ABNER: The ASA Computer

Part II: Fabrication, Operation, and Impact

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This is the second excerpt from Mr. Snyder's study of ABNER, a project originally established under the Army Security Agency, and then adopted by AFSA and NSA. Part I appeared in the NSA Technical Journal, *Volume 25, Number 2 (Spring 1980).*

(U) It was probably not just blind coincidence that at about the same time (July 1948) we were negotiating with the National Bureau of Standards (NBS) for their design and consulting services, Dr. Solomon Kullback, Chief of Research and Development at ASA, effected a reorganization that made available the nucleus of the team of engineers that built ABNER. A new division, CSGAS-77, had been created, headed by Charles Schierlmann, to be responsible for analytic equipment development. In July 1948, a new branch, CSGAS-77A, was formed, with the specific responsibility to learn about the new electronic computers. Dwight Ashley headed the new branch. Roger D. Moulton and Kirk V. ("K.V.") Bell were among the first to join Ashley; Ray Bowman had been requested, but was not released from his other assignment until about a month later. As far as I know, my 11 August 1948 lecture to Ashley's group, about computers and the basics of computer programming, was their first exposure to the principles of computer logic and to some of the ways we thought a computer could be used in Agency applications.

(U) It was during July and August 1948 that several internal discussions and meetings with Bureau of Standards officials resulted in the agreement which has been described in Part I. Among those who took part for ASA were Leo Rosen, Schierlmann, Ashley, and Moulton. Since the agreement with NBS provided that ASA would build its own computer using designs and drawings to be furnished by NBS, it seemed that our people would have to "mark time" until the ASA Computer design was completed for us. Of course, during the next five or six months, they were not exactly idle. There were several meetings to settle the design details of our computer, and also a regular series of lectures by NBS for our engineers' indoctrination. In these tutorials at NBS, conducted by Samuel Lubkin (at first), Sam Alexander, Al Leiner, Bob Elbourn, and Ralph Slutz, the principles of computer logic, serial dynamic circuitry, and the implementation of arithmetic processes with binary logic were described. Ashley, Bell, and Bowman were the ASA engineers who met regularly with NBS, and within the first few weeks they were already testing some of these design principles by laying out for themselves what they felt our computer might be like.

(U) By December 1948 the engineering staff had begun to grow, and specific assignments in the various specialties were being made. Tom Lane joined the group in September 1948 and was given responsibility for timing, instrumentation, and basic pulse circuitry. Kirk Bell had begun a study of one of the most important components in all serial dynamic logic: the electric delay line (more on this later). Carroll T. Robinson assisted K.V. with electric delays, and also concentrated on pulse tranformers. Walter McGough joined the group in December 1948 and started work on gate structures. William Syphax was responsible for the main power supply, and later worked in the input-output area. Ashley and Bowman were the chief logic designers. This latter relationship worked out very well, although Ashley more and more became the overall administrative supervisor, while Bowman spent almost full time on logic design of individual instructions.

(U) *ASA Design Decision.* On 15 December 1948 a conference took place in Dr. Kullback's office, at which we discussed the delays in NBS' getting started on our design work and in placing the order for the mercury delay memory. The following day these sentiments were passed on to NBS people, with inconclusive results. The Bureau was still considering two companies, Sylvania and Technitrol, for the memory work. The issue was finally settled in February 1949: Technitrol Engineering Company of Philadelphia got the contract to build mercury delay memories for both NBS and ASA. The Bureau's computer was to have a 512-word memory (one cabinet containing 64 8-word tanks), and ASA's would be for 1,024 words (two cabinets).

(U) In the previous section, we have described some of the design changes from the basic EDVAC which were being proposed and later adopted for our machine. This was an exciting time for us all, particularly because of the mutual stimulation among programmers and engineers, which brought about the many refinements for which ABNER has been noted. But Ashley and company had an additional stimulus, and a very serious responsibility: they were undertaking to *build* the computer.

(U) Among the early questions considered was how we planned to express data and instructions for input. That is, since the computer would deal with everything in binary form, should we attempt to get into that form *before* entering the computer, or use the computer itself to do the conversion? We programmers were already familiar with ATLAS and its octal system (three binary bits = one octal character) for expressing the binary values (data and instructions) stored and manipulated by the machine. We decided to adopt for the ASA Computer a system of decimal and alphabetic representation that did not require a programmer to learn an unnatural system of notation. Because the mercury memory was limited in size and would be needed for actual problem programs, it was decided to perform the necessary conversions from decimal or alphabetic to binary form externally. Thus, the first actual

construction for the ABNER installation was a "stand-alone" decimal-to-binary converting device; it was completed in March 1949. It was later dismantled when the decision was made to build a more sophisticated converter capable of data conversion among several different media. This is discussed more fully below.

(U) By January 1949, it was becoming apparent that NBS engineers were not likely to be able to do the ASA Computer design job in a reasonable time, largely because they were putting a great push on finishing their own machine as soon as possible. In fact, while our engineers were already designing improvements in, and additions to, our original plan, such as automatic accumulation and repetition, the NBS engineers were still resisting, and arguing against most of our ideas. Ashley and Bowman proposed to Mr. Schierlmann and Dr. Kullback that we go ahead and complete our own computer design without waiting for NBS. Permission was granted, with the condition that we not reveal this to NBS, but continue regular contacts with them.

(U) *Instrumentation.* Just as a carpenter cannot begin to function without hammer, screwdriver, and the like, the electronics engineer needs proper tools. And of primary importance is the oscilloscope, his way of looking at and comparing pulse shapes. As the ABNER team was being formed, and began to face the realities of dealing with dynamic serial logic in the speed range of a megacycle per second, it became apparent that the then current scopes being used in our labs, such as the Dumont Model 208, were not adequate. Fortunately, World War II radar developments had brought about new instruments such as the Tektronix-511. These were ordered and soon became the workhorse in the field.

(U) An interesting scope adaptation, made in our own lab, was an ingenious application of the recently-developed "Milisec" relays. One of our engineers worked out the circuitry which made it possible to display simultaneously two pulse shapes and two straight lines (for reference). With such a display, one could adjust timing and voltage levels more readily.

