

WWW

The first 100 years

# NIST Radio Station WWV celebrates a century of service.

- What technological application has had musical, timekeeping, navigational, scientific, traffic-control, emergency-response, and telephone applications?
- [WWV](#), one of the world's oldest continuously operating radio stations.

# WWV history highlights

- **1919**—First public announcement of call sign WWV being assigned to NBS in Washington, D.C.
- **1923**—First WWV broadcast of standard frequencies to help users calibrate their radios. (In subsequent years, the station began broadcasting at higher frequencies, as well, to get better transmission and reception.)
- **1931**—The WWV broadcasting station moves to College Park, Maryland.
- **1933**—The WWV station moves to Beltsville, Maryland.

# WWV history highlights (CONTINUED)

- **1936**—The FBI asks NBS to conduct tests using WWV to determine the feasibility of using one transmitter to cover the entire country. (Such a system was eventually ruled out.)
- **1936**—In response to requests, WWV broadcasts its first musical note. Such tones are useful to piano tuners, for example, and in later years to the police for calibrating radar used to check vehicle speeds.
- **1937**—WWV begins broadcasting time interval signals.
- **1939**—Pioneering NBS effort to reflect WWV transmissions off the moon. It didn't work then but the military later accomplished it. (It turns out that bouncing signals off the moon is easier and scientifically more useful if done with lasers.)

# WWV history highlights (CONTINUED)

- **1943**—NIST begins using quartz crystal oscillators to provide greater accuracy in setting standard frequencies.
- **1945**—WWV begins broadcasting the time using telegraphic code.
- **1948**—NBS' second high-frequency radio station, WWVH, begins operating in Maui, Hawaii (later moved to Kauai), in order to broadcast to the West Coast and to ships and countries throughout the Pacific Ocean.
- **1950**—WWV voice announcements of standard time begin.

# WWV history highlights (CONTINUED)

- **1954**—The NBS Central Radio Propagation Laboratory moves to Boulder, Colorado, and the quartz crystals are flown to Denver and driven to Boulder (although WWV still broadcasted from Maryland).
- **1957**—WWV broadcasts its first solar-storm and geophysical data alerts.
- **1960**—WWV becomes the nation's first radio station to place a digital time code in its broadcasts.
- **1961**—The WWV station moves to Greenbelt, Maryland
- **1963**—NIST's low-frequency radio station, WWVB, goes on the air from Colorado, to broadcast accurate standard frequencies needed by satellite and missile programs.

# WWV history highlights (CONTINUED)

- **1966**—WWV moves to Fort Collins, Colorado, and begins broadcasting from there.
- **1967**—The second is internationally redefined to be based on the vibrations of the cesium atom, and NIST's radio stations begin broadcasting Greenwich Mean Time rather than the local time at the stations. (Several years later, WWV and the other stations begin broadcasting Coordinated Universal Time, as they do today.)
- **1971**—WWV begins offering the time of day by telephone, gets 1 million calls per year by 1975.
- **1980s**—GPS and the internet are introduced, offering new and more accurate ways to distribute time and to support navigation, and NBS is renamed NIST.

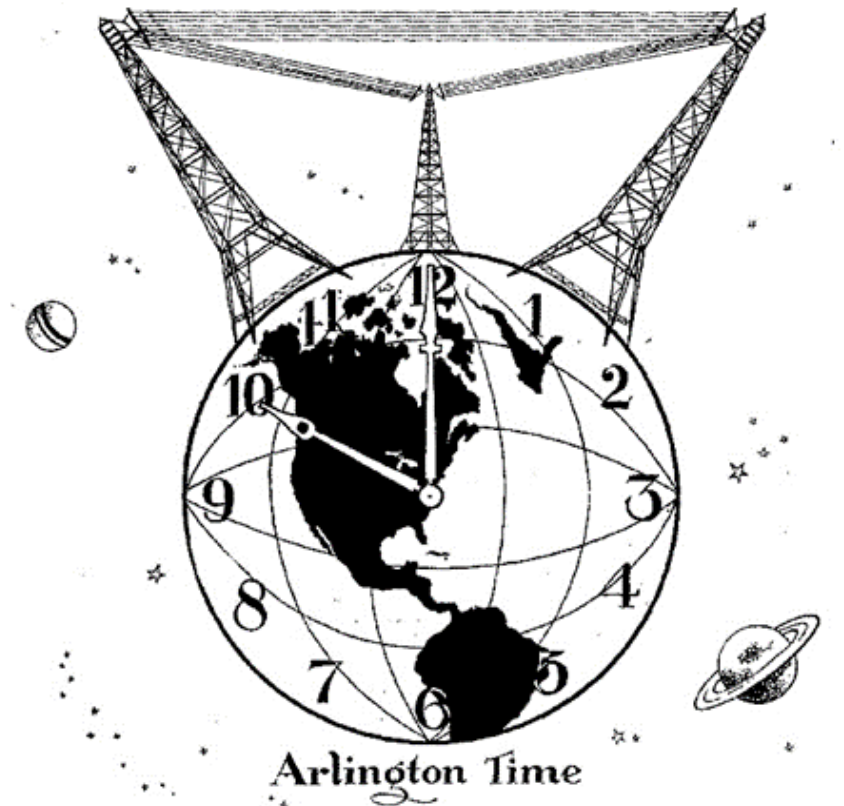
# Radio Pioneers

- Other radio transmissions predate WWV by decades. The U.S. Navy was one of the early adopters of this new technology, recognizing the tremendous advantage radio brought to communication from land to ships and from ship to ship. Admiral George Dewey stated in 1904: “But from ships at sea, out of sight of flags or lights, and beyond the sound of guns, the electric wave, projected through space, invisible and inaudible, can alone convey the distant message”



# Radio Pioneers

- One of their primary stations, with the call sign NAA, was built in 1912 across the Potomac from Washington, D.C., in Arlington, Virginia. The signal from the station, with its three distinctive towers, was often referred to as simply “Arlington Time.”



