Grace Murray Hopper (mathematician, computer pioneer, and naval officer)

(December 9,1906 -January 1, 1992)

Grace Murray Hopper was a mathematician, computer pioneer, and naval officer. She is credited with the development of computer programming languages that simplified computer technology and opened the door of computing to a large number of users. Although many people helped in its development, Grace Hopper is widely recognized for her work designing COBOL (**Co**mmon **B**usiness-**O**riented **L**anguage), a procedural, English-like programming language created in 1959 for business data processing. By the 1970s, COBOL was the 'most extensively used computer language" in the world. Grace also helped program the IBM Automatic Sequence Controlled Calculator (ASCC), known as the MARK I, the first electromechanical computer in the United States. One of the first three "coders" (now known as programmers), Grace also wrote the 561-page user manual for the MARK I. In the early 1950s while working on the Universal Automatic Computer (UNIVAC I and II), Grace pioneered the idea of automatic programming and explored new ways to use the computer code. In 1952, she developed the first "compiler" called A-0, which wrote machine-readable code for mathematical calculations. In 1956, her team developed FLOW-MATIC, the first programming language whose commands were ordinary English words. Grace's idea of creating word-based languages helped expand the community of computer users. As the

number of computer languages increased, it became clear that there was an increased need for a *standard* business language. In 1959, Grace participated in the Conference on Data Systems Languages (CODASYL). The goal of this conference was to develop a common business language that could be used across industries and sectors. That's how Grace helped develop COBOL.

One of the things she is credited for is the word "debugging". On September 9, 1947, while the MARK II computer was running, a moth got trapped between the electrical contacts of Relay 70 - an electromagnetic switch that opened and closed a circuit, something like a modern transistor. The moth has prevented the electrical contacts from closing properly, stopping the flow of signals through that part of the machine. When the computer tried to execute instructions requiring that particular relay, it couldn't complete the operation, so the entire program stopped. Grace used a tweezer to remove the moth, being careful not to damage the moth or the delicate electrical components. Grace told the computer technician that it "looks like we found a real bug in the system". Grace taped the moth into the logbook, labeled it "First actual case of bug being found". She wrote the date and time the bug was found. This logbook is now in the Smithsonian Institution. And removing the moth with a tweezer is the first "debugging" done in history. Now the word "debugging" means looking for errors in computer programs.

Her science journey began when Grace Brewster Murray was born on December 9, 1906, in New York City. Grace was the oldest of the three children of Walter Murray and Mary Brewster Murray. Mary studied mathematics before her marriage, unusual for women in her generation. Mary brought her love of numbers and logical thinking into her role as a mother. The children were encouraged to ask questions and learning was celebrated!

When she was seven years old, Grace unscrewed the back of her alarm clock to figure out how the alarm clock works. The parts spilled all over her bedroom floor. Then she tried to put the parts back, but she couldn't do it. She needed another clock to study. After opening seven clocks she finally figured out how the clock worked. But her mother was horrified to see all the mangled clock parts on the floor! This showed that Grace had a curious mind even at a very young age.

Grace was not only good at mathematics. She was also good at language. She read a lot of books on any subject. She read books about science, history, and adventure. She liked stories about inventors and explorers.

She attended Graham School for Girls. Her teachers quickly recognized her exceptional abilities, especially in mathematics. During her junior year her teacher asked her to tutor younger students in algebra. She found that she enjoyed teaching also. Explaining mathematical concepts to the students actually deepened her own understanding of mathematics.

In 1923, she took the entrance exam for college. When her grades arrived, she was surprised that she had failed Latin. Without Latin she couldn't go to college. So, she went back to her studies and finally aced Latin. She was then able to go to Vassar College in 1924. Vassar was one of the most prestigious women's colleges in the country. At Vassar, she became known as the most brilliant mathematics student in the class. Her mentor Professor Elizabeth Hazard encouraged Grace to go to graduate school. Grace thought only males go to graduate school, but Professor Hazard explained to her that exceptional women like Grace should take this opportunity to make it easier for the women after her.

In June 1928, Grace received her bachelor's degree in mathematics, graduating with the highest honors, and as a member of the Phi Beta Kappa Honor Society. She had been accepted to the graduate program in mathematics at Yale University with a fellowship.