(U) *Components.* In its simplest form, serial dynamic circuitry consisted of a diode gating structure which fed the grid of a 6AN5 pentode vacuum tube (See Fig. 1). The plate of the tube worked into a pulse transformer which drove other gating structures directly or through electric delay lines, depending on the desired timing. At the time ABNER was being built (1948–1951), the principal components required in a megacycle computer using dynamic circuitry were diodes, resistors, tubes, pulse transformers, and delay lines. These were the building blocks out of which the logic structures were to be created. Because in a serial machine streams of pulses were to be combined and switched according to certain rules of binary logic, timing was of paramount importance, and a first requirement was a "clock" pulse. Producing a one-megacycle master clock pulse oscillator was one of Tom Lane's first jobs. Each microsecond was further subdivided into three parts

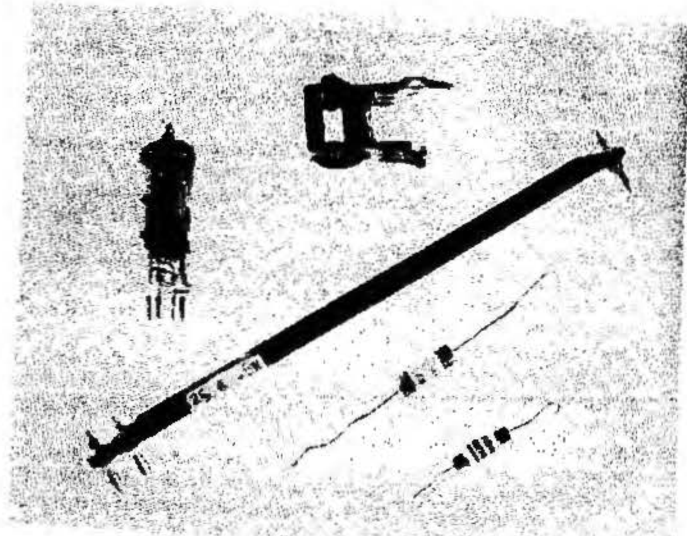

Fig. 1 — ABNER Components

Top to bottom: pulse transformer; pentode, type 6AN5, electric delay line, made by Technitrol Corp. for ABNER (2); Sylvania diode, R7115; Remtron diode, K345.

called "phases," so that the logical designers could assign to phase 1, 2, and 3 the different logic steps into which each instruction might be broken down.

(U) Another critical component in ABNER's dynamic circuitry was the electric delay line. Bell and Robinson early in the project made an investigation of commercial sources. The type more or less readily available was that known as "lumped-constant," which was felt to be too restrictive. That is, for the complex logic involved in many ABNER instructions, it would be desirable to have one finer tuned or with more flexible choice of lengths of delay. The NBS cut lengths of coaxial cable, called Millen line, to achieve this delay, but this was quite bulky. Bell and Robinson decided to experiment with methods of building the "distributed-inductance-and-capacitance" type of delay line. The result was a unique design that had certain advantages: small size, flexible lengths, and satisfactory electrical characteristics. The delay line was made of a polystyrene rod with silver coating containing cuts, or slots, in the silver; around the silver-coated rod was wound fine insulated wire. One problem that caused some setback arose when it was found that the cutting of slots in the silver layer gave rise to

"burrs" or rough edges which scratched through the insulation of the fine copper wire. It was necessary to include a step in the manufacturing process to smooth out the silver surface before winding. The delay lines were made in our own labs by a team under Bell's supervision.

(U) Every ABNER instruction consisted, logically, of circuits that included a number of "gates." Each gate, very simply, was an electrical mechanism for producing an output pulse upon receiving two or more input pulses. The two most common types of gates are "and" gates (deliver an output only if all inputs are present) and "or" gates (deliver an output if any one of its inputs is present). The gates were built up out of only a handful of diodes and resistors. Using various combinations of these gates, circuits were developed to perform standard computer functions, including the following: recirculation, dynamic flip-flop, full adder, complement, binary counter. The complex arithmetic, manipulative, and analytic instructions that made up ABNER's repertoire were created using these and similar circuits.

(U) *Power Supply.* Although not a tool, as is the oscilloscope, the power supply bears a similar relation to the rest of the computer in that all circuits make use of it as an energy source. The power supply in any large electronic equipment must deliver a number of regulated voltages; ABNER's circuits used +200, +120, +62, +4, +2, −5, −8, −10, and −65 volts. At the time our project was getting under way, commercial suppliers were "few-and-far-between," and it was decided we could build our own. William Syphax was assigned the job of designing it. The power supply was completed in September 1950; its several voltages were made available at each ABNER panel by means of open "bus bars" to which necessary connections were made. Unfortunately, maintaining voltage levels within required limits proved to be a problem, and in October 1951 the decision was made to order a new power supply from a commerical source. The new power supply was delivered on 7 November 1951; although bulkier (twelve standard 19-inch open relay racks), it proved quite dependable.

(U) *Memory.* On April 25, 1950, the first half of ABNER memory was delivered by Technitrol. This amounted to the 64 tanks (each was a glass tube 21-3/4 inches long, with inside diameter 3/8 inch, and quartz crystal at each end), electrical circuitry for pulse amplification, reclocking, and shaping, and cabinet. It was our responsibility to clean each tube with detergent and fill it with mercury obtained from a chemical supply firm. Donald M. Rickerson was in charge of this process, assisted by Charles Matthews. Apparently the cleaning and filling process went very well; in only about one in ten attempts was it necessary to repeat the process. A feature of the mercury delay line memory was the solid block of aluminum clamped tightly to the cabinet. This aluminum was important for maintaining a constant 50° temperature, and as we shall see, most of our memory failures were related to temperature variation. Several months later, the second cabinet of delay line memory was delivered and the tanks filled with mercury. Figure 2 is a

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view of one such cabinet, partially completed; positions for 32 delay lines are visible—the other set of 32 are in back and would be accessible from the other side of the cabinet.

