Applications of Small Digital Computers in the Aircraft Industry

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THIS paper will begin by defining small computers. Just what are they?

The *650*, the Datatron, the Elecom, and others that were once regarded as small computers have now been promoted to an intermediate class by the introduction to the market of a much smaller group.

This new small class is comprised of two main types. One type is binary and has an internally stored program, and the other type is decimal with an external program. The first type is of the same philosophy as the large computers; a coded language and the same programming techniques are used.

The other type of small computer is decimal and uses an externally stored program. The second type has its instructions stated directly. The instructions do not have to be put into coded form. This is the type of small computer to which the paper will refer most frequently.

Charles Adams has classified computers as being large, small-large, and large-small. The first type just mentioned would be in the small-large category as it is similar to the large computer. The second type would be in the large-small category as it emphasizes simplicity and ease of operation.

Now, if one were going to write the specifications for a small computer for everyday work, just what would be emphasized? The computer should certainly be simple. If it is difficult to use, one might as well continue to solve one's problems with a desk calculator, or slide rule, or however it is being done now. It should also be easy to operate, so that no special training would be needed in order to use it. One also might like to have combined with this ease of programming and ease of operation, all the latest powerful features of the large computers. These are the objectives of the small computer manufacturers. Judging from the experience of the authors' firm we feel these objectives are being met.

The Burroughs Corporation had an interesting experience in its first contact with the aircraft industry. A section properties problem had been analyzed and it was felt that it was better for it to be left on their large computer because they could do in 1 minute what took us 15 minutes. They said, "The real problem is in communication and scheduling. We have to get a messenger to take the data to our computation center, then it has to be programmed, punched and verified, scheduled for the computer, run off, printed in a form that the engineer can interpret, and finally sent back by a messenger. That takes easily a day and sometimes 2 days. We're planning on having a small computer in each engineering design area, so they can do their small problems directly." That company, by the way, has ordered three more small computers since the first one was installed.

Section properties calculations present a classical problem that involves calculating centers of gravity and moments of inertia of irregular-shaped bodies. The operations to determine these on a small computer involve merely entering the successive points in the keyboard. One would go through the same motions one would go through in punching data into cards but with a small computer one would have the answers almost immediately after one had finished entering the data.

In some cases data may be supplied on punched paper tape or punched cards. For instance, telemetered data are received directly on tape. Another company with which the author's firm is working is transmitting missile test data by teletypewriter from its test station located on the East Coast all the way across the United States to its engineering center. There it will be fed into the small computer with a punched paper tape-reader attachment. The computer will reduce the data, print the results, and ultimately will punch a tape to be fed into a plotter. The equations involved in the data reduction are quite simple and a large computer would be wasting its time.

Many readers are no doubt familiar with this type of data-reduction problem, as distinct from the more complex type which involves numerous table look-ups and a large number of operations. This same company has a large amount of flight-test data reduction work being done. When the authors visited them about a year ago, there were over 100 girls carrying out the detailed steps on desk calculators. Much of the computational work is on their large computer, but the work these girls were doing is of a nonroutine nature that would require reprogramming the problem each time it was run.

The type of work sheets that is usually set up for girls to follow is familiar. There are several columns on a sheet, perhaps 10 or 20, and the operations to be carried out are shown at the top of each column. For example, one might have the numbers in columns 1 and 2 given, column 3 might be column 1 multiplied by column 2, and column 4 might be the square root of column 3, etc. This company is planning to have its computer girls, some of the same girls that are now using the desk calculators, set up their problems for the computer directly from the work sheets. The memory locations used could correspond directly to the column numbers and the operations are simply add, subtract, multiply divide—a language with which they are already familiar. When trigonometric

Fig. 1. General view of Burroughs E101

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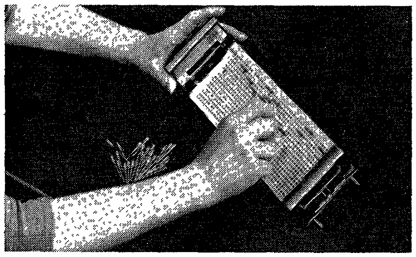