# Radio Pioneers

- A common element among all these early radio pioneers was the use of telegraphic code. A few had experimented with sending music or the human voice over the airwaves, but the primary use of the technology was point-to-point communication via the series of dots and dashes often referred to as Morse
- The first radio stations created the dots and dashes using sparks or arcs, essentially bursts of broadband noise that were then tuned to the transmitting antenna, in the process creating a great deal of electrical noise across the spectrum.

# Radio Pioneers

- Their low-frequency (below 300 kHz) operation required huge antenna systems and powerful transmitters for long-distance communication. Hams built smaller versions of these systems, often using an automobile spark coil and rudimentary antennas. Soon the airwaves became clogged with signals.

# Radio Pioneers

- The Radio Act of 1912 was an attempt to bring some order to the chaos. The U.S. Department of Commerce was tasked with enforcing the act, which among, other things, required all stations, amateur or commercial, government or military, to be licensed and to operate within their assigned frequency range. The Department of Commerce looked to the National Bureau of Standards (NBS) to develop standards to aid in enforcement.

# Why a Radio Station at NBS?

- The first documented radio research at NBS occurred in 1905, when Dr. Louis Austin developed a “Detector for Very Small Alternating Currents and Electrical Waves
- The U.S. Navy and the Army Signal Corps set up research laboratories for the study of radio at the NBS facilities in 1908.
- The laboratories were located at a site on Connecticut Avenue in Washington, D.C., which at the time was chosen due to the distance from the noise and interference associated with being downtown.

# Why a Radio Station at NBS?

- An aerial view of the NBS facilities; the photo was taken in 1940.



# Why a Radio Station at NBS?

- The Radio Section of the Electricity Division of NBS was established in 1913 by Frederick Kolster, chief, and Dr. John Dellinger, assistant. The Radio Section focused on supporting the Department of Commerce Bureau of Navigation and Bureau of Lighthouses, by designing and calibrating radio-frequency measurement devices, radio transmitters, and radio receivers and by developing a “fog-signaling” early direction-finding system to assist ships in navigating safely in foggy conditions.

# Why a Radio Station at NBS?

- The entry of the United States into World War I in April 1917 brought the end of any form of radio transmission or reception by private parties in the United States, with the government shutting down or taking over all privately owned amateur and commercial transmitting stations and banning the use of receivers by the public

