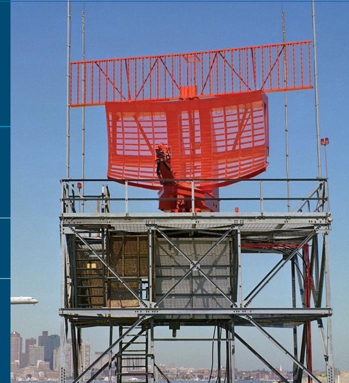
Presented by the
IEEE Boston Section

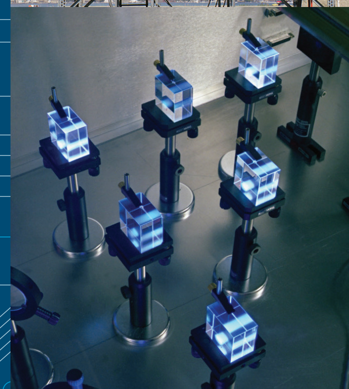
IEEE
Advancing Technology for Humanity

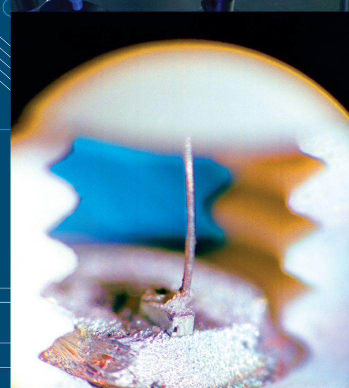
DEDICATING THREE NEW IEEE Milestones

2 February 2024

MIT Lincoln Laboratory
Lexington, Massachusetts







Mode S Air Traffic Control Radar Beacon System

193-nm Projection Photolithography

Semiconductor Laser

LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Welcome to the dedication

Today, we are extremely proud to dedicate three new IEEE Milestones. These awards honor technological innovation and excellence in all areas associated with the IEEE, including in electrical engineering, electronics, and computing. To be proposed as an IEEE Milestone, an achievement must be at least 25 years old, have benefited humanity, and have had at least regional importance. Milestones are proposed by any IEEE member, and are sponsored by any one or more IEEE organizational unit.

The IEEE Milestones to be dedicated are the Mode S Air Traffic Control Radar Beacon System, the Development of 193-nm Projection Photolithography, and the Semiconductor Laser.

The IEEE Boston Section has been active in installing commemorative milestone plaques for viewing by the general public and visitors coming to New England. Each new milestone plaque will be unveiled during the ceremony and will soon be installed in the lobby of MIT Lincoln Laboratory.

PROGRAM

3:30 PM INTRODUCTION

Welcome
Maíra Marques Samary, *Chair, IEEE Boston Section*

Introduction and Salute to Special Guests
Karen Panetta, *Milestone Master of Ceremonies*

IEEE Milestones: IEEE Region 1's Vision and Impact
Bala Prasanna, *Director, IEEE Region 1*

3:50 PM COMMENTARIES

The History of MIT Lincoln Laboratory
Eric Evans, *Director, MIT Lincoln Laboratory*

Mode S Air Traffic Control Radar Beacon System: A Brief History
James Flavin, *Principal Staff, MIT Lincoln Laboratory*

193-nm Projection Photolithography: A Brief History
Craig Keast, *Associate Division Head, MIT Lincoln Laboratory*

The Semiconductor Laser: A Brief History
Paul Juodawlkis, *Group Leader, MIT Lincoln Laboratory*

4:45 PM DEDICATION CEREMONY

Introduction
Karen Panetta

Award Ceremony
Kathleen Kramer, *2024 President-Elect, IEEE*

Mode S Air Traffic Control Radar Beacon System
Accepted by Eric Evans and Vincent Orlando

193-nm Projection Photolithography
Accepted by Eric Evans and Mordechai Rothschild

Semiconductor Laser
Accepted by Eric Evans, Richard Rediker (son of inventor Robert Rediker), Susan Zeiger (daughter of inventor Herb Zeiger), and Robert Lax (son of inventor Benjamin Lax)

