1. NAME OF PROPERTY

Historic Name: Philosophy Hall

Other Name/Site Number:

2. LOCATION

Street & Number: 1150 Amsterdam Avenue Not for publication:__

City/Town: New York Vicinity__

State: NY County: New York Code: 061 Zip Code: 10027

3. CLASSIFICATION

Ownership of Property		Category of Property	
Private:	X	Building(s):	X
Public-Local:	__	District:	__
Public-State:	__	Site:	__
Public-Federal:	__	Structure:	__
		Object:	__

Number of Resources within Property

Contributing	Noncontributing	
1	__	buildings
__	__	sites
__	__	structures
__	__	objects
1	0	Total

Number of Contributing Resources Previously Listed in the National Register: 0

Name of Related Multiple Property Listing:

4. STATE/FEDERAL AGENCY CERTIFICATION

As the designated authority under the National Historic Preservation Act of 1966, as amended, I hereby certify that this ____ nomination ____ request for determination of eligibility meets the documentation standards for registering properties in the National Register of Historic Places and meets the procedural and professional requirements set forth in 36 CFR Part 60. In my opinion, the property ____ meets ____ does not meet the National Register Criteria.

Signature of Certifying Official Date

State or Federal Agency and Bureau

In my opinion, the property ____ meets ____ does not meet the National Register criteria.

Signature of Commenting or Other Official Date

State or Federal Agency and Bureau

5. NATIONAL PARK SERVICE CERTIFICATION

I hereby certify that this property is:

___ Entered in the National Register
___ Determined eligible for the National Register
___ Determined not eligible for the National Register
___ Removed from the National Register
___ Other (explain): ____________________

Signature of Keeper Date of Action

6. FUNCTION OR USE

Historic: Education Sub: Research Facility

Current: Education Sub: College

7. DESCRIPTION

Architectural Classification: Late 19th & 20th Century Revivals, Italian Renaissance

Materials:

Foundation: Concrete
Walls: Brick and Stone
Roof: Metal (Copper)_
Other: Steel Frame & Concrete Structural System

Describe Present and Historic Physical Appearance.

Philosophy Hall was built in 1910, in the Italian Renaissance Revival style on the eastern side of the campus of Columbia University in New York City.[1] [See Figure #1 and Photograph #1] It is one of hundreds of buildings designed by the prominent architectural firm of McKim, Mead, and White (whose work includes: the original Madison Square Garden, New York City's Pennsylvania Station, the Boston Public Library, the Rhode Island State Capital, and the J. P. Morgan Library). Philosophy Hall is an eight-story building, rectangular in plan and 145 feet by 65 feet, built on a concrete and granite base foundation. The building is steel frame, of brick with limestone pilasters, courses, sills and lintels.

Philosophy Hall is situated on a high terrace relative to the street level. The main entrance is therefore at the third floor level on the west facade and the second floor level exits on Amsterdam Avenue at the east facade. [See Photographs #2, #3, #4 & #5] On the west elevation, six granite steps lead up to a two-story arched doorway to the third floor, flanked by two 12-foot bronze lamps. The low-pitched hipped roof is patina copper metal with an ornamental stone cornice, and the corners of the building feature rusticated limestone quoins. Two-story Palladian windows on the third floor (ground floor on the campus side) are on the north and south facades. The remaining windows on the third floor and the windows on the upper floors are double hung wood sash windows. There is a belt course between the fifth and sixth stories, which runs all the way around the building.

Inside Philosophy Hall, the (third floor) entrance hall is finished in marble, with a marble staircase with iron railings facing the doors. The majority of the rooms on the third floor are offices with wood paneled doors. Originally, the north and south ends of this floor contained two-story lecture rooms, but the one at the south end was later reduced to single-floor height to create usable space on the fourth floor level. The first and second floors house facilities operations spaces and offices, respectively. Floors four through seven contain mostly faculty and administrative offices and small classrooms. The attic (eighth floor) houses mechanical equipment and storage.

Several of the rooms in Philosophy Hall have specific associations with Edwin H. Armstrong, the major radio inventor. Room 402 (towards the northeast end) was the location of meetings of the Radio Club of America, of which Armstrong was president, and at whose meetings Armstrong often demonstrated his inventions. The heterodyne circuit, for example, was discussed in Room 402 on October 20, 1916, with a detailed question and answer session by Armstrong. The second floor, which used to house the Laboratories variously referred to in Armstrong's and other correspondence as "Hartley Research Laboratory," "Marcellus Hartley Laboratory," or "Dodge Laboratories," is now primarily used as office space. Room 206, which was Armstrong's office as head of the Hartley Research Laboratory, still retains its original wood paneling.[2] This office is 388 square feet. Room 204 (currently renumbered as Room 200), which was Armstrong's lab, is on the east side of the building next to the staircase and elevator shaft. [See Figure #2 and Photographs #6 & #7] It is 342

[1]Two additional individual buildings on the Columbia University campus have received NHL designation: the Low Memorial Library (designated in 1987 for its architectural significance) and the Pupin Physics Laboratory (designated in 1965 as the place where a uranium atom was split for the first time in the United States).

[2]Lawrence Lessing, *Man of High Fidelity: Edwin Howard Armstrong* (New York: Lippincott, 1956), p. 166.

square feet. As built, the elevator shaft encroaches into the lab space, and the resulting offset of the walls is visible and distinctive in historic photographs of Armstrong in his lab.[3] The southernmost window of the pair that looks out from Armstrong's lab onto Amsterdam Avenue has been removed, and the opening extended several inches down to street level. The window opening was converted into an entrance door for facilities operations access. [See Photograph #8] Building utility machinery currently occupies half of Room 204, and a chain link fence has been installed lengthwise across the room to enclose that equipment. This room's interior doorway has been realigned a few feet to the south so it does not open into the fence-enclosed portion of the room. Nevertheless, the overall configuration of Room 204 remains as it was during the four decades it was used by Armstrong.