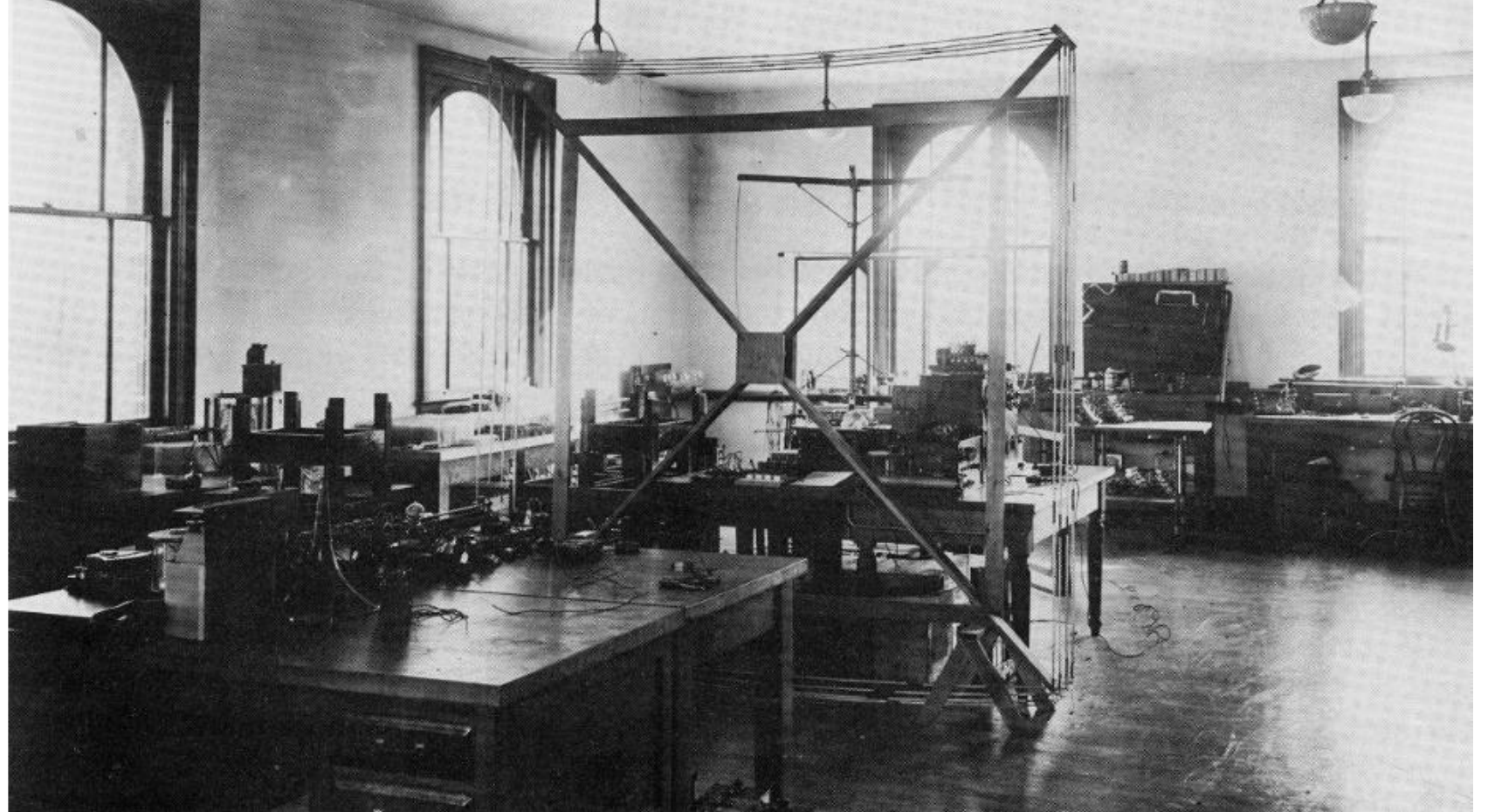


# WWV: The First Years

- After the war, the idea of broadcasting to the public began to catch on. The ban on privately owned and operated radio transmission and reception was finally lifted in 1919, and the broadcasting boom era began. The stage was set for WWV
- The call sign WWV was assigned to the Bureau of Standards Radio Section on October 1, 1919
- The NBS Technical News Bulletin article “WWV’s Golden Anniversary” refers to 1923 as the year that WWV began a regular schedule of frequency broadcasts.

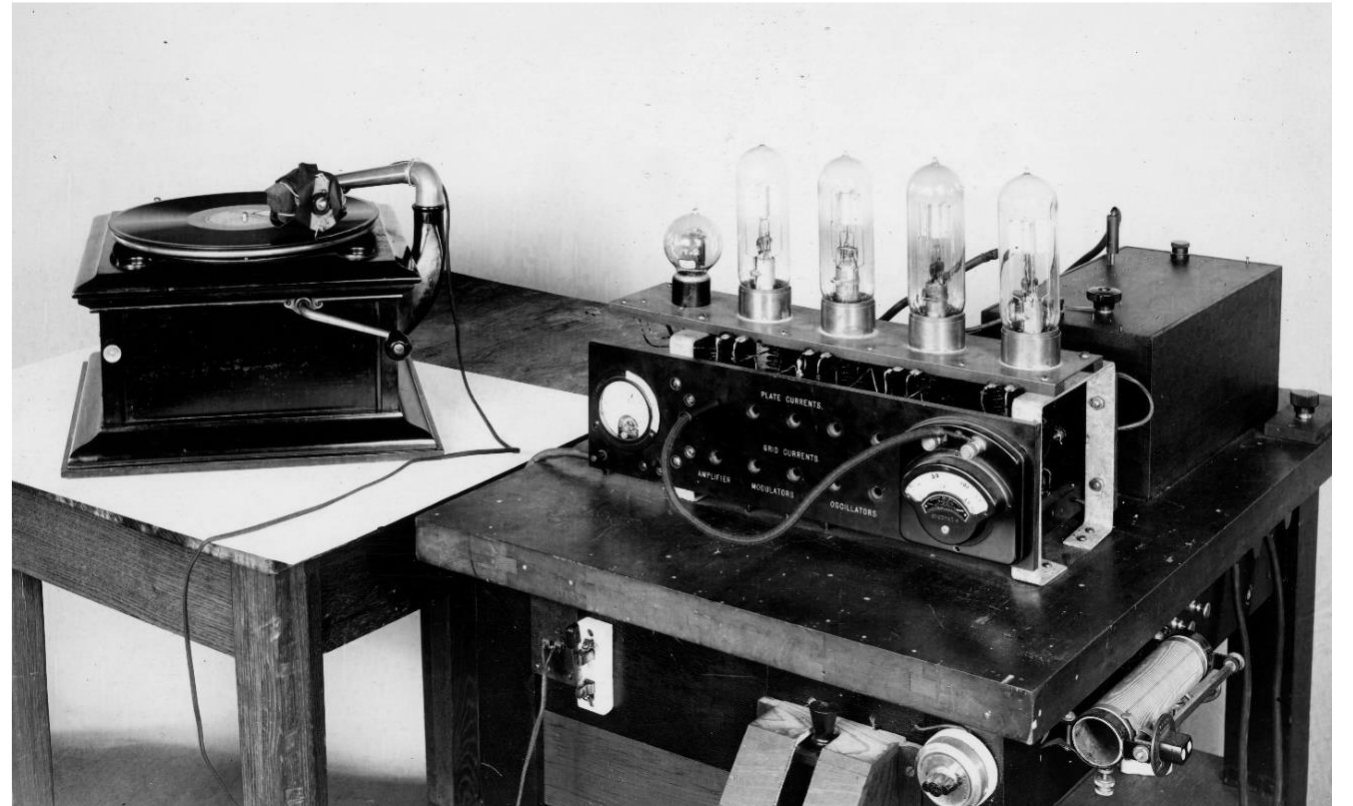
# WWV: The First Years

- Radio Section transmitting and receiving laboratory. 1920



# WWV: The First Years

- The Washington Times from February 26, 1919, declares the wonders of “music through the air,” when popular tunes were played on a Victrola driving an early transmitter and broadcast several hundred yards to an NBS auditorium for the listening enjoyment of the audience.



