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The contributions of Grace Murray Hopper to computer science and computer education

Mitchell, Carmen Lois, Ph.D.

University of North Texas, 1994

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This study explored the life and work of the late Grace Murray Hopper, Rear Admiral United States Naval Reserve. The study emphasized Hopper's contributions to computer science and computer science education, including her philosophy of teaching and learning, and her pedagogical legacy for today's teachers and scholars of computer science and computer science education.

The study employed historical methodology, including personal interviews by the author of individuals who knew Hopper, both in and out of the military. Some of these individuals worked with Hopper during the early days of her computing career, while others knew Hopper during her time at the Pentagon and after her retirement, until her death in January, 1992. The study also included a thorough review of the written record, including a search through the Grace Murray Hopper collection donated to the Smithsonian Institution in Washington, D.C. as well as articles and books written about and by Hopper and audio and videotapes of Hopper's interviews. Additionally, the author was assisted by Hopper's brother, Dr. Roger F. Murray, who provided access to personal, family mementoes.

Grace Murray Hopper worked in the field of computer science from 1944 to 1991. Her professional career paralleled the development of the computer science industry, in which she was a visionary and a pioneer.

THE CONTRIBUTIONS OF GRACE MURRAY HOPPER TO COMPUTER SCIENCE AND COMPUTER EDUCATION

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THE CONTRIBUTIONS OF GRACE MURRAY HOPPER TO COMPUTER SCIENCE AND COMPUTER EDUCATION

DISSERTATION

Presented to the Graduate Council of the
University of North Texas in Partial
Fulfillment of the Requirements

For the Degree of

DOCTOR OF PHILOSOPHY

By

Carmen L. Mitchell, B.A., M.S.

Denton, Texas

May, 1994

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION TO THE STUDY

This study explored the life and work of the late Grace Murray Hopper, Rear Admiral United States Naval Reserve. The study emphasized Hopper's contributions to computer science and computer science education, including her philosophy of teaching and learning, and her pedagogical legacy for today's teachers and scholars of computer science and computer science education.

Grace Murray Hopper worked in the field of computer science from 1944 to 1991. Her professional career paralleled the development of the computer science industry, in which she was a pioneer.

During her career, she taught at five universities, beginning at Vassar in 1931, as an Assistant in mathematics, becoming successively, Instructor, Assistant Professor, and Associate Professor. In early 1943, while still on the Vassar faculty, she was an Assistant Professor of mathematics at Barnard College, serving in a one-year special appointment. In December, 1943, Hopper left Vassar on a leave of absence to join the United States Naval Reserve, and, after completing USNR Midshipman's School at Northampton, Massachusetts, was assigned to the Bureau of Ordnance Computation at Harvard University. At Harvard she was one of the first three programmers for the Mark I, the first, successful automatically sequenced digital computer in the world. In 1946, she resigned her leave of absence from

Vassar and joined the faculty at Harvard as a research fellow in engineering sciences and applied physics at the Computation Laboratory. At the laboratory, she continued her work for the Navy on the Mark II and Mark III computers, successors to the Mark I. In 1946, she received the first of many awards, the Naval Ordnance Development Award, for her programming work on the Mark I and for her efforts in writing the first computer hardware manual for the Mark I, A Manual of Operation for the Automatic Sequence Controlled Calculator.[1]

In 1949, she left Harvard, but continued her affiliation with the Naval Reserve and joined the Eckert-Mauchly Computer Corporation in Philadelphia as a senior mathematician. At that time, the company was building the UNIVAC I, the first commercial, large-scale electronic computer. It was at Eckert-Mauchly that she would complete her pioneering work on the development of a natural-language interface for the programming language, Common Business Oriented Language (COBOL). She remained with Eckert-Mauchly, which would be merged into the Sperry Corporation, until December, 1971. In 1952, she was promoted to Director of Automatic Programming, after publishing the first paper on compilers, "The Education of a Computer."[2] In 1964, she was promoted to Staff Scientist, Systems Programming. Hopper retired from the UNIVAC Division of Sperry Rand Corporation in December, 1971, while on military leave.

From 1952 until her death in 1992, she published over fifty papers and articles about programming languages, especially Common Business Oriented Language (COBOL) which she helped develop. Hopper also wrote about the design and application of other types of

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[1] Staff of the Computation Laboratory, A Manual of Operation for the Automatic Sequence Controlled Calculator (Cambridge: Harvard University Press, 1946).

[2] G. M. Hopper, The Education of a Computer (Philadelphia: Association for Computing Machinery, May 2, 3, 1952), 12.

software and in her later years the use and misuse of computers in business and the military.

In 1959, she was named Visiting Lecturer at the Moore School of Electrical Engineering at the University of Pennsylvania. She continued her affiliation with the Moore School, and in 1973, was appointed Adjunct Professor of Engineering. In 1971, she was named Professorial Lecturer in Management Science at George Washington University in Washington, D.C., where she taught classes until 1978.

In 1962, she was elected Fellow of the Institute of Electrical and Electronics Engineers. In 1964, she received the 1964 Achievement Award given by the Society of Women Engineers. In 1969, the Data Processing Management Association selected her as their first Computer Sciences Man of the Year.

Throughout the seventies, eighties and nineties, Hopper received numerous awards. Among these were the Legion of Merit, given by the United States Navy in 1973; the W. Wallace McDowell Award, given by the Institute of Electrical and Electronic Engineers in 1979; and an Honorary Doctor of Science, given by Linkoping University of Sweden in 1980. In September, 1991, only four months before her death, Hopper received the 1991 National Medal of Technology presented by President George Bush. On April 20, 1992, Hopper was posthumously awarded the Centennial Medallion of the Daughters of the American Revolution, which had been awarded earlier to Barbara Bush and Justice Sandra Day O'Connor. Poor health had prevented Hopper from attending the earlier ceremony. In October, 1992, the Navy announced that a frigate would be commissioned in 1995 as the USS Hopper, in honor of Grace Hopper's work and more than 40 years of service in the Navy. A complete listing of her awards is included in her vita, Appendix A.

Grace Hopper stayed in the Naval Reserve until her first retirement as commander in December, 1966. She was recalled to active duty on a temporary assignment for the Navy on

August 1, 1967. On August 2, 1973, Hopper was promoted to captain; on November 8, 1983, she was promoted to commodore, a rank whose name was changed to rear admiral on November 8, 1985. She retired from active duty for the second time on August 31, 1986.

Hopper remained in the computer field for the rest of her life, serving as senior consultant to Digital Equipment Corporation in Washington, D.C. She died on January 1, 1992.

Although Grace Hopper contributed significantly to today's wide-spread acceptance of the use of computers and to the idea of standardized, user-friendly software, perhaps of even greater importance than her scientific achievements was her personal philosophy. Hopper was constantly looking forward, discovering new ways of teaching and learning and experimenting with new ideas. Even in her seventies, she battled entrenched attitudes of company presidents and commanding officers whom she referred to as the establishment: the phrase, "but it has never been done that way" was anathema to her. As a visual reminder of this personal philosophy Grace Hopper kept a ship's clock in her office at the Pentagon. It appeared to be a typical ship's clock until one looked closely: it ran backward.[3] Thus, because of her pioneering work in computer science and her leadership in computer science teaching and learning, the life and work of Grace Hopper was a worthy topic for research.

Statement of the Problem

The problem of this study concerned the life and work of Grace Murray Hopper with emphasis on her contributions to computer science and computer science education.

Purposes of the Study

The purposes of this study were (1) to examine the life and scientific work of Grace

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[3]Tropp, H.S. "Grace Murray Hopper," Encyclopedia of Computer Science and Engineering. (New York: Von Nostrand Reinhold,1983). 686.

Murray Hopper, (2) to ascertain her contributions to computer science and computer science education, (3) to describe her philosophy of teaching and learning, and (4) to determine how Grace Hopper can serve as a role model for today's teachers of computer science and computer science education.

Research Questions

In order to complete this study, the following research questions were posed:

1. What did Grace Hopper contribute to computer science and computer science education?

2. How did Grace Hopper contribute to the body of knowledge that came to be called computer science?

3. What was Grace Hopper's philosophy of teaching and learning?

4. What pedagogical legacy did Grace Hopper leave for today's teachers of computer science and computer science education?

Significance of the Study

This study provides useful information to educational historians. It also provides information to present and future computer science and computer science education scholars and may present them with a pedagogical role model.

Design of the Study

Historical Methodology

In his book, Understanding History, Louis Gottschalk quotes the noted French historian and philosopher, Charles Seignobos:

> History is not a science; it is a method (procede de connaissance). By that he [Seignobos] meant that the historical method may be applied to the subject matter of any discipline whatsoever as a

means of ascertaining fact.[4]

In his landmark book, Foundations of Behavioral Research, Fred Kerlinger has this to say about the historiographical approach to research:

> In education, however, historical research per se has great value, because it is necessary to know and understand educational accomplishments and trends of the past in order to gain perspective on present and future directions.[5]

Thus, historical methodology has long been considered, even by nonhistorians, as a valid and reasonable approach to research. Because of the nature of this study, i.e., the determination and reporting of the contributions of Grace Hopper to computer science and computer science education and their implications, if any, for today's teachers of computer science and educational historians, a historical research methodology was adopted.

In addition, because this study used personal interviews, oral history techniques such as those discussed in Oral History From Tape to Type were employed. For instance, interviews were conducted with one person at a time, and, so far as possible, interviews were conducted in the individual's home or office or other comfortable, familiar surroundings. The author of Oral History From Tape to Type also suggests that there are six interviewing tips that should be remembered:

1. Ask provocative questions -- Who? What? When? Where? Why? How?
2. Ask about specific experiences.
3. Use props.
4. Elicit emotions.
5. (Use) the past as dialogue.

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[4] Louis Gottschalk, Understanding History, (New York: Alfred A. Knopf, 1961), 29.

[5] Fred N. Kerlinger, Foundations of Behavioral Research (second edition), (New York: Holt, Rinehart and Winston), 1973, 701-702.

6. (Ask for) physical descriptions[6]

These interviews were used to supplement the written record. This record included a review of the literature, and a search through the Grace Murray Hopper Collection housed in the National Museum of American History of the Smithsonian Institution in Washington, D.C. Also employed were personal memorabilia and family mementoes from Grace Hopper's brother, Dr. Roger F. Murray, II, of Wolfeboro, New Hampshire.

Collection of the Data

According to Deobold Van Dalen in Understanding Educational Research, the best evidence available to a researcher following an historical research strategy, is as many primary sources as possible: ". . . the testimony of able eye-and earwitnesses to past events. . ."[7]

With this caveat in mind, data for this study included interviews, both by telephone and in person of individuals who could be located who knew Dr. Hopper either as a colleague or teacher: for instance, Ms. Diane Hamblen, editor Chips, a Navy computer magazine was interviewed; Dr. Stephen L. Mandell, a doctoral student of Hopper's and former professor at Bowling Green State University in Ohio, was interviewed; Ms. Sharron Crowder, Grace Hopper's aide from 1984-85, was interviewed; Paul Sutherland, former admiral at Naval Data Automation Command (NAVDAC), was interviewed; Robert Campell, retired research physicist, who worked with Hopper at Harvard on the Mark I, was interviewed; Dr. Robert Bloch, retired research physicist, also with Hopper at Harvard, was interviewed; Dr. Ruth Noller, retired Director of the Creative Learning Center at Buffalo State University in

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[6]Kathryn Back, Cullom Davis, and Kay Maclean, Oral History From Tape to Type (Chicago: American Library Association, 1970), 19-21.

[7]Van Deobold, etc.

Buffalo, New York and the other Navy WAVE officer on the Mark I project at Harvard, was interviewed; Mr. Richard Fredette, who worked with Hopper at the Pentagon, was interviewed; Mr. Howard Bromberg, who worked with Hopper at Remington Rand in the fifties, was interviewed; and Ms. Rita Yavinsky, vice president at Digital Equipment Corporation and good friend and colleague of Hopper's in the last years of her life, was interviewed. In all cases, an informed release document based on suggestions and advice from Richard Rafes, University of North Texas counsel, was employed (Appendix B).

In addition to these interviews, a thorough review of literature was made including a search through the Naval Reserve documents in Washington, D.C. for texts of several of the hundreds of speeches given by Hopper, a review of articles written about Hopper and authored or coauthored by her, books written by Hopper, and oral history collections that included Hopper such as Yale's 1983 "Women In Federal Government" project, the Voice of America's 1984 interviews with "Eight Women of Achievement", and the Smithsonian's Computer Oral History Collection. Additionally, a copy of an interview on National Public Radio's "All Things Considered" program was obtained from NPR and videotapes from the CBS program "Sixty Minutes" and NBC's David Letterman Show were viewed by the researcher. By way of insight into the mind of a young Grace Hopper, a request was made through interlibrary loan to the library at Yale University for a copy of her 1934 dissertation, New Types of Irreducibility Criteria. Hopper's Ph.D. degree was in mathematics because computer science as a field of study did not exist at the time.

Finally, Dr. Roger F. Murray II of New Hampshire and Mary Murray Westcote of New Jersey, Hopper's brother and sister were contacted. They directed the researcher to the Smithsonian Museum in Washington D.C. as the repository of Hopper's personal papers that have been released to date by the family and her estate. The Grace Murray Hopper

Collection at the Smithsonian is comprised of several boxes of information, including technical documents and worksheets from Harvard about the Mark I and Mark II, 1944-1949; photographs of the Mark II and its components, 1948; photographs of Harvard personnel, 1944-1945; reports and periodical articles, 1946-48; information from the Eckert-Mauchly Computer Corporation, 1949-1965; compiling routine documents, 1952-1954; clippings of newspaper and magazine articles, 1950-1953; and a humor file, 1944-1953. Some of the material is annotated, in Hopper's own hand, by means of three-by-five-inch pieces of paper attached to the item being described. Additionally, Dr. Roger F. Murray, II, Hopper's brother, gave invaluable assistance to the researcher by providing copies of personal memorabilia and other materials that are not included in the Smithsonian collection.

Data were validated by cross checking information to see that it remained the same across a variety of sources. Information gathered through taped interviews was checked to ensure agreement with the written record and vice versa, thereby accomplishing so-called data triangulation.

Treatment of the Data

Ideally, the researcher would have wished to interview Grace Hopper for this study; however, her death on January 1, 1992 precluded this option. The next most valid research data was obtained by a thorough review of Hopper's words, either written or spoken in the form of audio/video interviews, broadcast or not, and the numerous articles and two books authored by her, as well as speeches she gave. Of lesser importance, but still useful for the researcher were secondary sources, material written or spoken about Hopper. It was necessary, of course, to determine the accuracy of both primary and secondary sources.

Just as experimental data must be evaluated, so too must historical data be analyzed and evaluated to determine the data's authenticity. To accomplish this evaluation, the careful

researcher must subject historical data to both internal and external criticism.

Van Dalen defines external criticism as checking the "genuinesses and textual integrity of the source material --whether it is what it appears or claims to be --to determine whether it is admissible as evidence."[8] Kerlinger explains external criticism as an attempt to examine the data "for their validity. Is the document or source genuine? Did X really write the paper? If X wrote the paper, was he a competent and truthful witness?"[9] Thus, the researcher cannot assume that any record is genuine.

Internal criticism is that process which ascertains the "meaning and trustworthiness of the data within the document."[10] That is, "the intent of internal criticism is to determine the conditions under which a document was produced the validity of the intellectual premises upon which the writer proceeded, and the correct interpretation to be placed upon data."[11]

Obviously, the best historical sources are those closest to the event, person, or persons being researched, i.e., so-called primary sources: hence, the use of interviews and the actual words of Grace Hopper. Secondary sources, material spoken or written about her were used primarily for background information for the interviewer or as a means of providing

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[8] Deobold Van Dalen, Understanding Educational Research. (New York: McGraw-Hill Book Company, 1979), 356.

[9]Kerlinger Fred, Foundations of Behavioral Research. (New York: Holt, Rinehart and Winston,Inc., 1973), 702.

[10] Deobold Van Dalen, Understanding Educational Research. (New York: McGraw-Hill Book Company, 1979), 358.

[11]Ibid.

useful, interesting, or entertaining information for the reader. As Van Dalen points out, "History is life and it deserves better than a drab description."[12]

[12]Ibid., 374.

CHAPTER II

THE FORMATIVE YEARS

Grace Brewster (Murray) Hopper was born on December 9, 1906, in New York City. It was a year with its share of headlines: San Francisco had been destroyed by a tremendous earthquake and fire; President Theodore Roosevelt had won the Nobel Peace Prize for his mediation between the fighting Japanese and Russian empires; and The New York Times reported the continued arrival of thousands of immigrants to the Port of New York on their way to become Americans.[13] The Wright brothers had made their first successful flight from Kitty Hawk three years earlier, and the United States and the world were on the brink of unprecedented changes. Although Hopper's parents, Walter and Mary Murray, could not have known it on that snowy day in New York, their first child would be instrumental in making those changes.[14]

Walter and Mary Murray brought Grace Hopper, named for her mother's best friend, to a comfortable home on New York's Riverside Drive. There, Hopper spent her childhood years that she described as "very happy ones." [15] Her sister, Mary Murray Westcotte, and brother, Dr. Roger F. Murray, II, were born three and five years later respectively; so, Hopper would often relate stories about her being the big sister, who "took the brunt of

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[13]New York Times (New York City), 9 December 1906.

[14]Ibid.