The northern third of the second floor, at the northeast and northwest corners of the building (originally Rooms 201, 202A and 202B, its now open space with two small offices), was also Hartley Research Laboratory space used by Armstrong and his staff. [See Photograph #9] The laboratory spaces of Rooms 201 and 202 together comprised 2025 square feet. A suspended ceiling of acoustical tile has been hung below the original ceiling, and some fluorescent light fixtures added. The west partition wall of Room 201 has been removed since Armstrong's time, and a new wall has been built to make the northern end into a small conference room. The partition walls that separated Room 202B (shown on the 1910 plans as a small office) from the rest of the space have been removed. [See Photograph #10] Despite the loss of three interior partition walls, the original configuration of the laboratory spaces is recognizable from early photographs.

The campus plan, also designed by McKim, Mead & White, shows the landscaping in front (west) of Philosophy Hall to have remained substantially as it was originally designed. A bronze statue of Rodin's *Thinker* on the lawn in front of the building remains from the time the inventor Edwin H. Armstrong was a student there. One element of the McKim, Mead & White campus plan that was not implemented was the construction of a building originally planned as a twin of Philosophy Hall to its west. The space intended for it is occupied by a building that predates the University. As viewed from the west, Philosophy Hall's below grade, one-story connection to its southern neighbor, Kent Hall, is not visible. Also designed by McKim, Mead & White and built in 1910 in the Italian Renaissance Revival style, this passage allows easy access between the second floors of the two buildings. Since 1961 an elevated pedestrian bridge/plaza (Revson Plaza) on the east side of Philosophy Hall extends over Amsterdam Avenue at a height slightly higher than the third floor level of Philosophy Hall. [See Photographs #4 & #5] The elevated plaza connects the east campus to the north campus via steps from the plaza along both north and south facades of Philosophy Hall.

Philosophy Hall was originally built to house the engineering department of Columbia University, but later, upon the construction of other buildings, became the home of literature and history classrooms in the upper stories, while the first and second stories are part of the bursar's office. The interior of the building has undergone minor modifications on the first and second floors. In addition to Armstrong's general use of Philosophy Hall, his office (Room 206), laboratory (Room 204) and lecture facility (Room 402) maintain their original configuration. The removal of internal walls separating Rooms 201 and 202 alter the original configuration of those laboratory spaces, but the ease with which they could be reconfigured reveals the modesty of even those modifications.

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[3] Edwin H. Armstrong Papers, Rare Book and Manuscript Library, Butler Library, Columbia University, boxes 485-490.

Because of its continuous use as an educational facility, the building is in a good state of preservation.

8. STATEMENT OF SIGNIFICANCE

Certifying official has considered the significance of this property in relation to other properties:
Nationally: X Statewide:_ Locally:__

Applicable National Register Criteria:	A X B X C_ D__
Criteria Considerations (Exceptions):	A_ B_ C_ D_ E_ F_ G_
NHL Criteria:	1 & 2
NHL Criteria Exceptions:	N/A
NHL Theme(s):	VI: Expanding Science and Technology 1. Experimentation and Invention 2. Technological Applications
Areas of Significance:	Communications, Engineering, Invention
Period(s) of Significance:	1913-1954
Significant Dates:	1913, 1914, 1919, 1922 & 1933
Significant Person(s):	Edwin H. Armstrong
Cultural Affiliation:	N/A
Architect/Builder:	McKim, Mead and White
Historic Contexts:	XV. Communication D. Radio XVIII. Technology (Engineering and Invention) I. Information Processing, Transmission, and Recording

State Significance of Property, and Justify Criteria, Criteria Considerations, and Areas and Periods of Significance Noted Above.

Summary Statement of National Significance:

In the history of wireless communication technologies, a few individuals and organizations are likely to attain national significance on the basis of their contributions to the field and the resulting impact on the Nation's development. A list of the most important players in this story would probably be filled out with the following names: Ernst Alexanderson, Lee de Forest, Reginald Fessenden, Guglielmo Marconi, Nicola Tesla, AT&T, Bell Laboratory, General Electric, and RCA. By any measure, Edwin H. Armstrong would certainly be on that list.[4] A great deal of his work was conducted at Columbia University's Philosophy Hall between 1910 and 1954, including research and demonstrations relating to his four most important developments: the regenerative or feedback circuit (1912), which made reception of distant and weak signals practicable, the superheterodyne receiver (1918) which underlies modern radio and radar reception, the superregenerative receiver (1921) which allowed even stronger reception of distant radio signals previously believed to be unreceivable, and wide-band frequency modulation (1933) which made FM radio broadcasting possible. Philosophy Hall is nationally significant for its long and strong association with these, and other, aspects of Armstrong's life and work.

While the historical significance of radio technology has been acknowledged nearly since the time of its earliest development, an even broader perspective on its place in history is becoming possible as we enter another century. Following the wired communications technologies of the nineteenth century (telegraph and telephone), the development of the wireless technologies of radio and television are now understood as early, important elements of the broader Information Age. As gritty industrial activity defined an earlier "age," the transmission, processing and recording of electronic information represent primary threads in broad aspects of our culture. In the same way that the study of radio prior to the rise of commercial broadcasting in the 1920s has been called the "prehistory" of radio, the full history of radio during the first half of the twentieth century can be viewed as the prehistory of the Information Age.[5] Major advances in wireless communications are nationally significant because of their economic, military, and cultural impact on the history of the United States. Armstrong's contributions to wireless communications were important and fundamental to the development of that technology.