# WWV: The First Years

- The Radio Section conducted other experiments later in 1919 but before the call letters were granted, including “transmission experiments” to Johns Hopkins University in Baltimore, Maryland
- By May 1920, experimental concerts were being sent out on Friday evenings from 8:30 to 11:00 by the Radio Laboratory using a wavelength of 500 meters” (about 600 kHz). These “concerts,” thought to be the first scheduled broadcasts to a wide audience from WWV, were records being played on a Victrola with the output connected directly to the transmitter.

# WWV: The First Years

- The U.S. Department of Agriculture (USDA), which asked for assistance in disseminating market reports for the benefit of farmers. WWV was tasked with this effort, using a 2 kW spark gap transmitter and telegraphic code. This service began on December 15 and ran for 4 months on WWV; the broadcast consisted of a 600 word report provided by the USDA's Bureau of Markets, called the *Daily Radio Marketgram*.

# WWV: The First Years

- During the period from 1920 to 1923, the Radio Section continued the WWV experiment, working with “radiotelephony” to increase its range and explore its limitations using a variety of equipment.
- A portable receiver called the “Portaphone” was built in the summer of 1921

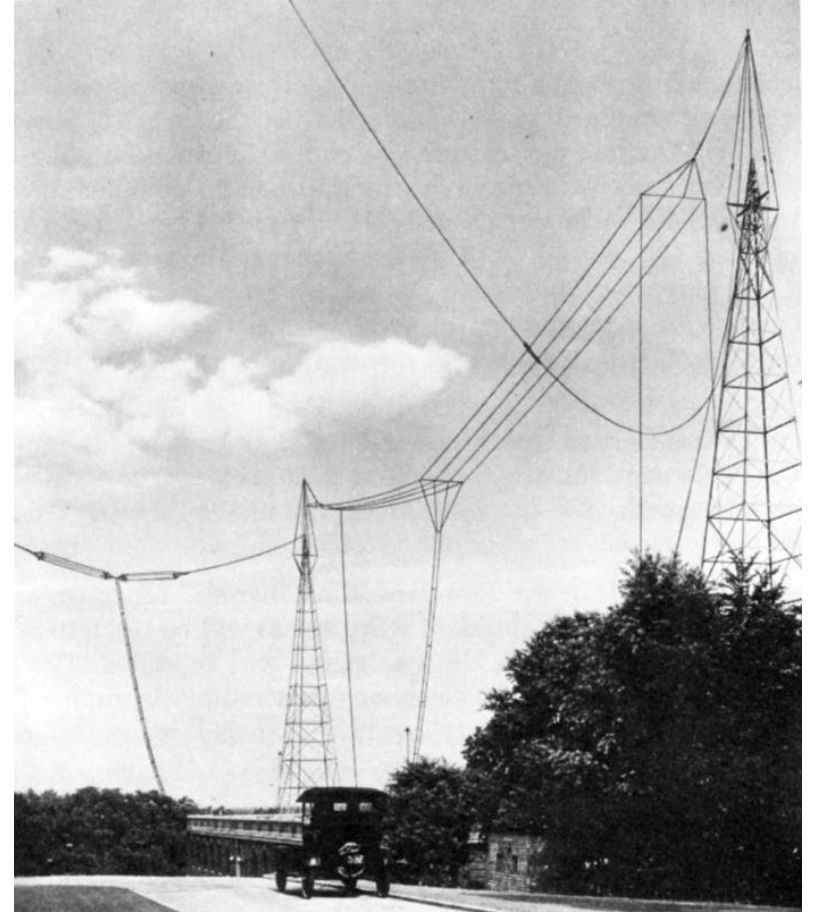


# WWV: The First Years

- By the end of 1922, about 570 commercial radio stations were broadcasting in a frequency band of 1000 kHz, and many were having a great deal of difficulty staying on their assigned frequency.
- As a standards organization, NBS was responsible for disseminating the means for compliance to the accuracy the new technology demanded.
- The first scheduled broadcast of standard frequencies on WWV would take place on March 6, 1923. To avoid interference from commercial stations, the broadcasts would begin at 11:00 p.m. and run until 1:15 a.m., local time, on several frequencies between 550 and 1500 meters (545 and 200 kHz), using a four-tube transmitter