[15]Marguerite Zientara, "Part II . . . Capt. Grace M. Hopper and The Genesis of Programming Languages, " Computerworld, 16 November 1981, 49.

everything."[16] She recalled one occasion where a "bunch of cousins" and she were caught scrambling around in a pine tree. "Since I was at the top, it was obvious who started it."[17]

Hopper's father, Walter Murray, was an insurance broker, as was his father before him. Her mother, Mary Campbell Van Horne Murray, the daughter of the senior civil engineer of New York City, had always loved mathematics and instilled this love in her first daughter.[18] As a girl, Hopper's mother would accompany her engineer father, John Van Horne, when he surveyed New York City. According to Hopper, her grandfather, "laid out all the streets in the city."[19]

Before she was married, Hopper's mother studied as much mathematics as she was allowed to study, including geometry, but not algebra or trigonometry. In the late 1800's, it was not considered proper for young ladies to study advanced mathematics. Hopper recalled that her own father also encouraged her and believed that his daughters should have the same educational opportunities as his son.[20] Hopper believed that her father, who had both legs amputated when she was a teenager, knew that he would not be able to leave his children a large inheritance, so he emphasized education as a way for them to be financially independent.[21]

Hopper and her siblings attended private schools all their lives. Dr. Roger Murray,

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[16]Ibid.

[17]Ibid.

[18]Diane Hamblen, "Looking Back: Grace Murray Hopper's Younger Years," CHIPS, April 1992, 8.

[19]Ibid.

[20]Ibid.

[21]Ibid.

Hopper's brother, recalled

> We children always went to independent schools. It was not a social thing. It was just that our mother and father felt that education was too important to be left to the vagaries of chance.[22]

Murray also believed that public schools in the early twentieth century were "not as advanced as some are now."[23] Hopper attended two private schools in New York City: The Graham School and Miss Mary Schoonmaker's School for Girls.

The Graham School, located only a few blocks from Hopper's home, is described in the 1915 edition of Sargent's, Handbook of the Best Private Schools, as "the oldest private school for girls in New York, " and as a "conservative Presbyterian school."[24] The school's founder, Mrs. Esther Smith, a young widow, was described as "a beautiful woman . . . . of great charm and manor, and without thought of self."[25] Hopper's parents need not have worried about her early instruction: there was nothing vague about the curriculum at the Graham School. Its founders' philosophy is described in a brochure commemorating the school's one hundredth anniversary:

> Shallowness and vanity were to her the unforgivable sins, and plain clothing, no jewelry, and simple pleasures figured large in her creed . . . Her aim was to mould and train the minds that came under her care by developing the highest sense of duty in the exercise of every faculty . . .[26]

Hopper attended the Graham School during her kindergarten and primary years from 1912 to

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[22]Dr. Roger F. Murray, II of Wolfeboro, New Hampshire, interview by author, 12 October 1993, tape recording.

[23]Ibid.

[24]Porter E. Sargent, A Handbook of the Best Private Schools (Boston: 1915), 123.

[25]Eveline Warner Brainerd, An Old New York School (New York: The De Vine Press, 1916), 6.

[26]Ibid, p. 12.

November, 1916. Upon arriving at school, the younger students were greeted with an " 'obligatory grin' and turned up nails before the password, 'J'ai dix, mademoiselle,' which meant they were on time and in order, let them enter."[27]

Instruction in the Primary Department of the Graham School consisted of phonetics, reading, literature, languages, geography, French, nature study, spelling, singing, Bible stories, physical training, drawing, and penmanship, as illustrated in Appendix C. In addition to regular lessons by school faculty members, an illustrated lecture delivered by a staff member of the American Museum of Natural History was given annually, with a quiz administered to older primary students. The school emphasized instruction in how to study and "training of pupils to do their own thinking."[28] The school's mission is further described: "The school endeavors to bring about an enjoyment of their studies that will awake enthusiasm in the girls and lead them to earnest efforts to improve their opportunities."[29]

Tuition at the Graham School was $750 a year, and it may have been the lower tuition of $350 a year at Miss Mary Schoonmaker's School for Girls that motivated Hopper's parents to send her there, beginning in December, 1916. By this time, Hopper's sister, Mary, was also attending school.

Miss Mary Schoonmaker's School for Girls was not as old as the Graham School nor as exclusive. It was begun in 1889 and is sometimes referred to as the New York Collegiate Institute in the listings of private schools in New York. It was also a conservative, Presbyterian school that emphasized studies and behavior as much as the Graham School. As

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[27]Ibid, p. 16.

[28]Howard Dwight Miner, The Graham School (New York City: Munder-Thomsen Press, 1915(?), 20.

[29]Ibid.

one of Hopper's report cards states, their motto was "Self Respect, Self Control, Self Reliance."[30] (See Appendix D.)

In addition to the academic curriculum, Hopper played basketball, field hockey, and water polo at the Schoonmaker School.[31] The regular, academic curriculum consisted of spelling, grammar-rhetoric, composition, French, German, Latin, literature, history, mathematics, geography, physical culture, penmanship, and fine arts. The girls' report cards also gave marks for deportment, general orderliness, days absent, and times late.

The Schoonmaker School gave each girl summer reading assignments for which reports had to be written and turned in the following fall. As Hopper said,

> Each summer we had to read 20 books and write reports on them. You were educated and had some background when you were through then, not like today. It didn't give us any inhibitions; it gave us an interest in reading and history.[32] (See Appendix E.)

Summers were spent by Hopper and her family in Wolfeboro, New Hampshire, at a cottage in the Point Breeze Area of Lake Wentworth.[33] Here, Hopper, her brother, sister, and cousins, like typical young children, spent days on the lake and exploring. Hopper recalled one summer that her life-long fascination with gadgets got her into trouble. The cottage had seven bedrooms, and each room had an alarm clock, an old-fashioned clock with a round face and large bell on top. The young Hopper proceeded to move from bedroom to bedroom taking apart all seven clocks, and having no luck reassembling the pieces. When she was

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[30]Grace Brewster Murray, Report, New York Collegiate Institute, 1917.

[31]Diane Hamblen, "Looking Back: Grace Murray Hopper's Younger Years," CHIPS, April 1992, 8.

[32]Marguerite Zientara, "Part II . . . Capt. Grace M. Hopper and the Genesis of Programming Languages," Computerworld, 16 November 1981,.

[33]Charlene Billings, Grace Hopper, Navy Admiral and Computer Pioneer, (Hillsdale, N.J.: Enslow Publishers, 1989), 18.

discovered, her mother restricted her to only one clock, but Hopper never lost her love for gadgets and how they worked.[34]

In 1923, when the family returned to New York City from their summer in New Hampshire, Hopper had graduated from Miss Schoonmaker's School and had failed the Latin portion of Vassar's entrance examination. Vassar College told her she should wait a year and Hopper's family agreed. Hopper was seventeen years old, and her mother and father decided to enroll her as a boarding student at the Hartridge School in Plainfield, New Jersey.

Unlike the Graham School or Miss Mary Schoonmaker's School for Girls, the Hartridge School still exists. It was founded in 1882 and merged with a male preparatory school, Wardlaw in 1960. In 1993, the Wardlaw-Hartridge School is still known for its record of preparing young women for acceptance at Vassar.[35]

When Hopper arrived at Hartridge in the fall of 1923, Miss Emelyn Hartridge, founder of the school, was headmistress. It was her practice to assemble all the young women in the school every morning and, after roll call, start the day with an inspirational speech. Adele DeLeeuw, an alumnus of the school, recalled those days and Miss Hartridge:

> She had high standards of deportment and learning. And it was her pride that most of her girls went on to college and did extremely well there. If you decided on Vassar -- her own alma mater-- you were in the top echelon. [Although] she managed to tolerate Bryn Mawr, Holyoke, and Wellesley.[36]

As might be imagined, rules for boarding students were strict. An early school catalog noted that there was to be, "no boisterousness anywhere at any time." These

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[34]Ibid, 19.

[35]Patricia Turner, "Hartridge School Reflected Qualities of Its Founder," Wardlaw-Hartridge, 100 Years of Growth, 1982, 1.

[36]Ibid.

regulations concluded, "Our class of girls naturally stand back on the stairs or in a doorway for older people and have pretty table manners and are well-behaved in church."[37] In addition to this social curriculum, the academic regimen included Greek, Latin, French or German, trigonometry, geometry, algebra, English and American History. Miss Hartridge herself taught all the Latin classes, so, at the end of a year, Hopper had no trouble passing Vassar's Latin examination and being accepted as a freshman there.

Attending Vassar was not only Hopper's dream, but also her mother's. According to her brother, Dr. Roger F. Murray, "Our mother grew up in the days when there was no thought of young ladies ever going to college . . . so that was far removed. Our mother wanted Grace to do those things."[38]

On Monday, September 22, 1924, Hopper began her undergraduate program at Vassar. It was with a great deal of eagerness that Hopper and the other freshmen assembled to hear Dean C. Mildred Thompson speak to them about, "The Business of Being a Student."[39] Dean Thompson exhorted them to elevate this business of being a student . . . [to] treat it with respect and with seriousness. . .[40]

Hopper, whose marks in mathematics had always been high, decided she would concentrate on mathematics while at Vassar, perhaps becoming a teacher or actuary. It was at Vassar that Hopper's ability to take the complicated and explain it simply was revealed. She tutored her fellow students in physics and used practical demonstrations to illustrate her

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[37]Ibid, 4.

[38]Dr. Roger F. Murray of Wolfeboro, New Hampshire, interview by author, 12 October 1993, tape recording.

[39]Charlene Billings, Grace Hopper, Navy Admiral and Computer Pioneer, (Hillside, N. J.: Enslow Publishers, 1989), 23.

[40]Ibid, 24 (brackets are the author's).

points. For instance, to teach the principle of displacement, she asked a fellow student to actually get into a partially-filled bathtub and record the rise of the water on the side of the tub. As Hopper observed, "I have always made the connection between the theoretical -- the theory itself -- and the reality. That's the way you explain things."[41]

At Vassar, Hopper's eagerness to try new things was graphically demonstrated. She recalled that a biplane landed in a field near Vassar; it was made of wood, linen and wire, and one could buy a ride. "It had an engine and an open cockpit so you got the full benefit of the wind. I squandered all my money -- it cost $10 -- and went up in that plane."[42]

Hopper graduated from Vassar with a bachelor of arts degree in mathematics and physics in 1928. That same year she was elected to Phi Beta Kappa, an honorary society, and was awarded a Vassar College Fellowship that allowed her to pursue a master of arts degree in mathematics at Yale University, her father's alma mater. Hopper completed her master's degree in 1930.

1930 was an eventful year for Hopper. On June 15, 1930, Grace Brewster Murray married Vincent Foster Hopper at the West End Collegiate Church in New York City. The ceremony was followed by a reception at the Savoy Plaza Hotel. Hopper met her husband in Wolfeboro, New Hampshire, where both of their families had summer homes; they became close friends over the course of several summers. Dr. Roger F. Murray, Hopper's brother, recalled the wedding and the couple's honeymoon in Europe with Hopper's family: " Both Agnes (now Mrs. Roger Murray) and I were in the wedding party. I was the best man and

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[41]Ibid, 25.

[42]Ibid.

she was a bridesmaid."[43] Murray said that the party sailed across the Atlantic on the ship, Mauritania, taking the family's seven-passenger Buick with them to use as transportation while in Europe. Murray recalled, "Our mother had to do all of the driving since by this time father had already had his operation."[44]

When the trip to Europe ended, eight weeks later, Hopper and her husband settled in New York City. She found a job teaching mathematics at her alma mater, Vassar, for $800 a year. Vincent, with degrees from Princeton, taught English at New York University's School of Commerce. Hopper continued her studies at Yale, graduating with a Ph. D. degree in mathematics in 1934. The title of her dissertation was "The Irreducibility of Algebraic Equations."[45] Hopper gave a bound copy of her dissertation to the then president of Vassar College, a family friend and also her employer. A copy of President Henry Noble MacCracken's reply is Appendix F. Hopper completed her Ph. D. degree while continuing to teach mathematics at Vassar and while, presumably, getting used to married life. To put her academic accomplishments into perspective, one must remember that from 1862 to 1937 only 1279 Ph. D.'s in mathematics were awarded in the United States, and in the three years from 1934-1937, Yale awarded only seven Ph.D. degrees in mathematics. Hopper was the only woman during that time to receive a Ph. D. degree in mathematics from Yale.[46]

While teaching at Vassar, Hopper rose to the rank of associate professor. Her husband

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[43]Dr. Roger F. Murray of Wolfeboro, New Hampshire, interview by author, 12 October 1993, tape recording.

[44]Ibid. Dr. Murray is referring to his father's operation that made him a double amputee. His father did not think he would survive the operation, but he did survive and lived to be seventy-five years old.

[45]Grace Brewster Murray Hopper, "The Irreducibility of Algebraic Equations" (Ph.D. dissertation, Yale University, 1934), 1.

[46]Henry S. Tropp, "Grace Hopper: The Youthful Teacher of Us All," ABACUS, Fall 1984, 8.

continued to teach in New York City, even after the couple built a two-story home in 1939, in Poughkeepsie, New York, where Vassar is located. Vincent commuted home on the weekends from NYU.

In 1941, Associate Professor Hopper was awarded a Vassar faculty fellowship to study at the New York University Courant Institute from 1941-43. In 1943, while on leave from Vassar, she was briefly a member of the Barnard College faculty. At about the same time, the United States was being drawn into war with Japan, after the attack on Pearl Harbor on December 7, 1941, and with Germany and Italy, whose governments declared war against the United States on December 11, 1941.[47]

Hopper's family, like so many Americans, joined the war effort. Her husband and brother volunteered for the Army; her father served on the Selective Service Board; her mother served on the Ration Board; and her sister worked for General Electric making fuses for bombs.

Besides a feeling that it was her patriotic duty to do something to help her country win the war, Hopper's family had a long tradition of service in the military. Her ancestors included a minute man and a rear admiral in the Civil War.[48] Hopper recalled her reasons for joining the United States Naval Reserve in 1943:

> There was a war on! It was not unusual for a woman at that time to join the Navy; there were 30,000 to 40,000 women there at that time.[49]

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[47]Charlene Billings, Grace Hopper, Navy Admiral and Computer Pioneer, (Hillside, N.J.: Enslow Publishers, 1989), 29-36.

[48]Navy Internal Relations Activity, Profiles of Navy Tradition Makers, (Washington, D.C.: Office of the Chief of Information, 1974), 14.

[49]Marguerite Zientara, "Part II . . . Capt. Grace M. Hopper and The Genesis of Programming Languages," Computerworld, 16 November 1981, 49.

Hopper was a member of the WAVES, Women Available for Volunteer Emergency Service. Hopper's brother, Dr. Roger Murray, speculated that, although his sister was patriotic, patriotism was not the only reason Hopper volunteered for the WAVES. Hopper and her husband were separated in 1941 and divorced in 1945. They had no children.[50] Her brother believed that they "grew apart. Their career interests were different."[51] He observed further, "A marriage where one is a professor in Poughkeepsie and one is a professor in New York [City] is not a way to bind people close together."[52]

Hopper must have taken the divorce badly because in some older biographical references, those before 1982, her husband is said to have been killed in World War II.[53] He was not. However, it is the author's belief that Hopper would have joined the Navy in any case. Her sense of duty and service had been honed from her early days at the Graham School, and her family's tradition with the Navy seemed to be significant to Hopper. Her great grandfather, Rear Admiral Alexander Weston Russell, had been a Union Navy officer in the Civil War.[54] As soon as she could, after being commissioned in the Navy, Hopper visited his grave to take flowers and to tell him it was "all right for females to be Navy

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[50]Diane Hamblen, "Looking Back: Grace Murray Hopper's Younger Years," CHIPS, April 1992, 8.

[51]Dr. Roger F. Murray of Wolfeboro, New Hampshire, interview by author, 12 October 1993, tape recording.

[52]Ibid.

[53]Marguerite Zientara, "Part II . . . Capt. Grace M. Hopper and the Genesis of Programming Languages," Computerworld, 16 November 1981, 50.

[54]Navy Internal Relations Activity, Profiles of Navy Tradition Makers, (Washington, D.C.: Office of the Chief of Information, 1974), 14.

officers."[55]

In addition, Hopper believed and said on frequent occasions that one should be a "venturer not an adventurer."[56] She recalled her ancestor, a colonist, who helped build Newbury, New Hampshire, and who, at the advanced age for those days of forty-two, "picked up his musket and marched to Concord Bridge and stood up to the British Army."[57] With the United States at war with three countries, it is the author's belief that Hopper felt she should do not less.

Hopper was commissioned as a lieutenant, junior grade on June 27, 1944. Navy Commander Howard Aiken at Harvard University needed another mathematician to help program the Mark I. So, Hopper's first Navy assignment was to report to the Bureau of Ordnance Computation Project at Harvard and Commander Aiken. This assignment would change the course of Hopper's career.

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[55]Charlene Billings, Grace Hopper, Navy Admiral and Computer Pioneer, (Hillside, N.J.: Enslow Publishers, 1989), 39.

[56]Grace Hopper, interview by Chantal Momporallan (Washington, D.C. 1984). Voice of America's Interviews With Eight Women of Achievement, 1.

[57]Ibid.

