History of Computing Resources in the Y-12 Plant – part one

(As published in The Oak Ridger's Historically Speaking column the week of August 12, 2019)

This series of Historically Speaking, provides insight into one of the most significant advances in computer technology. It happened at the Y-12 National Security Complex. Clyde Davenport brings us his perception of how things evolved over time regarding computing at Y-12.

He will review the usage of computing resources (computers, networks, etc.) over time in Y-12, beginning in the 1950s and continuing to around Year 2000. The series will include an outline all of the major advances in computer technology, and how they were applied in the Y-12 Plant. Also, we shall show that computing resources kept Y-12 viable in some very challenging times.

Clyde Davenport is a retired Y-12 Development Division engineer. He lived through the whole sequence, and participated in varying fashion, throughout. He points out that he did not singlehandedly do all of the work, and that teams of highly-qualified engineers were involved. Here is Clyde's story.

***

To begin, we need some background. In the mid-1950s, the Second World War had been won and the hydrogen bomb had been tested. The Atomic Energy Commission (AEC) decided that a reassignment of roles of the various facilities that made up the Nuclear Weapons Complex (NWC) was due. The national laboratories [e.g., Oak Ridge National Laboratory (ORNL), Los Alamos National Laboratory (LANL), etc.] were designated to handle all pure and applied research. The Y-12 Plant was transitioned from a uranium enrichment role to a nuclear weapons fabrication facility.

It became apparent that the Y-12 Plant was to be viewed as an ordinary machine shop, using standard, proven processes. Consequently, Y-12 was prohibited from doing any form of research. If, in the unlikely case that Y-12 ran into a technical problem, ORNL was right there to help.

Up through 1970, International Business Machines (IBM) was the overwhelmingly dominant computer manufacturer, having 85% of the market. Their computing paradigm was centered around large, expensive "mainframe" computers in central locations and fed by punched cards. There were no user terminals.

A well-equipped system, with site prep, peripherals, and operating staff could cost several million dollars.

Consequently, only a large, successful organization or institution could afford them. ORNL had one that was used primarily for computer technology research, and the Oak Ridge Gaseous Diffusion Plant (ORGDP, K-25) had one that was used primarily for the extensive gaseous diffusion problems.

Both were viewed primarily as research systems, consequently Y-12 was prohibited from having one. Their operation was consolidated into a Computer Sciences Division (CSD), which was charged with handling any and all requests for computer services.

The Y-12 Plant began to operate under these new role restrictions. It quickly became apparent that Y-12 *was not* a common machine shop. In the first place, Y-12 worked with some very exotic materials and processes that had not been applied before on a large scale (e.g., the Lithium-7 isotope chemical separation process), and in the second place, each new weapon system design introduced a new set of requirements and problems.

ORNL did not have technical staff just standing around waiting for Y-12's beck and call. Nor did the Computer Sciences Division provide much in the way of computer services to Y-12. They did eventually provide a remote punched-card reader for general use and a small mainframe at Y-12 to host a large

History of Computing Resources in the Y-12 Plant – part one

(As published in The Oak Ridger's Historically Speaking column the week of August 12, 2019)

repository of production data on the 10-inch diameter magnetic tapes. Again, no user terminals were available.

Much more was needed. The Atomic Energy Commission (AEC), to their credit, agreed. They came up with a creative solution. Y-12 was allowed to set up a Division of around 200 subject matter experts, to address applied research specifically targeted on Y-12 problems.

In concept, it was a Research & Development (R&D) organization, but Y-12 could not call it that. They were prohibited from using the word "Research," therefore the new organization became the "Development Division."

The AEC would continue to provide annual funding for operation of the Y-12 Plant, overall, and AEC Headquarters would provide review and oversight, as always. However, now, a certain block of the overall funding would be set aside for the Development Division, for which review and oversight would be conducted by AEC Albuquerque.

The Albuquerque Office would vigorously review to be sure that only applied research tied directly to Y-12 problems would be undertaken. This worked well.