Fig. 2. The pinboard. Eight of these make up the flexible external program

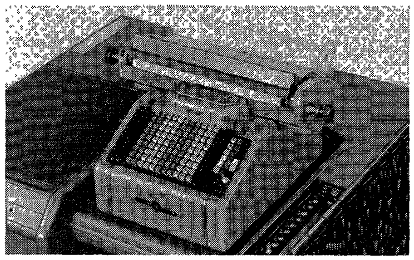

Fig. 3. The Burroughs Sensimatic flexible format input-output unit

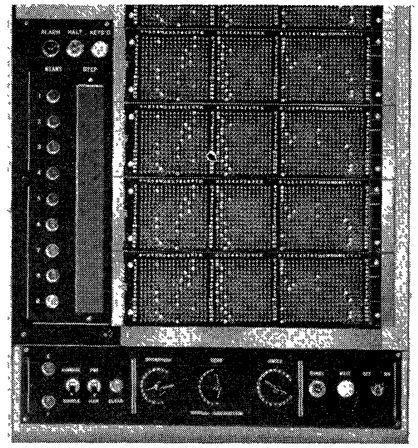

Fig. 4. The operator's control panel

functions, or any other subroutines are used, the girls would tell the computer to go to the subroutine, say sin x, after which it would automatically return to the next step in the problem.

A company near Philadelphia, Pa., inquired regarding matrix multiplications. It was set up on the pinboards in 11 steps and run. Two engineers from the company came in, learned to program and operate the computer, programmed their own problem, checked it out, and obtained a set of results in less than one day. The same thing could be done by using automatic programming routines on large computers, but it can be done on this small computer using its basic language directly.

Figs. 1–4, showing the Burroughs *E101*, will give a better idea of what is meant by small computers. This is quite typical, as far as size is concerned, of most of the small computers. As mentioned before, they all emphasize simplicity, ease of operation, and low cost.

Fig. 1 shows the entire computer not including the tape reader. The machine is about 38 inches deep and 60 inches wide, or about the size of an ordinary office desk.

The instructions or operations to be performed are set up on the pinboards on the right. There are eight separately removable boards, each with 16 steps.

The memory is a magnetic drum, and is located directly beneath the program unit. Its storage capacity is either 100 or 220 12-digit numbers plus sign.

Data are entered either through the full keyboard, or through an optional tape reader. The input-output unit shown is the Burroughs Sensimatic bookkeeping machine that has been modified for electrical input and output. With it there are all of the powerful format control features that are necessary for the bookkeeping operations under control of a separate panel that is mounted directly beneath and moves along with the carriage. It could be referred to as a format panel.

The electronic arithmetic unit and electronic control circuits are in the back section. This is one of the few machines that operates in straight decimal. For instance, the digit seven is represented by seven out of a possible nine pulses.

The power supply is on the left. It uses only about $2^1/_2$ kw and operates on the same power as most electric ranges.

The operator's control panel is on the right.

Fig. 2 is a close-up of a pinboard. The left-hand section specifies the operation and the second and third sections, the address or memory location. For instance, to perform the instruction "add the number in memory location 27 to the number in the accumulator," a pin is put under "plus" in the first section, a pin under "2" in the second section, and a pin under "3" in the third section. All of the instructions are equally as simple. A paper template is usually marked showing where the pins are to be inserted. The template is then placed over the board and the pins inserted where indicated. The paper templates can be filed for future use.

Fig. 3 shows the input unit. With the full keyboard it is as easy to enter numbers as it is in a desk calculator. There are four motor bars, all of which cause the computer to operate but have different control over the format. Printing is at the rate of 2 12-digit numbers per second. Continuous rolls of paper can be used or individual preprinted forms can be inserted from the front. Masters can also be prepared directly which simplifies reproduction of the results.

Fig. 4 shows the control section. The controls are very simple. Normally the operator presses the electronic clear button, then one of eight start buttons telling the computer where to start in the problem. The computer can also be operated one step at a time. It can also be set to manual operation and will perform that operation set up in the manual switches. The manual operations can also be under control of the push buttons on the keyboard. Indicator lights on the back of the operator's control panel are for checking circuits, also to show in what state the computer is. The power switch and associated wait and ready lights are at the right. That gives a general idea of what the small computers are like. Now some more of the applications that have been found in the aircraft industry will be discussed.