When, in the summer of 1912, Armstrong came up with his first of many important ideas about improving radio technology, the college senior was anxious to return to the laboratories on the second floor of Philosophy Hall to begin months of refining his soon-to-be famous regenerative

[4]In 2000, the National Historic Landmarks Survey and the History Center of the Institute of Electrical and Electronics Engineering (IEEE) initiated a project to identify important advances in the development of wireless communication technologies, and identify properties associated with those developments. This ongoing effort has thus far identified more than 100 properties of varied levels of significance, association, and historic integrity. As this project advances, several of these historic properties will be recommended for recognition by IEEE's "Milestones" landmarks program, and/or the National Park Service's National Register for Historic Places, and National Historic Landmarks programs.

[5]Susan J. Douglas, *Inventing American Broadcasting: 1899-1922* (Baltimore: Johns Hopkins University Press, 1987), preface, p. 1.

circuit. After graduation the following spring, he was made an assistant in the Engineering Department and was assigned his own laboratory, a facility he maintained for more than forty years (Room 204). [See Figure #2 and Photographs #6 & #7] Eventually, he was appointed as head of the entire Marcellus Hartley Laboratories in Philosophy Hall and acquired an office space as well (Room 206). Armstrong also used Philosophy Hall's other laboratory spaces (Rooms 201, 202A, 202B, and 204) to refine his inventions and develop new ones. [See Photograph #9] He used the buildings lecture rooms (including Room 402) to demonstrate his advances to small groups of potential buyers (industry engineers and executives), and larger assemblies of the interested public and press. Philosophy Hall also served as a point from where Armstrong waged a series of battles against those he believed were standing between him and his objectives. While there were obviously additional places associated with different parts of his life, Philosophy Hall is the one property strongly associated with each of his most important developments, and possesses a high degree of historical integrity. [See Photographs #2, #3, #4 & #5] All these factors make it the best property associated with Edwin Armstrong's life and work.

Background

Edwin H. Armstrong was born in Chelsea, NY on December 18, 1890. [See Photograph #11] In 1902, the Armstrong family moved to their home at 1032 Warburton Avenue, Yonkers, NY.[6] As a boy, Armstrong spent many hours tinkering with Leyden jars and radio equipment in the attic, and he built a 125-foot tall antenna in the back yard.

Armstrong's associations with Philosophy Hall began as soon as it was built. Armstrong matriculated at Columbia in 1909, and Philosophy Hall was built the following year, becoming available for classroom and laboratory use during Armstrong's junior year. As an undergraduate, Armstrong observed the regenerative (or feedback) phenomenon and made a careful study of the audion, a glass tube somewhat resembling a light bulb. The audion, invented by Lee de Forest, was one of a number of devices by which inventors had hoped to detect and amplify radio signals so as to enable reception of more distant, weaker signals. "Though Lee De Forest had invented the three-element tube late in 1906…he did not understand how it worked."[7] Although the audion itself had not proved very much more sensitive than other radio wave detectors, Armstrong had been experimenting and studying the currents and voltages in the audion's circuit since being given a pair of them in 1911. In the summer of 1912 (between his junior and senior years), while on a mountain climbing trip in Vermont, Armstrong came up with the idea that led to the regenerative circuit, which allowed the amplification of signals. Armstrong's research on the audion at the Marcellus Hartley Laboratories had shown that some alternating current was being produced in the plate current of the audion. "Careful measurements of the current emanating from the plate element of the tube…revealed that it oscillated in a steady, uninterrupted rhythm."[8] By placing a second tuning coil in the output circuit (called the "wing" circuit), and directing the output back into the grid circuit, Armstrong immediately noticed improved amplification. [See Figure #3] "He reasoned that as electrons move at the speed of light, he might feed the current through the grid many thousands

[6]1032 Warburton Ave. was destroyed by fire ca. 1982.
[7]Thomas S. W. Lewis, *Empire of the Air* (New York: Harper Collins, 1991), p. 69; Douglas, *Inventing American Broadcasting*, pp. 245-6.
[8]Lewis, *Empire of the Air*, p. 70.

of times a second, each time increasing the signal that had been received by the antenna." [9] As he worked through the winter of 1912-1913 to understand and improve the circuits, Armstrong regularly heard radio transmissions from distances never before achieved. "No commercial apparatus then known had such range or power of amplification."[10] [See Photograph #12]

Upon graduation in June of 1913, Armstrong was given a position as assistant in the Engineering Department and given room 204 in Philosophy Hall as his own laboratory. In December of 1913, Armstrong's mentor and head of the university's engineering department, Michael Pupin, arranged for him to give a demonstration of his regenerative circuit in Philosophy Hall to executives of the American Marconi Wireless Company. A second demonstration was given for leading American Telephone and Telegraph engineers J. J. Carty, Bancroft Gherardi, and F. B. Jewett on the evening of February 6, 1914.[11] "Stations never before heard in New York, like Glace Bay in Nova Scotia; Clifden, Ireland; Honolulu, and others came in loud and clear."[12] One of the American Marconi Company executives was David Sarnoff, the future president of RCA, who immediately recognized the importance of Armstrong's invention for making long-distance radio transmissions more economical and the messages carried over them less prone to error in transcribing the Morse code characters. In April, 1916, the American Marconi Wireless Company concluded a license under Armstrong's patents and began paying him royalties.

