IBM Stretch (aka IBM 7030 Data Processing System)

What Was Stretch?

In April of 1955, IBM submitted a bid to the University of California Radiation Laboratory (UCRL) to develop the Livermore Automatic Research Computer (LARC). IBM was not able to commit to as rapid a delivery as UCRL desired, so instead proposed a more powerful machine. In May, UCRL rejected IBM's bid, instead awarding the contract to Remington Rand.

Stretch operator's console in foreground; one of the CE consoles partially visible on left, and another in background.

Starting in May of 1955, IBM proposed development of high-speed memory ("Silo") and a high-performance computer ("Plantation") for the NSA. But the NSA was not likely to purchase a computer until 1957, so IBM decided to try selling a supercomputer to other customers. In August the supercomputer project became known as "Stretch."

IBM feared that Los Alamos Scientific Laboratory (LASL) might order a LARC, but in September of 1955 made a preliminary proposal to LASL which was received with interest. IBM began design studies, and starting in November of 1955, a series of "Stretch Memos" proposed the development of a computer with performance "100 to 200 times the 704". Project Stretch was formally initiated in January of 1956.

LASL formally sought bids in January of 1956, and IBM submitted a proposal in February. IBM was awarded the contract in November.

As a result of the Plantation study, in February of 1957, the NSA set forth the requirements for a system called "Harvest," using high-speed tape and handling streams of data for non-arithmetic processing.

Due to limited resources, it was desirable to develop a common system rather than three different machines for LASL, the NSA, and commercial sale. A comittee determined that a "three-in-one" system could meet the goals "with the possible exception of price." But by 1958 the three-in-one plan ran into trouble, and the system was substantially redesigned. In January of 1959 assembly of the first Stretch engineering model began.

The goal of 100 times the performance of a 704 was quite aggressive, given that the performance of the logic circuits increased by only a factor of ten to twenty, and memory performance by only a factor of six. Architectural improvements such as extensive use of parallelism were required to meet (or even approach) the goal.

The Stretch project drove advances in many key computer technologies, including core memory, transistor circuit design, and circuit packaging. For the first time, many architectural tradeoffs were determined through the extensive use of a simulator, written by John Cocke and Harwood G. Kolsky. Stretch pioneered many innovative computer architecture features which have since become commonplace:

- Interrupts
- Memory Error Detection and Correction
- Memory Interleaving
- Memory Protection

- Multiprogramming
- Pipelining
- Immediate operands
- Instruction prefetch
- Operand prefetch
- Speculative Execution
- Write buffer
- Result forwarding

Although Stretch was indeed the world's most powerful supercomputer when it was finally introduced, and retained that position until 1964, it fell short of the projected performance. IBM cut the price of the system, originally $13.5 million, nearly in half. Since they would lose money on each system, they only sold systems to the customers with whom they had already been negotiating.

Midway through the Stretch program, IBM installed a "Development Improvement Package" (DIP) which was primarilly an overhaul of lookahead to improve performance. The manuals were never updated to include DIP. [1]

It's hard to find much information about Stretch now. The only currently available book with technical details is *Computer Architecture: Concepts and Evolution*, listed in the Books section below.

Who Purchased Stretch?

The first two Stretch machines were assembled by IBM's Poughkeepsie Laboratory starting in January 1959.

The first machine was delivered to Los Alamos Scientific Laboratories (LASL) in April 1961, accepted in May 1961, and used until June 21, 1971. This system had 96K words of core memory (six Type 7302 Core Storage units) and two disk files. In November 1971 it was acquired by Brigham Young University as a source of spare parts for another Stretch.

The second was part of the Harvest system (IBM 7950 Data Processing System), accepted by the U.S. National Security Agency in February 1962. Harvest also included a specialized stream coprocessor (the IBM 7951 Processing Unit) and a high-performance automated tape library ("Tractor", the IBM 7955 Tape System).

