in the shore stations. It was, of course, a time of experiment and constant change, as the technicians tried to get more distance and greater reliability.

As the demand for wireless grew, so, naturally, did the need for wireless operators to man the installations. The wireless companies found an unexpected source of supply–teen-aged boys who had been building their own sets.

From the day the *Sherman* was sighted, dozens of boys were bitten by the "wireless bug." Marconi's spanning the Atlantic gave them added enthusiasm. Unlike wire telegraphy, there was no need to erect poles and string wires from point to point. A fellow could make his own parts, and listen in without getting permission from anyone. He could buy batteries and wires from a company like Paul Seiler's Electric Company on Market Street in San Francisco, or send away for supplies to the Electro Importing Company in New York. Hugo Gernsback, owner of this latter firm, carried much that the amateurs needed. Also, he published a magazine, *Modern Electrics*, which became the constant companion of amateurs everywhere. It carried articles on the latest ways to build or improve wireless sets, some written by the experimenters themselves.

The boys found that they could pick up each other's signals better at night than in the daytime, since light from the sun affects the transmission of wireless waves. After dark, a wireless amateur, or "ham" as they came to call themselves, would disappear from the family scene to some cold attic room or cubbyhole and start up his spark transmitter. What a thrill, after sending out his call, to have someone answer him–another boy 10 or even 30 miles away!

Much of the talk (in dots and dashes, of course) was about the kind of equipment they were using. There weren't many on the air at first. In 1905, there were not more than 150 good amateur transmitting stations in the United States. (By 1965, there were over 250,000.) Eager to compare notes and to see each other's "rigs," a group in the Bay Area organized a wireless club, the Bay Counties Wireless Telegraph Association. They started meeting in 1907, about once a month, in their own homes. They presented technical reports and even mailed mimeographed copies to the members. Most of them lived in the East Bay Area, but there were others from as far south as San Diego, and as far north as Walla Walla, Washington. This was one of the first wireless clubs in America. Some of its members were later national leaders in the radio industry. One San Francisco boy, Haraden Pratt, who had learned telegraph code at age six, became Telecommunications Advisor to United States President Harry Truman.

Another club was started in San Francisco in 1909, by a 12-year-old named Henry Dickow. Henry had built his first set when he was 10. The San Francisco Radio Club, Incorporated, grew to be one of the largest in America.

The young hams could practice fast translation of the Continental telegraph code by eavesdropping on the various wireless companies in the area, such as Pacific Wireless Telegraph, Massie, United, and American Marconi. This stood them in good stead if they wanted to go to sea as wireless operators. Haraden Pratt and Henry Dickow and many a Bay Area boy proudly earned the nickname "Sparks" by sailing out the Golden Gate on a ship, often the only one on board who knew how to use and repair the mysterious, crackling spark set.

The eager amateurs of those days had to develop three qualities: imagination, persistence, and courage. They needed inventive minds partly because so little was known about wireless and partly because money to buy supplies was scarce for most boys. It also helped to have sympathetic parents. Douglas Perham, one of the very earliest pioneers, tells about unscrewing the decorative round knobs from his mother's brass beds to make a spark gap like Marconi's.

For a while, detectors for the receiving sets were made by laying a sewing machine needle across two pieces of carbon. Haraden Pratt got his carbons by following the streetlight man around. Every day the man would come to renew the carbons in the arc lights, and when he tossed the old ones aside, Haraden gathered in his new supply. His first wireless set cost him all of 63 cents.

Ford King, another member of the Bay Counties Wireless Telegraph Association, tells of solving an antenna problem. His home in San Francisco was one of a solid line of 17 houses on Belvedere Street. Most of these homes were three-story flats, built side by side, with no space in between. Ford wanted to put up a very long antenna, but it seemed impossible on that crowded city block. He was determined, and at last hit upon a scheme. He and another amateur made friends with the family in the middle of the row of houses. One of them then got permission to go on the roof of this middle house. The other boy shot a cord with a bow and arrow from the roof of Ford's home to the middle house. Next, Ford climbed to the roof of the last house on the block, and his friend shot the cord on an arrow to him from the middle house. Now it was simple to use the cord to put his wire antenna over all the 17 housetops. Only the family in the middle house knew the wire was there. Says Ford, "It resulted in some wonderful reception for a long time."

The fellows needed a mixture of courage and good sense, for not only did their work involve climbing up tall masts and buildings, but they were working with dangerous amounts of high-voltage current. There was no legal limit as to how powerful an amateur station could be. Sometimes the danger was more to their neighbors than to themselves.

In those days electric wiring was open wiring, not enclosed in metal as it is now. The wires used for electricity in houses picked up high-voltage currents through induction. The new electric light fixtures which people were beginning to have installed were not built to stand these high voltages. Breakdowns in insulation would occur, often with explosive results.

One night Haraden Pratt was sending messages with his 8-kilowatt spark transmitter. In a nearby apartment house a woman was badly frightened when the light fixture over her bed blew out, blackening the plaster. The janitor of the building traced the trouble to young Pratt, whose loud, cracking spark signals could be heard all over the neighborhood. Haraden had to spend the next day rewiring her fixture, which was a rather complicated combination gas and electric one, common at that time.

Another Bay Counties Wireless Telegraph Association member, Bill Larzelere, had a rig even more powerful than Haraden's. The electric field from his antenna induced high voltages in the wires of the house next door to his on Haight Street in San Francisco. This resulted in a spark leaping over some insulation material in a small room in his neighbor's house. Unfortunately, there was a slight gas leak in this room. The spark set fire to the gas and there was a tremendous explosion.

They were sure it was his departed spirit come back to earth!

The whole front brick wall of the house was blown into the street!

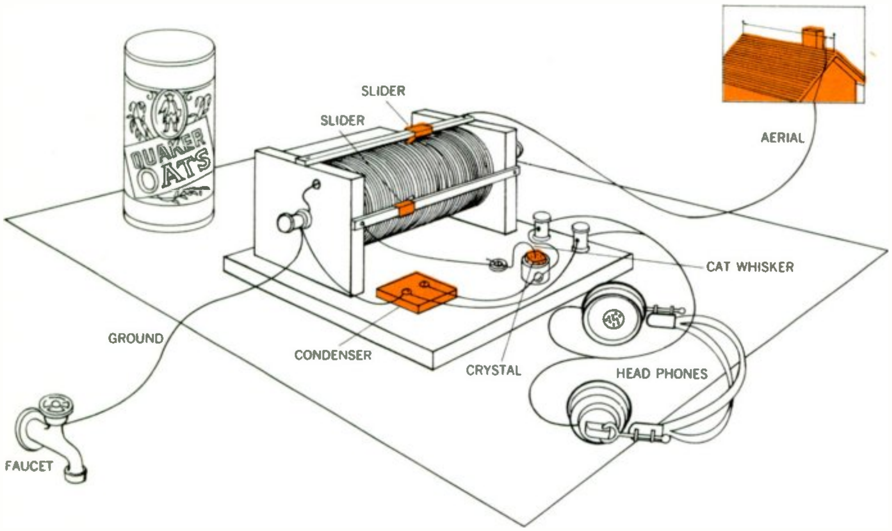
Even when the boys' spark sets weren't setting off explosions, they were causing the neighbors' electric lights to dim. Angry complaints forced the amateurs to wait until the rest of the world was asleep before going on the air.

One night two maiden ladies who lived in a second-story flat awakened to see an awesome sight. The huge gilt-framed picture of their deceased father, hanging on the wall in their bedroom, glowed with light. They were sure it was his departed spirit come back to earth!

The next morning they went downstairs in great distress to tell their neighbors, the Bories. As Louis Borie's older sister listened, she privately suspected that her brother's "experiments" might have something to do with this eerie event, and spoke to Louis about it. Louis had just put up a new antenna wire, from basement to roof, along the outside of the house. Reception on the night before had been fine. However, that day he quietly moved the wire to another position on the outside wall away from the gilded picture frame. The departed spirit never returned.

On April 18, 1906, wireless and most every other activity in the Bay region came to a shuddering halt. A huge earthquake shook the area. The ground heaved and buckled in waves. Buildings toppled. In San Francisco, gas mains caught fire and house after house burst into sudden flame. Acres of the city were completely destroyed. Thousands were made homeless. Telephone and telegraph lines were down. The young wireless operators were not organized for such emergencies as they are now. Their day of being indispensable in times of such disasters was to come later.

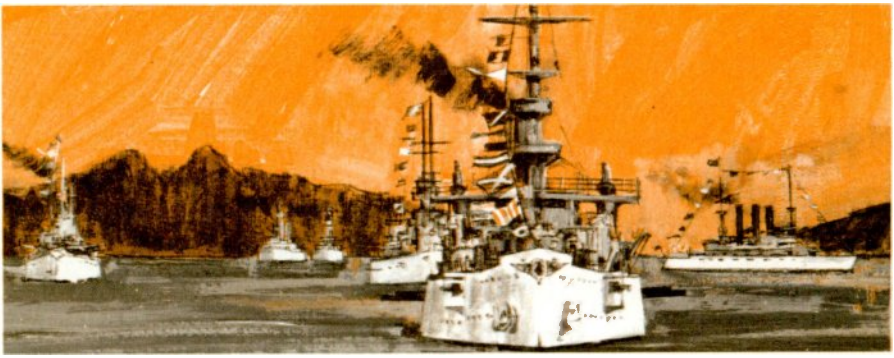
By 1908, San Francisco had dug itself out of the rubble and was rebuilding with vigor. This year the Bay was graced with some distinguished visitors, the ships of the United States Navy's "Great White Fleet." They were to bring a special surprise to the wireless amateurs.



Radio receivers with sensitive, inexpensive crystal detectors, such as this double-slide tuner crystal set, appeared as early as 1904, and were used by most amateurs until the early Twenties, when vacuum tubes replaced crystals. An oatmeal box was a favorite base upon which to wind the wire coils.

Chapter III

WIRELESS BEGINS TO TALK–AND FLY



In 1901, youthful, vigorous Theodore Roosevelt became President. He strode into the White House with a resolve to expand the power and prestige of the United States, and an enthusiasm for new ideas that would bring about such a change. In 1907, he decided to send a fleet of naval vessels around the world. They were all painted white and looked most impressive.

In 1908, the "Great White Fleet" was reported off the California coast, approaching San Francisco. One of the Bay Area wireless amateurs put on his headphones on the chance that a ship might be sending a telegraph message. To his amazement, he heard a man's voice speaking! He could hardly believe that it came out of his own apparatus, but the message was clear! "*Connecticut?* This is *Ohio*." After listening to more conversation, he realized that with his homemade amateur set he had picked up the battleship *Ohio* and the flagship *Connecticut* of Roosevelt's fleet . . . and that they were equipped with radiophones!

When the fleet sailed into San Francisco Bay everyone crowded the hilltops and shoreline to watch. But to the wireless operators, the big surprise and thrill the white ships brought was hearing spoken words on their telegraph sets for the first time, instead of dots and dashes. Until then they had only read about such a possibility in scientific magazines.

The amateurs learned that all of the fleet's 24 ships were fitted with "wireless telephones." In these sets, an apparatus called an electric arc was used instead of a spark gap to produce the Hertzian, or electromagnetic, waves. (You can see similar arcs in the searchlights sometimes used at the opening of a new store or the premiere of a movie.) Valdemar Poulsen of Denmark had invented a system of communication using an arc in 1902. His method had been described in technical journals and, by 1908, was being adopted by engineers in a number of countries. With an arc the electromagnetic, or radio, waves generated were continuous rather than the surge and fade-out waves of a spark transmitter. The continuous or "undamped" waves were far better suited to carry the complicated vibrations of voice.

Lee de Forest's Radio Telephone Company, organized in 1907, had built and installed the Navy's arc sets before the fleet sailed from the East Coast. Unfortunately, it had been a rush job, and there was little time to train the operators. Not all of them were able to use their new wireless phones, and had to fall back on their spark sets with dot-and-dash signals. The little phones were only powerful enough for the short distances between ships. As is still true today, telegraph code was used rather than voice for long-distance work at sea.

The officers on the ships soon discovered that the San Francisco area was alive with accomplished "hams" wanting to exchange signals with them, and made good use of the youngsters. The boys took messages and relayed them to local friends of the Navy men. Working with the U.S. Navy, even if unofficially, was exciting. Hearing voices on their receivers was really sensational!

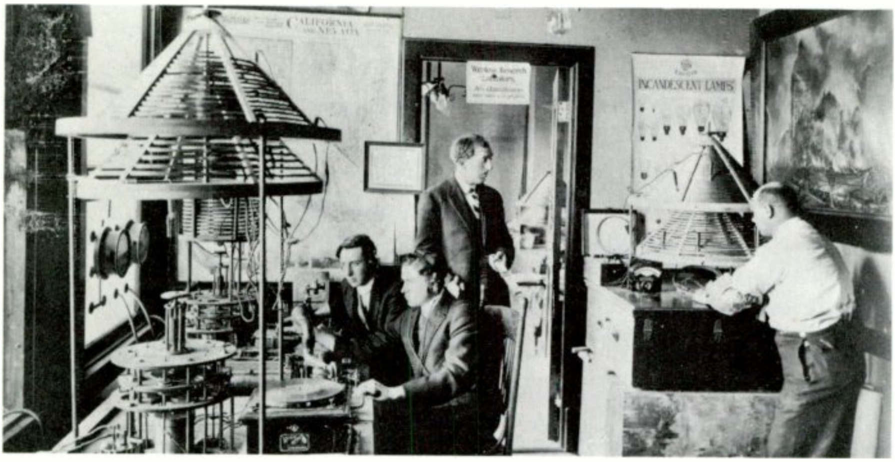
At this point in history, voice by wireless was called wireless telephone, radio telephone, radiophone, and other names. In subsequent years, communications men referred to all signaling with electromagnetic waves, whether involving voice or not, as radio. They still do. However, the general public came to think of "radio" as referring to radio broadcasting of voice and music. A "radio" was the set in their home with which they received the broadcast programs. To the average American, "wireless" meant dot-and-dash telegraphy. Even now these terms cause some misunderstanding. Adding to the confusion, an Englishman is likely to refer to his radio as "the wireless." Incidentally, the appearance of the word "radio" in the name "De Forest Radio Telephone Company" marked the first commercial use of that term on record.

The year after the Great White Fleet's visit, there were more voices on the air in the Bay region, and music, too. These new sounds came from Charles David Herrold's radio station in San Jose, the first one in the United States to broadcast regular, scheduled programs for any who wished to listen. Since its beginning in January, 1909, this pioneer station has been on the air regularly, except for a few years during World War I when the government took control. In the early days before call letters, Herrold merely announced, "This is San Jose." Later the station went through a whole series of call letters: FN, 6XE, 6XF, and SJN. Still later, Herrold's station had a commercial license as KQW. In 1949, when the station was purchased by the Columbia Broadcasting System, the call letters were changed to KCBS, today's powerful station now located in San Francisco.

Since about the only people who had radio receivers around San Jose in 1909 were the few hams who had made their own, Herrold decided to create a larger audience himself. This he did in a way which would seem strange to present-day broadcasters and radio manufacturers. He built receiving sets and gave them away to the people around the countryside who lived within range of his arc transmitter. (Herrold had experimented with spark systems, but shortly after opening his station, he switched to arcs as best for speech.)

The Herrold College of Engineering and Wireless was founded at the same time as the station, and was located in downtown San Jose in the building now known as the Wells Fargo Bank Building. It was from this school that he broadcast his programs. Kindly, generous "Doc" Herrold, a San Jose High School graduate with three years at Stanford, was a popular teacher. A man of broad interests, he was an accomplished musician and composer as well as being well versed in astronomy and mathematics. His pioneer wireless school was very successful; later, during World War I, over a thousand wireless operators were trained there.

The scheduled broadcasts served as excellent advertising



This first radio broadcasting station, built by Charles D. Herrold in San Jose, became KQW and is now KCBS. It has provided continuous service since its founding in 1909. Photo taken about 1913. (L to R) Kenneth Saunders, Emile Portal, Charles Herrold, and Frank Schmidt.

for the school. Herrold invited guest speakers and reported the news. His wife, Sybil, became the first lady disc jockey, borrowing records from the Sherman & Clay music store in San Jose. In 1908, the Columbia Gramaphone Company had come out with a revolutionary new item, a "double disc record." This was a record that had music on *both* sides. Columbia even made a recorded commercial: "Double the wear, double the value. Double your money's worth, clear as daylight!" While winding up the Victor Talking Machine, Mrs. Herrold advertised the new records, the music store, and the college. Every Wednesday evening she broadcast a special program for the hams in the area. Other nights the farmers were given weather and crop news.

Young amateurs and farmers were not the only ones who listened to the first broadcasts. A physics professor at Santa Clara College (now Santa Clara University) not only listened, he answered back. As early as 1903, the Reverend Richard Bell had sent Morse code messages from St. Ignatius College (now the University of San Francisco) to Santa Clara. In 1907, he established voice communication over a distance of seven miles. He and Herrold often talked on the air together. Assisting both of them from time to time was a skilled technician, Frank Schmidt. Father Bell received a number of patents for his wireless inventions. In later years, Marconi visited him at the University of Santa Clara and complimented him on his apparatus.

Working with Father Bell during those early days was another Santa Clara professor, John Montgomery. He was interested in wireless and did some inventing in this field himself, but was even more fascinated with another project—flying. He is credited with being the first to fly a heavier-than-air craft in controlled flight, in 1883. The "aeroplanes" which Montgomery designed had no motor, but were launched from hilltops. He guided the planes in flight by changing the angle of the cloth wings, adjusting hinged "ailerons," flexible wing tips, and a rear stabilizer. Some of the basic principles he employed are still used in modern plane design.

On a cold December morning in 1903, twenty years after Montgomery's first flight, Orville and Wilbur Wright succeeded in flying a plane with a gasoline motor on several brief but historic trips in North Carolina. The first flight took Orville ten feet up in the air, carried him for about 100 feet, and landed him, in a total of 12 seconds. Later that day Wilbur was able to stay up for 59 seconds. December 17, 1903, became famous as the first time a motor-powered plane had left the ground and returned safely, controlled by a human passenger.

In 1905, a hot-air balloon took one of Professor Montgomery's motorless planes 4,000 feet up in the air and released it over the Santa Clara College campus. For 20 minutes the pilot, Dan Maloney, guided the plane through figure eights, barrel rolls, and dives, and finished with a controlled landing at a previously designated spot below Poplar Street at Alviso, in Santa Clara. This height and control were history-making. Alexander Graham Bell, who had been studying and experimenting with aviation problems, said of this flight, "All subsequent attempts in aviation must begin with the Montgomery machine."

Thanks partly to Montgomery, by 1910 Californians had become so air-minded that it was decided to hold an "International Air Meet" in Los Angeles. This took place at the old Dominguez ranch from January 10 to January 20. There were 60 entrants, but not all were able to get up in the air. Louis

Paulhan, a dashing little Frenchman, and Glenn H. Curtiss were the star "birdmen" of the show. Paulhan was personally complimented by John Montgomery, and a group of men invited him to perform at the Tanforan race track in San Bruno, south of San Francisco, for three days, January 24, 25, and 26. He had his planes, Bleriots and Farmans, shipped to the track, but the weather was so windy he could fly very little the first two days. However, the enthusiastic spectators, most of them seeing a man fly for the first time, were most appreciative. Once, with the aid of the wind, he went 60 miles an hour, and stayed in the air 31 minutes. (In Los Angeles he had remained up for almost two hours.) Even to watch the brave pilot took some courage on the part of the audience for, as the Frenchman frankly announced, he could not always control his plane. Several times during the show, it swooped down right where the crowds were standing and there was a scramble for safety.

Perhaps few in the audience were more intensely interested than an 18-year-old radio amateur from Berkeley, Ralph Heintz. He hung around the planes and made friends with Paulhan's mechanics. One, Diddier Masson, was also a flier and could speak a little English. Ralph had the thrill of taking Masson home for dinner one night.

Not long after Paulhan's show at Tanforan, in the spring of 1910, Ralph went to see Earle Ennis to buy parts for his wireless telegraph set. Earle's Western Wireless Equipment Company and wireless station were in the Grant Building at Seventh and Market Streets in San Francisco. Earle built radios for private and commercial ships. He often used parts from the Wireless Specialty Apparatus Company of Boston and became their West Coast representative. Earle enjoyed broadcasting the news in code to ships' wireless operators as far as he could reach them at sea with his spark set, using the call letters "T-G." He was a six-foot-one, 240-pound, genial fellow with a keen mind and a lively sense of humor. He had grown fond of his bright young Berkeley customer.

"Ralph, how would you like to bring your receiver out to the Tanforan race track this week? I know a fellow who is going to fly his plane down there, and I'm going to see if it's possible to have him send a wireless message from the plane while he's up in the air."

"That sounds great!" replied Ralph eagerly. "I'll be there!"

The morning of the experiment, Ralph was up before the sun in order to catch the first train. He was loaded down with gear, including three spreaders for his antenna, each six feet long, and a shoe box containing earphones, as well as dilute acid and fine platinum wire for his "electrolytic" detector which he used instead of a crystal set.

Taking the train and the ferryboat was a daily routine for Ralph, as he had chosen to commute all the way to Lick High School (now Lick-Wilmerding High) in San Francisco for its excellent science and shop courses, not then available at Berkeley High. But this day, instead of taking the streetcar from the Ferry Building to school, he took a streetcar to the train station and a train to the race track.

Earle Ennis was already there when he arrived. He had brought his fiancee with him, a beautiful young woman named Carol Read. The pilot and Earle were installing the special lightweight spark-gap transmitter which Earle had assembled for the plane. They were puzzled as to where to put the ground wire for a transmitter that was about to *leave* the ground. They finally hooked it on the engine. Then they attached a coil of wire about 25 feet long near the pilot so he could let it out for an antenna after he was airborne. The pilot was to send just a few letters with the telegraph key, not attempting any complete sentences. Ralph hurried down the field looking for a quiet place away from the others to set up his receiving equipment. He found an old telephone pole that was ideal for his antenna.

There were not more than six people there that day, just friends of Earle Ennis and the pilot. Although no one had ever sent a wireless message from an airplane in flight, and many experts had assumed it could never be done, it did not occur to Earle Ennis to have official witnesses or to arrange for publicity. He was only interested in trying the experiment for his own information.

With what excitement Ralph Heintz watched the frail little biplane take off! He adjusted his headphones tightly over his ears to shut out the noise of the motor. At last he heard the dots and dashes, faint but perfectly understandable, tapped out by the pilot as he circled the field.

Ralph raced back to the rest. "Did you hear the signals?" Earle called to him jubilantly from his own receiving set. "Yes, I did!" answered Ralph. The pilot landed and there were congratulations all around. But Ralph couldn't stay. He had to pack up his gear and hurry back to San Francisco, for he dared not miss any more school that day. It was only years later that he realized how important the morning's adventure had been. He and Earle Ennis had been the first men in the United States to receive a wireless message from an airplane!

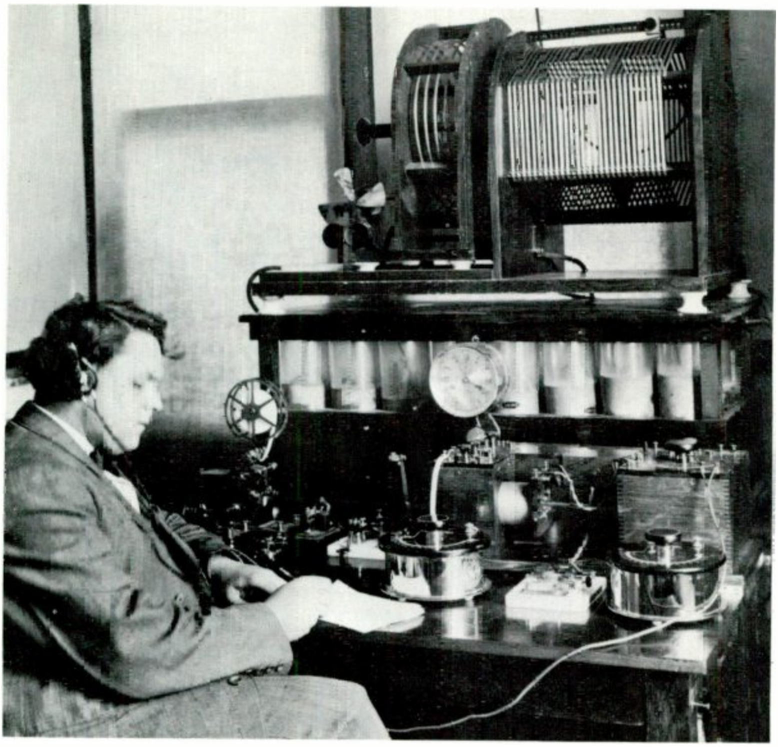
Neither of them kept a diary or any record of the experiment. However, Earle's fiancee recalled the timing of the event vividly even 57 years later, because shortly after that day the federal government, on June 24, 1910, passed a law requiring certain ships carrying 50 or more passengers to have a radio transmitter and a licensed operator on board. Earle invested and lost so much money in his efforts to equip with wireless the many ships coming into San Francisco that their wedding had to be postponed until the next year.

Neither Ralph Heintz nor Mrs. Ennis can remember today the name of the pilot. There were a number of fliers in the Bay Area in 1910. The year before, the Pacific Aero Club had been formed for the builders and pilots of airplanes, balloons, and gliders. The club's secretary, Cleve G. Shaffer, the area's first professional plane builder, had established the Shaffer Aero Manufacturing and Supply Company in 1909, and had built a plane that year.

Fung Joe Guey, a Chinese lad from Oakland, flew a "Curtiss-type" plane of his own design as early as September 23, 1909, when he is recorded as flying in Oakland a distance of 2,640 feet. One of the most successful local amateur pilots was Fred Wiseman of Santa Rosa. His first publicized flight was in May of 1910. In February, March, and April of 1910 Frank H. Johnson, the agent for Curtiss planes, gave exhibitions in Chico, Stockton, Woodland, Del Monte, Salinas, Alameda, and San Jose.

Another plane in the area that spring was one built by Dr. William Greene of the East Coast which belonged to Roy Crosby and was flown by 18-year-old Harold Hall.

George Loose, who had a cycle shop in Mayfield (now a part of Palo Alto), designed six airplanes, the sixth one of which



Earle Ennis at his wireless telegraph station in San Francisco's Grant Building, about 1910, the year he installed equipment on an airplane and received the first air-to-ground wireless message.

actually flew in 1910. The magazine *Aeronautics* listed nearly a dozen men who were making successful flights in California in 1909 and 1910. On May 29 and 30, 1910, San Francisco staged a "good roads meet" at Tanforan where airplane and glider pilots, "motor car" drivers, and motorcyclists were to perform. It was announced that "Proceeds will go to repairing the roads from the end of the boulevard to Millbrae. This is one of the worst stretches anywhere to be found and has long been one of the motorists' greatest worries."

Frank Johnson, Fred Wiseman, Harold Hall, and others were scheduled to fly, but it was too windy by the time the meet began. It is possible that one of these pilots took Earle Ennis' radio equipment up early in the morning, or a day before or after the meet. It is a matter of record that Hall flew his Greene biplane in a successful test just two days before the public show.

There is another wireless operator still living in 1967 who remembers conducting a similar, unpublicized, unofficial air-to-ground experiment on August 4, 1910. Elmo Pickerill sent and received telegraph signals from a Wright biplane which he himself piloted at Mineola, Long Island, with a friend at the other end of his two-way transmission, perhaps the first in radio history. Pickerill recalls that he also communicated with five steamships, two Marconi coastal stations, and a wireless station in Manhattan, during the hour he was airborne.

Also in August of that year, on the 27th, J. A. McCurdy, a Curtiss-trained pilot, sent to Harry M. Horton what *they* thought was the first message ever received from a flying plane. This was at an air meet at the Sheepshead Bay race track in New York. Since there were Signal Corps officers and representatives from Washington and from the Aero Club of America who witnessed the Horton-McCurdy demonstration, as well as newsmen and thousands of spectators, this is recognized as the first *official* transmission of a wireless telegraph message from the air to take place in the United States.

Earle Ennis' experience in 1910 was valuable in preparing equipment for *his* first official air-to-ground radio work which took place at California's "Second International Air Meet" held near the Tanforan race track from January 7 to January 26, 1911. An important objective of this particular meet was to explore the military uses of airplanes and airborne radio. Lt. Paul W. Beck of the Signal Corps at the Presidio in San Francisco had attended the first air meet in Los Angeles in 1910 and had become convinced that the Army should own its own airplanes, equipped with wireless, for scouting and combat purposes. As Secretary of the Aviation Committee, Beck was virtually in charge of the meet. He and Ennis established a radio "shack" at one end of the specially built grandstand. Here Sergeant Dunn of the Signal Corps sat with windows closed against the roar of the planes and the cheers of the crowds, ready to send and receive the wireless signals.

The Second Battalion of the Thirtieth Infantry took part in the exercises. When the soldiers established their camp in the fields near the race track, they promptly named it "Camp Selfridge" and the airfield "Selfridge Field" in honor of Lt. Thomas E. Selfridge of San Francisco, one of the Army's earliest fliers, who had been killed in a flight with Orville Wright in 1908.

Eugene Ely made naval history during the meet by landing a Curtiss biplane on the deck of the U.S.S. *Pennsylvania*, anchored in the Bay, and taking off again. The Selfridge Field wireless shack kept in constant touch with the ship, coordinating this first demonstration of the idea of naval aircraft carriers.

The infantrymen staged a mock war against the airfield, with troops marching from the Presidio. Planes were sent up to find and photograph the approaching "enemy." For the first time, a plane dropped explosives on targets (near the shoreline, far from the troops), hitting them with fair accuracy. A Curtiss biplane was used to establish radio communication while scouting for the advancing army. The pilot, Charles F. Willard, wore an Ennis-and-Beck-designed tiny receiver strapped to his wrist, and headphones with mufflers. According to Willard, whom reporters described as a "serious, businesslike member of the Curtiss team," he had no difficulty in making out the simple cipher message sent him, which was "Turn to the left and return to Camp Selfridge immediately." "Despite the roar of my engine and the whistling of the wind," said Willard, "I could hear the signal quite clearly and I am positive that the receipt of wireless communication by an aviator is thoroughly practicable."

On January 21, Lt. Beck went up with Phillip Parmalee, a modest, retiring member of the Wright team, in a Wright biplane equipped with one of Earle Ennis' transmitters. The apparatus was housed in a mahogany box which Beck carried on his lap, and which weighed 29 pounds. As Beck tapped out a half-dozen messages, Sergeant Dunn transcribed and handed them out the window of the wireless shack to the officials.

The first message to be sent was a sentence written on a slip of paper by the reporter from the Associated Press and handed to Beck with the instructions that he not read it until he reached an altitude of 500 feet. In this way the reporter could be sure that Beck and Dunn had not prearranged what the message was to be. Soon after Parmalee, Beck, and the big box were over the field, Sergeant Dunn began taking down the coded signals. When he handed the slip of paper to the reporter, the latter grinned. Lt. Beck had sent the sentence exactly as it had been written, but had added a few words of his own. The next day's newspapers carried the story of the successful wireless experiments. The first message of the day was quoted in full, with slight censoring: "500 feet up and running level. It's getting chilly. Blank, blank awfully chilly."

One of the messages tapped out by Lt. Beck was picked up by a puzzled amateur operator, Cyril T. Lotz, 40 miles away, who knew nothing of the transmissions being made at the air meet: "Scotford is not the only bird on the committee." F. E. Scotford, the 250-pound president of the Aviation Committee, had just had his first plane ride. When Lotz, a charter member of the Bay Counties Wireless Telegraph Association, read about the wireless tests in the newspapers the next day, he reported hearing the message. Ennis and Beck were happy to learn that their airborne transmitter had a 40-mile range!

At the end of the air meet, General Tasker H. Bliss, Commander of the Department of California, was well pleased with the effectiveness of both planes and airborne radio. Officials in Washington, hearing of this first use of airborne radio in military maneuvers, wrote to Earle Ennis for more information on his apparatus. His hopes high, Earle described the kinds and prices of his various transmitters and receivers which he had designed for airplane use. There the matter seems to have ended. We can imagine Earle's disappointment. He soon after gave up his radio business and became a newspaper reporter. An extremely modest man, he rarely mentioned his historic part in the beginning of air-to-ground communication, except among his family and close friends. Lt. Beck went on to take flying lessons from Glenn Curtiss, and to promote the cause of airplanes and airborne wireless with speeches and articles.

Just about the time that wireless was learning to fly at the Tanforan race track, talk on the Navy's ships, and broadcast radio programs in San Jose, Cyril Elwell, a recently graduated Stanford electrical engineer, was asked to do some research for a small wireless company in San Francisco. The results of his investigation were to lead to momentous changes in radio.

The McCarty Wireless Telephone Company had been founded to promote a wireless telephone system developed by a young San Francisco boy, Francis McCarty, in 1902, when Valdemar Poulsen was just patenting his arc transmitter for wireless telegraphy. Francis was only 14 when he discovered an ingenious method of modulating, or superimposing, speech on spark waves. He sent a message to his brother Ignatius across Stow Lake in San Francisco's Golden Gate Park. After working on his system for three years, he felt ready to give a public demonstration, inviting the newspapermen. He installed his spark-gap transmitter in the Cliff House, where the San Francisco *Call* experimenters had worked in 1899. A mile down the beach, in a building called Cyclers' Rest, reporters heard young Francis sing and talk. Although the reception was full of unwanted noise and far from what we would call "high fidelity," it was intelligible.

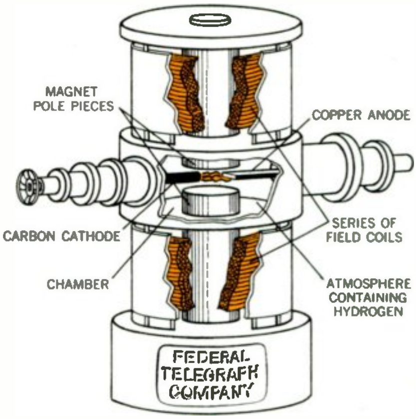
An enthusiastic few organized the McCarty Wireless Telephone Company, but found it hard to get others to invest their money in it. In 1905, the wireless telephone was thought of as just a substitute for the regular wire telephone. The promoters even predicted that it would make the telephone obsolete. The idea of using the wireless telephone for broadcasting news and music over the country for a large audience was almost undreamed of. Even "Doc" Herrold didn't start broadcasting until four years later. Indeed, in 1905, the fact that a spoken message could be heard by others than the one person it was intended for seemed a grave disadvantage, and dampened the enthusiasm of many a would-be investor. What good was a telephone if people for miles around could listen in on your conversation?

However, Francis felt he could produce a system that would be satisfactory, and he kept experimenting. One of his friends was a fellow named Charles Logwood. Charles was an amateur wireless enthusiast from San Luis Obispo who often assisted Francis in his spare time. Suddenly, on May 1, 1906, Francis' promising career came to an abrupt end. The horse cart he was driving tipped over and he was killed. Heartbroken, his mother gave Logwood all of her son's drawings. The McCarty Wireless Company announced in a brochure that Charles Logwood had "acquired a thorough, practical knowledge of the apparatus" and would help in carrying on the work. However, for some reason Charles did not stay with the company, but moved East shortly after this.

By 1908, some of the men who had an interest in the company became concerned about its future, and this is when Cyril Elwell was asked to evaluate its equipment. After a few months of testing the McCarty system in Palo Alto, Cy reported that the method was actually not practical for commercial use.

Elwell told them that what was needed for good voice transmission was continuous waves rather than the damped, or fading, waves of the spark transmitter. He suggested that they obtain permission from Valdemar Poulsen in Denmark to manufacture and use his arc in the United States. But the McCarty financial backers were no longer interested in wireless telephony.

Young Cy Elwell made a momentous decision. He would go to Denmark, get permission to use Poulsen's arc, and start his own company. In May, 1909, he left Palo Alto for Copenhagen. He had little money of his own, but he had those qualities



(L to R) Douglas Perham, C. Albertus, Peter Jensen with 5 kw Federal-Poulsen arc station equipment, about 1910. Arc is mounted on box at left. Note tuning knobs and multiple-unit microphone above telegraph key on operator's table. Drawing is a later 30 kw arc, about 4½ feet tall. Jensen became co-inventor of the loudspeaker. (See Ch. VI.)

which we have noted flourished among youthful amateur radio pioneers: imagination, persistence, and courage.

Even without the optimism of youth, could Elwell have anticipated that his new company was to become one of the largest of its kind in America? Perhaps, but surely he could not have guessed that from its Palo Alto laboratory and factory were to come forth men and inventions that were to revolutionize radio and influence the course of events all over the world.

Upon his arrival in Copenhagen, Elwell was given enlightening demonstrations by the Danish engineers. The Poulsen arc operated in an atmosphere of hydrogen, in a strong transverse magnetic field. Elwell was more convinced than ever that it was far superior to any other arc or method of generating radio waves then known. He ordered two large arcs to be shipped, and carried one of the small ones home with him. It looked simple enough: a hollow cube about eight inches high, with two sides of marble, and the other two and the base of brass. It delivered around 50 watts of power.

Elwell also arranged for the services of two of Dr. Poulsen's assistants, Peter Jensen and C. Albertus, who were to help in the installation of arc stations and then return to Denmark. Albertus was a skilled mechanic and Jensen had actually been the one on Poulsen's staff who in 1906 had discovered how to transmit voice with the arc.

