tion of combined experience in weapon control and digital technology.

5) The techniques for obtaining reliability in a digital computer are fundamentally the same as for any other electronic equipment of similar complexity. The principles for obtaining reliability of military electronics equipment through sound design, testing, and production controls are now fairly well established and should be applied to the fullest extent in new computer designs.

6) Careful attention should be given to systems engineering in the development of a weapon system employing digital computers to ensure that all system components are designed so as to minimize conversion of information between analog and digital forms.

7) Careful consideration should be given to logical design to obtain optimum simplicity of equipment design. Analog techniques should be employed for mechanizing functions where they are best for the purpose.

In closing, I would like to emphasize that they who are working in this relatively new field of digital computers have a great obligation in the defense of the country.

Many of the computing devices which are being designed are absolutely essential to military weapons and weapons systems, and they will become progressively more important as the capability and complexity of these systems continue to advance.

Although the challenge of making these new devices sufficiently reliable to be acceptable for military applications is great, there is a substantial background of knowledge and experience in reliability engineering to draw upon.

I see no reason why these new devices should not be completely reliable as they first become available to the using military services. If they are not, the future of digital computers for the dynamic control of weapons may be seriously affected.

Computers with European Accents

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The same company has recently announced a complete data processing system called the GAMMA 60 which includes a central processing unit with magnetic corestorage. The peripheral equipment includes magnetic drums, magnetic tape units, both card and paper tape readers and punches, lined printers, etc., all under internal stored program control.

Professor F. C. Williams of Manchester University has made many contributions to the computing art, perhaps the most well-known being the cathode-ray storage system to which his name is customarily attached. He has gathered around him at the University a small group of very competent men who have made and are continuing to make substantial contributions. The main location of the Ferranti Company happens to be in Manchester, and, as one might expect, a cooperative arrangement has developed in which Ferranti contributes to the support of a computer project at the University. It profits, in turn, by the developments made there, and manufactures commercial computers embodying some of the University's developments. Several machines of a first design, known as the MARK I, have been made and are in operation at such diverse places as Toronto, Canada, and Rome, Italy. This computer was followed by the MARK I STAR, and more recently the Ferranti Company has announced a new large-scale computer known as the Ferranti MERCURY Computer. This is a high-speed computer, using floating point, with a

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1024-word core memory, a 16,000-word drum, and 7 index registers and is quite comparable with the larger machines made in this country. A weakness of this, as well as of nearly all other European computers, is its dependence on punched paper tape as the primary input and output medium. This observation may, however, be biased because no one in the United States appears to have produced paper-tape equipment equivalent to that manufactured by the Ferranti Company. Several MERCURY machines are being constructed at the present time. One of the first machines is to go to Manchester University. A second is to go to the Norwegian Research Institute for Defense; a third will be installed at a Computing Center now being planned for the University of London, while Oxford University is getting a fourth. Mr. Brian Pollard, who is in charge of this activity at Ferranti, tells me that they have orders for 17. Altogether, there are some ten different industrial concerns in Great Britain making computers and they are reported to have orders for over 84 large computers on their books at the present time.

During the same symposium, Mr. Bill Elliott covered up a similar display of the letter “F” on the Ferranti PEGASUS Computer, or FPC, by saying that it stood for “Fast.” Incidentally, the letter “P” originally stood for “Package.” This was later changed to PEGASUS when the Ferranti Company waxed poetic and decided to name all of their computers after stellar constellations.

The Ferranti computer FPC I (to differentiate it from the FPC 3, a commercial version) is an amazingly fast computer in terms of its ability to get work done, although it is basically a small, fairly low-speed machine. These computers are currently being produced; 30 are on order, 2 have been delivered to customers, and one has been installed in a company-operated Computing Center at 21 Portland Place in London.

Most of the machines of Europe are binary rather than decimal. For example, the Swedish Board for Computing Machinery, after first building a relay computer called the BARK, later designed and built an electronic machine called the BESK. As originally built, the BESK was a 40-bit, parallel, asynchronous computer using Williams tube storage; in concept, very much like the Princeton machine.

