6.972 Project Histories

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1 Harold Edgerton and Side-Scan Sonar

Harold Edgerton, MIT electrical engineering professor from the 1930's until his death in 1989, is most famous for his work with high-speed flash photography and the "stopped time" pictures that that work produced. He also, however, developed camera equipment for deep-sea photography and "side-scan sonar," which applied the electronic principles from the flash tubes to acoustics. A side-scan sonar puts a single "flash" of acoustic energy into the water and then records the echoes. When towed behind a ship the device creates long, continuous image of the seafloor. Side scan is thus the most common technology used for searching for shipwrecks in the ocean, and was responsible for finding the Titanic as well as many other shipwrecks.

This project history will work with the Edgerton papers here at the MIT archives, and describe the development of side-scan sonar, as well as several startup companies that emerged from Edgerton's group. Edgerton's notebooks are beautifully kept, with detailed descriptions of his work and many photographs. The collection contains much correspondence with Jaques Cousteau, an early proponent of Edgerton's technologies, and many descriptions of expeditions around the world where Edgerton used his devices (often in a prototype state) to search for shipwrecks and even the Loch Ness monster.

Possible Themes: development of high-speed pulse electronics, intellectual continuity between strobe photography and side-scan sonar, "strobe culture" transforming into "undersea culture," relationship between testing and development in Edgerton's lab, technologies emerging from the lab and into commercial products.

Engineering Concentrations:

- Devices, Circuits, and Systems
- Electrodynamics and Energy Systems

Secondary Sources:

- *A Century of Electrical Engineering and Computer Science at MIT*, Chapter 8, by Wildes and Lindgren
- *Sonar Images*, by Harold Edgerton (Prentice Hall)
- Video, "How Fast is Fast?"

- *Stopping Time: The Photographs of Harold Edgerton*, by Estelle Jussim, Gus Kayafas, Gus Hayafas MIT Press)
- *Electronic Flash, Strobe*, by Harold Edgerton (MIT Press)
- *Seeing the Unseen: Dr. Harold E Edgerton and the Wonders of Strobe Alley* by Roger R. Bruce, ed.

Archival Sources: MIT Archives, MC 25, Edgerton Papers

- Lab Notebooks (box 51-57)
- Technical Specifications and plans (box 59-73)
- Trips (box 90-104)
- Maps (boxes 131-134, 59-82, ...)
- Correspondence (box 9-50)
- Publications (...)
- Cousteau Correspondence (Box 14)
- Klein (Box 24, folder 8)
- Raymond (Box 38, folder 12)
- Rines (Box 39, folders 4 & 5)

Contacts / Interviews:

- Charlie Mazel, director, MIT Edgerton Center
- Joyce Beatty, at Smithsonian, did research for Edgerton foundation
- Marty Klein, founder of side-scan sonar company (Edgerton student)
- Ed Curley, founder of EPC, ocean instrumentation company (Edgerton student)
- Sam Raymond, founder of Benthos, ocean camera and instrument company (Edgerton student)
- Bob Rines, Edgerton patent attorney

2 Magnetic Core Memory

Magnetic core memory replaced vacuum tubes and mercury delay lines with a much more compact and reliable technology. Jay Forrester, who was head of the Whirlwind computer project, invented core memory at MIT in the late 1940's. Whirlwind was MIT's first digital computer and the first digital computer built specifically for real-time control. IBM then licensed the technology, and core memory became commonplace in much of the first and second-generation of IBM computers. Semiconductor memories largely replaced magnetic cores in the 1970's, but they remained in use for many years in mission-critical and high-reliability applications. The Apollo Guidance Computer, for example (another project history) used core memory, as did the Space Shuttle until a recent computer upgrade.

This project history will work primarily with the core memory collection in the MIT archives, one of the richest sets of documentation for a particular invention that exists. A lawsuit was filed over the patent rights to the invention, so many lawyers spent a great deal of time documenting the invention and documenting the files. Forrester was a meticulous note taker and recorder of data, so his own thought process and the work of several of his students can be reconstructed with relative ease. Ken Olson, founder of Digital Equipment Corporation, was heavily involved as the liaison between MIT and IBM.

Possible Themes: birth of magnetic storage, critical developments in computing, relationships between innovations in components and innovations in systems, radical design, from invention to mass-produced product, cold-war technology and computing.