According to Footnote 112 on page 673 of Bashe et al, 1986, another seven 7030 systems were built by IBM's Kingston, New York plant:

- Lawrence Radiation Laboratory (now named Lawrence Livermore National Laboratory), delivered November 1961
- Atomic Weapons Research Establishment, Aldermaston, England (now named simply the Atomic Weapons Establishment), delivered February 1962
- U.S. Weather Bureau (now named the National Weather Service, part of the National Oceanic and Atmospheric Administration), delivered June-July 1962
- MITRE Corporation, delivered December 1962, acquired by Brigham Young University (BYU) as government surplus in May 1971
- U.S. Navy Dahlgren Naval Proving Ground, delivered September-October 1962
(IBM had previously built the Naval Ordnance Research Calculator (NORC) for the Navy.)
- IBM
- Commisariat a l'Energie Atomique, France

, delivered November 1963

The paper "Computer Development at IBM" by Cuthbert C. Hurd, published in *A History of Computing in the Twentieth Century* gives a similar list which includes one machine for the Bureau of Ships, U.S. Navy. According to Frederick P. Brooks, Jr. and Frances E. Allen, the Bureau of Ships was the contracting and cover agency for the NSA back when the very existence of the NSA was secret ("No Such Agency"). [2],[3]

Where are the systems now?

The MITRE Stretch was purchased by Brigham Young University. One account states that the MITRE Stretch was used until August of 1971, then acquired as government surplus by BYU in spring of 1972. Another account indicates that it went to BYU in May of 1971.

BYU also acquired the LASL Stretch as a source of spare parts.

Years later portions of the MITRE/BYU Stretch were donated to The Computer History Museum.

Much of the Livermore Stretch system has also been donated to the Computer History Museum. The console typewriter, core memory, disk and some of the other I/O devices are not present. A fair amount of documentation has been preserved.

Harvest was used until 1976. Apparently the main reason it was retired was that the cams in the Tractor tape system were worn out and could not be replaced. The NSA offered to give the system back to IBM for their historical collection. But the bean-counters decided that if IBM wanted it, it must be of value, so it had to be auctioned. IBM bid $20,050 (the entire annual budget for the historical collection, plus $50), and won the bidding. Unfortunately only a tiny portion of it still survives. [4]

One of the tape cartridges from Harvest is on display at the National Cryptologic Museum.

If any other remaining Stretch material is still in existence, I'd be interested in hearing about it.

Stretch Hardware

A typical IBM 7030 Data Processing System might have been comprised of the following units:

- IBM 7803 Power Distribution Unit
- IBM 7101 Central Processing Unit
- IBM 7302 Core Storage - 16384 words of 72 bits (64 data bits and 8 ECC bits) - up to eight units, typically six
- IBM 7619 Exchange - provides 8 I/O channels
- IBM 7620 Exchange expansion - provides an additional 8 I/O channels (32 maximum)
- IBM 7623 Console Control
- IBM 7152 Operator's Console
- IBM 7612 Disk Synchronizer
- IBM 354 Disk Storage Control
- IBM 353 Disk Storage Unit - similar to IBM 1301 Disk File, but much faster. 2,097,152 (2^21) 72-bit words (64 data bits and 8 ECC bits), 125,000 words per second
- IBM 7613 Magnetic Tape Control
- IBM 729 IV Magnetic Tape Unit - 112.5 IPS, seven track, 200 or 556 bpi
- IBM 7616 Printer Control
- IBM 1403-2 Printer - 132 column, 600 lines per minute with 49 symbols and blank, or 275 lines per minute with 119 symbols and blank
- IBM 7614 Card Reader Control

- IBM 7503 Card Reader
- IBM 7615 Card Punch Control
- IBM 7553 Card Punch

Harvest Hardware

The IBM 7950 Data Processing System included many of the same units as Stretch, but had some additons:

- IBM 7951 Processing Unit
- IBM 7952 High-Performance Storage - two or four units of 1024 words each, using special cores with multiple holes
- IBM 7955 Tape System ("Tractor"), consisting of:
  - one Tape Control Unit
  - three or four Cartridge Handlers, each capable of storing 80 or 160 tape cartridges
  - two Tape Units per Cartridge Handler
- IBM 7959 High-Speed Exchange

The tape system used two-reel cartridges containing up to 1800 feet of 1.75-inch 22-track tape. Sixteen tracks were used for data, and six tracks for ECC. The effective density was 2400 bits per inch, and the tape is run at a speed of 235 inches per second, for an effective tranfer rate of 141,000 64-bit words per second.