It was not long after his return to Palo Alto that Elwell was able to show his former professors how clearly this new system could send voice as well as telegraph signals. Dr. David Starr Jordan, President of Stanford University, was there for the first trial. He volunteered $500 to help Elwell start his company. This encouraged Dr. C. D. Marx, head of the Stanford civil engineering department, and other faculty members and businessmen in Palo Alto, and they, too, put money into the venture. Thus, in October, 1909, the Poulsen Wireless Telephone and Telegraph Company was founded. A year or two later its name was changed to the Federal Telegraph Company. Today, "Federal" is the oldest American name in radio. Known as the Federal Electric Corporation, the organization is still in business in New Jersey, where it moved in 1931 when it became part of the International Telephone and Telegraph Company.

In February, 1910, the company staged a dramatic demonstration with the hope of attracting more investors. With the help of the Danes, Albertus and Jensen, two stations had been constructed, at Sacramento and at Stockton, 50 miles apart. On the big day, reporters, businessmen, and the mayors of both cities were invited to the stations. Dr. Jordan journeyed from Palo Alto to Sacramento, and spoke on the wireless to the mayor of Stockton. Then some wealthy Chinese merchants spoke across the miles. The new phone without wires carried Chinese as wonderfully clear as it carried English! The merchants bought stock in the company that very week. So did many others. A group of San Francisco financiers, headed by Beach Thompson, were also impressed and they eventually joined and financed the company on a large scale. Thompson later became its president.

As good as the arc system was for telephony, it was not able to operate over the long distances of telegraphy. Also, businessmen objected to its lack of privacy. However, for telegraphy it was excellent. The Federal Telegraph Company decided to build a chain of wireless telegraphy stations throughout the West, to compete with the wire telegraph companies, Western Union and Postal Telegraph.

Cyril Elwell looked for a place in which to build the transmitters and receivers for the new stations. He mentioned his need to Douglas Perham. Doug had become an expert technician, and had recently built Palo Alto's first X-ray machine for a local dentist. Doug's tall amateur radio mast towering over his home at 913 Emerson Street was a landmark in Palo Alto. He was immediately enthusiastic about the Federal Telegraph Company's plans. He not only sold them his house and workshop, but went to work for the company. Federal then purchased a small green cottage on Channing Avenue, just behind Perham's house on Emerson. This corner of Emerson and Channing is now historically hallowed ground, for reasons you will discover in the next chapter.

Other helpers were hired, including Charlie Logwood, whom Elwell had seen on a trip to New York and had prevailed upon to return to California. By 1911 the company had a station in San Francisco and one in Los Angeles and was able to send 15 words for the same price that the wire companies were charging to send 10! Federal became one of the first companies to maintain profitable wireless telegraph traffic between two distant cities.

Next, Federal stations were built in Portland and Medford, Oregon, and in San Diego, El Paso, Phoenix, Fort Worth, Kansas City, and Chicago. By day, they could send messages 500 miles, and by night 1,000 miles. With Chicago able to contact San Francisco or Los Angeles in a matter of seconds, the Far West didn't seem so far. The widely separated states, old and new, were becoming united in fact as well as in name.

In May, 1912, Federal built a station in Honolulu, and established regular communication with the Hawaiian Islands, across a distance of 2,300 miles. This was the longest commercial wireless telegraph channel in the world. Before this, the Honolulu newspapers had received only around 120 words of news a day from the outside world, by cable. For this the papers had paid 16 cents a word. Federal signed contracts to send them at least 1,500 words every day, by wireless, for only two cents a word. And the Hawaiian newspapers could now send more news to the "mainland." The new wireless system brought the Islands closer to the nation, so many miles away, which had just acquired them as a territory 12 years before. Radio was beginning to knit the far-flung peoples of the world together with its invisible, electromagnetic waves.

Meanwhile, back on Emerson Street in Palo Alto, the Federal engineers were designing larger and better arcs. They were also attempting to develop a more sensitive detector for their receivers. Logwood came up with some clever improvements, but the results were still far from ideal. At this point a new man was hired to work on the problem, as head of the research laboratory. He brought with him a tiny lamp, like a light bulb, about two inches high. In the modest cottages of the Federal Telegraph Company the new employee and his assistants were to discover magic powers in this lamp which would have turned the genie from Aladdin's lamp green with envy.

Before making these discoveries with him, let us turn back a few years to an Eastern university late one afternoon.

The sound crashed in their ears like small explosions!

Chapter IV

LEE DE FOREST
AND THE PALO ALTO BREAKTHROUGH

The Yale University professor glared speechlessly at the physics laboratory table, then at the thin young graduate student beside it. Finally he sputtered, "A man who hasn't any better sense than to drive nails into a table will never amount to anything!" To Lee de Forest, pounding a few nails into the lab table to hold some stiff, unruly wires he was using in an experiment had seemed completely sensible. A few weeks later, while working alone at night in the lab, de Forest blew out all the lights in the building. Unfortunately, there was a lecture being given upstairs, and the audience had to be dismissed in the middle of it by candlelight. This was too much for the exasperated teacher. He demanded that Lee be expelled, and only the efforts of two other professors kept him in school. (Years later Yale awarded this "troublemaker" an honorary degree as one of their most distinguished graduates.)

De Forest gratefully continued his lone experimenting. He wrote in his diary, "After such experience it seems the sweetest joy of life to closet myself with hard work in science. May this be my lot in life, to live in a little artificial world, away from the crowd and its friction, surrounded by companions and tasks of my own choosing, thus to gain insight into the great world and the universe of science; to battle always, yes, but with inanimate forces."

De Forest's driving creativity gave him a relentless thrust that left little time or taste for people. Quick-tempered, outspoken, he sometimes made people angry or hurt their feelings. Yet he was capable of great tenderness. His father died while he was in college, and after that, as long as his mother lived, he wrote her a letter every week, for 31 years. He was a devoted husband and father, yet he would often forget to come home for dinner, once even on Thanksgiving Day!

Beneath his bushy eyebrows, his deep-set blue eyes could twinkle with humor or blaze with impatience. Whatever he did, he did intensely. His hobby was hiking. His idea of a good outing was to climb the steepest trail up the highest mountain, and to reach the top in half the time most people would take to do it. On his seventieth birthday, he climbed Mt. Whitney, second highest peak in the United States.

Like the mountains he loved, de Forest's life was full of extreme ups and downs. He made and lost several fortunes. When he had money, he spent it generously, lavishly. He loved big cars, and drove them fast. In his later years, which he spent in Hollywood, he had a yellow Oldsmobile convertible. Rain or shine, he drove it with the top down, his wispy white hair blowing in the wind. He never could seem to remember to slow down in the city. Riding with him down crowded Hollywood Boulevard, while he gestured with both hands as he talked, was a harrowing experience!

There were periods of his life when de Forest had so little money, he lived on one scant meal a day. But he was always full of self-confidence, certain he had a place in the world. From the time he was 13, he knew that he was an inventor. Even at that age, he built a steam locomotive out of boxes and barrels. Although his make-believe train couldn't go anywhere, it was obvious to the adults who inspected it that this youngster actually understood how a steam engine operated. He yearned to invent something really worthwhile that would make the world a better place because Lee de Forest had lived in it. During his long life (1873-1961), he surpassed even his wildest boyhood dreams. He took an active part in the development of radio, radar, television, color television, talking motion pictures, long-distance telephones, electric phonographs, diathermy machines, radio knives for surgery, and cosmic ray measuring instruments.

Nearly 300 patents were issued to him. One of these was world-changing, the three-element electron tube. Yet, of the many millions of people who used his inventions daily, few had any idea who had made them possible. He was awarded medals and honors by governments, universities, and professional societies, and his works were described in encyclopedias, but it is only today that the average man in the street is beginning to appreciate his debt to Lee de Forest.

Those in his own field of radio and electronics, of course, glimpsed the greatness of de Forest's most important invention; some of these copied and manufactured his tube devices without his permission, causing him to spend much time and money defending his patent rights in court.

De Forest's life was one of constant contrast, and the early years he spent in the San Francisco Bay Area were full of contrast, too.

When he first came to San Francisco from New York in 1910, he was founder and co-owner of a successful wireless telegraph company. The U.S. Army Signal Corps had just given the company a contract to install wireless telegraph sets on two U.S. Army transport ships. The units his company manufactured contained de Forest's "audion," as he called the tube which he had invented in 1906. It looked like a light bulb, but it had two other parts in it besides the filament which Edison had heated to make light: a flat piece of metal called a plate and a zigzag piece of wire called a grid. The audion was proving to be an excellent detector of wireless signals.

From his San Francisco office in the Phelan Building, de Forest was supervising the installation of his wireless sending and receiving sets in the building and in the ships. During his off-hours, he experimented with ways to transmit voice instead of telegraph signals. Telegraph signals were in code, of course, and these dots and dashes had to be translated into words by the operators. The telephone, although it brought voice messages directly, could only be used over fairly short distances and depended upon stringing wires over the rugged countryside. Telephones couldn't be used by ships at sea, and even on land the voice signals didn't carry far without fading. De Forest was convinced that he could devise something that would carry voice and music over long distances, without wires. He had already done this over short distances, in New York. He loved good music and wished that people everywhere could hear operas and symphonies, not just those who lived near the theaters and could afford tickets. Growing up as a poor boy in a small town in Alabama, Lee was 15 before he visited a city and heard a symphony orchestra play. Ever since, he had longed to find a way to bring such music to everyone. So, wherever he was, whatever else he was doing, he always spent his spare time working toward this goal.

In the meantime, he was pleased with his Army wireless telegraph installations. Messages sent from the transport ship in Honolulu were received clearly in San Francisco. At this point, he learned that one of the officers of his company in New York had dishonestly taken all the money out of the treasury, leaving the company in debt. De Forest had spent years building up the company and now it seemed doomed to failure. Soon there was so little money coming to him that he and his assistants were forced to take rooms in a cheap hotel over "Coffee Dan's" basement restaurant, where they could get ten-cent meals.

With no hope of saving his company back East and no funds, Lee looked for a job around San Francisco. He had met Cyril Elwell, of the Federal Telegraph Company in Palo Alto, and when he suggested to him that he might be needing employment, Elwell was enthusiastic. He immediately arranged with the president of the company, Beach Thompson, for de Forest to join them at a good salary.

And so, in July, 1911, Lee de Forest came to Palo Alto. It was to be one of the most momentous periods of his action-filled life, and one the world would have cause to remember.

In those days, Palo Alto was a peaceful country town. Lee wrote to his friends in noisy New York City, "It's so quiet I can hardly sleep for the silence!"

He loved the Peninsula, with its grassy hills and spreading oak trees. He moved into a house at 1301 Bryant Street and brought his mother out to live with him. She, too, liked California and she lived in Palo Alto the rest of her life, enjoying the friendship of her husband's cousins, the Albert de Forests and their daughter, Marie, who was a gifted soprano.

The Federal Telegraph Company, with its progressive engineers and technicians, was an ideal place for the inventor of the electron tube. Leonard F. Fuller, a radio amateur from Portland, Oregon, and recently graduated from Cornell University, was in charge of designing the big arc transmitters. Ralph Beal, Harold Elliott, and Archie Stevens were other engineers whose early work at Federal was to lead to later distinction in the field of radio.

De Forest was given free rein for his research in a laboratory which was located in a green cottage on Channing Avenue,

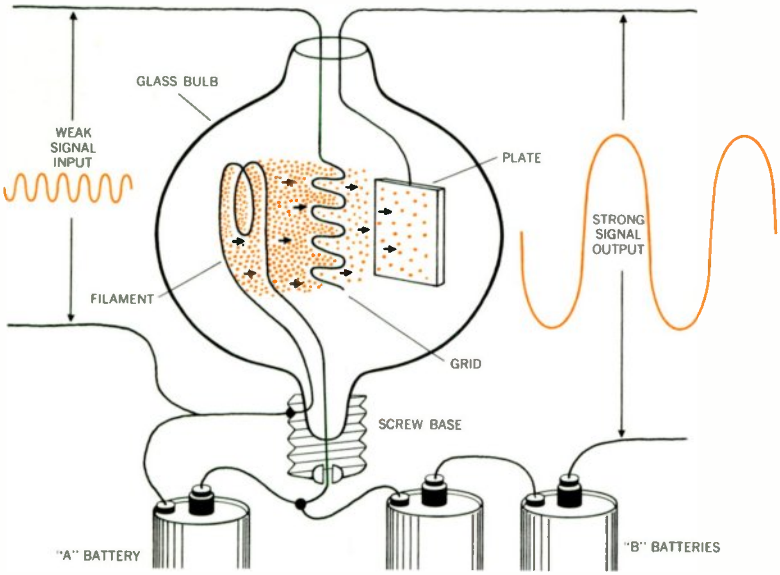
Federal Telegraph's first location in Palo Alto. The shop was in center building. The houses were used as laboratories where the de Forest team discoveries led to the Electronics Age.

just behind the house at 913 Emerson Street. He was given two younger men to assist him, Herbert Van Etten and Charles Logwood. Van Etten was a telephone engineer, bringing this knowledge to the problems of wireless telegraphy. At first de Forest was skeptical of Logwood's ability, since he lacked formal training in engineering and higher mathematics. However, de Forest soon discovered that Logwood had an instinct for invention and a determined way of sticking to things until he got some results, often amazing ones he wasn't expecting.

The forward march of science is highlighted by major breakthroughs such as those made by the Lee de Forests of a given era. Less momentous but nonetheless essential is the contribution of the men who work with them, like Charles Logwood—a special breed of men, often untrained, whose hands and minds seem mysteriously endowed with inventiveness. This is particularly true in the field of electronics. The difficult translation of a scientist's ideas into glass and metal, gears and circuits, by technical men has often given the scientist the tools and insights without which he would not have gone on to make his most important discovery.

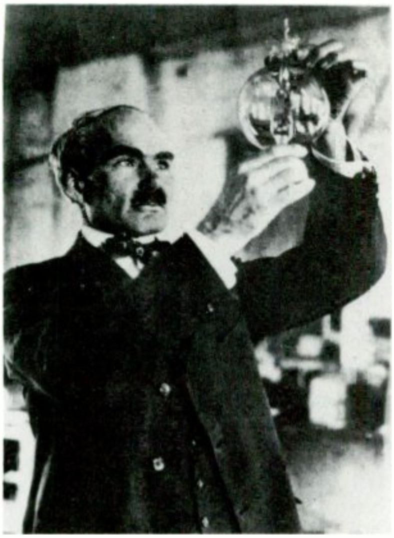
The three men, de Forest, Van Etten, and Logwood, grew in friendship, working long hours together and sometimes hiking on Sundays in the wooded hills of Marin County, across the Bay from San Francisco.

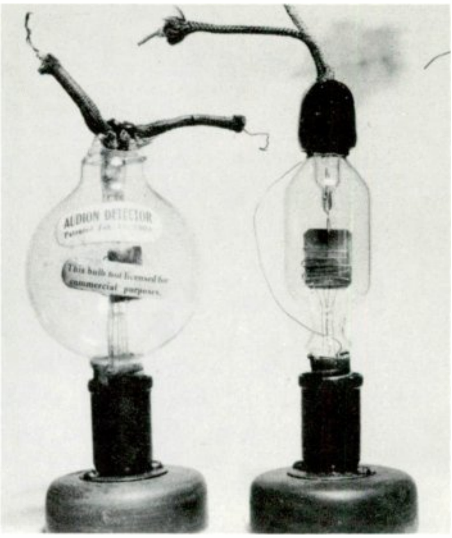
One day in March, 1912, de Forest was startled to have two men from the U.S. government come to the laboratory with a warrant for his arrest. The charge was that he and the other officers in his failing New York firm had misled people into buying stock in a company that manufactured a queer little bulb which Lee had claimed would make it possible someday



The audion, or three-element vacuum tube. The hot filament "boils off" electrons, and these negatively charged particles move toward the positively charged plate. On the way, they normally flow through the grid, a zigzag wire or metal screen. The signal or message, such as dots and dashes or music, comes into the grid from the antenna as a feeble current of varying strength. The grid operates in such a way that this incoming signal causes the grid to vary the steady flow of electrons passing from the filament to the plate. Thus the plate receives them in the same varying pattern as the signal or message which came in on the grid. However, the signal is now carried on a current from the B batteries, which is many times stronger than that in the grid.

By connecting a number of tubes together, de Forest was able to amplify and reamplify signals, in an ever-increasing degree. With today's far more advanced tubes, scientists are able to hear the signals from satellites millions of miles away.





Lee de Forest, inventor of the triode, or radio tube. At right is his first tube. Important grid is the zigzag wire in front of the metal plate. Round bulb of second tube was used only because Lee's glass blower had them on hand. (About 3 inches high.)

for people to talk with each other across the Atlantic Ocean. Obviously, the lawyers said, this was impossible and de Forest had deliberately fooled the public. (Three years later, using his "queer little bulb," engineers of the American Telephone and Telegraph Company sent radio messages from Arlington, Virginia, to the Eiffel Tower in Paris.)

The government agents told him he could stay out of jail until the trial came to court only by paying $10,000 bail. This would be returned to him after the trial. De Forest was able to reach Beach Thompson, Federal's president, in San Francisco and told him of his plight. Thompson and two of the directors of the company raised the $10,000 that night and Lee was released and allowed to stay in Palo Alto. The trial did not take place until the following year, and he had the worry of it hanging over him all during 1912. (They found him "not guilty," but they did send some dishonest officers of the company to the penitentiary.)

Lee de Forest threw himself into his work with more earnestness than ever. The Federal Telegraph Company needed greater telegraphic speed for their rapidly growing trans-pacific and coastwise traffic. The demand was for something which could record the messages at high speed, to be transcribed later at a slower speed by the telegraph operator. The men at Federal had tried using an invention of Valdemar Poulsen called a telegraphone. This was the first magnetic recording device, the grandfather of our present-day tape recorders. Instead of tape, Poulsen used fine steel wire. The telegraphone was being sold in this country as a dictating machine. However, it was found that the telegraph signals were too weak for satisfactory recording. If only there were a way to amplify the faint sounds of these dots and dashes. Lee brought down his electron tubes and batteries from his deserted Phelan Building station in the hope that he and his assistants could build a suitable amplifer with them.

Logwood had never seen a vacuum tube before and he was eager to explore its possibilities. For weeks various methods and combinations of the little bulbs were tried. Often Lee, Logwood, and Van Etten would work all night. Once, when they were all weary and frustrated with the poor results they were getting, de Forest grabbed a bottle of ink and threw it across the room. It crashed against the wall and the black liquid streamed over the floor. At first, Logwood and Van Etten were too shocked to speak. Then suddenly they burst into laughter. Finally, de Forest had to forget his anger and laugh, too, and the tired, tense men relaxed.

Soon after, they hit upon a way of connecting the tubes to a telephone transmitter so that they amplified or increased the electric signals, not just slightly, but to a dramatic degree. They tested the apparatus by placing a large telephone receiver with a horn attached to it as a loudspeaker in the window of the laboratory. Then de Forest walked down the street to see how far he could go and still hear the signals. When he still heard them two blocks away, he raced back shouting with joy. They called in the other engineers at Federal for a demonstration. Logwood connected the telephone transmitter and the audions to some headphones. When Lee held a watch a few inches from the telephone, the sound crashed in their ears like small explosions!

This was what telephone and wireless men had dreamed of for years—the amplification of feeble electric current. This was the discovery that would open up an unlimited new world of invention and make possible the Age of Electronics. The electron tube has been regarded by some as the greatest invention of all time. Its originator has been hailed as "The Father of Electronics."

Immediately, de Forest realized how valuable this device would be to a telephone company. With the encouragement of Thompson, he left in September for New York. There he demonstrated his amplifier to the engineers of the Bell Telephone Laboratory. They were amazed, and asked to borrow the equipment for a short time. Since de Forest had patented his tube in 1907, he agreed. They kept the apparatus for weeks, then months. (Eventually, after nearly a year, they bought the patent rights to use the tube as an amplifier for telephone signals, thus making possible long-distance telephone communication.)

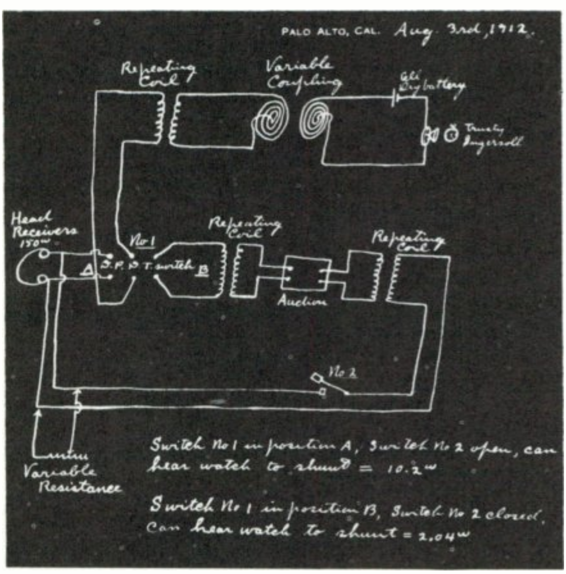
Meanwhile, he waited many anxious weeks in New York, hoping each day that the telephone company would call him and make him an offer for the use of his invention. One evening a friend arranged for him to visit Thomas Alva Edison in his laboratories in New Jersey. He found the "grand old man of electricity" hard at work, getting ready to manufacture in large quantities his clever new invention, the phonograph. He was sleeping even less than usual; in fact hadn't slept in a bed for three days. His clothes were rumpled, his tie askew, his white hair shaggy.

When Edison was introduced to de Forest he immediately asked about his work in wireless. As Lee described his new discovery – how enormously his vacuum tube could amplify – Edison was extremely interested. He told de Forest about some of his early experiments with electricity, making rough sketches as he talked. For ten minutes, the two inventors conversed, one in a soft, kindly voice, the other shouting, for Edison was quite deaf. De Forest left Edison with renewed respect and admiration for this famous American inventor. Edison had given the world light with his electric bulb. De Forest, who had added two more elements to the light bulb—a second wire and a piece of metal—was just about to give the world electronics.

Shortly after this, de Forest and a few other pioneers were asked to be charter members of the Institute of Radio Engineers. This was to become a nation-wide organization of great influence on radio and electronics.

In October, he and a friend went to a musical comedy in the Grand Opera House in New York. After the show, the friend introduced him to Mary Mayo, a beautiful young woman who was in the musical chorus. De Forest was captivated by her charm and wonderful soprano voice. He swept her up in a whirlwind courtship, and they were married a few weeks later. The year of 1912 closed with his returning joyously to Palo Alto with a chestnut-haired bride! Lee's mother welcomed them both home to the comfortable brown-shingled house on Bryant Street.

De Forest had high hopes that the telephone company in New York would soon be offering him a large sum of money. Meanwhile, he and Logwood and Van Etten continued experimenting with the audion tubes. They moved their laboratory from the house on Channing Avenue to the white cottage at 913 Emerson Street. During the previous August they had obtained strong evidence that the tubes could be used not just



Circuit diagram shows how de Forest's audion was made to amplify. (Note "trusty Ingersoll.")

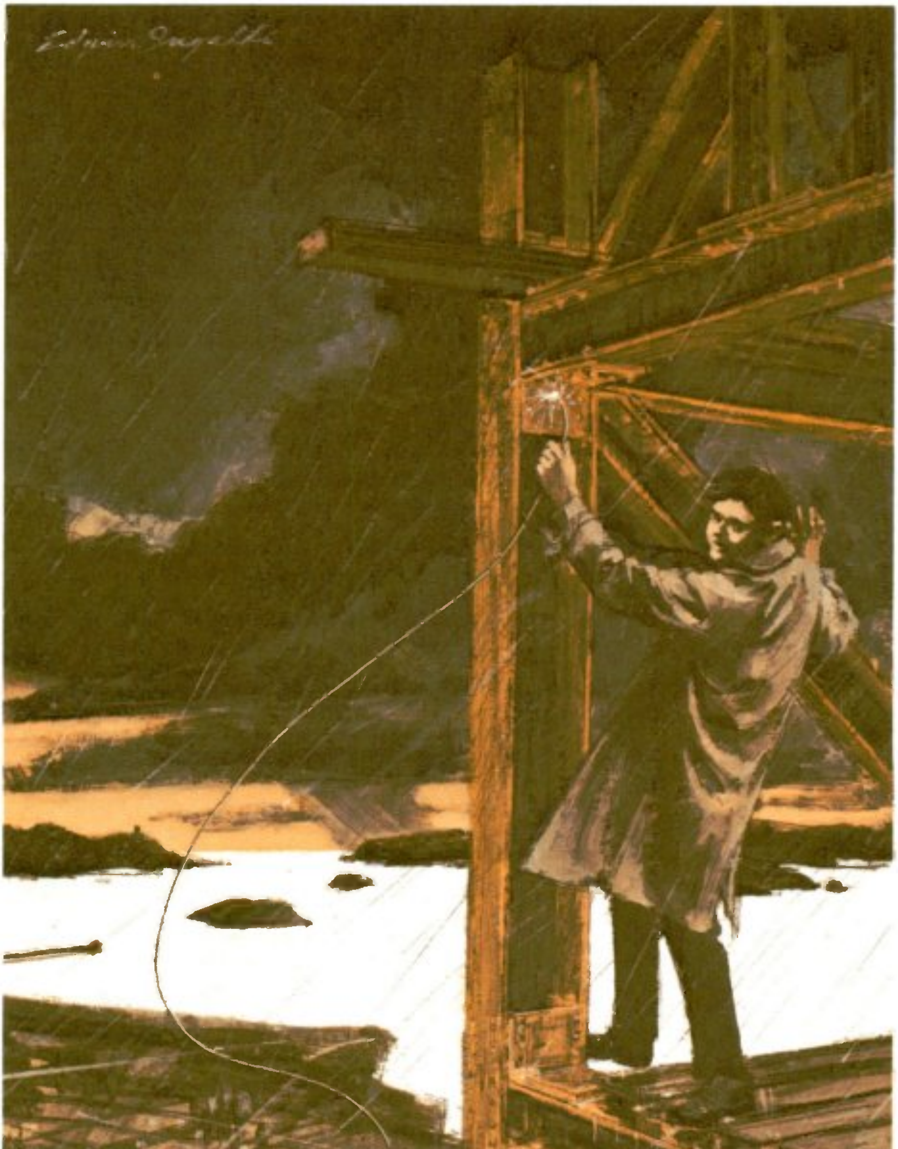
to amplify but to create electromagnetic waves. They pursued this until, in the spring of 1913, they were able to triumphantly demonstrate to the Federal engineers this new ability of the tube. This important discovery, that the three-element vacuum tube could generate continuous radio waves, was to revolutionize radio transmission, opening the way for modern radio broadcasting, radar, and outer-space communication. The spark gap and the Poulsen arc were destined to be replaced with the electron tube and thus to become museum pieces. However, there were years of development necessary before the tube was ready to do this.

Meanwhile, de Forest heard from a group he had talked with in New York on his last visit there. They were now ready and willing to finance his research on a new project, which he had told them would be possible with the electron tube—talking motion pictures. So in May, de Forest, ever the pioneer eagerly following the star of invention, moved back to New York.

Some years later, he had the unhappiness of a divorce. However, in 1930, he met and married (after a six weeks' courtship) a Hollywood actress who was perfectly suited to this intense, dynamic inventor. Pretty Marie Mosquini promptly gave up her career in movies and put her husband's interests first in her life from then on. She looked up to him as a genius and a great man. She preferred, as did he, a quiet home life with good music and a few friends. In addition, she loved to hike! Lee was delighted to discover this, and Marie soon had to get used to being wakened at 5 A.M. by her husband announcing, "Surprise! We're going camping. Hurry, the car is all packed!"

De Forest saw his tube give rise to a many-billion-dollar-a-year electronics industry, while his own life was plagued with financial worries. Even his last years were spent in modest circumstances. Yet, this bothered him very little. He had a loving wife, children, and grandchildren. He had discovered that the joys of fame and fortune are often fleeting, bringing no lasting happiness. And no matter what his circumstances, he never lost his own self-esteem. He knew that he had made a great contribution to mankind, and this brought him deep contentment. He continued to work and invent almost to the end of his long life of 87 years, in June, 1961.

"I received a violent shock"



Chapter V

WIRELESS GOES TO YAP, THE FAIR, AND WAR

Lee de Forest's vacuum tube with its magical third element, the wire grid, was born in 1906.* In its infancy, the tube was imperfect, temperamental, and not too well understood. Sometimes the results it gave as a detector or as an amplifier of wireless waves were spectacular. At other times, it wouldn't work at all.

However, the tube showed enough promise that a number of scientists in Germany, England, and America worked to improve it. By the time de Forest and his research team in Palo Alto discovered how to use the tube to generate, or create, wireless waves, as well as amplify them, other experimenters were also making this discovery. Each claimed to be first, and there followed years of lawsuits. The most famous of these went to the Supreme Court of the United States. This highest court ruled in 1928, and again in 1934, that de Forest was the first to use the tube for generating continuous electromagnetic waves.

While the tube was "growing up" in various laboratories, the Federal Telegraph Company in Palo Alto was setting new records with its arc transmitters. (You will remember that Cyril Elwell brought the first Poulsen arc from Denmark.) It was to be some years before the vacuum tube would be ready to replace the powerful arc as a generator of wireless waves. In December, 1912, the Federal Telegraph Company installed a 30-kilowatt transmitter at the Navy's new radio station in Arlington, Virginia. The first day it made perfect contact with Federal's South San Francisco station. This amazed the Navy officials, for they had never been able to reach California by wireless with such fine, strong signals. The next night, dot-and-dash messages were exchanged between Arlington and Federal's Honolulu station, 4,500 miles apart. This was a record distance, over land and sea, and with Honolulu working in the daylight. Impressed, the Navy decided to adopt the Federal arc system.

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*Invented in 1906, patent applied for in 1907, patent granted in 1908.

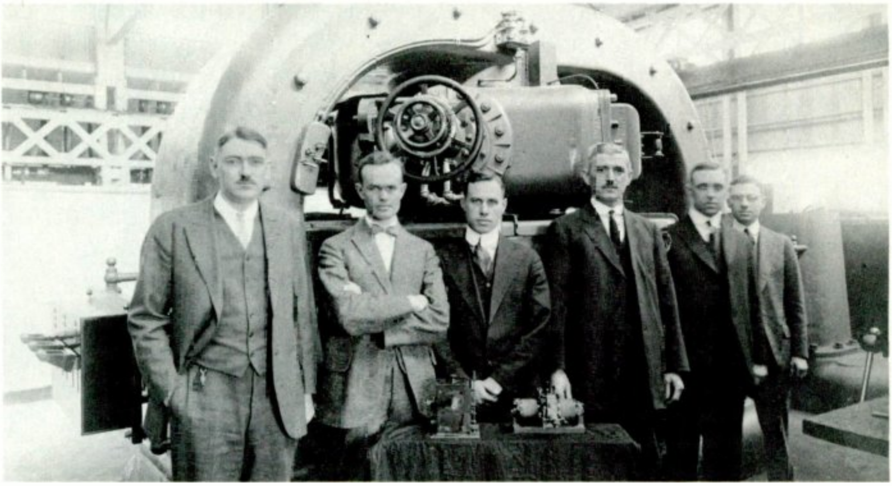
Shortly after, in 1913, Elwell left the company to take a position in England. The entire engineering effort fell upon Leonard Fuller, who became chief engineer. Under his able direction, Federal made the apparatus for naval stations built at Panama Canal Zone, San Diego, Pearl Harbor, and at Cavite in the Philippine Islands. Other naval stations equipped by the Federal Company soon followed at Annapolis, Long Island, Guam, and Puerto Rico. A national authority says of him, "Leonard Fuller was the first engineer who was able to increase successfully the power output of arc transmitters, which made the system practical for this large and important Navy network."

To build its increasingly massive arc generators (some weighing over 85 tons—heavier than 40 automobiles) Federal had moved from its modest little buildings at Emerson Street into a larger factory. The new buildings were between the Southern Pacific railroad tracks and the El Camino Real highway in Palo Alto. The buildings still stand and were for many years used by the city of Palo Alto.

In 1918, the Navy ordered two 1,000-kilowatt arc generators from Federal for a station in Bordeaux, France. When completed in 1920, it was the most powerful radio station ever built. It was not changed over to vacuum tubes until 16 years later.

At the end of World War I the Federal Telegraph Company led the world in the design and manufacture of high-power wireless apparatus for intercontinental communication. Its influence on the development of radio engineering was also world-wide.

Although individual companies like Federal and Marconi's Wireless Telegraph Company were making rapid strides in wireless in the early 1900's, this branch of technology was still so young that the amateur radio operators of ten knew more about it than did their schoolteachers. Many universities had little or no radio education facilities. During his senior year (1914) at the University of California in Berkeley, Haraden Pratt convinced his electrical engineering professor, Dr. Fischer, that the university needed a radio communication laboratory, which Haraden would build. Surprisingly, the school agreed, and provided the money needed. But when it



Federal Telegraph engineers in front of powerful 500 kw arc. Many were used by the U.S. Navy for world-wide communication. On the table at left is original Poulsen arc from Denmark; at right is first model made by Federal. (L to R) Leonard F. Fuller, chief engineer; Harold F. Elliott, Corwin C. Chapman, Kurt Bley, Ralph R. Beal, Adrian L. Anderson. About 1917.

came to putting up an antenna, Haraden hit a snag. He wanted to stretch a wire from the brick chimney on the Mechanics Building to the top of the Campanile, a high bell tower being constructed on the campus. The steel framework of the tower was up, and there were temporary stairs for the workmen leading to the top. Haraden's professor asked the Dean, and the Dean asked the Regents. The answer was no. There were too many wires overhead already. Haraden was ready to give up the project, when his professor teased him by asking, "Don't you have any resourcefulness?"

To a wireless operator, these were fighting words. Haraden resolved to put up an antenna "by hook or by crook." As he tells it now, some 50 years later, "There was a watchman's shack at the base of the tower, so I made friendly advances to the watchman, using his favorite cigars. One afternoon when it was raining, and no work was going on, I put a ball of twine in my pocket along with a pair of pliers and an insulator, and entered the watchman's shack. We chatted a bit and then I climbed up the construction stairways, which he had let me do freely before.

"At the top platform I dropped the string to an accomplice on the ground and hauled up the small 7-strand phosphor bronze wire he attached to it. When I got my hands on the wire I received a violent shock, as it was touching a power line somewhere. I did not lose my balance on the I-beam on which I was standing, but quickly swung the wire against a steel column. Grounding the end of the wire, I took a loop of it, climbed to the top of the bronze lantern, fastened the insulator and wire to the little ornamental tip on top of it, came down, chatted with the watchman, and then completed the job at the brick chimney."

Little did the watchman suspect that the tall, thin, dripping-wet lad had nearly been killed moments before! Haraden looked up at the Campanile and grinned: the wire was so small and so high it could only be seen by someone who knew it was there.

Next, Haraden connected his amplifier, which he had made with some de Forest audion tubes, to his crystal detector. Now he was ready to listen in. The first dot-and-dash signals he heard were just a jumble of letters. Then he realized that they were spelling words in German! Fortunately, Haraden's German mother had taught him that language even before he had learned English. As he copied the messages, he discovered they were coming from the Pacific islands of Yap and Nauru, in the Carolines. Germany had acquired these islands around the beginning of the century and now had powerful stations there to keep in touch with their ships in the Pacific, vitally important during war. Haraden located the islands on a map. Yap was over 6,000 miles away!

When Haraden's professor found out the following Monday what his "resourceful" student had accomplished, he was delighted. Soon afterward, an article by young Pratt describing his equipment was published in the official magazine of the Institute of Radio Engineers. (Some years later he was elected president of the Institute.) And to top it all off, a group of professors asked Haraden to conduct a class in radio communication for them—a new kind of challenge for a ham!

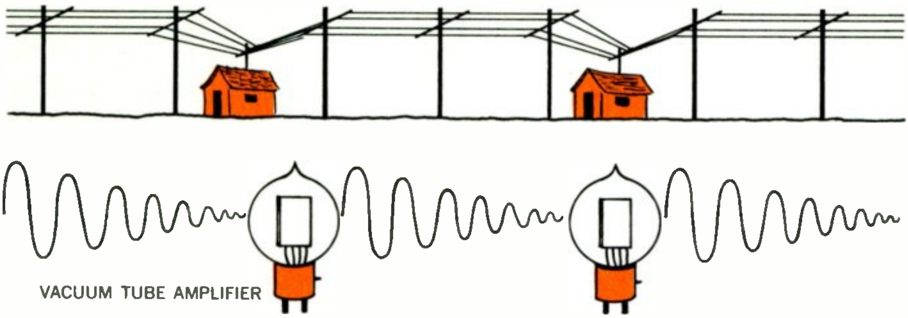
Helping Pratt with the campus radio station were fellow student workers and amateur club friends. They had many an exciting hour listening to distant stations, including one in eastern Siberia. A number of them went on to important careers in electronics, such as Ellery Stone, who became a vice president of the large International Telephone and Telegraph Company.

Working with government astronomers in Washington, the station was able to assist in determining the exact longitude of that city and of Berkeley.

In August of 1914, the Panama Canal was completed, bringing San Francisco closer to the East Coast and to Europe. To celebrate, San Francisco planned the Panama-Pacific International Exposition, to be held in 1915. Since the previous World's Fair, at St. Louis in 1904, much had changed. Automobiles, airplanes, and motion pictures had become commonplace. The twentieth century, destined to be a century of inventions, had gotten off to a dramatic start. And the year 1915 opened with additional drama.

On January 25, 1915, the first transcontinental telephone call took place, between New York and San Francisco. Alexander Graham Bell, his great beard now white, sat in the New York office of the American Telephone and Telegraph Company and talked to Thomas A. Watson in San Francisco, the same Watson to whom Bell had spoken the first words on his original crude telephone, "Watson, come here. I want you." In 1876, the distance had been between two rooms of a house. In 1915, the distance covered 3,400 miles of telephone lines. Many men and ingenious devices had made this longest of long-distance phone calls possible. John J. Carty, chief engineer of the telephone company, and H. J. Van der Bijl, one of his staff, had played leading roles. One of the most essential elements was de Forest's electron tube. In the hands of the telephone company's skilled workers, the vacuum tubes were used to amplify the signals, boosting them across the nation.