In 1930, Grace married Vincent Foster Hopper, who made a career as an English professor at New York University (NYU). They met at Wolfeboro, New Hampshire where their families have summer homes. At the time of their marriage, Vincent Hopper was a doctoral candidate in comparative literature at Columbia University and was already teaching at New York University. Grace was finishing her master's

degree in mathematics. Vincent was very supportive of Grace's ambition to finish her master's and doctoral degrees. She received her master's degree in 1930 and her PhD in 1934. She became the first woman to graduate from Yale with a doctorate in mathematics in the school's 233-year history!

WORK AFTER GRADUATE SCHOOL

Grace went back to Vassar College and became a professor in mathematics. She thought this would be her lifetime career, teaching her favorite subject. In 1940, she applied for a Vassar faculty fellowship which gave the recipient a one-year sabbatical to pursue research or coursework at another institution. When she was chosen for the fellowship, Grace chose to study with the famous mathematician Richard Courant at NYU. Courant was the director of the renowned Mathematics Institute at the University of Gottingen when Hitler came to power. In the spring of 1934, with conditions deteriorating and things becoming more dangerous for people with Jewish ancestry, Courant resigned and accepted a full professorship at NYU. He built a department of Applied Mathematics in the Gottingen tradition at NYU. In 1942, Grace worked with Courant in the growing field of partial differential equations. But other things happening in the world changed her career!

When Pearl Harbor was attacked in 1941, she felt a powerful desire to serve her country. She heard about a program called WAVES (Women Accepted for Volunteer Emergency Service). The WAVES program was run by the US Navy. For the first time women were being recruited to serve in the Navy in roles other than nursing.

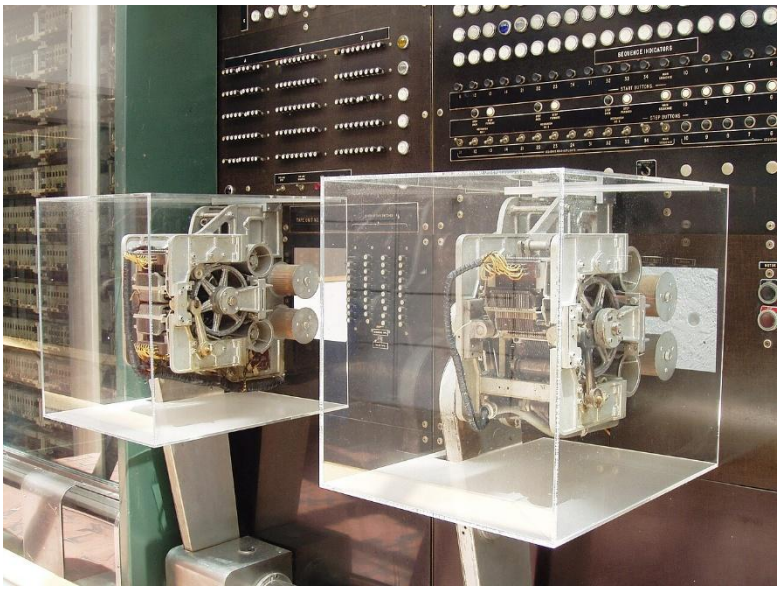
After finally admitting that her marriage had been a failure, Grace decided to sign up for WAVES but was rejected. She was too old and underweight for her height. She showed them her credentials – a PhD from Yale University - and she was accepted with a waiver.

Vincent Hopper left NYU and tried to get an officer's commission. He was rejected because of his age and poor eyesight. Grace's brother Roger, who had just finished his doctorate in economics, also had poor eyesight. Both men then left their promising academic and business careers and enlisted in the Army Air Corps. Both served the entire extent of the war in the Army. By 1942, Grace's husband, brother, cousins and many friends had joined the military. Only her sister who had

small children did not join. In the summer of 1942, not wanting to go back to Vassar, Grace taught an improvised summer school course designed to prepare mathematicians for the war effort.