# WWV: The First Years

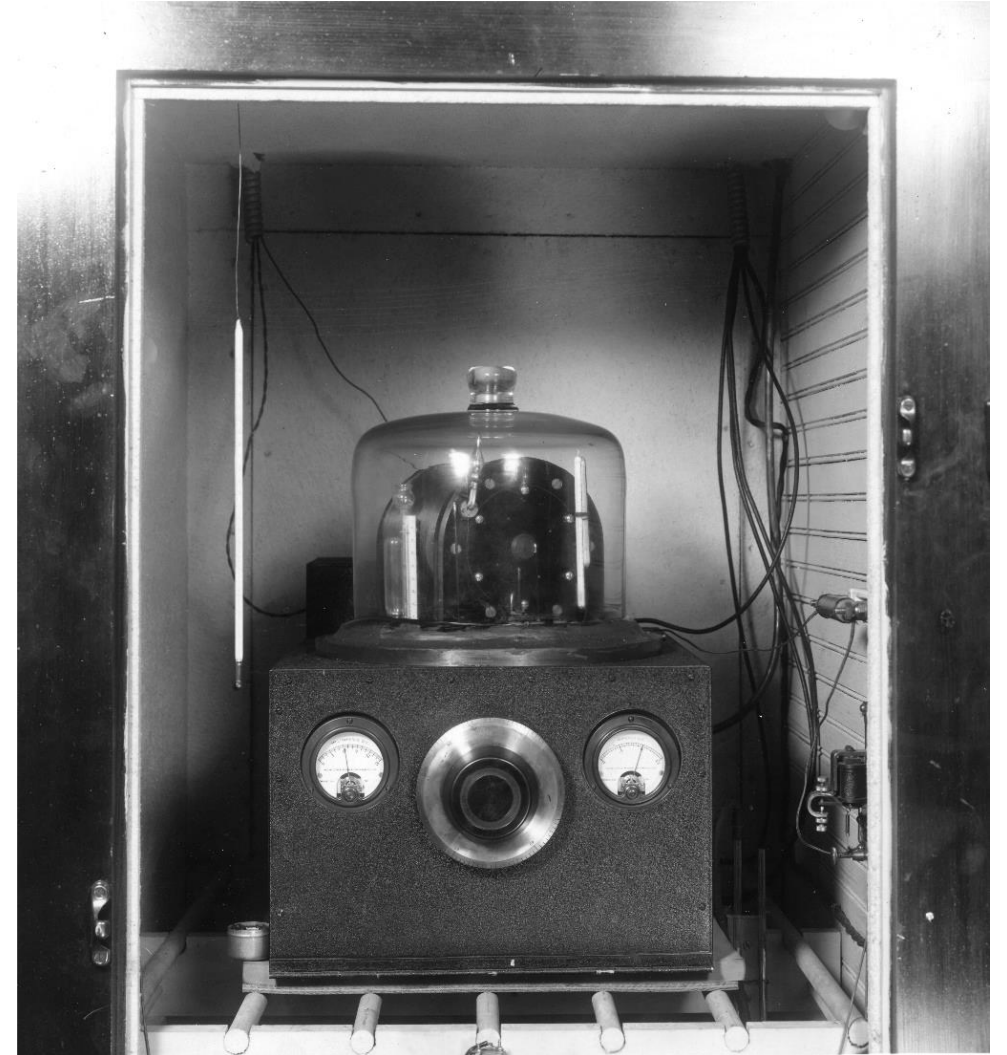
- A typical broadcast consisted of an announcement in code and voice repeated “QST de WWV Standard Wave Signals,” followed by an announcement of the wavelength of the signal.
- Radio Section building with antennas, 1923





# WWV: The First Years

- A quartz oscillator was first used to control a WWV frequency in 1927
- One of the four 100 kHz quartz oscillators that made up the National Primary Standard of Radio Frequency



# WWV: The First Years

- As the 1930s approached, the need for a separate facility for WWV became more pressing.
- NBS owned several field sites in the area surrounding Washington, D.C. Initially, a site in College Park, Maryland, northeast of Washington, D.C., which was used for airplane navigation projects, was chosen as the new location for WWV. A 150 W transmitter operating on 5 MHz was constructed and put in operation in January 1931; by 1932, the power had been increased to 1 kW. Frequency accuracy of the broadcast was better than 2 parts in 10<sup>7</sup>, monitored from the NBS laboratories in Washington, D.C.

# WWV: The First Years

- However, the proximity of the site to an airport limited the height of the transmitting antennas, and, in December 1932, WWV was moved again to a 10 hectare (25 acre) site on the Experimental Farm of the USDA in Beltsville, Maryland, about 21 km northeast of the NBS grounds. A wood-framed building was used to house the transmitters and the standard frequency equipment. In April of the following year, a water-cooled 30 kW transmitter of the latest design was purchased and put in operation.

# WWV: The First Years

- The transmitter operated initially on 5 MHz, and, in February 1935, 10 MHz and 15 MHz frequencies were added at 20 kW. Half-wave horizontal doublet antennas for each frequency were suspended from 20 m high poles, fed by 600 ohm matched-impedance transmission lines
- The June 1936 issue of *QST* lists the schedule at that time:
- Each Tuesday, Wednesday and Friday (except legal holidays), the National Bureau of Standards station WWV will transmit on three frequencies as follows: noon to 1:00 p.m. E.S.T., 15,000 kc; 1:15 to 2:15 p.m., 10,000 kc; 2:30 to 3:30 p.m., 5000 kc. On each Tuesday and Friday, the emissions are continuous unmodulated waves (c.w.); and on each Wednesday they are modulated by an audio frequency. The audio frequency is in general 1000 cycles per second.

# WWV: The First Years

- The audio tone was added in October 1935. While this schedule may sound complicated, it was much simpler than the multiple frequencies and times of day (actually, night) broadcast by WWV previously.



# WWV: The First Years

- Additions to the WWV broadcasts in the 1930s included the 1000 Hz modulated tone already mentioned, and a tone at 440 Hz, the musical note A above middle C, in August 1936. This service was provided at the request of several musical organizations
- In June 1937, seconds pulses 5 ms long were added to the broadcast, as well as an announcement of current ionospheric conditions on Wednesday broadcasts. An audio voice announcement of station identification was included in the broadcast; this and other announcements were recorded on phonograph records using equipment at NBS. The 15 MHz frequency was temporarily replaced with 20 MHz until May 1940.

# The 1940s

- Disaster struck WWV in 1940. On the morning of November 6, a fire broke out in the wooden transmitter building.



# The 1940s

- A news release 4 months later gives an update on the service: the single broadcast frequency, 5 MHz at 1 kW, would now be operated continuously. The 440 Hz tone and seconds pulses were restored (but not the 1 kHz tone). The 440 Hz tone was omitted every fifth minute to allow the station identification to be sent out in telegraphic code.
- In August, a new site was selected about 5 km south of the old one



# The 1940s

- A view of the transmitter building, with one of the dipole antennas in the foreground.



