Vannevar Bush

The Differential Analyser

This machine was designed to solve an important class of mathematical functions that occur in many areas of science and engineering, known as second order differential equations. The method had first been suggested by Lord Kelvin and involved feeding the output of one 'integrator' (a device that effectively calculates the area under a curve) into the input of another. However, the strength of the output was generally too weak to act as an input and it was not until amplifiers were invented that the method could be applied.

Bush's 1931 machine was entirely mechanical and was a complex structure of gears, axles and electric motors. Input and output were in the form of shaft rotations and the feedback problem was solved by using a 'torque' amplifer.

In the 1940's, a more advanced differential analyser was built using electrical components, but the machine weighed over a hundred tons. The output from the five registers was in a digital printout form and was accurate to one part in 10,000. The initial conditions and control parameters were supplied on punched paper tape. The machine was used throughout the Second World War for cryptography and ballistic work

The differential analyser, designed by Vannevar Bush, was an electromechanical calculator that solved differential equations

Many people argue that Vannevar Bush is the father of the computer. His most important contribution to the development of computer science came in 1931 when he created a mechanical differential analyser, which stimulated research that eventually led to the development of the digital computer

Bush was born near Boston, Massachusetts, on 11 March 1890 and, following in his father's footsteps, studied engineering at college. After graduating in 1913, he worked briefly for the General Electric Company before taking up a junior lectureship at his old college. This was followed by postgraduate studies at Harvard University and the Massachusetts Institute of Technology (MIT). During the First World War, Bush was involved in the development of submarine detectors for the US military.

Bush developed his first invention, a device for surveying land, while he was still a student. The mechanism, which was suspended between two bicycle wheels, calculated the height of the ground over which it travelled and displayed the output as a profile of the land in graph form. It also incorporated a device known as an integrator, since the determination of the height at any position required a knowledge of all the previous values on its journey.

At MIT, Bush became professor of electrical power transmission, and set out to investigate one of the major problems involved in the supply of electricity — how to avoid blackouts that occur as a result of sudden unpredicted surges in demand. The mathematical equations that govern such a situation had been discovered at the end of the 19th century by the Scottish scientist James Clerk Maxwell (1831 – 1879). But there were so many simultaneous equations involved that the problem could not be solved by hand, and so Bush set about inventing a machine for this purpose. Bush was also inspired by the work of Lord Kelvin (1824 – 1907), a British scientist who had proposed a general purpose machine for solving the mathematical equations involved in predicting tides.

In the early 1920's, Bush built his first machine, which he called the 'product telegraph'. This machine enabled human operators to trace the paths of waves drawn on a graph (using a potentiometer — a device that turns a position measurement into a voltage). They then fed these electrical signals into a specially adapted watt meter — the spinning disc found in any power meter, which records the amount of power consumed by integrating the fluctuating values of current and voltage to give the 'product'.

The success of this machine in solving a set of simultaneous equations suggested that it might be possible to build a device that could solve even more difficult second order differential equations. Further research by Bush led to the completion of the first differential analyser in 1931. The machine proved extremely successful, and copies were built in Britain and Europe. In America, the Moore School of Electrical Engineering at the University of Pennsylvania — which was later to build the ENIAC computer (see page 88) — commissioned one. Where Bush's product telegraph had been accurate to only two per cent, the differential analyser gave results accurate to 0.05 per cent. However, the cost of improving the accuracy of this type of mechanical device increased by a factor of ten for every extra decimal place. With the development of the digital computer, however, the cost of a machine only doubled if its accuracy were similarly increased.

Bush became dean of the engineering school and vice president of the Carnegie Institute in 1939, and his able work in administering the millionaire's estate for scientific research resulted in his appointment as chairman of the National Defense Research Committee in the following year. In this office he was responsible for wartime US military research and, in particular, was influential in authorising the Manhattan project, which led to the creation of the atomic bomb. Bush retired in 1955 to devote time to his personal hobbies. These included boating and turkey farming, as well as inventing. He died in 1974.