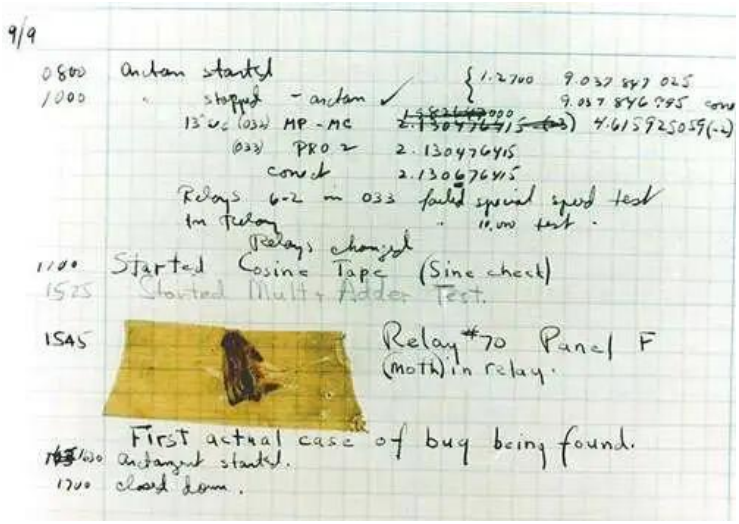
In June 1943, Grace reported at the Naval Reserve Midshipmen's School at Smith College. She had to learn military protocol, wear a uniform, and adapt to a regimented schedule, a life very different from her professor's job! But she worked hard and took her classes seriously. She graduated first in her class and was commissioned as a Lieutenant (junior grade).

Her first assignment was to report to Professor Howard Aiken at Harvard University. There, Professor Aiken introduced her to the new machine called MARK I, the first electromechanical computer in the United States. Her job was to figure out the machine's mechanical operations. Aside from understanding the hardware, she had to create programs - sequences of instructions that would make the MARK I solve useful problems. Her first programming assignment was to create a program that would calculate the sine of an angle. Grace spent hours working on the mathematical procedures step by step, then translating each step into the coded instructions that the Mark I could understand. When she finished with the sine calculation program, she fed the punched tape into the Mark I and watched as the machine slowly but surely produced results with the same values in the mathematical tables. And so began Grace's career as a computer programmer!



As Grace became more skilled at programming, she worked on more complex problems needed for the Allied war effort. The Navy needed calculations for aiming naval artillery. She wrote programs that could perform these calculations in minutes rather than the hours or days required by human mathematicians.

On September 9, 1947, Grace was reviewing a program that was giving out incorrect results, when one of the technicians told her that the Mark II stopped running because there was a moth trapped between the electrical contacts of Relay 70, an electromagnetic switch that opened and closed to control electrical signals. The moth had prevented the electrical contacts from closing properly, stopping the flow of electricity through that part of the machine's control system. Grace carefully removed the moth with tweezers. She told her technicians that now they could say they found a real bug in the system! As Grace removed the moth, she was "debugging" the Mark II. Now the word "debugging" means looking for problems and errors in computer programs.



After the war, Grace had to choose between returning to teaching at Vassar or working in a computer company. The computing industry was evolving, and she felt the excitement of new companies forming, promising to bring computing power to businesses and government agencies. When an opportunity came, she went to work at a small company in Philadelphia, to build the world's first commercial electronic computer. The Eckert-Mauchly Computer Corporation was in a converted factory building in Philadelphia, very different from the ivy-covered halls of Harvard. But it was teeming with activity, full of brilliant engineers working around the clock to build something the world had never seen, a computer designed not for scientific research but for business.

There Grace worked on the Universal Automatic Computer (UNIVAC I). Unlike the electromechanical construction of the MARK I, UNIVAC I was built only from electronic components-vacuum tubes, electronic circuits, and magnetic storage devices that operated at speeds impossible with mechanical systems. She found out that working with electronic computers came with new challenges. The electronic components of the day, mainly vacuum tubes, were less reliable than mechanical ones, i.e. relays.

One of her contributions was developing “subroutines” - reusable program components that could perform common mathematical operations. Instead of requiring every programmer to write their own instructions for tasks like calculating square roots and trigonometric functions, Grace created libraries of pre-written program segments that could be incorporated into larger programs.

In 1951, Remington Rand bought the Eckert-Mauchly Computer Corporation. Grace wondered how much of the programming process could be done by the computer itself. She began working on the first step of this idea, developing what she called a “compiler”. At first, this was a program that would automatically insert subroutines into a larger computer program. Later the term “compiler” would be extended to the full concept of translating human-readable programs into the machine’s code.