In the autumn of 1913, Lee de Forest -- the inventor of the audion -- addressed a session of the Institute of Radio Engineers[13] in a lecture hall at Columbia University. It was at this lecture that Armstrong gave his "black box" demonstration of the regenerative circuit (which he kept shrouded in a closed box located in an adjoining room). It was also from this first meeting between the two that began the enmity between de Forest (who had not himself been able to make much practical use of the audion) and the young graduate who was achieving such astounding results. Using oscillograms made at the Marcellus Hartley Labs with the help of Professor John H. Morecroft, Armstrong was able to correctly explain the amplifying effects of the audion. "Even today, when the vacuum tube has given way to the transistor, and the transistor to the integrated circuit, Armstrong's principle of regeneration has remained basic to electronics."[14]

Meanwhile, Armstrong continued to work on another enormous problem which plagued early radio static, in 1916, Armstrong was elected president of the Radio Club of America.[15] With the United States' entry into World War I in 1917, however, most of the Radio Club's members found themselves putting their expertise to work in the U.S. Army Signal Corps. Armstrong was made a captain in the Army Signal Corps and sent to France. His first technical problem when he arrived was the detection of high-frequency radio signals supposedly being used by the Germans for communications (these signals turned out to be imagined by the allies). While watching a German bombing raid on Paris, Armstrong speculated whether the accuracy of antiaircraft guns might be

[9]Lewis, *Empire of the Air*, p. 70.
[10]Lessing, *Man of High Fidelity*, *p*. 67.
[11]E. H. Armstrong, "Disclosure of the Regenerative Circuit," in *The Legacies of Edwin Howard Armstrong*, ed. John W. Morrisey (Radio Club of America, Inc., 1990), p. 84.
[12]Carl Dreher, *Sarnoff: An American Success* (New York: Quadrangle/The New York Times Book Co., 1977), p. 44.
[13]The Institute of Radio Engineers was one of the predecessor organizations of the Institute of Electrical and Electronics Engineers (IEEE).
[14]Lewis, *Empire of the Air*, p. 71.
[15]The Radio Club of America was formed by a small group of dedicated radio amateurs and experimenters in 1909.

improved if there were a way of detecting the extremely short electrical waves emitted by the ignition systems of the aircraft engines. This flash of insight was the germ of the idea behind what was to become the superheterodyne circuit. When the war ended in November, 1918, Armstrong was sent to Hindenberg's former headquarters in Spa, Germany, where the Armistice Commission was meeting, in order to keep the regenerative circuits working, which were keeping the American delegation in direct contact with the United States during the negotiations.

The superheterodyne circuit provided "a means of receiving a very wide range of frequencies from the lowest to the highest…it allowed amplification to a point where headphones could be discarded for a loudspeaker…and [was] capable of being finely tuned to separate stations without interference..."[16]

> The arrangement…used [Armstrong's] regeneration circuit both as a receiver and oscillator of radio waves and employed eight vacuum tubes in four different stages. First, his superheterodyne receiver would pick up a high-frequency wave and heterodyne it with another wave produced by one of his vacuum tubes in oscillation, thereby creating a wave of intermediate frequency. Second, the intermediate frequency wave would travel through an amplifier to increase its power several thousand times.[17]

(Heterodyning is the principle -- discovered by Reginald Fessenden -- of adding two incoming radio waves of differing frequency to produce a third signal equal to the difference between the first two. Armstrong's regeneration circuit had allowed the heterodyne principle to work, because it provided a method of correctly regulating the frequency within the receiver. The advantage is that the third intermediate frequency signal can be fixed at a range that is optimal for amplification.) "Since all the intermediate stages of a superheterodyne are tuned to the one intermediate frequency it was possible to use three or more such stages without complicating the tuning controls, and thus the overall amplification and the selectivity…could be made far superior…to any other contemporary receiver."[18] In short, the "superhet" offered much stronger amplification and simplicity of tuning. Superheterodyne-based radios would be able to develop into a mass consumer appliance to which buyers, who were not trained radio operators could listen comfortably, rather than a select preserve of enthusiasts crouched over sets with earphones, trying to hold the delicate tuning to a whisper of a frequency. [See Photograph #13] Also important to radio's consumer appeal, the superheterodyne made possible a simplified radio with single-knob tuning, a great improvement over the difficult to use multi-dial tuning previously in use.

In September 1919, Armstrong, now Major Armstrong, returned from wartime service in Europe with the Army Signal Corps, and developed his superheterodyne receiver. Armstrong gave lectures and demonstrations to meetings of the Radio Club of America, which were held -- among other locations around New York City and Columbia University -- in Philosophy Hall in room 402. The many returning veterans of the Army and Navy signaling arms swelled the ranks of radio operators, particularly amateur radio operators, and gave an impetus to radio development in peacetime.

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[16]Lessing, *Man of High Fidelity*, p. 116.
[17]Lewis, *Empire of the Air*, p. 133.
[18]Harold P. Manly, *Drake's Cyclopedia of Radio and Electronics* (Chicago, Drake & Co. Publishers, 1933).