5:20 PM RECEPTION

6:00 PM ADJOURN

BOSTON SECTION MILESTONES COMMITTEE

Maíra Marques Samary, *Chair, IEEE Boston Section*
Karen Panetta, *Vice Chair, IEEE Boston Section*
Rui Ma, *Executive Committee and Past Chair, IEEE Boston Section*
Ramon De la Cruz, *Executive Committee and Past Chair, IEEE Boston Section*
Denise Griffin, *Executive Committee and Past Chair, IEEE Boston Section*
Gilmore Cooke, *Executive Committee; Past Chair, IEEE Boston Section; and Milestones Advocate*
Robert Alongi, *Business Manager, IEEE Boston Section*

SPECIAL THANKS TO

IEEE Milestone ceremony speakers

Semiconductor laser proposal co-authors from General Electric's Schenectady and Syracuse facilities and IBM Thomas J. Watson Research Center

Kathleen Kramer, *2024 IEEE President-elect*

Bala Prasanna, *Director, IEEE Region 1*

Fred Schindler, *2024 IEEE Vice President-elect Technical Activities*

Peter Staecker, *IEEE Past President and former MIT Lincoln Laboratory employee*

Robert Colburn, *IEEE History Center*

Michael Geselowitz, *Senior Director, IEEE History Center*

MIT Lincoln Laboratory Professional Societies Committee, Co-chairs Joseph Campbell and James Kuchar

MIT Lincoln Laboratory Communications and Community Outreach Office

MIT Lincoln Laboratory event support

IEEE Milestone Ceremony Speakers

IEEE MILESTONE CEREMONY Speakers

Maíra Marques Samary

Maíra Marques Samary serves as the chair of the IEEE Boston Section. She is currently a visiting assistant professor in the Computer Science Department at Boston College. Her research interests include software processes, collaborative work, and software engineering education. Marques Samary received MS and PhD degrees in computer science from the University of Chile and holds an MEd from Boston College.

Karen Panetta

Karen Panetta is the vice chair of the IEEE Boston Section and the dean of graduate education for the School of Engineering at Tufts University. Her research areas include artificial intelligence, machine learning, automated systems, simulation, and visual sensing systems. She is the recipient of the Presidential Award for Excellence in Science, Math, and Engineering Mentoring from U.S. President Barack Obama. She founded the “Nerd Girls” program, which encourages young women to pursue engineering and science. Panetta is the editor-in-chief of IEEE WIE Magazine and co-author of the book, *Count Girls In*. She is an IEEE Fellow, NASA JOVE Fellow, and AAIA Fellow.

Eric Evans

Eric Evans was appointed director of MIT Lincoln Laboratory in July 2006. As director, he is responsible for the Laboratory’s strategic direction and overall technical and administrative operations. Evans joined Lincoln Laboratory in 1988 and held positions of increasing responsibility in air and missile defense technologies. Evans is currently the chair of the Defense Science Board, of which he has been a member since 2009. He is also an IEEE Fellow, AIAA Fellow, and a member of the National Academy of Engineering. Evans holds BS, MS, and PhD degrees in electrical engineering from The Ohio State University.

James Flavin

James Flavin is principal staff in the Homeland Protection and Air Traffic Control Division at MIT Lincoln Laboratory. Prior to this role, he served as the division head, where he was responsible for research, development, evaluation, and technology transfer for surveillance technology and decision support system architectures spanning air traffic control efficiency, airport surface safety, aircraft collision avoidance, border surveillance, and homeland air defense. He joined Lincoln Laboratory in 1986. He holds a BS degree in electrical engineering from Northeastern University and an MS degree in electrical engineering from the University of Michigan at Ann Arbor.