Because of this high data rate, the tape system was interfaced to the memory bus via the IBM 7959 High-Speed Exchange, rather than the standard IBM 7619 Exchange.

Warren Alva Hunt was one of the Harvest designers, and has written a short paper on the Early History of Harvest.

CPU

The Stretch CPU (Type 7101 Central Processing Unit) contained approximately 169,000 transistors on SMS cards, and had a power consumption of 21.6 KW. Its dimensions were approximately 31 feet long by 7 feet deep by 6 feet tall.

Stretch Software

- Master Control Program (MCP)
- STRAP II assembler (STRetch Assembly Program)
- FORTRAN IV compiler
- Autocoder 2
- another operating system, possibly called "S2"?

Harvest Software

Since it included a Stretch CPU, Harvest could run normal Stretch software. It also ran:

- HOPS operating system for Harvest
- ALPHA programming language

Documentation

IBM Corporation, 1961:
Reference Manual, 7030 Data Processing System
Major revision
Form A22-6530-2

IBM Corporation, 1960:
Reference Manual, 7030 Data Processing System
Form A22-6530-1

IBM Corporation, 1960:
704-709-7090 Programming Package for the 7030
Form C22-6531

IBM Corporation, 1962:
7030 Timing Guide
Form C22-6719

IBM Corporation, Data Processing Systems Division, Poughkeepsie, New York, 1 September 1961:
IBM 7950 Data Processing System Reference Manual
Contract NObsr 72781
Purchase Description No. R5-006-A

Reunion

- A Stretch/Harvest Reunion was held on September 28-29, 2002.

Lectures

- "The Stretch-HARVEST Compiler" by Frances E. Allen, IBM Fellow, November 8, 2000
  Part of The Computer History Museum Lecture Series 2000

Interviews

- An Interview with Norman Hardy
- oral history interview with Steve Dunwell, part of the archives of the Charles Babbage Institute

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Books

Computer Architecture: Concepts and Evolution
Gerrit A. Blaauw and Frederick P. Brooks, Jr.
Addison Wesley, 1997
Section 13.3 (pp. 770-809) contains a very detailed description of the Stretch architecture, including simulation code in APL. Also includes an overview of the Harvest stream coprocessor.

IBM's Early Computers
C.J. Bashe, L.R. Johnson, J.H. Palmer, and Emerson W. Pugh
MIT Press, 1986
Contains a chapter on the history of the Stretch project. An excellent book which has unfortunately gone out of print.

Planning a Computer System: Project Stretch
Werner Buchholz, editor
McGraw-Hill, 1962
Many chapters of this book are updated reprints of some of the technical papers listed below. Chapter 13 describes the Harvest stream coprocessor.

Papers

Blaauw, G.A., 1959:
"Indexing and Control-Word Techniques."
IBM Journal of Research and Development, **3**, 3: 288-301

Bloch, Erich, December 1959:
"The Engineering Design of the Stretch Computer",
Proc. IRE/AIEE/ACM Eastern Joint Computer Conference, pp. 48-58

Blosk, R.T., December 1960:
"The Instruction Unit of the Stretch Computers",
Proceedings of the IRE/AIEE/ACM Eastern Joint Computer Conference, pp. 299-324

Brooks, F.P. and D.W. Sweeney, 1957:
"Program Interrupt System."
U.S. Patent 3,048,332 (August 7, 1962, filed December 9, 1957)

Brooks, F.P., Jr., 1958:
"A Program-Controlled Program Interruption System."
Proc., IRE-ACM-AIEE 1957 Eastern Joint Computing Conf., **12**: 128-32

Brooks, F.P., Jr., G.A. Blaauw, and W. Buchholz, 1959:
"Processing Data in Bits and Pieces."
Proc. International Conf. on Information Processing '59, 375-82

Buchholz, W., 1959:
"Fingers or Fists (The Choice of Decimal or Binary Representation)."
CACM, **2**, 12: 3-11

Buchholz, W., January 1981:
"Origin of the Word 'Byte.'"
IEEE Annals of the History of Computing, **3**, 1: p. 72
Reprinted in **10**,4 (1989): 340.

