

The following notes are parsed from the IEEE site and pertain to the LIGO IEEE Milestone Award. Effort was made to only transcribe those sections requiring scrutiny. The items of a more administrative function on the IEEE site are deliberately omitted below:

[Original IEEE LIGO Milestone Award Site](#)

**Title of Award:**

Milestone-Proposal:1972 - Conceptualization of the Gravitational Wave Antenna Used in the Large Interferometric Gravitational Observatory (LIGO) and Virgo (EU)

**Year or range of years in which the achievement occurred:**

1972 - 2017

**Title of the proposed milestone:**

Invention of the Gravitational Wave Antenna used in the kilometer-scale interferometric gravitational-wave detectors LIGO and Virgo

**Hanford plaque wording:**

IEEE MILESTONE

Invention of the Gravitational Wave Antenna, 1972 -1994

Predicted by Albert Einstein's Theory of General Relativity in 1916, the Gravitational Wave Antenna enabled detection of ripples in spacetime propagating at the speed of light. Based on this antenna design, construction of the Hanford Laser Interferometer Gravitational-Wave Observatory (LIGO) commenced in 1994. At this site on 14 September 2015, LIGO detected gravitational waves produced 1.3 billion years ago from two merging black holes.

**Livingston plaque wording:**

IEEE MILESTONE

Invention of the Gravitational Wave Antenna, 1972 - 1995

Predicted by Albert Einstein's Theory of General Relativity in 1916, the Gravitational Wave Antenna enabled detection of ripples in spacetime propagating at the speed of light. Based on this antenna design, construction of the Livingston Laser Interferometer Gravitational-Wave Observatory (LIGO) commenced in 1995. At this site on 14 September 2015, LIGO detected gravitational waves produced 1.3 billion years ago from two merging black holes.

**Virgo plaque wording:**

IEEE MILESTONE

To be provided by Virgo

**Site Description:**

Each site has an operational gravitational wave antenna as first conceptualized by Dr. Rainer Weiss in his 1972 paper, and are the locations where the first gravitational waves were detected. All three sites constitute a global network operated together to independently validate detections, and to triangulate the location of where on the sky the event originated.

**Who is the present owner of the site(s)?**

LIGO is funded by the U.S. National Science Foundation (NSF). The design and construction of LIGO was undertaken by the California Institute of Technology (Caltech) and the Massachusetts Institute of Technology (MIT). Construction of the facilities began in 1994, and the advanced LIGO installation was completed in 2014. Caltech has a cooperative agreement with the NSF to operate (jointly with MIT) the LIGO facilities for the NSF. At the LIGO Hanford Observatory, the NSF owns all buildings; the Department of Energy owns the land and allows Caltech and MIT to operate the facility through an MOU and Permit with the NSF. At LIGO Livingston Observatory, the NSF owns all buildings and the land is leased to the NSF by the Louisiana State University (LSU).

Virgo to provide text here

**What is the historical significance of the work (its technological, scientific, or social importance)?**

Following the progression of Human knowledge, four fundamental forces of nature have been identified. Early in our recorded history Earth, Wind, Water and Fire were considered by the Greek philosophers as the basis for explaining nature and the complexity of all matter. As our knowledge and scientific method evolved, we eventually understood gravity as described by Einstein's General Theory of Relativity, and the other three forces as quantum fields that are described by the Standard Model of particle physics. The other three forces are the strong nuclear force, the weak nuclear force and the electromagnetic force. LIGO and Virgo represent the first time gravitational waves, the force-carrier of gravity as predicted by Einstein over 100 years ago, were directly observed.

The gravitational force was first described in mathematical terms by Isaac Newton in 1687 by inferring that all matter exerted an instantaneous attractive force directly related to the mass of individual objects and the square of the distance between them. From 1687 to the early 20th Century, Newton's model reigned supreme. However, astronomical observations over two centuries indicated that the orbit of Mercury deviated from that prescribed by Newton's laws of motion.

In 1915, Albert Einstein described in The General Theory of Relativity that gravity is the curvature of spacetime produced by the presence of mass-energy. Indeed, the anomalous precession of the perihelion of Mercury mentioned above was found to result from the intense gravitational field of the Sun. General Relativity further predicts that any rapid change in a gravitational field will travel through the Universe at the speed of light. These changes in the

gravitational field are described as gravitational waves. From Dr. Weiss's original paper he stated, "In 1918, Einstein, using a weak-field approximation in his very successful geometrical theory of gravity (the general theory of relativity), indicated the form that gravitational waves would take in this theory and demonstrated that systems with time-variant mass quadrupole moments would lose energy by gravitational radiation. It was evident to Einstein that since gravitational radiation is extremely weak, the most likely measurable radiation would come from astronomical sources." Given the requirements of the measurement, in his paper Dr. Weiss went on to describe a proposed antenna design capable of detecting gravitational waves as predicted by Einstein.

In 1979 the NSF funded Caltech and MIT to develop and mature the proposed gravitational wave antenna as described by Dr. Weiss. Following ten years of research and prototype development, Congress approved funding for LIGO in 1991, and construction of the sites began in 1994 and 1995.

[Need a paragraph from Virgo here](#)

The first gravitational waves were simultaneously detected using the gravitational wave antenna at the two LIGO sites on Sep 14, 2015. The gravitational waves were produced by the merger of two black holes, an event that occurred 1.3 billion years ago. Two years later the coalescence of a pair of neutron stars was detected and localized by the LIGO and Virgo detectors, leading to follow-up observations by electromagnetic observatories that allowed the details of the cataclysmic event to be monitored for weeks after the gravitational waves had been detected. The direct detection of gravitational waves in 2015 by LIGO resulted in co-founders Rainer Weiss, Barry Barish, and Kip Thorne receiving the 2017 Nobel Prize in Physics.

### **What obstacles (technical, political, geographic) needed to be overcome?**

Because gravity is the weakest of the four fundamental forces, gravitational forces are exceedingly small and, before the gravitational wave antennas used on LIGO, were impossible to measure directly. A strong astrophysical gravitational wave, caused by some of the most energetic events in the Universe, will produce a displacement at Earth of order  $10^{-18}$  meters, which is about 1000 times smaller than the diameter of a proton. Waves of this strength are produced by distant, very massive systems undergoing extremely large accelerations, such as two black holes merging into one at over half the speed of light. This measurement capability has been made possible [in part](#) through the development of state-of-the-art technology in multiple [electrical](#) engineering disciplines including photonics, lasers, controls, computer systems, software, instrumentation, signal processing, etc. It took over 100 years of advanced multidisciplinary technology development to provide the capability of making sufficiently sensitive measurements as required to detect gravitational waves.

### **What features set this work apart from similar achievements?**

There are no other similar achievements. This is a fundamental achievement.