On the night of December 11, 1921, Armstrong and his fellow radio experimenters transmitted the first shortwave radio signal across the Atlantic from Greenwich, CT.[19] Marconi's transatlantic transmission of December 12, 1901, and the commercial radio links following up until then, used the much more expensive long waves. Previously, shortwaves had been considered commercially useless frequencies. In fact, military and commercial interests of the time had pressured the United States government to restrict the amateurs to these higher frequencies (above 1.5 megahertz) to get them out of the more valuable lower frequencies. At the time, established theory held that shortwaves could not propagate as far as longwaves. The amateur operators, exploring this new frontier, began to learn some new things about shortwaves, most notably, that they could travel much farther than anyone had supposed. Using a transmitter of Armstrong's design, superregenerative equipment developed in the laboratories at Philosophy Hall, and a superheterodyne receiver, Armstrong and his Radio Club colleagues -- Paul F. Godley (who sailed to Scotland with the receiver), Minton P. Cronkhite (who owned the transmitter in Greenwich, CT), George Burghard (who was at the key when the first message got across), John Grinan (known for his clear Morse code, or "fist"), and Walter Inman -- succeeded in bridging the Atlantic by shortwave. By previous arrangement with British Marconi and RCA, Godley confirmed receipt of the message via regular commercial longwave. The test, and the transmitting schedule, had been announced in the summer edition of QST, the magazine of the American Radio Relay League, so amateur operators on both sides of the Atlantic were listening. The night after Godley's confirmation, Grinan tapped out the message, heard by amateur radio operators in England, Holland, and Germany. Their success in bridging the Atlantic "…was the new sensation of the wireless world. Amateurs jammed the ether calling 1BCG."[20] It was a dramatic demonstration of what the superheterodyne circuit could accomplish.

Armstrong followed up his shortwave triumph with the discovery of superregeneration. One night in 1921, while preparing equipment in his Philosophy Hall laboratory for use in court in a patent case, Armstrong heard a signal at many times the strength which could have been expected from regeneration. This new principle, superregeneration, was an extension of the feedback principle of the regenerative circuit beyond what had hitherto been considered its theoretical limit. Armstrong found that by introducing a periodic variation between the negative and positive resistance of a circuit, during those periods where the negative resistance is greater, the circuit produced a great amplification of an impressed electromagnetic frequency. The principle allowed amplification up to 100,000 times the original signal strength. The new circuit -- powerful and simple -- increased the interest in radio and was hailed -- overoptimistically -- as the solution to all of radio's problems. Superregeneration is particularly useful in high, well-spaced frequency applications where compact, light receivers are needed. Armstrong's discovery made possible police radio development, as well as other mobile applications. Superregeneration would also have applications in World War II, particularly in the Identify Friend or Foe (IFF) systems used by the Allies.

The decade of the Twenties was a busy one for Armstrong. In addition to development of his superheterodyne and superregenerative circuits, he was also fighting a number of court battles with de Forest, who -- having invented the audion -- was claiming the regenerative circuit as his own as well. Armstrong was active in the leadership of the Radio Club of America, presenting papers,

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[19]A stone marker commemorates the event near the site of the no longer extant structure.
[20]Lessing, *Man of High Fidelity*, p. 138.

giving demonstrations, and discussing advances in the new technologies.

Although Armstrong had extended radio's reach, the problems of static remained. Armstrong had been pushing ideas around on paper and in the lab to try to eliminate static as early as 1914. Previously, the attempted solution to the problem of static was to try to drown out atmospheric disturbances with more power in the transmission, however beyond a certain point, this becomes expensive and the equipment impractical because the energy in, for example, a single lightning bolt far overpowers even the most powerful transmitters. In 1922, Armstrong had said in an interview that static was the biggest problem facing radio.

The key, Armstrong realized, was to use radio waves which were different in character from the waves which static electricity produced. Frequency modulation (FM) had been tried before, without success, and abandoned. The problem, however, was that earlier experimenters had treated frequency-modulated waves in the same manner they had treated amplitude-modulated waves -- namely, confining the modulation to a very narrow range. Under those conditions, the sounds produced by frequency-modulated waves were distorted and useless. In 1922, a paper given by AT&T engineer John Carson before the Institute of Radio Engineers, had been thought to drive the final theoretical nails in frequency modulation's coffin. Armstrong never took theory or mathematics as final authority, however, and continued his experiments. In 1932, Armstrong's breakthrough was to realize that frequency-modulated waves were different and should be allowed to behave differently from amplitude-modulated waves. When Armstrong allowed his waves "to swing over a very *wide band* of frequencies…[he found he could transmit and receive] with a clarity and lack of distortion and interference unknown in amplitude modulation."[21] Radio historian Thomas Lewis provided a relatively uncomplicated explanation of FM:

> *Modulation* refers to the way in which voice and music information is impressed on a radio wave. In amplitude modulation (AM) the information signal varies the amplitude of the wave; what Armstrong proposed was a method of modulation that would vary the wave's frequency. By analogy to waves of water, AM imparted the signal through changes in the heights of the waves; FM did so by varying the spacing of the wave crests. Since most noise affected wave height, or amplitude, much more than frequency, FM was much less vulnerable to interference.[22]

In December of 1933, Armstrong invited Sarnoff uptown to his laboratory in Philosophy Hall to demonstrate a new radio technology, which would get away from "a radio that sounded like a radio."[23] Other RCA engineers were also given demonstrations of the new FM technology. In the two rooms in the north end of the laboratories of Philosophy Hall (Rooms 201, 202A and 202B), Armstrong and his assistants, Tom Styles and John Shaugnessy, had built the intricate circuits which would make wide band FM radio possible. RCA was impressed enough to suggest moving the equipment to a more suitable transmitting site, and by 1934, the FM transmitters developed in the Marcellus Hartley Dodge Laboratory were making experimental transmissions from the top of the Empire State Building in New York City. The first field test, on June 16, 1934, showed the possibilities of the new technology. The field test was monitored by Armstrong's associates using

[21] Lessing, *Man of High Fidelity*, p. 199.
[22] Thomas S. W. Lewis, "Radio Revolutionary" in *The Legacies of Edwin Howard Armstrong*, p. 8.
[23] Lessing, *Man of High Fidelity*, p. 218.

specially designed receiving equipment sixty-five miles away in the Westhampton, NY summer home of a friend of Armstrong's.[24] Throughout the summer, even through the enormous static caused by thunderstorms, the transmissions were received clearly. In order to make the tests more demanding, the receiver was moved to the basement of another friend's house in Haddonfield, NJ (eighty-five miles from the Empire State Building), disproving earlier assumptions that FM signals could not be received beyond the horizon.[25] FM transmissions at 2 kilowatts compared favorably to AM transmissions at 50 kilowatts.

