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The Information Storage Technology Program at Santa Clara University

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Abstract—**The major importance and growing significance of storage technology in computer systems and data processing has been well recognized in the commercial sector. However, data storage is still largely ignored by the academic community. In spite of this, the driving forces of research and development have led to advances in storage density and disk drive performance unprecedented in industry. This paper will address the challenges in introducing such subject matter into the academic curriculum, including the perceptions and attitudes that must be addressed. Data storage accounts for almost one third of total computer systems cost and provides one of the most essential ingredients: short access to massive amounts of data. Furthermore, computer systems in the information age are recognized as a key element of global competition. It is somewhat surprising, given this situation, that there has been so little response or change within the academic community.**

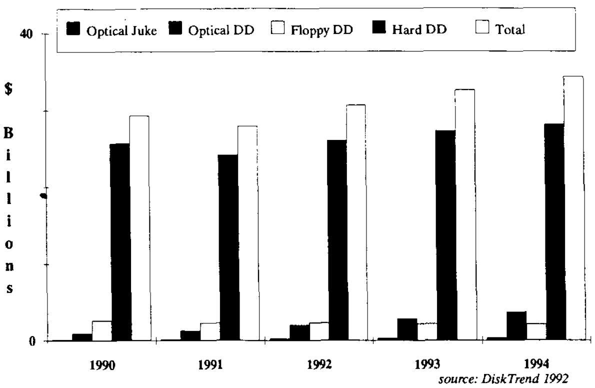

Fig. 1. Growth of the data storage industry.

I. Introduction

As storage technology advances at an increasing rate, demonstrated in Fig. 1 by revenues in excess of $30 billion US dollars, a larger knowledge base is required to remain competitive. Companies do not have the luxury of training engineers in all aspects of data storage. Typically, industry can only provide the skill immediately required. Universities must provide the balance. After 30 years of continuing advances in disk technology, it seems incredible that university research and teaching in this field is not flourishing.

This paper will describe the approach taken at Santa Clara University to establish an institute addressing the needs of the data storage industry. The paper will cover the challenges faced, the programs that have been established, and what we have learned.

II. First Steps

The Institute for Information Storage Technology (IIST) was founded at Santa Clara University in 1985. Prior to this step, coauthor A. Hoagland, while at IBM, played a key role in forming an industrial consortium to seed the creation of two university centers at Carnegie Mellon University (CMU) and University of California at San Diego (UCSD). The primary role envisaged for the centers and CMU and UCSD was to provide a source of Ph.D. graduates to meet the growing need for research in magnetics and allied fields that were becoming ever more complex as higher storage densities and device performance were required.

The "heart" of the data storage industry is located in Silicon Valley[1]. Santa Clara University (SCU) is ideally situated in Silicon Valley, and has a history of strong ties to the local community. Although not a major research institution, many other

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[1] Silicon Valley comprises the cities of Santa Clara, San Jose, Milpitas, and Cupertino CA. Due to the increasing amount of activity in data storage, the name is expected to be changed shortly.

opportunities presented themselves in which academia could cooperate with industry to enhance a competitive position in data storage. After forming the center at UCSD, Hoagland joined SCU where a proposal was prepared and accepted to establish the Institute of Information Storage Technology. Data storage technology is so interdisciplinary that it was not possible to map a program readily into the departmental structure of the typical academic institution. Therefore, the Institute was set up as a separate organization within the school of engineering and responsible for its own funding through industrial sponsors and associate members.

SCU has a strong tradition of high quality undergraduate education. Santa Clara also has an established "Early Bird" graduate program, providing a masters degree in engineering for part time students by offering courses from 7 to 9 am. This program has been well supported by industry, as it provides an opportunity to keep their work force up to date.

III. Initial Goals

A. At the Undergraduate Level

- Develop appropriate undergraduate courses.
- Expose undergraduates to storage technology.
- Introduce students to industry.