(U) *Input-Output.* Consider a relay race: runner number two is poised to receive the baton from runner number one. As runner number one approaches, runner number two begins to move into position; in fact, he accelerates to a speed almost equal to that of runner number one, so that he

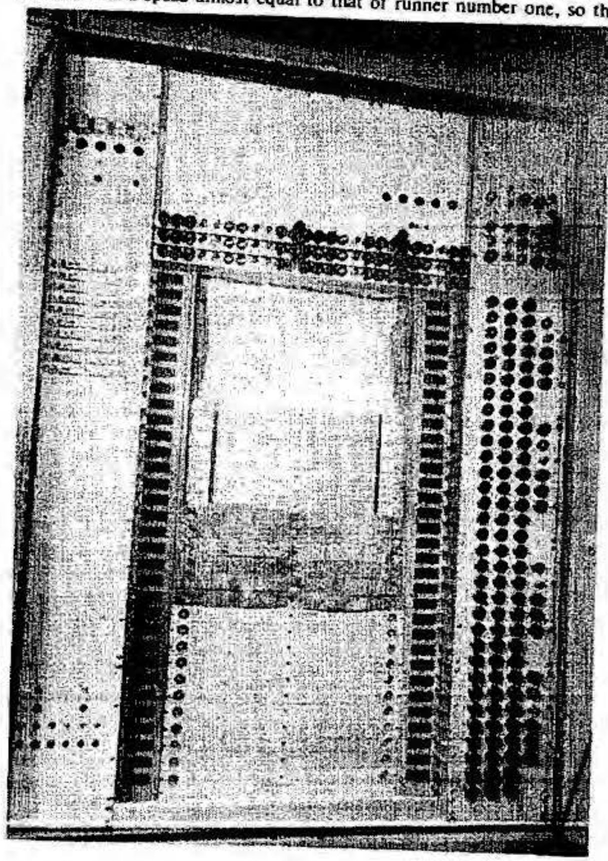

Fig. 2—Mercury Memory

can accept the baton and continue the race with minimum slackening, or loss at transfer. Even if the speed difference at transfer were great, such as two-to-one, the race could be continued. If the ratio of the two runners' speeds were several thousand-to-one, however, the race might be forfeited; at best the acceleration time would constitute a serious loss.

(U) Like the relay race, computer input-output must address the problem of "Interface," that is, the boundary or point where open accommodates the difference in speed between the human's and the computer's normal operating mode. Since ABNER's speed (actual memory recycling rate) was more than 20,000 nine-character words per second, it is easy to see why special provisions were required to take care of the man-machine interface. This interface problem usually has been overcome in two or more stages: typically, a keyboard (operated by a human) produces punched paper tape or punched cards. The tape or card may be "read" at somewhat higher speed and converted to magnetic tape. The magnetic tape can then become direct[1] input to the electronic computer, at still higher speed, and the data or program received and stored in computer memory, where the information is processed at even greater speeds. Similarly for output from computer.

(U) In the case of ABNER, we further compounded the input-output difficulties by deciding to provide maximum flexibility (read that "maximum variety") among input-output media. From the beginning, it was planned to have Raytheon magnetic tape drives; a CXCO electric typewriter and paper tape reader and punch were to be the mechanisms for producing the initial record. It was soon decided to add the capability to read and punch IBM cards, add a Ferranti photoelectric paper tape reader, and acquire a high-speed line printer. Add to this the capability of converting punched cards to magnetic tape and vice-versa, independent of computer operation, and it is apparent that ABNER engineers were putting together the world's most sophisticated input-output capability, as well as the computer with the most advanced logic.

(U) In September 1950 a sub-task was set up, called "Tape Preparation for ABNER," to give needed additional support to ABNER's input-output and conversion problems. In January 1951, William Syphax began work, part-time, on design of circuitry and devices required to put information on magnetic tape from paper tape or punched cards. "Sy" had completed his work on the power supply, and he was required only part-time to supervise its performance as the rest of the computer was being checked out. A converting unit was constructed to serve as a means of making magnetic tape from IBM punched cards. Since it contained its own buffer memory and control circuitry, it could be used to prepare magnetic tape while ABNER

[1](U) Even here, the input from magnetic tape is not, strictly speaking, *directly* received—it must pass through some form of temporary storage ("buffer") before going to internal computer memory.

was in operation. The converting unit could also be used to "input" data to computer directly from punched cards, and also to prepare punched cards as output. A standard IBM Collator was the mechanism for card input (16 words per second) and the output used a keypunch (2 words per second). About the time Syphax and company were designing circuits to operate magnetic tapes, three Raytheon magnetic tape drives were on order. There was some question at first whether the machines would be delivered, but in May 1951 the first magnetic tape drive was received. It was found to have faulty bearings in the capstan drive, and the defective unit was later replaced. A second tape machine came in July 1951, and 12 additional tape drives were ordered, several to be used with other analytic equipment.

(U) During the next several years, most of the effort under this project was concentrated upon attempts to achieve reliable operation of magnetic tapes. Many difficulties were attributed to poor magnetic head design or to mechanical defects in the Raytheon tape drives. Alignment problems were found to be due to poor design of tape guides. The quality of tape itself was one of the most serious difficulties; blemishes and lack of uniformity in magnetic coating were principal obstacles. Not the least of our problems was that we were moving tape at 45-1/2 inches per second (ips), a speed these drives were not designed to attain. In fact, Raytheon's own first computer project, HURRICANE, used the same type of drive at 30 ips in computer operations and only 15 ips in peripheral use. In February 1953, I.E. McElvy and Ed Groff were lent to the section and under McElvy's direction, a new attack was launched which eventually led to success.

(U) Because of the lack of uniform quality of magnetic tapes, each reel had to be inspected and a '"sync" track recorded, which served as a mark to identify "good" places on tape. At each position on tape so marked, the five-bit-wide data could be recorded, and in subsequent use, read into computer memory or rerecorded with changed information. The most serious difficulty was caused by *read-while-write* operation; that is, the machine would read a sync pulse (identifying a good place on tape) and immediately wrote up to five bits of information, physically adjacent to the pre-recorded sync pulse. Unfortunately, the voltages required to record on tape gave rise to "cross-talk" which affected the ability to read the sync pulse. This effect caused prolonged difficulties and resisted many efforts at a solution.

(U) These problems were finally solved by a combination of several strategies. The core windings on the two sides of read-write heads were connected in opposing polarities, thus greatly reducing the impact of the write signal on read transformers. Damping circuits were designed to get rid of residual oscillations. New improved reading heads were designed and built for us. Finally, better tape ("Irish") was obtained from Orradio Co.