In 1975, the Atomic Energy Commission was split into the Nuclear Regulatory Commission to regulate commercial nuclear power and the Energy Research and Development Administration (ERDA) to manage the energy research and development, nuclear weapons, and naval reactors programs. In 1977 ERDA was designated the Department of Energy (DOE).

In 1999, the nuclear weapons work was consolidated as the National Nuclear Security Administration (NNSA), a semi-autonomous organization under the DOE. Y-12 transitioned from AEC, to ERDA and then NNSA.

Up until 1984, Bill Wilcox was appointed as Technical Director of Y-12 and K-25, to enforce the above research restrictions. In the following, keep in mind that none of the following would have been possible without the special arrangement that provided separate oversight of the Development Division funding and applied research via Albuquerque, as described above.

In the late 1960s, the first shop-floor computers were appearing that were designed for real-time process control and light office work. Operation was carried out interactively via a user terminal in real time, rather than by punched cards. This was a major shift in paradigm.

The Development Division decided to explore the new technology. They bought a Digital Equipment Corporation (DEC) model PDP-15/35 so-called "minicomputer" for $100K, and set about to do a demonstration project. The computer was about the size of a small refrigerator, and had an 18-bit word length, 32K words of memory, a 512K-word hard disk, and a typewriter-like user terminal. In operation, it was similar to one of the first rudimentary, desk-top personal computers.

However, the PDP-15/35 had a very sophisticated operating system. Although very small, as compared to a mainframe, it was a technological marvel (for the time). It was fully-interactive. It had a priority-based interface for external devices.

For those of you who are computer professionals, it could do real-time, multiuser, multitasking, multithreading operation on a priority basis, and program segmentation and automatic overlay as

execution proceeded. It could support sizeable programs in a small memory space. It had a small video screen for interactive display. It supported assembler-level and Fortran coding.

The Development Division demonstration project began with automation of an electron-beam welder. This 6.0-kW welder had the capability for very precise welds, but the dynamics of a given weld were so fast-moving that a manual operator could not keep up.

I was hired in September, 1969 as a Development Engineer and was assigned to do the feasibility assessment, the conceptual design, and the programming. The automated welder produced unprecedented control and quality.

See the reports, C.M. Davenport, et al, "Automatic programmer for an Electron-Beam Welder," Y-1848, Union Carbide Nuclear Division, March 14, 1973; and C.M. Davenport, "Computer automation of an Electron-Beam Welder," *Proceedings of the Computer-Aided Manufacturing – International (CAM-I) Society*, New Orleans Louisiana, April 10-12, 1979.

Eventually, this control scheme was applied to all five of the Plant's production welders, where they made a quantum leap in quality and repeatability. This project clearly demonstrated the benefits of online, programmable, automated systems.

Next, the Division wished to evaluate the benefits of online, interactive, scientific computing, of a type that could not be done on a mainframe computer. Specifically, interactive, nonlinear least-squares analysis of data was an ongoing need, processing of X-ray diffraction data being a prime example.

The Y-12 Plant was having a problem with extrusion, rolling, and forming of a particular uranium alloy. The alloy was exhibiting changes in brittleness, ductility, and malleability. During processing, unacceptable cracking would occur. Dr. Don Carpenter undertook a metallurgical experiment called X-ray diffraction which could characterize the changes in the crystal structure of the metal at various points in the processing sequence, hence pinpoint the problem. In X-ray diffraction, a beam of X-ray photons with a particular energy is reflected through a flat coupon of the uranium alloy.

It is internally reflected (diffracted) in various ways because of the coupon's crystal structure, resulting in photons with altered direction and energy. A classical-looking energy spectrum is created, from which crystal structure can be deduced.

However, the required analysis is a very complicated, iterative process that requires the researcher's input at each step. It was not practical to put the problem on punched cards and send it to a mainframe. However, there were no commercial software packages for small computers that could address the problem.

I wrote, from scratch, a collection of online, interactive routines that could solve this and other problems. That included data plotting; video display; data filtering; linear least squares curve fitting; and interactive, nonlinear curve fitting. A very serious, Plant-level problem was solved.

