# *Computer Development at the National Bureau of Standards*

The first fully operational stored-program electronic computer in the United States was built at the National Bureau of Standards. The Standards Electronic Automatic Computer (SEAC) [1] (Fig. 1.) began useful computation in May 1950. The stored program was held in the machine's internal memory where the machine itself could modify it for successive stages of a computation. This made a dramatic increase in the power of programming.

Although originally intended as an "interim" computer, SEAC had a productive life of 14 years, with a profound effect on all U.S. Government computing, the extension of the use of computers into previously unknown applications, and the further development of computing machines in industry and academia.

In earlier developments, the possibility of doing electronic computation had been demonstrated by Atanasoff at Iowa State University in 1937. The ENIAC was completed in 1946 at the Moore School of the University of Pennsylvania, but programming in that machine consisted of setting appropriate switches and plug connections. The ENIAC had demonstrated that individual computations could be performed at electronic speed, but the instructions (the program) that drove these computations could not be modified and sequenced at the same electronic speed as the computations. Other early computers in academia, government, and industry, such as Edvac, Ordvac, Illiac I, the Von Neumann IAS computer, and the IBM 701, would not begin productive operation until 1952.

In 1947, the U.S. Bureau of the Census, in cooperation with the Departments of the Army and Air Force, decided to contract with Eckert and Mauchly, who had developed the ENIAC, to create a computer that would have an internally stored program which could be run at electronic speeds. Because of a demonstrated competence in designing electronic components, the National Bureau of Standards was asked to be technical monitor of the contract that was issued, to the company that became the Remington Rand Corporation, for the development of the first commercial computer, the Univac. Actually, there were three machines, two for the military and one for the Census Bureau.

**Fig. 1.** SEAC, showing the magnetic tapes and wire cartridges, the operators console, and the racks of logic circuitry.

It became clear during 1948 that unexpected technical difficulties would delay completion of the Univacs. The machine for the Office of the Air Comptroller was primarily for use by George Dantzig, noted for his work on Linear Programming applied to economic problems. He urged the Air Force to contract with NBS for the development of an interim machine which would serve multiple purposes. Furthermore, the Bureau was in need of a computer for its own scientific research. Consequently, NBS began development, in its own laboratory, of an interim machine for use by NBS, the Army and Air Force, and the Census Bureau, which wished to test automatic methods on the 1950 Census. The interim machine at NBS was completed and put into continuous operation in May 1950, a year before the first commercial machine was delivered. It was originally called the Standards Eastern Automatic Computer to distinguish it from the Standards Western Automatic Computer still under development at the NBS Institute for Numerical Analysis in Los Angeles.

In the early years of its use, SEAC was operated 24 hours per day, 7 days per week. During this time four different kinds of demand were made on the machine. It was used by mathematicians from NBS and many other institutions to do the calculations that spurred the advance of numerical analysis. It was also used by the engineering staff of the Electronic Computers Laboratory to develop new components and to expand the capabilities of SEAC. A maintenance staff kept constant watch on the 12,000 diodes and over 1000 vacuum tubes by doing diagnostic testing. Finally, with the support of other agencies, NBS developed entirely new uses for computers and tested these uses on SEAC. Despite these competing demands, SEAC achieved reliable operation 77 % of the time during its critical first three years of operation. This was both a surprise and a source of encouragement to the young field of computer development.

The mathematical applications of SEAC were well represented by the publication of the NBS *Handbook of Mathematical Functions* [2] (which is separately described in this volume). One major calculation carried out dealt with nuclear energy. The early engineering and maintenance developments are described in an NBS Circular published in 1955: *Computer Development (SEAC and DYSEAC) at the National Bureau of Standards* [1]. It consists of an introduction by S. N. Alexander, the Chief of the Electronic Computer Laboratory which developed SEAC, and reprints of eight papers by NBS staff which were previously published in various journals and computer conference proceedings. Their titles give an idea of the scope of NBS contributions to computer design.

*Foreword,* A. V. Astin

*Introduction,* S. N. Alexander

*SEAC,* S. Greenwald, S. N. Alexander, and Ruth C. Haueter

*Dynamic circuitry techniques used in SEAC and DYSEAC,* R. D. Elbourn and R. P. Witt

*DYSEAC,* A. L. Leiner, S. N. Alexander, and R. P. Witt

*System design of the SEAC and DYSEAC,* A. L. Leiner, W. A. Notz, J. L. Smith, and A. Weinberger

*High-speed memory development at the National Bureau of Standards,* R. J. Slutz, A. W. Holt, R. P. Witt, and D. C. Friedman

*Input-output devices for NBS computers,* J. L. Pike and E. L. Ainsworth

*Operational experience with SEAC,* J. H. Wright, P. D. Shupe, Jr., and J. W. Cooper

*SEAC-Review of three years operation,* P. D. Shupe, Jr. and R. A. Kirsch

The Greenwald, Alexander, and Haueter paper describes the organization of SEAC from the block diagram level down to the circuitry level. It exhibits pictures of the tens of thousands of hand-constructed components which today are manufactured by automatic methods. To us today, it seems even more amazing than it did in 1950 that the thing could work at all!