Unfortunately for Armstrong and FM, this revolutionary new technology threatened the huge investments which RCA and other corporations had made in building AM radio stations only fifteen years before. In the midst of the Depression, the high cost (to consumers and broadcasters) of converting to FM was daunting. In April, 1935, RCA asked Armstrong to remove his equipment from the Empire State Building to make way for the resumption of its experimental television broadcasts. Armstrong returned the equipment to Philosophy Hall, where he was determined to develop FM into commercial preparedness, using his own money if necessary. Also that year, Armstrong's mentor Michael Pupin died, and Armstrong was appointed his successor as head of the Hartley Laboratories.

During the summer of 1935, Armstrong and his assistants built and tested FM apparatus, transmitting from the Yonkers radio station W2AG -- owned by long-time Armstrong friend and amateur Randy Runyon -- to a receiver installed at Runyon's summer home in Mantoloking, NJ.[26] The modulator and the receiver for these experiments were built in the Philosophy Hall laboratories. On November 5, 1935, Armstrong demonstrated FM to a meeting of the Institute of Radio Engineers in the Engineers Building on 39th Street.[27] Not only was the near static-free clarity of the signal a revelation, so was the economy of power used by FM. Wavelengths previously believed to be too weak to carry a signal a hundred yards had been shown to cross many miles with clarity. FM opened up an entirely new range of wavelengths for commercial use outside of the crowded AM bands. Operating at these higher frequencies, Armstrong's completely new broadcasting (and receiving) system not only opened up new band space for broadcasting, but unlike AM, introduced the prospect of "high fidelity" broadcasts that "could transmit a signal corresponding to virtually the entire range of frequencies audible to the human ear."[28] Despite the advantages of Armstrong's FM system, the initial interest in his invention cooled.

At the same time Armstrong was enjoying the successes of his experimental FM broadcasts from the Empire State Building, he also suffered an extremely disappointing rebuke. After twenty years in the courts, Armstrong and de Forest's battle over who should be credited with discovering the important amplification capabilities of de Forest's audion or Armstrong's regenerative circuit, received a final legal judgement. This is a long and complicated story that raises fascinating issues about different approaches of fact finding between the worlds of science and that of jurisprudence.

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[24] George Burghard's summer home was destroyed in the great hurricane of 1938.

[25] Henry Sadenwater's house at 145 Colonial Ridge Drive is extant.

[26] The house at 544 North Broadway is no longer extant.

[27] The Engineers Building at 33 W. 39th St., was a shared headquarters for many of the engineering societies (e.g. AIEE, ASCE, et. al.) until 1962. In 1962, a new United Engineering Center was built on 47th St. and 1st Ave.

[28] David L. Morton, Jr., "Edwin Howard Armstrong and the History of FM Radio: A Contextual Approach," in *The Legacies of Edwin Howard Armstrong*, pp. 172-3.

Worthy of a fuller examination than is appropriate for this NHL nomination, the heart of the matter has been best summed up by radio historian Susan Douglas:

> De Forest had discovered the phenomenon first, but there is very little evidence that he understood its implications. Only after Armstrong's work did De Forest appreciate the significance of that mysterious howl….No radio patents have generated more controversy than these. The subsequent litigation between De Forest and Armstrong lasted until 1934, went to the Supreme Court twice, and reportedly cost one and a half million dollars in lawyers' fees. A prodigious amount of bile was expended as well, with acrimony high on both sides. After Armstrong won one of the early suits, he strung a banner with his patent number on it across his Yonkers home, which De Forest had to pass every day en route to and from his factory. Armstrong lost the case twice before the Supreme Court, yet many radio engineers and most radio historians consider him the bona fide inventor. He may have made the discovery months later than De Forest, but at least he knew exactly what he had. The discovery and the litigation were so momentous because the implications for radio transmission were revolutionary.[29]

Throughout 1937 and 1938, Armstrong built his 50 kilowatt FM transmitter at a large facility he built at Alpine, NJ, which used a 400-foot tower with huge cross-arms.[30] (The tower is still in service, and became the temporary transmitting station for television and radio stations whose antennas were destroyed in the September 11, 2001 terrorist attack on the World Trade Center.) He continued to file for FM patents. In the summer of 1938, Alpine began low-power tests. General Electric, a rival of RCA, began paying Armstrong for a manufacturing license. In the summer of 1939, Alpine went to full power. That same summer, the FM transmitter at Mt. Asnebumskit, MA began broadcasting programs to central New England. Armstrong had built a relay transmitter to beam the "Yankee Network's" programs from Boston the 40 miles to Mt. Asnebumskit, instead of via telephone. The relay was less costly and of higher fidelity than the telephone lines, and the possibilities offered by remote broadcasting made FM that much more commercially attractive. The discovery that FM stations in the same geographic area did not interfere with each other (indicating that they could be spaced closely in wavelength) was another plus. Autumn of 1939 saw 150 applications for FM station permits. By 1942, more than forty of them were in operation. In 1941 the Federal Communications Commission ruled that television audio would be transmitted via FM.[31] "It seemed that almost every week engineers were discovering new applications for wide-band FM, especially for police, emergency, and military applications. Already the Chicago police department and state police in Connecticut had adopted FM for radio communications with their automobiles."[32]

1939 also saw Armstrong adapting FM to mobile communications, something it was ideal for because of the modest power requirements and low weight of the equipment. In 1939, the Army Signal Corps, based at Camp Evans in Belmar, NJ, came to Armstrong for help in adapting mobile

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[29]Douglas, *Inventing American Broadcasting*, pp.245-6.