By September 29, 1915, the company was ready to repeat their feat, but this time they sent the human voice across the country without wires. The president of the company at the Navy's Arlington station talked to John Carty at Mare Island in the San Francisco Bay. Their conversation was heard distinctly by Lloyd Espenschied, another engineer with the telephone company, who was listening at Pearl Harbor, Hawaii! What Federal Telegraph had done in 1912 with dots



In 1915, electronics made possible the first transcontinental telephone call by wire. Words spoken in New York took 1/15 of a second to reach San Francisco. It was a triumph of both men and materials. Telephone crews strung four copper wires between 130,000 poles, over mountains and across deserts. At intervals, the wires dipped down to relay stations, where the current was fed into specially designed vacuum tubes. As a result, the fading telephone signals were given an enormous increase in strength.

and dashes, American Telephone did in 1915 with voice, using electron tubes instead of an arc to generate the waves.

In October, 1915, after days of trying, the first transatlantic message was received at the Eiffel Tower in Paris from the Arlington station. It was the voice of B. B. Webb of the telephone company saying, as he concluded his monologue for the night, " . . . and now, Shreeve, good night." Just a scrap of a message, but to the engineer in charge of the Paris end of the experiment, Herbert E. Shreeve, and the jubilant men working with him there, it was enough! Like Marconi's letter "S" which had found its way in code across that same vast ocean in 1901, this spoken message, " . . . and now, Shreeve, good night," opened a new chapter in wireless history.

Thus, it was especially appropriate that a World's Fair held in 1915 should be opened by a wireless signal. President Wilson in the White House pressed a golden telegraph key. This made a connection with the powerful Navy station in Tuckerton, New Jersey, which had been built by a German firm and equipped with a Federal arc transmitter. From its 835-foot tower, the signal flashed as fast as light across the United States to Federal's South San Francisco station. From there it was relayed to the fairgrounds in San Francisco. High on top of the Tower of Jewels, tallest structure at the fair, an antenna caught the electromagnetic waves and fed their message to a receiver operated by Leonard Fuller in the grandstand. According to the official account, "This tripped a delicate galvanometer and closed a relay. The main portal of the Machinery Palace swung open, the wheels of the great diesel engine began to rotate, bombs exploded, flags fluttered, whistles and sirens screamed joyfully from all the factories in the city and ships in the port, and all the fountains at the fair gushed forth. The Exposition was open."

This World's Fair was unusually beautiful. Its buildings, pools, and gardens were handsome by day and a fairyland by night. The telephone and the wireless exhibits were both housed in the Palace of Liberal Arts, because, according to the fair's official historian, "that building was quiet." Whether the books and pictures were chosen as a silent background for the communications men, or the communications provided quiet for the more cultural arts, is left for us to guess. Certainly this was the last World's Fair to consider radio "quiet"; it was, in 1915, still wearing headphones.

Almost side by side were Dr. Lee de Forest, with a rather unglamorous display of his audion tubes and amateur apparatus, and the American Telephone and Telegraph Company's lavish theater, with each seat equipped with earphones to hear transcontinental phone conversations. De Forest attended the demonstration and lecture, and was handed a pamphlet on the wonders of the long-distance telephone system. Not one mention was made of his tube! Bristling at the injustice of this, he sat up all night writing a duplicate pamphlet in which he told how the audion was the one invention which "alone enables you today to talk from the Panama-Pacific Exposition to New York or Maine." He and his co-workers took great delight in handing copies of this pamphlet to everyone, including the telephone company's staff. Then he had a huge sign made, over ten feet long, which he installed above his exhibit. Its bold letters proclaimed, "The de Forest Audion Amplifier Licensed to the American Telephone and Telegraph Company as a Telephone Relay Made the Transcontinental Telephone Service Possible."

The telephone company's demonstration lecture was just as specific: "In all the 3,400 miles of line," the audiences were assured, "there is no one spot where a man may point his finger and say, 'Here is the secret of the transcontinental line; here is what makes it possible to telephone from New York to San Francisco.'"

What conclusions, if any, the fairgoers came to after all these statements and counterstatements is uncertain. (In later years, the telephone company was generous in its praise of the three-element electron tube and in financial support of its inventor, although strangely enough, during the company's celebration of the fiftieth anniversary of this first transcontinental transmission, the tube and its inventor were again unmentioned!) The carnival spirit prevailed, and both exhibits were enjoyed by huge crowds. At the telephone company's theater they listened in on the cross-continent conversations between businessmen and dignitaries. More appealing to the children was hearing the roar of the waves breaking on the Atlantic coast.

In de Forest's "wireless telephone booth," they could pick up "Doc" Herrold's broadcasts from San Jose, or overhear the Navy operators in the Bay. De Forest's most enthusiastic visitors were the amateurs. Between the impulsive, ever-young, "cut and try" inventor and the eager, self-taught hams there was a happy bond of understanding.

Many exhibits at the Exposition included products either developed or improved by Edison. The dazzling electric light displays, the microphones used in both wire and wireless telephones, the phonographs and storage batteries, all were indebted to Edison. He was the boyhood hero of America, and in October the great inventor himself came to the fair. Meeting him there was his good friend, Henry Ford, whose Model T automobiles were doing their part to make the United States a nation on wheels. (The Ford Company had a model auto factory at the fair. Each afternoon the public would watch the new mass-production methods turn out Fords at the incredible rate of one every ten minutes. Incidentally, in these cars, like others of that day, the gasoline flowed into the engines by gravity. As a result, when a car started up one of San Francisco's steep hills, the gasoline simply didn't reach the engine. But many San Franciscans just turned around and drove up backwards!)

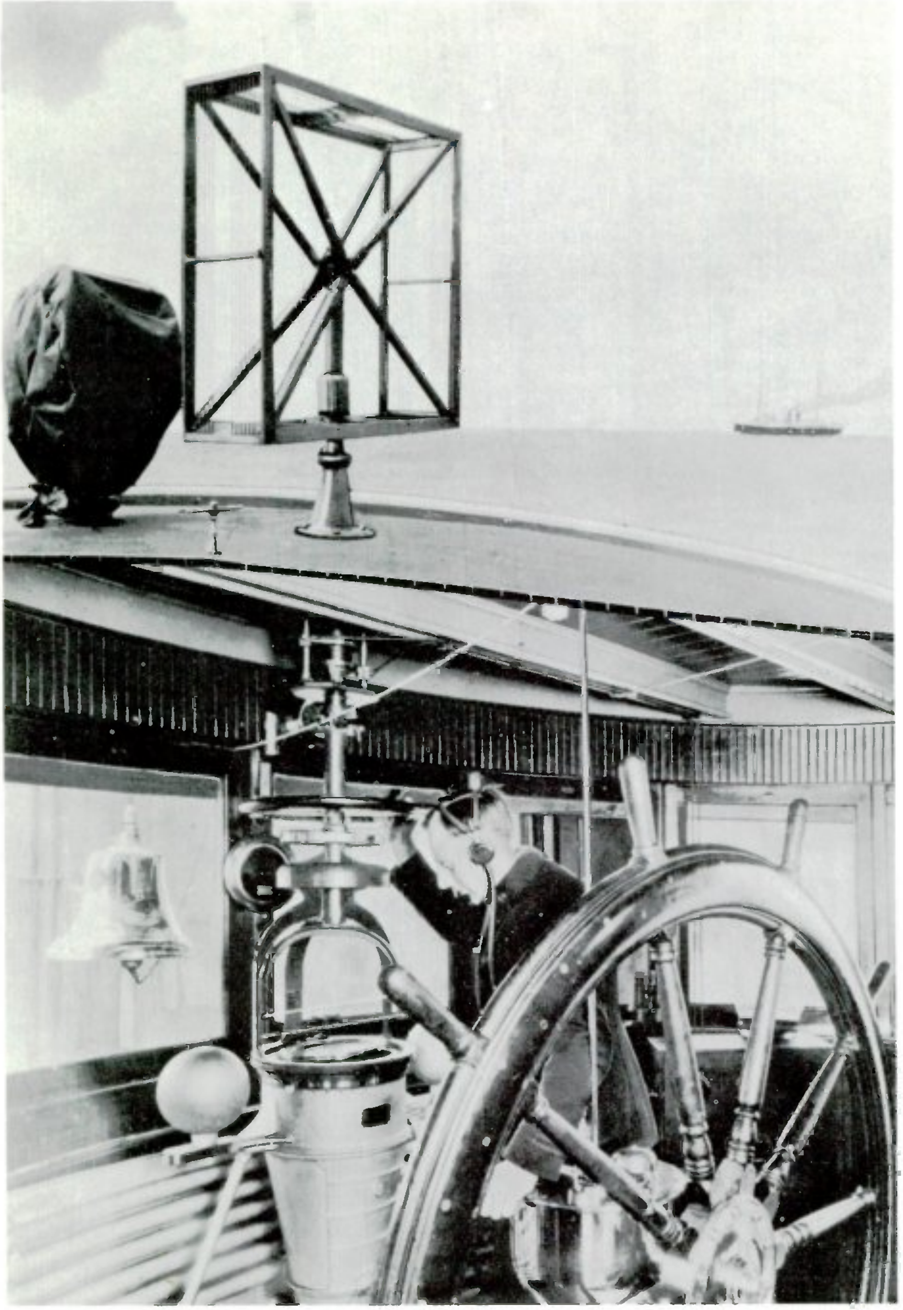
A unique banquet was given for Edison by about 500 telegraphers, honoring him as an early telegraph operator. All the speeches were made in code, by telegraph, with a sounder at each table. Edison's sounder had a special resonator to make it loud enough for him to hear. He had a wonderful time.

Colonel Theodore Roosevelt came to the Exposition, too. Ten thousand people lined up at the Ferry Building and along Market Street to cheer him, as former President and as the man who had played a big part in getting the Canal built.

When the Panama-Pacific Exposition closed in 1915, it also closed a chapter in the story of radio. Europe was at war, and the United States joined in by 1917. Wireless went to war, too, in communications sets; but it came home as the hero in "secret weapons."

John Hays Hammond, Jr., a San Francisco-born inventor, had experimented for years with remotely controlled boats. When the war came, he was ready with wireless-controlled torpedoes and secret methods of radio communication. Today's electronically controlled rockets are the latest relatives of these early Hammond inventions.

Another carefully guarded wartime invention was the radio compass developed by Frederick Kolster. Others had explored this idea; Kolster developed it into a very practical and efficient device, which played a vital part in Navy warfare. Kolster's compass had what is called a loop antenna. The wire was either looped around in a circle, or else in the shape of a hollow square, like the frame of a honeycomb of honey. This antenna was mounted on a ship. When the antenna was rotated in a slow circle, the strength or weakness of the signal received indicated from which direction the signal was coming. Thus, a ship lost at sea could listen to radio beacons from coastal lighthouses and lightships and so find its way home. The compass could also be used for ships to find each other at sea, by taking a bearing on their radio transmitters. After the war, Kolster joined the Federal Telegraph Company in Palo Alto, which then manufactured his radio compasses for civilian use.



Frederick Kolster's direction finder, or radio compass. Location was determined by rotating the loop antenna.

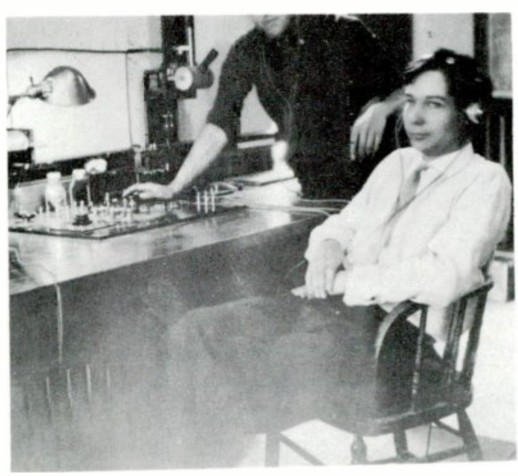
Today, ships and planes rely heavily on radio compasses as direction finders.

During the war, the government shut down all amateur and most commercial radio activity. The amateurs went to war where their skills were much in demand. Both behind the lines and at the front they were forced into inventiveness beyond even their wildest prewar schemes. They compared notes and learned from each other and from engineers in foreign lands. At home, manufacturers were swamped with requests for wireless equipment and vacuum tubes from countries all over the world. They learned how to make better material and new ways of using it.

When the war was over in 1918, radio came marching home with larger muscles and new wisdom. It was on its way into the engineering departments of the universities as a course called "radio" or "communication." And it was on its way into the homes and hearts of all America as "radio broadcasting."

Three of the Bay Area "hams" who became nationally known in electronics. Above, Frederick E. Terman in 1917 with spark gap transmitter, crystal detector, one-tube amplifier. He listened to voice from Herrold's San Jose station and to code from others as far away as Fred Roebuck in Phoenix, Arizona, before Fred moved to California.

A man's "wireless house" is his castle! In 1915, Charles V. Litton, 11, was proud owner of his own radio "shack."



Haraden Pratt and the University of California's first radio station, which he built in 1914. With de Forest audions and a crystal detector, he got Washington, Yap, Siberia.

Chapter VI

"THERE'LL BE SOME CHANGES MADE"

In the early 1920's a hit tune was on everybody's lips, "There'll Be Some Changes Made, Today, There'll Be Some Changes Made!" It could well be called the theme song of the Twenties. People in nearly every field–music, art, literature, education, business, government–challenged traditional patterns of thinking and came up with startlingly different ones.

Fashions in dress reflected the rebellion and the new freedom. Women's skirts went soaring from ankle length to the kneecap, shockingly higher than they had been in hundreds of years. The younger girls shed their long cotton stockings in favor of bare legs and short "bobby socks." Young boys went barelegged, too, in shorts, or wore suits with long pants like Dad's. Grown-ups began to drop the old saying, "Children should be seen and not heard." People were ready to accept new suggestions, even from youth.

There was a creative, energetic drive abroad in the land. Nothing could have better suited the growing science of electronics. And there was perhaps no place where this pioneering spirit could thrive more naturally than that of the "Far West." Radio engineers had discovered that even the physical atmosphere there was helpful, being unusually free of the troublesome electrical disturbances that plagued them in other parts of the country.

So many developments in electronics took place in California during the Twenties that we will have to divide this chapter into sections in order to trace the events.

FROM THE WEST, AMERICA GETS A VOICE TO MATCH ITS MOUNTAINS

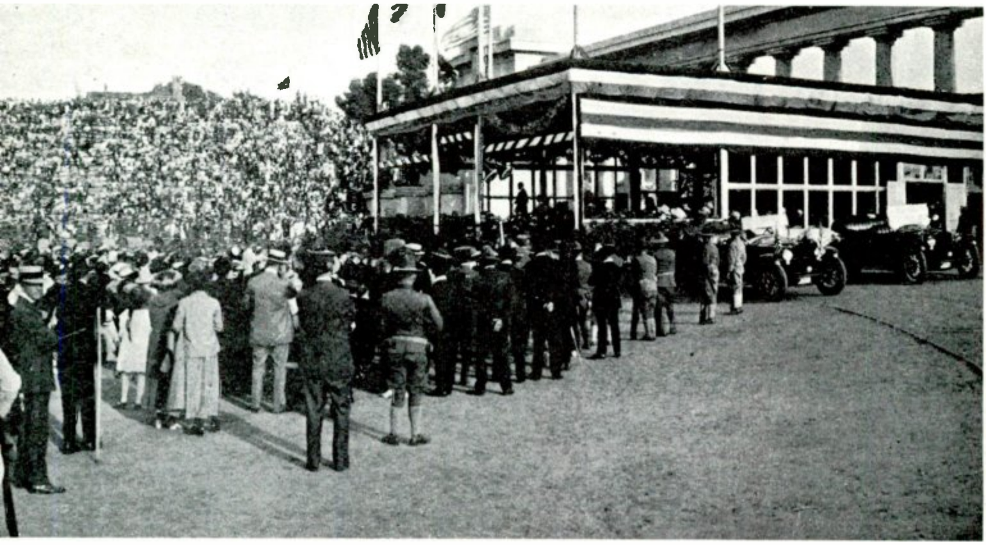
At the end of World War I, United States President Woodrow Wilson went on a tour of the nation, earnestly urging America's participation in the League of Nations. San Francisco prepared a lavish welcome. Children were allowed to miss school in order to see him parade up Market Street.

At the San Diego Stadium on September 19, 1919, President Woodrow Wilson addressed the largest audience any speaker had ever reached, 50,000. This first successful public address system was built by E.S. Pridham and Peter

By the time the President arrived in San Francisco in September, 1919, he was in ill health and weary from making two and three speeches a day. Like everyone appearing in public in those days, he had to shout his speeches in order to be heard. With regret, he was forced to cancel some of his local appearances. However, on September 19, the Bay Area newspapers carried a front-page story with amazing news from San Diego. President Wilson had talked to 50,000 people in an outdoor stadium there using a quiet, conversational tone of voice. Although he had been in a glass-enclosed platform to protect him from the weather, he had been heard by all. It was reported that he used an "amplifying instrument" made by the Magnavox Company of Oakland, California

Said the *San Francisco Chronicle*, "To the thousands directly in front of him his voice sounded somewhat hollow and strong. The two black, funnel-shaped horns that hung over his head picked it up and tossed it out over the sea of faces, and the audience followed every turn of his argument with as much ease as though he were talking in a small banquet room."

It was claimed that the speech was audible more than half a



Jensen, using their invention, the Magnavox loudspeaker. Two transmitting horns, suspended over Wilson's head, were connected to the amplifier and then to two Magnavox speakers mounted on top of the enclosed building.

mile away from the President. Government officials said that it was "probably the largest audience a speaker ever reached."

We might imagine that this amplifying system would have been a welcome relief to the asthmatic, overstrained President who was putting his ideals and hopes for a peaceful world above his own physical well-being. Unfortunately, he was not at all enthusiastic about the Magnavox. In fact, he privately confessed to his physician that the San Diego address was the most difficult one he had made in all his life. It seemed to him as though he was not able to talk naturally and directly to his audience, but "artificially through a mechanical contrivance." So instead of requesting that the amplifying device accompany him on the rest of his speaking tour, he resolutely continued without it.

Although the President was not comfortable with this first public address system, its success was undeniable and its two inventors, Peter Jensen and E. S. Pridham, were much encouraged. Jensen had not been able to help, as he was East on a business trip. When he returned, Pridham had a behind-the-scenes story to tell him.

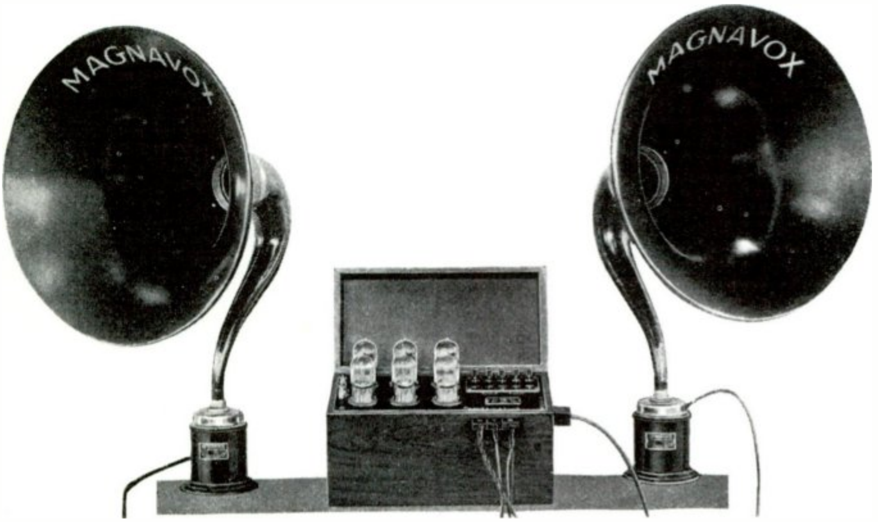
"A break any place in the sound system would have been fatal, for the President was completely enclosed, and not a soul could have heard a word of what he said. Had he spoken from an open platform, at least those nearby could hear, and a failure would not have been so disastrous.

"We put the apparatus up and arranged it as neatly as possible. Everything was in shipshape condition and working well. The whole stadium was filled to the last seat at least an hour before the President was scheduled to arrive.

"I played some appropriate phonograph music through the system while we were waiting, and we made announcements at regular intervals, informing the people of the progress of the parade, which was escorting the President through the town towards the stadium. Everything was in good working order, and the people applauded loudly every announcement we made.

"I knew the President was near the stadium and I was watching the entrance. As the President's car came into view, there was a deafening ovation, and in that same second the system went dead!

"I frantically snapped the power switch on and off, but no



The Magnavox speakers and vacuum tube amplifier used for President Wilson's address in San Diego. Manufactured at the Magnavox factory at 2701 East Fourteenth Street, Oakland. The Magnavox Company, founded in 1917, became a leading radio manufacturer.

clicks came from the horns. Each individual hair on my head stood on end, for I had not the slightest idea where to begin to look for the trouble. I knew it would be as impossible to find as a needle in a haystack.

"Thoughts of burned-out transformers impossible to replace flashed through my head; short-circuited or broken connections, impossible to locate; and the President's car was approaching nearer every second.

"A fine thread of smoke started to come out from the top of the amplifier. In utter desperation, and just for the sake of doing something, I automatically reached out and pulled the nearest tube out of its socket. A click, like a shot from a gun, came from the horns.

"I waited, and the smoke became fainter. I waited a few seconds more, and the President's car stopped in front of the glass house.

"As the President walked up the steps to the enclosure, I put in a new tube, and thanks to the everlasting glory of God, the system was alive again!

"I discovered later that the elements inside the tube had short-circuited; in a few more seconds the amplifier would have burned up. It so happened that the first tube I pulled out was the one causing the trouble. Never again do I want to go through such dreadful seconds!"

There had been long years of labor leading to that historic day in San Diego. E. S. Pridham and Peter Jensen were two of the first employees of the Poulsen Wireless Telephone and Telegraph Company (later the Federal Telegraph Company). Jensen, you may recall, came from Denmark and Pridham had just graduated from Stanford as an electrical engineer. Pridham helped the Dane with his English and they became fast friends. Later Jensen wrote, "In Pridham I found my ideal of a real American. During the next 15 years, which was the period of our closest association, he never ceased in his efforts to change me from a foreigner into a true American, and I hope he was satisfied with his product. He was first and foremost a scholar and a gentleman, as well as a good engineer and a philosopher inspired by the loftiest ideals."

In the fall of 1910 the two young men left the Palo Alto company to establish their own research and development firm in

Napa, some 35 miles northwest of San Francisco. According to Jensen, a couple of months after they arrived in Napa they hit upon the idea of using an electrical moving coil to vibrate the diaphragm of a sound reproducer. They later developed this into the first "moving coil" loudspeaker. So basic was the device which they patented in 1913 that present-day speakers still use this moving coil principle.

Pridham and Jensen established a laboratory on F Street in Napa, a few miles from the big Navy Yard at Mare Island. There, with C. Albertus, their Danish technician, they worked for years perfecting their speaker. By 1917 they had brought it to a point of good performance, but they were without money to produce or distribute the device. In fact, one of the men had only two shirts and the other had but one, which he washed out every evening. At this point fate came to their rescue in the person of a dashing lieutenant commander from the Mare Island Navy Yard, George C. Sweet. Sweet was a friend of the Wright brothers and had in 1909 become the first naval officer in the United States to fly. Now he was working on radio telegraph communications agreements between the Navy and the Federal Telegraph Company.

One day as Commander Sweet was driving along a street in Napa he heard extremely loud voices coming out of a building. He went in and found Pridham and Jensen experimenting with their moving coil speaker. Sweet recognized its importance and immediately took the inventors to the radio laboratory at Mare Island where Haraden Pratt was now a Navy Expert Radio Aide. Jensen set up the apparatus at a window facing the town of Vallejo, which was across the river from the Navy Yard. It was after 5:00 P.M. and the streets were deserted. Sweet saw a man on a dock in Vallejo, about a quarter of a mile away, and said to Jensen, "Ask that man on the dock to take off his hat." Jensen spoke into a microphone, and the loudspeaker boomed the message out to the lone figure across the river. The startled man promptly removed his hat, having no idea where such a huge voice was coming from, and seeing not a soul in sight.

The next day Sweet took Pridham and Jensen to Oakland to meet Frank M. Steers of the Sonora Phonograph Company of California. Steers was enthusiastic about their wonderful speaker, realizing what an improvement it was over any existing phonograph speaker. It was decided to merge their two companies into a new one to produce the moving coil speaker which Pridham suggested they call the "Magnavox," or great voice. The Magnavox Company, organized in 1917, was destined for a long and prosperous life. In 1967 it is still a leader in radio and builds some of the finest television sets available.

Just how did this first moving coil, or "dynamic," speaker (as it was also called) work? It consisted of a very light coil of copper wire placed in a ring-shaped gap in the magnetic circuit of an electromagnet. The coil was rigidly attached to the diaphragm of the loudspeaker. (In early experiments the diaphragm was flat, as in the ordinary telephone receiver. Later, cone-shaped paper diaphragms were employed. These are almost universally used today by manufacturers all over the world.) When the fluctuating audio-frequency current was sent through the coil in the magnetic field, the coil moved in step with the sound current. This moved the diaphragm which created sound waves corresponding to the original voice or other sounds.

This method of transmitting amplified sound was a vast improvement over previous inventions. It eliminated rattles and additional unwanted noises found in other speaker systems, and reproduced the very low and high notes with greater clarity. When used with a vacuum tube amplifier, such as was done for President Wilson's speech in San Diego, extremely loud reproduction was possible.

Shortly after the Magnavox Company was formed, the work on the loudspeaker was delayed for something more urgent. The United States entered World War I. At the Navy's request, Pridham and Jensen developed an antinoise microphone which could transmit voice over the roar of an airplane motor. The Navy put the Magnavox "antinoise airplane telephones" in its four-motored NC seaplanes, and one of these became the first airplane to fly across the Atlantic Ocean, in May, 1919. Each member of the crew could talk to the others during the long, daring journey. The success of this Magnavox instrument was publicly acclaimed by the Acting Secretary of the Navy, Franklin D. Roosevelt.

Pridham and Jensen also built an address system for destroyers and battleships, using the moving coil speaker and the antinoise transmitter in combination. It enabled a ship's captain to be heard by all the crew at once over loudspeakers installed in various areas of the ship, including the noisy engine room. So important to the war effort were the Magnavox devices that the company received a national award for "such vital help to the armed services."

After the war, Pridham and Jensen began immediately to develop their loudspeaker for peacetime uses, to give all of America a "magna vox," or big voice. The Magnavox Company made public address systems for factories, hospitals, and sports stadiums across the nation. As a result of this new type of loudspeaker, public speaking itself began to change from loud-voiced oratory with sweeping gestures to conversational speech delivered with care not to move too far from the "mike." Politics and politicians would never be quite the same!

Meanwhile, Magnavox speakers were ready for the big "radio boom" which was just around the corner.

"ON THE AIR, EVERYWHERE"–THE GROWTH OF RADIO BROADCASTING

After World War I, the government allowed the radio amateurs back on the air. There was a joyous rush to attics and basements where treasured spark sets had gathered two years of dust. Thousands of veterans, who had discovered the wonders of vacuum tubes while in the armed forces, began looking for tubes and other parts to build their home stations.

In California, Uncle Al's Radio Shop in Oakland and the Leo J. Meyberg Company of San Francisco sold both parts and ready-made crystal sets. (These Bay Area companies were still in business in 1967.) In 1919, Leonard Fuller of the Federal Telegraph Company and Colin B. Kennedy founded the Colin B. Kennedy Company in San Francisco. In addition to making radio receivers and parts for amateurs, the company had its own broadcasting station, called 6XAC. It was built by Emil A. Portal and Fuller, and was located in a garage in Los Altos. Not only was Portal a skilled designer, but years of experience with "Doc" Herrold's radio school and station in San Jose had made him a capable operations manager. This was one of the first vacuum tube radio broadcasting stations in the West. The building still stands in the 25000 block of O'Keefe Avenue, near Foothill College. The company moved East in 1921, and continued to produce receivers. They were expensive, and tops in performance and appearance. Today, Kennedy sets are prized by collectors of early radios.

Another radio company was founded by Ralph Heintz, the amateur who had helped pioneer air-to-ground radio telegraph communication at age 18. He had served overseas during the war, working with the British on airborne radio navigation aids. After graduating from Stanford University, he started his own radio manufacturing business in San Francisco in 1921. It occupied a tiny store space at 606 Mission Street. Heintz's company, called Heintz and Kaufman after some name changes, built several of the early broadcasting stations, including KROW, KJBS, and stations in Mexico and Alaska.

Berkeley, Oakland, and San Francisco all had stations in the Twenties. Herrold's San Jose broadcasting studio, grandfather of them all, was given the call letters KQW in 1921.

By 1922, "wireless telephony" had become "radio" and was no longer crowded into an attic or basement room, operated by a lone youngster. It had moved into the living room. In fact, it seemed as though every man and boy in the San Francisco Bay Area was working on some kind of a receiving set.

The crystal sets were the easiest and cheapest to make. Coils consisted of wire wound around a tube about three inches in diameter, which could be made by rolling up a small sheet of cardboard. With a piece of crystal such as galena or silicon, or a bit of carborundum, a thin wire called a "cat's whisker," an antenna, and a pair of earphones, one was ready to "listen in." The cat's whisker was used to "feel around" on the crystal for a sensitive spot which would detect the radio signals. Then, being very careful not to move the wire, one could get fairly good reception.

During the Twenties, vacuum tube sets gradually replaced crystal sets, and loudspeakers like those of the Magnavox Company took the place of earphones. This meant that the family could listen together, without having to take turns by passing the earphones around. One could move about freely instead of being harnessed by wires to the radio.

The early speakers were usually round, enclosed horns, placed on the table next to the receiver. Later, along with aerials, they moved into the cabinets which, incidentally, grew to be quite respectable pieces of furniture. Magnavox advertised, "Broadcast radio receivers in handsomely carved period cabinets for $150, not including the tubes or batteries."

Both amateurs and those with ready-made sets found a big thrill in drawing a faraway voice out of the air. By patiently turning the dials, one could often hear a program, or at least scraps of one, from a city hundreds of miles away. Sometimes San Franciscans were startled and delighted to hear Hawaiian music, strumming its way across the Pacific from KGU in Honolulu.

Youthful listeners complained about the lack of jazz on the radio. "All I can get," mourned one, "is salon orchestras, coloratura sopranos, and players of Bach and Wagner." Dance music was usually played only during the later evening hours.

The 1927 Rose Bowl football game in Pasadena was the first sports event ever broadcast coast-to-coast via radio. Telephone circuits linked the stations, just as they do today for all nationwide radio and television programs.

Everyone became spellbound listening to sports broadcasters like Graham McNamee giving such colorful play-by-play accounts that it was almost better to listen in at home than to be at the ball game in person. Babe Ruth, the homerun king, was a national idol.

At first there was great fear among the newspaper publishers that people would no longer buy papers when they could hear the news over the radio. Also, radio was beginning to use commercials, short spot announcements at the opening and close of programs, which the newspapers felt would mean less advertising dollars for them. So the newspapers refused to print the radio program schedules.

At this point, Henry W. Dickow came to the rescue. You may remember him founding the San Francisco Radio Club at age 12. Now, as the publisher of a radio magazine, Dickow filled the need for printed radio schedules by producing *Broadcast Weekly*. This radio guide (similar to the *TV Guide* of the 1960's) was so popular that in some weeks a quarter of a million copies were sold. By 1929 the newspapers climbed on the radio bandwagon and began to carry not only radio program schedules, but special radio news columns and even how-to-do-it articles for radio amateurs.

The amateurs' transmitters interfered with the commercial uses of radio, including some interference with broadcast reception which was particularly annoying to the hams' neighbors. Across the nation influential citizens and radio manufacturers and broadcasters began to bring pressure to bear on the government to put the noisy amateurs off the air.

At Stanford University there were some enthusiastic radio hams, among them Herbert Hoover, Jr., who had grown up on the campus in the Hoovers' home there. Young Hoover's father was now the United States Secretary of Commerce. It just so happened that the Department of Commerce regulated all radio activity in the United States. The amateurs found a real friend in Herbert Hoover. He saw the great value to the country of the thousands of skilled radio craftsmen, during both war and peace. So he defended their interests.

The American Radio Relay League had been organized in 1914, establishing an official organization for all the nation's amateurs. When it held its first national convention in 1921, Herbert Hoover told them, "The Department of Commerce is, by authority of Congress, the legal patron saint of the amateur wireless operators. Outside of its coldly legal relations the Department wishes to be helpful in encouraging this important movement." The great freedom enjoyed by American hams today, as compared with hams in other countries, is due in no small measure to the early efforts of Herbert Hoover. Also, because electronics engineers and technicians so often choose such careers through an interest in ham radio, it can be said that Hoover did much to assure the growth of electronics in the United States.

In 1927 Harold Elliott, a Stanford electrical engineering graduate who had worked for the Federal Telegraph Company in Palo Alto, invented a single-dial radio receiver which made tuning much easier. Instead of having to turn several dials to find a station, Elliott's mechanical tuning system enabled one to tune with just one knob, as is done today. It was advertised as "so simple a woman can operate it." Other single-dial tuners had been developed, but Elliott's design was well suited for mass production. It was adopted by the Radio Corporation of America (RCA) for its home receivers, of which Americans bought thousands.

Americans' enthusiasm for radio seemed to know no bounds. In 1926, there were 536 broadcasting stations and 4½ million radios in the United States.

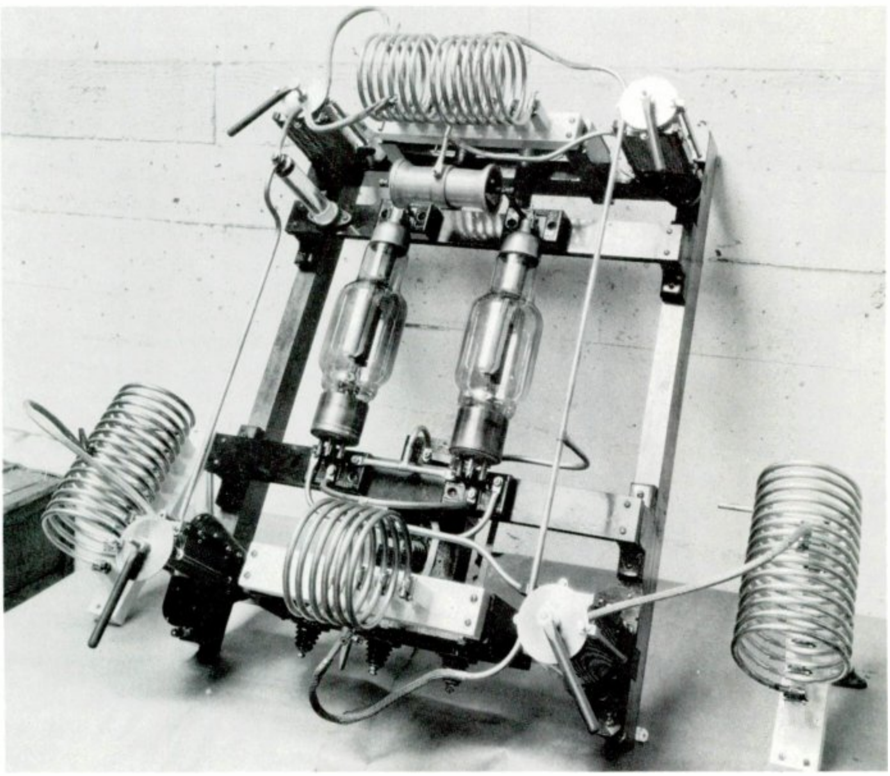
By 1928, over 10 million receivers were in use in America. This was as many as were used in all the other countries of the world combined. And yet, the next year, over 800 million dollars worth of additional radios were sold in the United States.

On March 1, 1929, the *San Francisco Chronicle* carried an advertisement by the Sherman, Clay and Company music store, which had, you may recall, helped Charles Herrold pioneer radio broadcasting 20 years before: "For the first time in history, the world will hear the inaugural ceremonies. If you have no radio, there is time to get one by March 4." The ad stated that only a small down payment would be necessary. Many sets were sold, and California listeners were especially interested to hear from Washington, D.C., the voice of the thirty-first President of the United States as he took his oath, "I, Herbert Hoover . . ."

Of the many changes occurring in the tumultuous Twenties, perhaps none had such a direct impact on the life of the individual American as the advent of radio broadcasting. In 1920, radio broadcasting was almost unheard of beyond those who knew of "Doc" Herrold's station. Ten years later, one out of every three homes, from tenements to mansions, boasted a radio. Isolated farmers and crowded city dwellers, school teachers and sharecroppers unable to read a newspaper, all were listening to the same news, laughing at the same comedians, judging the same political speeches, "attending" the same symphony concerts. By 1930, many of America's scattered millions had become one vast, impressionable audience with more in common than they had ever had before.

SHORT WAVES FOR LONG DISTANCES

After World War I, amateurs, Marconi, and others were investigating communication by short waves. Amateurs were forced by law to operate under 200 meters, but by November, 1923, they successfully spanned the Atlantic on 100 meters! Marconi and his colleagues found that daylight range increased greatly as wave length was decreased. And of course with wavelengths reduced to between 20 and 40 meters, it was possible to signal over long distances with smaller antennas and only a fraction of the power used by long-wave stations. During October, 1924, reliable signals on 32 meters were received in Australia from England—halfway around the globe! World-wide communication with low power transmitters was an exciting breakthrough, and a hint of today's conversations with astronauts.



