# Margaret Hamilton

Margaret Hamilton has a surprisingly extensive list of accomplishments. She was a mathematician, one of the first ever software engineers, and businesswoman. Margaret is an inspirational woman in a male dominated sector who has accomplished great things. She is usually accredited with coining the term "software engineering," and one of her most notable achievements was the key role she played in coding man to the moon. Her legacy lives on today through the application of software engineering to all areas of our lives.

## Why Margaret?

For several reasons, I decided to write this piece about Margaret Hamilton after studying several software engineers. First, and most importantly, she is one of the 20th century's most influential software developers. In a male dominated industry, she is a woman and a mother, but this did not stop her from following her passion. In her early career, she remembers working with only a few women, and saw herself as "one of the guys"[1]. I believe this feeling remains all too prevalent in the STEM workplace. The feeling of alienation that Margaret must've experienced is one I, like many others, can relate to. Her gumption and self-belief in the face of low adversity are traits that I hope to adopt. She embraced intimidating tasks, unfazed by the significance of the assignments she took on or the critical consequences of failure. In taking man to the moon, a historic achievement in human history, she was part of a team of unsung heroes. The software engineering industry today is more diverse than ever, thanks in no small part to the path Margaret blazed.

## Early Life

Margaret Elaine Heafield was born to Kenneth Heafield and Ruth Esther Heafield in Paoli, Indiana, on August 17, 1936. She has two younger brothers: David and Kathryn[2]. Before moving to Earlham College, where her mother was a pupil, she studied mathematics at the University of Michigan in 1955, receiving a BA in mathematics with a minor in philosophy in 1958. She cites Earlham 's head of the math department, Florence Long, as helping with her ability to study abstract mathematics and become a

*Figure 1: Earlham College, Richmond, Indiana*

[1] https://sheromargarethamilton.wordpress.com/
[2] https://en.wikipedia.org/wiki/Margaret_Hamilton_(software_engineer)

professor of mathematics. Like her father (a scholar and poet), and her grandparents (a school headmaster and Quaker minister), she had other inspirations. She says these men encouraged her to have in her education a minor in philosophy. It was at Earlham where Margaret would meet her husband James Cox Hamilton, a chemistry major. They would move to Boston together where Margaret would teach French and Maths at a public school. While her husband continued his studies, Margaret raised their child Lauren and worked in the meteorology department at MIT. Men tended to occupy the more prestigious and better paid hardware engineering positions at this pre-1970 period, also delegating the writing of applications to women. With hands-on practice, she studied at work when computer science was not yet a developed discipline. This was how Margaret started her career and took her first steps in becoming one of the leading pioneers of software engineering, perhaps unknowingly.

## SAGE Project

Margaret spent 2 years on the Semi-Automatic Ground Environment Project at MIT. The SAGE project was a network of large computers processing radar data all over the country, producing a single unified image of airspace over a wide area. Hamilton discovered her eventual career-long interest in mistakes, what triggers them, and how to eliminate them while working on the SAGE initiative. This fascinated me as a student who has only been programming for just over two years, as solving errors is a basic programming element. On this topic, Hamilton details:

*Figure 2: SAGE building, McGuire Air Force Base, New Jersey, circa 1958*

> *"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.*
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> *The only information the computer provided to the developer for debugging his program was to light up a very large register on the console of the computer, showing the address where the program halted."*[3]

Margaret, like all recruits to the SAGE project, was assigned an almost impossible programming task when she joined the organization. Margaret was the first recruit to get this program to run, to the

[3] https://futurism.com/margaret-hamilton-the-untold-story-of-the-woman-who-took-us-to-the-moon

surprise of her peers, and this later made her candidate for the position of lead developer for Apollo flight software at NASA.

> *"When I first got into it, nobody knew what it was that we were doing," Hamilton told Wired Magazine. "It was like the Wild West. There was no course in it. They didn't teach it."*[4]

## NASA & Apollo missions

Hamilton then joined a separate lab at MIT, which at the time was working on the Apollo space mission. Software and scripting were not high on NASA 's priority list at the time, and interestingly, software was excluded from the initial budget that defined the technical specifications for the missions. She quickly put herself forward to work on a contract MIT had won the contract to create software to take man to the moon for the first time. This would later become her magnum opus.

> *"I immediately called MIT to see if I could be involved in what sounded like the opportunity of a lifetime, and within hours I set up interviews with the two project managers at MIT. Both of them offered me a position on the same day as the interviews."*[5]

In a ground-breaking moment for software engineering, Hamilton welcomed the ability to operate on a real-world device built in unchartered terrain in a challenging environment. The position also carried great responsibility. In an interview with MIT news[6], Hamilton details leaving a late-night party and rushing to the lab to modify a piece of code she had realized was flawed.