# The 1940s

- The building was occupied in January 1943. Broadcasts began at that time using lower powered transmitters until the installation of new, higher powered equipment was completed in August, at which time WWV began operating continuously on 5 MHz and 10 MHz, with daytime operation on 15 MHz. Audio tones were broadcast at 440 Hz and 4 kHz concurrently, and ticks each second were included. The 5 min time intervals continued to be synchronized with the basic time service of the U.S. Naval Observatory (USNO). Station identification voice announcements were added at the hour and half-hour. Standard frequency was supplied by three 100 kHz quartz crystal oscillators placed in a concrete vault about 8 m below ground level, where the nearly constant temperature and humidity contributed to their stability, and the output of each oscillator could be connected remotely.

# The 1940s

- Interior view of the new WWV building.



# The 1940s

- Perhaps the most momentous change for many users of the WWV broadcasts occurred in June 1944, when the superintendent of the USNO authorized the synchronization of the WWV time signals with those of the USNO.
- In January 1946, WWV began broadcasting propagation disturbance warnings automatically using telegraphic code at half-hour intervals. In December of that year, broadcasts resumed on 20 MHz and added on 25, 30, and 35 MHz, and the transmitted accuracy of the signals was 2 parts in 108. The 30 and 35 MHz signals were discontinued in January 1953.

# The 1950s

- Although WWV was now firmly established as a resource, changes to the broadcasts continued in the 1950s in an attempt to make them even more useful. On January 1, 1950, time of day voice announcements began running every 5 min, and the 4 kHz standard audio frequency was replaced by a 600 Hz tone. Twelve-hour ionospheric condition forecasts of North Atlantic transmission paths began in July 1952. In January 1953, the 30 and 35 MHz broadcasts were shut down

# The 1960s

- The 1960s can be viewed as the high point of WWV's popularity
- CRPL continued to work with WWV to enhance the broadcasts to the greatest extent with the resources and technology at hand. In April 1960, the first time code was placed on the WWV broadcasts. Developed in collaboration with a number of organizations, it was known as the National Aeronautics and Space Administration (NASA) 36 bit time code, after one of the main contributors to its development. The binary coded decimal (BCD) code contained seconds, minutes, hours, and day-of-year information broadcast 10 times per hour, and it is believed to be the first digital time code available by radio in the United States. This technology allowed the development of self-setting radio-controlled clocks for the first time. The following January, the location name of the station was changed from Beltsville to Greenbelt, Maryland

# The 1960s

- WWV was on the move again.
- In 1966 Congress had appropriated nearly a million dollars for the development of a new, state-of-the-art facility at the Fort Collins, Colorado, property.

# The 1960s

- The new transmitter building under construction; the concrete call letters are the only part of the Greenbelt station that was installed in new Fort Collins facility.





# The 1960s

- The new station included all new transmitters for each WWV frequency, plus two standby transmitters. The main transmitters were each directly connected to a dedicated half-wave vertical dipole antenna, in the form of guyed steel towers arranged on a low ridge directly to the east of the building. The standby transmitters were connected to broadband antennas capable of carrying any of the six frequencies

# The 1960s

- Interior of WWV building in Fort Collins, Colorado, 1966.



# The 1960s

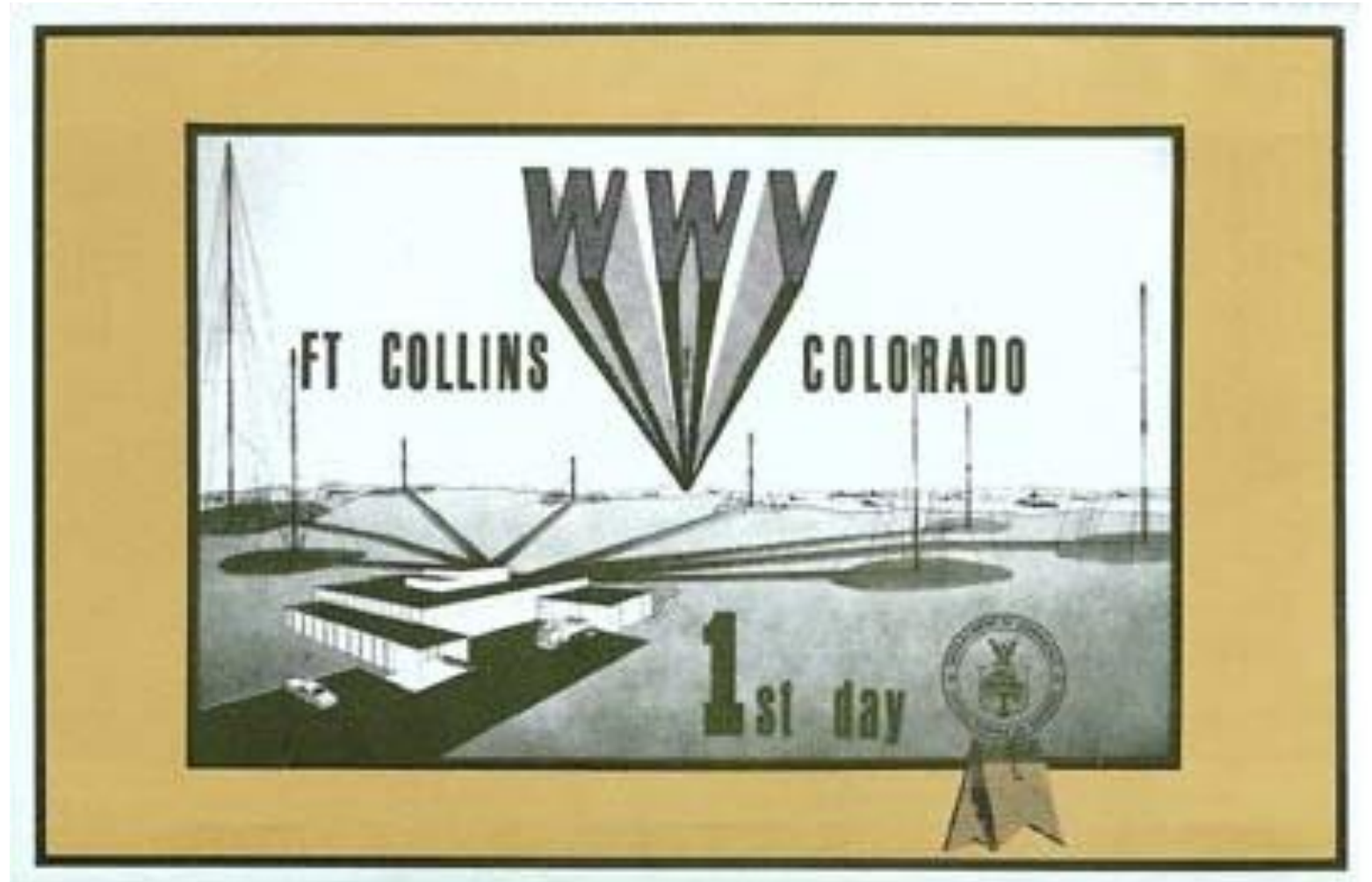
- On December 1, 1966, at 0000 h Greenwich Mean Time, the transmitters in Greenbelt, Maryland, were shut down for the last time, and the new station went on the air. WWV was now operating at 10 kW radiated power on 5 MHz, 10 MHz, and 15 MHz, and 2.5 kW on 2.5 MHz, 20 MHz, and 25 MHz. The location near the center of the 48 contiguous states ensured more reliable reception of at least one of the signals from coast to coast