Craig Keast

Craig Keast is the associate head of the Advanced Technology Division and the director of operations for the Microelectronics Laboratory at MIT Lincoln Laboratory. The Advanced Technology Division performs research in high-performance imaging sensors, deeply scaled silicon microelectronics, solid-state lasers, optoelectronics, superconductive devices, and biological sensors. Keast began his career at Lincoln Laboratory in 1981 as a semiconductor process technician before holding positions of increasing responsibility in the advanced electronics area. Keast holds a BA degree from Hamilton College and SM, EE, and PhD degrees in electrical engineering and computer science from MIT.

Paul Juodawlkis

Paul Juodawlkis is the leader of the Quantum Information and Integrated Nanosystems Group at MIT Lincoln Laboratory, where he leads research and development of quantum processors, quantum and classical sensors, superconducting digital electronics, and integrated photonic technologies. Previously, Juodawlkis led a team that developed the semiconductor slab-coupled optical waveguide amplifier; made key contributions to the development of optical sampling techniques; and worked as a radar systems engineer beginning at the Laboratory in 1988. Juodawlkis is a Fellow of both the IEEE and Optica (formerly the Optical Society). He holds a BS degree from Michigan Technological University, an MS degree from Purdue University, and a PhD degree from the Georgia Institute of Technology, all in electrical engineering.

Kathleen Kramer

Kathleen Kramer is the 2024 IEEE president-elect and is a professor of electrical engineering at the University of San Diego in California. Her teaching interests are in the areas of signal processing, mechatronics and robotics, and communication systems. Kramer has previously held technical staff positions at ViaSat, Hewlett Packard, and Bell Communications Research. She is a distinguished lecturer for the IEEE Aerospace and Electronic Systems Society and served on the IEEE Board of Directors as secretary and chair of governance, and as IEEE Region 6 (Western USA) director. Kramer received a BS degree in electrical engineering with a second major in physics from Loyola Marymount University, and MS and PhD degrees in electrical engineering from the California Institute of Technology.

Celebrating Three New **Milestones**

Mode S Air Traffic Control Radar Beacon System *MIT Lincoln Laboratory*

Development of 193-nm Projection Photolithography *MIT Lincoln Laboratory*

Semiconductor Laser *Jointly awarded to MIT Lincoln Laboratory, General Electric, and IBM*

Mode S Air Traffic Control Radar Beacon System, 1969–1995

CITATION

In 1969, MIT Lincoln Laboratory began developing the Mode S selective secondary surveillance radar beacon system to enable safe air traffic control in busy, spectrum-congested airspace. This technology made more efficient use of the radio spectrum than previous systems. By 1995, the Mode S techniques and transmission codes became the worldwide standard for air traffic control radars.