The overall goal is to motivate students to choose data storage as a career path. Undergraduate course work provides a basis, allowing the students to be exposed to the technical complexities of data storage. Summer co-op employment gives students a feeling of the climate fostering new technology. Seniors are encouraged to focus on a single area of data storage within the required senior design project. Hopefully, students would be exposed to the excitement of the industry and seek a career in this area.

B. At the Graduate Level

- Establish a comprehensive curriculum.
- Initiate research activities.
- Create state of the art short courses and tutorials.

Course work at the M.S. and Ph.D. levels should reflect the needs of the professionals working in the data storage industry. Research activities encourage graduate students to enter the M.S. or Ph.D. program full time, and may provide financial support. However, many professionals have neither the time nor the motivation to enter a formal, degree oriented graduate program. For these individuals, short courses and tutorials in data storage are offered.

IV. Challenges

One challenge immediately faced is that consumers see data storage in forms like audio or video recorders, black boxes that stimulate little awareness or appreciation of the level of technology involved. Thus, the very large high technology disk drive industry is practically unnoticed. This attitude translates into the fact that students not only are unaware of the career possibilities but are unmotivated to take relevant courses.

Another challenge arises from the difficulty that a university has pursuing areas that are heavily engaged in by industry.

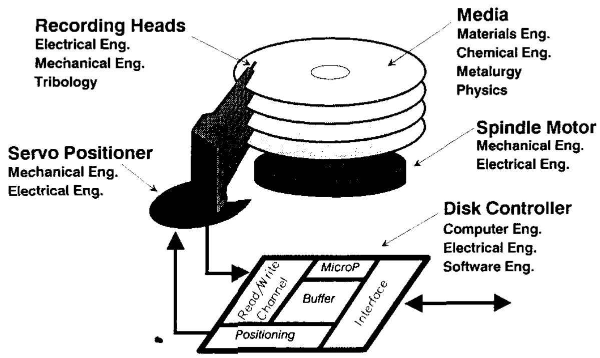

Fig. 2. Multidisciplinary nature of data storage.

With magnetic recording having been very actively pursued since the late 1940's for data storage, there is a basic feeling that the technology is mature and therefore not as appropriate for a university environment. While the curriculum at IIST emphasizes magnetic disk recording technology, tape and optical disk technology are not excluded. With the resources available, IIST recognized an immediate opportunity in terms of the need for a set of educational programs to meet the unfulfilled needs of the data storage community.

The interdisciplinary nature of data storage presents a formidable challenge in education. Fig. 2 illustrates the many areas of engineering behind a typical disk drive. It is not obvious where exciting innovations may arise and how technology of data storage will be advanced. Because the technology is so broad and interdisciplinary it does not map into the conventional academic departmental structure.

V. Curricula and Programs

A. Undergraduate Program

Many of the disciplines required to obtain a good background in data storage were already offered in the ABET accredited Electrical, Mechanical and Computer Engineering departments. Courses such as control theory, electromagnetics, digital logic, and programming are required in most curricula. By drawing on existing courses, the number of new courses was kept to a well focused minimum.

Commencing with the 1988 academic year an undergraduate option in Information Storage Technology in Electrical and Computer Engineering was available. Also, undergraduates meeting certain grade point restrictions may elect to take courses from the graduate curriculum, with instructor and advisor approval. Two new undergraduate courses were developed to complete the curriculum:

EECS 180	Introduction to Information Storage Technology.
EECS 107	Information Storage Technology (Magnetic and Optical Recording).

