# TO WHOM IT MAY CONCERN

My name is Paul Pierce. I collect old computers and related items. My background is in computer software, specializing in operating systems, a discipline that typically requires in-depth knowledge of computer hardware. I studied at the University of Wisconsin from 1972 to 1979, receiving a Bachelor's degree in Electrical Engineering and a Masters in Computer Science. During that time I used the computing facilities there including machines in the keypunch room of the academic computing center, which included an IBM 407 accounting machine. I worked at Intel Corporation most of the years from 1979 until 2002. From 1985 to 1995 I worked in the Supercomputing Systems Division, where I became familiar with aspects of scientific computing. In 2002 I retired to concentrate on my collection. The collection includes IBM 650, IBM 709, IBM 7094 complete computer systems and several IBM print-wheel printers, including the 407 accounting machine and 716 and 717 line printers. In addition the collection includes extensive documentation for all of these machines, including user manuals, maintenance information and schematic diagrams. None of these machines is currently operational. With one exception noted below, all of the historical information presented here is based on recent study of the materials in my collection.

**IBM print-wheel printers**

IBM manufactured a series of machines using a print-wheel mechanism, which has 120 individual print wheels, one for each character position on a line, spaced at exactly 10 characters per inch. These machines share a characteristic font style and spacing characteristics. The spacing is very precise for a line printer, with nearly perfect horizontal positioning, due to the fixed horizontal position of each print wheel, and very good vertical position,  due to the slow speed of the wheel at the time of printing.

Probably the most common of the print-wheel machines was the type 407 accounting machine (accounting machines were also called tabulators), which was originally developed to prepare reports from punched cards. IBM punched cards contain 80 columns of information on each card. The 407 could also be attached to a 650 computer. There were some other 400-series accounting machines with the print-wheel mechanism, for the purposes of this report they all seem to be equivalent. One common use of the type 407 (this is from my experience, it is the exception mentioned above) was to simply make listings of card decks. This was sometimes referred to as 80/80 list, because the machine was set up with the 80 card columns wired to 80 adjacent print positions, so each card was listed on a separate line. This was the purpose of the type 407 in the keypunch room at the University of Wisconsin computing center in the 1970's.

Two other print-wheel machines were the type 716, which was directly attached to the 704, 709, 7090 and 7094 scientific computers, and the type 717 which was either attached to the 705 commercial computer or could be used alone to print from magnetic tape which was written by any of these computers.

The print-wheel machines were fitted with a "tape-controlled carriage" to handle the paper, typically a type 922 or 923 with an F-2 tractor feed. The carriage and tractor feed was usually set to feed 6 lines to the inch. The paper came in continuous forms, with holes along the sides for the tractor feed and perforations between pages. In scientific computing people commonly used paper 14 7/8 inches wide, with pages 11 inches long. The carriage is capable of precise vertical and horizontal adjustment, so that printing could be lined up with boxes on specialized pre-printed forms. The tractors could be loosened to move freely horizontally, to accommodate different widths of paper and roughly position the paper. There are knobs for fine adjustments, in both vertical and horizontal directions. This feature was not typically used in scientific computing, so that forms printed on different machines or even at different times on the same machine (after a new box of paper has been loaded) do not typically line up.

The 400-series accounting machines had a number of options, to increase their capacity to create complex reports or to handle unusual forms such as labels. Nowhere in the materials in my collection is there any mention of a clock device that would keep track of the time and date, either as a standard feature or as an option.

**The IBM 650 computer**

The type 650 [5,6,7,9] is a decimal machine with a 10-digit word. That is to say, it did all of its calculations in a decimal numbering system instead of the more common two's-complement binary system, and the standard range of numbers it could handle is from -9999999999 to 9999999999. To increase this range for scientific work, there was software to perform arithmetic in a floating point number system, which corresponds to scientific notation. IBM also manufactured optional hardware to do this. There are a number of different implementations described in documents in my collection (e.g. [8, 9]). Many used the same number format except for the position of the decimal point in the mantissa (the fractional part) and the order in which the mantissa and exponent were stored in a 10-digit word. This common format consists of a 2-digit exponent of 10, with an offset of 50, and an 8-digit mantissa with the decimal point either between the leftmost two digits (as in scientific notation, seen in the early 650 floating point library software) or to the extreme left (as is common practice today in binary floating point, seen in the hardware floating point option for the 650.) So for example, in this form the number 123.456, which is in scientific notation $1.23456 \times 10^2$, would be stored as mantissa 12345600 with exponent 52 or 53, depending on where the decimal point is in the mantissa. These numbers were usually printed with the 8-digit mantissa first followed by the 2-digit exponent (still with its offset of 50) as a compromise between readability and the amount of code (or control panel wiring) needed, so this example would be printed as 12345600 52 or 12345600 53.