See the reports C.M. Davenport, "Instructions for running the X-ray diffraction data analysis routines," Union Carbide Corporation, Oak Ridge Y-12 Plant, Report Y/DA-8085, October 23, 1978, and D.A. Carpenter, et al, "Phase and texture analysis of the alpha-phase extruded uranium-2.4 weight percent niobium alloy," Union Carbide Corporation, Oak Ridge Y-12 Plant, Report Y-2239, December 1981.

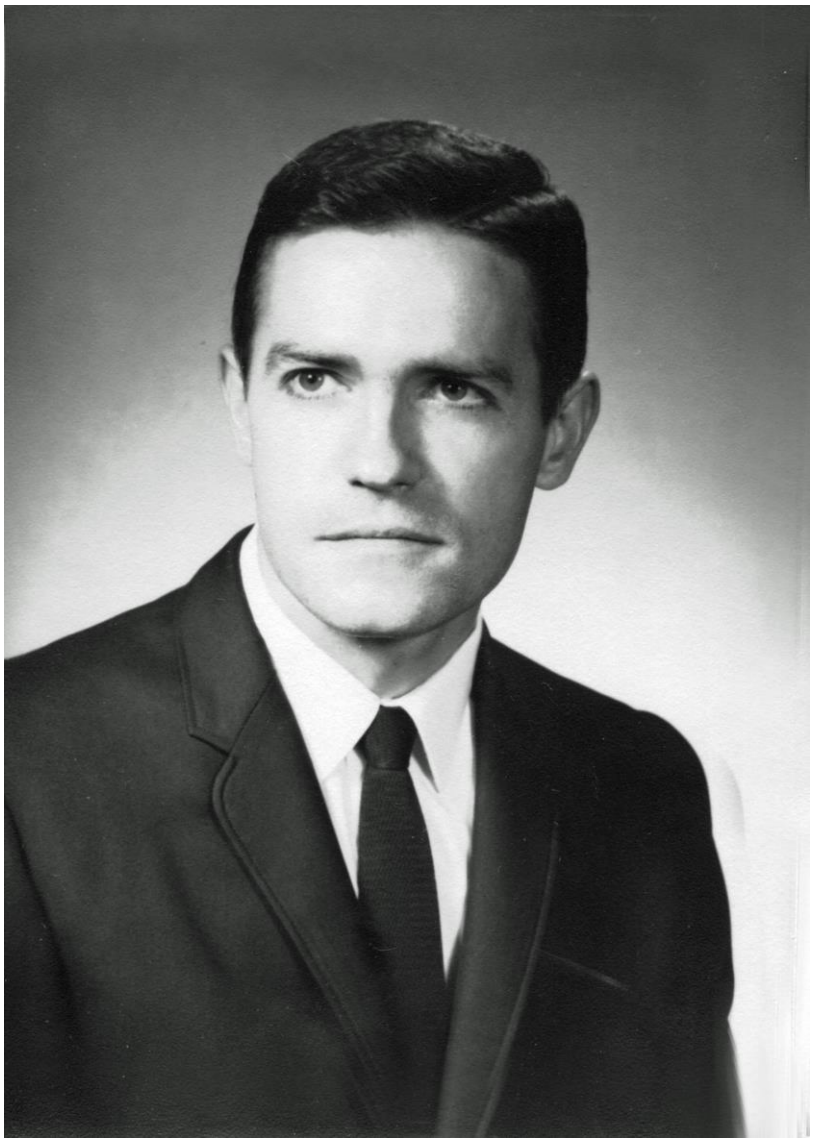
History of Computing Resources in the Y-12 Plant – part one

(As published in The Oak Ridger's Historically Speaking column the week of August 12, 2019)

Dr. Carpenter's work was so innovative that it was designated by the National Institutes of Science and Technology (NIST – formerly the National Bureau of Standards) as a standard method. This project clearly highlighted the benefits of online, interactive computing.

***

Thank you, Clyde! What a great insight into the world of computing that most never see and from a perspective of one who was actually involved in the details of each step.



A young Clyde Davenport at age 22