However, here the resemblance ends. The construction details, the exact circuitry, and all the many different features which give a machine its character were distinctly original. Some of the more original features of this machine are the use of a dielectric paper tape reader which operates at 400 characters a second, and an unusual record for economy in the use of vacuum tubes to achieve the desired results with, of course, an astounding record for reliability. They quote figures like 85 per cent good time on a three-shift basis.

For years the Swedish Board for Computing Machinery has been living on year-by-year appropriations, not unlike the situation confronting certain government-supported activities in this country. Possibly for this reason the situation became critical roughly a year ago and almost the entire engineering staff left in a body and joined an industrial organization known as Atvidabergs Industries. Dr. Havermark tells me that the present staff consists of 35 members, these being 13 mathematicians, 11 engineers for running and maintenance, 3 keypunch operators, and 8 employees for general administration. This group at Atvidabergs is now busily engaged in building a copy of the BESK to be called the FACIT which will form the nucleus of a second computer center in Sweden. This machine is an exact copy and, consequently, incorporates all of the improvements which have been made to the original BESK in the last three years, such as the use of a 1024-word magnetic core memory. In addition to this work at Atvidabergs, the BESK is being copied elsewhere in Sweden and in several different places in Europe. The Svenska Aeroplan AB, known as the SAAB, had, prior to the trouble at the Board, arranged to build a copy for their own use to be called SARA. Another, to be known as the SMIL is under construction at the University of Lund, although this is a stripped down version without core storage.

The Danish Academy for Technical Science is planning a copy of the BESK for their Institute of Computing Machinery, which is to be called the DASK. The Board for Mathematical Machines of the Royal Norwegian Council for Scientific and Industrial Research has also been considering a BESK to supplement the small magnetic drum computer called the NUSSE which was completed in 1953. However, the most recent information seems to indicate that the Norwegian Defense Research Institute is purchasing a Ferranti MERCURY and this may obviate the need for a BESK.

Over-all developments in Europe are following an amazingly similar course to that pursued in the United States, with some striking differences in timing. Many of the earlier machines were built by schools, others by government laboratories—perhaps rather more in proportion than here—and very few by industry. These machines were all plagued by difficulties of completion similar to those experienced in the United States. Recently, industrial concerns have been entering the field in Europe so that there are appearing a number, or are shortly to appear a surprisingly large number, of different machines, some of which are decimal.

Elliott Brothers in Great Britain had early exploited the possibilities of using nickel delay lines for storage and had built a computer known as the NICHOLAS using these lines. As a result of this work, this company was commissioned by the NRDC (the National Research Development Corporation) to build a small computer. This computer, known as the 401, was unique at the time, for its use of a limited number of differently designed package units. After making three copies of the 401, the Elliott organization has gone ahead with a more pretentious design for commercial applications.
which is now being marketed as the 405 series of machines and for which there are said to be a dozen orders.

Having successfully launched the PEGASUS and the 405, the NRDC is now turning its attention to commercial data processing assemblies, with the word “assembly” used advisedly.

It has contracted elsewhere for the design of an all-transistor-driven core logic and core-store data processing assembly in which the main feature will be a marshalling yard for information external to the computer. The strategic object of this will be to provide a device to which a number of independent keyboard operators can send information in an uncorrelated fashion. This is still in an early stage.

The main preoccupation of the Manchester University group at present is with the input-output facilities of the computer which, as I have indicated, follow European rather than American practice. For example, the Manchester Group has found that a fair proportion of the results printed by their MARK I computer had to be subsequently plotted. They are, therefore, building a cathode-ray plotter which is 80 per cent completed. This plotter uses a 9-inch tube for visual observation and a second tube to be photographed by an automatic camera. Each coordinate of the beam is specified by the least significant 8 digits of a 10-bit word, thus providing a 256 X 256 array of dots which may be used.