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*"There were no second chances. We knew that"*

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Hamilton and her MIT team wrote all the code by hand. On a special source coding document, they wrote the Apollo Guidance Computer (AGC) source code and sent it to the "keypunchers" to copy, a procedure that took hours. The code is written in assembly language, and each line printed was a single instruction from the computer, hence the sheer paper amount as seen in figure 3. Then specialist seamstresses, or "Little Old Ladies," threaded copper wires into magnetic strings to generate rope memory that was built into the on-board navigation device.

*Figure 3: Hamilton with the source code her MIT team produced for the Apollo mission, 1969*

[4] https://sheromargarethamilton.wordpress.com/
[5] https://futurism.com/margaret-hamilton-the-untold-story-of-the-woman-who-took-us-to-the-moon
[6] https://sheromargarethamilton.wordpress.com/

It was here in the Draper Laboratory in MIT while Hamilton worked on the Apollo mission where she coined the term 'software engineering'. While nobody today would question whether software engineering was truly a science or simply an art, this was not the case in the 1960s. With time, and as awareness has grown, software engineering has developed the same respect as any other technical discipline, thanks in no small part to Hamilton's influential work.

Due to the importance of the Apollo space mission, Hamilton's work focused on ultra-safe software engineering, which involved error detection & recovery, end-to-end testing, quality assurance, and priority systems. For Hamilton and her colleagues, adding coding to stop bugs and errors was a major priority. In Apollo 8, she was prevented from doing so, as she recounted:

> *"I remember trying very hard [to get] permission to be able to put more error detection and recovery into the software. So that if the astronaut made a mistake, the software would come back and say "You can't do that." But we were forbidden to put that software in because it was more software to debug… So we were very worried that what if the astronaut, during mid-course, would select pre-launch, for example? Never would happen, they said. Never would happen. It happened."*

Hamilton's ability as a software engineer became apparent on July 20, 1969, 3 minutes before man would land on the moon. A 'checklist error' occurred and the on-board computer was no longer able to complete all the tasks it was sent, due to one of the astronauts inadvertently leaving a switch on. Hamilton's software was smart enough to recognize this, notify the team, and continue working on tasks important for landing.

> *"The software's action, in this case, was to eliminate lower priority tasks and re-establish the more important ones ... If the computer hadn't recognized this problem and taken recovery action, I doubt if Apollo 11 would have been the successful moon landing it was."*[7]

Hamilton continued her work with the Draper lab and applied her expertise from her work on the Apollo program to Skylab, the US' first space station, and some of the preliminary system software requirements for flight software. This was the obvious continuation of the work she had completed, as she explained to a conference at the Apollo Guidance Computer History Project in 2001:

> *"It might surprise today's software makers that one of the founding fathers of their boys' club was, in fact, a mother — and that should give them pause as they consider why the gender inequality of the Mad Men era persists to this day."*[8]

[7] https://wehackthemoon.com/people/margaret-hamilton-computer-got-loaded
[8] https://authors.library.caltech.edu/5456/1/hrst.mit.edu/hrs/apollo/public/conference1/hamilton-intro.htm

# Business

Over her years working at MIT, Hamilton had developed and published a methodology known as Higher Order Software, a method of designing reliable, multiprocessor, large-scale software. In 1976, she co-founded a company called Higher Order Software to further develop these ideas and provide her expertise to the free market. Together with her co-founder Saydean Zeldin, they created a product called USE.IT, which was successfully used by numerous government agencies, including NASA and the US Air Force. She would later leave Higher Order Software and found another company, called Hamilton Technologies, which is still around today. Hamilton Technologies describes its mission statement as 'to provide technology, products and services to modernize systems engineering and software development through innovation: maximize reliability and productivity, minimize cost and risk, and accelerate time to market'. Hamilton developed a new programming language called Universal Systems Language (USL), which eliminated errors from software as early as possible during the development process, thus removing the need to look for errors after-the-fact, which increased the efficacy of the software and reduced the cost of development. This made the advancements made by Hamilton during her time at MIT and Higher Order Software available to a much wider range of businesses.