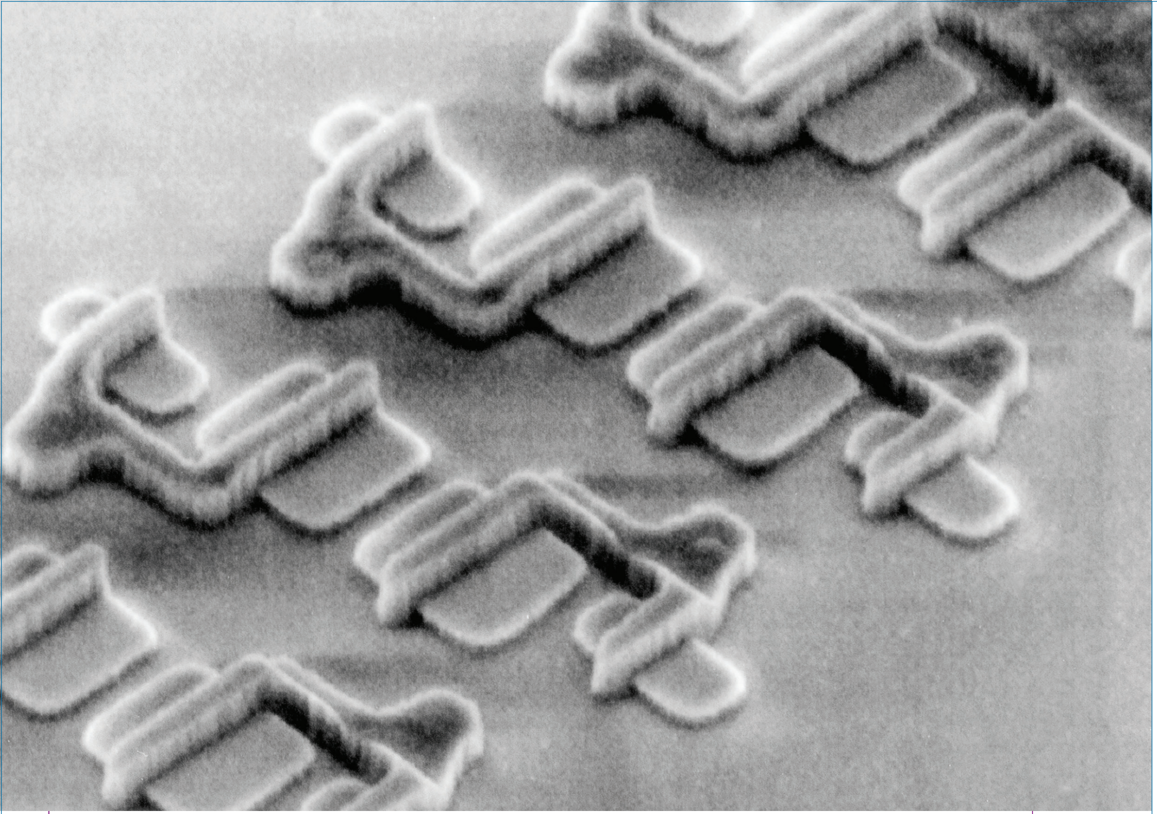
The Mode S air traffic control (ATC) radar beacon system was developed to address the challenges posed to the existing ATC beacon radar system in use in the late 1960s. Commercial air traffic was growing quickly, causing overlap between the increasing number of beacon replies from aircraft to the increasing number of beacon requests from ATC ground radars. This overlap threatened to disrupt aircraft surveillance in the highest-density airspace.

Under Federal Aviation Administration (FAA) sponsorship, Lincoln Laboratory led the technology developments necessary to address this safety issue. The advanced communication architecture of Mode S allowed radars to select a specific aircraft to interrogate. To selectively communicate, the system design included improved aircraft transponders, each assigned a unique address code. Upgrades to radar antennas and signal processing also allowed Mode S to accurately determine airplane position with far fewer air-to-ground messages than required by prior systems.

Today, an estimated 100,000 aircraft are equipped with Mode S transponders, and more than 900 Mode S radars are deployed across the globe. The technology has enabled other breakthrough safety systems, such as collision avoidance, and is the foundation for the FAA's newest ATC surveillance system, which allows continuous flight tracking independent of ground radars by using aircraft-broadcast position and velocity information.

Lincoln Laboratory developed and prototyped the first Mode S antenna—the white, rectangular shoebox design shown at upper left—at the Mode S Experimental Facility (MODSEF), pictured here in 1973. The antenna and processor prototypes were operated at MODSEF to support development, flight-test campaigns, and technology transfer.

By the middle of the 1990s, the white shoebox antenna at MODSEF was replaced with the orange production antenna, now a familiar sight at major airports throughout the world.



This scanning electron micrograph shows the first functional electrical devices fabricated with the 193-nm lithography system.

The world's first full-field step-and-scan 193-nm lithography system, built by SVG Lithography, was installed in Lincoln Laboratory's cleanroom facilities in 1993.

Development of 193-nm Projection Photolithography, 1984–1996

CITATION

MIT Lincoln Laboratory pioneered the research, development, and demonstration of 193-nm projection lithography. This technology became the dominant high-resolution patterning technique, enabling the continuous performance scaling of integrated circuits for decades. During 1984–1996, Lincoln Laboratory established an international research center with industrial partners and consortia to guide microelectronic chip manufacturing with 193-nm lithography, which paved the way for its widespread commercial adoption.