This 500-watt transmitter, designed in 1925 by Ralph M. Heintz for M. R. Kellum's yacht, *Kaimiloa,* was one of the first mobile short-wave radios to be installed on a ship in the Pacific. There were no shoreside commercial short-wave stations.

In the Twenties, big, slow-spoken Ralph Heintz became known as the man to see for short-wave and other advanced radio equipment. He also had the reputation of being one of the finest electromechanical designers in the country. Heintz and the men who worked with him particularly enjoyed attempting the new and unusual. As a result, Heintz and Kaufman, Ltd., was able to equip the adventurers of the period with communications apparatus that was as record-making as the adventurers themselves.

In 1925, Heintz was asked by wealthy Medford Kellum to provide short-wave communication equipment on his yacht, the *Kaimiloa*. Kellum liked to visit among the tropical islands in the Pacific and felt the short-wave radio would be an improvement over the *Kaimiloa's* spark set which his commercially licensed operator, Fred G. Roebuck, used to keep contact with other ships and with land stations. The *Kaimiloa* was one of the first ships in the Pacific to have short-wave radio. After the apparatus was installed, Kellum embarked on a long trip, with plans to land at Fanning Island, north of Fiji. However, he arrived at the island on a dark and stormy night, and couldn't find the lagoon which was the only safe place to anchor. The island was inhabited by about 100 natives and 14 cable operators.

Unless the operators were expecting a supply ship, they didn't turn on the lighthouse light or those that marked the entrance to the lagoon. The seas grew rough and the *Kaimiloa* was in danger of being shipwrecked. Fred Roebuck tried to get the cable operators by radio but, like the lighthouse, the island radio wasn't operated unless a supply ship was expected.

Roebuck decided to take a wild chance. He put out a call on his short-wave radio hoping to catch an amateur listening in somewhere. In a matter of minutes, he had a reply from "Bart" Molinari, a ham in San Francisco who had picked him up on *his* short-wave radio, 4,000 miles away. Roebuck could hardly believe his luck. He knew Bart and told him to telephone Ralph Heintz. Heintz went immediately to a cable office and sent a message to Fanning Island: "Turn on your light!"

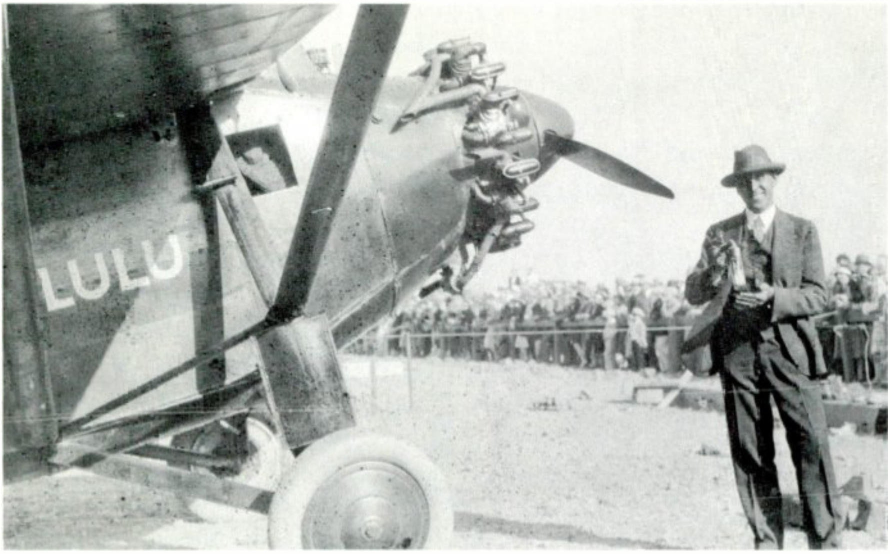
Within 40 minutes from the time Roebuck sent out his call the surprised cable operators on the island turned on the lighthouse light and watched the *Kaimiloa* sail safely into the quiet waters of the lagoon. Ralph Heintz's short-wave radio was hailed as a lifesaver, and so was Bart Molinari. It was a title to be earned by many amateur operators, especially when floods, earthquakes, or other emergencies made commercial phone or radio service impossible.

The 1920's were years of airborne adventurers, flying for fame and fortune, "barnstorming" at fairs, entering cross-country contests, and exploring, literally, the ends of the earth. These aviators came to Ralph Heintz for the lightweight, short-wave radios he made so well. Heintz and Kaufman built complete systems, including generators, transmitters, and receivers. Later they designed and produced some very special vacuum tubes.

The *Pabco Flyer* was perhaps the first plane in the world to be equipped with short-wave radio. This wireless telegraph system was designed by Ralph Heintz and built by Heintz and Kaufman, Ltd. The plane was to fly from the Oakland airport to Honolulu in a race sponsored by James D. Dole of pineapple fame. The "Dole Flight" of August, 1927, was the longest, most dangerous air event that had ever been held.

The San Francisco *Call and Post* sent a reporter, Carroll Peeke, up in a United States Army Douglas observation plane to watch the contest planes take off and to send wind and weather reports from as far out as the Farallone Islands, 33 miles from the coast, by "wireless telephone" direct to *The Call* office. Here Earle Ennis, now on the staff of *The Call* and described by his paper as "one of the earliest of radio men and the first to send code from a plane in the days of the Tanforan air meet," sat with headphones and typewriter writing the news as it came from the airborne reporter and relaying the weather reports to the Oakland airport.

The *Pabco Flyer*, a bright orange monoplane built in San Francisco and piloted by Major Livingston Irving of Berkeley, cracked up on its take-off on August 17, 1927. No one was injured, and Ralph Heintz and Fred Roebuck, who now worked for Heintz and Kaufman, salvaged and installed the radio on the *Dallas Spirit*. The pilot, William Erwin of Texas, had won the Distinguished Flying Cross in World War I. He and his radio operator, Alvin Eichwaldt, had started on an even longer



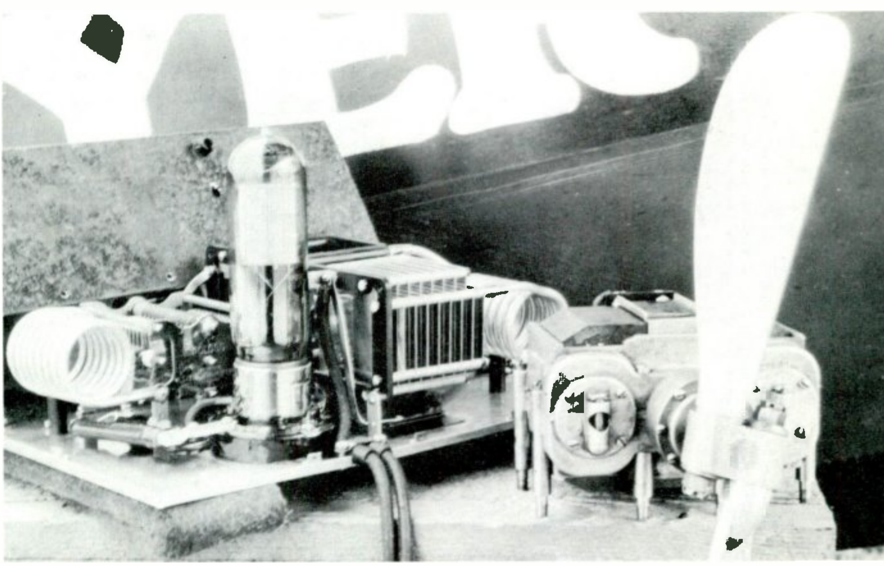
Ralph Heintz holding a 50-watt "Radiotron" tube from what may be the first short-wave transmitter to be installed on an airplane—on the *Pabco Flyer* first, a few days later on the *Dallas Spirit*, August, 1927.

flight, planning to go to Tokyo by way of Honolulu, but had been forced to return for repairs. In the meantime, two planes had arrived safely in Hawaii, but two others, the *Golden Eagle* and *Miss Doran*, were reported missing. The latter had a woman passenger, for whom the plane was named. A reward of $40,000 was offered to anyone finding the missing five persons. Erwin and Eichwaldt decided to take a zigzag route from San Francisco to Honolulu, covering the path the two planes had followed. With their short-wave radio, Erwin and Eichwaldt could immediately notify ships and land stations as soon as they found any sign of the planes or survivors. All ships at sea were alerted to listen for the signals from the *Dallas Spirit*, 33.1 meters, call letters KGGA.

The radio was powered by a wind-driven generator attached to a wing. The antenna streamed out behind the plane. As the little green monoplane with its silver wings took off from San Francisco on August 19, no one dared admit what a slim chance there was of finding anything in that vast, dark ocean. The lost planes had no radio of any kind with which to send or receive signals. And the *Dallas Spirit's* long, zigzag course, off the main route used by the ships, was a particularly hazardous one.

However, the *Dallas Spirit's* crew were in high spirits as those listening in to their coded messages could hear. Ralph Heintz, Fred Roebuck, and Earle Ennis gathered in Ralph Heintz's home where Ralph's wife Sophie had her own ham station with the call letters 6GI. Here Fred and Earle and Sophie took turns keeping a log of every word from the *Dallas Spirit.*

The plane had been out over the ocean for about seven hours when the pitch of the signal became very high. Heintz exclaimed, "They're in trouble! Only a vertical dive could rev that generator up to that note's pitch!" Then came a rush of dots and dashes, "SOS. We are in a tailspin. Belay that. We came out of it O.K. but we are sure scared. It sure was a close call. Bill thought it was all over. But we came out of it. The lights on the instrument board went out and it was so dark that Bill couldn't see things."



Heintz's 33-meter short-wave transmitter and wind-driven 400-cycle alternating-current generator which sent messages for seven hours from the *Dallas Spirit* flying toward Honolulu until the moment when the plane, in a tailspin, crashed into the sea.

The anxious listeners in San Francisco whistled their relief. However, seconds later they heard the pitch of the generator grow higher and louder until it became a shriek. Eichwaldt tapped frantically, "We are in a spin again . . ." The signals wobbled and then suddenly there were no signals, no shrill whine, just an abrupt, final silence. Stunned, the four people in Sophie Heintz's radio room sat staring at one another.

Finally Ennis picked up the phone and called in the tragic news to his paper: "The *Dallas Spirit* is believed lost at sea." The last entry in the radio log for August 19 reads, "10 P.M. Complete silence on KGGA's wave, but standing by balance of night on the possibility of his coming out of final tailspin and putting out spare antenna. By the character of last few signals it was plain that regular antenna had either fouled or become wrapped around tail during spin. Signed: Fred G. Roebuck, receiving operator for Heintz and Kaufman."

Through the long night's vigil, there was no KGGA signal from across the waters of the Pacific which had claimed six men and a girl in this one race.

The tragedies of the Dole Flight forced a realization upon the public, soberly stated by the *San Francisco Chronicle*, "There is a most pressing need for air navigation instruments and improvement in portable radio. Producing these is the job of the laboratory, and the road to travel is long."

Nine months later, with greatly improved radio apparatus designed by Ralph Heintz, Charles Kingsford-Smith and his crew made the first successful flight across the Pacific to Australia. They left Oakland on May 31, 1928, and arrived in Sydney, Australia, on June 9, after stops in Honolulu and the Fiji Islands. In his report of the trip, Kingsford-Smith said, "Our radio equipment had been praised by every expert on the West Coast of America, and was declared to be the finest ever installed in aircraft. . . . We could send and receive both long and short wave lengths. The short-wave communication was used mostly for communication with shore stations, and the long wave for the reception of the radio beacon signals communication with vessels at sea, securing radio bearings, etc. . . . Our biggest safety factor was a special emergency radio transmitter which was completely watertight. The aerial for this transmitter could have been lifted by means of a kite or gas balloon, three or four of which we carried. This emergency transmitter is battery actuated, the rest of our radio equipment being operated from two air-driven generators."

In 1929, Admiral Richard E. Byrd flew to "Little America" to conduct a daring expedition across windswept, frozen reaches to the South Pole. The explorers sent daily reports to the United States from both planes and ground stations by short-wave radio equipment designed by Ralph Heintz and built by the engineers and technicians at Heintz and Kaufman in San Francisco. Even the dog-sled teams, pushing through blizzards to rescue stranded airmen, used Heintz's short-wave radios. Receiving the dramatic news each day from the Antarctic, San Franciscans and New Yorkers felt they were sharing those adventures, but in the snug comfort of heated homes.

During the same year as this Byrd expedition, the Dollar Steamship Company formed a wireless telegraph company, Dollar Radio, later becoming Globe Wireless, to handle their ship-to-shore communications. Ralph Heintz was asked to design the radio equipment. (The manager of Globe Wireless, Jack Kaufman, had known Ralph Heintz since college days and had joined Ralph as a partner in 1924, when Heintz's company became Heintz and Kaufman, Ltd.) Heintz's short-wave apparatus was installed in stations in Los Angeles, Portland, Seattle, New York, Hawaii, Manila, Guam, and Shanghai, as well as on the ships owned by the Dollar Steamship Company.

Later, Jack Kaufman went on to make significant contributions to electronics, and was made a Fellow of the Institute of Electrical and Electronics Engineers in recognition of his work in vacuum tube research. The Globe Wireless Company served the steamship company and the public for many years and eventually became part of the International Telephone and Telegraph Company.

In the late Twenties, Thorpe Hiscock of Boeing Airlines asked the Heintz and Kaufman company if it could equip their planes with short-wave radio for voice transmission. Like other airlines, Boeing had started as a mail-carrying service. The planes took mail between the Oakland airport and airports in Oregon, Washington, Wyoming, Nevada, and Illinois. Inevitably, some brave souls asked to come along as passengers, sitting on the mail sacks. Boeing put in a few seats for them, then a few more. With heavier mail and passenger responsibilities, two-way voice communication between air and ground became a necessity. Heintz and Kaufman equipped an experimental plane and all the airports used by Boeing. As far as Heintz knows today, this was the first time such an airborne short-wave radio-phone system was used. Its success paved the way for others.

All of the experience Heintz gained in the Twenties and Thirties was to prove of great value to his country later, during World War II. With a friend, Bill Jack, he organized a new company in 1940, Jack and Heintz, Ltd. The company moved to Cleveland, Ohio, where it employed over 9,000 people.

Another pioneer in short-wave transmission in the Twenties was Frederick Kolster, whom we have met as the inventor of a radio compass. In 1928, while at Federal Telegraph in Palo Alto, Kolster began to experiment with directional antennas, employing extremely short waves. Instead of the usual radio signal broadcasting which went out in all directions like ripples in a pond, Kolster sent the signals out in one direction, like a flashlight beam. To do this, he put a reflector behind the beam, something like the shiny reflector behind the light bulb in a flashlight. The antenna could be revolved in a circle and tipped at different angles. Thus the beam of radio signals could be "aimed."

Of course, such "aiming" wasn't new. Heinrich Hertz, the first man to demonstrate the existence of electric waves, had shown that they could be focused and directed. He used mirrors of zinc to reflect his waves. To be efficient, a reflector must be several wavelengths in diameter. For long radio wavelengths, reflectors have to be large and are too expensive. Thus, when very short waves came into use, reflectors became practical. During the Twenties, scientists were investigating the possibilities of radio beam transmission.

Kolster used what were considered very short waves, about three meters long. His work was merely an experimental attempt, but you can see the successful "descendants" of such early reflector antennas as Kolster's on the hills behind Stanford University today. These lacy, metallic "dishes" glistening in the sun are able to catch the signals sent from satellites and space ships in outer space.

ELECTRONICS AT STANFORD

The 1920's saw the beginning of instruction at Stanford University in the new postwar radio science, based on vacuum tubes. The University of California and others across the nation also started similar courses. In 1924, Stanford established a "Radio Communications Laboratory" in an attic in the electrical engineering building. The head of the electrical engineering department, Dr. Harris J. Ryan, was an enthusiastic supporter of the radio students. A much-loved professor, Ryan was world-famous as a pioneer in high-voltage electric power and radio frequency insulation.

In 1925, Stanford appointed one of its young graduates, Frederick E. Terman, to teach in the new laboratory. It was an appointment with far-reaching consequences. The son of a Stanford professor, Fred Terman had grown up on the campus. He was highly organized, efficient, and gifted. Everything he did, he did thoroughly. As a boy he and Herbert Hoover, Jr., had built an amateur radio station. Terman's interest in radio continued during college, and eventually his hobby led to his

Frederick E. Terman talks with a student in 1940 when he was head of electrical engineering at Stanford University. Terman later became Dean of Engineering, then Provost of the University. He is given much credit for the development of the Bay Area as a world-renowned center of electronics research and industry.

life work; he was, in fact, to become an international authority on radio engineering.

After graduation from Stanford University in 1920 with a degree in chemistry, Fred spent some months as a laboratory assistant at the only electronics company in the Palo Alto area, Federal Telegraph. At this time, Haraden Pratt (whom you may remember on the Campanile at Berkeley) was acting chief engineer, supervising the rebuilding of Federal's chain of stations which had been taken over by the Navy during the war. Stimulated by this experience, Terman returned to Stanford for a degree in electrical engineering, and later went East to the Massachusetts Institute of Technology for his Sc.D. degree. It was on his return home that Stanford offered him the job at the laboratory.

Soon the "radio lab" became the gathering place for bright electronics-minded men at the University. (Terman later affectionately described this new breed as "electronics nuts, those young men who show as much interest in vacuum tubes, transistors, and computers as in girls.")

Following his first year of teaching, Terman was put in charge of the laboratory. Under his dynamic direction the crudely equipped attic lab developed over the years into the now internationally known Stanford Electronics Laboratories. Terman established close relations with the few electronics companies in the University area, and encouraged his students and others to start their own businesses there. Stanford assisted local electronics inventors and enterprises in many ways, and gradually both scholars and industries were drawn to the region. Eventually Stanford was training more graduate electronics engineers each year than any university in the United States. Bay Area electronics leaders, in turn, donated millions of dollars to the school.

During the more than forty years that Terman was at Stanford, the school made vital contributions of both men and ideas to the Electronics Age. When Terman retired in 1965 from duty at Stanford (most recently as Vice President), he was honored by the community as the man who, more than any other single person, was responsible for the Bay Area becoming a world-renowned center of electronics industry and research.

ELECTRONICS COMPANIES BORN IN THE 1920'S

The Johnson-Williams Electronic Nose – the Gas Sniffer

In addition to the companies we have already mentioned, there sprang up after World War I a number of small firms based on original inventions. The oldest existing one of these in Palo Alto was founded by Oliver Johnson and Philip S. Williams in a garage at 430 Tennyson Avenue in 1927.

These two engineers from Stanford were employed by the Standard Oil Company of California, where part of their work involved controlling explosion and fire hazards. The oil company faced the same life-and-death problem that mines, ships, and fuel-handling companies were facing in an ever-increasing degree: how to detect the presence of invisible, combustible, often odorless, gases which can accumulate without anyone being aware of them until they cause an explosion. In the past, dogs were trained by miners to howl when they sensed certain gases. Even canaries were used, being especially sensitive. Various types of detecting devices had been attempted, but none was widely useful. As industry expanded and the automobile "boom" brought about increased storage and shipping of fuel, explosions due to undetected gases grew alarmingly more frequent.

Johnson and Williams designed a portable instrument for Standard Oil's use that could make fast, accurate measurements of the presence of combustible gases. The company felt that the invention was so valuable that they encouraged the men to develop it for other industries to use. The inventors were thus able to continue to work for Standard Oil – which they did until they retired 34 years later – at the same time operating their own company. They called their company Johnson-Williams and their invention the "J-W Sniffer." The Sniffer was constructed so it would blow a sample of the air being tested over a specially prepared wire through which electricity was flowing. This special wire was made to react chemically when even a tiny amount of the combustible gas came into contact with it; this chemical reaction caused the wire to get hot. The increase in the wire's temperature changed its electrical resistance, and the effect of this change could be instantly read on an electrical meter. It could also be made to trigger a bell or blow a horn in warning.

Word of this much-needed new instrument quickly spread. The two engineers suddenly found themselves with a thriving business and customers in nearly every country in the world. With the Sniffer, literally hundreds of precise observations can be made in the time one unreliable result might be obtained with previous methods of gas detection. The Sniffer can keep watch in tanks, ships, trucks, manholes, underground tunnels, sewers, paint and plastic factories, and laboratories.

Utility companies no longer dig up hundreds of feet of busy streets to expose gas lines in searching for leaks; with a Sniffer at hand they test a series of tiny holes neatly drilled in the paving, chart the results, and locate the point of leakage precisely.

It is now a rule that every United States petroleum tank ship must carry an instrument like the J-W gas detector.

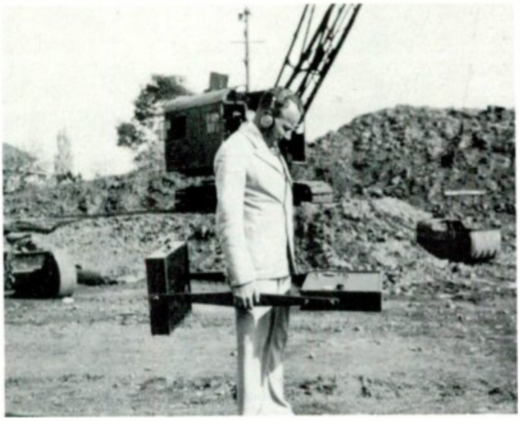
While the original invention was not an electronic instrument, a whole family of electronic devices to be used with the basic Sniffer has been developed by Johnson-Williams. At present the company's automatically operated gas-detecting systems are protecting men and equipment from Cape Kennedy in Florida to the world's longest atom-smasher, at Stanford University.

Although Johnson-Williams remained small compared to some of the pioneer electronics companies in the West, its contribution to mankind has been substantial. Lives have been saved, research has been aided, and human capability has been extended dramatically by this sensitive "nose."

Electronic Eyes to See the Unseen

Another "garage inventor" was an enterprising, energetic young man from Germany, Gerhard R. Fisher. As a boy he had a keen interest in radios, taking them apart and fitting them back together with care. When he came to America he first worked for Lee de Forest's company in New Jersey. The West lured him, and he made the long trip across the United States on an old motorcycle in 1926. Considering the roads and the motorcycles of those days, this was quite an accomplishment.

Fisher worked for the Federal Telegraph Company in Palo



Gerhard R. Fisher using his M-Scope to locate Palo Alto's underground utility pipes when the University Avenue underpass was built beneath the railroad tracks, 1939.

Alto for a time, where he assisted Frederick Kolster in building directional antennas. Then in 1928, in the garage of his home at 1505 Byron Street, he invented what he called the Metaloscope, or M-Scope. This is a device that can detect metal such as pipe or gold or explosive land mines, lying as deep as 20 feet underground.

The M-Scope is composed of a small transmitter which feeds current into a rectangular coil of wire at the back end of the M-Scope carrying frame. At the front end a receiver is connected to another coil of wire. The operator walks along with the device held parallel to the ground. When the magnetic field set up by the coil in the transmitter strikes buried metal, the field is distorted or pulled out of shape and some of the magnetic lines pass through the receiver coil. This sets up a current in the receiver which results in a high-pitched buzz being heard in the earphones of the operator. The presence of metal can also be registered on a meter carried by the operator.

From the very beginning, the M-Scope has enjoyed wide use and praise from a variety of customers. It is standard equipment on many cities' gas and water trucks, for it can trace buried pipes and also find leaks in them. Murderers have been caught because police were able to find bullets and guns in snow or water, or hidden behind brick, wood, or plaster walls. Warning buzzes from M-Scopes have revealed buried artillery shells, often saving lives. Miners all over the world have found the M-Scope invaluable in locating silver, gold, zinc, and copper.

Perhaps most enthusiastic of all the M-Scope users have been the treasure hunters, both professional and amateur. "In the first 10 days," wrote one, "I located $72,000 in buried money, near New Orleans, believed to be pirate loot."

In 1929, Fisher invented a radio direction-finder which enabled planes and ships to know where they were and how to find their way home. Two years later, Fisher had the thrill of demonstrating this apparatus on a cruise with a fellow German-born scientist, Dr. Albert Einstein.

In 1936, Fisher organized the Fisher Research Laboratories in Palo Alto, which produces a variety of electronic products, including radio telephones and marine radios. Its short, fast-paced founder, with 19 patents to his credit, is still directing the company 30 years later with the same bounce and verve that characterized the young immigrant who motorcycled across the nation on the rough roads of the Twenties.

Dalmo Victor Gets Its Start As a Job Shop

While the years between 1920 and 1930 have been called "The Roaring Twenties," they could with as much accuracy be called "The Electrifying Twenties." Everything became electric: flatirons, iceboxes, toasters, stoves, washing machines, carpet cleaners. Women, who had just been given the right to vote in 1920, were offered other forms of emancipation: easier housework and freedom from daily marketing. And the daring ones who "bobbed" their hair could get it curled electrically, "permanently."

One of the men who helped in this minor revolution was Tomlinson I. Moseley. As a boy in Tamalpais High School in Mill Valley, California, Tim Moseley had been the student foreman of the school's excellently equipped machine shop. In 1921, when he was just 19, he established his own company, the Dalmo Manufacturing Company, in San Francisco. This was a job shop where Tim built such things as permanent-wave machines, thermostats, and electric dental equipment, even an electric toothbrush. His customers found that the soft-spoken young machinist often had clever suggestions to improve their designs. His business thrived. Soon he was patenting and producing his own inventions.

During the years of World War II, Tim Moseley's company, now called the Dalmo Victor Corporation, moved to Belmont, on the San Francisco Peninsula. There was an urgent need for airborne radar equipment on military planes. Dalmo Victor developed one of the first successful airborne radar antennas, became the nation's leading manufacturer of such antennas, and thus found itself prospering in a new field, electronics. In 1966 it was producing 90 percent of the nation's submarine antennas and was preparing the communications antenna system for the first U.S. spaceship to the moon.

Charles Litton and His Glass-Blowing Lathe

Among the many Bay Area radio hams in the Twenties who later became leaders in electronics was a tall, lanky fellow named Charles V. Litton. He built his own ham set when he was 10. At Lick-Wilmerding High School in San Francisco he received both trade school and college preparatory training.

At Stanford University, Charles Litton met other radio amateurs. With Phil Scofield (who later spent many years with Ralph Heintz as his highly valued chief engineer), he put up two 100-foot towers near Litton's home in Redwood City which enabled them to talk with Australia and New Zealand. The young men made their own radio parts, including a power generator. Litton even learned to blow glass vacuum tubes. His tubes were so good that he was able to sell them to fellow amateurs. He decided to make the production of tubes his life work.

In 1928, Litton was given the job of building and managing a department of the Federal Telegraph Company which would make glass vacuum tubes. There was one large hurdle to be overcome. The Radio Corporation of America (RCA) had been formed through the pooling (sharing) of most of the vacuum tube and radio patents of several companies including General Electric, Wireless Specialty Apparatus, American Telephone and Telegraph, and Westinghouse. This made it very difficult for a new company to make tubes or to compete in the radio communications business. However, 23-year-old Charles Litton was able to devise means for the manufacture of tubes that were so different they could not be considered to infringe on any existing patents. This drew grudging praise from the surprised RCA patent attorneys, for many older men had tried unsuccessfully to get around these radio patents. This and other Litton inventions made it possible for Federal to equip the Mackay Radio and Telegraph Company with the tubes it needed to push ahead with its international communications system. (By 1928, Leonard Fuller was Vice President of Federal, and Haraden Pratt was Vice President of Mackay. The two companies merged that year with the International Telephone and Telegraph Company.)

Today Litton claims, "I was just a lucky kid," but fellow engineers like Fuller and Pratt say, "He was a gifted designer who could do the seemingly impossible with metal and glass."

The first short-wave transmitting station built by Federal for Mackay in Palo Alto is still in operation. As you drive past the city along the Bayshore Freeway, you can see its acres of towers and antennas, apparently so silent yet sending a constant stream of messages across the ocean to foreign lands.

When the Federal Telegraph Company moved East in 1931, Charles Litton started his own business in Redwood City, later moving it to San Carlos. Litton Engineering Laboratories produced an ingenious invention of Litton's: a lathe or tool which could make glass radio transmitting tubes of uniform high quality, quickly and in great numbers. This was an important contribution, for there was an urgent demand for such tubes. Litton Labs became and still is the leading source of precision glass-forming machinery in the United States.

In 1940, Charles Litton expanded his laboratories to manufacture vacuum tubes. During the next few years the company worked hard supplying America and its allies with machines and tubes during World War II. At the end of the war, Litton says, "I woke up one day, and out of a clear blue sky I suddenly found myself the sole owner of a million-and-a-half-dollar concern."

In 1946, Litton Industries was formed as a corporation for the purpose of eventual separation of the tube business from the machinery business. By the end of 1953 the expanding tube company was sold. Litton Industries continued to grow until it has become one of the largest electronics companies in the world.

Charles Litton moved his first company, Litton Engineering Laboratories, to Grass Valley, California.

A distinguished engineer, noted for his conservative observations, says of him, "Charlie Litton is without a doubt one of the cleverest men in his field in the world."

OTHER MILESTONES IN THE TWENTIES

While the 1920's saw great activity in the field of radio and electronics in the San Francisco Bay Area, there were far-reaching events taking place elsewhere in the United States. For example, on April 12, 1923, the Rivoli Theater in New York held the first public showing of talking motion pictures, made possible by Lee de Forest's newest invention, sound-on-film.

An event also notable for its sound effects took place in March, 1926. A mild-mannered, little-known physics professor fired off a noisy, smoky contraption in Auburn, Massachusetts. Local citizens seemed completely unimpressed with the fact that Dr. Robert H. Goddard (later to be hailed as the Father of Modern Rocketry and the Space Age) had just shot off the world's first liquid-fuel rocket. It was about four feet high and lifted 42 feet off the ground. In July, 1929, he sent up a larger rocket near Worcester, Massachusetts. This one went faster and higher than the first – and was noisier. The alarmed inhabitants of Worcester demanded that he cease such dangerous activity. As a result, he was officially forbidden to do any further experimenting in that state. Dr. Goddard was careful not to tell anyone the goal he had in mind: to build rockets so powerful they would enable men to fire themselves off to the moon. The good townspeople of Worcester would have thought him dangerous indeed!

In the same year of the Twenties that Goddard launched his first rocket, another breakthrough was taking place. In a crudely equipped laboratory in San Francisco, a 20-year-old country boy was working on a sophisticated electronic invention that was to change the eating, living, and learning customs of many millions. His name was Philo T. Farnsworth.

In the language of science fiction, let's turn our time machine back to 1917 and look in on Philo when he was 12 years old.

"I propose to do it by wholly electrical means"

Chapter VII

"THE GREEN STREET LAD"

It was three o'clock in the morning. The farm was utterly quiet. Black velvet darkness shrouded the Idaho landscape. Inside the farmhouse, however, in a pool of light, sat a thin, intense boy, hunched over a round dining-room table. Sheets of paper, each covered with drawings and numbers, littered the table and floor. The boy ran his long fingers through his hair, pushing it back from his high forehead. He bent over his drawings again. There was a stir in the hallway, and his mother appeared at the door, holding her bathrobe closely around her against the chill of the air.

"Don't you think you should come to bed, Phil? It's nearly time to get up."

"I'm almost finished, Mama. I've just designed a thief-proof ignition switch for automobiles. It's a Jim Dandy, and I'm sure it will win a prize!"

It did. The prize awarded by the magazine *Science and Invention,* which held the nation-wide contest, was $25. Phil was jubilant. For years he had secretly hoped that he could become an inventor. Now he knew he *was* an inventor. Feeling ten feet tall, he used part of the $25 to buy his first pair of long pants. For what few people knew was that the designer of the ingenious, prize-winning automobile switch, Philo T. Farnsworth, was only 12 years old, a farm boy whose family had never owned an automobile. When Phil and his family had moved from Utah to Idaho two years before, in 1917, they traveled with horses and wagons.

The farm in Idaho was different from the other farms where the Farnsworth family had lived. It had electricity, produced from its own generator. Phil was intrigued with this machine. He soon understood it well enough to repair it when necessary (and even, his father suspected, when it wasn't necessary).

One of Phil's many chores was to help with the clothes washing, a boring job, pushing a wooden handle back and forth. Out of old parts, Phil built a motor, winding the electric coils himself. Now the wash could be done electrically! Phil's two brothers and two sisters were impressed. As they worked side by side in the fields with their big brother, he would tell them of the far more wonderful things he planned to invent someday.

Phil enrolled in a correspondence school to learn more about electricity. He eventually became an expert electrician at age 17, but in the process he became intrigued with electrons. What made them do what they did? He began to ask himself questions about the very nature of matter itself.

In 1919, during a total eclipse of the sun, scientists were able to prove the correctness of part of Albert Einstein's theories about matter, time, and space. Since Einstein's ideas were so radically different from those generally accepted, the possible proof of their accuracy was headline news around the world. Phil read everything he could find on the subject of relativity.

The next summer, when Phil was 13, he had some long hours by himself in which to think, for most of his time was spent on a horse-drawn hay mower. Bumping along over the rough ground in the hot sun, he turned over in his mind all that he had been learning about electricity, electrons, and electromagnetic waves. Gradually, he conceived of a way that something might be photographed electronically, the image be sent through the air, and then reconstructed into a picture. It seemed logical, but would it really work? He longed to discuss his idea with someone, but with whom? He was fond of his junior high school teacher, Frances Critchlow, who always encouraged him, but she knew little about electron theories. So Phil kept this dream to himself.

By the time he entered high school, Phil had a workshop in his attic, but practically no equipment. As he rode his horse the four miles to school each morning, he thought about how much he would like to be able to do experiments in the chemistry laboratory, like the older boys in school.

Finally, during his second semester at Rigby High, he summoned up his courage and asked the chemistry teacher, Justin Tolman, if he could enroll late and make up the work of the first semester.

Mr. Tolman laughed at first, hardly believing that the shy, lanky boy could be serious. "Chemistry in this school is open only to seniors," he explained. "It is a difficult subject which requires hard work. Even then, failure is not uncommon. How can you, a freshman, come in here thinking you can carry the regular work of a senior and in addition make up the work that these boys and girls have been struggling with for almost five months?"

The chemistry teacher answered his own question, shaking his head with finality. "Such a thing cannot be done. Come back two years from next September and we will be glad to have you."

Somewhat crestfallen, Phil went away. But the next day he was back again. "Please, Mr. Tolman, why not give me a chance? I'm sure I could do the work."

Philo T. Farnsworth (center) with high school friends, about 1922, when he first dreamed of building an all-electronic television system.

The teacher explained again to him that it was a physical impossibility, and added, "I admire your courage, but I can only laugh at your judgment."

Tolman thought that surely this would end the matter. Not so. The third day Phil came back with a note from his general science teacher stating that the boy had completed a year's work in less than a semester and that he had proved to be an outstanding student.

"Mr. Tolman," pleaded Phil, "why couldn't I just come into the class and learn what I can without receiving credit?"

At this, the teacher reluctantly gave in, feeling that the boy would surely find the course too hard and drop out. In relating the incident later, Tolman said, "I soon learned that his real attitude was, 'If I can just get into that class I will soon show that teacher what I can do.'

"A week had hardly passed," said Tolman, "before I found myself going to school a little earlier in the morning and coming home a little later at night so that this young boy might receive special instruction and have more laboratory time to make up the work of the first semester. This he did in a few weeks time. It was at the end of one of these special classes that he told me of his dreams of a complete television system.

"I do not think a day ever passed that he did not come to me with from one to a dozen questions on science. While these questions covered a wide field, they all seemed to hinge in some way or another around television.

"My answer to these questions was generally, 'I do not know.' However, occasionally, I could give him the information he wanted. Other times I was able to place in his hand books that gave him the information. I recall one of these books had to deal with the cathode ray, and he all but wore it out. Other books dealt with the kinetic molecular theory, the electron theory, a set of twelve books by Croft that dealt with all phases of electricity. These and many others he readily devoured and came back for more."

Besides the cathode ray tube, Phil studied all he could find out about photoelectric materials which release a stream of electrons whenever light hits their sensitive surfaces. The cathode ray tube does just the opposite: it changes a beam of invisible electrons into glowing light. These became the two key elements of Farnsworth's television scheme. He designed a vacuum tube with a light-sensitive surface that would react to the light and dark areas of an object and transmit these as weak or strong electrical impulses. When the phosphor-coated surface of the cathode ray tube received these varying intensities it would glow, faintly in some areas, brightly in the others, to correspond with the number of electrons hitting it. Thus, a picture of the object "looked at" by the first tube would be reproduced by the second tube. And just as radio could transmit sound by first translating it into electromagnetic waves, a photoelectric tube could transmit an image by translating light into electromagnetic signals, and later turn these back into a picture.

The biggest problem was to divide the first image into tiny blocks of electrons to be sent in rapid succession, line after line, just as words are read across a page. The electrons in the photocell had to be manipulated or moved along in an orderly, extremely fast sequence, so fast that they would produce a complete picture because the eye was fooled into thinking it saw all the bits at one instant. Phil worked long hours and finally evolved the idea of a special camera tube which he later called an "image dissector." It had no moving parts. The guidance of the stream of electrons through the tube was done by magnetic coils. He worked out his complete television system on paper, in detail—the magnetic scanning coils, a specially shaped sending tube, magnetic lenses, and many other parts. How he longed to really build one, but there was no equipment in the school for such a project.

At this time, 1922, television was practically unheard of by the general public. There had been some pioneer work done over thirty years before by Paul Nipkow of Pomerania, who had invented a television system using a perforated flat disc, or scanner. His was the basic idea of breaking up the light reflected by an object into small bits, which later could be reassembled to form the picture again. His scanner, which "looked" at the object, allowed points of light to come through a spiral of holes punched in the revolving disc. There was another scanning disc at the receiving end. In the early Twenties, variations of this mechanical scanning method were being used by the few scientists who were experimenting with television here and in Europe. All were heavy, complicated devices which were operated manually, and one had to be an expert to operate them. There was nothing that could be sold commercially for home use. The pictures they produced were crude, and only fairly recognizable. Fifteen-year-old Phil was convinced that what they were trying to do was impossible.

