Description of document:	**National Security Agency (NSA) report "General and Special-Purpose Computers: a Historical Look and Some Lessons Learned," 1986**
Requested date:	15-June-2009
Released date:	29-June-2010
Posted date:	19-October-2010
Source of document:	National Security Agency ATTN: FOIA Office (DJP4) 9800 Savage Road STE 6248 Ft. George G. Meade, MD 20755-6248 Fax: 443-479-3612 Online request form

NATIONAL SECURITY AGENCY
CENTRAL SECURITY SERVICE
FORT GEORGE G. MEADE, MARYLAND 20755-6000

Serial: MDR-59141
29 June 2010

This responds to your request of 15 June 2009 to have a 1986 report by Douglas Hogan, entitled "General and Special-Purpose Computers: a Historical Look and Some Lessons Learned," reviewed for declassification. The material has been reviewed under the Mandatory Declassification Review (MDR) requirements of Executive Order (E.O.) 12958, as amended and is enclosed. We have determined that some of the information in the material requires protection.

Some portions deleted from the document were found to be currently and properly classified in accordance with E.O. 12958, as amended. The information denied meets the criteria for classification as set forth in Section 1.4 subparagraph(c) and remains classified TOP SECRET, SECRET and CONFIDENTIAL as provided in Section 1.2 of E.O. 12958, as amended.

Section 3.5 (c) of E.O. 12958, as amended, allows for the protection afforded to information under the provisions of law. Therefore, the names of NSA/CSS employees and information that would reveal NSA/CSS functions and activities have been protected in accordance with Section 6, Public Law 86-36 (50 U.S. Code 402 note). In addition, information regarding other individuals has been deleted from the enclosure in accordance with the sixth exemption of the Freedom of Information Act. This exemption protects from disclosure information that would constitute a clearly unwarranted invasion of personal privacy. In balancing the public interest for the information you request against the privacy interests involved, we have determined that the privacy interests sufficiently satisfy the requirements for the application of the sixth exemption.

Since your request for declassification has been partially denied you are hereby advised of this Agency's appeal procedures. The Initial Denial Authority for NSA is the Deputy Associate Director for Policy and Records, Diane M. Janosek. Any person denied access to information may file an appeal to the NSA/CSS MDR Appeal Authority. The appeal must be postmarked no later than 60 calendar days after the date of the denial letter. The appeal shall be in writing addressed to the NSA/CSS MDR Appeal Authority (DJP5), National Security Agency, 9800 Savage Road, STE 6884, Fort George G. Meade, MD 20755-6884. The appeal shall reference the initial denial of access and shall contain, in sufficient detail and particularity, the grounds upon which the requester believes the release of information is required. The NSA/CSS MDR Appeal Authority will endeavor to respond to the appeal within 60 working days after receipt of the appeal.

Sincerely,

Kristina M. Grein

KRISTINA M. GREIN
Chief
Declassification Services

Encl:
a/s

~~TOP SECRET~~

~~TOP SE[illegible] UMBRA~~ 87 Sheets

S-229, 712

one

23 May 86

Douglas L. Hogan

1, Very, very IMP for 1950-1980 + critical bibliography

GENERAL AND SPECIAL PURPOSE COMPUTERS

A HISTORICAL LOOK AND SOME LESSONS LEARNED

P.L. 86-36
EO 1.4.(c)

IDA-SRC LOG NUMBER 20038
COPY 9 OF 9
SHEET 1 OF 87

1.0 INTRODUCTION

1.1 Purpose

(U) This paper has been written for the Supercomputing Research Center of the Institute for Defense Analyses. Its purpose is to explore the interaction between NSA's needs as it pressed the limits of computing technology in the past. This computing technology was employed in general purpose computers, in special purpose computing systems, and in combinations of the two. In the context of this paper the term technology is primarily that of architecture and hardware; software, including operating systems and specialized languages are deferred for another paper.

does not mention analog computers that were used

Data Not in card file

[redacted] The areas addressed in this paper are not intended to provide an exhaustive or detailed history; rather, they have been selected to bring out key ideas and lessons learned which are intended to be of value to IDA-SRC in their mission.