(U) Besides the design flexibilities already mentioned, special note should be made of the following capabilities of the magnetic tape system, finally operational after overcoming so many serious shortcomings. It became possible to interchange tapes; that is, tapes written on one machine could be read on a different machine. This system was one of the country's pioneering efforts in this respect. Also, the ability to read and write tape in either forward or backward direction of tape motion, with selective alteration, was a feature still not generally available almost 25 years later.[2]

(U) There were some occasions when producing output printed copy was too cumbersome via CXCO electric typewriter. The ANELEX high-speed "on-the-fly" printer, developed by Anderson-Nichols Company with partial support by NSA, was ready to be tested, so it was decided to attach this equipment to ABNER. Its operation was under program control, as with the CXCO typewriter; setting a manual switch on the ABNER Console determined which mode of output printing was in effect. There were forty print wheels, each containing 26 letters and 10 digits. The wheels were in continuous rotation, and timed hammer stroke selected the character to be printed. Speed was 8 lines per second, yielding an effective maximum rate of 19,200 characters per minute.

(U) *Check-Out.* By September 1951 ABNER construction was far enough along to begin checking out individual instructions. Lane and Rickerson took on this responsibility. Even though much of the computer was still to be built (console, input typewriter, tape reader not yet connected), and the first power supply was far from reliable, they succeeded, on 5 September, in executing a "write" operation into memory. And on 14 September the first operation of the "add" order took place. Within a few days, several other instructions were successfully executed, and on 21 September 1951 our first real program ran successfully! It was a repetitive sequence of "add" instructions together with test for end; it verified our estimates of ABNER's operating speed by executing 60,000 such operations in 1.5 minutes. The *repetition* and *accumulate* features, plus one halt register, were checked out on 27 September, and a few days later all three halt registers ran perfectly.

(U) In October 1951 the console and control table were installed, and wiring connections for CXCO typewriter and paper tape equipment were being made. The first console and control table included unique mechanical equipment for automatically converting four decimal addresses and alphabetic operation symbol to binary form, for manual input of instructions, and also for binary-to-decimal conversion of data and instructions from memory. The mechanical conversion arrangement turned out to be unreliable, and a few months later it was replaced by one using electrical relays. My diary entry for 31 October notes, "Tom succeeded in executing an automatic tape order!

U/[redacted]

[2](U) In addition to McElvy, Groff, Sikes, and Bostick, others who provided valuable assistance in finally getting the magnetic tape drives into reliable operating condition, were Ted Stewart and J.A. Keels. A special appreciation should be expressed for creative contributions by [redacted] on loan to the group.

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information directly into memory!" My brief diary comments in those days only hint at the excitement accompanying each triumph.

(U) *NBS Design Delivery.* On 30 October I received a telephone message from Al Leiner of NBS: they would soon be sending us our ABNER design! We had all but forgotten the Bureau of Standards original agreement—here we were, in test operation of a nearly completed ABNER, and NBS was still promising delivery of their design for a (much less sophisticated) machine for us. It was almost six months later, on 11 April 1952, that Leiner and Sam Alexander finally delivered our computer plans. In a meeting with Kullback, Schierlmann, Ashley, and myself, they unveiled the rather large package. The description of their work was preceded by the statement that they had used up all our money and had finished the job using part of U.S. Air Force funds—we were getting a bargain! After listening to their description of the design details, we then revealed our little secret by letting them see copies of the ABNER Manual, complete with analytic instructions. I proceeded to describe the system details, and concluded by explaining the operation of a program we would be demonstrating on the actual completed machine: a routine to form an idiomorphic pattern from alphabetic text. Needless to say, our NBS friends were shocked and surprised (maybe "dumfounded" is the right word). By this time, of course, most of the analytic instructions had been checked out, but we were not at all sure ABNER would perform for our visitors. We need not have worried—we fed in the tape containing the program, followed by a data tape, and pushed a button: in a couple of seconds the typewriter was banging out perfect results!

(U) *Final Check-Out; Early Operations.* On 25 April 1952, the last analytic order, *cyclic transfer*, was checked out. By this time, incidentially, several full-scale programs were operational. However, programs requiring large quantities of input data and others with fairly massive output printing could not be tried, principally because our converting unit was not completed. We also began to make firm plans and design work for attaching a high-speed printer. Of course, at this time (mid-1952) our magnetic tape system was far from operational. In May 1952 we had gotten the Ferranti high-speed photoelectric paper tape reader into operation; it turned out to be the most reliable and popular input mechanism.

ABNER Serial 2

(U) In November 1950, while we were still toying with improved analytic features for ABNER, Arnold Dumey remarked that he could foresee the need for designing an "ABNER II". It was not until June 1951, however, that formal recommendations for building one or more logic copies of ABNER were forwarded. In March 1952 a Purchase Description was prepared; the official designation of the equipment was "AFSAF D-53." The machine came to be referred to as "DEF-53," or ABNER Serial 2.

(U) The contract was under way in July 1952, providing for a machine logically identical to ABNER(1). By November 1952 Technitrol's experiments with alternate means for constructing delay lines seemed to favor use of quartz instead of mercury as the acoustic medium for ABNER(2)'s memory. It was felt that quartz was less sensitive to temperature variations, and also had the advantage of smaller size and greater reliability, and would eliminate the messy filling problems connected with a mercury memory. By January 1953 the decision had been made to go ahead with the quartz-type delay lines for ABNER(2).

(U) Another change from ABNER(1), proposed in December 1952, was for a small group of memory locations to be built physically apart from main memory, and each individually accessible in a single cycle. A serious preoccupation among ABNER programmers[3] was the placement of instructions and operands optimally with respect to the eight-word-long delay lines of the mercury memory. The new proposal, nick-named "SCAT" memory, would make 16 words available to the programmer without any delay beyond the one-word cycle time. The SCAT idea was well received, especially by programmers, who could plan for their most frequently-needed routines to be placed in these special locations. After some programming experiments indicated that a larger number of SCAT words would be justified, a contract modification was approved, in February 1953, providing for a SCAT feature of 128 words. Other design changes called for the use of 4-phase (as opposed to 3-phase) timing; a set of four "operational plug-in units" for the memory, associated circuitry, and the computer itself; and improved temperature regulation and electric delay line packaging.

(U) Still another important difference between the two ABNERs was in redesign and construction of the console. Whereas the ABNER(1) console emphasized compactness (it was probably the world's smallest electronic computer console), it was the butt of some semi-derisive comments ("What! No flashing lights?"), and possibly a problem area for maintenance engineers. There were also programmers and operators who expressed a legitimate desire for a full-size, desktop operations and maintenance console for ABNER(2) having larger, more flexible controls and displays. Figure 3 is a photograph of the ABNER(2) control desk, and Figure 4 shows the controls diagrammatically.