CHAPTER III

THE HARVARD YEARS

When Grace Hopper decided that she wanted to join the United States Navy Reserve and serve during World War II, she persuaded Vassar to give her a leave of absence. However, convincing the Navy to allow her to join the WAVES was more difficult: she was already thirty-four years old, which was considered too old for enlistment, and her occupation as a mathematics professor had been declared by the government to be crucial to the war effort. Navy officers told her she should stay at Vassar, but Hopper would not be dissuaded. She managed to get special permission to leave her teaching job and to get a waiver on the weight requirement for enlistment, since she weighed only 105 pounds, sixteen pounds underweight for her five feet, six inches. Years later she would counsel young Navy colleagues to never take no as an answer from the Navy: "Ask them for a waiver."[58] So, in December, 1943, she found herself sworn into the United States Naval Reserve. Hopper was a member of the WAVES; her first assignment found her at Midshipman's School in Connecticut from which she graduated top in her class on June 27, 1944. She was commissioned as a lieutenant (j.g.) and assigned to the Bureau of Ordinance Computation

[58]John Hammond, "If It's Worthwhile, Go Ahead and Do It, Fisher Grads Told," The Rochester Democrat and Chronicle, 25 May 1985, 1(B).

Project at Harvard University where she would be introduced to the first modern computer,the Mark I.[59]

The idea for an automatic sequence controlled calculator began some six years before Hopper was assigned to work with the Mark I. It was the result of a collaboration among Clair D. Luke, James W. Bryce, Benjamin Dufee and Frank E. Hamilton, all IBM engineers, and Dr. Howard H. Aiken, associate professor of applied mathematics at Harvard. IBM provided funding and some expertise, Aiken provided guidance in the machine's building, and the United States Navy directed its use for twenty out of every twenty-four hours in each day under the supervision of Aiken, who, by now was Commander Howard Aiken, USNR.[60]

Aiken conceived of the machine as a physics doctoral student at Harvard in 1939. His dissertation, "Theory of Space Charge Conductions," dealt with the properties of vacuum tubes, and the complex mathematics necessary for proving solutions to his hypotheses were impossible. This frustration motivated Aiken to seek IBM's help in building a calculating machine. Even before he had written his dissertation, he had researched early attempts to build a computing engine, from Blaise Pascal in the seventeenth century to Charles Babbage in the nineteenth. Aiken decided that Babbage had been on the right track, and the culmination of his research efforts was a paper written in the summer of 1937 (almost exactly 100 years after Babbage's paper on the analytic engine) entitled, "Proposed Automatic Calculating Machine."[61]

Not surprisingly, on August 14, 1944, President Thomas J. Watson of International

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[59]Diane Hamblen, "Looking Back: Grace Murray Hopper;s Younger Years." CHIPS, April 1992, 8.

[60] Staff, "The University," Harvard Alumni Bulletin, War Summer 1944, 14-16.

[61]Gregory W. Welch, "Howard Hathaway Aiken The Life of a Computer Pioneer," The Computer Museum Report, Spring 1985, 4.

Business Machines Corporation presented Harvard University with the automatic sequence controlled calculator, later known as the Mark I. The Mark I was a parallel, synchronous calculator with a word length of twenty-three decimal digits plus the algebraic sign. One of the first large-scale, automatic, digital computers, it was fifty-one feet long, eight feet high, and weighed 9,445 pounds. Although it was separated from its programmers and operators by a wall of glass, its 3,304 mechanical relays, 225 circuit breakers, and 1,2110 ball bearings made considerable noise, along with two electromatic typewriters that printed the machine's output.[62] The Mark I could handle all kinds of mathematical problems including computation and tabulation of functions, evaluation of integrals, solution of ordinary differential equations, solution of algebraic linear equations, harmonic analysis, and statistical analysis. When a problem was coded into the machine, a solution was carried out, accurate to twenty-three significant figures, by use of the machine's logarithmic and other functional tables, stored in the Mark I or coded on tapes.[63] The press instantly dubbed it Harvard's "Mechanical Brain", and Aiken spent the next several years denying that the machine could do anything more than solve very large arithmetic problems.

Although the formal presentation took place on August 7, 1944, the Mark I had been installed in the basement of the Crufts Physics Building on the Harvard campus some months before. It was, therefore, ready to go when Lieutenant Hopper reported for duty in July, 1944. Hopper was part of a Navy team at Harvard that included, besides Commander Aiken,

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[62]IBM Automatic Sequence Controlled Calculator, (Endicott, New York: International Business Machines Corporation), 5. There is some evidence to suggest that Dr. Konrad Zuse's Z3 machine, alleged to have been operational in Germany in 1941, predates the Mark I and its contemporaries. However, the Z3 did not survive World War II. Certainly, Dr. Zuse contributed to the design and development of computer hardware although when, where, and to what extent is outside the scope of this study.

[63]Ibid.

Lts. Robert Campbell and Richard Bloch, and the one other Navy WAVE, Ensign Ruth Brendel, now Dr. Ruth Noller, among others.

As Hopper recalled to Captain Rosario Rausa, U.S. Naval Reserve (retired), in a 1991 interview, upon reporting to Commander Howard Aiken for her first Navy duty at the Computation Laboratory of Harvard University, Aiken looked up and snapped, "Where the hell have you been?"[64] She tried to explain how she had started at Navy Headquarters in Boston and searched for several hours before arriving at the laboratory. "I meant for the last two months!" Aiken said. [65] Apparently Hopper's reputation had preceded her, and Aiken was impatient for her to get started with the Mark I. Grace Hopper recalled that Aiken then said to her,"That's a computing engine. I would be delighted to have the coefficients for the interpolation of the arc tangent by next Thursday."[66]

Both former Navy ensigns Robert Campbell and Richard Bloch were already programming the Mark I when Hopper reported for duty in 1944: "I was the first programmer for the Mark I, Dick Bloch was the second, and Grace Hopper the third." Robert Campbell said in a 1993 interview. Campbell, who is 77, now lives in Concord Massachusetts. He is retired from the Mitre Co., which produces electronic systems for the U.S. Air Force.[67]

Campbell recalled how he and Richard Bloch had heard that an "old lady school teacher " from Vassar was going to be assigned to the project, but Hopper turned out to be

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[64]Rosario Rausa, "In Profile, Grace Murray Hopper," Naval History (Fall 1992) 58.

[65]Ibid.

[66]Ibid.

[67]Robert Campbell of Concord, Massachusetts, interview by author, 26 March 1993, tape recording.

anything but that. Campbell said in a 1993 interview that he had to show Hopper how the Mark I operated. He stated that she did not have much background in machines but was very curious, asking all kinds of questions. Campbell, along with Richard Bloch, taught Hopper how to program the machine.[68]

Richard Bloch, retired after many years in the computer industry with companies such as Raytheon, Honeywell, etc., remembers his first impression of Hopper was of a "learned, professorial type." He said that although her Ph.D. was in mathematics it was more theoretical mathematics, and that this fact says even more for Hopper's abilities, since all the work going on at Harvard was applied mathematics.[69]

One of Hopper's first problems to solve with the Mark I was compiling ballistics tables for shipboard guns. During and after World War I, the Navy had used a simple, electro mechanical device, based on Hannibal C. Ford's mechanical rangekeeper called the Baby Ford, to calculate range rate, bearing rate, and present range for guns. Gunners had always needed to consider crosswinds, air density, temperature and weight of the shells they were shooting, but with the development of high capacity shells and new powder charges during World War II, keeping up with computational changes became an impossible task to complete with a simple, hand device.[70] As Hopper recalled in a 1989 interview,

> There was a rush on everything, and we didn't realize what was really happening. All of a sudden we had self-propelled rockets, and we had to compute where they were going and what they were going to do.[71]

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[68]Ibid.

[69]Richard Bloch of West Newton, Massachusetts, interview by author, 14 June 1993, tape recording.

[70]Rosario Rausa. "In Profile, Grace Murray Hopper, " Naval History (Fall 1992) p. 58.

[71]Charlene Billings, Grace Hopper Navy Admiral and Computer Pioneer (Hillside, N.J.: Enslow Publishers, 1989), 52.

In addition, Hopper and her colleagues, Campbell, Block, and Brendel, used the Mark I to calculate the area covered by a mine sweeping detector as it was towed behind a ship, to calculate the optimum placement of mines on the sea floor, and to calculate a top secret mathematical simulation of the shock waves that would result when the first atomic bomb was exploded.[72] As an ancillary project for the Naval Research Laboratory, the group produced an eight-foot-wide set of books documenting the Bessel functions.[73]

Both Richard Bloch and Ruth Noller affirmed in 1993 interviews that the Harvard group was an elite, top secret cadre of scientists. Noller recalled in an interview at her home in Sarasota, Florida, how they would work round the clock, sometimes sleeping at their desks with armed guards posted at the top and bottom of the stairs leading to the Computation Laboratory. She also confirmed that some of the calculations they worked on were for the atomic bomb, but that most of the time the group was not told how their work would eventually be used.[74] As an interesting aside, when asked to confirm the group's calculations for the atomic bomb, a very reticent Robert Campbell simply stated, "I guess I'm not in a position to talk about that."[75]

Hopper herself was interviewed in 1972 about her time at Harvard as part of the Smithsonian's Computer Oral History Project. She recalled how every member of the Mark I

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[72]Rosario Rausa, "In Profile, Grace Murray Hopper," Naval History (Fall 1992): 60.

[73]Ibid. Bessel functions are of a class of transcendental functions (in mathematics) expressible as infinite series and occurring in the solution of differential equations.

[74]Dr. Ruth Noller of Sarasota, Florida, interview by author, 20 March 1993, Sarasota, Florida, tape recording.

[75]Robert Campbell of Concord, Massachusetts, interview by author, 26 March 1993, telephone tape recording.

project worked as hard and fast as they could because "there was a war on!"[76] Hopper said that if one of her problems was running on the machine, she stayed at the laboratory around the clock. She recalled a particular instance when she had been in the laboratory, "three days and nights and there was a hurricane blowing outside [in Cambridge]."[77] All three of the women working that night decided they would try to get home and did so by holding hands and moving from tree, to lamppost, to tree, so that no one would be blown away. Hopper remembered, "We made our way laughing from tree to post because we had been there for three days, and we were going out even in a hurricane. We were going to get home and get washed."[78] Hopper observed that no one working on the Mark I during World War II had time to theorize about the future use of computers. As she said, during those war days, "the future in a sense didn't exist."[79]

The Mark I understood only one language, a machine language consisting of code numbers. Each code instructed the machine to perform a particular mathematical operation.

Ruth Noller recalled laboring over the coding sheets used to program the Mark I, and discussed how programmers had to keep four columns of information for each, single calculation the Mark I performed. The first three columns consisted of code numbers telling the machine, for example to "take a number from A, add to B, and perform operation C," and so on. The fourth column was reserved for comments telling any programmers coming

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[76]Grace Hopper, interview by Beth Lupert and Dr. H.S. Tropp, 5 July 1972, transcript, Computer Oral History Collection, National Museum of American History, Smithsonian Institution, Washington, D.C.

[77]Ibid.

[78]Ibid.

[79]Ibid.

after them how this particular operation would work with the whole program.[80] Noller showed the researcher some of the original coding sheets that were done in her own hand that she had kept along with other memorabilia from the war years. Many more examples may be viewed as part of the Grace Murray Hopper Collection at the National Museum of American History, a part of the Smithsonian Institution in Washington, D.C.

One of Hopper's assignments while working on the Mark I was writing the machine's technical documentation. To complete this assignment, she had to work closely with the project's commanding officer, Commander Howard Aiken, a brilliant but abrasive Harvard professor. Aiken had earned a reputation for abrasiveness while an applied mathematics professor at Harvard before World War II began. As a result of his being named Navy Commander of the Harvard group, apparently, his natural abrasiveness was given free reign, and it can be said that he was not universally beloved by all members of the group. Hopper described Aiken as "just terrific. He was a real leader . . . We all worshipped him."[81]Robert Campbell described Aiken as "pretty much all work."[82] Ruth Noller referred to Aiken as "that awful man." Noller, who was only nineteen years old when she came to the Computation Laboratory, recalled that she was never comfortable around Howard Aiken and that Hopper was her buffer between the Commander and herself. She says that she felt grateful to Hopper because:

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[80]Dr. Ruth Noller of Sarasota, Florida, interview by author, 20 March 1993, Sarasota, Florida, tape recording.

[81]Charlene Billings, Grace Hopper, Navy Admiral and Computer Pioneer. (Hillsdale, New Jersey: Enslow Publishers, 1989), 64.

[82]Robert Campbell of Concord, Massachusetts, interview by author, 26 March 1993, telephone tape recording.

> . . . she was always there for me. When I had a project she made sure that I fully understood what it was all about. She was my commanding officer, not Aiken, and she was my mentor in the best sense of that word.[83]

Noller recalled that Aiken threatened to court martial a young, enlisted man and "really gave him hell" after Aiken found him asleep at his post one morning at 4 a.m.: "Grace went to bat for that young man with the Commander . . . Grace always championed the underdog."[84]

Noller, Campbell, and Bloch stated that the group seldom got together socially except at two Christmas parties and an occasional Navy event. Noller did state that she and Hopper, with whom she shared a rooming house, would get together for lunch and that Hopper would always order a double manhattan to drink.[85] In part of the memorabilia that is contained in the Grace Murray Hopper Collection at the Smithsonian, there are pictures of a picnic that everyone at the laboratory attended, except Noller, who had leave. The picnic took place at Hopper's parents summer home in Wolfeboro, New Hampshire, and two of the more interesting photographs in the collection are one of Hopper pulling a child's red wagon and one of Aiken contemplating a swim in the lake.

Noller might have stayed in the field of computer science had it not been for her experience with Aiken: "Grace wanted me to stay at Harvard and in the WAVES, but I couldn't get out of there fast enough." Noller left Harvard in 1946 and completed both a master's and Ph.d. in mathematics at Buffalo State University. Subsequently, she taught at

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[83]Dr. Ruth Noller of Sarasota, Florida, interview by author, 20 March 1993, Sarasota Florida, tape recording.

[84]Ibid.

[85]Ibid.

Buffalo State where she retired as Director of the Creative Learning Center in 1985.[86]

It is clear that Grace Hopper was a great admirer of Howard Aiken; although, she allowed that working for him was a challenge, particularly when Aiken asked her to write the complete documentation manual for the Mark I. Hopper recalled in a 1989 interview, how she was sitting at her desk in the laboratory one day and Aiken walked up behind her: "I got to my feet real fast. He told me he wanted me to write a book. I said I couldn't write a book. He said I was in the Navy now; so, I wrote a book." That book was A Manual of Operation for the Automatic Sequence Controlled Calculator.[87]

Although the author of the manual is stated as "Staff of the Computation Laboratory," Aiken credits Hopper for completing the project when he says in the preface: "Lieutenant Hopper also acted as general editor, and more than any other person is responsible for the completion of the book."[88] Hopper would later recall how she was able to write about five pages a day, which she had to read to Aiken each evening. If he found something wrong with her day's work, she would have to start over. She recalled, "One section in there, on division, I've forgotten how much time I spent on it."[89] Hopper mused that Aiken asked her to do the writing rather than another member of the team because in writing reports for him she had written "a little better English . . . and I'd always bugged all my students about writing things . . . I've always been careful about getting things written clearly even back

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[86]Ibid.

[87]Charlene Billings, Grace Hopper, Navy Admiral and Computer Pioneer. (Hillside, New Jersey: Enslow Publishers, 1989), 53.

[88]Staff of the Computation Laboratory, A Manual of Operation for the Automatic Sequence Controlled Calculator. (Cambridge: Harvard University Press, 1946), Preface.

[89]Grace Hopper, Interview by Beth Lupert and R. H.S. Tropp, 5 July 1972, transcript, Computer Oral History Collection, National Museum of American History, Smithsonian Institution, Washington, D.C.

when I was teaching, and I taught 13 years before I went into the Navy."[90]

As might be suspected, the Manual, as it was referred to by the team, was not exactly light, bedside reading. It was curiously literary, however, no doubt thanks to Hopper's early tutelage by Misses Schoonmaker and Hartridge: each chapter began with a literary quote, sometimes humorous. For instance, Chapter IV, Coding, began with an early Elizabethan quote from "Secret and Urgent" by Fletcher Pratt: "These Babes of Grace should be taught by a master well verst in the cant language or slang patter, in which they should by all means excel."[91] The book's introduction began with an historical nod to those mathematicians who had come before the Computation Laboratory team: John Napier; Blaise Pascal; and, of course, Charles Babbage, English inventor of the calculating engine, among others. It included photographs and schematic diagrams of the inner workings of the Mark I. (See Appendix G.) It also included extremely detailed directions for how to work with punched cards, and how to print the results of the machine's calculations. Chapter VI, "Solutions of Examples," describes various problems and their solutions, including how to write code so that a minimum of very expensive machine time would be needed to achieve the desired results. However, Hopper and Aiken cautioned that

> A fine balance must be maintained between computation time and the ensuing complexity of the coding. The conservation of one or two cycles of machine time, will, for example, not be profitable if it means that the counters containing essential parts of a computation must be reset before the results are checked.[92]

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[90]Ibid.

[91]Staff of the Computation Laboratory, A Manual of Operation for the Automatic Sequence Controlled Calculator. (Cambridge: Harvard University Press, 1946), 98.

[92]Ibid., 287.