Not content with this unit only, they are also building a roughly 10-inch square electroluminescent matrix panel which will plot an array of 512 X 512 points using the power law voltage characteristic of the phosphor to provide the discrimination. They hope to use direct contact photography for recording.

For high-speed numerical output, they are building magnetic tape units which operate at a maximum rate of 1000 characters a second, each character consisting of five binary digits. The magnetic head actually consists of two heads, one for writing and one for reading, separated by 20 mils, the read head being of the static reading variety. Characters are recorded on the tape at a fixed packing density of 50 per inch independent of the tape speed.

Using this same magnetic reading head, they are also constructing a tape editing unit entirely transistorized, with an input power of less than 10 watts, which can be used at teleprinter speeds of approximately 6.7 characters per second.

Turning to storage devices, the Manchester group has obtained a magnetic tape drive unit built by the Pye Company which drives the tape in either direction at a maximum speed of 100 inches a second. They intend to use addressed records, each containing 1280 digits, with the records sequentially addressed and provisions being made to exclude automatically imperfect regions of the tape.

This group is also turning to evaporated ferromagnetic films as a storage medium and they have built an evaporation unit which has all necessary facilities for rotating large substrates at elevated temperatures, etc.

The Manchester group attaches a great deal of importance to its autocoding system which they expect will virtually replace direct coding at a maximum expense for the worst possible case of a factor of 2 in computational speed. They have written a translation program which they liken to the IBM FORTRAN system and they are attempting a general program which will automatically solve any linear second order partial differential equation by finite difference techniques. All in all, this is quite an ambitious program for a small group at a University, but this is the way things are done in England.

Professor Wilkes at Cambridge University built the first modern stored-program computer in England, known as the EDSAC I. This computer is still in operation after many years of useful service, but its days are now numbered, since Professor Wilkes and his able associates are in the midst of building a second computer, the EDSAC II. In fact, that portion of EDSAC II which has been completed has been linked up with a temporary decoder using an abbreviated order code, and this is actually operating. Since this is a portion of the II machine, and since like all machines only 80 per cent completed, Professor Wilkes, in the true British tradition of understatement, calls this machine EDSAC 1.5. Professor Wilkes’ group has programmed and has in operation an interpretative routine which will accept program codes for EDSAC I and will execute them faster than they can be run on EDSAC I. A problem in stellar structure is in process on EDSAC 1.5 which is similar to the problem that Hoyle and Haselgrove have just been doing on a 704 in Pasadena.

EDSAC II uses the microprogramming technique in its decoder which came out of the Cambridge work and has been described in the literature. The computer employs a rather unique packaging arrangement in which all of the components for each stage of the arithmetic unit are contained in one pluggable unit. Forty of these units are used to make up the 40-bit accumulator and a substantial number of the same units are used in various other parts of the machine. In terms of order complexity and speed, this machine compares favorably with the better commercial machines. The EDSAC 1.5 will remain in its present form for two or three months when they will begin to install the EDSAC II control matrix.

Professor Biermann of Gottingen is an astrophysicist, and he and his able technical leader, Dr. Heinz Billing, at the Max Planck Institute, have built a series of computers known as the G1, the G1-A, the G2, and now the G3. The G1 is a small drum machine and has piled up an impressive record of 28,000 hours of operation with 82.3 per cent of this as useful time. The G1-A, a modernized version of this machine, is ready for its trial runs. This machine is controlled by photoelectrically...
read paper tape. Their second machine, the G2, has also been in operation for some time, although it is at the moment down for a general overhaul. However, the G3 is currently of the greatest interest. This is a parallel 40-bit binary machine with floating point arithmetic, designed, as were all of the Gottingen machines, for scientific computing. It will have a core memory for 4096 words and will have adequate indexing features for automatic address modifications. Incidentally, this machine uses a whole word for each instruction, thus reversing the previous practice almost universal in Europe up to now of following the Institute for Advanced Study's practice of confining each instruction to a half word. Wired microprogramming is to be extensively applied in this machine and they are, at the moment, entirely revising their projected order code in an attempt to make it especially efficient for the use of computer programs.