# The 1960s

- The year 1967 was also when, by international agreement, the second was defined as the duration of 9,192,631,770 periods of the electromagnetic radiation associated to the hyperfine transition of the ground state of the Cs133 atom. The redefined second officially began the era of atomic timekeeping. In April of that year, WWV and WWVH began broadcasting the time of day in Greenwich Mean Time (GMT), rather than the local time at the stations.

# The 1960s

- WWV Fort Collins first-day QSL card, 1966.



# The 1970s

- The 1970s brought more changes to WWV, and the broadcasts began to take the format they hold today. Many changes were implemented on July 1, 1971. Beginning on that date, the time announcements were made every minute rather than every 5 min, and telegraphic code time announcements were dropped. A 500 Hz audio frequency was added to the broadcast in addition to the 440 Hz and 600 Hz tones, and the geoalerts and propagation forecasts were now in voice rather than telegraphic code. The 36 bit NASA time code was replaced with a modified IRIG-H code, with 1 bit-per-second modulating a 100 Hz subcarrier. This new code included a daylight saving time (DST) indicator.

# The 1970s

- Another service introduced on July 1971 was the telephone time-of-day service, which made the WWV audio signal available over the telephone system. Users could dial a Boulder telephone number, 303-499-7111, and be connected to the live audio feed for about 2 min.
- The first leap second was inserted in the WWV broadcast on June 30, 1972; in January 1974, the station began broadcasting Coordinated Universal Time (UTC).

# The 1980s and 1990s

- In 1988, NBS became the National Institute of Standards and Technology (NIST), and the WWV broadcasts continued as before, operating as part of the Time and Frequency Division. New, more energy-efficient transmitters were procured in 1990 for the 5 MHz, 10 MHz, and 15 MHz broadcasts, and the old transmitters were relegated to standby status.
- A typical time of day announcement on either station reads: “At the tone, 17 hours, 43 minutes, Coordinated Universal Time” followed by a 1000 Hz tone at WWV and a 1200 Hz tone at WWVH. The station identification announcements include the call sign, a brief description of the content, broadcast frequencies, and the mailing address of the radio stations.



# The 1980s and 1990s

- In 1991, the magnetic drum recorders that managed the voice announcements, complicated mechanical systems that were becoming increasingly prone to failure, were replaced with a solid-state electronic voice storage system using digitized audio recordings
- As newer methods for disseminating time and frequency information became more readily available, the signals provided by WWV began to take on a lower profile.
- The introduction of the Global Positioning System (GPS) beginning in the 1980s was a game-changer for users of precise time and frequency. Each GPS satellite has cesium clocks on board controlled by USNO and continuously broadcasts the time of day and its position.

# The New Millennium: 2000 to the Present

- Technological advances such as GPS altered the landscape, but the need for reliable terrestrial time signals did not go away as the new millennium dawned.
- Concurrent with the development of the GPS system was the advent of inexpensive WWVB receivers designed for the consumer market. The idea of a wall clock or wristwatch that was always correct and did not need to be adjusted for DST was attractive

# The New Millennium: 2000 to the Present

- WWV operates on six frequencies: 2.5 MHz, 5 MHz, 10 MHz, 15 MHz, 20 MHz, and 25 MHz. The radiated power is 10 kW on the 5 MHz, 10 MHz, and 15 MHz frequencies and 2.5 kW on the rest. All frequencies use a half-wave vertical dipole antenna, and all frequencies except 25 MHz have a dedicated standby transmitter that starts automatically in case of main transmitter failure.