The chapter then described how the coder, the programmer,[93] must give explicit operating instructions for each sequence tape, i. e., each calculation. In order to run the tape, information must be included about: (1) switches (which were set by hand); (2) tapes; (3) card feeds; (4) card punch; (5) typewriters; (6) storage counters; (7) functional counters; (8) checks, i.e., error-checking and finally, (9) rerun instructions. Even with this labor-intensive approach, at the end of two years the Computation Laboratory had managed to solve a wide variety or problems, from statistical analysis to the solution of partial differential equations.

By the time Hopper finished writing the Manual, World War II was almost over. Ensign Ruth Brendel was looking forward to leaving the Navy and returning to Buffalo, New York, both Richard Bloch and Robert Campbell had already begun work on the Mark II computer, the Mark I's successor, and Hopper determined she would not return to Vassar, but would remain at Harvard and join the regular Navy, which by now was allowing women to take up active duty.[94]

Aiken was instrumental in getting Hopper appointed as a Harvard Research Associate; but Hopper was not successful, in her bid to join the regular Navy, because at forty years old, she was told that she was too old for active duty. Hopper would recall later that being told you are too old at the tender age of forty was probably a good thing because "you can go through the experience and it doesn't bother you again."[95] Hopper did remain in the Naval Reserve and directed the first large-scale, commercial use of a computer when the Mark I was used to print the Prudential Company's premium notices. Curiously, Hopper was one of the

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[93]No such thing as programmer existed then although the term was known in England. It would take several years for program to replace code in the United States. Rosario Rausa, "In Profile, Grace Murray Hopper," Naval History (Fall 1992), 60.

[94]P. Sweet, "A living legend: still making new waves," Computing (U.K.) 29 (March 1984): 24.

[95]Rosario Rausa, "In Profile, Grace Murray Hopper," Naval History (Fall 1992), 61.

few people at Harvard during those days who could envision the wide spread use of computers in business. Even Aiken believed that computers would be used exclusively by scientists and mathematicians.[96]

Although the Mark I remained in operation until 1959, in early 1946 Hopper joined her former colieagues, Bloch and Campbell in programming the Mark II, the Navy's successor to the Mark I. In early 1945, Ensign Robert Campbell was assigned to help Howard Aiken design the Mark II computer, installed at the Navy Proving Ground, now the Naval Surface Weapons Center in Dahlgren, Virginia. The Mark II was five times faster than the Mark I and was huge. It occupied 4,000 square feet of space, contained 13,000 relays, and had six, large walk-in relay racks. It took the Mark II 0.3 seconds to perform addition, 2.0 seconds for multiplication, and 2.2 seconds for division[97] as compared to the Mark I's .15 seconds for addition, 5.7 seconds for multiplication, and 15.3 seconds for division.[98] The Mark II was the first multiprocessing computer and the first machine that used vacuum tubes and magnetic tape for faster input and output.[99]

In a 1989 interview, Hopper explained the concept of multiprocessing computers by describing how, under program control, the Mark II could be split into two computers, working in parallel and exchanging data through the transfer registers. Then, again under program control, the operator could put the two halves back together again. Hopper went on to point out that Howard Aiken has never really been given credit for his application of

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[96]Charlene Billings, Grace Hopper, Navy Admiral and Computer Pioneer. (Hillsdale, New Jersey: Enslow Publishers, 1989), 64.

[97]Rosario Rausa, "Computers in the Navy," Naval History (Fall 1992) 4-5.

[98]IBM Automatic Sequence Controlled Calculator, (Endicott, New York: International Business Machines Corporation), 5.

[99]Rosario Rausa, "Computers in the Navy," Naval History (Fall 1992) 4-5.

parallel processing in the Mark II.[100]

While working on the Mark II, Hopper and the rest of the Navy crew recorded the world's first instance of a computer bug. The group was housed in a World War I vintage building with all the windows open on a hot summer afternoon, when suddenly the Mark II stopped. They traced the problem to a moth that had been captured in one of the relays. As Hopper recalled later:

> We got a pair of tweezers. Very carefully we took the moth out of the relay, put it in the logbook, and put scotch tape over it . . . . From then on if we weren't making any numbers, we told . . . Aiken that we were debugging the computer.[101]

The logbook with its taped bug can be viewed in the Naval Museum at the Naval Surface Weapons Center in Dahlgren.

Hopper and the Navy crew continued to work on the Mark II until late 1948, solving ballistics problems. The Mark II, unlike the Mark I, was wholly a Navy project, designed and built by Navy personnel and running twenty-four hours a day, seven days a week under their auspices. By this time the crew had grown from its original twelve, to twenty officers, fifty-eight enlisted personnel, and twelve civilians. The Mark II would later be renamed the Aiken Relay Calculator in honor of Howard Aiken.[102]

In 1948, the Navy commissioned another computer, the Mark III, also installed at the Naval Surface Weapons Center in Dahlgren, Virginia. The Mark III was promoted as the "fastest machine ever built", since its mechanism was electronic and not based on relays as

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[100]Charlene Billings, Grace Hopper Navy Admiral and Computer Pioneer. (Hillside, New Jersey: Enslow Publishers, 1989), 58.

[101]Ibid. This incident is thought to be the origin of the term bug, when used to mean computer bug.

[102]Anthony G. Oettinger, "Howard Aiken," Communications of the ACM (May 1973): 298-299.

the Mark I and Mark II had been. It was Howard Aiken's last machine built for the Navy and was fully functional in early 1950.[103]

However, the Mark III was a disappointment because it turned out to be much slower than advertised.[104] One of the reasons for its failure may have been the difficult conditions under which its operators had to work. Operators for both the Mark II and Mark III had to stand up to activate the switches and buttons on the machine. When someone suggested to Aiken that he design a console for the buttons and switches so that operators could sit down while working, he said, "If any operator wears out his shoes, I'll buy him a new pair."[105] Ergonomics was apparently not a consideration in those days.

Hopper remained with Harvard, programming the Mark II and Mark III until 1949. During that time, Hopper and her crew developed the habit of collecting pieces of code that they had already been tested and debugged and writing them down in a notebook. For instance, there was a piece of code or subroutine used for finding the sine, another for finding the cosine, arc tangent, etc. Thus, when a problem called for a mathematical operation that had already been programmed, they could simply look up a subroutine. They also refined other programming techniques that are still in use today, such as modular programming, error checking, and jumping forward in a program to a section that had not been written (assembled) yet.[106]

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[103]Ibid.

[104]Rosario Rausa, "Computers in the Navy," Naval History (Fall, 1992) 6.

[105]Ibid.

[106]Charlene Billings, Grace Hopper Navy Admiral and Computer Pioneer. (Hillsdale, N.J.: Enslow Publishers, Inc., 1989), 70-71. Today a computer language known as Assembly, a language in-between machine code and higher-level languages such as COBOL and Pascal, is used to program primarily large, mainframe machines.

In a 1989 interview, Hopper describes how she formulated the concept of "jumping" in a program by using the old rules of women's basketball that she had played while a student at Miss Hartridge's School in New Jersey. Under the old rules, a player could dribble the ball only once and could not take a step with the ball still in her hands. So, to get the ball under the basket and set up a goal, a player had to pass the ball to another girl, who was standing near the basket, and then "run like the dickens" so that other girl could pass it back and the initial player could try to shoot a basket. Hopper said that she used this same technique to tuck an area of memory at the bottom of a program that she called the "neutral corner." Then, whenever, she needed to jump forward in a program, she would jump to the "neutral corner", and set up a flag for an operation which said, "I've got a message for you." That meant that as each routine was assembled in the program, it had to look and see if it had a flag; if it did, it put a second jump from the neutral corner to the beginning of the routine. In that way, Hopper and her crew had a primitive, single-pass compiler, and she states that the idea did come from playing basketball.[107]

By 1949, many of Harvard's original group of mathematicians and scientists that worked on the Mark I had gone on to more lucrative ventures in private industry. Hopper was still in the Navy Reserves, and was looking for new challenges. She recalled that 1949 was a time of job hunting for her, since her contract at Harard had run out. She attended a meeting of the Association for Computing Machinery in Oakridge, Tennessee, where she received "a wild assortment of job offers."[108] She narrowed the offers to two: one from

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[107]Ibid. (A compiler is software that converts the programmer's procedural-language program, source code, into machine language, object code, that is understood and processed by the computer.)

[108]Grace Hopper, Interview by Dr. M. Cohen, 4 February 1969, transcript. Computer Oral History Collection, National Museum of American History, Smithsonian Institution, Washington, D.C.

Howard Engstrom in St. Paul, Minnesota, to work at Engineering Research Associates; and the other from John Mauchly at the Eckert-Mauchly Computer Company. Hopper recalled that what finally persuaded her to join Eckert-Mauchly was that "they had BINAC running and UNIVAC I was well underway. . . whereas it looked as though out at St. Paul, the computer was further away, and I wouldn't be able to actually code and run problems on it."[109] She also recalled that besides professional considerations, Eckert-Mauchly was located in Philadelphia, much closer to New York than St. Paul, and thus much closer to her family. She also believed that Mauchly was the "kind of person I would enjoy working for."[110] By that, she meant that Mauchly was looking ahead:

> He was envisioning much larger problems which hadn't even been stated yet. I mean going into all that weather prediction. . . He was looking way ahead. . . Even though he was a college professor, he was visiualizing the use of computers in the business and industrial area, the things that they would be able to do.[111]

So, Hopper accepted a job as senior mathematician at the Eckert-Mauchly Computer Corporation in Philadelphia, Pennsylvania.

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[109]Ibid.

[110]Ibid.

[111]Ibid.

CHAPTER IV

A CORPORATE CAREER

Grace Hopper went to work for Eckert-Mauchly as a senior mathematician in 1949, only two years after its founders, J. Presper Eckert and John W. Mauchly, started the company. From 1943 to 1946 Eckert and Mauchly had worked for U.S. Army Ordnance, building and programming the ENIAC, an all-electronic, digital computer that could perform 5,000 additions or subtractions per second.[112]

In 1947, Eckert and Mauchly left the Army's employ and incorporated their venture as the Eckert-Mauchly Computer Corporation. They developed the BINAC or Binary Automatic Computer, the first electronic and fully self-checking computer. When Grace Hopper arrived at Eckert Mauchly in 1949, the company had just shipped a BINAC to Northrup Aircraft Corporation in Hawthorne, California. It was to be used for the short-lived, secret SNARK missile project. One of Hopper's first assignments at Eckert-Mauchly

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[112]Martin H. Weik, "The ENIAC Story," Army Ordnance XLV, No. 244 (January-February 1961): 571-575. Also working on the project with Eckert and Mauchly was John von Neumann, the brilliant mathematician. Concepts that would manifest themselves later as Eckert and Mauchly pursued careers in the private sector, such as stored programs, program counters, mercury-delay line storage, and magnetic storage may have been discussed with Von Neumann. Certainly, it is clear the idea of a computer with a stored program that could be accessed the same way as data was written about by Von Neumann as early as 1946 in his article, "Preliminary Discussion of the Logical Design of an Electronic Computing Instrument." The ideas this article contains came to be collectively referred to among computer scientists and mathematicians as the von Neumann machine.

was as a member of the team sent to California to teach Northrup employees how to use the computer.

In contrast to the computer Hopper had used at Harvard, the BINAC could solve problems about a thousand times faster. Its programs were written in octal or base eight numbering system, rather than the decimal system used at Harvard. The BINAC was also one of the first stored program computers, i.e., instructions for performing various operations were held in the machine's internal store and were available to be operated on in much the same way as data during execution of a program. Thus, it was possible to alter a program during execution, and in the late forties and fifties this simple concept increased enormously the scope of automatic computing, and was undoubtedly the first step on the road to compilers, in whose development Hopper would play an essential part.

In 1969, Hopper reminisced about her first days at the Eckert-Mauchly Company. The company was housed in an old, long narrow plant that had been a factory. There was a junkyard on one side of the building and a cemetery on the other. Hopper recalled, "We always said we would push the computer out of one side if it didn't run, and we'd jump out the other."[113] Although the war had ended years earlier, Hopper recalled that there was an armed guard stationed at a desk on the first floor of the company's building. BINAC and later UNIVAC I were located on the first floor also, and that is where Hopper and the other programmers worked. Hopper described an elevator that ran "once in a while," and a wooden floor which had had grease and oil spilled on it for years from the machinery that had been there previously. She characterized her colleagues as a fun-loving group who hung mobiles from the exposed, bare beams of their room, and who "plastered all kinds of signs

[113]Grace Hopper, interview by Dr. M. Cohen, 4 February 1969, transcript, Computer Oral History Collection, National Museum of American History, Smithsonian Institution, Washington, D.C.

around, like the one: 'Don't think . . . let UNIVAC Do It,' which was a doctored-up IBM sign."[114]

The experience that Eckert-Mauchly gained in building and programming the BINAC was used to successfully complete the first commercially-available computer, the UNIVAC I, or Universal Automatic Computer. As Hopper recalled: "John Mauchly wrote the C-10 code [Assembly Language] for the UNIVAC I, and it has been the basis of most codes since. A was add, M was multiply, B was bring, C was clear; it was a beautiful code."[115] The very first UNIVAC I was delivered to the U.S. Bureau of Census in 1951. At about the same time, Eckert Mauchly was acquired by Remington Rand Inc. which subsequently merged with The Sperry Company in 1955.

The UNIVAC I could handle both numbers and alphabetic characters, and it separated the complex problem of input and output from the actual computational part of the machine. This was the first time that input and output had been treated as separate problems with separate solutions.

The machine accessed a program stored in mercury-delay lines. The stored program circulated within the lines in the form of acoustical pulses that could both be read from the line and written to it. Mercury-delay line storage was cyclic rather than random access in nature, and the word or number that a programmer needed had to be accessed sequentially. A faster program was possible by making sure that each instruction had a second address, specifying the location of the next instruction needed.[116]

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[114]Ibid.

[115]Charlene Billings, Grace Hopper, Navy Admiral and Computer Pioneer. (Hillsdale, New Jersey: Enslow Publishers, 1989), 65.

[116]C. G. Bell and Newell, Computer Structures. (New York: McGraw-Hill, 1971), 92-119.

The UNIVAC I could use punched cards and magnetic tape for both input and output, and there was also a keyboard console for input while the program ran. The machine had been rigorously tested before being delivered to the U.S. Bureau of Census, and it was in later testing and refinement of UNIVAC I and II that Grace Hopper and her team would complete pioneering work in automatic programming and compilers.

Hopper arrived at Eckert-Mauchly as a member of a loosely-organized group of individuals but her management experience and leadership experience soon surfaced, making her a logical choice for team leader. And, her years of experience in the classroom allowed her to teach the younger members how to work effectively.

At Remington Rand Hopper managed one of the workgroups charged with testing the UNIVAC I and II and with developing and refining new programming techniques. During that time, Hopper influenced many younger people with whom she came in contact. One of those people was Howard Bromberg.

In a September, 1993, interview Bromberg recalled his experiences with Grace Hopper. Bromberg was a young, civilian employee at Remington Rand working for the Navy in the early fifties. Since there were few computers available in those days, the Navy made arrangements with the UNIVAC Division of Rand in Philadelphia to use one of their test computers. Remington Rand was producing about one computer every three months, testing them for sixty days before they were shipped to customers. Bromberg recalled that the Navy used one of the computers during its second thirty days of testing. He stated that when the machine was shipped out, " we moved to the next location on the manufacturing floor -- we moved out staff and tapes and everything."[117]

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[117]Howard Bromberg of San Francisco, California, interview by author, 19 September 1993, telephone tape recording.

While working on the manufacturing floor, Bromberg met Hopper. Bromberg said of Grace Hopper, "Grace never had anyone do anything for her that she couldn't do herself. She was a complete hands-on individual, intimately involved in every aspect of programming."[118]

He explained that, since the Navy program was given highest priority, and he had control of that program, Hopper introduced herself, explained what she did, and said she sure could use some more computer time. Bromberg said he replied, "You bet, " because he was very interested in Hopper's work in automatic programming. According to Bromberg, as a result of their frequent encounters at work, they became good friends, and not too long afterward, Hopper invited him to join her group. They lived in the same neighborhood outside of downtown Philadelphia and commuted back and forth to work together. Bromberg stated, "Grace never went out with the rest of us to lunch or when we went out on the weekends. She would rather go home. She used to grow African violets, and she had a very select group of social friends, but they were different from anyone at work."[119]

Bromberg recalled two incidents in particular that he believed summed up the person Grace Hopper was. One of these incidents happened when he picked her up for work one morning. "The night before we had been discussing a particular problem that someone had encountered during the day. When I picked her up for work the next morning, she had the solution." [120]

Bromberg said that he told her she was not giving the rest of the group a chance to

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[118]Ibid.

[119]Ibid.

[120]Ibid.

solve problems because they all went home to "crying babies", and that they wanted to relax from the problems of the day. He said that she shot back, "That's their problem, that's their choice!"[121] Bromberg speculated that she was so well organized that she did not like outstanding, unresolved problems and was not able to dismiss them until they were solved.

Bromberg also described an incident that happened before he left Remington Rand to join RCA. He said that for Hopper, "nothing was too difficult, boy, she would tackle anything -- would jump in feet first."[122] He also said that "Grace was a master politician and shared with us her Machiavellian pursuits." [123] At Remington Rand, Hopper was on the same corporate level as John Mauchly, according to Bromberg, and "both of our programming groups were in a little internal competition for funding."[124] Both Hopper and Mauchly reported to Presper Eckert, who was a vice president. Bromberg described how one day Hopper was on the manufacturing floor introducing a family friend of Eckert's to all the group members. Apparently, this young man was making the rounds of various departments looking for a job. According to Bromberg, a short time later Hopper announced that she had hired the young man. Bromberg said he complained to Hopper, "How can you hire him? He knows nothing about computers, and everything we do will get back to Eckert."[125] When Hopper asked if there was anything that the group did that Bromberg was ashamed of, and he said, "No," she stated, "What better way to get our message across?"[126]

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[121]Ibid.