The IBM 650 was extremely slow by today's standards, and quite slow compared to other larger computers of its day. It has a magnetic drum main memory, so that the timing of the computer is determined by the mechanical speed of the drum, which is 12,500 RPM. IBM's other scientific computers of the time (the 704, 709 and 7090) have magnetic core memory that operates at electronic speeds. For scientific calculations the 650 was a factor of 100 to 1000 or more slower than those larger machines, depending on whether the hardware floating point option was installed.

The basic 650 consists of the computer cabinet, a cabinet containing the power supplies, and a type 533 card reader and punch. To run a problem on the basic computer you would keypunch your code and data onto punched cards and combine these with cards containing any library software needed, placing the combined deck in the card reader. You would then operate the switches on the computer to make it go, and it would read the cards and punch the results into new cards. You could then take the punched deck to, for instance, a type 407 machine wired for 80/80 list to print them out.

The optional equipment for the 650 included a 537 card reader and punch that punches the results onto the same cards it read, a way to attach a 407 so that results can be printed directly, various electronic options (including the hardware floating point option) to enhance its computing ability, and tape drives or a disk drive. Nowhere in any of the material I have is there any mention of a clock that keeps track of the date and time, either as a standard feature or as optional equipment.

**Comments on the materials provided**

The materials provided to me include the following on which I will comment: Xerographic reproductions of two pages of printed listings [1,2], a page explaining some of the numbers on one of those pages [3], and a 1994 paper by Richard H. Battin [4]. In particular, on page 6 of the paper is the following paragraph:

> It was very exciting indeed when the double fly-by finally worked. A large number of iterations on the IBM 650 had been required. The initial conditions for each iteration had to be key-punched and inserted in the card-reader. The output was produced on punched cards which then had to be listed on an IBM tabulator. The trial failed if the spacecraft were required to fly beneath the surface of either planet to obtain the necessary energy exchange to carry it to the next planet.

Note that this paragraph describes the normal operating procedure described above for a basic 650, one without a directly connected 407 printer or tape drives.

The first of the two pages of printed listings contains a single line of text as follows (not to scale), occupying 106 character positions.

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92656 TIME CONVERSION          0000 01-26-61                                        24
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The second of the two pages of printed listings contains the following text, occupying 63 character positions. Underneath the printing is written "Double reconnaissance trajectories."

```
14440000 52 -63260000 54 -12628000 55 -50510000 54  30000000 51
43077363 50  28253000 55  26980000 54  33500000 53  20000000 51
             20000000 50  50000000 50
14870774 52  23564000 55  15771000 55 -12740000 54  20000000 51
39494105 50  19624000 55 -17633000 55  17900000 54  40000000 51
             20000000 50  40000000 50
15265715 52  16713000 55 -20418000 55  17360000 54  40000000 51
43479526 50 -40370000 55 -73030000 54  18360000 54  30000000 51
```

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             20000000 50  50000000 50
81000000 51 -79070000 54 -13922000 55  39850000 54  30000000 51
41961776 50  29837000 55  11640000 54 -63130000 54  20000000 51
             20000000 50  50000000 50
85196178 51  23529000 55  18335000 55 -64530000 54  20000000 51
54542003 50  60610000 54 -14285000 55  29570000 54  40000000 51
             20000000 50  60000000 50
90650378 51  86590000 54 -13164000 55  11150000 54  40000000 51
89504715 50  39120000 55  51200000 53  28390000 54  30000000 51
             20000000 50  10000000 51
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From the font and the precise spacing it appears that both pages were printed on IBM print-wheel printer(s).

The first page is more than 80 characters wide, so it is unlikely that it was printed from punched cards. The tabulator could have been wired to print something (e.g. a page number) outside the area printed from the cards, but this does not appear on the second page. Thus it is reasonably certain the pages were not produced in the manner described.

Using scanned images of the two copies I evaluated the average horizontal distance between characters and the alignment of characters with respect to the left edge of the paper, which was faintly visible in the copies. I used the single printed line on the first page, and the first and last lines on the second page. I found that the standard deviation of character position on a line from the perfect 10 characters per inch spacing was about 5% of character width. This indicates the accuracy with which I estimated the centers of different digits. The difference between the average character position on the first line of the second page to the average corresponding character position on the last line was only about 1%. However, the difference between the average position (with respect to the paper edge) of the characters on the first page and the average position of the closest corresponding characters on the first line of the second page was 25% of character width. It is difficult to say how accurate this is because the page edges were not distinct. However, if this analysis is accurate it shows that the two pages could not have been printed one after the other as described, because the characters do not line up one above the other between the pages nearly as closely as they should for this type of printer.

