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The Work and Impact of Margaret Hamilton

A Brief Background

The software engineer I have chosen to write about is Margaret Hamilton, the woman behind the term 'software engineering'. The first time I heard about Margaret was the story of her contribution to the Apollo 11 mission and I was immediately intrigued. I researched her further and uncovered an incredible story of a woman whose contribution to the field of software engineering was unquantifiable. The fact that she was so successful at such an early stage when the phrase 'software engineering' didn't even exist just makes her an even more inspirational role model.

My fascination with this great figure begins with her education. She was not a student of computer science but rather earned her BA in Mathematics with a minor in philosophy at Earlham College. She then went on to teach high school mathematics and French at a public school in Boston, Indiana. Hamilton did not even have the fundamental education of programming but rather learned on the job, adding to the incredulity of her story. *(Lori Cameron, 2018)* While she postponed her own postgrad studies in abstract maths, she embarked on a career in software that was more by chance than design. Hamilton then went on to work for Edward Norton Lorenz, known for the Lorenz effect, chaos theory and the butterfly effect. Hamilton, having no background in the area, began developing software for predicting weather, programming on the LGP-30 and the PDP-1 computers. Hamilton said she learned how to build software, in hexadecimal, and how to take advantage of the of the LGP30 computer hardware to most benefit the software's performance.

The Work of Margaret Hamilton

Moving to more significant projects in her career, Hamilton worked on the SAGE project, the Semi-Automatic Ground Environment Project at Lincoln Lab. This project was an extension of Project Whirlwind, the aim of which was to create a computer system that could predict weather systems and track their movements through simulators. SAGE built on this basis to create a system to help the US Air Force to use in defence against possible Soviet attacks during the Cold War. Hamilton's role was to write software for the XD-1, the first AN/FSQ-7 computer. SAGE had their own initiation procedure where they gave each new beginner a program which nobody could ever figure out or get to run and all the comments were in Greek and Latin. *(Zoe Corbyn, 2019)* A complete novice, Hamilton was the first one to get it to work. This story exposes her ingenuity and natural born talent for computer science. As well as this SAGE led Hamilton to her career-long mission as it was on this project she became determined to discover what causes errors in code an how to avoid them.

Hamilton then joined the Charles Stark Draper Laboratory at MIT, which worked on the Apollo space mission. The opportunity to work on this team made Hamilton put her postgrad study of abstract maths to one side. When she heard that MIT had received a contract from NASA to develop the software for sending man to the moon, Hamilton was quick to put herself forward for the job. Programming was not seen as a high priority at the beginning of the Apollo project and didn't even include

software in the budget. Hamilton together with her team at MIT coded all of the code by hand. *(The Editors of Encyclopaedia Britannica)* There is a photo of Hamilton with stacks of paper reaching her own height, paper which had the source code for the Apollo Guidance Computer (AGC) printed on it. It is almost beyond my scope of imagination to comprehend the amount of work and level of complexity that was involved in producing this software, especially with such little precedence. It was during this period that Hamilton made her legacy and coined the term "software engineering" to gain recognition for the work her and her team were doing. A quote from Hamilton herself that resounded with me-

"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 to term 'software engineering'… I had always believed that both art and science were involved in its creation".

Hamilton's team was responsible for developing in-flight software, which included algorithms designed by various senior scientists for the Apollo command module, lunar lander and the subsequent Skylab. *(Lori Cameron, 2018)* Another part of her team designed and developed the systems software. This included error detection and recovery software such as restarts and the Display Interface Routines (also known as the Priority Displays), which Hamilton designed and developed.

As head of her team, she tried to get permission to be able to put more error detection and recovery into the software. She wanted to get the software to react if an astronaut made a mistake. However, they were forbidden to put that software in because it was more software to debug, to work with and she was told astronauts didn't make mistakes. Hamilton was proven right during the Apollo 8 mission when an astronaut select P01 during flight which wiped all of the collected data, making it impossible to figure out how to get the astronauts home. *(Lori Cameron, 2018)* Nine hours later, her team managed to product a solution and the crew returned to safety.

Although not as well known a name as Neil Armstrong, Margaret Hamilton was a major factor in the success of the Apollo 11 mission. Three minutes before the lunar lander reached the Moon's surface the crew had prematurely initiated the radar system needed for leaving the mood which produced "executive overflow condition" of the 72K on-board computer. Due to the flight software's system-software's error detection and recovery techniques that included its system-wide "kill and recompute" from a "safe place" restart approach to its snapshot and rollback techniques, the Display Interface Routines together with its man-in-the-loop capabilities were able prioritise the task of the landing the lunar module above all competing tasks. Margaret Hamilton's software effectively saved the mission.

In 1976, Hamilton co-founded a company called Higher Order Software (HOS) to further develop ideas about error prevention and fault tolerance. The software was based on her theory with six axioms that have to do with defining software in such a way as to avoid interface errors. Hamilton and her colleague, Saydean Zeldin, created a product called USE.IT based on the HOS methodology. *(Zoe Corbyn, 2019)* It was successfully used in numerous government programs including a project to formalize and implement C-IDEF, a

modelling language developed by the US Air Force in the Integrated Computer-Aided Manufacturing Project.

After her first company was bought out by venture capitalists, she started a second one, Hamilton Technologies, of which she is still CEO at the age of 80. The company was developed around the Universal Systems Language (USL) and its associated automated environment, the 001 Tool Suite. This is based on her paradigm of the Development Before The Fact theory for systems design and software development. The theory is described by Hamilton as 'system-oriented objects each of which integrates the functional, the timing and the data side of a system'.

In 1986 she was an early recipient of the Ada Lovelace Award established by the Association for Women in Computing. In 2003 she was granted a NASA Exceptional Space Act Award for her scientific and technical contributions. In nominating her, Dr. Paul Curto, senior technologist for NASA's Inventions and Contributions Board commented that he was surprised she was never formally recognised for her ground-breaking work and said that her concepts of asynchronous software, priority scheduling, end-to-end testing, and man-in-the-loop decision capability, such as priority displays '*became the foundation for ultra-reliable software design.'* Presenting her with a check for $37,200, the largest award to an individual in NASA's history, NASA Administrator Sean O'Keefe said that '*she and her team created became the building blocks for modern 'software engineering'.' (Zoe Corbyn, 2019)*

Conclusion

In conclusion, Margaret Hamilton is an inspiration to me for a wide array of reasons. As a female STEM student, she is a personal role model in that she did not view her gender as a barrier to success in this field nor did she let other people see her as a '*female software engineer'.* She did not come from the generic computer science background which again is something personal for me since I am new to coding and software engineering. It can sometimes feel that I am so far behind other students who have been doing this since a young age but once again Hamilton's story is heartening and motivational as it proves to me that this is not the right attitude. Finally, her career and impact on the world of software engineering speaks for itself. Her story is incredible, encouraging and truly one of a kind.

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