Filed: Computers - General (S2)

1.2 ORGANIZATION OF THE PAPER

(U) In aggregating material for this paper it became evident that there was no simple, single, or truly logical way in which to organize the material. A number of different dimensions needed to be explored, and a heterogeneous organization seemed to be appropriate. Accordingly the paper is organized as follows:

~~(TS)~~ Section 2 contains three case studies which are representative of three kinds of activity. The first, spanning about 20 years from 1950 to 1970, describes what was in effect a continuing attempt to to obtain the maximum general purpose data handling abilities. It includes the plans for NOMAD, a system which needed a level of technology that was not yet available, and the eventual development of HARVEST, a system which utilized technology at its maximum limit. The second case study deals with the series of machine aids that have been brought to bear on the [redacted] These aids have been in the form of both special and general purpose machines; the reasons why one or the other was chosen are explored. The third case study traces some of the ways in which networking of computers has developed from simple remote terminal operation to high bandwidth connections among powerful processors.

~~(U)~~ Section 3 presents material concerning the Agency's attempts to push computing technology to its limits. Both "successes" and "failures" are discussed. As a sidelight, a few examples in which the first instances of true computer innovations appear to have been made at the Agency are presented.

P.L. 86-36
EO 1.4.(c)

(U) Section 5 is a discussion of the development of special purpose processors, their competition with general purpose processors, levels of parallelism, and the effects of automated design.

(U) Section 6 attempts to draw some useful general and specific conclusions from the material presented in Sections 2 through 5.

(U) Section 7 presents references for the paper; some of the references are also singled out as being of general interest for those who would like to read farther in the area of this paper.

2.0 CASE STUDIES

~~(TS)~~ This chapter presents three diverse case studies are intended to illuminate some of NSA's historical interactions with computers as they attempted to:

- press general purpose computing technology and mold it toward COMINT processing,
- use computing device technology to perform cryptanalysis [redacted]
- provide remote access to machine resources for users and to provide interchange among machine resources.

(U) In Section 2.1 there is a discussion of a major data handling machine development, NOMAD, which did not come to fruition and the machine which was eventually built, HARVEST, which can be viewed as its logical successor.

~~(TSCW)~~ Section 2.2 traces the development of machine aids for cryptanalysis [redacted]

~~(TS)~~ Section 2.3 discusses the way in which groups of powerful general purpose and special purpose machines were brought together and interconnected on high speed local area networks.

P.L. 86-36
EO 1.4.(c)

P.L. 86-36
EO 1.4.(c)

These specifications must be considered in terms of the technology available at that time. NOMAD was envisioned as a machine [redacted] in order not to inhibit suggestions of other technologies, only performance specifications were called out. [redacted]

[redacted]

(U) After evaluation of multiple bids the NOMAD contract was awarded to Raytheon in 1951. [redacted]

[redacted]

(U) The NOMAD effort at Raytheon began to get badly behind schedule. This is attributable to a number of causes including changes in senior project staff, [redacted]

(U) Finally, in June 1954, the NOMAD project was killed; the result of too little, too late, and for too much money. [redacted]

2.1.2 FARMER-NOMAD

P.L. 86-36
EO 1.4.(c)

(U) In April 1954, just prior to NOMAD's demise, a system called FARMER was proposed; this system was to provide a general purpose computer with special purpose attachments. It was anticipated that such a combination could take advantage of the efficiency of special purpose processors (see Section 5 below) and provide a capability for very powerful and large scale data handling. With the termination of NOMAD a FARMER-NOMAD Special Study Group was established for "the purpose of surveying the Agency's needs for large-scale analytic equipment and preparing recommendations for design studies" [SNY 64].