Engineering Concentrations:

- Electrodynamics and Energy Systems
- Devices, Circuits, and Systems

Secondary Sources:

- *Memories that Shaped an Industry*, by Emerson Pugh
- *Project Whirlwind*, by Kent Redmond and Thomas Smith
- *The Closed World* by Paul Edwards
- *System Dynamics*, by Jay Forrester

Archival Sources: MIT Archives, AC 337 Magnetic Core Memory Collection

- Forrester Notebooks (series I, box 4)
- Ken Olson Notebooks (box 8, folders 19-21)
- Chronological File

Contacts / Interviews:

- Jay Forrester, MIT Sloan School
- Ken Olson, DEC
- William Papian, student of Forrester who developed core memory systems
- Perry Crawford, who gave Forrester the idea to switch from analog to digital computing

3 Apollo Guidance Computer

The Apollo Guidance Computer (AGC) was the main control system on the spacecraft which went to the moon. It performed both automatic and manual (fly-by-wire) control of the command module as well as the lunar lander. The film Apollo 13 shows how frequently the astronauts relied on the AGC for a wide variety of tasks. The AGC included an inertial guidance system (similar to that on a missile) which was interfaced to numerous other devices through a digital computer. It was built at Draper Labs during the 1960's by many of the same people who appear in MacKenzie's book, and included the radical new technology of integrated circuits. It was quite an effort for the Draper group to convince NASA to accept a digital computer at all, and especially one using integrated circuits. This project consumed virtually the entire industrial output of integrated circuits in the U.S. for several years.

The project history will deal with material in the Draper Laboratories Library, which includes numerous technical reports and discussion of various aspects of the AGC design. Furthermore, many of the engineers who worked on the design are still around and willing to talk to students.

Possible Themes: acceptance of radical new technologies, development of digital real-time control, systems engineering as both technical and organizational activities, relationship between fabrication techniques and architecture, role of large projects in spurring market activity, role of the human beings in automatic control systems,

Engineering Concentrations:

- Communications, Control, and Signal Processing
- Computer Systems and Architecture

Secondary Sources:

- *Apollo 13*, film, dir. Ron Howard
- *The Right Stuff*, by Tom Wolfe
- *Aiming at Targets*, by Robert Seamans
- *Apollo: The Race to the Moon*, by Charles Murray and Catherine Bly Cox

- *Inventing Accuracy*, by Donald MacKenzie
- *The Apollo Guidance Computer*, by Eldon C. Hall
- *Beyond the Limits*, by Paul Ceruzzi

Archival Sources: Draper Laboratories Archive

- See document list

Contacts / Interviews:

- Richard Battin, ex-Draper
- Robert Seamans, MIT, Draper student, General Manager at NASA
- Linda Petkunas, Draper library
- David Hoag, Draper head engineer
- Tom Sheridan, MIT, human factors design on AGC
- Eldon Hall, computer design at Draper, wrote a book on AGC

4 Spreadsheets and Killer Apps

Sitting in a classroom at Harvard Business School in the late 1970's, Dan Bricklin invented the spreadsheet. With his friend Bob Frankston, he developed a program call VisiCalc which could manipulate numbers in a matrix-like graphical fashion. This program initially ran on the Apple II computer, one of the first personal computers, and it helped drive the personal computer revolution. Independently, Mitch Kapor developed a graphing and data analysis program called Tiny Troll, which was later renamed to VisiPlot and sold as an independent piece of software by the same company selling VisiCalc.

Kapor and his friend Jonathan Sachs were thinking ahead, however. They began development of an integrated package containing both spreadsheet and graphical capabilities, as well as word processing. In addition, they targeted IBM's first personal computer as their platform at a time when industry analysts were divided as to whether IBM's entry could compete with the Apple II. They founded a Cambridge company, called Lotus Development Corporation, and their product 1-2-3 became the "killer app" for the IBM hardware.

Possible Themes: the impact of social need on software integration, killer apps and the relation between software and hardware, user interfaces, corporate culture, entrepreneurship.

Engineering Concentrations:

- Computer Systems and Architecture

Secondary Sources:

- Harvard Business school case on Lotus. 9-285-094.
- Kapor Bibliography

Archival Sources: Kapor Archive

- Papers, documents, manuals, notes
- See index to papers

Contacts / Interviews:

- Mitch Kapor, founder, Lotus Corp.

- John Murphy, Kapor archivist
- (Dan Bricklin)
- Bob Frankston, Microsoft Corp.
- (Jonathan Sachs), founder, Lotus Corp.