The first page contains the phrase "TIME CONVERSION". I did not find that phrase in any of the materials in my collection that I studied for this exercise. Since the 650 does not have a clock, it is no surprise that I did not find any reference to time and date headings on the output of 650 programs. I have seen such headings on 7094 output, but the examples I have do not say "TIME CONVERSION".

**Observations on the numerical listing**

In this section I will make some observations about the numbers listed on the second page, based on observable properties of the numbers and my understanding of some basic principles of scientific computing. One thing I will attempt to determine is which of the numbers might have been input or initial conditions to the computer program and which might have been output produced by calculations in the program. It was and is common practice in scientific computing to reproduce input values next to the resulting output values, in order to document all of the values involved and clearly identify which output values are which.

In scientific computing using floating point number representation there is a common effect where during the course of non-trivial calculations a sort of numerical residue spreads throughout the digits of the mantissa. In decimal arithmetic this is directly apparent as a sequence of mostly non-zero digits at the left end of the mantissa. The amount of residue tends to increase in all the basic operations of addition, subtraction, multiplication and division. In some rare instances of multiplication it will decrease if the two factors contain a lot of 2's and 5's as prime factors. Usually however the numerical residue decreases only when subtracting two numbers that are very close in value.

The amount of apparent numerical residue in a floating point number can indicate whether it is an input or output value. Input values, if prepared by a person who understands their meaning, will typically contain a limited number of non-zero digits to avoid typing digits that have no meaning. Output values will typically be filled with mostly non-zero digits unless the very last operation producing the value was a subtraction of numbers close in value, then the amount of non-zero digits will vary arbitrarily. There is a special case for small integers (whole numbers, with no fractional part) used to control a calculation. These are typically involved in separate calculations where they remain small integers, so it is hard to tell whether they are input or output. They play a side role and are not typically the primary useful result of a scientific calculation.

The numbers in the listing on the second page are in the characteristic form used for floating point numbers with the IBM 650. To interpret them, it is necessary to decide whether the decimal point is at the far left of the mantissa or one digit in. Referring to the explanation page supplied and comparing numbers there with some of the numbers in the listing, it appears the decimal point would be at the far left. With this assumption, the numbers listed on the second page correspond to the following numbers in more conventional form.

| | | | | |
|---|---|---|---|---|
| 14.44 | -6326. | -12628. | -5051. | 3. |
| .43077363 | 28253. | 2698. | 335. | 2. |
| | .2 | .5 | | |
| 14.870774 | 23564. | 15771. | -1274. | 2. |
| .39494105 | 19624. | -17633. | 1790. | 4. |
| | .2 | .4 | | |
| 15.265715 | 16713. | -20418. | 1736. | 4. |
| .43479526 | -40370. | -7303. | 1836. | 3. |
| | .2 | .5 | | |
| 8.1 | -7907. | -13922. | 3985. | 3. |
| .41961776 | 29837. | 1164. | -6313. | 2. |
| | .2 | .5 | | |
| 8.5196178 | 23529. | 18335. | -6453. | 2. |
| .54542003 | 6061. | -14285. | 2957. | 4. |
| | .2 | .6 | | |
| 9.0650378 | 8659. | -13164. | 1115. | 4. |
| .89504715 | 39120. | 512. | 2839. | 3. |
| | .2 | 1. | | |

In transcribing the numbers above I have removed rightmost zero digits from the mantissas while observing apparent consistencies in the numbers, to help show where there apparently is and is not a quantity of numerical residue. The numbers appear to be in groups of three lines, in the first two lines of each group the numbers in each of the five columns have similar characteristics. The numbers in the last line of each group seem similar to each other but not to the other numbers in the group.

Considering the first two lines of each group, only the numbers in the first column seem to be usually filled with a full 8 digits of numerical residue. These would seem to be the output values of a calculation. The numbers in the middle three columns, which match the numbers in the explanation sheet under the heading "Relative Velocity Vector Components", all seem to be integers regardless of the number of non-zero digits, and so are most likely input values. The numbers in the last column are small integers and so likely to be control values. The numbers on the third line of each group are mostly fractions with only one non-zero digit, and so are most likely input values.