The Max Planck Institute Computer group in Gottingen is shortly to move to Munich. This will make Munich quite an important center as far as computers are concerned since one machine, the PERM, constructed at the Munich Institute of Technology, is already located in this city.

The PERM, a parallel magnetic drum machine, is a cooperative venture between the Electrical Engineering Department under Professor Piloty and the Mathematical Department under Professor Sauer, now Chancellor of the Institute. This is a fine example of a fast drum machine which, with some projected improvements, will become a very good machine indeed. Their drum, which runs at 15,000 rpm, is extremely quiet. At the moment they are just recovering from troubles with the contacts on their pluggable units, these being ordinary tube sockets which had to be replaced—quite a formidable task for such a small group.

One other group in Germany deserves special mention, this being the Institute for Practical Mathematics at Darmstadt under Professor Walther. Their machine, the DERA, a magnetic drum machine operating in floating decimal, is complete as far as construction is concerned and is now going through the final debugging stage. This group has also recently acquired a commercial machine of American design but manufactured in Germany. Work at these three places in Germany has been supported by the German government. A much larger number of universities are shortly to get computers of commercial manufacture. Some of these will be of foreign design, some even of foreign manufacture, but a substantial number of German firms are currently entering the computing field.

The firms of Siemens and Halske in Munich, and Standard Electric of Stuttgart (actually an affiliate of an American firm) are reported to be building transistorized computers. Two firms of the A.E.G. group, Olympia-Werke at Wilhelmshaven, and Telefunken at Backnang, are developing electronic computers. The firm of Zuse KG in Hunfeld, after a successful experience in producing relay machines, is now accepting orders for their Z-22, an electronic computer, about equal to its G1-A.

The ERMETH Computer which was designed at the Swiss Federal Institute of Technology is also a magnetic drum machine, decimal with floating point, which is currently running with a 400-word drum, although ultimately intended to operate with a 10,000-word drum which is currently not in operation because of magnetic head difficulties.

In Holland the Mathematical Center under Dr. van Wijngaarden and the P.T.T. have done work that is particularly worthy of mention. At the P.T.T. a group under Dr. van der Poel has designed a drum computer, called ZEBRA, based on the principles published by Dr. van der Poel. The S.T. & C. organization in England is building several of these machines; the first one should be completed during the next few months. Dr. van der Poel's ideas were quite novel when first proposed, and have been used in the Zuse machine.

There are some transistorized computers in Europe, such as the all-transistor machine built by E. H. Cooke-Yarborough at Harwell in England. There are perhaps a half a dozen other places in Europe where transistor computers are in operation or in an advanced stage of construction. Most of these are rather small experimental machines, and almost without exception they are rather slow by American standards. Transistor production in Europe has lagged behind that in the United States. This is particularly true with respect to high-frequency units, and this lack of transistors has inhibited their extensive use.

There are many other machines that should be mentioned, for example, the work done in the government laboratories in Great Britain, such as the National Physical Laboratories. Their first attempt, known originally as the ACE, was used as a basic design for the machine now being manufactured by the English Electric Company as the DEUCE. Meanwhile, the N.P.L. is going ahead with a new ACE machine which will be several times as fast as the DEUCE.

Europe is perhaps behind the United States in computer developments and we need fear no immediate reversal in relative positions. However, there are many clever people in Europe; they have a tradition in England of achieving a lot with a little, in Germany of thoroughness, and in France of mathematical intuition, to name but three countries. These people are not going to permit us to continue in undisputed mastery of this expanding field. We can expect many new ideas to come from Europe. European accents, this time in computing, may again be heard in this country. European concerns, particularly those in England and in Germany, are known to be looking with envious eyes to the American market and it may not be long before they are offering their wares at prices which will be highly competitive.