(U) The final important modification to ABNER(2) was initiated in May 1953, with an amendment to the contract to provide a means for later increasing the size of ABNER memory. To make this possible, the last remaining order symbol ("N") was used. The new memory selection instruction was designed so as to permit specification and eventual utilization of one of four 1024-word memory banks, for each address in subsequent

[3](U) See "ABNER The ASA Computer, Part I," *NSATJ*, 25, 2 (Spring 1980).

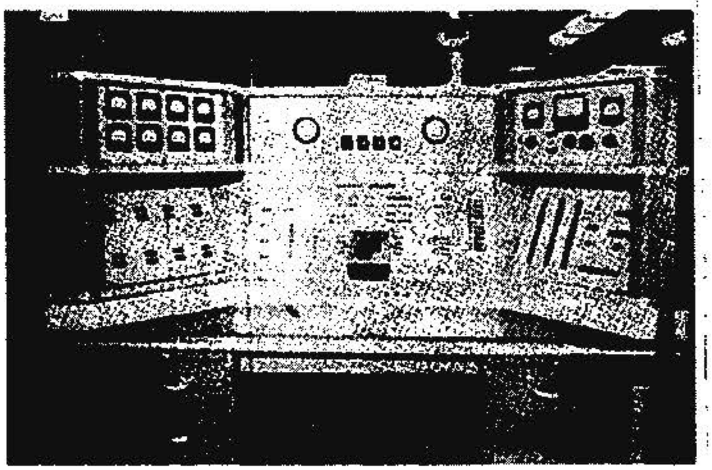

Fig. 3 — ABNER(2) console (U)

instructions. As implemented and delivered, ABNER(2) had 2,048 words of quartz delay lines, including the 128-word SCAT memory.

(U) By October 1954 (the original estimated delivery date was September 1954), testing at the contractor site indicated several more months would be needed. Finally, trucks and vans arrived and unloading began. On 9 May 1955, installation of ABNER(2) in B Building at Arlington Hall began. Getting the machine assembled and working properly proved to be extremely troublesome. Perhaps the best remembered problem was the "flooding" beneath the main computer cabinets. Because the air-cooling was at times excessive, there was so much condensation from the humid environment that water collected in puddles. One of the first emergency steps taken was to buy and install a sump pump. After Technitrol baked the electric delay lines to reduce short circuits caused by moisture, machine operation improved sufficiently to pass R/D acceptance tests (November 1955).

ABNER OPERATIONS

Programmer Training

(U) As the ABNER design approached its final stages, plans were being made to train programmers in anticipation of the use of ABNER for operational jobs. Also, there was growing interest among Agency analysts and management people in the new ABNER computer because of its special emphasis on cryptologic processes. To satisfy this interest, I was asked to

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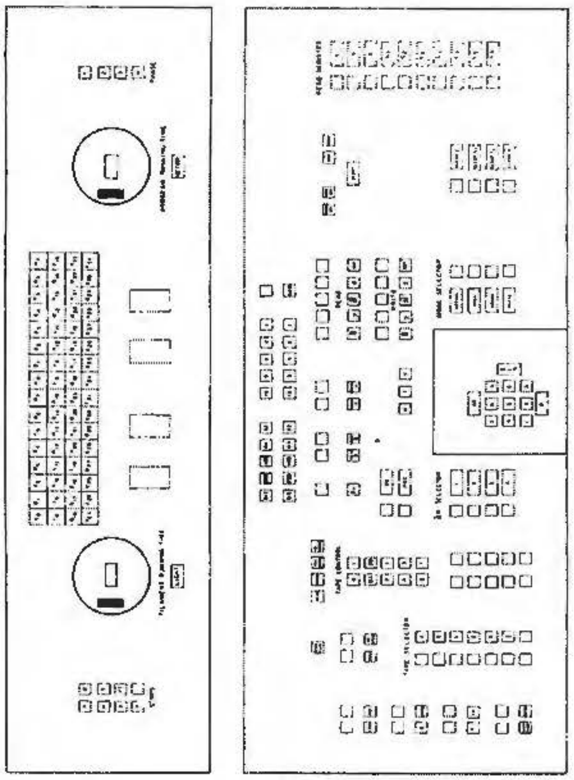

Fig. 4 — ABNER(2) controls (U)

conduct a seminar on use of computers in cryptanalysis. I gave the first lecture on May 9, 1949; other speakers included May, Lathroum, and Rixse. The talks were given three times a week, until June 13, 13 sessions in all. About 35 analysts from operational units of the Agency attended. In addition to such scheduled sessions, we had numerous informal meetings with, for example, mathematicians and others from the Navy group responsible for ATLAS, including, in January 1950, Dr. Howard Engstrom and Commander Steinhardt of Engineering Research Associates (ERA), and Dudly Buck. Frequent meetings with Dr. Campaigne, Dr. Cramer, Captain Pendergrass and others served to keep the two groups abreast of developments.

(U) The next stage in our expansion came with acquisition in February and March 1950 of Lucien G. Berry and James M. Willard. After some preliminary training, "Luke" began maintaining a file of commercial computer characteristics, which could have become (with financial backing and aggressive outside promotion) the world's first computer characteristics clearing house. Unfortunately for our clearing house idea, we needed Luke more urgently for ABNER business, and the file was discontinued. Luke developed into a skilled computer operator, data conversion specialist, and programmer-analyst. Jim Willard, originally engineering trained, became a first class programmer. He learned to program both ATLAS and ABNER, and wrote several operational ATLAS programs before shifting over to engineering aspects of R/D's computer developments.

(U) During the next year or so, our section really began to grow, with arrival in June 1951 of Paul Smith, and of Betty Jean Buckley and Janet Salt in October 1951. With Betty's addition, the group took on the appearance of, and began to earn the respect due a permanent and professional computer organization—she was our first secretary.