This circuitry using diodes, vacuum tubes, and pulse transformers is described in the Elbourn and Witt paper.

The memory of SEAC initially consisted of what we would today describe as 3072 bytes, (not kilobytes or megabytes!). This memory, in the form of acoustic pulses in mercury columns, is described in the paper by Slutz, Holt, Witt, and Friedman, as are subsequent developments of a higher speed electrostatic memory and a memory design using individual components for each bit.

Because of the very limited memory capacity of SEAC, it was important to be able to store information on external media. These media were also used for feeding data and programs to SEAC. The paper by Pike and Ainsworth describes the various magnetic and paper tape media which served this purpose. One magnetic device was an adapted office dictating machine, modified to store digital information. Each programmer had one of these wire cartridges on which the whole history of his or her programming experience would be stored. These wire cartridges still exist today, but there are no devices to read them, thereby losing to history much of the detailed early experience on the first computer!

The two papers by Wright, Shupe, and Cooper and by Shupe and Kirsch describe how SEAC was maintained in productive operation despite the fact that failure in any one of the tens of thousands of components or solder connections would render the computer inoperative, or so it was believed. Actually, after about ten years of ostensibly fault-free operation, it was discovered by Kirsch that there had been a wiring error in SEAC from the beginning of its useful life. A program written in a certain way would have failed, but the conditions for this failure had never occurred in the many years of normal operation. Computers of today are not as reliable as SEAC aspired to be, so we use "workarounds" to live with errors.

Two important lessons learned from the design of SEAC were incorporated in the design of DYSEAC in 1953. The reliability of SEAC's components led to the use of similar components in DYSEAC, and new kinds of logical organization were also incorporated. These are described in the two papers by Leiner, Alexander, and Witt and by Leiner, Notz, Smith, and Weinberger.

DYSEAC was built in movable trailers for the U.S. Army and is believed to be the first computer to use printed circuits. In the short time after its construction at NBS, before it was removed by the sponsoring organization, it was possible to demonstrate some of its important properties. It had extensive abilities for real-time interaction with outside devices. One of these was SEAC itself, which was able to interrupt computations on DYSEAC and send data into files on DYSEAC without disruption of the DYSEAC computation. This was an early example of hardware-based time-sharing. Other examples that ultimately led to industrial process control were first demonstrated on the DYSEAC.

The last of the four kinds of uses of SEAC was the development of entirely new applications for computers. The first uses of SEAC (and indeed most computers) were for mathematical calculations. Soon thereafter it was recognized that computers, as symbol manipulators, could also process alphabetical information. This led to so-called business data processing. But the ready availability of SEAC for innovation without the need for commercial motivation encouraged its use beyond these two conventional areas. Two examples of the many such innovative areas started on SEAC were Image Processing and Chemical Structure Searching.

**Fig. 2.** Father and daughter—two scans separated by 40 years and storage requirements in the ratio of 1400:1.

In 1957 the first picture was fed into a computer when a rotating drum scanner was connected to SEAC [3]. This project demonstrated that it was possible to perform image processing operations on scanned pictures, using the (for that time) great processing speed of the computer. Progress in scanning technology can be seen in the difference between one of the first scans and a modern one (Fig. 2). Among the many disciplines impacted at NBS by this new field of image processing were metallurgy [4], character recognition [5], and criminology [6]. Today, this technology, first started on SEAC, allows us to do CAT scans in medicine, receive satellite images from space, scan bar codes in grocery stores, and do desktop publishing [7].

Experience with non-numerical processing techniques led to the realization that different kinds of data structures could be manipulated with SEAC. One of these was the structural diagram used in organic chemistry. In the process of examining new patent applications, the U. S. Patent Office needed to search files of chemical compounds. Previously, chemical names had been the only means of representing compounds, but this type of search was not very satisfactory owing to inconsistent nomenclature. It was shown [8,9] with the use of SEAC that structural diagrams could be represented in digital form and searched on the computer, thereby finding records that could not have been found using nomenclature alone. Chemical structure searching is now a multimillion dollar industry which plays a major role, for example, in design of new drugs.

The rapidity with which SEAC and its descendants influenced a wide variety of scientific, commercial, and even intellectual disciplines encouraged the early pioneers to believe that "Nothing will be restrained from them which they have imagined to do" [10]. Many people still believe that today.

*Prepared by Russell A. Kirsch.*

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