[122]Ibid.

[123]Ibid.

[124]Ibid.

[125]Ibid.

[126]Ibid.

Bromberg said she then smiled and scurried off, and, the group did receive its funding. Bromberg recalled that many of the group eventually left Remington Rand taking, "Grace's message of striving for a higher level of technical accomplishment with us."[127]

Although Bromberg and Hopper and their respective companies would eventually become rivals in the race to produce a COBOL compiler, he remembers his time at Remington Rand fondly, chiefly because of her. He and Hopper kept in touch through the years, and Bromberg, who is now a private consultant for software companies in San Francisco where he lives, states that he was always grateful for his "fortuitous association with this grand lady . . . She was a teacher, an innovator, and always a renegade."[128]

Throughout her years in a corporate environment, Grace Hopper published articles that, looking back from today's vantage, can be said to be truly visionary. One of these, "The Education of a Computer," which was published as part of the proceedings of the Association of Computing Machinery meeting in May, 1952, expresses her, then, revolutionary concept of how programming languages should work.

In this article, Hopper compares a computer program, from a single operation to a whole library of routines, to a production line: "input of raw materials, controlled by human beings, possibly with instruments supplied with machine tools; the operation produces an automobile, a rail, or a can of tomatoes."[129] Carrying out her analogy, she explained that, in the beginning, computers simply took the place of a mathematician's pencil and paper, or instruments as referred to above: computers carried out mathematical operations at a faster

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[127]Ibid.

[128]Ibid.

[129]G. Hopper, "The Education of a Computer," in Proceedings of the Association of Computing Machinery held in Philadelphia, May 2, 3, 1952, 1.

and faster rate of speed. In the future, Hopper stated, computers that have been supplied with a catalog of subroutines, stored in their primary memory, or accessible via secondary memory, will allow the programmer to spend more time solving higher order problems, and will allow the use of a computer in fields other than mathematics or science, employing them in business and manufacturing.[130]

The article included the first reference to and definition of what would become compiler tools and techniques that are commonplace today. These included subroutines, formula translators, relative addressing, and [computer] code optimization. Hopper also predicted correctly that software would be much more expensive to produce than hardware, because of a greater lag time from conception to production. All of these predictions were made in 1952, almost 10 years before the first integrated circuits and more than twenty years before personal computers became commercially available.[131]

One more example of Hopper's uncanny ability to predict the future of the computer industry should be pointed out: her May, 1953, article entitled, "Compiling Routines," published in the journal Computers and Automation. In this article reference is again made to subroutines or special orders as they were called then. Hopper understood that these special orders would get around the problem of being able to give no more than eighty, single instructions to the computers of that time. She understood that, by making use of a large catalog of subroutines, the computer would become a multipurpose machine:

> The trend is evident. In the future, customers will express less concern as to whether a computer is 'mathematical,' 'commercial,' or 'logistical'. . . The identical computer may be an engineering instrument at one moment with

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[130]Ibid.

[131]Encyclopedia of Computer Science and Engineering (New York: Van Nostrand Reinhold Company, 1983), s.v. "Personal Computing," by Jim Warren, Jr.

one program and a payroll clerk at the next moment with another program.[132]

Hopper was predicting the future of the computer industry in 1952, But, first, the development and implementation of a new kind of software, easier to use programming languages, would have to happen before the future could become a reality. This new kind of software, so-called high level languages, would free the programmer from the use of machine language, making her job less tedious and error-prone.

Throughout the 1950's, Grace Hopper and her team at Remington Rand, among others, were moving closer and closer to the concept of writing programs in English and having the computer translate the English into machine code that the computer could execute. Hopper understood that one of the greatest stumbling blocks to the widespread application of computers was that computer languages of that time were comprised primarily of mathematical and scientific symbols. She observed:

> There are a lot of people who don't get along with symbols, so they use words . . . . As far as I'm concerned, a word is a symbol, it's just a little bit longer. There's no difference between the word a-d-d, and the plus sign, so why not write it in English? It was common sense . . . .[133]

However, not all her colleagues, even her admirers at Remington Rand were convinced that writing programs in English was a good or even feasible idea. Company vice presidents told her that computers could not understand English words. As Hopper recalled in a 1986 interview, "I allowed that I never expected any computer anywhere to understand anything - - all I was going to do was compare the bit patterns."[134]

So, without management's blessing or even a budget, she and her team proceeded to

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[132]Grace Hopper, "Compiling Routines," Computers and Automation 2(May 1953:) 1.

[133]George Still, "Hopper: 'We're at the beginning,'" PENTAGRAM, 15 December 1983, 1.

[134]Grace Hopper, All Things Considered, interview on National Public Radio by Scott Simon, cassette ATC 860919, Washington, D.C., 1986.

refine the concept of automatic programming and compilers. This refinement would lead eventually to the development of the computer language COBOL, Common Business Oriented Language.

In some sources, Hopper is named the inventor of COBOL. She was not. As so often happens in a time of rapid innovation in a new field, many people contribute to the final iteration of an idea; this was true of the final version of COBOL, first marketed in 1960. However, Hopper can truly be called the mother of COBOL because it was she who nurtured its development along the way, and it was she who sold the idea of developing a business programming language to company management. In a 1986 article by George Leopold in Datamation, Betty Holberton, also a pioneer in the development of COBOL, said of Grace Hopper, "She spoke to management in terms they could understand. I think that was her real strength."[135] In the same article, Hopper says that with any new idea you have to "sell that idea and market it. In the long run, you don't do it by logic. You've got to show the guy why it is in his interest to accept a new way."[136] And, Hopper always put a premium on doing things a new way.

By sometime in the middle of 1952, Grace Hopper flatly stated, "I could make the computer do anything which I could completely define."[137] In that same year, she and her team at Remington Rand had completed the first compiler, the A-O, based to some degree on Betty Holberton's merge-sort generator. This compiler was a set of instructions that could

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[135]George Leopold, "Beacon for the Future," Datamation, October 1, 1986, 110.

[136]Ibid.

[137]Charlene Billings, Grace Hopper, Navy Admiral and Computer Pioneer. (Hillsdale, New Jersey: 1989), 68.

translate mathematical code into machine code that the computer could use to perform calculations.[138]

Hopper collected all the pieces of code that she knew would work and stored them on magnetic tape. Hopper numbered all these procedures, giving each a unique number. Then if she needed any of the procedures for a program that was being written, she did not have to copy them in machine language. "All I had to do was to write down a set of call numbers, let the computer find them on the tape, bring them over and do the additions. This was the first compiler."[139]

The A-O system and its descendants, A-1 and A-2, became the basis for a programming language that employed twenty instructions in English, Flowmatic. Some typical commands that Flowmatic used were, COUNT, DIVIDE, SUBTRACT, MOVE, REPLACE, and MULTIPLY. Flowmatic was used by Hopper and her team to program Rand's UNIVAC I and UNIVAC II. The team also wrote versions of Flowmatic in French and German to demonstrate its potential. And, it was Flowmatic that provided the heart of the final version of COBOL. By 1957, three major computer languages were being used in American corporations. These were IBM's FORTRAN, Automatically Programming Tools (APT), and Hopper's Flowmatic.

On April 8, 1959, a meeting was held in Professor Saul Gorn's office in the University of Pennsylvania's Computer Center in which Hopper participated to address the issue of how to develop a common business language. In addition to Hopper, there were

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[138]Ibid.

[139]Ibid., 70.

representatives from Du Pont, Honeywell, and Charles Phillips of the Department of Defense.[140] This loosely-aligned group would later add more members and call themselves the Conference on Data System Languages (CODASYL). It was Hopper who suggested that Charles Phillips of the Department of Defense be placed in charge of the effort, reasoning that since he had no corporate affiliation, he would be neutral about any proposals made.

After a great deal of hard work and an almost disastrous endrun made by Honeywell's representative to force an exclusively Honeywell programming language on the committee, in June, 1960, The Government Printing Office issued the COBOL 60 Report. As soon as IBM accepted the report, other companies fell in line. COBOL was officially accepted as the business programming language: now, the race was on to develop a COBOL compiler.[141]

Ironically, Howard Bromberg, a former colleague of Hopper's at Remington Rand, would best her in the competition for first place in the compiler race. Bromberg, was now working for RCA, and on August 26, 1960, the New York Times declared RCA the winner of the COBOL compiler race. The same article quoted Grace Murray Hopper, Chief Engineer for Automatic Programming, at Remington Rand: "We shall definitely have a COBOL programming system on our UNIVAC II computer by October 31."[142]

Not long afterward the U.S. Navy adopted COBOL, and one wonders how much influence Hopper, who was still in the Naval Reserves, had on this decision. In addition, the European Computer Manufacturers Association (ECMA) formed a committee to work with

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[140]Charlene Billings, Grace Hopper, Navy Admiral and Computer Pioneer. (Hillsdale, New Jersey: 1989), 79.

[141]Marguerite Zientara, "Part 11 . . . Capt. Grace M. Hopper & The Genesis of Programming Languages," Computerworld, November 16, 1981, 51-52.

[142]"The Computer Translating Race," The New York Times, 6 December 1960, E(13).

American developers of COBOL, eventually issuing more than a dozen information bulletins.[143]

COBOL was just one high-level language developed and distributed in the 1950's. Others such as FORTRAN, used by scientists, were also being discussed and implemented in the computing industry and academe. However, COBOL is still one of the very few programming languages that employs so much natural language interface, i.e., many commands are written in English. This may explain, in part, why COBOL remains popular as a programming language today.[144]

The programming language COBOL is a procedure-oriented, high-level language intended for business data processing. Procedure-oriented, high-level languages are distinguished from machine language and assembly language in that commands may be written in natural languages such as English. Procedure-oriented languages also differ from problem-oriented languages in which the programmer states the problem and then leaves the machine's system to choose a procedure for solving the problem.

The COBOL compiler, just like other compilers, provides the interface between the programmer's instructions and the machine code that can be executed. The compiler translates the source program, what the programmer writes, into a machine-language program called the object code.

A COBOL program is divided into four sections: the identification division; the environment division; the data division; and the procedure division. One of the most important concepts employed by COBOL as well as by other procedure-oriented languages, is

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[143]Marguerite Zientara, "Part 11 . . . Capt. Grace M. Hopper & The Genesis of Programming Languages," Computerworld, November 16, 1981, 51-52.

[144]Hopper's Legacy: Innovation, Education," IEEE Software 9 (March 1992): 95

the use of terminology from English grammar. Thus, a verb in COBOL is understood to be an operation or command to carry out some process, such as SELECT, MOVE, GO TO, etc. Verbs in COBOL are reserved words and cannot be used as data names. COBOL verbs always appear at the beginning of a sentence, telling the compiler immediately what is the meaning of the sentence.

Both Robert Campbell and Richard Bloch, who worked with Hopper on the Mark I at Harvard, agreed that, one of Hopper's greatest contributions to the field of computer science was her pioneering work in compilers and specifically her work to make COBOL a reality. Campbell observed that, "Grace would get a problem and not let go of it until it was solved -- I think it was this quality that allowed her to complete her work on COBOL."[145] Bloch said, "Grace was not the only one who was working on the idea of compilers, but she probably was the one who pushed the hardest . . . that was the kind of person she was, she never gave up."[146]

Since the very early days of COBOL its use has been continuous and widespread. Today, COBOL is the most popular programming language in the world.[147] Capers Jones of Software Productivity Research estimates that 577,500 programmers, more than one third of all the programmers in the United States use COBOL, and that there are 225 billion lines of COBOL source code in the world.[148] Grace Hopper is one of the reasons why.

Throughout the fifties, sixties and until her retirement from Remington Rand, now the

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[145]Robert Campbell of Concord, Massachusetts, interview by author, 26 March 1993, telephone tape interview.

[146]Richard M. Bloch of W. Newton, Massachusetts, interview by author, 14 June 1993, telephone tape recording.

[147]"Hopper's Legacy: Innovation, Education," IEEE Software 9 (March 1992): 95.

[148]Ibid.

Sperry Rand Co., in 1972, Hopper continued her work as staff scientist in systems programming. She also continued writing about the current and future use of computers. One of her articles, written in 1970, was "Standardization and The Future of Computers." In this article Hopper argues that only by standardizing high-level programming languages can progress in computer applications be accomplished efficiently and in a cost-effective manner. At the time the article was written Hopper cited ALGOL (ALGOrithmic Language), COBOL (Common Business Oriented Language), FORTRAN (FORmula TRANslation), JOVIAL (Jules Own Version of the International Algorithmic Language) as those high-level languages that would be used in future applications; languages such as C did not exist at the time, but her general principle stated in the article applies. As a way of persuading managers and company CEOs of the validity of her argument, she includes a chart showing how many man years can be saved by converting 500 assembly language programs into COBOL. As she says,

> Applying current salary rates indicates large savings every time a computer is replaced (approximately every five years at present) through salvage (conversion) of the application programs.[149]

She concludes the article with an even more cogent argument for management and computer science professionals:

> While dollar savings can be predicted through the use of standard languages, the real savings will lie in avoidance of expenditures, and of far greater importance are the savings of scarce programmer time, the mobility of programs and programmers and the freedom to progress readily to the computers of the future. END[150]

In 1971, the UNIVAC division of Sperry Rand established the Grace Murray Hopper

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[149]Grace Hopper, "Standardization and The Future of Computers," Data Management 8 (April 1970): 32.

[150]Ibid., 35.

Award for young computer professionals, now awarded annually by the Association for Computing Machinery.[151] In 1967, her first love, the United States Navy would again summon her. This summons would change her life.

[151]Marguerite Zientara, "Part 11 . . . Capt. Grace M. Hopper & The Genesis of Programming Languages, " Computerworld. 16 November 1981, 53.

CHAPTER V

THE PENTAGON YEARS

In 1966, Grace Hopper received a letter from the Chief of Naval Personnel telling her that she had served twenty-three years in the Navy and should retire. So, she completed the forms for retirement and on December 31, 1966, left the Naval Reserve with the rank of commander. "It was the saddest day of my life," Hopper recalled.[152] She also recalled that "thanks to our highly-automated pension system," her first retirement check did not arrive until April, 1967.[153]

But Hopper did not collect many retirement checks, because in August, 1967, she was called back to take up a six-month, temporary active duty post. In 1984, a bemused Hopper said, "So far, it's been the longest six months I've ever spent."[154] Hopper and her staff were charged with standardizing the Navy's application of COBOL and with training Navy personnel in its use. The result of the group's first year of work was a manual, Fundamentals of COBOL, which was distributed without cost to all Navy installations.

When Hopper arrived at the Pentagon in 1967 to start her second life with the Navy, she was assigned to an office in the basement of the Pentagon with a small staff and meager

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[152]Peter Sweet, "A Living Legend: Still Making Waves," Computing (United Kingdom) 29 (March 1984): 24.

[153]Ibid.

[154]Charlene Billings, Grace Hopper, Navy Admiral and Computer Pioneer, (Hillside New Jersey: Enslow Publishers, 1989), 88.

supplies, not even a computer. Hopper and her staff furnished the entire office within a couple of weeks. She followed some advice a Navy chief had given her long ago:

> If you need something, liberate or borrow it from the Air Force--they have everything; if you can't find it there, get it from the Army--they have almost everything and they don't know how to count; but there is no use trying to liberate it from the Seabees or Marines because they liberated it to begin with.[155]

"Admiral Hopper always had a Jolly Roger flag hoisted above her desk in honor of her staff's infamous midnight raids on other Pentagon offices," recalled Lt. Commander Angela Connelly.[156]

Richard Fredette worked for Hopper in the Pentagon from 1968 until he retired in 1986. Now living in Reston, Virginia, he was a civilian employee assigned to the Naval Data Automation Command until his own retirement in 1990. He was a part of the first team that wrote The Fundamentals of Cobol and that helped standardize the use of COBOL throughout the Navy. Fredette recalled Hopper as a mentor and as an "extremely supportive and trusting boss."[157] He said that she would put objectives before the group and then ". . . let us go. If you didn't get there [achieve the goal] that was fine, but it gave you something to shoot for, and you always did want to get there for Grace."[158] Fredette emphasized that one of Hopper's biggest concerns was finding standards for programming languages. He credits her as one of the pioneers of standardization and adds, "We had a little wrinkle on top of that, and that was you can standardize something all you want, but if everyone interprets the

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[155]Ibid.

[156]Lt. Commander Angela Connelly of Washington, D.C., interview by author, 26 March 1993, tape recording.

[157]Richard Fredette of Reston, Virginia, interview by author, 30 July 1993, tape recording.

[158]Ibid.

standards differently, you're in trouble. So in the beginning we really had no cross transference of programming."[159]Fredette explained that to solve this problem the group developed routines, actual computer code, that would validate COBOL standards, many of which are still in use today.

Fredette also credits Hopper with having a positive influence on his career. "I reached out for things I probably never would have reached out for without her: You know, I often surprised myself, and that is exactly what she expected. She had everybody who worked for her always extending themselves and reaching out."[160]

After Hopper and her group, including Fredette, completed the COBOL manual, she began what would become a nineteen-year speaking tour, travelling across the United States, meeting with other Navy officers to persuade them to use computers and to run COBOL on them, training personnel how to work with COBOL, and spreading the good word about computers in general. She also continued to write articles for computer journals and magazines during her years at the Pentagon, although less frequently as her travels increased.