(U) In 1952 our programming effort was significantly strengthened. Joan Gaffny (McDonald) arrived for duty in January, Mary M. Gadson (Taylor) in February, James Pederson in April, and Navy Ensign Edward "Ted" Friend in November. After only a few weeks' training, Joan began to make valuable contributions, starting with diagnostic programs, and later several large-scale data processing and cryptanalytic programs (ARC, ORIOLE, TURTLE, KEVIN). Joan's TURTLE program was the instrument for scoring a significant cryptanalytic success. Mary Gadson wrote several large-scale cryptanalytic programs, including RAIN-D, which is remembered particularly well by Mary because for several weeks after its completion, she had no success in debugging it. Finally, when the trouble turned out to be due to a machine-logic error, we all rejoiced with Mary, who felt her professional reputation to be intact. Jim Pederson's start in our section was unique, in that he was sent to Waltham, Mass., while still awaiting full security clearance, to participate in a programmers' training course offered by the Raytheon Corporation. Among the ABNER programs he worked on later was SAIL, a high-speed wired-rotor decipherment program which was one of

the first programs that utilized magnetic tapes successfully. Jim left the Agency in September 1959 to join Control Data Corporation in Minneapolis, where he has been ever since. Ensign Friend wrote several of the subroutines for our first "library" or so-called Series 2 routines. However, his principal contribution was a comprehensive study of sorting methods, and completion of a rather ambitious ABNER program to perform generalized sorting of large volumes of data, using magnetic tapes. Vera Shaffner (Russell) joined our group in August 1954, and soon became a dependable programmer. Vera wrote programs that tested the new Random Jump instruction by using it to generate random key. She also wrote diagnostic programs, and spent some time revising existing ABNER programs by optimizing for minimum access.

[redacted] In the period before ABNER was transferred to the Production Organization, several PROD people were detailed to our group for training and production programming. During this same time, a group of senior Agency analysts who were also Army reservists took their periods of active duty assigned to learn ABNER programming. In June 1953 the following officers began one such assignment: Bill May, Lambros Callimahos, Dale Marston, David Wagner, Albert Highly, and Arthur Levenson; Bill May, of course, was already an experienced programmer. He and Callimahos collaborated in producing the LAMBCHOP program for monome-dinome side-coordinate determination, later used operationally in PROD.

[redacted] In 1952-53 several mathematicians from Dr. Campaigne's mathematical research group were detailed in our group to learn ABNER programming. Of these, we have a record of a program called "AFSAW-7200 Counts." This program produced a series of statistics to evaluate or assess the randomness of one-time key tapes, each 10,000 characters in length. And a Lt. Johnson wrote LOON, a program designed to detect instances of key re-use by statistical and coincidence tests. Lt. Johnson also assisted a PROD programmer, Lt. John Richards, in producing HAYSTACKS, described below.

Early Operational Programs

(U) In October 1950, the first group of people from the Machine Division (AFSA-22) of the Office of Operations, John Powers, Joe Hyduke, and Dorothy Blum, was given introductory briefings on the ATLAS computer, including programming principles. Of these, only Mrs. Blum spent considerable time working with us. She collaborated with John Rixse on a rather ambitious ATLAS program, BLUEBIRD. Other people from AFSA-22 who got their start on ABNER included Lt. John Richards, William Hooker, John Young, Lt. Larry Michels, and Emory Coil. Lt. Richards' program HAYSTACKS was one of the first large-scale jobs that ran on ABNER in the spring of 1952, soon after ABNER was checked out. This program, which examined pages of key in a search for certain cyclic characteristics,

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had been in successful operation for about a year when a logic "bug" was discovered in one of its rarely exercised subroutines.

[redacted] Bill Hooker was responsible for producing several ABNER programs, including BICYCLE and DETOUR, [redacted] MAILBOX, [redacted] and SCARF, an experimental combinatorial analysis job. John Young wrote several ATLAS programs, and for ABNER wrote the DASHBOARD [redacted] and RAG MOP, [redacted] Lt. Michels produced a specialized sorting program intended to be used as part of a COPPERHEAD job [redacted] Mr. Coil's programs included ARTICHOKE, [redacted] CHATTERBOX, a ciphony key generator study, and PECAN, [redacted] In connection with PECAN, the following quotation from the September 1956 PROD Monthly Operational Summary is pertinent: [redacted]

[redacted] Of the PROD programmers who became ABNER specialists in the early 1950s, probably the two most enthusiastic were L. Russell Chauvenet and Richard A. Bentley. Both found the special analytic features of ABNER most fascinating, once their complexity and variability were mastered. Dick Bentley was responsible for the programs SHOWDOWN, FARO, CZAR, LABYRINTH, MAZE, WALNUT, RENO, and SUICIDE. Several of these programs (CZAR, MAZE, RENO, LABYRINTH) were among the Agency's earliest efforts in "diarization" of high-level systems. FARO made particularly good use of ABNER's unique forward and backward movement capabilities of the magnetic tapes.[1] Russ Chauvenet wrote JONQUIL, VITAMIN, and NIMATIV. The PROD Monthly Operational Summary for March 1954 contains the following references to one of these programs: [redacted]

(U) Perhaps the first use in ABNER of automatic program selection came about as the result of a suggestion by an ABNER operator, later turned programmer. Jim Bostic noted that programs which were routinely retained for reuse involved clumsy storing, filing, and manual retrieval of punched paper tapes. His suggestion was for use of the Raytheon magnetic tapes as library; each reel could hold many programs. Bostic wrote a program, MASTERMIND, that automatically assembled many paper tape programs,

[1](U) In the August 1977 issue of *Cryptolog*, Russ writes interestingly of his ABNER experiences.

together with identification and the means for retrieving a desired program for ABNER operation.