"It can't be done by mechanical means," he told his teacher. "I propose to do it by wholly electrical means, by manipulating electrons."

Phil's original, revolutionary ideas had to remain undemonstrated for some years, however. The Farnsworths moved to Provo, Utah, and in Phil's junior year, his father died and the whole family had to find jobs. Phil worked at various places. Although slim, he was strong, wiry, and had lots of endurance. For a time he was employed as a railroad electrician. He often had to climb around outside the locomotive, in below-zero weather, repairing the generators while the train was on the move. Another tough job was that of log peeling—stripping the bark from aspen trees 12 hours a day for a company that made excelsior from the bark.

He attended Brigham Young University part-time, whenever he could, and was thrilled to be able to work in the physics laboratory there. With the lab equipment, he was able to prove to himself that electrons could be directed magnetically—a fundamental part of his television scheme.

For a time Phil worked for an electrical equipment and supply company in Salt Lake City, Utah. On the job with him was his good friend, Cliff Gardner. Besides repairing electrical products, Phil and Cliff sold new products door-to-door. The radio boom of the Twenties was on, and Phil built some crystal sets and sold a few, but most people wanted the new factory-made, vacuum tube radios.

Cliff had a pretty sister, Elma, or "Pem" as everyone called her, who was fascinated with Phil and his inventive abilities. One night Phil invited her and a few others to hear KPO, San Francisco, on his crystal set. The announcer played a song "requested by Phil Farnsworth in Utah." San Francisco seemed a long way away, and so did Phil's dream of building a television system. Phil and Cliff's sister Pem sang "There'll Be Some Changes Made" around the piano that night, never realizing how soon and how suddenly the changes were to come.

Shortly after this, Cliff, Phil, and Pem found temporary jobs working for two men from California, George Everson and Leslie Gorrell, who were raising funds for the Community Chest in Salt Lake City. The men were impressed with Phil's keen intelligence. One evening, as the campaign drew to a close, Phil confided to them his television plans. As he talked, a change came over the pale, reserved 19-year-old. He was so enthusiastic, self-assured, and confident about his theories that he inspired the two men to help him. Everson knew nothing about electronics, but he felt convinced of Phil's ability.

"Figure what you think it would cost to build a first model of your invention and maybe if the cost isn't too great, we can find the money to do it." Phil drew a big breath and named a huge amount that he was sure would be enough, "Five thousand dollars." This was about the sum total of Everson's savings, but he decided to risk it. (It was to take over a million dollars to perfect the Farnsworth system for public use.)

The three men agreed that the work was to be done in California, and that they would leave right away. Phil then made another bold decision: he wanted to marry Pem and take her with him. Their families agreed, and a happy, hastily arranged wedding took place. The young couple left the following day for California.

Within a few months, enterprising George Everson succeeded in getting the financial support of some San Francisco bankers, James J. Fagan, W. W. Crocker, and Jesse B. McCargar, of the Crocker First National Bank. They looked upon it as a "wildcat scheme," but the spirit of the adventuresome Twenties and Phil's salesmanship prevailed, and they took the chance. To Phil's great joy, he found himself in October, 1926, in a laboratory where he was free to devote his full time and energy to the construction and perfection of his television apparatus. The lab was in San Francisco on the second floor of a two-story building at 202 Green Street, at the eastern foot of Telegraph Hill. (The building still stands at the time of this writing, 1967.) It was to be the scene of endless trials and failures. It was also to be the scene of the first successful all-electronic television transmission.

Pem studied mathematics and drafting in order to help her husband. The historic first drawings, as well as many later ones, were done by her. Pem also did the office work and often helped assemble delicate parts in the lab. Cliff Gardner came out from Utah and joined them in the work. Phil also brought his mother, sisters, and brothers to San Francisco.

One of the most pressing needs in the lab was for specially shaped glass vacuum tubes. Cliff knew nothing about glass blowing, but after months of study and experiment, he was able to produce the tubes as Phil ordered them. Some of his homemade equipment, such as the vacuum pump he built to pump the air out of the tubes, looked like creations from a cartoon of a "mad scientist."

A number of other members were added to the team in the early days, including Robert L. Humphreys who did much of the wiring, Professor Carl J. Christensen of the University of Utah, and Thomas Lynch, whom Phil called a "machinist extraordinary, who never complained at the long hours and exactitude required of him."

Farnsworth holding the first successful electronic camera tube, the type used in the first all-electronic television transmission in San Francisco, 1927, and still used in laboratories today. Moustache was grown to offset his youthful appearance; he was 21.

In the fall of 1927, the first television camera and receiving tubes were ready for the test that would prove whether Philo Farnsworth's ideas of electronic scanning would work. When everything was connected and ready to go, Phil put a piece of glass in front of the camera. On it was painted a black triangle. "This will be our first picture," said Phil.

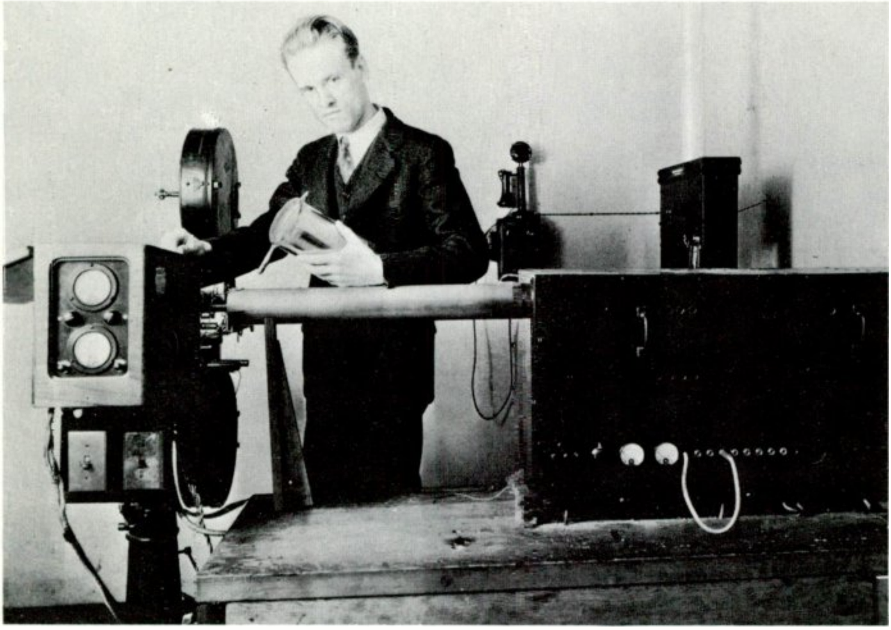
With what tenseness the young inventor, his wife, and his co-workers watched the bluish light come on in the little four-inch television screen! There appeared in the center of it not a black triangle, but a messy, dark blur. George Everson was sick with disappointment, but Phil immediately jumped up with suggestions for adjustments. Hours later, tired but triumphant, Phil and Cliff announced to Everson their success. A fuzzy-edged triangle appeared in the picture field—proof that Phil's theory was correct! The date was September 7, 1927, and it marked the birth of all-electronic television, the method now universally used. The entry in Phil Farnsworth's daily journal for that day reads in part, "Experiment No. 12–Transmission of Pictures. Lines of various widths could be transmitted and any movement at right angles to the line was easily recognized."

This first picture of the triangle was transmitted over wire from one room of the Green Street laboratory to another. Each day improvements were made. On December 27, 1927, Phil's daily log joyously reported, "All lines come over quite nicely up to about 50 lines, which corresponds to 50,000 cycles per second and which gives a breadth of line of the same order as the size of the hole in the Dissector. We demonstrated the apparatus to Mr. McCargar and Mr. W. W. Crocker. Simple pictures can be and have been transmitted."

Pem recalled that, "We all took turns sitting in front of the image tube setup to be televised." Soon they were sending pictures from the lab to the Hobart Building by air, about a mile away.

Now that Farnsworth's ideas of 1922 were proved practical, he applied for patents, and was finally granted them in 1930. One of these patents covered the circuits by which the signals sent by the transmitter were synchronized at the receiver. The electronic scanners at each end (sending and receiving) were kept absolutely in step with each other. The image was reproduced in straight, parallel lines, one under the other, snapping back at the end of each line to start a new one below. It did this so quickly that the observer at the receiving end saw the picture as a whole, almost at the very instant that the object was being observed or "photographed" by the camera tube. This electronic scanning and synchronization made modern television possible.

There followed years of careful development to perfect the system. One of the skilled men who came to help was Russell Varian, an electrochemist. He experimented with phosphors, the chemicals which glow when hit by electrons, trying to find the materials and techniques which would give the most light. He also worked on various kinds of oscillators, or wave generators, for television transmission. He found the research



Farnsworth with the 1930 version of his camera tube, the "image dissector." Apparatus shown is for televising motion pictures from film, anticipating the major part movies would have in TV programs.

stimulating and was able to make valuable contributions to the inventor. Little did either of them realize that a few years later Russell Varian was to be co-inventor of an electron tube that would be almost as world-changing as Phil's television system. (We will hear more of Varian's "klystron" in another chapter.)

As Phil's work became more and more successful, it reached the newspapers. The *San Francisco Chronicle* of September 3, 1928, carried a story with the full-page headline, "San Francisco Man's Invention to Revolutionize Television."

Scientists and professors found their way to Phil's modest laboratory. Men like Dr. Leonard Fuller and Ralph Heintz from industry, and Dr. Frederick Terman and William Hansen of Stanford University, all visited Phil and talked among themselves about the daring and original work of "the Green Street Lad." Even Lee de Forest came. No one was sure that Phil's ideas would prove to be completely practical, but they encouraged the modest, earnest young man and wished him well.

News of Farnsworth's work reached across the nation to the impressive new laboratories of the Radio Corporation of America in New Jersey. There Vladimir Zworykin, a Russian-born scientist, was working on a television system which used an oscillating mirror at the transmitter and a cathode ray tube at the receiver. Dr. Zworykin decided to pay this youthful western inventor a visit. Phil was excited at the prospect. Although he was always concerned about guarding the secrets of his invention, the opportunity to talk to another pioneer in this new form of communication was too appealing to resist. Zworykin was one of the few men in the world at that time who could understand Phil's ideas or who could evaluate what he had done.

The visit was a happy one for the two rival inventors. For days they were in constant conference. Dr. Zworykin had previously invented an electronic method of scanning an image, but it had not been successfully developed. He looked at Phil's scanning device, the "image dissector," with thoughtful admiration. With his Russian accent he said to Phil, "Your deesector eez marvelous. I veesh I had invented eet."

Zworykin also carefully noted Cliff's glass-blowing results. Phil assured him that Cliff deserved all the credit for the complicated work. Zworykin then told Cliff with some frustration in his voice that the expert glass-blowers in the East had assured him that such bonding together of odd shapes and materials was impossible.

When Zworykin returned to the RCA laboratories, he put aside his mechanical scanner and devoted his efforts to developing his own ideas for an electronic television system. His electronic scanning tube proved to be very successful. However, Farnsworth's early concepts were so basic that every manufacturer of television, even RCA, had to be licensed by "the Green Street Lad." Don Lippincott of San Francisco, an engineer turned patent attorney, provided Phil with invaluable help, protecting the young inventor with double-edged skill. Soon Lippincott was devoting all of his time to Phil's patents. They became close friends.

Stimulated by Dr. Zworykin's praise, Phil continued his research with new zest. His inventive mind led him to develop

In October, 1929, two years after their first transmission, the picture looked like this. Before it was perfected, a million dollars was spent in research and development.

By 1939, the Farnsworth system was producing pictures of this quality, and Don Lee's television station in Los Angeles was on the air. Further work on television was halted during World War II.

and patent many devices in the general field of radio and electronics, in addition to television. One of his most dramatic inventions was what he called a "multipactor." This was an electron tube in which electrons were "bounced" back and forth between two cold or unheated cathodes. The impact knocked additional electrons from the cathodes, causing a terrific multiplication or increase of current. A single electron built up or "created" billions of electrons in a billionth of a second. The multipactor was of great interest to the scientific world, and young Phil was invited to deliver a talk about it to the scientists of the Franklin Institute in Philadelphia.

In 1931, arrangements were made for Phil to move most of his laboratory to Philadelphia, where the Philco Company was to manufacture Farnsworth television sets. Philco was then the largest manufacturer of radios in the United States. Two years later, Phil and his San Francisco backers established their own laboratory in Philadelphia.

By 1934, Phil had brought his apparatus to a high point of development. His pictures were quite clear. The Franklin Institute asked Phil to make a public demonstration of his television system, at the Institute. For ten days Phil and his staff put on the first electronic television shows ever staged purely for public entertainment. They had little experience as showmen. As Farnsworth's wife related later, "The problems presented by a continuous program and a new audience every fifteen minutes were endless. We brought in trained bears, puppet shows and ventriloquists. One of our best troupers was Dr. Swan, Director of the Bartol Institute, who played his cello until the hot lights almost blistered its varnish. Perhaps the most popular of all was being televised yourself and seeing your friends over television."

The programs were shown in an auditorium holding about two hundred people. Morning, noon, and night the television receiver in the auditorium glowed with "live" pictures. Two Davis Cup stars, Lester Stoefen and Frank Shields, and Billy Herman, Jr., an Olympic tumbler, performed. Sometimes on clear days the guests were televised on the roof of the Institute or out on the lawn, but mostly the shows were photographed in an inside studio. When they ran out of program material, they just pointed the camera at the traffic in the street below.

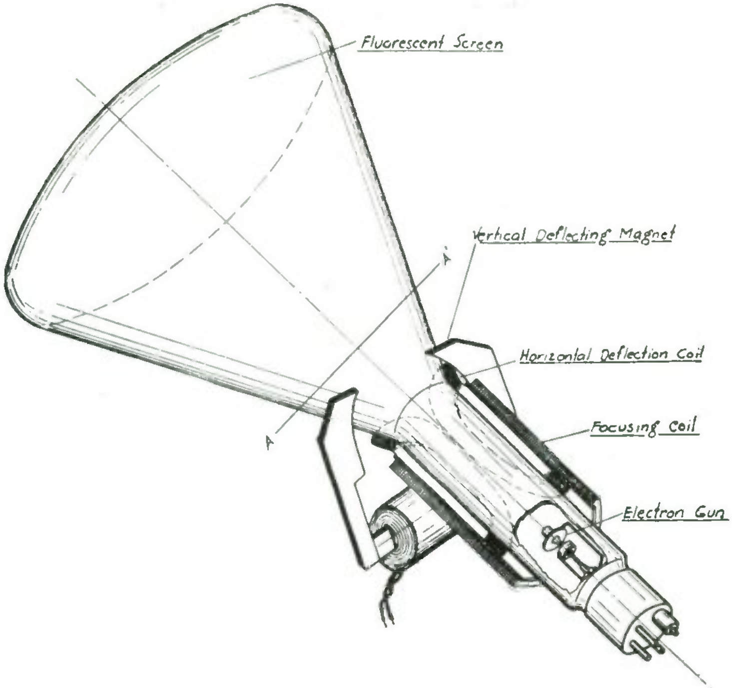
One clear night they had a special showing of the moon. A San Francisco paper announced the next day, "First recorded use of television in astronomy was announced yesterday in Philadelphia by Philo T. Farnsworth, young San Francisco scientist. And it was the man in the moon that posed for his first radio snapshot. The picture of the moon was taken as the ultimate test of the supersensitivity of Farnsworth's television invention."

Earle Ennis praised Farnsworth's achievements in a long article in the *San Francisco Chronicle* headlined, "S.F. Genius Perfects System of Television After Years of Study. Philo T. Farnsworth Offers Device Which Waits Business Recovery for Use Commercially." He described the system in detail and then concluded, "Television has added one more laurel to the honor of the great city, San Francisco, already building two giant bridges to bring the world to its doors. . . . Out of a San Francisco laboratory has come a system for . . . which hundreds of engineers have striven all over the world. It remained for a man who claims San Francisco as his home to achieve it."

Phil's fame spread abroad, and in the fall of 1934 he was invited by the leading television companies in England and Germany to demonstrate to them his electronic system. As a result of his presentations, the English Parliament was asked to appropriate funds for the British Broadcasting Company to establish television service for the London area. Two English and German companies drew up contracts with Farnsworth giving them permission to use the American's patented inventions.

There were years more of research necessary before all-electronic television was to be ready for widespread public use. Unlike radio, it was too difficult and expensive for most young amateurs to develop. Finally, by 1941, several large companies, the Radio Corporation of America and others, were ready to put television on the air and in every home. But a second World War interrupted their plans and the public had to wait for their long-promised pictures by radio.

When, after the war, television was finally made available, people were as enthusiastic about it as they had been about radios after World War I. (By 1964, it was estimated that 93 percent of all American homes had a television set.) For Philo



A 1934 drawing of Farnsworth's receiver, or picture, tube. Basic design with electromagnetically focused and deflected electron beam is widely used in today's receiver tubes.

Farnsworth it was the climax of 20 years of effort. His had been a major, an essential, contribution.

As a boy, Phil had helped plow his father's field, uprooting the old crop, turning it under, and planting something new. Likewise, in the field of electronics, Phil had overturned the old idea of mechanical scanning discs, which had yielded a poor crop, and had planted the seed of all-electronic television. What a rich and endless harvest the world reaped from this farm boy's sowing!

Today (1967), Farnsworth is head of a research laboratory of the International Telephone and Telegraph Company. He has been granted over 100 patents, and innumerable honors and honorary degrees have been awarded him. Who knows what future discoveries will result from the work of this quiet, pleasant man, who is accorded by scientists who have worked with him the rare title, "a true genius"?

Chapter VIII

PROGRESS IN DEPRESSION YEARS

In 1929, the United States was plunged into an economic depression that was to last through the Thirties. There was hardly a business, from the corner grocery store to large corporations, that didn't suffer. Many concerns went bankrupt and closed their doors. The effect on the thriving radio industry was unusual: the depression brought both "boom" and "bust."

Almost no new broadcasting stations were built. Manufacturers of receiving sets experienced a sudden drying-up of sales. Hundreds of skilled radio technicians were thrown out of work. A fortunate few found their way to Hollywood where the "talkies" were creating jobs for men with electronics backgrounds. Some were forced into non-radio work. Douglas Perham of Palo Alto, for example, became a brick layer for a short while.

But the depression years were boom years for amateur radio. The nation's 16,829 amateur stations of 1929 increased to 45,561 by 1935. People had more leisure, and amateur radio was a fairly inexpensive hobby. Manufacturers, seeking customers among the amateurs, began producing radio gear at lower and lower prices, including equipment for the new short-wave enthusiasts.

On the San Francisco Peninsula, two young men were brave enough to start their own business in mid-depression, producing vacuum tubes for their fellow amateurs. Here is their success story.

BILL AND JACK—TUBE MAKERS PAR EXCELLENCE

One cold wintry day a delivery boy from the general store in a mining camp near Merced, California, came to a conclusion: his heart wasn't in truck driving, nor in mining, but in radio. William W. Eitel went up to San Francisco to ask Ralph Heintz for a job at the Heintz and Kaufman company of short-wave radio fame.

Big, burly Heintz looked him over. "What kind of work are you doing now?"

Jack A. McCullough (left) and William W. Eitel with a power transmitting tube that was a forerunner of those which they produced for World War II radar. Eimac Inc. became a world leader in power tubes.

Bill Eitel swallowed hard. "I'm driving a grocery wagon."

"What other things do you have to recommend you?"

Bill hesitated, then offered, "I'm a radio ham."

"Well, that's good enough," Heintz replied laconically, and to Bill's surprise, he was hired on the spot.

Heintz's company at that time, 1929, was working with Dollar Steamship Company, building a complete coastal communications system, to be operated by Dollar's Globe Wireless Company. Heintz put Bill to work in the tube department which was developing an important invention of Heintz's—the gammatron tube. He related to Eitel how, when Globe Wireless needed a tube to transmit their wireless signals, but could not use the patented de Forest-type triodes, Heintz had designed this different type of tube that did not infringe any existing patents.

The first gammatron was pumped and tested in July, 1929. Bill Eitel learned the art of making tubes so quickly he was put in charge of that department within a few months. As he explained this advancement to one of his best radio amateur friends, Jack A. McCullough, "When Heintz gives you a job, he has faith you can do it and he leaves you with it—so you just have to do it."

As the months passed, Bill continued to praise his brilliant boss. "No obstacle is big enough to stop him." Once Bill reported in awe, "He can carry all the details of complete systems in his head." Jack McCullough decided that Heintz's company would be far more instructive and inspiring than his former jobs–selling Stutz automobiles and running a radio service shop–so he, too, went to work for Heintz, in 1930.

For four years the two radio amateurs learned the tube business. They designed tubes for their own ham rigs, and even convinced the company to make and sell these to other amateurs. But the company managers didn't agree with Eitel and McCullough on how the tubes should be marketed. In addition, the depression was forcing the company to dismiss more and more employees. It seemed just a matter to time before Eitel and McCullough would have to go, too. In September, 1934, they made a grand decision: they would become manufacturers themselves.

With borrowed money, they rented a shop in San Bruno that had formerly been used by a butcher. Then they placed an advertisement in *QST*, a magazine for radio amateurs. The ad described the 150T, a new tube that was more reliable and longer lasting than any similar tube. The response was immediate. Orders came in before the first one was built, from commercial users as well as amateurs. The Eitel-McCullough Company was in business, and the word "Eimac" on a tube soon began to be known in the electronics world as a mark of quality.

Eimac grew steadily. The company moved to larger quarters in San Bruno. By 1940 there were 20 employees. The little company suddenly received an order from the United States Government for half a million dollars' worth of radar tubes! (We will learn more about radar in the next chapter.) The company had to expand overnight. Then in December, 1941, the Japanese attacked Pearl Harbor, Hawaii. Eimac was directed to establish a second plant in Salt Lake City, Utah, for it was feared that the Japanese might invade or bomb the Pacific Coast. Within a year Eitel-McCullough had hired and trained 1,800 people in Salt Lake City, and had as many working in San Bruno. During the war, working 24 hours a day, Eimac made 4,000 radar tubes a day, 120,000 a month, probably more than any company has ever made. Eimac also supplied the government with many types of power transmitting tubes. Its contribution to the military success of the Allies was a significant one.

After the war, like many other manufacturers, Eimac faced a rather alarming condition. "Our tubes were poured into Army surplus stores at prices lower than it cost us to make them!" recalls Bill Eitel. Some people predicted that electronics businesses were "finished." One Eimac investor sold his interest in the company. But Eimac's founders were undaunted; they proceeded to build a large variety of tubes. And their faith was rewarded, for electronics – and Eimac – prospered.

In the ten years that followed World War II, the electronics industry in the United States increased its size over seven times. By 1956, the annual sales volume for the country was eleven and a half billion dollars.

Eitel and McCullough were so successful that 1959 found them moving into a new multimillion-dollar plant in San Carlos. To dramatize the dedication ceremonies, a radio signal was bounced off the moon, using a giant-sized klystron built by Eimac. The signal was sent from Alaska and made the trip to San Carlos, via the moon, in just two and one-half seconds. Eimac was ready with tools vital to the Space Age.

Within the next few years Eimac's tubes were used in satellite communications and in a host of other applications such as aviation, radio and TV broadcasting, telephony, nuclear research, oceanography, automatic machinery control, and computer data networks. Eimac became the world's largest independent manufacturer of electron power tubes.

Jack McCullough and William Eitel could look back and agree that they had come a long way from that brave beginning in the butcher shop.

Two years after Eimac was founded, another young man dared to start his own electronics company in the midst of the depression.

JOHN KAAR AND HIS TWO-WAY RADIOS

"I've brought you a surprise. Come and see!"

John Kaar was four years old in 1912 when his father came home with a brand new Edison phonograph for the family. Small John was entranced as he watched his father unwrap the records. Unlike the flat discs used on the "Victor Talking

Machine" and the Columbia record players which were also popular in that day, the Edison records were hollow wax cylinders about four and a half inches long and two inches in diameter, with the recorded grooves on the outside. A stylus, or needle, rested on top. As the cylinder turned, the sound came out of a huge horn attached to the top of the phonograph.

John's father showed him how it was possible to make one's own recordings on the Edison machine, and before long the boy learned how to do this by himself.

John built his first "oatmeal box" crystal set at age 13 while he was a student at the Palo Alto Military Academy. It didn't work. But by the time he was a high school student at the Harvard Military School in Los Angeles, he was using tubes, and built several sets that worked very well. Radio parts were expensive. John solved the problem of batteries by picking up old dry-cell batteries as they were thrown in the trash heap behind a nearby radio store.

"By connecting together a veritable sea of these almost-dead batteries," recalls Kaar today, "I was able to get enough energy to operate my one-tube set."

John's parents wanted him to go to Stanford University, but he had spent too much time on radio at the expense of his homework to qualify for Stanford. For three years he attended Pasadena Junior College (now Pasadena City College) taking electrical courses and physics. At last he was able to enter Stanford on a provisional basis. There, in Professor Frederick Terman's radio engineering courses, school work became intensely interesting. John, who had always avoided studying as much as possible, was transformed into an earnest student.

A year after entering Stanford, John married Ellene Johnson, from his home town, Bakersfield. He helped earn their expenses by repairing, building, and selling radios. When he finally received his Electrical Engineering degree in 1935, the middle of the depression, there was little electronics work available in Palo Alto. He found a job in San Francisco, at the Remler Company, one of the few radio manufacturers in the Bay Area. John was put to work assembling microphones and public address systems. The company paid its assemblers 43 cents an hour, but John was paid 46 cents, presumably because he had an engineering degree.

After Kaar had been with Remler about a year, Professor Terman recommended him to Charles Watson of Western Wireless Limited. Watson was a San Francisco pioneer in two-way mobile radio equipment. He hired Kaar as a "receiver engineer." John found the work challenging and instructive. Watching Watson operate his small company, Kaar decided that he, too, could start a radio company of his own.

In 1936 he opened a shop in his garage at 125 Princeton Road in Menlo Park. Within a few months the Kaar Engineering Company was able to move to downtown Palo Alto. Ellene, who was experienced in accounting, became the office manager, a position she held with the firm for 21 years. Her faith and encouragement and long hours of work did much to keep the little company going in the first lean years.

During those early days, Kaar built disc recorders, public address systems, and high fidelity equipment. He repaired and sold radios, and made recordings of plays and dance bands on the aluminum discs used at that time. He stocked radio parts for sale, his company being the first wholesale radio store in the mid-Peninsula area. He catered to other radio repairmen, Stanford engineers, home-set builders, and amateur radio operators.

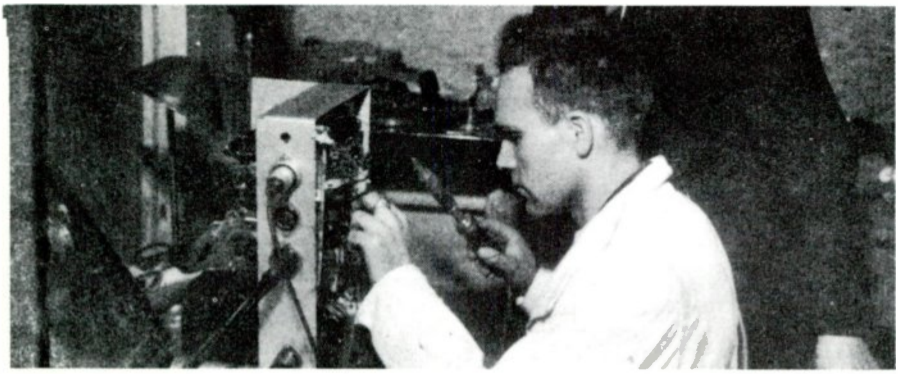
One of his early employees was a ham operator who convinced Kaar that he should start building amateur transmitters and two-way radio telephones. This was excellent advice, for people across the country were beginning to adopt two-way mobile radios as very useful tools. Police cars, yachts, taxi cabs, all wanted their own "direct line" telephones.

Kaar placed a small advertisement of his two-way radio in a national radio magazine, and sales representatives immediately responded. Kaar Engineering was soon doing such a large mobile radio telephone business that the parts sales, radio repairing, and recording activities were dropped.

The company was to meet more serious deadlines when the United States went to war. Kaar Engineering was swamped with orders from the Army, Navy, and Coast Guard, and soon became the largest wartime manufacturer of two-way mobile radio telephone equipment on the West Coast.

After the war, Kaar Engineering branched out into the manufacture of depth sounders and marine direction finders, in addition to new types of mobile radios. In 1952, John Kaar, at the unusually young age of 43, sold his company and retired. He returned to what he calls his "first love"–recording–which has fascinated him since he made his first record for the Edison phonograph. He spends long and happy hours in his home laboratory in Menlo Park, diligently experimenting with ways to perfect his equipment.

The company John Kaar founded is one of the oldest electronics companies still operating on the Peninsula. Now known as Kaar Electronics, it continues to expand in its new location in Mountain View.



John M. Kaar with the amplifier of one of his first products, a machine to make phonograph records, built for Menlo School, Menlo Park, 1936.

As you may have noted, Kaar was one of a long line of Bay Area electronics men to start out in a garage workshop. Two years after he began, a couple of fellow Stanford engineers also founded a business in a garage. Their company became so enormous and world-famous that, among Palo Alto engineers, starting in a garage became jokingly referred to as one of the keys to success. "Better find yourself a garage," is the solemn advice often given to men about to go into business for themselves, "then you can end up on the Hill." The hill they mean is the grassy, sloping Stanford Industrial Park, where power machines building new electronics factories are seldom stilled. The largest company of them all is Hewlett-Packard–first established in a garage. But their story starts in an attic . . .

ELECTRONICS FINDS TWO TO TAKE ITS MEASURE

It was raining, and the drops leaking through the attic roof would run together and then go plunk, plunk! into the big trays on the laboratory floor. The trays were homemade wooden affairs, several feet wide, lined with tar paper and patched with tar to make them watertight. The students walked around these obstacles with unconcern born of habit. They were permanent fixtures in the Stanford Communications Laboratory, for it was the depth of the depression and the University had little enough money for basic equipment for the laboratory, let alone repairs to a roof. On this particular day, Professor Frederick Terman, director of the Communications Laboratory, happened to look into one of the pools. It was filled with flashing goldfish! A student, William R. Hewlett, had added a bit of life and color to the damp, impoverished laboratory. Terman loved it.

Another student of whom Terman grew fond was a husky fellow, six-feet-five, named David Packard, who could throw the discus, put the shot, and play letterman football and basketball while scoring equally well in schoolwork. Begging a little money from friends like tube-maker Charlie Litton, Terman was able to hire Packard as a part-time assistant. Packard and Hewlett became fast friends and found themselves growing in knowledge under the hard scholastic demands of their director.

One day Terman took his students on a tour of the very few engineering companies in the Bay Area. He pointed out that many of the men who owned these factories had started them with less education and no more money than they had.

With help from Terman, Hewlett and Packard did start their own company in 1938 on a part-time basis, in the one-car garage of a house at 367 Addison Avenue, Palo Alto. Packard and his wife lived in the house; Hewlett slept in a cottage in the back yard.

As a graduate student, Bill Hewlett had designed a device for use in electronics research, an audio oscillator. Terman felt it held great promise of being commercially successful. Hewlett and Packard built one and Bill took it to a meeting of

William R. Hewlett (left) and David Packard with one of their precise measuring instruments. Without such tools, electronics could never have progressed beyond a crude experimental stage to become a science. Founded in 1939, Hewlett-Packard has become the leading manufacturer of electronic measuring instruments in the world. (Photo about 1946.)

the Institute of Radio Engineers, now the Institute of Electrical and Electronics Engineers. To his surprise and delight an engineer from the Walt Disney studios ordered nine of them. They were used in the production of "Fantasia," which flooded movie theaters with unusual stereophonic sound.

This first big order gave Hewlett and Packard the capital and the encouragement they needed. They formally organized their partnership in 1939, flipping a coin to see whose name would come first.

They early resolved to make only products that would be a real contribution, that would meet a need.

At this point in the development of radio and electronics, men had harnessed the elusive electron in a glass bottle, and had accomplished some amazing feats of communication with it. But the tubes were moving into the physicists' laboratories, and even the commercial electronics companies were demanding higher and higher standards, more exact measurements, more precise control. Hewlett and Packard saw that one of the biggest needs was for test and measuring instruments that were especially designed for the radio and electronics field. They began making instruments that could measure electronic phenomena, such as radio frequency, with scientific accuracy. Their devices were of such high quality that they soon had their own production staff in a rented building on Page Mill Road in Palo Alto.

By 1943 the company was deep in the war effort, turning out a million dollars worth of instruments a year. The postwar years offered no insurmountable problems. By 1953 the sales volume of the company had reached one million dollars per month. Today it sells over two hundred million dollars worth of devices a year. It is the world's leading manufacturer of electronic measuring instruments.

An example of one of Hewlett-Packard's more than 1,500 different instruments is their spectrum analyzer. Looking a

Hewlett-Packard's first electronic product (1939), an audio oscillator used to measure frequencies in the audible range, was invaluable to manufacturers of such products as loudspeakers.

Hewlett-Packard's spectrum analyzer gives an exact "picture" of all the short-wave signals on the air in a given area, vital information at today's airports and missile and space bases.

bit like two drawers on top of each other, it has a round little television-like screen and about a dozen knobs and switches. Across the screen march neat, bright vertical lines. The height of each one is a measure of the strength of each signal that appears. The content and the frequency or dial position of every short-wave radio signal that is on the air in the area are indicated by the pattern in the picture.

The spectrum analyzer can show, all at once, all radio signals such as aviation radio beacons, maritime communications stations, international short-wave broadcasts, mobile radio-telephone signals, and those from radio amateurs. It can show how and why they may interfere with one another.

Eighteen Hewlett-Packard engineers worked for more than two years to develop the instrument. The analyzer makes it possible to spot interference among radio signals quickly and thus prevent it from crippling communication and control. At the launching of astronauts there is a great quantity of different signals coming in at once, any one of which could indicate trouble. The analyzer thus is a powerful tool to help assure the safety of the astronauts and the success of rocket launchings. It will help preserve lives of persons flying in today's increasingly crowded air traffic.

With Hewlett-Packard instruments, men all over the world—physicists, engineers, and technicians—are able to test their own work, make more exact analysis, push back the frontiers of knowledge.

"HE CREATES AND HE DESTROYS"

Dr. Leonard Fuller walked down the oak-shaded glen to the University of California Faculty Club for lunch. Looking over the dining room as it filled with professors, he saw Dr. Ernest O. Lawrence sitting alone at a table and joined him.

"How goes it with your cyclotron?" he asked Lawrence. Fuller was head of the electrical engineering department, and was keenly interested in this brilliant young physicist. Lawrence had designed a unique device with which he hoped to split the nuclei of atoms. His idea was to create a stream of atomic particles, protons, which would travel around and around in a circle at ever-increasing speed until they were released to bombard a small target. The fast-moving particles would act like bullets and break up or smash open the heavy centers or nuclei of the atoms in the target material.

"It's operating as it should, according to my calculations," replied Lawrence. "Now I wish I could build a really big one, so I could see what could be done with more powerful bombardment. But I need a much larger magnet."

The magnet Dr. Lawrence was using was four inches in diameter. A large magnet would cost thousands of dollars, money that was not available, especially at that time, for it was in the beginning of the depression.

As Fuller listened to the frustrated scientist, his face broke into a slow grin. "How would you like to have an electromagnet with poles forty-five inches in diameter? I think I know where I could get one for you, for nothing."

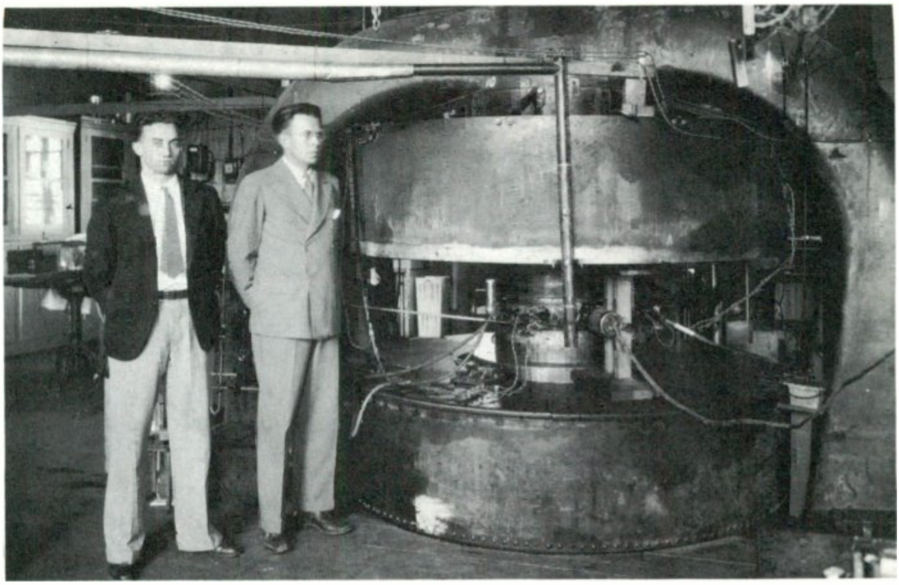
The physicist gasped. "Forty-five inches! More than ten times the diameter of my present cyclotron!" His quick mind started some mathematical calculations. He interrupted them. "Where? How?"

"In Palo Alto. Surplus from the war. The Federal Telegraph Company built two of them for a transmitting station on the East Coast, but the war ended before the station was built. I'm still executive vice president of the company, and I know that we have no further use for them."