[redacted]

[redacted]

(U) A number of studies were begun within the Office of Analytic Equipment Development to consider the mix of general and special purpose subsytems. In 1955 IBM approached the Agency about the use of STRETCH [BLO 59], a proposed machine rising out of their attempt to extend performance over the IBM 704 [redacted]

EO 1.4.(c)
P.L. 86-36

EO 1.4.(c)
P.L. 86-36

[redacted]

2.1.3 HARVEST

(U) The Agency "rejected" STRETCH initially, but awarded study contracts to IBM for high speed memory research (SILO) and for system design studies for an Agency-oriented system (PLANTATION, later RANCHO). The upshot of these studies was that the Agency and IBM agreed on the design of system to be called HARVEST. HARVEST is well documented in a number of places, especially [SNY 64, SNY 82]. As a result we shall consider only the principal features of HARVEST that made it a substantial advance for Agency applications.

EO 1.4.(c)
P.L. 86-36

2.1.3.1 The HARVEST CPU

~~(S)~~ After the Agency's initial rejection of STRETCH, IBM went to the Atomic Energy Commission (AEC) and proposed to build one for them. This proposal was accepted by the AEC Los Alamos National Laboratory [redacted] As a result, HARVEST as procured by the Agency had the features of STRETCH, [redacted]

EO 1.4.(c)
P.L. 86-36

[redacted]

2.1.3.2 HARVEST Memories

(U) HARVEST had two types of core memory [redacted]

EO 1.4.(c)
P.L. 86-36

(U) The other major memory advance for HARVEST was the TRACTOR storage system which used wide (1.75") magnetic tape with 16 logical tracks; the tapes were contained in large cartridges and these cartridges were retrieved by automatic handlers. [redacted]

[redacted]

w/ 14

~~(C)~~ HARVEST provided 14 years of service, from 1962 to 1976. Although, like STRETCH, HARVEST was ahead of its time when delivered, by the time it was retired the large scale commercial computers had overtaken it in both performance and reliability. (STRETCH itself, never became a commercial machine; IBM's high end machine of the era was the 7094, in its various versions, which was then superseded by the [redacted]

wow! why that long.

EO 1.4.(c)
P.L. 86-36

2.2 Evolution of Machine Aids [redacted]

[redacted]

P.L. 86-36
EO 1.4.(c)

P.L. 86-36
EO 1.4.(c)

P.L. 86-36
EO 1.4.(c)

P.L. 86-36
EO 1.4.(c)

P.L. 86-36
EO 1.4.(c)

P.L. 86-36
EO 1.4.(c)

EO 1.4.(c)
P.L. 86-36

2.3 Development of Networking

~~(FOUO)~~ Originally at the Agency, as elsewhere, computers were operated as stand-alone facilities; users brought their jobs to the computer or operated the computer themselves. Data was transferred between computers by punched cards or paper tape; these were eventually superseded by magnetic tape. The computer applications were generally part of an interactive problem solving process for the user. In this section we discuss some of the ways in which such interaction was enhanced. In using computers as near real-time turnaround tools which are directly available to individual analysts at their work location. In principle, much of this could be accomplished nowadays by stand-alone or by networked PCs. At the time the initial systems discussed here were introduced they represented both powerful (for the time) aids for the user and early institution of remote operation leading to modern networking.

2.3.1 Early Remote Diagnostic Aids

(U) A principal function in cryptanalyis is diagnosis of an unknown cryptographic system. The analyst is confronted with a quantity of unknown data; [redacted]

(U) The two earliest remotely operated computers were ROGUE and ROB-ROY [SNY 64]. ROGUE was a commercial computer, the ALWAC IIIE [redacted] It gave analysts access to the use of standard, "canned", programs as well as the ability to program their own specialized requirements.

(U) ROGUE was succeeded by ROB-ROY, a remotely operated version of BOGART, [redacted]

[redacted]

EO 1.4.(c)
P.L. 86-36

2.3.2 RYE

(U) The experience with ROGUE and with ROB-ROY was so encouraging that a large scale remote operation was planned. In 1963 the first increment of the RYE system [redacted] installed. [redacted]

[redacted]

~~(TS)~~ It had been determined that individual users had written many versions of (nearly) the same programs. As a result, attempts were made to generalize programs of common interests and General Utility Programs (GUPs) were provided [redacted]

P.L. 86-36
EO 1.4.(c)

Figure 2.3-1 [redacted]

EO 1.4.(c)
P.L. 86-36

~~(Title SECRET Drawing UNCLASSIFIED)~~

P.L. 86-36
EO 1.4.(c)

3.0 PRESSING TECHNOLOGY

~~(S)~~ In this chapter we examine some of the Agency's attempts to advance computing technology. [redacted]

~~(FOUO)~~ In Section 3.1 some of the developments involving the Agency and computing technology which can be called "successes" are described. These include: the LIGHTNING program and some of its consequences; enhancement of memories and specialized uses of memories; introduction of supercomputers; and deployment of computers into the field.