5 The RSA Public-Key Cryptosystem

In 1975, Diffie and Hellman discovered the idea of public-key cryptography, which separates the capacities for encryption and decryption. A public-key cryptosystem organizes keys into inverse pairs such that anything encrypted with one key can be dekrypted with the other, but given one member of the pair, it is infeasible to discover the other. This system allows one of the pair to be made public for anyone to use, while the other is kept private. Public-key cryptosystems allow a variety of problems to be solved with simple protocols, including that of making digital signatures. In 1977 Rivest, Shamir, and Adleman of the MIT Laboratory for Computer Science invented the celebrated RSA encryption algorithm, the most popular public-key cryptosystem to date, which is based on the number-theoretic idea of modular exponentiation.

Failing in their attempts to license their idea, Rivest, Shamir, and Adleman decided to start their own company, RSA Security. For many years, they worked to develop cryptographic products, while navigating a minefield of U.S. government security regulation. Eventually, with the widespread success of the Internet and the need for secure interchanges, the company became hugely successful.

Possible Themes: acceptance of radical new technologies, government regulation and private enterprise, entrepreneurship, issues of privacy, engineering revolution in cryptographic methods, applications of number theory and complexity theory, development of high-technology markets.

Engineering Concentrations:

- Theoretical Computer Science
- Computer Systems and Architecture

Secondary Sources:

- *Contemporary Cryptography*, Gustavus J. Simmons, ed.
- "Mathematical Games: A new kind of cipher that would take millions of years to break," by Martin Gardner, *Scientific American*, August 1977.
- *The Codebreakers*, by David Kahn.

Archival Sources: Rivest notes, Bidzos notes, patents.

- Rivest: "Introduction to the RSA public-key cryptosystem"
- Bidzos: memos, etc.
- RSA patent

Contacts / Interviews:

- Ron Rivest, MIT, founder
- Jim Bidzos, RSA Security
- (Whit Diffie, Sun Microsystems)
- (Adi Shamir, Weizmann Institute, Israel)
- (Len Adelman, USC)

6 The Connection Machines

Thinking Machines Corporation was founded in the early 1980's riding the wave of interest in artificial intelligence at the time. The Cambridge company was a spin-off of the MIT Artificial Intelligence Laboratory where Danny Hillis, the intellectual founder, was a graduate student. Over the course of the decade, Thinking Machines became a preeminent purveyor of massively parallel computation, producing a series of machines including notably the CM-1, the CM-2, and the CM-5. In the early 1990's, with the end of the Cold War and the declining interest of the government in parallel computing, the company fell on hard times and declared bankrupcy. The company still exists as a software company, but most of the principal players in the company left.

Their first machine, the Connection Machine CM-1, was designed to propagate tokens in parallel through a "semantic network." Shortly thereafter, the revised CM-2, which featured floating-point chips to do numerical computations, was released, and the company turned from predominantly AI applications to scientific ones. In the early 1980's the company developed the CM-5, a radical departure in architecture from the earlier machines. In addition, Thinking Machines developed the notion of "data parallel" computing, parallel programming languages, and networks for interconnecting processors.

Possible Themes: acceptance of radical new technologies, development of parallel processing, transition from AI to numerical computing, role of government support for emerging industries, theory of parallel algorithms and architectures, systems engineering as both technical and organizational activities, corporate culture, entrepreneurship, engineering/corporate success and failure.

Engineering Concentrations:

- Artificial Intelligence
- Computer Systems and Architecture
- Theoretical Computer Science

Secondary Sources:

- *The Connection Machine*, by W. Daniel Hillis (MIT Press)

- *Out of Their Minds: The Lives and Discoveries of 15 Great Computer Scientists*, by Dennis Elliott Shasha and Cathy A. Lazere
- *Transforming Computer Technology*, by Norberg and O'Neill
- *Vector Models for Data-Parallel Computing*, by Guy Blelloch (MIT Press)

Archival Sources: Denicoff files, TMC library

- Denicoff: Proposals to DARPA, contracts, minutes of management meetings, etc.
- Library: technical memos, journal articles, etc.
- patents

Contacts / Interviews:

- Marvin Denicoff, founder
- (Marvin Minsky, founder)
- Guy L. Steele
- (Sheryl Handler, founder/CEO)
- (Danny Hillis, founder)
- Charles Leiserson, MIT
- Alan Edelman, MIT
- (Tommy Poggio, MIT)
- Jill Mesirov, Whitehead Institute
- Sandra Raymond, Thinking Machines librarian
- `thunko` email list