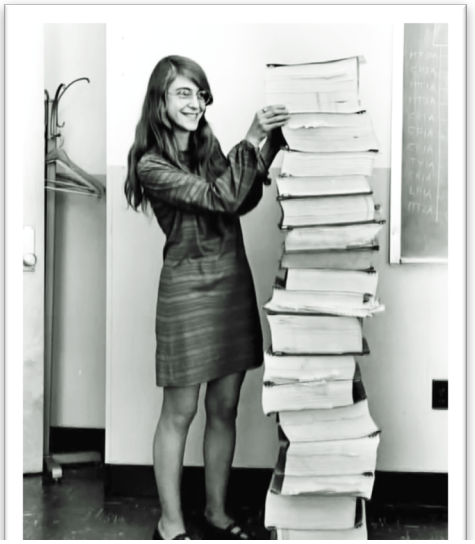
# Margaret Hamilton



## Introduction

Margaret Heafield Hamilton is an American computer scientist, systems engineer and businesswoman. She has accomplished much in her life not least of which is being credited with coining the term 'software engineering'. In an industry predominately dominated by men it should come as a pleasant surprise to many that it was in fact a woman who was the founder of this discipline.

## Early Life & Education

She was born in on the 17th of August 1936 in Paoli, Indiana to parents Kenneth Heafield and Ruth Esther Heafield. Her father was a philosopher and poet. He encouraged her to study arts. Margaret graduated from Hancock High School in 1954. She has said she enjoyed mathematics because she liked deriving the answers – she was too lazy to memorize them. She then went on to study mathematics at the University of Michigan. She earned a B.A in mathematics with a minor in philosophy from Earlham College in 1958. Margaret married shortly after and moved to Cambridge, Massachusetts where her husband studied law at Harvard. Margaret put graduate school on hold to support her husband while he pursued his law degree. In 1960 she took an interim position at MIT in the meteorology department. This was where Margaret was introduced to computing.

## SAGE

Margaret was hired to work under Professor Edward Norton Lorenz at MIT on a program to predict the weather. At the time the field of computing was still relatively new and there was little to no guidance available. Hamilton explained this to Wired

*"When I first got into it, nobody knew what it was that we were doing. It was like the Wild West. There was no course in it. They didn't teach it."*

She learned several coding languages herself while Professor Lorenz taught her about systems and software. In an interview with Futurism Hamilton explained that she began programming in hexadecimal and binary and under the guidance of Dr. Lorenz began the process of designing and building software.

From 1961 to 1963 she worked on the Semi-Automatic Ground Environment (SAGE) project at Lincoln Laboratories. Here Margaret wrote software for the first AN/FSQ-7 computer whose job was to search for unfriendly aircraft. This was

essentially the first U.S air defence system. Notably, it was while working on the SAGE software that Margaret first became interested in software reliability. She went on to spend a lot of her career focusing on what causes errors and how to avoid them.

*"SAGE was one of the first jumping off points where I became interested in the subject of software reliability. When the computer crashed during the execution of your program, there was no hiding. Lights would be flashing, bells would be ringing and everyone, the developers and computer operators, would come running to find out whose program was doing something bad to the system".*

Margaret's job at MIT was only meant to be temporary asshe had full intentions of returning to education to complete a degree in abstract mathematics once her husband had completed his degree at Harvard. It was however her work at MIT and especially on the SAGE project that made Margaret the perfect candidate for her next job at NASA as the lead developer for the Apollo fight software.

## NASA and the Apollo Missions

Apollo was the NASA program that resulted in American astronauts' making a total of 11 spaceflights including the first moon landing. The very first contract NASA issued for the Apollo project was with MIT to develop the guidance and navigation system for the Apollo spacecraft. In 1965 at the age of 28 Margaret joined MIT's Apollo project. She was still considered a beginner programmer when she started work on the Apollo program. She was a natural and went on to lead the team developing the on-board flight software.