[redacted] *STETHOSCOPE*. ABNER's most spectacularly successful program, STETHOSCOPE, followed from a casual conversation between Frank Lewis and myself, early in June 1953. We were discussing the well known (but still fairly new in 1953) capability of general-purpose computers to follow sets of instructions faithfully, once they had been prepared and checked. We felt that one class of cryptanalytic operations that might be ideal candidates for such computer treatment was the initial diagnostic tests which are typically applied to cipher texts of unknown systems. We decided to discuss the idea with other analysts and programmers, and on June 17 Frank and I met with Ted Leahy and Bill Lutwiniak; I brought with me three of our experienced ABNER programmers; John Rixse, Lt. Wilbur Peterson, and Lt. Jerry Kimble. At the meeting it was decided that, as a first step, Lewis and I would plan an outline of the kinds of cryptanalytic operations to be undertaken. Within the next month Frank had a chart that began with [redacted] Rixse had assigned Kimble and Peterson to program several of these routines. On October 15, 1953 the first successful test run of STETHOSCOPE was made on ABNER. The following month, the STETHOSCOPE program was demonstrated for George Hurley and several other cryptanalysts from PROD, using a known test message and one unknown message. During the next few months, additional routines were being added to the STETHOSCOPE collection. [redacted]

(U) When the first successful demonstration of STETHOSCOPE on ABNER was made in October 1953, George Hurley was among the first to sense its power and future possibilities. He proceeded to launch a campaign among PROD managers and cryptanalysts which soon took on the flavor of a one man crusade, spreading the STETHOSCOPE gospel to all potential users. George gave talks at meetings of various machine planning panels, as well as among individual PROD operations and management people. In addition, he made constructive suggestions for additions and improvements to STETHOSCOPE. Paul Oyer soon joined with George, not only presenting for cryppies the present power and future possibilities of STETHOSCOPE, but also taking the lead in drafting much of the written record.

(U) By the summer of 1954, STETHOSCOPE was considered operational, and thanks to Hurley, Oyer, and others, was more and more frequently used. But the method for specifying and assembling particular tests for each STETHOSCOPE run were still primitive and cumbersome. To overcome these problems and to expand the diagnostic capabilities of STETHOSCOPE, a new project called LULU was begun. Its purpose was to develop a compiler that would automate the construction of a program from a set of small subroutines as specified by a user in a higher-level language. This was a bold step because not even assemblers existed at that time. In the fall of 1954, Bill Cherry (from Operations) began the development by creating a set of "utilities"—program dumps, trace programs, selective traces, and the like.

(U) Another essential feature that would be required before a true compiler could operate was a relocator. Bill found this part of the job particularly challenging because ABNER's order code, more than other computers, was sprinkled with "addresses" that were not true addresses, but rather groups of bits varying from 1 to 10 each, which in effect extended the order code. In October 1955 Bill attended a short course of instruction in UNIVAC's A-2 Compiler, given by Grace Murray Hopper. The A-2 was probably the only operating compiler in existence, and Bill's attendance at that course enabled him to make some improvements in the ABNER compiler system under development. The finished product, LULU (also called AVAC Compiler), was enthusiastically received. For the first time, it became possible for the programmer to employ a higher-level language to specify and assemble, from magnetic tape storage, any desired set of pre-coded routines in the STETHOSCOPE library. In fact, LULU enjoys the distinction of being the first locally developed operational compiler in use on any computer at NSA.[5]

(U) In 1957 a major revision of STETHOSCOPE was made, called SUPERSTETH. Its principal improvements were in greater capacities (alphabet size, volume of data sets), enhanced capability to generate other streams of data from input streams, and additional more sophisticated statistics. For convenience, a sponsor could make selections from the library of routines, using the SUPERSTETH Rebus, together with sets of Rebus schedules, called "prescriptions." The ABNER SUPERSTETH program was written by Don Wood and Jim Bostic. SUPERSTETH was also implemented on other computers, including ATLAS II.[6]

Operations and Maintenance

(U) By December 1952 ABNER was being run several nights per week by PROD personnel plans were formulated for a team of PROD operators and maintenance people. Mr. Robert Lyons was to head up a maintenance team, to be assisted at first by Bob Winter of the R/D maintenance engineers. The date of 5 January 1953 was set for regular swing shift operation, under supervision of R/D. Several full-time ABNER operators were also being trained.

(U) Those first few evenings of swing shift ABNER operations were exciting. During the first evening Dr. Kullback, R/D Chief, telephoned to inquire how things were going. The program ORIOLE was run, with only slight difficulty. The next few nights were almost 100% trouble free, with successful runs of HAYSTACKS and tests of other programs. During the next few months much useful work came from ABNER, including successful runs on the RAIN-C, JONQUIL, BICYCLE, ORIOLE, and SCOOT programs. Also, the programs RAIN-D, SNAIL, and 5X5 Matrices were being readied for operational use. The percentage of useful time (of total available for operations) was as follows:

January 1953	79%
February	(*)
March	83
April	91

(*) Lower operational record due to Ferranti tape reader voltage fluctuations; trouble soon corrected.

(U) In May 1953 transfer of control of ABNER operations during swing and graveyard shifts to PROD was "... accomplished smoothly, reflecting the good training and close cooperation ..." between R/D and PROD.[7] The regular day shift was reserved for R/D engineers' continuing modifications and tests, including installation of magnetic tape drives, card reader, and high-speed printer.

(U) Bob Lyons headed the team of MPRO maintenance engineers and technicians; Lou Morgenweck, AF Sgt Stan Stoddard, and Navy Chief Fred Elliott were among the earliest members of the team. For more than a year (from mid-1951), this team of MPRO engineers worked alongside the R/D people who were building the machine. They performed at all levels, helping install coaxial cables, making diode gates, and checking tubes. Of course, this was valuable experience in view of the complexity of ABNER. As later noted by Dick Bernard [17] ABNER "... came close to being a maintenance nightmare." This, of course, was a direct result of the fact that ABNER was literally a "breadboard" machine. In fact, as we have said, additions and modifications continued to be made by R/D engineers during one shift each day, after the equipment was being used operationally.

(U) After the computer was turned over to MPRO for the two night shifts, one of the first projects undertaken was to inspect all germanium diodes in ABNER's memory circuits. During the four weeks required, about 20% of the diodes were replaced, and a marked improvement in operational

[5](U) Bill has documented LULU in his "AVAC Compiler Manual" [12], and also "Combinations of Routines in LULU Library," 25 Jan. 1957, [13]. Also, in 1961, Paul Oyer prepared a description of the STETHOSCOPE programs, designed to assist prospective new STETHOSCOPE users [14].

[6](U) SUPERSTETH has been documented by Paul Oyer, George Hurley, W. Rue Murray, and Edwin Hughes [15, 16, 17].