"When can I see one?" asked Lawrence. They drove to Palo Alto the next day. On August 15, 1931, Fuller wrote a letter to President Robert Gordon Sproul offering to give the University a 1,000-kilowatt Federal arc magnetic circuit complete with copper magnet coil windings. The huge 85-ton electromagnet was shipped to Berkeley, and Lawrence built with it the first powerful atomic disintegrator. The cyclotron was for years the most powerful atom-smashing machine in the world. It won for Ernest Lawrence the Nobel prize.

With the cyclotron, Lawrence not only broke up the heart of the atoms, but he was able actually to create atoms, even a few of gold. He hastened to assure people who heard of it that the expense of doing this with a cyclotron far exceeded the worth of the tiny amount of gold.

Pleasant, easy-to-work-with Ernest Lawrence was pictured on the cover of *Time* magazine in the peaceful days of November, 1937, over the caption, "He creates and destroys." It was unintentionally prophetic. For out of this machine was to come a vast amount of knowledge that was to be used both constructively and destructively. This knowledge was helpful in building the atom bomb. Dr. Robert Oppenheimer was also on the faculty at Berkeley and worked with Lawrence on the cyclotron. Oppenheimer was later put in charge of the production of the atom bombs at Los Alamos, New Mexico—the bombs that were dropped on Japan in 1945.



Ernest O. Lawrence (right) and M. Stanley Livingston with first large cyclotron, 1933. Strong magnetic field (from Federal's electromagnet) and alternating electrical charge from high voltage oscillator (e.g., vacuum tubes) caused particles to spin in the round vacuum chamber at the center fast enough to smash atoms in target material.

However, in 1931 when the cyclotron was built there was no thought of a war, certainly not in the minds of the physicists at Berkeley. The purpose in splitting atoms was to learn more of the nature of the atoms, of matter itself. The cyclotron contributed immeasurably to man's knowledge of atomic structure.

The cyclotron became a tool for many kinds of research on the Berkeley campus. Lawrence's brother, Dr. John Lawrence of the University's Medical School, used its powerful rays to treat cancerous tissue.

A chemistry professor who had graduated from the University of California, Willard F. Libby, put the cyclotron to work in an effort to discover Carbon 14. This is a radioactive form of carbon that is common to all life forms. He and his assistants were finally successful, and were able to give to science an atomic dating device, which could determine the approximate age of fossils, wood, and other organic matter as old as 25,000 years, by measuring the amount of radioactive carbon present. Among the many things that have been dated by this method are the Dead Sea Scrolls. Dr. Libby was awarded the Nobel prize in chemistry for his unique contribution.

Further research here and abroad, often directed by men who had been trained in Berkeley by Dr. Lawrence, led to ways of obtaining and handling the enormous power available in atomic reactions. Nuclear submarines and atomic reactor electric power stations that light and heat entire cities became realities. Atomic reactors are being used in areas of the world where there is a shortage of inexpensive fuels for the production of electric power. Instead of burning coal or oil, atomic fission produces the heat necessary to turn water into steam. The steam operates the turbines which generate electricity. Nuclear reactors have proved so efficient and economical to operate that they are also becoming widespread in the United States. The Pacific Gas and Electric Company has announced that after 1970 the majority of their new electric generating facilities will be nuclear. In 1966 the General Electric Company was given a government contract to design a nuclear power plant for the moon. Scientists inform us that we have barely begun to exploit the constructive possibilities of atomic power.

Ernest Lawrence's first cyclotron was powered by a vacuum tube oscillator. He later graciously told Dr. and Mrs. Lee de Forest, as they toured the cyclotron installation, that de Forest's invention of the vacuum tube "had made it possible." Each inventor builds with the blocks of his predecessors. At the very moment they were discussing this, three men in the physics laboratory at Stanford University were creating a new block. It was destined to be used, among many applications, to build an atom-smashing machine that would make Lawrence's first large cyclotron seem small in comparison.

Chapter IX

"THREE MEN AND A TUBE"

When Lee de Forest moved to Palo Alto in 1911, he probably took no more than passing interest in the children going to the school across from his home on Bryant Street. How keen his interest would have been had he known that two of those youngsters would one day develop an electron tube that would be acclaimed as "the most important advance in radio since the invention of the audion tube in 1906 by Lee de Forest."

Few would have predicted any such brilliant future for the Varian brothers, Sigurd and Russell, in those days when they were attending Castilleja School (now a private school for girls). To Sigurd, as he walked the two blocks home each day, school work was far less exciting than the horseless carriages that were roaring about the streets of Palo Alto in such reckless manner that the city fathers passed a law that, in the downtown area, both horse and horseless traffic must stay on the right side of the road.

Russell, on the other hand, liked school, and was an eager student who could quickly understand anything that was said or read to him. But he was so slow in reading, spelling, and simple arithmetic that he couldn't keep up with the other boys his age. However, when Russell transferred to Palo Alto's Lytton Grammar School, he received special instruction in an ungraded or mixed-grade class. Stanford's Professor Percy E. Davidson, who had pioneered this type of teaching, sometimes worked with the Lytton students himself, including Russell Varian. He and the tall, earnest boy became friends.

The Varian boys' parents had come to America from Ireland, moving to Palo Alto in 1903. Their father was a poet and playwright who made a meager living for his wife and three sons, trying various trades. For some years in Palo Alto he was a masseur. Their modest, brown-shingled house at 1044 Bryant Street was the gathering place for writers, musicians, and social reformers. Many of their guests were odd by conventional standards; some of them were world famous. Generous-hearted, idealistic Mrs. Varian provided an encouraging atmosphere for all with creative talent or new ideas.


Russell (left) and Sigurd Varian as they looked during their boyhood days in Palo Alto when they were backyard inventors, with Rus supplying the ideas and Sig doing most of the actual building.

There was never enough money for the usual children's toys, but for Russell and Sigurd it was the most natural thing in the world to make their own, using whatever scraps of wood and metal they could find. They worked well together, and in their own eyes they were true inventors. Their little brother Eric was all too happy to be included in their projects as errand boy and the one to "hold this while I hammer it."

Slow, deliberate Russell was always the idea man, and quick, energetic Sigurd the one to build. Once something was constructed, Rus lost interest in it. But Sig would work on it further, adding improvements and enjoying the use of it.

Their parents were impressed with Russell's imagination and Sigurd's cleverness. They were confident that eventually the boys would create something which would bring riches to the family. Rus and Sig shared this hope, too. They talked of how, when they had finished school, they would work together inventing things.

"I get so many ideas," Russell once laughingly said to his brothers, "one of them is bound to be good."

By the time Rus was 16, he was all arms and legs, over six feet tall, and still growing. His rough-hewn, open face was topped by a thatch of unruly red-brown hair. Uncoordinated, self-conscious, yet eager to be friends, he reminded his neighbors of a big Saint Bernard dog. When he came into their living rooms they had to control the temptation to put the breakables in a safer place. But the Irish lad with his disarming grin was always welcome.

In 1914, the Varian family moved to Halcyon, a little town about 225 miles south of Palo Alto. Here they operated a general store and post office. Rus attended the Arroyo Grande High School and, though still a slow reader, was a good student. Knowing that he didn't have time to read anything twice, Rus read everything very carefully the first time, and almost unconsciously memorized it. Once learned, it was easily recalled, even a long time afterwards.

Russell's interests were broad, so he was continually acquiring knowledge in many fields. In later years, when working on inventions, he was able to draw upon this vast fund of knowledge in unconventional ways; the method by which a problem in economics had been solved might suggest to Rus a way to solve a problem in physics.

Russell was 21 by the time he graduated from high school, but he had developed study and thinking habits far beyond his classmates. Hesitatingly, he applied for entrance to Stanford University. To his great joy he was accepted. He knew he would have to work his way, but this worried him far less than how he would be able to keep up with the heavy reading assignments. He liked sociology and economics, but chose experimental physics as his major. It would require the least amount of reading.

In the fall of 1919 Rus packed a small bag and started hiking the 225 miles to Palo Alto. His family soon received a happy letter stating that he had arrived safely, and that the trip had cost him ten cents. Russell Varian, physicist, had begun his career.

Meanwhile, Sigurd had also attended the Arroyo Grande High School, and then enrolled at a technical high school in San Luis Obispo, the California Polytechnical School. (In later years this became what is now California State Polytechnic College.) After one semester at "Cal Poly" Sigurd was bitten by a bug that affected many young men in the 1920's. He wanted to fly! Off he went to Los Angeles to join the daring, undisciplined fraternity of youngsters who had learned that there were hundreds of airplanes for sale there, very cheap. They were brand new planes, ready for shipment to Europe when World War I had ended. The government sold them to junk dealers, who found few customers. The prices dropped low, and suddenly the boys discovered them.

As Sigurd later described it, "Every young fellow who had lain on his back in tall grass dreaming of flying could now buy a real airplane still in its original crate, with glistening wings – and maybe dry-rotted spars. But who cared about dry rot? In fact, who knew what it was anyhow?

"A few of us took lessons from the few who knew how to fly – but just barely. If we owned our own plane and ran out of money for lessons, we were soloed. We rushed into the air before we were ready. We took every short cut in sight, with unlimited confidence in our individual good luck and ability."

By 1923 Sig had his own plane. "It was all a great miracle – kids still in their teens owning their own airplanes. We hardly needed to eat if we could only fly. Our craving for flight was almost overpowering. We just had to fly. We fought, and lied, and schemed to fly."

Inevitably there were accidents. "We smashed our planes all over the state of California," said Sigurd. "We cracked up in ditches, ran over harrows, flew through fences, and one unlucky pilot ran into a family of hogs. We found out a lot about farming, and the farmers found out a lot about flying, each to his own disgust."

Sigurd eventually had his own flying school. But planes and parts became scarce as the war surplus supplies dwindled. To keep the old planes patched up and flying was a challenge. As he improvised parts, overhauled motors, and repaired broken planes after crash landings miles from civilization, Sigurd's natural mechanical ability became imaginative skill. Sometimes it was as simple as pounding a few nails into the broken end of a propeller to add weight and thus balance the propeller. Once it meant one of the boys straddling the engine, squirting drops of a specially flammable liquid into the carburetor as they flew the sputtering plane homeward.

When Sig signed up with Pan-American World Airways to fly their recently established routes from Mexico to Central America, in 1929, he faced new dangers. For the next six years, he flew over mountains and jungles, in storms and darkness, landing by guess—and sometimes crashing. He was acutely aware of the need for better navigational aids. And something else greatly troubled the now seasoned senior pilot. He heard stories of the bombing of civilians in cities in Spain where a war was being fought. He realized how completely defenseless all people were against planes flying by night or hidden by clouds. How could fighter pilots or antiaircraft gunners fire at and hit something they could hear but could not see?

Sigurd had married the daughter of a British Consul in Mexico. The British were seriously concerned over the strong military air forces being built by some European nations. The threat seemed ominous to Sigurd. He wrote long letters about it to his brother Russell, asking him to give it some thought.

Meanwhile, Rus had graduated from Stanford and had been granted a Master's degree in physics in 1927. After working for an oil company, he spent four years with Philo T. Farnsworth helping with the development of television. By 1935 Russell was back at Stanford doing research in physics. It was then that Sigurd and Russell decided to establish their own laboratory, as they had planned to do as boys. Together with their brother Eric they set up a simple shop in Halcyon.

They worked on a variety of things, but Sigurd often brought the conversation around to his pet subject, the need for some way of enabling people to "see" enemy airplanes that were actually invisible. It occurred to Russell that the answer might lie with the use of a device which his former roommate at Stanford, William Hansen, had designed. He wrote to Bill and, after a number of letters between them, Bill accepted an invitation to go down to Halcyon for a visit.

Bill Hansen was almost as tall as Russell. They had been a memorable couple in school, striding across the campus, deep in technical discussion, oblivious to the rest of the world around them.

The son of an expert machinist, Bill had learned to work with machine tools at an early age. When he graduated from Fresno High School he was described by his teachers as an exceptional student, particularly outstanding in science and mathematics. With the aid of a scholarship, he was able to come to Stanford, where he found physics fascinating and Spanish so distasteful he dropped it. Later, he took German and liked it even less. He spent no time studying it, receiving an "incomplete" the first year. However, he found that he had to pass an examination in the course in order to get his degree in physics. The story is told that he secured copies of some of his professor's previous final examinations from former A students. In a very short period he committed all the papers to memory, questions and answers, and then reported for the examination. His hunch was correct. The professor had chosen one of his old finals which he had given a previous year. Bill passed with flying colors! There are perhaps some who would deny this tale, including the good German professor, but it serves to illustrate the reputation enjoyed by Hansen for nonconformity and a phenomenal memory.

Hansen's keen mind drove him to long hours of concentration, but he had often welcomed an interruption by his roommate. He found in Rus Varian a worthy mental sparring partner. During their undergraduate days the two men had developed an affection and deep respect for each other.

Hansen was now a physics professor at Stanford. Good students found him an inspiring teacher; lazy students found him impatient and ready to flunk them unmercifully even if they were key men on the football team!

When he arrived in Halcyon, Hansen brought Sig and Rus up to date on his "rhumbatron." This was an electromagnetic resonator, a cavity or cylinder in which electromagnetic waves were made to bounce back and forth at radio frequency. Rus had worked with Bill during the early stages of this resonator, and it was this device that Rus felt might be useful in "seeing" enemy airplanes.

Bill told Sigurd, "One of the graduate students, Leonard Pockman, called the resonator a 'rhumbatron' because the currents moved very little at the top and bottom and a great deal around the middle section."

Russell recalled that Dr. David L. Webster, head of the physics department, didn't think this name sounded very dignified, so Webster asked Ernest W. Martin of the Greek department to give them something more appropriate that still described it.

"After some study," said Bill, "Dr. Martin assured us that it was a good classical name, since the Latin word 'rhumba' originally came from a Greek word meaning 'rhythmic motion.' "

The Varians laughed and Russell said, "I wonder what Martin would have come up with if Pockman had been reminded of the hula!"

Then Sigurd discussed in technical detail his ideas on airplane navigation aids, stressing the need for enemy plane detection. Hansen happened to be taking flying lessons at that time and thus listened as both a pilot and a physicist. The three men talked of possible solutions, agreeing that it could be done with ultra-short waves, which might be directed in a narrow beam to sweep the sky like a searchlight. But this beam, unlike that of a searchlight, would be invisible. If the radio waves encountered an object, such as an airplane, they would be reflected or bounced back toward their source. If an instrument could then record how long it took the waves to make the round trip, one could tell how far away the plane was. This is in fact the system that later came to be called "radar" from the words *RA*dio *D*etection *A*nd *R*anging. (Unknown to the California men, engineers in England directed by a Scotsman, Robert Watson-Watt, were already secretly at work on just such a reflected short-wave scheme.)

Of course the great difficulty was that Russell, Sigurd, and Bill knew of no way to develop these very high frequency waves with power enough to reach out miles away and return. With the vacuum tubes of that time, the shorter the waves desired, the smaller the vacuum tube had to be made, and the less power you could get. Obviously, such vacuum tubes were not the answer. Hansen and the Varians talked about ways in which the rhumbatron might be used in generating the beam of high frequency waves they needed.

After Hansen returned to Stanford the men continued their discussion in letters. Sig felt sure that if the three of them could work together for a while on the problem, they could come up with an answer. With the "nothing is impossible if necessary" attitude of his barnstorming days, Sigurd finally convinced Rus that they should go up to Stanford to see what might be done.

As Russell later described the events, "My brother and I came to Stanford and talked the whole matter over very thoroughly with Dr. Hansen. The credit for the starting of this project should mainly belong to my brother, since he was the one who was most insistent that this development should be attempted. I must admit that I was rather dubious about the whole project, not because I didn't believe that anything could be done in this field, but because I thought the project might prove to be too large for our slender financial means. My brother's urging prevailed and we went and discussed the matter with Dr. Webster."

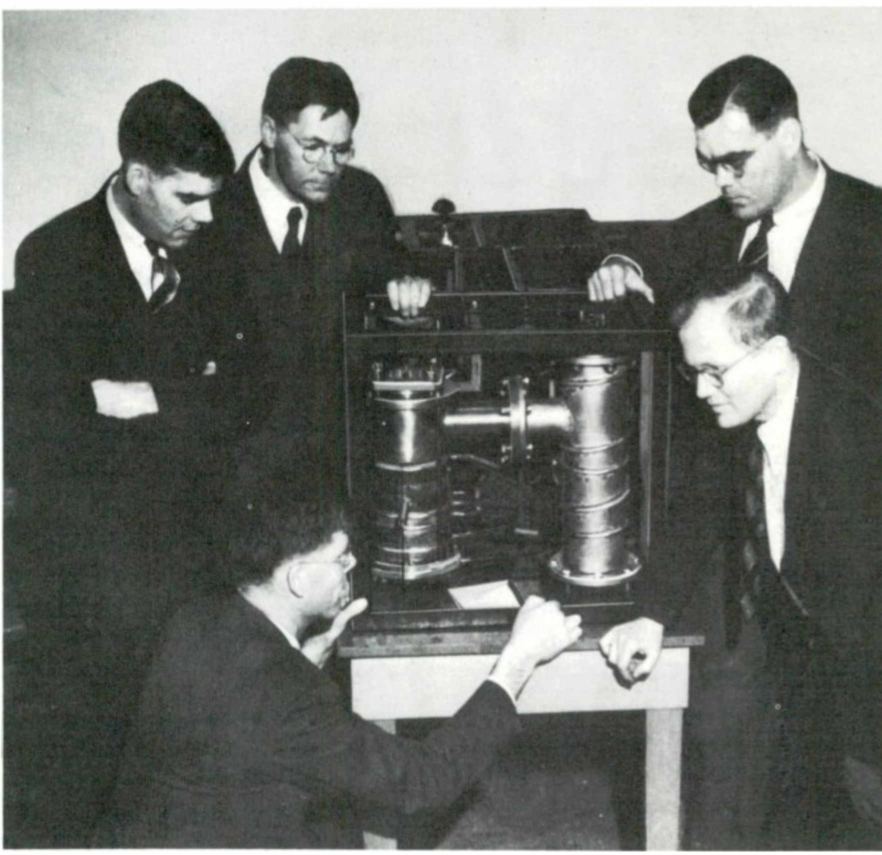
Honest, modest Russell Varian was always quick to give others credit for their part in his success. All his life he did his best work with a few close associates, whose talents complemented his own unique gifts. That is why the story of his most important invention is often titled "Three Men and a Tube." The work of all three was essential.

The Varians found Professor Webster a most sympathetic listener. He was a pilot himself and had worked on airborne bombsights during World War I. Also, he was the kind of teacher to whom students could take their ideas without fear of them being ridiculed or rejected, no matter how odd the ideas might seem. Webster always listened carefully. Then, with kind eyes sparkling, he would boom out in his deep voice, "It might work. Why not go ahead and try it?" Later, if the endeavor seemed to flounder and not look so sound after all, the students could count on him to pitch in and help them make the best of it.

After conferring with the Varians and Hansen, Dr. Webster decided to approach the president of the university, Dr. Ray Lyman Wilbur. The physics professor's hopes were not too high, however; it was 1937 and Stanford was still suffering from the depression. Great was the rejoicing when he returned to announce that Russell and Sigurd had been appointed research associates, enabling them to have full use of the physics department laboratory. They were to receive no salary, but the school was able to provide them with $100 to help pay the expenses of the project.

In return, the university was to share with the Varians and Hansen any financial return that might come of the research. Perhaps no university ever spent $100 so well. Over the next thirty years Stanford received almost two million dollars in royalties from the invention that resulted, and the money continues to come in.

Since the Varians had no income, they had to live on their savings, but to Russell this was like old times. During those



(Clockwise) Russell Varian (kneeling), Sigurd Varian, David Webster, William Hansen, John Woodyard, with early model of the klystron, revolutionary high frequency vacuum tube invented by the Varians and Hansen. Webster, head of Stanford physics department, and Woodyard, a graduate student, assisted in the development of early models.

lean days when he was working his way through Stanford he had learned the location of every fruit-bearing tree on the campus. Helping himself on the way to the physics laboratory each morning was perhaps not the most conventional way of eating breakfast, but no one seemed to mind.

During the following months, Russell and Bill Hansen did a lot of thinking and talking, rubbing their ideas together. Hansen was logical, analytical, brilliant. Rus thought in leaps and bounds and flashes. A fellow scientist, amazed at Russell's unorthodox but fruitful thought processes, claimed that "Rus has discovered a substitute for thinking." It wasn't easy to follow him. But Bill could. And while Bill was methodically tearing apart one of Russell's schemes to see if it was workable, Rus would be ready with two new ones.

Bill had a habit of rocking his chair back and forth on its back legs when he was concentrating on a problem. He wore two hollows in the old wood floor, and one day the legs finally crashed right through.

The first plan they considered for a microwave oscillator, or generator, was a Farnsworth multipactor and rhumbatron combination. This led to further ideas. Sig waited impatiently for them to decide on something he could build. At last they gave him the word to go ahead and construct a model. He had little formal training in what he was doing, and had to make most of the parts by hand out of whatever he could find around the laboratory and even at the university's dump. Ordinary radio parts he bought from John Kaar of Kaar Engineering, the only source of these in Palo Alto.

Dr. Terman would drop by from the electrical engineering department to check on their progress. He was impressed with Sig's ability. "Unlike his brother, who was rather clumsy with apparatus," said Terman later, "Sigurd had unusual design and mechanical sense, and great skill with his hands."

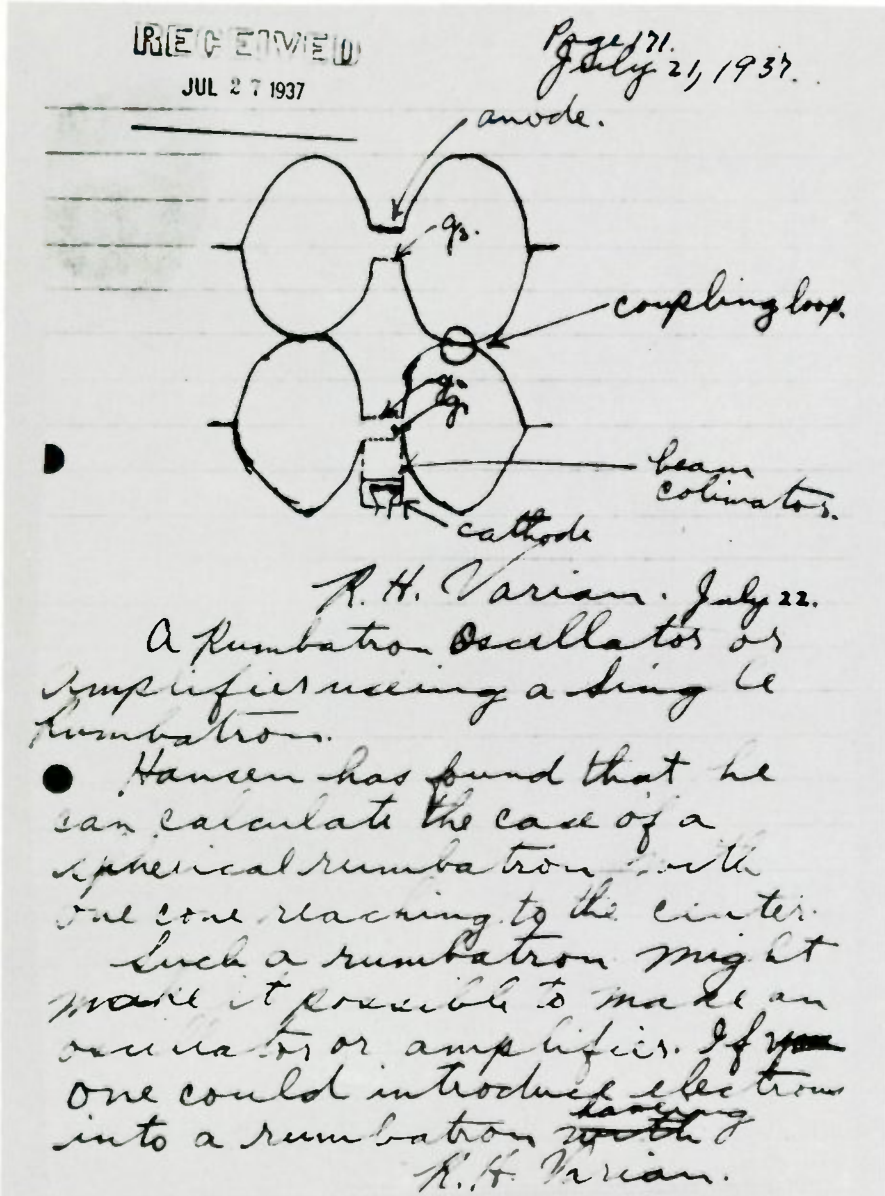
Sigurd had been working for three painstaking months building this particular model when, on June 5, 1937, his brother and Hansen suddenly told him to discard it. Russell had come up with a new idea which they felt was just what they had been searching for. It was a method whereby one could change and control the speed of electrons to cause them to flow in bunches. Now called "velocity modulation" this was a completely new principle in electronics, and a most important one. (Unknown to Rus, velocity modulation had been discovered independently by Oskar Heil and A. Arsenjewa-Heil in Europe in 1933. After World War II, German-born Dr. Heil came to California to work for Eitel-McCullough Inc.)

Russell's scheme involved Hansen's rhumbatron; in fact, two rhumbatrons placed together in a vacuum. Russell proposed sending a stream of electrons through the two cavities. Each electron would be either speeded up or slowed down a little in the first rhumbatron. Then, as the electrons went on in the vacuum toward the second rhumbatron, the faster ones would overtake slower ones ahead of them. Thus, most of the electrons would get into compact groups, called "bunches." When the bunches went through the second rhumbatron, they would give up their energy of motion to it–provided its electric oscillations were timed, or "phased," in the right way to pick up this energy. Thus the bunches acted like a person pushing someone in a swing, with one-way pushes, timed so as to keep the swing going.

If the bunches of electrons gave more energy to the second rhumbatron than just enough to keep its oscillations going, the excess energy could be taken out to form ultra-short waves, or microwaves. Therefore, this new kind of vacuum tube could be used to generate as well as to amplify microwaves, just as the de Forest-type vacuum tube had been the key to both amplifying and generating ordinary radio waves.

Once Hansen and Russell agreed that the theory would work, they had to design the apparatus. One of the problems was to find a suitable shape for each rhumbatron. It had to have room enough for a certain magnetic field, yet an electron had to go through it in a very short time. Dr. Webster studied this problem and presented the suggestion that each cavity, or rhumbatron, be shaped like a doughnut, with wires, or grids, stretched across the hole in the doughnut. This proved to be an excellent solution, and Dr. Webster took out a patent on the doughnut design. It was decided to build the rhumbatron of copper and to make the first one about three inches in diameter.

After the basic details of the rest of the tube had been decided upon, Sigurd was at last given the drawings. He spent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Page 171.
July 21, 1937.

R. H. Varian. July 22.

A Rumbatron Oscillator or Amplifier using a single rumbatron.

Hansen has found that he can calculate the case of a spherical rumbatron with one cone reaching to the center. Such a rumbatron might make it possible to make an oscillator or amplifier. If ~~you~~ one could introduce electrons into a rumbatron ~~with~~ having

R. H. Varian.

A page from Russell Varian's notebook during the period when he and Hansen were designing the klystron. Their tube was one of the first practical answers to the need for energy at microwave frequencies. An inventor's notebook provides important evidence in establishing the date of a new idea when there are similar inventions by others.

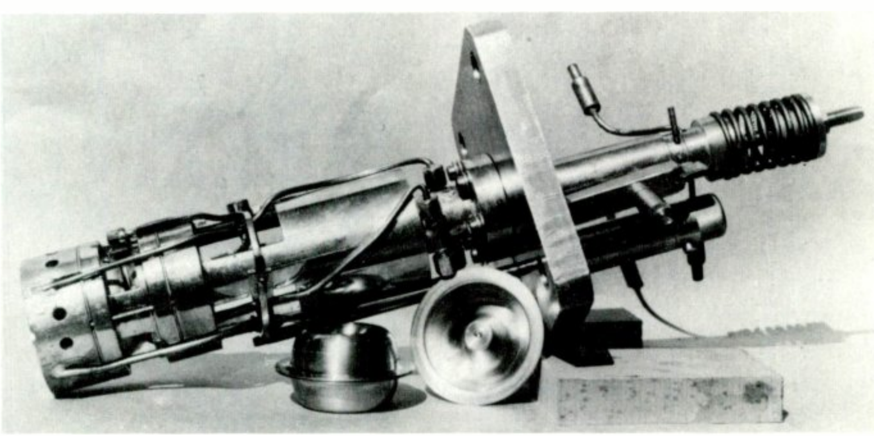
the following weeks, night and day, building the first model. There were enormous difficulties involved.

While the work was going on, Professor Webster approached the classics department once again. This time Professor Herman F. Frankel was the one asked to help find a name for the new tube.

"Dr. Webster said the new invention had the function of emitting successive bursts of waves," Dr. Frankel recalls today. The name he suggested was "klystron" from a Greek verb meaning "to splash," like waves on a beach. It was a prophetic name for a tool whose waves were one day to splash against ships, airplanes, and even the sun and the moon.

Dr. Frankel had been forced to leave his native Germany as a result of Hitler's persecution of the Jewish people. Frankel lived to see the klystron he named play an important part in bringing that persecution to an end.

On August 19, 1937, the first klystron oscillated—a few flashes appeared on the detector screen, but everything was very unstable and disappointing. Sig made some extensive adjustments. On the morning of August 21, 1937, he was ready to try again. He threw the switch, tuned the tube a little, and—there were oscillations spread all over the fluorescent screen!



The first, or Model A, klystron which oscillated in August, 1937, in the basement laboratory of the physics department at Stanford. Copper rhumbatrons in foreground show shape and small hole across which was a fine wire grid. Webster patented this "doughnut" shape.

"It oscillates! It oscillates!" Sig Varian called out excitedly to everyone. Russell, Dr. Webster, Hansen, and some of the graduate students who had been assisting rushed to see. They made a few quick tests. There was no doubt about it. The klystron worked!

Dr. Webster invited them all to his home that night to celebrate. It was a great day.

The men realized that there was a long way to be traveled before their invention would be ready for practical use. It would take months, and their meager savings were almost gone. They made attempts to interest the United States Navy, but nothing came of them.

And then, almost by chance, a man from the Sperry Gyroscope Company came by to see the klystron and was immediately enthusiastic. His company had been working on blind aircraft-landing systems, and the klystron was just what he needed. A contract was signed with Sperry, Stanford, the Varians, and Hansen. Russell and Sigurd were put on a regular salary. Dr. Hansen and Dr. Webster gave all of their time outside of teaching to work on the new tube.

On January 30, 1939, progress was such that Stanford's President Wilbur announced the invention to the public. Newspapers from coast to coast carried feature stories of the klystron.

The *Palo Alto Times* printed the story with pictures of the Varian brothers on the front page. But the biggest headlines on the page were about Hitler, who was overrunning all of Europe. He had just made a speech that day in which he said, ". . . we shall tolerate no attempts at interference." The klystron was to interfere decisively with the dictator's plans!

The first klystrons were manufactured in a crude laboratory in San Carlos, but in 1940 the project was transferred to the modern, well-equipped Sperry plant in New York. When the United States entered the war, the British divulged the secret that they had built a radar station as early as 1935, and by 1938 had already installed a chain of stations from Scotland down the east coastlines to the Isle of Wight. Their system was based on a tube called a magnetron, invented as a detector by an American, A. W. Hull, in 1921, but developed as an oscillator by the British to generate short waves of high power.

The first microwave radar apparatus using klystrons. Prior to 1941, this was tested on the Stanford campus by aiming at a rented airplane. Klystrons are directly behind the "dish."

The British magnetrons were more powerful than the klystrons of 1940; they were also very heavy. Putting the necessary pair of them (one to send, one to receive) into an airplane had been impossible. The klystron came to the rescue. Weighing less than six pounds, about seven inches long, the little vacuum tube with its "copper doughnuts" made a fine plane-mate for the magnetron. Now, at last, the British Royal Air Force (RAF) pilots could have airborne radar.

Before the klystrons had arrived on the scene, the British magnetrons, though lower in frequency than the klystrons, had served England wonderfully well. England had been forced by Hitler's massive army and air force to evacuate her troops from France, across the Channel back to England. Then in the fall of 1940, with England at her weakest, Hitler ordered preparations for the invasion of Great Britain. Germany's first step was to launch a massive air attack. The British magnetron radar stations had been installed just in time. The RAF, knowing in advance just where to find the German bombers, could take off and intercept them before they reached England. Some bombers got through and the loss of lives and buildings was enormous. The "Blitz," as the Germans called it, was something England would never forget.

However, the Germans' loss of airplanes was so heavy that they shifted to night bombing. The RAF fighter planes, unable to see to fight at night, were helpless. Besides, the RAF had been whittled down to a fraction of its former strength. The German Luftwaffe far outnumbered them. And it was at this crucial point in the Battle of Britain that the klystrons entered the war. With klystron receiver tubes in their planes, the RAF pilots could "see" in the dark or clouds. Flying high over the German bombers as they made their way toward England, the RAF fighters could suddenly dive down out of the night, attack, and disappear, flying home to land with the help of radar in the darkness of their blacked-out airfields.

Since there were so few RAF pilots, it meant that the exhausted men often no more returned from one mission than they had to go up on another. The fate of England hung upon their efforts. Churchill afterwards immortalized them with the words, "Never in the field of human conflict was so much owed by so many to so few."

Soon the loss of German planes became so great that the air raids were completely discontinued. The proud Luftwaffe which had dominated all of Europe was so battered that it never regained its former strength. Instead of the Germans following their bombing with an invasion of England, the invasion was canceled. England was left to dig herself out of the rubble. Within two years she was planning with her allies their invasion of Europe, to liberate the countries Hitler had conquered and the people who still survived in his concentration camps.

Before the allied invasion could take place, there was another job to be done. The Germans had a powerful fleet of submarines, which was sinking British Navy ships and also the ships bringing supplies from the United States. In fact, the submarines were sinking more ships than were being built in all of the allied shipyards combined.

The RAF adapted their klystron radar apparatus so that it could be used to search for objects on the water. When the German subs would surface at night, feeling safe in the darkness, the RAF radar screens could pick them up easily. Even if a submarine were submerged, the sensitive radar could spot the slim periscope when it poked up through the waves! Hitler's underwater killers no longer terrorized the Atlantic unchallenged.

By 1940, the United States was busy equipping its own ships and planes with radar. Charles Litton's plant in Redwood City, California, turned out magnetrons of such high quality that he became one of the nation's principal suppliers. When the United States entered the war, the Federal Telegraph Company called on Litton to build and equip a tube factory for them. For two strenuous years he assisted Federal in New Jersey, while also supervising his own plants in California.

Eitel-McCullough was busy turning out its 4,000 radar tubes a day. And the Dalmo Victor Company was feverishly supplying airborne radar antennas, more than all the rest of the American producers combined.

America's engineering companies were called upon during the war to produce tremendous quantities of equipment, often without adequate materials, and always in too short a time. The slogan of the weary, dedicated workers became, "The difficult we do today; the impossible, tomorrow."

The enemy had developed its own radar, and countermeasures had to be devised. Dr. Terman was appointed director of Harvard University's Radio Research Laboratory, operated under government sponsorship. This laboratory was responsible for research and development in the field of radar countermeasures, and grew to a size of almost 1,000 persons before the end of the war. One of its most famous operations was called "Window." Dr. Terman brought Harold Elliott out from California to design a machine that would slice thin aluminum into narrow strips, grouping them in bundles. (This was not as easy as it sounds.) The allied fliers took these bundles on their missions over Europe, releasing them as they came within range of the enemy's radar stations. When the silvery strips floated down over the countryside, the German radar screens were flooded with "blips," or signals, in meaningless confusion. Other operations were more complicated, involving various ways of "jamming" the enemy's radar electronically.

More than any previous war, World War II was a technological war, a conflict of electronic devices pitted against each other on the battlefront as well as on the war material production front–the factories of each side. Skilled scientists were as important as skilled generals, and in fact many were given Army appointments with the equivalent status and pay of generals.

To be a party to destruction was far from the natural inclinations of these scholarly men from research laboratories and ivy-covered halls. For some, to do so required much soul-searching. But like gentle, humanitarian Albert Einstein, who reluctantly aided in the development of the atom bomb, they felt that they had no other choice. For Sig and Rus Varian the issue was clear, due to their intense Irish dislike of dictatorship of any kind.

During the war, Bill Hansen not only worked with the Varians on klystron production at Sperry Gyroscope, but spent half his time on war projects in a research laboratory at the Massachusetts Institute of Technology. Hansen has been described as "that rare combination: a great theoretical physicist and a great experimental physicist." He gave of his unusual abilities unstintingly, 16 hours a day, for the duration of the conflict. At one point, he contracted pneumonia, and insisted upon returning to work before he was well. From this time on, his health was poor.

Because the klystron was wrapped in secrecy as soon as it went to war, it was years before people learned how much they owed to the "three men and a tube."

At the war's end, the country's engineers and scientists turned eagerly back to constructive, peacetime work. Bill Hansen returned to the Stanford physics department. He resumed his research on a dream he had had since the 1930's: the construction of a new kind of atom smasher. In 1946 Edward L. Ginzton and Marvin Chodorow, Stanford men who had also been working at Sperry Gyroscope Company, joined Hansen in this project. (We will hear of its outcome later in the chapter.)

Hansen also worked with Dr. Felix Bloch of Stanford, who was seeking a better understanding of the magnetism of the particles of the atom. In the winter of 1945-46, Bloch and his assistants devised a method for measuring magnetic properties

Called a "nuclear magnetic resonance spectrometer," this instrument can show what is in a substance. The peaks on the graph paper are the "fingerprints" of each element in the material being analyzed.

of atomic nuclei, calling it "nuclear magnetic resonance." With it, for example, chemists could place a substance in a special electronic machine and discover just which elements were present in the substance. The elements would be identified by pulses shown on a screen, always the same for each particular element, and unique to that element. In effect, Bloch and his colleagues made it possible to take the fingerprint of each known element. Discovery of nuclear magnetic resonance was made simultaneously by another scientist, E. M. Purcell, at Harvard. Purcell and Bloch were later awarded the Nobel prize for their contribution.