Grace’s first compiler, which she called the A-0 System, was completed in 1952. The A-0 System attracted attention from computer scientists and programmers

around the world. Grace also worked on compilers for different types of computers.

In 1955, Grace became one of the most respected computer programmers in the field. Grace had another idea she wanted to accomplish. She wanted to create a programming language that would allow people to write computer programs using something very close to ordinary English. She realized that most people who use computers for business applications were not mathematicians or engineers but accountants, managers, clerks, and analysts. She began working on a new programming language specifically designed for business applications. She called it FLOW-MATIC. It was completed and released in 1957. For the first time, businesspeople could write computer program using language like English, focusing on describing what they wanted the computer to do rather than learning complex technical details. FLOW-MATIC was used in many business applications: handling payroll calculations, inventory management, report generation, etc.

In 1959, Grace attended a meeting at the Pentagon to discuss developing a standard programming language for the Department of Defense. Charles Phillips, the Department of Defense official who organized the meeting, explained that there were many computer manufacturers developing their own computer programs. He said that there should be a common programming language for business applications, something that could be used on different computer systems, suitable for data processing and easily learned by people who were not computer scientists. Representatives from companies such as IBM, Burroughs, Remington Rand, and other major computer manufacturers were concerned that such a program would not work on their computers. Grace's experience with FLOW-MATIC helped the committee come up with the new programming language which the committee called COBOL, **Co**mmon **B**usiness **O**riented **L**anguage. Grace advocated making COBOL as English-like as possible. The committee spent months on the COBOL's design. Grace was influential in shaping COBOL's approach to data handling and file processing. COBOL was completed in 1960, and the first COBOL specification was published. Grace worked with several computer manufacturers to help them create COBOL compilers for their machines. She developed training materials to help programmers learn the new language.

In 1966, Grace received a letter from the Navy asking her to come back. She has been working in the private sector for twenty years. Now they want her back in uniform! The Navy had a problem that required her technical expertise and leadership. She had retired from the Naval Reserve when she reached the mandatory retirement age. She was recalled to active duty in August 1967 and promoted to the rank of commander. She was to work in the Navy's office of Information Systems Planning and Development to help standardize the Navy's programming languages and data processing procedures. Her first major project was to help the Navy adopt COBOL as its standard programming language for business applications. She also worked on developing standards for data formats, establishing procedures for software testing and validation.

In 1973, Grace was promoted to Captain and in 1983 was promoted to Commodore by special Presidential appointment. In 1986, she was promoted to Rear Admiral, making her one of the first women to achieve flag rank in the US Navy[1]. Grace finally retired from the Navy in August 1986 when she was 79 years old. She was the oldest active-duty commissioned officer in the United States Navy. Her great-grandfather, Alexander Wilson Russell would have been proud! Alexander Russell was an admiral in the US Navy and fought in the Battle of Mobile Bay during the Civil War.

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[1] "Flag rank" refers to senior naval or coastal guard officers ranked above a captain, empowered to fly a personal flag to denote their command presence. These officers command fleets, squadrons, or shore commands.

After her retirement from the Navy, she continued working as a consultant and speaker. She worked for Digital Equipment Corporation (DEC) as a senior consultant. She also advocated for women and minorities in computing. Throughout her career, she has been aware of the glass ceiling for women in the technical fields. She experienced this when she first arrived in Harvard and saw firsthand the skepticism showed by her male counterparts – a feeling that a woman couldn't possibly understand complex machinery.

She mentored young, female computer scientists, providing guidance, encouragement, and practical advice. She spoke publicly about the contributions made by women to computing.

Grace died in her sleep of natural causes on New Year's Day, 1992 at her home in Arlington County, Virginia. She was 85 years old. She was interred with full military honors in Arlington National Cemetery.

HER LEGACY

She will forever be known for COBOL, the programming language she helped create thirty years ago. COBOL is still being used to process most of the world's business transactions.