In 1973, Hopper gave the keynote address, "Possible Futures and Present Action," at Canada's Data Processing Institute Conference, held in Ottawa. Although the personal computer as it is now known did not exist in 1973 when she made this speech,[161]there were minicomputers, with an amazing 16K of memory that Hopper suggested could be made to talk to each other and take the place of what she called "mainframe dinosaurs."[162] She also

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[159]Ibid.

[160]Ibid.

[161]Personal computing as a mass movement has existed only since 1975. Encyclopedia of Computer Science and Engineering, 1983 ed., s.v. "Personal Computing," by Jim Warren, Jr.

[162]Data Processing Institute, "Possible Futures and Present Actions," Proceedings of Conference '73 (Ottawa, Canada), 74-80.

continued her life-long crusade for computer manufacturers and users to be more selective about what information they stored, and not just keep all information on hand because it was possible with computers to do so.

> So, there is a challenge to bring down the myth of a monolithic, all-powerful computer and replace it with a more powerful but more manageable system or multiple computers. A world concerned with population, food supplies, ecology, will need a multiplicity of facts and relationships to meet the requirements for better management in the future. Computers can assist, but only insofar as they are recognized as man's most sophisticated tool, and as they are re-formed to meet each man's specific needs rather than to flood the world with an unrequired avalanche of raw data.[163]

But, whether sitting at her Pentagon desk writing articles or hurrying through Dulles airport at five a.m., Hopper always wore her uniform. And this habit attracted a great deal of comment and attention through the years. She loved to relate the story of the couple she met in an elevator at the San Francisco airport who thought she was a security guard, or the number of times someone would come up to her in the Delta terminal and ask, "What time does the plane for Houston leave?"[164] But, perhaps, one of her favorite stories was about an immigration officer in the Toronto, Canada airport who challenged Hopper to prove who she was. When she said, "United States Navy," he replied, "You must be the oldest thing they've got!"[165]

Although Hopper enjoyed poking fun at herself, she took the business of her travels around the country very seriously. She believed that by speaking to young audiences at colleges and universities and in corporate and military classrooms, she would be able to

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[163]Ibid., 80.

[164]Grace Hopper, The Captain Is A Lady, interview by Morley Safer, 15 min., "Sixty Minutes," 1983, videocassette.

[165]Ibid.

persuade them to think of the computer as a tool that could be used in any career they pursued and to challenge old ways of thinking and doing things. However, she frequently despaired of what she called "man's allergy to change."[166]

In 1972, she mused about how complacent people become during long periods of peace: "They go back to ordinary living and learning anything new is not something they want to do. People push it [change] away. The job of changing people's minds is one of the biggest challenges we have."[167] Hopper believed that, although she was older than most of the members of her audience, she was more comfortable with change because she had experienced so much of it during her lifetime. She recalled how growing up in New York City the tallest building was only seven stories high, and that electricity had been so unreliable her family would use gas jets for light on those days when the electricity did not work. She also recalled travelling up Broadway first in a trolley and then on the subway. As she said, "So, I've had to go all the way from that, you see. I know far better than [they] do, that change accelerates--changes are coming faster."[168]

In 1971, she had been named Professional Lecturer at George Washington University in Washington, D.C. In addition to her duties as lecturer, she served on a number of doctoral committees, including Stephen Mandell's. Now a software consultant in Toledo, Ohio, Mandell described Hopper as "a little, old gray-haired granny, but tough as nails."[169] Hopper provided liaison between Mandell and corporate computer managers whom he

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[166]Grace Hopper, "Grace Murray Hopper," interview by Chantal Momporullan (July 1984), Voice of America, Eight Women of Achievement, 2.

[167]Grace Murray Hopper, Interview by Miss Beth Lubert and Dr. H.S. Tropp, 5 July 1972, transcript. The Computer Oral History Collection, The Smithsonian Institution, Washington, D.C.

[168]Ibid.

[169]Stephen Mandell of Toledo, Ohio, interview by author, 20 July 1993, tape recording.

interviewed for his dissertation. He credits her with inspiring him to alter his personal philosophy:

> Her philosophy was to challenge your mind, your way of thinking because nothing is ever the same when you wake up the next day. That was her philosophy from the beginning until the very end, whether it was the idea that forcing math onto a machine was not the be all, end all of communication, to the end where people were saying large computers and she was saying small, broken up and interconnected. Viewing the world from different perspectives was critical to success, critical to her vision, anyway.[170]

In 1984, Hopper and Mandell coauthored a textbook used in college and university beginning computer science classes entitled, Understanding Computers. This textbook takes the student through computer theory and history as well as the discussion of the ethical and sociological impact of the use of computers. Mandell recalled how he was constantly amazed at Hopper's energy. When he worked directly with her, from 1973-1978, she was travelling more than 300 days a year. As he said, "She was moving more than just about anybody I knew."[171]

As Hopper traveled around the country, she became famous for some of the props she brought with her when she made a speech. One of these props was an 11.8 inch piece of wire representing a nanosecond. A nanosecond is one billionth of a second; computers have circuits that operate in nanoseconds. Thus, 11.8 inches represents the maximum distance electricity can travel in a billionth of a second. Hopper made sure that audience members always went home with their own nanoseconds.

Hopper described how she got the idea of handing out nanoseconds to explain a computer's speed. She said that she could not visualize a billionth and doubted that "those

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[170]Ibid.

[171]Ibid.

men downtown could either."[172] One morning "in total desperation", she called over to the engineering building and said, "Please cut off a nanosecond and send it over to me."[173] And engineering complied. After about a week she called back: "I need something to compare this to. Could I please have a microsecond?" [174] Again, engineering complied and sent her a microsecond, which turned out to be 984 feet long. Hopper would frequently hold the microsecond aloft and tell her audiences: "Here's a microsecond, 984 feet. I sometimes think we ought to hang one over every programmer's desk, or around their neck -- so they know what they're throwing away when they throw away microseconds."[175]

Hopper would often tell her audiences how useful nanoseconds were for explaining elementary computer concepts to children and admirals. One of her often-repeated stories was about an admiral who asked her one day why it took "so damn long" to send a message via satellite. She pointed out to him that in between where the admiral had sent the message and the satellite there were a great many nanoseconds.[176]

On December 15, 1983, Hopper was awarded a star and promoted to the rank of commodore, a rank later changed to rear admiral, by then President Ronald Reagan in a White House ceremony. Hopper's brother, Dr. Roger Murray, her sister, Mary Murray Westcotte, and nieces and nephews attended the ceremony. With that promotion, Hopper became the first woman to achieve flag rank and the oldest active duty officer, since Admiral

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[172]Grace Hopper, The Captain Is A Lady, interview by Morley Safer, 15 min., "Sixty Minutes," 1983, videocassette.

[173]Ibid.

[174]Ibid.

[175]Ibid.

[176]Henry S. Tropp, "Grace Hopper: The Youthful Teacher Of Us All," ABACUS 2(Fall 1984): 8.

Rickover had been retired the previous year. A life-long Republican, Hopper had been excited about meeting President Reagan. As she recalled, "When I first met him, I looked him in the eye and said, 'Mr. President, sir, I'm older than you are.' And you know what? That great big guy giggled! We got along great!"[177]When the ceremony concluded, Hopper was asked how she felt about being the oldest active-duty officer since Rickover was retired and she replied,"It's priceless. Of course, I'm a lot less abrasive."[178]

Retired Admiral Paul Sutherland, the then commanding officer of the Naval Data Automation Command and Hopper's boss, recalled the ceremony:

> I remember I thought at the time that this promotion was strictly political. Lehman was Secretary of the Navy then, and I was given the honor of escorting her to the White House and that was all -- period. But she probably did have more of an influence on computers in the Navy than I'm willing to give her.[179]

With Hopper's promotion to rear admiral at age seventy-eight, her life at the Naval Data Automation Command accelerated. There was even greater demand for Hopper to give speeches and lectures, and her list of honorary degrees and other awards began to grow precipitously. In 1984 alone, she received seventeen awards, from the USS Constitution Museum's Samuel Elliot Morrison Award for Distinguished Service given in Boston, Massachusetts, to her induction into the Engineering and Science Hall of Fame in Dayton, Ohio. More and more people began writing Hopper asking for help and advice, correspondence which she either did not have time to answer or chose to ignore.

As the stack of unanswered correspondence grew, Hopper's commanding officer,

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[177]Brad Bass, "Rear Admiral Hopper Finds Job and Plenty Else to Do," Government Computer News 5(September 1986): 2.

[178]Allan Frank, "Older Than Univac," Newsweek, January, 1984, 141.

[179]Retired Admiral Paul Sutherland of Reston Virginia, interview by author, 26 March 1993, tape recording.

Admiral Sutherland, began to get phone calls from his superiors saying, "Do something about Grace – get her an aide or something, but get that mail answered."[180] So, Sutherland decided Hopper should have an aide, but she did not think much of the idea. According to him, Hopper's reply to his suggestion about an aide was, "I don't want any snot-nosed brat following me around."[181] Sutherland said he pointed out to her that she was a "fine one to talk" since Hopper was always making speeches about what great young men and women the Navy had. He said he told her, "You don't even believe your own press,"[182] but Hopper continued to argue. Finally, according to Sutherland, he got angry and very red-faced and ordered Hopper to accept an aide: that individual, who knew nothing of the reception awaiting her, was Lt. Commander Sharron Crowder.

Crowder was first assigned to the Naval Data Automation Command in 1977, and that was when she was introduced to Hopper. Crowder recalled Hopper, who was then a captain, as "pretty spry."[183] Crowder also recalled that Hopper was the only one in uniform when she reported for duty, so it took her a moment to sort out "who was my captain and who was my admiral."[184]

Crowder's initial assignment at the Naval Data Automation Command was to put a COBOL compiler on the personal computers in Hopper's office. "PC's were just coming out

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[180]Ibid.

[181]Ibid.

[182]Ibid.

[183]Retired Lt. Commander Sharron Crowder of San Antonio, Texas, interview by author, 16 April 1993, Dallas, Texas, tape recording.

[184]Ibid.

then, and Grace wanted her group to start using them."[185] She described Hopper as:

> . . . my teacher and mentor from the very first assignment. I talked about my career with her and what I should or should not do. She was always very insistent that I stay 'techie', you know, keep that technical edge as I was promoted.[186]

Crowder explained that everyone who worked for Hopper was expected not only to complete whatever duties were assigned him or her, but also make personal improvements. Effective public speaking was a skill required of everyone in the office, according to Crowder. Hopper made each young Navy officer in her command accompany her from time to time as she went around the Washington, D.C. area making speeches. Crowder said, "She would talk for a while and then introduce you to talk about some specific area."[187] Crowder said it was Hopper who convinced her that she should pursue a graduate degree.

In 1980, Crowder left Washington, D.C., to attend the Naval Postgraduate School in Monterrey, California, where she received her master's degree in computer science in 1982. Whenever Hopper would come to the school to give speeches or seminars, Crowder was assigned to pick her up at the airport and generally make sure she was comfortable in her quarters. While Crowder continued her studies in Monterrey, she helped establish criteria for winning the Grace Murray Hopper Award for Excellence in Computer Science, which was established in 1981 and has been awarded annually since.

In 1983, Crowder found herself back in Washington, being assigned as Hopper's first aide. By this time, the Naval Data Automation Command had moved its offices from the Pentagon to the Navy Shipyard. Crowder recalled, "When I reported for duty to Admiral

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[185]Ibid.

[186]Ibid.

[187]Ibid.

Hopper, I could tell she was pissed. She wouldn't talk to me for a week, and she wouldn't tell me her schedule."[188] But, Crowder had her orders, and the first thing she had to do was try to answer Hopper's mail. Crowder said that she decided Hopper was not replying to her correspondence because she would have had to make a decision about where and to whom she would speak, and that she did not want to disappoint anyone. Crowder found out that Hopper kept her calendar on a very small date book in her "two-hundred-year-old Navy purse"[189]; so, Crowder decided the only solution to the correspondence dilemma was somehow to "get her hands on" Hopper's date book.[190] Since the admiral was in her office only a few days a month, this proved a difficult task.

Admiral Sutherland came to Crowder's rescue when he agreed to help her borrow the date book long enough to copy it. Crowder smiled as she recalled,

> Sutherland called Grace into his office, and I took the calendar out of her purse. I furiously xeroxed it while she was in the Admiral's office. When I finished, I carefully put it back exactly like I found it, and signaled to the Admiral. I was terrified I'd be caught.[191]

With Hopper's xeroxed personal itinerary, Crowder was able to start answering her mail, declining invitations and replying to inquiries. Crowder said that she began compiling a list of places to which she knew Hopper would refuse to travel: "Grace did not like to go any place Delta didn't fly because most of the Navy pilots who got out went to Delta. If Delta didn't go there she didn't want to see you . . . that was her airline, and they really pampered

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[188]Ibid.

[189]Ibid.

[190]Ibid.

[191]Ibid.

her. It was like having her own 747 and own crew.[192]Crowder believed that Hopper eventually worked out what had happened with her date book, but "she never said anything. I think she kind of admired my ingenuity."[193]

After the datebook incident, Crowder said her relationship with Hopper began to change, and she was allowed to accompany her on some trips. However, Crowder never went on the same flight, and they always had separate hotel rooms. As she recalled,

> I knew that Sutherland wanted someone with Hopper in case something happened to her on one of these trips. And, one time I really thought she had died. I came to get her to take her to dinner or something and knocked on her door. I got no response and I kept knocking harder, and thought 'Please don't die on my watch.' Finally, I heard her say, 'Just a minute, just a minute.'. . .And it hits you this little old lady should be at home and not doing all this travelling, but that is what she lived for.[194]

According to Crowder, Hopper traveled with only two bags, one contained her clothes for the week and the other contained her handouts and nanoseconds. She recalled that her duties for Hopper, besides answering mail, included copying relevant articles from the more than 140 magazines to which she subscribed and preparing nanoseconds that were handed out to students and others whenever Hopper spoke: "Grace wanted to be able to cite the latest and greatest in the computer world, so I would xerox and mail articles to her, and I made sure that I had people on site to collect any nanoseconds left behind, so I wouldn't have to keep making new ones."[195]

Crowder remained in Washington as Hopper's aide for eighteen months. During that

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[192]Ibid.

[193]Ibid.

[194]Ibid.

[195]Ibid.

time Crowder said, "I came to know Grace probably as well as anyone."[196] Crowder described Hopper as a small, frail woman who looked like a "gray-haired granny who should be at home knitting,"[197] until she got on stage to give a speech. She recalled that Hopper's eyes lighted up as she began to talk; she got excited talking about the future possibilities of computers, leadership, and the satisfaction of serving one's country. "Grace was a real patriot in an old-fashioned way, but she constantly pushed new technology on old dogs. She dedicated herself to loyalty up and down the chain of command . . . to many qualities that you don't have in leaders today."[198]

After Crowder left Washington, she did not see Hopper again until her retirement in 1986. By this time, Hopper was seventy-nine years old and beginning to travel less frequently. She had fallen in Dulles Airport, breaking her arm, and the Navy, which had allowed Hopper to remain past retirement age by annual review, decided Hopper should retire again.

Admiral Paul Sutherland, still the commanding officer of the Naval Data Automation Command, recalled that when the time came for Hopper to be retired, "people didn't have the courage to tell her."[199] He said that someone of Hopper's status and notoriety should have been asked to retire by the Secretary of the Navy or the Chief of Naval Personnel, and "then she would have accepted it."[200] However, Sutherland was given the duty of telling Hopper

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[196]Ibid.

[197]Ibid.

[198]Ibid.

[199]Retired Admiral Paul Sutherland of Reston, Virginia, interview by author, 26 March 1993, tape recording.

[200]Ibid.

that the Navy thought she was too old again. "I knew that she was not going to be happy to hear this and would want to talk to the Chief of Naval Personnel and the Secretary. Well, I made all her appointments for her, and she finally accepted the fact of her retirement. But she was like Rickover, she was certain that the Navy couldn't really do without her."[201]

Hopper's retirement ceremony took place on August 14, 1986, aboard the USS Constitution, the Navy's oldest commissioned warship, during its annual turn around in Boston Harbor. It was attended by 275 friends and relatives, including her brother and sister, nieces and nephews, and Robert Campbell and Dick Bloch from her Harvard days, among others. As the ship eased out of Boston Harbor, Hopper said, "I love this ship. She's the beginning of a great tradition. The oldest commissioned ship in the Navy. And I'm the oldest officer on active duty. We belong together."[202]

Hopper, who spent her professional life thinking about the future, that day remembered her first trip to Boston Harbor fifty years earlier to see the carrier Wasp "battered by kamikazes at Okinawa, limping home."[203] These events were connected in her mind. "Way back in 1775, one of my ancestors Samuel Fowler, picked up his musket on the nineteenth of April and marched from Newbury to Concord to stand up to the British. This is part of that long line."[204]

The retirement ceremony was conducted by then Secretary of the Navy, John Lehman, who presented Hopper with the Defense Distinguished Service Medal, the

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[201]Ibid.

[202]Tim Clark, "The Commodore and the Constitution," Yankee Magazine, October 1986, 160.

[203]Ibid.

[204]Ibid.