During the war years at Sperry Gyroscope, Russell and Sigurd Varian had looked forward to coming back to California and starting a research laboratory of their own. In 1946 Russell returned to Stanford and, while working in the physics department, kept in mind various kinds of research and development that his own laboratory might do when established. He became excited about the possibilities he could see for commercial applications of nuclear magnetic resonance. Neither Bloch nor Hansen were interested in making and selling such devices, so Varian prepared patents for the men, and in return they gave him exclusive manufacturing rights under these patents.

In 1948, the Varian brothers' hopes for their laboratory were at last realized. Four of the men who had worked with them both in California and in the East, and who had often discussed just such a venture with them, now eagerly joined in founding the "Varian Associates." They were Professor Ginzton, H. Myrl Stearns, Fred Salisbury, and Donald Snow. Russell's wife, Dorothy, was the company's first treasurer.

Because the men who founded Varian Associates were best known for their work on klystrons, most of the early orders were for the development of new types of klystrons for the communications industry – radio, television and telephone, as well as for military guidance and communications systems.

As the company grew, they rented part of a building next to theirs in San Carlos, owned by Douglas Perham. It contained his machine shop, and for a brief period Doug worked for the new company, making some of the klystron parts. Eventually Varian Associates took over Perham's entire building, much as the Federal Telegraph Company had done with his buildings in Palo Alto when Federal was just getting its start, 38 years before.

In 1953, Varian Associates moved into new million-dollar facilities in Stanford Industrial Park. This area was carved out of Stanford University land to bring engineering companies close to the campus, to help develop what Frederick Terman calls "a community of technical scholars." Varian Associates was the first company to build in the Park, and their street was named, appropriately, Hansen Way.

Varian Associates became the world's largest manufacturer of klystrons and a leading maker of scientific instruments. It was a far cry from the small, intimate laboratory that Russell had planned. But the company nevertheless maintained a climate as ideal as possible for research and invention.

The Varian brothers realized their boyhood dreams of producing important devices. Both were awarded honors. Both became multimillionaires. They died within a few years of one another, each perhaps in a way he would have chosen, doing what he loved. Russell, whose deep affection for the outdoors was lifelong, died on a cruise near Juneau, Alaska, in 1959. Sigurd died two years later at the controls of his own plane, in a crash in Mexico.

The new type of vacuum tube which they helped create opened heretofore unexplored areas of research in many fields—medicine, commerce, defense, and space travel. The invention of the klystron and the British development of the magnetron caused a revolution in technology. Future developments made possible by microwave electronics seem almost limitless.

One of the most dramatic uses of klystrons is in the field of atom smashing, where these microwave tubes are aiding physicists in their search for answers to the profound question, "What is matter?"

As we have mentioned, Bill Hansen had conceived of a new kind of atom smasher before the war—a *linear* accelerator. This was a long tube or pipe through which he could send electrons at such speeds that they could break up the nuclei of atoms at the end of the pipe. Unlike Dr. Lawrence's cyclotron which sent positively charged particles in circles, Hansen's machine would send negatively charged electrons in a straight line. At the time Hansen was first designing this apparatus there were no radio amplifying tubes that could provide the necessary energy-supplying radio waves to push the electrons down the tube fast enough. But now, in 1947, by using the British-developed magnetron, Hansen built a small linear accelerator—the first of its kind in the world. The "Mark I" was 12 feet long and operated successfully in just the way its designer had predicted.

Gratifying as this was, Hansen realized that he needed even higher power radio amplifiers than the magnetron tube in order to get the extremely high energy beam he desired. He and his Stanford colleagues decided to try to develop a high power version of the klystron.

Work was begun in 1948. William Hansen's wartime-incurred bronchial illness by now had become acute, but he

Aerial view of the Stanford Linear Accelerator on university land west of the main campus. Electrons begin their journey at end at right background, race two miles to smash the targets in buildings in left foreground. Note the many other buildings necessary for the project.

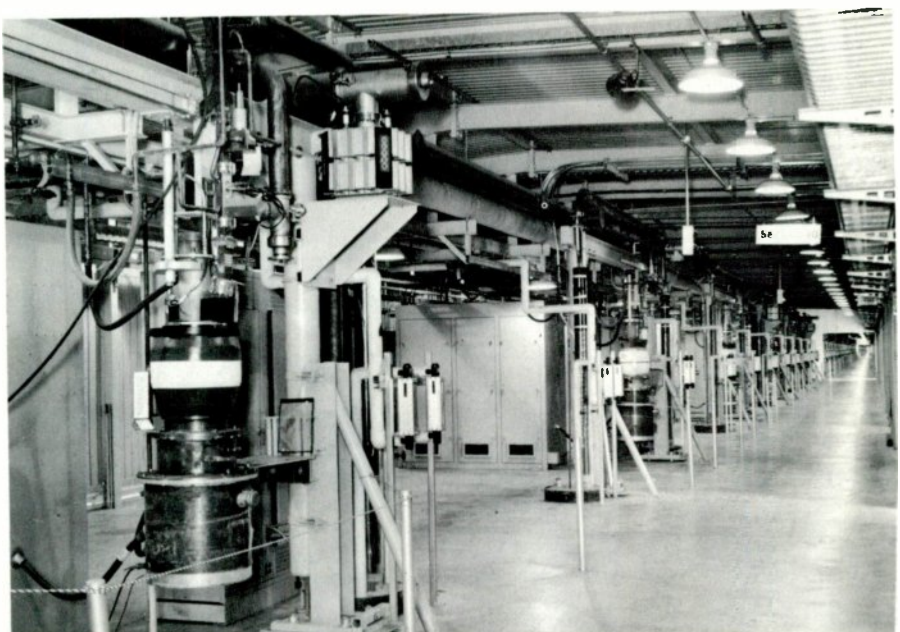
refused to give up his research. He even devised a portable oxygen mask which enabled him to continue his work. But by March, 1949, the dedicated 39-year-old physicist was gone, and his passing was a tremendous loss to the scientific world. He has been recognized as a genius and the foremost pioneer in microwave electronics.

Hansen's research team, headed by Professors Ginzton and Chodorow, continued the work on the new type of klystron. The very month that Hansen died they tested the first tube. It provided more power than a magnetron and nearly 10,000 times more than the previous klystrons. Klystron-powered linear atom smashers were now possible. Stanford University built a series of them, ever longer and longer, until they finally decided to build one two miles long!

Since the cost of such an accelerator was so enormous—114 million dollars—the federal government sponsored the project as a national facility. Under the direction of Dr. Wolfgang Panofsky, it was completed in 1966. Energized by over two hundred huge klystrons, it is at the date of this writing the most powerful accelerator of its kind in existence. It is also one of the most exact tools ever built to explore the subatomic world.

Like other electronic devices, a linear accelerator provides an extension of our senses. The accelerator's instruments can "see" distances between particles in the inside of the nucleus of the atom. These distances are so tiny that they can hardly be imagined. If you compare them to the thickness of a sheet of paper – the distance between one surface of it to the other – it is like comparing the thickness of the paper to the distance from us to the moon.

To put it another way, to look within an atom's nucleus is like standing on the moon and being able to glance down and measure the distance between two sides of a piece of paper

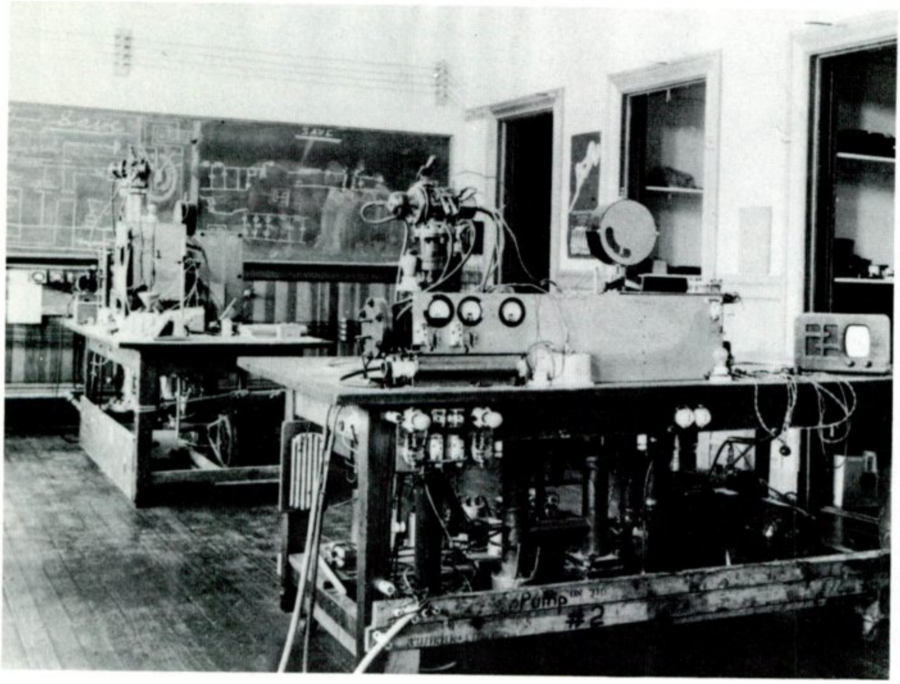


Klystron amplifiers, spaced every 40 feet in the two-mile atom smasher, feed energy every ten feet to the beam of electrons in the accelerator buried below ground. Striped, barrel-shaped magnet surrounds each klystron, so that only the output end of tube is seen.

blowing about on the earth. This is how far away or infinitesimal the world is which a high energy atom smasher enables us to observe. Indeed, Stanford men have called their accelerator "just a super-microscope."

Scientists from all nations are invited by the United States to use the Stanford linear accelerator. Nothing is kept secret. The fruitage from the cooperation of these men, coming from opposing sides in the "cold war" may be abundant, both in mutual understanding and in scientific discovery. It could well be history-making and world-changing.

What a rich heritage has been left by those "three men and a tube"—a tousle-headed inventor, a chair-rocking genius, a daredevil pilot, and their rhumba-dancing electrons in a copper doughnut!



Klystron development took place in this physics laboratory at Stanford. The tubes are the highest objects on tables, vacuum pumps are below. After 17 months' work, the invention was announced to the public, 1939.

Chapter X

JO JENNINGS AND HIS CHICKEN COOP

The drama of the growth of electronics in the West is bright with stars such as the klystron inventors, but there are many who played important supporting roles—minor inventors, skilled technicians, and engineers. We have mentioned a number, but there are literally dozens of others who deserve to be included in any account of western electronics. However, to report on each of these men would fill a second volume. We shall honor them all by telling the story of one who played his part so colorfully and well that he can perhaps carry the banner for the rest.

Like thousands of other boys in the Twenties, Jo Emmett Jennings of San Jose was excited about radio. He built his own one-tube set when he was 11, between chores on his father's ranch. During high school, Jo was the fellow to see when someone needed a speaker system for a speech or a dance. By the time he was 20, Jo had become so skilled that he was hired as an operator at the historic radio station, KQW. At San Jose State College, Jo took the few courses that were given in radio, but the closest thing to a major in radio or sound that the college offered was music, so this became his field.

When he graduated in 1936, Jo went to work for Eitel-McCullough Company. After four years, he felt ready to start his own vacuum tube manufacturing company. Whereas Bill Eitel and Jack McCullough had started theirs in a small butcher shop, and other electronics pioneers in the area had begun within the narrow confines of a one-car garage, Jo Jennings was able to move into the roomy luxury of a long chicken house in his father's orchard. There was even an accompanying outhouse. Jo cleaned out the buildings, and Jennings Radio Manufacturing Corporation was officially born on January 28, 1942, just seven weeks after the Japanese attack on Pearl Harbor had plunged the United States into World War II.

Although he made vacuum tubes at first, Jo's first big order was not for tubes, but for 1,000 capacitors. A capacitor is a device in which an electric charge can be stored. Nearly all radio systems use some form of capacitor.

Jo was naturally excited with this first contract, but these special capacitors called for tantalum, which was in short supply. Because his company was so new, it was low on the wartime priority lists for tools and materials. However, Jo was an inventive young man, and shortages merely stimulated him to resourcefulness. With a deadline to meet, he worked feverishly, trying one material after another, seeking a substitute for the scarce metal. He turned out the first or prototype capacitors using metal sheet salvaged from old motor oil cans. Later, he was able to get sheet nickel in time for the production models.

Jennings Radio could not buy one of the Litton glass-blowing lathes which were in such demand during the war, so Jo designed and built his own lathe. Men skilled in blowing glass were also scarce, so Jo trained his own glass-blowers.

One week after the first contract was received, the company moved into a new building nearby in the orchard. Jo kept the chicken coop for his laboratory; here he designed all the products the company manufactured during the war.

When Jennings Radio received a contract for 15,000 capacitors, the company had to expand again. A second factory building was erected in the orchard in a rush–just two weeks from start to finish! Later, an additional plant was opened in Salinas.

Soon after Jo had started his company, his aunt, Mrs. Doreen Townsend, began urging her husband to help her nephew. She knew that Jo lacked money and business management experience, but she had unbounded faith in his inventive ability and in the future of the electronics industry. Calvin K. Townsend, an industrial engineer 12 years older than Jo, was lukewarm about joining the orchard enterprise. He laughingly reminisces today, "She hounded me until I finally gave in."

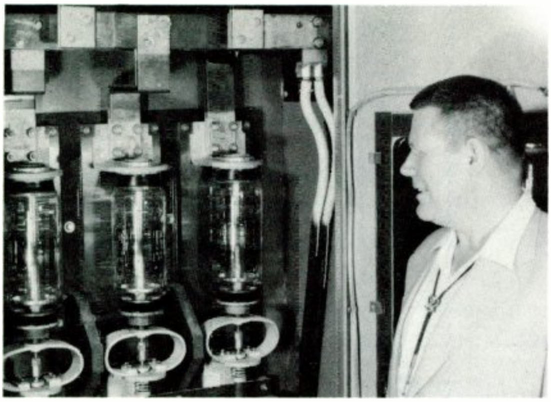
It was an unusual and happy partnership that was to last for 25 years. The two men were a study in contrast. Jo, the impulsive, energetic president, was usually tieless, coatless, and could be found working in the shop. He was greeted as "Jo" by all his employees. The "hams" in the company, especially, found him an ideal boss; he set up a special area in the plant, well stocked with parts, where these amateur radio enthusiasts could build and repair their radio gear. Supposedly this amateur activity was done at noon or after work, but Jo, a ham himself, understood how a job might take longer than a lunch hour. Many of the amateurs, as a result of their additional work in radio, came forth with excellent ideas for improving the company's products and manufacturing processes. The employees formed their own radio club, numbering 30 members including the company president. The club was active in the Military Affiliate Radio System (MARS) sponsored by the Air Force. This meant the group was trained and stood ready to help in case of sabotage or any breakdown of the country's military communications.

Calvin Townsend, the stable, businesslike general manager, was to be found in the office, pouring over government contracts, company budgets, and sales reports. Most of Jennings' employees were local people who stayed with the company for many years. They knew Calvin Townsend well, but somehow always addressed him as "Mr. Townsend." Jo's creative nature and his ability to inspire others to work imaginatively and hard was complemented by Cal's ability to convince local bankers and businessmen to loan the shaky new company money, at the same time that he was persuading electronics companies in the United States and abroad to buy Jennings Radio's products.

As the orders increased, the company grew to 450 employees. Meeting deadlines during the war was just as strenuous for the newly founded company as it was for the country's long-established ones. But there was a difference. At Jennings Radio, when the last of a rush order was shipped, Jo would take the entire work force out to a Chinese dinner. "There was another difference at Jennings," recalls a long-time employee. "There never was any alcoholic liquor served at company parties. Jo was a true teetotaler. When we planned a dinner or a celebration, we planned it without a bar."

Once when a project was completed that had been particularly long and difficult, with much overtime, Jo simply closed down the plant and said, "Let's go fishing for a week!"

Toward the end of the war, Jo worked on something he saw a great need for—a variable capacitor which would operate in a vacuum. (A variable capacitor is one whose capacitance can be changed. When you turn the tuning knob on your home radio you are probably adjusting a variable capacitor.) Jo



Jo Jennings inspects a factory installation of three of his vacuum switches.

realized that placing a capacitor in an evacuated glass or ceramic container would give the capacitor many advantages. Transmitters could be made smaller in size, and would be far easier to tune and keep tuned. Since the plates would be sealed in, there would be no surface contamination due to dust or moisture. The transmitters could operate over wider frequency ranges. Vacuum capacitors could handle high voltages better than ordinary capacitors, making possible the development of higher power transmitters than before.

Jo applied for a patent on his vacuum variable capacitor in 1944, and the patent was granted in 1947. His device involves an ingenious arrangement of hollow metal cylinders of increasing diameters, each nested within the other. These cylindrical plates are moved by the contraction or expansion of a bellows similar to a tiny accordion. As the plates move in relation to each other, the capacitance is changed.

With the Jennings vacuum variable capacitor, it is possible to change the frequency of a transmitter quickly, and to use a broad range of frequencies. For example, in combat conditions, ships and aircraft ranging over great distances must have this flexibility to operate efficiently, since they move very rapidly from the range of one frequency to another. Without vacuum variable capacitors, changing frequencies in this type of equipment is a cumbersome operation, often requiring apparatus as large as a desk. With the Jennings variable capacitors, which are often no more than a foot long, the frequency change can be made almost instantly.

Although Jennings Radio has made many improvements on the original product, the principle of the vacuum variable capacitor is still the same in nearly all of those manufactured in the world today.

After World War II, Jennings Radio also developed switches and relays in vacuum. A switch is a device used to close or open a circuit, thus either letting current flow or stopping it from flowing. A home light switch is a simple example of an electrical switch. A relay is also used to close or open a circuit, but it is operated indirectly, either automatically or by remote control. Your automobile horn is honked as a result of a relay's action. An electrical relay normally includes an electromagnet and can handle stronger currents than can a small hand-operated switch. But the weak current released by such a switch can be used to activate a relay. Relays and switches are widely used in electrical circuits to accomplish all kinds of results. Some of these operations are very complicated.

Enclosing relays and switches in a vacuum gives them certain advantages, just as it did when Jennings put his variable capacitors in a vacuum.

"We are called Jennings Radio," Jo Jennings would say with a grin, "but we make no radios." However, many radio communications manufacturers use Jennings capacitors, relays, and switches in building airborne, mobile, and marine radio systems. The Voice of America's powerful transmitters, for example, which beam U.S. news and views into countries behind the Iron Curtain, employ a large number of Jennings vacuum capacitors and switches.

In the 1950's, Jennings Radio decided to construct high-voltage and high-current testing facilities, primarily for testing their own products, such as the high-voltage vacuum capacitors and switches they were then developing. They enlisted the help of Dr. Joseph S. Carroll, an expert from Stanford University's famous Ryan High Voltage Laboratory. Professor Carroll had recently retired from many years of research and teaching, his students including such men as David Packard, William Hewlett, and Charles Litton. The Jennings engineers welcomed him.

Shortly after he arrived, one of them approached Dr. Carroll with a design conceived by Jo Jennings and which Jo had assigned the engineer to construct. The young man was certain the device would never work and wanted Dr. Carroll to tell Jo. Dr. Carroll was well aware of the "wild ideas" inventors like Jo could dream up, but he also knew that for ten that wouldn't work, there would be one "impossible" one that would.

He replied to the engineer, "No. I've learned never to say a fellow can't do a thing until he has tried it and failed. My advice to you would be to go ahead and build it!" It is not recorded whether this particular device worked or not, but dozens of Jo's inventions, made without either the benefit or hindrance of formal engineering training, were very successful. He was granted over 100 patents.

Jennings Radio kept pace with the ever-changing demands of postwar electronics. The company's engineers developed controls that would stand up to the severe extremes of heat, pressure, vibration, and shock involved in rocket technology.

Jennings products won a reputation for reliability. As a result, they have been used extensively in the nation's space program. For example, Jennings vacuum relays are used in changing the direction of orbiting satellites. A signal is sent from the earth through a radio wave to a satellite, where, faint though it may be by the time it arrives, the signal is picked up by a receiver, amplified, and then fed into a very sensitive relay. The still weak current closes the relay's contacts, which enables a heavier current to flow, strong enough to be used to ignite a retro-rocket.

The company's unique vacuum capacitors, relays, and switches have been useful in many other special applications where there was nothing else that could do the job. Today, every cyclotron in the country and many public utility companies are finding Jennings vacuum switches essential.

In the 1960's, Jo Jennings and Calvin Townsend agreed to sell the company to the International Telephone and Telegraph Corporation and found themselves suddenly millionaires. The enterprise they had so diligently built had grown from 6 employees to 500. It was not a large company by comparison to others that had blossomed on the Peninsula; however, their special devices had played a small but vital role in the development of electronics itself.

Chapter XI

"MAGNETIC RECORDING WILL NEVER HAVE A FUTURE"

During the latter part of World War II, two events occurred, half a world apart, which were to be of major importance to electronics technology. An American Signal Corps officer in Paris, France, carefully took apart two captured German devices and shipped the pieces home to northern California, in Army mailbags. And an aviator from Russia started a manufacturing company in northern California in the loft of an old warehouse. These moves destined the two men to meet some years later with dramatic and far-reaching consequences.

In 1944, T. I. Moseley's Dalmo Victor Company was given a large contract by the government for radar scanner antennas to be used in Navy fighter planes. However, Moseley needed a certain type of small generator and motor for this airborne system and could find no firm which had ever made them. Moseley discussed the problem with an engineer in his company, Russian-born Alexander M. Poniatoff, who had a keen interest in the design of electrical equipment. Slim, resilient Poniatoff was a man who seemed to thrive on difficult problems. His response was typical. "If generators and motors are not available, we can develop them ourselves!" Moseley was delighted and suggested that Poniatoff start a new company for this purpose. The Russian engineer named it "Ampex" using his own initials and adding "ex" for "excellence."

The organization was first housed on the top floor of the Dalmo Victor Building, a four-story former furniture warehouse in San Carlos. There, amid exposed pipes and crudely finished walls, Poniatoff and five employees began work. Within 20 years Ampex was to become one of the 500 largest manufacturing corporations in the nation, employing over 10,000 people.

During its first year, Ampex made various kinds of small generators and motors. Douglas Perham, whose machine shop was kept humming by many Peninsula firms during the hectic war years, was one of those who produced some of the parts for the Ampex products.

Alexander M. Poniatoff, Russian-born engineer, founded Ampex Corp. and developed magnetic tape recording into a major industry in the United States. Recorder is special type used to tape impulses from instruments such as those measuring heartbeats of an astronaut.

Fighting a war behind the scenes was a change for Poniatoff. He had fought first against the Germans in World War I, as a Russian Navy pilot, and then against the Communists in Russia's violent civil war, as an Army pilot. One day, during the civil war, he made a daring flight into Communist-held territory to the village of Aisha, near Kazan, where his parents lived. He flew so low his parents recognized him and waved wildly. He dared not land in "enemy" territory. As he pulled up and away he looked back and saw his parents standing in the field, still waving. It was the last time he ever saw them.

When the Communists took control of the country, Poniatoff escaped by way of Siberia in a boxcar, in a 30-below-zero storm. As he huddled with the other men for warmth, one of them described a visit he had once made to a beautiful city of mild winters and friendly people—San Francisco, California. As Poniatoff bumped along in the icy freight car he decided that since he could never return to his own country, he would go to San Francisco, on the other side of the world. He was able to make his way only as far as Shanghai. He could speak no Chinese although, in addition to his Russian, he spoke German and a little English. However, he had a degree in mechanical engineering, and he was eventually able to find a position. The job involved much electrical engineering, and Poniatoff spent long hours studying and mastering this phase of the work.

After seven years, he was finally granted a visa and arrived in San Francisco. The immigration officer refused him entry, saying they would not accept "deportees" from Shanghai. It took masterful argument on the Russian's part, but he at last convinced the authorities of his eligibility. San Francisco was all that he had dreamed it would be, but he was not able to find suitable work there. He took a position with the General Electric Company in Schenectady, New York. In 1930, he was at last able to return to San Francisco, where he worked for the Pacific Gas and Electric Company for ten years. He joined Dalmo Victor just in time to serve his adopted country in its World War II effort.

As more and more military orders poured into Poniatoff's newly formed company, it was necessary to expand. Ampex moved out of the loft into its own building a block away at 1155 Howard Street in San Carlos. In 1945, the war ended and Ampex's business slowed to a halt. Many similar small companies, which had put all their efforts into supplying the nation with wartime necessities, were forced to close when their military contracts were canceled. But Alexander Poniatoff was tempered, as steel is tempered to hardness and toughness, by the fires of his past experience in wars and as an orphan in alien lands. He did not quit easily in the face of adversity. "After some sleepless nights of indecision," he recalled later, "I resolved not to go out of business."

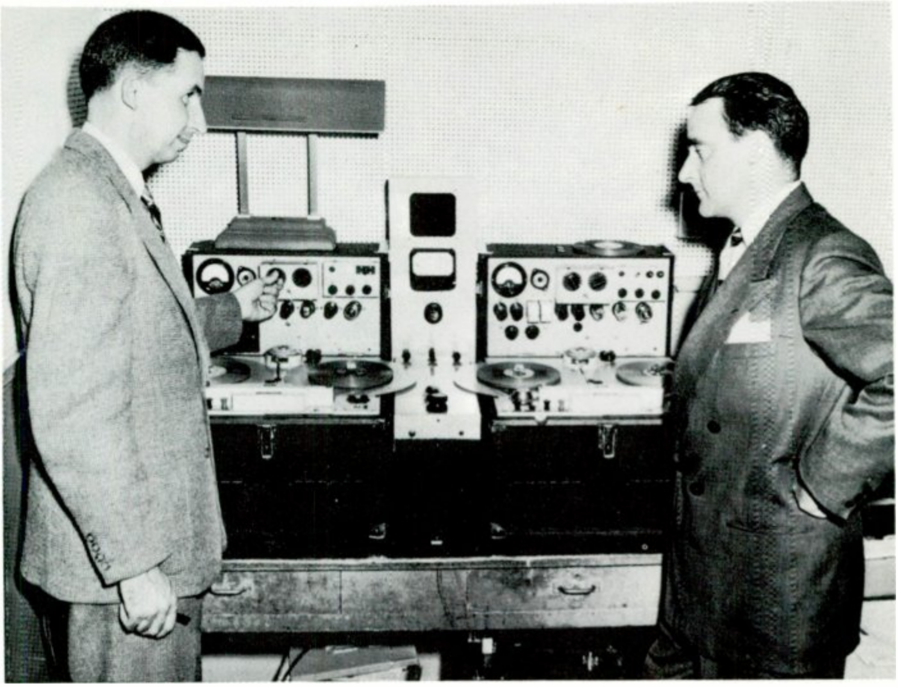
Ampex's first postwar products were small commercial motors. When the company began to consider making high-fidelity sound reproduction equipment, G. Forest Smith, the general manager, introduced to Poniatoff a friend of his, Harold W. Lindsay, who had a strong background in sound reproduction.

Lindsay was a man of varied experience, including wartime work with Dr. Ernest O. Lawrence of cyclotron fame. From early boyhood Harold was interested in electricity and chemistry. In high school he was president of the Science Club. Once he and a friend were experimenting with some explosive chemicals on top of his mother's washing machine on the back porch. Harold suddenly realized that they had made a mistake, and he yelled to everyone in the house, "Run outside quick! Get outside!" Fortunately the family obeyed, just in time to hear a tremendous explosion. "Karoom!" All the windows in the rear of the house were blown out. Leaves were stripped off the trees and shrubs in the garden. Pieces of glass and wood sailed into the neighbors' yards. Most of the dishes in the Lindsays' kitchen were broken. The washing machine was ruined. It took Harold months to replace all the windows. His friend somehow never came over to play with him again.

After graduating from high school, young Lindsay went to work to help his father support their family. At every opportunity he continued his education, taking mathematics and engineering courses. Through the years he also developed skill in his hobby: high-quality reproduction of sound. In July, 1946, Lindsay went to a meeting of the Institute of Radio Engineers in San Francisco, to hear a talk on sound recording by a former Signal Corps officer, John T. Mullin.

John Mullin described how, during World War II, communications officers in Europe had been amazed to hear German broadcasts of recorded music and speech of an unusual fidelity. They sounded so "live" that the Germans could pretend to broadcast a symphony concert from a city which the Allies knew was at that moment being badly battered by bombs. Hitler was sometimes announced as speaking from a city under bombardment, while he was in reality miles away. The Allied officers were puzzled as to what the equipment could be. It played too long without interruptions to be a disc recorder. Its quality seemed to be too good to be that of a wire recorder.

Jack Mullin was working in the Paris communications laboratory when the first of these German recording devices to



John T. Mullin, sound production engineer, with the German Magnetophone which he brought to the U.S., improved, and demonstrated. As a result, Bing Crosby and others became interested in tape recording.

be captured was brought into the laboratory. The secret of the "live" programs was revealed: rolls of plastic tape winding past small electromagnets.

In the early 1920's a number of men were attempting to use magnetic tape as an alternative to the magnetic wire recorder pioneered by Valdemar Poulsen, who has been heralded as "the father of magnetic recording." About 1927, a German, Fritz Pfleumer, experimented with tape coated with powdered magnetic materials. Pfleumer experienced the same problems with his tape that others had had with wire; it would break and snarl. It was difficult to get the magnetic powder to adhere to the tape. But several German companies took up the development of Pfleumer's ideas. By 1940, they had produced a tape using a durable plastic backing to which iron oxide would adhere. This was a giant step forward in magnetic recording. The

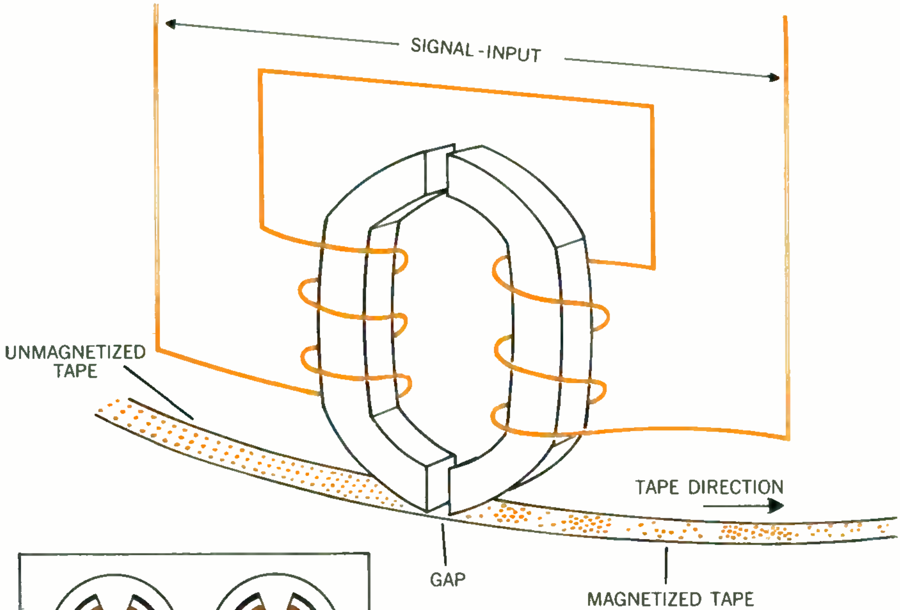
Germans called their recorder the Magnetophone. Several American companies had also experimented with magnetic tape recording, but Jack Mullin, a recording engineer by profession, knew that the Magnetophone was superior to anything that Americans had yet achieved.

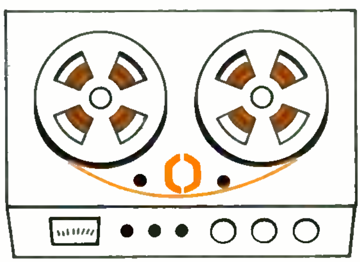
To Mullin's dismay, the Paris Signal Corps laboratory was ordered to send one of the captured tape recorders to the United States for further analysis and to destroy the rest of them with a sledge hammer, a common procedure with enemy apparatus during the fluctuating tides of war.

The young radio engineer from San Francisco begged permission to keep two of the recorders, and it was finally agreed that he could do so. He carefully disassembled them and shipped them home, part by part, along with about 30 reels of tape.

As soon as Mullin returned home from the war in 1945, he assembled and improved his German recorders. He was a partner in the W. A. Palmer Company in San Francisco, a firm which produced 16-millimeter color films. Mullin used the tape recorders to record the sound for the films, with excellent results. (Another officer, Richard Ranger, after hearing Mullin praise the Magnetophone during the war, was later able to return to Europe and get apparatus and information sufficient to enable him to manufacture almost exact copies of the Magnetophone, in the United States. They were used in making talking pictures.)

When Jack Mullin had concluded this background story of the Magnetophone for the assembled San Francisco engineers, he gave a simple description of the instrument, before starting his demonstration of its performance. First, sound was changed into electric signals in a microphone, just as is done with a telephone transmitter. These signals were amplified with vacuum tubes and then passed through a recording head, in the form of varying current. This head was a small ring-shaped structure about an inch in diameter and about one fourth of an inch thick which served as an electromagnet. When the plastic tape was moved past the recording head, the minute iron oxide particles on the tape were magnetized as the signals came through the head. With each signal, weak or strong, the particles would be magnetized correspondingly, weak or





Magnetic tape recorder. Particles on the tape become magnetized in a pattern corresponding to the electrical impulses running through the wire. These impulses may come from a microphone. When the tape is played back, the particles excite electrical impulses in the wire which can be translated back into the original voice message.

strong, each becoming a tiny magnet in itself. The tape could be wound on a spool or reel and stored indefinitely. When it was unwound and drawn past a playback head, an electromagnet similar to the recording head, the magnetic pattern of the particles on the tape reproduced the original sequence of electric signals. These could then be translated back into voice or musical notes through a vacuum tube amplifier, and then sent through either headphones or a loudspeaker.

When Mullin played the tapes for the engineers at the San Francisco meeting, his audience seemed impressed with the high quality of the reproduction, but perhaps few realized the significance and future possibilities of what they had just witnessed. Certainly no one in the large crowd was as excited as Harold Lindsay, who rushed up to meet the speaker and talked with him long after everyone else had left. Their friendship was to be lifelong and their mutual enthusiasm for magnetic tape recording was also never to wane, but to have historic results.

"This is what I would like to work on, if I ever get the opportunity," Lindsay told him. "If you ever do, contact me!" replied Mullin. Neither realized how soon this was to be.

It was just three months later that Lindsay met Poniatoff. He was hired as a consultant. Lindsay told the Ampex men about the Magnetophone, and the usefulness magnetic tape recording would have for commercial reproduction. Poniatoff said, "Why not call Jack Mullin so I can see the equipment?" Mullin told Lindsay he was just leaving for Hollywood where he was to demonstrate the Magnetophone for the Society of Motion Picture Engineers. Poniatoff decided to attend also, and upon his return told Lindsay enthusiastically, "Now I see what you mean. It is certainly worth looking into. Let's give it more thought." And after more thought and discussion, Poniatoff announced one day, "I am going to make the leap!" Lindsay was asked to leave Dalmo Victor and be the project engineer for developing an Ampex tape recorder.

Mullin was not free to show Ampex the electronic circuits he had devised for the Magnetophone, as he had tentatively promised them to another company. But Ampex was able to get microfilm copies of the original German circuitry from the U.S. government. With these as a basis, work on the first Ampex tape recorder was begun on December 10, 1946. Lindsay says now that if they could only have foreseen the important and rewarding consequences of the event, it would have helped their morale during the following months. For these months were lean and sometimes dark with discouragement.

Early in 1947, while the Ampex recorder was still on the drawing board, a number of top electrical engineers were invited to evaluate the new product. Their verdict: it could never be a practical device.

Nor were these the only engineers who shook their heads at the idea. As Poniatoff recalls today, "Many doubted the usefulness of the machine. As a matter of fact, Dr. Heine of Telefunken (a German electronics company) had brought a Magnetophone recorder to America, hoping to interest General Electric. Their unanimous decision was, 'Magnetic recording

Harold W. Lindsay, project engineer, with the first Ampex tape recorder, a great improvement over previous magnetic recorders. Crosby ordered 20 in 1947. Many industries soon found them invaluable.

will never have a future.' Dr. Heine said to me later, 'I went home heartbroken.' "

Ampex found it difficult to borrow money for the production of their tape recorders. There were some weeks when there were no pay checks. Harold Lindsay remembers having to leave his car home to save money, and riding his bicycle to work, carrying his sack lunch on the handle bar. Later, these dedicated workers were rewarded with shares in the company; as Ampex prospered, these shares proved to be a rich reward indeed.

Working with Lindsay was Myron Stolaroff, an electrical engineer and an expert on small motors. His important suggestions are still used in Ampex recorders today. Jack Mullin was consulted as to what he felt needed improvement in the Magnetophone. And it was at this point, when the small Ampex team was working on their first laboratory model, with insufficient funds and an uncertain future, that a most unexpected fairy godfather appeared on the scene: Bing Crosby.

The famous "crooner" had a weekly radio show on the American Broadcasting Company network, and he insisted that it be prerecorded on discs rather than go on the air "live." However, when a mistake was made on a disc, the good part had to be re-recorded. There were usually many re-recordings from disc to disc to disc, eliminating unwanted parts. This caused a build-up of distortion, which became objectionable to home listeners. Bing's audience began to grow smaller. His sponsor put pressure on him to go on the air directly.