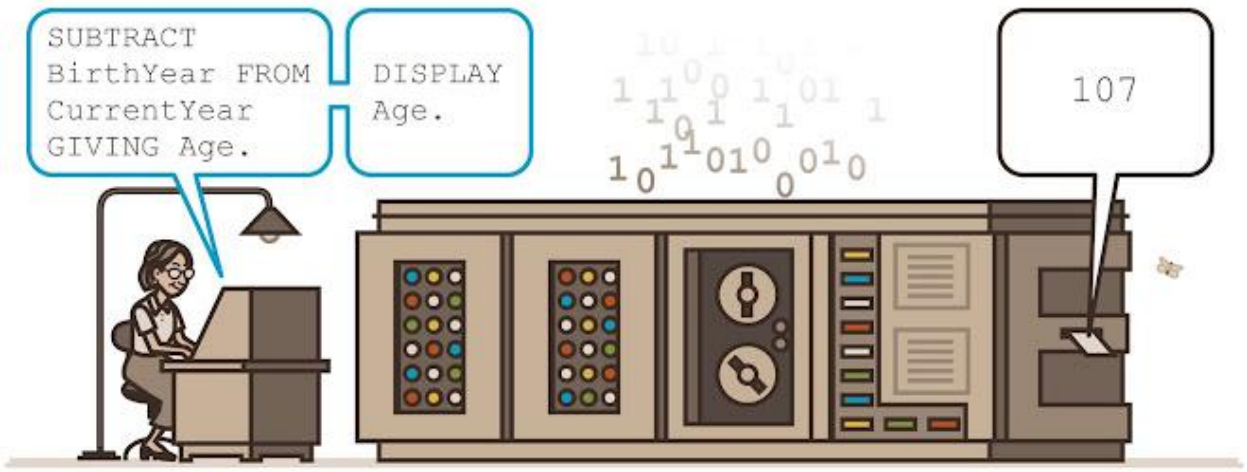
In 1994, a group of computer scientists organized the Grace Hopper Celebration of Women in Computing. The conference was designed to honor Grace's memory while addressing the ongoing challenges facing women in the computing industry.

The USS Hopper, a US Navy destroyer, was named in her honor.

The Grace Hopper Archive at the Computer History Museum contained thousands of documents, photographs, and artifacts from her career.

Her logbook with the moth is displayed at the Smithsonian Institution.

The Grace Hopper Google Doodle was featured on her 107th birthday in 2013.



In 2017, Grace Hopper College in Yale University was named after her.

In 2028, Vassar University will celebrate Grace Hopper, America's "Queen of Code" with an event at the Vassar Institute for the Liberal Arts.

HER SCIENCE JOURNEY

1906 - Grace Brewster Murray was born on December 9 in New York City

1924 - Finished high school at Graham School for Girls

-Enrolled at Vassar College

1928 - Grace received her bachelor's degree in mathematics from Vassar College graduating with the highest honors in the Phi Beta Kappa Honor Society

- Enrolled in graduate school in Mathematics at Yale University

1930 - Married Vincent Foster Hopper, an English professor at New York University

1930 - Received her master's degree in mathematics from Yale University

1934 - Received her PhD in mathematics from Yale University

- Went back and became a professor of Mathematics at Vassar College

1941 - Joined WAVES but was rejected for being too old and underweight. She was accepted by the Navy on a waiver

- Separated from her husband

1943 - Reported at the Naval Reserve Midshipmen's School at Smith College

1944 - First assignment was to go to Harvard and program the Mark I computer

1945 - Divorced her husband

1947 - Found the moth in the Mark II electrical contacts

1949 - Accepted a job at Eckert -Mauchly Computer Corporation to do programming for the UNIVAC I

1951 - Eckert-Mauchly Computer Corporation bought by Remington Rand

1952 - Developed the first compiler A-0

1957 - Created the FLOW-MATIC program

1960 - Developed the COBOL compiler, in collaboration with several computer manufacturers

1966 - Retired from the Naval Reserve

1967 - Recalled to active duty by the Navy

1973 - Promoted to Captain

1983 -Promoted to Commodore

1986 - Promoted to Rear Admiral

- Retired again from active duty

1992 - Died in her sleep of natural causes

1994 - Grace Hopper Celebration of Women in Computing was founded

1996 - The USS Hopper was launched

2013 - The Grace Hopper Google Doodle featured on her 107th birthday

2017 - The Grace Hopper College in Yale was named after her

2028 - Vassar University will celebrate Grace Hopper, America's "Queen of Code" with an event at the Vassar Institute for the Liberal Arts.

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