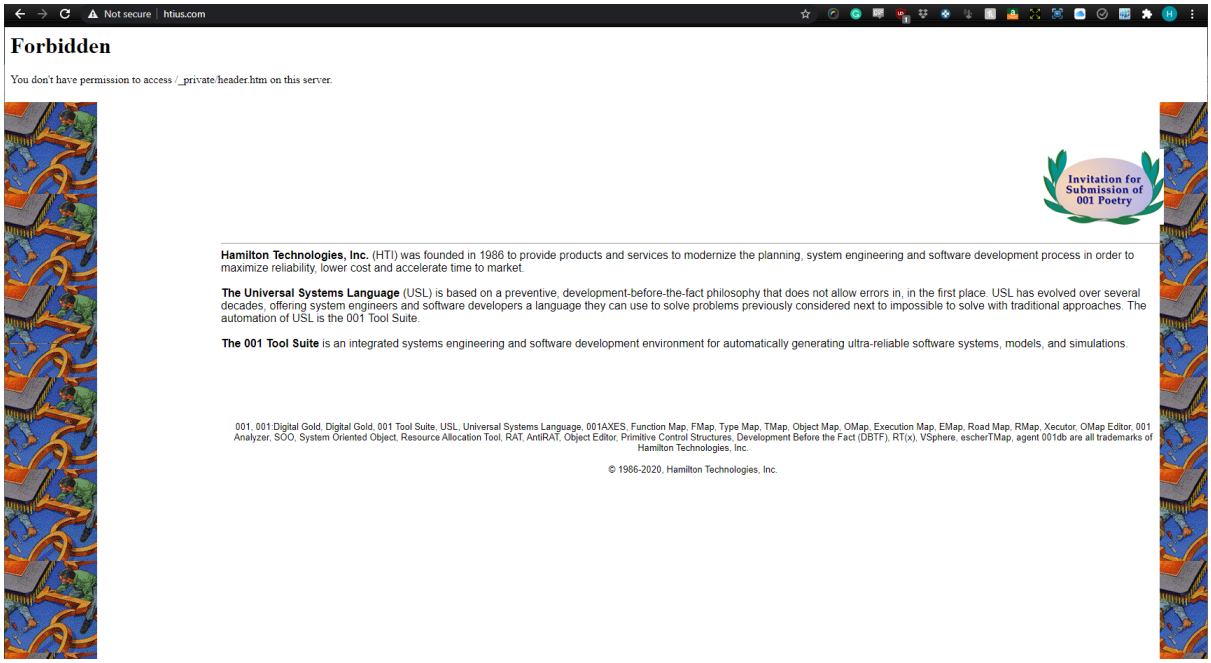


*Figure 4: Homepage for Hamilton Technologies*

# Legacy

Hamilton's contribution to the Apollo mission, and software engineering in general, is incomprehensible, although quantifiable by the $836 billion software industry that exists in the US

today[9]. Had Neil Armstrong not landed on the moon on that faithful day, and had Hamilton not laid the foundations for future software engineers such as Linus Torvalds (principal developer of Linux) to build upon, we might be living in a very different world today. And Hamilton has been recognized as such. In 2003, NASA awarded Hamilton with an award in appreciation of the importance of her Apollo software creation inventions. In 2009, Earlham College honoured her with an Outstanding Alumni Award. In 2016, President Obama awarded Hamilton with the Presidential Medal of Freedom, the United States' highest civilian decoration, for having made a highly commendable contribution to the United States' national interests. She was awarded the Tech History Museum Fellow Award in 2017, which recognizes outstanding men and women whose ideas have changed the world. Hamilton received an honorary doctorate from the Polytechnic University of Catalonia and Bard College in 2018 and 2019, respectively. In 2019, the Intrepid Sea, Air, and Space Museum awarded Hamilton the Intrepid Lifetime Achievement Award.

*Figure 5: Margaret Hamilton, 2015*

In Robert McMillan's 2015 WIRED profile of Margaret Hamilton, he stated:

> *"It might surprise today's software makers that one of the founding fathers of their boys' club was, in fact, a mother — and that should give them pause as they consider why the gender inequality of the Mad Men era persists to this day."*[10]

I couldn't agree more. In an industry which employs hundreds of millions of people, there is no excuse for the continued exclusion of minority groups. For every Margaret Hamilton we know about, there may be dozens that were excluded, intentionally or otherwise, from environments which would've allowed them to unleash their potential, and the world is worse off because of it.

[9] https://www.marketwatch.com/press-release/software-development-market-size-competitive-landscape-and-key-country-analysis-to-2025-benefits-business-opportunities-future-investments-2020-08-13#:~:text=In%202018%2C%20the%20U.S.%20software,growth%20of%208.9%25%20in%202019.
[10] https://www.wired.com/2015/10/margaret-hamilton-nasa-apollo/