About this time, Crosby's sound engineers attended the same meeting in Hollywood which Poniatoff had gone to, and had also come away most interested. They invited Jack Mullin to give Crosby a demonstration of the Magnetophone. Bing was immediately enthusiastic over its advantages. With magnetic tape, errors could be remedied right in the middle of the tape. The best parts of a recording session could be spliced together with no re-recording necessary. And all the tapes could be erased after a show and used over and over again. Best of all, the Magnetophone's tapes sounded "live" over the radio.

So, in the summer of 1947, Jack Mullin began recording a series of 26 consecutive shows to be broadcast during the 1947-48 program season. Those recording sessions are something Jack Mullin, even skilled as he was in recording and editing, will never forget.

"The pressure put on these two solitary Magnetophones was tremendous, as it was on my own nerves!" he recalls. "At that time they were the only two machines in the United States, to my knowledge even today, that were capable of thoroughly professional performance. I lived in constant fear of breakdown. Consequently, when it was clear that the first show was a great success and that I would be expected to produce all succeeding ones, I contacted Ampex and told them of this great opportunity. As a result, the Crosby people and the Ampex people got together and I rendered to them whatever technical assistance I could from then on." (Mullin was now free to help Ampex, as he was no longer involved with the company which had earlier been interested in his circuitry.)

Ampex completed its first experimental model in August, 1947, and promptly took it to Hollywood to show to Bing Crosby. It was a great improvement over the Magnetophone. The magnetic heads were superior. The tape was easier to thread and not as likely to break. Crosby was so pleased with its performance that, in October of 1947, he ordered 20 of them for himself and the network stations, at $4,000 apiece. They were to be delivered in six months. It was a staggering order for the fledgling company and its handful of employees. The men worked long hours, often around the clock. Even the office manager, Charles McSharry, and the accountant, Elmer Longfellow, became assemblers by night. Mrs. Lindsay brought midnight sandwiches to the men.

The 20 machines were delivered on time and were a huge success. Crosby's millions of fans tuned in to his show and they stayed tuned in. His sponsors were happy, too. And Ampex was launched as a manufacturer of fine magnetic tape recorders.

Harold Lindsay's team looks back with some pride at these first recorders. Frank Marx, Vice President in charge of engineering of the American Broadcasting Corporation, wrote to Ampex, "Commencing April 25, 1948, and continuing through September 25, 1948 (a total of 22 weeks), the American Broadcasting Company in Chicago recorded on the Ampex approximately 17 hours per day. For this 2,618 hours of playback time, the air time lost was less than three minutes, a truly remarkable record."

The principle of this first Ampex tape recorder is still the basis for the advanced recorders Ampex produces today, 20 years later.

Jack Mullin became head of Crosby's magnetic recording development laboratory and later went on to make further contributions in the field of tape recording.

In order to interest professional engineers in buying their recorder, demonstrations were staged by Ampex around the country. As Poniatoff describes one of these meetings, "The top technical experts of the radio and recording industries were gathered to evaluate the quality of our equipment. Our representative who was in charge of the demonstration arranged an orchestra in a separate studio, and sound was brought into another studio for the listeners with an A-B switch in their hands. On one position of the switch they were listening to the orchestra through microphones and loudspeakers not going through the recording system. On the other position of the switch, they were listening to the same orchestra after it was recorded and instantaneously played back to them. The positions of the switch giving either direct sound or recorded sound were unknown to the audience. After being given ample time, they were asked which position gave them the direct sound. No one could be sure. This was something new in recording!"

The fame of the recorder spread, and soon the major networks and recording engineers in other fields were converted by Ampex to tape. Other companies developed magnetic tape recorders after the war, but Ampex led the field. One of the reasons for their success, according to Poniatoff, was that, living up to their name based on "excellence," "We worked on the basis that everything must be of the highest quality. We considered cost to be secondary."

What perhaps few of the Ampex men realized in those early days was that they had produced a tremendously useful instrument which was to become an essential part of postwar technology. With its magnetic tape recorder, Ampex supplied the Electronics Age with a means of recording and storing information faster and more compactly than any other practical medium previously available. Anything that can be translated into electrical signals can be recorded on tape.

When the giant computers came into wider use in the 1950's the magnetic recorder was ready to act as a "memory" to store the huge bulk of information processed by these "electronic brains."

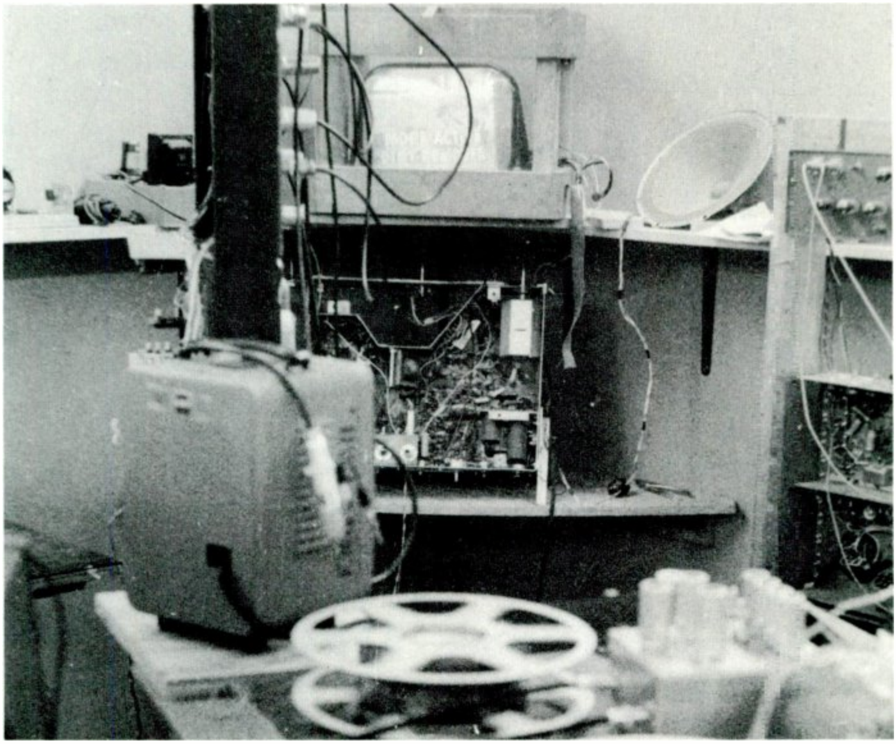
Early in the 1950's Ampex developed special instrumentation recorders which were used at airplane and rocket test centers. Measurements such as altitude, speed, vibration, temperature, and pressure could be sent as electrical signals to an Ampex recorder which could store the information for study. Ampex recorders became standard equipment at tracking stations and defense posts around the world. Later, as we moved into the Space Age, tape-recorded knowledge obtained from the instruments we sent into space enabled scientists to design space suits to ward off cosmic rays and to bolster space capsules against meteorite strikes.

In 1955, Ampex developed the world's first stereo home music system. Today it is the biggest producer of prerecorded stereo tapes in existence.

Magnetic tape recorders are increasingly useful to science, industry, and the field of medicine. New applications are being discovered continuously.

One of the most important events in tape-recording history was the production by Ampex of its first television or videotape recorder. To be able to record both the sound and the picture of television on a ribbon of tape had been a dream of engineers. The Radio Corporation of America, the Bing Crosby Enterprises Laboratory under Jack Mullin, and Ampex were among the organizations earnestly striving to achieve this. In 1951, the Mullin group gave what may have been the first demonstration of video from tape ever recorded. Far from perfect, it was nevertheless a light on the road.

At Ampex, a 31-year-old radio engineer from San Francisco, Charles P. Ginsburg, was put in charge of the videotape proj-



Charles P. Ginsburg's Ampex laboratory about 1955 when the first videotape recorder was being designed and built. Many technical men doubted the possibility of a television recorder, and Ginsburg's team worked uphill much of the time. (Note picture tube in wooden slats.)

ect. Ginsburg had been a studio and transmitter engineer with the historic Station KQW, now KCBS. During the years while Ginsburg was attempting to develop a television recorder at Ampex, there were many technical men who doubted that top-quality television recording was really possible. Ginsburg and his handful of engineers and technicians were even occasionally taken from their research and used elsewhere in the plant. However, they persisted in their efforts and, after one or two breakthroughs, Ginsburg's team triumphed. In April, 1956, Ampex introduced its first videotape recorder. It caused a revolution in the television industry. Within a few days Ampex was flooded with orders, even though the first machines cost $75,000 each!

As with its first audio tape recorders, Ampex's first television recorders were used by the national networks. Actors, directors, and sound engineers were all appreciative. With tape, television shows could be shot and reshot until perfect, just as could be done with film; but tape offered the advantage of needing no processing. It produced immediate pictures and of better quality than film. In the late 1960's home models were developed that could be plugged into a television set in such a way that they would record a show, then play it back at a time more convenient to watch. The home models also included a compact video camera for those wanting to put their own activities "on television." Unlike movie film, the videotape of course could be used over and over again.

"Douglas Edwards With the News" was the first regularly scheduled television program to be broadcast on tape, on November 30, 1956, over the Columbia Broadcasting System. Like Ampex's original sound recorder, this first Ampex videotape recorder performed like a seasoned trouper from the start, and for many years afterward. It was finally retired by CBS after nine consecutive years of service and more than 17,550 hours of air time.

In 1958, just two years after Ampex introduced the first practical videotape recorder, the company produced a unit for recording and reproducing color television.

Charles Ginsburg was showered with honors, among them the David Sarnoff Gold Medal Award, the Vladimir K. Zworykin Award from the Institute of Radio Engineers (now IEEE), and the Valdemar Poulsen Gold Medal Award from the Danish Academy of Technical Sciences. The Academy of Television Arts and Sciences honored both the Ampex videotape recorder and the color recorder by giving each an "Emmy" award.

The first Ampex videotape recorder as it looked when it emerged from the laboratory and was introduced to the public. It was an instant success.

Within ten years after its initial appearance, Ampex's videotape recorders were entertaining air passengers and showing TV audiences "instant replays" of football plays. Ampex recorders were on board United States Navy aircraft carriers showing jet pilots how they looked as they landed just a few minutes before. Teachers of ballet, golf, tennis, and bowling all found the videotape recorder an invaluable aid. Lectures, concerts, surgical operations, and scientific experiments could all be videotaped and shown at later dates to many audiences.

Foothill College in Los Altos Hills, California, used its videotape machines to help the teachers improve their instruction methods. They were televised while actually conducting a class. Then they were given a "teachers only" show of themselves. One instructor was almost unbelieving when he saw himself pacing back and forth like a caged animal in front of his class. He never paced again. Another teacher had an even more embarrassing experience; as he listened to his own voice and watched himself lecture, he fell sound asleep!

With an ever widening list of products being distributed to many nations, Ampex kept adding new buildings at its headquarters which had been established in Redwood City. Today (1967) it finds itself on more than 40 acres, with other plants in the United States and abroad. Alexander Poniatoff, at 75, still takes an active interest in the company he founded. But his creative, problem-solving talents are also turned toward a variety of projects remote from tape recording. In his own outside laboratory he leads a small group of scientists in special research in the field of preventive medicine.

Poniatoff designed his own home and it is to his credit that Frank Lloyd Wright found only two items he would have treated differently, enlarging a room and moving a fireplace from one wall to another. His swimming pool is filled with salt water. His shoes are custom-made to his own design.

He drinks carrot juice in his office because—and there is a twinkle in his deep-set blue eyes—"I have discovered that carrot juice is much better for you than coffee." Nor does he offer cigarettes to those who call on him. "When I was in school," he told a recent visitor, "my mother, whom I loved dearly, said, 'If you want to do something to please me, don't learn to smoke.' " There was a pause, and one might almost imagine that he was looking back to that scene where he last saw his parents in that field in Russia, waving to him. Then Poniatoff added quietly, "I never did."

The former Russian pilot is warmly loyal to the Russian people, generously helping others in America who were forced as he was to leave their homeland. As he sits in his office today, looking out over the green lawns and the Ampex fountains sparkling in the California winter sunshine, it brings him particular pleasure to tell of his friend in the icy boxcar in Siberia who first told him about San Francisco. "He was able to come to San Francisco, too, and lived there the rest of his life!"

Chapter XII

POSTWAR ELECTRONICS

A GIANT BOOKKEEPER

World War II gave thousands of Americans their first chance to visit California. Many came to work in the shipyards and aircraft factories; others passed through on their way to serve in the war in the Pacific Ocean area. Most people liked what they saw and resolved to stay or to return. After the war, the more or less steady trickle of people moving from east to west, since the Gold Rush days, became a flood. The great migration westward eventually gave California the largest population of any of the states of the Union.

During the years following World War II, the Bank of America found itself almost swamped by the increase in its customers from the tremendous influx of people. It pioneered the idea of branch banks, bringing money to many small California towns and thus assisting them to build and grow. It became the largest bank in the nation. Thousands of checks poured in each day, and it grew more and more difficult to process them by hand. So the bank's president, S. Clark Beise, turned to the Stanford Research Institute in Menlo Park, California, for help.

SRI is an institute which was established in 1946 by the trustees of Stanford University and a group of West Coast business leaders to provide Western industry with a center where diversified applied research could be performed. Researchers at the Institute have looked for the answers to a wide range of questions for their customers, such as why mosquitoes prefer to bite some people rather than others, or how to build a machine that will be able to look at thousands of pictures of cloud formations, almost instantly, and predict from them whether it will rain tomorrow. When Walt Disney wanted to know the best place to build his storybook playground, Disneyland, he took the advice of the economists and engineers at SRI.

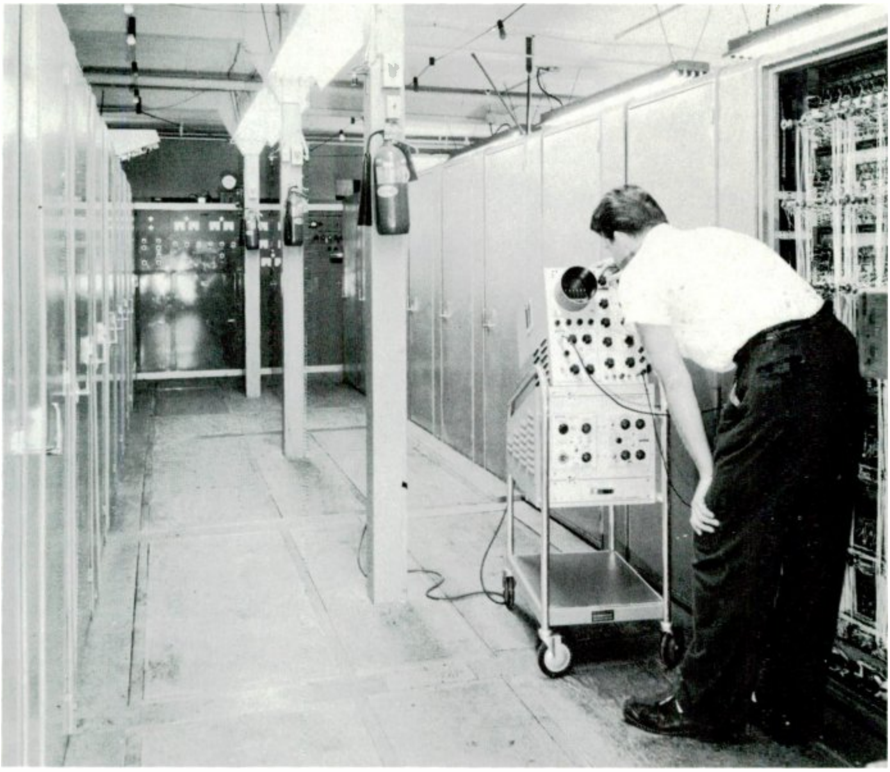
From its start, Stanford Research Institute was well staffed with electronics engineers. (Today, of its 3,000 employees 800 are engaged in electronics projects.) Yet so difficult was the challenge put to the SRI engineers by the Bank of America that it took them five years—until 1955—to meet it. What they then proudly presented was an electronic bookkeeper which they called ERMA, short for Electronic Recording Machine, Accounting.

ERMA contained 8,000 vacuum tubes, took up several rooms, and weighed about 25 tons, but she soon became the darling of the bankers. "ERMA can read!" they cried delightedly. "ERMA can file and remember what and where she filed." "ERMA can sort a stack of a thousand checks five inches high in a minute and a half!" ERMA's arithmetic units, made up of electron tubes, enabled her to add and subtract with amazing speed. The tubes generated so much heat, however—enough to heat an eight-room house—that a special air-conditioning system had to be built to keep her cool.

In designing ERMA, the SRI engineers benefited from previous work in the field of computers. As early as 1822 Charles Babbage, a brilliant Englishman who had invented numerous things, including the speedometer, drew extensive plans for a machine to assist mathematicians and astronomers in deriving more accurate calculations. The fundamentals of Babbage's design are those of our modern computers, but his device was never completed, as certain essentials had not yet been invented.

In 1885 our country was faced with the problem of compiling the census of 1890. It had taken seven years to complete the previous ten-year census for 1880. In the meantime the population had increased almost 25 percent. It became obvious that taking the next regular census, due in 1890, would consume so much time that before it was done it would be time to start counting for the census due in 1900. Dr. Herman Hollerith, a statistician, prepared punched cards which, when fed into specially designed accounting machines, completed the 1890 census in one-third the time of the previous one. Hollerith's system and the company he formed eventually resulted in that huge computer manufacturer, International Business Machines Corporation, with its now famous "Don't fold, mutilate, or spindle" IBM cards.

World War II made new demands upon computer technol-

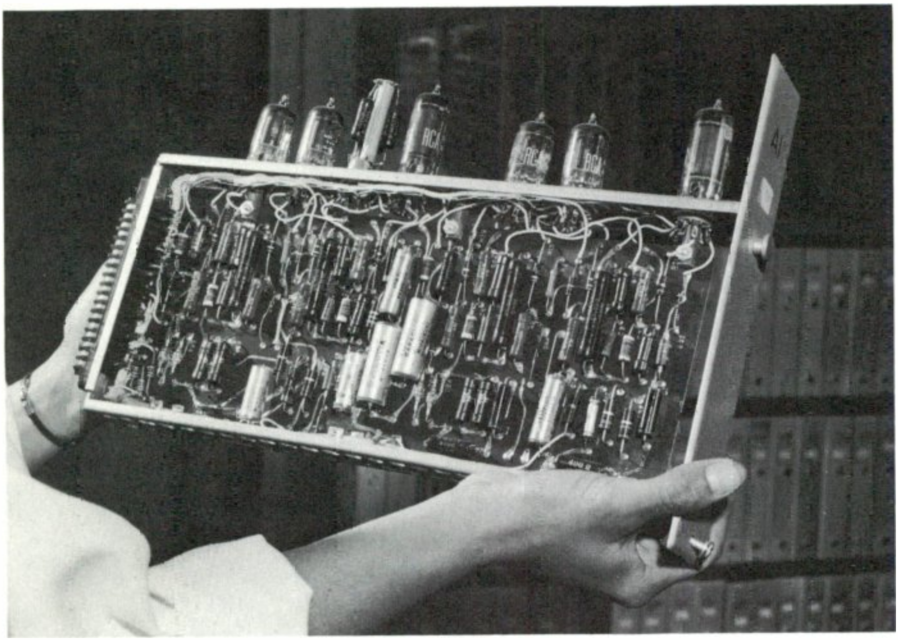


Checking the "heart" of ERMA, giant bookkeeping machine developed by Stanford Research Institute for the Bank of America. These two rows of cabinets contained 50 miles of wiring, over 8,000 tubes.

ogy. In an answer to these needs, the first large-scale electronic computer ever built was designed at the University of Pennsylvania. Called ENIAC, or Electronic Numerical Integrator and Computer, it assisted in mathematically determining the flight path of projectiles such as bombs. It was also employed in the development of the first atom bombs which brought such a sudden, devastating end to the war.

ENIAC, being completely electronic, used vacuum tubes instead of the relatively slow mechanical movements of gears and electromagnets which earlier computers had used. The tubes enabled ENIAC to perform mathematical calculations 1,000 times faster than heretofore possible.

Even with the knowledge derived from ENIAC and other



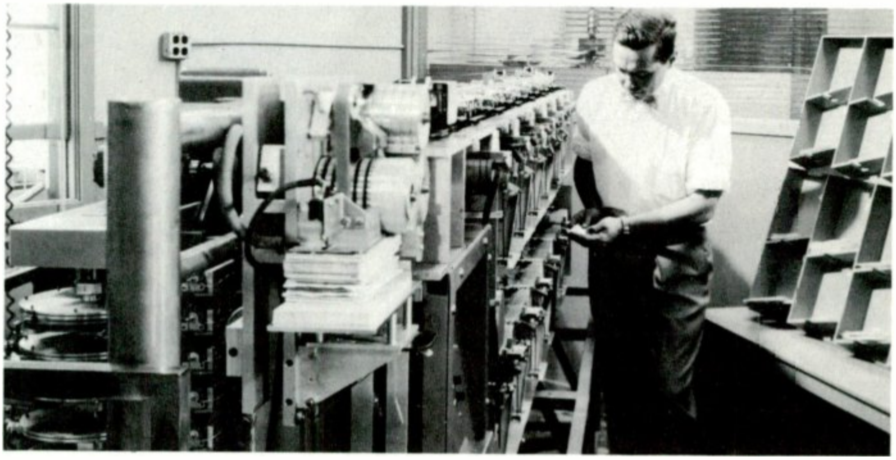
Hundreds of these units were contained in the cabinets shown in the preceding photo. By the time General Electric's production model of ERMA was ready, transistors had replaced the tubes.

data or information processing systems, ERMA presented the Stanford Research Institute engineers with completely new problems. For example, how print information on a check that could be read by both men and machines? An SRI physicist, Dr. Kenneth R. Eldredge, and his research team devised an excellent solution. Borrowing from the techniques of magnetic recording which were being perfected by Ampex and other companies, a special set of numbers for each individual's account was printed on the checks with magnetic ink. These were oddly shaped numbers, to be sure, but they could be read by the machines and, with a little extra effort, by people, too. When the checks were passed before electromagnetic heads, similar to those on a tape recorder, the machine could read the numbers at the rate of 1,000 characters a second. ERMA then looked up the account, subtracted the amount of the check, and finally recorded the new balance on a reel of magnetic tape, ERMA's "memory."

After SRI completed the prototype, General Electric Company was selected to manufacture ERMA in quantity. The Bank of America's Charles Conroy, who had acted as coordinator with SRI, now assisted the General Electric men. There were many challenges to be met before ERMA could be made ready for the business world. G. Frederick Hughes-Caley, a General Electric engineer, played an important part in this work. Using the facilities of the National Press in Palo Alto, he set up an experimental laboratory where various magnetic inks and special papers were tested.

ERMA's influence on banking was far reaching. Within a few years the queer magnetic numbers began appearing on the lower left-hand corner of bank checks all over the United States. The magnetic ink coding system pioneered by ERMA was soon adopted by the American Banking Association for all of its member banks.

ERMA was a significant step in the development of what has come to be called the "Computer Revolution." While many complained about the impersonality of computerized banking, the same people insisted on the kind of instant information and service that simply could no longer be provided "by hand" in a nation which by 1940 was already scribbling three billion checks a year. (In 1966 Americans wrote over 20



Check sorter designed for ERMA "read" lines or letters written in magnetic ink at the rate of 10 checks per second. California Inks Inc. of San Francisco did pioneer work on special inks.

billion checks. In 1967 the Federal Reserve Bank, a kind of bank for bankers from every state, was forced to announce that it could no longer process any checks not encoded with magnetic ink.)

During the first 50 years of this century, we have seen how electronics provided communications which drew people living across the country and around the world closer together. Local business and local government became national and international in scope. As the population increased in the United States, government and business paper work increased in proportion. It became difficult to keep track of so many people. There was even the threat that the individual would be lost in the paper shuffle.

At the same time, a social revolution was taking place, in part due to the new technology. There was a growing concern for the individual, particularly the poor, the sick, the aged, and the oppressed. Legislation such as Social Security was passed by the federal and state governments. But to keep the necessary records of every individual in the United States, in order to insure that each received money and care when appropriate, would have been impossible without computers. We had to give our fellow man a number before we could give him our assistance. Some people mistakenly claim that this step has made us each "just a number," implying that computers have somehow de-humanized us, have taken away our identity as human beings. Actually, computers have been used as tools of compassion, weapons against want and its consequent loss of human dignity.

It is also true that computers have been used as weapons of destruction, such as when they are used in the design of bombs. The tools of electronics technology are no different from others which man has invented, in this respect: in themselves they are neither good nor bad. With dynamite we can entirely destroy a small village, or build a dam with which to bring power and water and food to an otherwise impoverished country. The choice is ours.

There is one choice we do not have, however; we cannot go back to pre-electronics days. One careful observer, Shirley Thomas, has written, just ten years after ERMA's California debut, "Should all of the functions and productivity of computers suddenly be withdrawn from the world, utter and absolute chaos would inevitably result."*

However, along with this dependence we have also found increased freedom from certain limitations. Just as other electronic instruments extended our senses, so computers have extended our mental capabilities. A computer can do only what we tell it to do, but it can do it faster, more accurately, and at a time and place where sufficient manpower is not available. For example, computers can give individual instruction in mathematics or a language to a large class of students which would be impossible for a single teacher to attempt alone.

Stanford University has been an important pioneer in using computers as an aid in education. Computer-programmed teaching machines are giving special lessons to culturally disadvantaged children. A computer at Stanford is also directing the daily instruction of each student in an elementary school class in Appalachia, where there is a shortage of skilled teachers. The program for Johnny is sent to Appalachia from Palo Alto each day through telephone wires; his work on the teaching machines is automatically recorded and evaluated at Stanford, and specific directions for Johnny are sent to him by the next morning.

With computers, one scientist can conduct experiments under perfectly controlled conditions in a short time which would take a team of men years to do. Airplanes can be designed and their performance predicted before they are actually built.

By freeing us from dull, time-consuming work, the Computer Age can result in more individuality, more scope for creativity.

One computer authority, Richard H. Bolt, predicts of these machines that they "will make possible a level of creative intellectual achievement that in the past could be attained only through a long and grueling process of trial and error—if at all."

Computers may also help us overcome the uniformity—the thousands of things all identical—of the Machine Age. A

*Shirley Thomas, *Computers–Their History, Present Applications, and Future,* New York: Holt, Rinehart and Winston, Inc., 1965, p. 8.

leading textile designer, for instance, has prophesied that we will no longer have to choose a suit or dress from hundreds of similar, mass-produced garments. We will instead step into a dressing room, and while our figure is photographically measured, we can select the style, fabric, and color we prefer from among an almost limitless variety. The suit or dress will then be extruded, seamless, perfect in fit, from a machine on the premises within a matter of minutes!

Computer technology has been significantly influenced by an event which took place in 1948, even before ERMA the bookkeeper was designed. This was the invention by three American scientists of a tiny device that was eventually to greatly increase the speed and usefulness as well as to reduce the cost and size of ERMA and all computers. In fact, this device was to have an enormous impact upon every phase of electronics and to affect the lives of nearly every man, woman, and child in the civilized world.

A MIGHTY MIDGET

In 1913, when Lee de Forest, at 40, was excitedly experimenting with his three-element vacuum tube in the cottage laboratory on Emerson Street in Palo Alto, and the Varian brothers, in their early teens, were "inventing" things in their backyard on Bryant Street, a three-year-old, William Shockley, moved to Palo Alto with his family and immediately climbed the stairs to explore their two-story home at 959 Waverley Street.

As we know, de Forest had recently discovered that his audion could both amplify and generate radio waves; and the Varians 24 years later were to develop the klystron, a new kind of vacuum tube that would also amplify and generate radio waves, extremely short waves. And this toddling new neighbor of theirs was destined in 35 years to produce with two other scientists a third device, so tiny and so unique that it would revolutionize electronics. For a brief period these creative inventors lived within a few tree-shaded blocks of one another.

Bill Shockley's parents were his only teachers until he was nine. His mother had studied both mathematics and art and had been a mining surveyor. His father was a world-traveled mining engineer who spoke eight languages, including Russian and Chinese. During the years that the Shockleys lived in Palo Alto, the senior Shockley was a lecturer at Stanford University and an editor of an engineering magazine in San Francisco. With such excellent tutors, young Bill found himself well prepared when he entered grammar school. After a year in public school he transferred to the Palo Alto Military Academy.

At an early age he learned the fundamentals of electricity and radio, and from then on home life for the Shockleys was never the same. "Our house was haunted," his mother recalls. "Hidden wires caused ghostly thumps on the walls, and doors mysteriously to creak open." One electrical circuit was concealed under the rug near the fireplace in the living room. Bill placed a metal plate on the bottom of his shoe, and when he casually stepped over toward the mantel, the plate closed the circuit, and doleful bells clanged in the attic!

When Bill was 11 he met Professor P. A. Ross, a physics teacher at Stanford University, who lived near by. The professor and the bright young boy struck up what was to become a lifelong friendship. After the Shockleys moved to Hollywood

Bill Shockley, age 8, with his dog, Bob, in front of their home in Palo Alto, 1918. Right, William Shockley receiving the Nobel prize from the King of Sweden in 1956 for his part in the invention and development of the transistor. Standing just behind him and sharing in the proud moment are his wife and mother.

in 1922, the two kept in touch with each other. When Bill was 15 his father passed on, and he valued the advice of Professor Ross more than ever. He attended Hollywood High School, and then entered the California Institute of Technology in Pasadena, where he decided to become a physicist like Dr. Ross.

After graduation from college, Shockley went on to the Massachusetts Institute of Technology, where he was an instructor while he studied for his Ph.D. As Dr. William Shockley, he joined the Bell Telephone Laboratories in New Jersey. Here engineers and scientists were looking for new devices that would do the work of vacuum tubes but without the disadvantages of tubes. Along with all their wonderful abilities, tubes were delicate, fragile, wasted power, and required constant maintenance for top performance. During and after World War II, technology had developed to such an extent that some electronic systems were requiring tens of thousands of electron tubes. Engineers could dream of advanced designs in television, computers, and telephone communication systems but if built with tubes they would be almost impossibly expensive to construct and maintain.

Bill Shockley joined a group of men at Bell Laboratories who, in their search for some different physical way to replace the tubes, had turned back to the kind of materials which had been used with the first crystal radio receivers. In those early days it had not been well understood just what happened in galena and silicon and germanium when an electrical current was introduced into them. A little more had been learned about them since, in the World War II laboratories which had worked on radar detectors and other electronic apparatus.

Now Shockley, with John Bardeen and Walter H. Brattain and other scientists at Bell, began to challenge the accepted theories about these materials which are commonly called "semiconductors," since they usually offer much resistance to electrons, but under certain conditions do provide a pathway for some electrons. By 1948 Shockley and his fellow scientists were able to produce a new effect with these "sometimes" conductors. They created a device which they called at first a "transit resistor." Later this name was shortened to the now-famous "transistor."

In a transistor, electrons move through a piece of germanium or silicon crystal, as small as your little fingernail. This is quite different from a vacuum tube where the stream of electrons flows across empty space. What happens in a transistor is actually a rearrangement of the electrons within the atoms of the crystal itself. Because the crystal is solid, in comparison with the vacuum in an electron tube, the transistor is called a "solid-state" device.

The first transistor that Shockley, Brattain, and Bardeen made was called a "point-contact" transistor because it had two fine, pointed wires contacting the top surface of a miniature block of crystal much like a "cat's whisker" in the old crystal set detectors. A third wire was attached to the base.

The second type of transistor developed by the three-man team was built in three layers like a sandwich, alternating two different kinds of semiconductor materials. A wire was attached to each of the layers. Shockley completed his analysis of the theory for this "junction" transistor in 1949, and it was demonstrated in 1951.

The point-contact transistor is particularly useful when a high-speed switch is needed to turn electricity on and off as fast as possible, such as in electronic computers. The junction transistor has become the more common type, very effective as an amplifier of low- and medium-frequency waves.

Science and industry found that the transistors could perform almost all the functions of vacuum tubes, including the generation of electromagnetic waves. One of the first applications of junction transistors was in hearing aids. Unlike the vacuum tube, a transistor can be operated with a small, inconspicuous battery; it is tiny and lightweight itself, needs no "warm up" time, and is not easily damaged.

Next, hand-sized radios appeared and were immediately popular. Few of the owners even faintly understood what the transistors did, but they were pleased with the end result, often referring to their little radios as "my transistor."

As improved transistors became commercially available, the effect upon the whole field of electronics was revolutionary. Manufacturers "transistorized" their products. New industries sprang up to meet the demand for semiconductor components, or parts, such as the crystals themselves. By 1954 there were close to 1.4 million transistors sold. Just ten years later the annual sales had mushroomed to 300 million.

In 1956 the three co-inventors of the transistor were honored with the Nobel prize. William Shockley's family accompanied him to Sweden where each year the Nobel prizes are awarded to men and women who have been of significant service to humanity. Watching her son on that impressive occasion, Shockley's mother might well have remembered with a smile the years of living in an annoyingly haunted house; his electrical experiments had brought him—and the world—a long way!

INDUSTRIAL EXPANSION ON THE PENINSULA

The same year that the transistor inventors received the Nobel prize, the Shockley Semiconductor Laboratory was founded in Palo Alto, with Shockley himself as head. The company was a subsidiary of Beckman Instruments. (It later became a division of International Telephone and Telegraph Corporation, and Shockley transferred to academic life at Stanford.)

Ten different electronics companies were established in Palo Alto that year and seven the next year. These included Alfred Electronics, Pek Labs, Granger Associates, Melabs, Components for Research, and Watkins-Johnson. It was the beginning of a period of unprecedented growth of electronics companies in both the Los Angeles and the San Francisco Bay areas, particularly on the San Francisco Peninsula. The trend has been continuous up to the present, with the West leading all other national areas in the rate of sales increase each year.

In 1965, the electronics industry of the Bay Area employed about 45,000 people and produced some three-quarters of a billion dollars' worth of goods and services.

In the 1950's the local companies in Palo Alto were joined by national corporations which began to establish electronics facilities there. By 1957, Admiral, General Electric, Sylvania, Kaiser, Fairchild, General Precision, and Lockheed corporations had opened electronics laboratories in Palo Alto. These all became major plants. Within ten years Lockheed Aircraft Corporation's Research Laboratory in Palo Alto and its Missiles and Space Company in nearby Sunnyvale were employing over 26,000 people.

In 1952, a small group of engineers and scientists from the International Business Machines Corporation arrived from the East to establish a research laboratory in San Jose. Today IBM has over 5,000 employees in the San Jose area engaged in research and the production of data processing systems and computer components.

Elsewhere on the Peninsula, other electronics companies, already established, were expanding in this postwar period. One of the fastest growing was Lenkurt Electric in San Carlos, founded in 1944 by Lennart G. Erickson and Kurt E. Appert, the name of the company being derived from the founders' first names. Lenkurt specialized in communications systems and for years was, and still is, the leading supplier of microwave and carrier systems to the U.S. independent telephone industry, as well as furnishing communications equipment for many others such as railroads, power companies, and television broadcast firms. Today, as a division of General Telephone and Electronics, Lenkurt Electric employs over 3,000 people.

Transistor research and production was leading to yet another innovation, the "integrated circuit," in which a number of electronic elements such as resistors, capacitors, and transistors may be formed in a tiny, single-crystal chip of semiconductor. All of these can be included on a chip no larger than one of the letters printed on this page. The same parts in the usual, conventional circuit would require more power, cost more, be less reliable, and of course take up more room. Integrated circuits and other miniaturized electronic components have brought about a new field of activity: microelectronics! Numerous companies devoted to the development of these miniature devices were formed in the Bay Area, and branches of nationwide companies were set up especially for such production. (By 1966 the mid-Peninsula was reported to have the largest concentration of microelectronics companies in the nation.) Electronics was progressing to the point where it was ready to play its essential part in man's next great adventure—the breaking of his bonds with earth, the exploration of space.

On the night of October 4, 1957, a slim rocket roared up into the dark skies over Russia, releasing a 184-pound ball which became the earth's first artificial satellite. Traveling

18,000 miles an hour, it circled the globe about every 95 minutes, making over 400 orbits. Amateurs around the world could hear the "bleep-bleeps" of its two radio transmitters. *Sputnik I* was one of the most exciting achievements of the century. Just 50 years after the invention of the first crude vacuum tube, electronics had entered the Space Age.

It is at this point in time that we have, in this book, paused to look back and survey the development of electronics. It has been a world-wide evolution, yet again and again its leaders, its leaps forward, were to be found in a comparatively small area of the Far West. Enterprising San Franciscans built the nation's first ship-to-shore and air-to-ground wireless telegraph communication systems, using spark gap techniques. Pioneers in Palo Alto led the way from spark gap to continuous wave transmission with powerful arcs, spanning continents and oceans with the most powerful transmitters ever constructed. In San Jose, the nation's first radio station broadcast, with an arc, regularly scheduled programs of voice and music for years before the listeners had even heard the word "radio." In a Palo Alto laboratory, soon after the opening of this arc station, the three-element vacuum tube became an amplifier and oscillator for the first time, thus replacing the arc and marking the actual beginning of modern electronics. In Napa, the loudspeaker was born. In San Francisco, the first successful all-electronic television transmission took place. At Stanford and the University of California at Berkeley, klystrons, cyclotrons, and linear accelerators were dramatic breakthroughs in the fields of radar, microwave, and atom-smashing. Computers, transistors, and microelectronics all are indebted in some measure to Western pioneers. It has been a fruitful half-century!

Indeed, when we think of how rapidly electronics has developed since the day when the U.S. Navy depended upon carrier pigeons for communication, we cannot help wondering if changes as great will take place within the next 50 years. Perhaps the greatest changes will come through our learning how to use our new electronics tools for the preservation, prosperity, and peace of mankind.

Fred Terman, commenting on the Electronics Age, says in confident anticipation, "This is only the beginning!"

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