**Summary**

Based on my experience and on study of the materials in my collection, I have the following comments and observations on the materials presented to me, in particular, the two pages of printed listings.

Both pages appear to have been printed by an IBM print-wheel printer.

The pages were not prepared in the manner described in the paper, because the single line on the first page is too wide.

The pages were not printed together in one run, because it appears the characters do not line up vertically between the two pages.

The first page normally could not represent a date heading produced by an IBM 650 because the 650 did not have a time of day clock.

The second page appears to contain numbers in the form used with the IBM 650.

Of the numbers on the second page, only the numbers in the first column appear to be the output of calculations on an IBM 650.

I declare that all of the above statements are true and made under the penalty of perjury under the laws of the state of Oregon.

Paul R. Pierce — 6/30/03

Signed — Dated

State of Oregon

County of Multnomah

Paul R. Pierce
2933 NE 17th Ave.
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Subscribed and sworn/affirmed to before me this 30th day of June 2003, by Paul R. Pierce

Mayumi S Shimada

Notary Public

Feb 8 2005

OFFICIAL SEAL
MAYUMI S. SHIMADA
NOTARY PUBLIC-OREGON
COMMISSION NO. 342872
MY COMMISSION EXPIRES FEB. 8, 2005

References / Attachments (9)


1. Xerographic copy of a first page of printed listing.
2. Xerographic copy of a second page of printed listing.
3. Page of explanation, "Double Reconnaissance Trajectories", June 6, 2000.
4. Battin, R. H., "On Algebraic Compilers and Planetary Fly-By Orbits", 45th Congress of the International Astronautical Federation, October 9-14, 1994.
5. IBM, "650 Data Processing System Bulletin - General Information, Console Operation, Special Devices", Form G24-5000-0, 1958.
6. IBM, "650 Data Processing System Bulletin 533 Card Read Punch, 537 Card Read Punch, 407 Accounting Machine", Form G24-5001-0, 1958.
7. IBM, "650 Data Processing System Bulletin - Basic Operation Codes, Program Optimizing, Program Loading", Form G24-5002-0, 1958.
8. Battin, R. H., O'Keefe, R. J., Petrick, M. E., "The MIT Instrumentation Laboratory Automatic Coding 650 Program", from IBM Technical Newsletter No. 10, October 1955, proceedings of a Computation Seminar held in the IBM Department of Education, Endicott, New York, August 1-4, 1955.
9. IBM, "650 Programming Bulletin 7 - Floating Decimal Arithmetic on the IBM 650", Form 32-7675, 1957.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 14440000 | 52 | -63260000 | 54 | -12628000 | 55 | -50510000 | 54 | 30000000 | 51 |
| 43077363 | 50 | 28253000 | 55 | 26980000 | 54 | 33500000 | 53 | 20000000 | 51 |
| | | 20000000 | 50 | 50000000 | 50 | | | | |
| 14870774 | 52 | 23564000 | 55 | 15771000 | 55 | -12740000 | 54 | 20000000 | 51 |
| 39494105 | 50 | 19624000 | 55 | -17633000 | 55 | -17900000 | 54 | 40000000 | 51 |
| | | 20000000 | 50 | 40000000 | 50 | | | | |
| 15265715 | 52 | 16713000 | 55 | -20418000 | 55 | 17360000 | 54 | 40000000 | 51 |
| 43479526 | 50 | -40370000 | 55 | -73030000 | 54 | 18360000 | 54 | 30000000 | 51 |
| | | 20000000 | 50 | 50000000 | 50 | | | | |
| 81000000 | 51 | -79070000 | 54 | -13922000 | 55 | 39850000 | 54 | 30000000 | 51 |
| 41961776 | 50 | 29837000 | 55 | 11640000 | 54 | -63130000 | 54 | 20000000 | 51 |
| | | 20000000 | 50 | 50000000 | 50 | | | | |
| 85196178 | 51 | 23529000 | 55 | 18335000 | 55 | -64530000 | 54 | 20000000 | 51 |
| 54542003 | 50 | 60610000 | 54 | -14285000 | 55 | 29570000 | 54 | 40000000 | 51 |
| | | 20000000 | 50 | 60000000 | 50 | | | | |
| 90650378 | 51 | 86590000 | 54 | -13164000 | 55 | 11150000 | 54 | 40000000 | 51 |
| 89504715 | 50 | 39120000 | 55 | 51200000 | 53 | 28390000 | 54 | 30000000 | 51 |
| | | 20000000 | 50 | 10000000 | 51 | | | | |

Double reconnaissance trajectoire.