The 193-nm projection photolithography technique has enabled the fabrication of every chip in every laptop, smartphone, military system, and data center for the last 20 years.

Photolithography uses light to print tiny patterns onto a silicon chip. The patterns are projected over a silicon wafer, which is coated with a chemical that changes its solubility when exposed to light. The soluble parts are etched out, leaving behind tiny structures that become the transistors and other devices on the chip.

Shorter wavelengths of light allow for printing smaller features, enabling more densely packed chips. By the 1980s, the accepted wisdom in the industry was that 248 nm was the shortest wavelength possible for photolithography.

Despite widespread skepticism and technical obstacles, Lincoln Laboratory pioneered photolithography at the 193-nm wavelength, enabling the semiconductor industry to stay on the path charted by Moore's law. The Laboratory's microelectronics researchers, along with their collaborators, addressed all major science and engineering aspects—from materials science and polymer chemistry to optical engineering and system integration—and fabricated the world's first microelectronic devices using the technique. In 1993, the first-ever 193-nm projection system was installed in the Microelectronics Laboratory at Lincoln Laboratory, which became the international center of excellence to develop this technology. Today, 193-nm projection photolithography is the industry's mainstream technique and has enabled increasingly powerful integrated circuits.

Semiconductor Laser, 1962

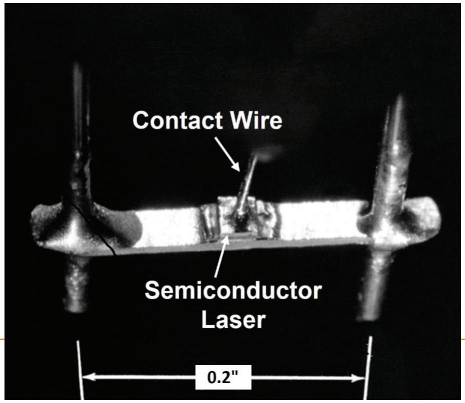
CITATION

In the autumn of 1962, General Electric's Schenectady and Syracuse facilities, IBM Thomas J. Watson Research Center, and MIT Lincoln Laboratory each independently reported the first demonstrations of the semiconductor laser. Smaller than a grain of rice, powered using direct current injection, and available at wavelengths spanning the ultraviolet to the infrared, the semiconductor laser became ubiquitous in modern communications, data storage, and precision measurement systems.

In the 62 years since its invention, the **semiconductor laser** has become the most widespread laser in the world and a foundational element in a vast range of technologies: DVDs, CDs, computer mice, laser pointers, barcode scanners, medical imagers, and printers, to name a few. However, its greatest impact is arguably in communications. Every second, a semiconductor laser encodes information onto light that is transmitted through fiber-optic cables across oceans and into many homes, forming the backbone of the Internet. This capability is possible at tremendous scale and economy because the semiconductor laser realizes all the elements of a laser—light generation and amplification, lenses, and mirrors—within a solid microminiature block of material.

When it was reported in the summer of 1962 that nearly 100% of the electrical energy injected into a gallium-arsenide semiconductor could be converted into light, several research groups were poised to translate this knowledge into a working semiconductor laser. Within the span of roughly one month in the fall of 1962, the first semiconductor lasers were independently demonstrated at four institutions.

The enabling characteristics of the semiconductor laser include its small size, its efficiency at converting electrical energy into coherent laser light, and its availability in a wide range of colors. These attributes attracted the imagination of scientists and engineers worldwide. Through decades of innovation, the initial, comparatively feeble semiconductor laser has been transformed into the society-underpinning technology it is today.



This photograph shows Lincoln Laboratory's first diode laser, which is soldered to the horizontal tab of a transistor header-mount. The laser was made from a small block of gallium arsenide, with a wire contact attached to the top for injection of an electrical current.

Lincoln Laboratory researchers (left to right) Robert Keyes, Theodore Quist, and Robert Rediker are shown demonstrating transmission of a television signal in 1962 using a semiconductor light-emitting diode, the precursor of the semiconductor laser. Keyes, Quist, and Rediker were part of the Lincoln Laboratory team that independently demonstrated the semiconductor laser, concurrently with three other teams—two at General Electric and one at IBM.