~~(FOUO)~~ In Section 3.2 some of the "failures" are discussed. [redacted]

~~(FOUO)~~ Section 3.3 provides a brief discussion of some innovations in computing technology which we believe were originated at the Agency [redacted]

EO 1.4.(c)
P.L. 86-36

3.1 "Successes"

3.1.1 LIGHTNING

(U) LIGHTNING was an attempt, motivated by the first Director of NSA, General Canine, to advance computing technology by three orders of magnitude; the goal was stated as "1000 Mcycle computation" (we would now say nanosecond computation). Some of the work is described by Campaigne [CAM 59] and by Wigington [WIG 63]. A series of reports summarizing the work was prepared by NSA R&D in 1962 (these reports cannot be located as of the writing of this paper; two of the reports are in Snyder's "archives"). The LIGHTNING program was a 5 year effort (1958-1963) with three major contractors, International Business Machines (IBM), Radio Corporation of America (RCA), and Remington Rand Univac (RRU); smaller efforts were carried out by Philco, Ohio State University, the University of Kansas, and MIT.

(U) IBM's LIGHTNING work concentrated on the cryotron, Dudley Buck's invention of a magnetic field switchable superconducting device operating at about 4 degrees K [BUC 56]. (The Agency had tried to use cryotrons earlier - see Section 3.2.3 below.) RCA's work concentrated on applications of the tunnel diode, one of the fastest switching devices known at that time. RRU concentrated on thin magnetic film devices.

(U) A major problem in attacking such (for the time) extremely high speed circuits was that of adequate instrumentation for observing these circuits. The development of high speed instrumentation was one of the major accomplishments of the

LIGHTNING program. Other accomplishments of the program were less evident. The work in magnetic thin films was one of the most long lived technologies which came out of the program. Tunnel diodes, although capable of extremely fast switching speeds, had all of the difficulties inherent to a two-terminal switching device and were overtaken by advances in transistor ciruitry. The cryotron proved not to scale to high speed operation as had been hoped and this topic is discussed more extensively in Section 3.2.3 below.

(U) Although some of the points cited in the previous paragraph do not sound very "successful", the LIGHTNING program as a whole was deemed to be a success as it stimulated industry to press on to higher speed circuits. In addition to the high speed instrumentation which furthered industrial work, a far better understanding of the problems associated with pulses transmitted over lines on circuit boards was developed. In addition to circuit developments the potential of very high speed components provided some creative ideas in computer architecture. For example, the idea of a very fast, although small, "scratchpad" memory was explored by RCA. This study foreshadowed the cache memory while considering whether or not the programmer or the system should control its use.

EO 1.4.(c)
P.L. 86-36

3.1.2 Memories

[redacted]

3.1.2.1 Magnetic Tape [redacted]

(C) The Agency became an early major user of magnetic tape and at one time was the major U. S. consumer (over 50%) of [redacted] In addition the Agency quickly became a major user of digital tape and established what came to be recognized as the premier government tape testing laboratory which was eventually transferred to the National Bureau of Standards. The extremely high performance tape system of HARVEST was discussed in Section 2.1.3.2 above.