# The New Millennium: 2000 to the Present

- Aerial view of the WWV site with the 2.5 MHz antenna in the foreground.



# The Anniversary Cake

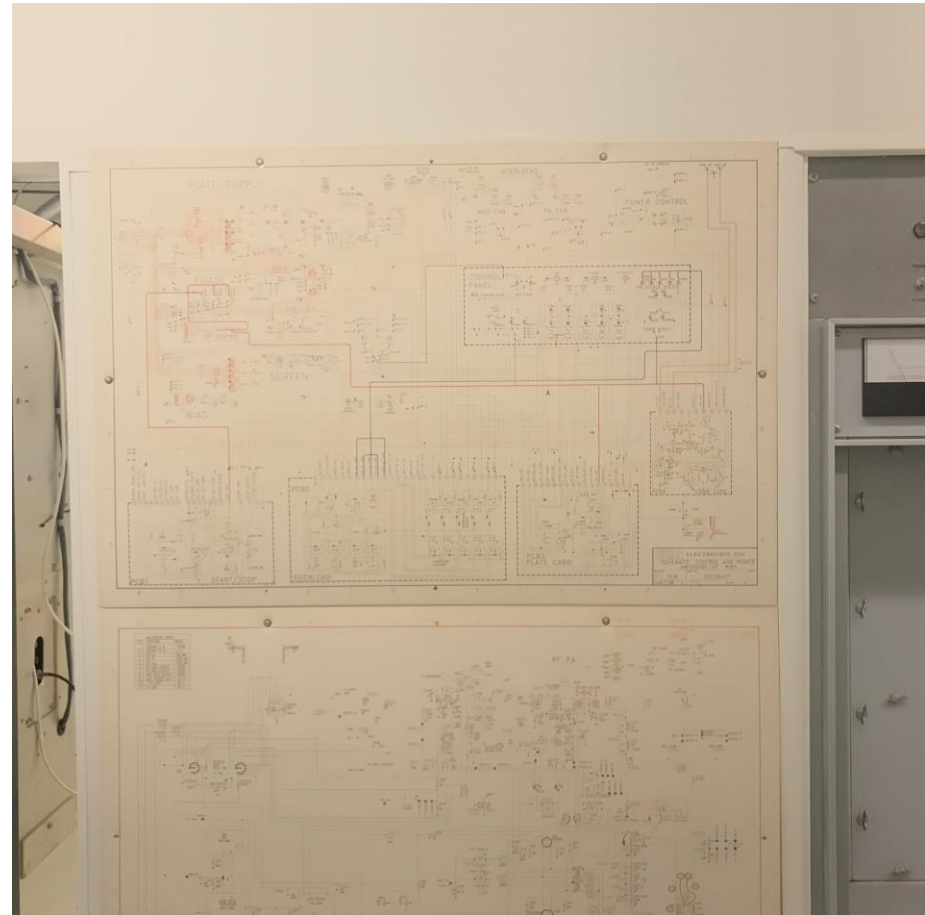


# Phil KL7VO and Joe WB2SAI at WWV



# WWV Anniversary tour

- A drawing of part of the schematic.

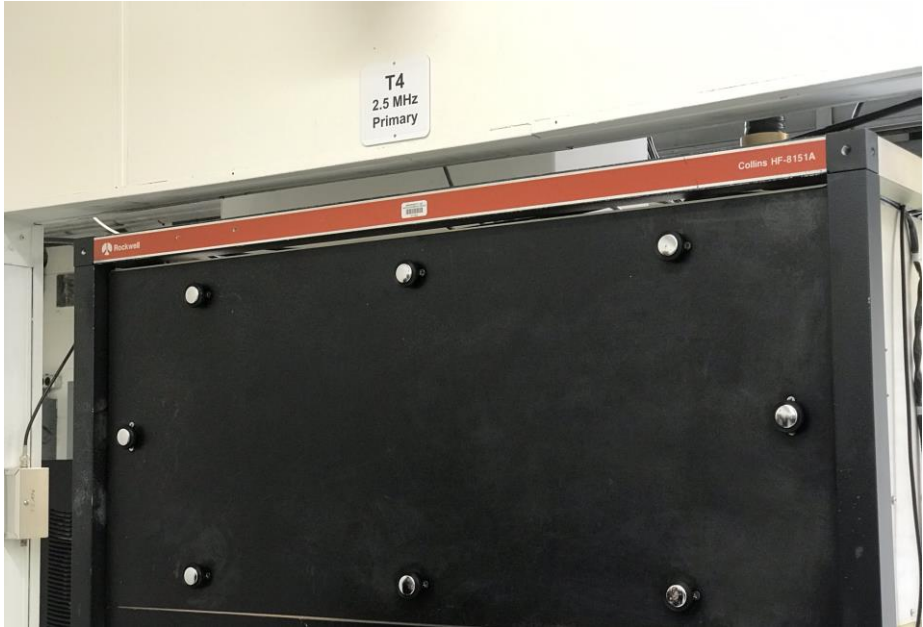


# WWV Anniversary tour

- The tour guide standing next to an antenna switch for one of the transmitters







# The 2.5 MHz Transmitter

- The tour guide standing next to a dummy load



# WWV Anniversary tour

- Inside of a transmitter



# Web sites

- <https://nist.time.gov/?t=24>
- <https://www.nist.gov/pml/time-and-frequency-division/radio-stations/wwv>
- <https://nvlpubs.nist.gov/nistpubs/jres/124/jres.124.025.pdf>
- <https://en.wikipedia.org/wiki/WWV> (radio station)