IEEE Boston Section Milestone *Awards*

1. **MIT Radiation Laboratory,** 1940–1945
2. **Electric Fire Alarm System,** 1852
3. **Power System of Boston's Rapid Transit,** 1889
4. **First Intelligible Voice Transmission Over Electric Wire,** 1876
5. **First Wireless Radio Broadcast,** 1906
6. **First Real-Time Speech Communication on Packet Networks,** 1974–1982 *
7. **Apollo Guidance Computer,** 1962–1972
8. **LORAN,** 1940–1946
9. **Whirlwind Computer,** 1944–1959 *
10. **SAGE (Semi-Automatic Ground Environment),** 1951–1958 *
11. **Claude E. Shannon's Development of Information Theory,** 1939–1967
12. **Harvard Mark 1 Computer,** 1944–1959
13. **Mode S Air Traffic Control Radar Beacon System,** 1969–1995 *
14. **Development of 193-nm Projection Photolithography,** 1984–1996 *
15. **Semiconductor Laser,** 1962 *

* MIT Lincoln Laboratory recipient

Previous IEEE Boston Section Milestone **Awards**

1 MIT Radiation Laboratory, 1940–1945

Infinite Corridor, MIT, Cambridge, MA

The MIT Radiation Laboratory, which operated between 1940 and 1945, advanced the Allied war effort by making fundamental contributions to the design and deployment of microwave radar systems. Used on land and sea and in the air in many adaptations, radar was a decisive factor in the outcome of the conflict. The Radiation Laboratory's 3,900 employees made lasting contributions to microwave theory and technology, operational radar, systems engineering, long-range navigation, and control equipment.

2 Electric Fire Alarm System, 1852

Boston Fire Department, Boston, MA

On 28 April 1852, the first municipal electric fire alarm system using call boxes with automatic signaling to indicate the location of a fire went into operation in Boston. Invented by William Channing and Moses Farmer, this system was highly successful in reducing property loss and deaths due to fire and was subsequently adopted throughout the United States and in Canada.

3 Power System of Boston's Rapid Transit, 1889

Park Street T Stations, Boston, MA

Boston was the first city to build electric traction for a large-scale rapid transit system. The engineering challenge to design and construct safe, economically viable, and reliable electric power for Boston's rapid transit was met by the West End Street Railway Company, beginning in 1889. The company's pioneering efforts provided an important impetus to the adoption of mass transit systems nationwide.

4 First Intelligible Voice Transmission Over Electric Wire, 1876

Intersection of Ave de Lafayette and Essex Street, Boston, MA

The first transmission of intelligible speech over electrical wires took place on 10 March 1876. Inventor Alexander Graham Bell called out to his assistant Thomas Watson, "Mr. Watson, come here! I want to see you." This transmission took place in their attic laboratory located in a building near 5 Exeter Place.

5 First Wireless Radio Broadcast, 1906
Blackman's Point, Brant Rock, MA

On 24 December 1906, the first radio broadcast for entertainment and music was transmitted from Brant Rock, Massachusetts, to the general public. This pioneering broadcast was achieved after years of development work by Reginald Aubrey Fessenden (1866–1932), who built a complete system of wireless transmission and reception using amplitude modulation (AM) of continuous electromagnetic waves. This technology was a revolutionary departure from transmission of dots and dashes widespread at the time.

6 First Real-Time Speech Communication on Packet Networks, 1974–1982
MIT Lincoln Laboratory, Lexington, MA

In August 1974, the first real-time speech communication over a packet-switched network was demonstrated via ARPANET between MIT Lincoln Laboratory and USC Information Sciences Institute. By 1982, these technologies enabled Internet packet speech and conferencing linking terrestrial, packet radio, and satellite networks. This work in real-time network protocols and speech coding laid the foundation for voice-over-internet-protocol (VoIP) communications and related applications including Internet videoconferencing.