[7](U) PROD Monthly Operational Summary for May 1953.

efficiency was noted. To assist in isolating sources of malfunctions, a "Dictionary of Operands" was created; this served to supplement the R/D engineers' own catalog showing all possible variations of each of the instructions. Besides the lack of hardware or software diagnostics, there were instrumentation problems. Oscilloscopes adqeuate to observe and correct timing problems, for example, were not at first available. Special external circuits were designed and fabricated which in effect provided a delayed sweep capability. These circuits were the predecessors for the delayed sweep feature which is now on all oscilloscopes. Gradually, the MPRO maintenance team, with help from R/D engineers, was able to get control of the situation. One of the steps taken towards alleviating the pressure was the setting aside of a portion of time each day for preventive maintenance. Marginal checking of the ABNER memory began in December 1953, and was later extended to the whole machine. In August 1953 a second magnetic tape mechanism was being installed, and the converter was successfully used for punched card input to ABNER in an operational job. Also, about this time two standard service routines were in operation for printing and punching out the decimal addresses and letter operation symbols for any selection of consecutive memory locations. By December 1954 a modification was completed making it possible to read paper tapes containing 6- or 7-level coding directly into ABNER. And magnetic tape was used successfully on two operational ABNER programs. Preparation of accurate magnetic tapes for use on ABNER had been among the difficult problems, requiring changes in reading heads and much adjustment of the tape transports. By April 1955 an average of one 8,000-block magnetic tape per day was being made, with 100% accuracy. On 1 August 1955 ABNER was officially turned over to PROD. By December 1955 several steps were being taken to increase its operational time including effective control of preventive maintenance and allocation of blocks of time for checkout of new programs. As a result, available time for ABNER operation was up about 25%.

(U) In February 1956 a modified Remington-Rand line printer was connected to the ABNER Converting Unit, for use with ABNER(2). The R-R printed 10 lines per second, with up to 120 characters on a line. This completed the installation of ABNER's auxiliary equipment, making it now possible to print from the Converter information from a magnetic tape drive, IBM Card Collator, or from ABNER itself. A little later (September 1956) the converting device MAYBE was completed. It could be used to (1) print from ABNER magnetic tape on line printer, (2) convert from punched paper tape to magnetic tape, and (3) convert punnched cards to paper tape. In June 1957, MPRO accepted ABNER(2).

(U) The various modifications being made by R/D engineers and technicians, plus adjustments and repairs, occupied so much time that ABNER(2) had not given much productive operation when, in October 1957, it was disassembled and moved to Fort Meade. (ABNER(1) of course had not been

designed for relocation, so it was dismantled soon after.) After the move to Fort Meade, ABNER(2) actually performed more reliably than before the move. This was, of course, the cumulative result of the series of modifications and additions, some of which we have described, and also partly due to better tools and more experience gained by engineers and operators. But by the end of 1959, the computer engineering art had improved so much that it was no longer worth the effort to keep ABNER running, and the machine was retired in February 1960.

IMPACT

(U) A favorite exercise among writers of history is to speculate, with the benefit of hindsight, on "what might have been." Such an exercise is not often useful, but on occasion may be educational.

(U) As a sometime writer on computer history, I am often inclined to wonder about the direction the computer industry would have taken (the first few years anyway) if the first modern machines had been planned in response to the needs of business instead of the military (ENIAC's ballistics computations). Or, if this Agency's machine planners had gone a step beyond our World War II Bombes and the like (which were really large-scale data processors and statistical analyzers), and had come up with the first stored-program devices, we might have designed an ABNER-like machine five or ten years earlier. That is to say, if the first applications of stored-program electronic "things" were non-arithmetic (or non-mathematical), we might be calling them "analyzers" or "information handlers" instead of computers (how about "datalyzers"?).

(U) As a practical matter, I'm not sure that computer history would have been much different; after all, UNIVAC I was designed for the Census Bureau. But I have felt all along that their ability to compute at "out-of-this-world" speeds was secondary, as far as innovative contribution is concerned, to the computer's revolution in logical organization: the stored-program, the discrimination-type instructions. Let me hasten to acknowledge the vital contributions of our engineer friends who came through with high-speed circuits and components, as well as the well-known memory and input-output developments just in time for the computer revolution.

(U) Even though ABNER was a "breadboard" machine, and its operating record did not match that of some of the machines that were delivered by commercial computer developers, it did perform well enough to produce useful results in vital cryptologic situations. Further, it was the darling of those programmers who were attracted by its many housekeeping and cryptologic shortcuts. It was these aspects of the ABNER experience that justify a special place in our historical record. ABNER's repetition feature was the immediate ancestor of that feature in both ATLAS II and BOGART, as well as their respective commercial counterparts. And the electronic comparators DELLA and CICERO grew out of, or were Ray Bowman's inspirational follow-ons from ABNER's "swish" instruction. Even more striking, the HARVEST Streaming Units may be said to have been based on the same ABNER feature.

(U) Probably of more significance to the outside computer world, although not generally known in time to have much impact, was ABNER's immensely flexible complement of input-output features:

(1) ABNER was the world's first electronic computer that could compute simultaneously with input-output.

(2) Blocks of words to be read from or written on magnetic tape could be either consecutively numbered or individually addressed words in memory.

(3) Direction of tape motion could be forward or reverse.

(4) Block size on magnetic tapes could vary, in multiples of eight words.

(5) Output printing could interpret each word's set of nine characters as being read in forward (right to left) or backward (left to right) direction.

(U) Of course, as we have said earlier, the very comprehensiveness of its many input-output options was impressive if not unique: conventional paper tape reader and punch; photoelectric paper tape reader (315 characters/second); IBM card reader and punch; four magnetic tape drives operating at about 250 words per second; output typewriter; high-speed printer (Anelex on ABNER(1), eight 40-character lines/second, Remington-Rand line printer on ABNER(2), ten 72-character lines/second.) In addition, it was possible to convert data among the above media, simultaneous with computation, using the Converting Unit, as well as enter or read out data manually from the Console, binarily, decimally, or biliterally.

(U) Not much has been said about software for ABNER. In fact, programming was done at machine-language level. But NSA's first operating compiler was developed for LULU, the outgrowth of STETHOSCOPE. And of course SUPERSTETH built on and expanded this still further.

(U) Finally, as in most large innovative developments, a great impact was felt in respect to the personal and professional growth of all those involved in ABNER—the planners, designers, builders, programmers, operators, maintainers—even the administrators whose "yesses" came through when needed! We who were associated in this pioneering effort in a pioneering industry can look back on one of the most rewarding experiences that can come to anyone, and we are thankful for the support we all enjoyed.

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