EO 1.4.(c)
P.L. 86-36

(U) In about 1970 there was an extensive effort to obtain a "terabit" memory. This work was done in conjunction with Ampex and was an enhancement [redacted] TABLON [redacted] provided alterable storage. When files became stable they could be transferred to TABLON's other mass storage system, [redacted]

IMP

EO 1.4.(c)
P.L. 86-36

P.L. 86-36
EO 1.4.(c)

P.L. 86-36
EO 1.4.(c)

P.L. 86-36
EO 1.4.(c)

3.1.3 Supercomputers

(

P.L. 86-36
EO 1.4.(c)

P.L. 86-36
EO 1.4.(c)

P.L. 86-36
EO 1.4.(c)

P.L. 86-36
EO 1.4.(c)

P.L. 86-36
EO 1.4.(c)

P.L. 86-36
EO 1.4.(c)

(U) In the mid-1960s the Josephson Junction (JJ) phenomenon was discovered. This is another very low temperature phenomenon in which switching an electron tunneling junction between two states is accomplished by means of a magnetic field. This technology has been described by Anacker [ANA 79] and in a special issue of the <u>IBM Journal of R&D</u> [IBM 80]. The potential of JJ technology brought about a renewed interest in cryogenic devices in spite of the environmental problems presented by operating a system in liquid helium. The two primary arguments in favor of JJ computing were fast switching speed and minimal energy dissipation during switching.

P.L. 86-36
EO 1.4.(c)

[redacted]

(U) At a later time an attempt was made to consider the use of some "macro-modules" being developed at Washington University. These modules provided general arithmetic functions; the upshot of the investigation was that the overhead in line drivers and receivers and requirements for asynchronous operation appeared to offset the potential advantage of stockpiling. It is interesting to note that some of these ideas have recently reappeared (from the same Washington University group! [BAR 85]). This topic, like many other topics in this paper conform to the "wheel of reincarnation" [MYE 68].

3.2.5 Microprogramming

(U) In 1956 and 1957 interviews were held with a large number of computer programmers asking about features which they thought would contribute to Agency processing [GAF 56, GAF 57]. Although a number of specialized instructions were proposed there was a distinct disinterest in microprogramming. No one thought that the analyst or programmer wanted to be concerned with such a three

topic.

3.3 "Innovati'ons"

(U) In this section we describe briefly a few specific innovations in computer architecture which were probably first invented or implemented at the Agency or IDA-CRD. They tended not to be publicized and most did not get implemented in their original form. It seemed to be of interest to list them here.

3.3.1 Stack and Tagged Architecture

(U) Both of these concepts were invented for NOMAD and are discussed in Section 2.1. They certainly predate all other work (such as that at Rice University and at Burroughs) known to this author. #

3.3.2 77 Instruction

(U) This instruction for the CDC 1604 was proposed by Mitchell et. al. [MIT 61] at IDA-CRD in 1961. It took advantage of an unused opcode on that machine to provide a microprogrammed instruction dealing with logic and counting on registers.

EO 1.4.(c)
P.L. 86-36

3.3.3 Cache Memory

(U) As noted in Section 3.1.1, it became clear in the early days of project LIGHTNING, that although there could be some very high speed memory it would be in short supply, and consequently an effective way of making use of that memory would be needed. Both stack and cache type memory configurations were proposed. At the time of writing this paper no reference material for these architectural features in the LIGHTNING work can be found.

3.3.4 Fast Adders

P.L. 86-36
EO 1.4.(c)

4.0 ALGORITHMS

EO 1.4.(c)
P.L. 86-36

4.1 Introduction

~~(TSCW)~~ Advances in computing applications are made in many ways. They may be the result of advances in hardware technology, in software technology and programmer aids; they may also be the result of better fitting of the problem to a computer. An extreme case of this latter is one in which an apparently complex and/or very large computational process can be restated or transformed into a less complex and/or less large computational process. Many of these processes are to be found in the computer science literature; [redacted]

P.L. 86-36
EO 1.4.(c)

P.L. 86-36
EO 1.4.(c)

P.L. 86-36
EO 1.4.(c)

P.L. 86-36
EO 1.4.(c)

P.L. 86-36
EO 1.4.(c)

EO 1.4.(c)
P.L. 86-36

5.0 THE ROLE OF SPECIAL PURPOSE PROCESSORS

P.L. 86-36
EO 1.4.(c)

5.1 Introduction

~~(TS)~~ In earlier sections of this report we noted many instances of special purpose processors which have been constructed and used by the Agency for cryptanalytically oriented purposes. [redacted] These functions, however, closely follow the general trend in commercial communications and will not be discussed here. This chapter contains two major sections; the first discusses special purpose processors and the second discusses "general purpose/special purpose" processors.