Margaret and her team had no choice but to be pioneers. As Hamilton explains on her NASA Home Page:

*"Computer science and software engineering were not yet courses to be taught (or disciplines to be named). These were pioneering times. Learning was by "being" and "doing" on the job; as more people came on board, the more I became an "expert" and rose up through the ranks. A real world system developed in uncharted territory, one could not have asked for a better research environment to set the stage for what would come next and remain thereafter (a life long career centered around developing more advanced methods and tools for designing systems and developing software)."*

Programming for Margaret and her team meant writing the code in longhand, before punching it into stacks of punch cards which would be processed overnight. Simple programming tasks could require thousands of punched cards because each card described just one task for the computer to perform. The resulting 'deck' of cards can be seen in the infamous image of Margaret included at the beginning of this biography. This deck would contain a detailed description of exactly what the program would eventually do.

It was during this period that Margaret coined the term 'software engineering'. She explained why she chose to call it that in an interview with Spanish newspaper *El Pais*.

*"I fought to bring the software legitimacy so that it—and those building it—would be given its due respect and thus I began to use the term 'software engineering' to distinguish it from hardware and other kinds of engineering, yet treat each type of engineering as part of the overall systems engineering process."*

Many considered Margaret and the very concept of software engineering foolish at first. In the first document laying out the engineering requirements for the Apollo mission the word software is not even mentioned. It soon became clear that software engineering would be central to NASA's quest to get men on the moon and by mid 1968 more than 400 people were working on Apollos Software.

As a working mother in the 1960's Hamilton was an exception to the norm. She used to bring her daughter Lauren to the lab in the evenings and on weekends as she didn't have someone to mind her. After watching her daughter play with the simulation equipment one evening, Hamilton realised the need for code to protect against human error. Initially NASA disagreed with her as they believed astronauts were trained never to make a mistake.

Eventually Margaret won the fight and added code to the Apollo software to account for human error. With her Priority Displays error detection and recovery programs, she created new man in the loop concepts that provided the ability for the on-board flight software to communicate asynchronously in real-time with the astronauts. In case of an emergency the program was able to warn the astronauts by replacing their normal screens with priority screens. Margaret's zeal paid off. One example of the value of her software occurred during the Apollo 11 mission. Approximately three minutes before touchdown on the moon, the software over rode a command to switch the flight computer's priority processing to a radar system whose 'on' switch had been manually activated due to a faulty written operations script provided to the crew. The action by the software permitted the mission to safely continue.

## Post Apollo

Margaret continued to work at MIT on NASA's remaining Apollo missions as well as Skylab America's first space station. Eventually Margaret left to start her own company.

While working on Apollo Margaret found many bugs which she carefully documented and categorized. That work allowed her to recognize that many bugs occur at the boundaries between software modules.

By the time Hamilton left NASA in 1976 she had evolved a theory with six axioms, that have to do with defining software in such a way as to avoid interface errors. This was initially called Higher Order Software and she co-founded a company with the same name to devise a complete tool suite environment that could eliminate such errors. They created a product called USE.IT, based on the HOS methodology developed at MIT. It was successfully used in numerous government projects.

Margaret left the company HOS in 1985. In March 1986 she became the founder and CEO of Hamilton Technologies, Inc. The company was developed around the Universal Systems Language and focuses on creating tools to make software safer and more bug free.

## Recognition & Achievements

In 1986, Hamilton received the Augusta Ada Lovelace Award by the Association for Women in Computing. This award is given to individuals who have excelled in either (or both) of two areas:
1. Outstanding scientific and technical achievement and
2. Extraordinary service to the computing community through their accomplishments and contributions on behalf of women in computing

In 2003 Hamilton was honored by NASA when she received the NASA Exceptional Space Act Award recognizing the value of her innovations in the Apollo software development. The award included the largest financial award that NASA had ever presented to any individual up to that point.

In 2009 Margaret received the Outstanding Alumni Award from Earlham College.

In 2016 Margaret was honored again when President Obama selected her as a recipient of the Presidential Medal of freedom for her work on Apollo and the creation of the Universal Systems Language. The highest civilian honour in the United States, which is awarded to those who have made an especially meritorious contribution to the security or national interests of the United States, to world peace, or to cultural or other significant public or private endeavors.

## Conclusion

Margaret Hamilton is credited for popularizing the concept of software engineering. From her fledgling days with NASA to her current standing as a software engineering legend and luminary, she helped pave the way for an industry now worth well over a trillion dollars.
Hamilton paved the way for the next generation of female software engineers and changed the way the world views female engineer's. Hamilton's original Apollo 11 code is now available on GitHub. She continues to work to change the field of software engineering – and the world – for the better.

## Bibliography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