7 Apollo Guidance Computer, 1962–1972
One Hampshire, Cambridge, MA

The Apollo Guidance Computer provided spacecraft guidance, navigation, and control during all of NASA's Apollo Moon missions. It was developed under the leadership of Dr. Charles Stark Draper at the MIT Instrumentation Laboratory—now Draper Laboratory. This pioneering digital flight computer was the first real-time embedded computing system to automatically collect data and provide mission-critical calculations for the Apollo Command Module and Lunar Module.

8 LORAN, 1940–1946
Stata Center, MIT, Cambridge, MA

The rapid development of LORAN—long-range navigation—under wartime conditions at MIT's Radiation Laboratory was not only a significant engineering feat but also transformed navigation, providing the world's first near-real-time positioning information. Beginning in June 1942, the United States Coast Guard helped develop, install, and operate LORAN until 2010.

9 Whirlwind Computer, 1944–1959
Barta Building, MIT, Cambridge, MA

The Whirlwind computer was developed at 211 Massachusetts Avenue by MIT, with contributions from MIT Lincoln Laboratory. It was the first real-time high-speed digital computer using random-access magnetic-core memory. Whirlwind featured outputs displayed on a cathode-ray tube and a light pen to write data on the screen. Whirlwind's success led to the United States Air Force's Semi-Automatic Ground Environment (SAGE) system and to many business computers and minicomputers.

10 SAGE (Semi-Automatic Ground Environment), 1951–1958
MIT Lincoln Laboratory, Lexington, MA

In 1951, MIT undertook the development of a continental air defense system for North America. The centerpiece of this defense system was a large digital computer originally developed at MIT. MIT Lincoln Laboratory was formed to carry out the initial development of this system, and the first of some 23 SAGE control centers was completed in 1958. SAGE was the forerunner of today's digital computer networks.

11 Claude E. Shannon's Development of Information Theory, 1939–1967

Stata Center, MIT, Cambridge, MA

The mathematical principles of Information Theory, laid down by Claude Elwood Shannon over the period of 1939–1967, set in motion a revolution in communication system engineering. These principles quantified the concept of information, established fundamental limits in the representation and reliable transmission of information, and revealed the architecture of systems for approaching these limits. Today, Information Theory continues to provide the foundation for advances in information collection, storage, distribution, and processing.

12 Harvard Mark 1 Computer, 1944–1959

Harvard School of Engineering and Applied Science, Cambridge, MA

The Mark I computer was a general-purpose electromechanical computer that could execute long computations automatically. It was conceived by Harvard University's Dr. Howard Aiken, and built by International Business Machines Corporation in New York. The machine used mechanical punch-card tabulating equipment. Considered the first large-scale electromechanical computer, it was a leap forward in modern computing.

About IEEE

IEEE, an association dedicated to advancing innovation and technological excellence for the benefit of humanity, is the world's largest technical professional society. IEEE and its members inspire a global community through IEEE's highly cited publications, conferences, technology standards, and professional and educational activities.

IEEE, pronounced "Eye-triple-E," stands for the Institute of Electrical and Electronics Engineers, and its mission is to serve professionals involved in all aspects of the electrical, electronic, and computing fields and related areas of science and technology that underlie modern civilization.

IEEE's roots go back to 1884 when electricity began to become a major influence in society. Today, however, technology has become prevalent and essential to all; IEEE's mission continues to expand beyond traditional topics to include efforts in the biotechnology and biodevice industries, earth sciences, and social impact.

IEEE Boston Section serves more than 8,500 members of the IEEE.

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IEEE Boston Section

IEEE
Advancing Technology for Humanity

Readers are encouraged to access the IEEE Milestones Wiki to study the Mode S Air Traffic Control Radar Beacon System, 193-nm Projection Photolithography, and Semiconductor Laser nomination documents, images, and reference material submitted for these Milestones.

Mode S

193-nm Projection Photolithography

Semiconductor Laser

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