5.2 Special Purpose Processors

~~(S-HVCCO)~~ In 1977, the National Security Agency Scientific Advisory Board (NSASAB) established an ad hoc group to prepare a "Report on Technology for Special Purpose Processors [SAB 78]. This report contains much of the history and rationale for the use of special purpose processors by the National Security Agency; it is recommended to anyone reading this paper. An interesting sidelight is the concern expressed in the NSASAB report report that "NSA should be prepared to detect and respond to a slowing of the commercial development of supercomputers". This slowing, predicted nine years ago, has not happened yet.

5.2 Special Purpose Processors

~~(S)~~ The discussion of this section is principally concerned with the computer science/computer architecture issues. It does not take into account two major topics discussed in [SAB 78]: (1) the extent to which a special purpose processor is classified by its inherent design and the management and cost difficulties of constructing it in-house or under contract; and (2) the decision as to the lifetime of the problem versus the lead time to produce a machine and its expected lifetime.

5.2.1 General Discussion

(U) Special purpose processors (SPPs) can be very effective theoretically when compared to classical, von Neuman, stored program computers. Specifically, a measure of effectiveness/efficiency can be taken by asking how "busy" each binary element (both logic and memory) in the system is. In a SPP many registers and many data paths can be kept busy at the same time. This sort of specialization is found in general purpose processors (GPPs) in pipelined arithmetic units, in use of multiple arithmetic units which have simultaneous operation, in overlap of instruction processing and arithmetic processing, etc. When discussing keeping binary elements busy we must factor in the different cost for memory elements versus logic elements. Memory elements are much less expensive, hence it is sometimes possible to make trade-offs between memory size and logic; a function can be performed by logic or by table look up. Further, a fixed function can be performed in ROM table look up (it can also be performed with wired or microprogrammed logic).

5.2.2 Technology Discussion

5.2.2 Functionality

EO 1.4.(c)
P.L. 86-36

EO 1.4.(c)
P.L. 86-36

[redacted]

5.3 "General-Purpose/Special Purpose" Processors

(U) Again, as noted in [SAB 78], GPPs have been used in conjunction with SPPs to provide the user interfaces, the I/O, in some cases secondary testing of results, etc. [redacted] As a result we can think of mixed processors which are a combination of GPPs and SPPs. The view of such systems depends upon considering which is the dominant system/function. Is an array processor or its associated computer dominant? Additionally, ever since microprogramming began being used in computer implementation, general purpose processors have been capable of being specialized for efficiency in narrower tasks.

P.L. 86-36
EO 1.4.(c)

5.3.1 [redacted]

[redacted]

5.4 Summary

It seems clear that the Agency will continue to use both general and special purpose computers in the future as they have in the past. General purpose computers provide a base which can run a desired program as soon as it is written. We have learned a lot about matching problem requirements to computer idiosyncrasies. [redacted]

P.L. 86-36
EO 1.4.(c)

6.0 LESSONS LEARNED

Intro. needed - also - some lessons learned should be the same as known in commercial world.

Lesson 1

(U) Don't try to make advances in architecture and technology at the same time, especially for a single or a few machines. The time scale to completion is most likely to stretch out to the point where the completed machine is no longer cost effective. There are two major reasons for this lost of cost effectiveness: (1) the extra cost of development because of the extended development time; (2) the loss in expected performance because of the delay in beginning use vis-a-vis outside developments.

EO 1.4.(c)
P.L. 86-36

[redacted]

Corollary 1

(U) Don't allow technical/political arguments delay planning of a system. It will result in "too little - too late".

[redacted]

Corollary 2

(U) Don't let technology delay strestch out the development time or the window of opportunity will be past.