In Los Angeles, Calif., in the fall of 1955, a demonstration of conic lofting on the Burroughs small computer seemed to impress aircraft companies more than any of the other problems. The part of conic lofting demonstrated involved determining the coefficients of the equations of the curves formed by the percentage points between successive sections. It involves dividing an airfoil into percentage lines from the leading to the trailing edge. At each percentage line the co-ordinate points for the top and bottom of the airfoil are given along with various slopes and other known data. What is wanted is to obtain the coefficients of a curve representing that surface. There are 17 algebraic equations to solve and 8 keyboard entries. The total time for each point including the entry of data was 1 minute and 15 seconds. This was not too impressive because there might be from 50 to 100 per cent (%) lines per section, but the aircraft people were extremely impressed. Their delay at present is in scheduling the problem for their large computer. It takes at least a day before they get the results back from the computation center. Again, scheduling as well as communication is the big time factor. The conic lofting group, by the way, has the full support of their central computation laboratory to obtain their own computer because it is the small problems such as conic lofting that bog down the large computer. The preparation of the data alone exceeds the computation time on the large computer.

In December 1954, a session on small computers was held at the Eastern Joint

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Computer Conference. Emphasis was placed on use of the small computer for checking programs for the large computers. That is actually being done now at the first installation of the Burroughs *E101*. They are doing sample calculations on the small computer to check against results from their large computers. They were previously performing the calculations by hand and found they were invariably erroneous. They found they were using the large computer for checking their hand calculations as it necessitated printing all the intermediate results from the large machine. With the simplicity of programming a person familiar with the problem can set it up for the small computer and obtain a set of check calculations in less time than it takes to perform one calculation by hand. The small computer is not being used to interpret the codes literally, as was predicted at the Eastern Joint Computer Conference, but rather to perform the check point calculations.

There is another way in which small computers are being used to aid the large computers. If, when formulating a problem one is not quite sure the equations derived will give him what he wants, one would perhaps sit down at a desk calculator, crank out the answers, make a change in the formulation, then try it again. Would not a small computer be a handy tool for this work? Many trial runs could be made with minor changes in the formulation each time by merely changing a few of the pins and pressing the buttons. Then once the problem is formulated, one could put it on a large computer and let it carry out the multitude of repetitive solutions. Of course, the same thing could be done by using automatic programming routines for the large computers, but there is still the scheduling problem. It is not economical to tie up such power equipment while one is essentially at a loss. One would certainly feel more at ease if one knew it was costing closer to $5.00 an hour than to $300.00 an hour.

The research group of a company in Philadelphia recently requested a small computer from their management. Management said, "What do you need a small computer for when we already have a large computer that will solve your problems?" The person from the research group replied, "That's just the trouble, we don't know what our problems are. We need a small inexpensive computer to help us in the formulation of the problems."

Now what the small computer can do for smaller companies as well as departments in large companies will be considered. Many small aircraft companies neither have economic justification for a large computer, nor the problems to keep it busy. Even though the large computer is more economical per unit of operation, a small computer would be better suited for these companies. There is an engineering company in Wilmington, Del., with less than 400 employees, including production and clerical staff, that is using one of our small computers for the design of arresting mechanisms on aircraft carriers. They are using it for many other engineering problems, but this is the major application. In the first week they had the computer they checked the hand calculations for a design that was ready for production. They found the plane would still be traveling at the rate of 30 miles per hour when it was supposed to be stopped. This could have been a costly error if it had not been caught until the final test. In one morning, for example, they ran off four of their design calculations. They estimated that these calculations would have taken 4 weeks by hand.

One of the first users of the small computer made a survey of the engineering problems in his organization. He found that 50 per cent could be done most efficiently on a small computer such as is being discussed, 45 per cent would be most efficiently done on an intermediate size computer, and only 5 per cent on a large computer.

In order to give a better idea of how people are planning to use these small computers, here is a breakdown by type of customer:

50% are companies that do not now have computers.

20% have large computers and are using the small computer independently.

30% are planning to use the small computer along with their large computer as an aid either for checking out problems, or doing parts of problems to be fed into a large computer, or just to keep the small problems off the large computer where they cannot be solved efficiently.

The breakdown by line of business is also very interesting.

30% are in the aircraft industry.
10% in business.
10% in banking.
8% chemical and pharmaceutical.
12% optical industry.
12% engineering.
6% research.
2% oil industry.

In summary, small computer manufacturers are emphasizing simplicity, ease of operation, and low cost. The major role of small computers in the aircraft industry appears to be:

1. To reduce the high percentage of communication and scheduling time associated with running small problems on large computers.

2. For the formulation of problems.

3. As an aid to large computers for performing check calculations and for checking programming techniques, and

4. For small companies and departments of large companies that do not have a work load for a large computer.

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