[30]Although the Alpine transmitter no longer contains Armstrong's equipment, the building and tower came under preliminary consideration in this NHL study for their association with the FM portion of Armstrong's national significance. Further consideration was not possible once the current owners declined a request to visit the facility and explore its NHL eligibility in more detail.

[31]Dana M. Raymond, "The Armstrong FM Litigation," in *The Legacies of Edwin Howard Armstrong*, p. 263.

[32]Lewis, *Empire of the Air*, p. 278.

FM to military uses. Armstrong undertook these Signal Corps projects in his laboratories, between his other projects. The United States entry into World War II changed Armstrong's priorities. By government order, all production of FM radio equipment for civilian uses was halted. Armstrong patriotically put his FM patents at the disposal of the government. "…from the earliest stage of the war, every U.S. Army tank, command car, jeep and other vehicle with facilities for short-range communications was equipped with FM, making U.S. Armies among the fastest in the world."[33] The mobility of U.S. army units, especially in the ground assault on Germany, was a factor in their effectiveness. Philosophy Hall's contributions to Army and Navy communications were large and important, but Armstrong's particular contribution to radar was even more significant. In 1942 Armstrong reported that the superheterodyne circuit "…is one of the indispensable elements of an aircraft-detection scheme of the present war [World War II]…."[34] Nearly forty years later another writer commented about Armstrong's World War II activities:

> During the war, the Signal Corps had an arrangement with Maj. Armstrong whereby he carried out work for the Evans Laboratory, working to determine the utility of frequency modulation for radar….The major had made extensive modifications to the equipment [an SCR-271, similar to the one which had detected Japanese planes at Pearl Harbor and Guadalcanal]. The result was a powerful transmitter and complex receiver with multiple superheterodyne stages….[35]

The radars used in World War II were pulsed-wave radar. In addition to the helpful modifications Armstrong made on pulsed radars, he and his colleagues began developing a new kind of radar: continuous wave radar. Although CW-radar was slower than its pulsed sibling, it has a considerably longer searching range. Among other areas, the post-war radar work at Camp Evans was directed towards detecting and tracking incoming ballistic missiles. The danger that had been posed to London by the dreaded German V-2 rockets had not been lost on American military planners. Tracking long-range enemy missiles or bombers required radar designs which would have the long range capability to reach hundreds of miles beyond its own borders. Armstrong's work would continue to produce results long after he had returned to his own labs.

As a postscript to Armstrong's insight that night in Paris during World War I about detecting the spark frequencies from German aircraft (the insight which had led to the superheterodyne circuit), British intelligence was indeed often able to derive detailed information about the size and type of aircraft in an impending raid by monitoring the radiation given off when the Luftwaffe warmed up its airborne radars on the ground.

After World War II, Armstrong returned to his laboratories at Columbia, and to the bitter court battles over his FM patents. His powerful radar sat temporarily idle at Camp Evans, but it was soon to be used for a notable and special project.

Beginning in 1945, the Diana Project was established to explore the capabilities of long range radar. Its famous achievement -- bouncing a radar signal off the moon -- was not the primary purpose of

[33]Lessing, *Man of High Fidelity*, p. 251.
[34]E. H. Armstrong, "Vagaries and Elusiveness of Invention," in *The Legacies of Edwin Howard Armstrong*, p. 287.
[35]Trevor Clark, "How Diana Touched the Moon," *IEEE Spectrum* (May 1980): 44-48.

the project (investigating the feasibility of detecting incoming ballistic missiles by means of radar was). At the time, it was not known whether radar could penetrate the ionosphere. The Signal Corps modified Armstrong's FM radar equipment, and on January 10, 1946, received an echo of the signal they had sent 2.5 seconds earlier.[36] Historians often point to Project Diana as the beginning of America's space program, and mankind's first reach beyond the ionosphere to make contact with a non-terrestrial object, though it should be pointed out that the choice of the moon as a test target was partly an opportunity of satisfying a long-standing dream of radio engineers. Nonetheless, the feat excited the U.S. public as well as the international technical community.

When he died in 1954, Armstrong was working on a fifth radio development with his assistant John Bose -- FM multiplexing which allows an FM station to transmit more than one signal over the same FM wave simultaneously. Among other things, this technique makes stereo broadcasts possible.

Conclusion

Radio was one of the major technologies, as well as one of the major cultural forces of the twentieth century. Not only did radio and radio broadcasting spawn new industries, particularly within the entertainment field, it changed the political world (for example, Franklin Delano Roosevelt's "Fireside Chats" as well as its darker uses by dictators such as Hitler and Mussolini). Radio also changed the way people received and perceived, as well as considered themselves affected by and involved in news of world events. Radio and radar led to technologies such as instrument landing systems in our airliners, mobile military communications, and portable telephones. Edwin H. Armstrong's contributions to radio technology were fundamental, and long distance communication as we know it would not be possible without his work in Philosophy Hall. Pupin himself had written: "Edwin H. Armstrong's contribution to the radio art, particularly the vacuum tube radio art, is epoch-making…The regenerative receiver and the regenerative oscillator will always figure among the classical inventions and will occupy a foremost position in the research laboratory, as well as in the commercial wireless service."[37] Armstrong's research and experiments contributed substantially to Allied victory in two world wars, as well as to the beginnings of the U.S. space program. Whether the modesty of FM's broader success during Armstrong's lifetime was due to obstructions put up by competing interests, or whether it was merely a technology developed before its time, FM (and the high fidelity and stereo it afforded) became an important conduit of American culture by the 1960s.