Example: Josephson Junction (Section 3.2.3)

EO 1.4.(c)
P.L. 86-36

Lesson 2

~~(TSCW)~~ When should processes be placed on general purpose machines or special purpose machines? Experimentation and analysis are well suired to GP machines. [redacted]

P.L. 86-36
EO 1.4.(c)

Lesson_3

Lesson 4

~~(TS)~~ Not enough attention is given to reprogramming, automatic or otherwise. [redacted]

Lesson 5

~~(TS)~~ Algorithms are imortant

[redacted]

P.L. 86-36
EO 1.4.(c)

Lesson 6

[redacted]

EO 1.4.(c)
P.L. 86-36

Lesson 7

(U7) Does reconfiguration merit continued attention?

P.L. 86-36
EO 1.4.(c)

Lesson_8

[redacted]

P.L. 86-36
EO 1.4.(c)

EO 1.4.(c)
P.L. 86-36

7.0 REFERENCES

ALL 81 Allen, G. R., A Reconfigurable Architecture for Arrays of Microprogrammable Processors, Chapter 8 in Special Computer Architectures for Pattern Processing, K. S. Fu and T. Ichikawa eds., Boca Raton, CRC Press, 1981.

ANA 79 Anacker, Will, Computing at 4 Degrees Kelvin, IEEE Spectrum, 16, 5, 26-37 (May 1979).

BAG 81 Bagg, Thomas C. and Mary E. Stevens, Information Selection Systems Retrieving Replica Copies, NBS Technical Note 157, December 31, 1961.

[redacted]

BAR 85 Barney, Clifford, Logic Designers Toss Out the Clock, Electronics, December 9, 1985, pp 42-45

[redacted]

BLO 59 Bloch, Erich, The Engineering Design of the Stretch Computer, Proc.EJCC, 1959, 48-59.

[redacted]

BRO 75 _____, BRONSON Instruction Manual, Vol. 1, August 1975, R324,SECRET, (S-211,801).

BUC 56 Buck, Dudley A, The Cryotron, A Superconductive Computer Element, Proc. IRE, 46, 482-493 (1956).

[redacted]

P.L. 86-36
EO 1.4.(c)

EO 1.4.(c)
P.L. 86-36

[redacted]

CDC 79 _____, AFP Specification, Control Data Corporation, InformationSciences Division, December 1, 1979.

EO 1.4.(c)
P.L. 86-36

CDC 85 _____. An Introduction to the Cyberplus Parallel Processing System, Control Data Corporation, 1985.

[redacted]

CRO 57 Crowe, J. W., Trapped-Flux Superconducting Memory, IBM Jour. R & D. 1, 295-303 (October 1957).

[redacted]

EVA 86 Evans, B. O., System/360: A Retrospective View, Annals of the History of Computing, 8, 2, p 160, (April 1986).

EO 1.4.(c)
P.L. 86-36

[redacted]

EO 1.4.(c)
P.L. 86-36

[redacted]

FRE 83 Freund, Comments on Supercomputing. Cryptologic Quarterly, 2, 1-2, Spring-Summer 1983, 11-21.

GAF 56 Gaffny, Joan M., Report on Programmer Interviews, Dec 1956, SECRET. S-85,940

GAF 57 Gaffny, Joan M., Proposed Machine Features, R&D, Feb 1957, CONFIDENTIAL. S-85,942.

[redacted]

GEN 71a Gentile, R. B., and J. R. Lucas, The TABLON Mass Storage Network, 1971 SJCC, pp 345-356, AFIPS Press.

GEN 71b Gentile, R. B. and R. W. Grove, Mass Storage Utility: Considration for Shared Storage Applications, IEEE Trans. on Magnetics, MAG-7, 4, 848-852 (Dec 71).

[redacted]

IBM 80 _____, Special Issue on Josephson Computer Technology, IBM Jour. of R & D, 24, 2, (Mar 1980).

