Margaret Hamilton – The First Software Engineer

Margaret Hamilton is best known for her work as the head of the Apollo Flight Software Development Team who built the on-board flight software for the Apollo 11 mission that that first landed humans on the Moon. However, that was not the end of her accomplishments as she also later founded two software companies of her own, published over 130 papers, proceedings and reports and has been involved in more than sixty projects and six major programmes. She was the first computer scientist to use the term *software engineering* to describe her work.

Margaret Heafield was born on the 17th of August in Paoli, Indiana and was the eldest of three children. The family moved to Michigan where Margaret attended Hancock High School and graduated in 1954. She went on to study Mathematics at the University of Michigan before transferring to Earlham College, Richmond, Indiana where she graduated with a BA in Mathematics and a minor in Philosophy in 1958. That same year, she married James Cox Hamilton, a senior majoring in chemistry and their daughter, Lauren, was born in November of 1959. She then took a research position working for Edward Norton Lorenz in the meteorology department at the Massachusetts Institute of Technology to pay for grad school.

At MIT, Hamilton encountered her first computer and learnt to program. To support Lorenz' research into the new field of chaos theory, she developed software for the LGP-30 and the PDP-1 that could predict the weather. Hamilton later joined MIT's Lincoln Laboratory and wrote software for the Semi-Automatic Ground Environment (SAGE) project, the first US. air defence system. Her work allowed the system to identify enemy aircraft. She was able to fix a previously inoperative radar system so that it functioned correctly and became very interested in the reliability of software. In 2001 she said "I was and still am very interested in what causes errors and how to avoid them throughout. That was one of my very first experiences in this regard… from day one, it's been a fascination - the subject of errors…".

Due to her work at MIT, she was considered for a position at NASA as the lead developer for Apollo flight software. Though she planned to pursue a PhD in Abstract Mathematics, she instead accepted an offer to join MIT's Instrumentation Lab under renowned engineer Charles Stark Draper. Draper and his Instrumentation Lab had been awarded the first contract for the Apollo program that had been announced by US President John F. Kennedy earlier that year. The Apollo program's aim was to put humans on the Moon. NASA tasked the Instrumentation Lab's over 400 engineers with developing a compact digital flight computer that was to be called the Apollo Guidance Computer. The computer was intended to navigate and control the spacecraft based on input from the astronauts, and to fit within one cubic foot of space.

Hamilton was soon appointed head of all Command Module software, which was all the software for navigation and lunar landing guidance. She led the team tasked with building the on-board flight software for both the command and lunar modules.

It was around this time that Hamilton coined the term "software engineering" to describe her work. She wanted to provide legitimacy to the science of software and hoped it would be given the same respect as other disciplines of engineering.

One of Hamilton's team's tasks was programming the computer to be used for Apollo 8, the first manned mission to orbit the Moon. During a simulation of the mission, Margaret's four-year-old daughter Lauren, whom she had brought to work, started a program intended to be used pre-launch, causing the computer to crash. Hamilton understood that this could well be a problem that could occur during the actual mission and asked if she could program user error checking into the code, but NASA refused. However, five days after the launch of Apollo 8, one of the astronauts pressed the wrong button and the same error occurred, erasing part of the data the computer would need to return the astronauts to Earth. The incident almost led to the failure of the mission, and it took NASA engineers nine hours to devise a solution, which involved sending a replacement set of data to the Apollo computer.

From then on, inspired by the incident during the Apollo 8 mission and concerned by the danger and high stakes involved in space missions, Hamilton decided to prioritise developing software that could detect system errors and recover information in the event of a computer crash. She wanted to create software that could quickly detect unexpected errors and correct them. To accomplish this, Hamilton designed her programs to be "asynchronous". She and her team devised a priority system in which every task was assigned a unique priority. The idea was that more important tasks could interrupt less important ones if necessary. She also designed priority displays that could interrupt the astronaut's regularly scheduled tasks in the event of an emergency.

It was because of this clever design decision that the Apollo 11 mission could be carried out successfully. Just as the team of Commander Neil Armstrong and lunar module pilot Buzz Aldrin were about to land on the Moon, the computer displayed numerous errors that threatened the success of their landing. Aldrin had accidently flipped the switch for the rendezvous radar, which was intended to be used only during their return home, using up vital computational resources. However, because of Hamilton's precautions, the Apollo Guidance Computer prioritised the programs necessary for landing, and the mission was a complete success.

In the 1976, Hamilton left MIT to co-found a company called Higher Order Software with Saydean Zeldin. She wanted to elaborate on her ideas of error correction and fault tolerance. In 1986, she established her own company, Hamilton Technologies, Inc in Cambridge, Massachusetts.

In 2003, NASA honoured her with the Exceptional Space Act Award. This was the largest financial award they had ever given to an individual. In 2016, then President Barack Obama presented her with the Presidential Medal of Freedom.

It can be said that Margaret Hamilton's contributions to computing have been significant; in addition to her historic work on SAGE and the Apollo programme, she proved the merits of asynchronous programming in real world applications, she was a pioneer for women in STEM fields, and of course coined and popularised the term *software engineering,* which has since become the standard name for the field.

Sources

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