To provide an undergraduate more familiarity with data storage whenever possible, classroom teaching is supplemented with laboratory activity. Simple experiments, such as attaching a disk drive to a host and sending a read command us-

TABLE I
GRADUATE COURSE LISTINGS

EECS 451- Magnetism and Magnetic Materials	EECS 465-High Performance Head Positioning
EECS 453-Information Storage Systems	EECS 466-7-Direct Access Storage Devices 1,2
EECS 454-Optical Recording Systems	EECS 468-Magnetic Circuit Design
EECS 456-Configuration of Rigid Disk Drives	EECS 469-Magnetic Recording Head Design
EECS 457-Signal Processing for Data Storage	EECS 470-2-Read Write Mag Rec Circuits 1,2,3
EECS 458-Coding for Data Storage	EECS 473-Flexible Disk Controller Design
EECS 460-2-Magnetic Recording Theory 1,2,3	EECS 475-High Speed Rigid Disk Ctrlr Design
EECS 463-Disk Magnetic Channel Design	EECS 479-Special Topics in Info. Storage

ing SCSI (the popular Small Computer Systems Interface) protocol, build the confidence of students and encourage them to dig deeper. A systems approach to storage hardware allows students to become involved quickly. Students are introduced to data storage at an early stage, instead of waiting until they complete courses in electromagnetics and advanced mathematics. The students become more aware of the theory behind the magnetic recording process.

The undergraduate curriculum is supported by topics in related areas. Here, the data storage is used as a practical example of the application of the knowledge they acquire in their core courses. Additional classes in File Structures and Operating Systems provide applications for computer engineers. Classes in Microelectronics, Communications, and Control Theory provide additional breadth for electrical engineers.

In spite of the classroom effort, most students are unfamiliar with the internal function of data storage devices, such as disk drives. To remedy this, the local data storage industry has offered organized tours of manufacturing facilities. The students learn outside the classroom from engineers who discuss and demonstrate the design, manufacture, and test of disk drives.

In addition, students are encouraged to take co-op assignments with sponsor and associate members to provide exposure to career opportunities in industry. An annual "Evening with the Data Storage Industry" is held in conjunction with the local data storage industry. Students learn about full time and co-op opportunities, while industry participants provide information regarding career opportunities in data storage.

In summary, the typical undergraduate student with an interest in data storage would take two additional undergraduate courses as departmental electives. He or she could spend up to two summers working as a co-op intern in the data storage industry. Additional interaction with industry is provided through organized tours of local disk drive manufacturers. A senior design project in data storage is reviewed by local engineering alumni, and the program is completed.

B. Graduate Degree Program

Some subject matter cannot be adequately handled by the full time faculty. IIST courses fall under one of the traditional academic departments yet industry experts, serving as adjunct faculty members, are invited to teach in their specific areas of expertise. Experts also augment the graduate program as guest lecturers. Our location in Silicon Valley is ideal in terms of drawing upon internationally recognized experts in the relevant fields and greatly expands the range of possible offerings. The courses found in Table I are available to both M.S. and Ph.D. students. Course descriptions and prerequisites may be found in [2].

TABLE II
RECENT SHORT COURSE OFFERINGS

Mar 86-Signal Processing for Digital Magnetic Recording
Dec 86-Storage Controllers & Interfaces
Mar 87-Optical Data Recording
Jun 87-Magnetic Recording Technology
Dec 87-Challenges in Winchester Technology
Mar 88-Head Positioning Servo Systems & High Track Density
Dec 88-Disk Drives-Advanced Manufacturing Issues
Mar 89-Magnetic Recording Heads: Technology & Applications
Dec 89-Head Disk Interface
Mar 90-Removable Data Storage
Dec 90-Hard Disk Drives-The Decade of the 90s
Mar 90-Magnetic Recording Technology
Dec 91-Tribology of the Head/Medium Interface
Dec 91-Digital Signal Processing for Data Storage
Jun 92-Controlling Intelligent Storage Devices

C. Professional Program

Short courses lasting one to three days bring a select group of industry experts to focus on a single topic in data storage. The objective here is to keep working engineers up to date on the latest state of the art. These short courses may be better called miniconferences since a typical three day course usually involves twelve instructors, each well recognized for the particular topic he or she will cover. The scope of topics is extremely broad and the choice is based on the dynamics of the technology. As an example, the past five years of short course offerings are listed in Table II.

Tutorials lasting five days provide intensive exposure to the basic elements of information storage. Classes are limited to 25 or fewer students and taught by full time faculty. Professionals desiring to benefit from a broader perspective of the technological base of the industry are the target audience.

