FAIL-SAFE

by Michael L. Umbricht

NASA Astronauts training in the Shuttle Mission Simulator. Courtesy: NASA

Planning for the Space Shuttle program began in 1972. The NASA Space Shuttle was a revolutionary design. Prior to this, pilots would use a control stick to tilt the flaps on the wings to control an aircraft. Moving the control stick would send an electrical signal to a motor that moves a flap. This replaced an even earlier technology where the stick was mechanically connected to the flap by a rod.

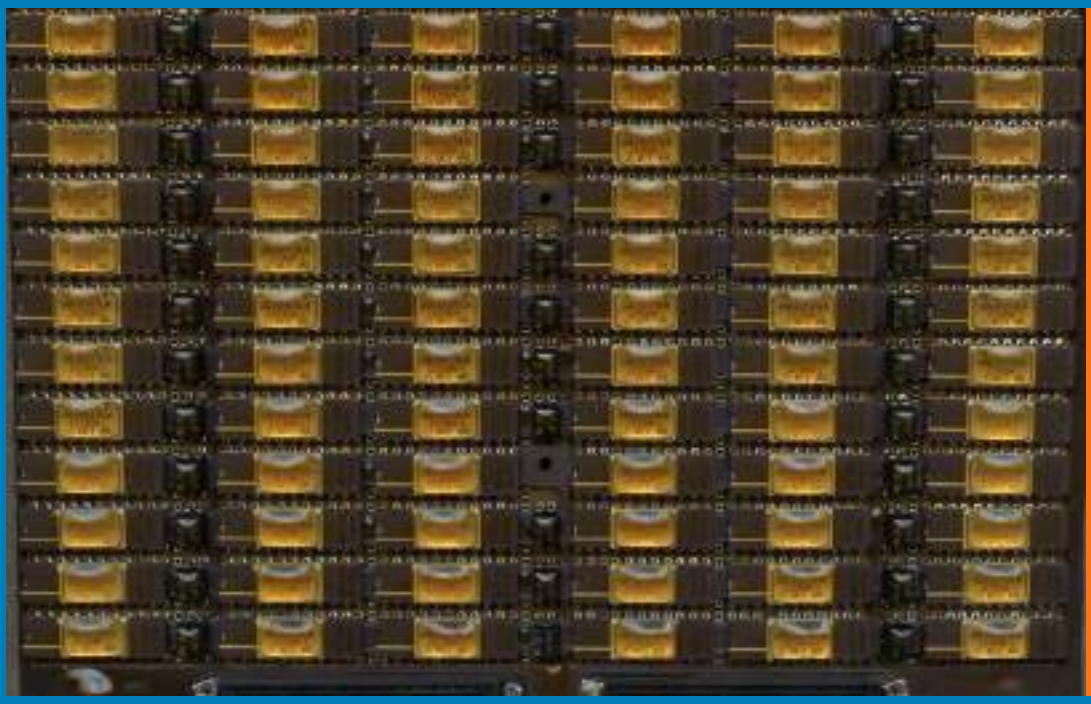
NASA pioneered a new control method for the shuttle. It was called "fly-by-wire." The control stick would send a signal to a computer that would measure the pilot's hand position. The computer would then calculate how much to move the flap. Then the computer would directly control the electric motor. The aerodynamics of a shuttle landing would make it difficult to control the vehicle. The fly-by-wire would control the shuttle more easily, and precisely, than could be accomplished by a human directly controlling it.

A second-generation space shuttle computer with the top cover removed. Courtesy: Dave Fischer

The computer that was selected was the IBM AP-101. It does not have a single microprocessor chip like a modern computer. Instead, it has circuit boards with many chips on them that are interconnected. The AP-101 was a model of aerospace computer used in military aircraft for navigation, radar, and weapons. The AP-101 was part of a series based on the design of the IBM System/360 mainframe. It was much smaller than the room-sized mainframes used in science and business. The first-generation AP-101 consisted of two chassis: one contained the processor and memory, the other contained the input / output circuits to read information from sensors and control the shuttle's flight. The pair was called the DPS, or Data Processing System.

A logic circuit board from the computer. Courtesy: Dave Fischer

There was a great concern that if the computer failed or there was an incorrect calculation, there would be a loss of control leading to a crash. The radiation passing through the shuttle is higher on orbit than on the ground. A cosmic ray could corrupt the memory or cause an error. The solution was to use multiple redundant computers that would each perform the same calculations. A total of five computers were installed in each shuttle. They would then "vote" on the correct answer and ignore the error. This is called fail-safe. A single failure won't put the shuttle at risk. The first shuttle flight to orbit was in 1981. As an added precaution, the first few missions carried a sixth computer that was not plugged in. Astronauts could swap it for a failed computer. The set of five computers worked so well that they discontinued carrying a spare.



A close up view of the semiconductor memory chips in the computer. Courtesy: Dave Fischer

From 1991 to 1993 NASA upgraded each of the shuttles to a second-generation computer model called the AP-101S. The memory circuit boards were much smaller, allowing the entire DPS to fit in a single chassis. The earlier computer uses a memory technology called core memory. The binary 1 and 0 bits are stored by magnetizing a tiny donut shaped piece of iron. The core stores the bit like the polarity of a magnet. Many of these boards of core were required to have enough memory for the shuttle software. The upgrade to semiconductor memory chips in the 1990s allowed a much smaller design. These computers remained in use until the space shuttles were retired in 2011.

The gauge that displays how many hours the computer was in operation.

(2,779 hours is about 116 days, if operated 24 hours per day)

In 2013, one of the AP-101S computers was donated to Ladd Observatory. It was manufactured in 1991. This particular computer was only used in the space shuttle flight simulator on the ground. Sadly, we don't have a space shuttle to plug the computer into.