IBM 82 _____, Josephson Junction Applications Study, Final Report, Contract MDA 904-81-C-0425, IBM Federal Systems Division, Gaithersburg, MD, March 1982. {UNCLASSIFIED Report with SECRET Appendix}

IBM 83 _____, Josephson Junction Applications Study, Phase II, Final Report, Contract MDA 904-81-C-0425, IBM Federal Systems Division, Gaithersburg, MD, November 1983. (UNCLASSIFIED report with SECRET Appendix)

KEY 85 Keyserling, Charles, SPD Impact on Supercomputer Needs. R8, 1985, TOP SECRET CODEWORD.

KRO 76 Kronlage, Carl R., FLEMING Completion Report, NSA R325, February 1976, TOP SECRET CODEWORD. (S-213,554)

LEI 72 Leibler, Richard A., Mathematics and Computers in Cryptanalysis, NSATJ Special CLO Issue on Changing Frontiers in Computer Cryptology, 1973, 15-22. TOP SECRET CODEWORD.

LUC 64 Lucas, Joseph R., Jr., CAM II, NSATJ, IX, 2, 27-75, FOUO.

[redacted]

MAT 60 Matthews, Charles W., Quick Reference Memory, Technical Memorandum 352-7931/17, 26 october 1960, FOUO. (S-125-238)

MCE 77 McEliece, R., Theory of Information and Coding: A Mathematical Foundation for Communication, Addison-Wesley, 1977.

MCW 78 McWilliams, J. F. and N. J. Sloane, The Theory of Error Correcting Codes, Elsevier,1978.

[redacted]

MIT 61 Mitchell, G. J., Rice, R. A., and E. Stoffel, A Description of a 77 order for the CDC 1604. IDA-CRD Working Paper No. 20, April 1961, (S-134,709).

[redacted]

P.L. 86-36
EO 1.4.(c)

[redacted]

MOO 61 Moore, D. P. and J. D Swift, Note on Sorting Repeats, SCAMP Working Paper No. 12/61, IDA, 4 August 1961.

[redacted]

MYE 68 Myers, T. H. and I. E. Sutherland, On the Design of Display Processors, Comms.. of the ACM. 7 6, 410-414 (June 1968).
NOTE: also discussed in SIE 82.

[redacted]

NEV 64 Nevins, W. D., The REDMAN Program, NSATJ, IX, 1, Winter 1964, 97-195, UNCLASSIFIED.

NEW 59 Newhouse, V. L., and J. W.Bremer, High-Speed Superconductive Switching Element Suitable for Two-Dimensional Fabrication, Jour. Applied Physics, 30, 1458-1459 (1959).

[redacted]

OME 74 _____, The OMEN Processor, Appendix K in Multiprocessors and Parallel Processing, P. Enslow ed., Wiley, 1974.

[redacted]

P.L. 86-36
EO 1.4.(c)

[redacted]

SIE 82 Sieworek, D. P., C. G. Bell, and A. Newell, (eds.), Computer Structures, Principles and Examples, McGraw-Hill, 1982.

SLA 56 Slade, Al, A Cryotron Catalog Memory System, Proc. EJCC, December 1956.

[redacted]

YAT 37 Yates, F., Design and Analysis of Factorial Experiments, Harpenden, Imperial Bureau of Social Science, 1937.

[redacted]

CLASSIFIED REFERENCES

P.L. 86-36
EO 1.4.(c)

IBM 80 _____, Special Issue on Josephson Computer Technology, IBM Jour. of R & D. 24, 2, (Mar 1980).

P.L. 86-36
EO 1.4.(c)

IBM 82 _____, Josephson Junction Applications Study, Final Report, Contract MDA 904-81-C-0425, IBM Federal Systems Division, Gaithersburg, MD, March 1982.
SECRET Appendix

IBM 83 _____, Josephson Junction Applications Study, Phase II, Final Report, Contract MDA 904-81-C-0425, IBM Federal Systems Division, Gaithersburg, MD, November 1983.
SECRET Appendix

EO 1.4.(c)
P.L. 86-36

P.L. 86-36
EO 1.4.(c)

P.L. 86-36
EO 1.4.(c)

P.L. 86-36
EO 1.4.(c)

P.L. 86-36
EO 1.4.(c)

P.L. 86-36
EO 1.4.(c)