B.G. Carlson and E.A. Voorhees, October 1963:
"Use of the Disk File on STRETCH",
Disk File Applications: Reports Presented at the Nation's First Disc File Symposium

Cocke, John and Harwood G. Kolsky, December 1959:
"The Virtual Memory in the Stretch Computer",
Proceedings of the IRE/AIEE/ACM Eastern Joint Computer Conference, pp. 82-93
Note that this use of the term "virtual memory" predates its modern definition. In this case, it refers to what is now called cache memory.

Codd, E.F., E.S. Lowry, E. McDonough, and C.A. Scalzi, November 1959:
"Multiprogramming Stretch: Feasibility Considerations",
Communications of the ACM **2**, 11: p. 13-17

Datamation, June 1961:
"The Shrinking of Stretch", p. 17

Dunwell, S. W., 1957:
"Design Objectives for the IBM Stretch Computer."
Proceedings of the AIEE-ACM-IRE 1956 Eastern Joint Computer Conference 10: pp. 20-21

Herwitz, P.S. and J.H. Pomerene, 1960:
"The Harvest System."

Proc., IRE-AIEE-ACM 1960 Western Joint Computer Conf., **17**: 23-32

New Media News
IBM's Stretch Computer - Bigger and Faster Isn't Always Better

Norman Hardy, undated, untitled:
notes on Stretch

Norman Hardy, undated:
"Finite Element Analysis & General Relativity"

R.A. Henle, December 1956:
"High-Speed Transistor Computer Circuit Design",
Proceedings of the Eastern Joint Computer Conference, pp. 64-66

Paul S. Herwitz and James H. Pomerene, May 1960:
"The Harvest System",
Proceedings of the Western Joint Computer Conference, pp. 23-32

D. MacKenzie, 1991:
"The Influence of Los Alamos and Livermore National Laboratories on the Development of Supercomputing",
Annals of the History of Computing 13: pp. 179-201

Mark Smotherman, April 1998:
"IBM Stretch (7030) -- Aggressive Uniprocessor Parallelism"

S.S. Snyder, 1977:
Influence of U.S. Cryptologic Organizatons on the Digital Computer Industry,
No. SRH 003, National Archives

S.S. Snyder, January 1980:
"Computer Advances Pioneered by Cryptologic Organizations",
Annals of the History of Computing 2, pp. 60-70

Spicer, Dag, 2000:
"History of Computing #2: It's Not Easy Being Green (or "Red"): The IBM Stretch Project",
Dr. Dobbs Journal

H.S. Yourke and E.J. Slobodzinski, February 1957:
"Millimicrosecond Transistor Current Switching Techniques",
Proceedings of the Western Joint Computer Conference, pp. 68-72

Computer History Museum
Timeline of the IBM Stretch/Harvest Era (1956-1961)

Archives

- The Computer History Museum collection contains some Stretch-related materials.
- The Charles Babbage Institute has an oral history interview with Steve Dunwell, and they have some Stretch-related manuals in their Computer Product Manuals Collection (link out of date). The 7030 material is in Box 39.I.6.B, and the 7302 core storage material is in Box 39.J.6.B. Under the MITRE category is listed a "Facility Manual 7030" in Box 39.B.7.A, which probably relates to Stretch since MITRE purchased a 7030. They also have in their NBS collection:
  - Haines, E. C. TREET Programming System: IBM 7030 Implementation, 1967 Mar. NBS #: 6723726.
  - Herring, Travis L. MTRAN-A Stretch Computer Program to Preprocess Data for the DA-MRCA Multiple Regression Program, 1966 Jul. NBS #: 69345056.
  - Moores, B. L. User's Manual for the Computerized Electronic System Cost Model: 7030 Modifications, 1964 Oct. NBS #: 6421128.

Footnotes:

1. Brown, Dick, private communications, 27 Nov 1999
2. Brooks, F.P., Jr., private communications, 19 Oct 1999
3. Allen, Frances E., lecture, 8 Nov 2000
4. Capek, Peter G., comments at lecture, 8 Nov 2000

Last updated June 17, 2009

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