Department of Defense's highest award. He praised her for the "uniqueness of her vision, her feistiness, and her youth."[205] Hopper rose to accept the award and said, in part, "I regret leaving active duty . . . . I've loved every minute of it. I'm the very last of the WAVES to leave. To this day, I'm still a Woman Available for Volunteer Emergency Service. . . ."[206] She added, "The only phrase I've ever disliked is, 'Why, we've always done it that way.' I always tell young people, 'Go ahead and do it. You can always apologize later.'"[207]

As the Constitution returned to shore, Hopper was officially retired from the Navy, but retirement from the world of computers was not on her agenda. She had already accepted a job as senior consultant to Digital Equipment Corporation's Government Systems Group. As Hopper said, "You live longer if you stay active and don't retire. When you don't have any contact with people especially bright, young ones, and are making no more contributions to society, you fall apart."[208]

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[205]Richard Taffe, Jr., "The Navy's Last WAVE Quits Active Duty at 79," The Philadelphia Inquirer, 15 August 1986, 3(C).

[206]Ibid.

[207]Baltimore Sun (Maryland), 14 August 1986, 3(A).

[208]James Longo, Navy Times, 13 January 1992, 28(A).

CHAPTER VI

THE FINAL YEARS

Grace Hopper started her job as senior consultant for Digital Equipment Corporation (DEC) in Washington, D.C., in September, 1986, as soon as she got back from her Navy retirement ceremony. She was already booked six months ahead to travel around the country giving lectures and speeches.[209] Until several months before her death, Hopper particularly enjoyed speaking at schools and colleges. As she said, "I like our young people. They know more, they question more, and they learn more than people in the in-between years."[210] By in-between years, Hopper meant people who were ages forty to forty-five.

The individual at DEC who was assigned to keep up with Hopper and assist her was Rita Yavinsky, now the Worldwide Public Administration/Market Investment Manager at DEC in Washington. Yavinsky recalled the first time she ever saw Hopper: "we met at a gate in Logan Airport a couple of times. I was asking her for a light for my cigarette, and we just kind of became friends."[211] Yavinsky said that her boss at DEC, Chief Executive Officer Ken Olson, was a "big fan of Grace's," and when Hopper announced her retirement from the Navy, Yavinsky persuaded Olson to offer her the job of senior consultant.[212]

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[209]"Looking Ahead," All Hands, April 1986, 26.

[210]Ibid.

[211]Rita Yavinsky of Washington, D.C., interview by author, 14 May 1993, tape recording.

[212]Ibid.

During the first year Hopper worked for DEC, Yavinsky kept trying to get her to visit corporate headquarters to meet everyone. Hopper refused until Olson's office called one day to invite her to a corporate event, no longer held, called The State of the Corporation. High-level officers of the company, dignitaries, and important stockholders were the only ones invited to this event; so, Hopper finally agreed to attend saying," Okay, one time, then I'm not going anywhere else."[213] Yavinsky recalled that Hopper was, of course, a smoker, and DEC was a non-smoking company. Yavinsky said they rode the elevator to the Board Room where the meeting was to take place, with "No Smoking" signs posted everywhere. She recalled that, at this time, her job was not at a high enough level to be invited to the meeting, so "I put Grace next to someone I trusted and went downstairs. About half an hour later I got this phone call -- 'We've lost her.'"[214] Apparently, out of respect for Olson, Hopper had listened to his speech and then, as she said,"I looked at that row of vice presidents, and I was reminded of IBM . . . I just couldn't bear the thought of doing that all day when I could go downstairs and sit and talk to everybody."[215] Hopper had gone downstairs, where she could smoke, and was "receiving at her leisure" most of the other employees and visitors who were filing out of the meeting upstairs.[216] Yavinsky said that she never tried to get Hopper to do anything she did not want to again.

Hopper maintained her post-retirement pace for DEC, travelling about 200 days a year, from 1986-1990. During that time, she continued her crusade to get people to think of

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[213]Ibid.

[214]Ibid.

[215]Ibid.

[216]Ibid.

computers as a general purpose tool, the "ubiquitous computer", as Hopper said.[217]

Yavinsky recalled that Hopper was constantly thinking about the future:

> She would never get involved with saying that this has to be done by Friday. . . She had a generational view of technology, and she was able to apply it in such a way that she could perceive how computers would change people's lives, would be used one hundred years from now.[218]

Yavinsky noted that Hopper talked about small, hand-held computers that individual might use as portable checkbooks or portable offices. In late 1993, Apple Computers, Inc., began to market the "Newton," which is indeed a small computer meant to be used as a portable office.

During the last years of her life, in addition to working as a senior consultant for DEC, Hopper became a popular celebrity. She was frequently interviewed by both print and broadcast media concerning her views on the future of technology; she was the Grand Marshall of the 1987 Orange Bowl Parade; she made an appearance on the David Letterman television show in October, 1986; and she continued to publish an occasional article about computers and their use and misuse.

Yavinsky became very close to Hopper during these last years, and would visit with her about twice a week. She said that she consulted Hopper about all kinds of subjects, not just computers or technology, but personal matters, including when she decided to remarry. It is the author's belief that Hopper viewed Yavinsky as the daughter she never had, and there was obviously great fondness for Hopper when Yavinsky spoke about her.[219] In addition, since Yavinsky was one of the few people to whom Hopper would listen, DEC counted on Yavinsky's being able to smooth over any difficulties that Hopper might have. As she said,

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[217]Ibid.

[218]Ibid.

[219]Ibid.

"Grace had little tolerance for unnecessary authority . . . for obstacles or paperwork or anything that would prevent her from directly accomplishing what she wanted to accomplish. . . She understood chain of command because she was Navy, but she had no tolerance for interference or puffery."[220]

Yavinsky believed that it was this no-nonsense attitude of Hopper's that led some people to believe, wrongly, that Hopper was a feminist. As she observed, "Grace felt that people should be evaluated on their ability and contribution rather than their race or gender. She was very sanguine about the fact that she was the first female flag officer in the Navy, but she also recognized that women had different contributions to make."[221] Yavinsky cited an example of this awareness when she said that Hopper "pestered me unmercifully" to have DEC make a significant contribution to the construction of the Women's War Memorial located near the Vietnam War Memorial in Washington, D.C. She also believed that Hopper was a role model for many young women in and out of the military. "The Grace Hopper legacy for women is to reach beyond your grasp, to achieve with grace, dignity, and excellence."[222] Yavinsky believed that this legacy was particularly appealing to women, but stated flatly that Hopper never thought of herself as a feminist. Indeed, Hopper stated this on many occasions herself: "I'm not a woman's libber. I have no desire to be liberated at all. I'll have all my privileges, thank you, and use them too."[223]

Hopper kept up her travel schedule with DEC for the first two and a half years that she was a senior consultant. However, in a fall in Dulles Airport in October of 1990 she

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[220]Ibid.

[221]Ibid.

[222]Ibid.

[223]Corey Sandler, "Keeping Up With Grace," PC Magazine, December 1983, 211.

broke her arm again. Perhaps because of her advanced age of eighty-four, Hopper took a long time to recover, and as former colleague, Dick Fredette said, "I would call her once a week, but she was getting very reclusive."[224] Fredette helped Hopper balance her checkbook after the fall.

As Hopper was able to leave her apartment less and less, Yavinsky would check up on her, taking her milk, orange juice, and cigarettes. Hopper did manage, with the help of an office aide at DEC, to publish an occasional article about computers. One of the last of these, published only seven months before her death was entitled, "Prioritizing Information."[225] In this article, Hopper continued her crusade for organizations to determine what is their most valuable information and to make this information what they use valuable computer time and equipment to manage. Hopper cited her often-used analogy of the early days of automobiles in the United States. According to Hopper, because "we totally neglected the concept of transportation as a whole, . . . today roadbeds and railbeds are falling apart."[226] Hopper said that the total flow of information through any organization, activity, or company is what matters. "You need to know what is the most valuable information. That's the hard part. How do you value your information?"[227] She cites the computing industry itself as one of the worst violaters, being seduced by technology rather than making the most prudent use of it: "I'm afraid we'll continue to go out and buy pieces of hardware with flashing lights and lovely 'user-friendly' software and totally neglect the underlying subjects. . . selecting the

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[224]Dick Fredette of Reston, Virginia, interview by author, 30 July 1993, tape recording.

[225]Grace Hopper and Janet J. Barron, comp., "Prioritizing Information," Byte (May 1991): 169.

[226]Ibid.

[227]Ibid.

[best] equipment to implement that information flow."[228] Hopper described convincing scenarios about the misuse of computers when she takes on the question of accuracy and how we have relied on the accuracy of information simply because it "came from computers. We've gone that way far too long."[229]

In the last months of her life, Hopper continued to receive awards. She was the first woman ever to receive the National Medal of Technology as an individual, the United States' highest award of this kind. Then President George Bush presented the award to Hopper on September 16, 1991, for her "pioneering accomplishments in the development of computer programming languages that simplified computer technology and opened the door to a significantly wider audience of users."[230] According to Yavinsky, Hopper had wanted to attend the awards ceremony, but by this time, her health would not permit her to do so. Jill S. Baylor, the then president of the Society of Women Engineers, accepted the award on Hopper's behalf at a White House Rose Garden ceremony. In part of Hopper's written acceptance remarks for that day she said, "If you ask me what accomplishment I'm most proud of, the answer would be all of the young people I've trained over the years; that's more important than writing the first compiler."[231]

Hopper often said that she wanted to live until the year 2000.

> "I have two reasons. The first is that the party on December 31, 1999, will be the New Year's Eve party to end all New Year's Eve parties. The second is that I want to point back to the early days of

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[228]Ibid.

[229]Ibid., 171.

[230]"Computer pioneer receives national recognition," Around the Fleet, 20 September 1991, 5.

[231]Ibid.

> computers and say to all the doubters, 'See? We told you computers could do all that.'"[232]

However, this was one goal she was not able to achieve. Hopper died in her sleep at her home in Arlington, Virginia, of apparent natural causes on January 1, 1992. She was eighty-five years old.[233] Her funeral and burial, with full military honors, was at Arlington Cemetery on January 7, 1992. Family members, Rita Yavinsky, and former colleagues from Navy days, including Admiral Paul Sutherland, attended the funeral. Sutherland observed, "When Grace Hopper passed away, I thought the Navy treated her shabbily. . . After all Grace did for recruiting . . . I would have thought some high-level, active duty would have been there."[234] In late 1992, the Navy announced that a frigate, the USS Hopper, would be commissioned in 1995, in honor of Hopper's more than 40 years of service to the Navy.

Yavinsky recalled that she was the one initially notified of Hopper's death, since she lived in the Arlington, Virginia area. Yavinsky also helped Hopper's family members with local funeral arrangements. A particularly poignant recollection of Yavinsky's concerned Hopper's habit of wearing gloves . "Grace was such a lady, she got that from her mother . . . she must have had 5,000 pairs of gloves; in fact, we put a pair of gloves in her casket because I said to Roger [Hopper's brother], 'Grace can't be buried without her gloves.'"[235]

Public notice of Hopper's death was published in national and Navy print media and

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[232]Elizabeth Dickason, "Remembering Grace Murray Hopper: A Legend in Her Time," CHIPS, April 1992, 7.

[233]John Markoff, "Rear Adm. Grace M. Hopper Dies; Innovator in Computers was 85," The New York Times, 3 January 1992 17(A).

[234]Retired Admiral Paul Sutherland of Arlington, Virginia, interview by author, 26 March 1993, tape recording.

[235]Rita Yavinsky of Washington, D.C., interview by author, 14 May 1993, tape recording.

was broadcast worldwide on Cable News Network, National Public Radio, and the three, major U.S. television networks, ABC, CBS, and NBC. Hopper's contributions to the computing industry and the Navy were enumerated in these announcements, including her pioneering work with programming language standardization and her inspiring leadership of students and colleagues. In part these cited, "[Hopper's] helping to invent the COBOL programming language, which is still used in business today . . . Her work led to the first practical compiler for modern computers. . ."[236] "She was a visionary in every sense of the word. Our Navy and our nation have lost an innovator, a teacher, a patriot, and a friend."[237]

Most of the individuals that the researcher contacted for this study affirmed Hopper's contributions to computer science not only in terms of her own research, but also in terms of the numbers of young people she inspired to research and study. Robert Campbell, who worked with Hopper at Harvard on the Mark I, noted Hopper's significant contribution to the development and standardization of COBOL but allowed that her greatest contribution may have been "getting people to go into computer science . . . to get people interested in using computers."[238]

Howard Bromberg, who was Hopper's colleague during her UNIVAC days, observed that she was a "true visionary,"[239] who conceived of the computer's use by a much wider

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[236]John Markoff, 'Rear Adm. Grace M. Hopper Dies; Innovator in Computers was 85," The New York Times, 3 January 1992, 3(K).

[237]Barbara Burfeind, "Loss of a Legacy," All Hands, February, 1992, 47.

[238]Robert Campbell of Concord, Massachusetts, interview by author, 26 March 1993, tape recording.

[239]Howard Bromberg of San Francisco, California, interview by author, 19 September 1993, tape recording.

audience than scientists and mathematicians through the availability of tools that were both "programmer- and application-friendly."[240] He also noted that although Hopper's workgroup at UNIVAC was "fiercely loyal" and none of them thought they would leave, "Grace always said that her best people would [leave] and take her message with them."[241] And many of them, including Bromberg, did leave, for RCA, Burroughs, GE, and IBM.

Stephen Mandell, who was a student and colleague of Hopper's while she worked in the Pentagon, said that the concept of a compiler represented a revolutionary change in the way computer technology could be used. He also noted her early focus on microcomputers rather than mainframes, "even before they became commercially available."[242] Mandell further observed, that as his teacher, Hopper would not let him limit his scope of thought about any problem, and that this attitude was what "she left everybody with, on top of the fact that she moved the computer and information industry significantly in her own way."[243]

Richard Fredette, who also worked with Hopper at the Pentagon, observed that Hopper's emphasis on standardization of programming languages, particularly COBOL, represented her greatest contributions to the computer industry. In addition, he described her as a dynamic and inspirational teacher: "She was a strong person, extremely bright, single-minded, magnetic, and friendly all at the same time."[244]

Lastly, Rita Yavinsky, who was Hopper's colleague during her final years with

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[240]Ibid.

[241]Ibid.

[242]Stephen Mandell of Toledo, Ohio, interview by author, 20 July 1993, tape recording.

[243]Ibid.

[244]Richard Fredette of Reston, Virginia, interview by author, 30 July 1993, tape recording.

Digital Equipment Corporation, said that Hopper's genius was her generational view of computers and technology. Yavinsky observed that "Grace didn't want this technology to be the property of some elite group . . . [she] was one of the first people I ever heard use the phrase 'ubiquitous computing.'"[245] Yavinsky noted that although Hopper believed her work with COBOL was significant, more important to Hopper was her personal philosophy, "[that] if you could inspire learning and education in young people, then you have done something extraordinarily significant for a country."[246]

Thus, Hopper's work in the early days of computing, including her development and implementation of a compiler for programming languages, her development of the modern language COBOL and its standardization, and her early emphasis on microcomputers made her not only a pioneer in the computing industry, but also one of its champions and visionaries. Hopper began her professional career as a Vassar mathematics professor, and, it is the author's belief that, although her classrooms changed, her ability and desire to teach did not. Hopper had respect for authority, but she believed individuals should "do what's right."[247] As Howard Bromberg wrote in his eulogy, "I keep thinking about another of Grace's messages. When she thought she was right, she would do it and apologize later. I know that she did this many times, and she's probably still doing it now. Hasta la vista, Grace."[248]

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[245]Rita Yavinsky of Washington, D.C., interview by author, 14 May 1993, tape recording.

[246]Ibid.

[247]Howard Bromberg, "Grace Hopper: A Remembrance," IEEE Software, 9(May 1992): 103.

[248]Ibid.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

This study examined the life and career of Grace Murray Hopper: computer pioneer and gifted teacher. The study recognized Hopper's contributions to the field of computer science from her pioneering work on language translators begun at Harvard and later at Eckert-Mauchly and Remington Rand, including early compilers, Flowmatic, and COBOL, to her early support of microcomputers and campaign to network specialized machines rather than continuing to rely on large, mainframe machines. As Richard Fredette remarked in the closing minutes of his interview: "You know, Grace had this ability to project the future of the industry . . . if IBM had listened to her, they wouldn't be in the trouble they are today -- and she actually tried to tell IBM."[249] Hopper was one of a small group of Americans who were in at the beginning of computers and the computer science industry during World War II. And from those very early days, she had a vision of what computers would be capable of doing and how they would be used by a wider audience. She understood the importance of marketing a revolutionary scientific idea to management and the importance of compelling every young mathematician, physicist, or programmer, whom she knew, to think in terms of systems rather than in terms of how will we solve today's problems. As Howard Bromberg,

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[249]Richard Fredette of Reston, Virginia, interview by author, 30 July 1993, tape recording. Fredette refers to IBM's downsizing by laying off 200,000 employees worldwide during 1992-1993.

who worked with Hopper in the fifties stated in his eulogy to Hopper:

> To me, Grace Hopper was the quintessential programmer. She maintained a continuous love affair with her machines and delighted in pushing them to progressively greater accomplishments.[250]

This study also examined Hopper's philosophy of teaching and learning by reviewing the written and spoken record as well as by interviewing individuals who knew and worked with Hopper during her lifetime. As a teacher she set high standards of excellence, demanded loyalty, and returned it to students, enlisted personnel, and admirals all of whom were taught by Hopper. As her students and colleagues recalled, she loathed the phrase, "but we've always done it that way," and she prodded them to consider new approaches, new ways of doing things. She felt people were "pretty much allergic to change," and she saw her role of changing people's minds as one of the biggest challenges she had.[251]

She explained complex concepts in a way students, colleagues, even admirals could understand; when she wanted to lecture about how computers worked and what a nanosecond was, each member of her classroom received an 11.8 inch-long piece of telephone wire so they could better understand the concept of nanosecond. She surrounded herself with young people and with those who were young-thinking. She took seriously what she perceived as a teacher's or leader's obligation to her students -- to set the pace for excellence, to lead the way to new knowledge.