D. IIST Project Activity

Since IIST relies on industry support, there is an Advisory Board that oversees the activities, providing advice and a critique of the program. The Advisory Board is a mechanism to keep abreast of industry changes and needs and maximizes our ability to be responsive.

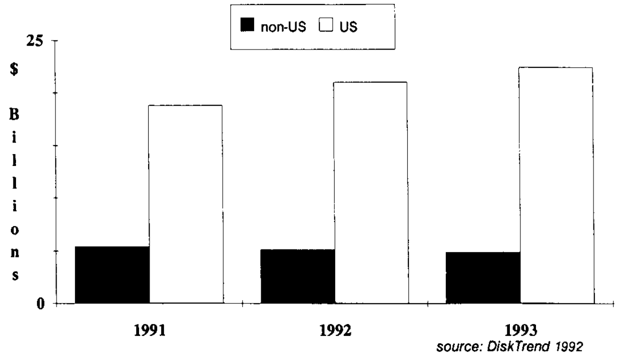

Fig. 3. US market share of data storage industry.

IIST research activities are chosen to be compatible with the research facilities at SCU. Thus, we are not in a position to perform capital intensive research such as thin film media and head design. Rather, we concentrate on recording systems, channels, and disk controllers and interfaces, a focus which has led to very close relationships with many small companies that address the test equipment business for components and drives. The drive, component and instrumentation companies have been extremely generous in making heads, media, and test equipment available.

VI. Conclusion

While the continuing challenge to keep the Institute prospering never seems to diminish, all the feedback we have received endorses the success we have achieved. The continuing challenges are:

- Attracting undergraduates into the program.
- Keeping courses current.
- Securing instructors as topic areas change in significance.
- Maintaining a close link with industry on research project activities.

Our circumstances at IIST may be unique. However, we believe other schools should establish programs to support the data storage industry, as they have in the semiconductor electronics field. The data storage field is filled with remarkable achievements, beginning 35 years ago with the invention of the disk drive. The US has continuously led this industry and US market share has even grown in the last two years, as shown in Fig. 3. A global manufacturing environment exists, with US companies manufacturing disk drives in Singapore, Korea, and Japan. The majority of research and design work remains in the US, including Japanese companies that design disk drives here. Data storage continues to grow, in spite of increased competition from abroad, and without prevailing on the government for help. Data storage is an extremely critical technology and, so far, our industry seems to have been doing something right. We believe it deserves and needs involvement from the academic community and look forward to sharing our experiences with those willing to join with us.

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Albert S. Hoagland (S'50–A'54–SM'57–F'66–LF'92) received the Ph.D. degree, in 1954, from the University of California, Berkeley.

He joined IBM in 1956 where he worked for 28 years. He made major contributions to magnetic recording technology and the design of magnetic disk drives, holding many key positions in both research and development. He also served as Director for Technical Planning for the IBM Research Division, led advanced efforts on flexible magnetic media mass storage, served as a senior technical consultant in Europe and played the principal role in the formation and leadership of an Industry/University consortium that established the first University Centers in data storage technology. He took early retirement from IBM in 1984 to join Santa Clara University where he founded the Institute for Information Storage Technology (IIST). He is currently Chairman of the TMRC Advisory Board, Director of the Institute for Information Storage Technology, and Professor of electrical engineering in the School of Engineering, at Santa Clara University, Santa Clara, CA.

Dr. Hoagland is past President of both the American Federation of Information Processing Societies and the IEEE Computer Society, an author of the well known book *Digital Magnetic Recording* (a new, second edition of this book was published in 1991), as well as numerous publications in the fields of data storage and magnetic recording, including a Best Paper Award from the AIEE.

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He is currently teaching courses in computer architecture, programming, and information storage at IIST. Prior to joining IIST, he worked with National Semiconductor, Scientific Microsystems, and IBM, designing and developing storage controllers and devices.