

*Journey to the Moon: The History of the Apollo Guidance Computer*

Few people really understood the magnitude of President Kennedy's challenge to the American nation in 1961 to put a man on the moon by the end of the decade. This enormous task was accomplished through the efforts of thousands of people who pushed the limits of technology to new boundaries. Today, when most people think of the Apollo project, they think of Neil Armstrong, the lunar lander, and the rocket technology that was developed to get to the moon. However, in his book, Eldon C. Hall discusses the development of a somewhat overlooked aspect of the Apollo project: the Apollo Guidance Computer. The contract for the development of a guidance computer for the Apollo project was given to the MIT Instrumentation Laboratory. Hall joined the MIT Instrumentation team in 1952 after finishing his graduate work in physics at Harvard. While some engineers were developing powerful engines or designing a vehicle to land on the moon, Hall and the other members of the MIT Instrumentation lab were figuring out how these vehicles were actually going to get to the moon.

In today's society where we complain if we have to wait for 20 seconds while our online bank payment is processed, it is easy to forget that computers weren't always part of everyday life. In fact, at the time of President Kennedy's challenge, the first digital computers were barely coming into existence. Hall argues that the challenge to develop a computer to successfully navigate to the moon and meet the reliability, weight, and memory requirements rivaled any of the other challenges associated with the Apollo project.

In the early 1950s, most computers were still operating off of vacuum-tube technology. A major step was made when transistors started to replace the large vacuum tubes that frequently broke. Transistors were smaller, consumed less power, were not as susceptible to breaking as vacuum tubes, and allowed for increased computational ability without an increase in volume. However, the jump from vacuum tubes to transistors would not be enough to satisfy the demands of the Apollo Guidance computer. Integrated circuits came along about the same time as the conception of Apollo. At first,

industry was reluctant to use IC's, but the MIT Instrumentation team realized that IC's were exactly what they needed in order to meet the guidelines for size, weight, cost, reliability, and schedule. As the first major project to use IC's, the Apollo Guidance Computer helped establish the reliability and define the advantages of integrated circuits, thus paving the way for their extensive use in electronics today.

The Apollo Guidance computer exhibited other significant advancements in terms of both hardware and software. One of NASA's goals for Apollo was to have an autonomous spacecraft in order to prevent the Soviets from interfering with U.S. space missions. An important engineering decision that needed to be made by the designers was the level of autonomy that their computer would have. Originally, NASA thought that having a computer that was entirely autonomous would be necessary so that the spacecraft could land itself if the astronauts ever became disabled. The astronauts argued that as pilots they should have complete control of the spacecraft and there should be no need for a computer that could fly the spacecraft. Dr. Draper, an important player on the MIT Instrumentation team recognized that inertial navigation techniques would be needed in order to have an autonomous system. However, it was also determined that a computer that was entirely automatic would place a dangerous degree of complexity on the system. A consensus was finally reached and it was decided that while the system would be mostly autonomous, the astronauts would play a limited role in the navigation of the spacecraft.

The astronauts would make angle measurements between Earth, moon, and stars, and then enter these values into the computer. The computer would use these measurements and measurements from a set of accelerometers to solve navigation equations to keep track of the spacecraft's position and velocity. In order to compute these calculations, the computer would need to perform real-time operations – a new and untested concept in the field of digital computing. Additionally, the computer would need to provide an interface for the astronaut's display and controls, be able to align the inertial measurement unit, and control the spacecraft's engines. This new combination of support, computation, and control features would set the Apollo computer apart from all other aerospace digital computers at the time.

As a member of the team that actually designed the Apollo computer, Hall presents some unique insights and details into the project's progress and development. However, Hall is also able to shed light on the views and opinions that others had at the time. In his book, Hall gives several examples of critiques from Bellcomm, IBM, Grumman, and others who challenged the validity and reliability of the design for the Apollo guidance computer. The concerns of multiple groups is summarized by astronaut Dave Scott when he said, "I can remember times that we thought that the computer won't work, not enough memory, memory cycle time isn't fast enough, can't do this, can't do that, etc. Now, it seems unbelievable that we were able to do all that we did with that old stuff." The fact that the MIT Instrumentation team was able to address the valid concerns of these other groups adds credence to the level of sophistication that Hall attributes to the Apollo guidance computer.

The real test for the Apollo computer came in its performance during flight. For today's PC-users, the term, blue screen of death is very much a figurative one, but for the MIT Instrumentation team, a failure could literally mean the death of Apollo astronauts. Some computer issues arose during some of the flights, but overall there was not a single computer failure during any of the Apollo missions. For a computer design that was using new techniques in regard to both hardware and software, this was truly a remarkable achievement.

The Apollo project is often heralded as a time in which Americans put forth their very best efforts and expanded the horizons of possibility and understanding. The development of the Apollo guidance computer is an embodiment of that idea. Alternatively, others feel that the space race was strictly a political decision. While the decision to go to the moon may have been largely a political one, the development of the Apollo guidance computer illustrates that it was the efforts and ingenuity of engineers that actually made that decision become a reality. The guidance computer was one aspect of the Apollo project that helped to really define what engineering was. Before the Apollo guidance computer, the term software engineering meant nothing, but the developments that blossomed from the design of the Apollo guidance computer not only demonstrated the awesome potential for software in aerospace and military systems, but it also proved that software could be relied on even when human life was on the line.