Armstrong's achievements were recognized within his lifetime by numerous prestigious awards. The French made him a *chevalier de la Legion d'honneur* in 1919 for his services to the allies in World War I. The Institute of Radio Engineers awarded him its first Medal of Honor in 1917. The Medal of Honor became the highest award in the radio engineering profession, given only to those who had attained preeminence in the field through outstanding technical contributions. The Franklin Institute awarded Armstrong its Franklin Medal in 1941, while the American Institute of Electrical Engineers (which merged with the Institute of Radio Engineers in 1963 to become the

[36]John DeWitt and E. K. Stodola, "Detection of Radio Signals Reflected from the Moon," *Proceedings of the IRE* (March 1949): 229-242.

[37]Michael I. Pupin, quoted in *The Legacies of Edwin Howard Armstrong*, p. 65.

Institute of Electrical and Electronics Engineers) awarded him its Edison Medal in 1943.[38]

Despite these honors and recognitions, the court battles over patents took an increasing toll on Armstrong's psychological health and sapped his energy. His determination to commit as much money as necessary to secure vindication in the courts was easily matched by opposing corporations with teams of attorneys and even deeper pockets. As Armstrong's legal expenses soared, his once formidable income declined sharply once his FM patents expired, and his royalty payments dropped off precipitously. The resulting strains apparently spilled over to his personal and family life. On February 1, 1954, he committed suicide by leaping from the thirteenth story window of his luxury East Side apartment. Despite the desperation that crushed his hopes of prevailing, Armstrong's FM technology was eventually used throughout the field of radio engineering, and his FM patent claims prevailed in court after his death.

Even if he had developed *only* the regenerative circuit, or *only* the FM system, Edwin Armstrong would be a nationally significant figure. Based on the importance and long tenure of his association with Philosophy Hall, this property is nationally significant as the place where Armstrong either conceived, developed, and/or fought for some of the most important developments in electronics.[39]

[38] Among his other honors, Armstrong was inducted into the National Inventors Hall of Fame in 1980. (The National Inventors Hall of Fame was established in 1973 by the National Council of Patent Law Associations, and the Patent and Trademark Office of the U.S. Department of Commerce.)

[39] In addition to Armstrong's research, Philosophy Hall may be significant for its associations with Michael I. Pupin, inventor and Pulitzer Prize winner, who, as founder and head of the Engineering Department at Columbia University, oversaw the operations of the Marcellus Hartley Laboratories and was a teacher and mentor to Armstrong. Pupin is known for his inventions in x-ray photography, his discovery of secondary x-ray radiation, and particularly for his induction coils which made long-distance telephony possible. His autobiography *From Immigrant to Inventor* won the Pulitzer Prize in 1924. Although Pupin's inventions took place at Columbia University prior to the building of Philosophy Hall, his associations with the building as teacher are important. "He held forth in a room in the basement of Philosophy Hall [Room 206], a room which, with its elegant walnut paneling, its early Edison lamps glowing yellowly in the gloom…and its associated clutter of laboratories, was a mecca for aspiring young electrical engineers." [Lessing, p. 45] While Pupin's role in history is outside the scope of this project, additional study of his significance and association with Philosophy Hall may justify an additional nationally significant association for this building.

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Previous documentation on file (NPS):

__ Preliminary Determination of Individual Listing (36 CFR 67) has been requested.
__ Previously Listed in the National Register.
__ Previously Determined Eligible by the National Register.
__ Designated a National Historic Landmark.
__ Recorded by Historic American Buildings Survey: #
__ Recorded by Historic American Engineering Record: #

Primary Location of Additional Data:

__ State Historic Preservation Office
__ Other State Agency
__ Federal Agency
__ Local Government
_X_ University: (E. H. Armstrong Papers, Rare Book and Manuscript Library, Butler Library, Columbia University, New York, NY 10027)
__ Other (Specify Repository):

10. GEOGRAPHICAL DATA

Acreage of Property: Less than one acre.

UTM References:	Zone	Easting	Northing
	18	587600	4517680

Verbal Boundary Description:

Philosophy Hall occupies a relatively small portion of the super block that comprises the core Columbia University campus (bounded by Broadway, 120th St., Amsterdam Ave., and 114th St. [Manhattan block 1973, lot 1 & block 1886, lot 1]). The boundary of the nominated property is as follows: The southeastern end of Philosophy Hall begins on the western edge of the western sidewalk of Amsterdam Ave., at a point approximately 115' north of 116th St. (which was formerly a vehicular street and currently a pedestrian walkway known as College Walk). From there the boundary runs approximately 145' north along the western edge of the sidewalk to the northeastern end of the building, continuing approximately another 7' along the retaining wall that projects beyond the building line. At that point the boundary turns west, following the northern edge of the building for approximately half of the north elevation's 55'. At that point the boundary turns south approximately 7', back to the building line. (This cutback reflects the removal of the western portion of the retaining wall so the steps leading down from Revson Plaza [1961] can touch down at grade level near Philosophy Hall's northwest corner.) At the northwest corner the boundary continues to run west for approximately 12' until reaching the eastern edge of the sidewalk that parallels Philosophy Hall's west facade. At this point the boundary turns south, following this line for approximately 145'. At that point the boundary turns east and runs approximately 62' along the building's southern edge until returning to the starting point at the southeastern corner of Philosophy Hall.

Boundary Justification:

The nominated boundary encompasses the historic and current footprint of the building, plus an additional 12' wide section of lawn on either side of the projecting steps on the west facade.

11. FORM PREPARED BY

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Date: July 2002

DESIGNATED A NATIONAL HISTORIC LANDMARK
July 31, 2003