As Howard Bromberg recalled:

> I learned many things from Grace and had a lot more confirmed. I learned that there is no substitute for quality; that thoroughness is the

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[250]Howard Bromberg, "Grace Hopper: A Remembrance," IEEE Software, 9 (May 1992) : 103.

[251]Grace Hopper, "Voice of America Interview with Grace Hopper," interview by Chantal Mompoullan (27 May 1983) : 1-10.

> essence of excellence, and that people are marvelous -- and much smarter than you think.[252]

Conclusions

In many ways, Grace Hopper was a creature of her own design. She leaves behind former students and colleagues who will not forget her admonition that if they are ever content with the ways things have always been she will come back and haunt them. She leaves behind two awards given in the computer science industry for innovative solutions to problems, and she leaves behind a Navy computer magazine, CHIPS, begun as a result of a challenge by Hopper to a member of her crew and kept alive by its editors who promised "a wrinkled little lady in an admiral's suit to take care of the baby." [253]

It is the author's belief that Hopper also leaves behind a legacy for leaders, to set the pace for leadership, to lead by example, rather than merely manage people. Additionally, it is the author's belief that Hopper, among others, forced colleges and universities to consider computer science as a valid part of their curriculums; and whether as a teacher or leader, she pushed, prodded, and cajoled each student and colleague to do more. Hopper had many favorite sayings, but, there is one motto that became her dictum and which she passed along to all the young people she met. And, perhaps, it is fitting that Hopper should have the last word: "A ship in port is safe, but that is not what ships are built for. I want all the youngsters to sail out to sea and be good ships."[254]

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[252]Howard Bromberg, "Grace Murray Hopper: A Remembrance," IEEE Software 9 (May 1992) : 105.

[253]Diane Hamblen, "Editorial," CHIPS, April 1992, 3.

[254]George Leopold, "Beacon for the Future," Datamation, 1 October 1986, 109.

APPENDIX A

VITA OF GRACE MURRAY HOPPER

Vita of Grace Murray Hopper

EDUCATION

BA (Mathematics) Vassar College 1928
MA, Yale University, 1930
PH.D. Yale University, 1934

PROFESSIONAL ACTIVITIES

1931-43	Instructor to Associate Professor, Department of Mathematics, Vassar College
1943	Assistant Professor of Mathematics, Barnard College
1944-46	Mathematical Officer, U.S. Navy, Bureau of Ordinance
1946-49	Research Fellow in Engineering Science and Applied Physics, Computation Laboratory, Harvard University
1949-52	Senior Mathematician, Eckert-Mauchly Computer Corporation
1959-	Visiting Lecturer to Adjunct Professor, Moore School of Electrical Engineering, University of Pennsylvania
1964-71	Staff Scientist, Systems Programming, UNIVAC Division of Sperry Corporation (on military leave 1967-71) retired (first time) 1971
1967-77	Active duty, U.S. Navy, serving in the Information Systems Division as OP-911F
1971-78	Professional Lecturer in Management Sciences, George Washington University
1977-83	Active duty, U.S. Navy, serving as NAVDAC-OOH retired (second time) 1983
1983-1992	Senior consultant to Digital Equipment Corporation. Grace Hopper died January 1, 1992.

AWARDS

Phi Beta Kappa	1928
Sigma Xi	1934
Naval Ordinance Development Award	1946
Fellow, IEEE	1962
Fellow, American Association for the Advancement of Science	1963
Society of Women Engineers, SWE Achievement Award	1964
IEEE Philadelphia Section Achievement Award	1968
Connelly Memorial Award, Miami Valley Computer Association	1968
Data Processing Management Association Computer Sciences "Man of the Year" Award	1969
Upsilon Pi Epsilon, Honorary Member, Texas A&M, Alpha Chapter	1970

American Mothers Committee, Science Achievement Award	1970
American Federation of Information Processing Societies - Harry Goode Memorial Award	1970
Honorary Doctor of Engineering, Newark College of Engineering Newark New Jersey	1972
Wilbur Lucius Cross Medal, Yale University, New Haven, Connecticut	1972
Fellow, Association of Computer Programmers and Analysts	1972
Epsilon Delta Pi, Honorary Member, SUNY Potsdam Chapter Potsdam, New York	1973
Honorary Doctor of Science, C.W. Post College of Long Island University, New York	1973
Elected to membership in the National Academy of Engineering	1973
Legion of Merit	1973
Distinguished Fellow of the British Computer Society	1973
Honorary Doctor of Laws, University of Pennsylvania Philadelphia, Pennsylvania	1974
Distinguished Member Award, Washington, D.C., Chapter, Association of Computing Machinery	1976
Honorary Doctor of Science, Pratt Institute	1976
W. Wallace McDowell Award, IEEE Computer Society	1976
Honorary Doctor of Science, Linkoping University, Sweden	1980
Honorary Doctor of Science, Acadia University, Nova Scotia	1980
Navy Meritorious Service Medal	1980
Honorary Doctor of Science Loyola University, Chicago Illinois	1981
Honorary Doctor of Science, Southern Illinois State University, Carbondale, Illinois	1981
Honorary Doctor of Public Service, George Washington University Washington, D.C.	1981
Honorary Doctor of Humane Letters, Seton Hill College Greensburg, Pennsylvania	1982
Dedication of the Grace Murray Hopper Center for Computer Learning, Brewster Academy, Wolfeboro, New Hampshire	1982
Honorary Doctor of Business Administration, Lake Forest College, Lake Forest, Illinois	1983
Honorary Doctor of Science, Clarkson University, Potsdam, New York	1983
IEEE Computer Pioneer Medal	1983
Honorary Doctor of Science, Hood College, Frederick, Maryland	1983
Honorary Doctor of Science, Russell Sage College Troy, New York	1983
Honorary Doctor of Science, Villa Julia College, Baltimore, Maryland	1983
American Association of University Women Achievement Award	1983
Association of Computing Machinery Distinguished Service Award	1983

Living Legacy Award, Women's International Center San Diego, California	1984
Woman of the Year Award, Young Women's Christian Association of the National Capital Area	1984
Honorary Doctor of Science, University of Maryland, College Park, Maryland	1984
Honorary Doctor of Science, Smith College, Northhampton Massachusetts	1984
Honorary Doctor of Science, St. Peter's College, Jersey City, New Jersey	1984
Honorary Doctor of Science, Worcester State College, Worcester, Massachusetts	1984
Honorary Doctor of Science, Hartwick College, Oneonta New York	1984
Honorary Doctor of Science, Providence College, Providence Rhode Island	1984
Honorary Doctor of Science, City College of Morris, Morristown, New Jersey	1984
Honorary Doctor of Science, Bloomsburg College Bloomsburg, Pennsylvania	1984
Honorary Doctor of Science, Aurora College Aurora, Ohio	1985
Honorary Doctor of Letters, Western New England College Springfield, Massachusetts	1985
Honorary Doctor of Laws, College of William and Mary, Williamsburg, Virginia	1985
Honorary Doctor of Science, River College, Nashua, New Hampshire	1985
Honorary Doctor of Science, Marist College, Poughkeepsie, New York	1985
Honorary Doctor of Science, Saint John Fisher College Rochester, New York	1985
Golden Plate Award, American Academy of Achievement	1984
Beta Phi Sigma, George Washington University Chapter Washington, D.C.	1984
Jane Addams Award, Rockford College, Rockford, Illinois	1984
Andrus Award, American Association of Retired Persons Annual Award	1984
IEEE Centennial Award	1984
Engineering and Science Hall of Fame, Dayton, Ohio	1984
USS Constitution Museum, Samuel Eliot Morison Award for Distinguished Service, Boston, Massachusetts	1984
Award of Merit, American Consulting Engineer Council, Colorado Springs, Colorado	1985
Henry T. Herald Award, Illinois Institute of Technology Chicago, Illinois	1985

MILITARY RECORD
United States Naval Reserve

Apprentice Seaman and Midshipman	1944
Lieutenant (junior grade)	1944
Lieutenant	1946
Lieutenant Commander	1952
Commander	1957
Retired with rank of Commander	1966
Recalled to active duty	1967
Captain	1973
Commodore (title changed to Rear Admiral November 1985)	1983
Legion of Merit Award	1973
Navy Meritorious Service Medal	1980

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"The Interlude 1954-56" Symposium of Advanced Programming Methods for Digital Computers, Proceedings, pp. 1-2. Navy Mathematical Computing Advisory Panel, ONR, June 1956

"Programming Business-Data Processors," Control Engineering, Vol. 36, No. 2, February 1957

"Tomorrow- Automatic Programming," Petroleum Refiner, Vol. 36, No. 2, February 1957

"Automatic Programming for Computers," Punched Card Annual, Vol. 5, 1956-57.

"Computer Programs 'in English'," Systems, Vol. 21, Sept. -Oct. 1957, pp. 13-14.

"Automatic Programming for Business Applications," American Management Association,

Fourth Annual Electronics Conference Handbook, 1958, New York.

"Automatic Programming in Business and Industry," University of Alabama, Proceedings of Electronic Data Processing Conference, May 1958, pp. 1-5.

"From Programmer to Computer," Industrial and Engineering Chemistry, Vol. 50, Nov. 1958, p. 1661.

"Automatic Programming--Present Status and Future Trends," London, England - Nov. 1958.

"Automatic Programming Language and Programming Aids," U.S. Army Artillery and Missile School, Proceedings of Computers for Artillery Conference, Feb. 1959, pp. 157-159.

"Education can be 'Secondary'," Systems for Educators, Vol. 6, No. 2, Nov.-Dec. 1959.

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"A Data-Processing Compiler," National Machine Accountants Association, Data Processing 1959, Proceedings, pp. 69-76.

"The Development of Automatic Programming," Machine Accounting and Data Processing, The Punched Card Semi-Annual, Vol. 8, 1959, pp. 28-32.

"Automatic Coding--1960," Automatic Data Processing Seminar for Federal Executives, USDA Graduate School, Washington, D.C.

"Business Data Processing -- A Review," Proceedings of the IFIP Congress 1962, pp. 35-39.

"Business Data Processing," Tydschrift voor Efficientie in Docuentiatie Jaargang 33, No. 6, 1962, pp. 269-273.

"Automatic Coding to COBOL," Historical Development: AIEE 1962, Conference paper 62-397.

"Automatic Coding," Proceedings of the NOMA Conference, Tokyo, Japan, June, 1965.

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CO-AUTHOR OF:

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Understanding Computers, Grace Murray Hopper and Steven L. Mandell, West Publishing Co., 1984.

APPENDIX B

INTERVIEW RELEASE FORM

Interview Release Form

This will certify that I have agreed to be interviewed on _____ by Carmen Mitchell as part of her doctoral dissertation research as a Ph. D. student at the University of North Texas. I understand that this interview will be taped and I agree to relinquish all rights to the audiotape and this interview.

_____

Name of person interviewed Date

APPENDIX C

COURSE OF STUDY

Course of Study

PRIMARY DEPARTMENT

Three Years

PHONETICS: Word building.

READING: New Education Readers, Books I-IV; Summer's Primer, First Reader; Craik's "Bow-Wow and Mew-Mew;" Baldwin's "Fairy Reader;" Turpin's "Classic Fables;" Johnson and Barnum's "Plays for Little Actors;" Collodi's "Pinocchio;" Baldwin's "Gulliver's Travels;" Turner's "Short Stories;" Holbrook's Dramatic Reader; other selections.

LITERATURE: Reading, by teacher, of selections; fables, myths, stories of famous men; memorizing of simple poems.

LANGUAGE: Sentence building; simple rules for punctuation and use of capitals; oral and written reproduction of stories; short narrative and descriptive compositions; letter-writing.

GEOGRAPHY (begun in third year): Home geography; general geography; conception of maps.

FRENCH: Simple conversation; reading; writing.

NATURE STUDY: Training powers of observation; seasons; common fruits, vegetables, trees, birds.

SPELLING

SINGING

BIBLE STORIES

PHYSICAL TRAINING

DRAWING

PENMANSHIP

APPENDIX D

REPORT CARD FROM MISS MARY SCHOONMAKER'S

Miss Mary Schoonmaker's
SCHOOL FOR GIRLS
345 West End Ave.

Record of Grace Brewster Murray

Class Senior College Division

Class Standing

A + = 95% and over
A = 90 to 95%
B = 80 to 90%
C = 60 to 80%
D = below 60%

	FEB.	MAR.	APRIL	MAY
Spelling				
Grammar-Rhetoric	90	90	90	90
Composition	88	91	90	90
French	97	99	100	90
Latin	81	78	80	85
Bible Study	100	100	100	—
Literature C.R.	90	90	90	98
Poetry	100	100	90	100
History (Am.)	95	95	92	95
Mathematics				
Science				
Physical Culture	95	95	95	
Penmanship				
Business Methods				
Fine Arts				
Deportment	95	95	97	98
Gen'l Orderliness	95	95	97	98
Days Absent	0-100	0-100	0-100	0-100
Times Late	0-100	0-100	0-100	0-100

Summer Reading

Examined by Mary Van A. Murray Mar. 13 — 1923

" C. Schoonmaker Apr. 10, 1923

" Mary Van A. Murray May 7th — 1923

" C. Schoonmaker June 19

APPENDIX E

SUMMER READING

Summer Reading

The Household of Sir Thomas Moore
Mrs. Manning

The Battle Ground – Miss Glasgow

The Hoosier Schoolmaster. – Edw. Eggleston
Standish of Standish – Jane Austin
Conquest of Peru – Prescott
Dolph Heyliger – Washington Irving
Life of Samuel Adams – Hosmer
Harold – Edward Bulwer Lytton

APPENDIX F

LETTER FROM PRESIDENT HENRY NOBLE MACCRACKEN

VASSAR COLLEGE
POUGHKEEPSIE NEW YORK
Office of the President

Dear Grace

Thank you for letting me see your thesis. It bears from [illegible] does not help me to understand its scope, but Professor Whites' pride in it is all the guarantee needed of its value.

Cordially yours,

April 19.

APPENDIX G

DESIGN OF THE CALCULATOR

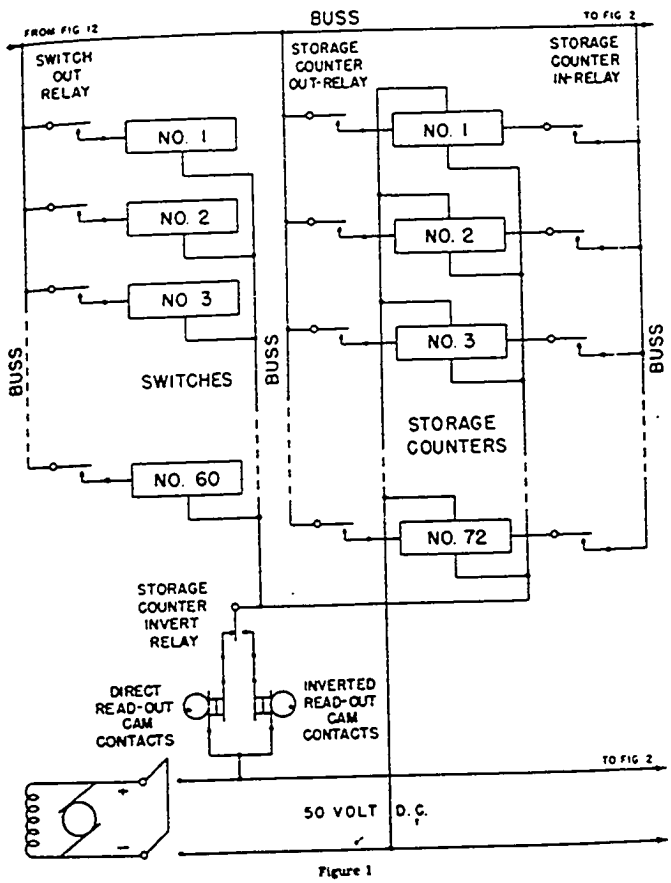

Figure 1

APPENDIX H

INTERVIEW QUESTIONS

Interview Questions

Grace Hopper and You:

1. How did you come to know Grace Hopper? When? Where?
2. Were you a student of Grace Hopper's?
3. Was she a mentor? Describe in what way she was a mentor.
4. How has your career been affected by knowing Grace Hopper?
5. Have you published with Grace Hopper?
6. Have you cited Hopper in your work? Often?
7. When did you last see and/or speak with Grace Hopper?

Grace Hopper, the Individual:

1. Describe the personality of Grace Hopper, as you knew her.
2. Describe her professional strengths--were there weaknesses?
3. In your opinion, what was her chief contribution to the computer science field?
4. Describe Hopper's philosophy of teaching and learning.
5. Is there an incident or anecdote that is particularly descriptive of Hopper that you can relate to me?
6. What other information can you add about Grace Hopper?

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